Annual Research Report

2019

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, Mr Cheah See Siang

September 2020

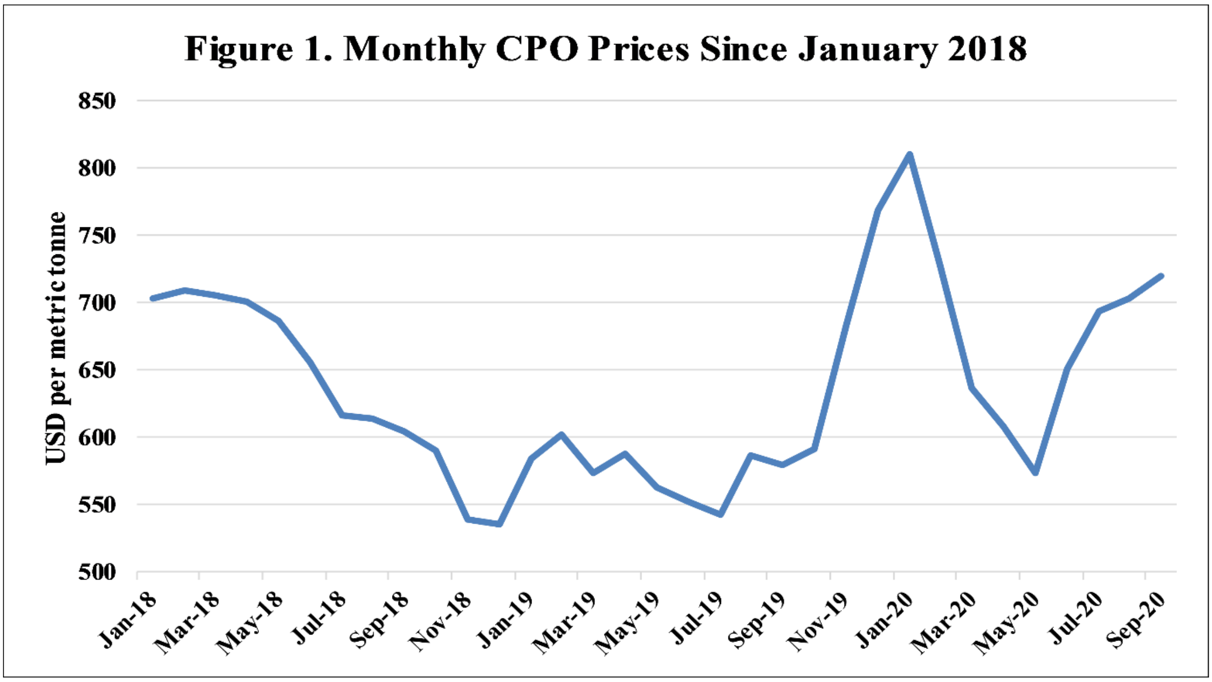
A.1. CONTEXT

The 2019 crop budget presented by PNGPOPRA members was only 1% lower than the 2018 FFB production for both milling companies and smallholders. However, the realized FFB production in 2019 was 10.8% and 10.2% lower than the 2019 budgeted crops committed by the milling companies and smallholders, respectively. Overall, FFB production in 2019 was down by 12% compared to 2018 (Table 1). Exceptional high FFB production realized in 2018 has certainly stressed the palms and consequently resulted in lower production in the following year. In addition, eruption of Ulawun Volcano in June 2019 has devastated large areas of productive plantations at HOPL resulted in huge crop losses. Both events have led to lower FFB production in 2019.

Table 1. FFB production (MT) of PNGOPRA members between 2011 and 2019.

Year	Milling companies	Small holders + Outgrowers	Total	Versus 2011	Versus 2012	Versus 2013	Versus 2014	Versus 2015	Versus 2016	Versus 2017	Versus 2018
2011	1,844,783	871,394	2,716,177								
2012	1,702,393	887,981	2,590,374	95%							
2013	1,558,522	776,406	2,334,928	86%	90%						
2014	1,794,404	832,297	2,626,701	97%	101%	112%					
2015	1,832,222	771,442	2,603,664	96%	101%	112%	99%				
2016	1,767,166	737,593	2,504,759	92%	97%	107%	95%	96%			
2017	1,973,180	794,041	2,767,221	102%	107%	119%	105%	106%	110%		
2018	2,185,823	785,880	2,971,703	109%	115%	127%	113%	114%	119%	107%	
2019	1,928,914	696,589	2,625,504	97%	101%	112%	100%	101%	105%	95%	88%

The CPO prices did not help neither, mostly ranged bound between USD500 and USD600 per tonne in 2019 and ended the year with an average price of USD601 per tonne. This was USD37 per tonne lower than the 2018 average price. Coupled with lower FFB production in 2019, the member companies saw an estimated revenue loss of USD49.3 million. In early 2020, the industry enjoyed a short period of buoyant CPO prices before it crumbles down to USD573 per tonne in May as a result of global Covid-19 pandemic. Nonetheless, CPO prices have since recovered from its low to the recent high of USD720 per tonne at the time of writing this report (**Error! Reference source not found.**). The current CPO p rice, if sustains, would augur very well for the member companies and the oil palm industry in PNG as a whole.



The depressed CPO prices saw in 2019 have certainly affected the expansion of oil palm planted area in PNG. Based on Dami seed sales, approximately 1,750 hectares were developed into oil palm plantations in 2019. This was a great contrast to 2018 where an estimated 9,085 hectares were developed. The depressed CPO prices in 2019 have forced many oil palm growers held back their expansions. Nonetheless, the oil palm planted area in PNG continued to increase steadily since 1989, from 47,900 hectares to the presence estimated total planted area of 238,928 hectares (Table 2). NBPOL Group remains as the largest oil palm grower in PNG with a total planted area of 83,848 hectares representing 35% of the total oil palm planted area in PNG while smallholders represent the second largest group of oil palm growers in PNG with a total planted area of 57,571 hectares. To date, members of PNGOPRA account for 65% of the total oil palm planted area in PNG while non-PNGOPRA growers account for the remaining 35%. If CPO price remains buoyant for the next few years, non-PNGOPRA growers will resume their expansions and traditional members of PNGOPRA could be outpaced very soon. Hence, PNGOPRA recommends that communication regarding Pest and Disease should be encouraged between the two sides of the industry. POPA seems to be the appropriate forum to hold those discussions.

In line with the increase in planted area, the number of palm oil mills operating in PNG has grown from 18 mills in 2019 to 20 mills in 2020 (Table 3). Two new oil mills started operating this year making a total national capacity of 1060 metric tonnes per hour. In August 2019, NBPOL acquired Markham Farms and an oil mill with processing capacity of 10 metric tonnes FFB per hour was built at Erap Estate and was commissioned in March 2020. Sepik Oil Mill which was under construction last year has started processing FFB. The oil mill belongs to Wewak Agriculture Development Limited has a processing capacity of 30 metric tonnes per hour. The construction of Ove Oil Mill which was originally aimed to process FFB from Silovuti project has been put on hold while the Waraston Oil Mill which has a processing capacity of 60 metric tonnes FFB per hour has ceased to operate since 2019. Albright Plantation still plan their first mill in Central Province in 2021, no other mills were mentioned during our surveys.

Table 2. Oil palm planted area in Papau New Guinea and Solomon Islands.

	Country	Plantation	Smallholders	Total
PNGOPRA Member				
NBPOL (WNB)	PNG	38,939	28,250	67,189
Ramu Sugar Ltd (RAIL)	PNG	18,169	644	18,813
Higaturu Oil Palm	PNG	10,523	10,910	21,433
Milne Bay Estates	PNG	10,756	1,560	12,316
Poliamba Limited	PNG	5,461	2,815	8,276
SIPEF Hargy OPL	PNG	13,687	13,392	27,079
Sub-total		**97,535**	**57,571**	**155,106**
Guadalcanal Plains Palm Oil Limited	Solomon Islands	6,766	712	7,478
Sub-total		**104,301**	**58,283**	**162,584**
Non-PNGOPRA Member				
ARAB Pltns Mngmt, Kavieng	PNG	356	-	356
Ex'Damansara Aitape Samas Ltd	PNG	2,950	-	2,950
Bewani Palm Oil Development Limited	PNG	16,125	-	16,125
NASYL No.98 Limited	PNG	631	-	631
Tzen Plantation Limited	PNG	17,194	-	17,194
Vanimo Jaya Limited	PNG	3,656	-	3,656
Wewak Agriculture Development Limited	PNG	14,553	-	14,553
Memalo Holdings Limited	PNG	19,463	-	19,463
SPZ Enterprise (PNG) Limited	PNG	3,125	-	3,125
Ome Oil Palm Project (Albright Limited)	PNG	4,500	-	4,500
Konoagil	PNG	1,269	-	1,269
Sub-total		**83,822**	**-**	**83,822**
Total planted area in PNG		**181,357**	**57,571**	**238,928**
Total planted area in PNG & Solomon Islands		**188,123**	**58,283**	**246,406**

Table 3. List of palm oil mills operating in Papua New Guinea.

	Mill	Location	Site	Company	Capacity (mt/hour)
1	Mosa Oil Mill[1]	Mosa	WNB	NBPOL	60
2	Kumbango Oil Mill[1]	Kumbango	WNB	NBPOL	60
3	Kapiura Oil Mill	Kapiura	WNB	NBPOL	60
4	Numundo Oil Mill	Haella	WNB	NBPOL	80
5	Waraston Oil Mill	Numundo	WNB	NBPOL	60
6	Sangara Oil Mill	Sangara	Oro	HOPL, NBPOL	80
7	Sumberipa Oil Mill[3]	Sumbiripa	Oro	HOPL, NBPOL	30
8	Mamba Oil Mill	Mamba	Oro	HOPL, NBPOL	30
9	Gusap Oil Mill	Gusap	Ramu	RAIL, NBPOL	75
10	Erap Oil Mill	Erap	Ramu	RAIL, NBPOL	10
11	Hargy Oil Mill	Hargy	WNB	SIPEF HOPL	45
12	Barema Oil Mill[1]	Barema	WNB	SIPEF HOPL	45
13	Navo Oil Mill	Navo	WNB	SIPEF HOPL	45
14	Poliama Oil Mill	Poliamba	NIR	POL, NBPOL	30
15	Hagita Oil Mill	Hagita	MBE	MBE, NBPOL	80
16	Liguria Oil Mill[2]	Pomio	ENB	TZEN Plantation PNG Limited	60
17	Narangit Oil Mill[2]	Vunapalading	ENB	TZEN Plantation PNG Limited	60
18	Mamusi Oil Mill[2]	Pomio	ENB	Memalo Holding (Rimbunan Hijau)	60
19	Imbio Oil Mill[2]	Sandaun	WSP	Bewani Palm Oil Development Limited	60
20	Sepik Oil Mill[2]	Wewak	ESP	Wewak Agriculture Development Limited	30

[1] *are equipped with CDM;* [2] *are not milling FFB of PNGOPRA member companies;* [3] *foot print of 60*

Following the production level achieved in 2019, there were no changes of voting rights in 2020 (Table 4). The Board of Directors remains unchanged to previous year and there was no change of Chairmanship with Mr James Walter Graham as Chairman of PNGOPRA Board. On the Board of Directors, NBPOL currently have three representatives who represents all NBPOL interests and the other two organisations each have one representative.

Table 4. FFB production in 2019 and voting right in 2020 per PNGOPRA associate members.

	FFB produced in 2019		Votes[1]	
Member	**MT**	**%**	**Number**	**%**
New Britain Palm Oil Limited	1,673,400	63.7	17	61.4
Smallholders (OPIC)	696,589	26.5	7	25.6
Hargy Oil Palm Pty Ltd	255,515	9.7	3	9.4
Director of Research[2]	na	na	1	3.7
Total	**2,625,504**	100	**27**	**100**

[1]*calculated based on one vote for each 100,000 metric tonnes of FFB produced by members of PNGOPRA.*
[2]*the Director of Research shall have one vote in accordance to the Rules of PNGOPRA.*

PNGOPRA continued to be financed by levy paid by all member companies and also by external grants (Project funding). The total budgeted expenditure for PNGOPRA in 2019 was 19% higher than the previous year with total budgeted operating expenditure amounted to PGK7.45 million while budgeted capital expenditure amounted to PGK1.11 million. On expenditure incurred in 2019, PNGOPRA spent K6.37 million on operating expenses while PGK1.01 million was spent on capital expenditure. Total revenue collected from member companies through FFB levy amounted to PGK5.25 million, 11% lower than budget but control was enforced throughout the year. With prudent spending, PNGOPRA remained cash positive and has not engaged in large capital investment. On that note the Director of Research thanks the Section heads for their understanding when restriction was enforced during 2019.

The share of the external grants has increased to 27% in 2019 budget due to the CRB-G project financed by the milling companies, with total budgeted expenditure of PGK2.30 million. The PNGOPRA member's levy was maintained at PGK2 per tonne FFB for all growers and was applicable on first January 2019. This levy has not changed since but was proposed and endorsed by LPC members to raise to PGK2.2 per tonne FFB effective first January 2020. 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. MANPOWER

In 2019, PNGOPRA has seen some changes in its management. Dr Luc Bonneau, the former Director of Research left PNGOPRA on the 10th of September 2019 and his role was assumed by Mr Steven Nake (Head of SSR) who was appointed as Acting Director of Research until 31st of December 2019. During the PNGOPRA BOD meeting held on the 19th of December, Mr Cheah See Siang, Head of NBPOL Research and Development was appointed as Director of Research of PNGOPRA. He assumed the role of Director of Research on the 1st of January 2020. In agreement with PNGOPRA BOD, he remains an employee of NBPOL and NBPOL is compensated for the service rendered by Mr Cheah See Siang to PNGOPRA.

Dr Emad Jaber from Jordan has finally joined PNGOPRA as Head of Plant Pathology, filled up the vacant position left by Dr Carmel Pilotti who retired at the end of 2018. Dr Emad Jaber was employed by NBPOL as Principal Plant Pathologist and seconded to PNGOPRA. Accordingly, similar arrangement was made that NBPOL is compensated for his service rendered to PNGOPRA.

Mr Benoit Burel, the consultant for CRB-G project has completed his 2 years contract with PNGOPRA at the end of 2019. The employment contract of Brenda Clayton, the entomologist engaged for CRB-G project has been terminated due to absent from work for more than one month without notice. Whilst the consultancy contract of Dr Carmel Pilotti who was engaged in January 2019 as consultant for plant pathology was ended on the 20th May 2020 as her service is no longer needed since the capacity of Plant Pathology Department has been rebuilt at PNGOPRA. Apart from that, there was no other external consultants engaged in 2019. PNGOPRA continues to appoint Wau Accountants and Business Consultants as Financial Auditor in 2019. At the time of writing this report, PNGOPRA has todate 2 non-PNGOPRA executives, 9 executives and 95 non-executives, so a total of 104 permanent staff. PNGOPRA at the time of report uses 30 casuals' workers.

The distribution by age of employees is presented in Figure 2 and 3. There are 3 executives aged between 51 and 53 years old. They are Ms Jenny Ramoi (Head of Admin, Finance and Human Resource), Dr Murom Banabas (Head of Agronomy) and Mr Paul Simin (Officer in-charge of Bialla Station). Their succession plan has been addressed. The remaining executives are all well below 50 years old and they are being groomed as successor.

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 35% female (-2%), 65% male (+2%).

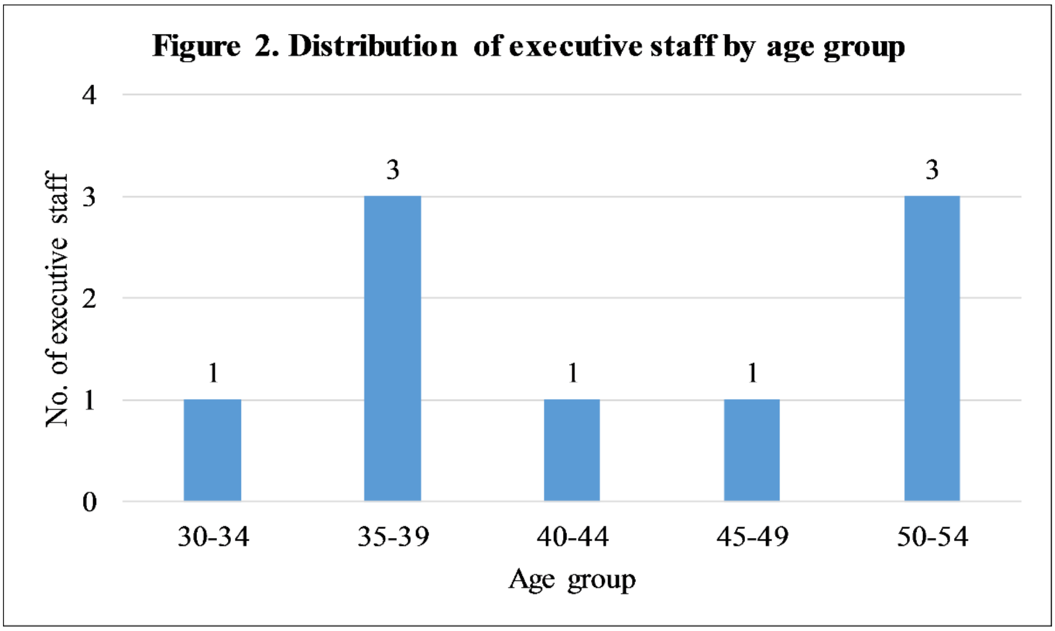


Figure 1. Distribution of the 9 executive staff employed by PNGOPRA by age group.

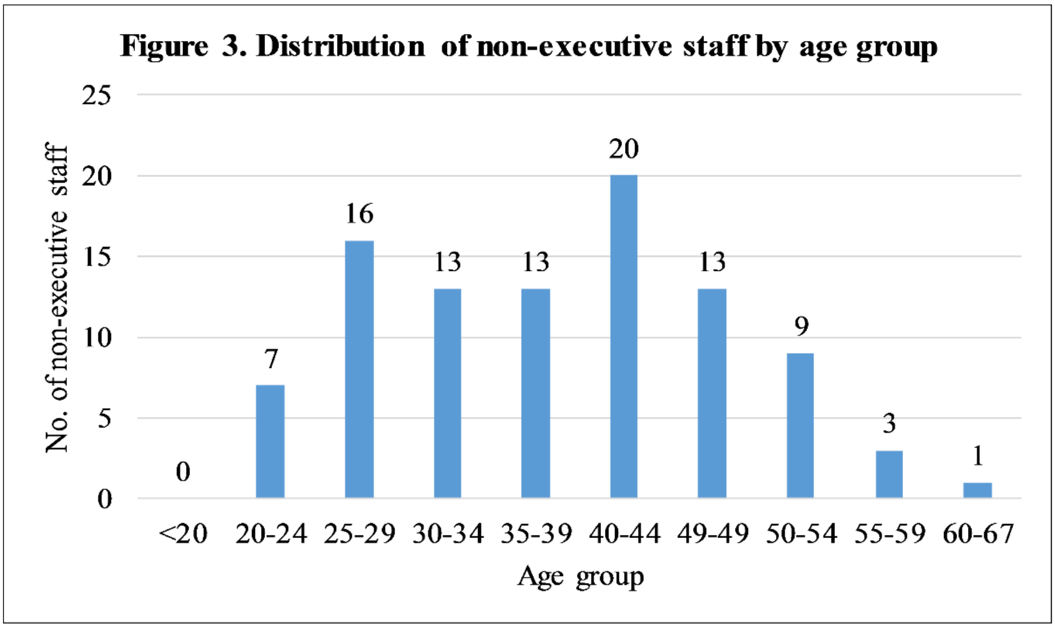


Figure 2. Distribution of the 95 non-executive staff employed by PNGOPRA by age group.

On the development of human resources, PNGOPRA continued to encourage its employees to pursue further study either locally or abroad. Below summary highlights the employees who currently pursuing further study locally.

<u>2019 - 2021</u>
2-years Undergraduate Program. 2019 November intake. Program Ends November 2021 (Distance Mode) - PNG Unitech
1. Nason Jerry- Plant Pathology Field Supervisor (Milne Bay Based) - Bachelor of Agriculture.
2. Andy Samuel-Agronomy Field Supervisor (Bialla Based) - Bachelor of Agriculture.

2018-2019
2-years MPhil Program. Jan 2018 Intake. Program Ends November 2019 (Distance Mode) - PNG Unitech
1. Evah Tokilala- Competed her program in 2019.
2. Sharon Agovaua- Did not complete due to extension. Hopeful to graduate in November this year.

A.3. RESEARCH IN 2019

In 2019, 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 materials that are now being planted by the member companies, the SuperFamily®. At the time of writing, all new trials have been planted and the first five trials are already yielding. The strategy for Agronomy is to keep up the advance in breeding to supply bespoke agronomic information to the oil palm agronomists, 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 the oil palm industry in PNG and Solomon Islands, with to date no effective biocontrol agent being identified though chemical control is effective against CRB-G. Collaboration works with SPC (Fiji), AgResearch (NZ), and NRI (UK) have been on going to mine and find a more environmental friendly solution. The two-year CRB-G project funded by the member companies (NBPOL and HOPL) has ended in December 2019 and a project final review report has been submitted to PNGOPRA Board for further assessment on the milestones achieved. Meanwhile all outstanding works on CRB-G are continued using the remaining project fund.

- The Plant Pathology section continued to focus on the management of basal and upper stem rat disease caused by *Ganoderma boninense*. With Dr Emad Jaber on board and with his knowledge in molecular techniques. Research focus is now diverted to using molecular techniques to expedite screening of *Ganoderma* tolerant planting materials but this shift in research focus will not neglect the importance of management of *Ganoderma boninense* in the field. Two-pronged approach will be employed to manage basal and upper stem rot.

- The Smallholders and Socioeconomic (SSR) activities have now grown to a steady pace and very well accepted by the stakeholders. The number of BMP blocks has increased and two events a week are organized by the association to demonstrate and educate smallholders in oil palm husbandry. OPIC has continued to underperform and plagued by its internal politics. As such PNGOPRA does 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. In 2019, the SSR section has started sampling oil palm leaves in smallholders' blocks to assess palm nutritional status. The findings clearly showed smallholders' blocks are in critical need of N and K fertilisers, and financial arrangement must be found to resolve this one of many contribution factors to the steady fall in smallholder's yield nationwide.

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. The number of nutrition trials has generally been increasing over time with known progenies. Two new fertiliser trials were planted in 2015 in NBPOL-WNB, and one each at RAIL, HOP, MBE, GPPOL, HOPL and HOP in 2017, in Poliamba NIP in 2018 at Malilimi WNB in 2019. These new trials are planted with consideration of probable progeny effects on the oil palm responses to fertilisers. Yield data collection and preliminary measurements have started in all trials planted in 2017 and continued to 2019.

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.

In 2019, Thomas Maiap and Joel Ben (Assistant Agronomists) continued at Dami and Stanley Yane, Assistant Agronomist remained at RAIL. Andy Samuel at Popondetta and Andy Ullian at Bialla swapped at beginning of the year. All supervisors remained at respective sites (Peter Mupa and Samuel 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	Not significant
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 5.

Table 5. 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 KCI extraction, det. by ICP-OES
CEC	Sum of exchangeable cations plus exch. Acidity
Volume weight	Weight/ volume of dried, ground soil
Base saturation	Calculated from exchangeable cations and CEC
Reserve' K	IM nitric scid extraction, det. By AA
Reserve' Mg	IM HCI extraction, det. AA, exch. Mg subtracted
Total N	Dumas combustion
'Available' N	7 day anaerobic incubation, 2M KCI extraction of NH_4^+
Organic S	0.02 M K_2PO_4 extraction followed by ICP-OES for total S, then subtraction of sulphate-S
Sulphate-S	0.02 M K_2PO_4 extraction followed by ion chromatography
Hot water soluble B	0.01IM $CaCI_2$ 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 closed.

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 6.

Table 6. 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 7). 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 7. Trial 154 Treatment fertilizer levels in 2019.

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 2019 and 2017-2019 (Table 8). Fertiliser levels increased FFB yield from 22.1 t/ha to 25.3 t/ha in 2019 (Table 9). A similar trend in yield increase was seen for 2017-2019. FFB yield in progeny T038 was greater than the other three progenies by 1-9 t/ha and this was due mostly to high bunch numbers and single bunch weight.

Table 8. Trial 154 effects (*p values*) of treatments and progenies on FFB yield and its components in 2019 and 2017-2019.

Source	2019			2017-2019		
	FFB yield	BNO	SBW	FFB yield	BNO	SBW
Fert levels	**0.018**	0.043	0.259	**0.002**	**0.034**	0.260
Progenies	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**
Fert x Progeny	0.088	0.182	0.333	0.220	0.275	0.993
CV %	7.5	7.5	3.4	6.8	6.3	5.2

Table 9. Trial 154 main effects of N rate treatments on FFB yield, bunch number and single bunch weight in 2019 and 2017-2019.

Treatments	2019			2017-2019		
	FFB yield (t/ha)	BNO/ha	SBW (kg)	FFB yield (t/ha)	BNO/ha	SBW (kg)
Fert level - 1	**22.1**	**2095**	10.5	**21.5**	**2515**	4.8
Fert level - 2	**24.4**	**2308**	10.6	**24.4**	**2746**	5.0
Fert level - 3	**25.3**	**2353**	10.7	**25.1**	**2774**	4.9
Fert level - 4	**24.6**	**2255**	10.9	**24.8**	**2698**	5.0
l.s.d$_{0.05}$	*1.93*	*181.6*		*1.75*	*180.4*	
Prog - T038	**27.8**	**2493**	**11.2**	**28.0**	**2963**	**4.7**
Prog - T118	**23.9**	**2284**	**10.4**	**23.5**	**2761**	**4.9**
Prog - T120	**18.6**	**2025**	**9.2**	**19.8**	**2542**	**5.5**
Prog - T123	**26.1**	**2209**	**11.8**	**24.5**	**2467**	**4.8**
l.s.d$_{0.05}$	*1.93*	*181.6*	*0.39*	*1.75*	*180.4*	*0.21*
GM	24.1	2253	10.7	23.9	2683	4.9
SE	1.8	169.36	0.36	1.64	168.2	0.26
CV %	7.5	7.5	3.4	6.8	6.3	5.2

Leaflets and rachis nutrient contents

Effects of fertilizer levels and progenies on leaflet and rachis nutrient contents for 2019 are presented in Table 10 and Table 11, respectively. Fertiliser levels affected leaflet Cl contents only while in the rachis, N, K, Mg and Ca contents were affected. The different progenies expressed significant differences in their leaf tissue nutrient contents except for leaflet Cl and rachis N contents. The fertilizer levels increased leaflet Cl content (Table 12) and rachis N, P, K, and Ca contents (Table 13). The leaflet N, K, Ca, B and S were higher in progenies T038 and T123 than in the other two progenies. However, in the rachis, K content was highest only in T123.

Table 10. Trial 154 effects (*p values*) of fertilizer levels and progenies on leaflet nutrient contents in 2019.

Source	Leaflets nutrient contents								
	Ash	**N**	**P**	**K**	**Mg**	**Ca**	**Cl**	**B**	**S**
Fert levels	0.348	0.963	0.838	0.159	0.686	0.058	**<0.001**	0.369	0.780
Progenies	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	0.171	**0.039**	**<0.001**
Fert x Progeny	0.685	0.733	0.960	0.708	0.309	0.081	0.533	0.116	0.621
CV %	3.5	3.0	3.3	8.2	4.5	2.9	6.4	9.8	4.0

Table 11. Trial 154 effects (*p values*) of fertilizer levels and progenies on rachis nutrient contents in 2019.

Source	Rachis nutrient contents					
	Ash	N	P	K	Mg	Ca
Fert levels	**0.004**	**0.017**	0.035	**0.008**	**<0.001**	**0.012**
Progenies	0.069	0.154	**<0.001**	**0.012**	**0.002**	**0.007**
Fert x Progeny	0.221	0.327	0.394	0.572	0.350	0.526
CV %	7.7	4.0	8.3	9.5	7.1	7.2

Table 12. Trial 154 effects of fertilizer levels and progenies on leaflet nutrient contents in 2019.

Treatments	Leaflets nutrient contents (% DM except B in mg/kg)								
	Ash	N	P	K	Mg	Ca	Cl	B	S
Fert level - 1	14.5	2.48	0.144	0.68	0.25	0.91	**0.40**	15	0.19
Fert level - 2	14.2	2.50	0.145	0.63	0.25	0.88	**0.51**	15	0.19
Fert level - 3	14.4	2.50	0.145	0.62	0.25	0.91	**0.54**	16	0.19
Fert level - 4	14.6	2.48	0.144	0.63	0.25	0.92	**0.57**	16	0.19
l.s.d$_{0.05}$							*0.034*		
Prog - T038	**13.9**	**2.58**	**0.150**	**0.72**	**0.22**	**0.96**	0.49	**16**	**0.19**
Prog - T118	**15.8**	**2.36**	**0.139**	**0.57**	**0.27**	**0.92**	0.51	**17**	**0.18**
Prog - T120	**14.9**	**2.33**	**0.139**	**0.60**	**0.30**	**0.85**	0.53	**15**	**0.18**
Prog - T123	**13.2**	**2.68**	**0.150**	**0.67**	**0.21**	**0.88**	0.50	**14**	**0.20**
l.s.d$_{0.05}$	*0.537*	*0.079*	*0.005*	*0.056*	*0.012*	*0.028*		*1.629*	*0.008*
GM	14.4	2.49	0.145	0.64	0.25	0.90	0.50	16	0.19
SE	0.501	0.074	0.005	0.052	0.011	0.026	0.032	1.519	0.008
CV %	3.5	3.0	3.3	8.2	4.5	2.9	6.4	9.8	4.0

Table 13. Trial 154 effects of fertilizer levels and progenies on rachis nutrient contents in 2019.

Treatments	Rachis nutrient contents (% DM)					
	Ash	N	P	K	Mg	Ca
Fert level - 1	**4.30**	**0.29**	**0.068**	**1.20**	0.06	**0.44**
Fert level - 2	**4.70**	**0.29**	**0.074**	**1.33**	0.08	**0.46**
Fert level - 3	**5.06**	**0.31**	**0.078**	**1.44**	0.08	**0.50**
Fert level - 4	**4.96**	**0.30**	**0.076**	**1.41**	0.08	**0.48**
l.s.d$_{0.05}$	*0.39*	*0.013*	*0.0070*	*0.137*		*0.036*
Prog - T038	4.46	0.30	0.061	**1.20**	0.07	**0.49**
Prog - T118	4.98	0.29	0.082	**1.35**	0.07	**0.48**
Prog - T120	4.73	0.29	0.076	**1.36**	0.08	**0.47**
Prog - T123	4.86	0.30	0.078	**1.46**	0.07	**0.43**
l.s.d$_{0.05}$				*0.137*		*0.036*
GM	4.76	0.30		1.34		0.47
SE	0.366	0.012	0.006	0.127	0.005	0.034
CV %	7.7	4.0	8.3	9.5	7.1	7.2

Physiological growth measurements

Results of 2019 vegetative measurements are presented here from Table to Table .

The effect of progenies on vegetative growth parameters were significant (p<0.001) for all the parameters measured (Table 14) and dry matter production in 2019 (Table 15). Fertilisers only affected BDM and TDM.

Progenies T118 and T120 have greater values than the other two progenies and were consistent with time for PCS, FDM, FA and LAI (Table 16).

Table 14. Trial 154 effects (*p values*) fertilizers and progenies on physiological growth parameters in 2019.

Source	Radiation interception				
	FL	PCS	FP	FA	LAI
Fert levels	0.735	0.128	0.928	0.199	0.144
Progenies	**p<0.001**	**p<0.001**	**p<0.001**	**p<0.001**	**p<0.001**
Fert x Progeny	0.288	0.655	0.144	0.842	0.946
CV %	1.4	3.3	2.1	5.1	5.2

Table 15. Trial 154 effects fertilizers and progenies on physiological growth parameters in 2019.

Source	Dry matter production				
	FDM	BDM	TDM	VDM	BI
Fert levels	0.132	**0.018**	**0.011**	0.060	0.070
Progenies	**p<0.001**	**p<0.001**	**p<0.001**	**p<0.001**	**p<0.001**
Fert x Progeny	0.466	0.088	0.082	0.352	0.131
CV %	3.9	7.5	4.5	3.4	3.9

Progeny T038 had the highest FFB yield compared to the other three progenies in 2019 but rank low in PCS and LAI (Table 16). This is also reflected in the high BI ratio of 0.61 (Table 17).

Table 16. Trial 154 effects of fertilizer levels and progenies radiation interception parameters in 2019.

Treatments	Radiation interception				
	FL	PCS	FP	FA	LAI
Fert level – 1	560	37.5	28.4	11.5	5.7
Fert level – 2	557	37.0	28.2	11.7	5.7
Fert level – 3	556	38.1	28.4	12.2	6.0
Fert level – 4	558	38.6	28.4	11.8	5.8
l.s.d $_{0.05}$					
Prog - T038	**581**	**26.8**	**29.8**	**11.2**	**5.4**
Prog - T118	**557**	**41.4**	**28.1**	**12.8**	**6.4**
Prog - T120	**543**	**46.4**	**26.7**	**12.5**	**6.1**
Prog - T123	**550**	**36.4**	**28.7**	**10.6**	**5.3**
l.s.d $_{0.05}$	*8.44*	*1.36*	*0.64*	*0.64*	*0.33*
Grand mean	558	37.8	28.3	11.8	5.8
SE	7.87	1.26	0.59	0.60	0.11
CV %	1.4	3.3	2.1	5.1	5.2

Table 17. Trial 154 effects of progenies on fertilizer levels and progenies on dry matter production in 2019.

Treatments	Dry matter production (t/ha/yr)				
	FDM	BDM	TDM	VDM	BI
Fert level – 1	13.8	**18.1**	**35.5**	17.3	0.51
Fert level – 2	13.6	**20.0**	**37.3**	17.3	0.53
Fert level – 3	14.0	**20.8**	**38.6**	17.9	0.54
Fert level – 4	14.2	**20.2**	**38.2**	18.1	0.52
l.s.d $_{0.05}$		*1.582*	*1.806*		
Prog - T038	**10.7**	**22.8**	**37.3**	**14.4**	**0.61**
Prog - T118	**15.2**	**19.6**	**38.6**	**19.0**	**0.50**
Prog - T120	**16.0**	**15.3**	**34.8**	**19.5**	**0.44**
Prog - T123	**13.7**	**21.4**	**39.0**	**17.6**	**0.55**
l.s.d $_{0.05}$	*0.577*	*1.582*	*1.806*	*0.646*	*0.022*
Grand mean	13.9	19.8	37.4	17.6	0.53
SE	0.538	1.475	1.684	0.602	0.02
CV %	3.9	7.5	4.5	3.4	3.9

B.1.2.5. *Conclusion*

The fertilizer levels significantly increased FFB yield. There were significant effects of progenies on yield, leaf tissue nutrient contents and physiological growth parameters. The trial is closed.

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

(RSPO 4.2, 4.3, 4.6, 8.1)

B.1.3.1. *Summary*

The trial was established to assess full potential of clonal palm materials with nutrition non-limiting. Fertiliser affected nutrient contents but not FFB yield while significant differences are reported from the progenies in their yield and nutrient contents. The sex ratio of the palms remained at above 90% for 38 months. The trial is recommended to continue.

B.1.3.2. *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 not limiting. 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 18.

Table 18. 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.1.3.3. *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 19).

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 19. 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.1.3.4. *Results*

Yield and yield components

Yield and yield components data for 2019 and running 30 months are presented here.

There were significant differences in FFB yield and its components from the effects of progenies (Table 20). Progenies SF108.07 had higher FFB yields than the other three progenies mostly due to high single bunch weight (Table 21).

Table 20. Trial 155 effects (*p values*) of fertilizer treatments and progenies on FFB yield and its components in 2019 and July 2018-December 2019.

Source	2019			July 2017 - Dec 2019		
	FFB yield	BHA	SBW	FFB yield	BHA	SBW
Fertiliser	0.894	0.975	0.622	0.400	0.218	0.260
Progeny	**0.010**	**0.006**	**<0.001**	**0.010**	**<0.001**	**<0.001**
Fert x Prog	0.928	0.711	0.975	0.766	0.428	0.993
cv %	7.4	4.6	5.0	6.2	4.4	5.2

Table 21. Trial 155 effects of fertilizer treatments and progenies on FFB yield (t/ha) and its components in 2019 and July 2018-December 2019.

	2019			July 2017 - Dec 2019		
Source	**FFB yield (t/ha)**	**BHA**	**SBW (kg)**	**FFB yield (t/ha)**	**BHA**	**SBW (kg)**
Fert. Level 1	26.2	3997	6.4	15.9	3019	4.8
Fert. Level 2	26.4	4000	6.5	16.1	2986	5.0
Fert. Level 3	26.5	3979	6.5	15.7	2917	4.9
Fert. Level 4	26.8	4014	6.6	16.3	3016	5.0
l.s.d$_{0.05}$						
Prog. SF46.01	**26.4**	**4124**	**6.3**	**15.7**	**3106**	**4.7**
Prog. SF21.11	**26.6**	**4074**	**6.4**	**16.1**	**3020**	**4.9**
Prog. SF108.07	**27.9**	**3889**	**7.0**	**16.8**	**2836**	**5.5**
Prog. SF08.06	**25.0**	**3903**	**6.3**	**15.4**	**2976**	**4.8**
l.s.d$_{0.05}$	*1.63*	*153.4*	*0.32*	*0.83*	*109.5*	*0.21*
GM	26.5	3997	6.5	16.0	2984	4.9
SE	1.96	183.99	0.38	1.00	131.3	0.26
CV	7.4	4.6	5.0	6.2	4.4	5.2

Leaf tissue nutrient contents

2019 was the third year of leaf tissue sampling. NK fertilisers significantly affected leaflet Mg and Cl contents (Table 22). Fertiliser treatments increased leaflet Cl but lowered Mg contents (Table 24).

There were significant differences between the progenies for leaflet Ash, K, Mg, Ca and B (Table 22). Progeny SF21.11 had higher leaflet cation contents than the other progenies (Table 24).

The fertilizer treatments affected rachis K, Mg and Ca contents while the progenies affected rachis N, P, K and Ca contents (Table 23). The fertilizer levels increased rachis K, Mg and Ca contents (Table 25). Rachis K content of SF21.11 was greater than the other three progenies however all had K contents above 1.50 % DM.

Table 22. Trial 155 effects (*p values*) of fertilizer treatments and progenies on leaflet nutrient concentrations in 2019, *p values* <0.05 shown in bold.

Source	Leaflet nutrient contents								
	Ash	N	P	K	Mg	Ca	Cl	B	S
Fertiliser	0.865	0.823	0.461	0.329	**0.032**	0.098	**<0.001**	0.699	0.528
Progeny	**0.034**	0.932	0.745	**0.008**	**0.010**	**0.038**	0.574	**<0.001**	0.528
Fert x Prog	0.805	0.245	0.851	0.552	0.536	0.944	0.264	0.163	**0.013**
CV %	3.7	2.6	2.8	5.5	5.5	3.7	8.0	4.8	2.9

Table 23. Trial 155 effects (*p values*) of fertilizer treatments and progenies on rachis nutrient concentrations in 2019, *p values* <0.05 shown in bold.

Source	Rachis nutrient contents					
	Ash	N	P	K	Mg	Ca
Fertiliser	0.294	0.140	0.451	**0.004**	**0.041**	**0.006**
Progeny	0.052	**0.005**	**<0.001**	**0.026**	0.246	**0.022**
Fert x Prog	0.819	0.204	0.056	0.383	0.449	0.410
cv %	7.9	6.3	7.2	7.9	8.5	6.7

Table 24. Trial 155 effects of fertilizer treatments and progenies on leaflet nutrient concentrations % DM except for B in 2019, *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	12.4	2.82	0.161	0.78	**0.27**	1.00	**0.47**	16	0.21
Fert. Level 2	12.5	2.84	0.161	0.76	**0.26**	1.02	**0.51**	16	0.21
Fert. Level 3	12.5	2.85	0.163	0.74	**0.26**	1.04	**0.54**	16	0.21
Fert. Level 4	12.5	2.84	0.162	0.76	**0.25**	1.03	**0.55**	16	0.21
***l.s.d*$_{0.05}$**					*0.012*		*0.035*		
Prog. SF46.01	**12.2**	2.83	0.161	**0.74**	**0.26**	**1.00**	0.51	**15**	0.21
Prog. SF21.11	**12.4**	2.84	0.163	**0.80**	**0.26**	**1.04**	0.52	**17**	0.21
Prog. SF108.07	**12.7**	2.84	0.162	**0.76**	**0.24**	**1.04**	0.51	**16**	0.21
Prog. SF08.06	**12.6**	2.84	0.161	**0.74**	**0.26**	**1.03**	0.53	**16**	0.21
***l.s.d*$_{0.05}$**	*0.386*			*0.035*	*0.012*	*0.032*	*0.035*	*0.638*	
GM	12.5	2.84	0.162	0.76	0.26	1.02	0.52	16	0.21
SE	0.463	0.073	0.0045	0.04	0.0140	0.038	0.042	0.77	0.006
CV %	3.7	2.6	2.8	5.5	5.5	3.7	8.0	4.8	2.9

Table 25. Trial 155 effects of fertilizer treatments and progenies on rachis nutrient concentrations in 2019, *p* values <0.05 shown in bold.

Source	Rachis nutrient contents (% DM)					
	Ash	N	P	K	Mg	Ca
Fert. Level 1	5.32	0.36	0.113	**1.64**	**0.10**	**0.52**
Fert. Level 2	5.67	0.38	0.116	**1.81**	**0.11**	**0.57**
Fert. Level 3	5.48	0.38	0.115	**1.61**	**0.10**	**0.56**
Fert. Level 4	5.52	0.37	0.119	**1.71**	**0.11**	**0.58**
				0.111	*0.007*	*0.031*
Prog. SF46.01	5.30	**0.36**	**0.109**	**1.69**	0.10	0.53
Prog. SF21.11	5.77	**0.39**	**0.110**	**1.80**	0.11	0.57
Prog. SF108.07	5.55	**0.36**	**0.111**	**1.65**	0.10	0.58
Prog. SF08.06	5.36	**0.37**	**0.132**	**1.64**	0.11	0.56
***l.s.d*$_{0.05}$**		*0.019*	*0.0069*	*0.111*		
GM	5.50	0.37	0.116	1.69	0.11	0.56
SE	0.434	0.023	0.0083	0.134	0.009	0.037
CV %	7.9	6.3	7.2	7.9	8.5	6.7

Flowering monitoring

Flowering monitoring data from June 2016 to May 2020 data is presented here. Reporting of weeks for flowering started a month after field planting and the first flowers coming into anthesis were recorded 27 weeks (June 2016) after field planting. Ablation was done from week 60 to week 63.

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. There is a general decrease in the number of female flowers from week 185 to week 208. 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 208 (48 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 % from week 60 to week 162. After week 162 there were changes in the ratio due to changes in the number of male and female flowers at anthesis however the ratio was generally above 90 %.

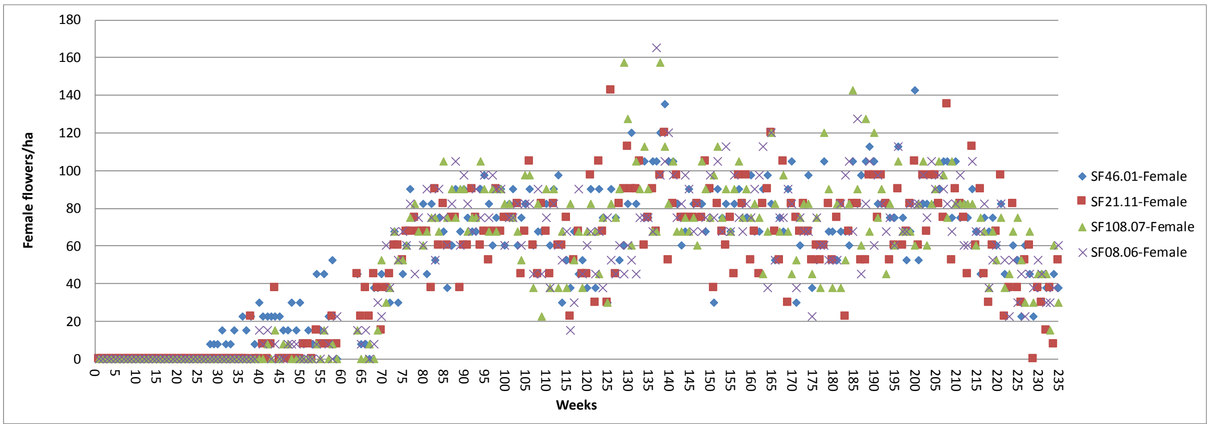


Figure 4. Trial 155 number of female flowers/ha at anthesis from June 2016 to May 2020.

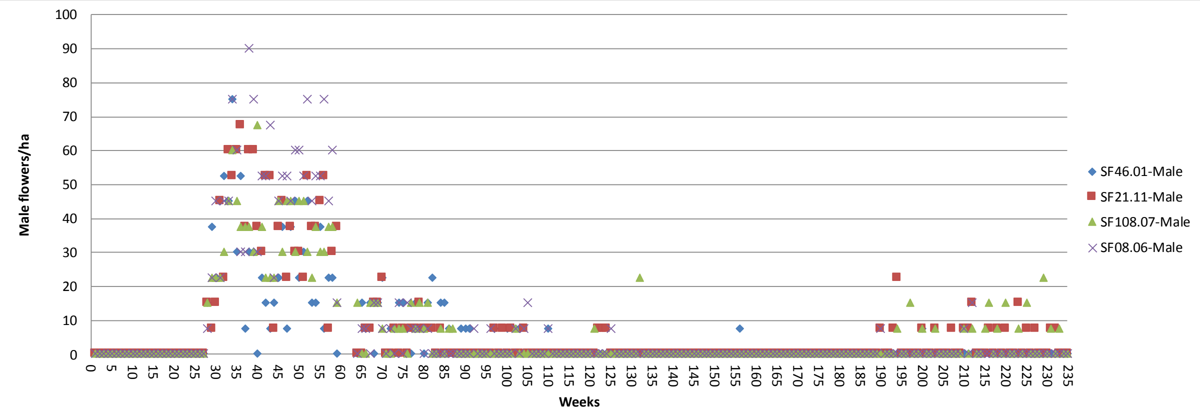


Figure 5. Trial 155 number of male flowers/ha at anthesis from June 2016 to May 2020.

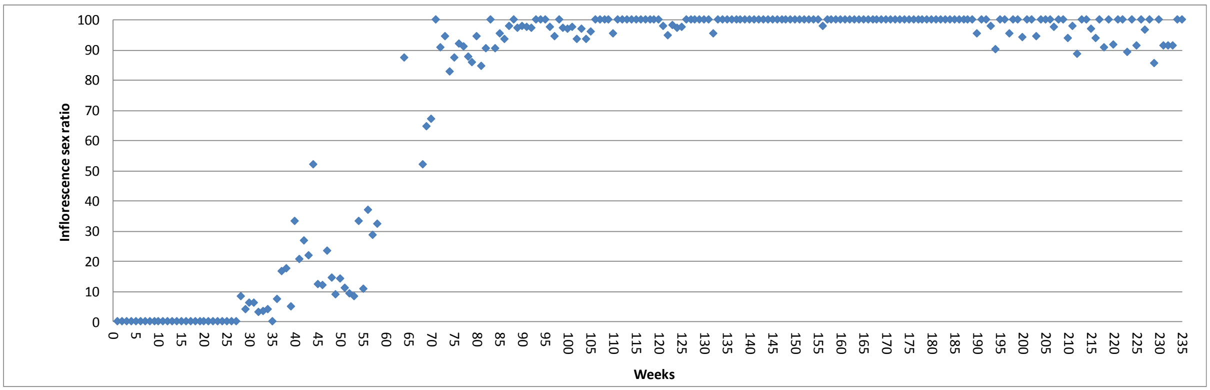


Figure 6. Trial 155 mean sex ratio for the progenies from June 2016 to May 2020.

B.1.3.5. *Conclusion*

There were differences in the yield components and leaf tissue nutrient contents for the different progenies. The sex ratio remained at greater than 90%. The trial is recommended to continue.

B.1.4. Trial 157 Ground Cover Scoring under oil palm stands

By: Thomas Maiap

B.1.4.1. *Summary*

Good ground cover is important to minimise soil erosion and contributes to sustainably managing oil palm systems. A standard method of assessing ground cover is essential for monitoring ground cover and this trial was established to develop a system that can be used by the industry to monitor ground cover under the palms. A scoring method is used here. Results of the first 18 months of scoring showed total cover and legume cover reach 80 – 100 % cover within six months cover but decline thereafter due to management practices. Ground cover monitoring trial will continue.

B.1.4.2. *Introduction*

One of the important components of a sustainable oil palm system is maintaining a good ground cover. Ground cover is important for the conservation of soil. Surface soil erosion under the oil palm stands is inevitable especially during oil palm development and replanting where most of the above ground vegetation is removed. Ground cover minimises soil erosion and retains much of the organic matter and the important nutrients required by plants stored in the top soil.

Having a standard scoring method for estimating total cover and legume cover to an acceptable accuracy for the purpose of estimating carbon-nitrogen balance and erosion of bare areas is important to sustainably manage oil palm systems. Total cover and legume cover scoring was done to determining a standard scoring method. Trial information is presented in Table 26.

Table 26. Trial 157 Kumbango field background information.

Trial number	**157**	**Company**	**Kumbango Plantation - Division 1**
Estate	Kumbango Div. 1	Block No.	Kumbango MU 01A – A7
Planting Density	120	Soil Type	Volcanic
Pattern	Triangular	Drainage	Freely draining
Date planted	June 2018	Topography	Flat
Age after planting	12 Months	Altitude	
Scoring Start	June 2018	Previous Land-use	Oil palm 3rd generation
		Area under trial (ha)	18.6 Ha
Progeny	Known*	Assistant Agronomists in charge	Thomas Maiap and Joel Ben
Planting material	Dami D x P		

B.1.4.3. *Method and materials*

Site selection and field setting

A replanted block was selected at Kumbango Plantation, Division One in mid-2018 during replanting. Five permanent scoring points were selected across the 18.6 ha field as a representation of the entire field.

Scoring of the Cover

The cover scoring was done by using a set of given scores to determine the percentage of the ground area in 1m^2 quadrats covered by vegetation (Table 27). The quadrats were placed at the different management zones under oil palm stands which included the frond pile (FP), the weeded circle (WC), harvest path (HP), and between zones (BZ).

Table 27. Trial 157 scoring criteria for the total and legume cover.

% of total cover	**Legume cover as % of total cover**			
0-5 (0.1)	0-25 (1)	25-50 (2)	50-75 (3)	75-100 (4)
5-20 (0.6)	0-25 (1)	25-50 (2)	50-75 (3)	75-100 (4)
20-40 (2)	0-25 (1)	25-50 (2)	50-75 (3)	75-100 (4)
40-60 (3)	0-25 (1)	25-50 (2)	50-75 (3)	75-100 (4)
60-80 (4)	0-25 (1)	25-50 (2)	50-75 (3)	75-100 (4)
80-100 (5)	0-25 (1)	25-50 (2)	50-75 (3)	75-100 (4)

Capturing of images

In addition to scoring the cover, digital images of each scoring points were taken in a clockwise direction. The camera was mounted on a tripod at a fixed position which was a meter from the palm base adjacent to the management zones where quadrats were placed for scoring. The quadrats placed at different zones were also captured. The images were kept for monitoring the development trend of the cover.

Data collection
Scoring of the cover was done on a weekly basis. Data collected includes the scoring of the legume cover (any legume type) present and the total cover (overall vegetation) using the set of scores.

B.1.4.4. *Results and discussion*

Ground cover development at zones

The total ground cover across all zones was initially low in June 2018 after land clearing with a mean of 0.9 (0-5%) (Figure 7). The mean cover increased with time to 4.77 (80-100%) in December 2018, after six months. The total cover in the BZ was higher than the other zones throughout the six months. The fall in score in the BZ in November was due to weeding upkeep around the palms. A similar trend is observed with legume cover crop (Figure 8).

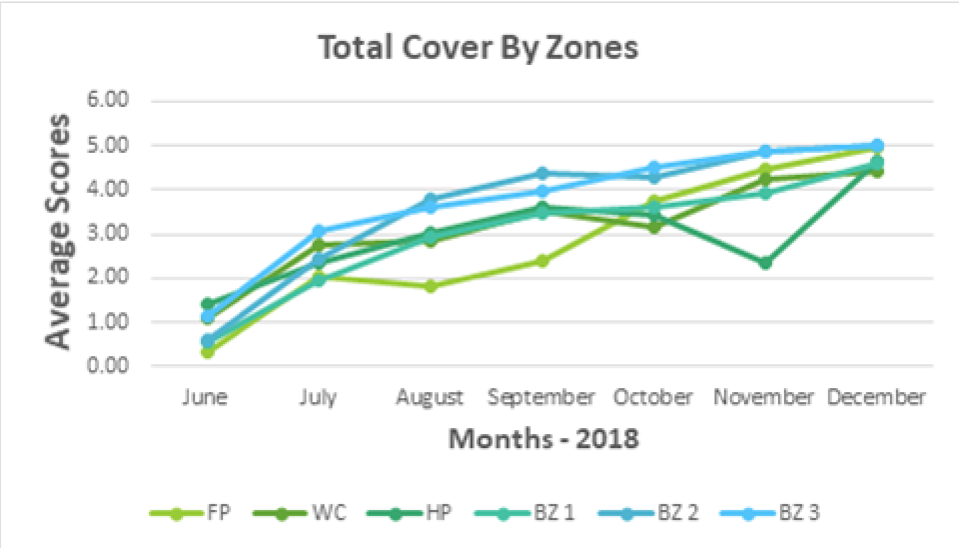


Figure 7. Trial 157 mean total cover scores from June to December 2018 (first six months).

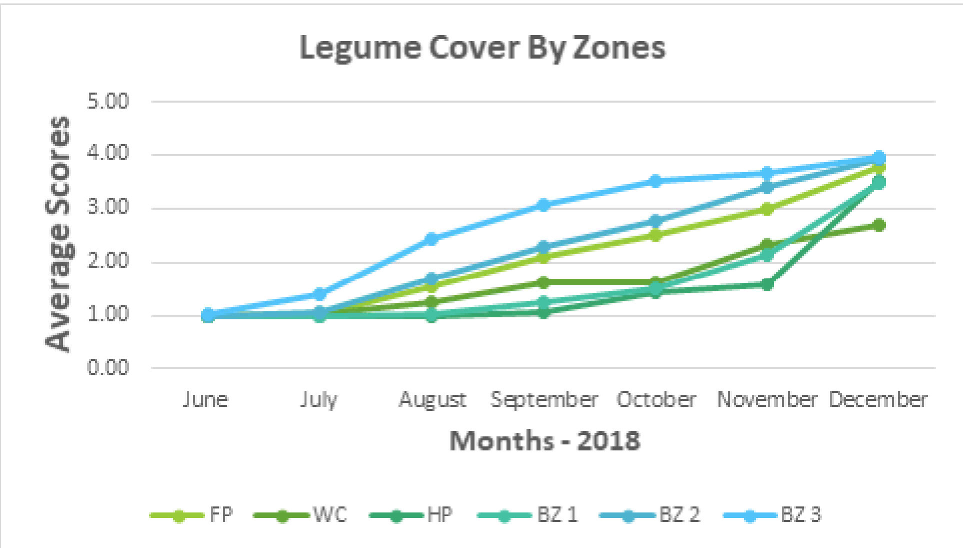


Figure 8. Trial 157 mean legume cover scores from June to December 2018 (first six months).

Ground cover in 2019, 7-18 months

The data from 2019 represents the phase after the first 6 months in 2018. After the total cover reached 80-100 % in 2018 (Figure 9), the overall cover score fell to 2 (20-40%) and steadily increased to between 60-80% at the end of the year. This was most probably due to weeding management practices under the palms. Them legume cover fell steadily in all zones and did not increase during the second half of the year (Figure 10). This was probably due to weeding management and also probably other non-legume plants becoming dominant under the palms.

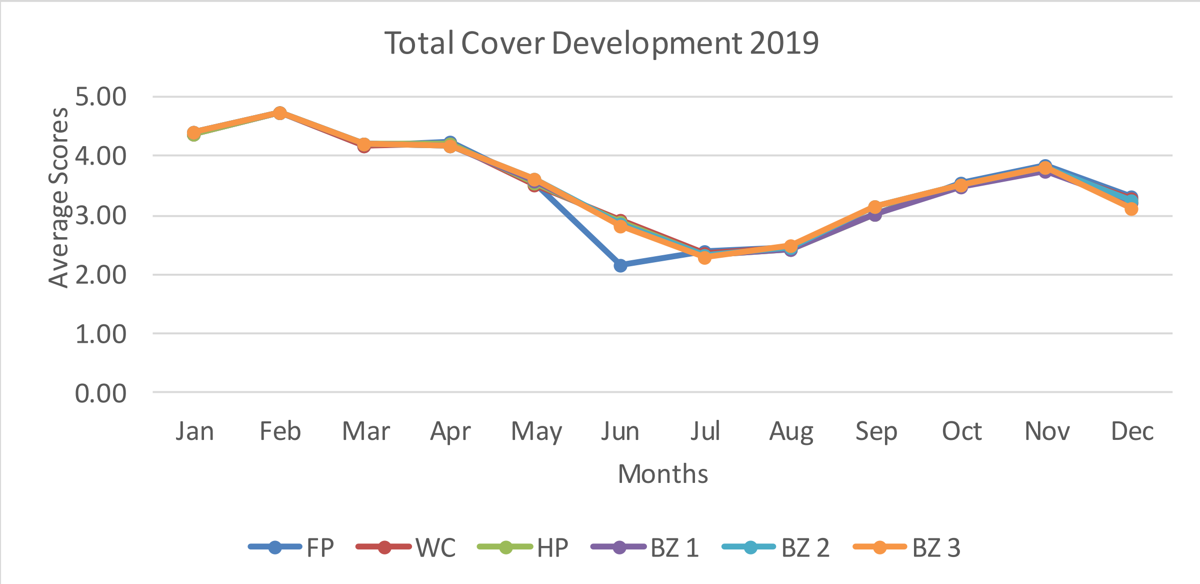


Figure 9. Trial 157 mean total cover scores in from all management zones under the palms 2019.

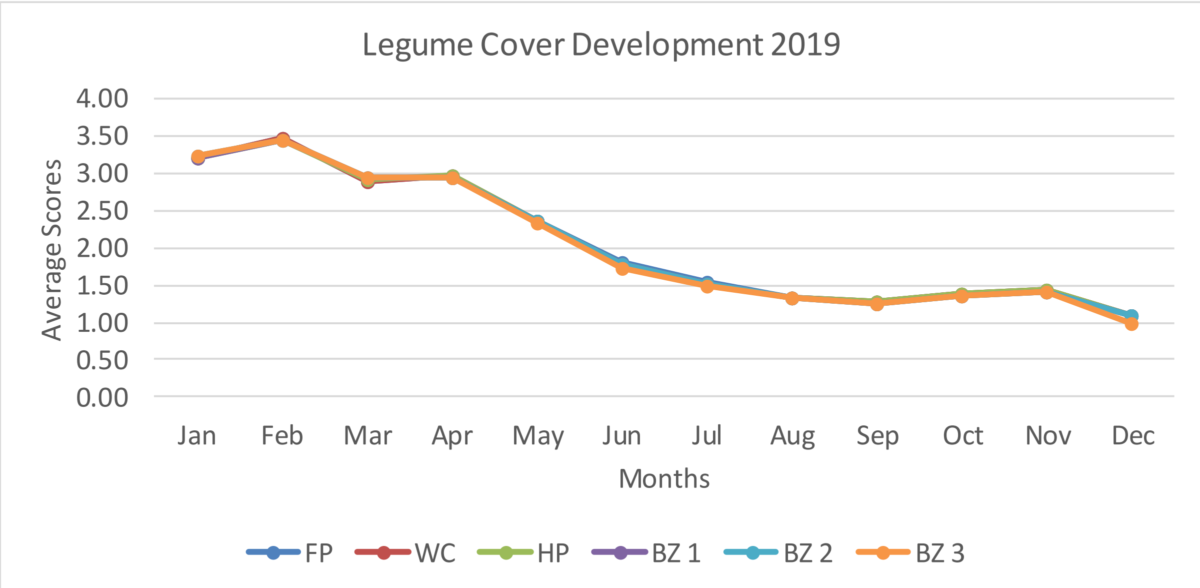


Figure 10. Trial 157 mean legume cover scores in from all management zones under the palms 2019.

B.1.4.5. *Conclusion*

Total cover and legume cover reach 80 – 100 % cover within six months cover but decline thereafter due to management practices. Ground cover monitoring trial will continue.

B.1.5. Trial 160: NPKMg Fertiliser Trial on Volcanic soils, Bebere Plantations

(RSPO 4.2, 4.3, 4.6, 8.1)

B.1.5.1. *Summary*

The NPKMg trial is aimed to provide information for fertilizer recommendations on the volcanic soils in WNB. Urea and kieserite increased yield by 1-1.5 t/ha/yr. The trial is recommended to continue.

B.1.5.2. *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 28.

Table 28. 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.1.5.3. *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 29). 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 29. 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.1.5.4. *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 and Table). 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 30. Trial 160 main effects (*p values*) of fertilizer treatments on FFB yield (t/ha) and its components in 2019 and July 2017-December 2019.

Source	2019			July 2017-December 2019		
	FFB yield	BNO	SBW	FFB yield	BNO	SBW
Urea	**0.037**	0.708	**0.008**	0.161	0.307	0.112
MOP	0.725	0.350	0.771	0.707	0.220	0.679
TSP	0.920	0.715	0.748	0.364	0.102	0.642
Kieserite	**0.026**	**0.025**	0.927	0.168	0.181	0.925
Urea x MOP	0.100	0.192	0.337	0.173	0.535	0.207
Urea x TSP	0.707	0.890	0.456	0.475	0.791	0.528
Urea x Kieserite	0.200	0.495	0.369	0.167	0.647	0.067
MOP x TSP	0.234	0.911	0.106	0.455	0.794	0.177
MOP x Kieserite	0.948	0.971	0.984	0.889	0.741	0.932
TSP x Kieserite	0.134	0.472	0.365	0.097	0.049	0.995
CV %	5.7	5.1	4.9	6.0	4.9	4.6

p values <0.05 shown in bold

Table 31. Trial 160 effects of fertilizers on FFB yield and yield components in 2019 and July 2017-December 2019.

Treatments	2019			July 2017-December 2019		
	FFB yield (t/ha)	BNO/ha	SBW(kg)	FFB yield (t/ha)	BNO/ha	SBW(kg)
Urea-1	**28.5**	4303	**6.5**	15.9	2993	4.8
Urea-2	**30.1**	4368	**6.8**	16.5	3036	4.9
Urea-3	**29.7**	4281	**6.8**	16.2	2939	4.9
Urea-4	**30.1**	4303	**7.0**	16.6	3009	4.9
l.s.d$_{0.05}$	*1.20*		*0.24*			
MOP-1	29.8	4336	6.8	16.4	3014	4.9
MOP-2	29.5	4339	6.7	16.2	2994	4.8
MOP-3	29.9	4353	6.8	16.4	3037	4.9
MOP-4	29.3	4227	6.8	16.1	2931	4.9
TSP-1	29.6	4324	6.8	16.4	3025	4.9
TSP-2	29.6	4304	6.8	16.2	2963	4.9
l.s.d$_{0.05}$						
Kieserite-1	**29.1**	**4250**	6.8	16.1	2969	4.9
Kieserite-2	**30.1**	**4378**	6.8	16.5	3019	4.9
l.s.d$_{0.05}$	*0.85*	*111.4*				
GM	29.6	4314	6.8	16.3	2994	4.9
SE	1.68	219	0.33	0.98	146.8	0.22
CV%	5.7	5.1	4.9	6.0	4.9	4.6

Effects of treatments on leaf nutrient concentrations

All fertilizer treatments affected various nutrient contents in the leaflets and rachis tissues in 2019 (Table 32 and 33). Urea increased leaflet N, and Cl but lowered Mg contents and increased rachis N contents (Table 34 and Table 35). MOP increased leaflet Cl contents and increased rachis Ash, P, K, Mg and Ca contents. TSP increased leaflet Ash and Cl contents. Kieserite increased leaflet Mg but lowered Ca contents. In the rachis, kieserite decreased P contents but increased Mg contents.

K appears to be required in this environment.

Table 32. Trial 160 effects (*p values*) of treatments on leaflet nutrient contents in 2019.

Source	Leaflet nutrient contents								
	Ash	N	P	K	Mg	Ca	Cl	B	S
Urea	0.455	**0.013**	0.115	0.918	**0.021**	0.129	**0.010**	0.472	0.737
MOP	0.689	0.384	0.585	0.190	0.201	0.273	**<0.001**	0.518	0.961
TSP	**0.050**	0.731	0.654	0.507	0.090	0.054	**0.045**	0.435	0.756
Kieserite	0.504	0.099	0.929	0.322	**<0.001**	**0.001**	0.372	0.574	0.355
Urea x MOP	0.649	0.930	0.576	0.964	0.855	0.965	0.932	0.747	0.642
Urea x TSP	0.688	0.430	0.969	0.343	0.776	0.555	0.770	0.838	0.279
Urea x Kieserite	0.709	0.068	0.097	0.977	0.386	0.943	0.089	0.398	0.461
MOP x TSP	0.073	0.616	0.507	0.816	0.960	0.377	0.643	0.922	0.737
MOP x Kieserite	0.653	**0.026**	**0.026**	0.612	0.542	0.869	0.286	0.366	0.783
TSP x Kieserite	0.504	0.504	0.204	0.580	0.042	0.793	0.643	0.488	0.355
CV %	4.0	2.7	2.6	5.8	5.8	5.3	8.4	7.1	4.0

Table 33. Trial 160 effects (*p values*) of treatments on rachis nutrient contents in 2019.

Source	**Rachis nutrient contents**					
	Ash	N	P	K	Mg	Ca
Urea	0.738	**0.022**	0.376	0.568	0.448	0.602
MOP	**0.003**	0.168	**<0.001**	**0.001**	**0.040**	**0.001**
TSP	0.333	0.887	0.386	0.366	0.622	0.882
Kieserite	0.384	0.670	**0.005**	0.329	**0.003**	0.108
Urea x MOP	0.329	0.053	0.102	0.853	0.152	0.152
Urea x TSP	0.397	0.074	0.632	0.172	0.913	0.448
Urea x Kieserite	0.775	0.648	0.482	0.873	0.325	0.795
MOP x TSP	0.147	0.185	0.054	0.111	0.122	0.211
MOP x Kieserite	0.116	**<0.001**	0.546	**0.039**	**0.029**	0.063
TSP x Kieserite	0.097	0.478	0.430	0.815	0.869	0.151
CV %	7.7	5.1	8.8	8.2	8.1	8.1

Table 34. Trial 160 effects of treatments on leaflet tissue nutrient concentrations in 2019, *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	**2.77**	0.162	0.77	**0.24**	0.97	**0.46**	15.7	0.20
Urea-2	12.4	**2.77**	0.162	0.77	**0.24**	0.98	**0.47**	16.3	0.20
Urea-3	12.5	**2.85**	0.165	0.76	**0.23**	1.00	**0.51**	15.8	0.20
Urea-4	12.2	**2.76**	0.162	0.76	**0.23**	0.96	**0.47**	15.8	0.20
***l.s.d*$_{0.05}$**		*0.055*			*0.010*		*0.029*		
MOP-1	12.4	2.81	0.162	0.78	0.24	0.96	**0.44**	16.1	0.20
MOP-2	12.3	2.79	0.164	0.77	0.24	0.97	**0.45**	16.2	0.20
MOP-3	12.3	2.78	0.163	0.76	0.24	1.00	**0.48**	15.8	0.20
MOP-4	12.2	2.77	0.162	0.75	0.23	0.99	**0.53**	15.6	0.20
***l.s.d*$_{0.05}$**							*0.029*		
TSP-1	**12.2**	2.79	0.163	0.77	0.23	0.97	**0.46**	15.8	0.20
TSP-2	**12.4**	2.79	0.162	0.76	0.24	0.99	**0.49**	16.0	0.20
***l.s.d*$_{0.05}$**	*0.251*						*0.020*		
Kieserite-1	12.4	2.77	0.163	0.76	**0.23**	**1.00**	0.47	16.0	0.20
Kieserite-2	12.3	2.80	0.163	0.77	**0.24**	**0.96**	0.48	15.9	0.20
***l.s.d*$_{0.05}$**					*0.007*	*0.026*			
GM	12.3	2.79	0.163	0.77	0.24	0.98	0.48	16	0.20
SE	0.494	0.076	0.0042	0.045	0.014	0.052	0.040	1.123	0.008
CV%	4.0	2.7	2.6	5.8	5.8	5.3	8.4	7.1	4.000

Table 35. Trial 160 effects of treatments on rachis tissue nutrient concentrations in 2019, *p values* <0.05 shown in bold.

Treatment	Rachis nutrient contents (%DM)					
	Ash	N	P	K	Mg	Ca
Urea-1	5.11	**0.33**	0.109	1.59	0.095	0.50
Urea-2	5.20	**0.34**	0.105	1.59	0.093	0.52
Urea-3	5.25	**0.35**	0.105	1.65	0.093	0.52
Urea-4	5.13	**0.35**	0.109	1.61	0.091	0.52
l.s.d$_{0.05}$		*0.013*				
MOP-1	**4.95**	0.33	**0.101**	**1.53**	**0.089**	**0.48**
MOP-2	**5.01**	0.34	**0.104**	**1.57**	**0.091**	**0.51**
MOP-3	**5.27**	0.34	**0.108**	**1.62**	**0.094**	**0.53**
MOP-4	**5.46**	0.35	**0.116**	**1.73**	**0.097**	**0.54**
l.s.d$_{0.05}$	*0.286*		0.0068	*0.095*	*0.0054*	*0.030*
TSP-1	5.22	0.34	0.106	1.63	0.092	0.52
TSP-2	5.12	0.34	0.108	1.60	0.093	0.51
l.s.d$_{0.05}$						
Kieserite-1	5.21	0.34	**0.111**	1.63	**0.090**	0.52
Kieserite-2	5.13	0.34	**0.104**	1.59	**0.096**	0.51
l.s.d$_{0.05}$			*0.0048*		*0.0038*	
GM	5.2	0.34	0.107	1.61	0..093	0.52
SE	0.398	0.017	0.094	0.132	0.0075	0.042
CV%	7.7	5.1	8.8	8.2	8.1	8.1

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.1.5.5. *Conclusion*

Urea and kieserite increased FFB yield by 1-1.5 t/ha. Fertilisers also affected various nutrient contents in the leaflets and rachis. The trial is recommended to continue.

2. HARGY OIL PALMS – BIALLA

Paul Simin, Andy Ullian and Peter Mupa

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 36. Formal recording commenced in Dec 2014 and treatment application started in 2015 (4 years after planting).

Table 36. 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 m asl
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*

2019 was the fifth year of treatment application and data collection and data analysis indicated no significant yield responses to the fertilizer treatments in 2019 (p=0.587) and combined yield for 2017-2019 (p=0.808). The estimated yield parameters for 2019 are presented in Table 37. The estimated yield at nil fertilizers in 2019 was 24.4 t/ha/year. The FFB yield range was 22.5-30.0 t/ha/year and 29.5-34.6 t/ha/year in 2019 and 2017-2019 respectively. There was a fall in mean FFB yield from 36.2 t/ha/yr in 2018 to 26.1 t/ha/yr in 2019.

Table 37. Trial 217 estimated yield parameters from regression analysis for 2019.

Parameter	estimate	s.e.	t(14)	t pr.
Constant	24.37	4.99	4.88	p<0.001
AC	0.44	1.67	0.27	0.794
TSP	-0.38	1.6	-0.24	0.817
MOP	6.61	4.01	1.65	0.121
AC squared	-0.088	0.158	-0.55	0.588
TSP squared	-0.115	0.228	-0.51	0.621
MOP squared	-2.47	1.42	-1.74	0.105
AC x MOP	0.232	0.323	0.72	0.484
AC x TSP	-0.623	0.807	-0.77	0.453
AC x TSP X MOP	-0.013	0.182	-0.07	0.942

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. 2019 was the fifth 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 deepens 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 38.

Table 38. 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. *Materials and method*

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 39.

Table 39. 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, and kieserite did not affect yield and yield components in 2019 and 2017-2019 except TSP (Table 40). TSP increased FFB yield by 2 tonnes in 2019 and 1 tonne in 2017-2019 (Table 41). The mean FFB yield increased from 25.6 t/ha in 2018 to 28.3 t/ha in 2019.

Table 40. Trial 220 main effects (*p values*) of fertilizer treatments on FFB yield (t/ha) and its components in 2019 and July 2017-December 2019, *p values* <0.05 shown in bold.

