Annual Research Report

2011

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Report by the Director of Research

August 2012

INTRODUCTION (Director of Research, Bill Page)

With the changes in 2010, when NBPOL took over the management of the former CTP palm developments in Oro, Milne Bay and New Ireland Provinces (now Kula Palm Oil Ltd), NBPOL manages about 87% of the country's oil palm Plantation area (Table 1) and, with the production from their associated smallholders, process 84% of the country's FFB (Table 2).

Table 1.

Area Estimates Dec 2011 (ha)

Project Area	Plantation	Smallholders	Others Outgrowers	Total	
Hoskins (*NBPOL, WNB*)	36,127	25,366	540	62,033	44.9%
Popondetta (*NBPOL, Kula Group*)	8,533	11,835	0	20,368	14.8%
Milne Bay (*NBPOL, Kula Group*)	11,136	1,900	0	13,036	9.4%
New Ireland (*NPOL, Kula Group*)	5,466	2,386	0	7,852	5.7%
Ramu (NBPOL, *RAIL*)	10,685	260	0	10,945	7.9%
Bialla (*Hargy Oil Palms*)	10,670	11,192	1,948	23,810	17.2%
TOTAL	82,617	52,939	2,488	138,044	
	59.8%	38.3%	1.8%		

Table 2.

FFB Production in 2011 (tonnes)

Project Area	Plantation	Smallholders	Other Outgrowers	Total	
Hoskins	959,432	452,345	12,259	1,424,036	52.4%
Popondetta	212,096	167,864	0	379,960	14.0%
Milne Bay	237,221	13,634	0	250,854	9.2%
New Ireland	118,505	20,710	0	139,215	5.1%
Ramu	89,000	1,344	0	90,344	3.3%
Bialla	228,597	205,798	<-	434,396	16.0%
TOTAL	1,844,851	861,695	12,259	2,718,805	
	67.9%	31.7%	0.5%		

There are currently 13 palm oil mills operating in Papua New Guinea with one additional mill under construction (Barema). There are also two Clean Development Mechanism (CDM) biogas projects constructed at NBPOL's Mosa and Kumbango sites and these are expected to be fully commissioned during 2012. There are six other proposed CDM biogas projects due to be constructed in the future at other sites within the PNG oil palm industry. NBPOL has two palm oil refineries (Liverpool, UK and Kumbango, PNG) that process exclusively CSPO as segregated identity-preserved oil.

The industry's focus on sustainable production of palm oil continues. NBPOL, Hargy Oil Palms Ltd and Ramu Agri-industries Ltd are all currently Round Table for Sustainable Oil Palm (RSPO) certified. For Kula Oil Palms Ltd, Poliamba is certified while Higaturu and Milne Bay await certification.

PNGOPRA is an Affiliate Member of the RSPO and has an important role to play in supporting PNG's plantations and smallholders in their commitment to sustainable development, particularly in the area of continuous improvement. PNGOPRA's research programme has been aligned with the RSPO Principles and Criteria and these are indicated for the various components of the research in this report.

PNGOPRA is an incorporated 'not-for-profit' research Association - a non-governmental organisation. The current Association membership comprises New Britain Palm Oil Limited (NBPOL), Kula Palm Oil Limited, Hargy Oil Palms Ltd, Ramu Agri-Industries Ltd and the Oil Palm Industry Corporation (OPIC). OPIC, through its Membership, represents the smallholder oil palm growers of PNG.

The Members of the PNGOPRA have full say in the direction and operation of the organisation and this ensures that PNGOPRA is responsive and accountable to the needs of its stakeholders. The organisation is truly demand driven. On the Board of Directors, NBPOL currently have one representative who represents all NBPOL interests and the other two organisations each have one representative. Each Member holds voting rights within the Board that reflect the Member's financial input to the organisation calculated on the previous year's FFB production (the PNGOPRA Member's Levy is charged on a FFB basis). Voting rights for 2012 are presented in Table 3.

Table 3. PNGOPRA Members Voting Rights in 2012

MEMBER	FFB Produced in 2011	VOTES	
		Number	%
New Britain Palm Oil Limited	959,432	**10**	33.3
Smallholders (OPIC)	873,954	**9**	30.0
Kula Palm Oil Ltd	567,822	**6**	20.0
Hargy Oil Palms PTY Ltd	228,597	**3**	10.0
Ramu Agri-Industries Ltd	89,000	**1**	3.3
Director of Research	n/a	**1**	3.3
TOTAL	2,718,805	**30**	100.0

A sub-committee of the Board of Directors, the Scientific Advisory Committee (SAC), meets once a year. It reviews and recommends to the Board the research programme for the coming year. Thus the Members can directly incorporate their research and technical service needs into the work programme of PNGOPRA. The Members voting rights within the SAC meeting are the same as for the Board of Directors meeting.

The Managing Director, Ian Orrell, left PNGOPRA at the end of April 2011 to set up the PNG Palm Oil Council (POC) which was incorporated on 21st September 2011. Ian Orrell is the Chief Executive Officer (Executive Director) of POC and he remains the public officer of PNGOPRA. The Head of Research, Bill Page, became Director of Research in May 2011.

OPIC is a statutory organisation responsible for the provision of agricultural extension for the smallholder oil palm growers. The link between PNGOPRA and smallholder extension is strong. As part of the PNG's National Agriculture Research System (NARS), both PNGOPRA and OPIC are included together as servicing PNG's smallholder oil palm growers.

PNGOPRA is financed by a levy paid by all oil palm growers and also by external grants. The total budgeted operating expenditure for PNGOPRA in 2012 is about K6.12 million. The Member's levy finances 92.5% of this expenditure and external grants 7.5%, although the latter has increased during 2012 because of outside funding for Bogia Coconut Syndrome (BCS) pathology and entomology research and also work on Plant Growth Regulators (PGRs). The Member's levy is set at a rate of K1.85 per tonne of FFB for all growers with an additional K0.15 collected for POC expenditure. In

2012 PNGOPRA's expenditure is distributed as 39.4% agronomy research, 23.5% entomology research, 12.9% plant pathology research, and 24.1% management and centralised overheads.

RESEARCH 2011

PNGOPRA continues to carry out work for the stakeholders in the Association. This means that PNGOPRA has to be flexible enough to meet the research and technical services needs of all the players within the whole of the PNG oil palm sector, both the smallholders and the plantation companies. All players are represented on the Scientific Advisory Committee (SAC) that meets to review PNGOPRA's current work and decide on future research proposals and prioritise them. Thus the Association addresses only the most significant restraints to the sustainable production of palm oil.

With the increasing influence of RSPO PNGOPRA, as an Affiliate Member, has taken on the Principals and Criteria set by RSPO and is actively involved in helping plantations and smallholders achieve certification and improve over time by research on improving plantation and smallholder practices, undertaking research on improved insecticides, environmental indicators, smallholder food security and understanding the constraints to smallholder production. The main text of this Annual Report shows which main RSPO Principals and Criteria are being addressed for each research and technical services work. For convenience, a summary of the RSPO Principals and Criteria, as adopted by the PNG's National Implementation Working Group and approved by RSPO's Executive Board, is found at the end of the Annual Report in Appendix 1. A matrix of which RSPO Principles and Criteria are addressed by each PNGOPRA study is also provided in Appendix 2.

Agronomy Programme

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

The bulk of the work undertaken by the Agronomy Team has been fertiliser response work. At most of the plantations there are trials in collaboration with our funding partners (Plantation Companies and Smallholder Sector). The types of trials established are different between areas and depend on where the gaps in knowledge are and soil type differences. A number of new trials started during the last 2-3 years at the various sites have taken into consideration possible effects of progenies on yield responses and therefore known progenies were planted for the trials. Trials in New Britain Palm Oil Ltd. (NBPOL) plantations in WNB were handed to OPRS to manage while PNGOPRA is concentrating on fertiliser/demonstration trials on smallholder blocks.

There are also several experiments looking at a) the effects of different spacing arrangements on yield, b) yield monitoring and forecasting. These non fertiliser related trials are very important in providing management information to the industry.

The Australian Centre for International Agricultural Research (ACIAR) funded project looking at sustainability of oil palm production in PNG started May 2010. As part of this project, Rachel Pipai has been studying for her masters at University of Adelaide in Australia looking at nitrogen fixation by legume cover crops under the oil palm systems in PNG. Another important project funded by AIGS (ARDSF project funded by AusAID) is looking at food security in smallholder farming systems. This was a joint project between PNGOPRA and OPIC. There was also another joint project between OPIC and PNGOPRA looking at raising fish in fish ponds in smallholder blocks in Oro Province. The two AIGS funded projects finished early in May 2012 when the ARDSF project was discontinued by AusAID. Funding is being sought for the continuation of the food security project. The other interesting project has been looking into the effect of plant growth regulators on ripening bunches.

There has also been an increased involvement in smallholder related activities. There are smallholder fertiliser-demonstration blocks in Hoskins, food security activities have started and are continuing in Oro, Hargy and Poliamba, collection of leaf tissues for analysis continue in Oro and have started in Hargy, and fertiliser demonstration blocks have been set up in Milne Bay and Poliamba. The aim here is to increase FFB yields in the smallholder sector from 10-15 t/ha/year to >25 t/ha/year.

Across all sites, there is continuous involvement in training for the industry. There has been increased PNGOPRA involvement with OPIC on smallholder field days and radio broadcasts. Training has also been carried out in the plantations on N Loss studies regarding timing and placement of fertiliser applications.

Entomology Programme
There was a reduction of reported infestations in 2011 compared with 2010. Operational visits by Entomology Section to smallholder blocks and plantations have continued and the required Pest Recommendations were produced. The treatment teams were generally well organised and worked efficiently under Smallholder Affairs Department of NBPOL. Plantation Groups managed their own teams and operations were effectively organised in New Ireland Province. No Targeted Trunk Injection (TTI) for oil palm pest control was undertaken on mainland PNG. The insect composition of pest reports remained similar to previous years, but there were changes in abundance among the commonest taxa.

The Bill and Melinda Gates Foundation BREAD project on entompathogenic fungi is progressing and Solomon Sar will be travelling to the US for training on the project. ACIAR funding has been made available for the study of Bogia Coconut Syndrome (BCS) vectors and this study in now under way.

Laboratory rearing and releases of parasitoids continued. Numbers produced and released were increased for *Doirania leefmansi* but numbers of *Leefmansia bicolor* released were low and the latter is being addressed. Success was achieved with the mass rearing for release of a parasitoid belonging to a previously undescribed species of Eupelmidae found in the eggs of *Eurycantha calcarata* (Giant Spiny Stick Insect) in West New Britain (WNB). There are now three new species of parasitiod being described in the literature. Field investigations of populations of *E. calcarata* have uncovered some useful new facts including that the stick insects roost in shaded areas in large numbers during the day.

Laboratory rearing studies on the life history and fecundity of the two main species of sexavae from WNB have also proved very useful in helping to develop a possible modification of the methodology for the trunk injection regime. Destructive palm sampling analysis has shown that there may be a correlation between activity in the lower and upper canopy. Work on alternative insecticides did not progress during 2011 due to staff constraints, but are being pursued during 2012.

All oil palm growing areas have now received an introduction of the new genetic line of pollinating weevils from the quarantine-reared stock originating from Ghana. Rearing has now ceased having fulfilled the objective of increasing genetic heterogeneity in the *E. kamerunicus* population.

A comprehensive review paper on *Ornithoptera alexandrae* (Queen Alexandra Birdwing Butterfly) has been co-authored by WW Page, CF Dewhurst and D Mitchell is near completion and will be published during 2012. A project framework for research on QABB has also been developed.

An SADP-funded project on "Aquatic ecosystem health: determination of indicators" has begun with the recruitment (SADP-funded) of an aquatic invertebrate specialist who is looking at invertebrate species as an indicator of water health.

Plans for the extension and upgrade of the Entomology Section building at Dami were submitted and approved for financing by NBPOL. Construction began in June 2012. A portable office/lab has been provided by the SADP project to ease space problems within Entomology.

Plant Pathology Programme

Work continued to concentrate on the epidemiology, population dynamics, physical and biological control of *Ganoderma boninense,* the fungus that causes Basal Stem Rot in oil palms. Basal stem rot is a difficult disease to control as infection cannot, at present, be identified until the symptoms appear.

Studies on the disease epidemiology have two main objectives (i) To determine the mechanism(s) of secondary spread of Ganoderma within plantations in order to apply this data to refine control methods (ii) To generate epidemiological models from survey data that will allow growers to make predictions of crop loss and economic thresholds in future plantings. The research on epidemiology will continue until the blocks under study are replanted. After this the new plantings will be monitored to delineate any pattern of infection compared with the previous plantings.

Monitoring of the effects of Ganoderma infection on yield continues. The theoretical threshold at which yield begins to decline in a mature oil palm crop is in the vicinity of 20% of crop loss. This threshold will be dependent on a number of factors including the age of the palms, planting density, nutritional status and prevailing weather conditions, however, a knowledge of the approximate level at which production begins to decline in different areas of PNG will provide a basis for future recommendations for replanting.

Blocks were designated Ganoderma Better Management Practice (BMP) blocks in an attempt to determine the effects of efficient and timely roguing on disease rates. Monthly surveys were conducted in BMP blocks and removals of all palms including suspect palms were also carried out on a monthly basis. The monthly disease surveys were ceased in December 2011. After 2.5 years, disease level in the untreated block were 20.9% compared to BMP block with a disease incidence of 16.7%

Biological control research continued, with funding from the ARDSF AIGS, to examine the use of indigenous fungus Trichoderma to suppress the growth of Ganoderma. The project came to an end in February 2012. Several species of the fungus Trichoderma are used throughout the world for the control of diseases in a number of crops. Control is based on the ability of Trichoderma to antagonize other fungi in a number of different ways such as parasitism, production of inhibitory volatile compounds and production of compounds that dissolve the hypha of other fungi. The project successfully delivered a product that can be used in the field for the control of basal stem rot and minimize future disease risk. The results from this project have set the basis for further development of the research that will assist in minimizing the impact of the disease.

The ACIAR funded project on screening for Ganoderma resistance continued in 2011 with the 3 field trials at GPPOL in Solomon Islands. Trial 1 tests the hypothesis that E.o x g hybrids are resistant to Ganoderma. Trials 2 and 3 test selfed progenies against a single Ganoderma isolate. Some progenies showed consistency in results against Ganoderma. None of the progenies were totally resistant with each showing degrees of partial resistance. In preliminary work, representative seedlings from each of 20 progenies were analysed by PCR analysis using microsattelite markers at the University of Queensland to assess the genetic diversity among parental lines and progenies from the various crosses used in a field trial in Solomon Is. The results of the genetic testing revealed that parental lines could be separated and some diversity in the microsattelite alleles was present.

Funding for the pathology work on Bogia Coconut Syndrome (BCS) has been mostly provided by the PNG Government through NAQIA. DNA extractions of samples collected from Bouganville and Morobe have been completed and analysis is underway.

A small nursery trial was set up in April 2012 to test the Mycogold (mycorhizzae) product. The trial will finish in October 2012.

Socio-economic programme

In 2011 the socio-economic section began work on a research project on Smallholder Engagement Strategy within the support framework of the Smallholder Agricultural Development Project (SADP). The object of the project is to determine the most effective and appropriate extension methodologies to apply in SADP project areas. The overall aim of the project is to produce a Smallholder Engagement Strategy for OPIC that will lead to more effective and efficient delivery of extension services.

Work continued, with OPIC and the World Bank, to standardise and introduce a new Clan Land Usage Agreement (CLUA) for use on Customary Rights Purchase Blocks. The majority of CRPB land transactions are informal and land surveys are rarely undertaken. Written agreements often do not specify the agreed 'sale' price of the land, the amount and timing of payment instalments, and the specific rights of the purchaser. Seldom is there any written evidence that the land 'sale' has the approval of the clan. This can lead to much misunderstanding and disputes between the 'purchaser' and the customary landowners. In most cases, the sales are not in accordance with customary law. Section 81 of the Land Act prohibits the sale of customary land except to citizens of PNG in accordance with customary law. Thus, unless the sale of the land can be shown to be in accordance with customary law then the sale is illegal. An illegal sale is not compliant with RSPO criteria. The new Clan Land Usage Agreement template addresses these legal issues.

Work was carried out during 2011on the smallholder project "Improving food security and marketing opportunities for women in smallholder cash crop production". Funding for the project was received from AIGS, an initiative of the Australian Government through the Agricultural Research and Development Support Facility (ARDSF). Because of the closing down of the ARDSF Project the AIGS funded project also had to come to a complete end by May 2012. Food and income security among oil palm smallholders in Papua New Guinea is central to the long term sustainability of the oil palm sub-sector. A major highlight from the project was the interest from farmers from the first day that the project was started. Field days were organised at each of the demonstration sites (established in 4 of the 6 oil palm growing areas: Popondetta, Kimbe, Bialla and New Ireland) and farmers were really interested because food security and land pressure are of major importance to them. There was also interest from other organisations such as milling companies and Provincial Health and DAL Departments on the results and outcome from this project. The implications here is that information gathered from the project has a wider application and not specific to Oil Palm Smallholder farmers only. Further funding is being sought to continue and expand the work.

Data from the household survey collected by the socio-economic section among smallholders at Hoskins, Popondetta and Bialla found that almost 55% of households are adopting new labour and payment arrangements on their block, which they term skelim hecta. The types of labour and payment arrangements operating on smallholder blocks have a significant impact on harvesting rates and block maintenance. Earlier studies conducted by the socio-economic section revealed that a major determinant of low smallholder productivity was the considerable level of under-harvesting. Under-harvesting leads to substantial production losses amongst smallholders and is a major cause of low productivity. Whilst low productivity is explained by low farm inputs in the smallholder sector (e.g. low rates of fertiliser application, delayed replanting, poor block maintenance, etc) and range of other socio-cultural factors, a key factor is high rates of under-harvesting. The types of labour and payment arrangements operating on a smallholder block are linked closely with smallholder harvesting strategies.

The socio-economics section hosted a three-day training workshop in Social Science Methods, titled "Qualitative, Quantitative and Mixed Methods Approaches" conducted by Gina Koczberski, George Curry and Sean Ryan from Curtin University, Perth. The training aims to improve the social science research skills of junior and middle-level research staff at PNG Oil Palm Research Association (PNGOPRA), the Cocoa and Coconut Institute (CCIL), the Coffee Industry Corporation (CIC) and the National Agricultural Research Institute (NARI). Each of the research staff attending the workshops is involved in collecting socio-economic data associated with ACIAR projects; however, none has had any formal training in social science research methods apart from the first introductory training workshop in 2009. The training was based on the tenet that through a better understanding of the socio-cultural and economic factors influencing smallholder farming practices, research will better reflect the needs and priorities of smallholders, and, therefore, be more successful in developing appropriate interventions to increase smallholder production.

1. AGRONOMY RESEARCH

HEAD OF SECTION: MUROM BANABAS

OVERVIEW

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

The bulk of the work undertaken by the Agronomy Team has been fertiliser response work. At each of the plantations a large number of trials in collaboration with our funding partners (Plantation Companies and Smallholder Sector). The types of trials established are different between for the different areas and depend on where the gaps in knowledge are and soil type differences. A number of new trials started during the last 2-3 years at the various sites took into consideration possible effects of progenies on yield responses and therefore known progenies were planted for the trials. Trials in New Britain Palm Oil Ltd. (NBPOL) plantations in WNB were handed to OPRS to manage while PNGOPRA is concentrating on fertiliser/demonstration trials on smallholder blocks.

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

The Australian Centre for International Agricultural Research (ACIAR) is funding a project looking at sustainability of oil palm production in PNG that started May 2010. As part of this project, Rachel Pipai has been studying for her masters at University of Adelaide in Australia looking at nitrogen fixation by legume cover crops under the oil palm systems in PNG. Another important project funded by AIGS (ARDSF project funded by AusAID) has been looking at food security in smallholder farming systems. This is a joint project between PNGOPRA and OPIC. There is also another joint project between OPIC and PNGOPRA looking at raising fish in fish ponds in smallholder blocks in Oro Province. The two AIGS funded projects finished early in April 2012 when the ARDSF project was discontinued by AusAID. The other interesting project has been looking into the effect of plant growth regulators on ripening bunches.

There has also been an increased involvement in smallholder related activities. There are smallholder fertiliser-demonstration blocks in Hoskins, food security activities have started and are continuing in Oro, Hargy and Poliamba, collection of leaf tissues for analysis continue in Oro and have started in Hargy, and fertiliser demonstration blocks have been set up in Milne Bay and Poliamba. The aim here is to increase FFB yields in the smallholder sector from 10-15 t/ha/year to >25 t/ha/year.

Across all sites, there is continuous involvement in training for the industry. There has been increased PNGOPRA involvement with OPIC on smallholder field days and radio broadcasts. Training has also been carried out in the plantations on N Loss studies regarding timing and placement of fertiliser applications.

HARGY OIL PALMS LTD

(Susan Tomda and Steven Nake)

SUMMARY

Fertiliser Response Trials with Hargy comprised of two main interests:

1. Factorial trial response to N, P, K and Mg: three factorial trials have been operational at Hargy for many years. One of the factorial trials (T205) did not include a N treatment, however, in 2007 two different rates of N were applied to this trial on half of the replicates.
   Outcome: N fertiliser increased FFB yield and other measured parameters (leaf tissues and vegetative parameters)
2. Systematic N trials: two systematic N trials have been established (one at Hargy and the other at Navo) to determine the optimum N rate for the volcanic soils at Hargy Oil Palm. The systematic trials are of similar design to those at NBPOL (see closed trial report-NBPOL).
   Outcome: the systematic trials are showing increase in FFB yield with increase in N rates. The response of N fertiliser will continue to increase as the tissue N levels in the control plots are starting to decrease.

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

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

A synopsis for the trial work undertaken with Hargy Oil Palms Limited is provided (Tables 1 and 2). A short recommendation for trial work operation and plantation management based on our results is also provided.

Table 1. Hargy Oil Palms Ltd: Synopsis of 2011 PNGOPRA trial results and recommendations

Trial	Palm Age	Yield t/ha	Yield Components	Tissue (% dm)	Vegetative	Notes
205 Hargy EFB,TSP,KIE,AMC (factorial) Soil: Volcanic ash	18	29.8 to 31.7	B/ha: 1090-1187 SBW: 26.9-27.8 kg	LN:2.40-2.50; RN:0.34-0.36 LP:0.142-0.164; RP:0.09-0.20 LK:0.64-0.66; RK:1.56-1.70 LMg:0.16-0.20 ; LB:18.8-19.7ppm	PCS:53.52-57.3 GF:33-34 FDM:16.2-17.8 BDM:15.5-16.6	2.3t/ha yield increase in 2011 by applying 4.6 kg AN. No yield benefits of applying EFB in combination with AN, TSP or KIE.
211 Navo AN (Sytematic) Soil: Volcanic ash	13	25.2 to 32.8	B/ha:1209-1413 SBW:20.8-23.5 kg	AN LN:2.15-2.49; RN:0.3-0.37 LP:0.133-0.144; RP:0.06-0.07 LK:0.69-0.74; RK:1.98-2.15 LMg:0.18 ; LB:22ppm	PCS:35.9-45.7 FP:23 to 24 (NS) LAI:4.92-5.70	Large increase in yield in 2007-2009. 6 t/ha average drop in 2010 Significant response in N fertiliser over time Boron –high, rachis K-high
212 Hargy AN (Systematic) Soil: Volcanic ash	13	23.0 to 26.5	B/ha:923-1062 SBW:22.9-25.8 kg	AN LN:2.25-2.47; RN:0.29-0.35 LP:0.137-0.144; RP:0.04-0.05 LK:0.61-0.67;	PCS:40.6-49.8 FP:19-21 (NS) LAI:5.8 -6.8 BDM:23-26.5	2-5 t/ha increase in 2011, High rachis K

				RK:1.67-1.84 LMg:0.18 ; LB:16ppm		
214 Hargy TSP placement Soil: Volcanic ash	17	20.0-24.9	B/ha:839-974 SBW:24.0-25.3	LN:2.29-2.39; RN:0.22-0.23 LP:0.134-0.137; RP:0.04 LK:0.61-0.65; RK:1.03-1.11 LMg:0.17-0.18 ; LB:15ppm	PCS:41.3-43.3(NS) FP:22 (NS) LAI:6.4-6.8 BDM:10.3-11.3	4 t/ha drop in yield in 2011. No significant response in yield, its components, vegetative growth and all nutrient concentrations except Rachis P

Table 2. Apparent adequate tissue nutrient levels:

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

Recommendations to Hargy Oil Palm:

- At Hargy 30+ t/ha FFB should be attainable in matured plantations. Improved agronomic practices have resulted in good crop recovery with FFB yield > 35 t/ha in some of the treated plots.
- Leaf tissue analysis and physiological growth measurements will help in determining limiting factors in the particular soils.
- Most of the focus for nutrition should be on N, followed by K and P. Tissue Mg levels appear to be adequate.

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

SUMMARY

The FFB yields and bunches per hectare (BHA) were significantly ($p<0.05$) increased by nitrogen (AN) application. A yield response of up to 2.3 t/ha was obtained at the higher level of AN (4.6 kg/palm). BHA was increased by 114 bunches when the AN rate was increased from 2.3 kg/palm to 4.6 kg/palm. While EFB application increased single bunch weight (SBW) by 1 kg, TSP and KIE showed no significant effect on the yield, BHA and SBW. Some nutrient levels in the leaflets and rachis were increased by the fertiliser treatments in 2011. Similarly, some of the vegetative parameters were also affected by the fertiliser treatments. There was no yield benefits of applying EFB in combination either AN, TSP and KIE.

BACKGROUND

The purpose of the trial is to investigate the response of oil palm to the application of EFB and nitrogen, and to investigate whether the uptake of phosphorus (P) and magnesium (Mg) from TSP and KIE can be improved by applying the fertilizer in conjunction with EFB. Fertilizer responses in trials can lead to more accurate fertilizer recommendations for oil palm grown on volcanic soils at Bialla. Table 1 provides background information to the trial.

Table 1. Trial 205 background information.

Trial number	**205**	Company	Hargy Oil Palm Ltd
Estate	Hargy	Block No.	Area 9, Blocks 7 & 8
Planting Density	135 palms/ha	Soil Type	Volcanic
Pattern	Triangular	Drainage	Free draining
Date planted	1993	Topography	Gently sloping
Age after planting	18 years	Altitude	120 m asl
Treatments 1st applied	June 1997	Previous Land-use	Oil Palm
Progeny	Known*	Area under trial soil type (ha)	
Planting material	Dami D x P	Agronomist in charge	Susan Tomda

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

METHODS

Experimental design and treatments

The EFB x P x Mg x N trial was set up with two rates of each organic/inorganic fertilizer in a factorial design, replicated three times resulting with 48 plots (Table 2). The N treatment was included in late 2007 because the palms were found to be N deficient (based on tissue test analysis). Nitrogen was then applied at a basal rate of AC at 3kg/palm in previous years. On half the number of replicates (ie. on three out of the six original replicates) the N rate was increased to 9 kg of AC/palm for 2008 only (the other replicates continued to receive 3 kg AC/palm). After 2008, the high AC treatment was reduced 6 kg/palm and applied at that rate since then. Extra N fertilizer (6 kg/palm) was applied on replicates 2, 4 and 6; while replicates 1, 3 and 5 continued to receive 3 kg/palm. In 2011, N source was changed to Ammonium nitrate (AN). Each plot has 36 palms and recordings and measurements were taken on the central 16 palms. The recorded palms consist of 16 different identified Dami DxP progenies, which have been arranged in a random spatial configuration in each plot.

Statistical Analysis

Yield and its components and tissue nutrient concentration were analysed using ANOVA (General Analysis of Variance). Basal fertilizer applied in 2011 was MOP at 2kg/palm and Borate at 150g/palm.

Table 2. Fertilizer and EFB treatments applied in Trial 205 in 2011

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

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

Data Collection

The number of bunches and bunch weights were recorded fortnightly on an individual palm basis. Leaf sampling was carried out according to standard procedures and analysed for nutrient concentrations using standard analytical procedures. Physiological growth parameters (frond length, petiole cross section, leaflet width and length, number of leaflets on one side of the frond, frond production rate) were done on frond 17. Frond production was done twice a year (every 6 months). The palm height was also measured to calculate height increment each palm per year.

RESULTS

FFB yield and its components - mean trend over time

The FFB yields from the trial block suffered a yield loss of about 11.5 t/ha in 2002, after reaching its maximum of 43 t/ha in 2001. Despite the peaks and troughs observed in the yield after 2002 (2002-2011), the yields have generally exhibited an inclining trend. In 2011, there was a slight increase in FFB yields. The single bunch weights experienced a gradual increase from 1997 to 2011. As palms mature, individual bunch weights are expected to increase. The bunch number per hectare experienced a drastic drop by 15% from 1997 to 2002. Thereafter, the bunch number was maintained between 1100 and 1500 bunches (Fig.1).

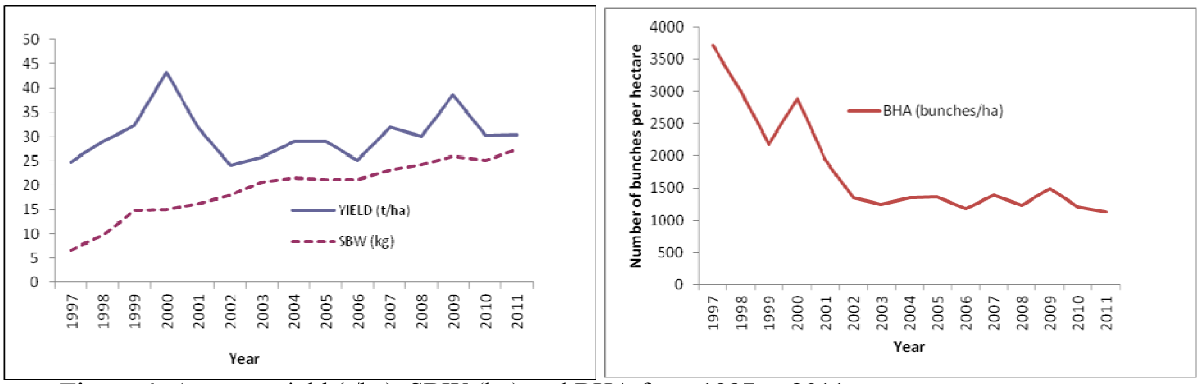

Figure 1. Average yield (t/ha), SBW (kg) and BHA from 1997 to 2011

Yield response to fertiliser treatments in 2011

A significant (p=0.033) yield response of 2.3 t/ha of FFB to AN was recorded in 2011 (Table 3 and Figure 2) and this was due to a significant increase in BHA (p=0.008). There were no FFB yield responses to EFB, TSP and KIE treatments, however SBW was increased by EFB (p=0.031). EFB applied in combination with AN, TSP and KIE fertilizers continued to show no significant effects on FFB yield, BHA and SBW in 2011. Despite that, some levels of significant interaction between the inorganic fertilizers (AN, TSP, KIE) were also observed (Table 4). There was evidence of antagonistic effect between TSP and KIE (Table 4). When TSP was applied in the absence of KIE or vise versa, FFB yields were improved (increased), however, when both fertilizers (TSP/KIE) were applied in combination, FFB yields were reduced.

Table 3. Treatment effects (main) on yield and its parameters in 2011 and 2008-2011. Significant effects (values) are shown in bold.

		2011			2008-2011		
Treat Levels	Rate (kg/palm)	Yield (t/ha)	BHA (bunch/ha)	SBW (kg/bunch)	Yield (t/ha)	BHA (bunch/ha)	SBW (kg/bunch)
AN-1	2.3	**29.4**	**1073**	27.7	31.4	1243	25.5
AN-2	4.6	**31.7**	**1187**	27.0	33.3	1290	25.9
EFB-0	0	30.7	1151	**26.9**	32.3	1262	25.6
EFB-1	230	30.4	1109	**27.8**	32.5	1271	25.7
TSP-0	0	31.3	1170	27.1	32.8	1295	25.5
TSP-1	3	29.8	1090	27.6	31.9	1238	25.9
Kie-0	0	30.7	1141	27.5	32.5	1279	25.6
Kie-1	3	30.4	1119	27.2	32.2	1254	25.7
Significance		**p=0.033**	**p=0.008**	**p=0.031**	NS	NS	NS
LSD		2.1	82	0.82	-	-	-
CV %		11.6	12.3	5.1	8.0	8.0	4.9

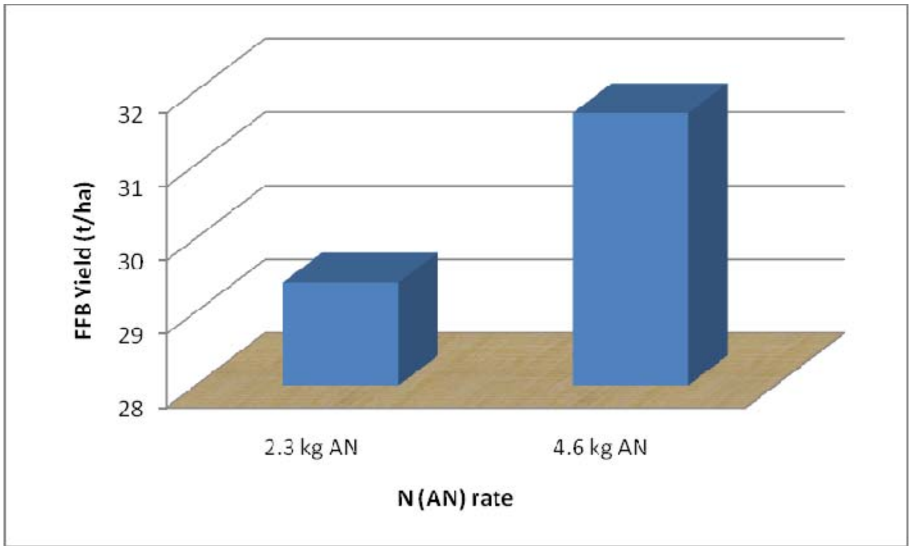

Figure 2. Yield response to 2.3 kg/palm and 4.6 kg/palm AN in 2011

Table 4. Two-way interaction between TSP x KIE and their effects on FFB yield in 2011

	TSP-0	**TSP-1**
KIE-0	30.4*a*	31.0*a*
KIE-1	32.3*a*	28.6*a*
P=0.044		
LSD = 3.0		

Note: Same letter denote means are not different even though the results are significant

Effect of fertilizer treatments on Tissue nutrient concentration in 2011
The impact of fertilizer on tissue nutrient concentrations is presented in Table 4:

- AN increased leaflet N and P, and rachis K while reducing leaflet Mg contents.
- EFB increased leaflet N only (EFB as a mulch breaks down and releases mineral N, P and K)
- TSP increased rachis P contents
- Kieserite increased leaflet Mg contents

Nitrogen fertiliser played an important role in raising the nutrient levels in both the leaflets and rachis when it was included as a treatment in 2007. By 2009 (1-2 years after N was applied), both leaflet and rachis N and P have increased steadily (Figure 3). By 2010, both leaflet and rachis N were elevated to the adequate levels of 2.45% and 0.32 %, respectively. Similarly, leaflet and rachis P were also pushed into the adequate range (0.145 and 0.08%) respectively.

Apart from the main treatment effects in Table 5, two-way interaction between EFB x AN significantly (p=0.017) affected the leaflet N levels. By applying EFB and 2.3 kg AN (AN-1), leaflet N can be raised to its adequate level (Table 6).

Table 5. Tissue nutrient concentration for Trial 205 in 2011 (figures in bold are significantly different).

Fertiliser Level	Leaflet (% dm)				Rachis (% dm)		
	N	**P**	**K**	**Mg**	**N**	**P**	**K**
AN-1	**2.40**	**0.142**	0.65	**0.19**	0.34	0.160	**1.56**
AN-2	**2.50**	**0.164**	0.65	**0.18**	0.36	0.130	**1.70**
EFB-0	**2.42**	0.155	0.64	0.18	0.34	0.136	1.63
EFB-1	**2.47**	0.152	0.66	0.18	0.35	0.153	1.64
TSP-0	2.44	0.150	0.66	0.18	0.33	**0.092**	1.69
TSP-1	2.45	0.156	0.64	0.18	0.36	**0.198**	1.58
KIE-0	2.44	0.148	0.66	**0.16**	0.35	0.154	1.63
KIE-1	2.46	0.159	0.64	**0.20**	0.34	0.135	1.64
$LSD_{0.05}$	0.06	0.019	NS	0.009	NS	0.061	0.133
CV%	4.0	21.6	7.5	8.4	16.6	71.1	13.8

Table 6. Two-way interaction between EFB x AN and their effects on Leaf N levels in 2011

	AN-1	**AN-2**
EFB-0	2.34*b*	2.51*a*
EFB-1	2.46*a*	2.49*a*
P=0.017		
LSD = 0.08		

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

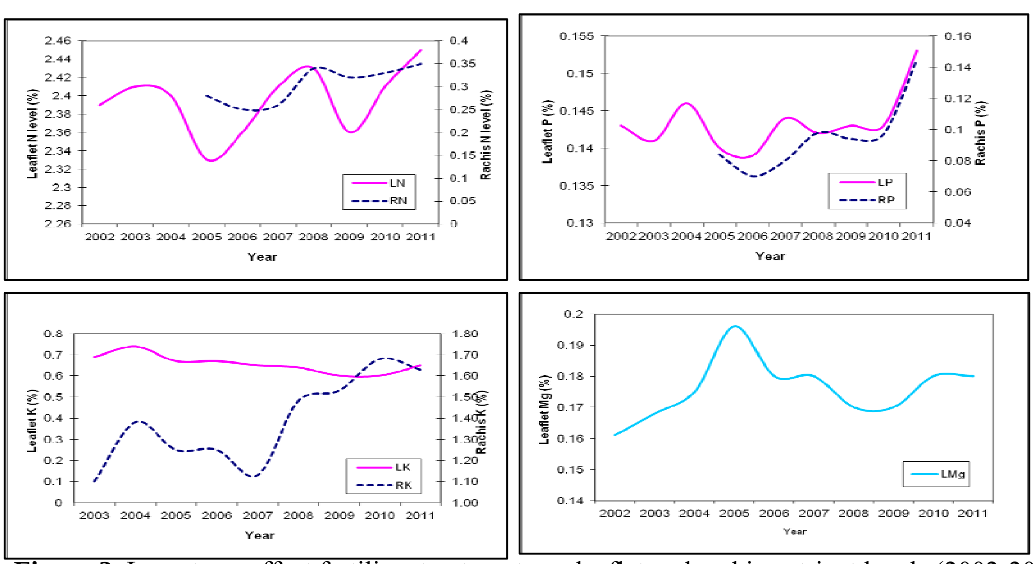

Figure 3. Long term effect fertiliser treatments on leaflet and rachis nutrient levels (2002-2011)

Effects of fertilizer treatments on vegetative growth parameters

AN application in 2011 had significant effects on 6 out of the 9 vegetative growth parameters measured. The number of green fronds (GF) also responded significantly to TSP (Table 7). The parameters that responded to AN and TSP are shown in Table 8. AN increased the size of the petiole (PCS), number of green fronds (GF) on the palm and the palm dry matter production (FDM, BDM, TDM and VDM). TSP also increased the number of green fronds (GF) on the palms. EFB when applied in combination with KIE, AN and KIE did have significant effects ($p<0.05$) on number of green fronds and LAI.

Table 7. Effect (p values) of treatments on vegetative growth parameters in 2011. P values less than 0.05 are in bold.

Fertilizer	PCS	Radiation Interception				Dry Matter Production (t/ha)			
	(cm^2)	**GF**	**FP**	**FA**	**LAI**	**FDM**	**BDM**	**TDM**	**VDM**
AN	**0.050**	**0.008**	0.096	0.868	0.091	**0.030**	**0.049**	**0.002**	**0.020**
EFB	0.654	0.095	0.986	0.315	0.823	0.712	0.754	0.916	0.728
TSP	0.871	**0.004**	0.070	0.916	0.127	0.643	0.129	0.528	0.729
KIE	0.398	0.872	0.860	0.419	0.537	0.419	0.783	0.612	0.427
EFB.KIE	0.050	0.352	0.521	0.268	0.756	0.123	0.895	0.217	0.122
EFB.N	0.896	0.317	0.711	0.947	0.569	0.807	0.746	0.672	0.786
KIE.N	0.633	0.315	0.988	0.712	0.433	0.654	0.163	0.575	0.733
EFB.TSP	0.222	**0.013**	0.788	0.316	**0.046**	0.313	0.935	0.361	0.306
KIE.TSP	0.216	0.481	0.557	0.145	0.167	0.193	**0.043**	0.789	0.249
N.TSP	0.693	0.638	0.950	0.932	0.858	0.747	0.854	0.879	0.756
EFB.KIE.N	0.394	**0.037**	0.492	0.053	0.841	0.314	0.909	0.350	0.305
EFB.KIE.TSP	0.840	0.974	0.429	0.216	0.396	0.675	0.591	0.999	0.703
EFB.N.TSP	0.166	**0.048**	0.571	0.645	0.418	0.285	0.440	0.688	0.308
KIE.N.TSP	0.136	0.966	0.748	0.205	0.392	0.150	0.924	0.242	0.148
EFB.KIE.N.TSP	0.676	0.451	0.516	0.808	0.611	0.882	0.152	0.277	0.791
CV %	13.0	3.6	4.7	4.4	6.6	14.4	11.9	8.7	14.1

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

Table 8. Effect of AN and TSP on selected vegetative parameters with significant response ($p<0.05$)

Fertiliser (kg/palm)	PCS (cm^2)	GF	FDM (t/ha)	BDM (t/ha)	TDM (t/ha)	VDM (t/ha)
AN2.3	53.2*a*	33.0*b*	16.2*b*	15.5*b*	35.2*b*	19.7*b*
AN4.6	57.3*a*	34.0*a*	17.8*a*	16.6*a*	38.2*a*	21.6*a*
LSD	*4.2*	*0.70*	*1.4*	*1.0*	*1.9*	*1.6*
TSP0		32.9*b*				
TSP3		34.0*a*				
LSD		*0.70*				

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

DISCUSSION

The initial objective of the trial was to see if EFB when applied in combination with TSP and KIE will have any positive effects on both yield and growth of the oil palm. When palms started to show signs of N deficiency, nitrogen was taken on as a treatment in late 2007. Since then, the leaflet N levels have gradually increased and the palms have improved. Similarly, yields have responded positively to nitrogen fertilisers and we are starting to see responses by other yield components (BHA and SBW). Since application of N, the vegetative growth parameters have responded well to the nitrogen and the other fertilisers as well, especially TSP. Nitrogen is the main driver for growth and production of the oil palm. It was established from tissue results, yield and fertiliser inputs from trial 511 in Milne Bay that applying P or K without N will result in the accumulation of P or K in the rachis without there being a yield benefit (2006 Annual Report). The responses in the last couple of years could have been due to other covariates. It is obvious from the 2011 results that the observed parameters (yield, leaf tissues and vegetative parameters) are starting to respond to the treatments, especially N (AN) effect on the FFB yields, leaf/rachis N levels and vegetative parameters. However, the effect of combining EFB application with other fertilisers (AN, TSP and KIE) have not shown any significant effect on the yields, but are starting to show on the leaflet levels and the vegetative growth parameters.