Source	2019			2017-2019		
	FFB yield	BNO	SBW	FFB yield	BNO	SBW
Urea	0.672	0.922	0.456	0.624	0.461	0.287
MOP	0.716	0.982	0.231	0.291	0.598	0.385
TSP	**0.009**	0.186	**0.001**	**0.010**	0.168	**0.005**
Kieserite	0.851	0.532	0.178	0.965	0.322	0.156
Urea x MOP	0.648	0.663	0.868	0.828	0.775	0.878
Urea x TSP	0.027	**0.042**	0.616	0.075	0.119	0.816
Urea x Kieserite	0.688	0.657	0.290	0.929	0.968	0.599
MOP x TSP	0.579	0.686	0.261	0.560	0.370	0.922
MOP x Kieserite	0.450	0.284	0.311	0.324	0.209	0.539
TSP x Kieserite	0.798	0.726	0.982	0.538	0.450	0.811
CV %	11.3	11.1	4.6	8.1	7.2	4.0

Table 41. Trial 220 main effects of fertilizer treatments on FFB yield (t/ha) and its components in 2019 and 2017-2019.

Treatments	2019			2017-2019		
	FFB yield (t/ha)	BNO/ha	SBW(kg)	FFB yield (t/ha)	BNO/ha	SBW(kg)
Urea-1	28.1	1931	14.4	29.6	2104	14.0
Urea-2	29.2	1959	14.7	30.1	2100	14.3
Urea-3	28.2	1929	14.5	29.5	2094	14.0
Urea-4	27.8	1907	14.4	29.0	2030	14.3
MOP-1	27.9	1919	14.2	29.1	2064	14.1
MOP-2	28.0	1922	14.5	29.0	2069	14.0
MOP-3	28.5	1940	14.5	29.6	2068	14.3
MOP-4	29.1	1945	14.7	30.5	2126	14.3
TSP-1	**27.2**	1895	**14.2**	**28.7**	2056	**14.0**
TSP-2	**29.5**	1968	**14.8**	**30.4**	2108	**14.4**
l.s.d$_{0.05}$	*1.63*		*0.34*	*1.22*		*0.29*
Kieserite-1	28.4	1915	14.6	29.5	2063	14.3
Kieserite-2	28.3	1949	14.4	29.6	2101	14.1
GM	28.3	1932	14.5	29.6	2082	14.1
SE	3.21	214.2	0.67	2.4	149.6	0.57
CV%	11.3	11.1	4.6	8.1	7.2	4.0

Effects of treatments on leaf nutrient concentrations

The effects (*p values*) of the fertilizers on leaflet and rachis nutrient contents in 2019 are presented in Table 42 and Table 43 respectively. Urea affected leaflets Cl contents only. MOP affected leaflet Mg ($p=0.036$), Ca ($p<0.001$) and Cl ($p<0.001$) and rachis Ash ($p=0.001$), K ($p<0.001$) and Ca ($p=0.038$) contents. TSP affected leaflet N ($p=0.031$), P ($p<0.001$) and Mg ($p=0.035$). In the rachis, TSP affected all the nutrient contents. Kieserite affected leaflet Mg and Ca contents and rachis Mg contents.

Urea increased leaflet Cl contents (Table 44). MOP increased leaflet Cl and rachis K and Ca contents but lowered Mg contents in the leaflets and rachis (Table 45). TSP increased leaflet N, P and Mg contents and all rachis nutrient contents. Kieserite increased leaflet and rachis Mg contents but decreased leaflet Ca contents. The results suggested K and P apart from N are limiting nutrients in this environment. There was also a very strong interaction between Urea and MOP on leaflet Cl contents. MOP increased leaflet Cl contents but the increase was further enhanced by Urea fertilisers. Note there is no Nil Urea plot in the design.

Table 42. Trial 220 effects (*p values*) of treatments on leaflet nutrient contents in 2019.

Source		Ash	N	P	K	Mg	Ca	Cl	B	S
Urea	0.071	0.781	0.702	0.537	0.783	0.956	**<0.001**	0.316	0.827	0.071
MOP	0.360	0.060	0.064	0.467	**0.036**	**<0.001**	**<0.001**	0.143	0.405	0.360
TSP	0.249	**0.031**	**<0.001**	0.641	**0.035**	0.818	0.741	0.749	0.213	0.249
Kieserite	0.702	0.917	0.253	0.439	**0.016**	**0.020**	0.459	0.714	0.857	0.702
Urea x MOP	0.236	0.694	0.913	0.114	0.805	0.357	**<0.001**	0.557	0.459	0.236
Urea x TSP	0.587	**0.024**	0.186	**0.048**	0.346	0.751	0.474	0.058	0.368	0.587
Urea x Kieserite	0.736	0.280	0.555	0.394	**0.035**	0.819	0.191	0.414	0.303	0.736
MOP x TSP	0.023	0.147	0.310	0.956	0.371	0.236	0.125	0.220	0.446	0.023
MOP x Kieserite	0.842	0.809	0.971	0.488	0.126	0.560	0.411	0.361	0.992	0.842
TSP x Kieserite	0.951	0.053	0.530	0.756	0.542	0.276	**0.031**	0.784	0.590	0.951
CV %	4.6	2.3	3.2	4.6	8.4	4.1	6.1	8.7	3.6	4.6

Table 43. Trial 220 effects (*p values*) of treatments on rachis nutrient contents in 2019.

Source	Ash	N	P	K	Mg	Ca
Urea	0.796	0.934	0.802	0.857	0.324	0.507
MOP	**<0.001**	0.622	0.056	**<0.001**	0.736	**0.038**
TSP	0.351	**0.023**	**<0.001**	**0.006**	**<0.001**	**0.003**
Kieserite	0.915	0.889	0.987	0.982	**0.007**	0.765
Urea x MOP	0.586	0.136	0.668	0.896	**0.012**	0.417
Urea x TSP	0.503	**0.015**	0.758	0.461	0.607	0.253
Urea x Kieserite	0.087	**0.015**	**0.019**	0.202	**0.008**	**0.032**
MOP x TSP	0.280	0.548	0.494	0.794	0.607	0.533
MOP x Kieserite	0.244	0.411	0.669	0.433	**0.011**	0.156
TSP x Kieserite	0.122	0.381	0.573	0.062	0.347	0.160
CV %	9.8	8.8	17.6	9.7	10.5	11.0

Table 44. Trial 220 effects of treatments on leaflet tissue nutrient concentrations in 2019, 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	14.14	2.56	0.147	0.69	0.17	1.18	**0.46**	19	0.19
Urea-2	13.76	2.57	0.148	0.69	0.17	1.18	**0.49**	19	0.19
Urea-3	13.65	2.58	0.148	0.69	0.17	1.18	**0.51**	18	0.19
Urea-4	13.57	2.57	0.148	0.68	0.17	1.17	**0.52**	18	0.19
l.s.d$_{0.05}$							*0.022*		
MOP-1	13.96	2.56	0.146	0.69	**0.18**	1.13	**0.41**	19	0.19
MOP-2	13.72	2.6	0.150	0.70	**0.17**	1.16	**0.50**	19	0.19
MOP-3	13.58	2.57	0.149	0.69	**0.17**	1.21	**0.52**	19	0.19
MOP-4	13.87	2.54	0.146	0.68	**0.16**	1.21	**0.54**	18	0.19
l.s.d$_{0.05}$					*0.010*	*0.033*	*0.022*		
TSP-1	13.87	**2.55**	**0.145**	0.69	**0.16**	1.18	0.49	19	0.19
TSP-2	13.69	**2.58**	**0.151**	0.69	**0.17**	1.18	0.49	19	0.19
l.s.d$_{0.05}$		*0.03*	*0.0024*		*0.007*				
Kieserite-1	13.75	2.57	0.149	0.69	**0.16**	**1.19**	0.50	19	0.19
Kieserite-2	13.81	2.57	0.147	0.69	**0.17**	**1.16**	0.49	19	0.19
l.s.d$_{0.05}$					*0.007*	*0.03*			
GM	13.8	2.57	0.148	0.69	0.17	1.18	0.49	19	0.19
SE	0.632	0.059	0.0047	0.032	0.014	0.049	0.0301	1.625	0.0070
CV%	4.6	2.3	3.2	4.6	8.4	4.1	6.1	8.7	3.6

Table 45. Trial 220 effects of treatments on rachis tissue nutrient concentrations in 2019, p values <0.05 shown in bold.

Treatments	Rachis nutrient contents (%DM)					
	Ash	N	P	K	Mg	Ca
Urea-1	5.52	0.31	0.085	1.73	0.064	0.59
Urea-2	5.63	0.30	0.087	1.75	0.060	0.59
Urea-3	5.69	0.30	0.090	1.77	0.064	0.61
Urea-4	5.54	0.30	0.088	1.72	0.062	0.62
l.s.d$_{0.05}$						
MOP-1	**5.16**	0.30	0.078	**1.54**	0.061	**0.57**
MOP-2	**5.36**	0.30	0.089	**1.67**	0.062	**0.58**
MOP-3	**5.85**	0.31	0.092	**1.86**	0.062	**0.61**
MOP-4	**6.01**	0.31	0.091	**1.89**	0.064	**0.64**
l.s.d$_{0.05}$	*0.392*			*0.122*		*0.047*
TSP-1	5.66	**0.30**	**0.068**	**1.80**	**0.057**	**0.57**
TSP-2	5.53	**0.31**	**0.107**	**1.68**	**0.067**	**0.63**
l.s.d$_{0.05}$		*0.0140*	*0.0078*	*0.09*	*0.003*	*0.034*
Kieserite-1	5.60	0.30	0.087	1.74	**0.060**	0.60
Kieserite-2	5.59	0.30	0.087	1.74	**0.065**	0.60
l.s.d$_{0.05}$					*0.003*	
GM	5.60	0.3	0.087	1.74	0.060	0.600
SE	0.546	0.027	0.0154	0.169	0.007	0.066
CV%	9.8	8.8	17.6	9.7	10.5	11.0

B.1.7.5. *Conclusion*

Responses to fertilizer treatments continued in the fifth year of fertilizer applications suggesting fertilizer management was important in the environment for high yields in the future. To date only TSP significantly increased FFB yield. The trial is to continue to build up knowledge for fertilizer recommendations.

B.1.8. Trial 221. Nitrogen x Phosphorus x Potassium fertiliser trial on volcanic soils, Hargy Oil Palms

(RSPO 4.2, 4.3, 4.6, 8.1)

B.1.8.1. *Summary*

Selected oil palm progenies were planted throughout the oil palm industry for fertilizer trials to generate information for fertilizer recommendations. Measured yield and vegetative parameters increased with time. The sex ratio increased with time and remained above 90%.

B.1.8.2. *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. Kera Kera Plantations is on volcanic ash and colluvial materials derived soils and is the major soil type on the slope areas. This trial is aimed to provide information for fertiliser recommendations in Hargy Oil Palms and other neighbouring areas with similar soil and climatic conditions. Trial information is presented in Table 46.

Table 46. Trial 221 background information.

Trial number	221	Company	Hargy Oil Palms
Plantation	Hargy	Block no.	Division 3, Field 9
Planting density	128 palms/ha	Soil type	Volcanic ash soil
Pattern	Triangular	Drainage	Freely Draining
Date planted	July 2017	Topography	Flat
Age after planting	2 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	Andy Ullian and Peter Mupa
Planting material	Dami DxP		

B.1.8.1. *Materials and 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 84 plots were planted.

In addition to the 84 plots, four plots of single progenies were planted, bringing the total number of plots to 88 plots. The four additional plots were to be used for flower monitoring for three of the progenies. Weekly recording of male and female flowers at anthesis started in March 2018, 7 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

Yield recording started August 2019. Frond length and rachis thickness and width were measured on frond 3 in August 2017 straight thereafter planting. Later measurements were done on frond 17. Full frond measurements started in March 2019 on frond 17.

B.1.8.2. *Results and discussion*

Yield and yield components

Summarised yield data from August 2019 to April 2020 is presented in Table 47. Monthly yield started at 0.6 t/ha at month 24 after planting and reached 2.14 t/ha at month 32. The increase was due to increase in bunch numbers and single bunch weight.

Table 47. Trial 221 mean yield data from August 2019 (month 24) to April 2020 (month 32).

Parameters	Age in months after planting								
	24	25	26	27	28	29	30	31	32
Mean FFB yield (t/ha)	0.60	0.82	0.97	1.06	1.19	1.69	1.16	2.25	2.14
Mean BNO/ha	185	236	261	290	346	429	284	394	334
Mean SBW (kg)	3.3	3.5	3.8	3.8	3.6	4.1	4.2	5.9	6.5

Vegetative measurements

Mean frond area and leaf area index are presented in Table 48 and mean PCS and frond length are presented in Table 49. The mean frond area and leaf area index, petiole cross section and frond length increased with time.

Table 48. Trial 221 mean frond area and leaf area index in 2019.

	Frond area (m^2)				Leaf area index		
	Mar-19	Jul-19	Nov-19	Mar-20	Mar-19	Jul-19	Nov-19
Mean	2.8	3.3	4.2	5.7	1.4	1.4	2.1
Std dev	0.3	0.4	0.3	0.6	0.2	0.2	0.3
CV%	10.4	10.6	8.2	10.1	12.8	13.1	12.1
n	88	88	88	88	88	88	88

Table 49. Trial 221 mean petiole cross section and frond length in 2017 and 2019.

	Petiole cross section (cm^2)					Frond length (cm)				
	Aug-17	Mar-19	Jul-19	Nov-19	Mar-20	Aug-17	Mar-19	Jul-19	Nov-19	Mar-20
Mean	1.8	8.5	10.9	12.2	15.1	80.2	255.4	279.4	354.4	477.2
Std dev	0.6	0.8	1.1	1.3	2.0	3.7	11.1	10.6	14.9	49.3
CV%	31.9	9.4	10.4	10.5	12.9	4.6	4.3	3.8	4.2	10.3
n	88	88	88	88	88	88	88	88	88	88

Flower census

The first flowers at anthesis were recorded in March 2018, 35 weeks after field planting. There was no difference between the female flowers for the different progenies at anthesis however the number of flowers increase with time (Figure 11). There was also no difference between male flowers of the different progenies however there was a downward trend after week 33 and remained generally at nil male flowers (Figure 12). The mean sex ratio of the palms increased and remained at greater than 90% (Figure 13).

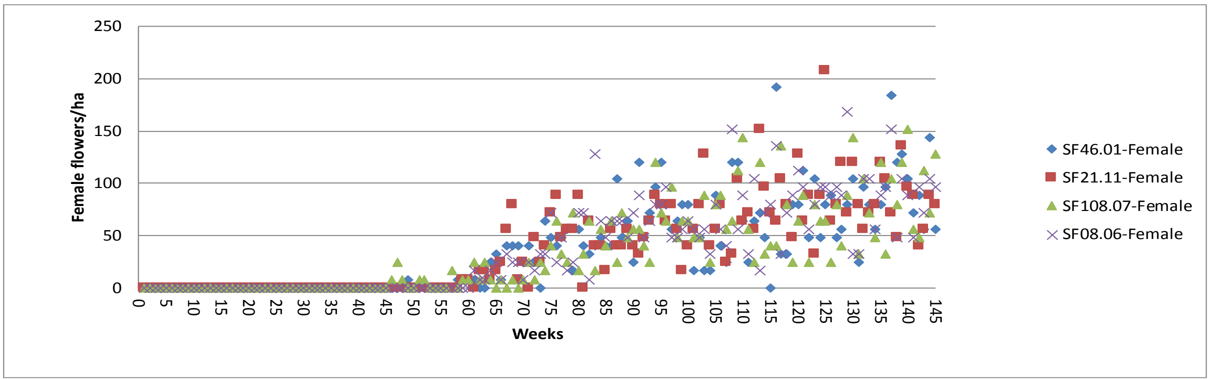


Figure 10. Trial 221 number of female flowers/ha at anthesis from March 2018 to April 2020.

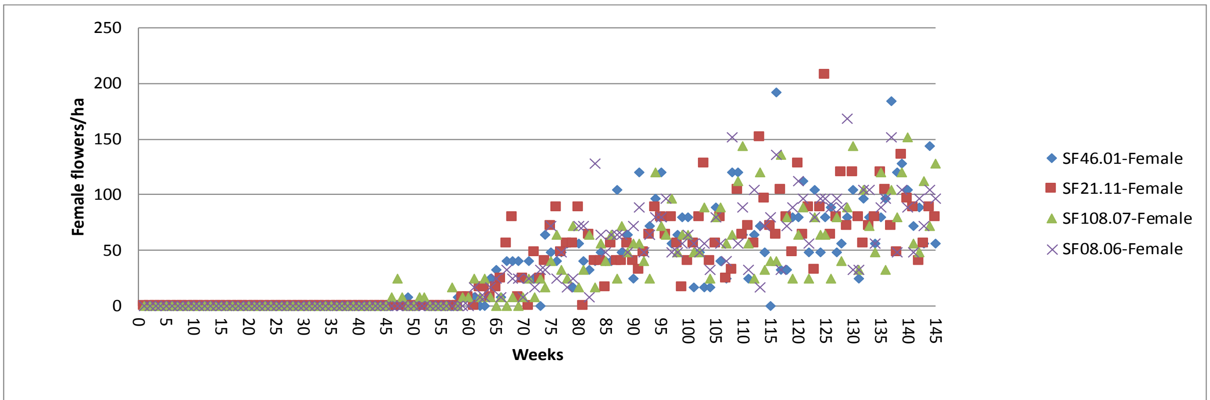


Figure 11. Trial 221 number of male flowers/ha at anthesis from March 2018 to April 2020.

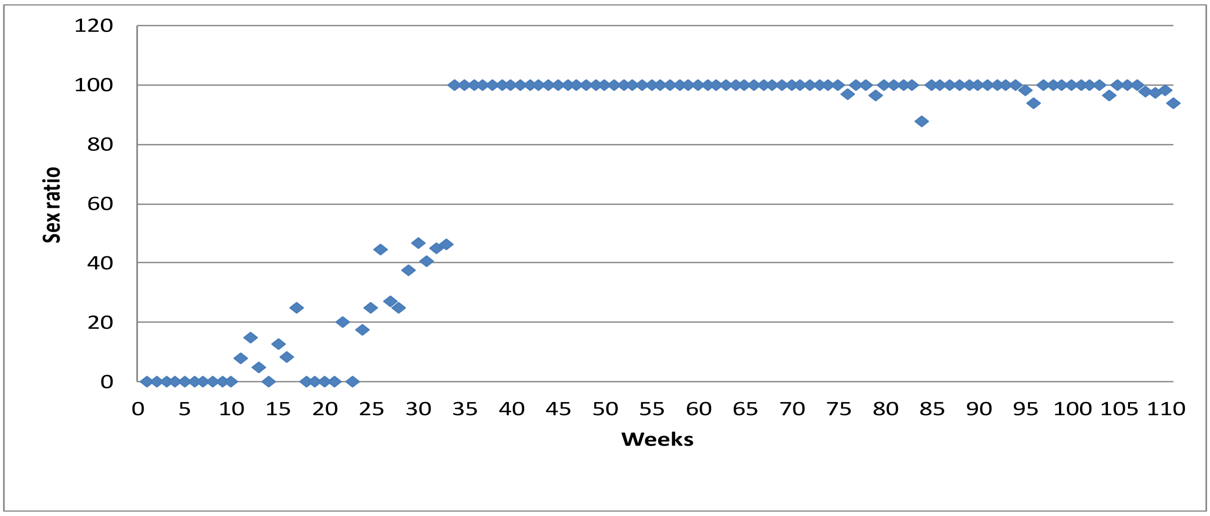


Figure 12. Trial 221 mean inflorescence sex ratio from March 2018 to April 2020.

B.1.8.1. *Conclusion*

Measured yield and vegetative parameters increased with time. The sex ratio increased with time and remained above 90%. The trial to continue.

3. NBPOL, HIGATURU OIL PALM

Andy Ullian and Richard Dikrey

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 2019, 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 50.

Table 50. 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. *Materials and Method*

The Urea x TSP trial was set up as a 3 x 5 factorial arrangement, resulting in 15 treatments (Table 51). 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 51. 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 52 and Table 53. Urea had significant effect on FFB yield, the number of bunches and SBW in 2019 and 2017-2019. In 2019, FFB yield increased by 1.80 t/ha for every kg increase in Urea (Table 54). The average FFB yield decreased from 36.7 t/ha in 2018 to 33.9 t/ha in 2019.

Table 52. Trial 335 effects (*p values*) of treatments on FFB yield and its components in 2019 and 2017-2019

Source	2019			2017-2019		
	FFB yield	BNO	SBW	FFB yield	BNO	SBW
Urea	**<0.001**	**<0.001**	0.095	**<0.001**	**<0.001**	**0.001**
TSP	0.392	0.591	0.458	0.447	0.934	0.832
Urea x TSP	0.630	0.598	0.973	0.448	0.188	0.960
CV %	8.4	8.7	4.9	5.6	6.0	4.3

Table 53. Trial 335 main effects of treatments on FFB yield (t/ha) in 2019 and 2017-2019.

Treatments	2019			2017-2019		
	FFB yield (t/ha)	BNO/ha	SBW (kg)	FFB yield (t/ha)	BNO/ha	SBW (kg)
Urea-1	**31.5**	**1536**	20.6	**31.4**	**1562**	**20.1**
Urea-2	**33.5**	**1605**	21.1	**33.6**	**1610**	**21.0**
Urea-3	**36.6**	**1727**	21.3	**36.9**	**1743**	**21.2**
l.s.d$_{0.05}$	*1.81*	*90.6*		*1.22*	*62.5*	*0.57*
TSP-1	33.4	1602	20.9	33.4	1619	20.7
TSP-2	32.8	1618	20.7	33.4	1634	20.6
TSP-3	34.7	1661	20.9	34.3	1647	20.8
TSP-4	33.8	1579	21.4	34.4	1642	21.0
TSP-5	34.7	1653	21.0	34.3	1650	20.8
GM	33.9	1623	21.0	34.0	1638	20.8
SE	2.84	141.9	1.02	1.91	97.9	0.89
CV %	8.4	8.7	4.9	5.6	6.0	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 2019 and 2017-2019 (Table 52), however a 2-way yield results for 2017-2019 is presented here. FFB yields were greater than 37 t//ha at high N rates and were achieved at TSP-2 and above (Table 54).

Table 54. Trial 335 effect of Urea and TSP (two-way interactions) on FFB yield (t/ha/yr) in 2017-2019.

	TSP-1	TSP-2	TSP-3	TSP-4	TSP-5
Urea-1	32.3	31.0	30.9	31.8	31.1
Urea-2	32.9	32.0	34.2	34.5	34.3
Urea-3	35.1	37.0	37.9	37.0	37.7
Grand mean	34.0		sed=	1.35	

Effects of Urea and TSP treatments on leaf nutrient concentrations

Urea had significant effect on leaflet and rachis N and P, and leaflet S contents (Table 55 and 56). Urea increased leaflet N, P S contents (Table 57). In the rachis, urea increased N contents however lowered the P contents (Table 58). TSP increased rachis P contents. Mean nutrient contents were above the critical nutrient contents.

Table 55. Trial 335 effects (*p values*) of treatments on frond 17 leaflet nutrient concentrations in 2019. *p values* <0.05 are indicated in bold.

Source	Ash	N	P	K	Mg	Ca	Cl	B	S
Urea	0.420	**<0.001**	**0.006**	0.365	0.544	0.243	0.308	0.840	**0.001**
TSP	0.147	0.957	0.060	0.686	0.922	0.176	0.388	0.453	0.458
Urea x TSP	0.069	0.390	0.454	0.236	0.264	0.036	0.846	0.151	0.476
CV%	4.7	3.1	2.3	4.9	7.5	5.7	6.5	11.1	3.0

Table 56. Trial 335 effects (*p values*) of treatments on frond 17 rachis nutrient concentrations in 2019. *p* values <0.05 are indicated in bold.

Source	Ash	N	P	K	Mg	Ca
Urea	0.544	**0.010**	**p<0.001**	0.120	0.447	0.963
TSP	0.812	0.529	**0.006**	0.904	0.472	0.961
Urea.TSP	0.436	0.194	0.715	0.320	0.463	0.195
CV%	9.6	9.8	18.6	9.4	11.5	11.1

Table 57. Trial 335 main effects of treatments on F17 leaflet nutrient concentrations in 2019.

Treatments	Leaflets nutrient contents (% DM except B in mg/kg)								
	Ash	N	P	K	Mg	Ca	Cl	B	S
Urea-1	13.53	**2.26**	**0.146**	0.71	0.27	0.77	0.50	19	**0.18**
Urea-2	13.38	**2.33**	**0.148**	0.70	0.27	0.79	0.49	19	**0.18**
Urea-3	13.65	**2.44**	**0.149**	0.70	0.26	0.77	0.48	19	**0.19**
l.s.d$_{0.05}$		*0.046*	*0.0028*						*0.004*
TSP-1	13.18	2.33	0.145	0.71	0.26	0.78	0.48	20	0.18
TSP-2	13.57	2.35	0.148	0.69	0.27	0.81	0.49	20	0.19
TSP-3	13.42	2.34	0.147	0.71	0.27	0.77	0.48	19	0.18
TSP-4	13.57	2.34	0.149	0.71	0.27	0.77	0.51	19	0.19
TSP-5	13.86	2.35	0.149	0.70	0.27	0.77	0.49	19	0.19
l.s.d$_{0.05}$									
GM	13.5	2.34	0.148	0.70	0.27	0.78	0.49	19	0.18
SE	0.637	0.072	0.0034	0.034	0.020	0.044	0.0320	2.139	0.0060
CV %	4.7	3.1	2.3	4.9	7.5	5.7	6.5	11.1	3.0

Table 58. Trial 335 main effects of treatments on F17 rachis nutrient concentrations in 2019.

Treatments	Rachis nutrient contents (% DM)					
	Ash	N	P	K	Mg	Ca
Urea-1	6.16	**0.29**	**0.267**	1.88	0.11	0.40
Urea-2	6.03	**0.30**	**0.223**	1.79	0.11	0.40
Urea-3	5.96	**0.32**	**0.175**	1.77	0.10	0.39
l.s.d$_{0.05}$		*0.019*	*0.0263*			
TSP-1	5.95	0.30	**0.190**	1.81	0.10	0.40
TSP-2	6.04	0.30	**0.209**	1.81	0.11	0.40
TSP-3	6.2	0.31	**0.218**	1.85	0.10	0.39
TSP-4	5.96	0.31	**0.238**	1.80	0.11	0.39
TSP-5	6.11	0.31	**0.253**	1.78	0.11	0.40
l.s.d$_{0.05}$			*0.034*			
GM	0.05	0.31	0.222	1.81	0.11	0.40
SE	0.58	0.003	0.0413	0.170	0.012	0.044
CV %	9.6	9.8	18.6	9.4	11.5	11.1

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.

B.1.10. Trial 336: NPK fertiliser response trial on super clonal materials at Akute Plantation – Higaturu Oil Palms

(RSPO 4.2, 4.3, 4.6, 8.1)

B.1.10.1. *Summary*

Selected oil palm progenies were planted throughout the oil palm industry for fertilizer trials to generate information for fertilizer recommendations. Measured yield and yield components and vegetative measurements increased with time. The sex ratio increased and remained above 90%. The trial to continue.

B.1.10.2. *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. Higaturu Oil Palms is on volcanic outwash and ash plain soils. This trial is aimed to provide information for fertiliser recommendations in Higaturu Oil Palms volcanic outwash plains soils on grassland areas on the Popondetta plains. Trial information is presented in Table 59.

Table 59. Trial 336 background information.

Trial number	336	Company	Higaturu Oil Palms
Plantation	Sambogo - Akute	Block no.	LKF010
Planting density	128 palms/ha	Soil type	Alluvial flood outwash plain
Pattern	Triangular	Drainage	Freely Draining
Date planted	May 17	Topography	Flat
Age after planting	2 year	Altitude	
Recording start	2017	Previous Land- Use	Grassland
Treatment start	Not yet	Area under trial soil type (ha)	
Progeny	Known	Supervisor in charge	Andy Ullian
Planting material	Dami DxP		

B.1.10.3. *Materials and 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 85 plots were planted.

In addition to the 85 plots, four plots of single progenies were planted, bringing the total number of plots to 89 plots. The four additional plots were to be used for flower monitoring for the four progenies. Weekly recording of male and female flowers at anthesis started in May 2018, 12 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

Yield data recordings started in May 2019 on all the plots.

Rachis thickness and width were measured to determine petiole cross section (PCS) on frond 3 May 2017 and August 2017, and frond 17 in 2108 and 2019. Full frond measurements were done in May 2018 and July 2019.

B.1.10.4. *Results and discussion*

Yield and yield components

Yield data all plots from May 2019 (age 24 months) to March 2020 (age 34 months) are presented in Table 60. Mean FFB yield increased from 0.36 t/ha from month 24 to 1.25 t/ha in month 34. This was due to corresponding increase in mean BNO/ha and SBW.

Table 60. Trial 336 mean FFB yield and yield components from age of 24 months (May 2018) to 34 months (March 2020).

Parameters	Age (Months)										
	24	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**34**
Mean FFB yield (t/ha)	0.36	0.18	0.40	0.43	0.50	0.71	0.54	0.96	0.99	1.26	1.25
Mean BNO/ha	223	87	162	159	162	204	153	232	231	252	228
Mean SBW (kg)	1.5	2.0	2.4	2.7	3.0	3.3	3.4	4.1	4.4	4.9	5.5

Vegetative measurements

All measured vegetative parameters increased with time (Table 61 and 62).

Table 61. Trial 336 mean measured vegetative parameters in 2017-2019.

	2017	2018			2019			
	FPC	FL (cm)	FA (m^2)	LAI	FPC	FL (cm)	FA (m^2)	LAI
Mean	31.2	167.7	1.3	0.5	28.8	272.0	3.0	1.6
Std dev	4.03	11.6	0.18	0.08	1.85	26.8	0.4	0.3
CV%	12.9	6.9	14.0	17.5	6.4	9.9	14.3	17.5
n	89	89	89	89	89	89	89	89

Table 62. Trial 336 mean petiole cross section (cm^2) measurements from 2017 to 2019.

	May-17	Aug-17	May-18	Jul-19
mean	1.5	3.4	5.9	10.2
Std dev	0.09	0.46	0.71	1.35
CV%	6.2	13.3	12.1	13.2
n	89	89	89	89

Flower census

The first flowers at anthesis were recorded in May 2018, 37 weeks after field planting. There was no difference between the female flowers at anthesis however the number of flowers increased with time (Figure 14). There was also no difference between male flowers of the different progenies and the numbers were very low (Figure 15). The mean sex ratio of the palms started increasing after week 30 and remained above 90% for about 80 weeks (Figure 16).

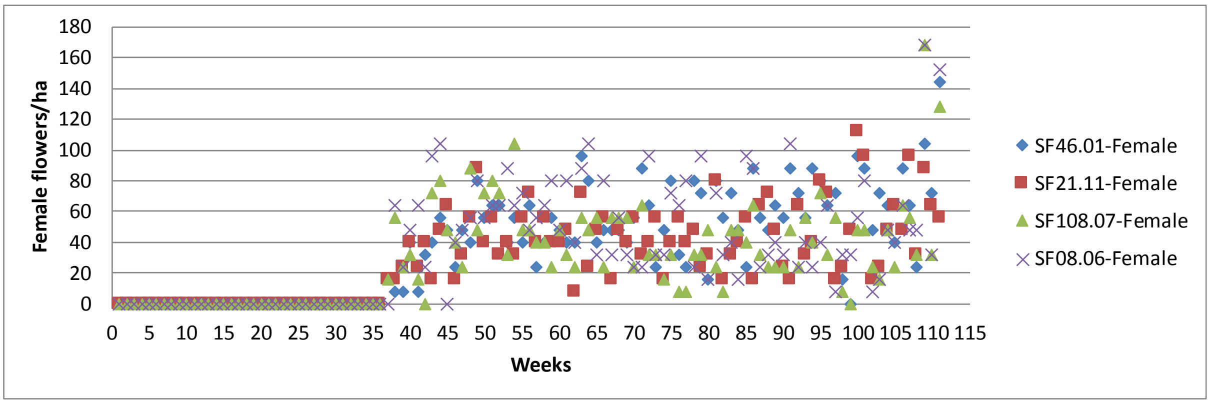


Figure 13. Trial 336 number of female flowers/ha at anthesis from May 2018 to March 2020.

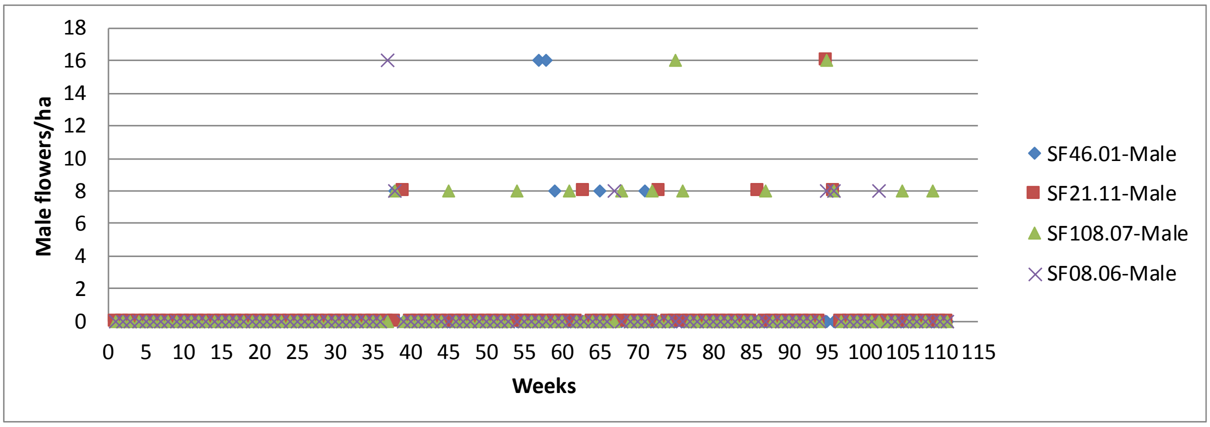


Figure 14. Trial 336 number of male flowers/ha at anthesis from May 2018 to March 2020.

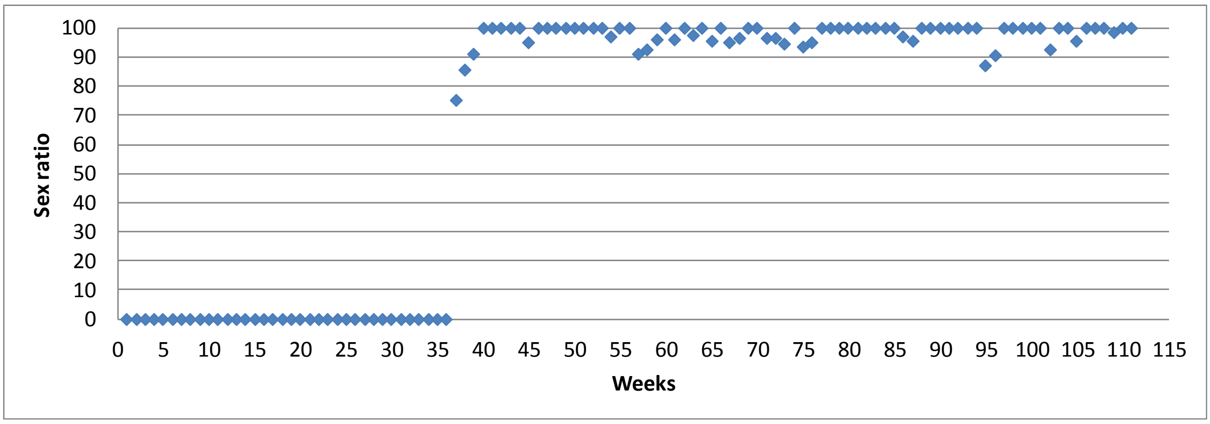


Figure 15. Trial 336 mean inflorescence sex ratio from May 2018 to March 2020.

B.1.10.5. *Conclusion*

The FFB yield and yield components and vegetative measurements increased with time. Sex ratio also increased with time and remained at greater than 90%. The trial to continue.

4. NBPOL, MILNE BAY ESTATES

Wawada Kanama and Jethro Woske

B.1.11. Trial 516: New NxK trial at Maiwara Estate

(RSPO 4.2, 4.3, 4.6, 8.1)

B.1.11.1. *Summary*

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.1.11.2. *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 63.

Table 63. 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 2019: 0.5 kg TSP

B.1.11.3. *Materials and Method*

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.1.11.4. *Results and discussion*

Yield data (2019 and 2017-2019) and leaf tissue nutrient contents for 2019 were analysed using multiple linear regression function in Genstat. The results are presented in Table 64. The regression significantly explained FFB yield and yield components responses for 2017-2019, however not in 2019. With FFB yield for 2017-2019, 78.2 % of the variances was explained by the regression. The regression also significantly accounted for 59.9% leaflet K and 80.1 % rachis K.

FFB yield for the period 2017-2019 was chosen to develop a response surface. In 2017-2019, Urea appeared to explain significant (p=0.042) increase in FFB yield (Table 65). Yield was at 15.9 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 17).

Table 64. 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	0.704	Residual variance> response variate	3.58
BNO/ha 2018	5	0.660	Residual variance> response variate	99.7
SBW 2018	5	0.377	9.7	2.04
FFB yield 2016-2018	5	0.005	78.2	1.57
BNO/ha 2016-2018	5	0.004	78.8	42.8
SBW 2016-2018	5	0.039	58.7	0.835
Leaflet N contents	5	0.168	33.1	0.0602
Leaflet K contents	5	0.036	59.8	0.0443
Rachis N contents	5	0.262	21.5	0.0209
Rachis K contents	5	0.004	80.1	0.171

Table 65. Trial 516 estimated coefficients for FFB yield in 2017-2019.

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

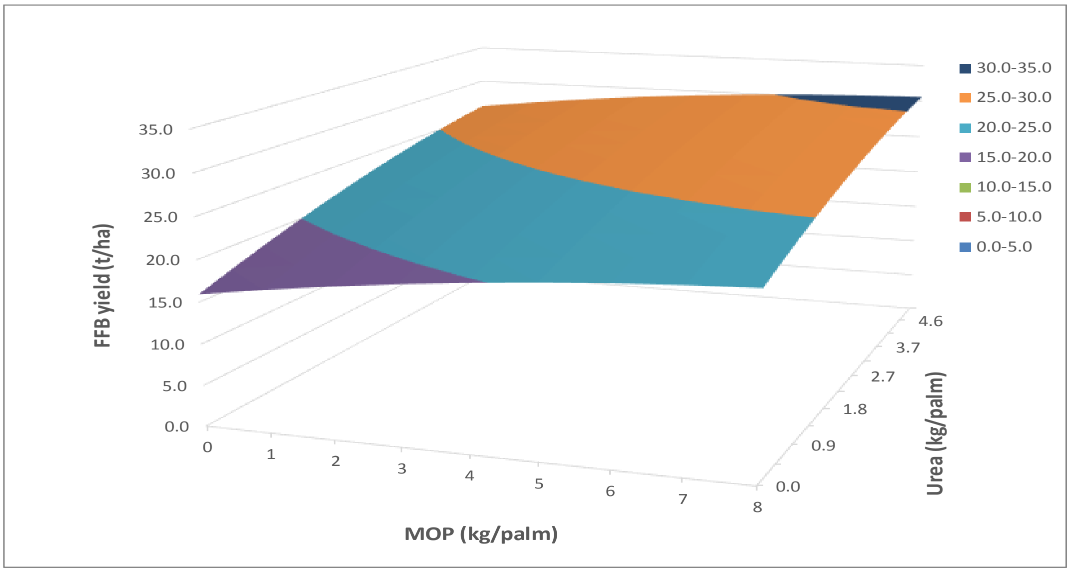


Figure 16. Trial 516 2017-2019 FFB yield surface for Urea and MOP combination.

B.1.11.5. *Conclusion*

In 2019, 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.

B.1.12. Trial 522: NPK fertiliser response trial on super clonal materials at Salima Division – Sagarai Estate, MBE

(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. Yield and measured vegetative parameters increased with time. The sex ratio increased however fluctuated between 50%and 100 %. 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. This trial is aimed to provide information for fertiliser recommendations in Milne Bay Estates. Trial information is presented in Table 66.

Table 66. Trial 522 background information.

Trial number	**522**	**Company**	**Milne Bay Estates**
Plantation	Salima - Sagarai	Block no.	AS 358R
Planting density	128 palms/ha	Soil type	Alluvial flood plain
Pattern	Triangular	Drainage	Poor to free Draining
Date planted	June 2017	Topography	Slightly steep to flat
Age after planting	2 years	Altitude	
Recording start	2017	Previous Land- Use	Oil Palm
Treatment start	Not yet	Area under trial soil type (ha)	
Progeny	Known	Supervisor in charge	Wawada Kanama and Jethro Woske
Planting material	Dami DxP		

B.1.12.3. *Materials and 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 109 plots were planted.

In addition to the 109 plots, four plots of single progenies were planted, bringing the total number of plots to 113 plots. The four additional plots were to be used for flower monitoring of the progenies. Weekly recording of male and female flowers at anthesis started in June 2018, 12 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

Yield data recordings started in July 2019 on all the plots.

Petiole cross section measurements and frond production count started in 2017. Full frond measurements were done in November 2018 and March, July and November 2019.

B.1.12.4. *Results and discussion*

Yield and yield components

Mean FFB yield increased with time from 0.36 t/ha/month at month 24 to 1.25 t/ha/month in month 34 (Table 67). The increase was due to increase in the number of bunches/ha/month and single bunch weight.

Table 67. Trial 522 yield and yield components from month 24 (July 2019) to month 34 (April 2020)

Parameters	Age (Months)										
	24	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**34**
Mean FFB yield (t/ha)	0.36	0.18	0.40	0.43	0.50	0.71	0.54	0.96	0.99	1.26	1.25
Mean BNO/ha	223	87	162	159	162	204	153	232	231	252	228
Mean SBW (kg)	1.5	2.0	2.4	2.7	3.0	3.3	3.4	4.1	4.4	4.9	5.5

Vegetative measurements

Mean vegetative measurements results are presented in Table 68 and 69. The measured parameters increased with time.

Table 68. Trial 522 mean vegetative measurements in 2018-2019

	Nov-18			**Mar-19**		
	FL (cm)	FA (m^2)	LAI	FL (cm)	FA (m^2)	LAI
Mean	201.2	2.0	0.9	204.1	1.9	0.9
Std Dev	12.5	0.2	0.1	15.7	0.2	0.1
CV %	6.2	9.0	9.0	7.7	11.4	14.9
n	113	113	113	113	113	113
	Jul-19			**Nov-19**		
	FL (cm)	FA (m2)	LAI	FL (cm)	FA (m2)	LAI
Mean	254.8	2.7	1.3	293.0	3.5	1.7
Std Dev	17.2	0.3	0.2	23.4	0.5	0.3
CV %	6.7	12.6	16.1	8.0	14.0	17.1
n	113	113	113	113	113	113

Table 69. Trial 522 mean petiole cross section 2018-2019.

	Frond 17 PCS (cm^2)				
	Jun-18	Nov-18	Mar-19	Jul-19	Nov-19
Mean	1.0	7.3	7.7	10.5	11.2
Std Dev	0.1	0.7	0.7	1.2	1.3
CV %	6.9	9.7	9.7	11.6	12.1
n	113	113	113	113	113

Flower census

The first flowers came into anthesis in July 2018, 54 weeks after field planting. There was no difference between the female flowers at anthesis however the number of flowers increase with time (Figure 18). There was also no difference between male flowers of the different progenies however there was a fluctuating trend developing (Figure 19). The mean sex ratio of the palms started increasing after week 25 and remained above 50% with a fluctuating trend (Figure 20).

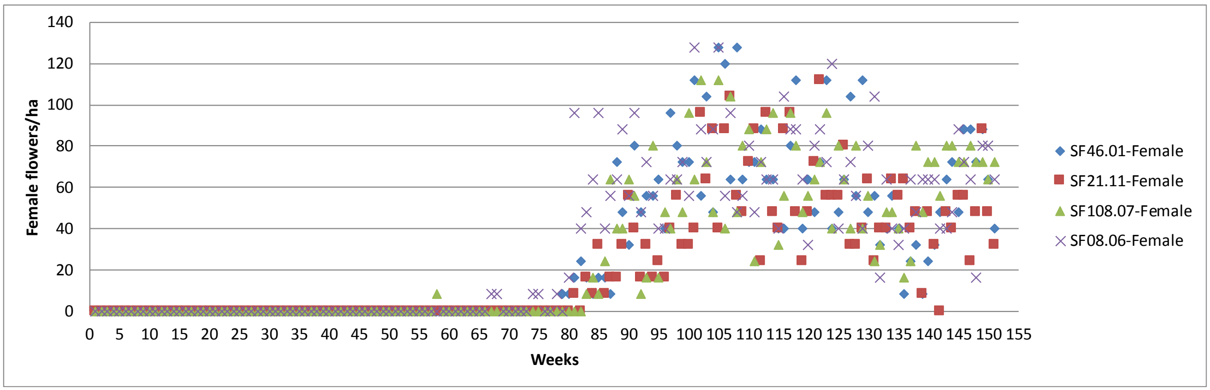


Figure 17. Trial 522 number of female flowers/ha at anthesis from July 2018 to April 2020.

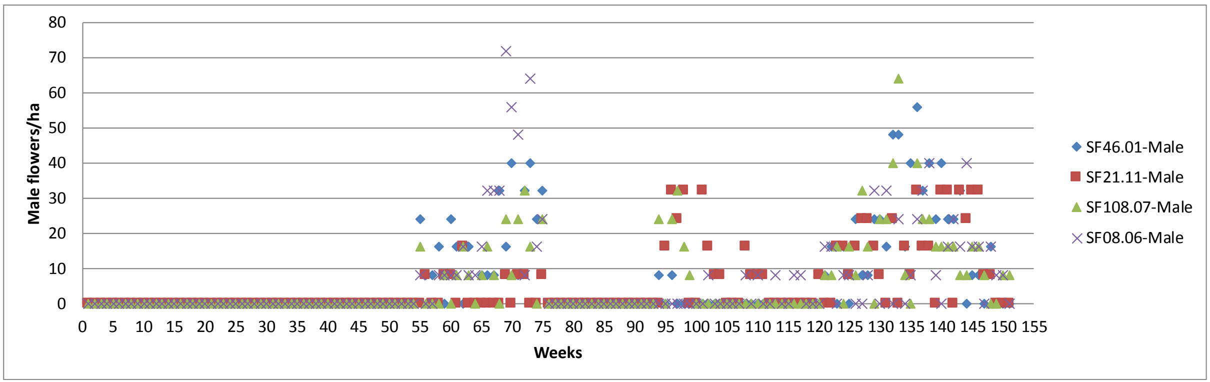


Figure 18. Trial 522 number of male flowers/ha at anthesis from July 2018 to April 2020.

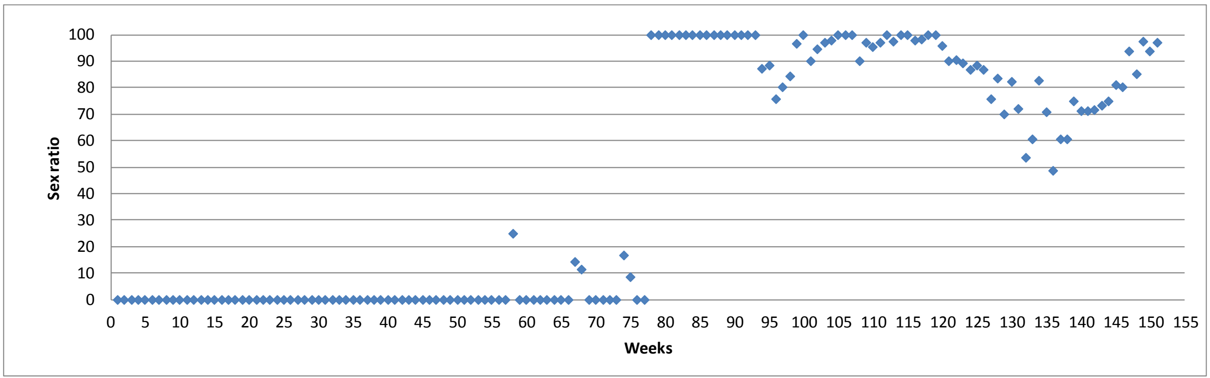


Figure 19. Trial 522 mean inflorescence sex ratio from July 2018 to April 2020.

B.1.12.5. *Conclusion*

FFB yield and measured vegetative parameters increased with time. The sex ratio increased but fluctuated between 50 and 100%. The trial to continue.

5. NBPOL RAMU AGRI INDUSTRIES LIMITED

Stanley YANE

B.1.13. 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)

B.1.13.1. *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. Pre-treatment 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.1.13.2. *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. 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 70.

Table 70. 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.1.13.3. *Materials and 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.1.13.4. *Results and discussion*

Yield and vegetative parameters

FFB yield and yield components data from June 2019 to May 2020 are presented in Table 71. Yield increased with time from 40 kg to 570 kg/ha/month. Similar trend is observed with the number of bunches and single bunch weights.

Measured vegetative measurements data and 12 months running yield data are presented in Table 72. The measured parameters for the four progenies are also presented on the same table. Progeny SF108.08 had the lowest vegetative parameters values and corresponding yield as well. It is also noted here that coefficient variation between vegetative parameters were low (1.1-13.6 %) compared to 85.9% in yield. This implies large difference in the yield performance of the progenies.

Table 71. Trial 605 mean FFB yield from June 2019 (month 28) to May 2020 (month 39).

Parameters	Age (Months)											
	28	29	30	31	32	33	34	35	36	37	38	39
Mean FFB yield (t/ha)	0.04	0.03	0.05	0.04	0.08	0.11	0.06	0.07	0.12	0.13	0.26	0.57
Mean BNO/ha	23	14	28	21	34	45	35	32	50	50	83	168
Mean SBW (kg)	1.7	1.7	1.7	1.9	2.1	2.3	1.9	2.1	2.4	2.5	2.8	3.3

Table 72. Trial 605 vegetative growth parameters for the different progenies across all plots 2019.

	FL (cm)	FPC	PCS (m^2)	FA (m^2)	LAI	Yield (t/ha/yr)
Mean	194.0	11	7.7	2.15	1.46	1.27
Std dev.	12.9	1.2	1.05	0.23	1.45	1.09
CV %	6.7	11.1	13.6	10.7	1.1	85.9
n	80	80	80	80	80	80
Progenies						
SF46.01	202		8.7	2.21	1.46	1.64
SF21.11	190		7.7	2.30	1.45	0.96
SF108.07	175		**6.9**	**1.94**	**1.12**	**0.49**
SF08.06	210		8.9	2.17	1.41	1.99

Flower census

Flowering monitoring data from March 2017 to June 2020, a total of 172 weeks data is presented here.

The first male flowers came into anthesis in July 2018, 74 weeks (18 months) after from month of planting (Figure 22). There was a further delay in female flowers coming to anthesis in week 86 (Figure 21). There were no progeny differences in the number of female and male flowers at anthesis. There were no progeny differences in the number of female and male flowers at anthesis. The sex ratio (proportion of female flowers at anthesis to total flowers) started increasing after week 23 (Figure 21). The ratio averaged at around 60 % after week 60.

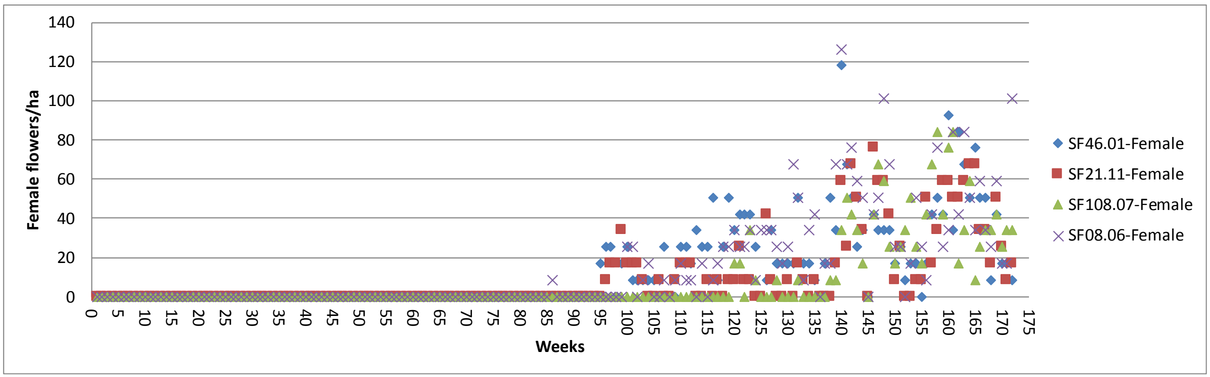


Figure 20. Trial 605 number of female flowers/ha at anthesis from March 2017 to June 2020.

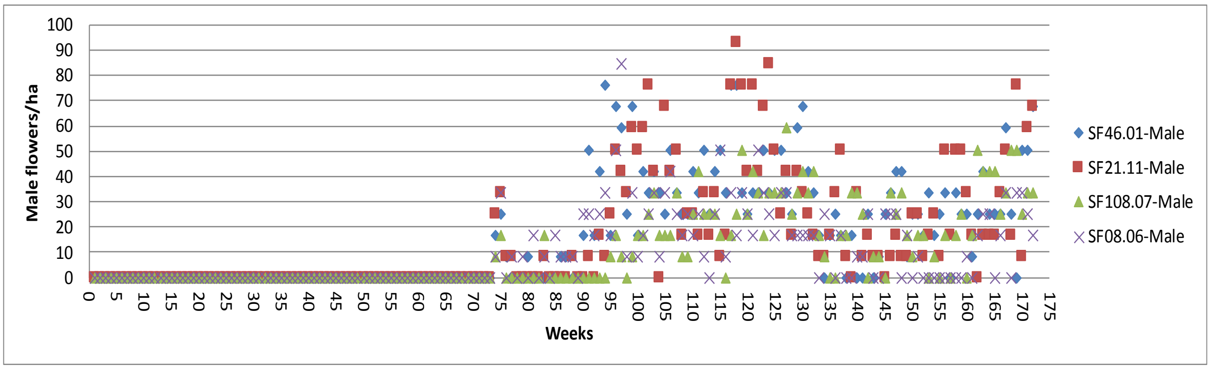


Figure 21. Trial 605 number of male flowers/ha at anthesis from March 2017 to June 2020.

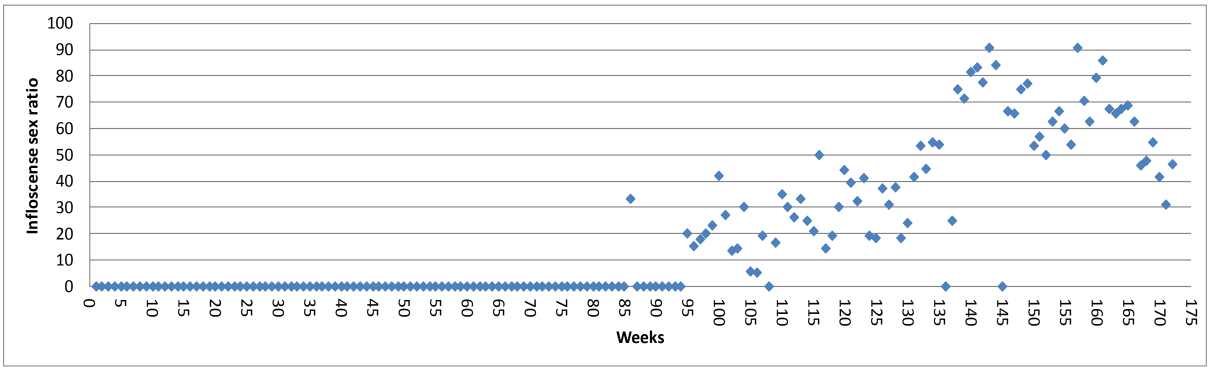


Figure 22. Trial 605 mean inflorescence sex ratio from March 2017 to June 2020.

B.1.13.5. *Conclusion*

The measured physiological growth parameters were less variable compared to FFB yield. The palms came into flowering 18 months after field planting. The sex ratio averaged at around 60%. The trial is to continue.

6. NBPOL, GUADALCANAL PLAINS PALM OIL LIMITED

JAYDITA PUE

B.1.14. Trial 703: NPKCl fertiliser response trial on super clonal materials at Tetere Plantation - GPPOL

(RSPO 4.2, 4.3, 4.6, 8.1)

B.1.14.1. *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.1.14.2. *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 .

Table 73. 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.1.14.3. *Materials and 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.1.14.4. *Results and discussion*

Petiole cross section measurements

The petiole cross section data is summarized in Table 74. There were 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 74. 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

Flower census

There was no difference between the female flowers at anthesis however the number of flowers increase with time Figure 24. There was also no difference between male flowers of the different progenies however there was a downward trend after week 40 (Figure 25). The mean sex ratio of the palms started increasing after week 40 towards 90% in week 65 (Figure 26).

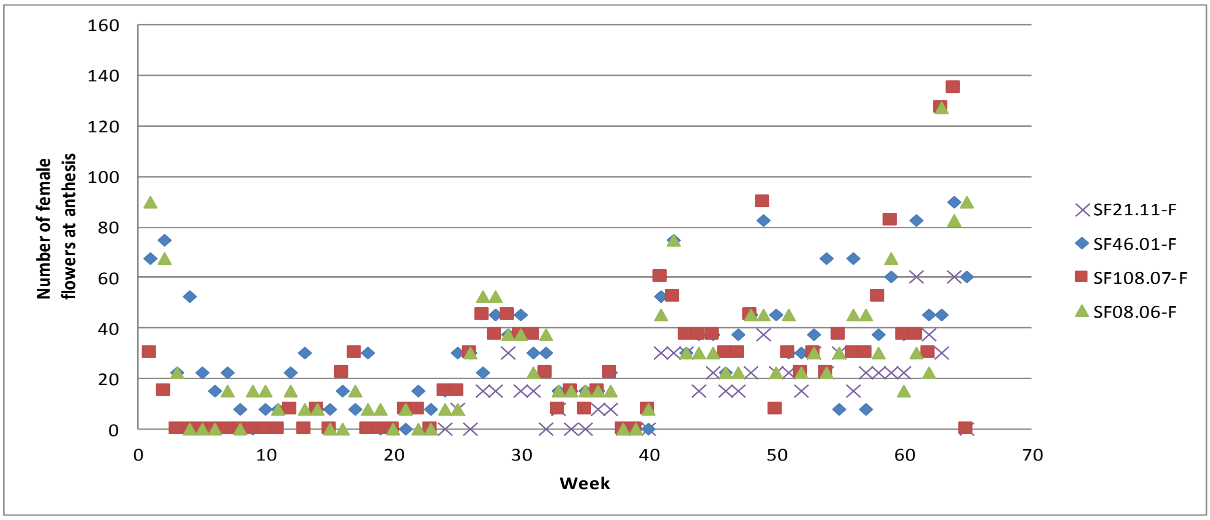


Figure 23. Trial 703 number of female flowers/ha at anthesis from January 2018 to March 2019.

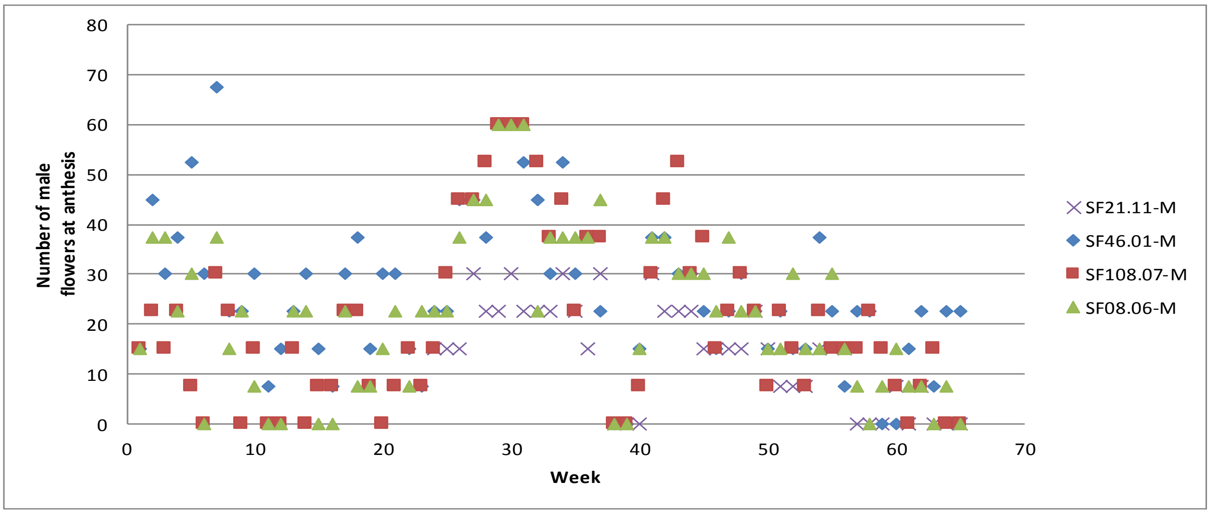


Figure 24. Trial 703 number of male flowers/ha at anthesis from January 2018 to March 2019.

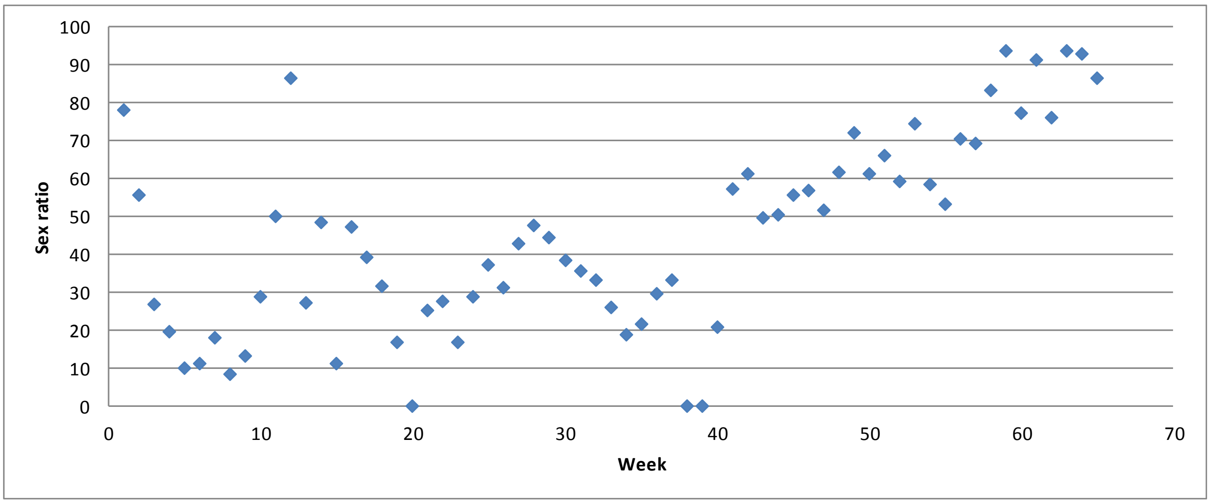


Figure 25. Trial 703 mean inflorescence sex ratio from January 2018 to March 2019.

B.1.14.5. *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.

7. NBPOL, KULA GROUP, POLIAMBA LIMITED, NEW IRELAND ISLAND

Joel Ben and Henry Seki

B.1.15. Trial 801: Nitrogen and potassium fertiliser response trial on super clonal materials at Lenaru Plantation - POL

(RSPO 4.2, 4.3, 4.6, 8.1)

B.1.15.1. *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.1.15.2. *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. Soils in POL are developed on raised coral seabed. This trial is aimed to provide information for fertiliser recommendations in Poliamba Plantations. Trial information is presented in Table 75.

Table 75. Trial 801 background information.

Trial number	801	Company	POL
Plantation	Lenaru	Block no.	
Planting density	128 palms/ha	Soil type	In situ soils on lime stones
Pattern	Triangular	Drainage	Freely Draining
Date planted	Nov/Dec 2018	Topography	Flat
Age after planting	1 year	Altitude	
Recording start	2019	Previous Land- Use	Oil Palm
Treatment start	Not yet	Area under trial soil type (ha)	
Progeny	Known	Supervisor in charge	Henry Seki
Planting material	Dami DxP		

B.1.15.3. *Materials and 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 71 plots were planted.

In addition to the 71 plots, four plots of single progenies were planted, bringing the total number of plots to 75 plots. The four additional plots were to be used for flower monitoring for four of the progenies. Weekly recording of male and female flowers at anthesis started in February 2020, 14 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 February and July 2019, and January 2020. First frond marking for frond production count was done in February 2019 and frond production counts were done in July 2019 and January 2020.

B.1.15.4. *Results and discussion*

Petiole cross section measurements and frond production counts

The petiole cross section data is summarized in Table 76. Mean PCS and FPC increased with time. PCS values of SF08.06 was greater than the other three progenies.

Table 76. Trial 801 petiole cross section measurements (cm^2) and annual frond production counts.

Plots statistics	Petiole cross section (cm^2)			Annual FPC	
	Feb-19	Jul-19	Jan-20	Jul-19	Jan-20
Mean	1.68	2.50	5.27	27	32
Std dev	0.12	0.25	0.60	4.6	2.5
CV %	7	10	11	17	8
n	75	75	75	75	75
Progenies					
SF46.01	1.69	2.51	5.08	27.6	31.7
SF21.11	1.64	2.43	5.21	27.3	32.7
SF108.07	1.65	2.49	5.27	27.9	32.9
SF08.06	1.74	2.58	5.51	26.9	31.4

Flower census

The recording of flowers at anthesis were only for the first 25 weeks of recording and therefore no clear trend can be seen from the data presented. However, for the female flowers at anthesis, SF108.07 and SF08.06 had higher numbers of flowers at anthesis compared to the other two progenies (Figure 27). With the male flowers at anthesis, SF08.06 had the highest number of male flowers at anthesis (Figure 28). The mean sex ratio of the palms ranged from 50 % to 100% (Figure 29).

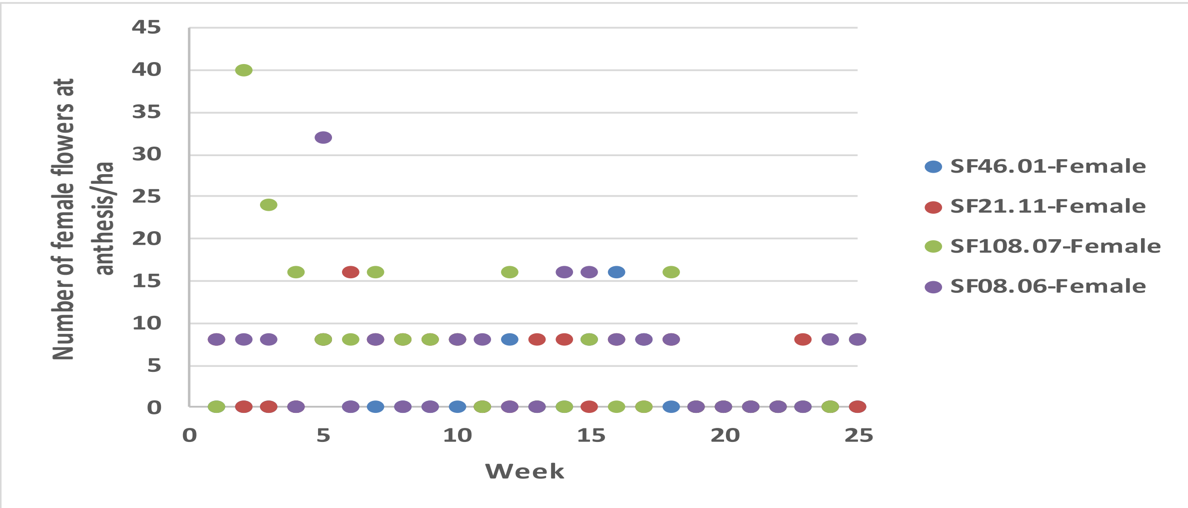


Figure 26. Trial 703 number of female flowers/ha at anthesis from February 2020 to July 2020.

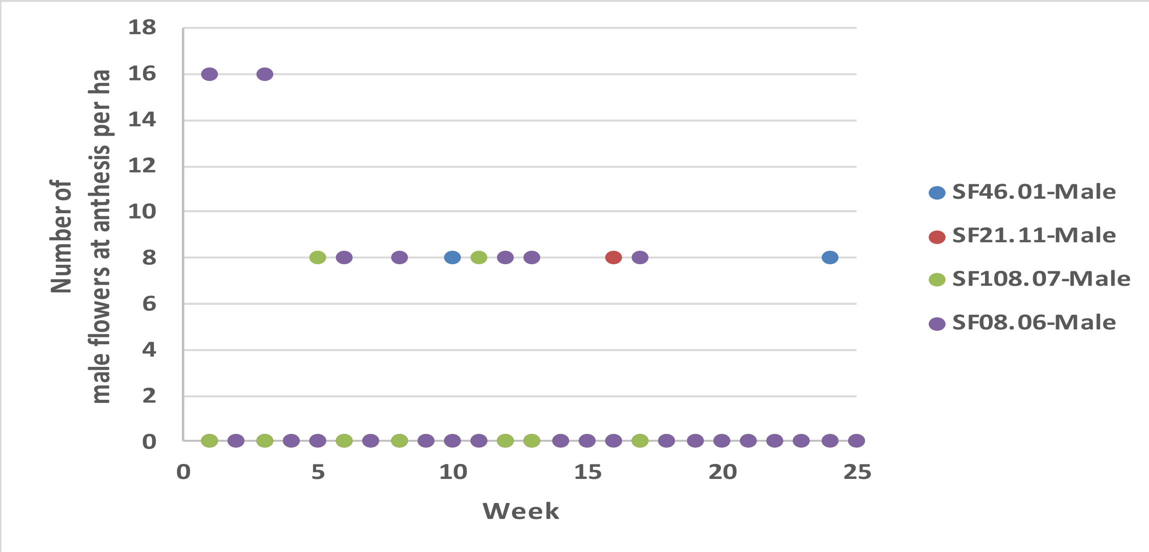


Figure 27. Trial 703 number of male flowers/ha at anthesis from February 2020 to July 2020.

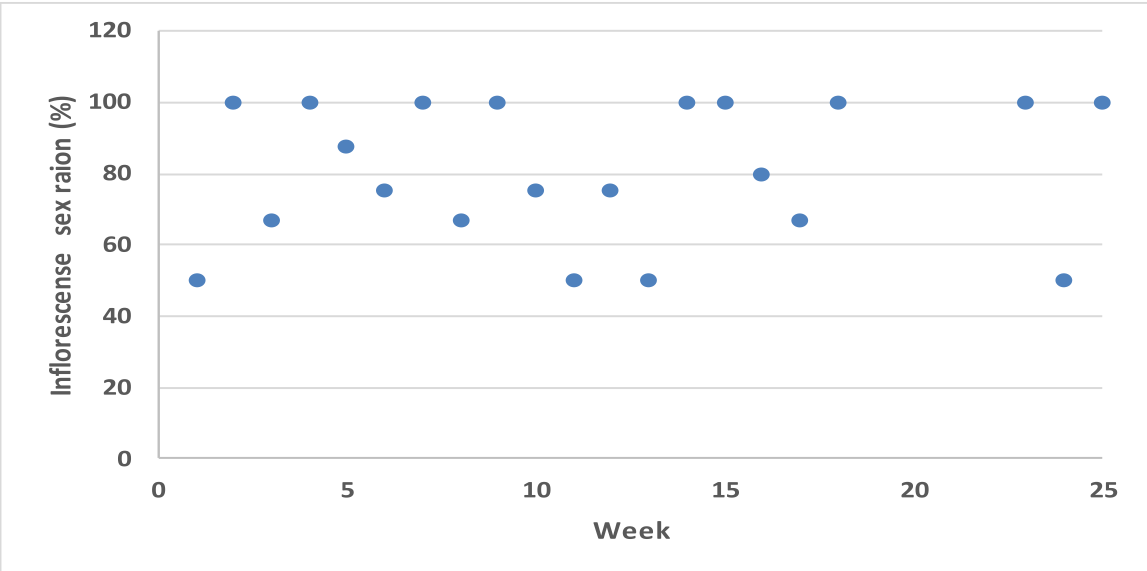


Figure 28. Trial 703 mean inflorescence sex ratio from February 2020 to July 2020.

B.1.15.1. *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 ranged from 50 % to 100%. 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 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 (*Segestes decoratus, Segestidea defoliaria, Segestidea gracilis*), and 1 species of stick insect (*Eurycantha calcarata*). *Segestes decoratus* and *S. defoliaria* occur in WNB whilst *S. gracilis* occurs in New Ireland. *Eurycantha calcarata* occurs in both WNB and New Ireland. Apart from these pests, the coconut flat moth (CFM), *Agonoxena* sp. was frequently encountered in Milne Bay.

Where required, Dimehypo® (*Thiosaltap disodium*) was used for most of targeted trunk injection (TTI) control of the pests during the year. Slightly less insecticide was applied (through TTI) in 2019 (6,931L) than those applied in 2018 (7,034L). This is 3L less. Between the smallholders and the plantations, the later had slightly more volumes applied (3,380L and 3551L respectively). As is often the case, most of the chemical treatment (5,932L) was done in WNB for sexavae and stick insect control. This covers for both New Britain Palm Oil Limited (NBPOL) and Hargy Oil Palms Limited (HPOL). The other sites where treatment was done were Poliamba (358L) for the control of the same pests in the plantation and Milne Estates (641L) for the control of CFM. The main reason for slide decline in the volume of insecticide applied was the continued maintenance of effective monitoring and reporting system, where infestations were reported earlier and treated in smaller areas containing further spread. The penalty system introduced for smallholder growers with poorly sanitised blocks also helped minimise the rate of infestation.

The biological control agent release programme in WNB continued during the year for most of the biocontrol agents after re-establishing *Stochotrema dallatoreanum* and *Anastatus eurycanthae* cultures during the year. *Doirania leefmansi* releases remained consistent throughout the year with an estimated total of 10,425,800 insects released, whilst the release of *S. dallatoreanum* and *A. eurycanthae* started in July and August respectively. An estimated total of 77,000 triquilins of *S. dallatoreanum* were released whilst 9,162 *A. eurycanthae* were released.

The field parasitism rate of sexavae eggs sampled by OPIC from Hoskins Project area remained high throughout the divisions. The high level of parasitism reflected the routine release of the egg parasitoids within the project area. The rate of egg parasitism was complimented by predation from general predators as well as nymph and adult stages infection of *S. defoliaria* by *S. dallatoreanum*.

As was the case in 2018, *Oryctes rhinoceros* (CRB-S) infestation was continued to be encountered at Lamasong and Siccacui for Poliamba Estate. Control was mainly through pheromone trapping. The number of beetles trapped from each site continued to decline towards the back end of the year. A total of 7,466 beetles were trapped from Lamasong and 1,263 beetles from Siccacui. The effort was augmented by natural *Oryctes* NudiVirus infection. *Metarhizium* infection and release of male beetles was not done due to the long distances involved for PNGOPRA officer to cover.

The incursion of the Guam biotype (CRB-G) *O. rhinoceros* at Guadalcanal Plains Palm Oil Ltd (GPPOL) in the Solomon Islands continued to be a major challenge. Various control options including pheromone trapping, and mechanical and chemical control options were applied for its management, whilst research continued with the evaluation of lab held virus stocks obtained from AgResearch, NZ. Incursion in PNG also continued to spread with the beetle detected further from the 2015 points of spread. The eastern coastline spread remained within the Central Province whilst the western coastline spread extended into the Gulf Province. DNA analysis of samples collected from within the areas of incursion confirmed all samples to be CRB-G without virus infection. The biotype has not got into oil palm areas, but is gradually moving towards it, particularly Milne Bay Estates. If nothing is done to contain the beetle at the points of spread, it will only be a matter of time before the population enters the oil palm catchment areas. The point of spread along the east coast is not more than 200km from the oil palm project areas in Milne Bay.

Pheromone trap monitoring for CRB-G (Guam biotype) in Milne Bay, Northern, New Ireland and West New Britain continued throughout the year. No *O. rhinoceros* were caught in any of the traps. Only *O. centaurus* were caught in Milne Bay and Northern. The activity will continue into the new year. RAIL maintained the pheromone traps within the Markham Valley. Samples collected during the year showed symptoms of virus infection suggesting *Oryctes* NudiVirus released adjacent to Markham Farms in 2017 has established. The results will be confirmed through DNA analysis.

Mimosa pigra eradication programme for WNB (Numundo and Wandoro) continued. At Wandoro, 200 immature stands were treated/uprooted. This is 62 more than those treated/uprooted in 2018. For Numondo, the number treated/uprooted dropped from 1,348 to 998 (350 less). The decrease is due to routine monitoring and treatment. The activity will continue until the weed is eradicated from both sites.

For the research projects, the results of only the completed and partially completed research projects are presented in this report. These include the results of the CRB-S management study in WNB and NI (Poliamba Estates), CRB-G management project activity results, beneficial weeds preference evaluation against biocontrol agents (BCAs), and chaffer beetle damage assessment and alternative hosts survey study results.

The fallen palm trunk decomposition rate measurement study at Kumbango replant (WNB) continued. A mean of around 2 meters remain to be decomposed completely after more than two years from felling. It could potentially take three years before full decomposition. Similar trend has been noted for the decomposition of palm trunks at Leinaru replant (Poliamba Estates). CRB damage assessments were continued at both sites. Whilst no damage by the beetle was detected at Kumbango replant, there was damage at Leinaru replant. The damage level was light but gradually increasing towards moderate level. The CRB breeding substrate preference study at Numondo Plantation (WNB) confirmed preference of palm trunks (fallen and standing [dead]) over other potential breeding substrates (cow dung, EFB, cattle feed stockpile).

Coconut Rhinoceros Beetle (CRB) collection in the native range for NudiVirus infection on CRB-G was done in the Philippines, Cambodia and Thailand. Among the countries, extensive sampling was done in the Philippines due to an old report confirming the presence of CRB population resistant to NudiVirus infection in the country. A total of 505 gut tissue samples were extracted for DNA analysis. All samples from Cambodia were analysed and all samples were CRB-S with virus infection. Around 48 samples from the Philippines samples were analysed. A mixed population of CRB-G (31%) and CRB-S (79%) was confirmed. For the CRB-G samples 60% were with virus infection. All samples from Thailand remain to be analysed. Two strains of NudiVirus (V23B and DUG 42) provided by AgResearch, NZ were evaluated against CRB-G population at GPPOL. Infection and transmission by both strains was confirmed, but the transmission trial needs repeating due to contamination in the control treatment.

Five beneficial weeds (Brazilian snapdragon, coral vine, rattle box plant, white alder, yellow alder) were evaluated for natural enemy preference. Brazilian snapdragon and coral vine had high sugar (glucose) concentration but were least preferred for feeding. The two alders and rattle box plant were preferred for feeding. The influence of other sugars on preference among beneficial weeds by natural enemies needs further investigation.

The chaffer beetle damage assessment and population survey results demonstrated that rainfall influenced the infestation. The beetle population increased during dry weather and declined during wet weather. Infestation needs to be closely monitored during dry weather. Five alternative host plants were confirmed. Preference among the alternative hosts and oil palm needs to be screened.

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 *Segestidea defoliaria* (31%), *Eurycantha calcarata* (31%) and *Segestes decoratus* (27%). *Segestidea gracilis* reported this year was low constituting only 3% of the reports. Sporadic pests recorded during the year, apart from the common pests included *Oryctes rhinoceros*, *Agonoxena* sp., *Scapanes australis*, *Rhabdocerus obscurus*, *Brontispa longissima*, *Manatha corbetti*, *Eumetha variegata*, *Promecotheca* sp. and *Dermolepida* sp. The reports of each of these pests constituted less than 5% (Figure 30). GPPOL continued to battle the incursion of the Guam biotype Coconut Rhinoceros Beetle (CRB-G), whilst the common population of the beetle (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 Chaffer Beetle (*Dermolepida* sp.) recurred at Embi Estate (Higaturu Oil Palms) in Popondetta. Infestation level was light, and no treatment was done. *Brontispa longissima*, *R. obscurus* and *Promecotheca* sp., were recorded for the first time this year from West New Britain. *Oryctoderus latitarsis* infestation observed in Kerakera Division, Hargy Plantation (Hargy Oil Palms Ltd) the previous year (2018) had dropped off. Fruit bunch damage by the beetle was not observed.

The proportion (%) of pest infestations reported per month fluctuated throughout the year (Figure 31). Highest proportion of reports was received in May (16%) followed by January, March and October with 10% infestation reports each. This was followed by April (7%) and September (6%). February, November and December all had 5% each of the reports. The least number of reports were received in June (3%).

Across the sites, most of the report was from WNB constituting 98% of the reports (Figure 32). Poliamba Estates and MBE had 1% each. None was reported from Higaturu. WNB reports covered those from both NBPOL and Hargy Oil Palms Ltd, and their respective smallholder projects. The highest proportion of pest infestation reports coming from WNB was expected as all the regular pests occur within the province with recurrent infestation encountered over time

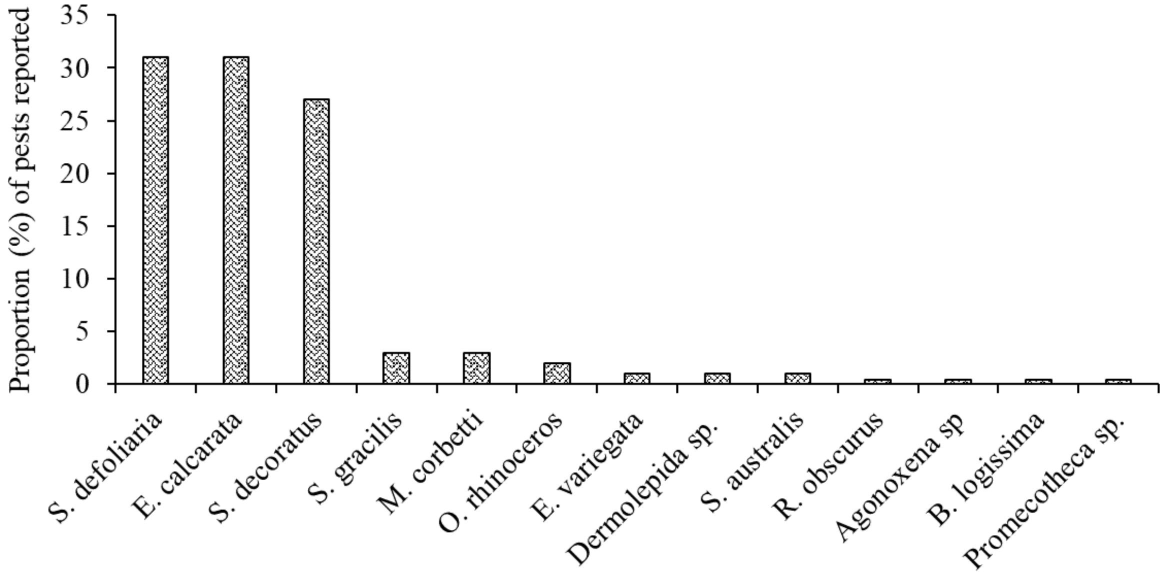


Figure 29. Proportion (%) of different pests reported during the year.

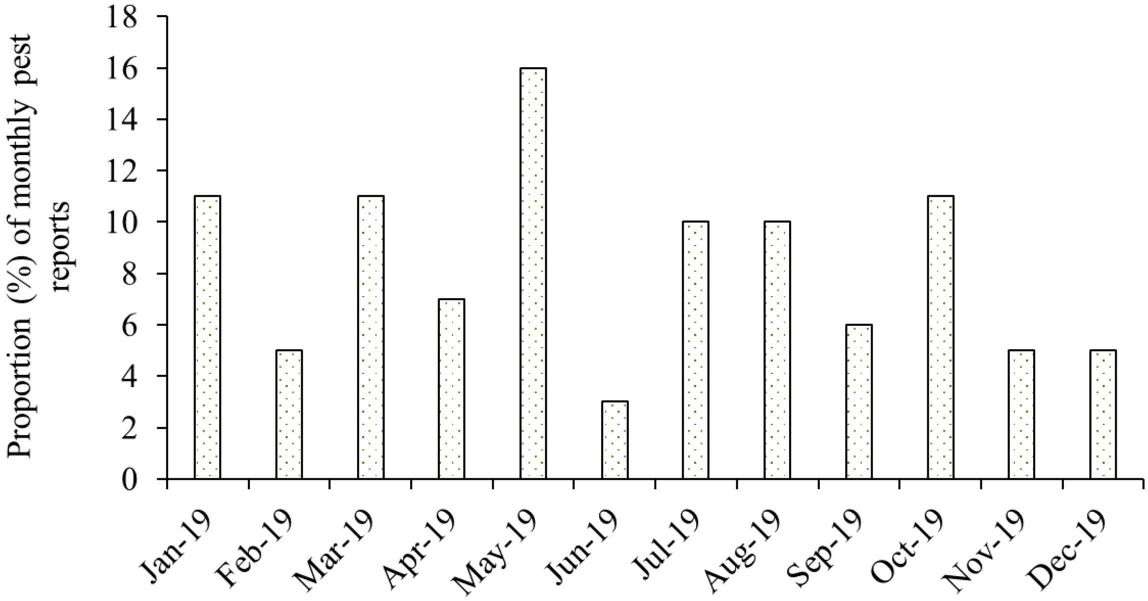


Figure 30. Proportion (%) of infestation reports received per month throughout the year.

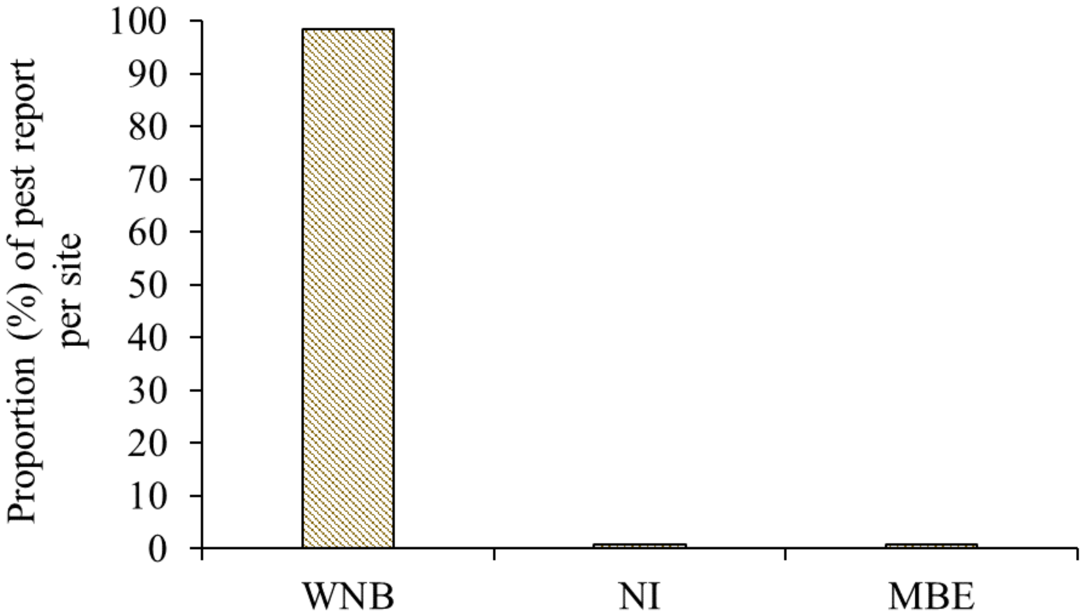


Figure 31. Proportion (%) of infestation reports received from different sites during the year.

C.2.2. Pest damage levels, management recommendations and targeted trunk injection (TTI) in 2019

As is usually the case, the most common pest species that were treated using insecticide (Dimehypo®) in 2019 included the three species of sexavae (*S. decoratus*, *S. defoliaria*, *S. gracilis*) and one species of stick insect (*E. calcarata*). 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.

Slightly lower volume of Dimehypo® was used in 2019 (6,931L) than 2018 (7,034L). This was 103L less than the volume used in 2018. Slightly higher volume of insecticide was applied in the plantation (3551L) than smallholders (3380L). For both, most of the chemical application was done in WNB. Poliamba Estates applied 358L. Lesser volume (641L) than 2018 was used in Milne Bay for CFM control in plantations. This constituted all the treatment done on the mainland. No smallholder blocks were treated both on the mainland and New Ireland. The rest of the smallholder treatments were done in WNB. As was the case for the previous year, the main reason for slide 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 in WNB also helped minimise the rate of re-infestation.

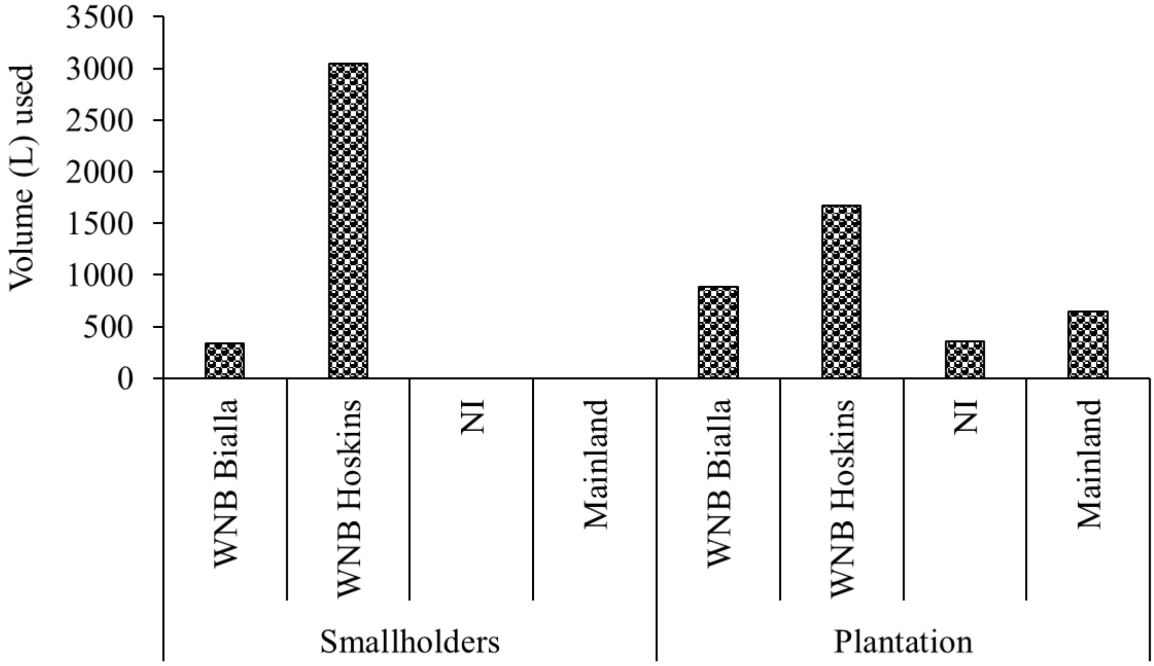


Figure 32. Volumes (L) of Dimehypo® used in Plantations and Smallholder blocks in 2019.

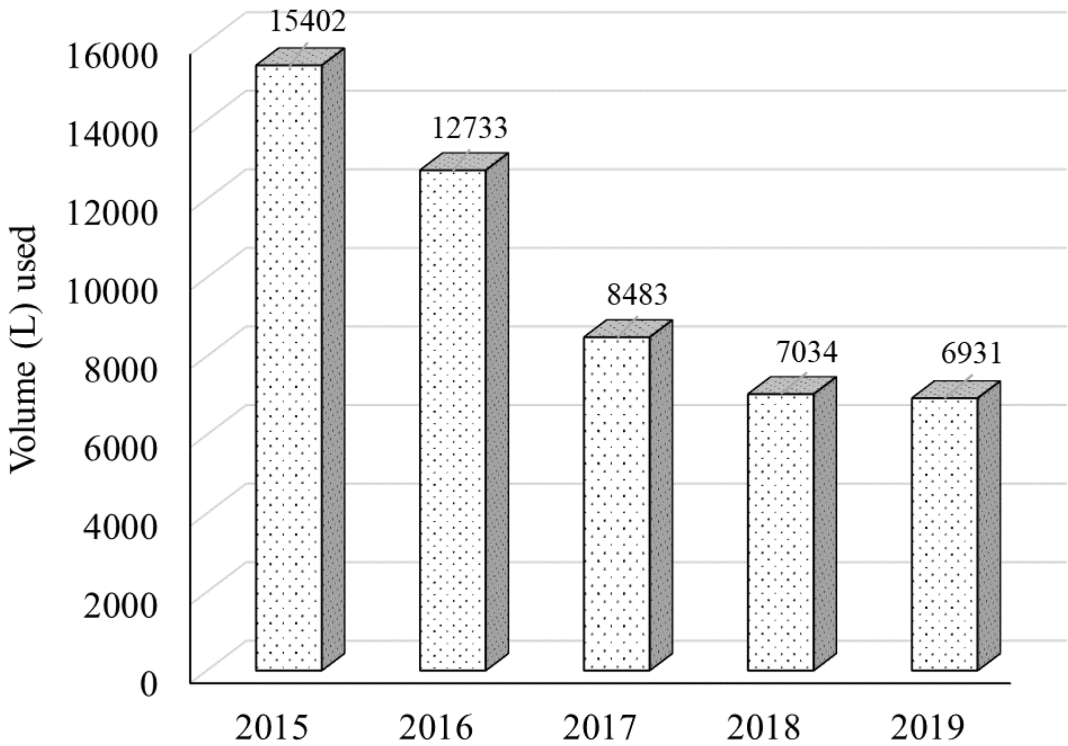


Figure 33. Volume (L) of Dimehypo™ used between 2015 and 2019.

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.

For sexavae egg parasitoids, only *D. leefmansi* was consistently maintained and released. The estimated number of releases remained in millions throughout the year with an estimated total of 10,425,800 insects released (Figure 34). *Leefmansia bicolor* collapsed last year and attempts to retrieve them was without success. A trip was made during the year to New Hanover where the initial stock was collected and checked for sexavae eggs with the intention of retrieving the parasitoid from them, but infestation was low, and no eggs were collected. Another attempt will be made in future whenever sexavae infestations are confirmed.

Stichotrema dallatoreanum that collapsed during the previous year (2018) was re-established in June and releases resumed in July. An estimated total of 77,000 triquilins were released during the year (Figure 35). No releases were done in December to maintain and establish the lab culture for releases in the new year.

Similar situation as *S. dallatoreanum* was experienced for *A. eurycanthae*. The culture was re-established in July after it collapsed in 2018, and the releases resumed in August. A total of 9,162 insects were released during the year (Figure 36).

The release programme for all biocontrol agents will continue into 2020. 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, Talasea) within Hoskins Project to determine parasitism and predation levels. Active sampling for all divisions started in 2013 and was continued during the year.

Generally, the proportions (%) of parasitized and hatched eggs remained high for all divisions, whilst the proportions of predated and unhatched eggs were lower (Figure 37). The results show that the parasitoids release programme is contributing effectively to the suppression pf the pest population through egg parasitism complimented by the predation from general predators. The hatching of equally higher proportion of eggs has also been reflected by the high proportion of pest infestations encountered within the project area.

The routine natural enemies release programme needs to be maintained as part of the IPM programme for the sustainable management of the pests. Beneficial weeds play a critical role in the sustenance of parasitoid populations as food sources and will also need to be promoted as part of the oil palm cropping system.

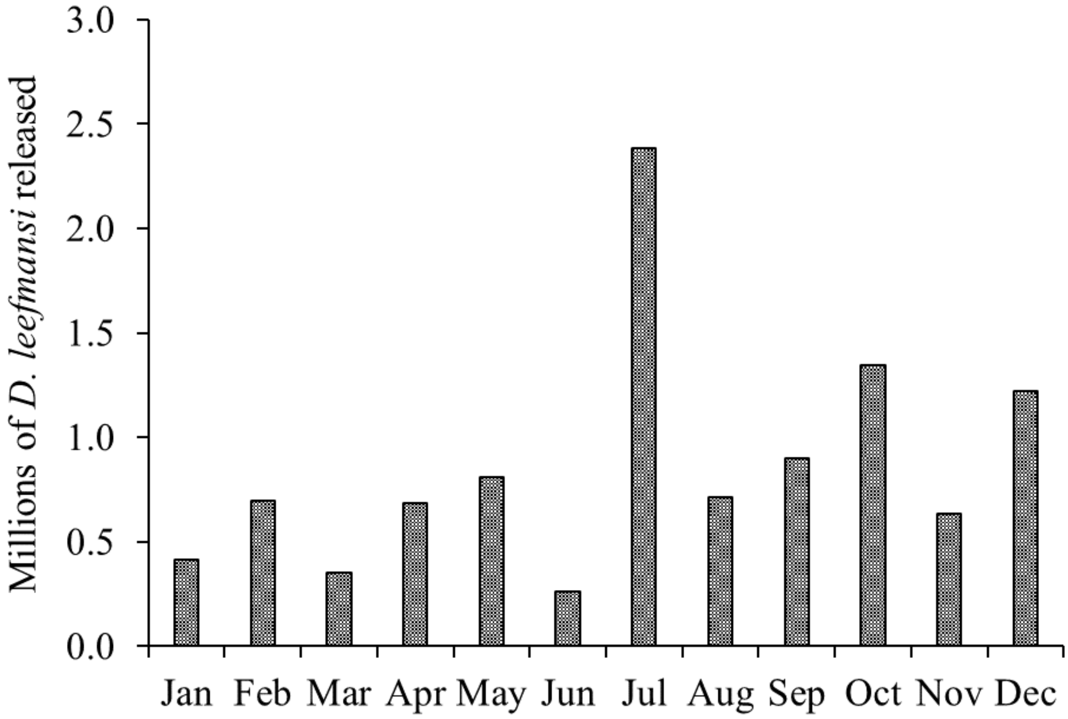


Figure 34. Estimated number (in millions) of *D. leefmansi* field released in WNB during the year for the control of Sexavae through egg parasitism.

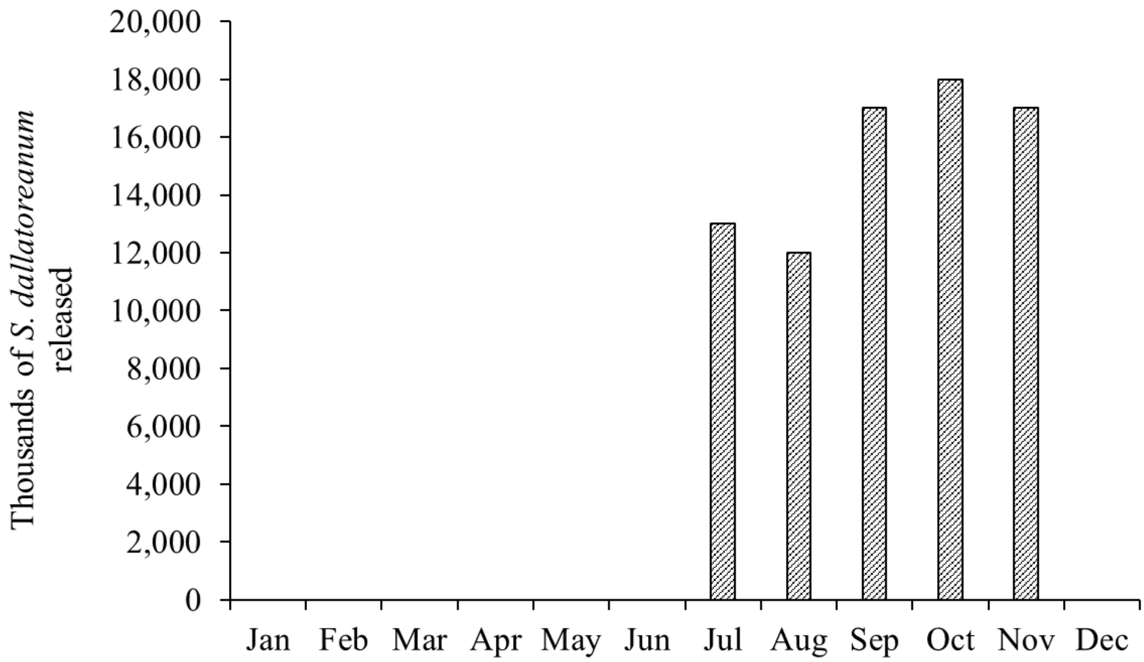


Figure 35. Estimated number (in thousands) of *S. dallatoreanum* field released in WNB during the year for the control of Sexavae through nymphs and adult infection

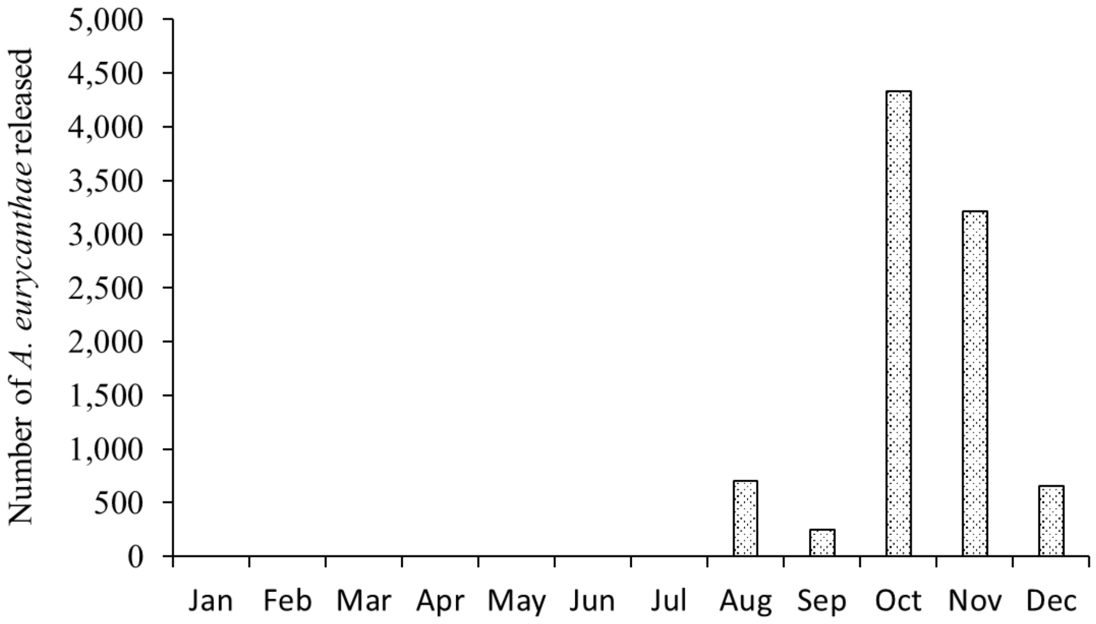


Figure 36. Number of *A. eurycanthae* field released in WNB during the year for the control of stick insect through egg parasitism.

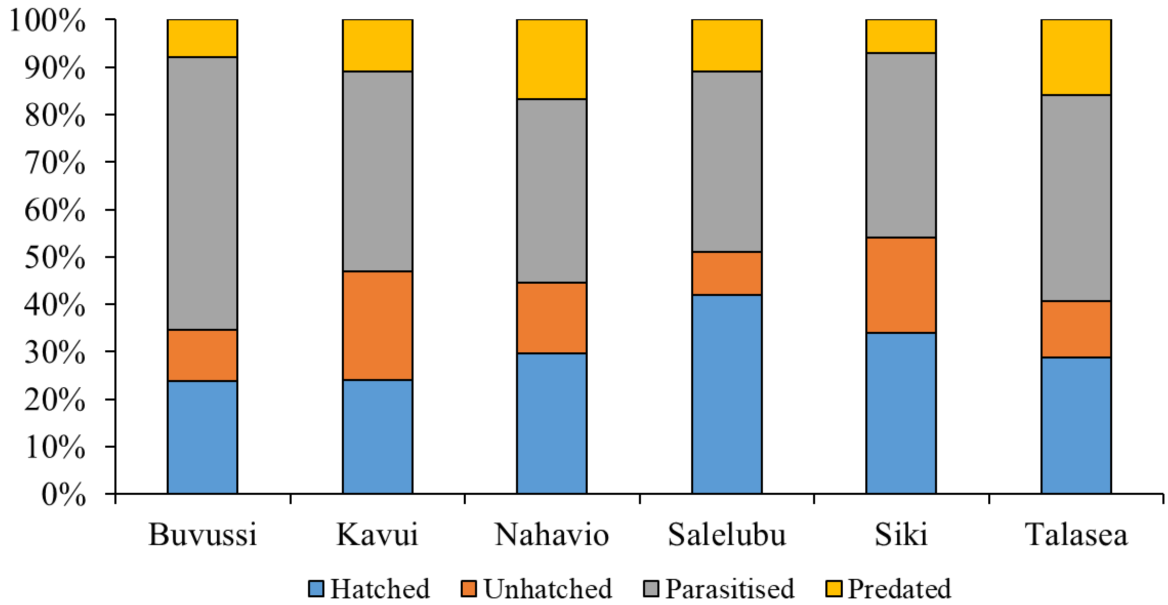


Figure 37. Proportion (%) of different categories (hatched, unhatched, parasitized, predated) of Sexavae eggs sampled in Hoskins OPIC Project Divisions (Buvussi, Kavui, Nahavio, Salelubu; Siki and Talasea) during weekly monitoring in the year.

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

In Poliamba Estates, *O. rhinoceros* (CRB-S) infestation was continued to be encountered at Lamasong and Siccacui replants. The infestation was managed only through pheromone trapping. *Metarhizium* infection and release, and dissection for virus infection confirmation were not done because of the long-distance involved for the plantations concerned. It was not possible for PNGOPRA officer to travel on motor bike to conduct these activities. The plantations monitored the pheromone traps and provided the trapping data.

Since the plantations managed the traps, inconsistencies were encountered with data not provided for some of the months (Table 77). A total of 8,729 beetles were trapped from both plantations with more beetles (7,466) trapped from Lamasong than Siccacui (1,263) (Table 77). Trapping will continue into 2020 at both sites until no more beetles are caught.

Table 77. Number of *O. rhinoceros* beetles trapped at Siccacui and Lamasong replants.

Month	Siccacui	Lamasong	Comment
Jan-19	52	291	Both plantation data available
Feb-19	32	156	Both plantation data available
Mar-19		1596	Data for Siccacui not available
Apr-19	208	1471	Both plantation data available
May-19	193		Data for Lamasong not available
Jun-19	181		Data for Lamasong not available
Jul-19	162	998	Both plantation data available
Aug-19	151	914	Both plantation data available
Sep-19	128	816	Both plantation data available
Oct-19	82	738	Both plantation data available
Nov-19			PNGOPRA Officer on leave
Dec-19	74	486	Both plantation data available
Total	**1,263**	**7,466**	**8,729**

Apart from CRB-S management in Poliamba, pheromone trap monitoring for CRB-G was maintained in Milne Bay, New Ireland, Northern and West New Britain Provinces at potential points of incursion (Figure 38). CRB-S was caught in traps set at Kimbe Wharf and Poliamba oil loading dock. No *O. rhinoceros* were caught from traps in Milne Bay and Northern Provinces. Only *O. centaurus* were caught. The activity will continue until an effective virus strain is confirmed for the biotype.

RAIL has set up pheromone traps for the beetle infestation in the Markham Valley and trapped some *O. rhinoceros*. DNA analysis of the samples at AgResearch in 2017 has confirmed all to be the common biotype (CRB-S) but without *NudiVirus* infection. In October 2018, seven male *O. rhinoceros* dosed with Oryctes *NudiVirus* from WNB were released close to Markham Farms. Further samples including some symptomatic samples collected during the year have been sent to AgResearch for confirmation of virus establishment, but the analysis is still pending.

C.2.5. CRB-G delimiting survey along Central-Gulf coastlines

A joint follow up delimiting survey for CRB-G spread was conducted along the Central-Gulf coastlines by KIK, NAQIA and PNGOPRA. The initial survey was conducted in 2015 by NAQIA and PNGOPRA. During the survey gut tissue samples were collected and sent to AgResearch for DNA analysis. For PNGOPRA, this was necessary as the eastern population was heading closer towards Milne Bay Estates (MBE).

The 2015 delimiting survey confirmed for the beetle to spread as far as Kwikila along the eastern coastline and as far as Hisiu along the western coastline confined to the Central Province (Figure 39). The current survey confirmed for it to spread further to Lalaura (approximately another 100km) along the eastern coastline and as far as Meii in the Gulf Province (approximately another 350km) along the western coastline within a space of four years (Figure 40). The beetle is moving and will continue to spread if no containment exercises are implemented at the points of spread. It is necessary that this is considered before it gets into the oil project areas.

A total of 112 gut tissue samples were collected from various locations along both coastlines. DNA analysis conducted at AgResearch has confirmed for all samples to be CRB-G without virus infection. Analysis of samples collected in 2015 confirmed for coexistence of both biotypes. The current result entails the possibility of CRB-G out competing CRB-S. The persistence of the later population could potentially be limited by the virus infection. Identification of a virus strain effective against CRB-G will be given a priority.

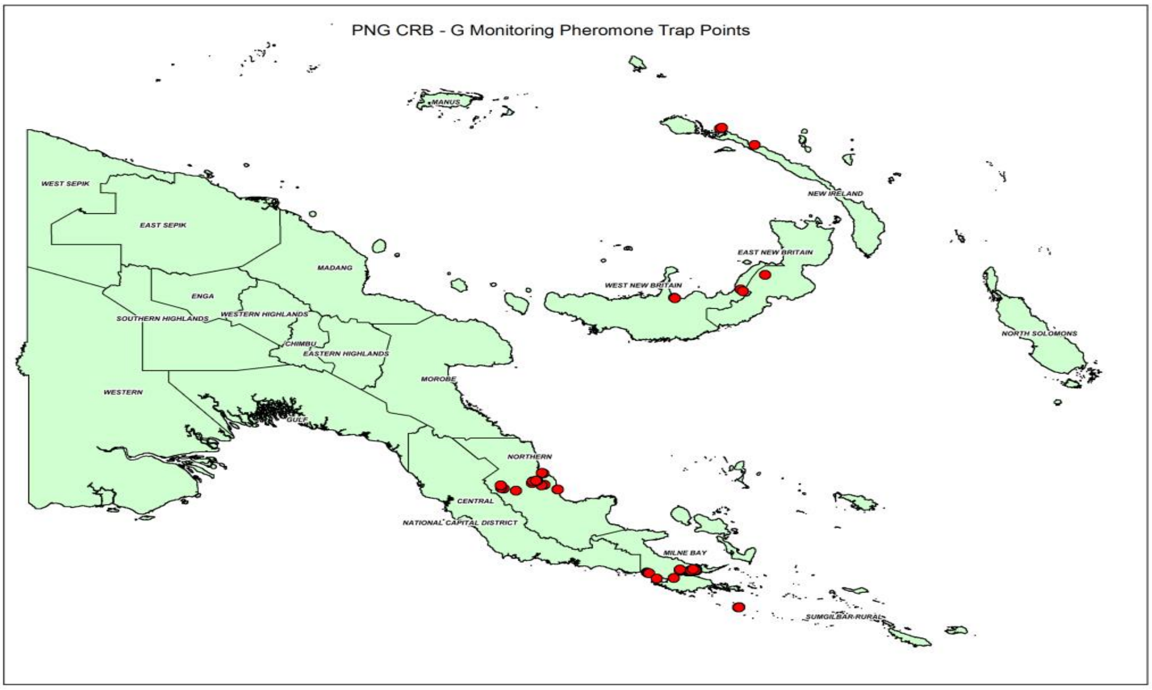


Figure 38. Map of PNG showing where the monitoring pheromone traps were set up.

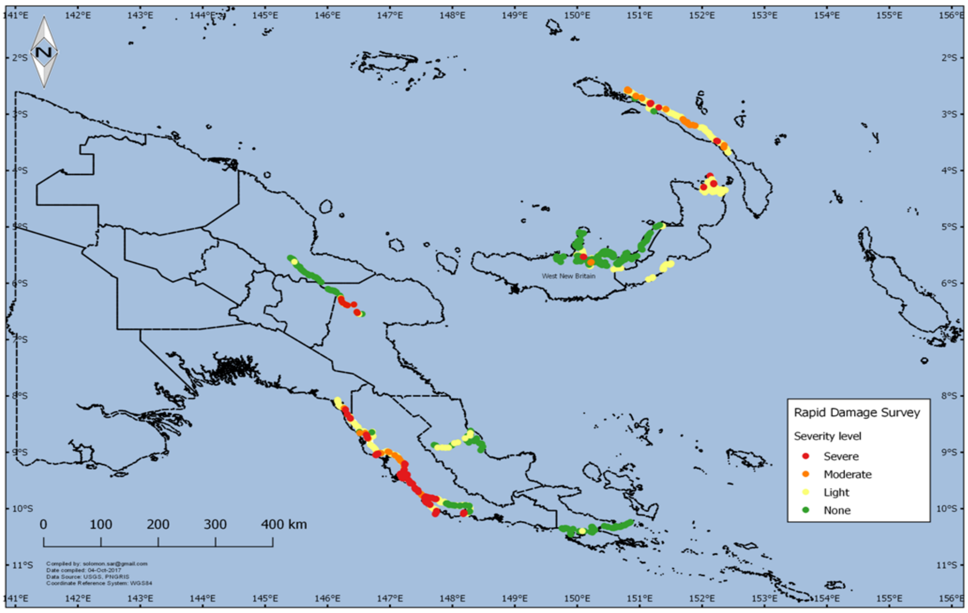


Figure 39. The 2015 delimiting survey results map. The damage on other sites were by CRB-S.

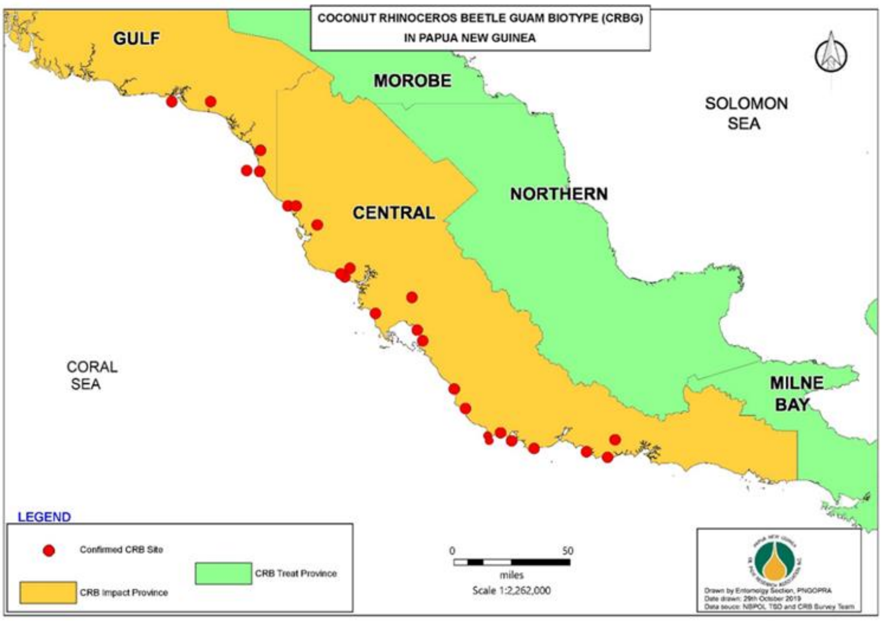


Figure 40. The 2019 delimiting survey results map showing where the insects were sampled.

C.2.6. 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 focus in 2019 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 (Figure 41).

The treatment at Wandoro (Pusuki Estate) started in August 2014 with fortnightly herbicide application/manual uprooting done. Since then 122 rounds of treatment have been done with 8,400 plants treated/uprooted. A total of 200 (141) weeds were treated/uprooted from this site in 2019. This is 59 more weeds than those treated/uprooted (141 weeds) in 2018. Generally, there is declining trend in the number of weeds treated/uprooted since the start of programme. This trend shows that the control programme implemented for this site is having an impact (Figure 42). The slight increase in 2019 compared to the previous year reflects vigilant monitoring.

The treatment programme for Numondo site started a year later in February 2015. A total of 5,919 weeds have been treated after 113 rounds of treatment/uprooting. There was a decrease in the number of weeds treated/uprooted with 998 weeds treated/uprooted compared to 1,372 treated/uprooted in 2018. It is generally showing a declining trend in the number of new detections, but it remains higher than the new germination detected at Wandoro (Figure 43). The persistence of high numbers of new germination is due to 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 dispersed the seeds widely before the eradication programme started.

The exercise will continue at both sites until no new germinations are detected for up to 12 months before it is considered as been eradicated. The persistence of new germinations is expected to continue for some more years before eradication is achieved due to the long dormancy period of the weed's seeds (up to around 25 years).

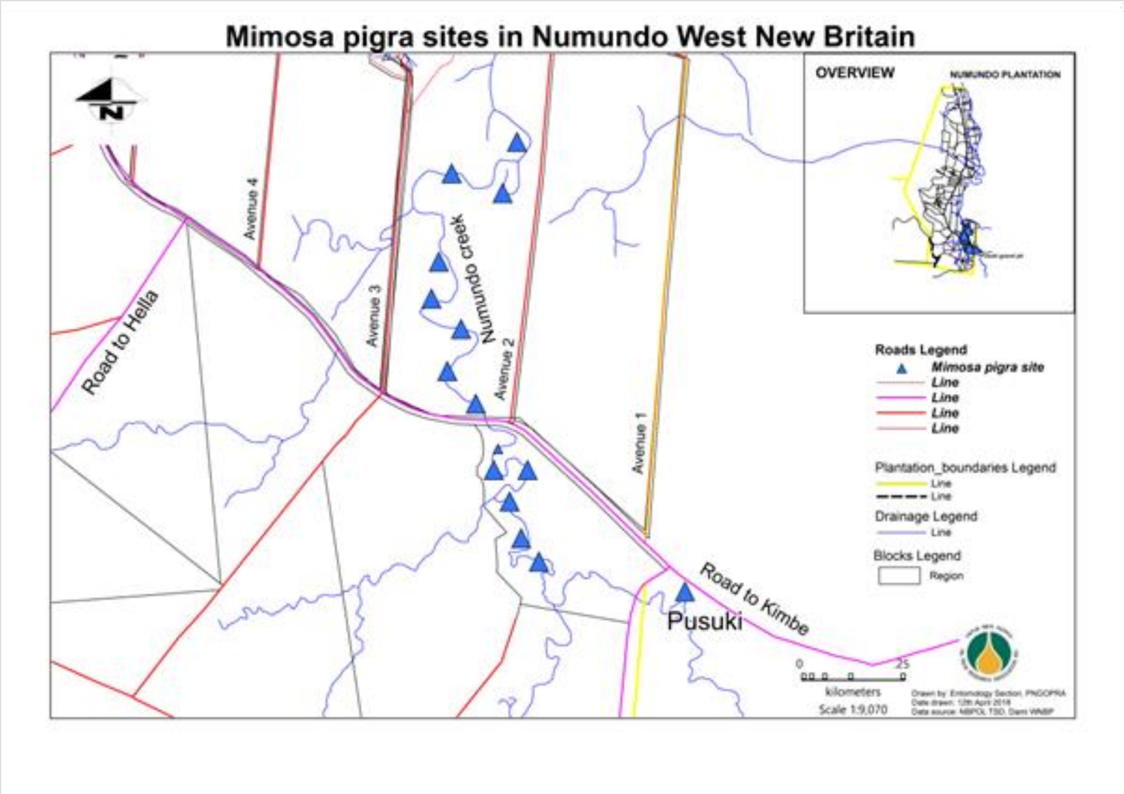


Figure 41. Map of Numondo-Wandoro area showing the locations of *M. pigra* infestation.

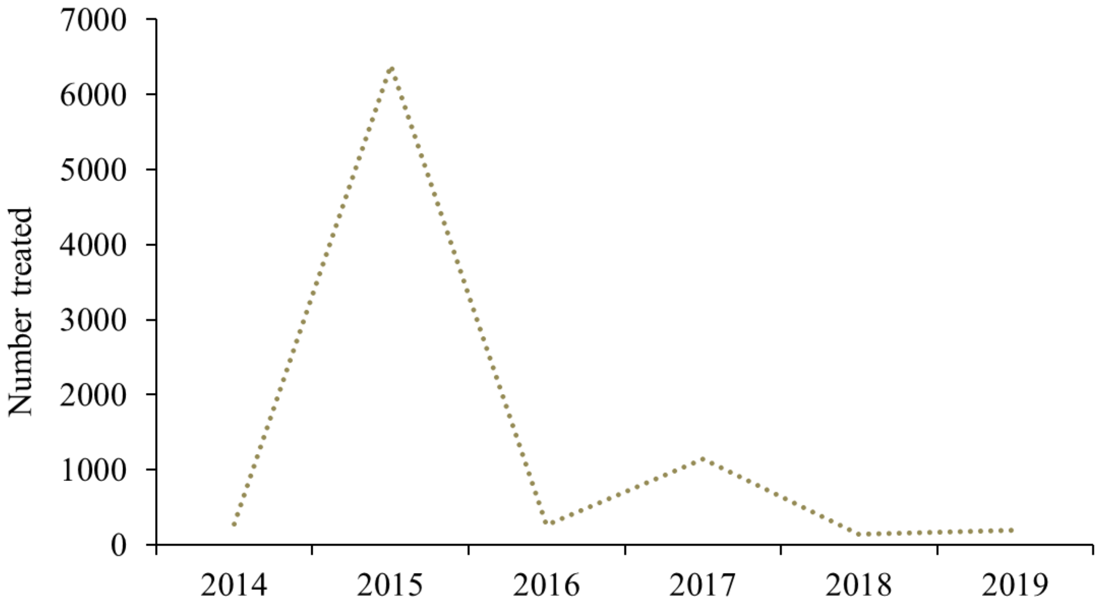


Figure 42. Number of *M. pigra* treated/uprooted at Wandoro (Pusuki Estate) per year from 2014 to 2019.

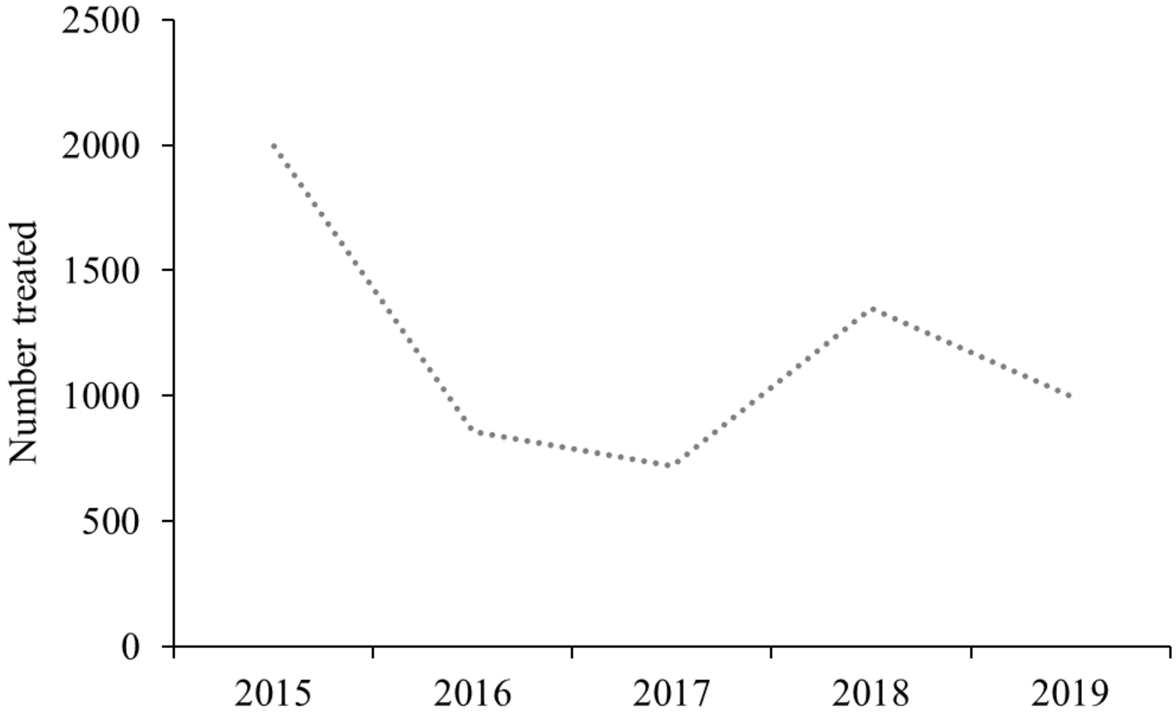


Figure 43. Number of *M. pigra* treated/uprooted at Numondo per year from 2015 to 2019.

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.

C.3.1. Palm trunk decomposition rate measurements and breeding substrate preference evaluation studies

C.3.1.1. *Introduction*

The Coconut Rhinoceros Beetle (CRB), *Orycetes rhinoceros* L. (Coleoptera: Scarabaeidae) is one of the key pests of oil palm, particularly during replanting where the breeding substrates (fallen or poisoned palm trunks) are readily available (Ero, *et al*., 2016). The palm trunks create perfect breeding substrates for the beetles. They breed within the dead palm trunks and the emergent adults cause damage to the young replanted palms by tunnelling through the palm bases and feeding on the apical meristem tissues. The damage can be severe with some palms killed if no timely control measures are applied and the population pressure builds up. Severe damage normally results in retarded palm growth and crop loss. In Malaysia, it has been recorded for the beetle to cause 40–92% damage during the first year of harvest (Chung, *et al*., 1999).

Chemical control of the beetle can be done on younger palms as part of an IPM approach but is often difficult on mature palms because of tall height. The beetle also often burrows through the palm base and conceal itself within before causing the damage, hence application of contact insecticides is often not effective. For systemic insecticides, the beetles would have to cause the damage to pick up the translocating chemical. In addition, the cost of chemical would likely limit its use as the most cost-effective control measure against CRB, particularly among the oil palm and coconut smallholder growers.

The use of pheromone trapping and biocontrol agents such as *Oryctes NudiVirus* (for classical biocontrol), and sanitation would likely become the most cost-effective control measure. Apart from these control options, the dust formulation of the Green Muscardine fungus (*Metarrhizium anisopliae*) is often applied but the limitation is the lack of its mobility between breeding populations (Gnasasegaram, *et al*., 2014).

The palm trunk decomposition rate measurement studies were conducted at Kumbango (WNB) and Leinaru (NI) replants whilst the breeding substrate preference evaluation study was conducted at Numondo replant. The palm trunk decomposition rate measurement study was conducted to determine the decay stages at which the beetle starts breeding (thus starts causing damage) and stops breeding (thus stop causing damage). Damage assessment survey was conducted concurrently to determine stage of beetle incursion. The breeding substrate preference study was conducted to determine the most preferred breeding substrate. This report provides the results of the pending activities of the study that continued from 2018.

C.3.1.2. *Materials and methods*

Monitoring of fallen palm trunk decomposition rate

The decomposition rate assessment for the fell palm trunks at Kumbango replant continued. The same was replicated in Leinaru replant at Poliamba Estate. Five (5) fallen palm trunks each were marked and numbered in each of the 10 rows. 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. The assessments are continuing and will stop once all marked palm trunks have fully decomposed. The measurements at Kumbango started in March 2017 whilst those at Leinaru replant started in March 2019.

Rhinoceros beetle palm damage assessment

The damage assessment surveys were done in the same fields where the fallen palm trunk decomposition rate measurements were done. 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. The studies started at the same time with the palm trunk decomposition rate measurement studies.

Calculation of the damage levels were done as per below:

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

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

$$\%\ \text{fresh damage} = \frac{\text{no.of palms with old \& fresh damage}}{\text{total no.of palms surveyed}} \times 100$$

Severity level was calculated as follow:

$$\text{Severity level (\%)} = \frac{\text{no.of fronds with damage}}{\text{total no.of fronds per palm}} \times 100$$

Severity levels
0 %**: No damage**
0.1 to 10% overall damage: **Light**
11% to 30% overall damage: **Moderate**
> 30 % overall damage: **Severe**

Breeding preference evaluation

Five potential CRB breeding substrates were identified and surveyed for the different life stages (eggs, larvae, pupae, adults) of the beetle. The potential breeding substrates included cow dung, cattle stock feed pile, empty fruit bunches (EFB), fallen dead palm trunks and standing poisoned palm trunks. Separate piles of each substrate were checked for the different stages of the beetle. For the cow dung, 2-3 days old lumps were checked, and for the palm trunks those that have already started decomposing were checked. The standing dead palm trunks were fell with a chain saw and split up to check. Three abiotic factors (RH, temperature, pH) of the substrates were also measured to determine their potential influence on the beetle. The trial was replicated 25 times for each substrate. The study was conducted at Numondo plantation replant where the beetle population pressure was high.

C.3.1.3 *Results and discussion*

The decomposition rate of fallen palm trunks at Kumbango replant was gradual and took almost two years (March 2017 to March 2019) to attain 50% (half the length) decomposition. The decomposition of the remaining 50% of the trunks accelerated thereafter with an average length of two meters remaining before full decomposition (Figure 44). The measurements will continue until these trunks have completely decomposed. The full decomposition will potentially take more than three years. Unexpectedly, around 38% of the palm trunks within the trial block grew back and were omitted from the study.

Similar trend has been noted for palm trunks at Leinaru replant. An average of not more than one meter of the palm trunks have decomposed ten months after the start of the monthly measurements (Figure 45). The measurements will also continue until the palm trunks have fully decomposed. None of the trunks have grown back as they were all poisoned before felling.

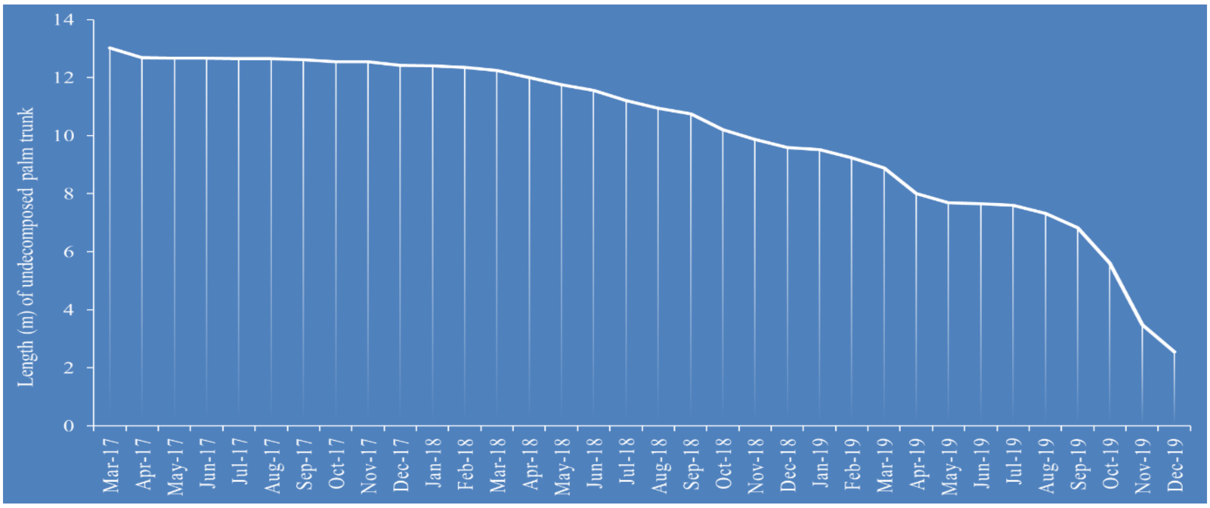


Figure 44. The rate of fallen palm trunk decomposition over time at Kumbango replant (NBPOL, WNB).

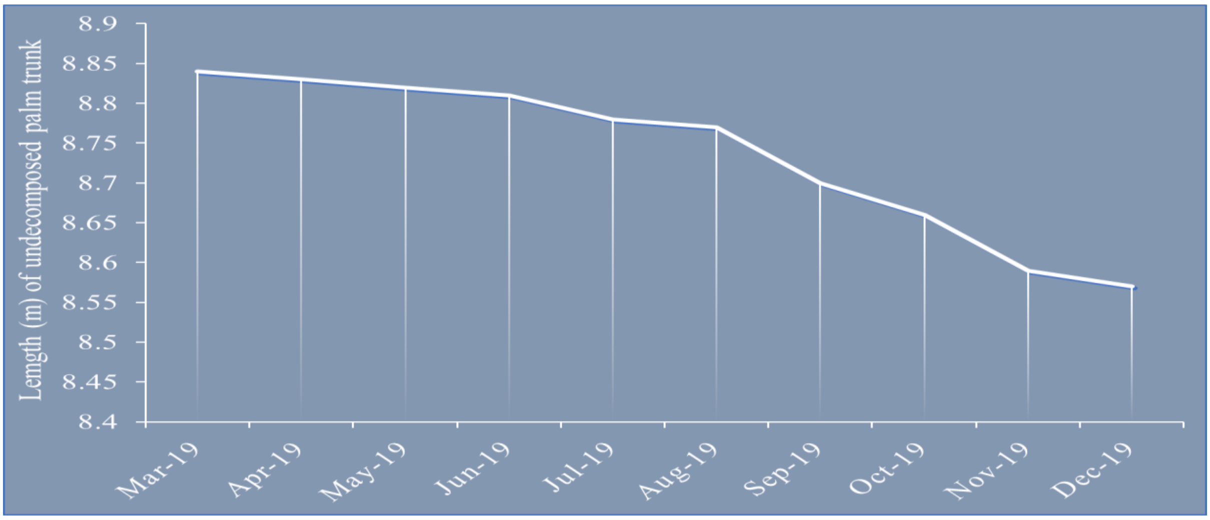


Figure 45. The rate of fallen palm trunk decomposition over time at Leinaru replant (Poliamba Estate).

There was no *O. rhinoceros* damage detected on replant palms at Kumbango Plantation. They remained healthy throughout the palm trunk decomposition measurement period. However, beetle damage was detected at Leinaru replant. The incursion was observed six months after replant and five months after the start of damage assessment and trunk decomposition measurement in August 2019. The field was replanted in February 2019. The damage remained light throughout the remainder of the year but showing an increasing trend (Table 78). Pheromone traps will be set up after the damage level reaches moderate stage to determine the impact of pheromone trapping and virus infection on the beetle population. The damage assessment will continue until the palm trunks have fully decomposed.

Table 78. *Oryctes rhinoceros* damage (%) assessment at Leinaru replant (Poliamba Estate).

Month	Percentage (%) damage level (mean ± SE)
Mar-19	0 ± 0.0a
Apr-19	0 ± 0.0a
May-19	0 ± 0.0a
Jun-19	0 ± 0.0a
Jul-19	0 ± 0.0a
Aug-19	1 ± 0.2a
Sep-19	1 ± 0.4a
Oct-19	1 ± 0.4a
Nov-19	2 ± 0.4a
Dec-19	5 ± 1.1b

Except for RH where those in EFB and standing dead palm trunks were significantly lower, all parameters remained relatively constant for all substrates. The temperature remained within the optimum range of 29 - 35°C whilst the pH remained neutral (7) (Figure 46). Hence, the chances of these factors influencing breeding potential of the beetles in the substrates are minimal.

No life stages of the beetle were found in cow dung and cattle stock feed piles. Very low numbers were found in EFB, potentially influenced by the application of thin layers. Higher numbers of all stages except eggs were found in both the fallen and standing palm trunks. Among the substrates assessed, palm trunks are the most preferred breeding substrate (Figure 47). The fibre in the palm trunks provide a good source of food for larval development and growth. They breed in both the standing (poisoned) and fallen palm trunks, and this has implications for both plantations and smallholder growers with the current replanting practices. Effective management of the trunks is critical for minimising beetle population in areas where the pest is an issue.

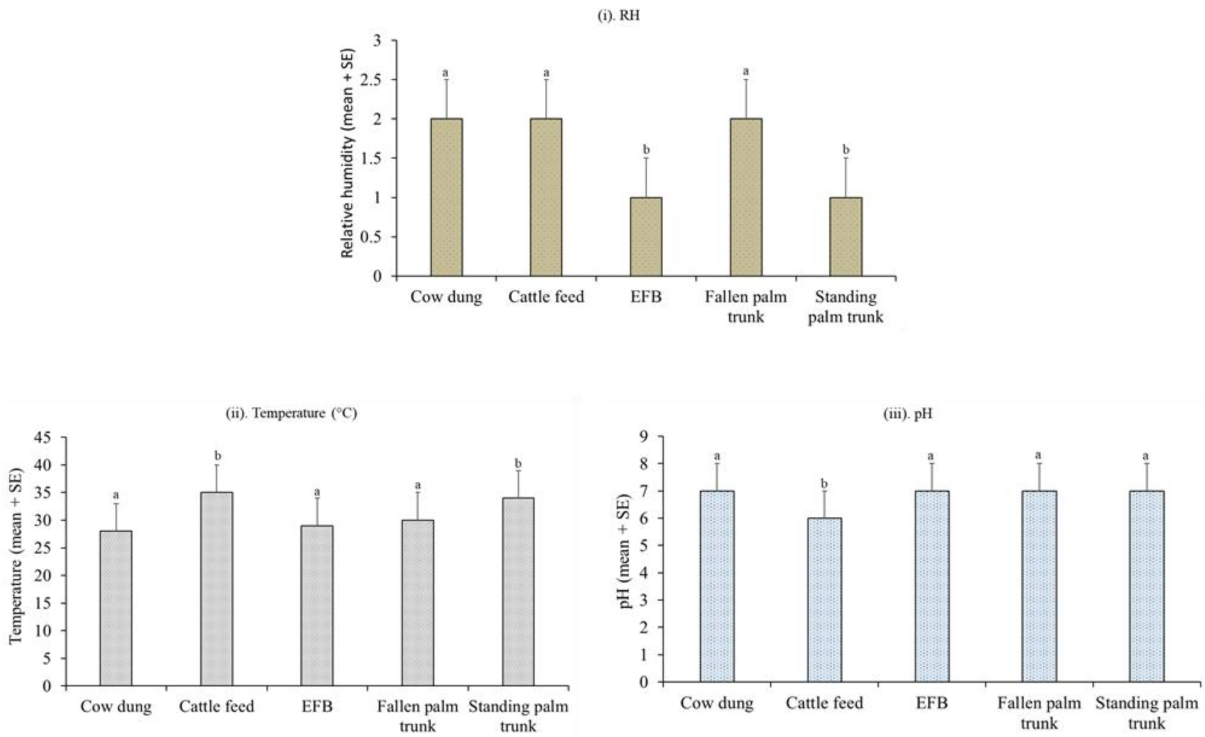


Figure 46. Abiotic factors (RH, temperature, pH) measured in the potential *O. rhinoceros* breeding substrates.

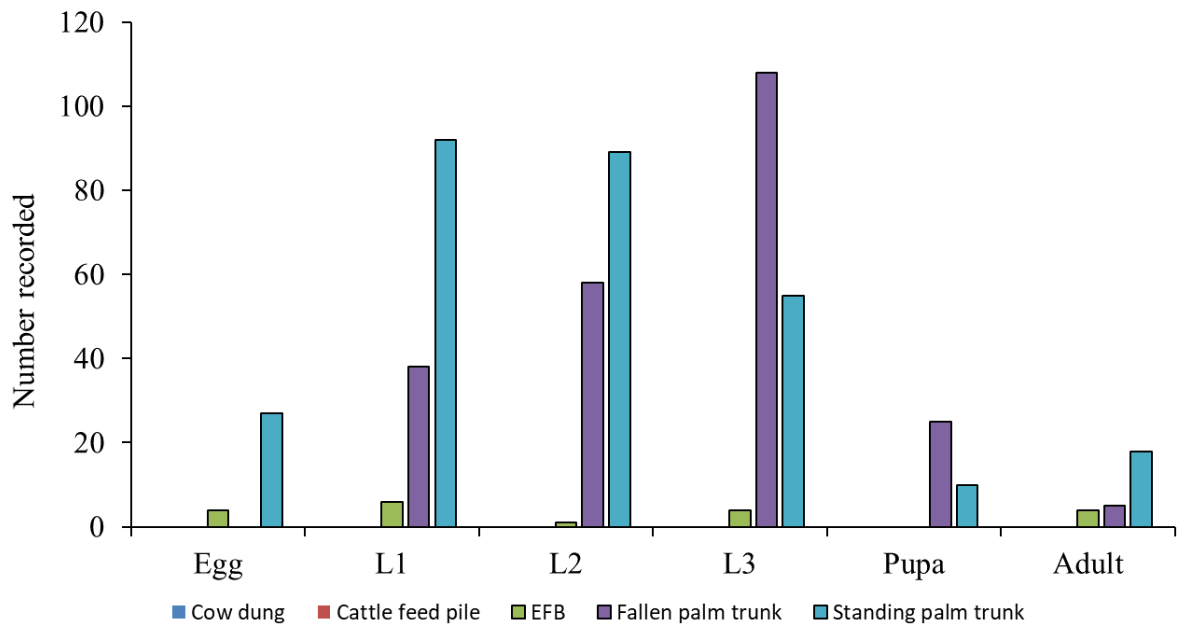


Figure 47. Number of the different stages of *O. rhinoceros* recorded from potential breeding substrates.

C.3.1.4 *Conclusion*

In West New Britain, the detectable beetle damage remains confined to Numondo Plantation. No damage was detected at Kumbango Plantation. During breeding the beetle plays a significant role accelerating the decomposition process. The lack of breeding potentially contributed to the delayed decomposition of palm trunks at Kumbango. This notion can further be confirmed once the palm trunks at Leinaru replant where there is beetle infestation have fully decomposed.

The confirmation of preference of both fallen and standing palm trunks for breeding over other substrates has implications for both the plantations and smallholders. Effective management of the felled and poisoned palm trunks during replants is critical.

C.3.1.5 *Recommendations*

The following are recommendations for the study:

- Continue palm trunk decomposition measurements and beetle damage assessment at both sites (Kumbango and Leinaru) until all trunks have fully decomposed.
- Set up pheromone traps at Leinaru replant once the damage has reached moderate level and continue the damage assessment.
- Dissect subsamples of beetles trapped at Leinaru to monitor NudiVirus infection.

C.3.2. CRB tissue sampling from the native range for bio-typing and histology testing

C.3.2.1. *Introduction*

The incursion of the Coconut Rhinoceros Beetle resistant to *Oryctes NudiVirus* into PNG and the Solomon Islands has posed serious threat to the oil palm industry in both countries. In the Solomon Islands it has entered GPPOL and has caused serious damage to replant palms whilst in PNG the spread is heading towards the oil palm project areas from its point of initial incursion in the National Capital District (NCD).

It is important that effective control measures are developed for the management of the pest. Whilst emergency mechanical and chemical control options have been devised for its management, it was necessary that search for any potential natural enemies within the native range in South East Asia begin.

The sampling of beetle tissues to determine viral infection was conducted in the Philippines, Cambodia and Thailand. Extensive collection was done in the Philippines because of a report for the existence of a CRB population resistant to *Oryctes NudiVirus* infection within the country (Zelazny, *et al*., 1989). Once most of the country was covered, it was extended to parts of Cambodia and Thailand. A consultant was engaged to conduct the sampling.

This report provides the results of the sampling and the preliminary DNA analysis done for some of the samples from the Philippines and the Cambodian samples.

C.3.2.2. *Materials and methods*

Sampling locations

All travels amongst the three countries were done through air, whilst domestic travels were done either through air (planes), land (vehicles and scooters) and/or sea (boats). The local travels covered within the three countries are indicated on the respective maps below (Figure 48).

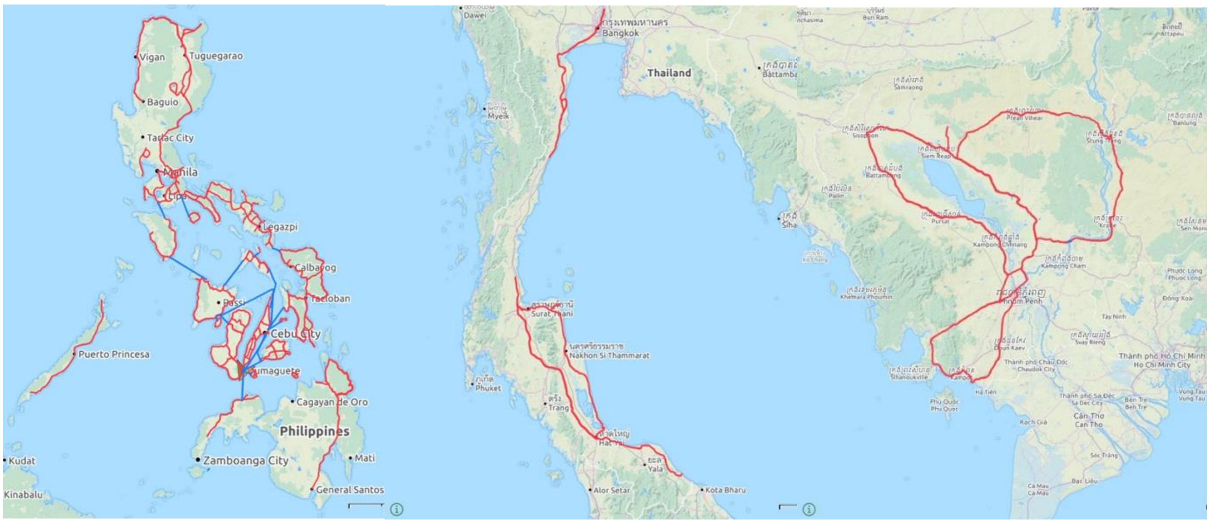


Figure 48. The maps indicate the areas where the trips were taken (*Left*: Philippines, Middle: Thailand, *Right*: Cambodia).

Pheromone trapping

The locations for pheromone traps were selected relative to accessibility, anthropogenic activity, coconut presence and heterogeneity of the general vegetation. As much as possible, traps were set up in shaded areas near coconut trees close to the main road. If locations close to main roads were not suitable, they were set up further in, away from the main roads. Average distance between traps were approximately 100km. Two types of traps made from 20L plastic buckets were used. They included the Barrier (Figure 49 left) and Vane Traps (Figure 49 right). Holes were drilled at the bottom of the buckets to allow for water to drain out. Saw dust or any other moist organic matter were placed inside the buckets for the attracted beetles to burrow in and hide for retrieval. They were installed at about 5m height on poles or pieces of tree nailed to standing palms. Examples of the traps are shown in Figure 49 and Plate 1 below. Both types of traps were efficient and easy to transport. Apart from pheromone trapping, manual collections were done in identified potential breeding sites.