CONCLUSIONS

There has not been any significant interaction between EFB application and the other inorganic fertilisers (AN, TSP, KIE) on FFB yields in 2011. However, the results are starting to show some significant benefits of applying EFB in combination with AN, TSP and KIE on tissue levels and vegetative growth parameters. When considering the main treatment effects, FFB yields and BHA were significantly increased by nitrogen (AN). The N fertiliser (AN) had also increased leaflet N, P and Mg.

Trial 211: Systematic N Fertiliser Trial on Volcanic soils, Navo Estate (RSPO 4.2, 4.3, 4.6, 8.1)

SUMMARY

This is a systematic N fertiliser trial established to investigate effects of applying 9 different rates of N (0-2.0 kg N/palm) on oil palm growth and production. A 7 t/ha yield response resulted from the application of 3.7 kg/palm AN (1.25 kg N/palm) in 2011. There was a drop in yield of 2-4 t/ha in 2010 and this was due to drop in bunch numbers (bunches/ha), however single bunch weight (kg/ha) remained steady. Regardless of the N fertiliser rates, an average yield of 30 t/ha was obtained at 2.22 kg AN/palm. Even some of the trial treatments archived a yield of around 37 t/ha. N application had significant effect in leaflet N and dry matter production.

INTRODUCTION

Factorial fertiliser trials with randomised spatial allocation of treatments have been generally showing poor responses to fertilisers in NBPOL trials since late 1980s. Yields and tissue nutrient concentrations in control plots have been generally higher than would be expected. It is suspected that fertiliser may be moving from plot to plot (nutrient poaching). Large plots, guard rows and trenches between plots were introduced to avoid poaching of nutrients between plots, but lack of response persisted. Systematic designs are seen as a way of avoiding this problem, by ensuring that high and low rates of application are not adjacent. The purpose of the trial is to provide a response curve to N fertiliser that will be used to determine optimum N input in the area.

Table1. Trial 211 background information.

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

METHODS

Experimental Design and Treatments

This trial was established at Navo in 2001. The Nitrogen systematic trials have been designed especially for coarse textured volcanic soils to minimize the effect of fertiliser applied to one plot having an effect on the adjacent plot. The systematic design treatment structure of 9 rates of N x 8 replicates, resulting in 72 plots. For each replicate, 9 treatments were randomly allocated to 72 plots. The rates applied increase from 0 to 2kg N/palm in 0.25kg N/palm increments (equivalent to 0 to

5.92kg AN/palm at 0.74kg AN/palm increments). The trial is designed such that in each adjacent replicate block the N rates increase or decrease systematically (Figure 1). Each plot consisted of 4 measured rows of palms with 13 palms each resulting in 52 palms/plot. The trial at Hargy has the same design as trials 137 and 138 with NBPOL.

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

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

decrease - increase

increase - decrease

Figure 1. N rate increase and decrease and increase systematically (N rate increments are at 0.25kg N/palm)

Table 2. Nitrogen treatments and rates

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

Data Collection

Recordings and measurements were taken on the central 16 palms in each plot. The number of bunches and bunch weights were recorded at 10 day harvesting intervals (started in 2011) in line with company practice on an individual palm basis and totalled for each plot, then totalled for each harvest and expressed as per ha per year. Single bunch weight (SBW) was calculated from these data. Leaf sampling was carried out once annually according to standard procedures and analysed for nutrient concentrations using standard analytical procedures. Vegetative measurements, including height measurement and frond production (frond mark and frond count) were also done annually. Quality checks were also done every month on yield recording and other vegetative parameters (leaf sampling, height measurement, frond production and trial block assessment.

Statistical Analysis

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

RESULTS

Effects of treatments on FFB yield and its components

In 2011, the effects of N fertiliser rates on yield, number of bunches per hectare and single bunch weights were all significant ($p<0.001$). Similarly, the fertiliser effect on the 3 year means (2009-2011) were also significant (Table 3). Generally, the yields increased with increasing rates of AN fertiliser with a yield response of 2.0 to 6.0 t/ha in 2011 and 2.9 to 7.9 t/ha in 2009-2011 respectively (Table 3). The responses were also similar for the last five years' (2006-2010) running average.

Table 3. Main effects of treatments on FFB yield (t/ha), Bunch number (b/palm and b/ha) and SBW (kg/bunch) by N rate for 2011 and 2009-2011. P values <0.05 are in bold.

		2011			2009-2011		
N rate (kg/palm)	**Equivalent AN rate (kg/palm)**	**FFB yield (t/ha)**	**BNO/ha**	**SBW (kg)**	**FFB yield (t/ha)**	**BNO/ha**	**SBW (kg)**
0	0.0	**25.2**	**1209**	**20.8**	**28.6**	**1430**	**20.0**
0.25	0.74	**27.2**	**1257**	**21.6**	**31.5**	**1508**	**20.9**
0.5	1.48	**28.5**	**1279**	**22.3**	**33.0**	**1554**	**21.4**
0.75	2.22	**30.0**	**1331**	**22.6**	**34.5**	**1582**	**21.9**
1.0	2.96	**32.2**	**1413**	**22.8**	**36.0**	**1649**	**21.9**
1.25	3.70	**32.5**	**1394**	**23.3**	**36.9**	**1648**	**22.5**
1.5	4.44	**31.4**	**1357**	**23.1**	**35.7**	**1620**	**22.1**
1.75	5.18	**32.8**	**1394**	**23.5**	**37.8**	**1685**	**22.5**
2.0	5.92	**31.2**	**1345**	**23.1**	**36.5**	**1654**	**22.1**
Grand Mean		30.1	1332	22.6	34.5	1591	21.7
Significance		**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**
LSD		2.3	78.5	0.78	2.21	85.9	0.67
CV %		7.6	5.9	3.4	6.4	5.4	3.1

Yield response over time

By applying N, gradual and noticeable increase in yield occurred from 2003 (palm age: 5 years) to 2009 (palm age: 11 years) but dropped to about 4 t/ha in 2010. A slight increase in yield of 2-4 t/ha was observed in 2011 (Figure 2).

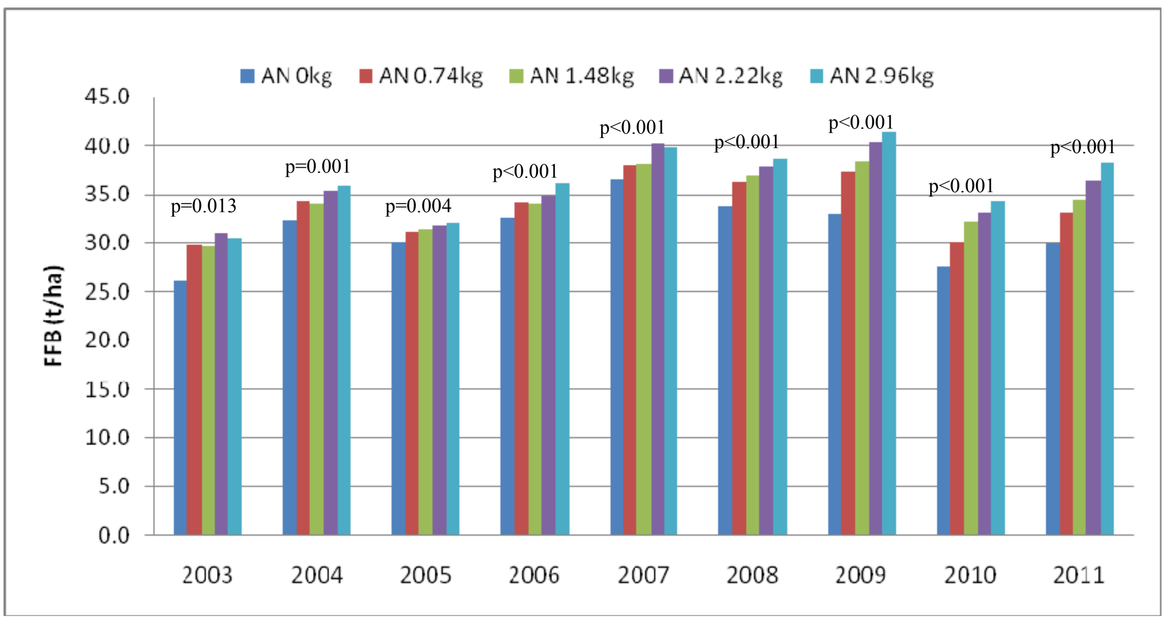

Figure 2. Yield response to 5 rates of N(kg/palm) over time (fertiliser N was first applied in late 2002)

Effects of treatments on leaf (F17) nutrient concentrations

Tissue nutrient concentration was investigated for both leaflets and the rachis (Table 4). Leaflet N and Rachis N increased with N rates (p<0.001) whilst there was no significant effect of N on leaflet K and B, and Rachis P and K. Leaflet Mg was also significant (p<0.001) and Boron levels are high (22 ppm) but not significant.

Table 4. Effects (p values) of treatments on frond 17 nutrient concentrations in 2011. P values less than 0.05 are in bold.

N rate (kg/palm)	Equivalent AN rate (kg/palm)	Leaf (% dm)					Rachis (% dm)		
		N	P	K	Mg	B (ppm)	N	P	K
0.00	0.00	**2.26**	**0.136**	0.69	**0.193**	23.1	**0.320**	0.078	2.15
0.25	0.74	**2.15**	**0.133**	0.69	**0.206**	24.0	**0.299**	0.062	2.09
0.50	1.48	**2.26**	**0.135**	0.71	**0.189**	24.2	**0.305**	0.064	2.04
0.75	2.22	**2.34**	**0.137**	0.71	**0.179**	22.2	**0.295**	0.061	1.98
1.00	2.96	**2.42**	**0.140**	0.71	**0.171**	21.8	**0.326**	0.067	2.10
1.25	3.70	**2.47**	**0.143**	0.73	**0.161**	21.2	**0.330**	0.067	2.11
1.50	4.44	**2.47**	**0.142**	0.73	**0.171**	21.5	**0.359**	0.071	2.14
1.75	5.18	**2.49**	**0.144**	0.73	**0.169**	20.3	**0.348**	0.072	2.07
2.00	5.92	**2.42**	**0.144**	0.74	**0.164**	21.0	**0.365**	0.070	2.12
Grand Mean		2.37	0.139	0.71	0.178	22.2	0.327	0.068	2.09
Significance		**<0.001**	**<0.001**	0.06	**<0.001**	0.13	**<0.001**	0.092	0.73
LSD		0.09	0.004	-	0.02	-	0.284	-	-
CV %		4.0	3.0	5.7	9.3	13.6	8.7	16.6	8.7

Tissue N concentration over time - 2004 to 2011

The mean leaflet N contents fell with time from 2.70 % in 2004 to 2.30 % in 2011 (Table 5). The low N rates (0, 0.25 and 0.75 kg N/palm) have fallen below critical levels in 2011. Leaflet N levels are slowly changing over time with control treatment (0kg/palm) now reaching low levels whereas the highest rates of N is maintaining good leaflet N status from 2004 to 2009 but below critical level in 2010 and 2011 respectively.

Table 5. Leaflet N (% dm) over time.

N rate (kg/plm)	Equivalent AN rate (kg/plm)	Leaflet N (%DM)							
		2004	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
0	0	2.66	2.60	2.44	2.40	2.36	2.25	2.20	2.26
0.25	0.74	2.67	2.63	2.46	2.48	2.38	2.29	2.21	2.15
0.5	1.48	2.72	2.65	2.51	2.51	2.46	2.37	2.31	2.26
0.75	2.22	2.72	2.67	2.50	2.53	2.49	2.42	2.34	2.34
1	2.96	2.71	2.68	2.52	2.57	2.54	2.45	2.40	2.42
1.25	3.7	2.71	2.66	2.51	2.56	2.56	2.50	2.40	2.47
1.5	4.44	2.67	2.69	2.54	2.60	2.57	2.46	2.38	2.47
1.75	5.18	2.69	2.68	2.50	2.57	2.57	2.52	2.41	2.49
2	5.92	2.72	2.65	2.52	2.56	2.46	2.54	2.40	2.41
Grand mean		2.70	2.66	2.50	2.53	2.49	2.42	2.34	2.37
Significance		**NS**	**p=0.02**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**
LSD		-	0.05	0.08	0.04	0.09	0.08	0.08	0.09
CV %		2.1	1.9	2.2	1.5	3.6	3.3	3.3	4

Effects of fertiliser treatments on Vegetative parameters

The nitrogen rate treatment had significant effects on PCS (p<0.001), FA (p=0.005), LAI (p<0.001), FDM (p=0.04), BDM (p<0.001),TDM (p<0.001) and VDM (p<0.001) (Table 6). An average of 24 new fronds were produced in 2011 (one in every 15 days), indication of good growing conditions during the year. Total green fronds counted per palm averaged at 34 fronds which is slightly low. AN fertiliser application had no clear effects on either parameters measured. The two assessment of canopy coverage, Frond area (based on leaflet length and width) and LAI (Leaf Area Index) as based on Frond area, frond number and palms per ha, were within the expected range for 13 year old palms (average frond area 13m^2 and LAI 5.5). Both FA and LAI were affected by the AN fertiliser applied (p=0.005 and P<0.001) respectively.

Table 6. Main effects of N treatments on vegetative growth parameters in 2011. Significant effects (p<0.05) are shown in bold

N rate Kg/palm	Equiv- AN rate kg/palm	Radiation Interception PCS	GF	FP	FA	LAI	Dry matter production (t/ha/yr) FDM	BDM	TDM	VDM
0.00	0	**35.9**	**33.6**	24.4	**12.8**	**4.92**	**10.8**	**14.4**	**28.0**	**13.6**
0.25	0.74	**37.7**	**34.6**	24.7	**13.3**	**5.31**	**11.5**	**15.7**	**30.2**	**14.5**
0.50	1.48	**39.1**	**33.0**	23.4	**13.7**	**5.18**	**11.2**	**16.3**	**30.6**	**14.3**
0.75	2.22	**41.9**	**35.1**	25.6	**13.5**	**5.44**	**13.2**	**17.2**	**33.8**	**16.6**
1.00	2.96	**45.7**	**34.8**	23.8	**13.8**	**5.51**	**13.2**	**18.5**	**35.2**	**16.7**
1.25	3.7	**43.0**	**35.4**	23.2	**13.9**	**5.65**	**12.2**	**18.6**	**34.2**	**15.6**
1.50	4.44	**43.4**	**35.8**	23.9	**14.0**	**5.78**	**12.7**	**18.0**	**34.1**	**16.1**
1.75	5.18	**41.5**	**35.2**	23.1	**13.7**	**5.55**	**11.8**	**18.9**	**34.1**	**15.2**
2.00	5.92	**41.9**	**35.7**	23.8	**13.9**	**5.70**	**12.3**	**17.8**	**33.4**	**15.6**
Grand Mean		41.1	34.8	24.0	13.6	5.45	12.1	17.24	32.6	15.4
Significance		**<0.001**	**0.001**	0.602	**0.005**	**<0.001**	**0.04**	**<0.001**	**<0.001**	**0.011**
LSD		3.4	1.39	-	0.6	0.362	1.6	1.3	2.35	1.8
CV %		8.3	4.0	10.6	4.5	6.6	13.3	7.6	7.2	11.7

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

DISCUSSION

Nitrogen (N) is an important nutrient for both oil palm yield and growth. N fertiliser elevated yields to more than 25t/ha in 2011. Yields of over 30 t/ha were realized at N rates more than 0.7kg N/palm (equivalent of more than 2.0 kg AN/palm). The optimum yield of 32.5 t/ha was achieved at 1.25 kg N/palm (equivalent of 3.70kg/palm AN). There was drop in FFB yield (6-8 t/ha) in 2010 compared to 2009 yield, however a slight increase was evident in 2011.

Leaf N levels in each treatment have been gradually falling over the years. The results in 2010 and 2011 indicated the N leaflet levels in the three lowest N treatments plots (0.00, 0.25, & 0.50 kg N/palm) were deficient, (critical level 2.30%). This was also obvious with the visible symptoms in the field. The N fertiliser had improved the growth of the palm in the vegetative dry matter production of the oil palm.

CONCLUSION

Effects of treatments (N) on FFB yield (t/ha) were significant in 2011 and this positive response had been consistent since record started in 2003. N rate treatment had significant effects on yield, tissue N, P, Mg and most physiological growth parameters. Leaflet N contents and yield in the low N rate plots have been falling with time. Increase N rate from 0.74 – 5.92 kg/palm to higher rates increased yield, PCS, GF, FA, LAI, FDM, BDM, TDM and VDM. N fertiliser increased the PCS which is a primary indicator of N fertility.

Trial 212: Systematic N Fertiliser Trial on Volcanic soils, Hargy Estate (RSPO 4.2, 4.3, 4.6, 8.1)

SUMMARY

Trial 212 is a systematic Nitrogen (N) fertiliser trial established in 2002 at Hargy estate to investigate effects of applying 9 different rates of N (0 – 2.0 kg N/palm) on oil palm growth and production. A 3.5 t/ha yield response resulted from the application of 4.44kg/palm AN (1.50 kg N/palm. Regardless of the N fertiliser rates, optimum yield for the trial block was achieved at more than 25t/ha – at a rate of 2.22kgs AN/palm. Similarly, leaf N and P levels significantly increased with N application.

INTRODUCTION

Factorial fertiliser trials with randomised spatial allocation of treatments have been generally showing poor responses to fertilisers in NBPOL trials since late 1980s. Yields and tissue nutrient concentrations in control plots have been generally higher than would be expected. It is suspected that fertiliser may be moving from plot to plot (nutrient poaching). Large plots, guard rows and trenches between plots were introduced to avoid poaching of nutrients between plots, but lack of response persisted. Systematic designs are seen as a way of avoiding this problem, by ensuring that high and low rates of application are not adjacent. The purpose of the trial is to provide a response curve to N fertiliser that will be used to determine optimum N input around Hargy area.

Table 1. Trial 212 background information.

Trial number	**212**	Company	Hargy Oil Palms Ltd.
Estate	Hargy	Block No.	Area 8, blocks 10 and 11
Planting Density	140 palms/ha	Soil Type	Volcanic
Pattern	Triangular	Drainage	Free draining
Date planted	Feb 1996	Topography	Moderate slope
Age after planting	13 years	Altitude	103 m asl
Treatments 1st applied	2002	Previous Land use	Oil palm
Progeny	unknown	Area under trial soil type (ha)	
Planting material	Dami D x P	Agronomist in charge	Susan Tomda

METHODS

Experimental Design and Treatments

The Nitrogen (N) Systematic trial ahs a structure of 9 rates of N are applied in 8 replicated blocks. The rates applied increase from 0 to 2kg N/palm in 0.25kg N/palm increments (equivalent to 0 to 5.92kg AN/palm at 0.74kg AN/palm increments). The trial is designed such that in each adjacent replicate block the N rates increase or decrease systematically (Figure 1). It is purposely set out that way so that any nutrient shift from high to low N rate under ground can be detected. Unlike Trial 211, Trial 212 has 2 measured rows of 15 core palms each (30 palms/plot) and one guard row palm at both ends (3-4 guard row palms in a plot).

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

decrease - increase

increase - decrease

Figure 1. N rate increase/decrease systematically (N rate increments are at 0.25kg N/palm)

Table 2. Nitrogen treatments and rates

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

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

RESULTS

Effects of treatment and FFB yield and its components

Applying N fertiliser increased the FFB yield significantly (p=0.03) in 2011 and the combined 2009-2011 respectively (Table 3). A yield increase of 3 t/ha was archived at 4.4 kg AN/palm. Apart from yield, the N fertiliser rates had a significant effect on single bunch weight (kg/bunch) (p=0.02) and the number of bunches (bunch/ha) (p<0.001) in 2011. There was a significant effect in yield and yield component average in the last three years (2009-2011). A 2 t/ha drop in yield in 2010 was due to decrease in bunch/ha however, the yields improved by 4 t/ha in 2011 (Figure 2).

Table 3. Main effects of N treatments on FFB yield (t/ha) for 2011 and 2009-2011. p values <0.05 are shown in bold.

		2011			2009-2011		
N rate (kg/palm)	**Equivalent AN rate (kg/palm)**	**FFB yield (t/ha)**	**BNO/ha**	**SBW(kg)**	**FFB yield (t/ha)**	**BNO/ha**	**SBW(kg)**
0	0.0	**23.0**	**1008**	**22.9**	**23.3**	**1078**	**21.7**
0.25	0.74	**23.0**	**979**	**23.6**	**23.5**	**1046**	**22.5**
0.5	1.48	**25.9**	**1062**	**24.4**	**27.4**	**1166**	**23.5**
0.75	2.22	**25.1**	**1007**	**25.0**	**27.6**	**1144**	**24.3**
1.0	2.96	**23.8**	**923**	**25.8**	**27.6**	**1117**	**24.9**
1.25	3.70	**24.6**	**990**	**24.9**	**28.7**	**1193**	**24.2**
1.5	4.44	**26.5**	**1041**	**25.6**	**30.5**	**1247**	**24.7**
1.75	5.18	**25.5**	**1008**	**25.4**	**30.1**	**1228**	**24.6**
2.0	5.92	**26.2**	**1042**	**25.2**	**30.8**	**1292**	**23.9**
Grand Mean		24.9	1007	24.7	27.7	1168	23.8
Significance		**0.03**	**0.002**	**<0.001**	**<0.001**	**<0.001**	**<0.001**
LSD		2.5	98.9	1.2	2.1	94.9	1.1
CV %		10.0	9.8	4.8	7.4	8.1	4.8

Yield response over time

Since recording started in 2002, there was a significant effect of applying N on yield. The yearly yield response to N fertiliser has been slowly increasing over time. There has been an increase in yield of 9 t/ha since 2002 and gap between nil N fertiliser and N fertiliser plots have widen with time.

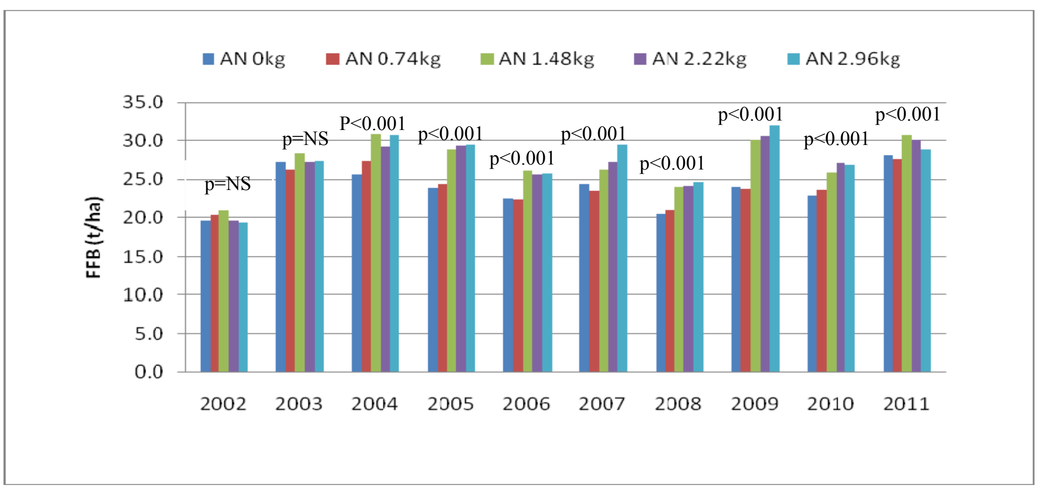

Figure 2. Yield response to 5 rates of N (kg/palm) over time (fertiliser N was first applied in 2002)

Effects of treatments on leaf (F17) nutrient concentrations

N rate treatment had a significant effect on the concentration of leaflet N (p<0.001), P (p=0.002) and Mg (p<0.001) and rachis N (p<0.001) contents (Table 4). Leaflet K and rachis P and K contents did not respond to the N treatment. The N concentrations were generally low and below the optimum range (2.45 – 2.50 %). Similarly, the leaflet P contents were also below the adequate level of 0.145. The rachis K content was adequate.

Table 4. Main effects of treatments on frond 17 nutrient concentrations in 2011, in units of % dry matter.p values less than 0.05 are shown in bold.

Nrate (kg/palm	**Equivalent AN rate (kg/palm)**	**Leaflet nutrient concentration (% DM)**					**Rachis nutrient concentration (% DM)**		
		N	**P**	**K**	**Mg**	**B**	**N**	**P**	**K**
0.00	0.00	**2.25**	**0.137**	0.64	**0.193**	17.3	**0.29**	0.053	1.77
0.25	0.74	**2.31**	**0.138**	0.66	**0.196**	17.4	**0.30**	0.044	1.67
0.50	1.48	**2.34**	**0.139**	0.61	**0.193**	17.7	**0.31**	0.049	1.75
0.75	2.22	**2.32**	**0.138**	0.62	**0.189**	16.5	**0.32**	0.045	1.75
1.00	2.96	**2.41**	**0.141**	0.64	**0.178**	16.4	**0.32**	0.045	1.80
1.25	3.70	**2.43**	**0.143**	0.64	**0.168**	15.8	**0.32**	0.049	1.72
1.50	4.44	**2.42**	**0.143**	0.65	**0.170**	16.8	**0.34**	0.051	1.84
1.75	5.18	**2.44**	**0.142**	0.64	**0.164**	16.5	**0.35**	0.050	1.78
2.00	5.92	**2.47**	**0.144**	0.67	**0.159**	15.8	**0.34**	0.050	1.81
Grand mean		2.39	0.141	0.64	0.179	16.7	0.32	0.049	1.76
Significance		**<0.001**	**0.002**	0.22	**<0.001**	0.15	**p=0.007**	0.279	0.71
LSD		0.06	0.004	-	0.02	1.5	0.03	-	-
CV %		2.4	2.7	6.7	8.9	9.0	9.2	16.7	9.9

Tissue N concentration over time 2004 to 2011

There was a significant effect (p<0.001) in N rate treatments from 2004 to 2011. In each year, leaflet N levels increased with increasing rates of applied N but gradually decrease over time (Table 5). The mean leaflet N contents fell with time from 2.43% in 2004 to 2.39% DM in 2011. The low N rates (0-1.75 kg N/palm) have fallen below critical levels in 2010.

Table 5. Leaflet N (% DM) from 2004 to 2011

N rate (kg/palm)	*Equivalent AN rate (kg/palm)*	***Leaflet N (% DM)***							
		2004	***2005***	***2006***	***2007***	***2008***	***2009***	***2010***	***2011***
0	0	2.35	2.3	2.25	2.21	2.2	2.18	2.26	2.25
0.25	0.74	2.38	2.35	2.29	2.24	2.2	2.15	2.28	2.31
0.5	1.48	2.45	2.44	2.36	2.33	2.29	2.24	2.27	2.34
0.75	2.22	2.43	2.45	2.36	2.35	2.3	2.28	2.34	2.32
1	2.96	2.42	2.47	2.41	2.39	2.34	2.33	2.36	2.41
1.25	3.7	2.45	2.51	2.41	2.36	2.34	2.35	2.4	2.43
1.5	4.44	2.46	2.51	2.43	2.4	2.36	2.38	2.44	2.42
1.75	5.18	2.45	2.5	2.44	2.45	2.4	2.4	2.46	2.44
2	5.92	2.48	2.54	2.43	2.42	2.39	2.41	2.43	2.47
Grand mean		2.43	2.45	2.37	2.35	2.31	2.3	2.36	2.39
Significance		**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**
LSD		0.05	0.05	0.04	0.05	0.06	0.04	0.06	0.06
CV %		2.3	2.1	1.8	2	2.4	1.9	2.7	2.4

Effects of fertiliser treatments on vegetative parameters

The N fertiliser treatment had significant effects ($p<0.05$) on all the vegetative growth parameters except the number of fronds produced per year (FP) (Table 6). PCS was increased by 1 to nearly 10 cm^2, similarly the dry matter production were also increased with N fertiliser. The frond area and the LAI were also elevated with N fertiliser treatment.

Table 6. Main effects of treatments on vegetative growth parameters in 2011.Significant effects ($p<0.05$) are shown in bold

N rate kg/palm	Equiv. AN rate kg/palm	Radiation Interception					Dry Matter Production (t/ha)			
		PCS	**GF**	**FP**	**FA**	**LAI**	**FDM**	**BDM**	**TDM**	**VDM**
0	0	40.6	31	19	13.2	5.8	11.6	23	38.4	15.4
0.25	0.74	41.8	31	20	13.4	5.8	12.3	22.7	38.8	16.1
0.5	1.48	45.1	31	20	13.9	5.9	13.3	25.2	42.8	17.6
0.75	2.22	46.8	31	20	14.3	6.2	14	24.7	42.9	18.3
1	2.96	47	32	21	14..2	6.4	14.4	23.6	42.2	18.6
1.25	3.7	48.5	32	21	14.8	6.6	14.8	24.9	44.2	19.3
1.5	4.44	49.7	33	20	15	6.8	14.5	26.7	45.7	19
1.75	5.18	48.4	33	21	14.8	6.8	14.9	25.7	45.1	19.4
2	5.92	49.8	33	21	14.8	6.8	15.5	26.5	46.6	20.1
Mean		46.4	32	20	14.3	6.4	13.9	24.8	43	18.2
Significance		**p<0.001**	**p=0.006**	**NS**	**<0.001**	**<0.001**	**<0.001**	**p=0.004**	**<0.001**	**<0.001**
LSD		2.52	1.4	-	0.9	0.4	1.75	2.27	3.14	1.96
CV %		5.4	4.4	10.8	6.3	6.3	12.6	9.1	7.3	10.7

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

DISCUSSION

Nitrogen (N) is an important nutrient for both oil palm yield and growth. By applying N fertiliser, yields had significantly increased and remain above 23 t/ha. Yields of 26 t/ha were achieved at N rate1.5kg N/palm (equivalent of 4.44 kg AN/palm). Yield from the nil fertilised plots produced was on average 23.9 t/ha for the last 10years. The leaf N levels in these plots (nil N) are lower than 2.45% (deficient) for the last eight years, as was expected. Leaf N levels at each of the treatment levels has been gradually falling. The results in 2011 also indicate that in the first four (4) low N treatments plots (0.00, 0.25, 0.50 & 0.75 kg N/palm) leaflet N contents were deficient (critical level 2.45%) and this was evident with visible symptoms in the field.

CONCLUSION

N fertilisers had significant effect on yield and its components in 2011 and combined 2009-2011. There was a general decline in yield (t/ha) and bunch numbers. The leaflet N contents in the leaflets have been falling with time. N rate treatment has a significant effect on yield, tissue N and P and most physiological growth parameters. Increasing rate from 0.25 kg N/palm to higher rates increased yields.

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

SUMMARY
The P treatments had significant effect on P level in rachis only in 2011 in tissue analysis results but not any significant effects on the yields, other tissue nutrient levels and vegetative growth of the palms since the treatments started in 2008. Regardless of yield, there was an increase in SBW from 21.9 kg to 24.5 kg. However, an average yield for all plots decreased from 26.6 t/ha in 2010 to 24.4 t/ha was evident in 2011. There was a drop in nutrient concentrations in N leaflets (2.34 %) and K (0.61 %) and P (0.136 %) but not in rachis P (0.055 %).

INTRODUCTION
Trial 214 was originally set up as a Magnesium trial in 2007, however was changed to a P (TSP) placement trial in 2008. The two most important influences on P nutrition on volcanic soils are (i) high allophane content of these soils, and (ii) soil acidification caused by the use of N based fertilisers. Allophane will bind to phosphate making it unavailable for plant uptake, thus it is important to minimise the direct contact of phosphate with the mineral soil (which is where the allophone material is). Volcanic ash soils have moderate to very low CEC with variable charge and contain allophone and iron oxides which fix phosphates (by forming complexes such as aluminium and iron phosphates). The topsoil at the site contained 6 – 8 % allophone (high) and the subsoil around 12 % (very high). In addition, soils around the weeded circle are being acidified and hence P in phosphate is becoming less available for uptake. Applying P on the frond pile where the soil is high in organic matter, low in mineral soil and where there are an abundance of palm feeder roots should enable more rapid uptake of P as phosphate. Therefore the aim of the trial is to identify the best option for the placement of TSP in light of volcanic soils containing high levels of allophane. The initial work on pre-treatment data and soil samples were collected in 2007. The application of treatment fertilisers was done in October 2008. Harvesting of ripe bunches and all other upkeep work is done by the plantation. Fertiliser applications and data collections are done by PNGOPRA. The background information for the trial is shown in Table 1.

Table 1. Trial 214 back ground information

Trial number	**214**	Company	Hargy Oil Palms Ltd
Estate	Hargy	Block No.	Area 4, block 2
Planting Density	129 palms/ha	Soil Type	Volcanic
Pattern	Triangular	Drainage	Well drained
Date planted	1994	Topography	Rising and hilly
Age after planting	17 years	Altitude	263 m asl
Recording Started	2006	Previous Land use	Oil palm
Progeny	Unknown	Area under trial soil type (ha)	
Planting material	Dami D x P	Agronomist	Susan Tomda

Pre- treatment Data
Pre-treatment yield (Table 2) and tissue nutrient (Table 3) data (for use as co-variate in following years) were all done in 2007. Plot layout and first round of P fertiliser application (as treatment) was done in October 2008. Soil sampling was also done on selected sites and samples were sent to NZ for chemical analysis and allophane content determination (result not available).

Table 2. Pre-treatment yield, PCS and nutrient concentrations for leaflets and rachis in 2007

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

METHODS

Experimental design and Treatment

The trial has a structure treatment of 5 levels of TSP fertiliser applied in zones (WC- weeded circle and FP- frond pile) around the palms in each plot (Table 3). Fertilisers are applied twice a year.

Table 3. Fertiliser treatments and rates

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

Basal application in 2010 N (AC) - 4kg/palm/year, MOP (K) - 2Kg/palm/year, Kie (Mg) 1kg/palm/year and Borate (B) 150g/palm/year.

Statistical Analysis

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

RESULTS

The yields with other components (Bunch number and SBW) have not shown any significant response to the treatments since the application of the first treatment in 2007. The average yield for all plots in 2011 was 22.4 t/ha, (Table 4), a decrease of 4.0 t/ha from 2010. Bunch number decreased slightly from an average of 1218 in 2010 to 907 bunches/ha in 2011. The average single bunch weight was 21.9 kg in 2010 and increased slightly to 24.7 kg in 2011. The 2009-2011 data also showed no response to the treatments (Table 5).

Table 4. Effects of yield and its components in 2011 and 2009-2011

Treatment levels	P rates kg/palm/yr	Placement	Yield (t/ha) 2008	2009	2010	2011
1	0	Control	18.5	23.5	25.2	22.4
2	1	1 - WC	22.1	25.6	26.9	19.96
3	1	2 - FP	18.5	23.9	27.2	21.48
4	2	1 - WC	20	23.3	25	24.85
5	2	2 - FP	19.1	24.7	28.4	23.33
Mean			19.6	24.2	26.6	22.4
Significance			**NS**	**NS**	**NS**	**NS**
CV %			16.8	19.9	10.1	24.3

(*WC- Weeded circle, FP – Frond pile*)

Yield response over time

Yield responses were not significant with time, however mean yield increased for all P treatment levels from 2008 -2010 but decrease with 4 t/ha in 2011 (Table7).

Table 5. FFB yield trend from 2008 to 2011.

Treatment levels	P rates kg/palm/yr	Placement	Yield (t/ha)			
			2008	2009	2010	2011
1	0	Control	18.5	23.5	25.2	22.4
2	1	1 - WC	22.1	25.6	26.9	19.96
3	1	2 - FP	18.5	23.9	27.2	21.48
4	2	1 - WC	20	23.3	25	24.85
5	2	2 - FP	19.1	24.7	28.4	23.33
Mean			19.6	24.2	26.6	22.4
Significance			**NS**	**NS**	**NS**	**NS**
CV %			16.8	19.9	10.1	24.3

Effects of treatments on leaf (F17) nutrient concentrations

The effects of P placement treatments on leaf tissue nutrient contents are presented in Tables 6. Leaflet P did not show a response in 2011 however, Rachis P content was significantly increased in 2011 (p=0.005). There appears to be no difference in P contents between 1 and 2 kg TSP and between the two zones.

The mean nutrient contents are at adequate levels. Rachis N and K increased but were not statistically significant.

Table 6. Tissue nutrient concentrations for leaflet N, P, K, Mg, B and rachis N, P, K in 2011

Treatment levels	Prates/placement kg/palm	2011							
		Leaflet (%dm)					Rachis (%dm)		
		N	**P**	**K**	**Mg**	**B**	**N**	**P**	**K**
1	Control	2.34	0.136	0.61	0.163	17.6	0.31	0.054	1.43
2	1 - WC	2.35	0.135	0.61	0.159	17.5	0.29	0.050	1.42
3	2 - FP	2.34	0.136	0.62	0.163	18.1	0.30	0.052	1.48
4	1 - WC	2.33	0.136	0.6	0.165	17.7	0.30	0.060	1.46
5	2 - FP	2.33	0.135	0.6	0.163	17.1	0.30	0.057	1.39
Mean		2.43	0.144	0.61	0.163	17.6	0.30	0.055	1.43
Significance		**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**p=0.005**	**NS**
LSD		**-**		**-**	**-**	**-**	**-**	**0.014**	**-**
CV %		2.5	2.7	4.9	8.3	10.4	11.9	21.4	13.0

Effects of fertiliser treatments on vegetative parameters

Similar to the other parameters, there was no significant response on the vegetative growth of the palm to the P rates and fertiliser application zones (Table 7). On average of 22 new fronds were produced in 2011 (one every 26 days) an increase of 8 fronds from 2010/2009. Total green fronds counted per palm averaged 36 fronds which is low and indicating possible over pruning.

The two assessments of canopy coverage, Frond area (based on leaflet length and width) and LAI (Leaf Area Index) as based on Frond area, frond number and palms per ha, were within expected values for 17 year old palms (average frond area 14.5m^2 and LAI of 6.6). Both FA and LAI were not affected by P treatments and placements. Regardless of the treatments, there was an increase in FA,LAI and FDM, BDM in 2011

Table 7. Effects of N treatments on vegetative growth parameters in 2011.

TSP(P)Levels	P rate / placement (kg/palm)	PCS	Radiation Interception			Dry Matter Production (t/ha)				
			GF	FP	FA	LAI	FDM	BDM	TDM	VDM
1	0.0 - Nil	42.3	36	22	14.5	6.6	12.8	10.8	26.2	15.4
2	1.0 - WC	41.3	35	22	14.3	6.4	12.6	10.3	25.4	15.2
3	1.0 - FP	41.7	36	22	14.2	6.5	12.8	10.7	26.1	15.4
4	2.0 - WC	43.3	36	22	14.7	6.8	13.0	11.3	27.0	15.7
5	2.0 - FP	42.9	35	22	14.7	6.7	12.9	10.9	26.4	15.5
	Mean	42.3	36	22	14.5	6.6	12.9	10.8	26.2	15.4
Significance:		**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
CV%		**5.1**	**4.4**	**3.5**	**4.6**	**5.3**	**6.4**	**21.4**	**11.0**	**6.5**

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

DISCUSSION

There was no significant response in yield since treatment started in 2008. P was significant in rachis but not significant in leaflet tissue levels in 2011. There were no significant responses from the other nutrient concentration and the overall vegetative growth of the palms. Application of N as basal since the inception of the trial has improved the N levels in the leaflets which had increased to optimum or adequate range. The rachis N levels are reasonably high (adequate) due to eventual translocation of N to the leaflets from the rachis, which had boosted the N concentration in the leaflets in 2010 and 2011. Rachis N, P, K nutrient concentrations have increased in 2011.

CONCLUSION

There was no response of TSP and placement on yield, its components and vegetative growth parameters except on rachis P concentrations.

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

INTRODUCTION

This trial was set out in March 2009 where unknown progenies of 2 year olds were growing in the field. 24 plots were marked out and the 16 would be core palms were removed in each plot and replaced with four known commercial progeny palms (Dami material: 0710226N; 0791065N; 0791195C and 0709668C). Four (4) known progenies were identified/selected (from the commercial Dami material) and planted randomly in each plot including the guard row palms from the same progeny. TSP (100g/plm) was applied at the bottom of the planting hole. Guard row can be any progeny. A total of 50 plots were planted, after width and thickness (W x T) is done, the final 24 plots will be selected for proper treatments. Commence trial fertiliser application will be in March 2013 (year 4 after planting).

This trial is to develop robust fertiliser recommendations using nutrient response curves by applying N x P x K at three rates each. The same four progeny planted in each plot will remove progeny effect from the fertiliser response, using central Composite Design requiring 24 plots (see Verdooren in Oil Palm, Management for Large and Sustainable Yields, Fairhurst and Hardter, 2003). Each plot has 16 monitored palms with 20 guard palms.

Table 1. Basic information on trial 216

Trial number	**216**	Company	Hargy Oil Palms Ltd
Estate	Barema	Block No.	Field 14
Planting Density	135 palms/ha	Soil Type	Gravel old Barema river
Pattern	Triangular	Drainage	Freely draining
Date planted	2009	Topography	flat
Age after planting	3 years	Altitude	40 m asl
Recording Started	2013	Previous Land-use	Forest
Progeny	Known*	Area under trial soil type (ha)	
Planting material	Dami D x P	Agronomist in charge	Susan Tomda

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

METHODS

Design and Treatment

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

Table 2. Fertiliser levels and rates used in Trial 216

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

Table 3. Block layout (including randomisation of treatments)

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

Work progress so far:
In 2009:

- 16 central palms planted with four identified progenies
- Guard rows, perimeters also planted
- GPS reference each ‘supply’ palm
- GPS reference every palm 1 in each plot for future plot/palm location

- Replaced dead core palms with the same spare progenies as supply palms planted near by after five months of initial planting.
- 1 x three monthly periodic checks to ensure that cover crops and weed are not over grown in the trial
- Palm census once a year.
- Ensure trial upkeep up to plantation standard

In 2010:

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

In 2011:

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

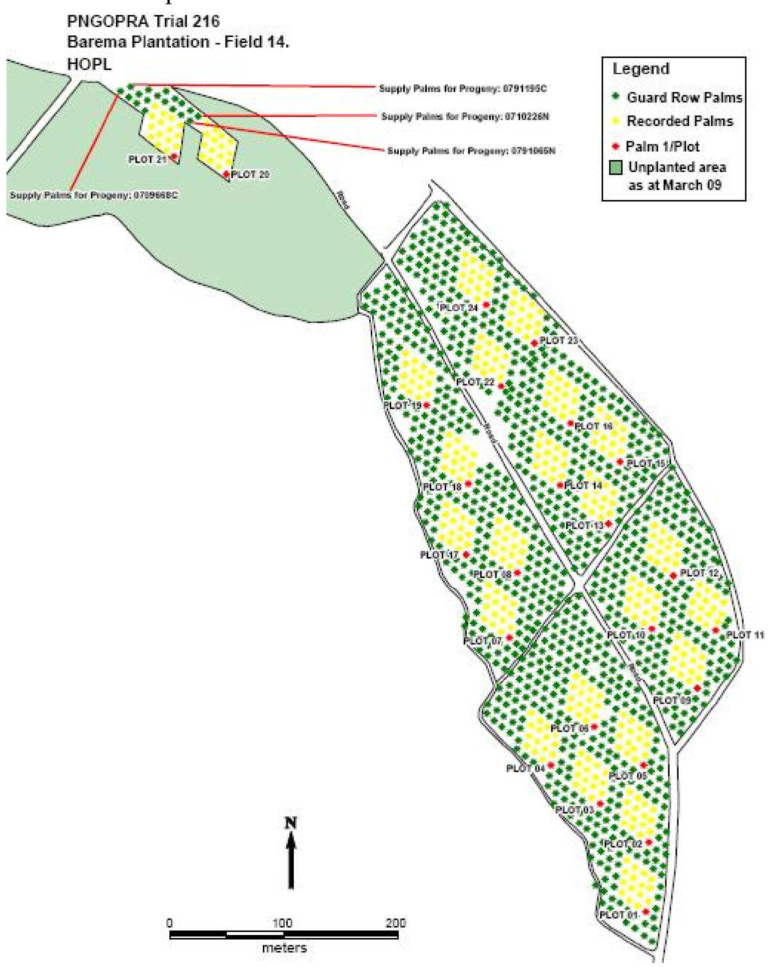

Figure 1: Map showing T216 – plots and palm numbers

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

INTRODUCTION
The trial design will be the same as trial 216 at Barema and intended for setup at Navo. Four (4) known progenies (09080221, 09070112, 09071493, 09110165) were identified/selected from the commercial Dami material and planted randomly in each plot including the guard row palms from the same progeny. TSP (100g/plm) is placed at the bottom of the hole. A total of 50 plots were planted, after width and thickness (W x T) is done, the final 24 plots will be selected for proper treatments.