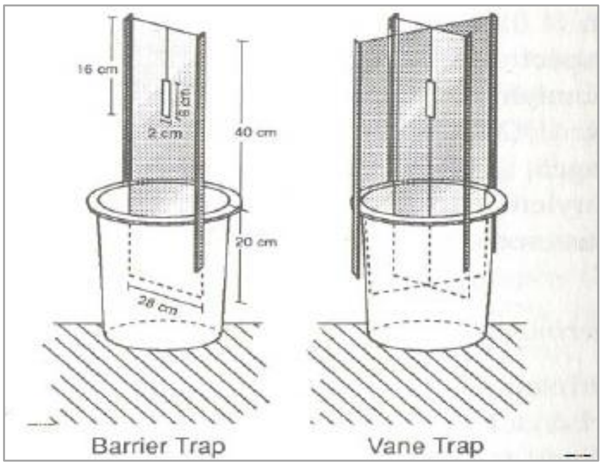


Figure 49. Schematic illustration of the two types of pheromone traps used (*Left*: Barrier Trap, *Right*: Vane Trap).

Plate 1. Photographs showing how the different traps were set up (*Left*: Barrier Trap, *Right*: Vane Trap).

Damage assessment

Visual damage assessments were conducted in areas where the traps were set up by quantifying the proportion of fronds damaged. It was given a damage category of "light" if the damage level was < 5% (less than 5% of fronds damaged), "moderate" if between 11-30% (11-30% of fronds damaged) and "severe" if > 30% damage (> 30% of fronds damaged).

Beetle dissection and gut extraction

The beetles collected were dissected and gut tissues extracted using the dissection and gut extraction protocol compiled by the project team (adopted from Jackson *et al*., 2010 SPC document) (Plate 2). The beetles were kept alive and brought to sites of residence and dissected 1 to 2 days after collection. Maximum of 50 to 100 beetles were dissected per dissection round. Prior to dissection and gut extraction, the sexes of the beetles were determined. They were killed by twisting the neck. The gut samples were sampled following the extraction protocols. Gloves were worn and dissection kits were sterilized (rinsed in alcohol and flamed) for every dissection to prevent any cross contamination. Gut samples were closely checked for potential virus infection. Guts that were "milky white and swollen" were recorded as symptomatic whilst those that were "thin and dark" were recorded as healthy. Duplicate samples were prepared in 1.5ml vials containing either 90% ethanol (EOH) or mono propylene glycol (MPG). The tissue samples were sent to Dami for DNA analysis to confirm beetle biotype and virus infection. Duplicate samples were sent to AgResearch, NZ to be analysed for comparison (quality check) and histology testing.

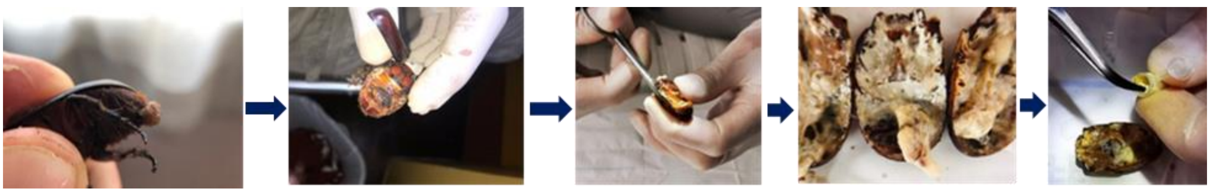


Plate 2. Processes involved in the dissection and extraction of gut tissue samples for DNA analysis.

C.3.2.3. *Results and discussion*

Twenty-three trips were taken among the three countries (Philippines, Thailand and Cambodia) where the collections were done by the consultant. The trips covered an estimated distance of 30,000 km. From the samples collected, nine batches representing 505 tissue samples were sent to Dami Oil Palm Research Station for DNA analysis.

The Philippines was covered most extensively as it was the target country for sampling. Repeat trips were done to areas where few insects were sampled during the first round of sampling. These areas included North Negros, Bohol, Cebu and Samar.

Figure 50 shows where the pheromone traps were set up for beetle collection, and Figure 51 shows the density of beetles trapped. The biggest violet spots in the Philippines had between 50 to 100 beetles. In Thailand and Cambodia, the biggest ones in dark red were catches of around 30 beetles. Medium-sized orange dots represent catches from 10 to 20 beetles, and small yellow circles represent areas where 1 to 7 beetles were caught. Collection points where no beetles were sampled are not shown on the map.

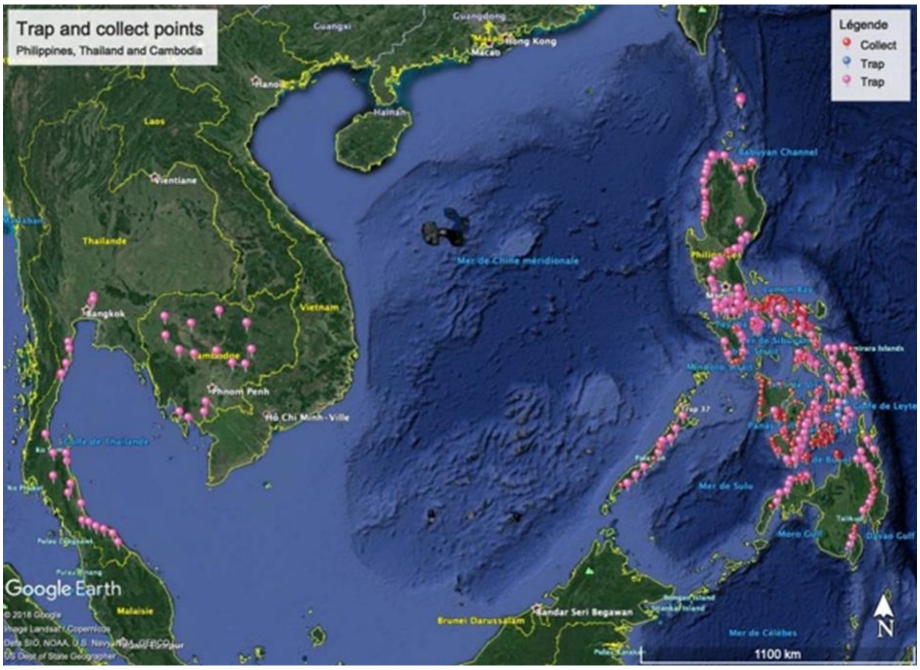


Figure 50. Locations of the sampling points across the three countries.

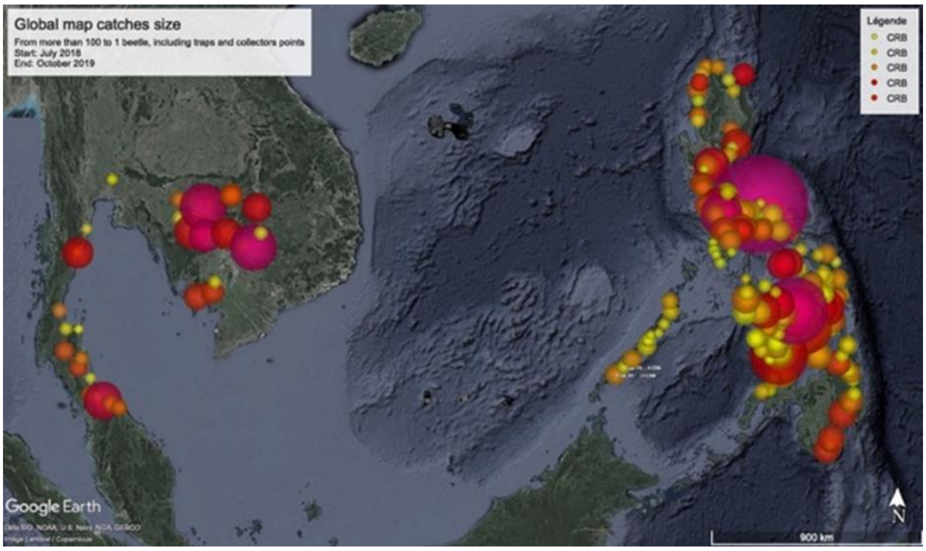


Figure 51. The density of beetles sampled from the different sampling points.

The Philippines had the most diverse landscape, mainly mountainous with some medium-sized rice fields along the coast lines. There were more than 7,100 islands but the collection was concentrated on the main islands. In Thailand and Cambodia, the coconut plantations were not as big as in the Philippines. There were two provinces in each country with plantations. In other areas coconut trees were mostly small batches of around 10 trees surrounded by rice, rubber or oil palm trees. The landscape of the areas where the collections were done were flat with no big natural boundary vegetation.

Most of the coconut plantations in Thailand were in the South (Prachuap Khiri Khan and Surat Thani provinces). In some areas, farmers had monkeys that climbed coconut trees and collect the nuts for them. Around Bangkok and in the north, coconut trees were planted in family gardens or in hedges between rice fields. In the south of Prachuap Khiri Khan, coconut trees were in small batches surrounded by family oil palm or rubber tree plantations covering less than 5 ha area.

Because of the short schedule and bad road conditions, the collection in Cambodia was concentrated around the central part of the country. Along the way to Kampot Province, coconut trees were more abundant on the coastlines. Around the capital Phnom Penh, coconut trees were in family gardens except from Kambong Chhnang Province to Phnom Penh where coconut trees were all along the road intercropped with cocoa trees. Plantations were less than 1ha in size. Going north along the Mekong River, coconut trees were in batches mostly in village family gardens. There were no coconut trees in rice fields (which were flooded at the time of sampling). Around Strung Teng Centre north of Cambodia, coconut trees were noted along the Mekong River and in villages where the land was more recently deforested. The dominant palm tree in Cambodia was the “sugar palm” forming part of rice fields landscape.

Since the sampling effort was focused in the Philippines, more samples were collected from there than Thailand or Cambodia. Larger proportion of the samples were preserved in MPG than EOH as the preservative was more easily accessible (Table 79). An average of one EOH and MPG sample each were prepared from each pheromone trap for sampling points with pheromone traps. However, for manually collected samples higher proportion were preserved in MPG than EOH.

In total, more than 4,000 beetles were collected and dissected (Table 80). In the Philippines and Thailand, the sex ratio (males: females) was around 1:1 whereas in Cambodia it was around 1:3. Beetles had been trapped throughout the year in the Philippines, but the number was very low during the dry season. The collection in the South of Thailand and Cambodia were done at the beginning of the rainy season to maximize the chances of catching enough beetles.

For all three countries, less than 50% of gut samples prepared were symptomatic (Table 80). Most of the samples did not show any symptoms of infection. Molecular analysis will further confirm the biotype and the true status of infection. Duplicate samples were prepared with one set each sent to PNGOPRA Dami and AgResearch, NZ.

Table 79. Proportion (%) of the gut samples preserved in the two different preservatives.

Country	No. of traps	No. of manual collection points	No. of samples	No. preserved in EOH	No. preserved in MPG
Philippines	175	340	440	198 (45%)	242 (55%)
Thailand	24	0	38	16 (42%)	22 (58%)
Cambodia	15	0	37	14 (38%)	23 (62%)

Table 80. Proportion (%) of symptomatic and non-symptomatic gut samples extracted and preserved for DNA analysis.

Country	No. of males	No. of females	Total beetles	No. non-symptomatic	No. symptomatic
Philippines	1691	1533	3224	2427 (75%)	797 (25%)
Thailand	147	157	304	173 (57%)	131 (43%)
Cambodia	149	371	520	387 (74%)	133 (26%)

Out of the 440 gut tissue samples collected from the Philippines, only 48 (10.9%) of the samples were analysed at Dami. The results are presented in Table 81. The rest of the samples (392 [89.1%]) remain to be analysed. The analysis of duplicate tissue samples sent to AgResearch, NZ has started. The results will be provided in 2020 once the analysis is completed.

Out of the 48 samples analysed, 15 were CRB-G (31.3%) whilst the remainder (33 [78.7%]) were CRB-S. Nine (60%) of the samples were infected with virus, whilst 6 (40%) were free of infection. For the CRB-S samples, 19 (57.6%) had virus infection. The remaining samples (14 [42.4%]) were free of virus infection (Table 81).

The decision on where to target the CRB-G collection for virus extraction and importation will be made once the analysis by AgResearch, NZ is completed for the duplicate samples. This is to ensure quality check before the targeted sampling and virus importation is organised.

Table 81. CRB samples from the Philippines analysed at Dami.

Sample ID	Country	Sampling location	Haplotype	OrNV detection	Comments
479	Philippines	Barangay Talaga	CRB-S	No	No virus detected
479	Philippines	Barangay Talaga	**CRB-G**	Yes	Virus detected
479	Philippines	Barangay Talaga	**CRB-G**	No	No virus detected
479	Philippines	Barangay Talaga	CRB-S	Yes	Virus detected
480	Philippines	Barangay San Jose	CRB-S	No	No virus detected
480	Philippines	Barangay San Jose	CRB-S	No	No virus detected
481	Philippines	Barangay Mayasang	CRB-S	Yes	Virus detected
481	Philippines	Barangay Mayasang	**CRB-G**	No	No virus detected
482	Philippines	Barangay Bocana	**CRB-G**	Yes	Virus detected
482	Philippines	Barangay Bocana	CRB-S	No	No virus detected
483	Philippines	Barangay Balitoc	**CRB-G**	Yes	Virus detected
483	Philippines	Barangay Balitoc	CRB-S	No	No virus detected
484	Philippines	Barangay Dakanlao	**CRB-G**	Yes	Virus detected
484	Philippines	Barangay Dakanlao	**CRB-G**	Yes	Virus detected
485	Philippines	Barangay Bolo	**CRB-G**	Yes	Virus detected
485	Philippines	Barangay Bolo	**CRB-G**	No	No virus detected
485	Philippines	Barangay Bolo	CRB-S	Yes	Virus detected
474	Philippines	Barangay Tilambo	CRB-S	Yes	Virus detected
474	Philippines	Barangay Tilambo	CRB-S	Yes	Virus detected
474	Philippines	Barangay Tilambo	CRB-S	Yes	Virus detected
474	Philippines	Barangay Tilambo	CRB-S	Yes	Virus detected
474	Philippines	Barangay Tilambo	CRB-S	No	No virus detected
474	Philippines	Barangay Tilambo	**CRB-G**	Yes	Virus detected
475	Philippines	Barangay Escribano	CRB-S	No	No virus detected
475	Philippines	Barangay Escribano	CRB-S	No	No virus detected
475	Philippines	Barangay Escribano	CRB-S	No	No virus detected

475	Philippines	Barangay Escribano	CRB-S	No	No virus detected
478	Philippines	Barangay Santo Nino	CRB-S	Yes	Virus detected
478	Philippines	Barangay Santo Nino	CRB-S	Yes	Virus detected
486	Philippines	Barangay Balimbing	CRB-S	Yes	Virus detected
486	Philippines	Barangay Balimbing	CRB-S	Yes	Virus detected
487	Philippines	Barangay Gatid	CRB-S	Yes	Virus detected
487	Philippines	Barangay Gatid	**CRB-G**	Yes	Virus detected
487	Philippines	Barangay Gatid	CRB-S	No	No virus detected
496	Philippines	Barangay Amoingon	CRB-S	No	No virus detected
489	Philippines	Barangay Sumanga	CRB-S	No	No virus detected
489	Philippines	Barangay Sumanga	**CRB-G**	No	No virus detected
490	Philippines	Barangay Dolores	**CRB-G**	Yes	Virus detected
490	Philippines	Barangay Dolores	**CRB-G**	No	No virus detected
491	Philippines	Barangay Matuyatuya	CRB-S	No	No virus detected
491	Philippines	Barangay Matuyatuya	CRB-S	Yes	Virus detected
491	Philippines	Barangay Matuyatuya	**CRB-G**	No	No virus detected
493	Philippines	Barangay Malbog	CRB-S	Yes	Virus detected
493	Philippines	Barangay Malbog	CRB-S	Yes	Virus detected
493	Philippines	Barangay Malbog	CRB-S	Yes	Virus detected
494	Philippines	Barangay Bachao Ibaba	CRB-S	Yes	Virus detected
494	Philippines	Barangay Bachao Ibaba	CRB-S	Yes	Virus detected
494	Philippines	Barangay Bachao Ibaba	CRB-S	Yes	Virus detected

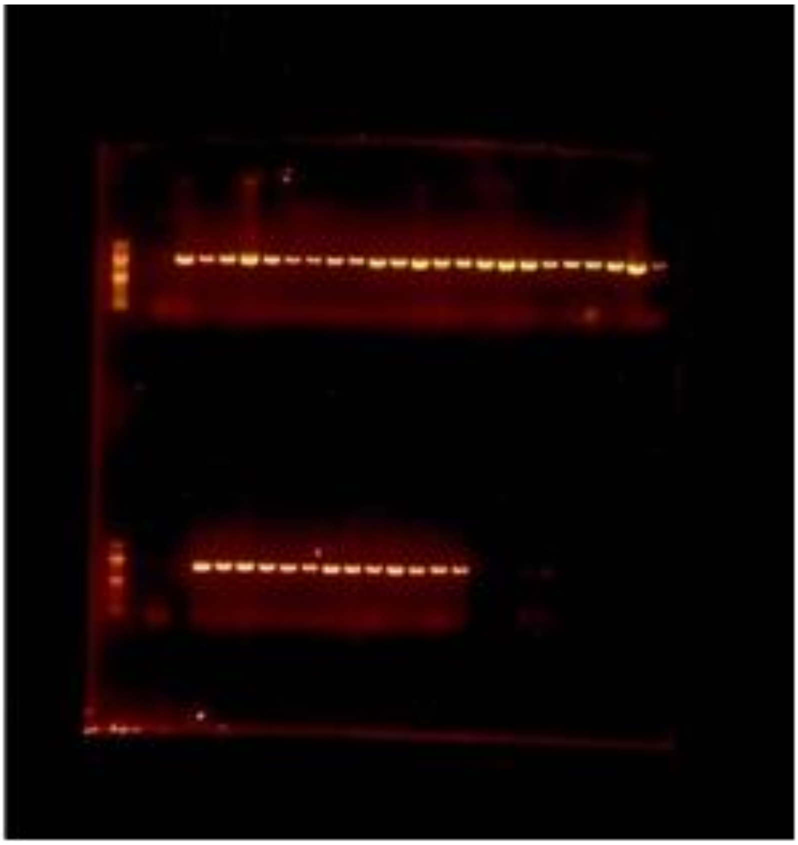


Plate 3. Example of a gel run at Dami to confirm the beetle biotype and virus infection.

The samples from Cambodia were analysed by AgResearch, NZ. They were all CRB-S with NudiVirus infection (Table 82). It is unusual to have all samples infected with virus. The possibility of cross-contamination of healthy samples cannot be ruled out although the sampling procedures were strictly followed. There won't be any need for further sampling in Cambodia. The samples sent in from Indonesia by Minamas R & D team have not be analysed. The DNA analysis and histology testing (AgResearch, NZ samples) for the pending duplicate samples is planned for next year (2020).

Table 82. Cambodia gut samples DNA analysis results provided by AgResearch, NZ.

Country	Collection No.	Current specimen label	Visual inspection notes	Site	COI RFLP	Virus detection
Cambodia	1680	441	Female	Khum rohal, Cambodia	CRB-S	yes
Cambodia	1681	442	Female	Khum rohal, Cambodia	CRB-S	yes
Cambodia	1682	443	Female	Pankha, Cambodia	CRB-S	yes
Cambodia	1683	444	Female	Pankha, Cambodia	CRB-S	yes
Cambodia	1684	445	Female	Bakan, Cambodia	CRB-S	yes
Cambodia	1685	446	Female	Bakan, Cambodia	CRB-S	yes
Cambodia	1686	447	Female	Bakan, Cambodia	CRB-S	yes
Cambodia	1687	448	Male	Krakor, Cambodia	CRB-S	yes
Cambodia	1688	449	Male	Krakor, Cambodia	CRB-S	yes
Cambodia	1689	450	Female	Krakor, Cambodia	CRB-S	yes
Cambodia	1690	451	Female	Krakor, Cambodia	CRB-S	yes
Cambodia	1691	452	Female	Tasat poum, Cambodia	CRB-S	yes
Cambodia	1692	453	Female	Tasat poum, Cambodia	CRB-S	yes
Cambodia	1693	454	Male	Prek Pdiav village, Cambodia	CRB-S	yes
Cambodia	1694	455	Female	Prek Pdiav village, Cambodia	CRB-S	yes
Cambodia	1695	456	Female	Prek Pdiav village, Cambodia	CRB-S	yes
Cambodia	1696	457	Male	Rolous, Cambodia	CRB-S	yes
Cambodia	1697	458	Male	Rolous, Cambodia	CRB-S	yes
Cambodia	1698	459	Female	Rolous, Cambodia	CRB-S	yes
Cambodia	1699	460	Female	Rolous, Cambodia	CRB-S	yes
Cambodia	1700	461	Female	Mesa chrey, Cambodia	CRB-S	yes
Cambodia	1701	462	Female	Mesa chrey, Cambodia	CRB-S	yes
Cambodia	1702	463	Female	Phum han Chey 3, Cambodia	CRB-S	yes
Cambodia	1703	464	Male	Phum han Chey 3, Cambodia	CRB-S	yes
Cambodia	1704	465	Female	Phum Intrei kro hom, Cambodia	CRB-S	yes
Cambodia	1705	466	Female	Phum Intrei kro hom, Cambodia	CRB-S	yes
Cambodia	1706	467	Female	Stung treng, Cambodia	CRB-S	yes
Cambodia	1707	468	Female	Stung treng, Cambodia	CRB-S	yes
Cambodia	1708	469	Female	Stung treng, Cambodia	CRB-S	yes
Cambodia	1709	470	Female	Tbaeng mean chey, Cambodia	CRB-S	yes
Cambodia	1710	471	Female	Tbaeng mean chey, Cambodia	CRB-S	yes
Cambodia	1711	472	Male	Tbaeng mean chey, Cambodia	CRB-S	yes
Cambodia	1712	473	Male	Tbaeng mean chey, Cambodia	CRB-S	yes
Cambodia	1713	474	Male	Anlong Thom, Cambodia	CRB-S	yes
Cambodia	1714	475	Male	Anlong Thom, Cambodia	CRB-S	yes
Cambodia	1715	476	Female	Kakaoh, Cambodia	CRB-S	yes
Cambodia	1716	477	Female	Kakaoh, Cambodia	CRB-S	yes

Damage levels were estimated through visual observations from along the roads. In some areas, quantifying damage levels was difficult because of huge heterogeneity between neighbouring natural forests. For example, in some regions there were patches of coconut trees in family gardens like in the north of the Philippines but in the fields outside of the villages, no coconut trees were seen for tens of kilometres. In other areas like the central eastern part of the Philippines (Camarines, Quezon, Leyte and Samar provinces), there were huge coconut plantations stretching more than 50km. The width of the line corresponds to the density of coconut trees. The wider it is, the bigger the coconut plantations (Figure 52).

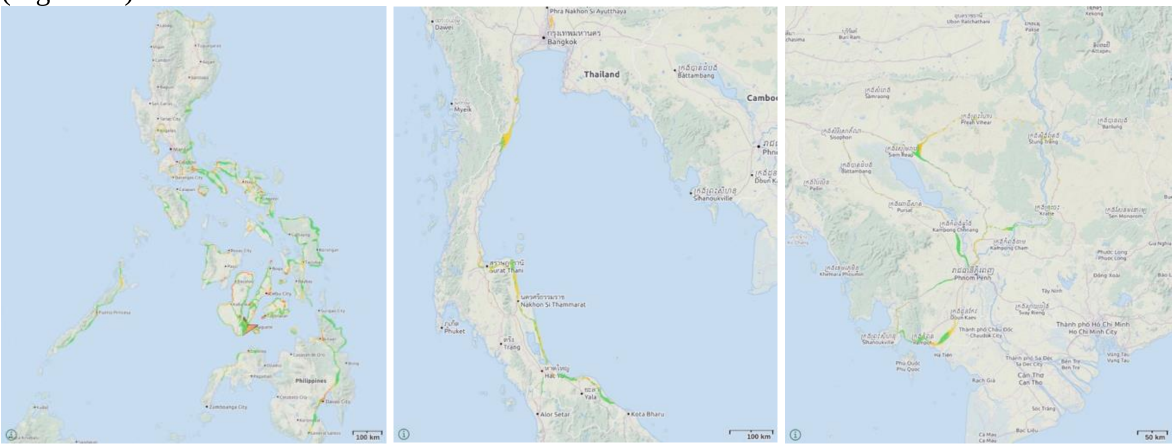


Figure 52. Maps showing the intensity of damage by Coconut Rhinoceros Beetle on coconuts (*Left*: Philippines, *Middle*: Thailand, *Right*: Cambodia).

C.3.2.4. *Conclusion*

CRB incursion is common in the region. The target areas for next round of sampling will be decided once all the DNA analysis is fully completed. The virus infection detected on CRB-G from Philippines samples in the analysis done at Dami will be verified by analysis at AgResearch, NZ once done. The analysis of the remaining samples both at Dami and AgResearch, NZ will be expedited in 2020.

C.3.2.5. *Recommendations*

1. Complete analysis of the remaining tissue samples (both at Dami and AgResearch, NZ). The analysis at Dami to be done in collaboration with the Plant Pathology Section.
2. Once the analysis is completed and virus infection on CRB-G are further confirmed, organise targeted sampling and importation of the virus from areas with infection. This will need to be done under AgResearch, NZ MFAT funded project.
3. Establish collaborative network with local organizations and arrange formal import permit documents from relevant bodies (DENR) before the importation of samples.
4. Expand sampling to countries in the native range such as Brunei, Indonesia, Malaysia and Taiwan, if no CRB-G or virus infection are detected in the current samples. Where possible, Sime Darby Plantation Berhad's networks can be utilized in some of the countries where the company is operating.
5. Develop a biotype map of the beetle for the sampling sites once the DNA analysis is completed and biotypes are all confirmed.

C.3.3. Infection screening of AgResearch, NZ supplied Oryctes NudiVirus strains (V23B and DUG42) against CRB-G at GPPOL

C.3.3.1. *Introduction*

Efficacy evaluation of biocontrol agents against target pests prior to field release is critical. Biological control programmes can fail without such screening. The detection of the CRB population that is resistant (CRB-G) against the strain of Oryctes NudiVirus used for classical control of the beetle meant that any new potential strains of virus to be used needed to be screened judiciously for virulence before any field releases were done. Apart from searching for new strains of virus within the native region AgResearch, NZ had some laboratory stocks of virus randomly sampled from CRB in various locations within the Pacific and South East Asian regions that needed to be screened.

Two strains of the lab cultured strains (V23B and DUG42) were provided to the project team at GPPOL by AgResearch, NZ for testing. Initially, lab infection tests were conducted to validate any potential infection prior to transmission trials. Transmission trials will be conducted as the next phase of the evaluation process to ensure there is natural transmission before any field releases are done.

This component of the report provides the results on the lab bioassay efficacy screening trial.

C.3.3.2. *Materials and methods*

The bioassay study was conducted using detailed protocol compiled by Marshall (2016) and further summarized by Ero (2017). Freshly emerged adult beetles were collected from breeding sites at Guadalcanal Plains Palm Oil Limited (GPPOL) plantations, in Ngalimbiu and Tetere Estates. The beetles were placed into individual containers (1 beetle/container) for a week and then treated with the respective viruses.

The virus solution for dosing was prepared using 50% sugar water stock solution. Using plastic transfer pipettes (1000 μL), a drop of virus solution was released onto the mouths of the beetles and allowed 5 -10 minutes to imbibe before another dose was supplied. The dosed beetles were transferred back into their respective containers containing sterilized sawdust bedding and sugarcane to feed. Sugarcane was replaced whenever they either dried out or were fully consumed.

The feeding behaviour of the beetles were monitored for around 22 days because longevity of infected adults often reduces to 25 days after infections (Gopal *et al*., 2001). First and second virus dosing and feeding took 4 days whilst monitoring took 22 days. After this period, the beetles were dissected, and guts observed for symptoms of viral infection. Symptomatic guts were milky white and swollen whilst non-symptomatic guts were dark and thin. Infected gut samples were extracted and preserved in vials containing Mono Propylene Glycol (MPG) and formaldehyde acetic acid (FAA), and sent to AgResearch, NZ for DNA analysis and histology testing. The summary of the dosing program is provided in Table 83 below.

Table 83. Outline of the treatment programme conducted for the test.

Bioassay and dissection descriptions	Treatments		
	CONTROL	**T2 - DUG42**	**T1 – V23B**
Total no of beetle/treatment	30	30	30
Sex ratio/treatment (male: female)	15M:15F (1:1)	15M:15F (1:1)	15M:15F (1:1)
Treatment date 1st dose	21.11.2018	21.11.2018	21.11.2018
Treatment date 2nd dose	24.11.2018	24.11.2018	24.11.2018
Treatment duration	22 days	22 days	22 days

Two previous bioassays were jointly carried out by Biosecurity Solomon Island (BSI) and AgResearch NZ. This batch by GPPOL was the third, also conducted with support from AgResearch NZ. The bioassay was supposedly the third replicate to statistically validate the infectivity of the two strains and to identify the potential candidate for further evaluation.

C.3.3.3. *Results and discussion*

The bioassay results from the infection trial have shown high percentage infection symptoms, with slightly higher infection by V23B than DUG42 (Table 84, Figure 53). The symptoms were characterised by swollen/enlarged milky white colouration of the guts (Plate 4).

The symptomatic results have been confirmed in both strains as well as the low infection in the Control treatment through DNA analysis at AgResearch, NZ. Both the histology test and PCR analysis have shown that infectivity by V23B is above threshold than DUG42. This result implies that V23B could be a better candidate for field release than DUG42.

Table 84. Summary of bioassay results for the beetles used for the infection trial.

	Treatment		
	Control	**V23B (T1)**	**DUG42 (T2)**
No. released	30	30	30
No. alive	25	21	19
No. dead	5	9	11
Decomposed guts	2	4	3
Symptomatic guts	1	20	17
% infection	**4**	**77**	**63**

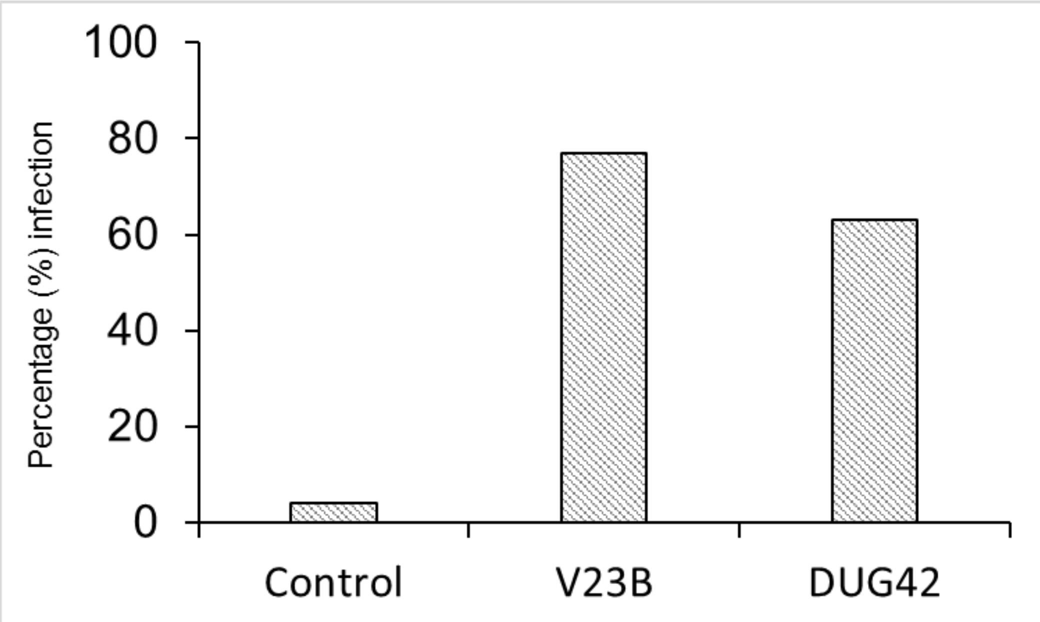


Figure 53. Percentage (%) viral infection by the two AgResearch, NZ lab cultured strains of NudiVirus tested.

Plate 4. Typical symptoms of viral infection (milky white swollen guts) observed in beetles dosed with the two strains of Oryctes NudiVirus (V23B-*Left* and DUG42-*Right*).

C.3.3.4. *Conclusion*

Preliminary DNA analysis results have confirmed infection. The molecular analysis result has backed the visual observation of high number of symptomatic samples. This warrants the study to proceed with the transmission trials.

C.3.3.5. *Recommendation*

Follow up on full analysis results report from AgResearch NZ.

C.3.4. Lab transmission screening of AgResearch, NZ supplied Oryctes NudiVirus strains (V23B and DUG42) against CRB-G at GPPOL

C.3.4.1. *Introduction*

When considering entomopathogens for classical biocontrol releases, it is critical to confirm effective transmission through lab and field bioassay transmission trials prior to actual releases. If releases are done without proper validation, natural field transmission and establishment can fail.

With the confirmation of infection by both strains of the virus in the lab bioassay study, it was necessary that transmission tests were conducted to validate this process for both strains of the virus prior to field release. The transmission tests were done during the year, and gut tissue samples extracted and sent to AgResearch, NZ for DNA analysis and histology testing to confirm transmission. This component of the report provides the progressive result of the trial.

C.3.4.2. *Materials and methods*

Adult droplet dose evaluation
Field collected young adults from breeding sites were used for the trial. Treatments were V23B, DUG42 and Control (Table 85). Four males each were used for each treatment. The 1st dose was administered on 9th May 2019, followed by the 2nd dose on 10th May 2019. Only male beetles were used for dosing (transmitters) whilst females were kept healthy (as recipients). As such the beetles were not marked as the sexes can easily be set apart by the distinct sexual dimorphic characters.

Virus dose for droplet feeding was prepared using 1 part 50% sucrose and 9 parts of the respective Virus (1:9). For the Control treatment, the beetles were dosed with water instead of virus. The 50% sucrose solution was prepared by dissolving 10 g white table sugar into 15 ml of clean bottled water. The solution was further topped up to 20 ml and stored in the refrigerator at 4 ^{0}C for a week before use. A new solution was prepared for further dosing after one week.

Clean 1 ml pipettes were used, and the male beetles were drop fed (2 drops) through the mouth. It was ensured that the 1st droplet was consumed before the second droplet was applied. The second dose was 2 days later using the same process. This provided a maximum dose and ensured that beetles were well dosed for transmission. A day after the second dose, rearing material (sawdust) was added to the rearing containers and fed with pieces of sugarcane to minimise any natural mortality. The feed (sugarcane) was replaced as per when needed (i.e. when all eaten, getting mouldy or have dried out).

Healthy un-dosed (untreated) female beetles were introduced into the holding containers 3-5 days after virus dosing of the male beetles, and both were monitored each day for 4 weeks for signs of infection and health status. During each observation the dates were recorded and health status (live and active, live but slow moving, moribund or dead) scored. Also made notes if anything unusual was observed.

During the bioassay period dead insects were immediately dissected and checked for symptoms of virus infection. Midgut tissues were extracted and preserved for histology testing and DNA analysis at AgResearch, NZ.

At the end of the 4 weeks observation period, remaining beetles were dissected, and gut tissues extracted also for analysis. The first 0.5 – 1 cm of anterior midgut tissues were preserved in MPG (for DNA analysis), and remaining half (1-1.5 cm) were preserved in FAA (for histology test).

Table 85. Beetle combinations (dosed vs healthy) for each treatment.

No. of combinations	Treatment 1 (V23B)	Treatment 1 (DUG42)	Control
1	1 infected male: 1 healthy female	1 infected male: 1 healthy female	1 healthy male: 1 healthy female
2	1 infected male: 2 healthy females	1 infected male: 2 healthy females	1 healthy: 2 healthy females
3	1 infected male: 3 healthy females	1 infected male: 3 healthy females	1 healthy male: 3 healthy females
4	1 infected male: 4 healthy females	1 infected male: 4 healthy females	1 healthy male: 4 healthy females

Virus isolate infection screening in CRB larvae through sugarcane virus contamination and feeding
Field collected third instar larvae (L3) were used for the trial. Each treatment had 15 replicates (in terms of the number of larvae used). The larvae were kept individually for at least 2 weeks to ensure they were healthy (no fungus infection or physical damage during collection) for the trial.

Sugarcane were cut into small pieces of approximately equal sizes (2 cm x 2 cm). Three drops of virus dose solution for each virus strain (V23B and DUG42) were applied to each piece of sugarcane. The Control treatment was dosed only with water. The sucrose-virus solution was prepared as per the procedure in adult transmission trial.

Plate 5. Application of virus dose on the sugarcane pieces (*Left*) and the set up after virus dosing (*Right*) for feeding and infection.

Each piece of sugarcane was placed into individual empty containers (used plastic drink cups with lids or 355ml drink cans with lids). A CRB larva each was then placed into each container and incubated at 28^{0}C. The set up was monitored each day, date recorded, any signs of infection checked and health status (alive, moribund, dead) recorded. The amount of sugarcane eaten were recorded as proportional feeding relative to original size (0% = none, 10% = hardly nibbled, 25% = obvious eating but not much, 50% = half eaten, 75% = mostly, 100% = almost all eaten) and any signs of virus infection (glassy, turgid/firm/swollen, prolapsed rectum, unusual colour etc.) were recorded. Any other unusual observations were also recorded.

Whenever any larva appeared moribund, several fresh frass pellets were collected and preserved in MPG (0.5 ml) for DNA analysis. For those that died, the larvae were dissected immediately after death, a portion of the gut and fat body tissue were extracted and preserved in MPG (0.5ml) in a separate tissue vial. Where possible head tissue was also included. The head tissue was used as backup for biotype confirmation whenever DNA extraction from the gut or fat body tissue was not possible due to degradation.

Virus isolate infection screening- CRB larvae through haemocoel injection
Third instar larvae (L3) were also used for this trial with the same number of replicates. They were also kept for one week before the infection, and the same procedure was used for preparing the virus solution.

The virus strains (2ml virus solution) were injected into the haemocoel of the larvae by injecting through the portion of the abdomen next to the legs using a syringe. The needle of the syringe was kept parallel to the gut to ensure no damage was caused to the gut. The Control treatment was injected the same volume of water.

Pieces of sugarcane were cut and placed into clean empty containers. Each larva was then added into each container and labelled according to treatment. The set ups were incubated at 28^{0}C. After 4-5 days, larval rearing materials were added to each container to minimise any natural mortality.

The larvae were monitored for signs of infection and health status (alive, moribund, dead) every day after the set up. They were also checked for any signs of virus infection (glassy, prolapsed rectum, unusual colour) and recorded (including the date of observation). Any unusual observations were also recorded.

Plate 6. Third instar larvae (L3) injected with virus solution (*Left*) and injected larva in rearing material (*Right*).

C.3.4.3. *Results and discussion*

The full DNA analysis results from AgResearch, NZ are still pending, awaiting the completion of the analysis of samples from the two later rounds of infection. However, preliminary indications from the first round of tests are that both the PCR and histology tests have shown positive trend with infection. Both the male (virus dosed) and female (virus free) adults from the adult assay trial have shown signs of infection by both virus strains (V23B and DUG42) (Table 86).

Although there were symptoms of infection for the bioassays with larval stages in both substrate dose feeding (on sugarcane) (Table 87) and haemocoel injection (Table 88), gut extractions were messy, with some of the dead samples difficult to differentiate. The DNA analysis results from the head tissue will fully confirm the results once done by AgResearch, NZ.

Table 86. Proportion (%) of female adults showing symptoms of infection.

Treatment	No. exposed	No. infected	Proportion (%) symptomatic
Control	10	0	0
V23B	10	7	70
DUG42	10	6	60

Plate 7. Adult beetles in copula in the transmission assay (*Left*), symptomatic gut samples from V23B treated beetle (*Middle*) and that from DUG42 treated beetle (*Right*).

Table 87. Proportion (%) of symptomatic larvae from sugarcane dose virus infection through feeding.

Treatment	No. of larvae	No. dead	No. alive	No. symptomatic	Proportion (%) symptomatic
Control	15	7	8	0	0
V23B	15	12	3	4	27
DUG42	15	10	5	3	20

Table 88. Proportion (%) of symptomatic larvae from haemocoel injection virus infection.

Treatment	No. of larvae	No. dead	No. alive	No. symptomatic	Proportion (%) symptomatic
Control	10	7	3	1	10
V23B	10	10	0	6	60
DUG42	10	9	1	3	30

A formal decision on whether to field release or not will be made once the molecular analysis results from AgResearch, NZ confirms the status of effective transmission. The third round of transmission study is still in progress.

C.3.4.4. *Conclusion*

The preliminary symptomatic transmission results have shown potential transmission by both strains of the virus but with greater transmission by V23B than DUG42. A formal field release will be done once the full DNA analysis results are provided by AgResearch, NZ.

C.3.4.5. *Recommendations*

1. Complete two more sets of adult transmission trials.
2. Set up field transmission trial.
3. Follow up with the analysis results from AgResearch, NZ.
4. Run further feeding impact and mortality studies.

C.3.5. Evaluation of sugar concentration and biocontrol agent preference among beneficial weeds

C.3.5.1. *Introduction*

An integrated approach to management of agricultural pests has gained prominence over heavy reliance on chemicals due to undesired impacts of the later on the environment, applicators and natural enemies of pests as well as the issues of insecticide resistance. An integrated approach involves synergetic use of a range of control measures that concomitantly contribute towards the management of the pest. Such approaches are often sustainable with minimal undesired impacts.

Integrated Pest Management (IPM) has strongly been promoted in the oil palm industry in PNG guided by RSPO and SAN guidelines. The two key pests of oil palm in West New Britain and New Ireland are sexavae and stick insects. Several biological control agents (particularly egg parasitoids) for both pests have been identified, mass reared and field released for augmentative control of the pests.

A critical component in biological control programmes that helps sustain the biocontrol agent (BCA) populations is the establishment of beneficial weeds. The weeds provide food sources for the natural enemies. If augmentative releases of BCAs are done without the establishment of beneficial weed systems, the agents are bound to collapse.

Although the BCA release programmes have been in place for a long time since the establishment of the crop (oil palm) in the country, the systematic use of beneficial weeds in the cropping system has never been studied. Hence, this study was instigated to evaluate the preferred beneficial weeds for the BCAs of oil palm pests and promote their integration into the cropping systems.

During the year, the sugar concentration measurements for five main beneficial weeds used widely and preference among them by one of the main parasitoids (Anastus eurycanthae = stick insect egg parasitoid) in PNG was done.

The primary objective of the study was to determine the beneficial weeds that can be integrated into oil palm cropping systems for both the smallholder blocks and plantations.

C.3.5.2. *Materials and methods*

Nectar extraction and sugar concentration measurement

The five beneficial weeds used for the sugar concentration measurements included *Crotolaria pallida* (rattle box plant [RB]), *Turnera subulata* (white alder [WA]), *Turnera ulmifolia* (yellow alder [YA]), *Antigonan lepitopus* (coral vine [CV]) and *Octacanthus caeruleus* (Brazilian snapdragon [BS]) (Plate 8).

Sampling of flowers for nectar extraction was done between 0700 to 0800 hours in the mornings. The nectar was drawn from the flowers using a 1-10 µL pipette (Pipetman/GILSOM™_Z53641k) fitted with plastic micro capillary tube to the estimated volume. For flowers with very low nectar volume, several flowers were used for the extraction of nectar to make up the required volume. Nectar was drawn from each flower and placed cumulatively in the cavity block tray until the required volume was attained. This was then drawn and placed on the Glucometer Strip for sugar (glucose) concentration measurement.

The digital blood Glucometer® used for the measurement was a medical home test kit for measuring human blood sugar level particularly for diabetic patients. Measurement of different sugar concentrations using a Refractometer® was not practical because it needed at least 0.3 ml of nectar as detectable level, which was higher than the volumes the flowers were producing. Hence, only glucose was measured as a representative of the three main sugar components (glucose, fructose, sucrose). Approximately 1 µL of nectar from the micro-pipette was transferred onto the blood glucose strip and inserted into the Glucometer® for the measurement. The sugar concentration volume was taken from the Glucometer® screen. The reading ranged from 30 mg/dL to 600 mg/dL. Any reading below the range was indicated as "Low" and reading above upper range was indicated as "High". The flowers that had high reading, were diluted with distilled water using a dilution factor of 1:10 (which comprised of 1 µL nectar to 9 µL distilled water). The actual sugar concentration was then calculated using the formulae C1 = C2 x V2)/V1 where C1 = actual concentration, C2 = measured glucose concentration, V2 = diluted nectar volume and V1 = volume of nectar. The number of readings taken was replicated 50 times.

Brazilian snapdragon- *Octacanthus caeruleus*

White Alder- *Turnera subulata*

Rattle box plant- *Crotolaria pallida*

Yellow Alder- *Turnera ulmifolia*

Coral vine- *Antigonon lepitopus*

Plate 8. Five different beneficial weeds that were evaluated for preference.

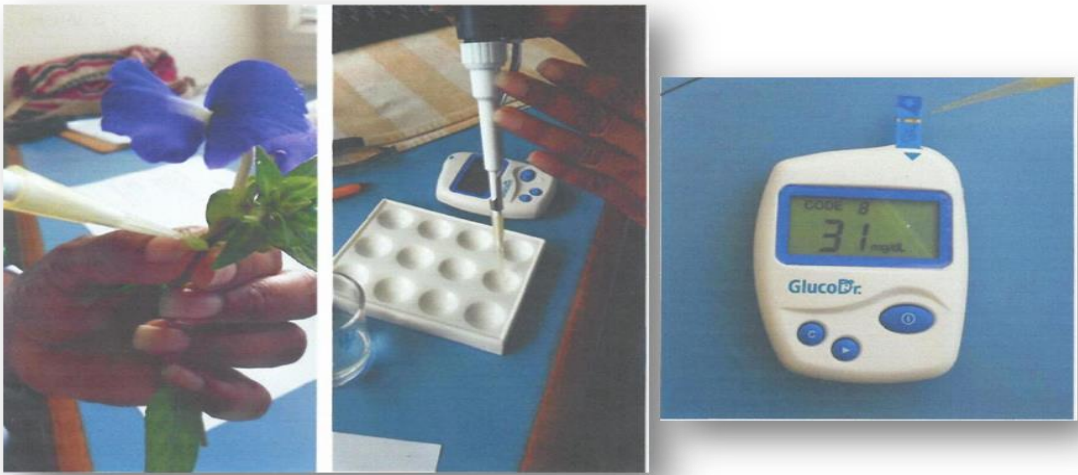


Plate 9. The different apparatus used for nectar extraction and sugar (glucose) concentration measurement.

***Evaluation of beneficial weed preference by* A. eurycanthae**

The preference among the beneficial weeds was evaluated in a four arm olfactometer using *A. eurycanthae* as a representative of the biocontrol agents. This insect was used as it was slightly bigger and was easier to deal with compared to the other mass reared biocontrol agents.

Floral heads of the beneficial weeds with couple of leaves were collected each morning between 0700 to 0800 hours and placed in the flower holding round flask chambers shown by the red circles in Plate 15. The flasks were washed after every use to clean the odour of the flower used before the introduction of a new flower. Individual insects were released in the insect release chamber indicated by the red arrow (Plate 10). Air was circulated to the odour (flower) chambers through the plastic tubes by an improvised air circulation system developed from a wall fan motor, cut out empty 1L coca cola container and a piece of thick balloon (refer red rectangle in Plate 10). Residence time in the flower chamber was recorded as soon as the insect entered the chamber and the feeding time once the insect started feeding.

Since there were five beneficial weeds and the olfactometer was four armed, five different combinations comprising four weeds (i.e. CV, BS, RB, WA; BS, RB, WA, YA; CV, BS, RB, YA; CV, BS, WA, YA; CV, RB, WA, YA) were done to ensure each weed was exposed in combination with every other weed for preference testing. Each combination was replicated five times. The results were combined for the analysis.

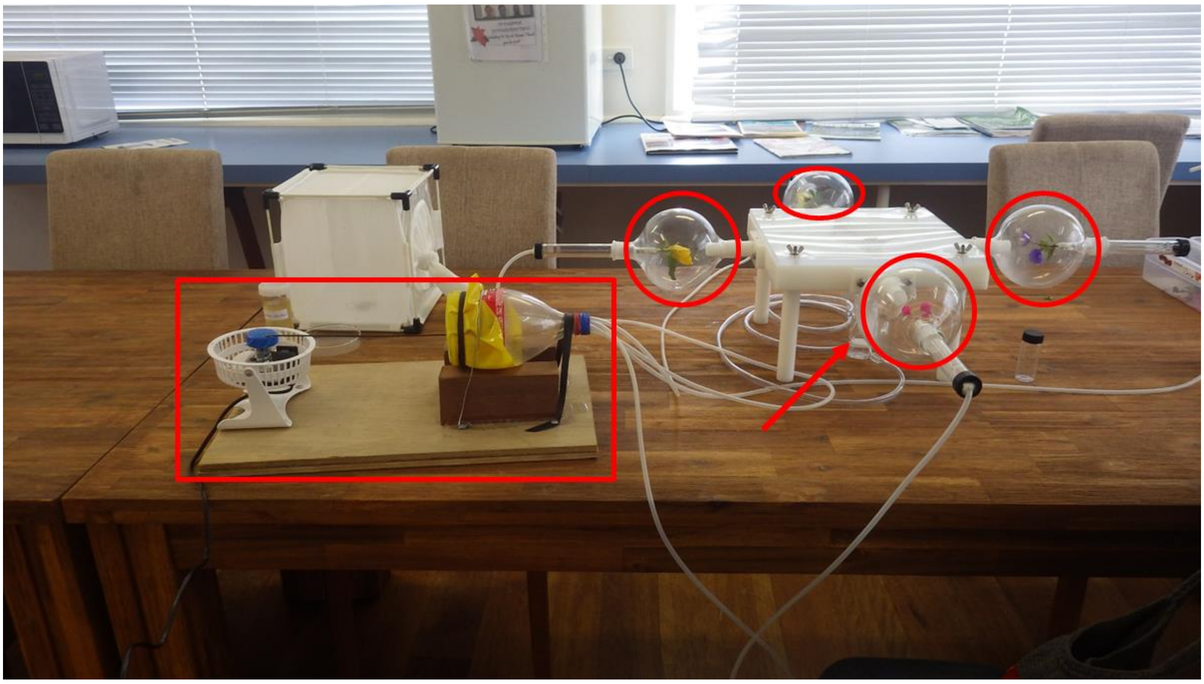


Plate 10. The olfactometer system used for preference evaluation study.

C.3.5.3. *Results and discussion*

The highest concentration (mg/dL) of sugar (glucose) was measured from the Brazilian snapdragon (*D. caeruleus*) followed by the coral vine (*A. leptopus*). The concentration in the two species of alder (*T. subulata* and *T. ulmifolia*) and Rattle box plant (*C. pallida*) were lower than a thousand mg/dL (Figure 54). Despite the low concentration of sugar (glucose), these weeds were most preferred than the weeds with high sugar concentration. The wasp (*A. eurycanthae*) spent more time in the feeding chamber (Figure 55) and fed more (Figure 56) on *T. subulata*, *T. ulmifolia* and *C. pallida* than *O. caeruleus* and *A. leptopus*. It spent sometimes in the flower holding chamber for *A. leptopus* but did not feed. Although, there was no feeding by the wasp, it was able to cue to the plant. Its preference by other natural enemies is possible. The reason for the lack of preference for weeds with high sugar (glucose) concentration is not clear, however the influence of other sugars on preference will need to be further investigated.

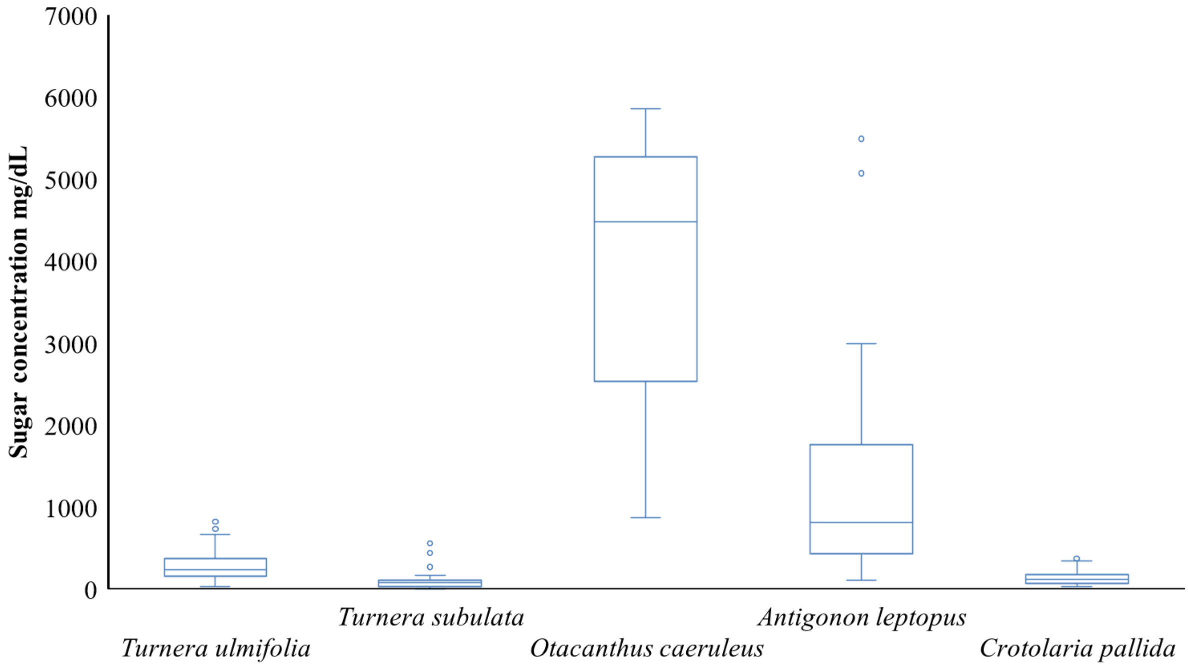


Figure 54. Sugar (glucose) concentration (mean ± SE) measured in each of the beneficial weed.

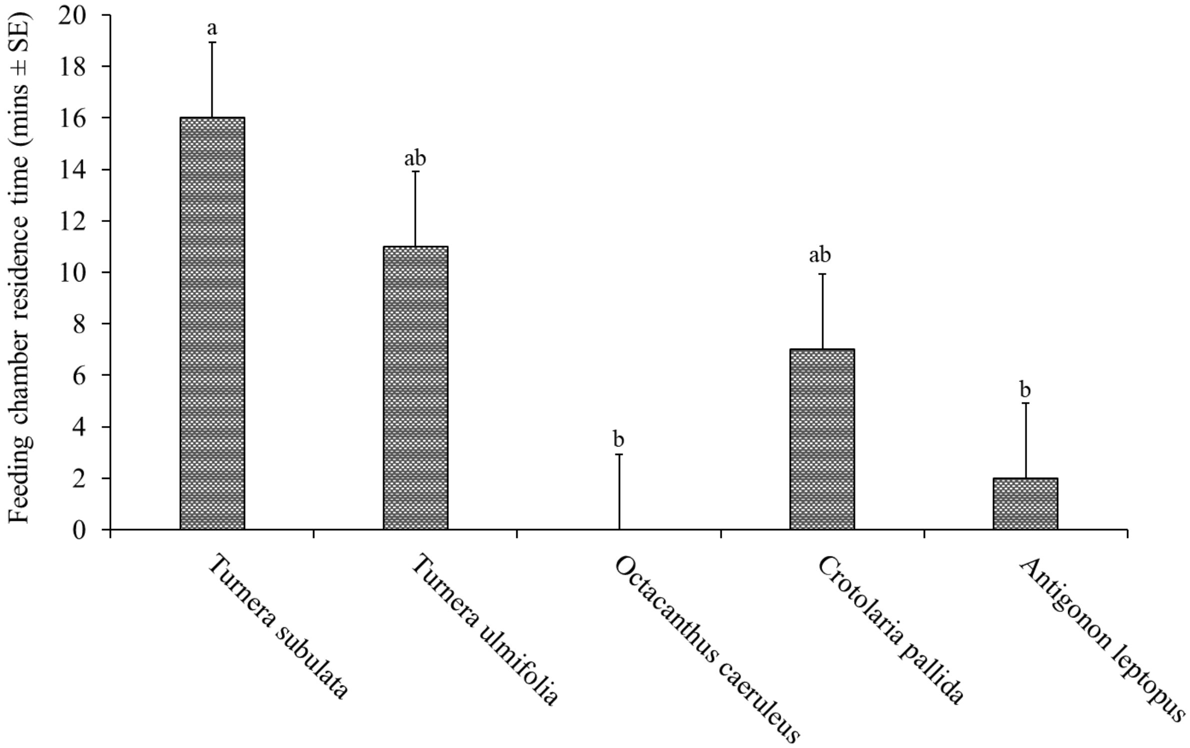


Figure 55. Residence time (mean + SE) by *A. eurycanthae* within the flower chamber.

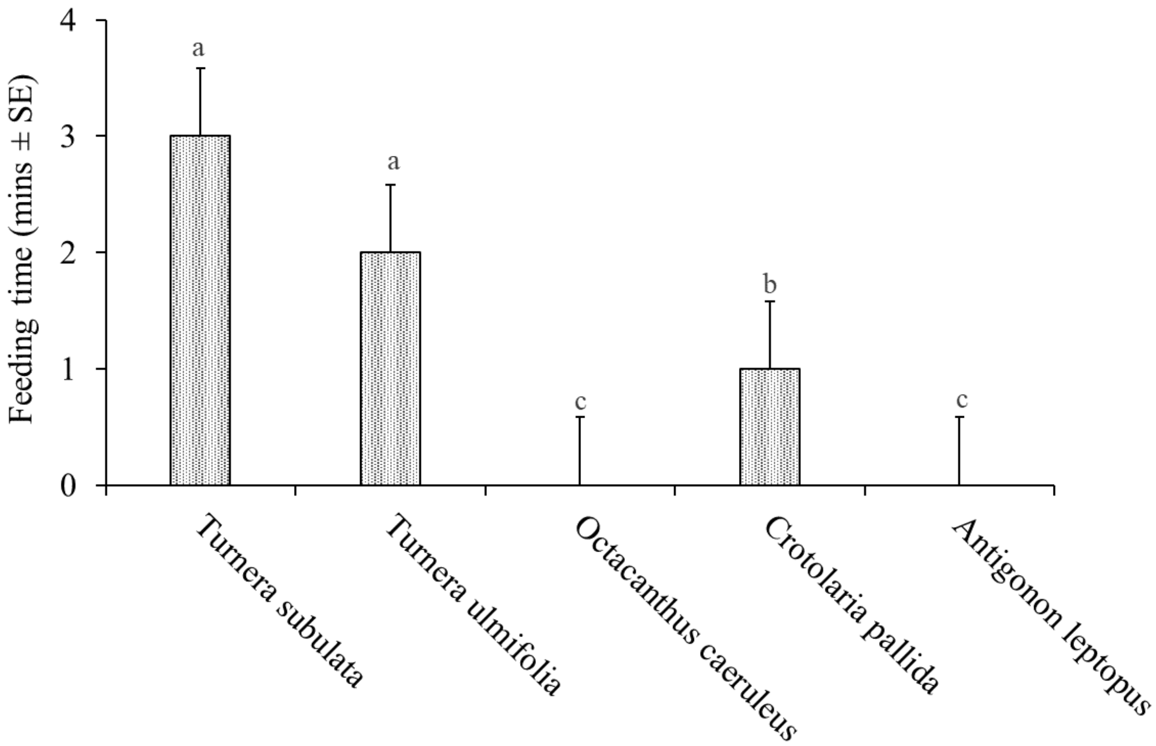


Figure 56. Feeding time (mean + SE) by *A. eurycanthae* on each beneficial weed.

C.3.5.4. *Conclusion*

The results from these trials show that *T. subulata*, *T. ulmifolia* and *C. pallida* are the most suitable beneficial weeds. These weeds can be planted in oil palm cropping systems to help support the natural enemy populations. The influence of other sugars on preference needs to be further investigated.

C.3.5.5. *Recommendations*

The following recommendations are made in relation to the results:
1. Develop a trial design and plant the three preferred beneficial weeds within the selected smallholder blocks where the baseline studies were done earlier and monitor natural enemy establishment and pest infestation rate over time.
2. Investigate the influence of other sugars on feeding preference.

C.3.6. Chaffer beetle (*Demolepida* sp.) monitoring and alternative hosts survey at Embi Estate, Higaturu Oil Palms

C.3.6.1. *Introduction*

The genus *Dermolepida* Arrow comprises of 11 described species. The distribution of the species is centred around the main island of New Guinea (Papua New Guinea and West Papua) and its adjacent islands (Britton, 1957). Nine of the 11 species have been recorded from Papua New Guinea.

The beetle is nocturnal with the adults active at night. Adults are polyphagous and feed on foliage of wide range of plants including both monocotyledons and dicotyledons. They also mate on the plants during feeding. The females return to the soil after feeding and mating, usually prior to dawn to lay

eggs. The eggs then hatch and proceed through 3 larval stages before pupation. The final instar builds a pupation chamber and pupates before emerging as an adult. The life cycle of the different species within the genus is variable, ranging from 6-12 months (Goebel, *et al*., 2010; Moxon, 1992).
Several species have been recorded as serious pests of a range of crops with both larvae and adults causing the damage. The most notorious pest from the genus is *D. alborhirtum* (Grey back grub) which attacks sugarcane. It is one of the most serious white grub sugarcane pests in north Queensland, Australia. It is estimated to cause around 10 million Australian Dollars crop loss annually.

Some unconfirmed species of the genus have been reported causing considerable damage to cocoa in both New Guinea Islands and the mainland of PNG. The larvae feed on roots of both young and mature cocoa trees. Mainly the 2nd and 3rd instar larvae chew and sever the tap roots of the seedlings by ring barking them during feeding. They can kill seedlings up to about 2 years old. The larvae have also been observed to feed on sugarcane, sweetpotato, taro, Singapore taro and bananas thereby rendering cocoa planted near food gardens susceptible to attack.

Both the adults and larvae have been recorded causing damage to oil palm. The adults feed on the foliage whilst the larvae feed on the roots as is the case for other crops. The damage was detected as early as 1968 in Higaturu when oil palm cultivation was initially piloted. The adults were observed resting along the rachis of fronds among the leaflet bases during the day after feeding overnight.

Since the initial report, there have been no further reports on the larval stages attacking young oil palms. Foliage damage on mature palms by adult beetles has been reported occasionally from Northern but was never severe to warrant any control intervention. However, more recently in 2017 and 2018, persistent moderate damage which required treatment was observed at Embi Estate.

Despite the pest status of the insect to oil palm, biology of the pest is poorly understood and the species responsible for the damage is uncertain. Whilst it is not a major pest of the crop, it can potentially cause severe damage under favourable weather and environmental conditions. It is, therefore, necessary that the species is confirmed, the biology is understood, and a management programme put in place.

The study is continuing, and the report provides an update on the progressive results.

C.3.6.2. *Materials and methods*

Monthly damage assessment surveys
Two blocks (ADO 060 and ADO 090) with chaffer beetle damage were selected in Warisota Division at Embi Estate to monitor the temporal beetle population and damage level. The number of beetles on the palms were counted and the damage levels scored (0 = no damage, 1 = light damage, 2 = moderate damage, 3 = severe damage). The standard foliage pest damage assessment protocol where every second palm for 10 palms from every second row from 10 rows was used for the assessment. A total of 100 palms covering almost 4 hectares at 120 palms per hectare planting density was used. The assessment was conducted routinely on a monthly basis starting in March 2019.

Alternative host plants survey
Two different categories of vegetation were used for the survey. The first was vegetation under palms whilst the second was vegetation at the edges of the plantation (including buffer zones where necessary). For the under-palm vegetation survey, same procedure as for the beetle damage assessment survey was used except that the plants surrounding the palms were surveyed for beetle presence and feeding on vegetation surrounding the palm. On each side of the palm, plants growing between the palms were checked for presence of beetles and (if present) potential feeding. The plants where beetles were found were identified if known, but if not known they were allocated morpho species and samples taken for further identification.

For the adjacent boundary sites, the survey was done by walking at the edge of plantation. The survey points were 10 m apart with a total of 10 points. At each point plants within 5 m radius periphery from the point was checked for beetle presence and feeding (if present). As was the case for under palm survey, the plant name was recorded if known, if not, they were designated morpho species number and samples taken for further identification.

The surveys were replicated 3 times (3 sites each) for each vegetation category.

C.3.6.3. *Results and discussion*

The average damage level remained moderate throughout the survey period, except for November where it dropped to light (Figure 57). This was despite the temporal fluctuations in the beetle population (Figure 58). The damage scores were for the combination of both fresh and old damages. Since the palms were tall (seven years old), it was difficult to differentiate fresh damage from old damage. Hence, for the months where the beetle population was low, the level of fresh damage could possibly be lower (light). This has implications for management decisions. The damage scores need to be complimented by the actual count of the beetle populations on the palms for management decisions.

High number of beetles were recorded from April to October, with the highest numbers recorded in July, August, September and October (Figure 57). There is a negative correlation between the number of beetles and the rainfall (Figure 59 and 60). The rainfall had an impact on the beetle population. The number of beetles increased when the rainfall decreased and conversely decreased when the rainfall increased. Similar observations were done for *D. albohirtum*, where it was noted for climatic factors (solar radiation, temperature, pan evaporation and rainfall) to potentially influence the population dynamics (Goebel, *et al*., 2010). Chaffer beetle incursion will need to be closely monitored during dry weather.

Plate 11. Photograph of a Chaffer Beetle (*Dermolepida* sp.) from Embi Estate, HOP.

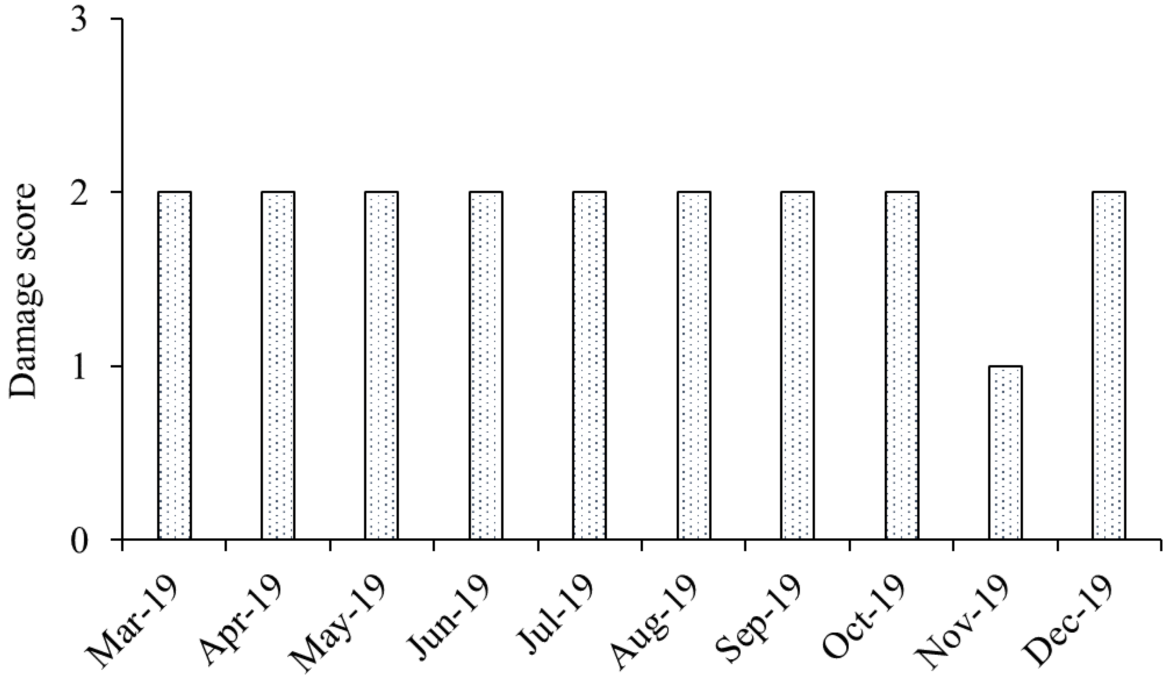


Figure 57. The beetle damage scores for the blocks monitored in Warisota Division at Embi Estate, HOP.

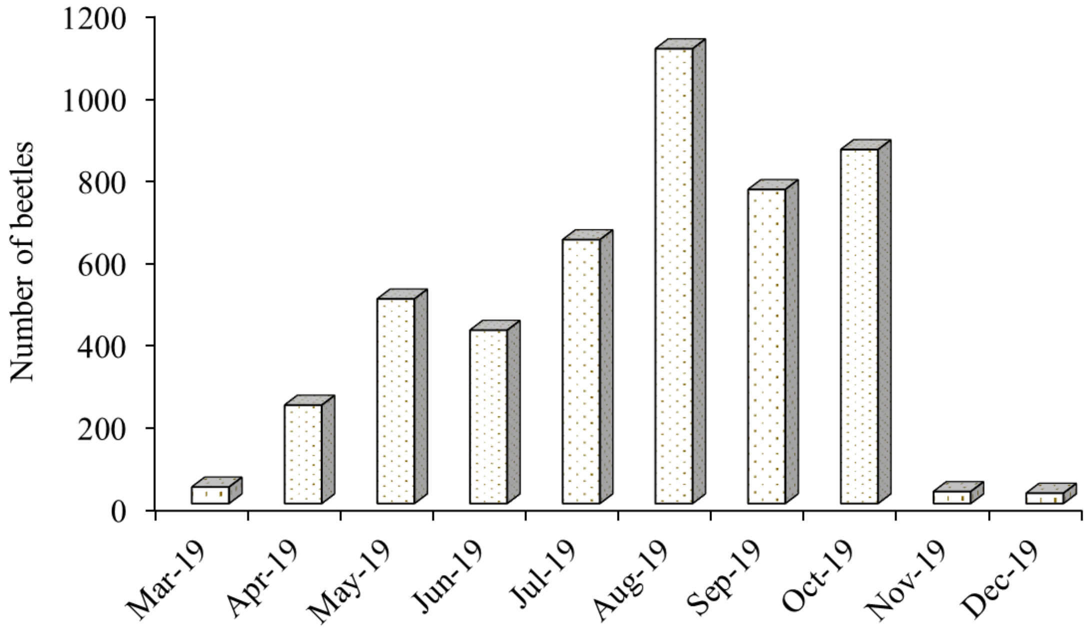


Figure 58. Number of beetles recorded during the damage assessment survey period from the monitoring blocks in Warisota Division, Embi Estate, HOP.

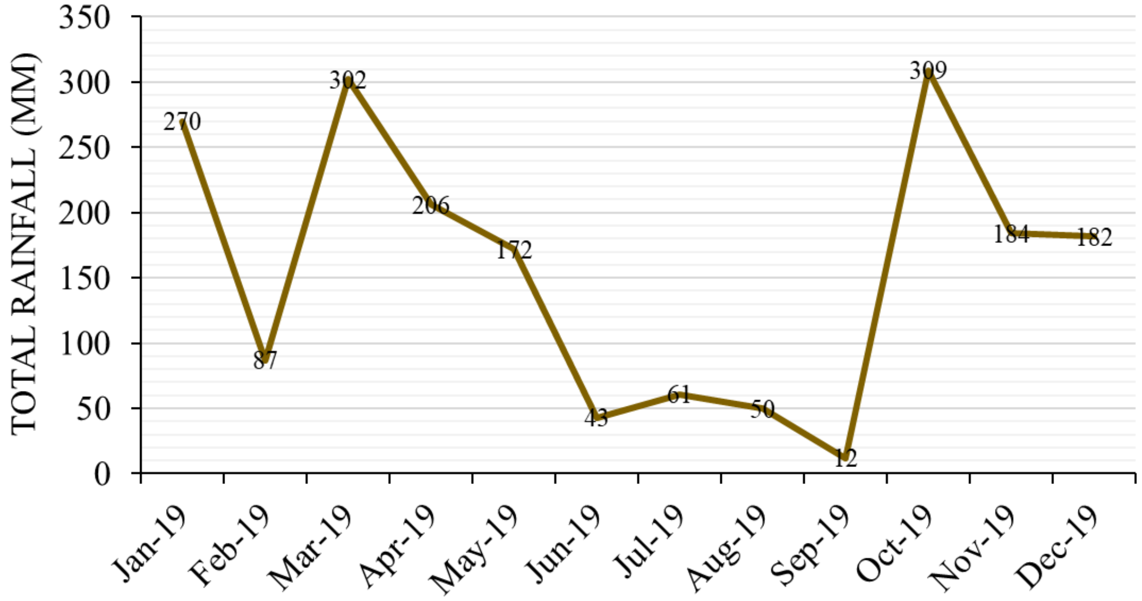


Figure 59. Monthly total rainfall (mm) for Embi Estate, HOP.