This trial is to develop robust fertiliser recommendations using nutrient response curves by applying N x P x K at three rates each. The same four progeny planted in each plot will remove progeny effect from the fertiliser response, using central Composite Design requiring 24 plots (see Verdooren in Oil Palm, Management for Large and Sustainable Yields, Fairhurst and Hardter, 2003). Each plot has 16 monitored palms with 20 guard palms.

Table 1. Basic information on trial 217

Trial number	**217**	Company	Hargy Oil Palms Ltd
Estate	Navo	Block No.	Navo, Field5 –Block K
Planting Density	135 palms/ha	Soil Type	Volcanic
Pattern	Triangular	Drainage	Well drained
Date planted	2011	Topography	Flat
Age after planting	2 months	Altitude	159 masl
Recording Started	2015	Previous Land-use	Oil Palm
Progeny	Known*	Area under trial soil type (ha)	
Planting material	Dami D x P	Agronomist in charge	Susan Tomda

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

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

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

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

INTRODUCTION
N.P.K.Mg factorial trial was setup at Alaba Estate in July 2011. Sixteen (16) known progenies were identified/selected from the commercial Dami material and planted randomly in each plot including the guard row palms from the same progeny. TSP (100g/plm) is placed at the bottom of the hole.

This trial is to develop robust fertiliser recommendations using for the soils in the area. The same 16 progeny planted in each plot will remove progeny effect from the fertiliser response over time. Each plot has 16 monitored palms with 20 guard palms. A total of 100 plots were planted

Table 1. Basic information on trial 220

Trial number	**220**	Company	Hargy Oil Palms Ltd
Estate	Navo	Block No.	Alaba,Field5-B_03
Planting Density	135 palms/ha	Soil Type	Volcanic
Pattern	Triangular	Drainage	Well drained
Date planted	2011	Topography	Moderate slope
Age after planting	7 months	Altitude	90 m asl
Recording Started	2015	Previous Land-use	Forest
Progeny	Known*	Area under trial soil type (ha)	31.95
Planting material	Dami D x P	Agronomist in charge	Susan Tomda

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

Work progress so far:
In 2011:

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

DATA QUALITY

Field and data quality and data entry checks

- 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 through to be sure that the weights recorded already by a recorder are actually correct and scale is not defective or misread.
- 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, pests and diseases. This information is passed on to the plantation management with quarterly reports to assist in improving the block management standards.
- The accuracy check for marking frond one (1) and cutting frond seventeen (17) is done during tissue sampling, vegetative measurements and frond count to be sure the activity is not based on any other fronds.
- Scales are checked against a known weight once a week.
- Other tools are inspected to ensure there are no defects before using them.
- 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 etc are included.

Trial maintenance and upkeep

- The trial block is maintained regularly by respective estates. This covers pruning, weed control (either herbicide spraying or slashing), wheelbarrow path clearance, cover crop maintenance and other routine plantation practices.
- Fertilisers (MOP, Kie, TSP and Borate) not used as treatments but normally applied by the plantations are also applied by the plantations.

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Steven Nake and Murom Banabas

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

EXECUTIVE SUMMARY

A trial with varying avenue widths of 8.2, 9.5 and 10.6 m at a constant palm density of 128 palms/ha was planted in 1999. Yield monitoring commenced in 2003. The trial continued to show no response in terms of yields, tissue levels in both leaves and rachis and vegetative parameters (except height increments; p=0.003) in 2011. An average block yield of 31.0 t/ha was obtained in 2011, which represented an increase of about 6 t/ha. Leaflet N, P and Mg have fallen below their adequate levels, while K and B were adequate.

BACKGROUND

The purposes of this trial is to investigate the opportunities for different field planting arrangements and how to make use of increased inter-row spacing to facilitate mechanised in-field collection of fresh fruit bunches (FFB). If there is no large yield penalty between the different spacing configurations then in a small holder context it may be possible to use the wider avenue widths for planting with either cash crops (e.g. vanilla) or a variety of food crops. Mechanical removal of FFB from the field after harvest is now a common practice in some plantations. This is intended to reduce harvesting labour cost and speed up the operation of getting freshly harvested fruit to the mill. Little is known about the impact of machine traffic on compaction and associated physical properties of volcanic soils. Background information for the trial is shown in Table 1.

Table 1. Background information on trial 139.

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

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

MATERIALS AND METHODS

The field layout comprises three replicates for each of the three spacing arrangements (treatments), giving a total of nine plots, each 10.6 ha in area. The planting density remains constant at 128 palms per hectare. The three spacing treatments are shown in Table 2. Leaf sampling, frond marking and vegetative measurements are being done in every 5th palm per recorded row per plot.

Table 2. Spacing treatments in Trial 139.

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

Data Collection

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

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

Trial maintenance and upkeep

The three trial blocks (3 reps) are maintained regularly by Kumbango Division 2 plantation. This covers pruning, weed control (either herbicide spraying or slashing), wheelbarrow path clearance, cover crop maintenance and other routine plantation practices. Fertilisers (MOP, Kie, TSP and Borate) were applied by the plantation.

RESULTS

Spacing treatment effect on yield in 2011

The spacing treatment continued to show no significant effect ($p<0.05$) on the yield, number of bunches and the single bunch weight in 2011 (Table 3). The Wide and Intermediate avenue spacing were slightly lower in yield and number of bunches per hectare compared to the Standard spacing (but statistically not significantly different).

Table 3. Impact on yield, bunch number and single bunch weight from three row spacing treatments in 2011

Avenue width	**Yield t/ha**	**Bunch number per hectare**	**Single bunch weight**
Standard	32.0 (25.5)	1414 (1114)	23.2 (23.9)
Intermediate	30.5 (25.1)	1306 (1075)	23.9 (23.4)
Wide	31.3 (24.5)	1373 (1067)	23.3 (22.9)
Significant difference	**NS**	**NS**	**NS**
LSD	-	-	-
CV%	**2.6**	**3.4**	**1.3**

2010 data in brackets for comparison.

The effect of the different avenue widths on yield (2003-2011)

Irrespective of the different avenue widths, the FFB yields reached its maximum peak in 2007 (average of 32.3 t/ha) after a steady increase from 2003, 2004, 2005 and 2006. From 2008 to 2010, the trial experience fluctuations in the FFB yield. In 2011, the trial recovered from a drop in yield in 2010 by an increase of about 6 t/ha pushing the average FFB yield for the trial to 31.2 t/ha. The yield increase in 2011 is more generated by the increased in the number of bunches (Figure 2), which increased from 1085 bunches in 2010 to 1364 bunches in 2011 (Figure 2). The single bunch weight in 2011 was at an average of 23.5 kg.

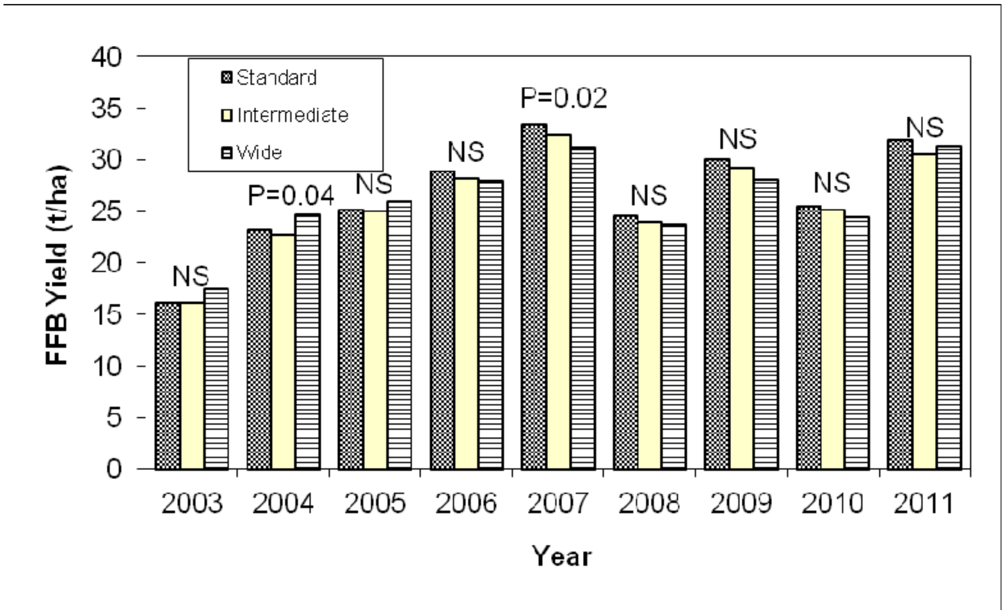

Figure 1. The impact of avenue width on yield (keeping planting density the same), 2003-2011.

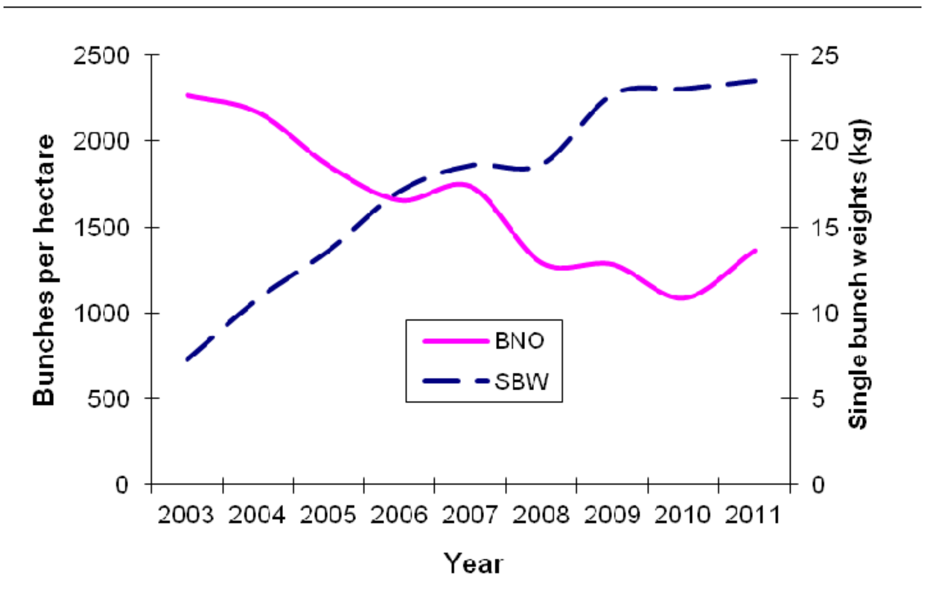

Figure 2. Mean bunch number per hectare (BHA) and SBW (kg/bunch) over the trial duration.

Spacing treatment effect on tissue nutrient levels

All leaf tissue nutrients tested were not significantly affected ($p>0.05$) by the spacing treatments in 2011 (Table 4). Irrespective to the spacing treatments (affecting the avenue spacing), leaflet N, P and Mg were slightly below the adequate levels, whereas leaflet K and B were well above the adequate levels. The rachis N, P and K concentration were all at adequate levels.

Table 4. Leaflet and rachis nutrient status for three different Avenue widths in 2011

Avenue Width	Leaflet nutrient concentration (% dm)					Rachis nutrient concentration (% dm)		
	N	**P**	**K**	**Mg**	**B (ppm)**	**N**	**P**	**K**
Standard	2.30	0.137	0.68	0.15	15.3	0.32	0.11	1.54
Intermediate	2.32	0.138	0.68	0.16	15.9	0.33	0.11	1.58
Wide	2.34	0.139	0.68	0.15	15.3	0.35	0.12	1.70
Adequate level:	2.45	0.145	0.65	0.20	15.0	0.32	0.10	1.2
Significance:	NS	NS	NS	NS	NS	NS	NS	NS
CV %	1.8	1.9	5.5	3.7	5.8	8.3	8.8	8.6

Spacing treatment effects on vegetative growth parameters

The spacing treatment had significant effect (p=0.003) on the annual palm height increment (HI) in 2011. Generally the HI declined with the avenue widths (Figure 3). All the other growth parameters (PCS, radiation interception and dry matter production) showed no response to the spacing treatment (Table 5).

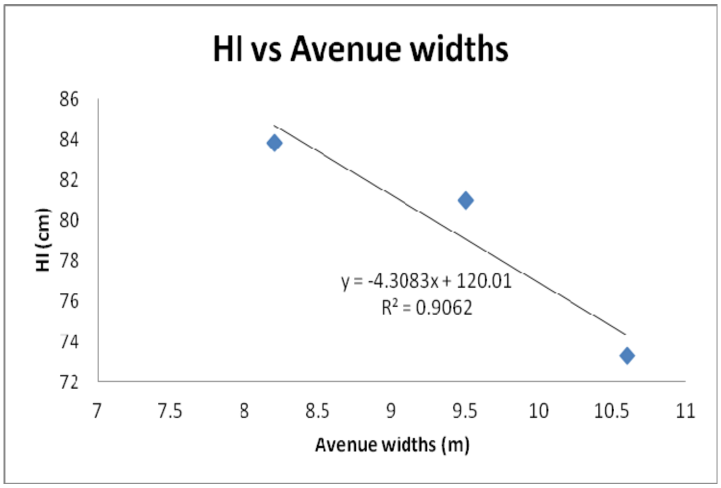

Figure 3. Relationship between height increment and avenue widths in 2011.

Frond production and frond number

The number of new fronds produced has been maintained at an average of 24 fronds from 2003 to 2011 (one every 15 days). Total green fronds counted per palm slightly dropped from an average of 39 fronds in 2010 to 38 fronds in 2011. The total green fronds have been maintained at an average of 38 fronds since 2003 until it was increased to an average of 41 and 39 in 2009 and 2010 respectively. In 2011, the total number of green fronds dropped back to 38 fronds.

Frond and canopy size

Frond area (based on frond length, leaflet number, leaflet length and width) and LAI (Leaf Area Index calculated from Frond area, frond number and palms per ha) are two parameters determining canopy coverage. Frond area in 2011 was reduced slightly to 12.9 m^2 while the LAI dropped plummeted to 6.3. Figure 4 shows the trend with actual values over time (palm age) for both the LAI and FA. The trend for both parameters was fitted using the polynomial regression, where y = LAI or FA and x = age of palms.

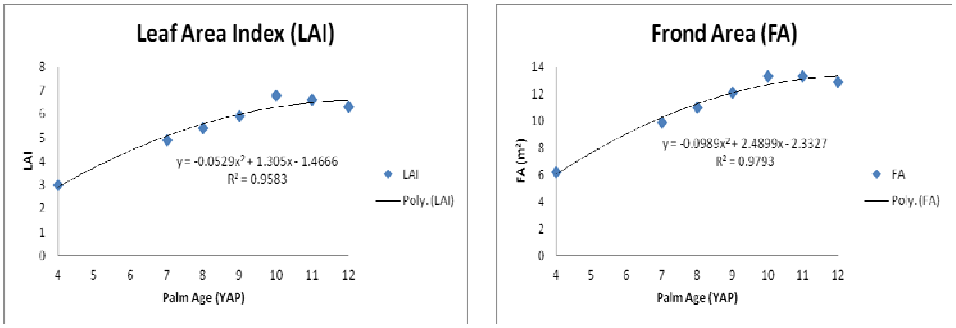

Figure 4. Leaf area index and frond area versus the palm age.

Vegetative dry matter production

Petiole cross section (PCS) is a primary determinant of vegetative dry matter production. PCS dropped to an average of 48 cm^2 in 2011. The other measures of foliar vegetative dry matter production (FDM (frond dry matter production), TDM (total dry matter production) and VDM (vegetative dry matter production) have either increased or remained the same in 2011 but not related to the spacing treatments (Table 5 and Figure 5).

Table 5. Effects of the different Avenue widths on vegetative growth, radiation interception and dry matter production in 2011

	HI	PCS	Radiation interception				Dry matter production (t/ha)			
	(cm)	(cm^2)	FA	GF	FP	LAI	FDM	BDM	TDM	VDM
Means	**80.7**	48.1	12.9	38.4	24.4	6.3	16.0	16.6	36.2	19.6
Significance	**p=0.003**	NS	NS	NS	NS	NS	NS	NS	NS	NS
lsd	**7.41**	-	-	-	-	-	-	-	-	-
CV%	**47.5**	3.4	2.3	2.2	4.5	2.8	4.7	2.4	3.1	4.4

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

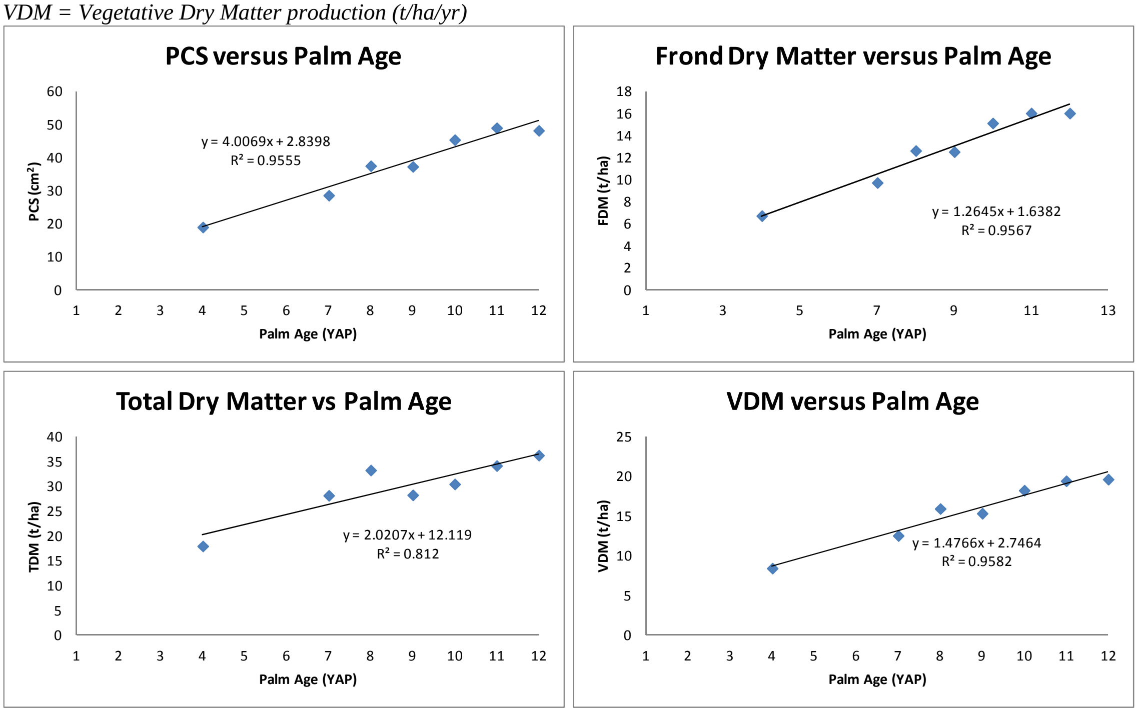

Figure 5. PCS, FDM, TDM and VDM versus the palm age.

DISCUSSION
The 2011 results showed that both yield and tissue nutrient levels (both in the leaflets and the rachis) did not respond to the spacing treatments. Similarly, the vegetative parameters used for determining radiation interception (FA, GF, FP, LAI) and the dry matter production (PCS, FDM, BDM, TDM, VDM) all did not respond to the spacing treatments. The increments in heights between 2010 and 2011 somehow responded to the spacing treatments in 2011. A negative relationship was observed between the height increments and the avenue widths, which implied that as avenue widths are widened causing the inter-row widths to narrow, the height increments decreased.

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

CONCLUSION
Most of the parameters (yield, tissue nutrient concentration and vegetative) did not respond to the spacing treatments in 2011, except the response in the height increments. The negative response could be due to the fact that the palms have reached maturity and the canopy has fully closed regardless of the spacing treatments. The overall FFB yields increased from an average of 25.0 t/ha in 2010 to 31.0 t/ha in 2011 (6 t/ha difference). In comparison, N, P and Mg levels in the leaf tissues were low while K and B levels were adequate.

NBPOL, KULA GROUP, MILNE BAY ESTATES

Murom Banabas and Wawada Kanama

Trial 511 Nitrogen, Phosphorus, Potassium and EFB trials at Milne Bay Estates (RSPO 4.2, 4.3, 4.6, 8.1)

SUMMARY
Trial 511 established in 1994/95 at Waigani Estate in Milne Bay. The trial is on a weathered terrace and the soils contain buckshot and alluvial in origin but have less clay (around 30%) and a higher sand content (50 to 60%). It was set up to test responses to N, P, K fertilisers in a factorial combination, with and without EFB. EFB was included to test whether it can be used to replace or supplement inorganic fertiliser. Treatments consisted of four rates of SOA (0, 2.0, 4.0 and 6.0 kg/palm), 4 rates of MOP (0, 2.5, 5.0 and 7.5 kg/palm), two rates of TSP (0 and 2.0 kg/palm) and two rates of EFB (0 and 0.3 t/palm). Yield recording and tissue analysis continued in 14 plots of the Trial 511 while the field await replant.

The following were responses observed in 2011:
- After four years of experiment in Trial 511, although small, there has been a significant response in yield and tissue nutrient concentrations in both low and high yielding plots.
- Average yield in low yielding plots changed significantly from 12.2 t/ha in 2007 to 25.7t/ha and remained at greater than 25t/ha on average.
- In the high fertilised plots, yield fell from 19.0 t/ha in 2007 to 12.5 t/ha in 2010, a drop in yield of 6.5 t/ha and remained at less than 15t/ha.
- Leaf N, P and K significantly increased in low fertilised plots after fertilisers were added.
- The trial stopped at the end of 2011.

BACKGROUND

Trial 511 was set up in 1994 to investigate the response to N, P and K fertilisers plus or minus EFB (Table 1).

Table 1. Trial 511 background information

Trial number	**511**		
Estate	Waigani	Block No.	Field 8501, 8502
Planting Density	127 palms/ha	Soil Type	Alluvial, interfluvial deposits
Pattern	Triangular	Drainage	Moderate
Date planted	1988	Topography	Hilly
Age after planting	20 years	Altitude	157 m asl
Recording Started	1994	Previous Landuse	Coconut plantation
Progeny	Unknown	Area under trial soil type (ha)	3165
Planting material	Dami D x P	Supervisor in charge	Wawada Kanama

**Data should be synchronous with OMP.*

MATERIALS AND METHODS

Trials 511 is a factorial fertiliser trial with 4 levels of ammonium sulphate (SOA), 4 levels of potassium chloride (MOP), 2 levels of triple superphosphate (TSP) and 2 levels of EFB (Table 2). Each treatment has a single plot (4 x 4 x 2 x 2 = 64 plots); the trial site has four replicate blocks within which the main effects of N and K are represented. Each plot contains 16 core palms, which are surrounded by a guard row and a trench. Trial fertilisers were first applied in late 1994 and EFB was first applied in 1995. EFB is applied by hand as mulch between palm circles once per year. Other fertilisers are applied in 3 doses per year. General ANOVA was used to analyse the effects of different treatments on yield and tissue nutrient concentrations in both trials.

Table 2. Amount of fertiliser and EFB used in Trial 511.

	Amounts (kg/palm/year)			
	Level 0	Level 1	Level 2	Level 3
SOA	0.0	2.0	4.0	6.0
MOP	0.0	2.5	5.0	7.5
TSP	0.0	2.0	-	-
EFB	0.0	300	-	-

The treatments ceased in 2007. Trial site on which Trial 511 was on was planned for replanting in late 2008 (actually replanted in 2012). It was proposed that while the trial was awaiting replant, it is worthwhile to consider whether there can be other benefits gained from the trials. In late 2007 it was decided to change fertiliser application to plots which had received the same fertiliser regime for over 14 years. The aim of the experiment was to determine what would happen when:

- low input plots receive high doses of fertiliser (i.e. how long does it take for poor palms to recover and start producing high yields)
- high input plots receive reduced doses of fertiliser (i.e. how long does it take for healthy palms to start running down).

Fourteen currently monitored plots out of the 64 plots were selected. The 14 plots represent the highest yielding treatments (plots 12, 18, 26, 44, 51 and 56) and the lowest yielding treatments (plots 2, 4, 24, 32, 35, 43, 55, 61). Thus in 2008 and up to 2011, the new plan was followed (Table 3).

Table 3. New fertiliser treatments in Trial 511

		Current fertiliser applied (kg/palm)			Proposed fertiliser 2008 (kg/palm)		
Plot	**YLD 04 to 06**	**SOA**	**MOP**	**TSP**	**SOA**	**MOP**	**TSP**
32	7.0	0	0	0	6	7.5	2
61	11.3	0	0	2	6	7.5	2
4	9.1	0	2.5	0	6	0	2
43	10.7	0	2.5	2	6	7.5	2
35	7.2	0	5	0	6	0	2
2	13.7	0	5	2	6	7.5	2
55	9.2	0	7.5	0	6	0	2
24	9.7	0	7.5	2	6	7.5	2
12	21.5	6	7.5	0	0	0	0
44	27.6	6	7.5	2	6	0	0
18	18.7	6	5	0	0	0	0
56	26.2	6	5	2	6	0	0
51	21.8	6	2.5	0	0	0	0
26	30.9	6	2.5	2	6	0	0

The lowest yielding plots were fertilised with highest fertiliser rates (6.0 kg SOA/palm) and 0 and 7.5 kg MOP (EFB excluded) and were monitored to see how long it would take for the palms to respond in (i) tissue nutrient content, (ii) female flowers and (iii) possibly yield (if enough time before felling). Also, the highest yielding treatment plots (excluding EFB) were stopped from being fertilised with SOA, MOP and TSP to see how long it would take for the palms to (i) rundown the K and P reserves and (ii) suffer in N deficiency. Some plots in the high yielding treatment plots continued to receive 6.0 kg SOA to see the effect of N on how fast K and P become deficient. Harvesting is done at normal 10 day harvest rounds, and trial maintenance inspections are carried out at the end of every month to ensure that the trial is maintained at good field standard.

DATA COLLECTION AND ANALYSIS

Leaf tissue samples (leaflets and rachis) are collected from frond 17 annually, oven dried, grinded and sent to AAR in Malaysia for analysis.

RESULTS AND DISCUSSIONS

The terms in Table 4 are defined for data interpretation.

Table 4. Trial 511 defined terms for data interpretation

Treatment	Fertiliser applied (kg/palm/year)						To determine;
	1994-2007			2008-2011			
	SOA	TSP	MOP	SOA	TSP	MOP	
T1	0.0	2.0	2.5, 5.0, 7.5	6.0	2.0	7.5	Response to N (SOA)
T2	0.0	0.0	2.5, 5.0, 7.5	6.0	2.0	0.0	K depletion
T3	6.0	0.0	5.0, 7.5	0.0	0.0	0.0	N and K depletion
T4	6.0	2.0	2.5, 5.0, 7.5	6.0	0.0	0.0	P and K depletion
T5	0.0	0.0	0.0	6.0	2.0	7.5	Response to N, P&K

The results from the 14 selected plots were analysed and were used to answer the following questions:

Question 1. What happens if N and K applications are stopped?

After fertiliser treatments were stopped in 2007, FFB yield in T3 plots continued to fall to 14.7 t/ha in 2008 by 5 t/ha from 2007 and remained at <15 t/ha (Figure 1). On the other hand in T5 plots, after N, P and K fertilisers were applied in 2008, FFB yield responded immediately and remained at greater than 20 t/ha average.

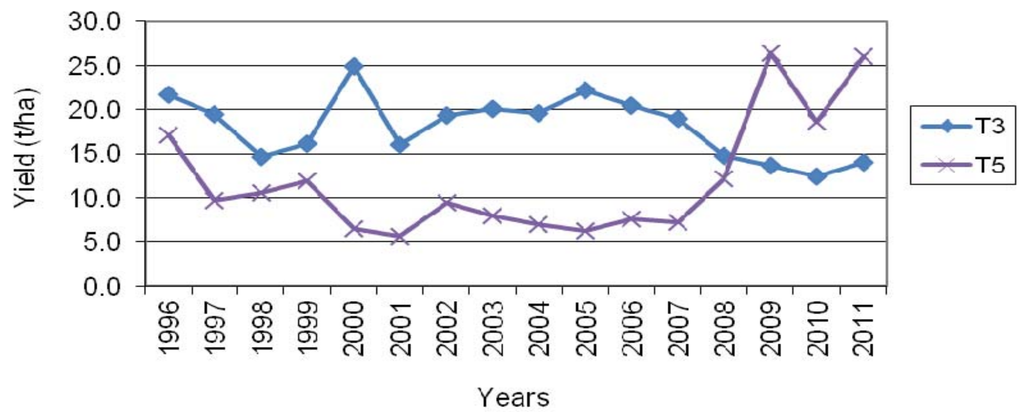

Figure 1. Yield trend in T3 and T5 plots from 1996 to 2011. Fertiliser treatments changed in 2008.

With the leaflet nutrient contents, after N and K fertilisers were stopped in 2008 in T3 plots, the leaflet N contents continued to remain above 2.3 % except for August 2008, which suggests N contents in the soil and the palms are still sufficient to sustain growth. However, in T5 plots, leaflet N contents increased immediately to 2.45% in 2008 and remained high throughout the sampling months. Similar trend was seen with leaflet P, leaflet K and rachis K contents in T5 plots (Figures 2, 3, 4 and 5).

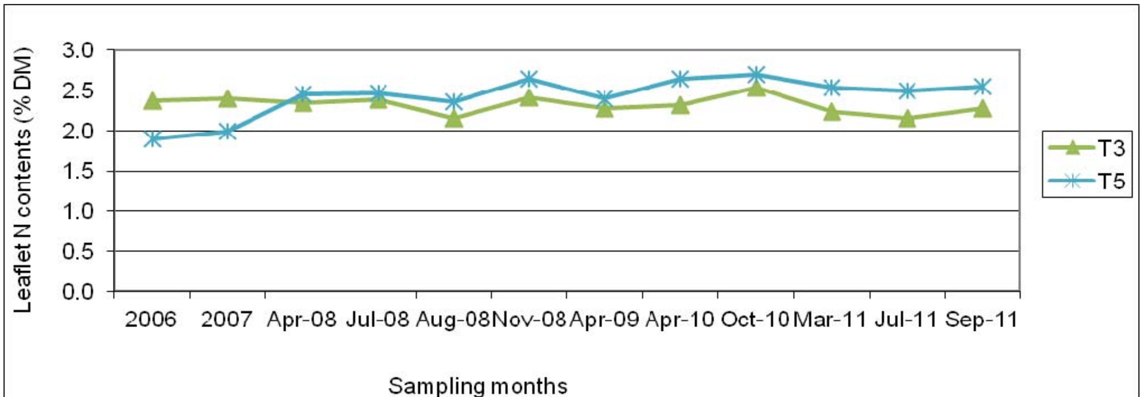

Figure 2. Leaflet N concentrations (% DM) in T3 and T5 plots.

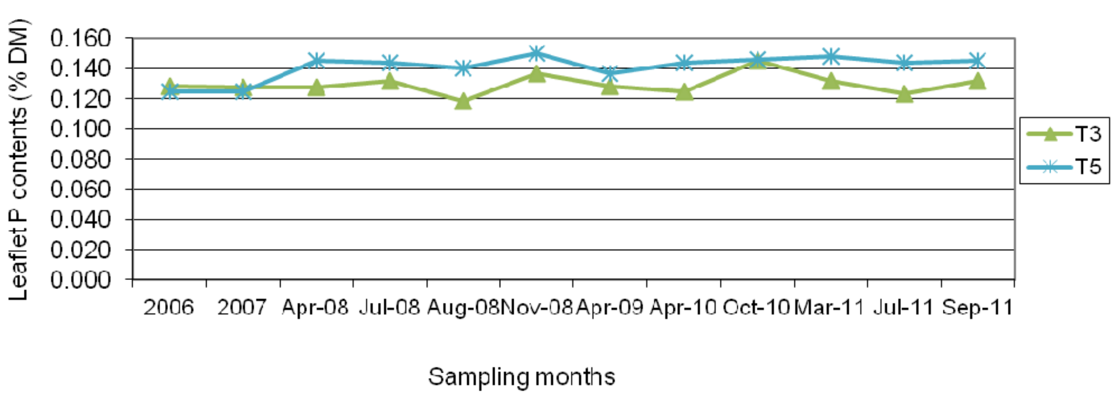

Figure 3. Leaflet P concentrations in T3 and T5 plots

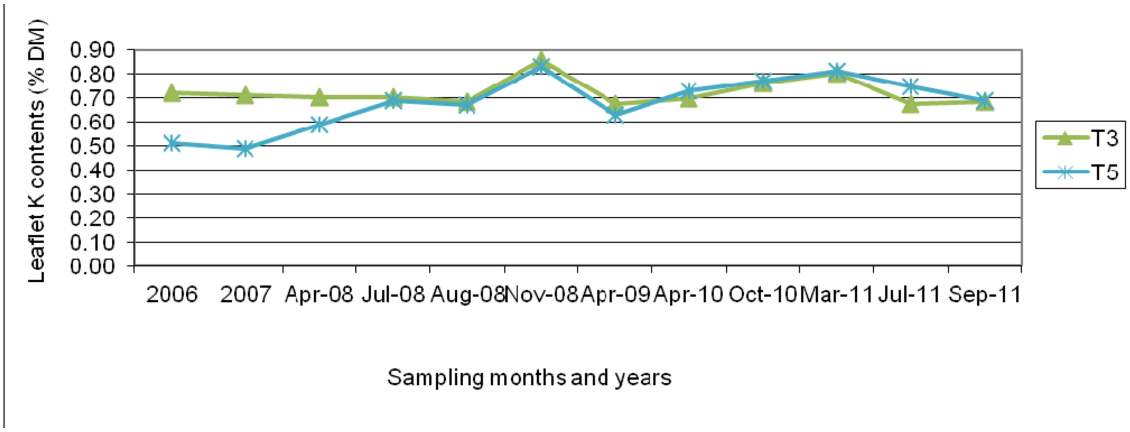

Figure 4. Leaflet K concentrations in T3 and T5 plots.

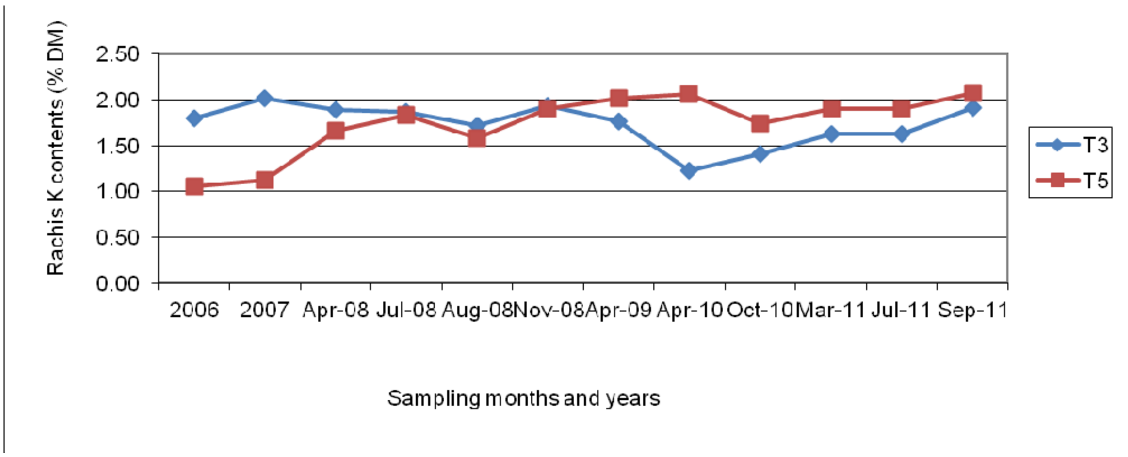

Figure 5. Rachis K concentrations in T3 and T5 plots.

Question 2. What happens if P and K fertilisers are stopped however N fertiliser is maintained?
FFB yield in T4 plots decreased in 2008 however increased to just above 25 t/ha in 2009 and continued to increase in 2010 but fell in 2011 (Figure 6). The fall in 2008 can not be fully explained by nil P and K fertiliser application in 2008 because there was a general fall in crop across all trials and plantations during 2008. In T3 plots where N was also stopped, yield was below 15 t/ha in 2011.

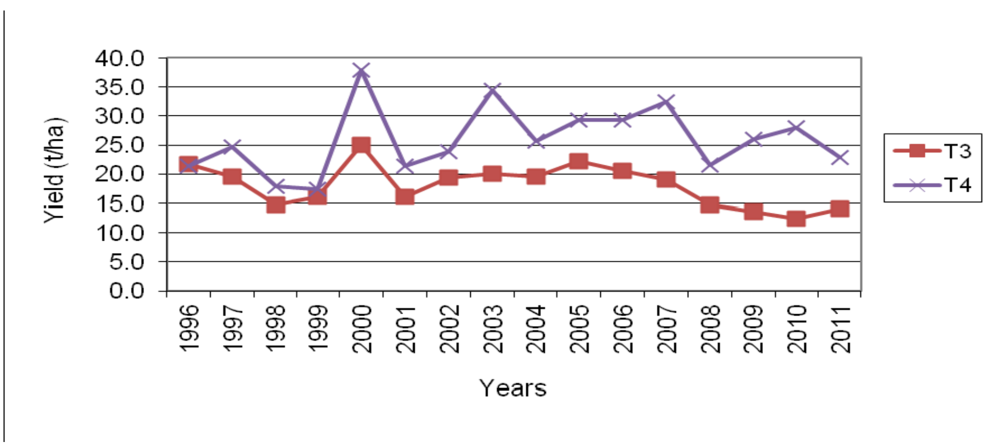

Figure 6. Yield trend in T3 and T4 plots from 1996 to 2010. Fertiliser treatments changed in 2008

In T2 plots, K was always applied but after N and P were added and K stopped, leaflet K contents improved from 0.60 % DM in 2007 to 0.80% in 2008 and 2009 but fell to 0.70% DM in September 2011(Figure 7). Addition of N and P fertilisers appeared to have improved the uptake and utilisation of K reserves in the soil and rachis. In T4 plots, K content was falling in the sampling months in 2011.

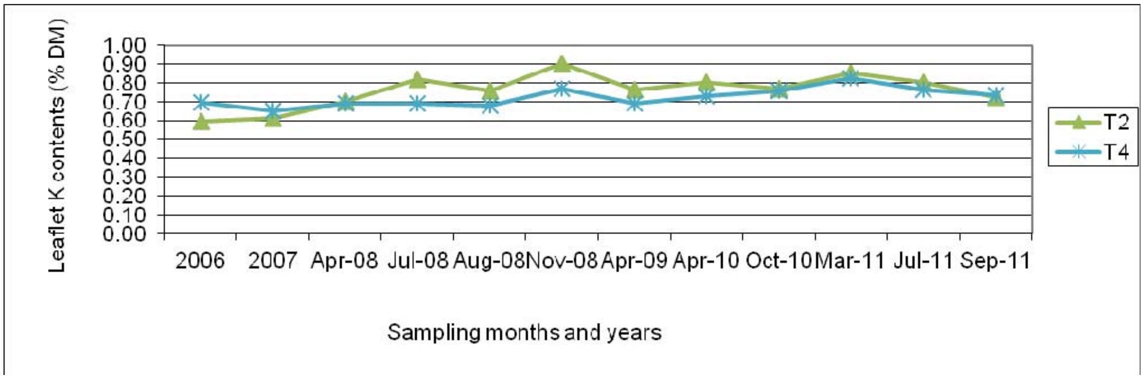

Figure 7. Leaflet K concentrations in T2 and T4 plots.

K addition was stopped in T2 and T4 plots, but remained above 1,5 % DM (Figure 8).

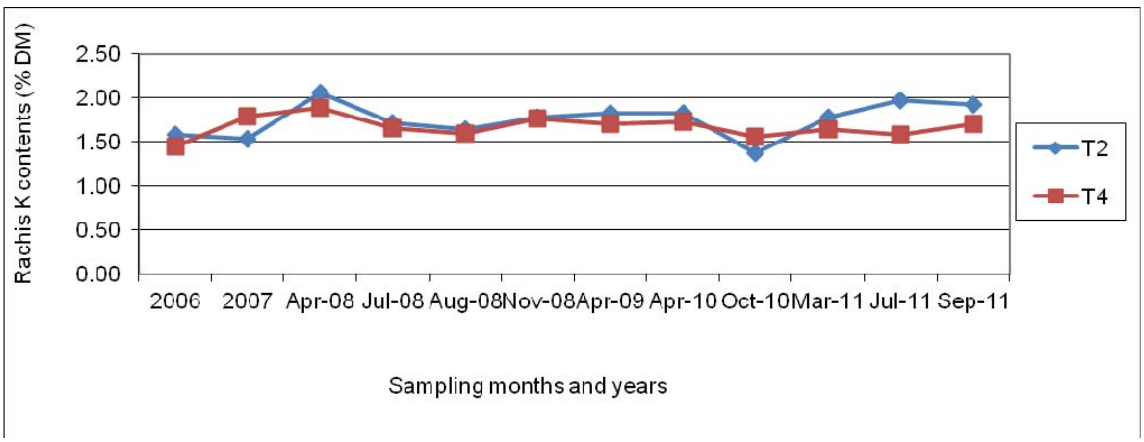

Figure 8. Rachis K concentrations in T2 and T4 plots.

Addition of N and P in T2 plots in 2008 improved leaflet P concentrations (Figure 9). The fall in P contents in April 09 and again in September 2011 happened in both T2 and T4 and therefore cannot be due to P depletion. There appears to be no indication of fall in P contents in the tissues suggesting sufficient P in the system from previous P fertiliser additions to maintain the levels in the palms.