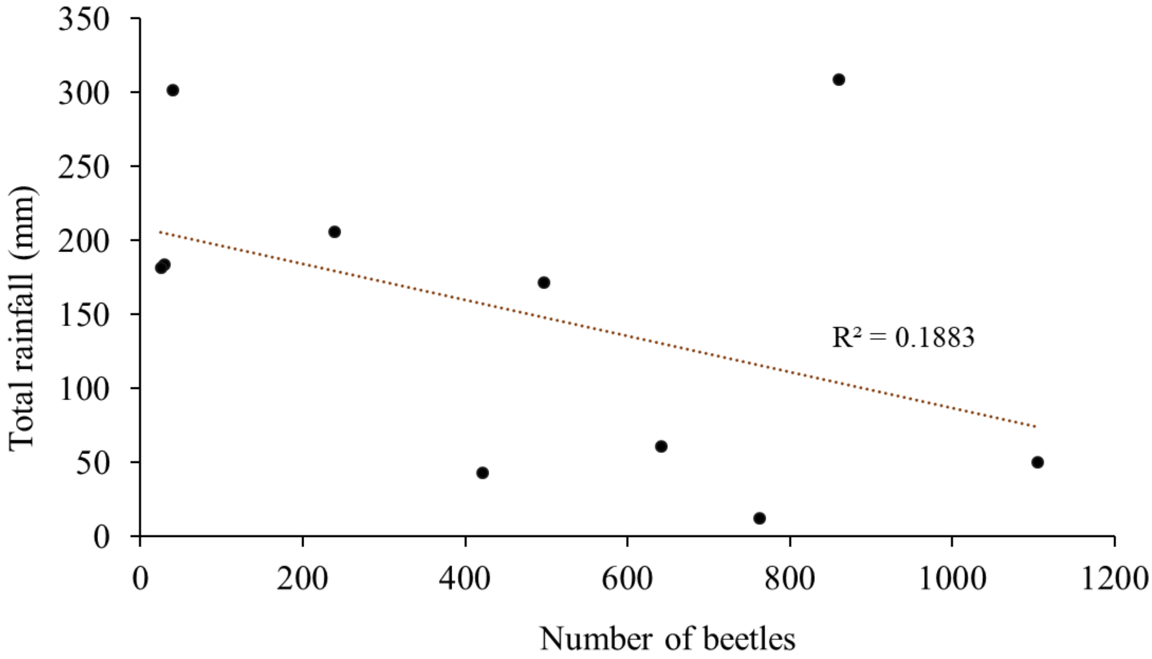


Figure 60. The correlation between total rainfall (mm) and the number of beetles counted from the sampling blocks in Warisota Division, Embi Estate, HOP.

The beetles were sampled from six different alternative plants (Figure 61). They included wild bitter gourd, *Ficus* sp., epiphytic fern, *Pueraria phaseoloides*, *Piper aducum*, and an unidentified tree (Plate 12). It fed on wild bitter gourd, *Ficus* sp., *P. phaseoloides*, *P. aducum* and the unidentified tree, but not the epiphytic fern. They were mainly sheltering on the epiphytic ferns after feeding on the oil palms. The confirmation of feeding by the beetle on five alternative hosts reaffirms the polyphagous status of the pest. Its preference among the different hosts remains to investigated. The feeding on the legume cover crop (*P. phaseoloides*) although often negligible needs to be closely monitored during outbreaks. Its status as the potential host for breeding needs to be confirmed.

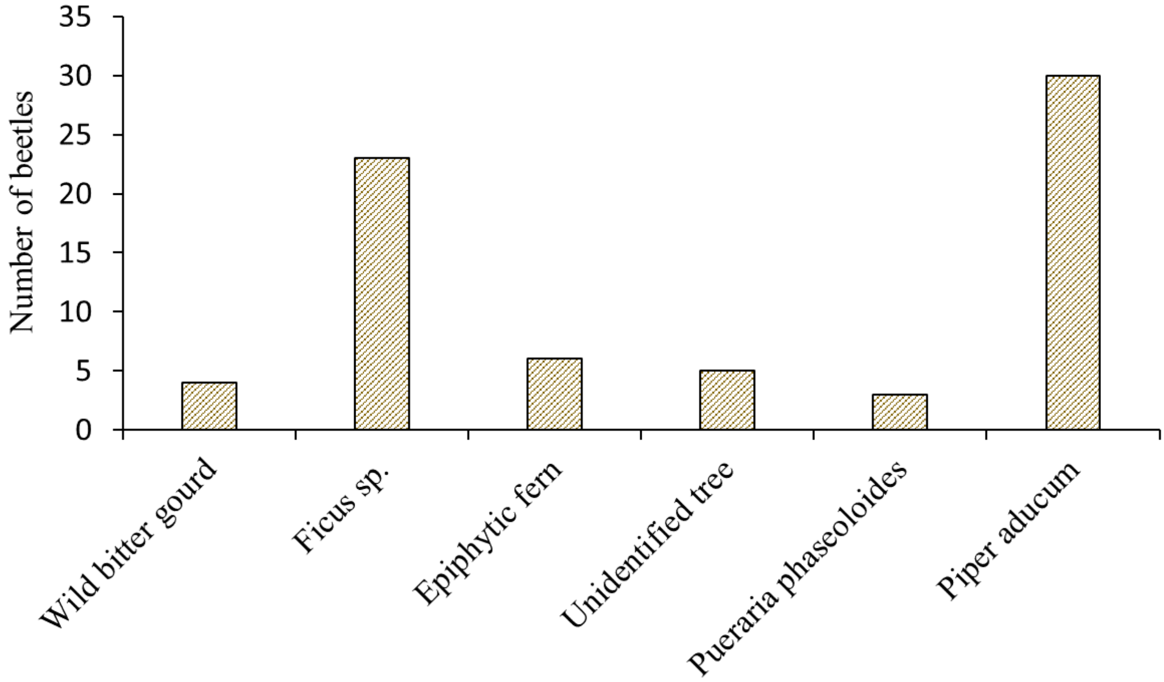


Figure 61. The number of Chaffer Beetles counted on the potential alternative host plants.

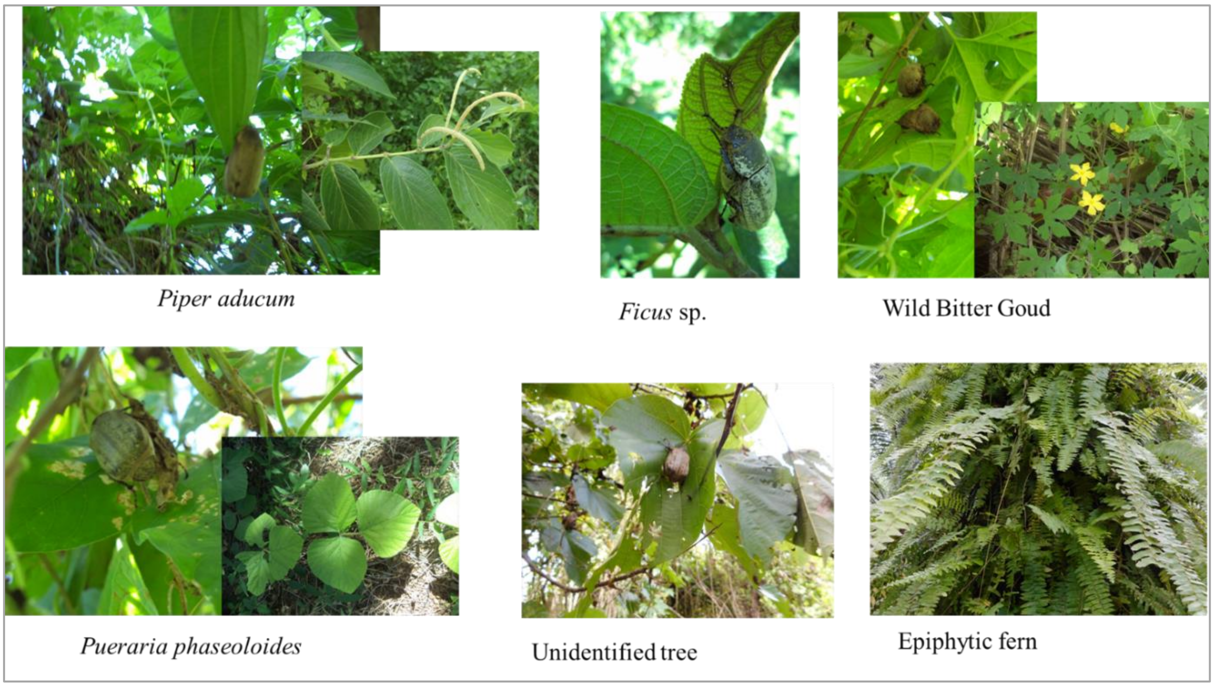


Plate 12. Photographs of the potential alternative host plants where the beetle was sampled.

C.3.6.4. *Conclusion*

The polyphagous status of the beetle and the influence of rainfall on its population dynamics are confirmed. With the confirmation of population build up during dry weather, its incursion needs to be closely monitored during the drier months of the year. Preference among host plants, breeding hosts, and the life cycle of the beetle remain to be investigated. The beetle species also needs to be confirmed.

Recommendations

The following recommendations are done for the continuation of the study:
1. The beetle species needs to be confirmed.
2. Investigate breeding host/s for the beetle.
3. Study the life cycle of the beetle.
4. Test preference among oil palm and alternative hosts.

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C.4. 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, NZ project on CRB management. PNGOPRA assisted in the training component of the project in PNG. The Sime Darby funded project has concluded and the project review report has been compiled.

C.5. FORMAL PUBLICATION AND TECHNICAL NOTES

Two papers were submitted to the Journal of Oil Palm Research. The paper on the “birdwing and swallowtail butterfly species conservation” study has been published whilst the paper on the “impact of little fire ant (LFA) on the pollinating weevil has been accepted but remain to be published.

[Bonneau LJG, Ero, M and Sar S (2019). The ranching and conservation of birdwing and swallowtail butterfly species in the oil palm systems of Papua New Guinea. Journal of Oil Palm Research, 31 (3). 448 – 458].

C.6. OTHER ACTIVITIES

C.6.1. Training, Field Days and Radio Talks- (RSPO 1.1, 4.8, 8.1)

In-house and external training for staff remains an integral part of the 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 continued here MPhil with PNG University of Technology (Unitech) during the year.

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 2019 are provided in the table below (Table 89). Two radio talks were done during the year.

All smallholder field days were run on weekly basis for Hoskins Project from April to October and for the other project sites 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 89. Number of trainings provided by Entomology Section in 2019.

Date	Division/Department	Training name	Conducted by	Received by	Area/ Location
20-Mar-19	PNGOPRA, Entomology	TTI Training	ME, SM	TTI Team Field Staff & Supervisors	Hargy
13-June-19	PNGOPRA, Entomology	TTI Training	ME, SM & TB	TTI Team	Dami Field
11-July-19	PNGOPRA, Entomology	Pest & Disease Training	ME, EG	Managers, Supervisory & Field Staff	Dami Conference Room
03-Dec-19	PNGOPRA, Entomology	LFA Sand Baiting	TB	Manager & Staffs	SQM Office - Dami

ME= Mark Ero, SM= Simon Makai, TB= Thom Batari, EG= Emmanuel Gorea

C.6.2. OPIC Pest and Disease Meeting- (RSPO 8.1)

The OPIC pest and disease meeting at Nahavio in WNB continued throughout the year. Both OPIC DMs and Smallholder Affairs Department (SHA NBPOL) representatives attended the meetings. From PNGOPRA, it was attended by 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.

Visitors to Entomology Section (Dami Head Office) in 2019

A total of 9 visitors passed through the Entomology Laboratory at Dami during 2019 (6 less than 2018). The visitors were from various organizations within the country and Plantation within the Province as well as abroad. The organizations from which they came from are listed below.
Rigula Plantation, NBPOL (WNBP)
Istom, France
Department of National Planning, Port Moresby
OPIC Head Office, Port Moresby
OPIC, Nahavio Office, WNB

C.6.3. Entomology Staff Strength in 2019

The Entomology team comprised of 17 staff in 2019. These included 3 executive staff (including the Head of Section), 4 Technical Supervisors and 10 Recorders.

D. PLANT PATHOLOGY

HEAD OF SECTION III: DR EMAD JABER

D.1. EXECUTIVE SUMMARY

- Ganoderma disease progress in all plantations continue to be monitored on an annual basis as well as in 8 study blocks in Milne Bay and at Numundo. Ganoderma disease incidence continued to increase in young plantings in all plantations and all the replant study blocks.
- Ganoderma infection rate continued to increase in 2019 in Milne Bay plantation with an average rate of 1.14 %, Poliamba plantation with an average rate of 0.78 % and Higaturu plantation with an average of 0.55 % rate of infection.
- High Ganoderma infections reported across all plantation are in blocks with older plantings. Regular surveys and efficient removal of all infected palms are recommended for the mixed plantings of both immature and older plantings, across all Milne Bay plantation and the blocks located at Madak and Noatsi divisions in Poliamba.
- High Ganoderma infections recorded for Sumberipa and Sangara which is expected with fields with high number of older plantings. These areas should be followed with regular surveys and sanitation nearing replant. Strict control is required in all young blocks to maintain low disease levels in the next 10 years.
- Disease levels in replanted blocks in Milne Bay continued to increase in young plantings with cumulative Incidences rate range in 2019 from 0.36 – 0.61 % reaching an accumulative rate of 0.67 – 1.88% since replanting.
- Morphological characteristics and genomic sequencing of Upper stem rot (USR) fruiting bodies collected at Dami confirmed that all isolates to be *Ganoderma boninense*.
- Nursery testing of identical families planted in the field trial show clear correlation of nursery data with field data. New trials: 12, 13, 14 and 15 are under testing, the scoring of infection and mortality will be verified and analyzed to be presented by the end of 2020.
- Incidence of BSR has increased in the trial palms over the past years at GPPOL, to a cumulative rate of 5.4 % and 10.1 % in Field 12 and 13, respectively. These findings suggest that sanitation by soil excavation and bole removal before replanting does reduce Ganoderma infection rate.
- Yield data for the 81 progenies per block is highly variable at GPPOL trial palms, there is no apparent trend regarding the most consistently best performing families since 2013.

D.2. EPIDEMIOLOGY OF BASAL STEM ROT

Basal stem rot (BSR) caused by Ganoderma boninense is an important disease of oil palm in Papua New Guinea. BSR is one of major concerns of the Plant Pathology section in PNGOPRA. BSR or what is referred to throughout this report as Ganoderma rot, spreads through root transmission. Moreover, there is a potential role of Ganoderma basidiospores in the diseases spread and infection.

Ganoderma rot has becoming increasingly prevalent in PNG, due to replanting of oil palm and ineffective current disease management. Ganoderma surveys and epidemiological information are very useful to understand the rate of disease development and progression. Also, survey data would help us identify the biological and environmental factors that interfere with pathogen survival, disruption of the process of oil palm infection in different regions in PNG. The data collected from plantations and smallholders' blocks will be used to assess Ganoderma disease incidence and provide advice on sanitation schedules and control measures to both smallholders and plantation according to the Ganoderma progression and development at each planting cycle and site.

D.2.1. Disease Progress in First- and Second-Generation Oil Palm Plantings

D.2.1.1.Epidemiology of basal stem rots caused by *G. boninense* in oil palm plantations

Ganoderma surveys and sanitation has continued in all sites in PNG for 2019. All sites recorded partial surveys and sanitation rounds for all respective divisions. Data reported for this period are unaudited data sets retrieved from Technical Services Division (TSD), Milne Bay, Higaturu and Poliamba. Cumulative Ganoderma rates are not presented herein, as all plantations data for the previous years is undergoing auditing. Furthermore, data reported is only for areas with survey information. Disease incidence is based on original stand and where planting density has not been provided for blocks assessed, a density of 128palms/ha has been used. No data sets were available for West New Britain plantations.

A. Milne Bay

Surveys in Milne Bay reported 83 % of blocks that were surveyed in 2019 while the 17 % not surveyed as most of these blocks were below five years (new replants).The average disease incidence (%) for 2019 was 1.14 % (Figure 62) which is four times the average disease incidence for 2018 (0.28 %). This marked increase is due to more blocks being surveyed in 2019 including high Ganoderma infections in older plantings. Disease incidence per division showed that Padipadi continued to show a high disease incidence (%) of 2.08 alongside Hagita, 1.8 % and Mariawatte, 1.38 %. All these blocks have disease incidences above the mean average for Milne Bay for 2019. Ganoderma levels in the older plantings > 15 years old are becoming established and more apparent for Padipadi, Hagita and Mariawatte. Infection rate of Ganoderma recorded at Giligili was lower at 0.58 % in contrast to 0.71 % in 2018. Waigani and Sagarai reported disease incidences that were 0.76 % and 0.23 % which were higher than 2018.

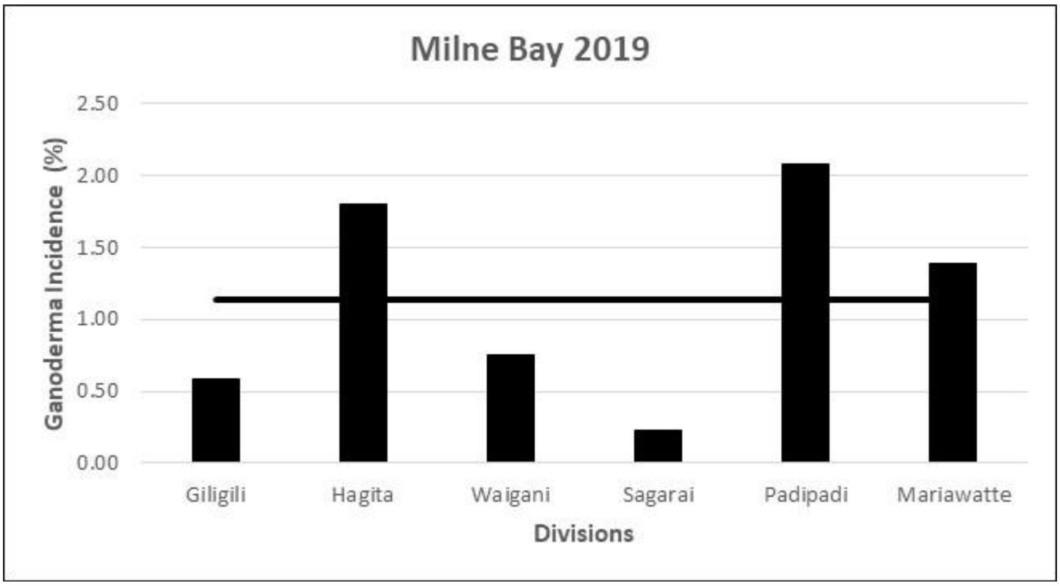

Figure 62. Disease incidence of Ganoderma rot at Milne Bay Estates plantation in 2019. The horizontal line is the plantation mean (1.14%).

Ganoderma incidence and palm age

Generally, older blocks show higher disease numbers and high rate of disease infection. This is due to high cumulative disease incidence and subsequent high disease pressure. The trend seen in the graph below (Figure 63) illustrates the impact of palm age on the Ganoderma incidence scored in 2019. However, in certain areas of different planting year, infection rates are fluctuating, and this might be due to different factors other than palm age including previous crop planted prior to oil palm, replant status, soil type, planting density and drainage etc. Evidently, older plantings (1996 -2008) surveyed in 2019 represent far fewer number of blocks in the Milne Bay Estates plantation as shown by the mean

Ganoderma incidence rate across all divisions in Milne Bay. It is certain that the cumulative Ganoderma infection rate at these older planting blocks is already high and above the Ganoderma controllable level (5%), therefore, older plantings are due for replanting in the immediate future and elevated disease levels in replants are therefore expected unless an intensive removals program is implemented.

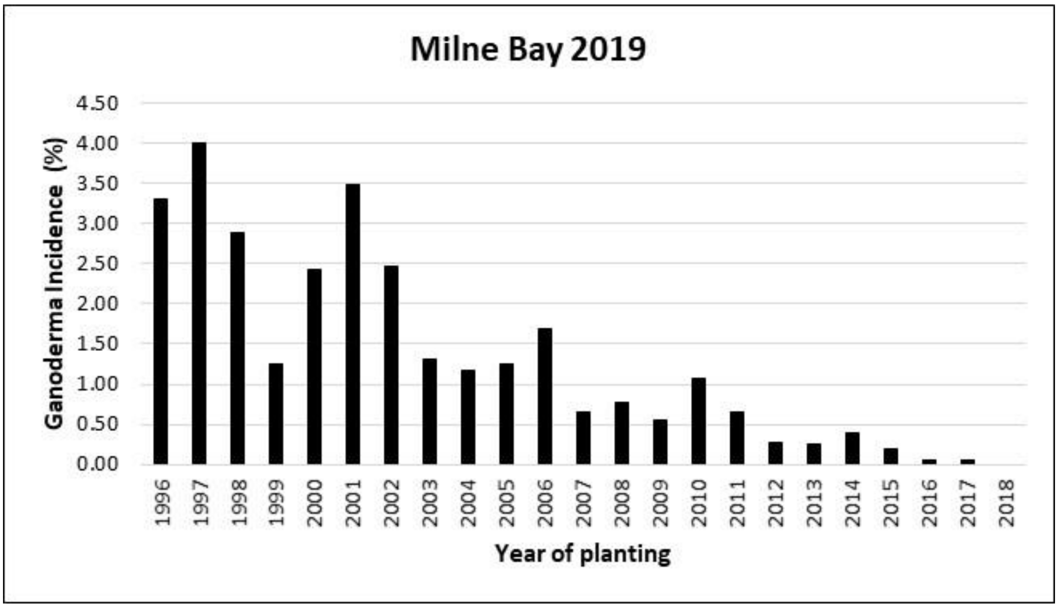

Figure 63. Annual (2019) incidence of Ganoderma rot in oil palms planted in different years at Milne Bay Estates.

Ganoderma incidence and planting density

Ganoderma incidence is presumably proportional to the planting density and high infection rates are associated with fields of high plant density. However, data collected in 2019 shows that the highest Ganoderma incidence of 2.61 % was reported for planting density of 143 palms/ha and that higher planting densities of 160 and 170 reported 1.03% and 0.71% Ganoderma incidence, regardless of palm age. Plantings of 143 palms /ha were planted in the year 2000. Whereas Plantings of 160/ha were planted in 2006 and Plantings of 170/ha were planted in 2010. Apparently, in Milne Bay Estates, the Ganoderma incidence is tightly corelated with older plantings rather than planting densities (Figure 64).

Ganoderma incidence and planting cycle

Comparison of disease incidence and planting cycle in Milne Bay (Figure 65) indicates that first generation plantings have high Ganoderma infections in contrast to second generation plantings. This again is attributed to high disease pressure from cumulative Ganoderma infections periodically. Second generation plantings reported a low disease incidence of 0.37 % and it would be difficult to make any assumptions now as many factors may influence the rate of infection per time point.

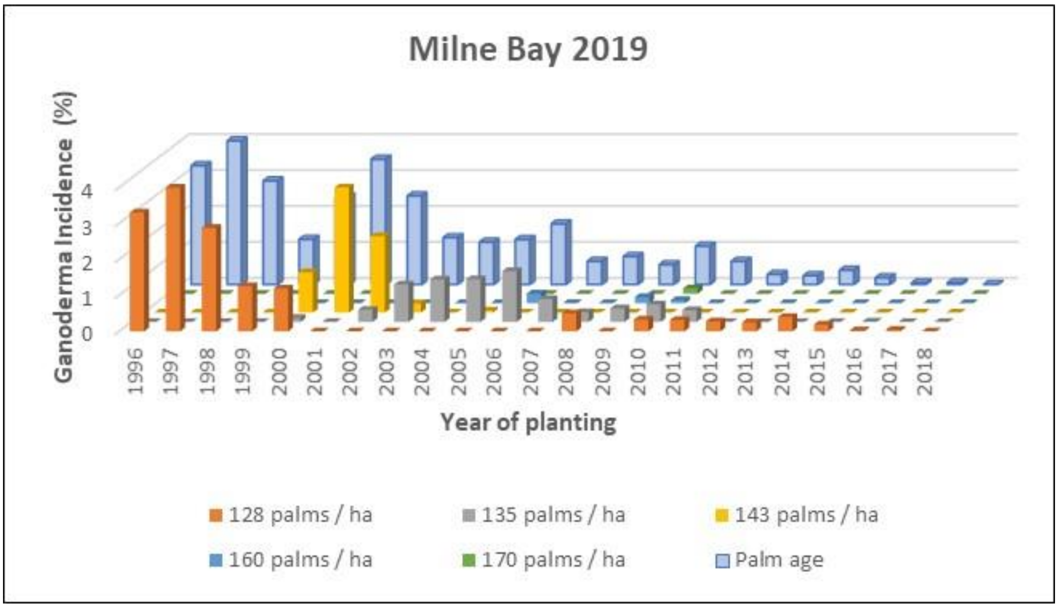

Figure 64. Annual (2019) incidence of Ganoderma rot in oil palms planted in different years with different planting densities at Milne Bay Estates.

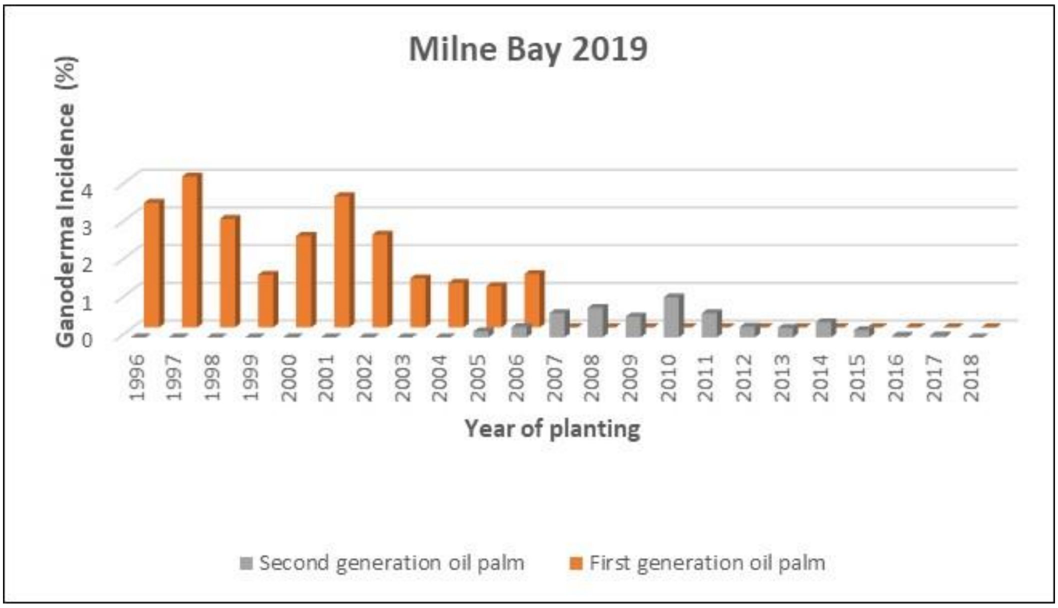

Figure 65. Annual (2019) incidence of Ganoderma rot in the first and second generations oil palms at Milne Bay Estates.

B. Poliamba

Poliamba recorded only one round of Ganoderma survey and sanitation in 2019. Only 49 % of plantations were surveyed and the remaining 51 % of fields were not surveyed since there is a significant proportion of the plantation at Poliamba which has been replanted within the last 8 years and disease data presented here is based on older plantings. At this time, disease surveys have not been implemented in any of the replanted areas as the palms are under 5 years old. The data presented in this report is unaudited and is representative for mostly older plantings within each of the five major divisions. The average mean disease incidence (%) showed a slight increase from 0.39 % in 2018 (data not shown) to 0.78 % in 2019 (Figure 66). Disease incidences for Kera (0.05%), West Coast (0.30 %) and Nalik (0.16 %) were below the mean disease incidence of 0.78 %. These three divisions have a majority (80 – 100

%) of younger plantings which are less than nine years old. Although most of Noatsi (90 %) is of relatively young plantings (<5 years old) it recorded the highest Ganoderma infection of 1.91 % which exceeds the mean disease incidence for the plantation and due to the remaining older plantings with higher Ganoderma infection rates (%). Madak, also mostly of older plantings (>17 years old) recorded a disease incidence of 1.50 %. Most of the blocks in both Madak and Noatsi Divisions are ex-coconut, and this might be a factor in the relatively high disease levels recorded. A full and regular surveys and sanitation rounds for removal of all infected palms rounds shall be implemented across the divisions, especially for the blocks located at Madak and Noatsi Divisions.

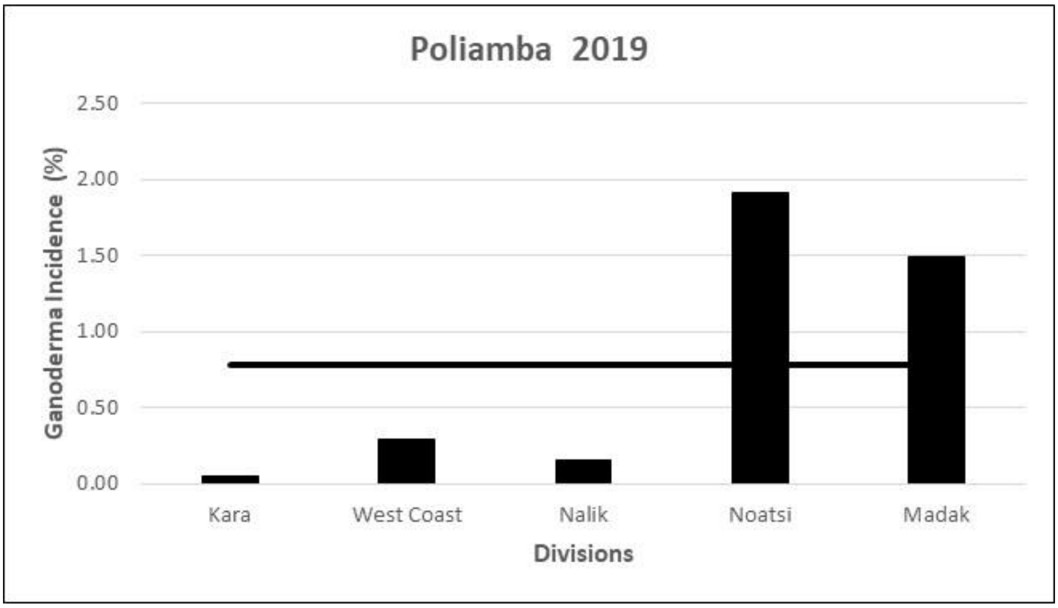

Figure 66. Disease incidence of Ganoderma at Poliamba plantation in 2019. The horizontal line is the plantation mean (0.78 %).

Ganoderma incidence and palm age

Ganoderma incidence recorded in 2019, showed high Ganoderma infections for the 1997 and 1999 plantings with 1.87 % and 1.75 % in contrast to 1998 (0.91 %) and 1995 (0.48 %) plantings (Figure 67). Generally older palms tend to have higher Ganoderma infections as opposed to younger plantings. The differences in Ganoderma infections for the older plantings (1995 – 2000) is due to the number of blocks surveyed per time point. Plantings in 1997 recorder higher disease numbers since all blocks within that planting date were surveyed as compared to 1995 planting which only one block was surveyed in 2019.

Ganoderma incidence and planting cycle

The effect of planting cycle on the rate of Ganoderma infection in Poliamba (Figure 68) is similar to the situation in Milne Bay. First generation plantings composed mainly of older plantings have a seemingly higher Ganoderma infection rate compared to younger replant and this in turn is a result of cumulative build-up of inoculum and disease pressure within older plantations. Comparison of planting cycle and rate of Ganoderma infection indicates that 1st generation plantings have high rate of Ganoderma infections in 2019 compared to 2nd generation plantings. This is the result of 2nd generation plantings having most blocks that are immature as opposed to more older plantings in the 1st generation plantings.

Ganoderma incidence and planting density

Data for Ganoderma infections and planting density (Figure 69) shows high Ganoderma infections (3.63%) for plantings planted at 143 palms/ha while plantings with 128 palms/ha recorded a low Ganoderma infection rate of 0.31 %. The high Ganoderma infections for planting density of 143 palms/ha is only reflective of older plantings (19 – 24 yrs.) in contrast to 128 planting density with younger palms of less than 8 years old.

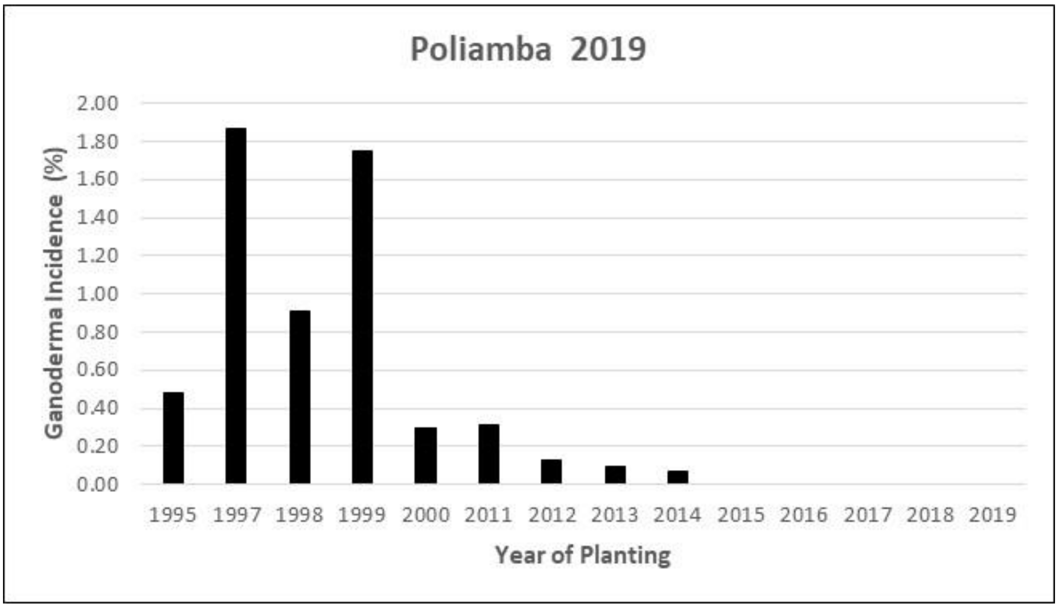

Figure 67. Disease incidence of Ganoderma in oil palms planted in different years at Poliamba in 2019.

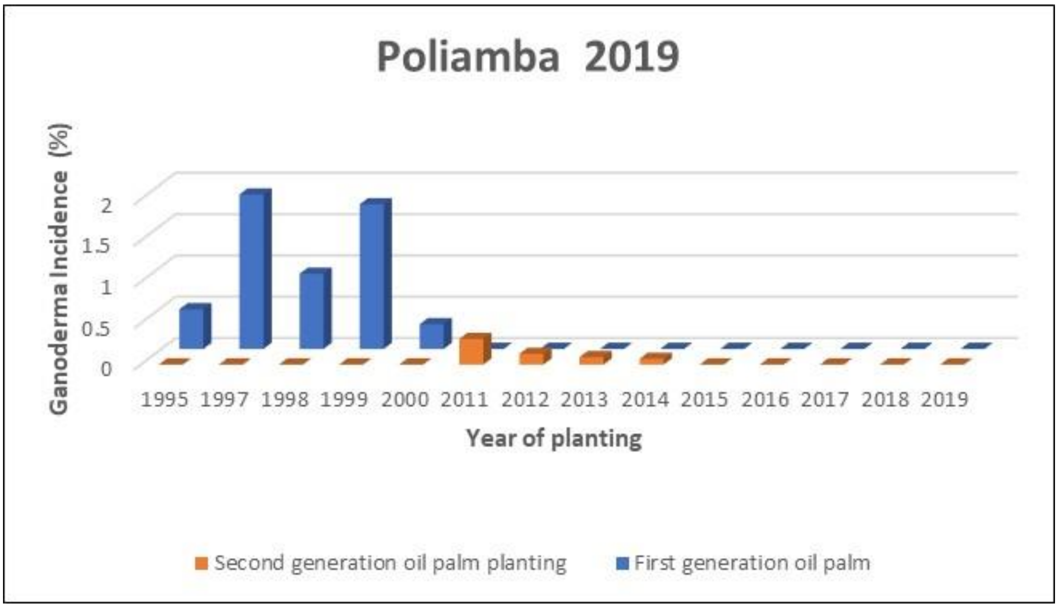

Figure 68. Annual (2019) incidence of Ganoderma rot in the first and second generations oil palms at Poliamba.

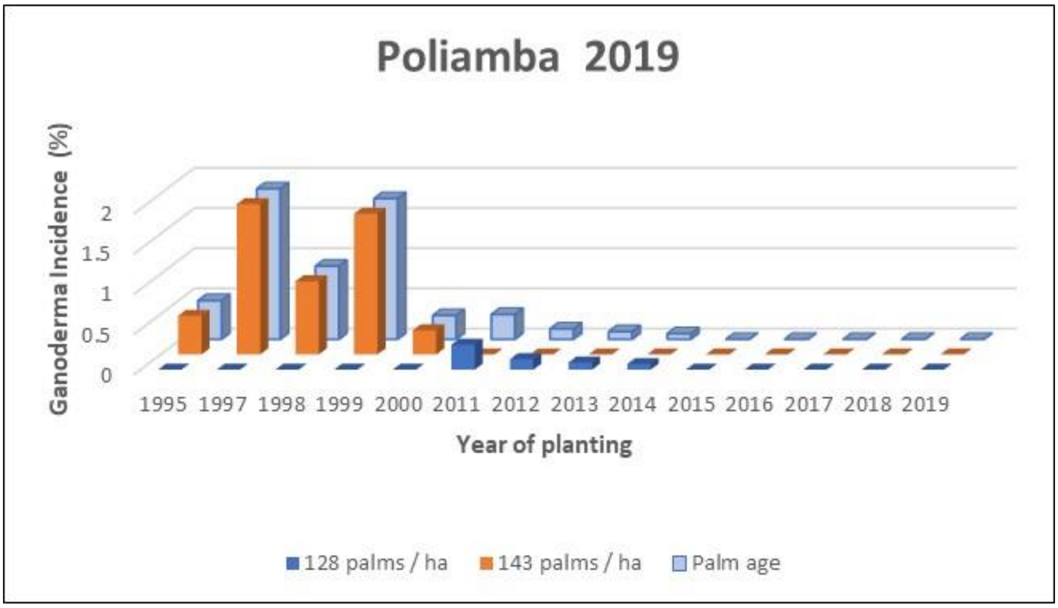

Figure 69. Disease incidence of Ganoderma rot in oil palms planted in different years with different planting densities at Poliamba plantation in 2019.

C. Higaturu

Ganoderma surveys and sanitation for Higaturu in 2019 recorded two rounds of surveys and sanitation. Approximately 88 % of plantations had been surveyed and sanitized for Ganoderma infections. The data represented here is only for areas surveyed and data is unaudited. Higaturu recorded a mean incidence of 0.55 % (Figure 9) which is higher rate than what was recorded in 2018 (0.27 %). Sumberipa (1.02 %), Sangara (0.64 %), Embi (0.57 %) and Sambogo (0.55 %) recorded disease incidences above the mean average in contrast to Ambogo (0.5 %) and Mamba (0.02%). High Ganoderma infections recorded for Sumberipa and Sangara which is expected with fields with high number of older plantings. These areas should be followed with regular surveys and sanitation nearing replant.

Ganoderma incidence and Palm age

High Ganoderma infections are observed with older plantings (1998 – 2005) as shown in Figure 10 below in contrast to younger plantings (< 14 yrs.). This is expected as older plantings are exposed to high disease pressure due to cumulative build up Ganoderma infections periodically.

Ganoderma incidence (%) and planting cycle

Ganoderma infections based on planting cycle for Higaturu (Figure 11) indicate a high disease infection for first generation plantings primary as a result of older plantings in contrast to second generation plantings. All second-generation plantings are young plantings (< 8 yrs.)

Ganoderma incidence (%) and planting density

Data for Ganoderma infections and planting density for Higaturu shows variable findings (Figure 12). The highest Ganoderma infection (1 %) was recorded for 132 palms / ha and 0.17 % for 128 palms / ha. It is difficult to make conclusions on the effect of planting density and Ganoderma infections as all these range of planting densities are composed of mixed plantings of both immature and older plantings.

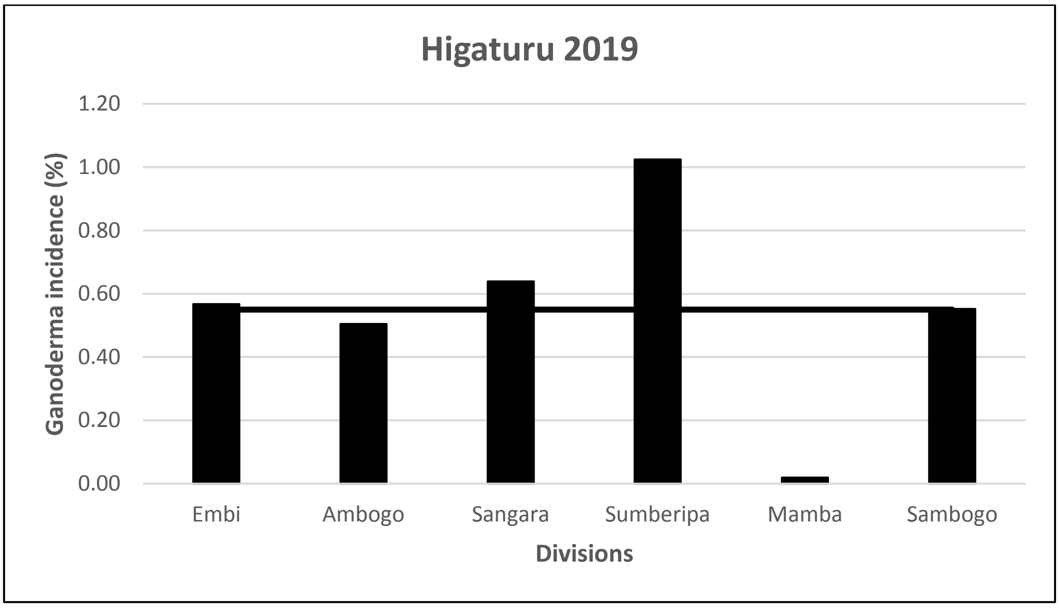

Figure 70. Disease incidence of Ganoderma rot at Higaturu plantation in 2019. The horizontal line is the plantation mean (0.55 %).

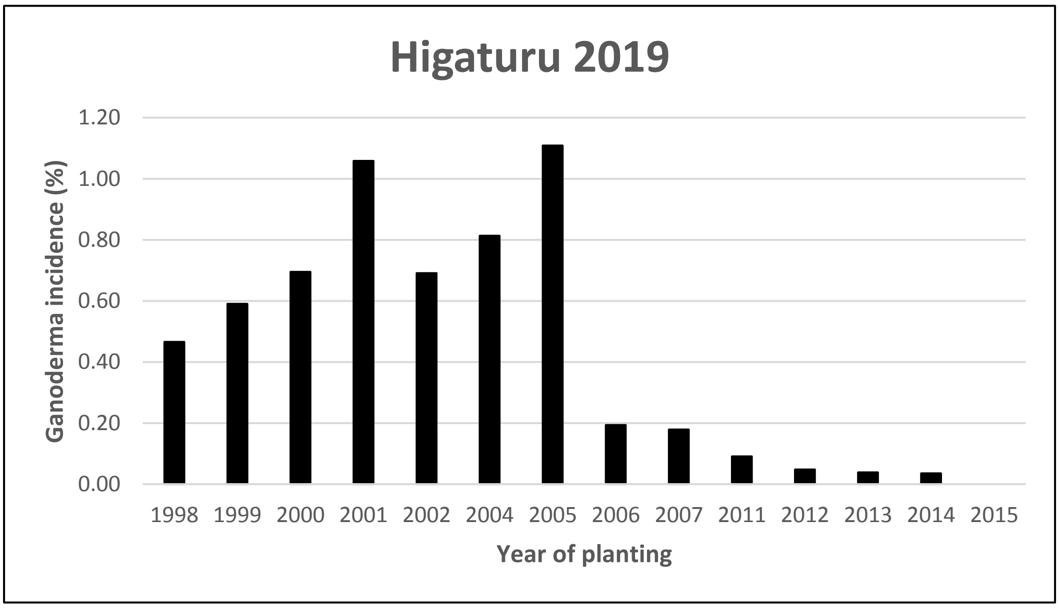

Figure 71. Disease incidence of Ganoderma rot in oil palms planted in different years at Higaturu plantation in 2019.

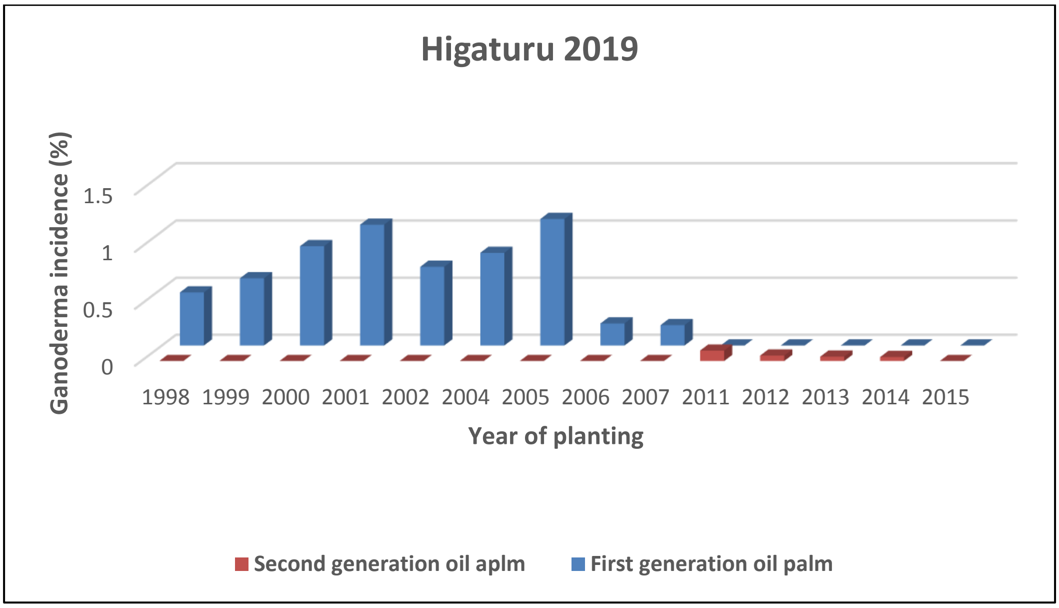

Figure 72. Disease incidence of Ganoderma rot in the first and second generations oil palms at Higaturu plantation in 2019.

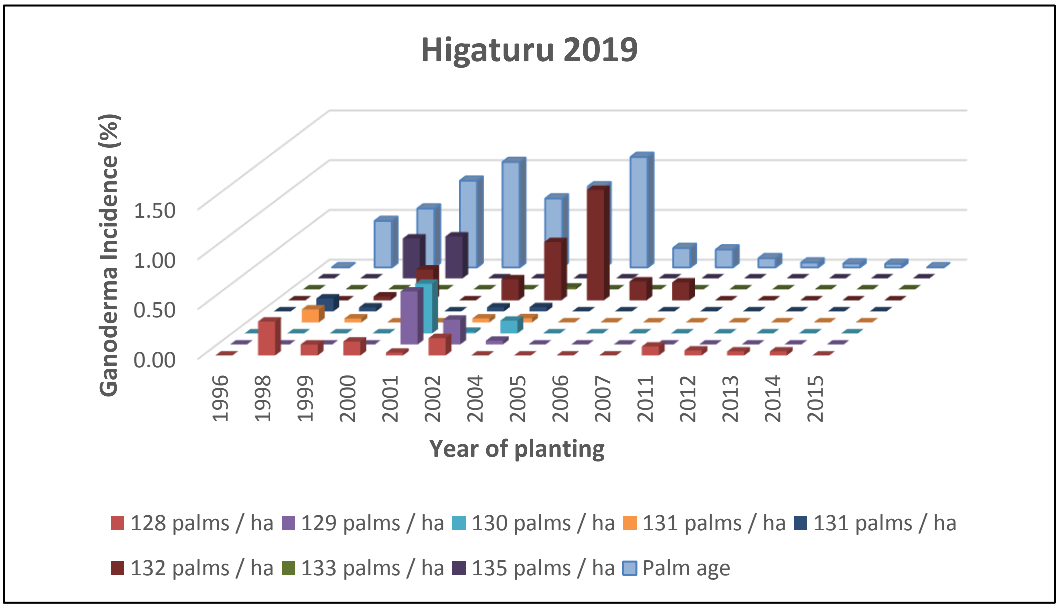

Figure 73. Disease incidence of Ganoderma rot in oil palms planted in different years with different planting densities at Higaturu plantation in 2019.

D.2.2. Disease Progress in Second Generation Oil Palm

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. Progression of Ganoderma infection continues to be monitored in 6 replanted blocks in Milne Bay and in two blocks in Numundo (E4 and E5) in West New Britain. This report is an update of recorded disease from monthly surveys in 2019. This information is vital for future plantings and will also enhance our knowledge on the succession of the Ganoderma population after 15-20 years residency in these study blocks.

A. Replanted fields at Milne Bay Estates

BSR surveys were continued for Milne Bay in six - second generation study blocks. Surveys for BSR infections have been carried out monthly during 2019. Blocks 7213 and 7214 were replanted in 2012 while blocks 6404, 6503, 6504 and 7501 were replanted in 2011. Disease surveys indicate a high number of suspect palms in contrast to palms with Ganoderma brackets. It is to be noted that the data is unaudited, and these numbers may be adjusted in future reports after the audits are conducted due to the high numbers of early stage BSR suspects. Surveys in 2019 showed a cumulative disease incidence that ranged from 0.36 – 0.61 % rate of infection. Cumulative disease incidence values in 2019 are shown in Table 1. Cumulative disease incidence data from 2013 – 2019 ranged from 0.67 – 1.18 % rate of disease infection. The highest cumulative rate of disease infection was recorded for Giligili for blocks 7213 (1.88%) and 7214 (1.54 %) followed by the blocks located within the Waigani division; 7501 (1.40 %), 6504 and 6404 with 0.80 % and 6503 with 0.67 % (Figure 13).

Table 90. Cumulative Ganoderma disease incidence in 2019 for 6 replanted blocks in Milne Bay

Block	Suspects	Bracket palms	Total	Total palms	Rate of suspect infections	Rate of bracket palm infections	Cumulative BSR total (%)
7213	11	8	19	3237	0.34	0.25	0.59
7214	10	2	12	1972	0.51	0.10	0.61
6404	22	13	35	6885	0.32	0.19	0.51
6503	27	13	40	8542	0.32	0.15	0.47
6504	12	5	17	4744	0.25	0.11	0.36
7501	21	31	52	8409	0.25	0.37	0.62

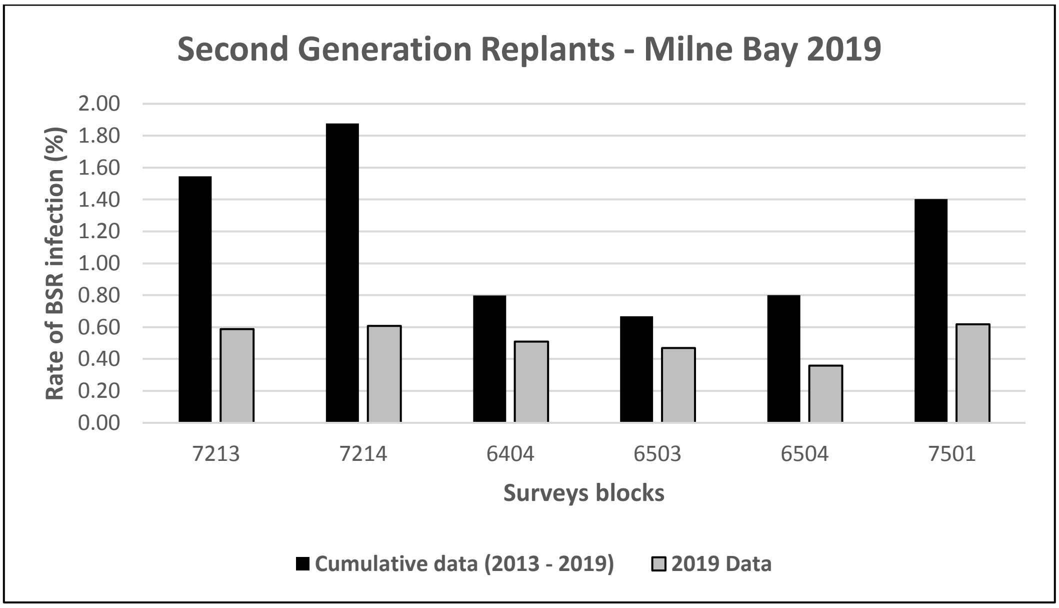

Fig 74. Cumulative Ganoderma disease rate (2013 - 2019) for 6 replanted blocks in Milne Bay

B. Numundo E4 and E5

Final surveys for E4 and E5 were conducted in May 2017 and the fields were replanted in June of 2017. The final cumulative disease incidence as time of replant was 40.6 % for E4 and 49.6% for E5 (Figure 14, PNGOPRA Annual report 2017). The report for 2018 makes no mention of any survey work for E4 and E5 in Numundo fields. Surveys were conducted in 2019 for the following months; January, April, July, and October 2019 (Figure 15).

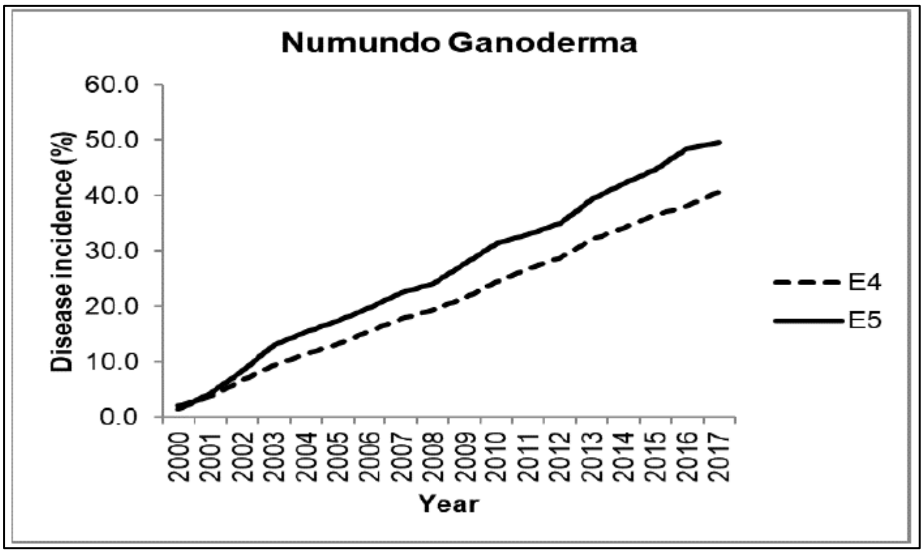

Figure 75. Cumulative Ganoderma disease incidence (2000 - 2017) for Numundo (E4 &E5) for first generation planting cycle (PNGOPRA Annual Report 2017)

Quarterly Ganoderma surveys in 2019 for fields E4 and E5 identified no immature palms with Ganoderma brackets. In account of the ambiguity scoring the early symptoms of Ganoderma rot of Suspect palms for both fields, all recorded palms are closely being monitored for further development of disease symptoms. Beetle damage and spear rot have also been recorded in both blocks and in general replants. Disease incidence of Ganoderma rot at Numundo (E4 &E5) in 2019 is shown in Figure 16.

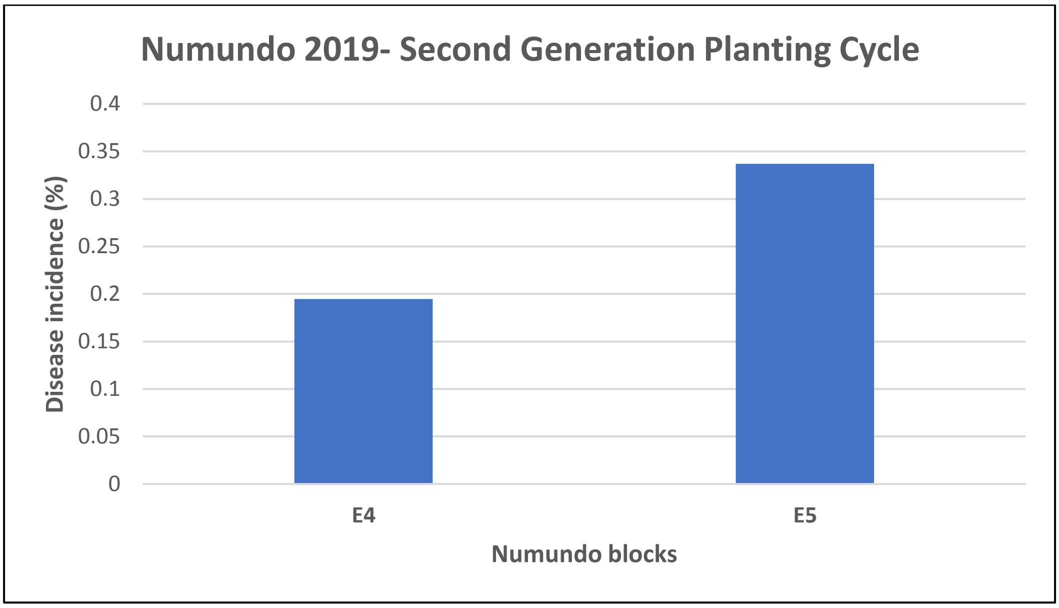

Figure 76. Disease incidence of Ganoderma rot at Numundo (E4 &E5) in 2019.

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

Ganoderma surveys for upper stem rot (USR) began in 2014 and final data collected ended in December 2019. A total of nine selected blocks from various plantation stages (1993 – 2014) have been studied (Table 2). Tissue samples of upper stem rots and fruiting bodies have been collected and isolated for pathogen identification. Morphological characteristics of fruiting body samples were consistent with *G.*

boninense. Molecular diagnostic after sequencing confirmed all isolates to be G. boninense in 2019. As of 2019, only five blocks were surveyed as the previous four study blocks been replanted 2017 – 2018. For the 2019 USR surveys only trial blocks 297 and 303 recorded three cases each of USR and BSR palms (Figure 16). In contrast, blocks 173, 291 and 334 only recorded cases of BSR palms. Cumulative Ganoderma survey data for all nine blocks indicated high cases of USR infections as compared to BSR palms (Figure 17).

High cases of USR infections in plantation is seldom present with relatively low (<1% disease infection). The high numbers of USR infections in selected trial blocks at Dami is most probably a direct result of continuous manual pollination for seed production. Frequent pollination causes injury and wounding of the upper palm trunk leading to opportunistic colonization and infection of Ganoderma. The proximity to the coastline is often accompanied with high humidity conditions coupled with constant wounding and injury during pollination are the possible main factors in relation to high USR cases in certain trial blocks in Dami.

Table 91. Summary of cumulative Ganoderma incidences in selected blocks in Dami seed gardens (2014 – 2019)

Trial no.	Year of planting	Area (ha)	Total palms	Cumulative BSR	BSR (%)	Cumulative USR	USR (%)	Years surveyed
291	2002	5.9	707	5	0.7	2	0.3	2018 - 2019
334	2014	18.7	2659	7	0.3	0	0.0	2018 - 2019
257	1993	9.9	1267	6	0.5	27	2.1	2014 - 2017
267	1998	17.6	2288	8	0.3	76	3.3	2014 - 2017
264A	1996	18.3	2562	19	0.7	90	3.5	2014 - 2018
264B	1996	18.3	2196	26	1.2	83	3.8	2014 - 2018
173	1998	1.84	218	2	0.9	32	14.7	2014 - 2019
297	2003	4.6	553	2	0.4	25	4.5	2014 - 2019
303	2004	7.1	944	17	1.8	36	3.8	2014 - 2019

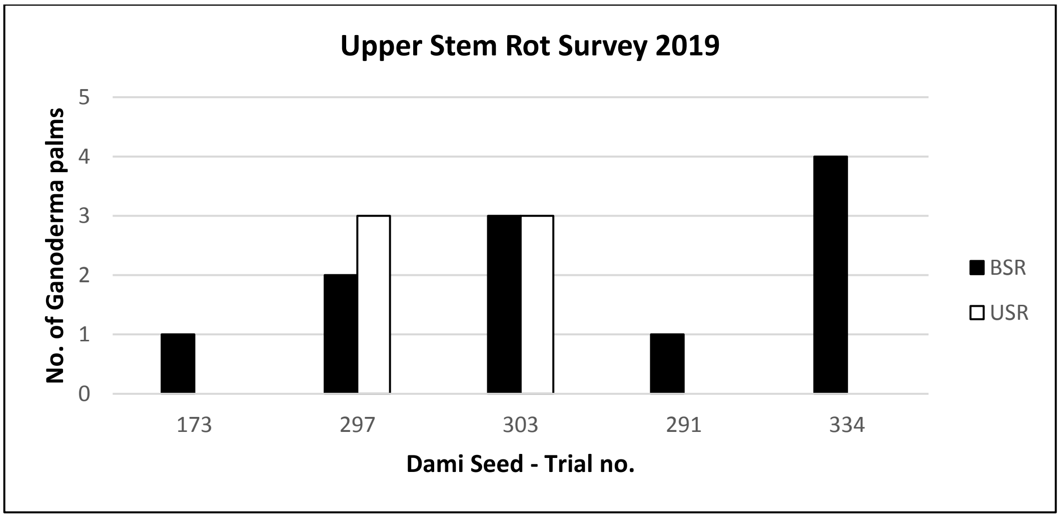

Figure 77. Number of upper stem rot palms recorded in five selected Dami trial blocks in 2019.

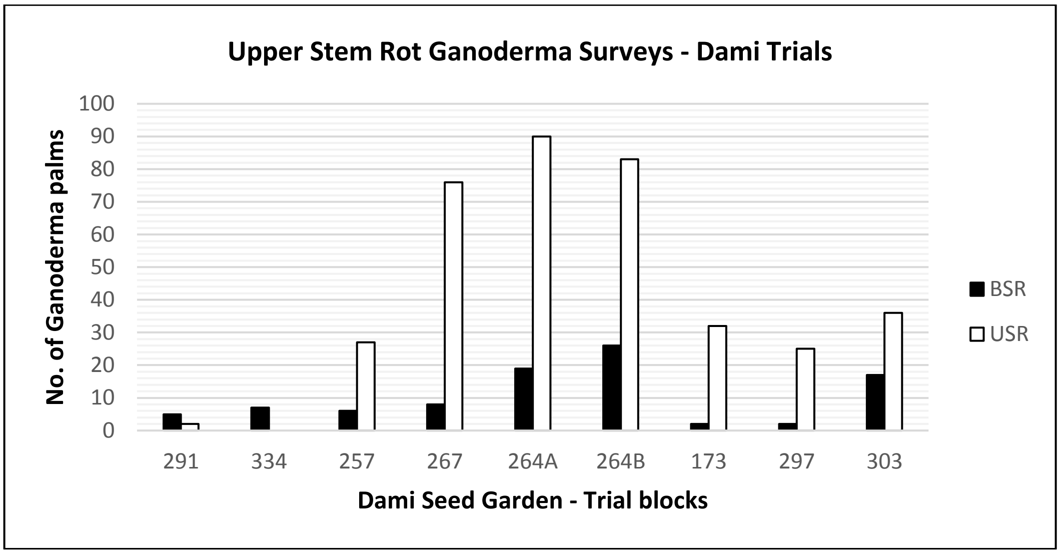

Figure 78. Total incidences of upper stem rot and basal stem rot palms for nine selected Dami trial blocks (2014-2019).

D.2.4. Site Factors That Contribute to The Prevalence of Ganoderma rot in Oil Palm - West New Britain blocks as a case study

Introduction

Basal stem rot is an important disease of oil palm in Papua New Guinea. The disease is caused by a fungal pathogen known as Ganoderma boninense which spreads through root transmission mainly and dispersal of spores. However, the role of Ganoderma basidiospores in disease initiation and spread of infection remains unclear so far and require investigation.

BSR disease levels in PNG are now above 15% for several plantations (PNGOPRA Annual Report 2016) With current activities such as replanting of oil palm and lack of effective field controls, disease levels are expected to increase leading to major loss of palms which may result in high economic losses. This study had two main objectives; the first objective was focused on investigating environmental factors which includes both physical and biotic factors that may influence the prevalence of BSR in oil palm blocks. Thirty oil palm blocks in New Britain Palm Oil Limited plantations in WNB were randomly selected within the age range of 16 - 21 years old for this study. Data collection included desktop surveys, field disease surveys, field soil and root sampling and lab analysis.

The second objective looked at comparing airborne spore inoculum between poisoned replanted smallholder blocks and commercial plantation blocks. Five smallholder blocks and five commercial blocks were selected for this study. A Rotarod air sampler was used to capture air particles to identify and quantify the concentration of Ganoderma spores per volume of air.

Results

a. Wind direction with highest speed influence on initial establishment of Ganoderma spores.

The wind direction with the highest wind speed revealed a moderate positive correlation with BSR incidences (Figure 18) especially with blocks with high incidences located in Numundo plantation. Apart from other plantations located inland, Numundo plantation runs horizontally along the coastline from North to South experiencing direct wind exposure from the sea (Figure 19) thus this might contribute to the initial establishment of Ganoderma spores from oil palm-ex coconut blocks containing high Ganoderma infection like Num 08 to blocks in the south of Numundo like Num11 and Numundo 16 which are ex-forest blocks but have high Ganoderma infection. This result may come along with studies by Pilotti (2001) revealing related alleles or mating types to be found over long distances of up to 15 km between plantations assuming the spread of basidiospores are aided by wind during replanting as the cleared land would mean less obstacles and direct movement of wind. Thus, similarly to Numundo which experiences direct exposure to North winds from the open sea, this strongly supports the evidence of spores playing a major role in the spread of infection (Rees et al., 2012) and this study indicate that wind may serve as a vector.

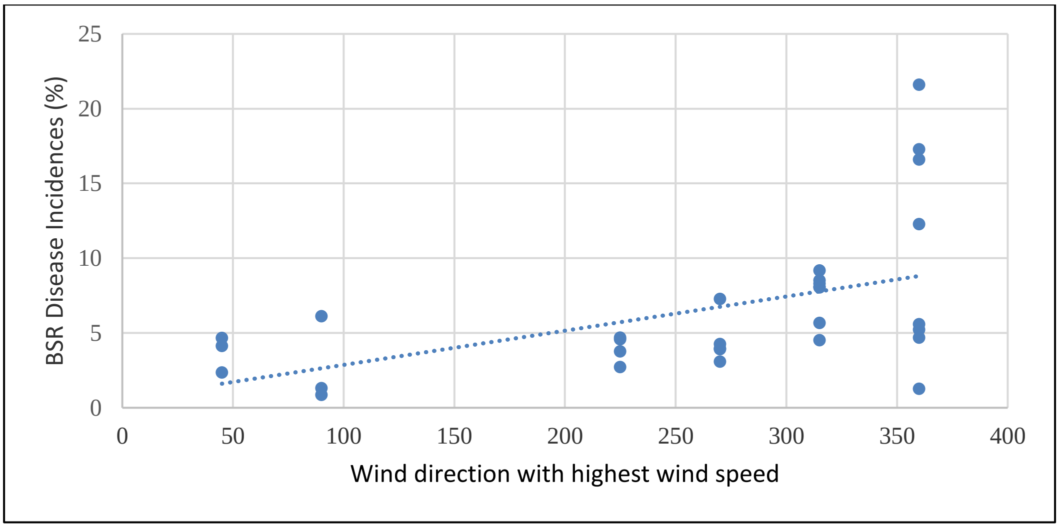

Figure 79. Correlation graph of wind direction with highest wind speed and BSR incidences in 30 selected blocks in WNB.

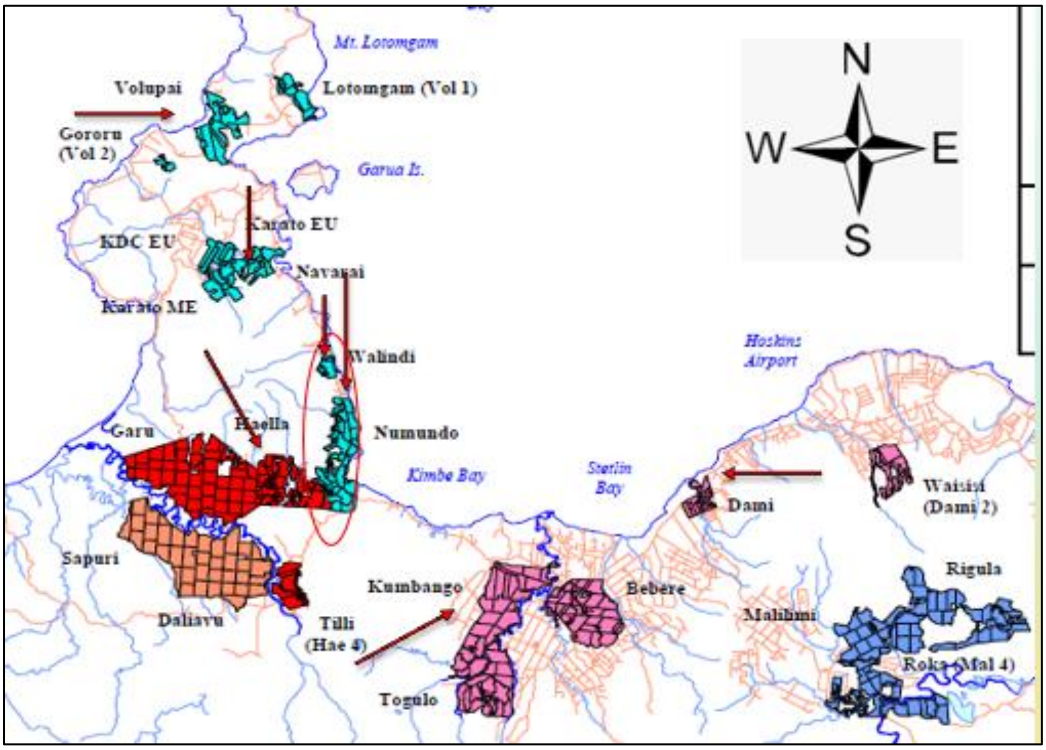

Figure 80. Map showing wind direction with highest wind speed for each target plantation.

b. Movement of Ganoderma spores from oil palm blocks with high infection to other blocks

Wind as a vector of dispersal of Ganoderma spores could also be the contributing factor to the positive correlation (r = 0.40) between BSR disease in the study blocks and their surrounding blocks with the movement of spores (Figure 20), contributing to BSR incidences in other surrounding blocks despite previous crop having no linear correlation with BSR incidences. Analysis reveals that there is a positive low correlation (r = 0.40) between disease incidence in study blocks and disease incidence in adjacent blocks. However, analysis (t-test) of the means reveals no significant differences (p =0.24) between disease incidences in the study blocks (ẋ = 6.5, SD = 4.8) and their surrounding blocks (ẋ = 5.2, SD = 3.3).

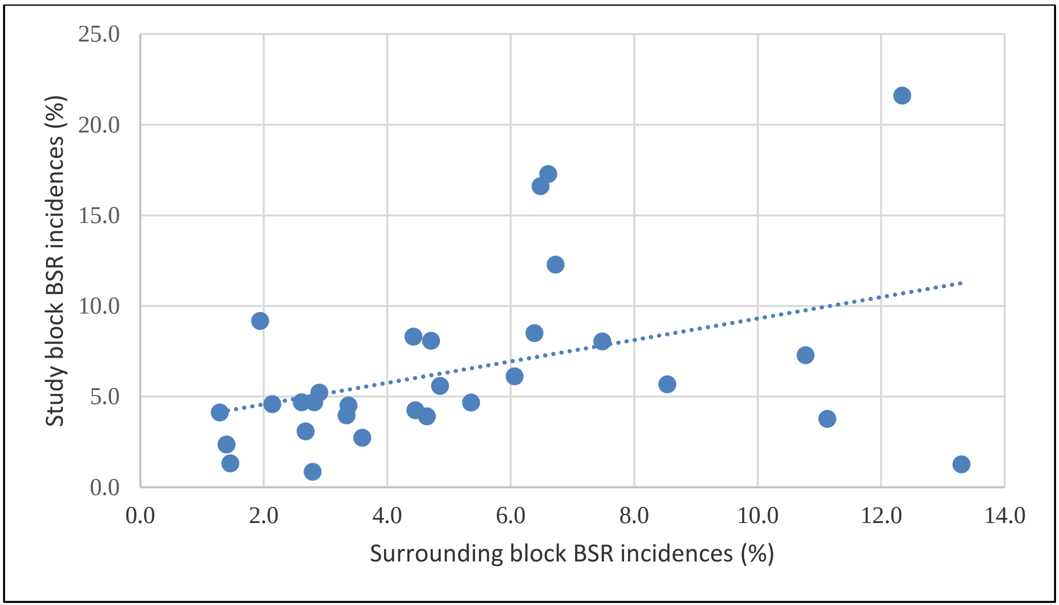

Figure 81. Correlation graph showing relationship between BSR incidences in selected blocks and their surrounding blocks.

Other findings under current verification are the impact of Mycorrhiza population on the prevalence of BSR infection rate and the spore inoculum difference between small holder blocks and plantation blocks.