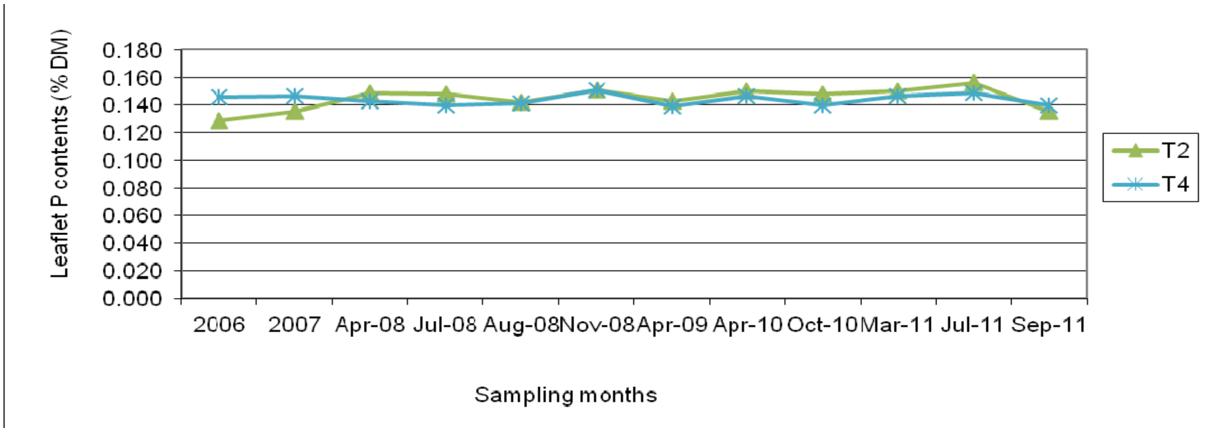

Figure 9. Leaflet P concentrations in T2 and T4 plots

CONCLUSION

The response to addition of fertilisers, especially N fertilisers, had an immediate effect on yield (within a year) and on leaf nutrient content. Addition of N fertilisers to N deficient palms improved the utilisation of K in the palms immediately.

Trial 504. Nitrogen by Potassium trial, Sagarai (RSPO 4.2, 4.3, 4.6, 8.1)

SUMMARY

Trial 504 was established at Sagarai Estate in Milne Bay Estates to test oil palm responses to N and K fertilisers. Soils in this area are of recent alluvial origin, consisting of deep clay loam soils with a reasonably good drainage status. Treatments consisted of four rates each of 0, 2.0, 4.0 and 6.0 kg/palm of SOA and 0, 2.5, 5.0 and 7.5 kg/palm of MOP. FFB yield, frond 17 nutrient concentration and vegetative growth parameters responded well to the fertiliser treatments, especially to SOA as the N source. N drives production in this estate. Over the last few years the response to K fertiliser has been increasing. Highest yields were obtained at high levels of SOA in the presence of MOP.

BACKGROUND

The background information for the trial is shown in Table 1.

Table 1. Trial 504 background information.

Trial number	**504**	Company	CTP Milne Bay Estates
Estate	Sagarai	Block No.	Field 0610, 0611 and 0612
Planting Density	127 palms/ha	Soil Type	Clays (alluvium)
Pattern	Triangular	Drainage	Moderate
Date planted	1991	Topography	Flat
Age after planting	21 years	Altitude	94 m asl
Recording Started	1995	Previous Land use	Ex-Forest/Rubber plantation
Planting material	Dami D x P	Area under trial soil type (ha)	1324
Progeny	unknown	Supervisor in charge	Wawada Kanama

METHODS

Experimental Design and Treatments

64 plots, each with a core of 16 measured palms, made up the trial site. In each plot the core palms are surrounded by a guard row and a trench. The 64 plots are divided into sixteen treatments (four levels of N by four levels of K), and replicated four times (Table 2). Fertiliser was first applied in 1994. Fertilisers are applied in 3 doses per year. TSP at 0.5 kg/palm was applied as a basal in 2011. The trial was closed at the end of 2011.

Table 2. Types of treatment fertiliser and rates used in Trial 504.

	Amount (kg/palm/year)			
	Level 0	Level 1	Level 2	Level 3
SOA*	0	2.0	4.0	6.0
MOP*	0	2.5	5.0	7.5

* SOA (Sulphate of Ammonia) contains 21% N and MOP (Muriate of Potash) contains 51% K.

Data Collection

Yield recording (weighing of bunches) is done on a ten day round basis. Vegetative measurements included: palm height; frond measurements (total frond length, leaflet width, leaflet length, total number of leaflets); and rachis cross-section width and thickness. Total number of fronds and new frond counts were undertaken twice annually. Leaflet and rachis sampling for tissue nutrient concentration was carried out on frond 17 using standard procedures. Samples were analysed by AAR. Trial data was analysed using standard two way analysis of variance.

RESULTS and DISCUSSION

Yield and other components response to fertiliser treatments

Treatment effects on FFB yield and other components are shown in Tables 3 and 4. The overall effect of the treatments, over the course of the trial, is illustrated in Figure 1. In 2011 and 2009-2011, SOA and MOP had significant effects ($p<0.001$) on FFB yield and this was due to significant increases in BN and SBW. The positive effect from MOP was mostly due to an increase in the number of bunches.

The treatments effects, especially from SOA in increasing yield, have been consistent over the last ten years. The yield difference between the maximum level and zero level of SOA application widened in 2005, 2006 and continued up to 2011.

Table 3. Effect (p values) of treatments on FFB yield and its components for 2011 and 2009 to 2011

	2011			2009 to 2011		
Source	Yield	BN	SBW	Yield	BN	SBW
SOA	**<0.001**	**0.006**	**<0.001**	**<0.001**	**<0.001**	**<0.001**
MOP	**<0.001**	**<0.001**	0.296	**<0.001**	**0.002**	0.164
SOA.MOP	0.632	0.552	0.656	0.391	0.561	0.148

3 years averaged data. P values less than 0.05 are presented in bold.

Table 4. Main effects of treatments on FFB yield (t/ha) and its components for 2011 and 2009 to 2011

	2011				2009-2011		
	Yield (t/ha)	BN (b/ha)	SBW (kg)		Yield (t/ha)	BN (b/ha)	SBW (kg)
SOA0	**23.4**	**911**	**25.6**		**21.0**	**842**	**24.9**
SOA1	**24.7**	**940**	**26.3**		**23.5**	**895**	**26.3**
SOA2	**27.1**	**970**	**28.0**		**26.3**	**942**	**28.0**
SOA3	**29.1**	**1041**	**28.0**		**27.3**	**978**	**27.9**
$LSD_{0.05}$	2.29	73.1			1.83	56.1	0.91
MOP0	**22.8**	**862**	26.5		**22.1**	**847**	26.3
MOP1	**26.2**	**975**	26.8		**24.6**	**919**	26.7
MOP2	**28.0**	**1014**	27.6		**26.0**	**950**	27.3
MOP3	**27.3**	**1010**	26.9		**25.2**	**940**	26.8
$LSD_{0.05}$	*2.29*	*73.1*			*1.83*	56.1	
GM	26.1	965	27.0		24.5	914.2	26.8
SE	3.22	102.8	1.73		2.57	78.9	1.29
CV %	12.4	10.6	6.4		10.5	8.6	4.8

Three years averaged data. P values less than 0.05 are presented in bold.

Combinations of both SOA and MOP produced the highest yields (Table 5). The highest FFB yields were obtained at 4 and 6 kg SOA in the presence of MOP.

Table 5. Effect of SOA and MOP on FFB yield (t/ha) in 2011 and 2009 to 2011 (three year average data). The treatment interactions are not significant.

SOA by MOP – 2011				
	MOP0	MOP1	MOP2	MOP3
SOA0	21.6	22.4	25.8	23.8
SOA1	21.9	24.4	**28.0**	24.5
SOA2	23.7	**27.7**	**28.1**	**28.9**
SOA3	24.0	**30.3**	**30.1**	**32.0**

SOA by MOP – 2009 to 2011				
	MOP0	MOP1	MOP2	MOP3
SOA0	20.1	20.1	22.1	21.8
SOA1	21.2	22.6	26.8	23.4
SOA2	23.3	26.4	**28.0**	**27.4**
SOA3	24.0	**29.4**	27.2	28.4

At various combinations of SOA and MOP over time, yields at nil SOA and MOP plots were on average at 20 t/ha while in the fertilised plots, the yields were greater than 25 t/ha (Figure 1).

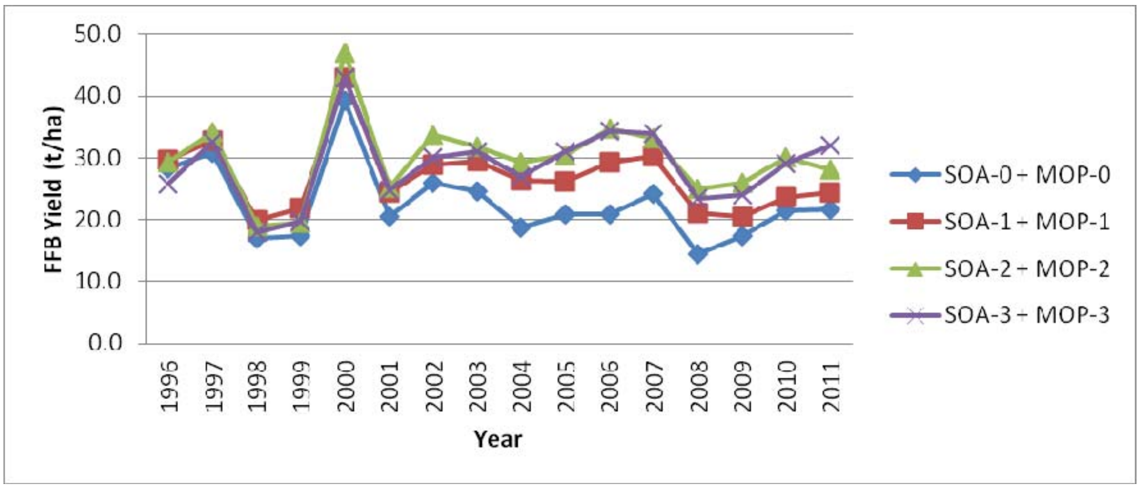

Figure 1. Effects of various combinations of SOA and MOP on yield from 1996 to 2010.

Fertiliser effects on Frond 17 nutrient concentrations

SOA and MOP had a significant impact on tissue nutrient concentration (Tables 6 and 7). SOA application increased the level of N in the leaflets and in the rachis whilst lowered rachis P and K concentrations. MOP increased leaflet K, Ca and Cl, and rachis Ash, P and K concentrations but lowered leaflet Ash and Mg contents.

In brief:

- In the leaflets N was low with the zero N treatment and adequate at higher rates
- P levels in leaflets were adequate
- K levels were low in the leaflet for the zero K treatment and adequate at higher rates
- B levels (12 ppm) were low
- N fertiliser mobilized P and K out of the rachis
- K in the rachis was very low for the zero MOP treatment

With very low values of K in the rachis for the zero MOP treatment, palms in these plots will experience increasing deficiency in K, as already exhibited in the leaflets with this treatment, and yields in this treatment are likely to fall in the near future.

Table 6. Effect (p values) of treatments of frond 17 nutrient concentration.

Source	**Leaflet nutrient concentrations**								**Rachis nutrient concentrations**			
	Ash	**N**	**P**	**K**	**Mg**	**Ca**	**Cl**	**B (ppm)**	**Ash**	**N**	**P**	**K**
SOA	**<0.001**	**0.004**	0.534	0.066	0.475	0.350	0.497	**0.716**	**0.013**	**0.039**	**<0.001**	**0.003**
MOP	**0.013**	0.267	0.268	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**0.027**	**<0.001**	0.234	**<0.001**	**<0.001**
SOA.MOP	0.673	0.295	0.516	0.335	0.423	**0.028**	0.104	0.593	0.568	0.322	0.489	0.747

P values < 0.05 are shown in bold.

Table 7. Main effects of treatments on frond 17 nutrient concentration.

	Leaflet nutrient concentrations								**Rachis nutrient concentrations**			
	Ash	**N**	**P**	**K**	**Mg**	**Ca**	**Cl**	**B (ppm)**	**Ash**	**N**	**P**	**K**
SOA0	**11.6**	**2.24**	0.149	0.60	0.39	0.80	0.48	12.3	4.61	**0.30**	**0.274**	**1.43**
SOA1	**11.7**	**2.26**	0.149	0.59	0.38	0.82	0.49	11.8	4.59	**0.31**	**0.233**	**1.40**
SOA2	**12.2**	**2.32**	0.150	0.57	0.39	0.82	0.50	12.0	4.25	**0.31**	**0.185**	**1.26**
SOA3	**12.5**	**2.34**	0.150	0.55	0.40	0.81	0.50	12.1	4.23	**0.33**	**0.165**	**1.14**
$LSD_{0.05}$	*0.329*	*0.058*								*0.023*	*0.0203*	*0.163*
MOP0	**12.3**	2.27	0.148	**0.51**	**0.43**	**0.78**	**0.42**	12.6	**3.39**	0.32	**0.179**	**0.65**
MOP1	**12.1**	2.29	0.150	**0.56**	**0.40**	**0.84**	**0.50**	12.4	**4.55**	0.31	**0.223**	**1.43**
MOP2	**11.8**	2.29	0.150	**0.61**	**0.37**	**0.82**	**0.53**	11.7	**4.91**	0.31	**0.229**	**1.60**
MOP3	**11.8**	2.33	0.150	**0.63**	**0.36**	**0.81**	**0.51**	11.4	**4.85**	0.30	**0.226**	**1.56**
$LSD_{0.05}$	*0.329*			*0.0374*	*0.0189*	*0.026*	*0.028*	*0.869*	*0.299*		*0.0203*	*0.163*
GM	12.0	2.29	0.149	0.58	0.39	0.81	0.49	12.0	4.42	0.31	0.214	1.31
SE	0.463	0.082	0.0039	0.0526	0.0266	0.036	0.0396	1.222	0.420	0.0324	0.0286	0.229
CV %	3.9	3.6	0.58	9.1	6.8	4.5	8.1	10.2	9.5	10.4	13.3	17.5

P values < 0.05 are shown in bold. All units expressed in % dry matter.

Though statistically not significant, the response of rachis K to addition of SOA and MOP is presented in Table 8. The lowest rachis K content was at SOA3 (6.0 kg/palm/year) implying high N have led to depletion of K reserves in the palms and or remobilizing K reserves in the rachis.

Table 8. Effect of SOA and MOP on rachis K concentrations in 2011

	MOP0	MOP1	MOP2	MOP3
SOA0	0.87	1.49	1.68	1.69
SOA1	0.80	1.54	1.72	1.53
SOA2	0.48	1.49	1.50	1.57
SOA3	0.45	1.20	1.45	1.46

Fertiliser effects on vegetative growth parameters

Effects of SOA and MOP on vegetative parameters are presented in Tables 9 and 10. Only SOA affected FP but both SOA and MOP had positive and significant effects on dry matter production parameters in 2011. The mean bunch index was 0.36 in 2011.

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Table 9. Effect (p values) of treatments on vegetative growth parameters in trial 504

			Radiation interception			Dry matter production				
Source	FL	PCS	FP	FA	LAI	FDM	BDM	TDM	VDM	BI
SOA	0.416	0.313	**0.014**	0.657	0.103	**0.037**	**<0.001**	**<0.001**	**0.013**	0.099
MOP	0.314	0.136	0.150	0.199	0.359	**0.036**	**<0.001**	**<0.001**	**0.011**	0.124
SOA.MOP	0.253	0.324	0.517	0.632	0.731	0.476	0.629	0.532	0.475	0.604

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

FL = Frond length (cm); PCS = Petiole cross-section (cm^2); FP = annual frond production (new fronds/year); FA = Frond Area (m^2); LAI = Leaf Area Index; FDM = Frond Dry Matter production; BDM = Bunch Dry Matter production; TDM = Total Dry Matter production; VDM = Vegetative Dry Matter production; BI = Bunch Index (calculated as BDM/TDM)

Table 10. Main effects of treatments on vegetative growth parameters in trial 504

			Radiation interception			Dry matter production (t/ha/year)				
	FL	PCS	FP	FA	LAI	FDM	BDM	TDM	VDM	BI
SOA0	631.3	61.4	**23.9**	13.8	5.49	**19.6**	**12.6**	**35.8**	**23.2**	0.35
SOA1	635.7	64.1	**24.3**	13.5	5.39	**20.8**	**13.2**	**37.8**	**24.6**	0.35
SOA2	631.1	64.7	**24.9**	13.8	5.70	**21.6**	**14.5**	**40.1**	**25.6**	0.36
SOA3	638.9	64.3	**24.9**	13.6	5.62	**21.4**	**15.5**	**41.0**	**25.5**	0.38
$LSD_{0.05}$			*0.707*			*1.419*	*1.240*	*1.956*	*1.565*	
MOP0	629.3	61.0	24.0	13.4	5.47	**19.6**	**12.1**	**35.1**	**23.1**	0.34
MOP1	635.6	63.9	24.7	13.6	5.46	**21.1**	**14.0**	**39.0**	**25.0**	0.36
MOP2	632.8	64.2	24.7	14.0	5.66	**21.3**	**15.1**	**40.4**	**25.3**	0.38
MOP3	639.3	65.4	24.6	13.8	5.61	**21.5**	**14.5**	**40.1**	**25.5**	0.36
$LSD_{0.05}$						*1.419*	*1.240*	*1.956*	*1.565*	
GM	634.3	63.6	24.5	13.7	5.55	20.9	13.9	38.7	24.7	0.36
SE	15.35	5.453	0.993	0.850	0.379	1.993	1.742	2.747	2.198	0.037
CV %	2.4	8.6	4.1	6.2	6.8	9.6	12.5	7.1	8.9	10.3

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

CONCLUSION

N fertiliser, applied as SOA, was the main driver of production in this trial. N treatments resulted in higher concentrations of N in the leaflets rachis and leaflets, increased frond dry matter production and subsequent high yields. The high yield of palms in the N treatments was brought about by more and heavier bunches. K fertiliser, applied as MOP, is becoming more important over time as K levels are dropping in the zero MOP plots. Palms in these plots have low rachis and leaflet K levels. Highest yield was obtained by a combination of the higher rates of SOA (4 to 6 kg SOA/palm or 0.8 to 1.2 kg N/palm) together with middle rate of MOP (5.0 kg MOP/palm or 2.55 kg K/palm).

Trials 517: K placement trial at Maiwara Estate (RSPO 4.2, 4.3, 4.6, 8.1)

SUMMARY

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

INTRODUCTION

Two new trials were established in 2007 at Maiwara. Trial 516 is a NxK factorial trial; and Trial 517 is a replicated K placement trial. The trial site was selected in 2005 and pre-treatment yield data was collected for eighteen months until the first fertiliser treatments were applied in May 2007. Site details are presented in Table 1.

Table 1. Trial 517 background information

Trial number	**517**	Company	Milne Bay Estates
Estate	Hagita, Maiwara	Block No.	AJ 1290
Planting Density	143 p/ha	Soil Type	Alluvial
Pattern	Triangular	Drainage	Site is often waterlogged
Date planted	2001	Topography	Flat
Age after planting	11	Altitude	Not known
Recording started	2005	Previous Land-use	Forest
Planting material	Dami D x P	Area under trial soil type (ha)	Not known
Progeny	Mix	Supervisor in charge	Wawada Kanama

Basal fertiliser applied in 2010: 0.5kg/palm TSP

METHODS

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

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

RESULTS AND DISCUSSION

Analysed yield data for 2011 and 2009-2011 are presented in Table 2. Yield data for the nil fertilised and the highest MOP rate plots are also presented in the same table. There was no effect of K placement on yield and yield components in 2011. Yield in the nil fertilised plot was 3t/ha less than highest MOP fertilised plot. Mean FFB yield was 27.1 t/ha in 2011.

Table 2. Main effects of fertiliser placement treatments on FFB yield (t/ha) and its components for 2011 and 2009 to 2011 (three years averaged data). P values less than 0.05 are presented in bold.

	2011			**2009-2011**		
	Yield (t/ha)	**BN (bunches/ha)**	**SBW (kg)**	**Yield (t/ha)**	**BN (bunches/ha)**	**SBW (kg)**
Nil fertiliser	25.4	1386	18.3	27.5	1504	18.3
Highest MOP rate	28.3	1404	20.1	29.4	1469	20.0
Edge of weeded circle	28.2	1402	20.2	28.1	1417	19.9
Weeded circle	25.7	1342	19.2	27.5	1455	19.0
Broadcast	26.5	1391	19.1	29.1	1523	19.1
Frond tips and piles	28.0	1499	18.7	28.9	1521	19.0
P values	*0.295*	*0.504*	*0.093*	*0.206*	*0.471*	*0.495*
GM	27.1	1408	19.3	28.4	1479	19.3
SE	2.06	144.3	0.77	1.10	109.4	0.93
C.V.%	7.6	10.2	4.0	3.9	7.4	4.8

P values less than 0.05 are presented in bold.

Analysed leaf tissue nutrient content data are presented in Table 3. Again, just as was with the yield data, there are still no responses to the different fertiliser placement. The mean rachis K concentration in nil fertiliser plot was 0.99 % DM and was much lower than the treated plots which had a mean of 1.72 % DM. The highest MOP fertilised plot has rachis K concentration of 1.87 % DM. The difference suggests there is response to MOP fertiliser addition, however there is no statistically significant difference between the placement treatments.

Table 3. Trial 517, main effects of treatments on frond 17 nutrient concentrations in 2011, in units of dry matter %. P values less than 0.05 are indicated in bold

	Leaflet nutrient concentrations									**Rachis nutrient concentrations**		
Treatments	**Ash**	**N**	**P**	**K**	**Mg**	**Ca**	**Cl**	**B (ppm)**	**Ash**	**N**	**P**	**K**
Nil fertiliser	13.8	2.48	0.145	0.52	0.36	0.80	0.50	12	5.1	0.35	0.088	0.99
Highest MOP rate	13.2	2.51	0.143	0.51	0.33	0.91	0.54	12	5.8	0.30	0.087	1.87
Edge of weeded circle	13.8	2.52	0.142	0.50	0.34	0.89	0.53	12.8	6.0	0.34	0.132	1.73
Weeded circle	13.8	2.45	0.141	0.52	0.34	0.85	0.51	12.4	5.9	0.33	0.116	1.65
Broadcast	14.1	2.40	0.140	0.52	0.33	0.87	0.55	11.8	5.9	0.31	0.115	1.66
Frond tips and piles	14.3	2.41	0.142	0.51	0.34	0.91	0.53	13.4	7.5	0.35	0.121	1.84
P values	0.535	0.013	0.749	0.472	0.718	0.249	0.372	0.280	0.048	0.510	0.946	0.271
GM	14.1	2.45	0.141	0.52	0.34	0.88	0.53	12.6	6.3	0.33	0.121	1.72
SE	0.611	0.0462	0.0037	0.022	0.021	0.043	0.027	1.098	0.844	0.035	0.043	0.148
C.V.%	4.3	1.9	2.7	4.2	6.3	4.9	5.1	8.7	13.3	10.6	35.9	8.6

P values less than 0.05 are indicated in bold

SUMMARY

There is response in yield and leaf tissue nutrient contents to K placement.

Trial 513: Spacing and Thinning Trial, Padipadi (RSPO 4.2, 4.3, 8.1)

SUMMARY

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

INTRODUCTION

The purpose of the trial was to determine the effects of spacing configuration, thinning and density on palm yield. The theory is that during the immature phase, the yield of palms planted at a high planting density will be higher compared to the lower planting density until canopy closure has been achieved (at approximately 5 years of age). Following thinning of the high density plots the wider avenues will allow more sunlight to penetrate the remaining palm rows and yield should be able to be maintained at a similar levels compared to the lower planting densities. The end result is a higher total yield over the immature phase with the higher planting densities without a subsequent loss in yield after canopy closure has been achieved. In a smallholder situation, it would also be possible to grow food or cash crops for extra income in the wider inter-rows. Back ground information of the trial is presented in Table 1.

Table 1. Trial 513 back ground information

Trial number	**513**	Company	Milne Bay Estates
Estate	Padipadi	Block No.	1051
Planting Density	See Table 3	Soil Type	Alluvial
Pattern	Triangular	Drainage	Good

Date planted	2003	Topography	Flat
Age after planting	8	Altitude	Not known
Recording started	April 2006	Previous Land-use	Savanna grassland
Planting material	Dami D x P	Area under trial soil type (ha)	Not known
Progeny	Known	Supervisor in charge	Wawada Kanama

METHODS

Design and treatments

The design is the same as Trial 331 at Higaturu. There are 6 treatments initially of different planting densities with equilateral triangular spacing (Table 2). In treatments 4, 5 and 6 every third row was removed 5 years after planting and treatments 1, 2 and 3 remain as planted (thinning took place in February, 2008). The final densities of treatments 4, 5 and 6 will be the same as treatments 1, 2 and 3 but they will have closely spaced pairs of rows with wider avenues between the pairs. There are 3 replicates of the 6 spacing treatments, giving a total of 18 plots. Each plot has 4 rows of recorded palms and these plots are enclosed by guard palms. Fertiliser application will follow normal plantation practice for an immature fertiliser program up to year 6.

Table 2. Treatment allocations in Trial 513. 'Thinning' involved the removal of every third row, 5 years after planting, in treatments 4, 5 and 6 (in February 2008).

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

( ) avenue width before thinning
* includes guard rows

Data Collection

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

Statistical Analysis

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

RESULTS and DISCUSSION

Density treatments had a significant effect on yield during the pre-thinning years - 2006 and 2007. There was no difference in yield in the treatments post-thinning in 2008, 2009 and 2010 (Table 3).

2006 Yield: treatments 4, 5 and 6 had a significantly higher yield ($P=0.006$) compared to treatments 1, 2 and 3

2007 Yield: treatment 6 had a significantly higher yield compared to treatments 4 and 5, which in turn had a significantly higher yield compared to treatments 1, 2 and 3 ($P<0.001$)

2008 Yield: there was no significant difference in yield between the treatments post thinning (P=0.11)

2009 Yield: there was no significant difference in yield between the treatments post thinning

2010 Yield: there was no significant difference in yield between the treatments post thinning

2011 Yield: there was significant difference between thinned and unthinned palms even at similar densities.

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

Table 3. Trial 513 Main effects of density treatments on FFB yield (t/ha) and its components for 2011 and 2009 to 2011 (three years averaged data). P values less than 0.05 are presented in bold.

	2011			**2009-2011**		
Density Treatment	**FFB yield (t/ha)**	**BNO/ha**	**SBW (kg)**	**FFB yield (t/ha)**	**BNO/ha**	**SBW (kg)**
128	27.1	1728	15.7	30.2	**2547**	12.6
135	25.9	1691	15.3	30.0	**2601**	12.4
143	26.1	1718	15.2	30.5	**2723**	12.1
128 (192)	23.4	1429	16.4	27.3	**2265**	13.0
135 (203)	22.8	1479	15.4	26.9	**2361**	12.3
143 (215)	22.7	1451	15.7	27.6	**2375**	12.6
$lsd_{0.05}$	*3.06*	*195.8*			*180.3*	
p values	**0.031**	**0.012**	0.495	0.102	**0.002**	0.410
Grand Mean	24.7	1583	15.6	28.7	2478	12.5
SE	1.68	107.6	0.789	1.808	99.13	0.530
CV %	6.8	6.8	5.0	6.3	4.0	4.2

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

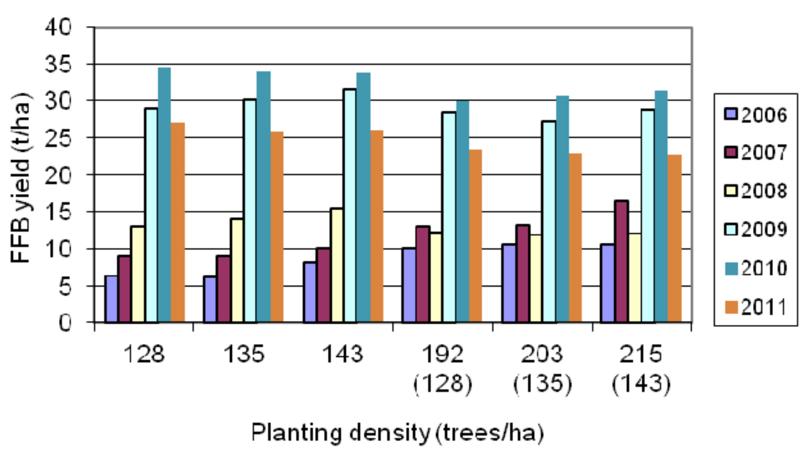


Figure 1. Trial 513: FFB yield for the pre-thinning years (2006 and 2007) and the post-thinning year (2008 - 2011).
Note 1. the planting density in brackets refers to post-thinning
Note 2. in 2006 harvest commenced in April (yield only for April to December)
Note 3. post-thinning in 2008 harvest commenced in April (yield only for April to December)

Leaf tissues nutrient contents are reasonably above critical levels except for rachis K content which is at 1.09 % DM. K could be limiting in this environment due to no proper fertiliser applications.

Table 3. Trial 513, frond 17 nutrient concentrations in 2010, in units of dry matter %.

	Leaflets nutrient concentrations (% DM)								Rachis nutrient concentrations (% DM)			
Plots	**Ash**	**N**	**P**	**K**	**Mg**	**Ca**	**B (ppm)**	**Cl**	**Ash**	**N**	**P**	**K**
1	16.09	2.52	0.155	0.65	0.39	0.95	20	0.67	4.70	0.33	0.094	1.16
6	14.77	2.63	0.157	0.61	0.46	0.93	19	0.70	4.57	0.34	0.090	0.95
14	14.16	2.65	0.156	0.67	0.33	0.86	21	0.50	5.09	0.34	0.093	1.16
Mean	15.01	2.60	0.160	0.64	0.39	0.91	20	0.62	4.79	0.34	0.090	1.09

P values less than 0.05 are indicated in bold

CONCLUSION

There was no effect of density treatments in the post-thinning phases but there are differences in yield between thinned and unthinned palms.

NBPOL, KULA GROUP, POLIAMBA ESTATES, NEW IRELAND PROVINCE

(Murom Banabas and Paul Simin)

SUMMARY AND SYNOPSIS

A single fertiliser response trial was undertaken with Poliamba Estates in 2011:

Factorial trial response to B and K: two types of Boron fertiliser (CaB and NaB) were compared to a zero control in a factorial combination with two rates of MOP.

Outcome: thus far after two years of treatment implementation there has been no yield response to either B or MOP. However, leaf boron levels have increased with applied B fertiliser, but K levels have not changed (and this nutrient is present at an adequate level).

Poliamba Estates: Synopsis of 2011 PNGOPRA trial results and recommendations

Trial	Palm Age	Yield t/ha	Yield Components	Tissue % DM	Notes
254 Poliamba B, MOP (factorial) Soil: Clay over coral	22	SOA x MOP 27.6 (NS)	BHA 1004 (NS) SBW 27.5 (NS)	MOP LK 0.74 (NS) RK 1.76 B LB 15 to 17 mg/kg LN 2.58, RN 0.33: LP 0.153, RP 0.135 LMg 0.24	Plantation standards improved. Crop recovery is higher. In 2007 and 2008 CaB was not available, trial has been changed to a NxKxB trial.

Recommendations to Poliamba Estates:

- At Poliamba 30+ t/ha FFB should be attainable in mature plantations
- Tissue testing and vegetative measurement criteria will help in determining deficiencies of particular nutrients
- Most of the focus for nutrition should be on N, followed by P and K, followed by Mg and B
- Economic return from different fertiliser strategies can be calculated if costs of production are provided to OPRA
- Plantation management (harvest time, pruning, clean weeded circles, fertiliser application and timing etc) all play a large role in the potential to optimize production

Trial 254: Boron Requirement Trial at Poliamba (RSPO 4.2, 4.3, 4.6, 8.1)

SUMMARY
The trial is in its fourth year of full monitoring and assessment. All 3 fertiliser treatments affected yield and or tissue nutrient concentrations in 2009. CaB was not available in 2007/2008 and the trial was changed in 2008 to a NxKxB trial.

METHODS

Trial Background Information
Nitrogen, Boron and Potassium deficiency is evident in many blocks at Poliamba. This trial is designed to provide information that will help make recommendations for N, K and B fertiliser applications at Poliamba. Specifically, the original trial was designed to test responses to Ca borate or Na borate at two rates, and secondly, to test the interaction between Boron with Potassium. CaB was not available in 2007 and the trial was changed in early 2008 to an NxKxB trial. Background information to the trial is supplied in Table 1.

Table 1. Trial 254 background information.

Trial number	**254**	Company	CTP Poliamba Ltd.
Plantation	Maramakas	Block No.	MKS 210 E2
Planting Density	128 palms/ha	Soil Type	Brown clay over raised coral
Pattern	Triangular	Drainage	Free, except for in depressions
Date planted	1989	Topography	Undulating, depressions and sink holes
Age after planting	22 years	Altitude	50 m asl
Recording Started	2005	Previous Landuse	Coconut plantation/forest
Progeny	unknown	Area under trial soil type (ha)	3170
Planting material	Dami D x P	Supervisor	Paul Simin

Experimental Design and Treatments
After the change in trial design (see 2007 Annual Report) the current treatments consist of 2 rates of N; 2 rates of MOP and 3 rates of B – replicated 4 times for a total of 48 plots. The trial layout is a randomized block design, with pre-treatment measurements and soil depth used as covariates if necessary. 12 treatments x 4 replicates was analysed using ANOVA. Basal fertilisers applied to all plots: TSP 1 kg / palm, Kieserite 1 kg / palm and Urea 2kg / palm. The trial treatments were first applied in 2005 and this was the fourth full year of monitoring and assessment.

Changes made to trial design (T254) in early 2008
Originally the trial was a Boron type by rate (NaB vs CaB, applied at 0, 0.08 and 0.16kg/palm) and a MOP rate (2.5 and 7.5 kg/palm). However, in 2007 and 2008 it became difficult to source CaB and it was decided to change the trial to a rate trial using different rates of N, K and B. The change in treatment application was implemented in April 2008. The CaB treatment plots now receive the same rate of NaB; the MOP treatment plots remained the same; and two rates of AC were implemented (4 and 8 kg/palm) (Table 2).

Table 2. Trial 254 new trial layout (April 2008)

Plot	**Rep**	**AC**	**MOP**	**NaB**	**Plot**	**Rep**	**AC**	**MOP**	**NaB**
1	2	4	2.5	0	25	2	4	2.5	0.08
2	2	8	2.5	0	26	3	8	2.5	0.08
3	4	4	2.5	0	27	3	8	7.5	0.08
4	3	4	2.5	0.08	28	3	4	7.5	0
5	4	8	2.5	0.08	29	3	8	7.5	0.16

6	2	4	2.5	0.16	30	1	4	7.5	0
7	3	4	7.5	0.16	31	1	4	7.5	0.08
8	2	8	7.5	0.16	32	3	8	7.5	0
9	4	8	2.5	0.16	33	2	4	7.5	0.08
10	1	4	2.5	0	34	4	8	7.5	0
11	4	8	7.5	0.16	35	2	8	7.5	0.08
12	3	4	2.5	0.16	36	4	8	2.5	0
13	4	4	7.5	0	37	1	8	2.5	0.08
14	1	4	2.5	0.08	38	3	8	2.5	0.16
15	1	8	7.5	0.16	39	4	4	2.5	0.16
16	1	8	2.5	0	40	4	4	2.5	0.08
17	1	4	7.5	0.16	41	4	4	7.5	0.16
18	2	4	7.5	0	42	1	8	7.5	0.08
19	1	4	2.5	0.16	43	4	4	7.5	0.08
20	2	4	7.5	0.16	44	1	8	2.5	0.16
21	2	8	2.5	0.08	45	2	8	7.5	0
22	4	8	7.5	0.08	46	3	4	7.5	0.08
23	3	4	2.5	0	47	2	8	2.5	0.16
24	3	8	2.5	0	48	1	8	7.5	0

Treatment fertilisers

The treatment fertilisers applied every year are:

- N as AC applied at 4 and 8 kg/palm applied twice per year
- K as MOP applied at 2.5 and 7.5 kg/palm applied twice per year
- B as NaB applied at 0, 0.08 and 0.16 kg/palm applied once per year

Basal fertiliser: TSP at 1kg/p and Kieserite at 1kg/palm, both once per year

RESULTS and DISCUSSION

Yield and its components

Effects of fertiliser treatments on FFB yield and its components are presented in Tables 3 and 4. AC and MOP did not affect FFB yield in 2011 (see Table 4) however AC had a significant for the 3 years 2009-2011 period. There was no effect of boron, and the mean yield was 38.9 t/ha in 2011, compared to 27.2 t/ha in 2010. Though statistically not significant, increased yields due to addition of AC were further enhanced with MOP (Table 5). The yields were averaged over all levels of B because there was no clear response trend addition of B. Prior to the trial starting the soil depth immediately adjacent to each palm was measured and this was used as a co-variate in the Anova analysis; the pre-treatment data for 2004 was also tested as a co-variate. There was no improvement in the explanation of yield resulting from the different fertiliser treatments if soil depth was used as the co-variate. When the pre-treatment data for 2004 was used as the co-variate the explanation of the effect of the fertiliser treatment on yield was slightly improved (but still not significant).

Table 3. Trial 254, effects (p values) of treatments on FFB yield and its components for 2011 and 2009 to 2011 (3 years averaged data).

Source		**2011**				**2009 to 2011**		
		Yield	**BN**	**SBW**		**Yield**	**BN**	**SBW**
AC		0.074	0.132	0.911		**<0.001**	**0.007**	0.530
MOP		0.298	0.271	0.804		0.193	0.314	0.876
BORATE		0.837	0.719	0.800		0.253	0.130	0.598
AC.MOP		0.136	0.134	0.667		0.858	0.924	0.995
AC.Borate		0.356	0.238	0.576		0.192	0.192	0.700
MOP.Borate		0.861	0.886	0.424		0.261	0.599	0.115

P values less than 0.05 are presented in bold.

Table 4. Trial 254, effects of treatments on FFB yield and its components for 2011 and 2009 to 2011 (3 years averaged data).

	2011			**2009-2011**		
Treatments (kg/palm)	**FFB yield (t/ha)**	**BNO/ha**	**SBW (kg)**	**FFB yield (t/ha)**	**BNO/ha**	**SBW (kg)**
AC 4.0	38.0	1339	28.5	**32.0**	**1183**	27.1
8.0	39.9	1406	28.6	**33.5**	**1258**	27.5
l.s.d.$_{0.05}$				*1.041*	53.1	
MOP 2.5	38.4	1349	28.6	32.8	1207	27.3
7.5	39.5	1397	28.5	33.5	1234	27.3
l.s.d.$_{0.05}$						
Borate 0	39.2	1382	28.5	33.5	1241	27.1
0.08	39.1	1388	28.3	33.5	1239	27.2
0.16	38.5	1348	28.8	32.6	1182	27.7
GM	38.9	1373	28.5	33.2	1221	27.3
Se	3.72	150.3	2.018	1.776	90.7	1.840
CV %	9.6	10.9	7.1	5.3	7.4	6.7

P values less than 0.05 are presented in bold.

Table 5. Trial 254, Effect of AC and MOP on FFB yield in 2011.

	MOP 2.5	MOP7.5
AC 4.0	38.2	37.7
AC 8.0	38.5	41.3

Yield over time

Over the course of the trial (established in late 2002 with the treatments first applied in 2005) there has been a steady increase in yield from 17 t/ha in 2003 to 32 t/ha in 2007 and stabilised thereafter (Figure 1). A 5-6 t/ha increase in yield was observed from 2005/2006 to 2007 – this was primarily due to improved harvesting and plantation standards. In 2008 the yield declined by about 2.5 t/ha, due to fewer bunches being harvested, however the crop recovered to 33 t/ha in 2009 but fell to 27 t/ha in 2010. There was a huge increase in FFB yield in 2011 up 38.9 t/ha.

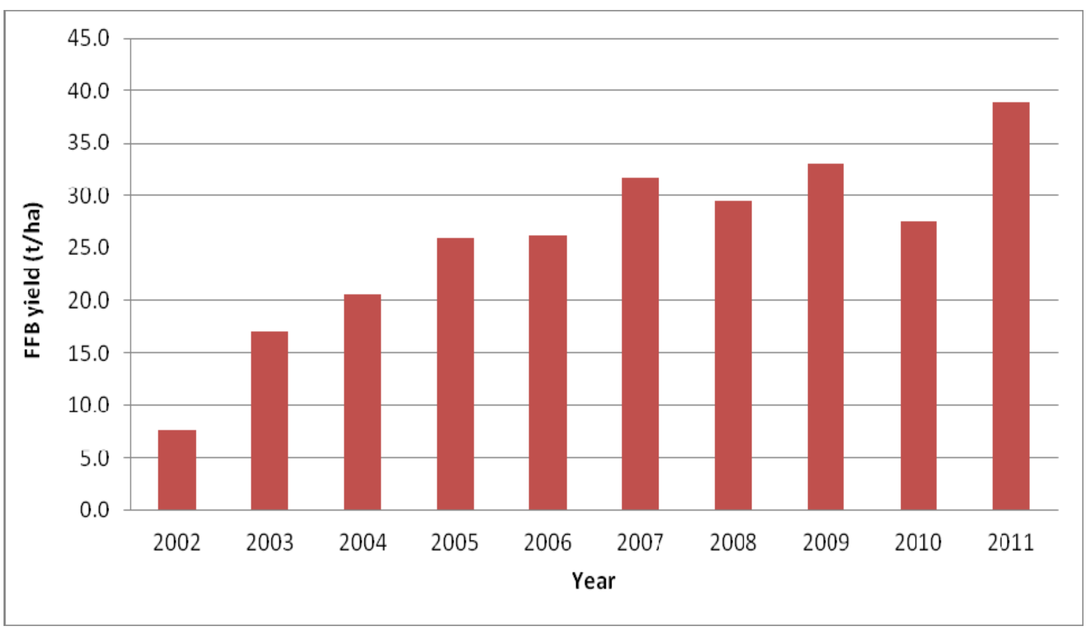


Figure 1. Trial yield since establishment in 2002.

Tissue nutrient concentrations

Effects of fertiliser treatments on leaf tissue nutrient concentrations are presented in Tables 6 and 7. AC significantly increased leaflet and rachis N concentrations in 2011 but reduced leaflet Mg contents. MOP increased rachis Ash, P and K concentrations but lowered leaflet B contents. Borate significantly increased B concentrations in the leaflets however this was not reflected in yield responses.

Table 6. Trial 254, p values of treatment effects on F17 nutrient concentrations in 2011.

Source	Leaflet nutrient concentrations								Rachis nutrient concentrations			
	Ash	N	P	K	Mg	Ca	B	S	Ash	N	P	K
AC	0.495	**<0.001**	0.094	0.760	**0.026**	0.518	0.908	0.360	0.485	**<0.001**	0.705	0.513
MOP	0.714	0.064	0.184	0.191	0.160	0.426	**0.021**	0.203	**<0.001**	0.177	**0.033**	**<0.001**
Borate	0.133	0.605	0.093	0.397	0.797	0.404	**<0.001**	0.293	0.674	0.218	0.710	0.191
AC.MOP	0.741	0.132	0.103	0.227	0.913	0.752	0.590	0.582	0.194	0.520	0.717	0.396
AC.Borate	0.485	0.476	0.440	0.622	0.074	0.419	0.928	0.096	0.701	0.833	0.563	0.561
MOP.Borate	0.469	0.631	0.897	0.880	0.497	0.291	0.214	0.432	0.899	0.011	0.936	0.707

Effects with p<0.05 are shown in bold.

Table 7. Trial 254, main effects of treatments on frond 17 nutrient concentrations in 2010, in units of dry matter % except for B (mg/kg).

Treatments	Leaflet nutrient contents (% DM)								Rachis nutrient contents (% DM)			
(kg/palm)	**Ash**	**N**	**P**	**K**	**Mg**	**Ca**	**B (ppm)**	**S**	**Ash**	**N**	**P**	**K**
AC 4.0	7.0	**2.42**	0.148	0.78	0.25	1.03	17	0.210	4.8	**0.37**	0.089	1.62
8.0	6.8	**2.52**	0.151	0.78	0.23	1.05	17	0.212	7.7	**0.47**	0.092	1.58
l.s.d.$_{0.05}$		*0.055*								*0.0325*		
MOP 2.5	7.0	2.50	0.150	0.77	0.24	1.03	18	0.212	**4.3**	0.41	**0.079**	**1.37**
7.5	6.9	2.44	0.148	0.79	0.23	1.05	15	0.210	**5.2**	0.43	**0.101**	**1.83**
l.s.d.$_{0.05}$									*0.280*		*0.0204*	*0.113*
Borate 0	6.7	2.47	0.149	0.79	0.23	1.05	**14**	0.211	4.8	0.42	0.087	1.59
0.08	6.8	2.45	0.147	0.79	0.24	1.02	**17**	0.209	4.8	0.43	0.088	1.67
0.16	7.3	2.49	0.152	0.77	0.24	1.06	**19**	0.213	4.8	0.40	0.096	1.54
l.s.d.$_{0.05}$							*2.227*					
GM	6.9	2.47	0.149	0.78	0.24	1.04	17	0.211	4.8	0.42	0.090	1.60
Se	0.982	0.094	0.0063	0.056	0.026	0.095	3.103	0.0078	0.484	0.0555	0.034	0.190
CV %	14.2	3.8	4.2	7.2	11.0	9.1	18.7	3.7	10.2	13.3	38.4	11.9

P values less than 0.05 are indicated in bold.

The mean concentrations (% DM) of leaflet N (2.47) and rachis N (0.42); leaflet P (0.149) and leaflet Mg (0.24) and rachis K (1.60) were all adequate.

CONCLUSION

AC had a significant effect on yield, leaf tissue nutrient concentrations and dry matter production.

Muriate of Potash (MOP) also affected yield and leaf tissue K contents but did not affect measured vegetative parameters. Borate fertiliser had no effect on yield and vegetative parameters but significantly increased B concentrations in the leaflets.

NBPOL, KULA GROUP, HIGATURU OIL PALM, ORO (NORTHERN) PROVINCE

(Murom Banabas and Winston Eremu)

Trial 324 Nitrogen Source Trial on Volcanic soils, Sangara Estate (RSPO 4.2, 4.3, 4.6, 8.1)

SUMMARY
The trial was established to test relative effect of different nitrogen fertilisers on volcanic ash soils. The trial design was Randomised Complete Block Design (RCBD). Five different sources of N were tested at 3 different levels; each treatment was replicated 4 times. In 2011 N-type treatment had significant effect on FFB yield and single bunch weight (SBW), no effect on bunch numbers (BNO) in 2011 and for 2009-2011 period, Also PCS, FP, FA, LAI, FDM TDM and VDM were significantly affected in 2011. N-rate treatment had a significant effect on yield, tissue N and most physiological growth parameters. For most variables, the difference between N-rate was significant for 0.42 kg N per palm and 0.84 or 1.68 kg N per palm but not for 0.84 and 1.68 kg N per palm. Compared to the grand mean yield of 32.2 t/ha for palms that received N fertiliser, mean yield for the palms that did not receive N fertiliser was 18.0 t/ha in 2011. This indicates the importance of N for oil palm production on volcanic ash soil. The results of this trial indicate that there are no differences in uptake and performance of the five most commonly used sources of N fertilisers, for oil palm grown on volcanic soils at Higaturu. For plantation management N fertiliser can be purchased on price and ease of application without loss of productivity.

INTRODUCTION
Nitrogen is the most limiting nutrient in oil palm growth and production. Oil palm requires substantial amounts of N to incorporate into organic compounds including proteins, nucleic acids and growth regulators. It was established that N is the major limiting element in soils derived from Mt Lamington volcanic ash material. However, it is not known which fertiliser is a better source for this environment both in relation to high yields and the long-term sustainability of the soils. Results from completed trials such as 309 and 310, which were both located on an outwash plain, showed that SOA is a better source of N compared to AMC or urea, in these ex grassland sandy loam soils. Whether this is the case on other soils is not known. Hence, the purpose of this trial is to test relative effectiveness of different nitrogen fertilisers on Higaturu Soils (Volcanic Plains). The trial commenced in January 2001, about 5 years after field planting. Other background information on the trial is presented in Table 1. Pre-treatment soil data for the trial field indicate high levels of N, organic matter and Ca (Table 2). Exchangeable K and Mg, and CEC are moderate, while pH is generally neutral.

Table 1. Trial 324 background information.

Trial number	**324**	Company	Kula Oil Palm
Estate	Sangara	Block No.	Sangara AB0020 & AB0030
Planting Density	135 palms/ha	Soil Type	Higaturu Soils
Pattern	Triangular	Drainage	Good
Date planted	1996	Topography	Flat
Age after planting	14	Altitude	71.18m asl
Recording Started	2001	Previous Land-use	Replanted oil palm
Planting material	Dami D x P	Area under trial soil type (ha)	32.22
Progeny	Unknown	Agronomist in charge	Winston Eremu

Table 2. Initial soil analysis results from soil samples taken in 2000

Depth cm	pH in water	Exch K	Exch Ca	Exch Mg	CEC	OM %	Total N %	Avail N kg/ha	Olsen P mg/kg	P Ret %	Boron mg/kg	Sulphate S mg/kg
		cmol/kg										
0-10	6.3	0.39	9.5	1.5	14.5	4.4	0.28	178.8	19.5	34.5	0.5	3.8
10-20	6.4	0.30	7.0	0.83	10.8	1.8	0.12	52.8	6.0	49.8	0.2	4.3
20-30	6.7	0.28	8.6	1.13	12.6	1.1	0.07	18.8	6.3	67.3	0.2	5.5
30-60	6.8	0.34	10.0	1.88	15.7	1.1	0.05	10.0	13.3	84.5	0.1	10.3
Control												
0-10	6.1	0.42	7.4	1.57	13.1	4.1	0.25	144	20	31	0.4	3
10-20	6.1	0.41	6.6	0.72	12.1	2.0	0.17	56	8	41	0.3	5
20-30	6.4	0.37	7.4	0.87	11.7	1.1	0.10	20	8	62	0.1	10
30-60	6.7	0.31	9.3	1.82	14.4	0.9	0.08	<10	18	83	<0.1	12

METHODS

Experimental Design and Treatments

This trial was a Randomised Complete Block Design (RCBD) with a treatment structure of 5 N sources x 3 rates x 4 replicates, resulting in 60 plots. For each replicate, 15 treatments were randomly allocated to 15 plots. There was one extra plot for every replicate block, which was the control plot (0 N) and all the 4 control plots were situated at the edge of the trial. In total there were 64 plots in this trial. Each plot consisted of 36 palms, the central 16 were recorded and the outer 20 were guard palms. To minimise poaching of nutrients by roots of palms between plots, trenches were dug around the edges of the plots in 2001/02. The N sources were ammonium sulphate (SOA), ammonium chloride (AMC), ammonium nitrate (AMN), urea and diammonium phosphate (DAP). The rates applied provide equivalent amounts of N for the different N sources (Table 3). Fertiliser treatments were applied in 3 doses per year. Blanket application of MOP at 2 kg per palm per year (2 doses per year) was applied to all palms in the trial field since the trial commenced. In 2008, 2009, 2010 and 2011, no AMN and DAP were applied due to unavailability and not being easily accessible. All palms within the trial field received an annual blanket application of kieserite, TSP and Calcium borate (B) as well, at 1.0, 0.5 and 0.2 kg per palm respectively. This trial was the same design as Trial 125 in Kumbango. See 2001 Proposals for background.

Table 3. Nitrogen source treatments and rates

	Amount (kg/palm/year)		
Nitrogen Source	**Rate 1**	**Rate 2**	**Rate 3**
Ammonium sulphate	2.0	4.0	8.0
Ammonium chloride	1.6	3.2	6.4
Urea	0.9	1.8	3.6
Ammonium nitrate	1.2	2.4	4.8
Di-ammonium phosphate	2.3	4.6	9.2
	(g N/palm/year)		
All sources	420	840	1680

Data Collection

Recordings and measurements were taken on the central 16 palms in each plot. The number of bunches and bunch weights were recorded at 10 day harvesting intervals in line with company practice on an individual palm basis and totalled for each plot, then totalled for each harvest and expressed as per ha per year. Single bunch weight (SBW) was calculated from these data. Leaf sampling was carried out once annually according to standard procedures and analysed for nutrient concentrations using standard analytical procedures. Vegetative measurements were also done annually.

Statistical Analysis

Analysis of variance (Two-way ANOVA) of the main effects of fertiliser and their interactions were carried out for each of the variables of interest using the GenStat statistical program. Data collected from the control plots were not used in the analysis of variance (ANOVA) but mean values were used for comparing treatment effects.

RESULTS and DISCUSSION

Effects of treatments on FFB yield and its components

The effects of different N fertiliser sources and their rates on FFB yield and its components are presented in Tables 4 and 5. There were statistical differences in FFB yield due to rates and N source type in 2011 and 2009-2011 periods. The effect of N type was most likely due to no DAP and AMN applied in the last 4 years (Tables 4 and 5). In 2011 the average yield for +N was 32 t/ha and –N was 18.2 t/ha. The difference between +N and **-** N was 14 t/ha. Even though the yield in control or –N had increased by 6 t/ha from 2010, the FFB yield t/ha gap between +N type and –N still indicate the importance of N in oil palm FFB production.

Table 4. Effects (p values) of treatments on FFB yield and its components in 2011 and 2009–2011.

Source	2011			2009 – 2011		
	Yield	BNO	SBW	Yield	BNO	SBW
Type	**<0.001**	0.065	**0.002**	**0.003**	0.617	**0.001**
Rate	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**
Type. Rate	0.088	0.775	0.085	0.588	0.999	0.097
CV %	*10.6*	*9.4*	*6.5*	*7.0*	*7.0*	*5.1*

p values <0.05 are shown in bold.

Table 5. Main effects of treatments on FFB yield (t/ha) for 2009 - 2011 and 2011.

	2011			2009 – 2011		
Treatments	FFB yield (t/ha)	BNO/ha	SBW (kg)	FFB yield (t/ha)	BNO/ha	SBW (kg)
Control	18.2	1118	**16.0**	15.8	1036	**14.5**
SOA	**34.3**	1490	**22.9**	**35.6**	1591.	**22.4**
AMC	**35.6**	1529	**23.3**	**36.6**	1638	**22.4**
Urea	**31.0**	1395	**22.1**	**33.6**	1579	**21.3**
AMN	**30.5**	1396	**21.8**	**34.5**	1621	**21.3**
DAP	**29.9**	1416	**20.9**	**32.8**	1579	**20.8**
l.s.d.$_{0.05}$			*1.188*			*0.900*
Rate 1	**26.9**	**1325**	**20.2**	**30.4**	**1479**	**20.5**
Rate 2	**33.4**	**1489**	**22.4**	**36.1**	**1654**	**21.9**
Rate 3	**36.4**	**1522**	**24.0**	**37.3**	**1672**	**22.5**
l.s.d.$_{0.05}$	*2.175*	*87.0*	*0..920*	*1.543*	*87.6*	*0.697*
Grand mean	32.2	1445	22.2	34.6	1602	21.6
SE	3.408	136.4	1.442	2.418	137.6	1.093
CV %	*10.6*	*9.4*	*6.5*	*7.0*	*8.6*	*5.1*

p values <0.05 are shown in bold.

Effects of treatments on leaf (F17) nutrient concentrations

The effects of N-type and rates on leaf and rachis tissues are presented in Tables 6 and 7. N-type had a significant effect on leaflet N (p=0.014), Ca (p=0.043) and Cl (p<0.001) and rachis P (<0.001) contents in 2011. N rates had a significant effect on N and P in leaflet and rachis concentrations. N-type x N-rate did have some interaction effect on leaflets P, K Ca and rachis K. Concentration of rachis P in the DAP treated plots was greater than in other N types treated plots. On the other hand, leaflet Ash, N and P and rachis N contents were increased with N rates. Rachis P was depressed with N rates implying high N in the leaflets remobilising rachis P into the leaflets. The leaflet N concentration for the control plots was below the value considered critical (2.3%DM) for oil palm, compared to leaflet N concentrations for palms that received fertiliser, The data shows accumulation of P and K in the rachis from the basal applications.

Table 6. Effects (p values) of treatments on frond 17 nutrient concentrations in 2011.

Source	Leaflet nutrient concentrations (% DM)								Rachis nutrient concentrations			
	Ash	**N**	**P**	**K**	**Mg**	**B**	**Ca**	**Cl**	**Ash**	**N**	**P**	**K**
Type	0.055	**0.014**	0.652	0.928	0.730	0.161	**0.043**	**<0.001**	0.161	0.409	**<0.001**	0.128
Rate	0.098	**<0.001**	**<0.001**	0.536	0.383	0.486	**<0.001**	0.527	0.486	**<0.001**	**<0.001**	0.636
Type. Rate	0.372	0.056	**0.008**	**0.022**	0.660	0.226	**0.008**	0.879	0.226	0.085	0.706	**0.046**
CV %	4.5	5.3	4.1	5.0	8.9	9.6	5.1	8.9	9.6	8.4	23.0	8.8

p values less than 0.05 are in bold.

Table 7. Trial 324, main effects of treatments on frond 17 leaf let and rachis nutrient concentrations in 2011, in units of % dry matter. Values for plots receiving zero N (control) were not included in the analysis of variance.

Treatment	Leaflet nutrient concentrations (% DM)								Rachis nutrient concentrations (% DM)			
	Ash	**N**	**P**	**K**	**Mg**	**B (ppm)**	**Ca**	**Cl %**	**Ash**	**N**	**P**	**K**
Control	14.7	1.87	0.130	0.70	0.20	21	0.770	0.420	6.6	0.30	0.35	2.18
SOA	15.5	**2.22**	0.141	0.72	0.19	19	**0.707**	0.425	6.0	0.32	**0.184**	1.89
AMC	15.4	**2.27**	0.144	0.72	0.19	17	**0.710**	0.513	5.9	0.32	**0.158**	1.89
Urea	14.7	**2.21**	0.144	0.72	0.19	18	**0.741**	0.430	5.6	0.30	**0.170**	1.74
AMN	15.1	**2.17**	0.142	0.72	0.20	18	**0.745**	0.466	6.2	0.32	**0.217**	1.90
DAP	15.3	**2.10**	0.143	0.73	0.20	17	**0.720**	0.439	5.8	0.30	**0.243**	1.85
l.s.d.$_{0.05}$											0.0368	
Rate 1	15.2	**2.05**	**0.138**	0.72	0.19	18	**0.764**	0.447	6.0	**0.29**	**0.228**	1.88
Rate 2	14.9	**2.21**	**0.142**	0.72	0.19	17	**0.731**	0.462	5.9	**0.31**	**0.192**	1.84
Rate 3	15.4	**2.32**	**0.148**	0.73	0.20	17	**0.679**	0.456	5.8	**0.36**	**0.217**	1.85
l.s.d.$_{0.05}$		*0.0739*	*0.004*							*0.0167*	*0.0285*	
GM	15.2	2.19	0.142	0.72	0.19	17	0.724	0.455	5.9	0.31	0.194	1.85
SE	0.678	0.116	0.006	0.036	0.017	1.750	0.037	0.404	0.568	0.026	0.0447	0.1630
CV %	4.5	5.3	4.1	5.0	8.9	9.6	5.1	8.9	9.6	8.4	23.0	8.8

p values less than 0.05 are shown in bold.

Effects of fertiliser treatments on Vegetative parameters

N-type affected PCS (p=0.002) and dry matter production in 2011 (Tables 8 and 9). Petiole cross section of palms in AMC fertilised plots were greater than those in the other N source treated plots.

N-rate significantly increased all the measured physiological growth parameters except FL and BI (Tables 8 and 9). Generally, physiological parameters in the control plots were lower than in the N fertilised plots. The results correspond well with yield and leaf tissue results.

Table 8. Effect (p values) of treatments on vegetative growth parameters in 2011.

Source				Radiation interception			Dry matter production				
	FL	**HI**	**PCS**	**FP**	**FA**	**LAI**	**FDM**	**BDM**	**TDM**	**VDM**	**BI**
Fert. type	0.184	0.337	**0.002**	0.074	0.083	0.075	**0.002**	**<0.001**	**<0.001**	**<0.001**	**0.040**
Rate	0.061	**0.046**	**<0.001**	**<0.001**	**0.003**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	0.065
Type.Rate	0.600	0.801	0.884	0.335	0.445	0.530	0.857	0.136	0.335	0.778	0.153
CV %	2.4	25.2	*6.4*	*5.9*	*3.3*	*5.0*	*9.4*	*10.7*	*8.7*	*9.0*	*4.9*

p values less than 0.05 are shown in bold.

FL = frond length (cm), HI = Height increment (cm), PCS = Petiole cross-section (cm^2); FP = annual frond production (new fronds/year); FA = Frond Area (m^2); LAI = Leaf Area Index; FDM = Frond Dry Matter production; BDM = Bunch Dry Matter production; TDM = Total Dry Matter production; VDM = Vegetative Dry Matter production; BI = Bunch Index (calculated as BDM/TDM).

Table 9. Main effects of treatments on vegetative growth parameters in 2011.

Treatments				**Radiation interception**			**Dry matter production (t/ha/yr)**				
	FL	**HI**	**PCS**	**FP**	**FA**	**LAI**	**FDM**	**BDM**	**TDM**	**VDM**	**BI**
Control	549.0	25.7	28.8	20.8	10.9	4.39	8.9	9.6	20.6	11.0	0.46
SOA	648.1	53.1	**46.4**	22.3	13.5	**5.82**	**14.9**	**18.0**	**36.5**	**18.5**	0.49
AMC	649.0	53.6	**47.4**	22.7	13.6	**5.86**	**15.4**	**18.7**	**37.9**	**19.2**	0.49
Urea	636.6	50.0	**42.4**	21.3	13.2	**5.54**	**13.0**	**16.3**	**32.7**	**16.3**	0.50
AMN	650.2	60.7	**44.8**	21.9	13.6	**5.76**	**14.2**	**16.1**	**33.6**	**17.5**	0.48
DAP	649.5	51.9	**45.4**	21.5	13.7	**5.75**	**14.1**	**15.6**	**33.1**	**17.4**	0..47
$lsd_{0.05}$			*2.398*			*0.235*	*1.110*		***2.503***	*1.321*	
Rate 1	**639.9**	**52.2**	**41.6**	**20.7**	**13.2**	**5.36**	**12.5**	**14.1**	**29.6**	**15.4**	**0.48**
Rate 2	**649.1**	**49.3**	**45.5**	**22.2**	**13.7**	**5.79**	**14.5**	**17.6**	**35.8**	**18.1**	**0.49**
Rate 3	**651.0**	**60.0**	**48.7**	**22.8**	**13.6**	**6.08**	**16.0**	**19.0**	**38.9**	**19.9**	**0.49**
$lsd_{0.05}$	***9.80***	***8.67***	***1.857***	***0.822***	***0.287***	***0.182***	***0.860***	***1.160***	***1.939***	***1.023***	**0.015**
GM	646.7	53.9	45.3	21.9	13.5	5.75	14.3	16.9	34.8	17.8	0.49
SE	15.36	13.59	2.910	1.288	0.450	0.285	1.347	1.818	3.038	1.604	0.024
CV %	2.4	25.2	*6.4*	*5.9*	*3.3*	*5.0*	*9.4*	*10.7*	*8.7*	*9.0*	*4.9*

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

FL = frond length (cm), HI = Height increment (cm), PCS = Petiole cross-section (cm^2); FP = annual frond production (new fronds/year); FA = Frond Area (m^2); LAI = Leaf Area Index; FDM = Frond Dry Matter production; BDM = Bunch Dry Matter production; TDM = Total Dry Matter production; VDM = Vegetative Dry Matter production; BI = Bunch Index (calculated as BDM/TDM).

CONCLUSION

N-type treatment had no significant effect on bunch numbers. However, significant effects were seen on rachis P concentrations, petiole cross section and dry matter production in 2011. N-rate treatment had a significant effect on yield, tissue N and most physiological growth parameters. Increasing N rate from 0.42 kg per palm to higher rates increased yield, leaflet N and HI, PCS, FP, FA, LAI, FDM, BDM, TDM and VDM production. Yield, leaflet N concentration and physiological growth parameters for the palms that did not receive N fertiliser were comparatively lower than the palms that received N fertiliser. This indicates that without fertiliser N, oil palm production cannot be sustained or increased.

Trial 326: Nitrogen x EFB Trial on Volcanic Soils, Sangara Estate (RSPO 4.2, 4.3, 4.6, 8.1)

SUMMARY

This trial tests 4 rates of sulphate of ammonia (SOA) and 3 rates of empty fruit bunch (EFB) in a factorial combination, resulting in 12 treatments. The trial design is Randomised Complete Block Design (RCBD). The 12 treatments were randomly allocated within a block of 12 plots and each treatment was replicated 5 times, resulting in 60 plots. The purpose of the trial was to provide information on minimum EFB and N requirements of palm to help formulate fertiliser recommendations on volcanic plain soils of Higaturu, Popondetta. SOA had a significant effect on yield ($p=0.001$) and the single bunch weight (SBW) ($p<0.001$) in 2011 and 2009-2011, no effect on bunch numbers (BNO). Empty fruit bunch increased yield from 32.5 to 36.6 t/ha. SOA treatment had significant effect on leaflet and rachis N concentrations. EFB significantly increased leaflet N and K, and rachis P and K concentrations but lowered leaflet Mg and B contents. Regardless of treatment effects only nutrients of rachis N, P and K were above their respective critical concentrations compare to concentrations of leaflets (less than critical values). SOA had a significant effects on PCS ($p=0.001$) and radiation interception and dry matter production but not any other measured or calculated vegetative growth parameter (FL, HI, BI). EFB significantly increased all the vegetative parameters except for FL, HI, FA, LAI and BI.

INTRODUCTION

The trial was established in 2002 at Higaturu Oil Palms (Popondetta) to provide information on minimum EFB and N requirements of oil palm to help formulate fertiliser recommendations on volcanic plain soils. Nitrogen is by far the main nutrient limiting fresh fruit bunch (FFB) production in oil palm and thus large amounts are required to increase yields of FFB. However, N requirement can be reduced when applied in combination with EFB as shown by results from closed PNGOPRA field trials 311 and 312. In trial 312, no FFB yield plateau was reached when increasing SOA from 0 to 6kg of SOA per palm but FFB yield did plateau off at a combined application of 4kg of SOA and 250 kg of EFB per palm per year. In trials 311 and 312, only 1 rate of EFB (250 kg/palm/year) was tested. This trial was designed to test 3 rates to determine which rate would produce optimum FFB yield, when applied in combination with varying rates of SOA. EFB contains 0.6, 2.0 and 0.05 % (dry matter) of N, K and P respectively. Background information of trial 326 is presented in Table 1. Pre-treatment soil data indicate that pH is slightly acidic in the topsoil and becomes less acidic at soil depth (Table 2). CEC falls between the low and moderate category, with adequate levels of exchangeable Mg. Exchangeable K is moderate in the top 0-10 cm layer, the next three layers have low levels of exchangeable K. Organic matter contents and total N are quite reasonable.

Table 1. Trial 326 background information.

Trial number	**326**	Company	Kula Oil Palms
Estate	Sangara	Block No.	Sangara AB0280
Planting Density	135 palms/ha	Soil Type	Volcanic ash
Pattern	Triangular	Drainage	Good
Date planted	1999	Topography	Slightly undulating
Age after planting	11	Altitude	188.70 m asl
Recording Started	2002	Previous Land-use	Oil palm
Planting material	Dami D x P	Area under trial soil type (ha)	28.67
Progeny	Not known	Agronomist in charge	Winston Eremu

Table 2. Pre-treatment soil analysis results from samples taken in 2002.

Depth (cm)	**pH**	**Exch K (cmol/kg)**	**Exch Ca**	**Exch Mg**	**Exch Na**	**CEC**	**Res. K**	**Base Sat. (%)**	**Org. Matter (%)**	**Total N (%)**	**Olsen P (mg/kg)**	**Sulfate S (mg/kg)**	**Org S**
0-10	5.5	0.28	5.5	1.09	<0.05	13	<0.1	51	4.4	0.25	6	7	7
10-20	5.6	0.18	4.6	0.71	<0.05	11	0.1	52	2.4	0.14	3	6	3
20-30	5.9	0.12	5.3	0.83	0.09	9	0.1	63	1.5	0.09	3	6	2
30-60	6.1	0.13	6.5	1.23	0.16	12	<0.1	67	0.9	0.07	4	11	1

METHODS

The SOA.EFB trial was set up as a 4 x 3 factorial arrangement, resulting in 12 treatments (Table 3). The trial design is Randomised Complete Block Design (RCBD). There are 12 treatments, replicated 5 times, resulting in 60 plots. Each plot consists of 36 palms, with the inner 16 being the recorded and the outer 20 being the guard palms. See 2001 Proposals for background. SOA treatments are applied in 3 doses per year. EFB treatments are applied once every year.

The plots are surrounded by a trench to prevent nutrient poaching between plots. Palms that are not in the plots but are in the same block are termed perimeter palms, and they receive 2 kg per palm of urea.Every palm within the trial field receives basal applications of 1 kg Kieserite, 0.5 kg of TSP and 0.2 kg of Calcium Borate annually. Recordings and measurements are taken on the central 16 palms in each plot. The number of bunches and bunch weights are recorded at 10 days harvest intervals on an individual palm basis and totalled for each plot, then totalled for each harvest and expressed per ha per year. Single bunch weight (SBW) was calculated from these data. Leaf sampling is carried out according to standard procedures and analysed for nutrient concentrations using standard analytical procedures. Analysis of variance of the main effects of fertiliser and their interactions were carried out for each of the variables of interest using the GenStat statistical program.

Table 3. Fertiliser treatments and levels for Trial 326.

Treatments	Amount (kg/palm/yr)			
	Level 1	Level 2	Level 3	Level 4
SOA	0	2.5	5.0	7.5
EFB	0	130	390	-

RESULTS and DISCUSSION

Effects of treatment on FFB yield and its components

Effects of fertiliser on yield and its components are presented in Tables 4 and 5. SOA had a significant effect on FFB yield (p<0.001) and SBW (p=<0.001) but did not affect the number of bunches in 2011 and 2009-2011period. EFB also had a significant effect on FFB yield (p<0.001) and SBW (p=0.006) and the two components except for the number of bunches in 2011. The mean FFB yield was 35.2 t/ha in 2011.

Table 4. Effects (p values) of treatments on FFB yield and its components in 2011 and 2009-2011.

	2011			2009 – 2011		
Source	FFB yield	BNO	SBW	FFB yield	BNO	SBW
SOA	**<0.001**	0.070	**<0.001**	**<0.001**	0.266	**<0.001**
EFB	**<0.001**	0.065	**0.006**	**<0.001**	**0.028**	**0.005**
SOA.EFB	**0.048**	0.377	0.057	0.182	0.490	0.147

Table 5. Main effects of treatments on FFB yield (t/ha) in 2011 and from 2009 to 2011.

Treatments	2011			2009-2011		
	FFB yield (t/ha)	BNO/ha	SBW (kg)	FFB yield (t/ha)	BNO/ha	SBW (kg)
SOA 0	**31.0**	1350	**22.8**	**31.6**	1417	**22.3**
SOA 2.5	**36.9**	1484	**24.8**	**35.8**	1490	**24.1**
SOA 5.0	**35.3**	1430	**24.8**	**34.1**	1435	**23.9**
SOA 7.5	**37.4**	1472	**25.5**	**35.9**	1476	**24.4**
l.s.d$_{0.05}$	*2.517*					
EFB 0	**32.5**	1369	**23.7**	**32.1**	**1397**	**23.0**
EFB 130	**36.4**	1471	**24.7**	**35.4**	**1493**	**23.8**
EFB 390	**36.6**	1462	**25.1**	**35.6**	**1473**	**24.2**
l.s.d$_{0.05}$	*2.180*					*0.847*
GM	35.2	1434	24.5	34.4	1454	23.7
SE	3.420	148.1	1.302	2.612	114.0	1.152
CV %	*9.7*	*10.3*	*5.3*	*7.6*	*7.8*	*4.9*

Effects of interaction between treatments on FFB yield

SOA x EFB interaction on FFB yield was significant in 2011(p=0.048). Yields were increased with N rates however the yields were further enhanced in the presence of EFB. The highest yield of 38.9 t/ha was obtained at 2.5 kg SOA and 130 kg EFB per palm (Table 6).

Table 6. Effect of SOA and EFB (two-way interactions) on FFB yield (t/ha/yr) in 2011. The interaction was not significant (p=0.739).

	EFB 0	EFB 130	EFB 390
SOA 0	**25.4**	**32.6**	**34.9**
SOA 2.5	**33.2**	**38.9**	**38.6**
SOA 5.0	**33.6**	**37.0**	**37.6**
SOA 7.5	**37.7**	**37.0**	**37.6**
Grand mean: 35.2	*sed 2.163*		

Effects of SOA and EFB treatments on leaf (F17) nutrient concentrations

SOA treatment had a positive significant effect on leaflet N, P, K, Cl and rachis N and P concentrations in 2011 (Tables 7 and 8). EFB treatment had a significant effect on the concentrations of leaflet Ash, N, P, K, Mg, Cl and rachis Ash, N, P and K (Tables 7 and 8) in 2011. SOA x EFB had significant interactions on N, P and B in the leaflets (Table 7) in 2011.The increase in rachis K concentrations was due to the high content of K in EFB (approx 2.0% DM).

Table 7. Effects (p values) of treatments on frond 17 (F17) nutrient concentrations 2011 (Trial 326).

	Leaflet nutrient concentration (%DM)								Rachis nutrient concentration (%DM)			
	Ash	**N**	**P**	**K**	**Mg**	**B**	**Ca**	**Cl (%)**	**Ash**	**N**	**P**	**K**
SOA	0.270	**<0.001**	**0.003**	**0.023**	0.422	0.429	0.144	**<0.001**	0.096	**<0.001**	**<0.001**	0.186
EFB	**0.002**	**<0.001**	**<0.001**	**<0.001**	**0.006**	0.508	0.338	**<0.001**	**<0.001**	**0.014**	**<0.001**	**<0.001**
SOA.EFB	0.249	**0.008**	**0.003**	0.471	0.992	**0.011**	0.869	0.114	0.502	0.941	0.2761	0.206
CV%	*3.8*	*3.1*	*2.2*	*5.4*	*11.0*	*8.2*	*1.7*	*9.5*	*10.2*	*7.9*	*14.1*	*11.3*

p values <0.05 are indicated in bold.

Table 8. Main effects of treatments on F17 nutrient concentrations in 2011, in units of % dry matter, except for B (mg/kg) (Trial 326).

	Leaflet nutrient concentration (%DM)								Rachis nutrient concentration (%DM)			
	Ash	**N**	**P**	**K**	**Mg**	**B**	**Ca**	**Cl (%)**	**Ash**	**N**	**P**	**K**
SOA 0	16.0	**2.27**	**0.139**	**0.80**	0.21	18.6	0.691	**0.373**	4.6	**0.25**	**0.104**	1.43
SOA 2.5	16.1	**2.43**	**0.142**	**0.78**	0.20	18.8	0.679	**0.441**	4.6	**0.26**	**0.083**	1.37
SOA 5.0	16.4	**2.46**	**0.143**	**0.77**	0.20	18.5	0.684	**0.482**	4.7	**0.29**	**0.090**	1.44
SOA 7.5	16.3	**2.49**	**0.142**	**0.75**	0.19	17.9	0.665	**0.479**	4.9	**0.21**	**0.083**	1.50
l.s.d$_{0.05}$		*0.06*								*0.016*	*0.009*	*0.119*
EFB 0	**16.6**	**2.36**	**0.140**	**0.74**	**0.21**	18.6	0.680	**0.423**	**4.1**	**0.26**	**0.077**	**1.14**
EFB 130	**16.2**	**2.42**	**0.141**	**0.79**	**0.19**	18.1	0.673	**0.430**	**4.8**	**0.27**	**0.092**	**1.52**
EFB 390	**15.8**	**2.47**	**0.145**	**0.80**	**0.20**	18.6	0.690	**0.478**	**5.2**	**0.28**	**0.101**	**1.64**
l.s.d$_{0.05}$	*0.393*	*0.048*		*0.027*					*0.304*		*0.008*	*0.103*
GM	16.2	2.41	0.142	0.78	0.20	18.4	0.680	0.444	4.6	0.27	0.090	1.44
SE	0.617	0.075	0.003	0.042	0.022	1.509	0.011	0.042	0.477	0.0216	0.0126	0.162
CV%	*3.8*	*3.1*	*2.2*	*5.4*	*11.0*	*8.2*	*1.7*	*9.5*	10.2	7.9	14.1	11.3

Effects with p<0.05are shown in bold.

Effects of fertiliser treatments on Vegetative parameters

The effects of SOA and EFB on measured vegetative growth parameters are presented in Tables 9 and 10. SOA had significant effect on PCS, the radiation interception parameters and dry matter production in 2011. EFB had significant effects on PCS, FP and dry matter production components. There was statistically significant difference in the interaction between the two fertiliser treatments on FP and TDM.

Table 9. Effect (p values) of treatments on vegetative growth parameters in 2011.

Source				**Radiation interception**			**Dry matter production**				
	FL	**HI**	**PCS**	**FP**	**FA**	**LAI**	**FDM**	**BDM**	**TDM**	**VDM**	**BI**
SOA	0.230	0.145	**<0.001**	**<0.001**	**0.033**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	0.548
EFB	0.708	0.089	**0.006**	**<0.001**	0.582	0.378	**<0.001**	**<0.001**	**<0.001**	**<0.001**	0.085
SOA.EFB	0.539	0.207	0.425	**0.049**	0.742	0.255	0.102	0.089	**0.034**	0.064	0.453
CV %	*2.4*	*14.4*	*5.8*	*3.7*	*4.3*	*6.1*	*6.7*	*10.6*	*7.3*	*6.4*	*4.9*

p values less than 0.05 are shown in bold.

FL = frond length (cm), HI = Height increment (cm), PCS = Petiole cross-section (cm^2); FP = annual frond production (new fronds/year); FA = Frond Area (m^2); LAI = Leaf Area Index; FDM = Frond Dry Matter production; BDM = Bunch Dry Matter production; TDM = Total Dry Matter production; VDM = Vegetative Dry Matter production; BI = Bunch Index (calculated as BDM/TDM).

Table 10. Main effects of treatments on vegetative growth parameters in 2011.

Treatments				**Radiation interception**			**Dry matter production (t/ha/yr)**				**BI**
	FL	**HI**	**PCS**	**FP**	**FA**	**LAI**	**FDM**	**BDM**	**TDM**	**VDM**	
SOA 0	680.0	63.3	**45.2**	**21.6**	13.4	**5.9**	**14.1**	**15.8**	**32.2**	**17.4**	0.47
SOA 2.5	685.5	67.9	**48.6**	**23.3**	13.4	**6.2**	**16.2**	**18.7**	**38.9**	**20.1**	0.48
SOA 5.0	691.8	71.5	**49.6**	**23.4**	13.9	**6.5**	**16.6**	**18.2**	**38.6**	**20.4**	0.47
SOA 7.5	689.6	69.6	**49.7**	**24.0**	13.9	**6.6**	**17.1**	**19.0**	**40.1**	**21.1**	0.47
$lsd_{0.05}$			2.078	0.621		2.806	0.785	1.394	2.012	0.935	
EFB 0	686.2	64.2	**46.7**	22.4	13.5	6.2	**15.1**	**16.4**	**35.0**	**18.6**	0.47
EFB 130	684.8	68.9	**48.4**	23.1	13.7	6.3	**16.1**	**18.7**	**38.7**	**19.9**	0.48
EFB 390	689.1	71.1	**49.7**	24.6	13.7	6.4	**16.8**	**18.7**	**39.5**	**20.8**	0.47
$lsd_{0.05}$			*1.799*				*0.680*	*1.207*	***1.742***	*0.809*	
GM	686.7	68.1	48.3	23.1	13.7	6.3	16.0	17.9	37.7	19.8	0.47
SE	16.5	9.82	2.823	0.844	0.586	0.381	1.067	1.894	2.734	1.270	0.023
CV %	*2.4*	*14.4*	*5.8*	*3.7*	*4.3*	*6.1*	*6.7*	*10.6*	*7.3*	*6.4*	*4.9*

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

FL = frond length (cm), HI = Height increment (cm), PCS = Petiole cross-section (cm^2); FP = annual frond production (new fronds/year); FA = Frond Area (m^2); LAI = Leaf Area Index; FDM = Frond Dry Matter production; BDM = Bunch Dry Matter production; TDM = Total Dry Matter production; VDM = Vegetative Dry Matter production; BI = Bunch Index (calculated as BDM/TDM).

CONCLUSION

SOA and EFB had positive significant effects on FFB yield. EFB continued to have significant effects on yield (and its components), leaf tissue nutrient concentrations and vegetative parameters. High yields are obtained in the presence of SOA and EFB.

Trial 334: Nitrogen x Phosphorus Trial (Mature Phase) on Volcanic Ash Soils, Sangara Estate (RSPO 4.2, 4.3, 4.6, 8.1)

SUMMARY

This trial tests 3 rates of urea and 5 rates TSP in a factorial combination, resulting in 15 treatments. The trial design is Randomised Complete Block Design (RCBD). The 15 treatments were randomly allocated and replicated 3 times, resulting in 45 plots. The purpose of the trial was to determine the optimum P and N supply rate and to determine critical P (or N/P ratio) deficiency level in leaflets and rachis of palms of different age and with differing N status. Urea had no significant effect on FFB Yield and its components but had effects in vegetative growth parameters in 2011. TSP had no significant effect on FFB yield and vegetative growth parameters.

INTRODUCTION

There has been little response to P fertiliser in previous trials in Higaturu. However P leaf levels have been falling over the last few years in Sangara Estate (0.154 in 2000; 0.143 in 2004) whilst the critical level has been increasing (0.158 in 2000; 0.164 in 2004) as a result of improved N nutrition. The critical leaf level for P also changes with palm age. Thus it has been decided to start a new trial with a wide range of P supply rates and palms of different age. In addition, N supply can affect the movement of P from rachis to leaflet; such that at low N supply, increasing P supply only results in increase P accumulation in the rachis and not improved P nutrition of leaflets. Thus this trial also has a number of rates of N so that there is a better understanding of the relation between N and P nutrition – especially with respect to leaf and rachis nutrient levels. Background information of trial 324 is presented in Table 1.

Table 1. Trial 334 background information.

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

METHODS

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

Table 2. Fertiliser treatments and levels for Trial 334.

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

RESULTS and DISCUSSION

Effects of treatment on FFB yield and its components

There was no effect of Urea and TSP on FFB yield and yield components in 2011 and 2009-2011. (Tables 3 and 4). The mean FFB yield was 33.7t/ha in 2011.

Table 3. Effects (p values) of treatments on FFB yield and its components in 2011.

Source	2011			2009-2011		
	FFB yield	BNO	SBW	FFB yield	BNO	SBW
Urea	0.241	0.762	0.196	0.417	0.920	**0.054**
TSP	0.763	0.610	0.484	0.243	0.3158	0.214
Urea.x TSP	0.240	0.523	0.792	0.466	0.582	0.862
CV %	*9.0*	*10.5*	*5.1*	*6.4*	*7.3*	*4.2*

Table 4. Main effects of treatments on FFB yield (t/ha) for the combined harvest for 2009-2011 and 2011.

Treatments	2011			2009-2011		
	FFB yield (t/ha)	BNO/ha	SBW (kg)	FFB yield (t/ha)	BNO/ha	SBW (kg)
Urea 1	32.6	1504	21.8	33.7	1659	**20.4**
Urea 2	34.0	1520	22.4	34.0	1641	**20.9**
Urea 3	34.5	1547	22.4	34.7	1648	**21.2**
TSP 1	34.4	1527	22.6	34.7	1636	21.3
TSP 2	34.3	1588	21.7	34.3	1702	20.3
TSP 3	32.7	1474	22.3	32.6	1563	21.0
TSP 4	33.4	1492	22.4	34.8	1682	20.9
TSP 5	33.7	1538	21.9	34.3	1665	20.8
GM	33.7	1524	22.2	34.1	1650	20.8
SE	3.042	159.8	1.121	2.184	121.2	0.870
CV %	*9.0*	*10.5*	*5.1*	*6.4*	*7.3*	*4.2*

p values <0.05 are shown in bold.

Effects of interaction between treatments on FFB yield

There was no interaction between Urea and TSP on FFB yield, however the highest yield of 37.4 t/ha was obtained at Urea-2 and TSP-2 levels (Table 5).

Table 5. Effect of Urea and TSP (two-way interactions) on FFB yield (t/ha/yr) in 2011.The interaction was not significant (p=0.215).

	TSP-1	TSP-2	TSP-3	TSP-4	TSP-5
Urea-1	35.6	32.7	32.3	32.2	30.3
Urea-2	33.2	37.4	31.2	33.6	34.7
Urea-3	34.3	32.8	32.8	34.4	36.0
Grand mean	33.7				

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

Urea had significant effects on leaflet N and Rachis P contents while TSP affected rachis P contents only in 2011. There was also Urea x TSP on leaf P contents. Nutrient concentrations for leaflets and rachis of all the plots were above their respective critical levels. (Tables 6 and 7)

Table 6. Effects (p values) of treatments on frond 17 (F17) nutrient concentrations 2011. p values <0.05 are indicated in bold.

Source	Leaflet nutrient contents (% DM)								Rachis nutrient contents (% DM)			
	Ash	N	P	K	Mg	B	Ca	Cl	Ash	N	P	K
Urea	0.858	**0.004**	0.129	0.653	0.664	0.513	0.060	0.105	0..186	0.263	**0.004**	0.091
TSP	0.493	0.446	0.255	0.772	0.136	0.480	0.809	0.482	0.886	0.971	**0.016**	0.713
Urea.TSP	0.186	0.425	**0.006**	0.195	0.252	0.388	0.466	0.318	0.601	0.748	0.108	0.065
CV%	*3.6*	*3.3*	*2.6*	*6.7*	*9.2*	*9.6*	*6.7*	*9.8*	*9.9*	*13*	*13.6*	*10.0*

Table 7. Main effects of treatments on F17 nutrient concentrations in 2010, in units of % dry matter, except for B (mg/kg) (Trial 334).

Treatments	**Leaflet nutrient contents (% DM)**								**Rachis nutrient contents (% DM)**			
	Ash	**N**	**P**	**K**	**Mg**	**B ppm)**	**Ca**	**Cl**	**Ash**	**N**	**P**	**K**
Urea-1	14.2	**2.34**	0.145	0.75	0.20	16.0	0.722	0.385	6.1	0.349	**0.19**	1.74
Urea-2	14.3	**2.41**	0.147	0.6	0.20	15.4	0.697	0.406	6.1	0.361	**0.16**	1.78
Urea-3	14.3	**2.44**	0.148	0.76	0.20	15.8	0.679	0.376	6.5	0.377	**0.16**	1.89
l.s.d$_{0.05}$											0.018	
TSP-1	14.3	2.41	0.145	0.74	0.19	15.2	0.713	0.391	6.2	0.357	**0.17**	1.79
TSP-2	14.5	2.42	0.146	0.76	0.21	16.5	0.694	0.383	6.2	0.369	**0.16**	1.82
TSP-3	14.2	2.36	0.146	0.75	0.20	15.6	0.694	0.371	6.3	0.357	**0.17**	1.78
TSP-4	14.2	2.37	0.146	0.77	0.21	15.6	0.689	0.398	6.1	0.367	**0.18**	1.76
TSP-5	14.1	2.41	0.149	0.77	0.19	15.8	0.706	0.401	6.4	0.363	**0.20**	1.88
l.s.d$_{0.05}$					0.018							
GM	14.3	2.40	0.147	0.76	0.20	15.8	0.699	0.389	6.2	0.362	0.17	1.81
SE	0.515	0.080	0.004	0.050	0.018	1.516	0.047	0.038	0.620	0.047	0.024	0.181
CV %	3.6	3.3	2.6	6.7	9.2	9.6	6.7	9.8	9.9	13.0	13.6	10.0

Effects with p<0.05are shown in bold.