Management strategies reinforced or recommended from this work include additional buffer zones for blocks situated along main highways, windbreak buffers for blocks exposed to strong northerly winds and removal of Ganoderma infected palms during disease surveys. Further research is required to consolidate these findings and investigate the impact of other site factors.

D.3. GANODERMA ECONOMIC IMPACT AND MANAGEMENT

Ganoderma rot is a disease that cannot be eliminated yet. Replanting into fields previously affected by Ganoderma-palms will result in new infections throughout the planting cycle. It is anticipated that infection levels will be higher in second and third generation plantings if proper control measures are not implemented especially at the time of oil palm replanting to eradicate the primary source of infection represented by tissues of the former stand of oil palms. Therefore, determining the best sanitation practices is vital to control the Ganoderma rot during replanting.

Yield reduction caused by Ganoderma rot is based on two reasons, no yield from dead palms and reduced weight and bunch numbers from palms with sub-clinical symptoms. The point at which disease threshold is reached such that yield begins to decline is still not clear and is likely to vary from between different locations (Turner, 1981).

Field control measures will become increasingly laborious to implement as disease onset manifests younger palms at each planting cycle. Thus, long-term control of basal stem rot through incorporation of more tolerant oil palm germplasm in breeding programmes is the only viable approach.

D.3.1. Management of Basal Stem Rot in PNG and Solomon Islands – ACIAR Project

Introduction

Trials were established in 2010 at Ngalimbiu plantations (Guadalcanal Plains Palm Oil Limited (GPPOL)) in Solomon Islands using F1 tenera (D x P) from Dami Research Station WNB. Palm status for disease assessment has been monitored since 2012 with yield recording commencing in 2013. Yield data and BSR disease levels continue to be monitored for progeny testing in fields 12 and 13 at Ngalimbiu plantations, Solomon Islands. A total of 81 commercial crosses were planted out in 14 replicates in a randomized block design with two treatments. Field 12 had boles of first-generation oil removed before replanting while field 13 had bole left in soil at replant. Planting density is 128 palms per hectare. This research is supported by ACIAR with collaboration with the University of Queensland. Aspects of this work have already been reported in the past and will not be reiterated here. The primary objective of the ongoing research is to collect data from the field trials (both yield and susceptibility traits) and subsequently eliminate the most BSR susceptible germplasm from breeding programs and oil palm cultivation. Furthermore, the project aims to assess the pathogenic aggressiveness within the population of Ganoderma isolates from the field trials. Palms from the field trials are regularly monitored for yield parameters (bunch numbers and weight) and for disease incidence. Yield data (bunch weight and bunch #) is collected regularly since 2013. Disease data is recorded monthly since 2015. Ganoderma isolate collection begun in 2011, initially from windrowed logs.

Results

Two planting treatments were established – in one field the old palms were cut at ground level (F13), and the new palms were replanted 4 meters from remaining stumps whereas in the second field (F12), sanitation by excavating the soil a depth of about 1,5 m and boles were removed. All excavated stumps and roots were left in the field to dry. New replants were placed 4 m in-between rows.

It is important to note that all Ganoderma disease surveys data was audited on site in 2019 by PNGOPRA Plant Pathologist during his follow-up visit to GPPOL. Incidence of BSR has increased in the trial palms over the past year, to 5.4 % and 10.1 % in Field 12 and 13 respectively. Disease incidences in the fields of study suggest that bole removal does reduce Ganoderma infection rate over years (Figure 21). However, the recommended procedure for sanitation by the Plant Pathology in PNGOPRA also includes the removal of all excavated roots and stumps from the oil palm field to minimize any source of initial inoculum in the future.

Yield data for progenies per block is highly variable, but overall, there is no significant difference between mean bunch weight between Field 12 (average of 21.1 t/ha) and Field 13 (average 21.0 t/ha), despite lower infection rate in Field 12. Yield losses due to the BSR infection in 2019 accounted for 3% and 5% for F12 and F13 respectively (Figure 22). The yield losses caused by Ganoderma rot are expected to rise in the next year's overtime.

Bracket sample collections for field 12 & 13 showed that F13 has higher number of brackets collected and sampled from standing infected palms for years 2015 - 2019. All isolates are collected from both trial palms and the guard row palms in each field (Figure 23). Collection of Ganoderma field isolates also continues with another 91 isolates found in 2019, all from living palms. In the collection, 45.2%

of the isolates come from windrowed logs (saprophytic), and 54.8% from living palms (pathogenic) of which 18% are from progeny/trial palms and 36.6% from guard row palms.

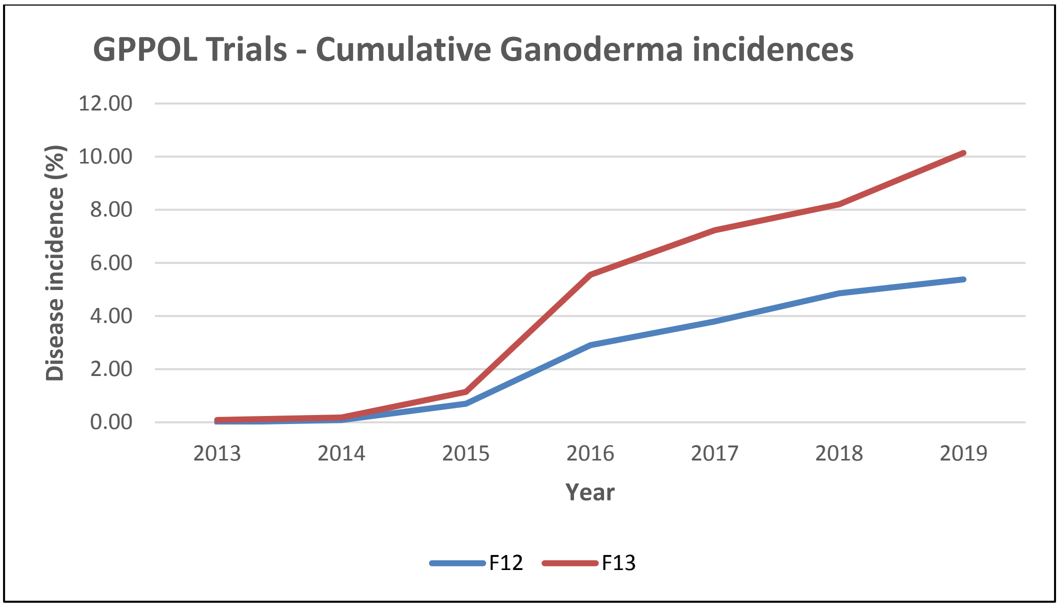

Figure 82. Impact of bole removal sanitation on cumulative BSR incidence in the replanted palms (F12 – bole removal and the excavation of roots and stumps of former palms, F13 – replanting without sanitation).

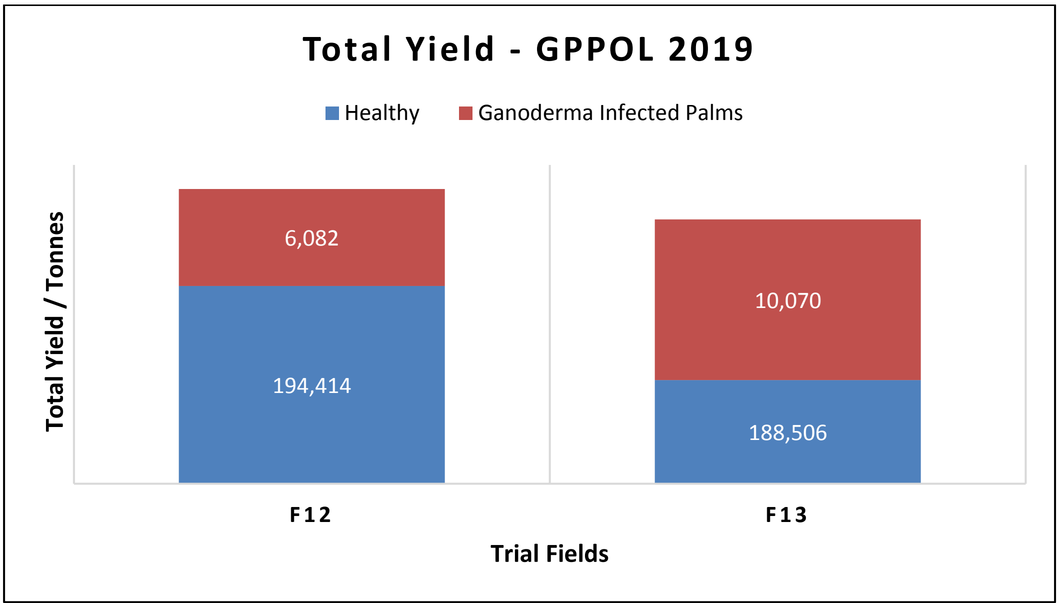

Figure 83. Effects of Ganoderma infection on the total yield for F12 and F13 in 2019.

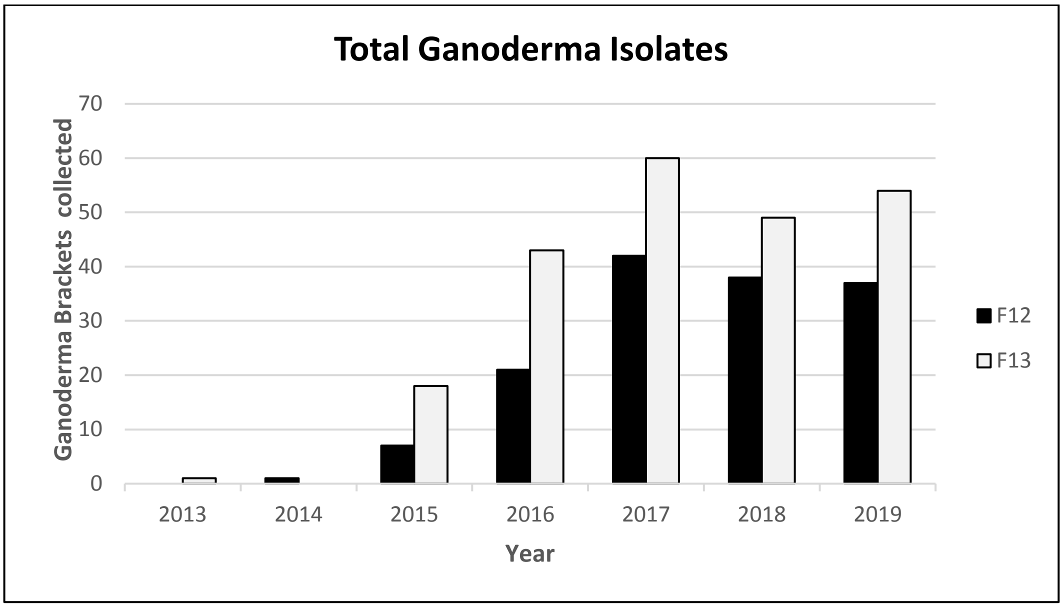

Figure 84. Total Ganoderma isolates collected from F12 and F13 in GPPOL.

D.3.2 Screening of Dami Families Planted in GPPOL Field Trial

Introduction

The long-term strategy for BSR control is the breeding of resistant or tolerant material. Nursery screening trials have been implemented to determine difference in BSR susceptibility of 81 commercial progenies in Milne Bay for trials 3, 4, 5, 7, 8, 9, 10, 11, 12, 13, 14 and 15.

Nursery screening with large trials of 120 plants/cross (60 test/60 control) x 3 reps were established during this period plus two smaller trials of the same crosses of 50 seedlings each. The aim to determine susceptible crosses and have this removed from the breeding program.

Results

Nursery inoculation of oil palm seedlings to screen for differences in susceptibility for 81 progenies planted for field trial in GPPOL as part of ACIAR project had been finalized for multiple trials in Milne Bay. Results so far are generally consistent for those parents and families that were retested with susceptibility or non-susceptibility being observed in the following trials: 3, 4, 5, 7, 8, 9, 10, 11. However, there is no clear correlation of nursery data with field data. although some lines performed/are performing particularly poorly in both the nursery and field trials (data not shown).

Nursery screening continued in 2019 in Milne Bay with 3 large trials of 120 plants/cross (60 test/60 control) x 3 reps plus one smaller trials of the same crosses of 30 seedlings each. New trials: 12, 13, 14 and 15 are under testing, the scoring of infection and mortality will be verified and analyzed to be presented by the end of 2020.

D.4. PLANT PATHOLGY ACTIVITIES

D.4.1. Disease Reports

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. A total of 71 disease reports were received for the year 2019 during the Pest and Disease meetings every Wednesday at Nahavio Oil Palm Industry Corporation (OPIC) office, while some reports were received during field days. 56 of the reports were of Ganoderma infection, 9 reports had other diseases reported and 6 reports had both Ganoderma infection and other diseases per block. All reports received were inspected by the Plant Pathology field team where recommendations for removals or sanitations were made for confirmed Ganoderma infection with brackets or dead palms. Recommendations of closed monitoring and observation were issued for suspect palms or other diseases.

From the total reports received in 2019, only 2 reports were from NBPOL plantations (Bilomi and Kumbango) of Ganoderma infections, Whereas, remaining inspection requests were smallholder disease reports within Hoskins project from Salelubu, Buvussi, Siki, Kavui, Nahavio and Talasea divisions (Figure 24).

Table 3 summarizes the total Ganoderma infection into areas where reports were received from. The highest number of Ganoderma palms of 7 were from the Sarakolok area and 6 from Wakanakai area in Talasea. However, the highest number of suspect palms were from Kapore and Kavui areas of 24 and 20 suspect palms, this indicates that the LSS Growers are more concerned about their palm's health status.

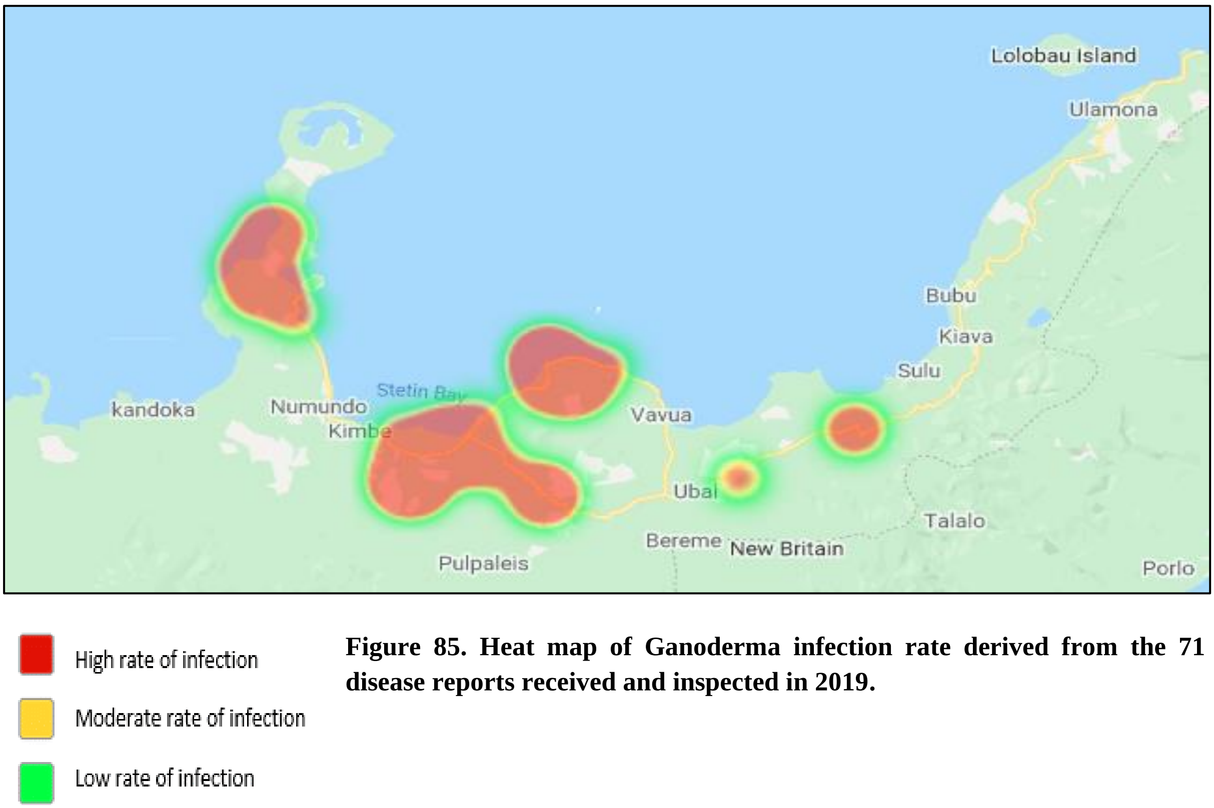

Figure 85. Heat map of Ganoderma infection rate derived from the 71 disease reports received and inspected in 2019.

Table 4 shows the other types of diseases that were reported apart from Ganoderma infection from the following areas of mostly spear rot, upper stem rot and unknown foliar disorder in newly planted seedlings. Two reports had damaged palms caused by environmental factors such as lightning and wind.

Table 92. Summary of total Ganoderma infections reported in divisions and areas in WNB.

Division	Area	No of Ganoderma palms	No of suspect palms	No of Ganoderma dead palms
Buvussi	Buvussi	5	12	4
Buvussi	Galai	2	0	0
Buvussi	Galai 2	3	0	0
Kapuira	Bilomi	2	3	0
Kavui	Buluma	1	1	0
Kavui	Gaongo	1	1	3
Kavui	Kapore	3	24	0
Kavui	Kavui	1	20	0
Kavui	Mosa	1	0	0
Mosa	Kumbango	0	4	4
Nahavio	Dagi	5	0	2
Nahavio	Mingae	0	1	0
Nahavio	Sarakolok	7	13	8
Salelubu	Silanga	1	0	0
Siki	Galoale	4	2	2
Siki	Gavaiva	0	4	0
Siki	Matavulu	2	0	0
Siki	Siki	3	3	1
Talasea	Bamba	0	0	0
Talasea	Dire	0	0	1
Talasea	Liapo	0	3	2
Talasea	Pasiloke	0	0	3
Talasea	Pinau	2	0	3
Talasea	Wakanakai	6	0	0

Table 93. Summary of other diseases reported in divisions and areas in WNB.

Division	Area	Disease type	No of live palms infected	No of dead palms
Buvussi	Galai	Lightning damage	1	0
Kavui	Buluma	Upper stem rot	0	1
Kavui	Kapore	Unknown foliar disorder	39	0
Kavui	Kapore	Upper stem rot	1	0
Mosa	Kumbango	Wind damage	2	0
Nahavio	Dagi	spear rot	0	2
Nahavio	Dagi	Upper stem rot	0	1
Nahavio	Mingae	Unknown foliar disorder	1	0
Nahavio	Sarakolok	spear rot	2	0
Salelubu	Silanga	Unknown foliar disorder	0	0
Siki	Galoale	spear rot	0	2
Siki	Galoale	Upper stem rot	1	0
Talasea	Bamba	crown disease	1	0
Talasea	Dire	spear rot	0	1

Figure 25 shows the noted age range of the disease reports in 2019 and the total number of Ganoderma infected palms within this age range. Results have shown that the incidence of Ganoderma infection of oil palms is greatest on old palms over 20 years of age. Ganoderma incidences were observed on younger plantings on sites which had previously borne coconut palms or Ganoderma infected oil palms that was not sanitized properly before replanting.

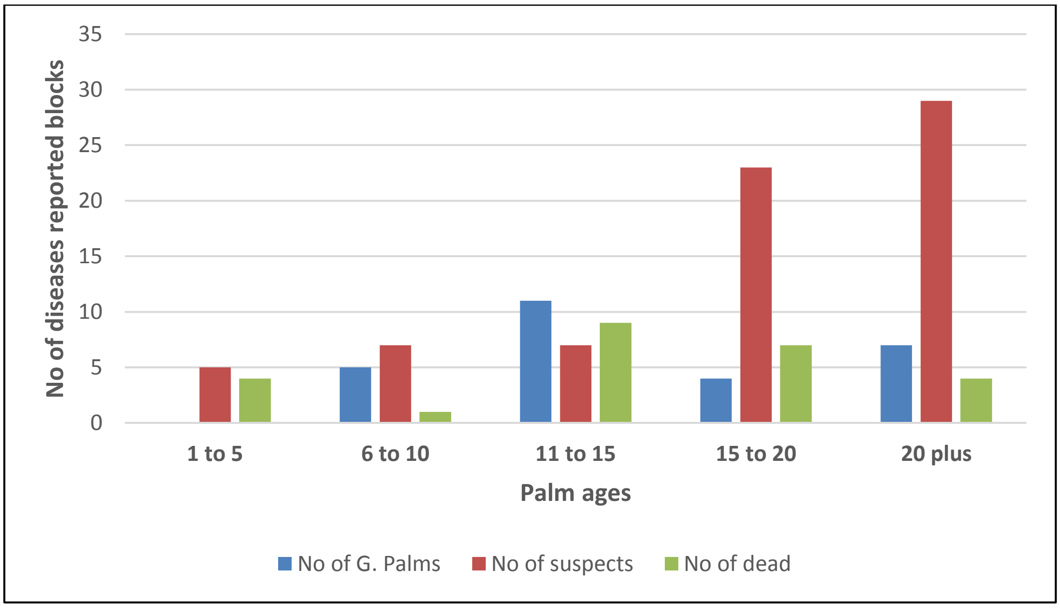

Figure 86. Age range of Ganoderma infected palms reported in WNB.

D.4.2. Training and Field Days

The field days held annually by oil palm stakeholders and others. All smallholder field days are run on weekly basis for Hoskins Project in West New Britain from March to September.

For Plant Pathology the field staff are the ones who attend and educate the Growers on the types of oil palm diseases, emphasizing on the most prevalent disease in PNG, Ganoderma infections causing basal stem rots. The Growers are educated on how to recognize signs and symptoms of Ganoderma infection, how to control the spread through preventive measures and sanitation and how the disease can affect the productivity of their oil palms.

For 2019 only 20 field days were held in 6 divisions beginning in Salelubu, Nahavio, Buvussi, Kavui, Siki and Talasea (Figure 26). Some field days were cancelled due to RSPO audits in smallholder blocks and other issues. The field day that had the highest turn up were mostly in the Land settlement scheme (LSS) blocks of Kavui and Buvussi having 270 and 261 people in attendance. Overall, a total of 2813 people attended the field day programs where 66% of males and 33% of females attended (Table 5).

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 (**Error! Reference source not found.**)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.

Table 94. Field days held in 2019 for each area in each division in WNB.

Date	Division	Area	Block No.	No. of Male	No. of Female	Total Attendance
3/5/2019	Salelubu	Kotou VOP	Village	136	71	207
3/19/2019	Salelubu	Mamota LSS	240-0992	135	68	203
2/26/2019	Salelubu	Ubae VOP	Village	97	30	127
4/2/2019	Nahavio	Sarakolok 6	003-0950	86	27	113
4/9/2019	Nahavio	Tamba sec.1	002-0567	95	77	172
4/16/2019	Nahavio	Hak CRP	066-0007	50	37	87
4/30/2019	Buvussi	Buvussi sec. 4	004-1209	169	92	261
5/7/2019	Buvussi	Buvussi sec. 8	004-1332	140	81	221
5/14/2019	Buvussi	Galai sec.19	005-2118	93	64	157
5/21/2019	Buvussi	Lilimo VOP	047-0004	33	19	52
6/4/2019	Kavui	Mai VOP	014-0126	83	32	115
6/11/2019	Kavui	Kavui sec.6	006-0249	177	93	270
7/9/2019	Kavui	Gaongo CRP	017-0358	56	17	73
7/16/2019	Siki	Gavaiva VOP	Village	113	49	162
7/30/2019	Siki	Kololo VOP	044-0082	68	34	102
8/6/2019	Siki	Koimumu VOP	Village	111	70	181
8/20/2019	Talasea	Tamambu VOP	019-0019	45	6	51
8/27/2019	Talasea	Wenge CRP	080-0031	30	13	43
9/10/2019	Talasea	Bamba VOP	050-0026	25	10	35
9/17/2019	Kavui	Kapore LSS	001-0322	115	66	181

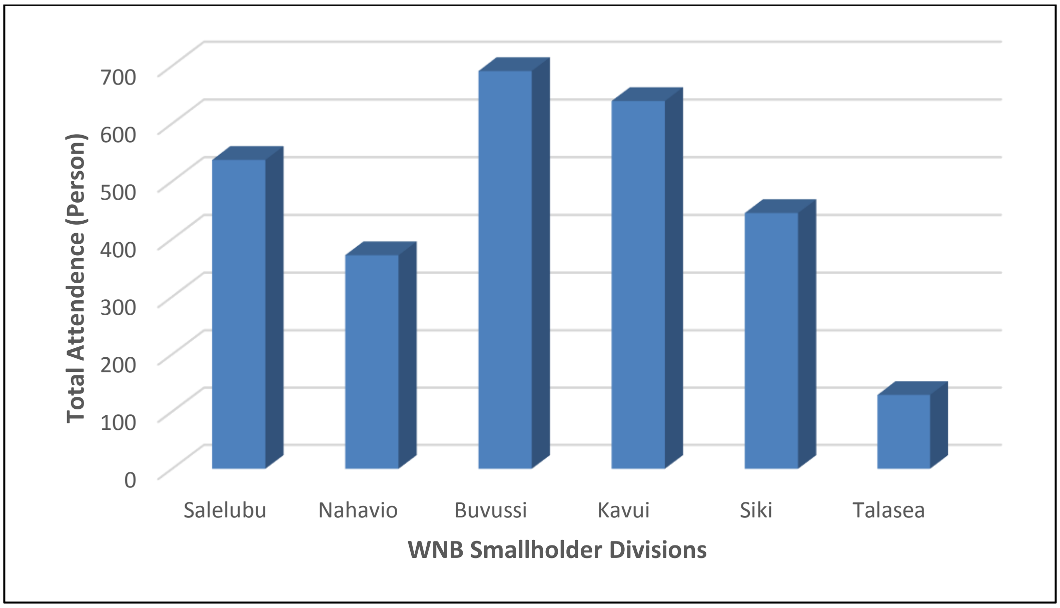

Figure 87. Total attendance for 2019 field days for each Smallholder divisions in WNB.

D.5. PUBLICATIONS

Site factors that contribute to the prevalence of Basal Stem Rot (BSR) in oil palm (*Elaeis guineensis*) blocks in West New Britain - A Thesis submitted in fulfilment of the requirement for the degree of Master of Philosophy in Agriculture to Papua New Guinea University of Technology by Evah Tatar Tokilala. Submitted Nov 2019.

D.6. 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.

Emmanuel Germis was promoted to Socioeconomist after completing his MPhil from Curtin University. A new driver (Sam Tomana) for the section was recruited. Ferdinand Baba, one of our trainee supervisors at Kapiura, WNB was transferred to Higaturu, Popondetta in April 2019. The Head of SSR, Steven Nake was appointed to be Acting Director of OPRA from 9th September to 31st December 2019 when the former Director Dr. Luc Bonneau resigned from OPRA.

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 mid-term review of ASEM-2014-056, a project on "Identifying opportunities and constraints for rural women's engagement in small-scale agricultural enterprises in Papua New Guinea" was successfully held on the 6th of March 2019 at Genesis Haven Kimbe, WNB.

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 WNB and other project sites. Through the section's efforts, smallholder trainings have now taken off well in other sites like Popondetta, Milne Bay and Poliamba where it went off radar for the last 5-10 years. There has been a lot of interest shown by both the stakeholders of the industry and the smallholder growers. In 2019, a total of 142 smallholder trainings were conducted throughout all sites. 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. SSR104: Assessing leaf nutritional status of smallholder blocks, Hoskins project

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

E.2.1.1. *Summary*

Leaf sampling was conducted in 145 smallholder blocks to assess their foliar nutritional status. Laboratory results revealed deficiency in leaflet N, P, K and S. 98.6% of 145 sampled blocks were N deficient of N, 95% deficient of P and100% K deficient. In contrast, leaflet Mg, leaflet B and rachis K were adequate. The 6-year trend also confirmed a consistent decline in leaflet Nand K over time, even though nitrogen is recommended for smallholders unlike K. 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.2.1.2. *Background*

One of the factors affecting smallholder production is negligence by smallholders to either apply fertiliser or lack of knowledge to apply fertiliser correctly. The reasons for this have 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. It 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 2019, 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.2.1.3. *Methodology*

One hundred and forty-five (145) smallholder blocks were randomly selected from the five divisions (Siki, Kavui, Buvussi, Nahavio and Salelubu) (Table 90). 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 3x3 or 2x2 depending on the size of the block. A 3x3 sampling intensity would mean that every 3rd palm in every 3rd 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^{0}C, ground, packed and dispatched to AAR Laboratory in Malaysia for analysis.

Table 95. Break up of Smallholder blocks utilized for leaf sampling in 2019

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

E.2.1.4. *Results and Discussion*

The leaflet nutrient concentrations are presented in Table 91. Leaflet N, P, K and S were deficient in all the 5 divisions. Leaflet Mg was low in Kavui and Nahavio while leaflet Cl was low in Siki and Buvussi. In contrast, leaflet Ca, B and rachis were adequate in all 5 divisions.

The foliar nutrient concentrations for the individual blocks are shown in Figure 2 to Figure 7. Leaflet N ranged from 1.62% to 2.68 % (average = 2.04%) with only 2 blocks with N levels above the critical level of 2.59%. The rest of the blocks (143) were low in leaflet N. For leaflet P only 7 blocks (5%) were above the critical level (0.142 %), the remaining 138 blocks (95%) were P deficient. Leaflet P ranged from 0.109 % to 0.152%. Leaflet K ranged from 0.30 to 0.59 %, with mean of 0.44%. All 145 blocks (100%) were deficient.

Leaflet Mg ranged from 0.11 to 0.33% with an average of 0.20 %. Sixty-seven (67) blocks (46 %) were above the critical level (0.20%), while 78 blocks (54%) were Mg deficient. All (100%) the blocks were at the adequate levels for leaflet B. Rachis K was adequate indicating N deficiency had limited translocation of K from reserve tissue to leaves. Leaflet Ca was significantly high in all the blocks, whereas Cl was low in Siki and Buvussi divisions. Leaflet S seemed to be low in all the blocks.

Table 96. Foliar nutrient concentrations for smallholder blocks in the 5 divisions in Hoskins Project in 2019.

Divisions	Leaflet N (%)	Leaflet P (%)	Leaflet K (%)	Leaflet Mg (%)	Leaflet Ca	Leaflet B (ppm)	Leaflet Cl (%)	Leaflet S (%)	Rachis K (%)
Siki	1.92	0.119	0.39	0.21	0.86	14.9	0.27	0.17	1.67
Kavui	2.09	0.126	0.46	0.19	0.88	13.5	0.30	0.17	1.65
Buvussi	2.03	0.127	0.42	0.20	0.88	15.5	0.20	0.19	1.42
Nahavio	2.14	0.129	0.47	0.18	0.81	13.1	0.34	0.19	1.72
Salelubu	2.06	0.127	0.44	0.24	0.80	13.4	0.26	0.18	1.60
Mean	**2.04**	**0.125**	**0.44**	**0.20**	**0.85**	**14.1**	**0.28**	**0.18**	**1.61**
Critical level	**2.59**	**0.142**	**0.75**	**0.20**	**0.25**	**8.0**	**0.25**	**0.20**	**0.95**

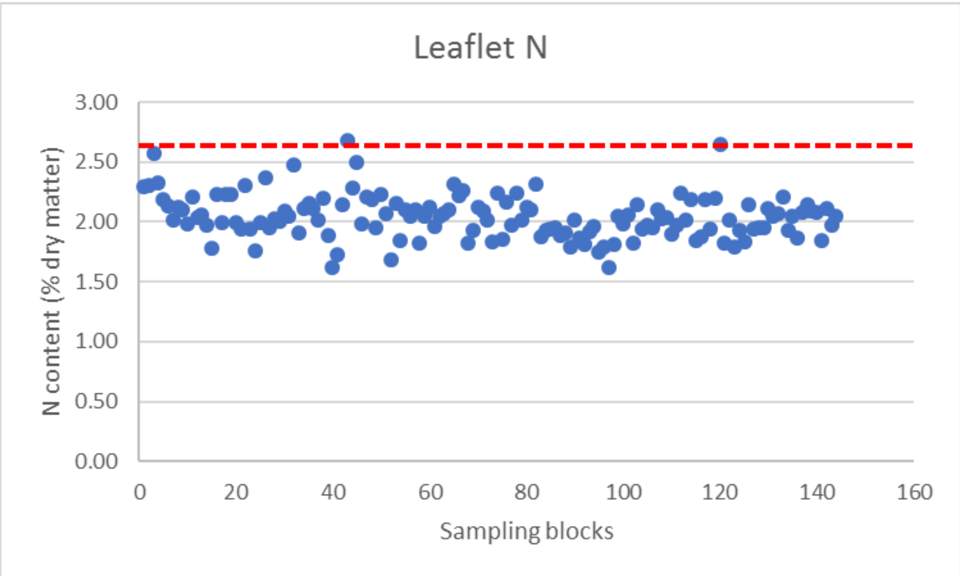


Figure 88. Leaf N concentration for the sampled smallholder blocks in 2019.

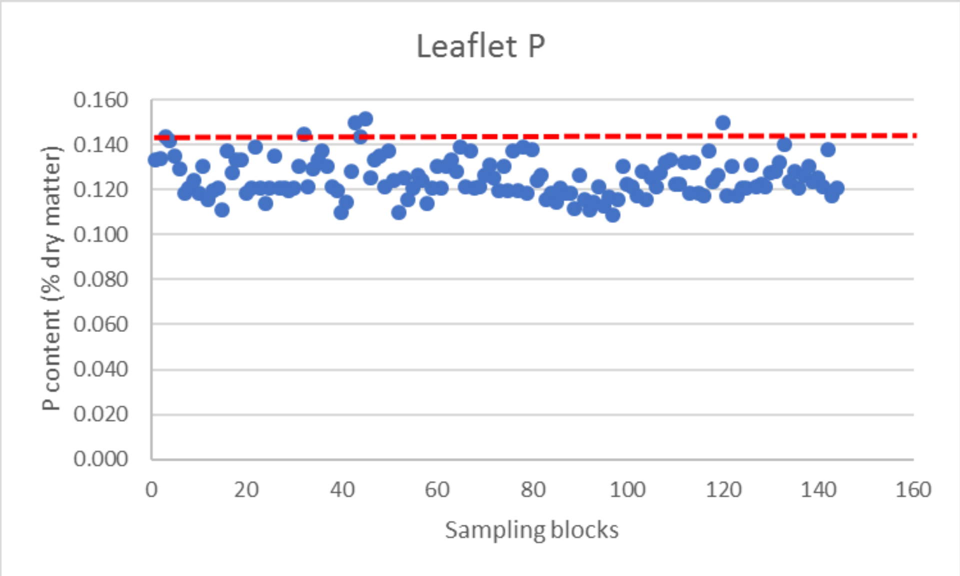


Figure 89. Leaf P concentration for the sampled smallholder blocks in 2019.

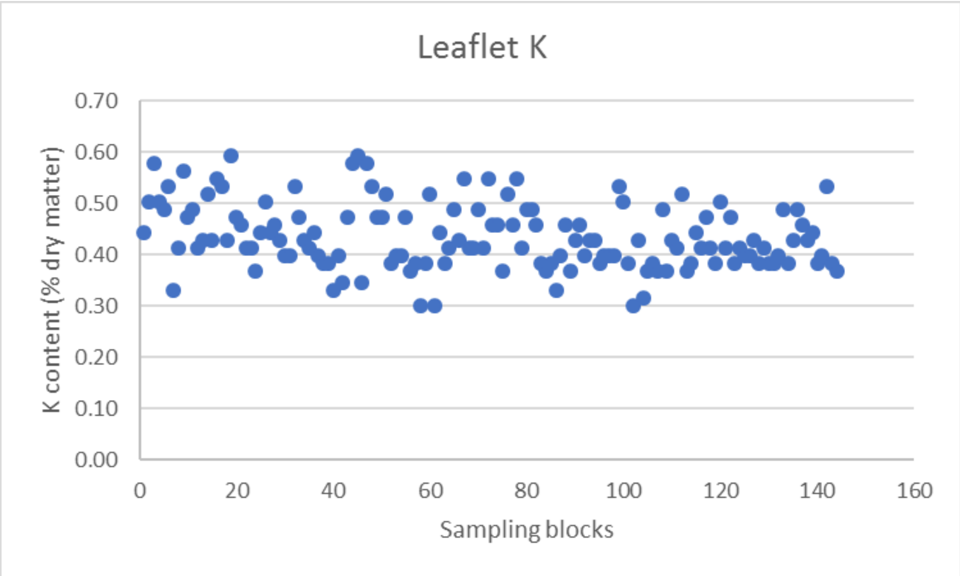


Figure 90. Leaf K concentration for the sampled smallholder blocks in 2019.

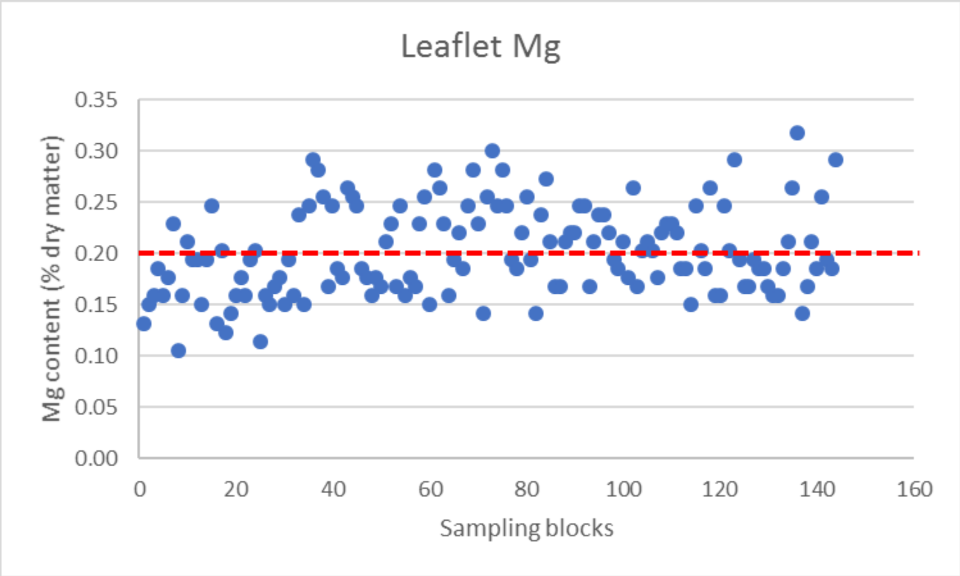


Figure 91. Leaf Mg concentration for the sampled smallholder blocks in 2019.

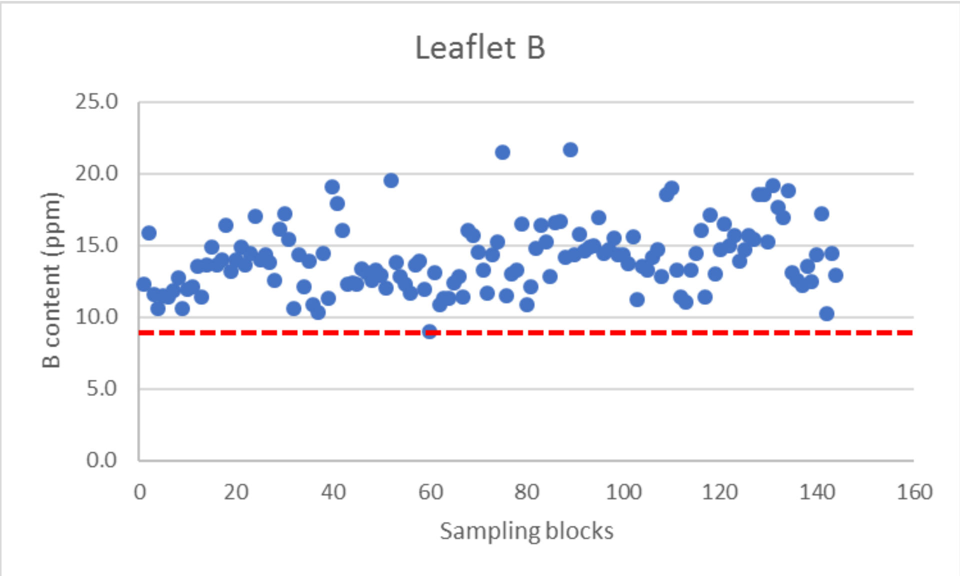


Figure 92. Leaf B concentration for the sampled smallholder blocks in 2019.

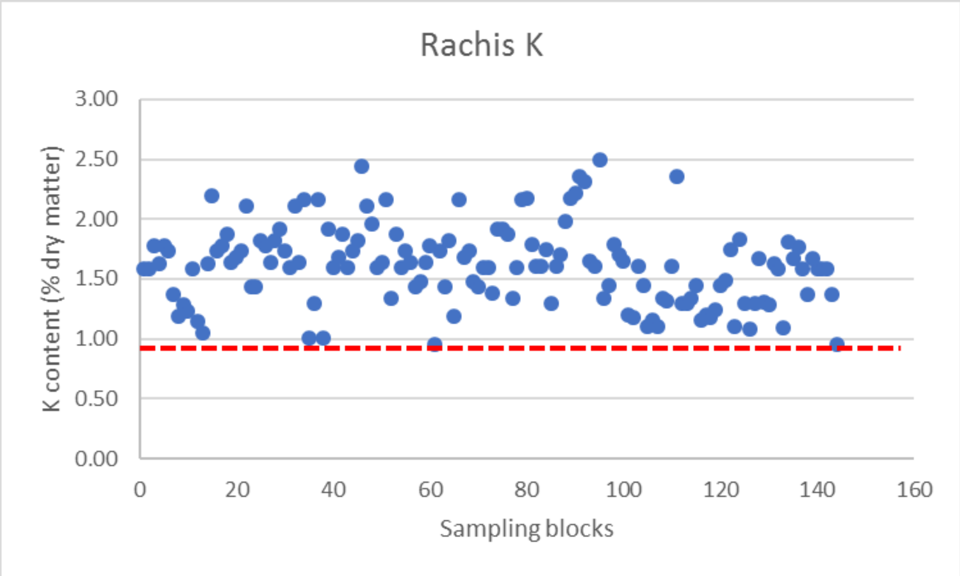
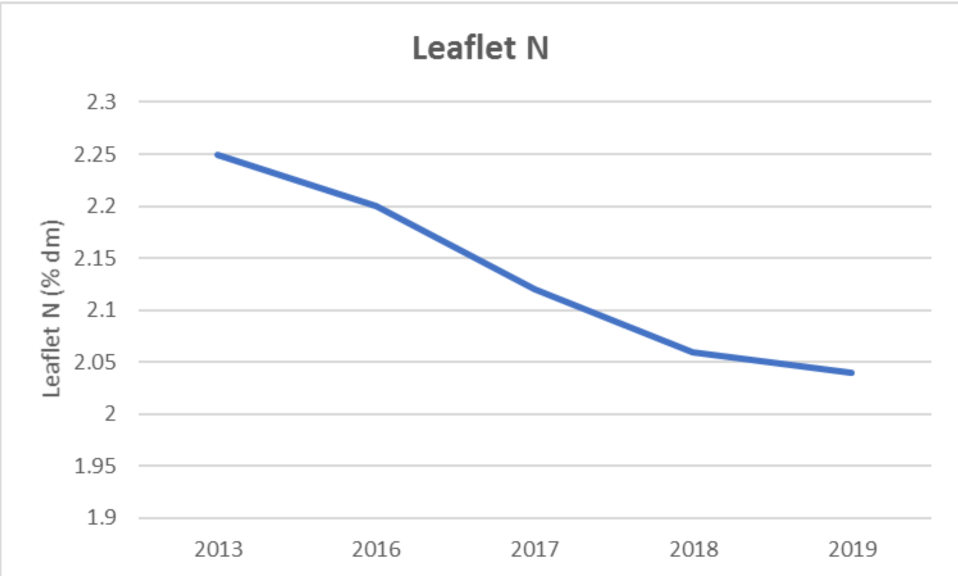


Figure 93. Rachis K concentration for the sampled smallholder blocks in 2019.

The 6-year (2013-2019) trend for the two critical elements, N and K are shown in Figure 9 and Figure 9. Both elements have been declining consistently since 2013. Leaflet N dropped from 2.3% in 2013 to 2.04% in 2019 while leaflet K from 0.84 % in 2013 to 0.44% in 2019. The declining trend was expected for K because K was not recommended for smallholders in Hoskins project. Nitrogen is recommended at 0.69 kg/palm which is equivalent to 1.5 kg of urea per palm. However, more than 50% of the smallholder either do not apply N consistently or apply less than the recommended rate and number of bags due to economic and social pressure on the blocks. On the other hand, plantations are applying higher rates of N than the smallholders and their palms are responding positively so considerations may be given to the smallholder N rates as well.



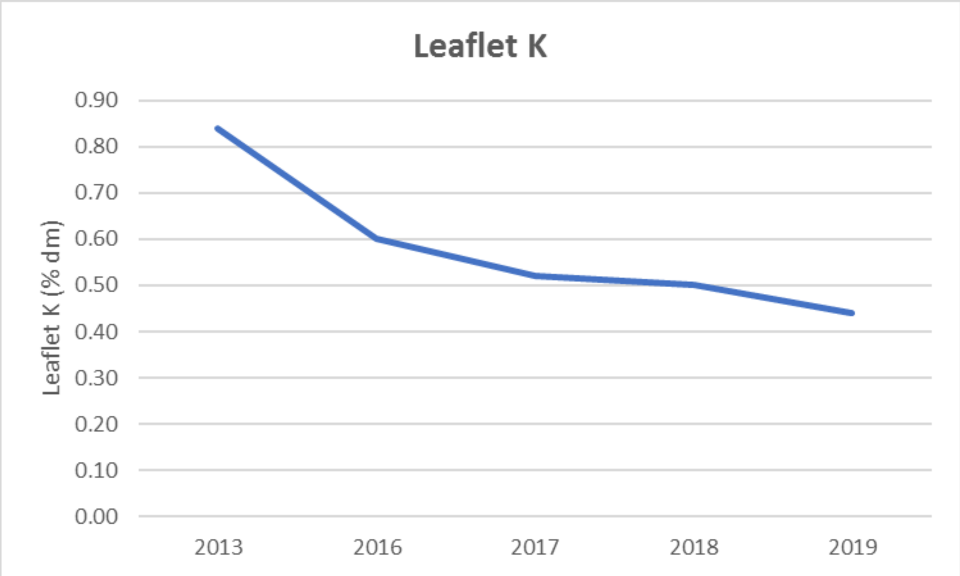


Figure 94. Mean foliar concentrations of N and K from 2013 to 2019.

E.2.1.5. *Conclusion*

Leaflet N, P, K and S were found to be deficient in the oil palm leaflets in 2019. In contrast, leaflet Mg, B, Ca, Cl and rachis K were sufficiently available. Leaflet N and K levels continue to plummet in the last 6 years of sampling. 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. SSR107: Investigation into the Adoption of Oil Palm Best Management Practice (BMP) by Hoskins Smallholders

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

E.2.2.1. *Summary*

The Best management practices of oil palm (BMP) is an agriculture technology/innovation to minimize yield gap hence improving both production and productivity. The study contributed to the oil palm industry to improve the standard of oil palm husbandry practices, general block management and the livelihoods of smallholder growers. It elevates, captures and educate the new line of block managers to come out of their traditional smallholder farming practices and adopt or adapt the current improved farming technologies. BMP demonstration trial blocks were established across the Hoskins project with the aim of demonstrating to growers that oil palm BMP can improve yields. Farmers' trainings were also conducted in these BMP blocks on all the standard practices which included block upkeep, pruning, harvesting standards, fertilizer application, pest and disease surveillance, financial literacy etc... Because of the significant amount of input into this project, we want to investigate the uptake and execution of these practices and ideas by the farmers. Hence the four objectives of this project were; to investigate the adoption of BMP by smallholder growers since its establishment; see if BMP have an impact on block management and livelihood of smallholder households; justify if the adoption of BMP by smallholders contributed to increase FFB production and investigate why BMP is not fully practiced by smallholder households.

E.2.2.2. *Background*

BMP is an agriculture technology/innovation to minimize yield gap hence improving both production and productivity. The study contributed to the oil palm industry to improve the standard of oil palm husbandry practices, general block management and the livelihoods of smallholder growers. It elevates, captures and educate the new line of block managers to come out of their traditional smallholder farming practices and adopt or adapt the current improved farming technologies.

There has been a huge transition of change in technology, its ownership and adoption by smallholders in the Hoskins Project since the first establishment in the late 1960s. The changes overtime was influenced by human, economic, physical, social and natural capitals. Despite the changes in smallholder oil palm technical advice, information, extension messages, and the inputs in-terms of resources invested into smallholder sector etc. overtime, smallholders' oil palm production performance is yet to reach its maximum potential. Therefore, maintaining oil palm plantations/blocks at BMP standard was seen as the way forward.

BMP demonstration trial blocks were established across the Hoskins project at strategic locations with the aim of demonstrating to growers that oil palm BMP can improve yields (seeing is believing concept). Run-down low yielding blocks (<10 t/ha) were identified and rehabilitated via timely application of all BMPs. Farmers' trainings were also conducted in these BMP blocks on all the standard practices which included block upkeep, pruning, harvesting standards, fertilizer application, pest and disease surveillance, harvesting standards and financial literacy etc.

E.2.2.3. *Methodology*

Study sites
The study sites include the Land Settlement Scheme (LSS), Village Oil Palm (VOP) and Customary Rights Purchase (CRP) smallholder areas of Hoskins Project. The smallholder areas and the number of smallholder blocks that were used in the study are presented in Table 97. The study sites were selected based on the number of BMP block demonstrations and trainings that were conducted in these areas since 2017. The interviewees also represented the three different smallholder schemes in the project.

Research technique
The study employed mixed method approach using random and cluster sampling of household and block inspection surveys. The smallholder blocks were selected based on attendance records from BMP focused demonstrations and trainings in the last 3 years (2017-2019). The interviewees were selected from the training attendance registry records. These individuals either attended a BMP block demonstration or training during the 3 years.

E.2.2.4. *Results and Discussions*

BMP Block Demonstrations and Trainings
There are 25 different practices that growers learnt from the BMP block demonstrations and trainings (Table). Fertilizer, Pruning and slashing have the highest percentage (24.8%) of practice combination followed by Fertilizer, Pruning, Slashing and Harvesting (20.08%). However, from the 25-practice or practice combinations, most growers learned something about fertilizer followed by Pruning, slashing and harvesting.

Specific skills learned from BMP block demonstrations and trainings
Apart from the general BMP knowledge and skills acquired by smallholders, there were specific knowledge and skills gained through the block demonstrations and trainings. The most specific skill that smallholders learnt is the boxing method of frond staking with 75%. The others included herbicide application (5%), oil palm income budget and savings (6%) and the economic importance of snakes (3%). However, there is also indication of growers standing the chance of forgetting what they learned from the block demonstrations and trainings (8%) (Figure 10).

Responses to the way BMP block demonstration and trainings were conducted

It was evident from the study that every respondent (100%) indicated that they liked the way the BMP block demonstrations and trainings were conducted (Figure 11). Similarly, smallholders were also satisfied with the topics that were presented and how each topic was demonstrated or explained to them (Figure 12). They indicated that the topics covered everything that they need to know. Moreover, smallholders also gave their own reasons why they like the mode of BMP dissemination and coverage (Table 7 and Figure 13). However, despite majority of smallholder farmers expressing satisfaction over the full coverage of BMP topics, some smallholders still think there are specific knowledge or skills and trainings that they (growers) would like to request to be conducted in separate block demonstrations or trainings (Table 6).

Table 97. Smallholder areas and the number of study blocks

No	Area code	Area	Scheme	Sample blocks
1	001	Kapore	LSS	10
2	006	Galai	LSS	51
3	008	Kaus	LSS	1
4	009	Siki	LSS	46
5	012	Mosa	VOP/CRP	6
6	013	Kwalakessi	VOP	24
7	014	Mai	VOP	1
8	015	Banaule	VOP	11
9	017	Gaungo	VOP/CRP	15
10	020	Gule	VOP	7
11	021	Rikau	VOP	9
12	023	Waisisi	VOP/CRP	28
13	029	Galeoale	VOP	8
14	032	Valoka	VOP	4
15	039	Koimumu	VOP	5
16	042	Gavaiva	VOP	6
17	043	Vavua	VOP	8
18	044	Kololo	VOP	3
19	045	Matavulu	VOP	4
20	046	Rapuri	VOP	4
21	085	Mandopa	CRP	7
Total smallholder study blocks				**258**

Table 98. BMP learned by smallholders during block demonstrations and trainings

BMP Practice learned	Percentage
Fertilizer	3.15
Fertilizer & Pruning	5.12
Fertilizer, Pruning & Slashing	24.80
Fertilizer, Pruning, Slashing & Harvesting	20.08
Fertilizer, Pruning, Slashing, Harvesting & Pest	2.36
Fertilizer, Pruning, Slashing, Harvesting, Pest & Disease	7.87
Fertilizer, Pruning, Slashing, Harvesting, Pest, Disease & Others	5.12
Fertilizer, Pruning, Slashing, Harvesting & Disease	1.57
Fertilizer, Pruning, Slashing, Harvesting, Disease & Others	0.39
Fertilizer, Pruning, Slashing, Harvesting & Others	5.91
Fertilizer, Pruning, Slashing & Pest	5.12
Fertilizer, Pruning, Slashing, Pest & Disease	3.54
Fertilizer, Pruning, Slashing & Disease	1.18
Fertilizer, Pruning, Slashing & Others	3.15
Fertilizer, Pruning, Harvesting, Pest & Disease	0.79
Fertilizer & Slashing	4.33
Fertilizer, Slashing & Harvesting	0.39
Fertilizer, Slashing & Disease	1.18
Fertilizer, Slashing, Disease & Others	0.39
Fertilizer, Slashing & Others	0.39
Fertilizer & Disease	0.39
Fertilizer & Others	1.18
Pruning & Slashing	0.39
Pruning, Slashing & Disease	0.39
Pruning, Slashing & Others	0.79
Total	**100**

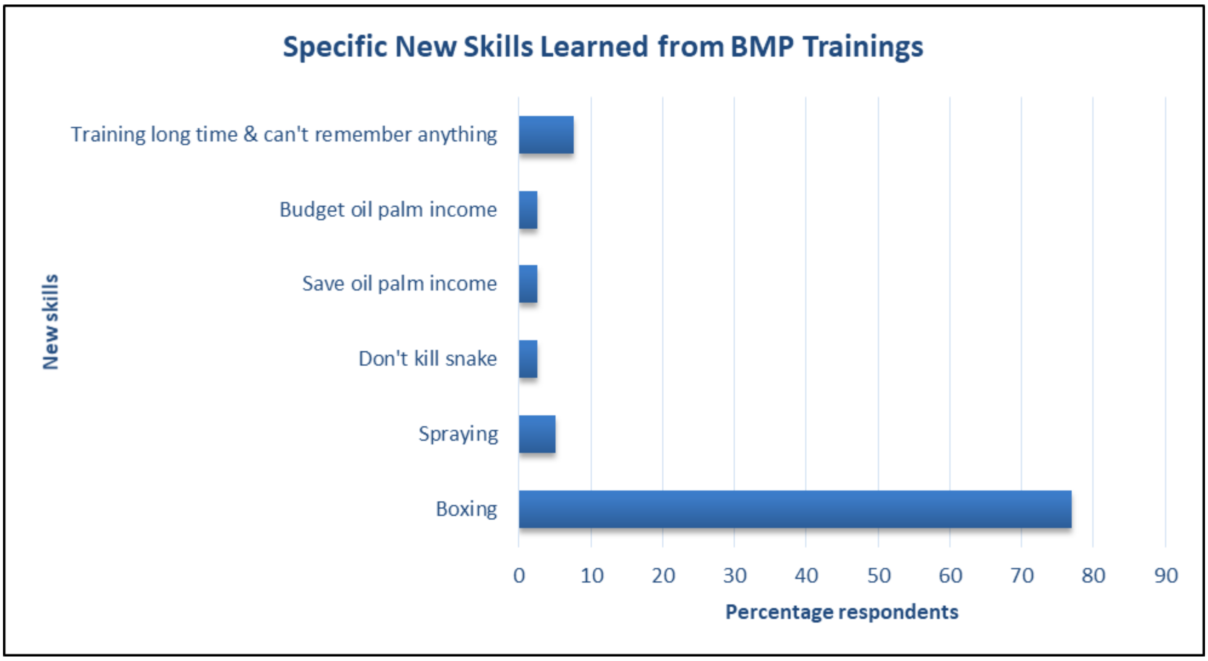


Figure 95. Other specific knowledge and skills sought by smallholders during BMP block demonstrations and trainings.

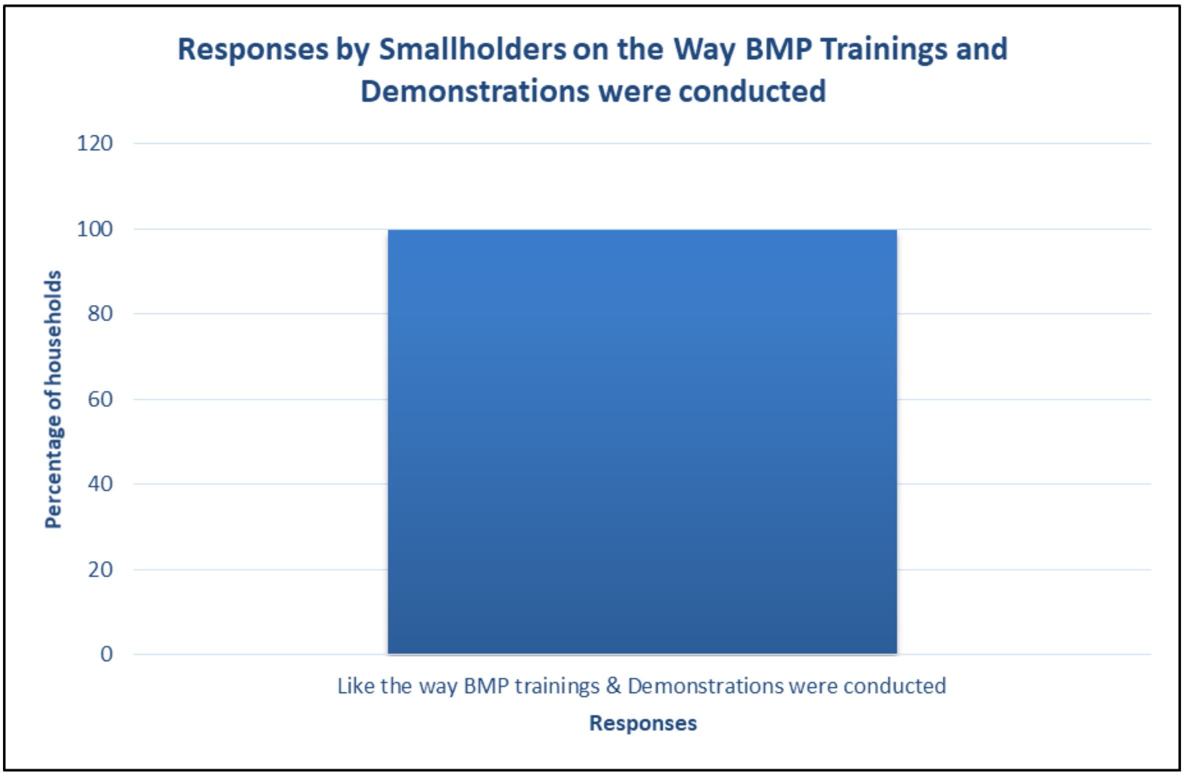


Figure 96. Smallholders' responses to how the BMP block demonstrations and trainings were conducted.

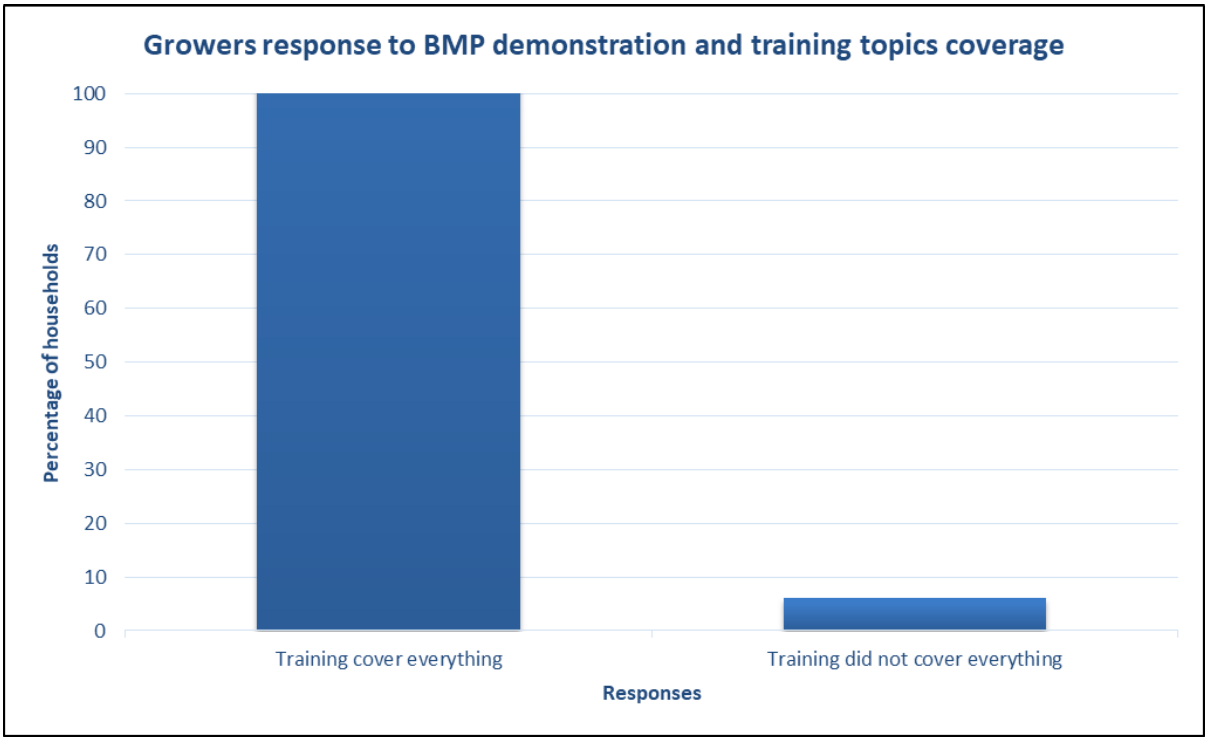


Figure 97. Smallholders' responses to BMP block demonstration and training topics.

Table 99. Other specific trainings requested by smallholder growers apart from BMP

Training coverage	Specific training requested
Training didn't cover everything	How to remove disease palms (e.g. Ganoderma and other palms diseases)
	How to use or apply herbicide to control weeds on block
	They need to actually demonstrate how to apply this practices on block e.g. applying fertilizer, doing boxing
	How to budget oil palm income

The reasons by smallholder's positive reaction towards block demonstrations in Table 7 is presented on the graph in Figure 13 using the codes for the indicated reasons. It is evident that smallholders gave multiple reasons for their positive views on BMP block demonstrations and trainings. Majority of the smallholders (49%) indicated that the training was both clearly explained and easy to understand. A minority of smallholders (7%) emphasized that the training was clearly explained, easy to understand, was on point and conducted at the right timing. Others (6%) indicated that the training was clearly explained, easy to understand, on point, conducted at the right timing and there was enough time for questions and answers. There was also other minor combination of reasons why smallholders are positive about the BMP demonstrations and trainings shown on Figure 13.

Table 100. The reasons for smallholders' positive view on BMP demonstrations and trainings

Code	Reasons
1	Training was easy to understand
2	Training was clearly explained
3	Training was on point/target
4	Training was conducted at right timing
5	Enough time for questions & answers
6	Positive feedback on raised questions
7	Provided take-home materials
8	Others

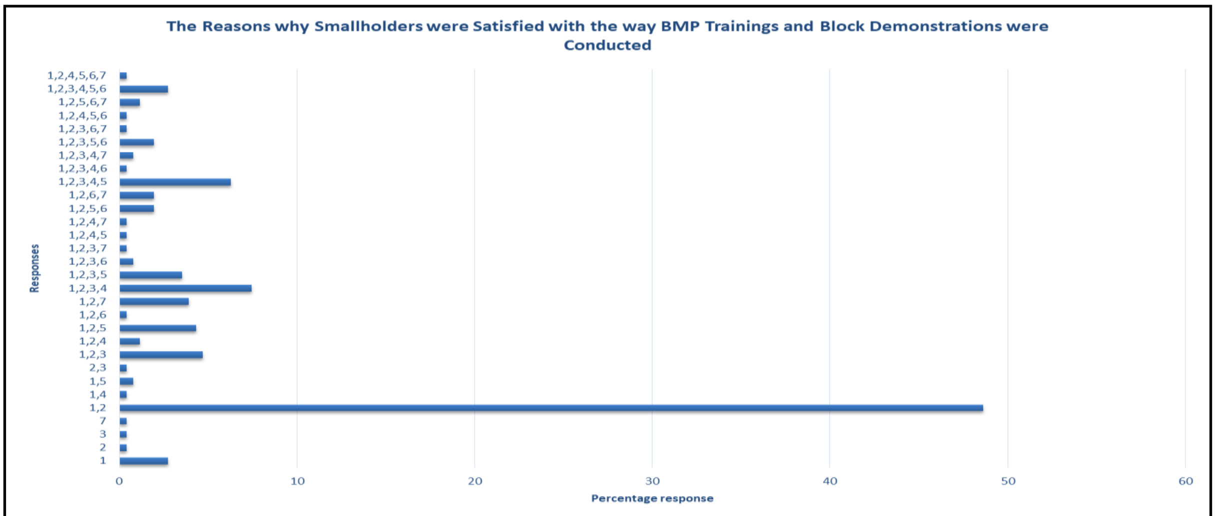


Figure 98. The reasons for smallholders' positive views on BMP block demonstrations and trainings

Information dissemination to household and other family members

From the study, ninety percent of the smallholders indicated that, they managed to disseminate information gathered from the BMP block demonstrations and trainings, to either their household or family members. However, ten percent of smallholder respondents admitted that they did not pass their acquired knowledge and skills (Figure 14). The reasons for not disseminating BMP acquired knowledge and skills by smallholder respondents are diverse and varied as indicated in Table 8. The negative approach to dissemination of information indicated block ownership and management disarray, different harvesting strategies used on the blocks, competition for information among household members and the general tendency of forgetting or translating information into other forms that are easier to grasp among household members on the blocks.

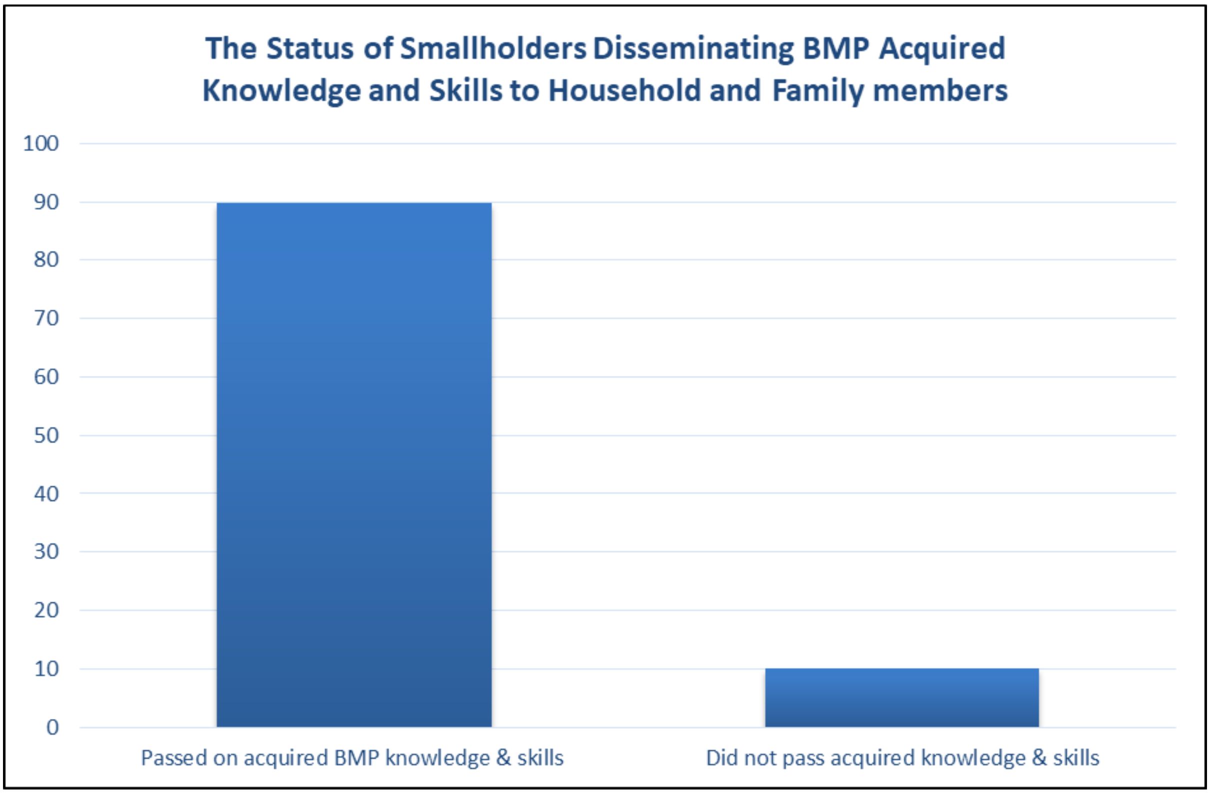


Figure 99. Status of BMP information dissemination by smallholders to their household and family members.

Activities and visits by surrounding and distant smallholders to BMP demonstration blocks

The demonstration blocks were purposely established for research trials and smallholder BMP trainings. These blocks are model blocks that smallholders will practically learn, adopt and apply in their own smallholder blocks. Some blocks are fortunate to be on the vicinity of these BMP blocks whilst others are located away from the BMP blocks. From the study (Figure 15 and Figure 16), generally, it was evident that despite how far or close smallholder location to BMP blocks, they spend less time to observe or pay less visit or attention to activities happening on the BMP blocks. Smallholders even spend less time to engage with OPRA staffs maintaining BMP blocks. However, only a handful of growers living close or far from the BMP blocks are learning something new (38%) and applying these acquired knowledge and skills on their own blocks (24%).

Table 101. Smallholders reasons why they did not disseminate BMP acquired knowledge and skills to other household members on the blocks

	Reasons
Did not pass acquired knowledge and skills	Because she came back from the training she was very busy so she didn't tell anybody.
	Because they are responsible for their own phases (2ha) on block. Therefore each of them should attend the training by themselves
	Because the training was held in our own block, so every family members attended the training
	Because, he though the training is very important that's why he want to keep it secret
	He and other household block members were advised about the training, but the other members did not attend the training. Therefore, he decided not to disclose the knowledge and skills and practice and implement them by himself
	She didn't passes the information because she don't want anybody to implement the BMP
	Because Anton is the manager of the block
	Because the training is very important, so he didn't want to pass the information to other members that did not attend the training
	Because there is no elder/youth in the household who are interested in working on block that she can pass the information to
	she forgot
	Because they don't want to work on the block
	Because he's the only one doing the upkeep work and also harvesting FFB on the block
	There is no need to pass the message to family members because they are not helping out with working in the block
	She want to keep in secret
	All responsible family members that work on block attended the training, therefore, no need to pass information
	Because she the only single mother living and depending on the block.
	Because they don't want to follow her to the training
	Because they don't want to attend training
	Because every person who are living on the block attended the training
	He really forgot
	Because every people on the block attended the training
	Because people who do all the work on block attended the training
	Because they are bigger boys and girls and they know how to manage the block
	Because other family members don't want to help in doing up-keep work in the block

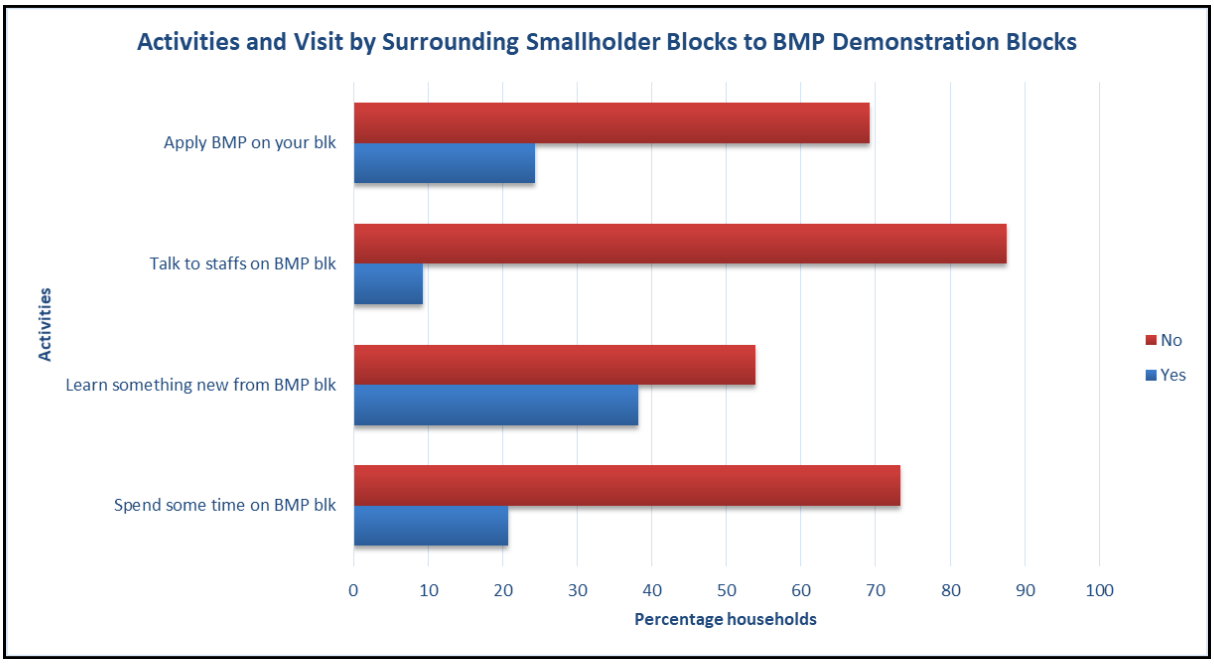


Figure 100. Activities and visits to BMP blocks by surrounding smallholder growers and their households.