Effects fertiliser treatments on vegetative parameters

Urea treatment had significant effect on FP (p=0.051), LAI (p=0.017) in radiation interception and FDM (p=0.012), VDM (p=0.003) in dry matter production. TSP did not have any effect on the measured vegetative parameters (Tables 8 and 9).

Table 8. Effects (p values) of treatments on F#17 nutrient concentrations 2011.

Source				**Radiation interception**			**Dry matter production**				
	FL	**HI**	**PCS**	**FP**	**FA**	**LAI**	**FDM**	**BDM**	**TDM**	**VDM**	**BI**
Urea	0.636	0.772	0.066	**0.051**	0.763	**0.017**	**0.003**	0.445	0.154	**0.003**	0.351
TSP	0.776	0.206	0.904	0.367	0.437	0.742	0.569	0.457	0.573	0.784	0.330
Urea x TSP	0.361	0.301	0.430	0.590	0.288	0.778	0.550	0.199	0.186	0.371	0.462
CV %	3.1	30.6	*5.6*	*5.2*	*3.4*	*4.0*	*7.0*	*8.5*	*7.0*	*2.8*	*2.2*

p values <0.05 are indicated in bold.

Table 9. Main effects of treatments on vegetative growth parameters in 2011.

Treatments				**Radiation interception**			**Dry matter production (t/ha/yr)**				**BI**
	FL	**HI**	**PCS**	**FP**	**FA**	**LAI**	**FDM**	**BDM**	**TDM**	**VDM**	
Urea-1	673.0	47.9	46.0	**6.5**	13.2	**5.92**	**4.3**	17.2	23.8	**6.6**	0.72
Urea-2	660.0	51.7	47.8	**6.7**	13.3	**6.11**	**4.6**	17.8	24.8	**7.1**	0.71
Urea-3	653.0	48.8	48.2	**6.8**	13.3	**6.20**	**4.7**	17.8	25.0	**7.2**	0.71
lsd$_{0.05}$									*1.246*		
TSP-1	663.9	42.7	47.6	6.7	13.5	6.03	4.6	17.9	25.0	7.1	0.72
TSP-2	654.5	44.9	46.9	6.5	13.2	6.01	4.4	18.1	24.9	6.8	0.72
TSP-3	656.9	47.9	47.2	6.7	13.2	6.10	4.5	16.9	23.8	6.9	0.71
TSP-4	656.6	54.8	46.9	6.8	13.4	6.15	4.5	17.4	24.4	7.0	0.71
TSP-5	651.9	54.1	47.9	6.6	13.1	6.09	4.5	17.6	24.6	7.0	0.71
lsd$_{0.05}$											
Grand mean	656.8	49.5	47.3	6.6	13.3	6.08	4.5	17.6	24.5	7.0	0.72
SE	20.0	15.14	2.663	0.343	0.445	0.246	0.317	1.500	1.725	0.400	0.016
CV %	3.1	30.6	*5.6*	*5.2*	*3.4*	*4.0*	*7.0*	*8.5*	*7.0*	*2.8*	*2.2*

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

CONCLUSION
Urea had no effects on FFB yield and its components but some effects on vegetative growth parameters, and it was still early to report any true responses to fertiliser treatments.

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

SUMMARY
This trial tests 3 rates of urea and 5 rates TSP in a factorial combination, resulting in 15 treatments. The design of the trial is a Randomised Complete Block Design (RCBD). The 15 treatments were randomly allocated and replicated 4 times, resulting in 60 plots. The purpose of the trial was to determine the optimum P and N supply rate and to determine critical P (or N/P ratio) deficiency level in leaflets and rachis of palms of different age and with differing N status.

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

Table 1. Trial 335 background information.

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

METHODS
The Urea.TSP trial was set up as a 3 x 5 factorial arrangement, resulting in 15 treatments. The design of the trial is Randomised Complete Block Design (RCBD). The 15 treatments were replicated 4 times, resulting in 60 plots. Each plot consists of 36 palms, with the inner 16 being the recorded and the outer 20 being the guard palms. Planned fertiliser treatment applications are as scheduled (Tables 2 and 3). Soils sampling, initial leaf tissues and vegetative measurements were done in 2008. Yield recording will commence in 2009. Recordings and measurements are taken on the central 16 palms in each plot. The number of bunches and bunch weights are recorded on 10 day intervals on an individual palm basis and totalled for each plot, then totalled for each harvest and expressed per ha per year. Single bunch weight (SBW) was calculated from these data. Leaf sampling is carried out according to standard procedures and analysed for nutrient concentrations using standard analytical procedures.

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

Table 2. P Fertiliser schedule (g TSP/palm).

Year	Age	P Rate (kg TSP/palm/yr)				
		0	2	4	6	10

Planting	Hole	200	200	200	200	200
1st	6m	0	300	600	900	1,500
	12m	0	300	600	900	1,500
	Year 1 total	***0***	***600***	***1,200***	***1,800***	***3,000***
2nd	18m	0	450	900	1,350	2,250
	24m	0	450	900	1,350	2,250
	Year 2 total	***0***	***900***	***1,800***	***2,700***	***4,500***
3rd	30m	0	500	1,000	1,500	2,500
	36m	0	500	1,000	1,500	2,500
	Year 3 total	***0***	***1,000***	***2,000***	***3,000***	***5,000***
4th	42m	0	750	1,500	2,250	3,750
	48m	0	750	1,500	2,250	3,750
	Year 4 total	***0***	***1,500***	***3,000***	***4,500***	***7,500***
5th onwards	Split 1	0	1,000	2,000	3,000	5,000
	Split 2	0	1,000	2,000	3,000	5,000
	Year 5 and onwards total	***0***	***2,000***	***4,000***	***6,000***	***10,000***

Table 3. N Fertiliser schedule (g Urea/palm)

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

RESULTS and DISCUSSION

Yield and yield components

Effects of fertiliser on yield and its components are presented in Tables 4 and 5. Urea significantly increased SBW only in 2011 and 2009-2011 but affected FFB yield as well for 2009-2011 period. There were no response to TSP and Urea x TSP interaction was not significant. The mean FFB yield was 27.6 t/ha.

Table 4. Effects (p values) of treatments on FFB yield and its components in 2010.

	2011			2009-2011		
Source	**FFB yield (t/ha)**	**BNO/ha**	**SBW kg/ha**	**FFB yield (t/ha)**	**BNO/ha**	**SBW kg/ha**
Urea	0.320	0.255	**<0.001**	**<0.001**	0.055	**<0.001**
TSP	0.260	0.281	0.722	0.448	0.268	0.540
Urea.x TSP	0.733	0.136	0.147	0.733	0.848	0.109
CV %	*7.4*	*9.2*	*6.0*	*6.4*	*7.3*	*4.7*

Table 5. Main effects of treatments on FFB yield (t/ha) in 2011

Treatments	**2011**			**2009-2011**		
	FFB yield (t/ha)	**BNO/ha**	**SBW (kg)**	**FFB yield (t/ha)**	**BNO/ha**	**SBW (kg)**
Urea-1	27.1	3503	**7.77**	**16.5**	2751	**5.36**
Urea-2	27.2	3340	**8.37**	**17.2**	2739	**5.70**
Urea-3	28.1	3388	**8.35**	**18.2**	2885	**5.83**
l.s.d$_{0.05}$			*0.312*			
TSP-1	27.1	3318	8.29	17,1	2701	5.74
TSP-2	27.2	3330	8.20	17.0	2780	5.59
TSP-3	27.1	3562	8.13	17.2	2757	5.64
TSP-4	28.4	3352	8.02	17.6	2858	5.57
TSP-5	28.3	3489	8.14	17.7	2862	5.60
Grand Mean	27.6	3410	8.16	17.3	2792	5.63
SE	2.056	315.2	0.489	1.109	205.1	0.622
CV %	*7.4*	*9.2*	*6.0*	*6.4*	*7.3*	*4.7*

Effects of interaction between treatments on FFB yield

There was no significant interaction effect of Urea x TSP but the highest yield of 29.4 t/ha was obtained at urea-2 and TSP-4 (Table 6). It is still very early to report actual response.

Table 6. Effect of Urea and TSP (two-way interactions) on FFB yield (t/ha/yr) in 2011.

	TSP-1	**TSP-2**	**TSP-3**	**TSP-4**	**TSP-5**
Urea-1	27.3	26.4	27.6	26.6	27.7
Urea-2	26.4	27.4	26.6	29.4	28.6
Urea-3	27.5	27.7	27.3	29.3	28.7
Grand mean	27.6		Sed=1.454		

In the three year period (2009-2011) monthly yields have increased to more than 3.0 t/ha (Figure 1). The number of bunches fluctuated but increased up to about 340 bunches/ha (Figure 2). Mean single bunch weight increased from <0.5 kg to 9.0 kg by the end of 2011 (Figure 3)

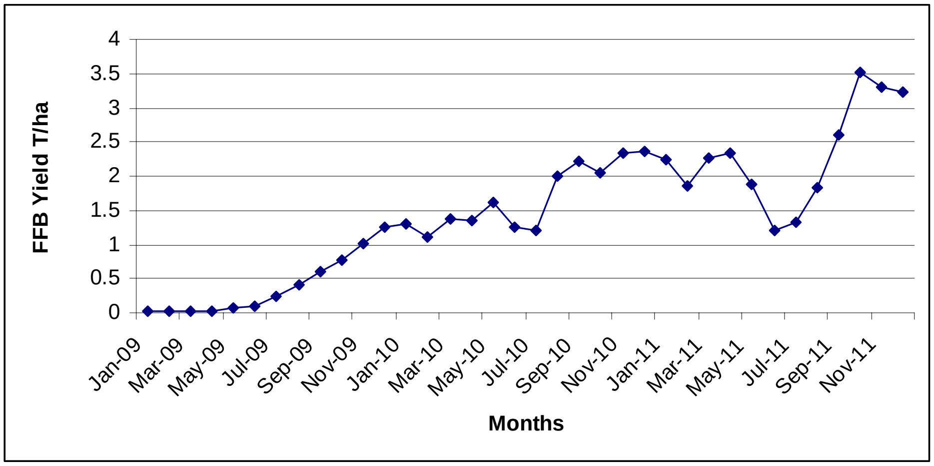


Figure 1. Mean FFB yield t/ha over the last three year period (Jan 2009 to Dec 2011)

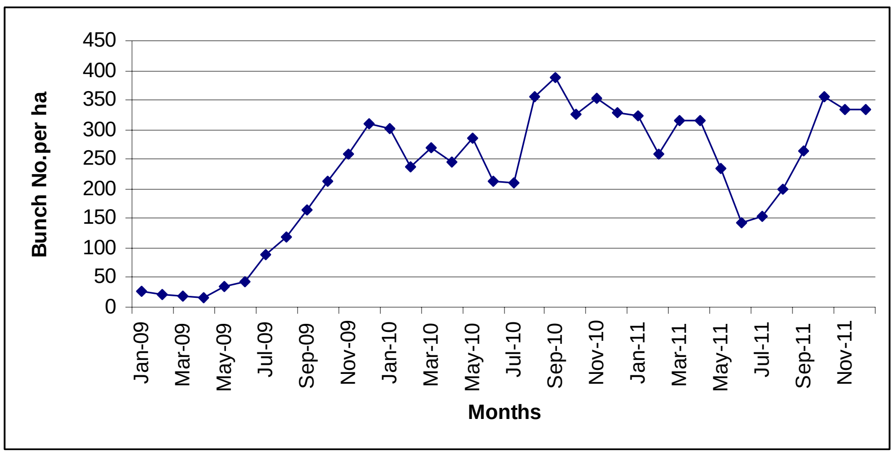


Figure 2. Mean number of bunches per ha over the last three year period (Jan 2009 to Dec 2011)

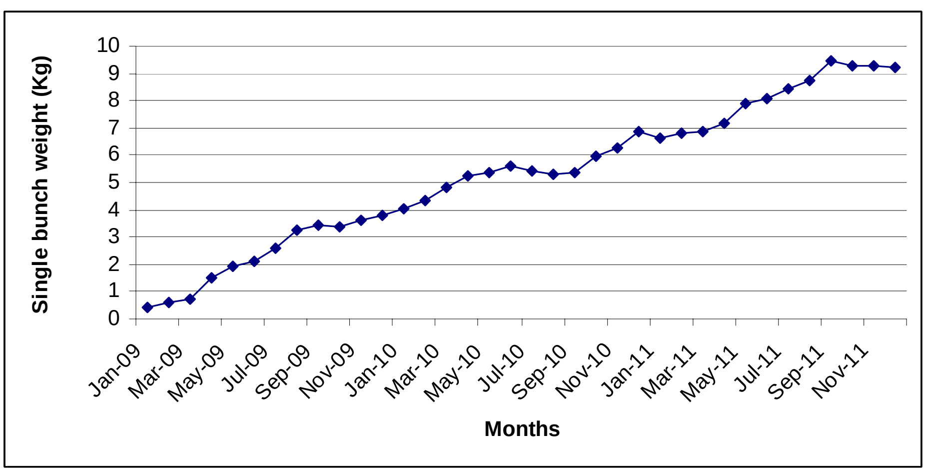


Figure 3. Mean single bunch weight per Kg over the last three year period (Jan 2009 to Dec 2011)

Effects of Urea and TSP treatments on leaf (F17) nutrient concentrations
Urea had significant effects on leaflet N, P, K, B, Ca and Cl and rachis N and P contents in 2011 (Tables 7 and 8).

Table 7. Effects (p values) of treatments on frond 17 nutrient concentrations 2011. p values <0.05 are indicated in bold.

Source	Leaflets								Rachis			
	Ash	**N**	**P**	**K**	**Mg**	**B**	**Ca**	**Cl**	**Ash**	**N**	**P**	**K**
Urea	0.082	**0.001**	**0.030**	**0.043**	0.553	**0.006**	**<0.001**	0.603	0.271	**0.010**	**<0.001**	0.816
TSP	**0.031**	0.872	0.603	**0.031**	0.601	0.299	**0.010**	0.237	0.323	0.793	0.175	0.457
Urea.TSP	0.190	0.096	0.344	0.887	0.772	0.250	0.314	0.856	0.136	0.703	0.180	0.096
CV%	*6.7*	*3.4*	*2.4*	*5.1*	*8.6*	*10.4*	*6.4*	*6.4*	*7.7*	*7.7*	*13.2*	*9.3*

Table 8. Main effects of treatments on F17 nutrient concentrations in 2011, in units of % dry matter, except for B (mg/kg).

Treatments	**Leaflet nutrient contents**								**Rachis nutrient contents**			
	Ash	**N**	**P**	**K**	**Mg**	**B**	**Ca**	**Cl**	**Ash**	**N**	**P**	**K**
Urea-1	12.8	**2.42**	**0.154**	**0.773**	0.308	**20.1**	**0.915**	0.442	4.92	**0.288**	**0.203**	1.54
Urea-2	12.4	**2.51**	**0.157**	**0.805**	0.302	**18.8**	**0.879**	0.428	4.95	**0.301**	**0.164**	1.57
Urea-3	13.0	**2.52**	**0.155**	**0.778**	0.298	**21.1**	**0.916**	0.430	5.10	**0.311**	**0.185**	1.57
l.s.d$_{0.05}$										0.014	0.015	
TSP-1	**12.1**	2.49	0.155	**0.792**	0.303	19.2	**0.877**	0.413	4.88	0.300	0.171	1.51
TSP-2	**12.6**	2.48	0.154	**0.810**	0.311	20.00	**0.902**	0.426	5.04	0.298	0.183	1.61
TSP-3	**12.7**	2.47	0.155	**0.788**	0.298	19.5	**0.902**	0.427	4.89	0.299	0.180	1.54
TSP-4	**13.1**	2.46	0.153	**0.755**	0.307	20.9	**0.919**	0.440	4.96	0.304	0.190	1.54
TSP-5	**13.1**	2.50	0.155	**0.782**	0.296	20.4	**0.915**	0.427	5.18	0.299	0.195	1.59
l.s.d$_{0.05}$	0.699											
GM	12.7	2.48	0.155	0.785	0.303	20.0	0.903	0.426	4.99	0.300	0.184	1.56
SE	0.848	0.084	0.004	0.040	0.026	2.086	0.027	0.027	0.386	0.020	0.024	0.145
CV %	6.7	3.4	2.4	5.1	8.6	10.4	3.3	6.4	7.7	6.8	13.2	9.3

Effects with p<0.05are shown in bold

Effects fertiliser treatments on vegetative parameters

Urea significantly increased FL, PCS, LAI, FDM, TDM and VDM in 2011 while TSP did not affect any of the physiological growth parameters (Tables 9 and 10). There were also no interactions between Urea and TSP.

Table 9. Effects (p values) of treatments on frond 17 (F17) nutrient concentrations 2010.

Source			**Radiation interception**			**Dry matter production**				
	FL	**PCS**	**FP**	**FA**	**LAI**	**FDM**	**BDM**	**TDM**	**VDM**	**BI**
Urea	**0.012**	**0.042**	0.090	0.146	**0.037**	**0.007**	0.077	**0.008**	**0.005**	0.438
TSP	0.687	0.633	0.856	0.499	0.373	0.892	0.544	0.625	0.852	0.904
Urea x TSP	0.952	0.721	0.059	0.280	0.153	0.358	0.891	0.756	0.407	0.417
CV %	*3.0*	*7.0*	*4.6*	*4.4*	*5.4*	*7.8*	*7.2*	*6.2*	*7.2*	*3.5*

p values <0.05 are indicated in bold.

Table 10. Trial 335, main effects of treatments on vegetative growth parameters in 2010.

Treatments			Radiation interception			Dry matter production (t/ha/yr)				BI
	FL	PCS	FP	FA	LAI	FDM	BDM	TDM	VDM	
Urea-1	**485.6**	**21.5**	31.9	6.7	**4.27**	**10.3**	15.3	**28.5**	**13.2**	0.54
Urea-2	**462.6**	**22.3**	32.9	6.8	**4.43**	**11.0**	15.8	**29.8**	**14.0**	0.53
Urea-3	**472.0**	**22.7**	32.8	6.8	**4.45**	**11.2**	16.1	**30.3**	**14.2**	0.53
lsd 0.05	*9.44*		*0.995*		*0.150*	*0.540*	*0.012*	*1.174*	*0.635*	
TSP-1	460.1	22.1	32,2	6.8	4.44	10.7	15.4	28.9	13.6	0.53
TSP-2	462.9	21.6	32.8	6.7	4.38	10.7	15.6	29.3	13.6	0.53
TSP-3	468.2	22.6	32.4	6.8	4.41	11.0	15.8	29.7	13.9	0.53
TSP-4	465.4	22.1	32.7	6.7	4.26	10.8	16.0	29.8	13.8	0.54
TSP-5	465.3	22.4	32.5	6.8	4.42	10.9	16.0	30.0	13.9	0.54
lsd 0.05										
Grand mean	464.4	22.2	32.5	6.8	4.38	10.8	15.8	29.5	13.8	0.53
SE	13.9	1.542	1.5	0.294	0.236	0.840	1.133	1.840	0.996	0.019
CV %	*3.0*	*7.0*	*4.6*	*4.4*	*5.4*	*7.8*	*7.2*	*6.2*	*7.2*	*3.5*

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

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

CONCLUSION

Urea had significant effects in FFB yield and its components in 2009-2011but not in 2011. Urea also affected leaf nutrient contents for the first time in 2011. Urea also affected TDM and its components.

SMALLHOLDER RESEARCH

Smallholder Research, Bialla Oil Palm Project

(Susan Tomda and Steven Nake)

INTRODUCTION

Smallholder work in Hargy comprised :

- Tissue sampling blocks: 75 selected blocks from 3 divisions (Ceneka, Maututu and Meramera). Tissue sampling started in 2009. Outcome: The nutrient concentration of LN,LP and RN,RP in all divisions were below adequate level.
- Smallholder block Assessment: 75 blocks were assessed on visible nutrient deficiency and the upkeep standards. Outcome: The assessments indicate that there is average scores in agronomic upkeep standards across all divisions.
- Food Security (Intercropping Oil Palm and food crop). Outcome: The food security trial started in Sale Sege -VOP (Ceneka Divsion) but did not go through due to lack of community participation. New trial started in October at Kabaiya –LSS (Meramera Division). Oil palm and food crop planted to date –monitoring in progress
- Fertiliser Demonstration –BMP. Outcome: 10 blocks will be selected within all divisions. Work in progress

Trial 218: Smallholder oil palm/food crop intercropping demo block, Kabaiya LSS (AIGS funded) (RSPO 4.2, 4.3, 5.1, 6.1, 8.1)

BACKGROUND

Food security exists when populations have access on an ongoing basis to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life. The trial was proposed to address food security problems in relation to land shortage in smallholder blocks (LSS) in the Bialla project area. This is the third food security demonstration block in the oil palm sector carried out by OPRA and OPIC and funded by AIGS. Fundamental to addressing the increasing population and land pressures on the LSSs is the need to explore innovative ways of cultivating cash crops to free up land for food production. Full detailed background is provided in Higaturus report on first food security trial (T337). It is also important that food gardens provide a buffer against falling oil palm prices and provide income security for the smallholder growers and their families.

PURPOSE

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

METHOD

Intercropping oil palm and food crop

The blocks will not be necessarily 2-6 ha as proposed but will depend on the selected grower's choice of the sizes they prefer for the demonstration/study purposes. The trial site is a 0.6 hectare block at Kabaiya LSS, Meramera Division. The site was mapped out by GPS team from OPIC assisted by OPRA/OPIC in the beginning of 2011. The block will have wider and narrow avenue rows for oil palm and crop planting. The block will be divided into plots, which will be planted with (a) food crops and (b) legume cover crops. The food crops will be rotated with legume cover crops within the wide avenue rows. The oil palms in both the normal and altered planting arrangements will receive fertilisers at the smallholder recommended rates. This will be the first demonstration block in the Bialla project area and will soon be rolled out if growers are interested in the idea.

DESIGN AND ANALYSIS

There will be no strict statistical design used for this experiment. The blocks will be divided into 2 and not necessary equal parts, will depend on the farmers wish. One half will be planted with normal equal spacing arrangements while the other with altered spacing arrangement. Soils and plant tissue samples were collected randomly and replicated in odd numbers for analysis. Block information is shown in table below.

Table1. Trial 218 background information.

Trial number	**218**	Company	OPIC – Bialla Project
Division	Meramera	Block No.	Kabaiya,1896 LSS
Planting Density	60 palms/ha	Soil Type	Volcanic
Pattern	Triangular	Drainage	Freely draining
Date planted	Dec 2011	Topography	Flat
Age after planting	5 months	Altitude	19 m asl
Recording Started	Not yet	Previous Land-use	Old garden left to fallow
Progeny	Unknown*	Area under trial soil type (ha)	0.6ha
Planting material	Dami D x P	Agronomist in charge	Susan Tomda

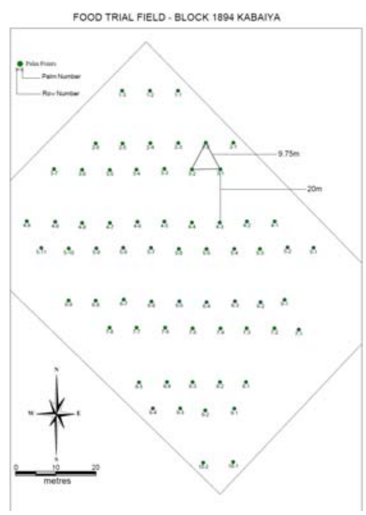
WORK PROGRESS SO FAR

- Site selected
- Area mapped out (OPIC-Bialla) including food crop
- Awareness made through the OPIC
- Slashing of bush/grass and Maintenance of trial

- Pre-treatment soil samples at depth (0-20cm,20-40cm,40-60cm)
- Palm census done on a quarterly basis
- Crop and legume planting

DATA COLLECTION
Plant tissue samples including yield and vegetative tissues will be collected and dry matter production determined. The measurements will be done to determine nutrient movement in and out of the smallholder blocks.

RESULTS AND DISCUSSION
Monitoring is in progress. Fig 1 shows how the trial is set out



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

OVERVIEW
PNGOPRA also participates in smallholder holder research and extension throughout smallholder blocks in PNG. This is done in collaboration with OPIC and the smallholder affairs department within the milling companies. This report highlights what was carried out for smallholder section in Bialla Oil Palm Project in 2011.

Main activities of smallholder in the Bialla project in 2011 were:

- Smallholder leaf sampling (73 blocks)
- Fields days
- Food security demonstration blocks
- NBC Radio program for Oil Palm Growers in West New Britain Province

BACKGROUND
The Bialla smallholder oil palm project (LSS and VOP) was established in mid 1970's. It is made up of (3) three Divisions, -Cenaka (Divison-1), Maututu (Division-2) and Meramera (Division-3), extending from Haila river in the West to the border of East and West New Britain provinces on the East, covering about 13-15,000ha. Ammonium nitrate, N source was supplied to LSS and VOP blocks by OPIC and applied either by the block owners or contractors. An application rate of 2.0kg AN/palm/year was first applied in 2011. The first leaf sampling was done in 2003 and then in 2004 but with no available data. There was no sampling done until in 2009 when PNGOPRA was asked to do the exercise. Leaf sampling was carried out in selected representative blocks of the three Oil Palm

Project Divisions,(Ceneka, Maututu and Meramera). Leaf tissues were collected from frond 17 from 73 smallholder blocks (36 LSS and 37 VOPs) and sent to AAR Laboratory in Malaysia for nutrient analysis**.** Standard block assessment was also carried out in 2011.

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

SMALLHOLDER BLOCK SELECTION AND SAMPLING
In March /April 2011, a total of 73 blocks from LSS and VOP were randomly selected, 20-24 blocks were chosen from the 3 divisions in the project area. The selected blocks from the 3 divisions were further grouped into 11 classes according to topographical features as presented in Table 1. The leaf samples were then collected from palms 5-10 years old, which were marked for future reference and sampling. Leaf and rachis samples were collected from frond 17 on 4-7 palms per block. The collected leaf tissue samples were sent to AAR for analysis.

Table 1. The table shows the topographical groupings

Division	*Group & Block location*	*Topography/Features*	*No blocks*
1	1- Lalopo, Uasilau,Sale	Flood plains/swamp	7
1	2-Kaiamo, Sulu, Malasi, Kiawa	Rock/ stones/sandy	7
1	3- Tiauru, Mataururu	Flat/foothills	7
2	4- Mataliliu, Ewase, Apupul, Baikekea	Flat/foothills	5
2	5- Bubu, Welolo	Sloppy/flat/swamp	8
2	6- Barema, Pakesi, Gigipuna	Flood plains/rocky/hills	7
3	7- Soi	Flood plains/ foot hills	7
3	8- Kabaya	Flat/ foot hills	7
3	9- Tianepou, Mauba, Galelolo	Flat/rocky, Kunai	7
3	10- Noau, Gamupa	Flat /gradual slope	6
3	11- Noua/Nantabu	Steep hills	5
			73

RESULTS
The nutrient contents of the analysed leaf tissues are presented in Tables 2 and 3. Leaflet N and P contents are below the adequate levels of 2.45 – 2.50 % DM and 0.148 % DM respectively. Leaflet K, Mg and B concentrations are reasonable; however, rachis K content is low. The palms are nutritionally deficient especially for N and P across all the 3 divisions. The only obvious increase in the nutrient contents was in rachis N from 0.24%DM to 0.28%DM

Table 2. Leaf tissue nutrient concentrations of the 73 blocks in the 11 groups within the 3 divisions 2011

Division	*Group*	***Leaflet nutrient concentration (% DM)***					***Rachis nutrient concentration (%DM)***		
		N	**P**	**K**	**Mg**	**B**	**N**	**P**	**K**
1	1	2.13	0.126	0.700	0.21	16.0	0.27	0.040	1.09
1	2	2.15	0.126	0.681	0.17	15.4	0.25	0.038	1.14
1	3	2.11	0.131	0.678	0.25	14.0	0.25	0.046	0.92
Division 1 mean		*2.13*	*0.128*	*0.687*	*0.21*	*15.1*	*0.26*	*0.041*	*1.05*
2	4	2.10	0.125	0.794	0.19	20.7	0.29	0.059	1.39
2	5	2.33	0.132	0.740	0.19	18.0	0.27	0.053	1.36
2	6	2.18	0.130	0.787	0.20	16.8	0.28	0.051	1.43
Division 2 mean		*2.20*	*0.129*	*0.774*	*0.19*	*18.5*	*0.28*	*0.054*	*1.39*
2	7	2.19	0.127	0.779	0.19	19.8	0.29	0.039	1.33

2	8	2.18	0.132	0.761	0.21	22.5	0.34	0.055	1.32
3	9	2.07	0.122	0.687	0.23	19.7	0.27	0.047	1.31
3	10	2.06	0.124	0.700	0.27	20.5	0.28	0.052	1.50
3	11	2.20	0.125	0.694	0.27	20.1	0.27	0.045	1.33
Division 3 mean		*2.14*	*0.126*	*0.724*	*0.23*	*20.5*	*0.29*	*0.048*	*1.36*
Grand Mean		**2.16**	**0.127**	**0.728**	**0.21**	**18.0**	**0.28**	**0.048**	**1.27**
Critical value		*2.45*	*0.145*	*0.65*	*0.20*	*15.0*	*0.32*	*0.08*	*1.30*

Table 3. Tissue nutrient concentration for leaflets and rachis summarized in divisions for the 73 blocks in 2011

Division	Leaflet (% DM, except B ppm)					Rachis (% DM)		
	N	P	K	Mg	B	N	P	K
1 - Ceneka(20)	2.13	0.128	0.687	0.21	15.1	0.26	0.041	1.05
2 – Maututu(19)	*2.20*	*0.129*	*0.774*	*0.19*	*18.5*	*0.28*	*0.054*	*1.39*
3 – Meramera(33)	*2.14*	*0.126*	*0.724*	*0.23*	*20.5*	*0.29*	*0.048*	*1.36*
Mean	**2.16**	**0.127**	**0.728**	**0.21**	**18.0**	**0.28**	**0.048**	**1.27**
Critical value	*2.45*	*0.145*	*0.65*	*0.20*	*15.0*	*0.32*	*0.08*	*1.30*

DISCUSSION AND CONCLUSION

Nitrogen and P contents in both the leaflet and rachis tissues are low (below the adequate levels) across the 3 divisions. Nitrogen, the most important nutrient is required in all blocks in the 3 divisions as suggested by the low N contents in the sampled blocks. The K contents in the rachis were also low but N status has to be improved first. However, there are some blocks that had reasonable nutrient contents, leaflet K,Mg,B and rachis K, that were above the critical level as indicated by the range of values. There could be a lot of reasons for having low N levels, which includes non application of fertilisers, rejected or disputed blocks, differences in palm age, poor upkeep, old blocks due for planting and palms planted on steep terrain.

Trial 219: (ii) Smallholder Block Assessments (RSPO 4.1-6, 4.8, 5.1, 8.1)

As part of the leaf sampling, block assessment was also done in 2011. While taking leaf tissue samples for nutrient analysis, visible nutrient deficiency from the surrounding 6 palms and legume cover crops were also assessed. The upkeep standards and pest and disease were also assessed and given a score out of three (refer to Figures 1a and 1b above for block assessment forms). The summarised scores are presented in Table 1

Table 1. Smallholder block assessment scores in 2011

Criteria used for scoring block assessment	**Divisions**			**Average Score**
	Ceneka(19)	Maututu(18)	Meramera(35)	
Nutrient Deficiency - OP	2.2	2.4	2.1	2.2
Nutrient Deficiency - Cover	2.1	2.4	2.2	2.2
Block standard	2.8	2.7	2.9	2.8
Harvest- fruit on ground	2.3	2.7	2.6	2.5
Weeded circle	2.0	1.5	1.3	1.6
LCP	2.5	2.7	2.4	2.5
Weed ground cover	2.1	1.9	1.9	2.0
Frond stacks	2.8	2.9	2.9	2.9
Harvest paths	2.8	2.9	2.8	2.9

Woody trunk weeds	2.5	2.4	2.8	2.6
Trunk weeds - ferns	2.7	2.7	2.3	2.6
Pruning<7 years	2.5	2.5	2.6	2.5
Pruning>7years	2.2	2.1	2.0	2.1
Insect damage	2.8	2.8	2.6	2.8
Ganoderma	3.0	3.0	2.9	3.0
Rat Damage	2.9	2.9	0.0	1.9

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

The mean nutrient deficiency score was 2.4 suggesting 2-3 (50-70 %) palms of the surrounding six palms showed nutrient deficiency symptoms. Nutrient deficiency was common across all blocks in all the 3 divisions and this is also reflected in the tissue analysis results in Table 2. General block upkeep (weeded circles, harvest paths and general weeds) were low in all the divisions, averaging at between 1.6 and 2.9. Average pruning standards were 2.5 for palms < 7 years and 2.1 for palms >7. The lower average at palms >7 years implies palms are probably too tall for pruning or only palms with bunches are being pruned. Harvesting standards are very high with an average score of 2.8 for all the divisions. Insects pests, diseases and rat damage scored very high (1.9-3.0), with high frequency of rat damage at Ceneka and Maututu respectively. The assessments indicate that there is average and above average scores in agronomic upkeep standards and pests and disease free blocks, however there are low scores in nutrient deficiency across all the divisions

FIELD DAYS AND RADIO BROADCASTS

There were 2 different extension methods used during the year with OPIC. The field days and radio broad casts were organized by OPIC and PNGOPRA attended to these presentations (Table 3).

Table 3. Number of field days and radio broadcasts in 2011

Extension mode	Section		Total
	Agronomy and others	Agronomy alone	
Field days	2	9	11
Radio broadcasts	31	3	34

Common questions raised during the field days include:

- Can company supply EFB as alternative fertiliser source?
- Why growers applying only Ammonium Chloride (AC) or Ammonium Nitrate (AN)- N-sources and not others as the HOPL plantations do?
- What is the difference between the N sources of fertilisers (AC & AN)?
- When is the appropriate time for fertiliser applications?
- How many rounds of fertiliser application per year?
- What are the effects on the yield if the fertiliser delivery is delayed?
- Comparison of the two planting materials from Dami in terms of yield.
- Awareness of Food security and fertiliser demonstration blocks

Radio broadcasts were also a means of disseminating the technical information to the growers. PNGOPRA Bialla had 31 broadcast sessions in 2011. Topics covered in field days and radio talks were:

- What is PNGOPRA and its functions.
- The main effects of fertiliser (N) applications, in relation to yield, rates to apply and when is appropriate time to apply.
- Emphasis on the importance of fertiliser applications backed by trial results.
- Gains and losses on fertiliser applications against yield productions.
- Sanitation - to increase yield, isolate blocks from pest and disease infestation.

- Awareness to report in advance when blocks are infested with sexava and ganoderma, on its symptoms and dangers.
- Report on annual report of how well the smallholders were doing in yield productions per year, against trial and plantations results.
- Budgeting income from the block and how to improve on their spending.
- Food security trial establishment

FIELD VISITS
There were field visits to smallholder blocks for various activities;

- Socio-economic follow up on mobile card
- Agronomy leaf sampling at 72 blocks and
- Food security survey at Sale Sege (VOP) and Kabaiya(LSS)

Smallholder Research, Oro Oil Palm Project

(Murom Banabas and Merolyn Koia)

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

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

Smallholder activities are ongoing in all oil palm project areas around the country. This report highlights the four main areas of work for the smallholder sector in the Oro Oil Palm Project in 2011.

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

TRIAL 336 SMALL HOLDER LEAF SAMPLING (RSPO 4.2, 4.3, 8.1)

Leaf sampling was carried out in selected representative blocks of the five Oil Palm Project Divisions; Sorovi, Igora, Saiho, Aeka and Ilimo Divisions. Leaf tissues were collected from frond 17 from 58 smallholder blocks and sent to AAR Laboratory in Malaysia for nutrient analysis**.** The results for each division are presented in Table 1. The mean nutrient contents of all the major nutrient elements were well below the critical levels. Nitrogen, the most important nutrient is required in all blocks in the 5 divisions as suggested by the low N contents in the sampled blocks. The K contents in the rachis were also low but N status has to be improved first. However, there were some blocks that had nutrient contents that were above the critical levels as indicated by the range of values. There are a range of reasons or possible combinations of reasons for the large range of values and they include; lack of fertiliser application, differences in palm age, negligence of block upkeep and very old palms due for replanting. In essence, the palms are very low in nutrients and need inorganic fertiliser inputs especially nitrogen and potassium fertilisers.

Table 1. Mean nutrient contents of 58 smallholder blocks in 2011

Division	Leaflet (% DM, except B ppm)					Rachis (% DM)		
	N	P	K	Mg	B	N	P	K
Aeka (6)	1.80	0.131	0.63	0.31	12	0.25	0.120	0.97
Igora (13)	2.00	0.131	0.71	0.24	13	0.26	0.071	0.89
Ilimo (10)	2.01	0.139	0.62	0.26	12	0.29	0.118	0.77
Saiho (11)	2.02	0.135	0.63	0.27	13	0.25	0.061	0.65
Sorovi (18)	2.06	0.134	0.72	0.28	14	0.26	0.118	1.14
Mean	2.00	0.134	0.67	0.27	13	0.26	0.097	0.91
Min	1.59	0.115	0.30	0.17	10	0.20	0.040	0.24
Max	2.49	0.155	0.95	0.45	22	0.33	0.249	1.65
Critical value	*2.45*	*0.145*	*0.65*	*0.20*	*15*	*0.32*	*0.08*	*1.30*

(..) = number of blocks

SMALLHOLDER BLOCK ASSESSMENTS (RSPO 4.1-6, 4.8, 5.1, 8.1)

While taking leaf tissue samples for nutrient analysis, visible nutrient deficiency from the surrounding 6 palms and legume cover crops were assessed. The upkeep standards and pest and disease were also assessed and given a score out of three (refer to Figures 1a and 1b above for criteria used for assessment). The summarised scores are presented in Table 2

Table 2. Smallholder block assessments scores in 2011

Criteria used for scoring block assessment	Divisions					Average Score
	Aeka (6)	Igora (12)	Ilimo (10)	Saiho (10)	Sorovi (22)	
Palm Nutrient Deficiency	2.2	2.3	1.6	2.0	2.0	2.0
Block Standard	3.0	3.0	1.9	3.0	3.0	2.8
Frond stack	1.8	2.2	2.4	2.3	2.2	2.2
Ganoderma	3.0	2.8	3.0	3.0	3.0	3.0
Ground cover-deficiency	3.0	3.0	2.4	3.0	3.0	2.9
Harvest standard	3.0	3.0	2.0	3.0	3.0	2.8
Harvest paths	1.3	1.6	2.1	2.0	1.6	1.8
Insect Damage	3.0	3.0	2.1	3.0	3.0	2.9
LPC	2.5	2.7	2.4	2.8	2.4	2.5
Pruning <7years			2.0		3.0	2.7
Pruning >7years	2.2	2.1	1.8	2.4	2.2	2.1
Rat Damage	3.0	3.0	2.0	3.0	3.0	2.8
Trunk weeds/ferns	2.8	3.0	2.0	3.0	2.9	2.8
Trunk weeds/woods/vines	1.7	2.1	1.4	2.2	2.0	1.9
Weeded circle	1.2	1.3	2.0	1.3	1.6	1.5
Weed-ground cover	1.5	1.4	1.5	1.5	1.6	1.5
	2.3	2.4	2.0	2.5	2.4	2.4

(..) = number of blocks

The mean nutrient deficiency score was 2.0 suggesting 1-2 (10-30 %) palms of the surrounding six palms showed nutrient deficiency symptoms. Nutrient deficiency was common across all blocks in all the 5 divisions and this is also reflected in the tissue analysis results in Table 1. General block upkeep (weeded circles (1.5), harvest paths (1.8) and general weeds (1.5)) were low in all the divisions. The low to average score in nutrient deficiency scoring correlates well with the low nutrient concentrations in the leaflets discussed earlier. Average pruning standards were 2.7 for palms < 7 years and 2.1 for palms >7. The lower average at palms >7 years implies palms are probably too tall for pruning or only palms with bunches are being pruned. Harvesting standards are very high with an average score of 2.8 for all the divisions. Insects pests, diseases and rat damage scored very high (2.8-3.0) implying no major problems with pests and diseases in the blocks. The assessments indicate that there is average and above average scores in agronomic upkeep standards and pests and disease free blocks, however there are low scores in nutrient deficiency across all the divisions. Harvesting at various frequencies is most likely leading to more nutrients leaving the blocks than going in and this could affect the long term sustainability of smallholder oil palm productivity.

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

SUMMARY
The planting in the second 2 ha was done and planting of food and tree crops in the wide avenues commenced. Monitoring and data collection commenced in 2009 and continued into 2010.

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

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

The trial was set up to:

- help develop effective policies for enhancing food and livelihood security amongst smallholder oil palm growers
- development strategies for intercropping oil palm with food and fuel wood crops which will have relevance for other export cash crops

- increase food production for domestic consumption and sale at local markets
- diversify and increase incomes, especially beneficial to women and blocks with large resident populations
- produce fuel wood and food on-block thereby reducing pressure on environmentally sensitive areas such as creeks and river banks and on steep slopes.