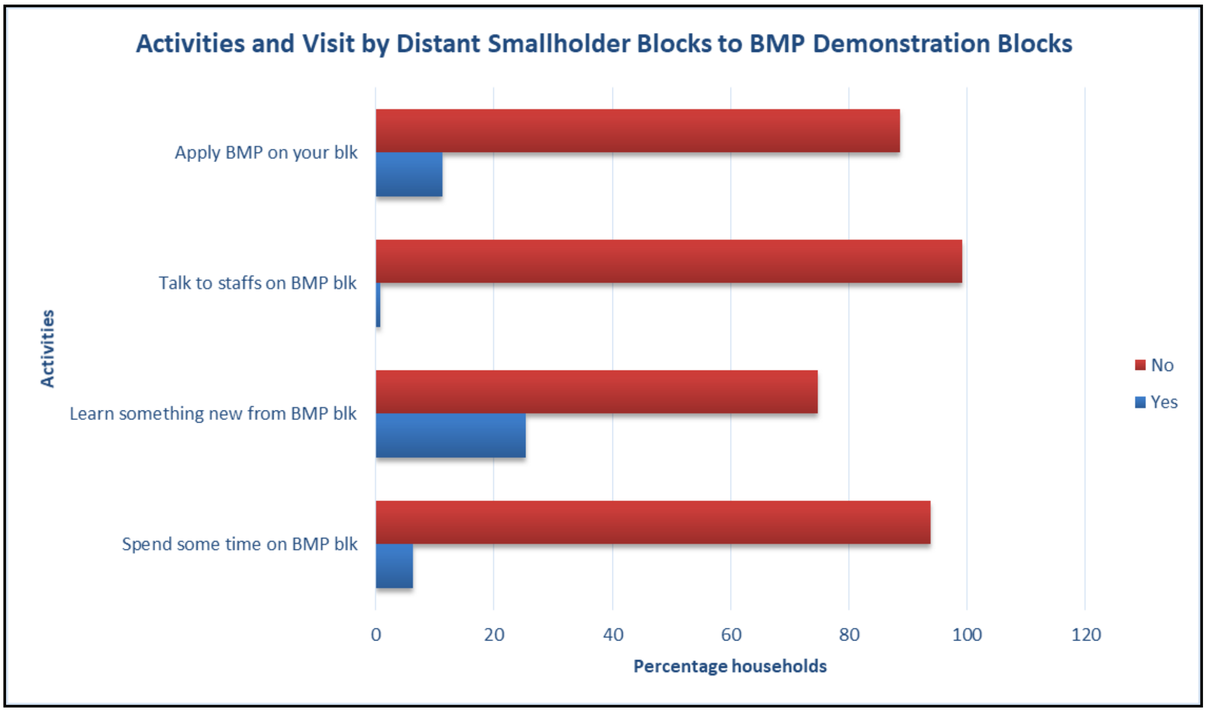


Figure 101. Activities and visits to BMP blocks by distant smallholder growers and their households.

Factors affecting adoption of BMP by smallholder households

Despite the partial implementation of BMP by smallholder households, there is still potential in the ability of smallholder households to adopt and apply BMP standards and practices in their oil palm blocks. The study found out that, from the majority of smallholder households who initially adopted BMP, ninety percent managed to continue to apply BMP standards and practices in their own blocks whilst others (7%) refrain due to multiple social and economic reasons (Figure 17).

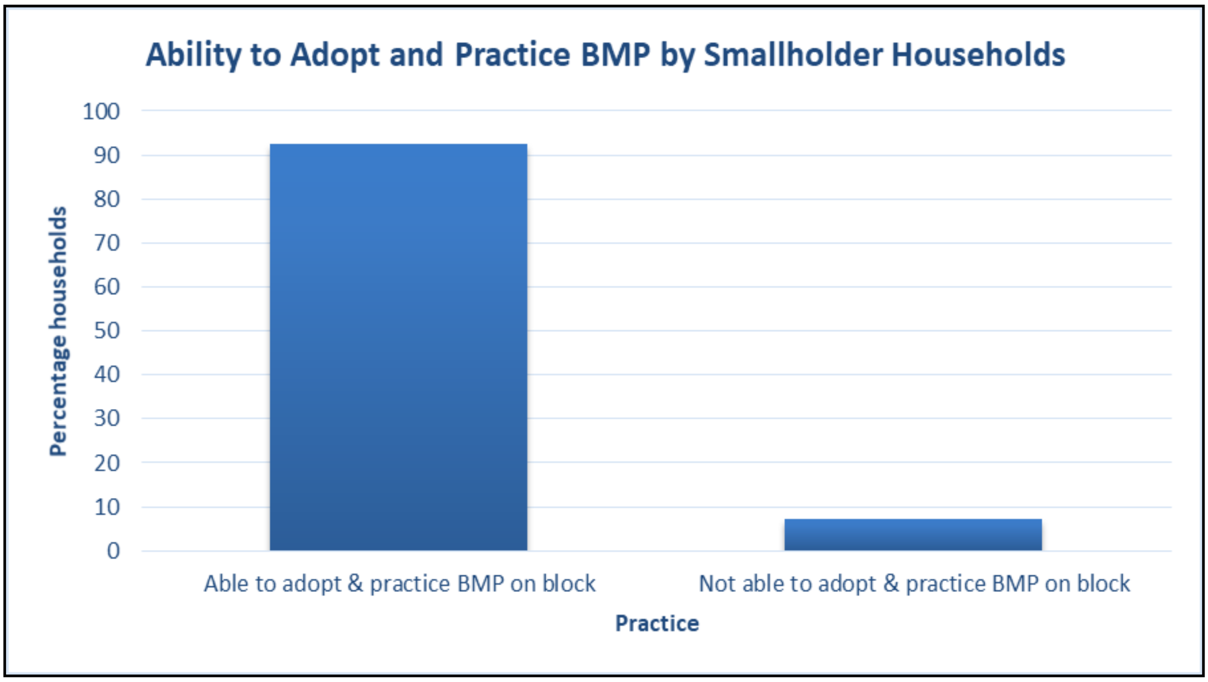


Figure 102. Smallholders' ability to adopt and continue apply BMP on their block

The reasons why smallholder households who initially adopted and are currently applying the concept on their oil palm blocks are shown in Table 9. From the study, 45% of the smallholder growers claimed that their adoption and application of BMP standard practices is a result of the increase in their FFB production and subsequent income that is generated from the FFB sale. Others (15%) expressed that BMP application increase their FFB production, income and their livelihood. There are also other range of reasons why smallholders who adopted BMP continued to apply and maintain its standards on their blocks (Table 9).

Identified strategies to improve BMP on smallholder blocks

From the study, smallholders also gave their views on how they perceive improvements to BMP standards and practices. These strategies vary and are diverse according to smallholders training needs as shown in Figure 18.

BMP standard assessment in smallholder blocks

Apart from the smallholder interviews, the study also did block and field inspections in the smallholder blocks that were in the study. From the block inspections, 32% of the smallholder blocks have proper FFB marketing platform (Figure 19). Some blocks have their block numbers not clearly written (17%), others have both proper market and their block numbers clearly written (16%). The statuses of smallholder FFB platforms and block numbering are shown in Figure 19. In-terms of tool shed presence on smallholder block (Figure 20), it was evident the study that only a handful of smallholder households have a tool shed present on block (23%), whilst the majority don't have a tool shed on block (77%).

The study revealed that in-terms of weeded circle on smallholder blocks, it was evident that majority of the smallholder blocks (51%) have 10%-50% ground cover, followed by some blocks (28%) on more than 50% ground cover and others (21%) on less than 10% ground cover (Figure 21). For legume or cover crop establishment and presence, majority of smallholder blocks (53%) has less than 10% ground cover, followed by 28% for 10%-15% ground cover. A few smallholder blocks (19%) have 10%-50% legume ground cover. For slashing and sanitation, most smallholder blocks (55%) have 10%-15% ground cover. Only a handful (24%) maintained less than 10% ground cover whilst 21% of smallholder blocks maintained more than 50% ground cover (Figure 21).

The field inspection also captured general assessment of weed height in smallholder blocks (Figure 22). Majority of the smallholder blocks inspected (54%) have the height of weeds in their blocks at 1-metre or less. 31% of the smallholder blocks have weed height of 50cm or less in their blocks. Only a handful have a bushy block of 15% weed height at more than 1-metre (Figure 22).

Table 102. The reasons why smallholders who adopted BMP continue to apply it on their blocks.

Reasons	%	Count
Increase crop production	2	4
Others	0	1
Increase crop production & income	45	92
Increase crop production, income & satisfied feeling	7	14
Increase crop production, income, satisfied feeling & pressurized by SHA/OPIC	1	2
Increase crop production, income, satisfied feeling, pressurized by SHA/OPIC & avoid contractors payment	0	1
Increase crop production, income, satisfied feeling, pressurized by SHA/OPIC, avoid contractors payment & improve livelihood	2	5
Increase crop production, income, satisfied feeling & avoid contractors payment	1	2
Increase crop production, income, satisfied feeling, avoid contractors payment & improve livelihood	2	4
Increase crop production, income, satisfied feeling, avoid contractors payment & others	0	1
Increase crop production, income, satisfied feeling & improve livelihood	12	25
Increase crop production, income, satisfied feeling & others	0	1
Increase crop production, income, avoid contractors payment & improve livelihood	2	4
Increase crop production, income, avoid contractors payment & others	0	1
Increase crop production, income & improve livelihood	15	31
Increase crop production, income & others	1	2
Increase crop production & satisfied feeling	0	1
Increase crop production, satisfied feeling & improve livelihood	0	1
Increase crop production & avoid contractors payment	0	1
Increase crop production, avoid contractors payment & others	0	1
Increase crop production & improve livelihood	2	4
Increase crop production, improve livelihood & others	0	1
Increase crop production & others	1	2
Increase income & satisfied feeling	0	1
Increase income & avoid contractors payment	0	1
	100	203

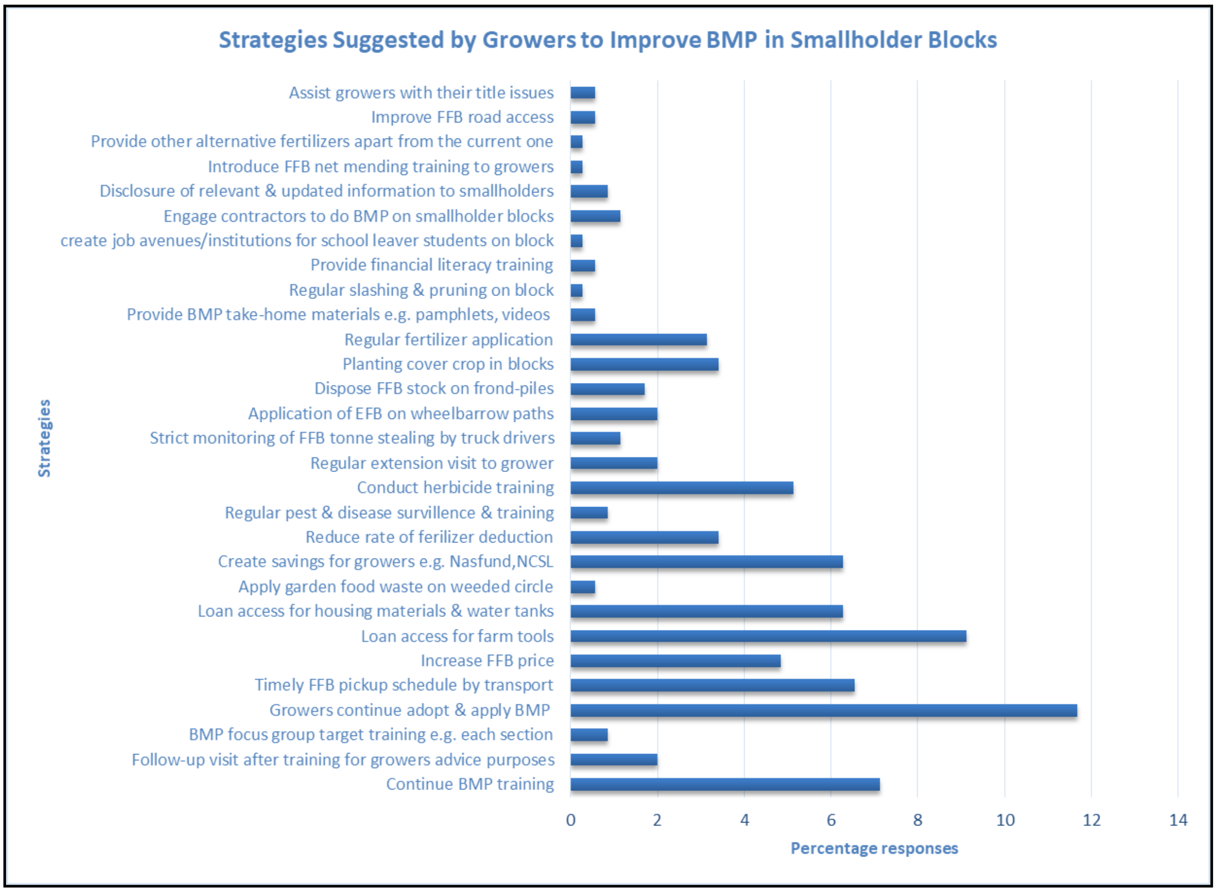


Figure 103. Strategies suggested by smallholders to improve BMP.

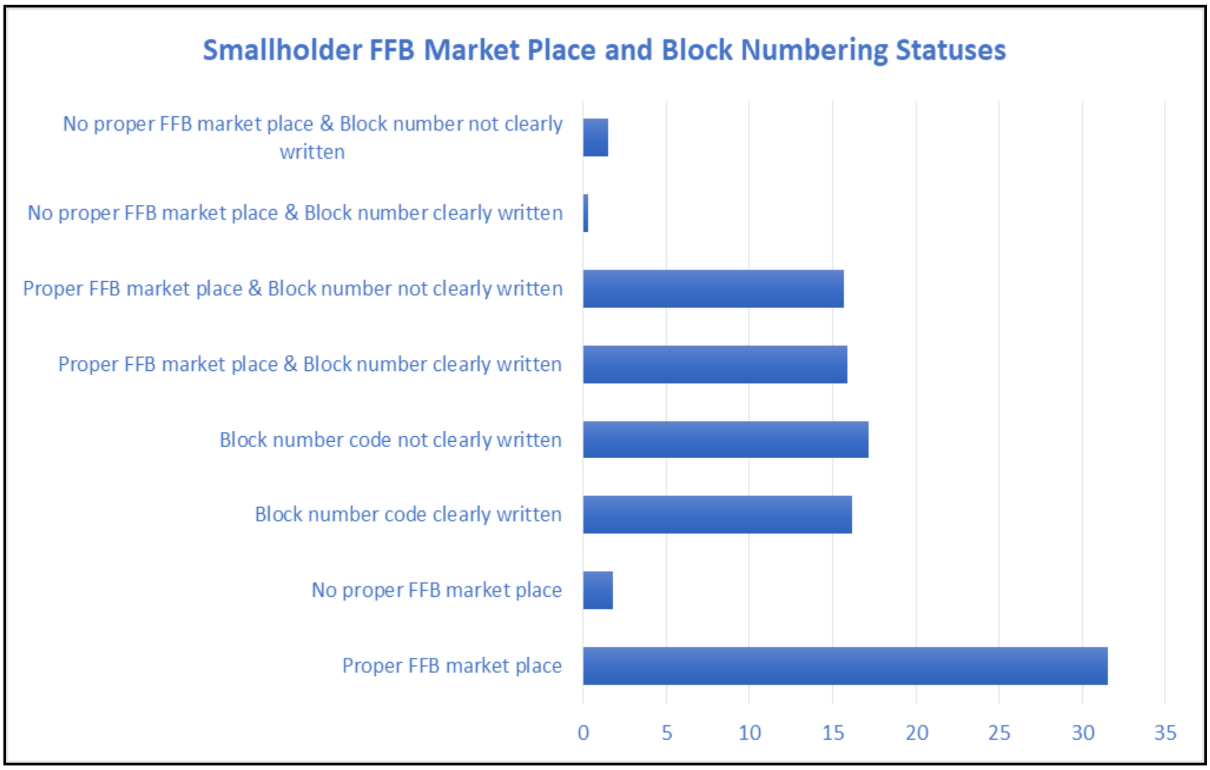


Figure 104. The statuses of smallholder FFB market platform and block numbering.

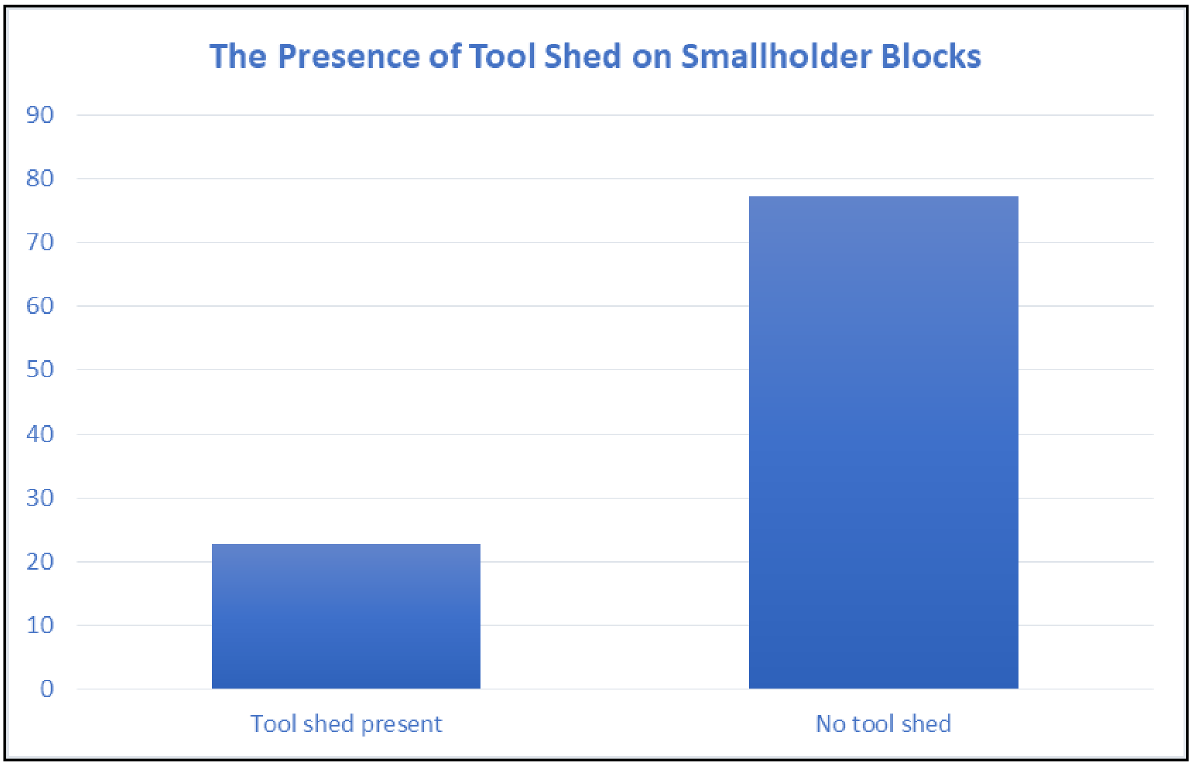


Figure 105. The presence of smallholder tool shed on block.

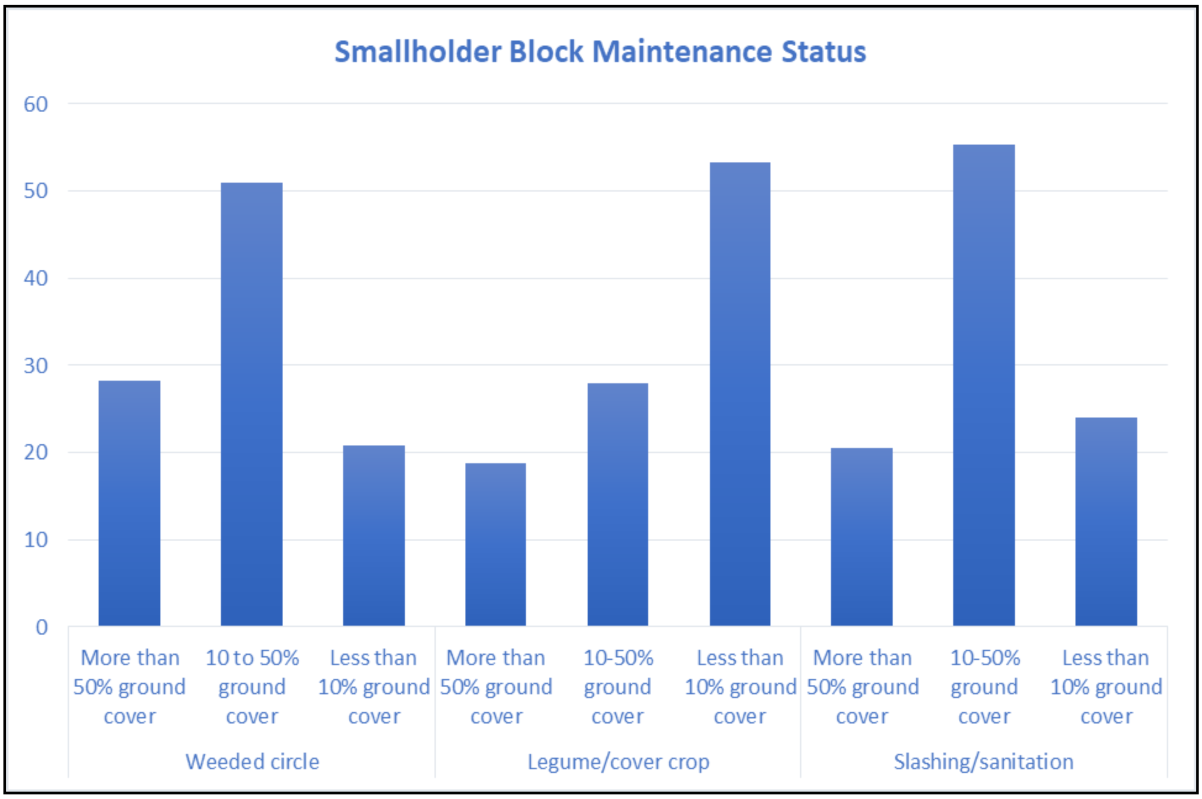


Figure 106. The statuses of block maintenance by smallholder households.

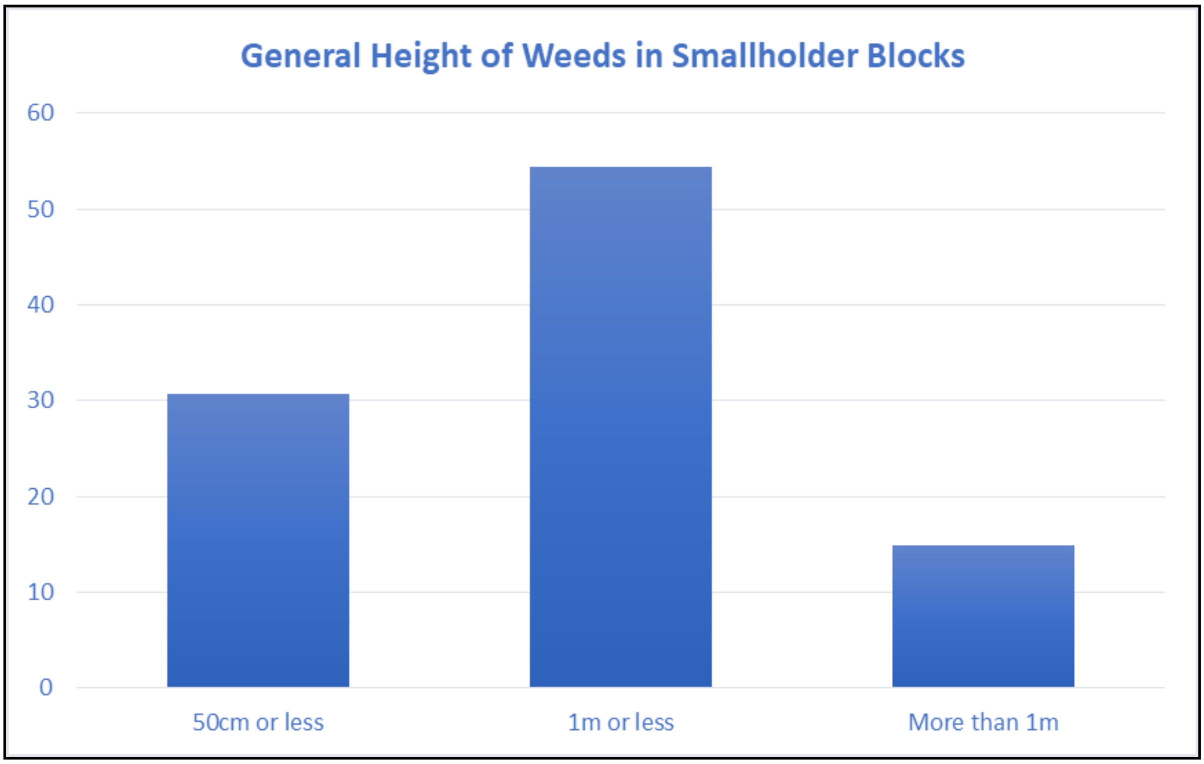


Figure 107. General assessment of weeds height on smallholder blocks.

E.2.2.5 *Conclusion*

The study investigated the adoption and application of the smallholder oil palm best management practices (BMP) by smallholders in the Hoskins project. BMP is a package of improved oil palm farming practices that address agronomic, pest and disease and socioeconomic issues aimed for smallholder farmers. This study evaluated the rate of adoption and application of BMP that were conducted in the form of block demonstrations and trainings. Though huge effort has been invested into the BMP work over the last 3-4 years, it is evident in this study that generally, the rate of initial adoption is above 50%, however, the rate of adoption and continued application is just approaching 50%. Majority of smallholder growers and their household and family members learned a lot of things from the trainings. However, putting these acquired knowledge and skills into practice is a common problem. This is because of no follow up training or visits, too much information to grasp or the negative mind-set of forgetting disseminated information by smallholders.

The study identified several factors both positive and negative that have effects and impacts on the adoption and the continuation of its application by smallholders. Some strategies identified as possible improvement to the BMP model included the reviving of tools loan scheme from the milling company. The study also identified some research gaps that needs further investigation. Some possible further work projects, programs or studies should base on focused audience target training and demonstration and not wide audience trainings on a particular skill or knowledge by relevant stakeholders. Some consultation work with stakeholders on rate of deductions for fertilizers, herbicides, tools and other livelihood developments.

The complete report of the BMP adoption study will be reported in closed report in the coming month.

E.2.3. SSR108: Income and expenditure study for high producing smallholder oil palm growers in Hoskins – West New Britain Province

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

E.2.3.1. *Summary*

A study was carried out in 2019 on 152 LSS blocks in Hoskins Project to determine the growers' income potential, how much they spend in a fortnight and whether they have the access cash to save. The study also focused on other livelihood strategies and living standard on the oil palm blocks. For the purpose of the annual report, the results from only 56 LSS blocks at Siki and Kavui divisions will be presented. The full report based on all the LSS blocks interviewed will be written up in the final project wrap up report.

The income earned from 1 hectare of oil palm in the last fortnight ranged from K100 -K1200 with an average K100.00. The fortnightly expenses ranged fromK76.50 to K34114.70 0 with an average of K231. The three main items/activities the household purchased in a fortnight were food (80%), payment of block labour (23%) and the repayment of debts (19%). After all expenses for groceries, garden food and other leisure items were paid from the oil palm income, the average free cash is K254.The block residents not only depend on oil palm income but have ventured into other income generating sources to meet their household needs. The two common income generating activities apart from oil palm were selling of garden produce (36%) and betelnut (25%). Interestingly prostitution (2%) has contributed to household income.

E.2.3.2. *Background*

The Hoskins Smallholder Land Settlement Scheme (LSS) was developed by British company Harrisons and Crossfield through the colonial administration in 1967. The Hoskins scheme was a success because it surpassed many of its early production and earning goals (Hulme 1984, 253) and provided an impetus to regional growth and development in the province. More than fifty years have passed and the once said success of the scheme must be revaluated at all levels in growth and development. Therefore, this study was initiated to identify the breakeven point or free cash from LSS FFB income. The break-even point is uncommitted cash that is available after smallholder oil palm farmers deduct all committed monetary fund from income earned from their fortnightly FFB sales.

The study was conducted to investigate and determine the average income and expenditure as a benchmark for high producing growers and identify free cash (break-even point).

E.2.3.3. *Methodology*

Quantitative research methods were used involving primary and secondary data. A structured questionnaire was formulated, trialed and household survey were conducted. Hundred and fifty-two (152) LSS blocks were selected for this study with an area planted to oil palm ranging from 2 to 6 hectares were selected from smallholder 2016 palm census and the smallholder production from years 2016, 2017 and 2018. However, the preliminary results for two divisions Kavui and Sikof of the Hoskins project are reported here.

E.2.3.4. *Results and Discussions*

Respondent details

A total of 61 LSS blocks in Hoskins Oil Palm project were interviewed, however 5 were omitted during data checks, from Kavui (36) and Siki (20). The blocks size ranged from 2 to 6 hectares. Majority of the interviewees were from East New Britain (29%) and West New Britain (29%) followed by East Sepik province (25%).

Block ownership

Only 32% of the interviewees were original block owners, an indication that majority of the original owners were deceased (55%). All original owners (100%) regarded themselves as mangers of the blocks while 58% of the interviewees were not original owners but managed the block. Table 10 shows relationship of the non-original owner or the manager to the original owner. In most cases where the original block owners have passed on or not residing on the block, the original owners' son (50%) and daughter (14%) steps in to manage the blocks.

Table 103. Relationship of the person managing the block to original owner.

Manager's relationship to original owner	Percentage (%) of interviewees
Son	50
Brother	0
Son In-law	5
Sister	5
Daughter	14
Niece	5
Uncle	9
Caretaker	5
Grandson	5
Father in-law	5

House of dwelling

Figure 23 shows the house categories on the blocks. The finding revealed that 54% of the blocks had permanent houses and in good condition while 24% were permanent house but old, run down and needed renovation. Apart from the permanent houses, 18% dwelled in semi-permanent houses and 4% were living in traditional houses constructed from bush material. When asked why they could not renovate the old permanent houses, 57% responded that it was too expensive to renovate while 21% mentioned that renovating the house was not an immediate priority. 7% each mentioned they could not renovate due to fear of sorcery/witchcraft, the shared plots of oil palms trees (skelim hecta) reduced production and income which caused difficulty in not renovating their houses while the others were caretakers.

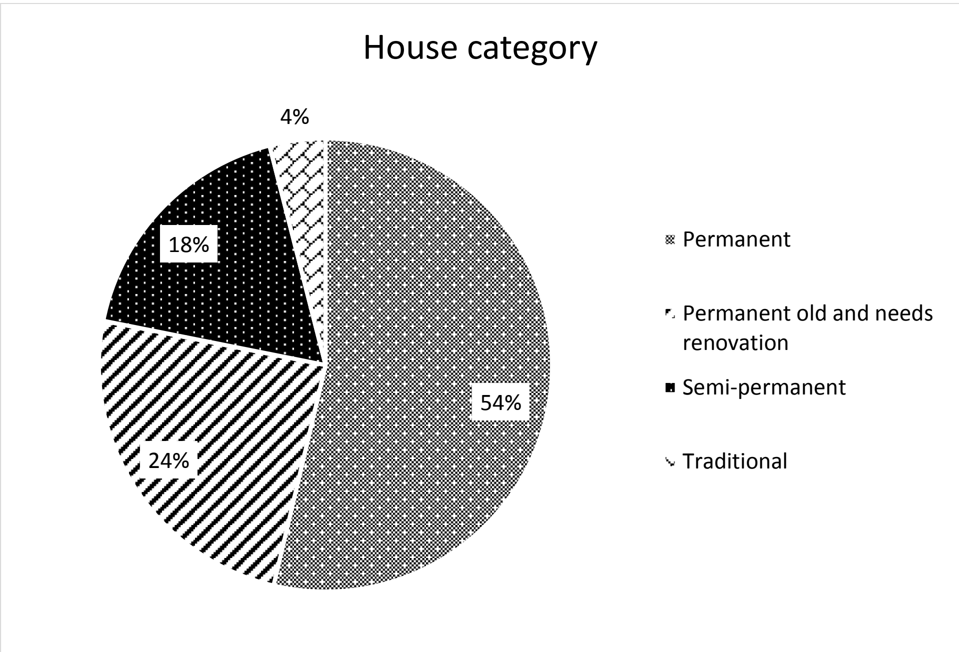


Figure 108. Category of houses on the blocks

Income status of household in the last fortnight

Income from Oil Palm
The blocks (56) interviewed had oil palm ranging from 2 hectares to 6 hectares. Figure 24 shows the income earned from oil palm in the last fortnight ranged from K100.00-K1200 with an average of K100.00/ha. Six blocks (11%) earned below K200/ha, 23% (13 blocks) earned between K200-K300.00/ha, 20% (11 blocks) earned between K300.00-K400.00/ha, 7% (4blocks) earned between K400.00- K500.00/ha while the remaining 22% (40 blocks) earned more than K500.00/ha in Figure 25).

Income for household employment, food gardens and other income generating sources.
The block residents not only depend on oil palm income but other income generating sources to meet their household needs. Only 27% of the blocks had residents with permanent employment who contribute to the household income. A lot of block residents depend of sale of garden produce for additional income hence in this study 36% of the blocks were involved in selling garden produce. Apart from selling of garden produce, 57% of the interviewees also ventured into other income generating sources, in-which they earned an average of K990 as shown in Figure 26 and Figure 27.

The two common income generating activities apart from oil palm were selling of garden produce (36%) and betelnut (25%) followed by selling of store goods/table market (21%), selling of cooked food (20%), selling of ice block (13%) and 11% each for selling of homebrew and poultry. Poultry project though generated highest income but was not very common; only 6 blocks were involved in this business. Interestingly prostitution contributed 2% of the household income (in 1 block). Selling of garden food is still a popular business activity generating on average K1470.00 in a fortnight as well as betelnut sales (K1485.00).

Household expenditure
Figure 28 shows the fortnightly expenses for primary households ranged from K77 to K8177, with an average of K625. Another 32% of the blocks spent less than K200.00, 18% spent between K200.00-K300.00, 20% of the blocks spent between K300.00-K400.00, 5% of the blocks spent between K400.00-K500.00,17% spent between K500.00-K1045.00 and the remaining 9% spent more than K1045with regular income earned from poultry sales, trade store (store goods sales), betelnut sale and interestingly from the sale of drugs and homebrew.

The three main items/activities the growers spend more money on in a fortnight were food (80%), block labour (23%) and the repayment of debts (19%) which was either repaying money lenders or paying for food which were taken on credit during the non-oil palm fortnight week (Figure 29). After all expenses were paid an average of K254.00 remained as free cash.

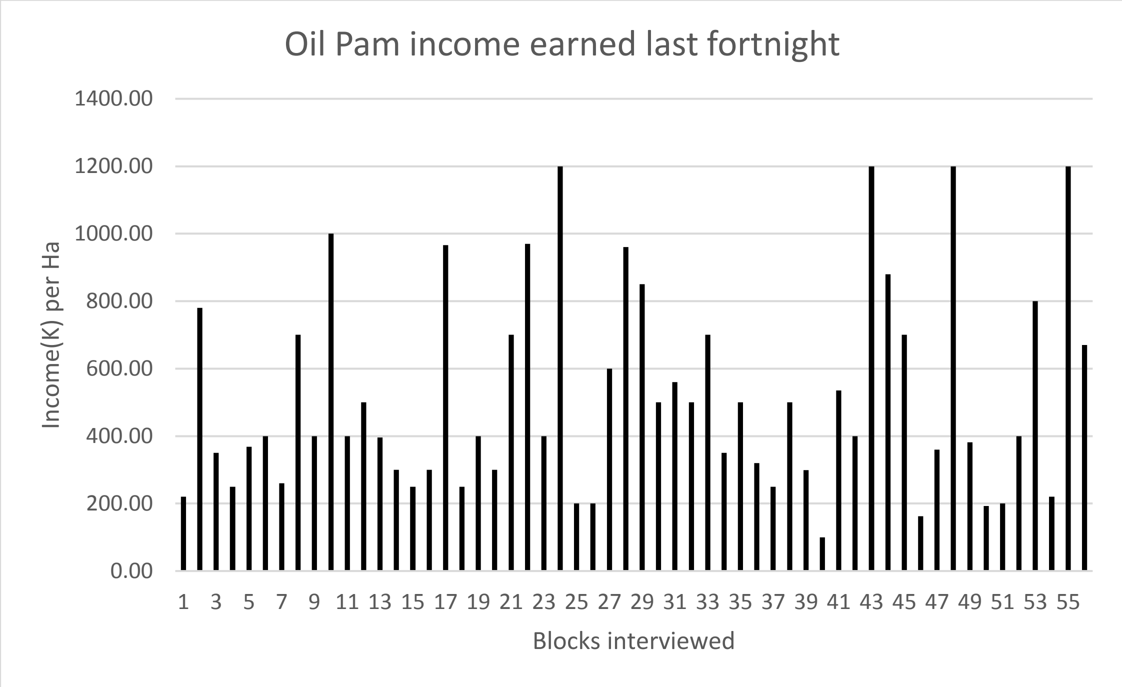


Figure 109. Oil Palm income earned in the last fortnight.

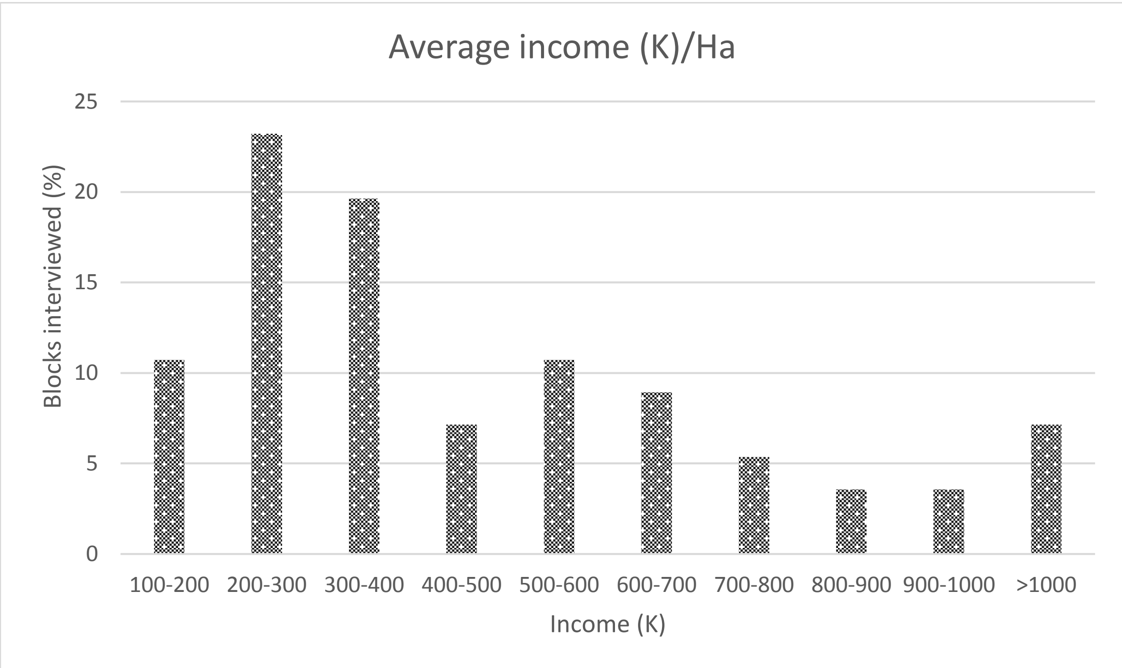


Figure 110. Average income per hectare (K/Ha).

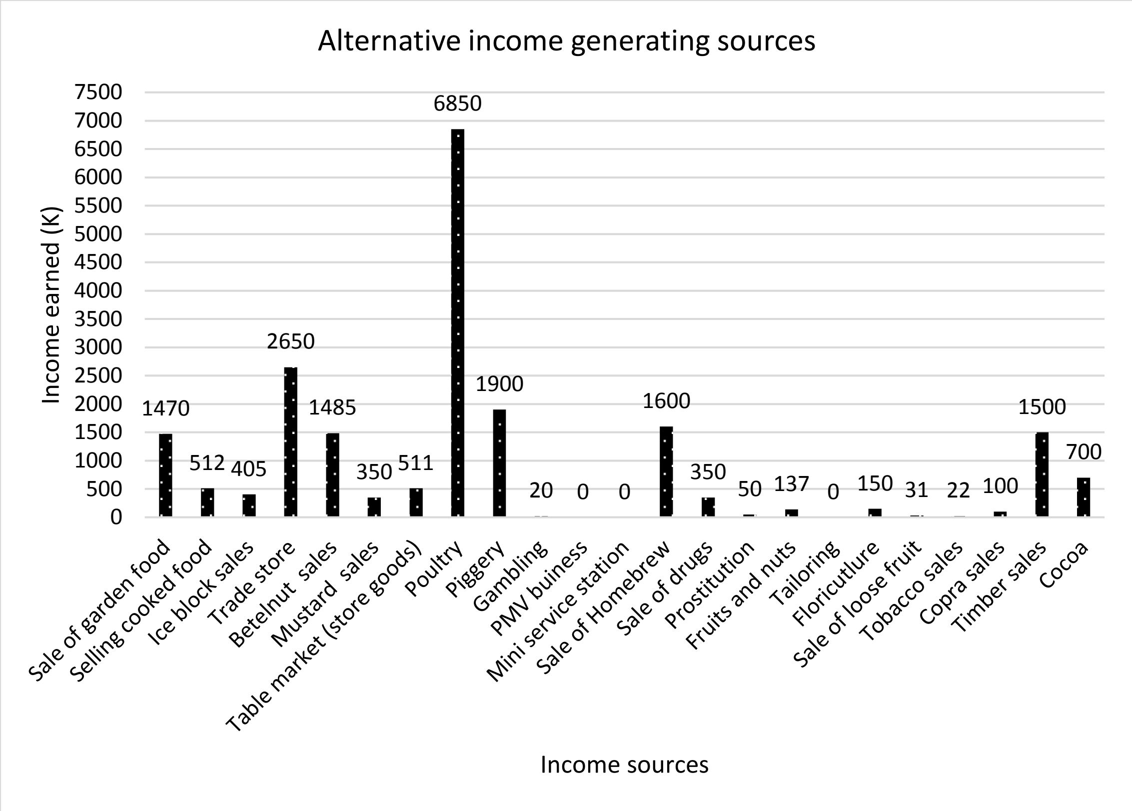


Figure 111. Alternative income generating sources.

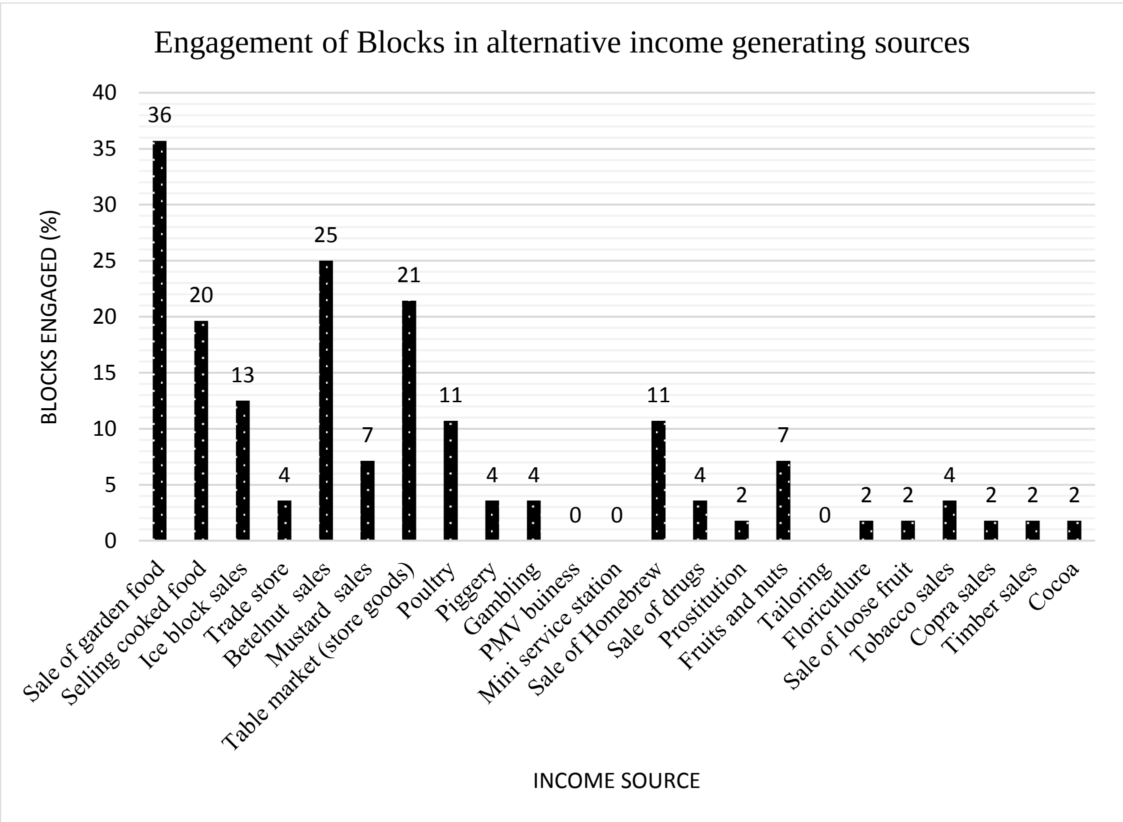


Figure 112. Blocks engaged in alternative income generating sources.

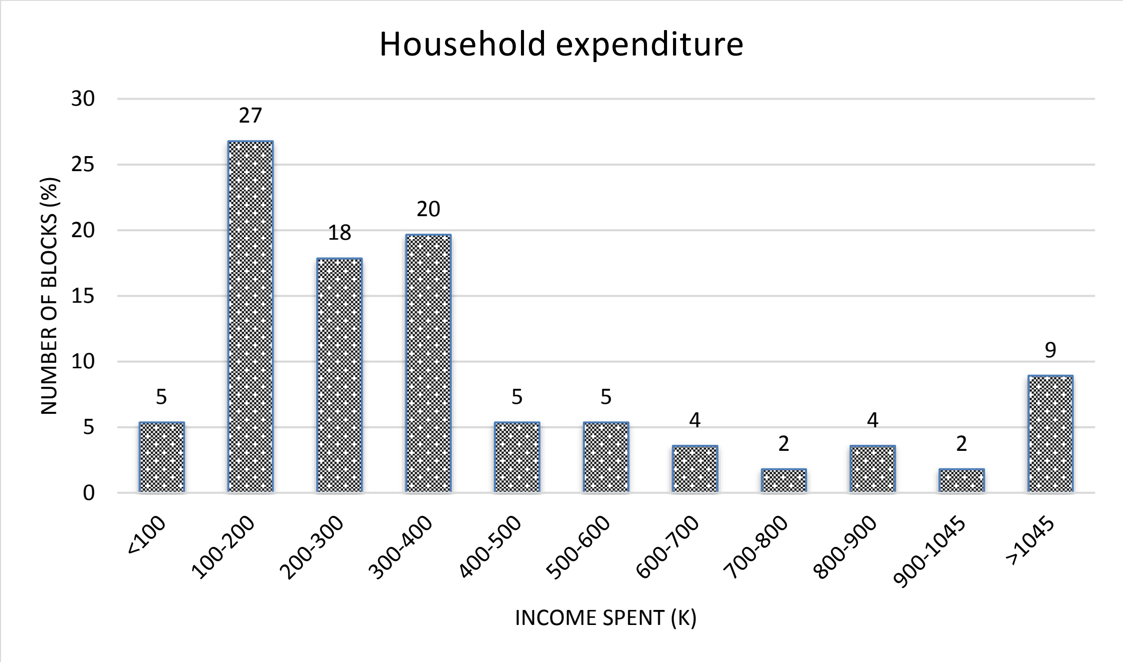


Figure 113. Household expenditure.

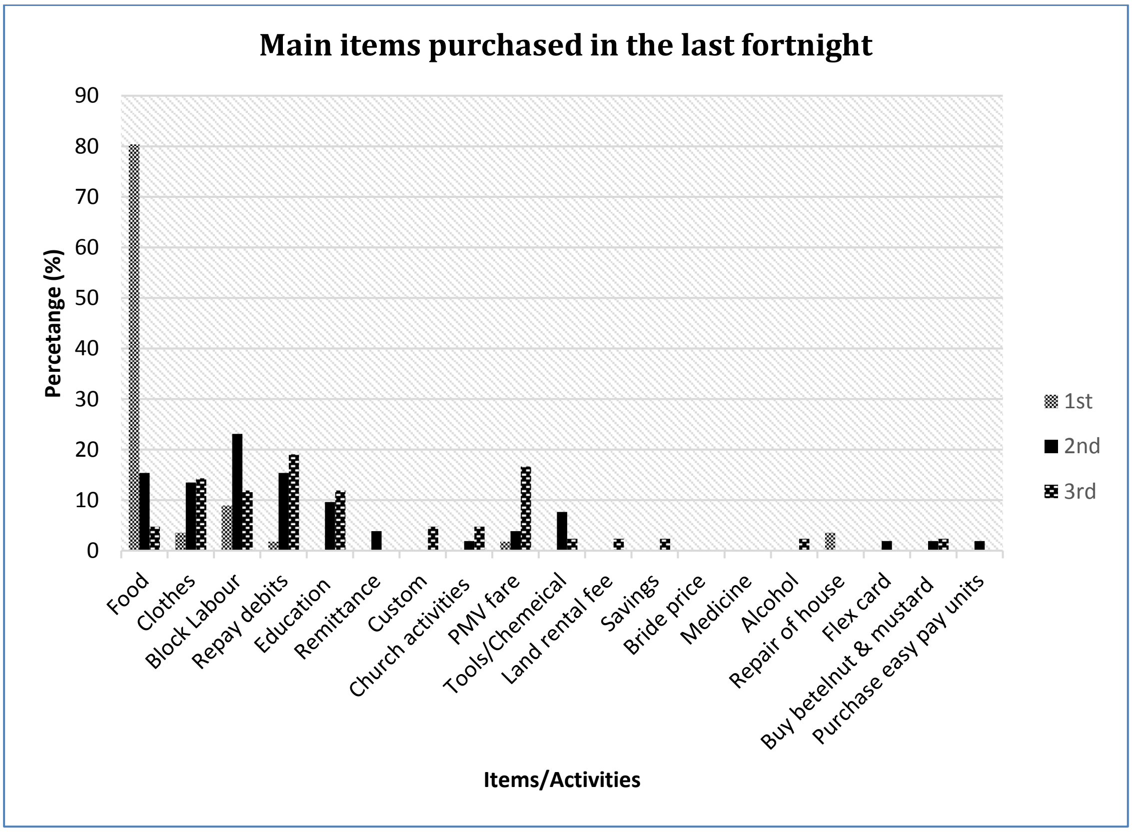


Figure 114. Main items purchased in the last fortnight.

Household savings

More than three quarters (93%) of the interviewees had bank accounts while 7% had no accounts. 84% of the interviewees had only one account, 12% had two accounts while 4% had 3 or more bank accounts. Unfortunately, only 34% indicated that they save money in their accounts.

Table 11 revealed that 29% could not save because the income earned from oil palm was not enough. Twenty percentage (20%) said rotational harvesting and shared plots of oil palm trees (skelim hectare) affected yields resulting in reduced income. Fourteen percent (14%) mentioned the low production affected their income causing them not to save and 11% each mentioned owning only a single bank account limited saving and multiple households residing on the block affected income as the block owner or manager considers everyone's needs. Another 6% saved informally which was considered an easy and quick access to meet urgent needs. 3% of the interviewees said that they did not save due to the illegal activities such gambling, violence experienced on the block. The remaining 6% had multiple factors affecting their ability to save.

Table 104. Factors limiting savings.

Factors limiting saving	Percentage (%)
Oil Palm income was not enough	29
Oil Palm production was not enough	14
More households on the block	11
Multiple households practised rotational	20
Only one account	11
Saved informally -at home it was quick easy access	6
Illegal activities experience on the block	3
More than one reason	6
	100

E.2.3.5. *Conclusion*

From this study income earned from oil palm ranged from K100/ha -K1200/ha with average K100/ha. The block residents not only depend on oil palm income, 57% ventured into other income generating sources to meet their additional household needs in which they earned an average of K990. The two common income generating activities apart from oil palm were selling of garden produce (36%) and betelnut (25%). An average of K231 was spent in the last fortnight. After all expenses were paid an average of K254.00 remained as free cash. However more than 50% could not save because they think the income, they earned from oil palm is not enough to cater for their needs as well as savings for future. Other reasons for not able to save included low yields/income due to sharing of the blocks into smaller portions and low income per capita due to increasing number of block residents.

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 and P were below their respective critical level and were deficient. The mean leaf concentration in 2019 for N and P were 2.13% and 0.129% respectively. In contrast, K, 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 have 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. Since 2013, leaf sampling was undertaken assess the nutrient status for 108 smallholder blocks across the 3 divisions of the project. In 2019, 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 Bialla project.

E.3.1.3. *Methodology*

One hundred and eight (108) smallholder blocks were randomly selected from the 3 divisions (Cenaka, Maututu and Meramera) (Table 12). The selected blocks were within the prime age group at the time of selection. In each block, both leaflet and rachis samples were taken from marked palms. The sampling points (palms) were identified using sampling intensity of 3x3 or 2x2 depending on the size of the block. A 3x3 sampling intensity would mean that every 3rd palm in every 3rd 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 105. Number of leaf sampling blocks per division in 2019.

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 and P for all divisions were deficient while leaflet K was slightly above critical level after being deficient for the last two years. In addition, leaf Mg, B and rachis K were above their critical levels (Table 13). 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 hence adequately available. Interestingly, K which was never applied in the smallholder blocks were at the adequate level.

Figure 30 to Figure 35 depicts foliar nutrient status for the 108 sampled blocks. Leaflet N ranged from 1.76% to 2.55% with a mean of 2.13%. All the blocks (108) were below the critical level of 2.59%.

Leaflet P ranged from 0.113% to 0.148% with a mean of 0.129%. Only 8% (9 blocks) of the sampled blocks had their P levels above the critical mark, whilst the other 92% of the blocks were deficient.

Leaflet K ranged from 0.30% to 0.79% (mean = 0.57%). While 71 blocks (65.0%) had leaflet K above the critical mark (0.54%), the other 37 blocks representing 35% of the sampled blocks were deficient.

For leaflet Mg, 93 blocks (86%) were adequately available. Leaflet Mg ranged from 0.15% to 0.47% with a mean of 0.26%. 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, 93 blocks (86%) were above the critical level. Leaflet B ranged from 8.8 to 36.4 ppm while rachis K ranged from 0.49% to 2.27%.

When comparing 2019 to 2018 foliar nutrient levels (Table 14), leaflet N has declined from 2.16 % to 2.13% while leaflet P and K have improved to 0.129% from 0.124% and 0.56% from 0.46% respectively in 2019.There is an indication of downward trend for leaflet N which is the main driver to palms growth and production.

Table 106. Foliar nutrient concentrations for smallholder blocks in Bialla Project

Divisions	**Leaf N (%)**	**Leaf P (%)**	**Leaf K (%)**	**Leaf Mg (%)**	**Leaf B (ppm)**	**Rachis K (%)**
Cenaka	2.15	0.133	0.57	0.27	12.83	1.34
Maututu	2.15	0.129	0.60	0.24	13.92	1.47
Meramera	2.08	0.125	0.52	0.29	17.80	1.39
Mean	***2.13***	***0.129***	***0.57***	***0.26***	***14.85***	***1.40***
Critical Level (Foster, 2015)	**2.59**	**0.142**	**0.54**	**0.20**	**8.0**	**0.95**

Table 107. Foliar nutrients in 2016, 2017, 2018 and 2019.

Foliar Nutrient	**2016**	**2017**	**2018**	**2019**
Leaflet N	2.15	2.17	2.16	2.13
Leaflet P	0.128	0.132	0.124	0.129
Leaflet K	0.57	0.51	0.48	0.57
Leaflet Mg	0.26	0.21	0.22	0.26

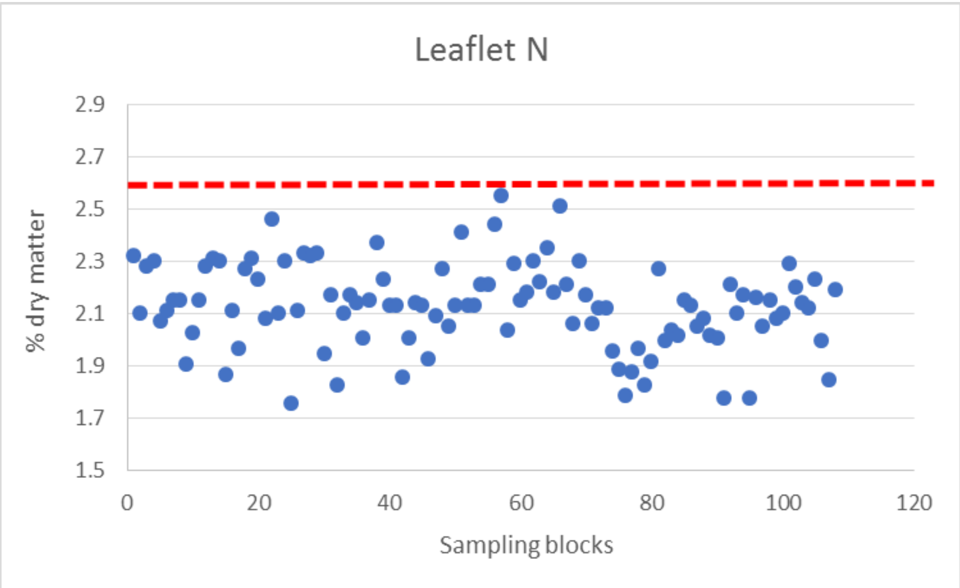


Figure 115. Leaflet N concentration for the sampled smallholder blocks in 2019.

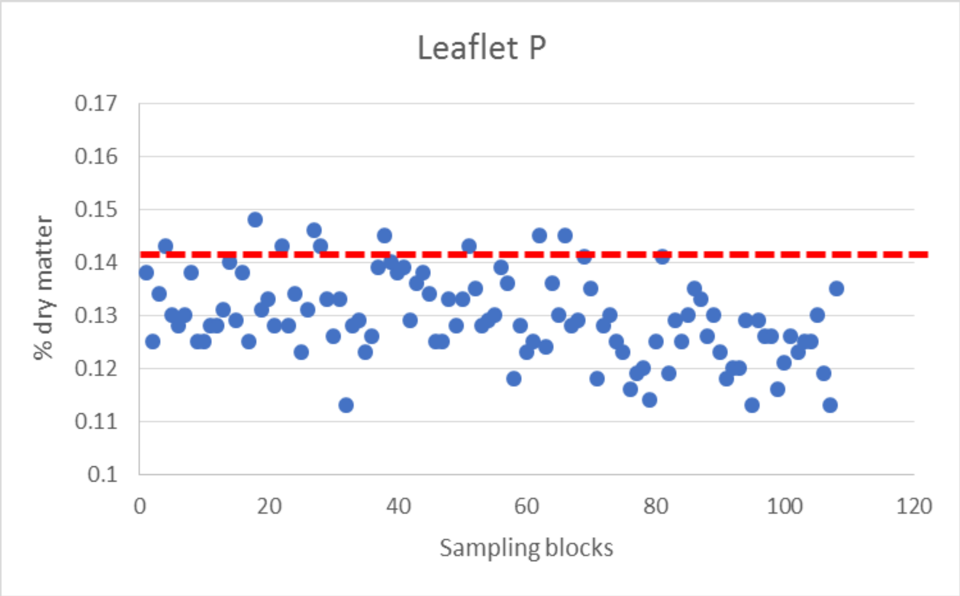


Figure 116. Leaflet P concentration for the sampled smallholder blocks in 2019.

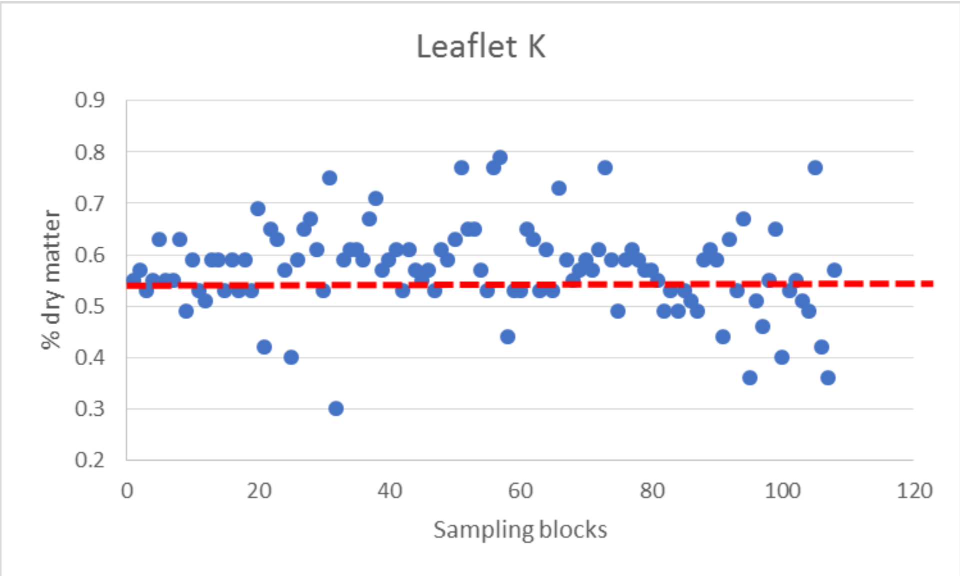


Figure 117. Leaflet K concentration for the sampled smallholder blocks in 2019.

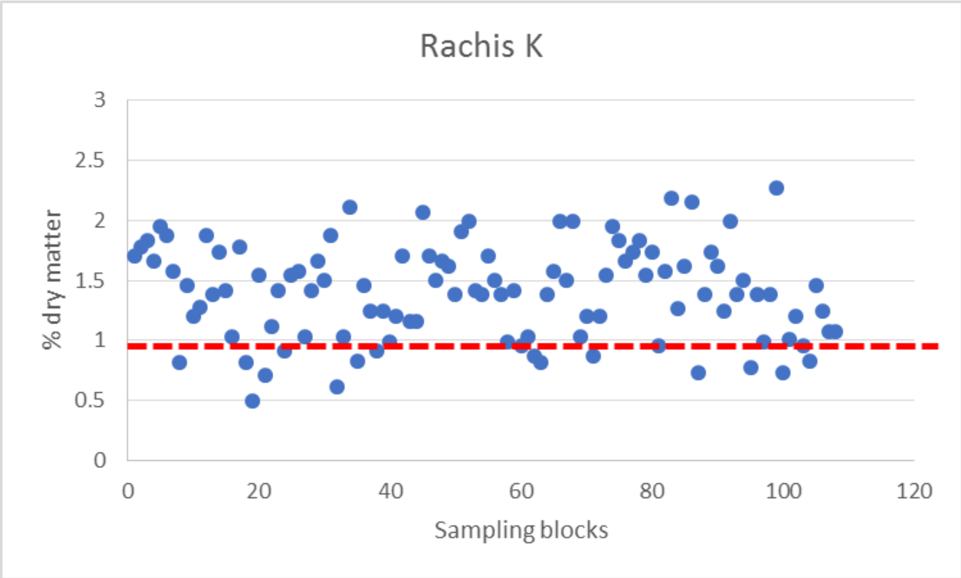


Figure 118. Rachis K concentration for the sampled smallholder blocks in 2019.

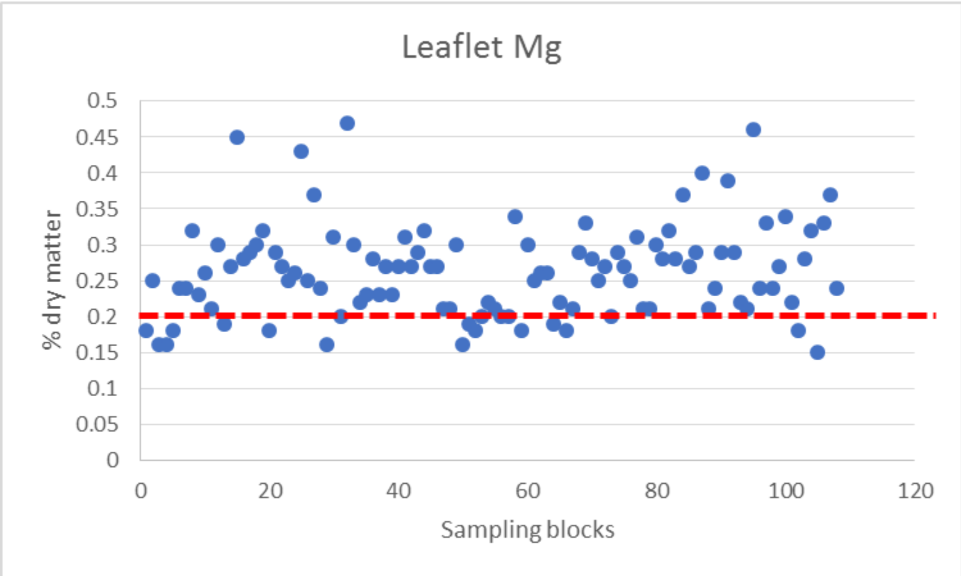


Figure 119. Leaflet Mg concentration for the sampled smallholder blocks in 2019.

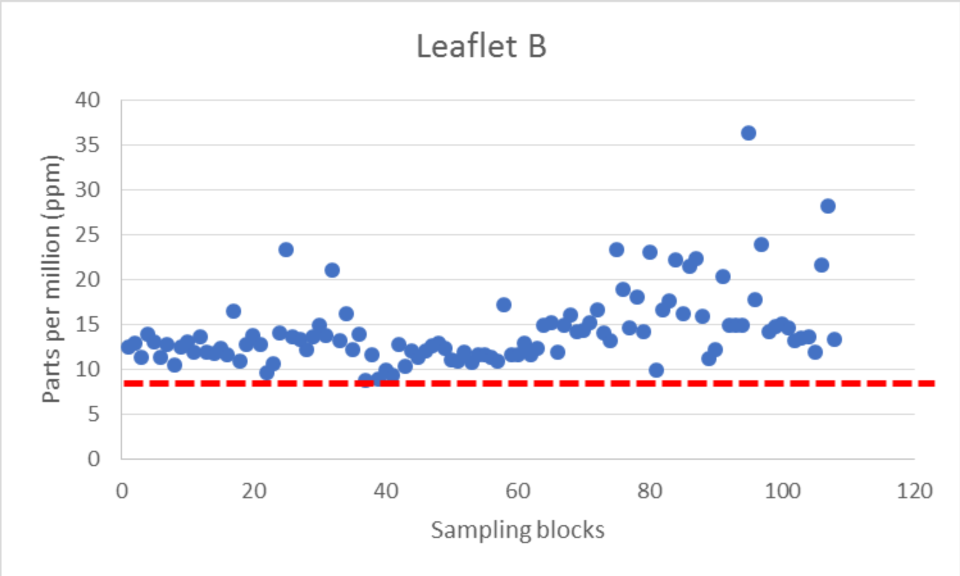


Figure 120. Leaflet B concentration for the sampled smallholder blocks in 2019.

E.3.1.5. *Conclusion*

There was a declining trend in foliar nutrient level in N while P, and K have shown slight improvements. Despite of the improvement, P and K continue to show deficiency on the oil palm leaflets while leaflet Mg, B and rachis K adequately available. Leaf sampling will continue in 2020 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 2 smallholder blocks with the aim of improving yields. The FFB production from the 2 BMP blocks in 2019 were 21.9 t/ha and 24.2 t/ha (average ~ 23.1 t/ha). This result demonstrates the significance of implementing BMP and potential of smallholder blocks to produce on New Ireland soil.

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 1. 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 108. List of BMP blocks established in New Ireland

No	Block	Trial code	Area	Scheme	Division	Year of initiation	Status
1	**S2818**	**SSR301a**	**Lakarol**	**VOP**	**North**	**2015**	**Current**
2	**S2606**	SSR301a	**Lakurumau**	VOP	**North**	**2016**	**Current**
3	**S2655**	SSR301a	**Lakurumau**	VOP	**North**	2009	Closed
4	**S1618**	SSR301b	**Bura**	VOP	**South**	2010	Closed
5	**S4518**	SSR301c	**Pangefua**	VOP	**West**	2012	Closed
6	**S1943**	SSR301b	**Luapul**	VOP	**South**	2014	Closed Dec 2018

E.4.2.4. *Results and Discussion*

The yields for the current 2 BMP blocks are shown in Table 8. Block S2818 experienced 4 t/ha decline in yield in 2019, however its yields were still maintained above 20 t/ha mark (24.2 t/ha). Block S1943 increased its yield significantly by 10 t/ha in 2019 from 10.1 t/ha to 21.9 t/ha. The monthly production also for both blocks ranged from 1.12 t/ha/month to 3.66 t/ha in 2020 (Figure 10). The high yield achieved by both blocks demonstrate the yield potential of oil palm in the New Ireland soils smallholder oil palm blocks are well managed with frequent harvesting.

Table 109. Annual Production (t/ha) for BMP blocks in New Ireland from 2013 to 2019.

	Yields (t/ha)						
Block	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
S2818			11.8	13.0	15.5	28.0	24.2
S2606					15.4	10.1	21.9

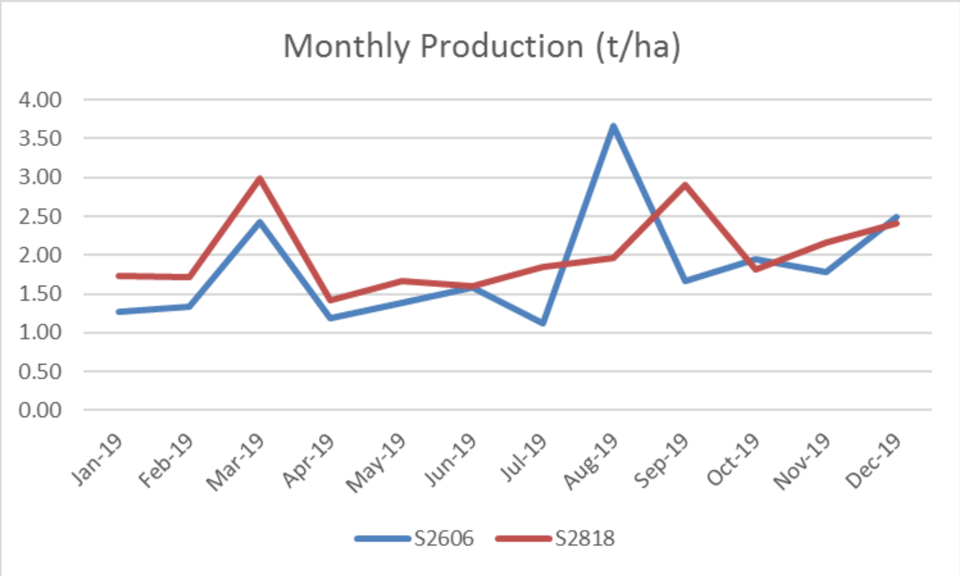


Figure 121. Monthly production trend for Blocks S2606 and S2818 in 2019.

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 (2.23%), leaflet P (0.137%), leaflet K (0.30%) and rachis K (0.40%). In contrast leaflet Mg and B levels were reasonably adequate.

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 have 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. In each block, both leaflet and rachis samples were taken from marked palms. The sampling points (palms) were identified using sampling intensity of 3x3 or 2x2 depending on the size of the block. A 3x3 sampling intensity would mean that every 3rd palm in every 3rd row is sampled. Apart from leaf sampling, leaf measurements were also taken from frond 17.