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

METHOD

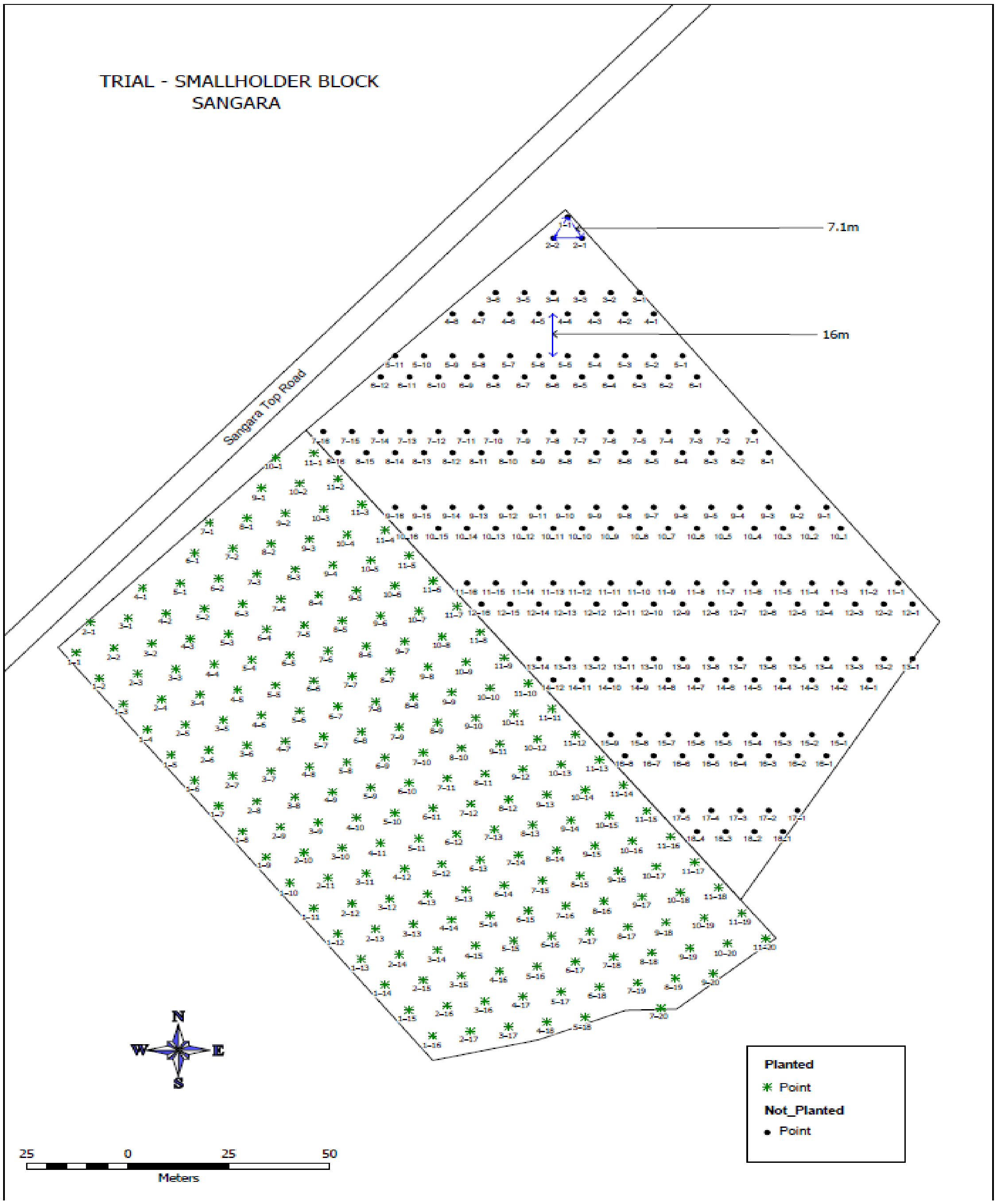
Intercropping trials.
Three to five smallholder blocks will be selected for this trial in each of the four oil palm growing projects. Depending on block sizes, the experimental areas will vary from 2 to 4 hectares each. The experimental area in each block will be divided into two: the first half will be planted with oil palm at the normal equilateral spacing of 128 palms per ha, while the second half of the block will be planted at the same density of 128 but with shorter planting distances between the palms and wider avenue widths between every second row of palms. The blocks will not be necessary divided into equal halves; the selected growers will have a choice of the sizes they prefer for the demonstration/study purposes. In the first half of the block (normal equilateral planting distance), legume cover crop will be established with no food crop. In the second half of the block, the wide avenue rows will be divided into plots. The plots will be planted with (a) food crops (b) legume cover crops and (c) tree crops (fuel wood spp). The food crops will be rotated with legume cover crops within the wide avenue rows. The oil palms in both the normal and altered planting arrangements will receive fertilisers at the smallholder recommended rates. To date, work has started in only one block at Sangara while negotiations are underway for more.

DESIGN AND ANALYSIS
There will be no strict statistical design used for this experiment. The blocks will be divided into 2 and not necessary equal parts, will depend on the farmers wish. One half will be planted with normal equal spacing arrangements while the other with altered spacing arrangement. Soils and plant tissue samples were collected randomly and replicated in odd numbers for analysis. Block information is shown in Table 1.

Table 1. Trial 337, Block information

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

SKETCH OF BLOCK



DATA COLLECTION

Plant tissue samples including yield and vegetative tissues are collected and dry matter production determined. The measurements are done to determine nutrient movement in and out of the smallholder blocks. A summary of major crops planted to date is presented on attached Table 2. Other crops not included include mandarin, noni, fuel wood, wood for house roof, pineapples, bananas and cassava.

Table 2. Major food crops and date of planting in Block 050136 at Sangara

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

RESULTS AND DISCUSSION

At the time of writing, tissue samples sent for analysis were not received and therefore nutrient contents exported from the system cannot be reported. The duration of cropping is 4-6 months for the major crops. Implications here are that on average 2 crops can be planted per year on the same land.

FIELD VISITS

There were field visits to smallholder blocks for various activities; Socio-economic surveys at 100 blocks, Agronomy leaf sampling at 58 blocks and Sustainability project 15 blocks.

FIELD DAYS AND RADIO BROADCASTS

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

The field days and radio broad casts were organized by OPIC and PNGOPRA attended to these presentations (Table 3).

Table 3. Number of field days and radio broadcasts in 2011

Extension mode	Section		Total
	Agronomy and others	Agronomy alone	
Field days (Major)	1	0	1
Field days (Minor)		0	0
Radio broadcasts			0

Common questions asked by the growers were in earlier field days:

- difference between the 1st and 2nd planting materials.

- why the company applying MOP (red marasin) & SOA (white marasin) while the growers only given SOA to apply.
- can the fertiliser application be divided into smaller portions.
- what is the orange spots/colour on the palm leaves.
- when and why is the company not giving fertilisers on time as per the calendar schedule.

The main topics presented to growers during field days were:

- What is PNGOPRA and its functions
- The Importance of fertiliser, the main type of fertiliser (SOA), main role of SOA in the oil palm production, the rates to apply in immature and mature palms.
- Fertiliser application calendar
- Block sanitation- to slow down the pest population (especially sexava and Stick insects in all the small holder blocks).
- Budgeting and savings of earnings from oil palm
- Biological control measures to control pest and weeds at the growers' level.
- Ganoderma awareness -Tok save to all block holders to check all the palms in their block for symptoms of ganoderma and also the brackets and report to their Area Extension Officers.
- Environment and sustainability project
- Food security and OPRA-OPIC food security project
- Impacts of HIV-AIDS on oil palm production

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

Work in progress

Trial 256 New Ireland Smallholder fertiliser/BMP demonstration blocks (RSPO 4.2, 4.3, 4.5, 4.6, 4.8, 8.1)

BACKGROUND

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

TRIAL SETUP

The demonstration trials started in 2008 and some of the information about the blocks is presented in (Table 1). Each of the 2 blocks has a different number of palms with nil fertilised and fertilised plots. At Lakurumau, Block 5655 has 40 palms not receiving any fertilisers while the rest of the block received fertilisers. Yield recording is done on the 40 nil fertilised palms and from 80 of the fertilised palms. The fertilised palms in both blocks received 6 kg SOA and 2 kg MOP per palm per year in 2008 but SOA was reduced to 3 kg and while MOP remained at 2 kg/palm/year in 2009 and thereafter. Another block (Block 1618) was established in 2010 to replace the previous block at Kafkaf because the grower at Kafkaf was having problems in harvesting.

Table 1. Trial 256 demonstration blocks information

Trial number	**256**	Soil Type	On raised coral
Block owner	Siri	Drainage	Good
Block No.	2655	Topography	Flat
Location	Lakurumau	Altitude	m asl

Division		Previous Land-use	Food gardens
Planting Density	(a)		
	(b)	Supervisor in charge	Paul Simin
Pattern	Triangular		
Date planted	(a)		
	(b)		
Trial started	March 2008		
Planting material	Dami D x P		
Progeny	Mixed Dami DxP		
Recording Started	2010 (Food crops)		

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

RESULTS AND DISCUSSION
Yield data and petiole cross section data are presented in Tables 2 and 3. Data collection started in June 2009 . The fertilised palms yielded more bunches and had higher single bunch weights than nil fertilised palms. This resulted in higher FFB yields from the fertilised palms than from the nil fertilised palms. In 2011, fertilised palms yielded 25.1 t/ha compared to 17.4 t/ha from the nil fertilised palms, a difference of 8 tonnes. A similar trend was seen in the second block (Block 1618) (Table 3).

Table 2. Trial 256, Yield, yield components results – Block 2655

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

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

Table 3. Trial 256, Yield and yield components in 2011 for Block 1618

Year	Treatment	FFB yield (t/ha)	BN (Bunches/ha)	SBW (kg)	PCS-1	FL (cm)
2011	- Fert	11.3	1315	8.6	20.7	533.3
	+ Fert	25.3	2582	9.8	21.5	531.3

Analysed results are presented in Tables 3 and 4 for the 2 demonstration blocks. At both blocks, leaflet N, K and rachis K were higher in the fertilised palms compared to the nil fertilised palm, however the diffierences are small in Block 1618 because the demonstration was started in 2010 and had only 1 year of fertiliser addition. Though the leaflets N increased to above adequate levels (2.50 % DM), leaflet and rachis K contents were still very low. The increase in rachis K from 0.20 % DM to 0.67 % at Lakurumau in 2011 corresponded with a yield increase of 8 t/ha, during the same period. There were increases in rachis K contents in 2011, but the contents are still lower than the critical levels of 1.35% DM.

Table 4. Trial 256, Leaf tissue nutrient contents (% DM except B in ppm) in 2009, 2010 and 2011 at Block 2655 Lakurumau.

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

Table 5. Trial 256, Leaf tissue nutrient contents (% DM except B in ppm) in 2011 at Block 1618.

Year	Treatment	Leaflet								Rachis			
		Ash	N	P	K	Mg	Ca	B	S	Ash	N	P	K
2011	Nil fert	7.73	2.18	0.143	0.4	0.57	1.35	16.7	0.18	2.9	0.38	0.086	0.20
	Fert	8.26	2.25	0.144	0.4	0.66	1.34	16.5	0.19	3.4	0.38	0.082	0.24

CONCLUSION

Addition of AC and MOP greatly improved yield and yield components, fronds petiole cross sections and leaf tissue N and K contents. Fertiliser addition increased yields by 8-14 t/ha in 2011.

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

SUMMARY
Work in progress

BACKGROUND
Refer to Trial 337

BLOCK DETAILS AND TRIAL SET UP
The set up of the food security demonstration site in New Ireland is different from Popondetta. The food security plot was set up outside of the block and fenced with bamboos to prevent pigs spoiling the food crops grown inside. Then small plots were setup inside the fenced area and planted with food crop. Empty fruit bunch from the mill was added to the plots before food crops were planted especially for the banana plots. Block information is shown in Table 1.

Table 1. Trial 257, Block information

Trial number	**257**	Soil Type	On raised coral
Block owner	Siri	Drainage	Good
Block No.	2655	Topography	Flat
Location	Lakurumau	Altitude	m asl
Division		Previous Land-use	Food gardens
Planting Density	(a)		
	(b)	Supervisor in charge	Paul Simin
Pattern	Triangular		
Date planted	(a)		

	(b)		
Trial started	March 2008		
Planting material	Dami D x P		
Progeny	Mixed Dami DxP		
Recording Started	2010 (Food crops)		

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

SUMMARY
Work is in progress and data collection has commenced into 2011 and 2012.

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

(Steven Nake and Graham Dikop)

SUMMARY
A trial on intercropping oil palm with food crops has been developed in Buvusi, Hoskins Project to address food security issues within smallholder oil palm blocks. About 1.5 ha was planted to full stand oil palms (196 palms) while 0.5 ha was planted with food crops. Eight different food crops were planted in 8 plots replicated 2 times. The food crops included kaukau, singapore, cassava, taro, yam, banana, peanut and rice. Unfortunately, the rice and peanut were eaten by human beings, birds and rats before reaching maturity. Other food crops will be harvested in 2012.

BACKGROUND
Refer to Trial 337 at Sangara, Popondetta project.

The trial was set up to:

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

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

METHOD

Intercropping trials.
Three to five smallholder blocks will be selected for this trial in each of the four oil palm growing projects. Depending on block sizes, the experimental areas will vary from 2 to 4 hectares each. The experimental area in each block will be divided into two: the first half will be planted with oil palm at the normal equilateral spacing of 128 palms per ha, while the second half of the block will be planted at the same density of 128 but with shorter planting distances between the palms and wider avenue

widths between every second row of palms. The blocks will not be necessary divided into equal halves; the selected growers will have a choice of the sizes they prefer for the demonstration/study purposes. In the first half of the block (normal equilateral planting distance), legume cover crop will be established with no food crop. In the second half of the block, the wide avenue rows will be divided into plots. The plots will be planted with (a) food crops (b) legume cover crops and (c) tree crops (fuel wood spp). The food crops will be rotated with legume cover crops within the wide avenue rows. The oil palms in both the normal and altered planting arrangements will receive fertilisers at the smallholder recommended rates.

DESIGN AND ANALYSIS

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

DATA COLLECTION

Plant tissue samples including yield and vegetative tissues will be collected and dry matter production determined. The measurements will be done to determine nutrient movement in and out of the smallholder blocks. Soil samples will be taken as well from the both farming systems (Full oil palm stand and intercropped area.

UPDATE REPORT ON TRIAL 151 IN BLOCK 1358, BUVUSI (HOSKINS PROJECT), WNB

Below is a brief progress report on status of the intercropping trial in Buvusi up to December 2011:

For the Hoskins Oil Palm Project, a block was identified and work commenced in July 2011 (Table 1). About 1.5 ha of the total area (2 ha) under replant was planted with oil palm at the spacing of 9.75 m x 9.75 m (120 palms/ha) (Figure 1). Only 0.5 ha was reserved for the intercropping with food crops, which the oil palm grower sacrificed 44 palms. The food crops were planted in 2 replicates of 8 plots. Each plot is approximately 8m x 8m (16 m^2 or 0.0016 ha). The list of planted food crops are shown in Table 2.We have not considered planting of tree crops and this will be considered in 2012. Similarly, crop rotations with legume plant/crops were not considered and should be taken into account after the first harvest in 2012.

Table 1. Trial 151, Block information

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

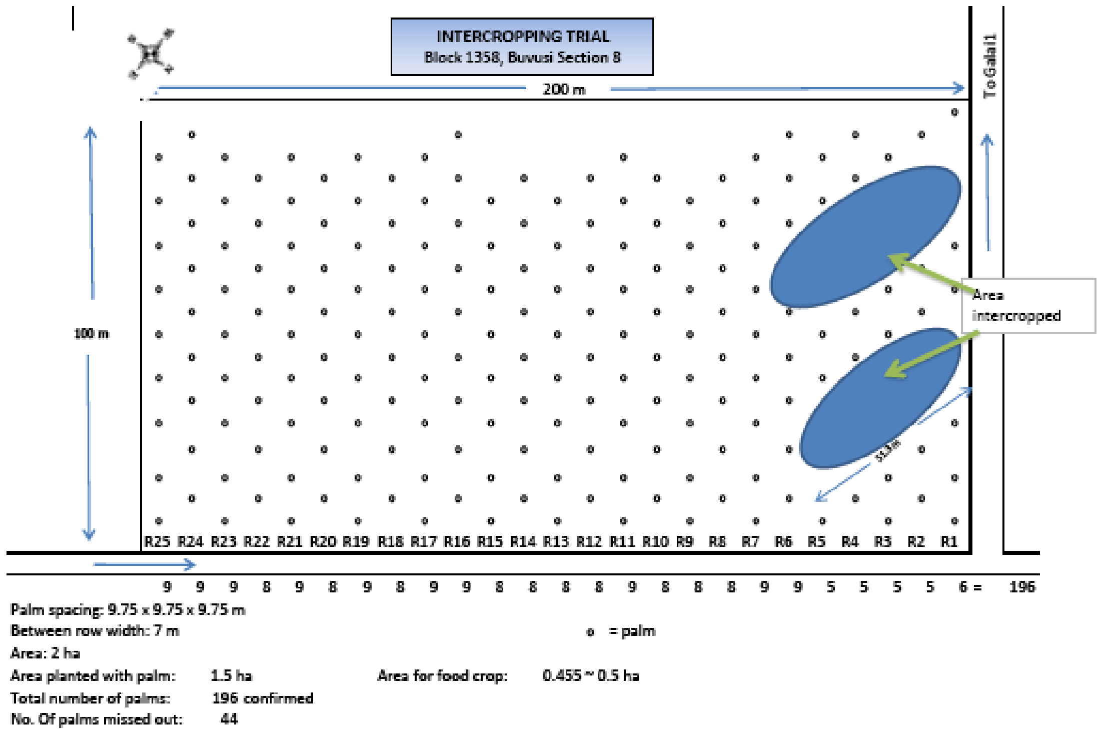


Figure 1: Trial Map of the Intercropping trial (Block 1358) at Buvusi section 8, Hoskins Project

Table 2: Information on food crops planted in the intercropping trial

Crop	Date of Planting	Rep	Plot	Number of plants, mounds etc	Comments
Oil Palm	July 2011	N/A	N/A	196	To be fertilised in 2012
Kaukau	September 2011	1	1	300	
Taro	Sep 2011	1	2	165	
Singapore	Sep 2011	1	3	169	
Yam	Sep 2011	1	4	45	
Peanut	Sep 2011	1	5	794	Stolen/eaten by humans and animals (rats/parrots)
Rice	Oct 2011	1	6	893	Grains all eaten up by birds
Banana	Sep 2011	1	7	24	
Cassava	Sep 2011	1	8	156	
Kaukau	Oct 2011	2	9	182	
Taro	October 2011	2	10	239	
Singapore	Oct 2011	2	11	125	
Yam	October 2011	2	12	24	
Rice	Not planted	2	13	-	Not planted, high chance of rice being eaten by birds
Banana	Sep 2011	2	14	28	
Cassava	September 2011	2	15	64	
Peanut	Noted planted	2	16	-	Not planted; insufficient space

Anticipated Work in 2012:

1. Harvest matured food crops
2. Take samples for chemical analysis for nutrient in food crops
3. Record vegetative dry matter production of all portions of the crops (leaves, tubers, corms, flowers, stems etc)
4. Soil sampling within 2 farming systems (full oil palm stand and intercropped area)
5. Apply immature fertiliser programme to the young palms
6. Series of Market surveys to be conducted as soon as any particular crop is harvested.
7. Arrange for a field day to be conducted in the block for OPIC extension officers (and later growers).
8. Incorporate rotations with legume crops (beans, peanuts and legume cover plants)
9. Plant few tree species as wind breakers around the block.


(a) Seedlings for replant


(b) Boundary between the two farming systems


(c) Plot (food crop) demarcation


(d) Planting cassava sticks


(e) Food crops in replicate 1


(f) Food crops in replicate 1

Trial 150: Hoskins Smallholder fertiliser/BMP demonstration blocks (WNBP) (RSPO 4.2, 4.3, 4.5, 4.6, 4.8, 8.1)

Steven Nake and Murom Banabas

SUMMARY

The FFB yields (t/ha), bunches per hectare (BHA) and single bunch weights (SBW) have all responded significantly ($p<0.05$) to the fertiliser treatments in 2011. Treatment 3 (3kg AN + 1 kg MOP) produced the highest crop (21.3 t/ha) while treatment 1 (current block fertiliser practice) and treatment 2 (recommended rate of 2 kg AN) yielded the same (20.1 t/ha). Irrespective of the treatments, the average yield was 21.3 t/ha which is 7.7 tonnes more than the 2010 average yield (13.6). N level in the leaflets also responded significantly ($p<0.05$) to the fertiliser treatments in 2011, however the N levels were still low (below the adequate mark). Another year of fertiliser (AN) application should push N levels up to the adequate mark.

BACKGROUND

The smallholder sector in PNG makes up about 42 % of the total area under production and produces 32 % of the total crop. The smallholder yield averages at 14 t/ha (range = 0.5 – 17 t/ha) while the plantations yields averages at 22 t/ha (range = 7 – 27 t/ha). PNG OPRA field trials in plantations across the country prove yields of 30 – 35 t/ha are achievable. The benefits of increased yields from the smallholder blocks can be substantial and are very important for the oil palm industry. The smallholder sector holds the key to a substantial untapped potential in production. Setting up of demonstration plots and experiments in smallholder blocks are one important way of contributing to increasing yields in the smallholder blocks, however trial and demonstration work with smallholders is never straight forward. The reasons behind the low production and productivity are complex. Smallholder Trials-Demonstration blocks in Hoskins Project were started in 2008 with the following aims:

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

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

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

MATERIALS AND METHODS

Site Selection

Blocks with low production, poor block upkeep and obvious symptoms of N deficiency on the palms (i.e. pale leaflet colour, small/reduced frond area, smaller PCS, erected fronds (with less small and less number of bunches) were selected for the trial/demonstration work. Most of these blocks were proposed by OPIC and confirmed by OPRA Agronomist upon site inspection. If the growers agree for the use of their block to set up the trial, then land usage agreement forms were completed and signed by the 3 parties (Grower/OPIC/OPRA). Information on Trial Blocks are presented in Table 1. Smallholder blocks are usually planted at 120 palms/ha (palms planted 9.8m apart with 8.5m between rows), thus in one hectare there are 12 rows and each row has 10 palms.

Since this work started in 2009, four trial blocks have been closed so far; 1 in 2009 and 3 in 2010 due to continuous skip harvesting which affected data collection. By the end of 2011, there were 22 trials in operation.

Table 1. Block data information on Trial 150

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

Experimental Design and Treatments

The trial layout is shown in Figure 1. The trial block consists of 4 rows of each treatment, total of 12 rows. However, only 10 palms in the two central rows in each treatment are used for various measurements and data collection (yield recording, vegetative measurements etc). Thus a treatment consists of two rows of 10 palms (total of 20 palms/treatment). Fertiliser treatments are applied to both the recorded palms and the guard row palms surrounding the recorded palms (with the same colour code). Other palms not included in the plots (outside the treatments) but still within the trial block are fertilised as well using the standard rate (2 kg AN/palm/year).

Fertiliser treatments are:

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

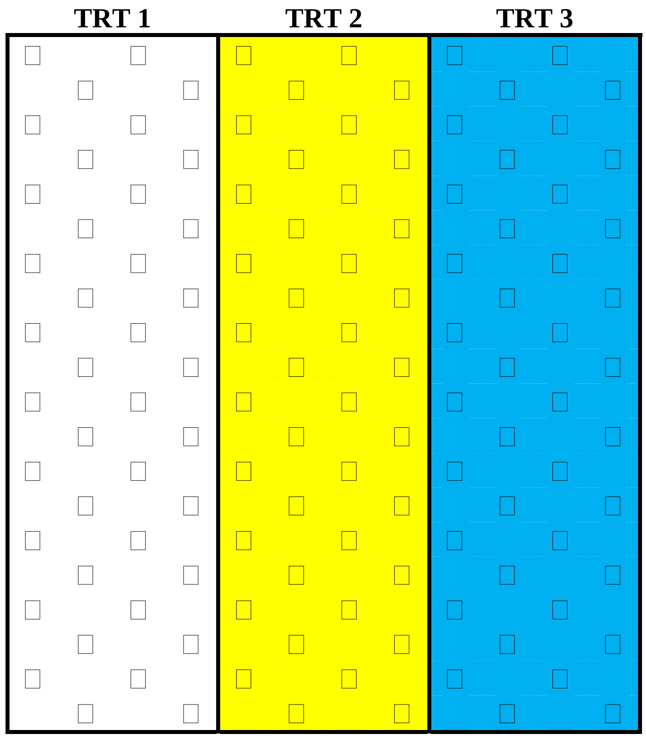


Figure 1. Treatment layout on a 1 ha block

Measurements and data collection done in the trial blocks

- Fortnightly yield recording (which includes recording number and weight of bunches). Some of the trials setup in 2009, did not have any yield data (t/ha) because only the number of harvested bunches were recorded with no weighing done fortnightly.
- Leaf sampling for leaflet nutrient analysis – once a year
- Normal upkeep work – as and when required
- Monthly field assessment (reported separately below)

Data analysis

The trial blocks were not established at the same time, but throughout the three year period since 2009. Therefore statistical analysis (using Genstat) was only done on trials that commenced in 2009 to eliminate the time effect because each of the trial blocks was considered as a replicate.

RESULTS

Yield trend in the trial blocks in 2010 and 2011The yield (and other components) trend from 2010 to 2011 are shown in Figure 2. Since the smallholder blocks were converted into fertiliser trial blocks in 2009, the yields have increased by 7.7 t/ha (36 %). Similarly, the single bunch weights also inclined from 12.1 kg in 2010 to 18.6 kg in 2011, an increase by 35%. Furthermore, there was an increase by 42 bunches (1093 to 1135 in 2011).

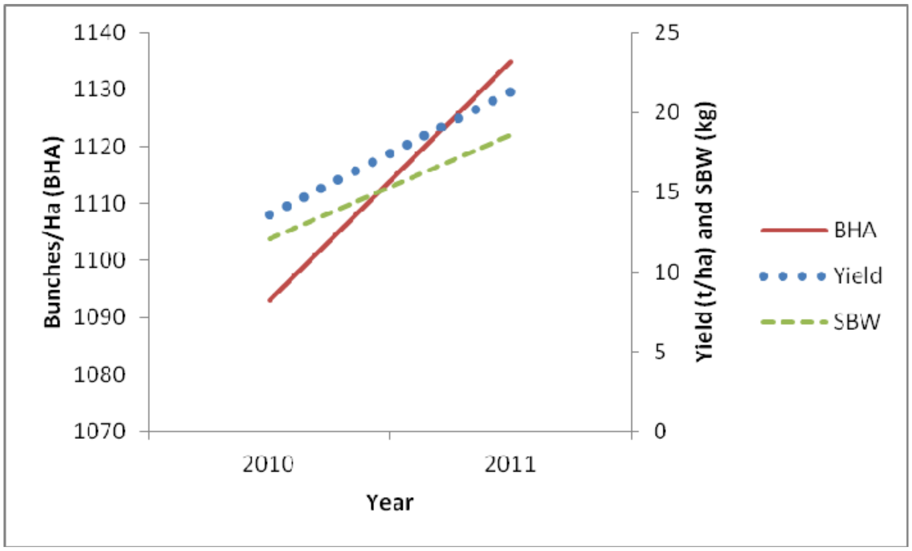


Figure 2. Mean yield (t/ha), BHA and SBW (kg) in 2010 and 2011.

Fertiliser treatment and their effects on the yield, BHA and SBW

The yields, bunches per hectare and single bunch weights did not respond to the fertiliser treatments in 2010 (Table 2). However in 2011, the yield parameters all responded positively and significantly ($p<0.05$) to the treatments. The yields have improved significantly to over 20 t/ha after the third year of treatment application. Treatment 3 (3 kg AN + 1 kg MOP) yielded 3 tonnes more than Treatments 1 (farmer practice) and 2 (2 kg AN). Similarly, the highest number of bunches per hectare were harvested from the plots that received treatment 3. Similar trend was observed with the single bunch weights as well. Interestingly, palms treated with treatment 1 and 2 produced similar yield, BHA and SBW (Table 2). This could imply that farmer practice conforms to the current fertiliser recommendations for OPIC.

Table 2. Effect of fertiliser on yield and its component in 2010 and 2011. Values in bold are significant at $p<0.05$.

Fertiliser Treatments	2010			2011		
	Yield (t/ha)	BHA	SBW (kg)	Yield (t/ha)	BHA	SBW (kg)
1	14.3	1166	11.9	**20.2*b***	**1132*ab***	**17.8*b***
2	13.4	1058	12.4	**20.2*b***	**1078*b***	**18.6*ab***
3	13.1	1055	12.1	**23.3*a***	**1195*a***	**19.5*a***
Mean	*13.6*	*1093*	*12.1*	*21.3*	*1135*	*18.6*
Significance (at 5 %)	NS	NS	NS	P<0.001	P=0.022	P=0.028
LSD	-	-	-	1.4	78	1.2
CV %	11.9	9.4	6.6	5.5	5.9	5.3

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

Treatment effects on Tissue nutrient concentration (% DM)

The effects of the three fertiliser treatments are presented in Table 3. The fertiliser treatments had significant effects ($p<0.05$) on leaflet N in both 2010 and 2011. In 2010, leaflet N level was significantly higher in treatment 3 than the two other treatments, which were no different from each other. Similar response was recorded in 2011, however the leaflet N levels from all three treatments were similar (statistically the same i.e. their difference were less than the calculated LSD. The rest of the nutrients in both the leaflets and the rachis showed no significant response to the treatments in both 2010 and 2011.

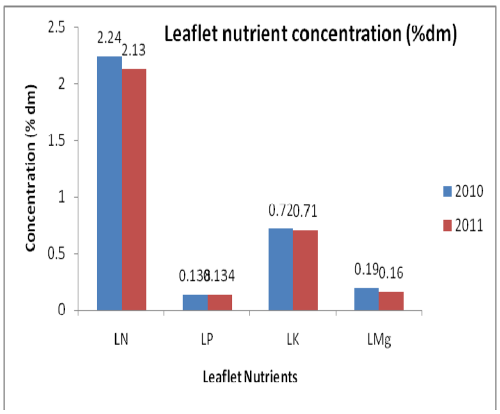
Irrespective to the treatments, there was a slight drop in leaflet N, P and Mg levels in 2011. In contrast, rachis N and P did not change in 2011, but rachis K was increased as expected but not significant (Figure 3). The following nutrients were still below the adequate level in 2010 and 2011: leaflet N, leaflet P, leaflet Mg and rachis N. Leaflet K, rachis P and K were within or above the adequate level (Figure 3).

Leaflet N levels are still below the adequate levels (2.45 % dm) after 3 years of treatment (2009 – 2011). This is because most of these blocks have not been receiving any fertilisers for some time, thus the low N levels prior to the treatment application. Similarly, rachis N has increased in 2010 increased from 2009 levels but the levels are still below the adequate N in the rachis (0.32 % dm).

Table 3. Nutrient levels (% dm) in leaflet (L) and rachis (R) tissues in 2010 and 2011. Values in bold are significant at p<0.05.

Fertiliser Treatments	2010							2011						
	LN	LP	LK	LMg	RN	RP	RK	LN	LP	LK	LMg	RN	RP	RK
1	**2.19*bc***	0.137	0.72	0.19	0.28	0.10	1.48	**2.09*a***	0.131	0.72	0.17	0.27	0.09	1.41
2	**2.22*b***	0.136	0.72	0.19	0.27	0.10	1.37	**2.12*a***	0.133	0.73	0.17	0.29	0.12	1.50
3	**2.30*a***	0.140	0.73	0.19	0.28	0.10	1.35	**2.17*a***	0.134	0.69	0.16	0.29	0.09	1.50
Mean	*2.24*	*0.138*	*0.72*	*0.19*	*0.28*	*0.10*	*1.40*	*2.13*	*0.134*	*0.71*	*0.16*	*0.28*	*0.10*	*1.45*
Adequate levels	2.45	0.145	0.65	0.20	0.32	0.10	1.2	2.45	0.145	0.65	0.20	0.32	0.10	1.2
LSD	*0.06*	-	-	-	-	-	-	*0.15*	-	-	-	-	-	-
CV %	2.3	2.6	6.8	10.8	11.2	24.4	16.3	6.6	2.4	10.7	9.9	7.9	22.7	9.1

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



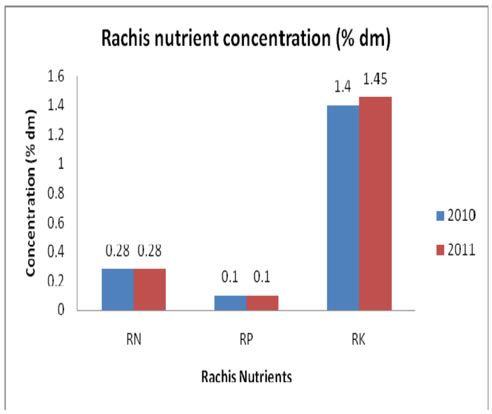


Figure 3. Average leaf and rachis nutrient concentration (%dm) in 2010 and 2011

DISCUSSION

Yield response to fertiliser normally takes around 2-3 years, whereas tissue levels in the oil palm leaves can respond within one year. From this trial, we have seen response with concentration of leaflet N to the fertiliser treatments from 2010, which is about two years after the first treatment application. Three years later, we are now picking up positive responses in the yield, BHA and SBW as a consequence of applying the treatments. Though the yields and components have increased from 2010 to 2011, leaflet N, P, K and Mg somehow dropped. This could be due to the high nutrient demand to sustain the large yield increase in 2011.

The inclusion of 1 kg MOP, as K source in treatment 3, elevated rachis K from 1.35 % in 2010 to 1.5 % in 2011. Despite the positive result, that response statistically was not significant because e the tissue results from 2009 and 2010 showed both leaf and rachis K to be within the adequate range, meaning no issues with K, thus the no response.

Regardless of the significant effect of the fertiliser on leaflet N in 2011, the N levels are still below the adequate mark. It is more likely that another round of fertiliser application in 2012 will push the levels of both leaflet and rachis N into the adequate level (2.45%). By then, we expect response from other nutrients as well.

CONCLUSION

The yield and its components (BHA and SBW) responded significantly to the treatments in 2011. By applying 3kg AN with 1 kg MOP (Treatment 3), FFB yield was significantly increased to 23 t/ha which was 3.1 t/ha greater than the yield from treatment 1 and 2. BHA and SBW were also maximised at treatment 3. Irrespective to the treatments, the average production in 2011 was 21.3 t/ha which represented an increase in yield by 7.7 t/ha from 2010. There was also significant response by the leaflet N to the treatments in both 2010 and 2011 with highest level of N (+K) with highest concentration of leaflet N. Unfortunately, leaflet N levels still below the adequate mark. Another year of fertiliser (AN) application should push N levels up to the adequate mark.

BLOCK ASSESSMENTS IN TRIAL 150 (RSPO 4.1-6, 4.8, 5.1, 8.1)

Block assessments are normally conducted (i) before work is done and treatments are applied in any smallholder trial block and (ii) end of every month after trial setup to determine visible nutrient deficiency from the surrounding 6 palms and legume cover with the same 6 palms. The upkeep standards and pest and disease were also assessed and given a score out of three (refer to Figures 1a and 1b for criteria used for assessment). The summarised scores are presented in Table 2.

Small holder block – hygiene and block management assessment

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

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

Small holder block – hygiene and block management assessment

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

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

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

Figure 1a. Inspection form for smallholder blocks.

Procedures for under taking assessment:	
• Select 6 palms randomly in block (each of these are called a palm site) • At each palm site make the observations for the six surrounding palms (not including the palm you have selected to make your observations from) • At each palm site record each of the criteria/standards listed and on the recording sheet fill in the average of the six palm sites Details for each criteria/standard	
No	**Criteria or Standard**
1	**Insects** • Record type of insect and extent of defoliation or frond damage
2	**Nutrient deficient palms** • Write in which nutrient is deficient and record no of palms (out of six) with the visual deficiency
3	**Ground cover deficiency** • Write in nutrient deficiency and record % of plants with the visual deficiency
4	**Harvest fruit on ground** • Assess number of loose fruit (total of fresh, old and rotten)
5	**Weeded circle** • Assess % of ground covered in the weeded circle with vegetation
6	**Legume cover plants** • Between the palms, assess % of ground covered with legume cover plants
7	**Weed ground cover (woody or grass weeds: Momordica, Kunai, Mimosa, Chromolaena, Weldaka)** • Between the palms, assess % of ground covered with these weeds
8	**Fronds stacks** • Record the placement of pruned fronds
9	**Harvest paths** • Record status of harvest paths
10	**Trunk weeds (woody or vines)** • Record % of trunk covered with woody weeds or vines
11	**Trunk weeds (ferns)** • Record % of trunk covered with ferns (at level 1 you cannot see bunches in the crown)
12	**Pruning (depending on palm age)** • Record the number of fronds below the most mature bunch
13	**Ganoderma** • How many of the six palms in each location have Ganoderma brackets
14	**Rat damage** • On either harvested bunches or bunches still on palms plus male flowers record the number of bunches plus male flowers with rat damage

Figure1b. Procedures for filling in smallholder block inspection forms

Table 2. Block assessments scores (average) for 12 trial blocks initiated in 2009

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

Generally, the smallholder blocks were not properly managed as indicated from the initial block assessment **BEFORE** any work was done (Table 2). A score of 1.0 was given under the Palm Nutrient deficiency suggesting that 3 or more palms (out of the 6 observed) showed signs of nutrient stress. The common deficiency symptoms would be nitrogen, magnesium, potassium and boron with particular attention given to nitrogen. By 2011, close to none (2.4) of the six surrounding palms showed signs of nutrient deficiency. Similarly, the scoring for frond stacking, harvest paths, pruning standards and weeded circle have all improved from an average score of 10-15 in 2009 to close to 3.0 in 2011 indicating best management practice implemented in those blocks. There were no major problems with rats and ganoderma within the blocks, though insect damage was moderate but managed to be controlled with proper pruning and treatment. The assessments indicate that there is average and above average scores in agronomic upkeep standards (including pest and disease). Harvesting standards have improved but couple of blocks are still skipping harvests

FIELD VISITS/INSPECTIONS

Field visits are normally done following request from smallholder growers and OPIC. In 2011, total of 39 blocks were visited upon requests. Apart from this list (below), the current 26 smallholder fertiliser trials are visited every fortnight for yield recording and once every month for the block assessment (reports). Therefore a trial block is visited roughly 2 times in a monthly which is equivalent to 24 times a year. For the entire current 26 blocks, the number of visits to the trial blocks adds up to 624 visits in 2011.

Table 3. Smallholder blocks in Hoskins project visited in 2011 upon requests from OPIC and smallholder growers.

Division	**Blocks**	**Number of blocks**
Siki	0003, 0070, 0015, 0013, 0090, 0023, 0012, Karapi Mini estate	8
Nahavio	0556, 0041, 0033, 0034, 0004, 0001, 0018, 0003	8
Buvusi	1261, 2016, 1502, 1540, 1563, 1571, 1501, 1507, 1503	9
Kavui	0299, 0311, 0381, 0347, 1637, 0257	6
Salelubu	0410, 413, 298, 0042, 1013, 967, 183, 119	8
Total blocks visited in 2011:		**39**

FIELD DAYS AND RADIO BROADCASTS

OPIC field days and radio broadcasts were also attended throughout the year in the Hoskins Project. Field days were conducted on Tuesdays of every week and attended by other stakeholders as well. This included OPIC, PNGOPRA, NBPOL and financial institutions (ANZ, PNG Microfinance Limited, Nationwide Microfinance). Radio broadcasts were organised by OPIC and attended by the stakeholders to give a 30 minute talk on issues relating to smallholder oil palm growers.

Table 4. Number of field days and radio broadcasts in 2011

Extension mode	Section		Total
	Agronomy and others	Agronomy alone	
Field days (Divisional)	18		18
Field days (upon request)		1 (Galai 1)	1
Radio broadcasts	3		3

Sustainability Project (SMCN/2009/013) (RSPO 1.1, 4.2, 4.3, 4.4, 4.8, 5.1, 5.6, 8.1)

INTRODUCTION

The full title of the Sustainability Project is: “Indicators of sustainable soil and water management for the Papua New Guinean oil palm industry” The objective of the project is to improve environmental sustainability and long-term viability of the PNG oil palm industry by the use of indicators that facilitate continuous improvements in management practices. There are 6 specific objectives:

1. Develop indicators of soil health.
2. Develop indicators of nutrient balances.
3. Develop indicators of carbon sequestration.
4. Develop indicators of aquatic ecosystem health.
5. Develop a crop system model that enables prediction of management effects on environment.
6. Test and implement an integrated monitoring and recommendation package, and build capacity.

FIELD MONITORING AND EXPERIMENTS

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

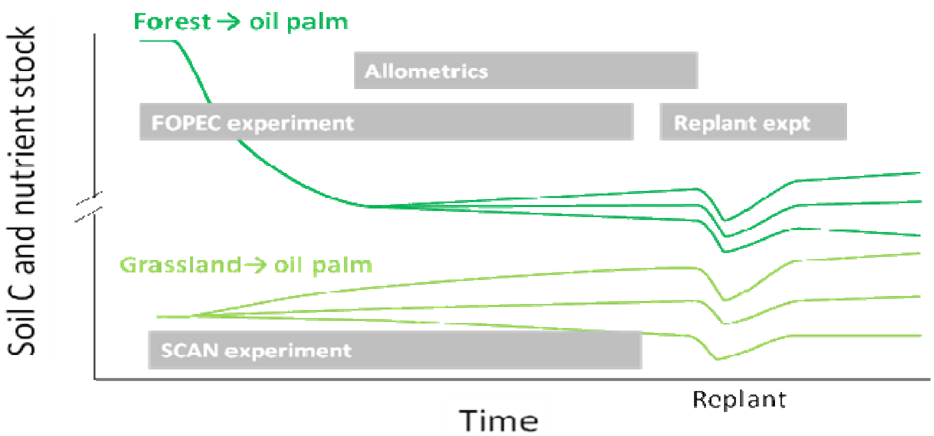


Figure 1. Hypothetical trajectories of carbon and nutrients stocks under various parts of the oil palm cycle, and the time period being covered by major field experiments.

Table 1. **Location of field research sites.**

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

Stream studies	West New Britain	150 sites in 22 stream systems	Water quality parameters and fauna surveys

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

CROSS-OBJECTIVE ACTIVITIES: 'ALLOMETRICS'

Allometric relationships are being developed so that amounts of biomass and nutrients can be estimated from simple routine measurements. These will be used to estimate nutrient and carbon balances as well as providing information for the modelling component.

Estimating Frond Biomass

Fronds of various ages from 6, 10, and 20 year old palms were sampled and fresh matter (FM) measured. FM and dry matter (DM) of subsamples were measured and DM for the total frond calculated from FM/DM ratios. The DM of fronds increased with palm age (Fig. 2). Frond DM also increased between frond 1 and frond 9, becoming almost constant or maybe even falling a small amount by frond 33.

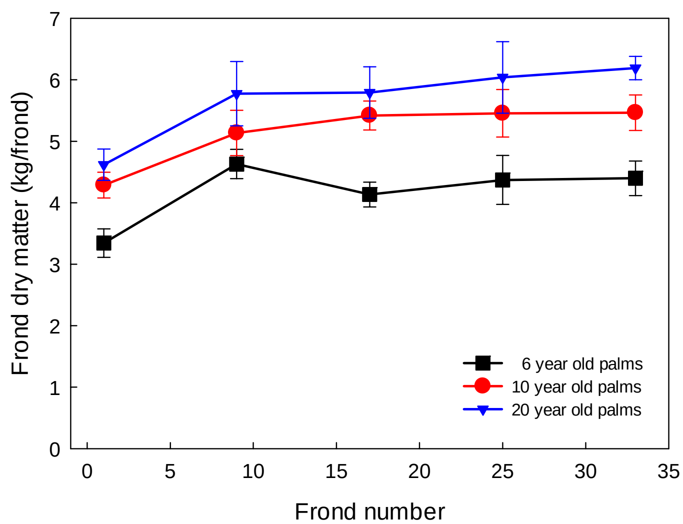


Figure 2. Relationship between frond mass and frond age for palms of different age. Data points are the mean of four replicates and the error bars are the standard error of the mean.