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

Table 110. Number of leaf sampling blocks per division in 2019.

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 (project mean 2.23%). Leaflet P is also low (project mean = 0.137). Leaflet K continued to be limiting in all 3 divisions with levels far below the adequate level. Rachis K was low in East Coast (North and South divisions) but high in the West coast (West Division). Leaflet Mg and B were high in all divisions.

The individual block nutrient levels are shown in Figure 37 to Figure 42. For leaflet N, only 4% (2 blocks) were above the critical level (2.71%), the rest were deficient. The leaf N levels ranged from 1.76% to 3.05%, with a mean of 2.23%. Leaf P ranged from 0.102% to 0.176%, with a mean of 0.137%with 36 % of the blocks (17 blocks) within the adequate range, while 64% (30 blocks) were deficient. All blocks (100%) were K deficient with a declining trend since 2016. Similarly, rachis K was critically low in 98% of the blocks. Leaflet K ranged from 0.15% to 0.55% (mean = 0.30%), while rachis K ranged from 0.23% to 1.58% (mean = 0.40%). Leaflet Mg and B was adequate in all blocks except one block that was Mg deficient.

The mean nutrient concentrations obtained from 2016, 2017, 2018 and 2019 sampling are summarized in Table 19. Leaf N and K have plummeted steadily since 2017. Other nutrients have be fluctuating but in a declining trend as well.

Table 111. Summary of leaflet and rachis nutrient concentrations in 2019.

Division	Leaf N%	Leaf P%	Leaf K%	Leaf Mg%	Leaf B ppm	Rachis K%
North	2.13	0.133	0.28	0.37	14.9	0.37
South	2.24	0.137	0.28	0.39	16.6	0.36
West	2.36	0.140	0.46	0.26	9.6	1.58
Project Mean	***2.23***	***0.137***	***0.30***	***0.38***	***15.9***	***0.40***
Critical level (Foster, 2015)	**2.71**	**0.142**	**0.70**	**0.20**	**8.0**	**1.23**

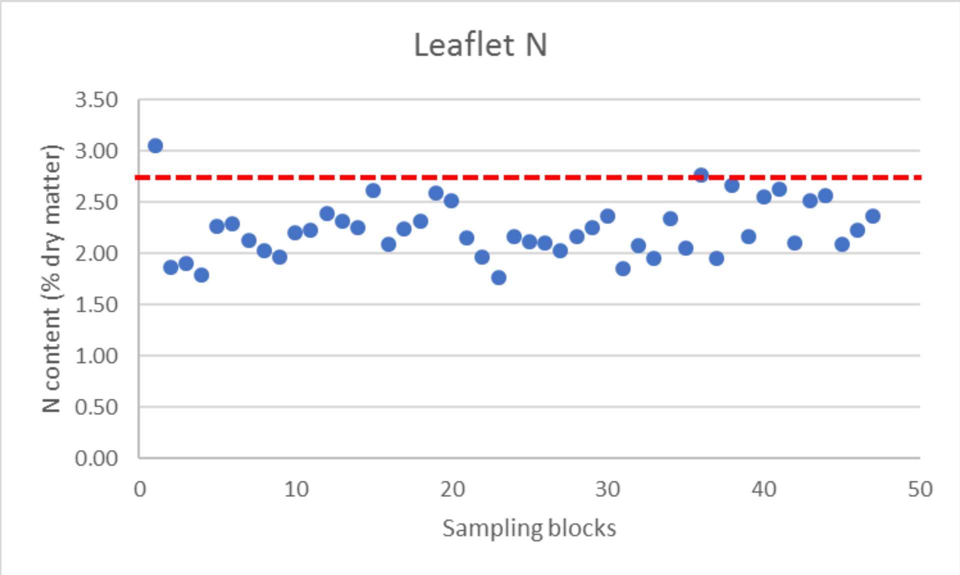


Figure 122. Leaflet N for all sampled blocks in 2019.

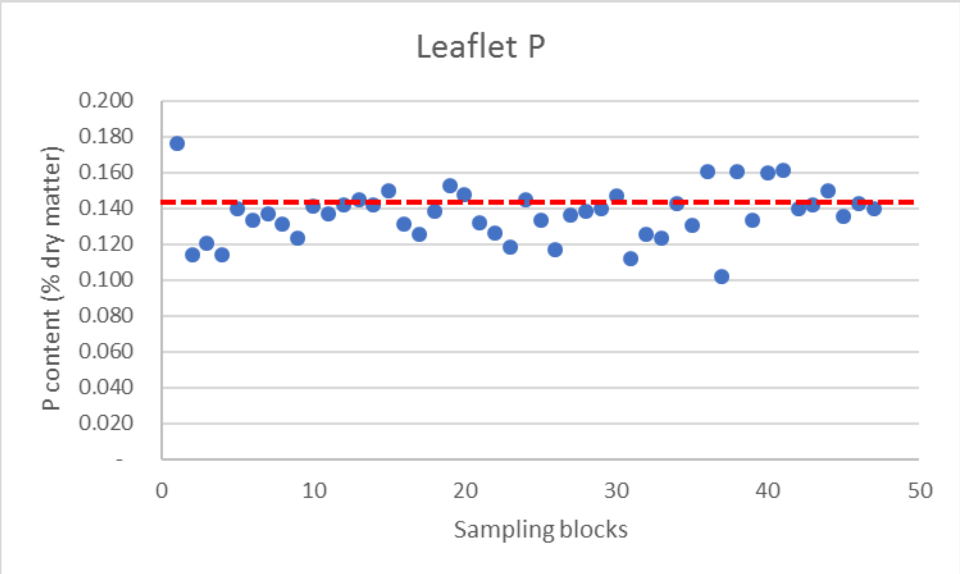


Figure 123. Leaflet P for all sampled blocks in 2019.

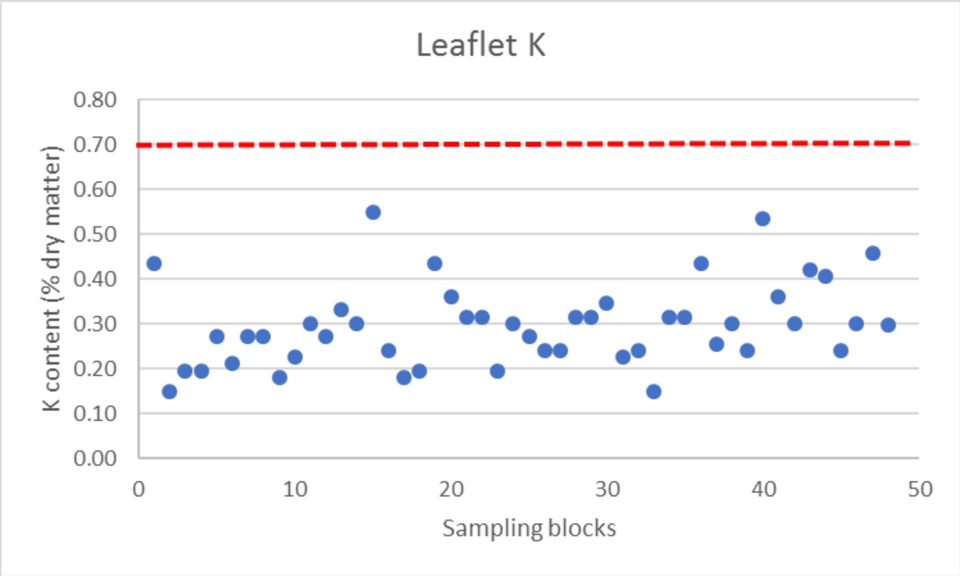


Figure 124. Leaflet K for all sampled blocks in 2019.

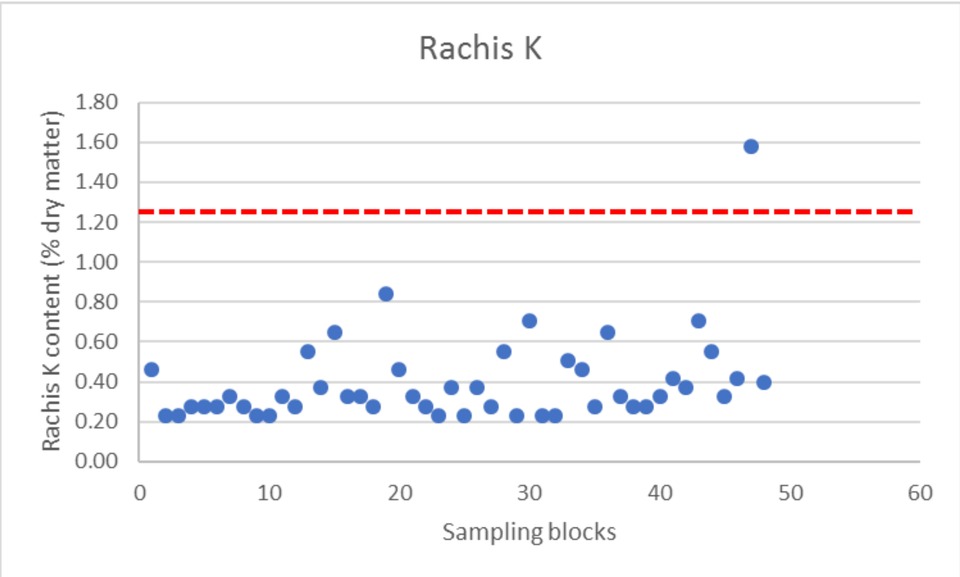


Figure 125. Rachis K for all sampled blocks in 2019.

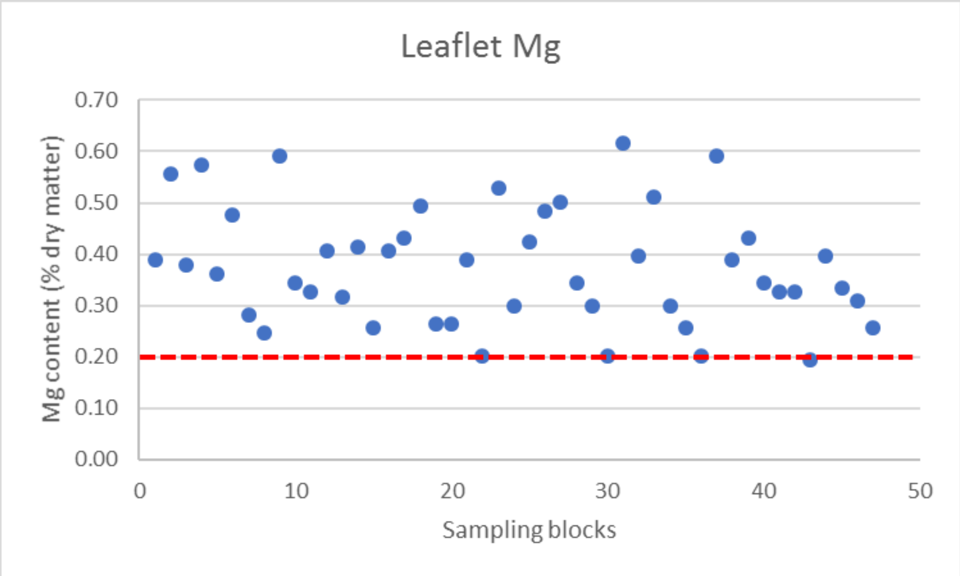


Figure 126. Leaflet Mg for all sampled blocks in 2019.

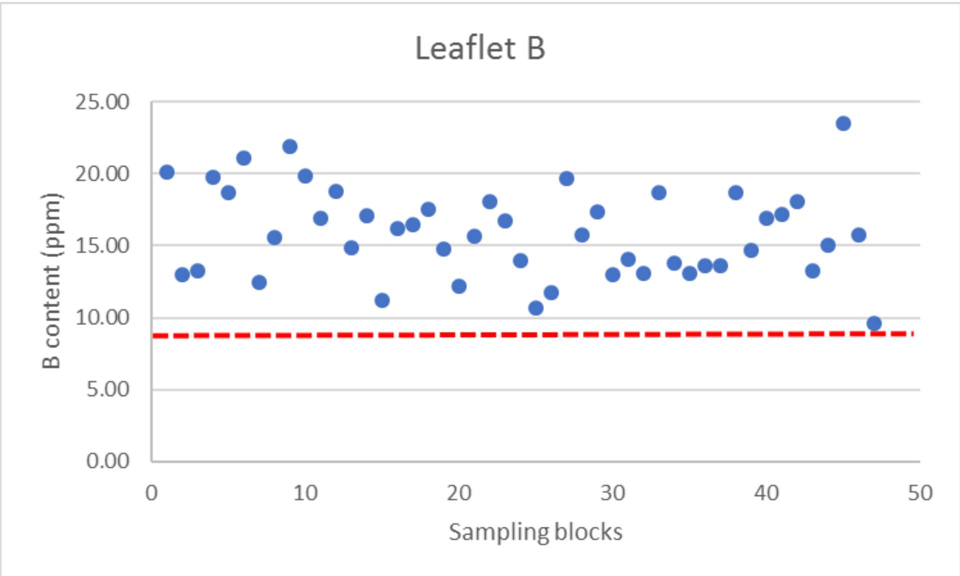


Figure 127. Leaflet B for all sampled blocks in 2019.

Table 112. Nutrient concentrations in both leaflet and rachis in 2016, 2017, 2018 and 2019.

Nutrient	Nutrient concentration (% for all and ppm for leaflet B)			
	2016	2017	2018	2019
Leaflet N	2.31	2.34	2.25	2.23
Leaflet P	0.144	0.148	0.136	0.137
Leaflet K	0.39	0.36	0.34	0.30
Rachis K	0.52	0.46	0.47	0.40
Leaflet Mg	0.40	0.37	0.40	0.38
Leaflet B	16.1	16.5	15.6	15.9

E.4.3.5. *Conclusion*

Leaflet N, P and K continued to be critically low in 60 to 90% of the smallholder blocks in Poliamba. Leaflet Mg and B were adequately available. The blocks in the West division fared well than the other two divisions. Leaf sampling will continue until there is enough data to review the smallholder fertiliser recommendation in New Ireland.

E.5. NBPOL POPONDETTA

Richard Dikrey and Steven Nake

E.5.1 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.5.1.1 *Summary*

Best management practices are demonstrated in 6 smallholder blocks in Popondetta to showcase its significance to the growers. The BMP practices include proper pruning standards, blocks upkeep/sanitation, cleaned paths and circles, frequent harvesting and fertiliser application. The 3 best performing blocks produced 17 t/ha, 31.6 t/ha and 35.2 t/ha respectively, demonstrating the yield potential smallholders can achieve in Popondetta if they apply BMP in their blocks.

E.5.1.2 *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.5.1.3 *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 20 gives the list of active BMP blocks.

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.

Table 113. 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	Closed
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

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.5.1.4 ***Results and Discussion***

The blocks' yields for the last six (6) years are shown in Table 21. The yields plummeted in all blocks except Block 840049.Despite the drop-in yield, two blocks (800158, 50400) continued to produce over 30 t/ha, while Block 690042 produced over 17 t/ha. The high FFB production (t/ha) was a result of grower adoption of BMP concept and consistency in block management.

The 3 other blocks did not perform to expectation due to the reasons discussed below. Block 680096 is located too far out limiting OPRA-Farmer contact in a month. The limited block visits resulted in low farmer moral/motivation resulting in farmer not fully implementing skills and knowledge imparted by OPRA to improve block management. We have observed from similar work in the Hoskins project in WNB that number of block visits/farmer contacts is a catalyst for technology adoption by the farmers. For blocks 840049 and 410029, the low yields resulted from prolonged absence of fertiliser application and poor block management. We are doing our best to rehabilitate these two blocks, but it may take a while before we start to see some positive changes.

Table 114. Annual Production (t/ha) BMP blocks from 2014 to 2019.

Block	Yields (t/ha)						Mean
	2014	2015	2016	2017	2018	2019	
800158	15.2	16.4	24.6	28.8	36.2	31.6	25.5
50400			18.9	25.1	35.4	35.2	28.7
680096	11.9	6.5	2.5	6.8	22.1	12.9	10.5
690042	16.4	14.2	13	15.4	24.5	17.0	16.8
840049					7.5	7.5	7.5
410029						4.4	4.4

E.5.1.5. *Conclusion*

There is huge potential to increase smallholder yields beyond the current actual yields, as observed from the current yields in the 3 best performing BMP blocks in Popondetta. The high yields can only be achieved with adoption of BMP, regular fertilization and regular fortnightly harvesting. OPRA must work in partnership with Smallholder, TSD and Sustainability department of HOP, OPIC and Grower Representatives to promote the BMP concept.

E.5.2. SSR403: Assessing leaf nutritional status of smallholder blocks, Popondetta Project

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

E.5.2.1 *Summary*

Total of 99 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 1.98%, 0.126 % and 0.48 % respectively. Leaflet Mg and B levels were adequately available.

E.5.2.2. *Background*

One of the factors affecting smallholder production is negligence by smallholders to either apply fertiliser or lack of knowledge to apply fertilizer correctly. The reasons for this have been extensively documented by Koczberski et al (2001) in their report. For palm to gain maximum production per hectare, inorganic fertilisers 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 smallholders in New Ireland apply urea and Muriate of Potash (MOP) at the rates of 1.5 and 2.5 kg/palm/year respectively.

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. It 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 Popondeta was initiated in 2017 to determine the leaf nutrient concentrations of oil palm in 99 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.5.2.3. *Methodology*

Total of 99 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^{o}C, ground, packed and dispatched to AAR Laboratory in Malaysia for analysis.

E.5.2.4. *Results and Discussion*

The leaf levels against the critical levels (Foster, 2015) are shown in Table 22. Leaflet N, P and K were deficient while leaflet Mg and B were adequate in all 5 divisions. Rachis K was deficient in 2 divisions (Saihio and Ilimo).

The individual block nutrient contents are shown in Figure 43 to Figure 48. Leaflet N ranged from1.51 % to 2.60 %. Only 1 block (1%) was above critical level, the rest (99%) were N deficient. Leaflet P levels were between0.106% and 0.162%, with 11 blocks (10%) above the critical level whereas the other 89 blocks were P deficient. Leaflet K level ranged from 0.24% to 0.74%, while rachis K levels were between 0.23 % to 2.43 %. About 45% and 79 % of the blocks had low levels of K in both the leaflets and rachis respectively. K deficiency was more pronounced in the Ilimo, Saihio and Aeka divisions. Leaflet Mg ranged from < 0.14% to 0.46 %, with 26 of the blocks (26%) in the deficient range. Most of blocks (74%) had adequate Mg content across all 5 divisions. Only 7 blocks (7%) were low in leaflet B. B levels ranged between 7.5 to 16.6 ppm.

Table 115. Summary of leaflet and rachis nutrient concentrations at the Divisional level.

Division	Leaf N%	Leaf P%	Leaf K%	Leaf Mg%	Leaf B%	Rachis K%
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 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***

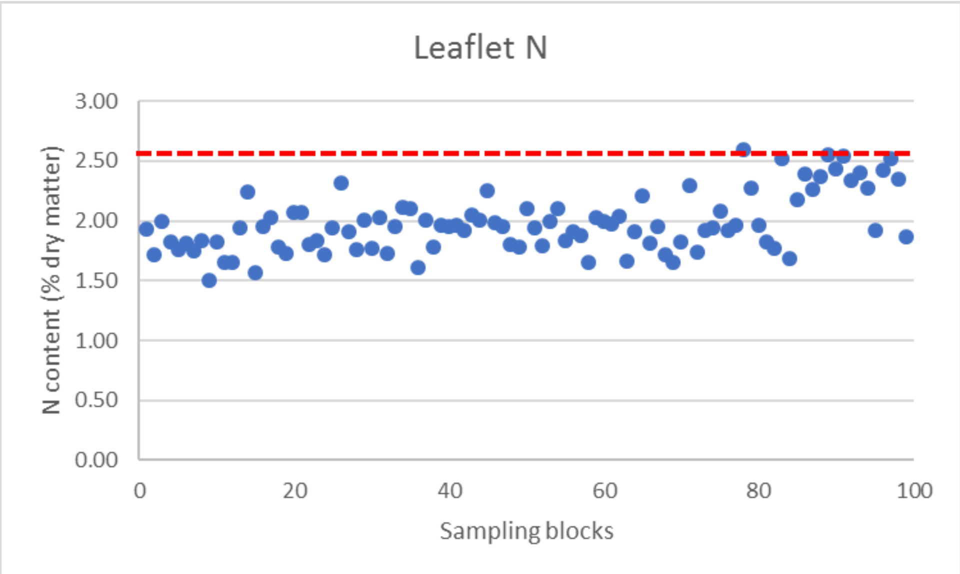


Figure 128. Leaf N concentration for all sampled blocks in 2019.

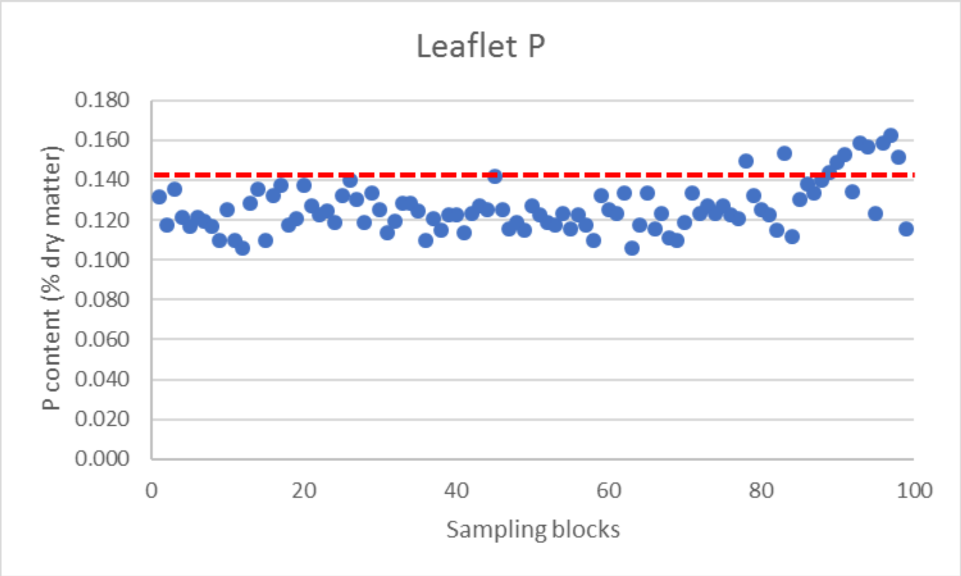


Figure 129. Leaf P concentration for all sampled blocks in 2019.

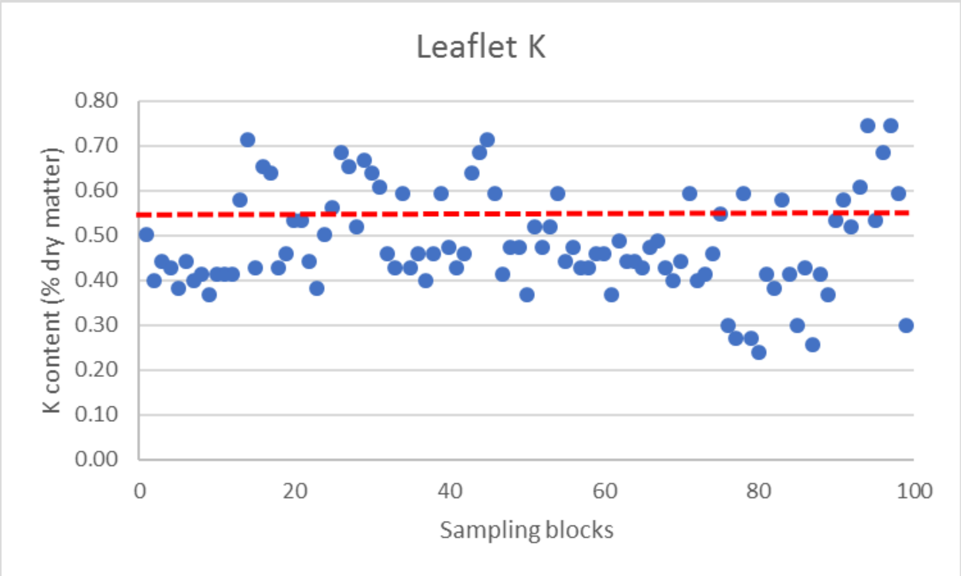


Figure 130. Leaf K concentration for all sampled blocks in 2019.

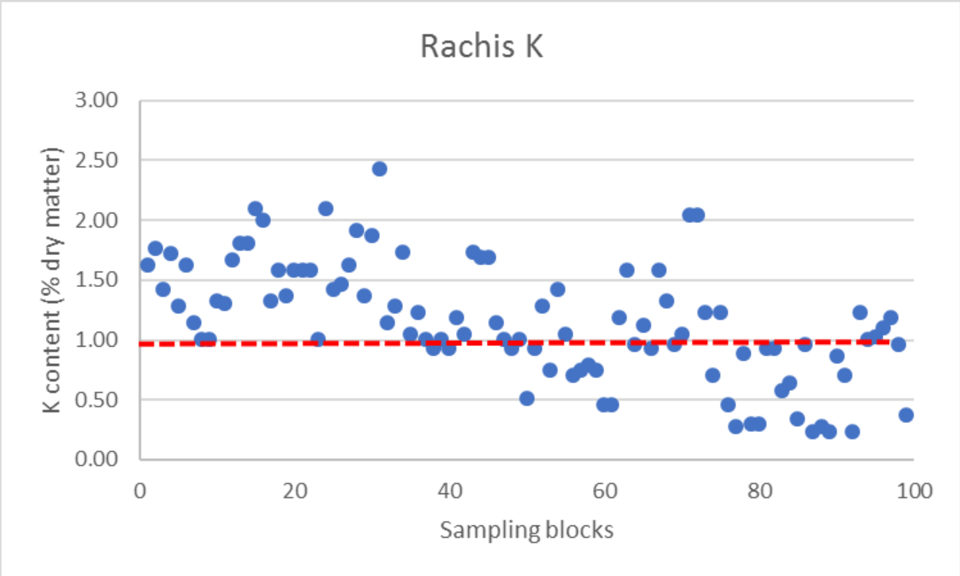


Figure 131. Rachis K concentration for all sampled blocks in 2019.

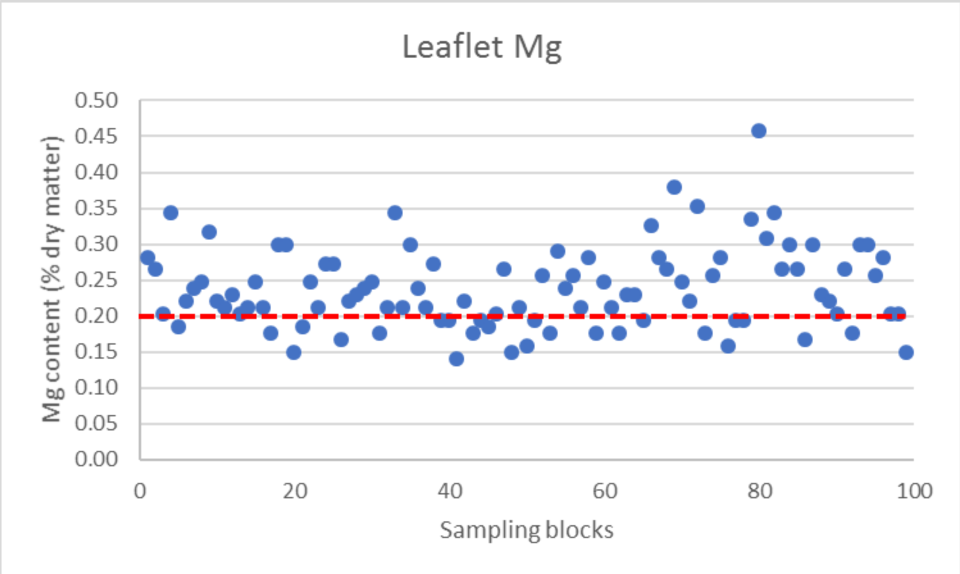


Figure 132. Leaflet Mg concentration for all sampled blocks in 2019.

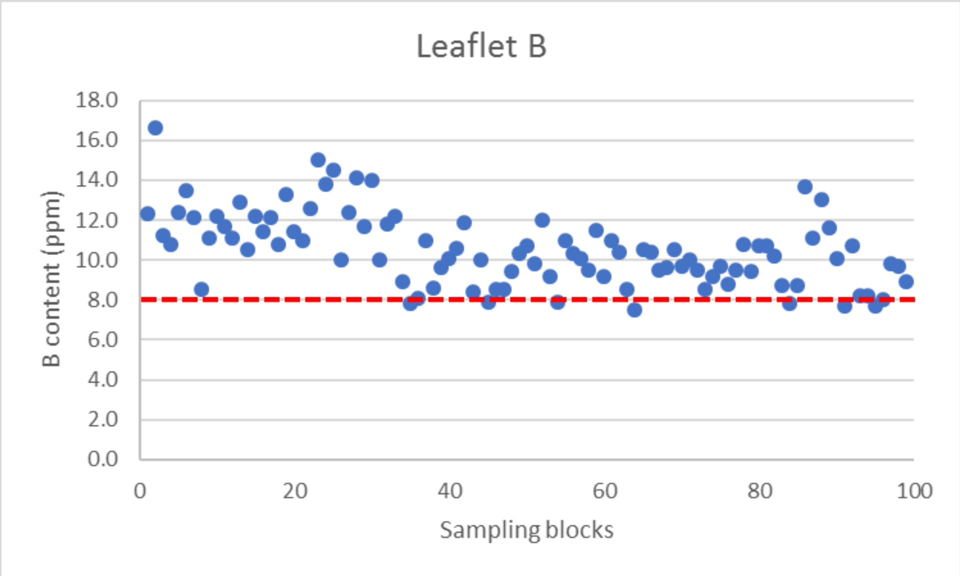


Figure 133. Leaflet B concentration for all sampled blocks in 2019.

E.5.2.5 *Conclusion*

Leaflet N, P and K were deficient in all divisions, with leaf N low in 90% of the blocks, while leaflet P and K were deficient in 89% and 72% of the blocks respectively. Leaflet Mg and B levels were at adequate levels. The main contributing factor to nutrient deficiencies were prolonged absence of fertiliser application or less amounts of fertiliser applied.

E.5.3. SSR404: Income and Expenditure Study for smallholders, Popondetta Project

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

E.5.3.1. *Summary*

This socioeconomic study was endorsed to quantify smallholder earnings from oil palm, their fortnightly expenditure and their ability to save. The fortnightly income from oil palm ranged from K120 to K660 with an average of K290.00 per block. The study further revealed that an additional K190 can be earned from alternative income generating economic activities such as selling of garden produce, betelnut, cooked food, table markets (vendor) and sale of other cash crops. The expenditure of the block is mainly taken up by purchase of store food and groceries, education related costs, PMV fare, betelnut/mustard, smoke and repaying of borrowed money. On average, individual blocks spent K299.55 in the last fortnight which was slightly higher than the income from oil palm. If proper planning and budgeting was done before the payday, it is believed that some of the cost can be either reduced or avoided, making their budget healthy with no deficit. Additionally, extra cash remaining can then be parked away into their savings account for future use. Currently, there is no saving culture due to no surplus cash. It is therefore important for awareness on financial literacy for smallholders.

E.5.3.2. *Background*

Oil Palm has been cultivated in Papua New Guinea for over 50 years, however, the smallholder grower's standard of living has barely improved. The smallholders have always blamed the fluctuating fresh fruit bunch (FFB) price for their current state of living. Others have alluded the rapidly growing population within the blocks adding pressure on income per capita thus no savings for further improvements to better their livelihoods. While commercial banks and other financial institutions including the milling companies are keen to come up with loan packages to assist the smallholders, there is uncertainty regarding the capability of the smallholders to repay their loan. Therefore, this study was initiated to determine from current income and expenses if there is any free cash remaining after the block income is spent in a fortnight. surplus cash. It is therefore important for awareness on financial literacy for smallholders.

E.5.3.3. *Methodology*

A mixed method approach was adopted in this study. This included both quantitative and qualitative interview in the form of survey questionnaires while secondary data was made available by Higaturu Oil Palms Smallholders OMP. The survey was administered between September 2019 and February 2020. A total of 110smallholder oil palm growers were selected for the survey study based on their harvesting performances in 2017 and 2018. For the purpose of the annual report, data from only 30 blocks were analysed and reported. We anticipate reporting on the full/complete data set from the 99 blocks in the close trial writeup.

The 30 blocks reported here are comprised of 17 Land Settlement Scheme (LSS) and 13 Village Oil Palm (VOP) Blocks selected from Sorovi, Igora and Saiho. From those block residents whom were interviewed, 47 % (14) are original block owners. The other 53 % (16) relatives of the original block owner (son 69%, brother 6%, son in-law 6%, sister 6%, caretaker 6% and others 6%), from which 83% are fully responsible for managing the block.

A total of 88 households (HH), ranging from 1 to 15 HHs were found in the 30 blocks that were surveyed, with an average HH of 2.9. The most common HH number per block was 1 (43%). The average number of persons per HH was 5 with 15 residents per block.

E.5.3.4. *Results and Discussion*

Household income status in the last fortnight

Income from Oil Palm
The size of the blocks interviewed ranged from 1.33 ha to 5.02 ha with an average block size of 2.81 ha. The block earnings by oil palm ranged from K120 to K660 with an average of K290 per block. Seven blocks (23%) earned below K200, 12 blocks (40%) earned between K201-K300, 6 blocks (20%) earned between K301-K400 while 5 blocks (17%) earned more than K401. The income generated depended on the size of the block (Figure 49). Therefore, majority of the blocks in this study earned between K201 and K300 in the last fortnight.

When the income by oil palm from the last fortnight was calculated on an income per hectare basis (Figure 50), income ranged from K43.00 to K420.00 with an average income of K118.00 per hectare.

Income from Garden and other income generating sources
Similar studies conducted on smallholders in West New Britain (Hoskins and Bialla) showed that income from oil palm is also supplemented by other income sources. This practice is common in densely populated blocks with multiple households. Unlike in Hoskins and Bialla, only 14 blocks (47 %) were engaged in other income generating sources in Popondetta. We identified 9 different alternative income sources and these were sales of garden produce, sale of cooked food, sale of store food (black market), betelnut sales, mustard sales, table market, sale of tobacco, cocoa and piggery (Table 23). The top 5 business activities with potentially high returns were piggery, cocoa, sale of store food (black market), table market and tobacco sales. Unfortunately, all these activities are not so popular and hence limited number of blocks (<10%) are engaged in them.

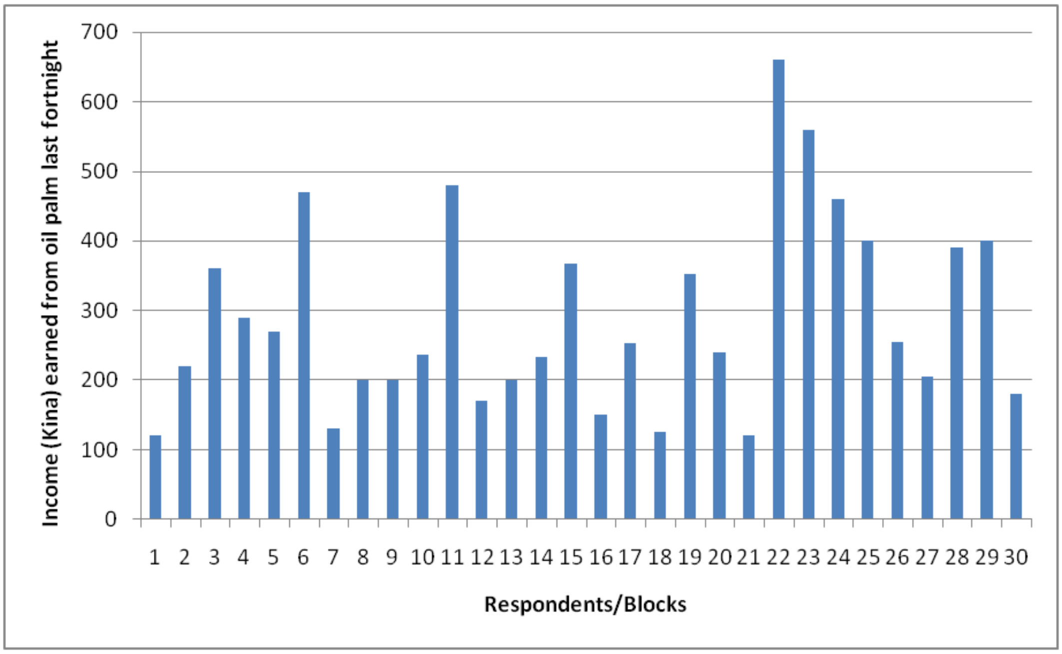


Figure 134. Income generated from oil palm in the last fortnight.

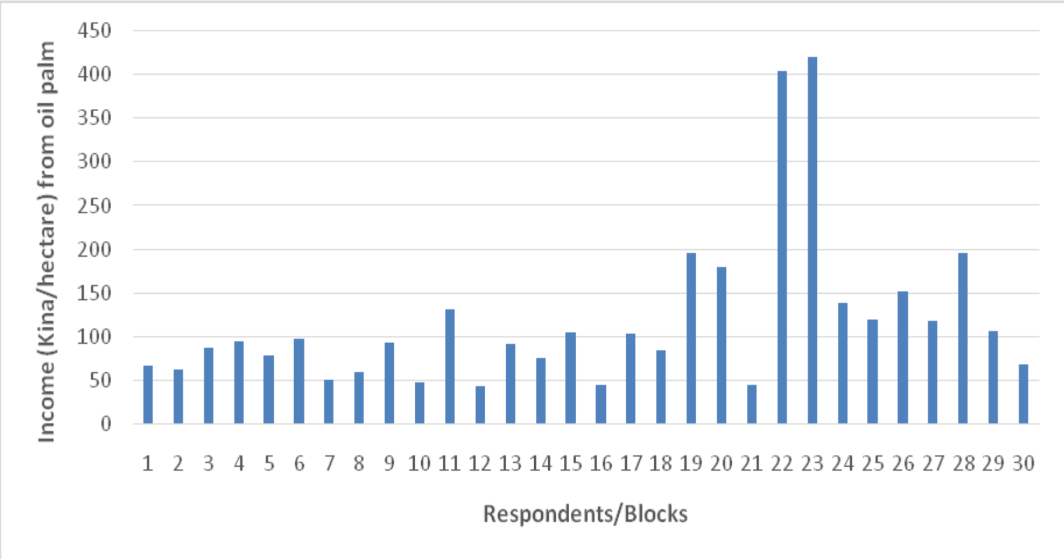


Figure 135. Income generated equivalent to 1 hectare of oil palm in the last fortnight.

Selling of garden produced for extra cash is the only other alternative income source that attracts the highest number of blocks (33%) to be engaged in. Though this is practiced by the highest number of blocks, the earnings from this activity ranged from K4 to K80, with an average of only K12.80. The two common alternative income generating activities apart from oil palm were selling of garden foods (33%) and betelnut sales (23%). Piggery, selling of dry bean or wet bean cocoa and sale of store food (black market) are potential alternative economic projects apart from oil palm that can generate good income to the block if they considered as a frequent activity on the blocks.

Therefore apart from depending entirely on oil palm for income to sustain the need and wants of the block residents, selling of garden produce and other alternative income generating sources have the potential of generating additional K190 to the K290 from oil palm if the block residents are frequently engaged in these activities.

Table 116. Alternative sources of income for block residents.

Income source	Count (n=30) of blocks engaged in this income activity	Proportion (%) of blocks engaged in this income activity		Average income earned from this activity (Kina)	Frequency of economic activity
Sale of garden produce	10	33		12.80	Occasionally
Sale of cooked food	1	3		30.00	Occasionally
Sale of store food (black market)	2	7		125	Occasionally
Betelnut sales	7	23		35	Occasionally
Mustard sales	3	10		13	Occasionally
Table Market	3	10		88	Occasionally
Sale of tobacco	1	3		50	Occasionally
Cocoa	2	7		365	Occasionally
Piggery	1	3		1000	Occasionally

Household expenditure in the last fortnight

The study identified 16 common items/activities block income is generally spent on in the last fortnight (Table 24 and Figure 51). The block expenditure ranged from K2.60 for betelnut/mustard to K66.50 for the purchase of store food and groceries. The top 5 expenses were for store food/groceries (K66.50), alcohol/homebrew (K36.00), repaying of borrowed money (K29.00), expenses relating to their children’s education/schooling (K23.60) and purchase of clothes (K22.70). However, the proportion (%) corresponds more to the commonness/regularity of the items or activities the respondents were engaged in. Hence, the 5 common items/activities, block income was spent on were store food/groceries, PMV fare, betelnut/mustard, expenses relating to their children’s education/schooling and repaying of borrowed money and smoke.

From the top 5 common items/activities where block money is spent on, three of those are essential needs (store food/groceries, PMV and education related costs), the other 2 (PMV betelnut/mustard, smoke and repaying of borrowed money) are non-essential items which can be easily avoided and monies diverted towards other important items like clothes, block labour, medicals, tools/chemicals and house repair. Unfortunately, there was no expenses towards purchase of tools/chemicals and house repair.

Younger generation these days tend to favor store foods over locally grown food from the gardens, that was why 100% of the blocks (respondents) said they at least some money at the shops for food in the last fortnight. The top 5 food items purchased from the store were rice (100%), Soap (29%), Sugar (28%), Noodles (26%) and canned protein (25%) (Table 25).

Only 4 out of 30 blocks (13%) spent K70.00 on tuber crops, vegetables and greens from the market, an average of K17.50 per block on market food. In Popondetta, there is still a lot of land available for gardening hence 90 % of the blocks have gardens where they access food crops from and don’t have to buy from the markets.

On average, individual blocks interviewed spent K299.55 in the last fortnight to satisfy their basic needs and wants on the block. The predicted expenditure was slightly more than the income from oil palm. If proper planning and budgeting was done before the payday, it is believed that some of the cost can be either reduced or avoided, making their budget healthy with no deficit. Additionally, extra cash remaining can then be parked away into their savings account for future use.

Table 117. Store items block income spent on in the last fortnight

Store items	Count (n=30) of respondents	Proportion of respondents (blocks)	Range of money spent (Kina)
Rice	30	100	7.60-77.00
Canned protein	25	83	3.20 – 25.90
Sugar	28	93	2.00 – 12.80
Salt	23	77	0.80 – 6.60
Tea/Coffee	24	80	1.20 – 10.00
Milo/Milk	4	13	1.70 – 10.90
Cooking oil	18	60	1.80 – 6.00
Noodles	26	87	0.80 – 6.90
Flour	3	10	5.00 - 26.50
Freezer goods	4	13	3.00 – 29.90
Soap	29	97	0.80 – 20.40
Omo	22	73	0.80 – 13.60
Bleach	13	43	2.10 – 7.90

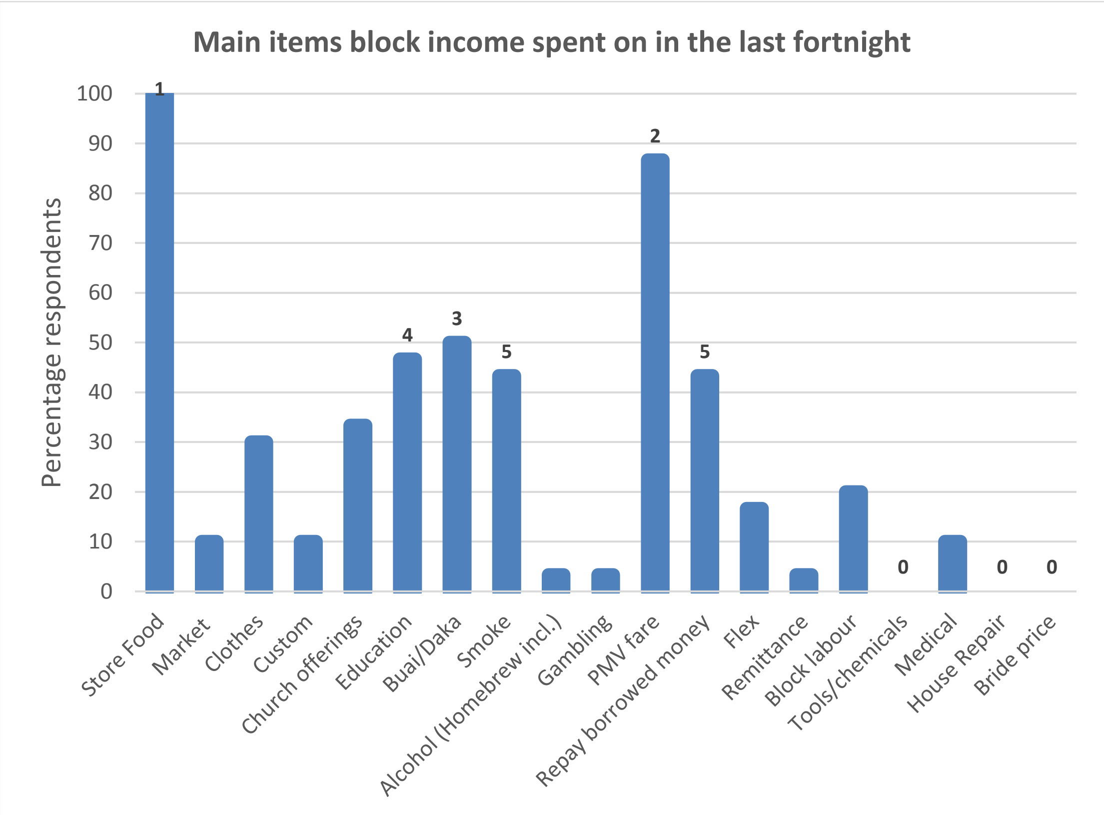


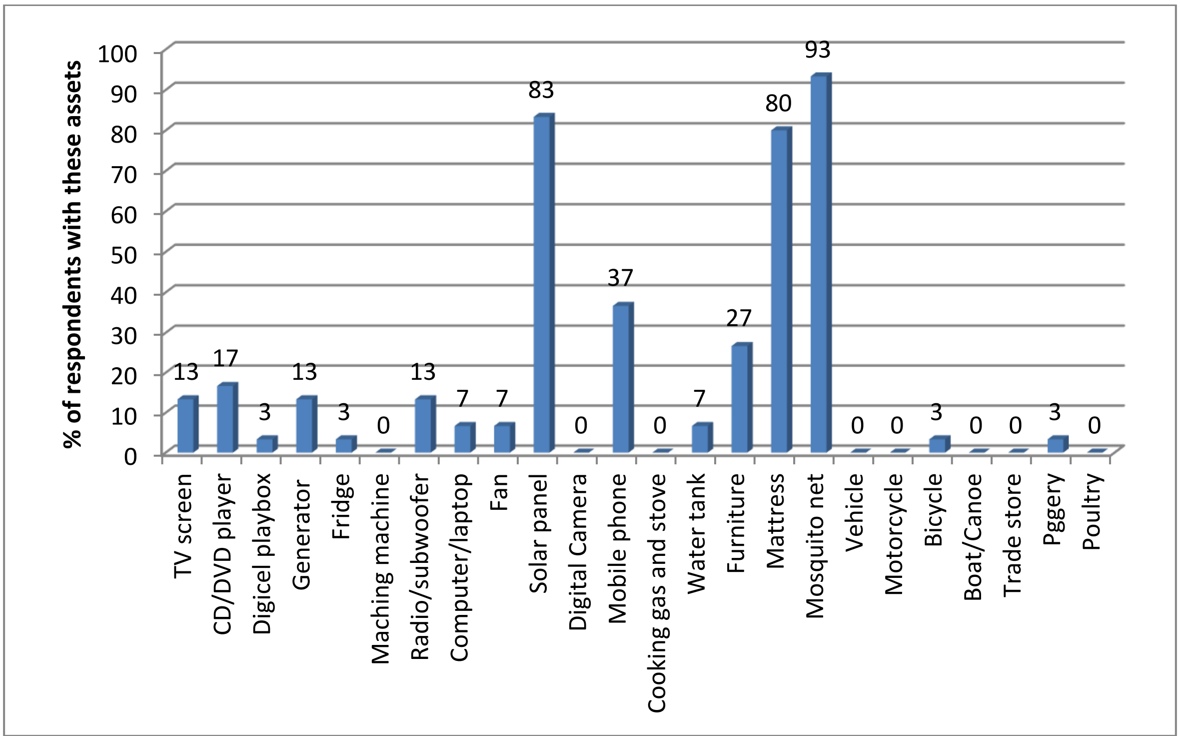
Figure 136. Household expenses in the last fortnight (Ranked Top 5).

Household Savings

When asked if the respondents have bank accounts, all (100%) said they have banks accounts. Those that had bank accounts, 14 (47%) had one account, while 16 (53%) operate two accounts. These account where mainly used as operational account (93%) while the other 7 % said they used their accounts for saving money for future use. However, when asked how much they have saved they indicated nothing in the account because of not enough money to save just like the others. The savings on their primary bank accounts were meant for immediate needs and eventually depleted before the next pay day.

Household Assets

Figure 52 shows inventory done on assets within the blocks. The five (5) common assets found were mosquito nets, solar panel, mattresses, mobile phones and furniture (mainly plastic chairs and wooden tables). The housing inventory revealed that most of the houses (>80%) in the blocks were either traditional or semi-permanent that is the reason why mosquito nets are required in every household to protect them from mosquitoes and subsequently illness from malaria. Solar was also common in every household due to easy accessibility and affordable prices in the shops. The solar panels are used for charging mobile phone batteries and lightings.



E.5.3.5. ***Conclusion***

From this study income earned from oil palm ranged from K100/ha -K1200/ha with average K100/ha. The block residents not only depend on oil palm income, 57% ventured into other income generating sources to meet their additional household needs in which they earned an average of K990. The two common income generating activities apart from oil palm were selling of garden produce (36%) and betelnut (25%). An average of K231 was spent in the last fortnight. After all expenses were paid an average of K254.00 remained as free cash.

However more than 50% could not save because they think the income, they earned from oil palm is not enough to cater for their needs as well as savings for future. Other reasons for not able to save included low yields/income due to sharing of the blocks into smaller portions and low income per capita due to increasing number of block residents.

E.6. NBPOL MILNE BAY

Steven Nake, Emmanuel Germis, Wawada Kanama and Sharon Agovaua

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

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

E.6.1.1. *Summary*

Milne Bay project has 9 existing BMP blocks in 2019. Their yields (t/ha) ranged from 7.3 t/ha to 31.4 t/ha with an average of 15.7 t/ha. The 5 blocks that have demonstrated consistent yield increments in the last 2 years have improved considerably, fertiliser applied and harvesting rounds have improved compared to 1-2 years ago whereby most of the blocks were not harvesting regularly. This demonstrates the positive impact of adopting BMP practices on the block regularly.

E.6.1.2. *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.6.1.3. *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 26). 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 requested from Milne Bay estates and applied in the blocks by the block owners with guidance from PNGOPRA. In the two old blocks, activities continued as normal.

Table 118. SSR501ab, Block information

No	Block	Trial code	Area	Division	Area (Ha)	Scheme	Year of initiation
1	**09017**	**1.59**	**SSR501**	**Figo**	**Sagarai East**	**2009**	**VOP**
2	**19022**	1.27	**SSR501**	Waema	Gurney East	2009	**VOP**
3	02024	1.81	**SSR501**	Kapurika	Gurney West	2018	**VOP**
4	11050	2.26	**SSR501**	Borowai	Sagarai West	2018	VOP
5	11069	0.76	**SSR501**	Borowai	Sagarai West	2018	VOP
6	12030	0.47	**SSR501**	Yaneyane	Gurney East	2018	VOP
7	15020	1.59	**SSR501**	Marayanene	Gurney West	2018	VOP
8	19036	0.37	**SSR501**	Waeme	Gurney East	2018	VOP
9	24037	1.42	**SSR501**	Ipouli	Sagarai West	2018	VOP
10	25010	1.34	**SSR501**	Gumini	Gurney West	2018	VOP

E.6.1.4. *Results and Discussion*

In 2019, seven (7) of the existing BMP blocks showed increments in their yields (Figure 53). The yield increments ranged from 2 to 17 t/ha between 2018 and 2019. The increase in yields was a direct impact of BMP being implemented on these blocks. Of the two other blocks which showed no yield increments, the FFB yields for block 19036 in 2019 was the same as in 2018 (i.e. no change in FFB yield). However, for block 19022, FFB yields plummeted by 5.5 t/ha in 2019. This was due to less harvests done in 2019 compared to 2018.

Despite the fluctuations in the FFB yield by the BMP blocks from 2017 to 2019, the average FFB yield consistently increased from 2017 to 2019 (Figure 54). The yield increment achieved between 2018 and 2019 was 4.5 t/ha compared to that 2017 and 2018 which was only 1.1 t/ha. This is because 8 of the 9 blocks were established in 2017 and all these blocks had poor block upkeep, with no fertiliser application and poor harvesting frequency. By 2019, all growers have undergone some form of training on block practices by PNGOPRA and would have received fertiliser within the 2-3 years.

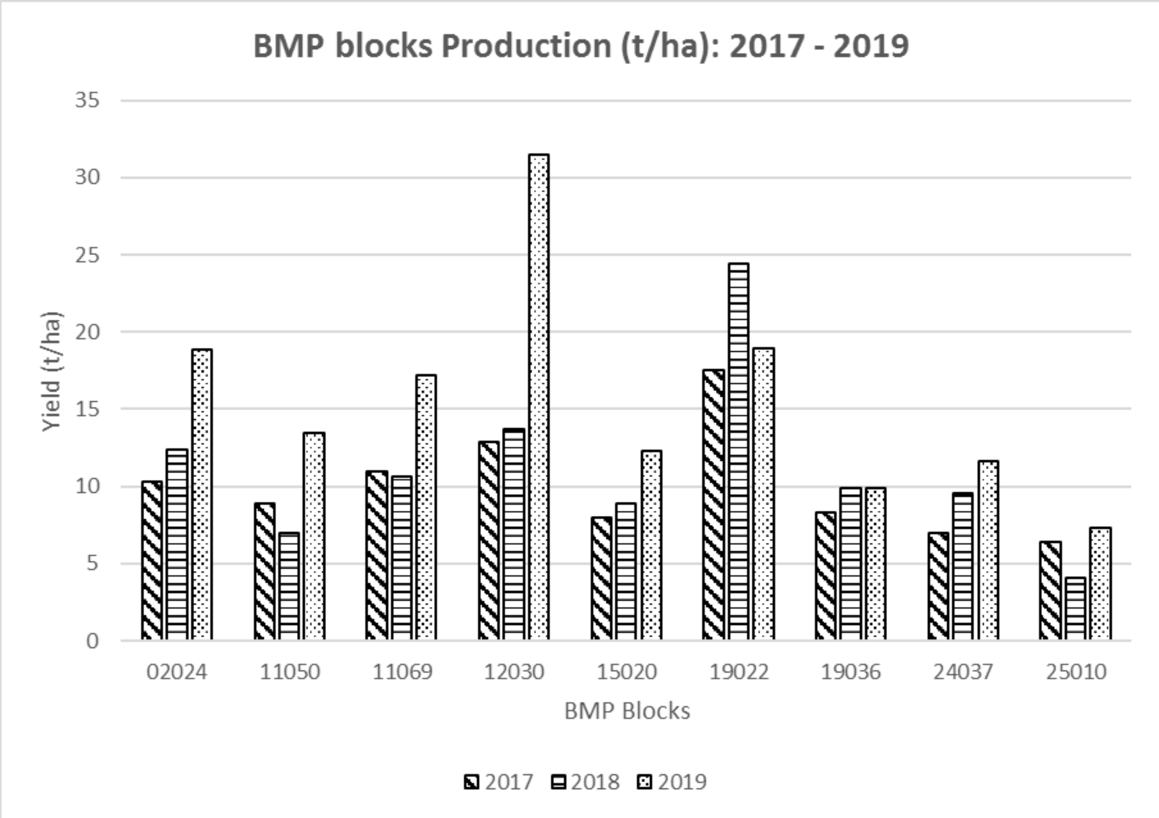


Figure 137. Production trend for BMP blocks 09017 and 19022 from 2017 to 2019.

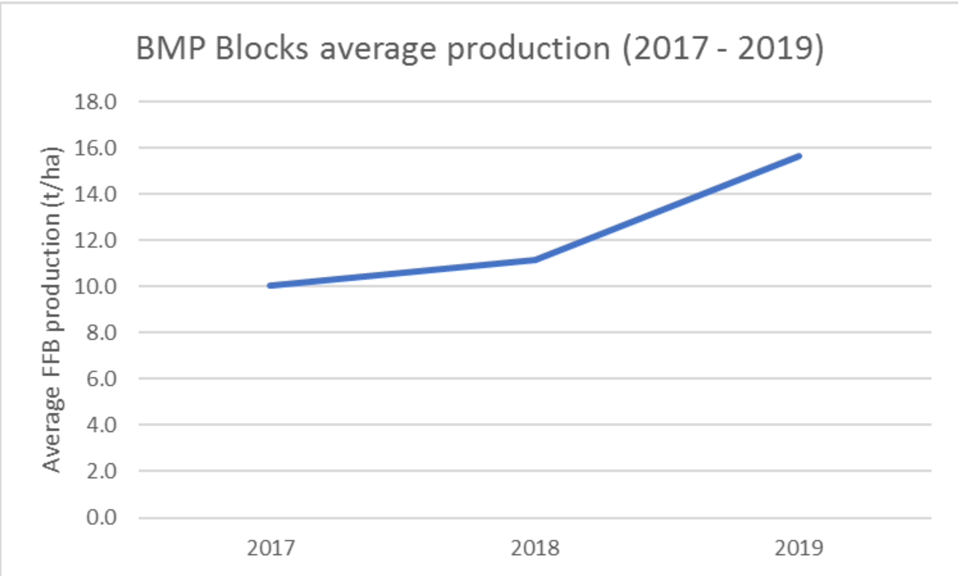


Figure 138. Three-year (2017-2019) average FFB production for BMP blocks in Milne Bay

E.6.1.5. *Conclusion*

In 2019, 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 adequate. Mean values of leaf N, P, K, Mg, B and rachis K were 1.99%, 0.131%, 0.37%, 0.42%, 14.4% and 0.83 % respectively. K deficiency and high Mg/Ca is common in these soils due to presence of clay minerals (smectite and vermiculite).

E.6.2. 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.6.2.1. *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.6.2.2. *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. 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.6.2.3. *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 4x3 (every 3rd palm in every 4th 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.

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E.6.2.4. *Results and Discussion*

Leaflet N, P and K deficiencies continue to persist in both Gurney and Sagarai divisions. Leaflet Mg and B were adequate while rachis K was deficient at Waigani division, whereas for Sagarai division, leaflet Mg, leaflet B and rachis K were all adequate (Table 27). The nutrient concentrations for the 78 sampled blocks are shown in Figure 55 to Figure 59. For leaflet N and leaflet K, 100% of the sampled blocks were deficient, whereas only 10 % of blocks were P deficient and 61% low in rachis K. In contrast, leaflet Mg and B were within their optimum levels 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 2019 leaf analysis also indicated a considerable decline in the nutrient concentrations of leaflet N, leaflet K and rachis K compared to 201 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.

Table 119. Foliar nutrient concentration in smallholder blocks at Gurney and Sagarai divisions

Division	**LN%**	**LP%**	**LK%**	**LMg%**	**LB (ppm)**	**RK (%)**
Gurney	2.03 (2.11)	0.130 (0.129)	0.35 0.37)	0.44 (0.50)	14.5 (14.0)	0.68 (0.76)
Sagarai	1.94 (2.03)	0.132 (0.127)	0.41(0.43)	0.39 (0.44)	14.2 (12.7)	1.08 (0.16)
Project Mean	***1.99 (2.08)***	***0.131 (0.128)***	***0.37(0.39)***	***0.42 (0.48)***	***14.4 (13.5)***	***0.83 (0.95)***
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.

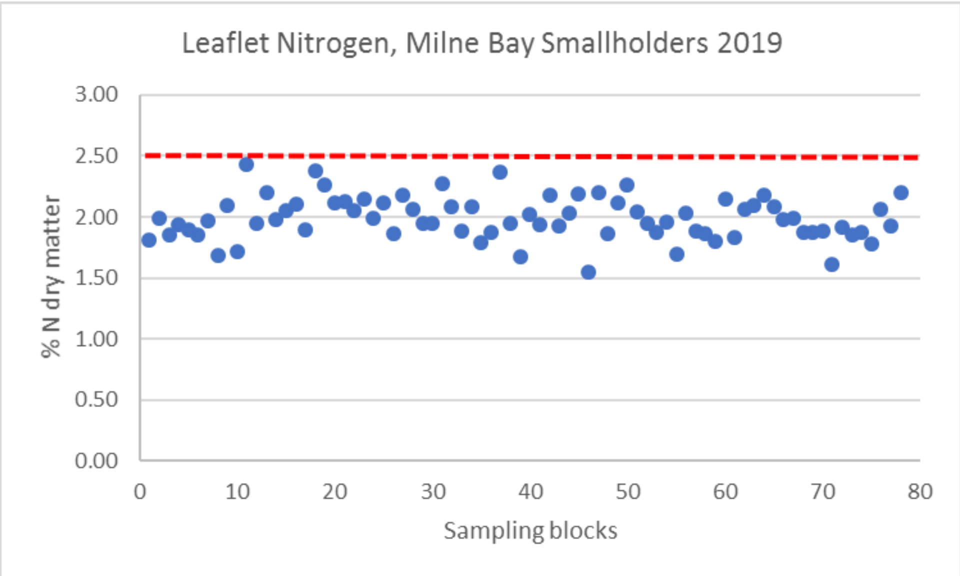

Figure 139. Leaflet N concentration for sampled blocks in Milne Bay

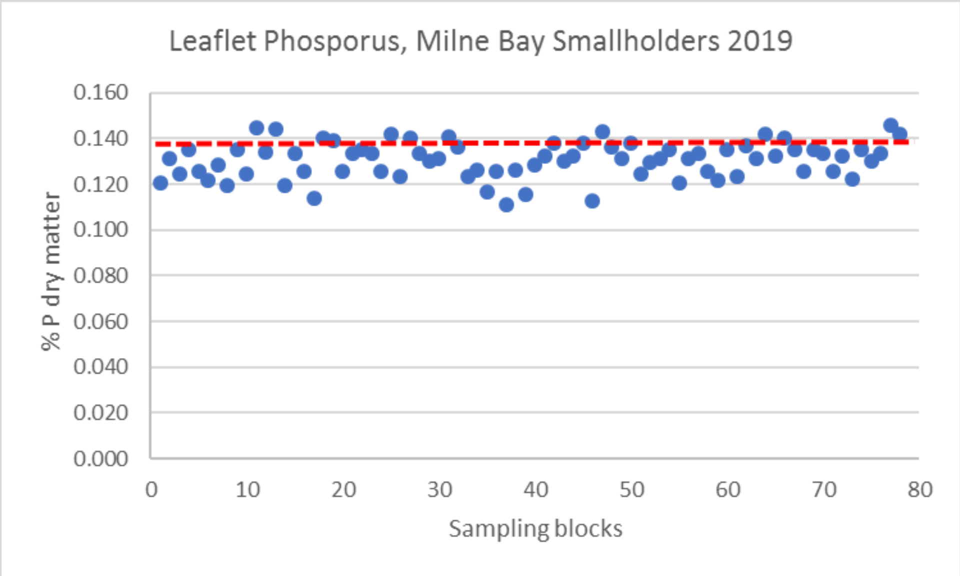

Figure 140. Leaflet P concentrations for sampled blocks in Milne Bay

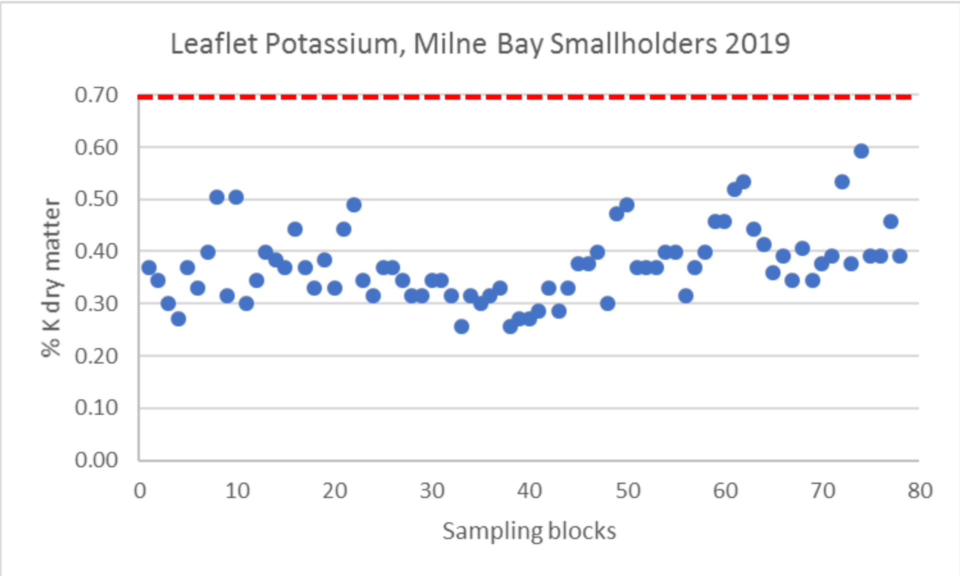

Figure 141. Leaflet K concentrations for all sampled blocks in Milne Bay

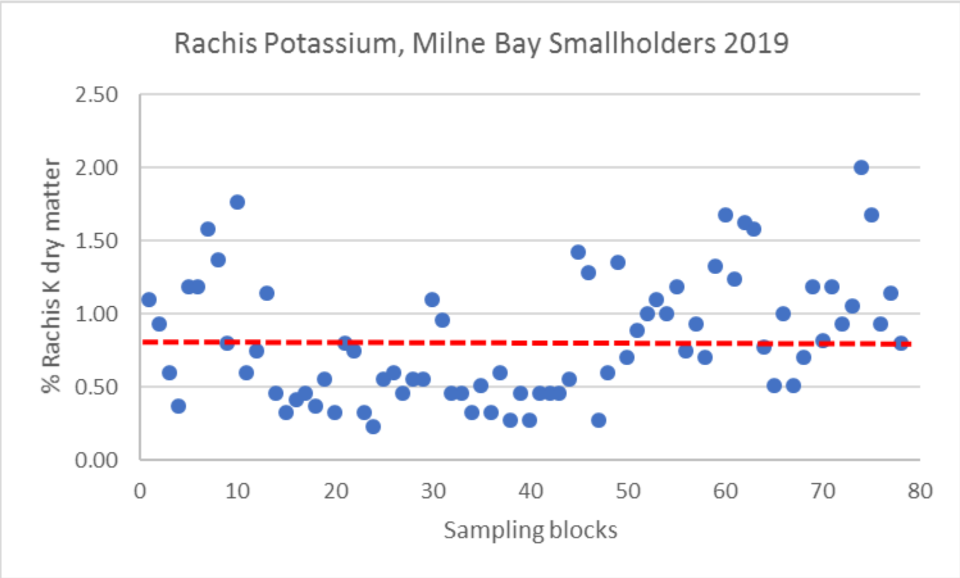

Figure 142. Rachis K concentration for all sampled blocks in Milne Bay

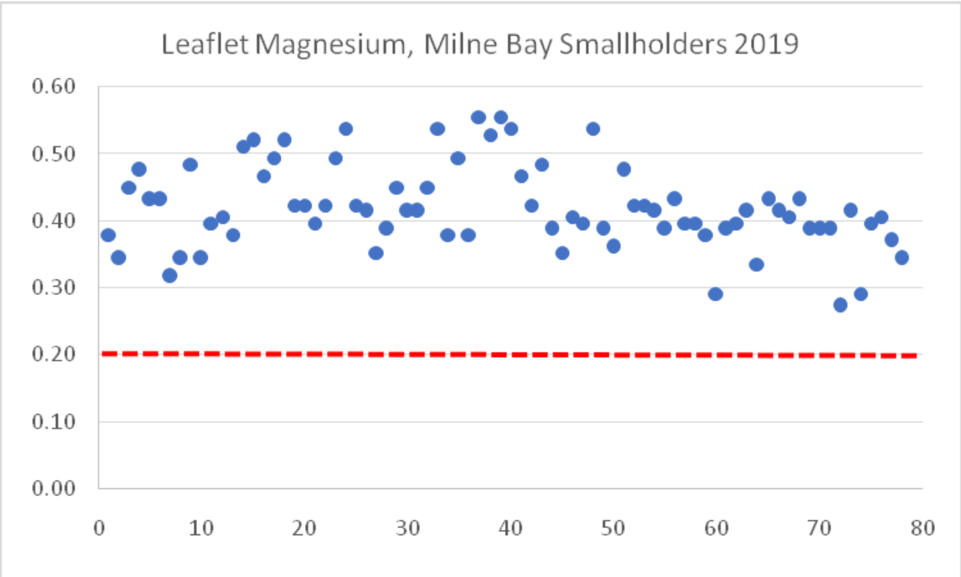

Figure 143. Leaflet Mg concentrations for sampled blocks in Milne Bay

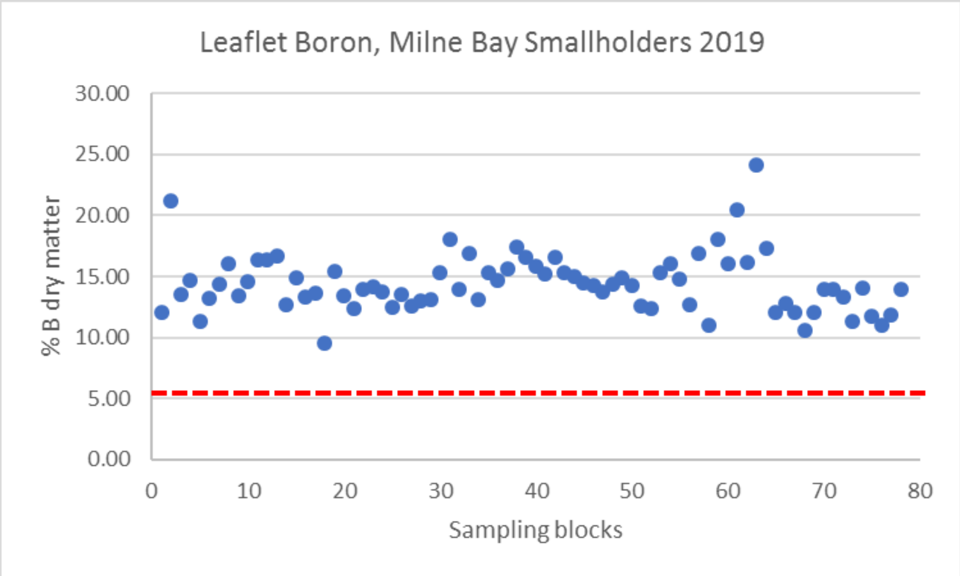

Figure 144. Leaflet B concentrations sampled blocks in Milne Bay

Table 120. 2016, 2017, 2018 and 2019 foliar nutrient concentrations

	Nutrient concentrations			
Foliar Nutrients	**2016**	**2017**	**2018**	**2019**
Leaflet N (%)	2.19	2.31	2.08	1.99
Leaflet P (%)	0.136	0.152	0.128	0.131
Leaflet K (%)	0.41	0.41	0.39	0.37
Leaflet Mg (%)	0.45	0.45	0.48	0.42
Leaflet B (%)	13.9	14.4	13.5	14.4

E.7. TECHNICAL SERVICES

E.7.1 Field trainings and radio broadcasts

Field training sessions and radio broadcast in 2019 is shown in Table 29. The field days were conducted in all sites except Bialla. Field days in Bialla were replaced by min-field days organized by individual departments and staged at their own timing. Number of block demonstrations in both Hoskins and Bialla were increased in 2019 to 62 and 25 sessions respectively. Overall, there has been big improvement in smallholder trainings in both Popondetta and Milne Bay.

Table 121. Smallholder trainings and radio extension programs conducted in 2019.

Project Sites	**Activities**				**Total Trainings**
	Field days	**Block Demos**	**Radio Broadcasts**	**Other trainings**	
Hoskins (Dami)	20	62	3	1	86
Bialla	0	25	0	2	27
Popondetta	13	1	0	0	14
New Ireland	5	0	0	0	5
Milne Bay	4	6	0	0	10

E.7.2 Stakeholder trainings and presentations

- 03rd August 2019 – Presentations for Smallholder Affairs Officers at MCC by Steven Nake, Emmanuel Germis and Merolyn Koia. The presentations highlighted Smallholder and Socioeconomic Research and some progressive results.

E.7.3. International Conferences

- 3rd April 2019 - Twenty years of economic empowerment for smallholder women in Papua New Guinea. A case study from West New Britain. Poster presentation by Merolyn Koia at the “Seed of Change” International Conference at Canberra from April 1st to 5th 2019.

- 21st May 2019 - Breaking open the black box: socioeconomic and cultural factors explaining adoption or rejection of innovations in agriculture. A presentation by Steven Nake and Prof. George Curry at the 4th World Congress on Agroforestry in Montpellier, France from 20th – 22nd May 2019.

E.7.4. Publications

1. Migrants as Social Entrepreneurs in PNG Smallholder Oil Palm Industry. Scientific Note No. 06. The OPRAtive Word. October 2019. By Emmanuel Germis.

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.