Even though frond DM increased with age, the relationship between frond number and frond DM was similar for each age. Thus, in order to develop a relationship between frond 17 (F17) DM and frond number that was independent of age, all weights were normalise to F17DM for each age a single relationship developed.

$$NFDM = -0.0004 \times FN^2 + 0.0196 \times FN + 0.811 \qquad (1)$$

where NFDM is Normalised Frond Dry Matter, FN is Frond Number. Thus the total dry matter of fronds is given by integrating equation (1) over the number of fronds present;

$$TNFDM = -0.00013 \times NoF^3 + 0.0098 \times NoF^2 + 0.811 \times NoF \qquad (2)$$

where TNFDM is Total Normalised Frond Dry Matter, NoF is Number of Fronds present on the palm. Because this is normalised to F17, the actual total DM is given by

$$TFDM = TNFDM \times F17DM \qquad (3)$$

where TFDM is Total Frond DM (kg), F17DM (kg). Thus if the dry matter of F17 and the number of fronds on the palm are known, the total frond biomass can be estimated. In order to determine the DM of F17, another relationship was developed between routinely measured parameters and F17DM. Corley et al. (1971) found a relation between FDM and the petiole cross section (PCS) at the point of the rudimentary leaves. This was tested with the current data and a slightly different relationship was found (Fig. 3, Equation (4))

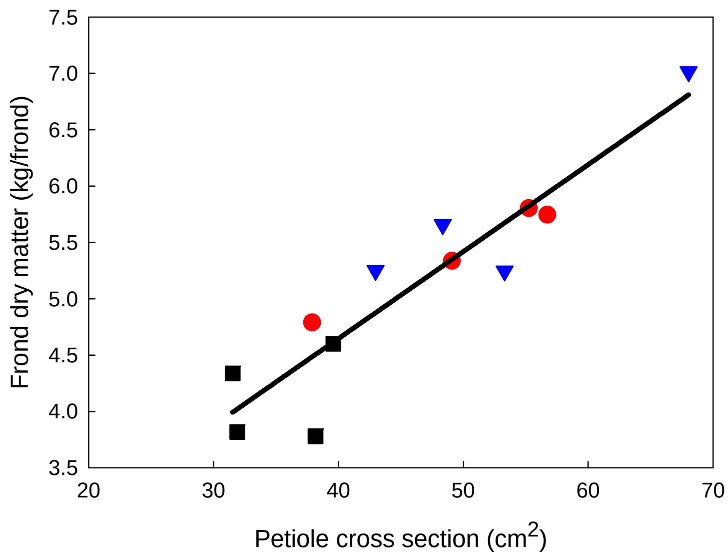


Figure 3. Relationship between frond dry matter and petiole cross section for frond 17 of palms that are 6 years old (squares), 10 years old (circles), or 20 years old (triangles).

$$F17DM = 0.077 \times PCS + 1.65, \quad R^2 = 0.89 \tag{4}$$

where PCS is Petiole Cross Section (cm^2) and is the petiole width multiplied by the petiole thickness. A slightly better relationship was developed if the rachis length was included.

$$F17DM = 0.058 \times PCS + 0.00541 \times RL - 0.902, \quad R^2 = 0.91 \tag{5}$$

where RL is Rachis Length (cm). However, the improvement is only minor and probably not worth the effort if RL is not routinely measured. As a 'reality check' the results from the current project were compared to those calculated using the formula of Corley et al. (1971) (Table 2).

Table 2. Comparison of predicted frond 17 dry matter and total frond dry matter by the method presented in this report and that of Corley et al. (1971) for a range of petiole cross sections (PCS). The calculations were made assuming 33 fronds on the palm.

PCS (cm^2)	Frond 17 Dry Matter (kg/frond)			Total Frond Dry Matter (kg/palm)			
	This project	Corley	Difference	This project	Corley	Difference	% from Corley
35	4.3	3.8	+0.5	139	125	+14	+12
50	5.4	5.3	+0.1	177	175	+ 2	+ 1
65	6.6	6.8	-0.2	215	226	- 11	- 5

Clearly the F17DM calculated with these new relationships is within scope of the method used by Corley et al. (1971). These new relationships should be used for current calculations as they have been determined with current genetic material.

Procedure for determining total frond dry matter

1. Measure PCS (cm^2, petiole width by thickness) of frond 17 at the point of insertion of the rudimentary leaflets.
2. Calculate dry matter of frond 17 (kg) using equation (4) or (5) above.
3. Count the number of fronds
4. Calculate Total Normalised Frond Dry Matter using equation (2)
5. Multiply the result from 2. by result from 4; see equation (3)

Estimating Frond Area

Frond area is used in the calculation of light interception by the canopy and thus important for the model. Total area of leaflets in a palm was calculated from the area of leaflets along a frond and then aggregated up to the whole palm.

Individual leaflet

The width of each leaflet was measured at 10 cm intervals from the base of the leaflet (Fig. 4). These widths were converted to a half-width and a relationship established (Fig. 4).
This relationship was of the form

$$HW = a \times P + b \times P^2 \qquad (6)$$

Where HW is half-width (cm), P is position (cm). The area of the leaflet was determined by integrating the area under the curve (equation (6)) for the leaflet length and multiplying by 2. The area of leaflets was determined at several points along the frond depending on its length (Fig. 5). The area of each leaflet was then modelled by fitting a formula to the curve (Fig. 5, equation (7)).

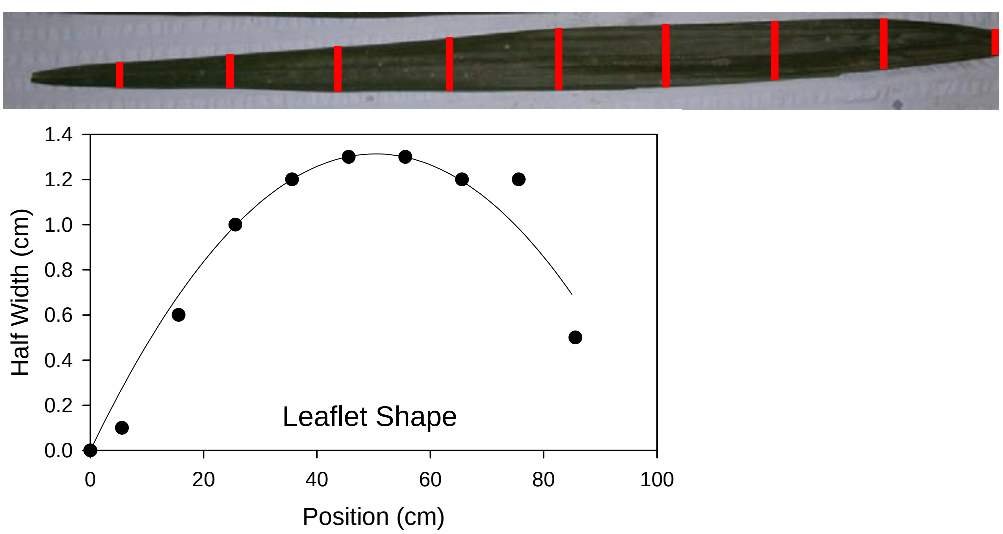


Figure 4. Location of leaflet width measurements and relationship between half-width and position.

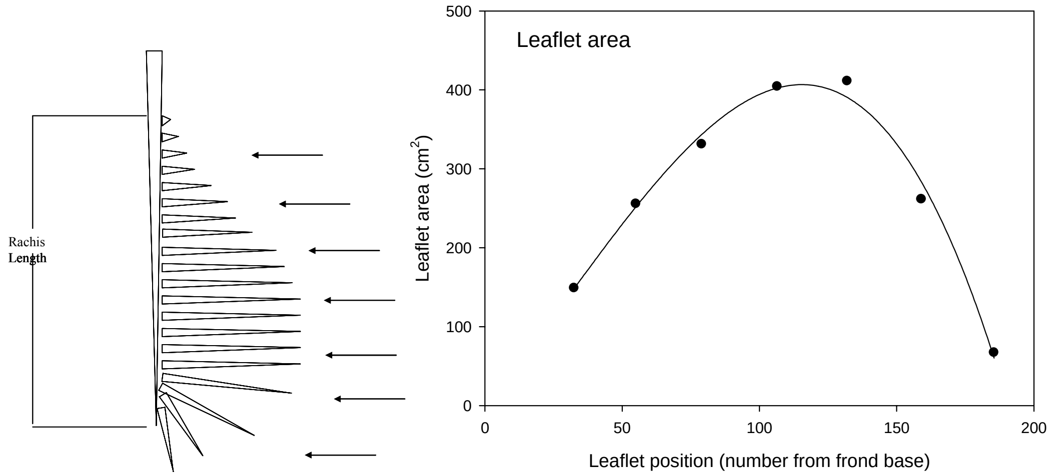


Figure 5. Location of leaflet area sampling positions and relationship between leaflet area and position

$$LeafletArea = a \times LP + b \times LP^2 + c \times LP^3 \qquad (7)$$

The total leaflet area for each frond was determined by calculating the area of each leaflet along the frond then summing and multiplying by 2 (for each side of the frond). This was repeated for each frond sampled to give a relationship between frond leaflet area and frond number (Fig. 6)

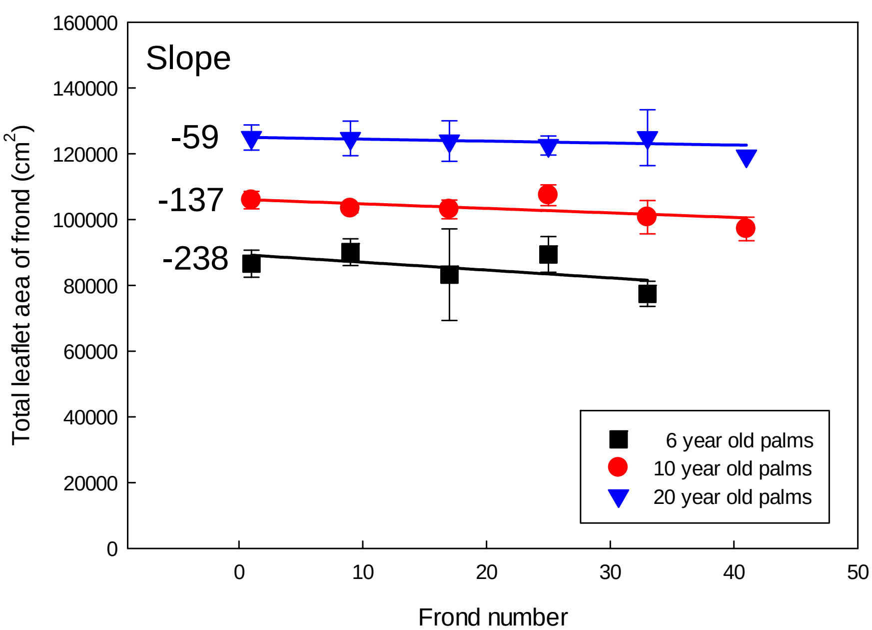


Figure 6. Relationship between leaflet area and frond number with palm age.

Clearly frond leaflet area increases with frond age; but the slope of the relationship between frond leaflet area and frond number becomes less steep with palm age. Thus in order to predict the slope of the relationship for other aged palm a curve was fitted to the slope and age (Fig. 7)

Figure 7. Relationship between slope of frond area versus frond number and age of palm.

This relationship is described by;

$$Slope = -629 + 585 \times (1 - e^{(-0.184 \times Age)}) \quad (8)$$

Where Age is the age of the palm. Once again we need a relationship between F17 leaflet area and other routine measurements. A number of relationships were tested:

1. Based on Leaflet Length, Leaflet Width, and Number of leaflets. This is based on Hardon et al (1969) where the uncorrected leaflet area (LL*LW) is compared to the average actual leaflet area of the frond. Hardon et al. (1969) found this ratio to be 0.57. On the palms we sampled this ratio is 0.52 for F17, thus;

$$TLA = LL \times LW \times NumL \times 2 \times 0.52 \quad (9)$$

Where TLA is Total Leaflet Area (cm^2), LL is Leaflet Length (cm), LW is leaflet Width (cm), NumL is the number of leaflets on one side of frond, 2 is to convert NumL to both sides of frond, 0.52 is the ratio of LLxLW to the average actual leaflet area. The predicted total leaflet area for F17 resulted in a R^2 of 0.61 when compared to the measured total leaflet area (Fig. 8).

2. Based on Leaflet Length, Leaflet Width, Petiole Cross Section, and Rachis Length. Using other parameters of growth, multiple linear regression gave the following relationship:

$$TLA = LL \times LW \times 226 + PCS \times 1337 - RL \times 169 + 28112 \quad (10)$$

This resulted in a R^2 of 0.78 when plotted against measured TLA (Fig. 8).

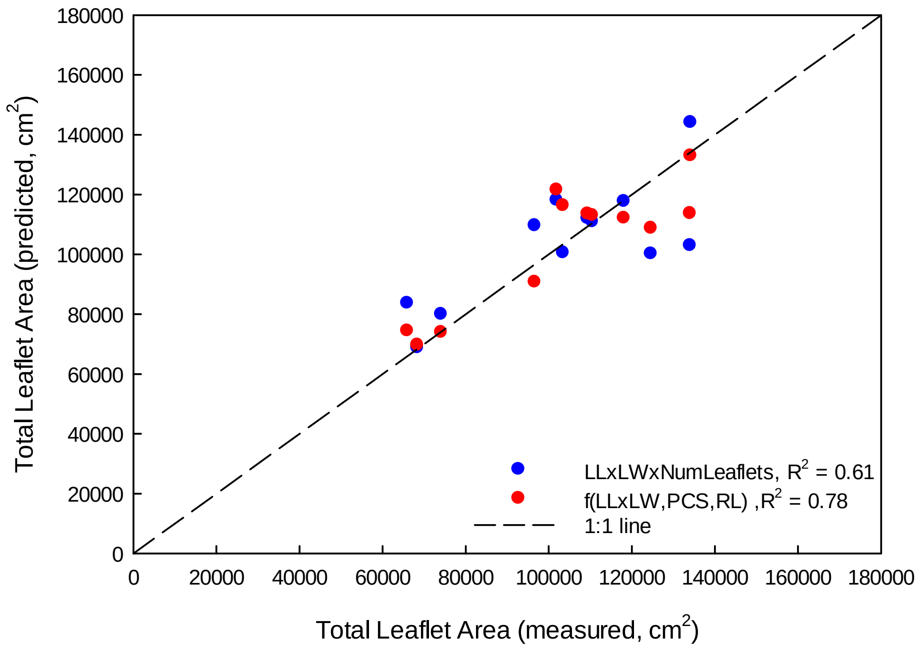


Figure 8. Relationship between predicted leaflet area and measured leaflet area

Procedure for determining total leaflet area
Data:
Palm age: 12 yrs
Number fronds: 38
Petiole thickness: 4.8 cm
Petiole width: 9.1 cm
Rachis Length: 651 cm
F17 Leaflet Length (at 0.6 sampling point): 95.7 cm
F17 Leaflet Width (at 0.6 sampling point): 5.6 cm
F17 Number of leaflets (on one side): 197

Step 1: Calculate total leaflet area of F17 from Equation (9) or (10).
For example, from equation (10);

= (LL x LW x 226) + PCS x 1337) – (RL x 169) + 28112
= (95.7 x 5.6 x 226) + (4.8 x 9.1 x 1337) - (651 x 169) + 28112
= 97611 cm^2

Step 2: Calculate slope of total leaflet area vs frond number from equation (8)

= -629 + 585 x (1-EXP(-0.184 x Age)
= -629 + 585 x (1-EXP(-0.184 x 12)
= -108

Step 3: Calculate y-intercept of total leaflet area vs frond number

= TLA F17 – (slope x 17)
= 97611 – (-108 x 17)
=99452

Step 4: Calculate total leaflet area for whole palm (integrate the linear equation from step 3)

= (-108 x $NumberFronds^2$) + (99452 x NumberFronds)
= (-108 x 38^2) + 99452 x 38
= 3700990 cm^2
= 370 m^2.

Estimating Root mass

Root mass has been estimated for a 'half hexagon' by intensively sampling to 2 m. The data for 20 year old palms has been analysed (Fig. 9).

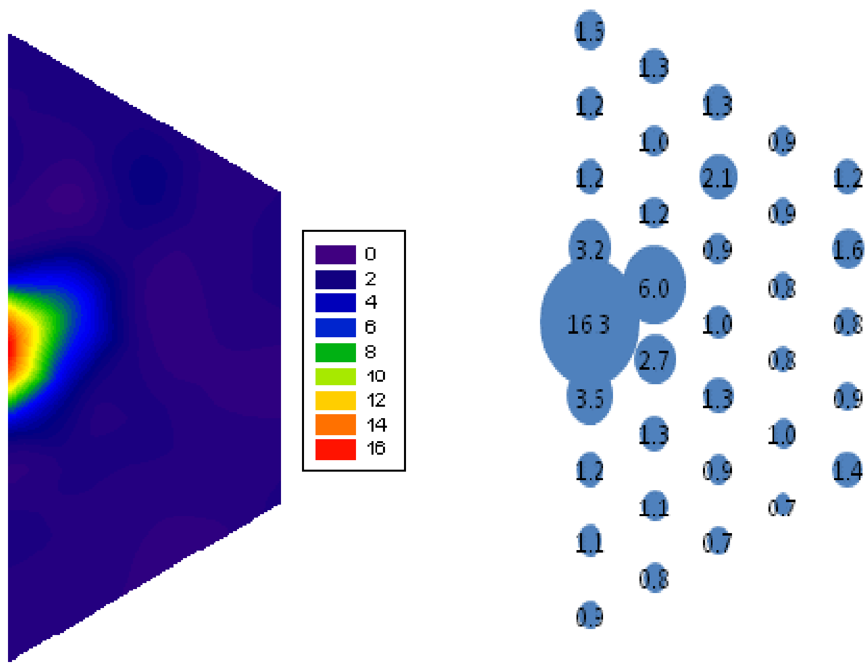


Figure 9. Root distribution (kg DM/m2 to 2m depth) under 20 year old palms at Bebere plantation, shown in two different ways. Average 1.8 kg DM/m2; 137 kg DM/palm; 18 t DM/ha

CROSS-OBJECTIVE ACTIVITIES: 'SCAN' EXPERIMENT

This experiment ('Silicon, carbon and nutrients' or 'SCAN') is designed to provide samples and information on the effects of conversion of grassland or forest to oil palm for Objective 1 (soil pH and microbiology), Objective 2 (soil nutrient stocks), Objective 3 (soil C stocks) and Sue Berthelsen's PhD project examining effects of vegetation on Si cycling.

Sites and sampling

In Hoskins, two ex-forest smallholder oil palm blocks (with 14-15 and 20-22 year old palms) and two corresponding forest sites were sampled. In Popondetta, 15 ex-grassland smallholder oil palm blocks were sampled, with palms planted between 1985 and 2009, each with corresponding grassland and forest. The forest sites are usually in or near drainage lines, so are not strictly comparable to the grassland and oil palm sites. There was one extra site with oil palm only (Embi). The oil palm sites were all chosen to have been ex-grassland, but $\delta^{13}C$ of soil organic matter suggested that at some sites the grassland had not been in place for a long time. A search for old aerial photos of the sites was conducted in the National Archives, the National Library and the War Memorial. A set of photos flown in 1952, soon after the devastating eruption of Mt. Lamington, was found at the National Library. It provided an excellent picture of grassland versus forest cover at that time. Sites 12-16 may indeed have been forest rather than grassland at the time; we are currently comparing the 2010 and 1952 vegetation cover in detail.

In 2010, soil samples from 0-1.5 m depth were taken for carbon and nutrient analysis (in Australia) and bulk density (in PNG). Samples of litter (in forests), grass (in grasslands) and fronds (F17 and oldest frond in oil palm were also taken for analysis and the cumulative number of fronds produced was measured. In Oro, samples were taken from grassland, forest, oil palm weeded circle, oil palm frond pile and oil palm between zones (4 replicates in each). Sampling was the same in the West New

Britain sites, except that there was no grassland. The dimensions of the various zones in oil palm were measured so that stocks of C and nutrients could be calculated on a 'per ha' basis. All samples sent to Australia were sterilised and released from quarantine before being dispatched to the laboratories.

Carbon content and composition

The mean soil carbon stocks (0-1.5 m depth, ± SD) across the Oro sites were 10.2 ± 3.4 kg m^{-2} in grassland, 10.6 ± 3.2 kg m^{-2} in oil palm and 9.0 ± 3.8 kg m^{-2} in forest. In most sites the soil C stock has increased slightly after conversion from grassland to oil palm, but there was no consistent trend with time under oil palm. The isotopic composition of the soil carbon has been measured at all sites. The grassland and forest sites generally have the highest and lowest values, due to their respective C4 and C3 photosynthetic pathways. The oil palm sites show a progressive shift in time away from the grassland values and towards the forest value, as oil palm has C3 photosynthesis (Figure 10). The lowering of $\delta^{13}C$ values near the surface is presumably due to Rayleigh distillation, and the lowering at depth, in the grassland soil, is presumably due to forest inputs a long time in the past. $\delta^{13}C$ values under the oil palm frond pile have shifted more than the other zones due to the higher C inputs there.
The isotopic composition of the soil C was used to calculate the proportions of soil C that were derived from grass and oil palm. Most of the soil C was grass-derived, even after 20 years of oil palm cultivation, even in the top 0-5 cm (Figure 11).

As grasslands burn frequently, a high proportion of the total C in grassland soils may be charcoal and this C might be expected to be stable against decomposition. The amount of 'black C', pure aromatic material derived from burning, was measured by hydrogen pyrolysis (Ascough et al. 2009) in the Site 1 grassland and oil palm (planted 1985). In the grassland soil, the proportion of total C that was 'black C' ranged from 6.5 % at 0-5 cm depth to 15.7% at 50-100 cm depth. Those proportions remained essentially unchanged in the oil palm soil. This black C was not sufficient to account for all the grass-derived C remaining in the soil. $\delta^{13}C$ of the black C remaining under oil palm showed that, in the top 20 cm, it was virtually all grass-derived (Figure 10). Interestingly, the black C at 50-100 cm depth appeared to be a mixture of grass- and forest-derived material, reinforcing the earlier deduction that, at depth, the grassland soil C was partially derived from forest at some time in the past.
Measurements of soil respiration at SCAN sites 1 and 9 showed clear spatial patterns, with emissions being highest under the weeded circle (where root density is high) and under the frond pile.

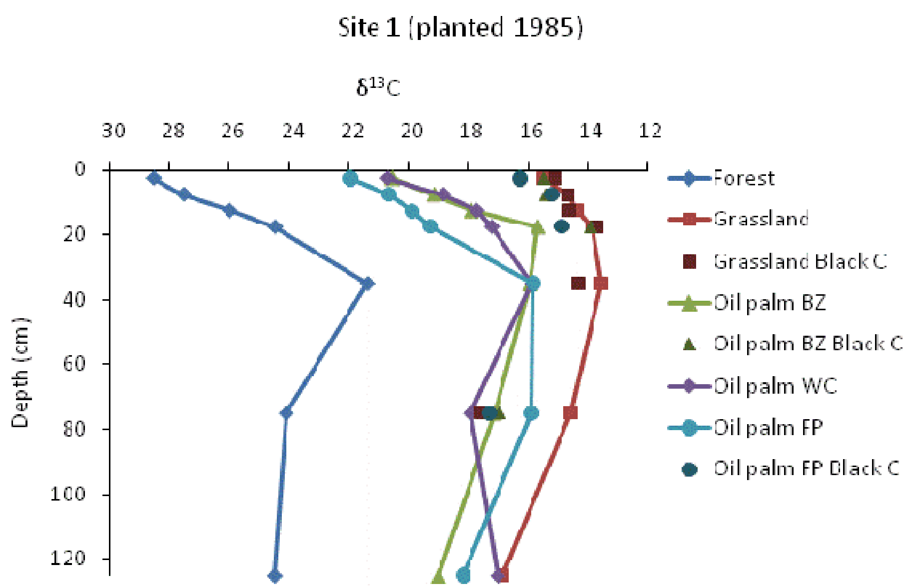


Figure 10. Isotopic composition of whole soil C and black C (charcoal) isolated from soil, at Site 1 in Oro Province. BZ= 'Between zones', WC = weeded circle and FP = Frond pile.

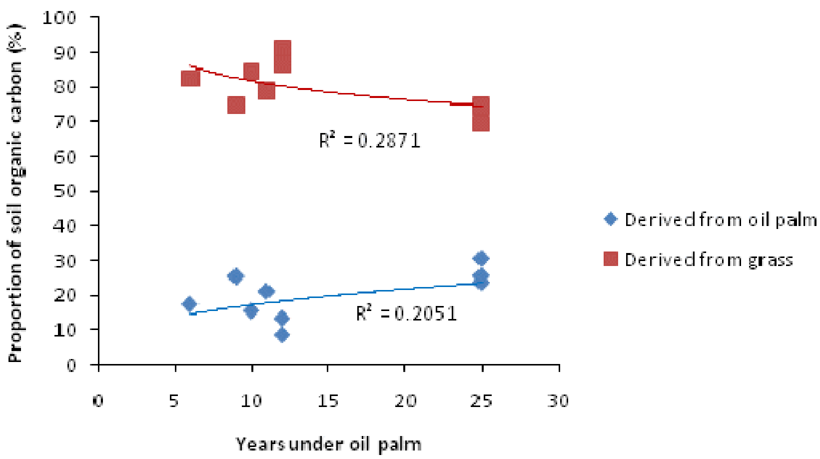


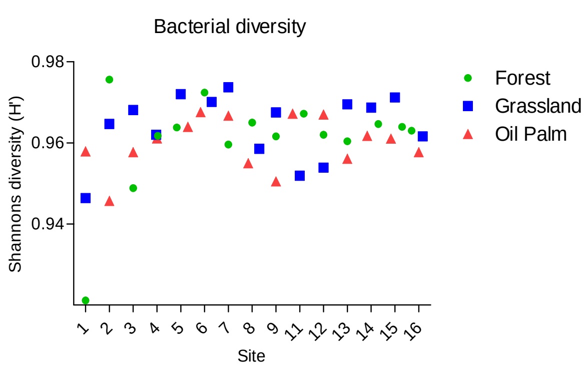
Figure 11. Origin of soil organic carbon in the 0-5 cm depth layer in relation to time since the grassland was planted to oil palm. Values are based on $\delta^{13}C$ values of -29 for oil palm and -12 for grass.

Nutrient content

Exchangeable cations, extractable P, pH and electrical conductivity are currently being measured in samples from 0-5 and 10-15 cm depth for all sites and all depths for Site 1 in Oro.

Microbiology

Soil samples from the 0-5 cm depth layer of the grassland, forest and oil palm (between zones) sites were analysed for microbiological parameters by Steven Wakelin, AgResearch, New Zealand. The parameters measured are bacterial richness and diversity, fungal richness and diversity, total DNA, and the abundance of the functional genes nirS (nitrite reduction), nosZ (nitrous oxide reduction), bacterial amoA (nitrification) and archaeal amoA (nitrification). For all parameters there were site and vegetation effects and interactions between them (eg. bacterial and fungal diversity, Fig. 12). The samples are now being analysed for chemical properties to determine the underlying causes of the differences.



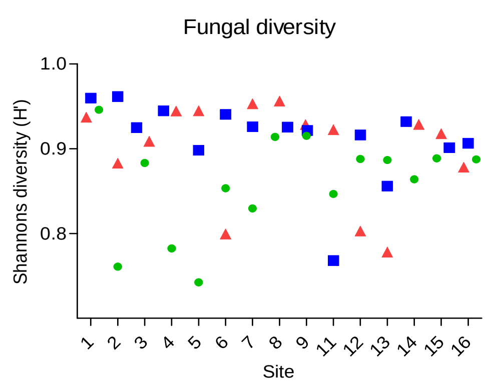


Figure 12. Bacterial and fungal diversity indices for soils (0-5 cm depth) under grassland, oil palm (between zones) and forest in Oro Province.

CROSS-OBJECTIVE ACTIVITIES: 'REPLANT' EXPERIMENT

While some research has been carried out into the changes in carbon stocks and soil fertility during initial establishment of oil palm, no studies have been carried out into the changes during the replant phase. The planting and replant phases are particularly vulnerable to losses due to low biomass, transpiration and ground cover and disturbance of the soil during removal of the old vegetation and establishment of the new. In this experiment we are accounting for the stocks of carbon and nutrients in palms, groundcover, litter and soil during the mature-felling-replant phase. The trial is being carried out in Milne Bay as that was the only place replanting was occurring at the time. The common composition of a mature stand, with many missing palms, is being accounted for in the sampling. Sampling of above-ground biomass and litter (apart from the standing palms) has been completed.

CROSS-OBJECTIVE ACTIVITIES: 'FOPEC' EXPERIMENT

The primary aim of the 'FOPEC' (forest to oil palm erosion and carbon) experiment is to obtain quantitative data on erosion under oil palm, but it will also allow us to measure losses of carbon. The time scale is most of the first cycle of a plantation, including the forest clearing and establishment phase. Quantifying erosion losses over this sort of stage and time scale is not possible using erosion plots, so we are using a Pu inventory approach, using Pu fallout of nuclear bomb testing (Everett et al. 2008; Tims et al. 2010). The sampling approach is to identify pairs of sites, with each site having the same landscape position, slope and soil type but one still forest and the other planted to oil palm. Such sites were available in Navarai and Karato plantations in West New Britain. There will be 4 groups of sites, each having 2 forest and 2 oil palm sites. The slopes are approximately 7%. Each oil palm site will be one palm hexagon, with 60 sampling points, but not all are sampled to all depth increments. Each forest site will be a square grid 7.5 x 7.5 m, with 36 sampling points, but again, not all are sampled to all depth increments. Sampling is in 6 depth increments to 100 cm depth. The top 4 increments (0-40 cm depth) will be analysed for Pu and all 6 will be analysed for C. Bulk density will be measured at all depth to enable calculation of stocks. Sampling, which commenced in November 2011, has been completed on the first pair of sites and is underway for the remainder. Samples will be analysed for bulk density at OPRA, Pu by Keith Fifield and ANU, and C at JCU.

OBJECTIVE 1. TO DETERMINE INDICATORS OF SOIL HEALTH

Our conceptual model of soil health is that it can be decreased by erosion, loss of organic matter, acidification, compaction and accumulation of toxins. The factors influencing these processes are soil type, climate, slope, nutrient inputs, net primary production, FFB removal, machinery use and pesticide applications (which can be obtained from records) and the amount and type of soil cover (which could be scored in the field). The main issues of potential concern are soil erosion, soil organic matter and soil acidification.

For indicators of soil erosion we intend to use scores of the area, orientation and connectivity of bare areas, together with information on soil type, slope and climate obtained from records. Some short term small scale (plot) data exists (Banabas 2006), and it could be used to calibrate the indicators. However, long-term data is lacking, hence the 'FOPEC' experiment, described earlier.

For indicators of soil organic matter we intend using a carbon balance approach rather than measuring actual soil organic matter contents. Soil organic matter content is difficult to quantify due to its extreme variability. Although occasional measurements will be made, which are useful, the main indicator will be based on the concept that 'the higher the inputs the higher the soil organic matter content'. Inputs will be determined by modelling, based on site-specific inputs such as palm age and biomass. To provide data for the modelling, we are measuring changes C inputs to the soil under oil palm (SCAN experiment) and changes in soil organic matter content during the forest-to-oil palm transition (FOPEC experiment) and felling-replant-immature phase (Replant experiment).

For the soil acidification component of the project, two main activities are being undertaken. The first is an assessment of the causes and rates of soil acidification expected under oil palm. The second is sampling of an N fertiliser field trial to assess the effects of fertilisers on acidification.

Soil acidification causes and rates

Although oil palm is quite tolerant of acidic conditions, addressing soil acidification is an important issue as it may limit productivity of future crops and may lead to detrimental off-site effects. In

addition, some of the changes induced by acidification are irreversible even if liming agents are applied to reverse the pH change.
There are a number of causes of soil acidification associated with agricultural production but the dominant ones are the use of ammonium-based fertilisers, product export, and a lack of using liming materials.

Use of ammonium- based fertilisers

Ammonium-based fertilisers undergo transformation of ammonium to nitrate by soil microorganisms. This process results in the production of acid. Depending on the fertiliser type, some or all of the acid produced can be neutralised through uptake of the resultant nitrate (Table 3). Some fertilisers such as potassium nitrate are alkalising depending on how much nitrate is taken up. It is important to note that some fertilisers will be acidifying even if all the nitrate is taken up; thus simply adding these fertilisers to the soil will cause acidification.

Table 3. Generation of acid by fertiliser addition under conditions where all nitrate produced is taken up or where none is taken up. The "Official value" is the value that has been adopted by the Association of Official Analytical Chemists, and is coincidently equal to the value expected if half of the nitrate was taken up.

Fertiliser	Application rate* (kg/palm)	Acid prod. If all N taken up by palms (kmol H^+/ha)	Acid prod. If all N lost by leaching (kmol H^+/ha)	Official Acidification value (Adams, 1984) (kmol H^+/ha)
Am. sulfate	3.5	7.1	14.3	10.7
Am. chloride	3.0	7.1	14.3	10.7
Am. nitrate	2.1	0	7.1	3.6
Urea	1.6	0	7.1	3.6
Diam. Phos.	4.1	3.6	10.7	7.2
Pot. nitrate	5.7	-7.1	0	

* at 135 palms/ha and 100 kg N/ha; 1 kmol H^+ equiv 50 kg lime

Thus, as an example, application of 3.0 kg ammonium chloride (AC) per palm would require 500 kg lime per ha to neutralise its acidifying effect. Similarly, application the same amount of N in the form of urea (1.6 kg urea per palm) would require only 170 kg lime per ha to neutralise its acidifying effect.

Export of product

Exporting biological material is a net export of alkalinity. Thus exporting FFB 'leaves behind' acidity (Table 4).

Table 4: Typical nutrient concentrations in FFB

Nutrient	Concentration (g/t FFB dry weight)	Charge associated with nutrient (mol charge/mol nutrient)
N	6270	0
P	949	-1
K	7358	+1
Ca	3377	+2
Mg	1402	+2
S	1200	-2
Cl	1940	-1
Na	234	+1
Excess cations (mol/t FFB dry weight)	+324	

At a yield of 30 t FFB/ha/a (= 16 t FFB dry weight) this would require 260 kg lime per ha to neutralise its acidifying effect of exporting FFB. Thus, depending on the fertiliser used, the amount of lime required to neutralise FFB production will typically range between 430 and 760 kg /ha/a for a 30 t yield FFB/ha/a. The sum of effects of fertiliser use and product export and any mitigating effects (eg liming materials) plus other sources of acid or alkali is referred to as the Net Acid Addition Rate (NAAR) for that production system. Typically it is expressed 'per ha per year' and often in units of lime required to mitigate the acid produced.

Effect of acidification on soil pH

If the acid generated by FFB production (NAAR) is not or only partially mitigated with liming products, the affect on soil pH will be determined by the magnitude of NAAR and the ability of the soil to resist a pH change (pH buffer capacity; pHBC). Thus soil pH, as a result of FFB production, is a function of initial pH, pHBC, and NAAR. Most land systems naturally produce acid to some extent. However, agricultural systems, because of product export and (high likelihood of) N fertiliser use produce greater amounts of acid (NAAR). Further, other possible consequences, such as decrease in soil organic matter may decrease pHBC. These acting in concert can result in rapid decline in soil pH.

Indicator of acidification

As crop performance is a function of soil pH, setting a critical pH, below which it is unacceptable, would be good point of reference. An indicator of sustainability of a system might be to then determine how long it will take to reach this level. Thus we propose a "time to critical pH" as an indicator of sustainability because:

- It integrates current pH, acidification rate (NAAR), and vulnerability to pH change (pHBC)
- It has meaning in relation to current and future land uses
- It incorporates remedial action (eg use of liming products and input of organic matter such as EFB)

Choosing a critical pH could be based on current and perceived future uses; or it could be based on physical attributes. For example, below pH 5.5 acid-sensitive species will suffer production losses, below pH 4.8 acid tolerant species will suffer production losses, and below pH 4.3, irreversible reduction in cation exchange capacity may occur through the dissolution of clay particles.

Data requirements for time to critical pH

- Current pH (routine measurements)
- Critical pH (expert/industry decision)
- Net Acid Addition Rate
    - Fertiliser amount and type (company records)
    - FFB yield and nutrient content (company records, OPRA experiments)
    - Organic addition, such as EFB, decanter cake (company records)
    - Liming materials such as POME, bunch ash (company records)
- pH Buffer Capacity (OPRA experiments)

Methods for calculating time to critical pH can be found in Helyar and Porter (1989).

Soil acidification due to various nitrogen fertilisers

The aim of this experiment is to determine the extent and rate of soil acidification under different N fertiliser types and rates. The application of ammonium-based fertiliser is one of the main causes of acidification. The trial being sampled is Trial 324 (N source trial) in Oro Province. The palms were planted in 1996 and treatments ran from 2001 to 2011 (11 years). The treatments are ammonium sulphate, ammonium chloride, ammonium nitrate, urea and diammonium phosphate, each applied at rates of 0, 420, 840 and 1680 g N $palm^{-1}$ $year^{-1}$. All soil samples have been taken and the next step is to analyse them.

OBJECTIVE 2. TO DEVELOP INDICATORS OF NUTRIENT BALANCES

The location of storage and the pathway of movement of nutrients in the landscape may have many effects on the environmental and economic sustainability of an oil palm production system.

Environmental effects

If nutrients are added in greater quantities than required, they may be vulnerable to loss to other parts of the environment (eg rivers and estuaries) where they may have detrimental effects. Conversely, if they are depleted, they may result in loss of soil fertility and thus productivity of the immediate oil palm site and surrounding garden areas. Soil acidification is a particularly insidious form of degradation. It can result from use of ammonium-based fertilisers and product removal if not mitigated with liming materials. Its effects may include loss of nutrient and water holding capacity, loss of productivity and limitations on future land use options (see section on Acidification).

Costs

An understanding of nutrient storage and movement can reduce the use of fertiliser and thus reduce costs as well and reducing potential acidification. Getting the balance of nutrients right will also reduce the likelihood of lost productivity.

Conceptual model of nutrient stocks and pathways

At a block scale, nutrients are stored in the palms, ground covers, and soil (soil particles, water, organisms, and organic matter). These stocks are quite stable in mature plantations but become vulnerable during felling and replant.

Nutrients are brought in through fertiliser application, N_2 fixation, rainfall, alluvial deposition, by-products (eg empty fruit bunches, palm kernel expeller, palm oil mill effluent, bunch ash) and possibly in dry deposition, sea spray, and volcanic materials. Depending on the time-scale, weathering might be considered an input to the available nutrients. Nutrients are exported from the block in FFB, deep drainage, and soluble and particulate run off. Volatilisation is an issue for certain nitrogen fertilisers.

Measurements

Currently nutrients are being measured in palm trunks, fronds, bunches and roots, as well as ground cover and soil. Nutrient sources will be obtained from records of fertiliser and by-product application. These will be used by developing allometric relationships to estimate nutrients in vegetation from simple measures. Nitrogen fixation is being measured separately (see next section) and will be related to palm age (shading). A large trial has been established to measure nutrient dynamics from before felling through to several years after replant.

Assessing Nitrogen fixation

Previous work has shown that about 150 kg N ha^{-1} a^{-1} can be derived from nitrogen fixation by legumes under oil palm (Agamuthu and Broughton, 1985; Broughton, 1976). However, these were all determined under young palm plantations (< 5 years old) with presumably little shade. Thus there is a need to assess the contribution of legumes to the nitrogen balance in older plantations as well.

To assess the contribution of atmospheric N fixed by legumes to the N balance in an oil palm plantation two components are needed:

1. the percentage of N in a legume that is derived from the atmosphere, and
2. the total N in the legume biomass

The first component can typically be determined by ^{15}N isotope dilution; however this can be difficult to use to assess nitrogen fixation in the field. Another technique is to measure ureide in plant stems, but this must be calibrated against an absolute measurement such as ^{15}N isotope dilution.

In a pot experiment, *Mucuna pruriens* was grown in a range of N fertiliser concentrations to manipulate the % of N derived from nitrogen fixation. Either sap or stems were analysed for relative ureide-N (RU-N) (Fig. 13).

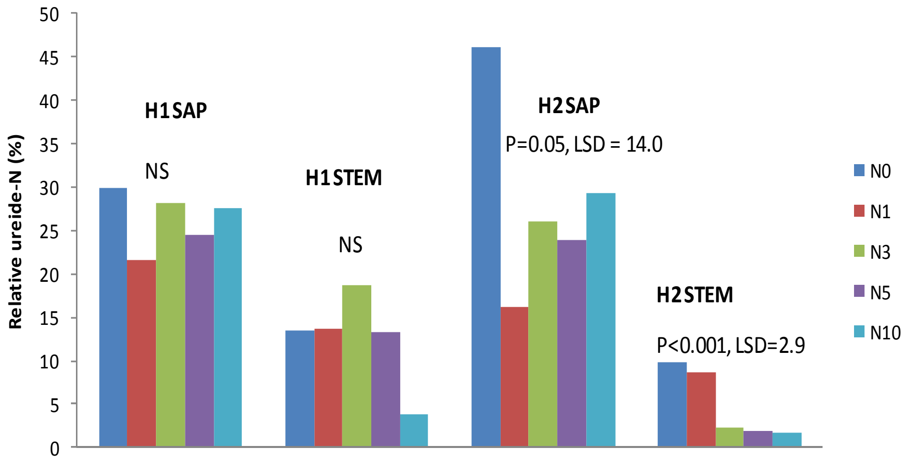


Figure 13. Relative ureide-N in *Mucuna pruriens* sap and stem at two times when grown in a range N-fertiliser concentrations (0 to 10 mM)

There was no significant difference at the first harvest but the N treatments significantly affected the RU-N at the second harvest. The relationship of sap RU-N to nitrogen treatment is difficult to explain, but the relationship of stem RU-N shows a clear and expected response, thus providing the basis for a RU-N field test. Samples are currently being analysed for ^{15}N in order to quantify the amount of atmospheric nitrogen that was fixed. To determine the second component, samples were collected in the field for biomass, nitrogen, and RU-N analysis. These samples are currently being processed for nitrogen and ureide analysis. When this and the ^{15}N analysis of component 1 are completed, the amount of N fixed per ha by ground cover legumes can be calculated for the various aged palm plantations.

OBJECTIVE 3. TO DEVELOP INDICATORS OF CARBON SEQUESTRATION

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

OBJECTIVE 4. TO DEVELOP INDICATORS OF AQUATIC ECOSYSTEM HEALTH

The aim for work to this point was to (a) develop an improved understanding of the functional ecology of aquatic ecosystems of palm oil landscapes, (b) produce a base-line evaluation of the affects oil palm operations may have on these ecosystems, and (c) make a preliminary evaluation of the current status of aquatic ecosystem health at a model study area in West New Britain (WNB). To date we have identified issues, categorised ecosystem types, identified aquatic ecosystem function and structure, evaluated present ecosystem status and developed indicators and monitoring protocols for understanding the functional ecology of aquatic ecosystems. We have evaluated over 150 sites in WNB between Walindi and Bialla, assessed water quality at 60 sites in 22 stream systems and sampled aquatic fauna from 41 sites across 22 stream systems.

Current status of aquatic ecosystems

Nitrate , phosphate and biochemical oxygen demand (BOD)

There was no evidence of systematic elevation of nitrate, phosphate or BOD in larger systems, e.g. Dagi River. However, water-borne nitrate and phosphate may be difficult to detect in well flushed systems. Some of the smaller, lower volume, slower flowing streams had elevated concentrations of nitrate and phosphate. Possible sources of nitrate and phosphate are fertiliser inputs, soaps and detergents or effluent from mill settling ponds. Because there was some evidence of eutrophication we have fish and aquatic vegetation samples undergoing stable isotope analysis and field experiments planned for June to help interpret stable isotope results.

Water quality

Analysis of water quality data identified two major problem areas; mill drainage systems (streams receiving effluent from settling ponds, Fig. 14) and turbidity levels.

Mill outfall streams

DO reached critically low levels close to effluent outfall points however impacts appear very localised suggesting this is not a major concern although improvements could be achieved. Of much greater concern is the turbidity issue (see below), to which mill effluent contributes, and the discharge of fibrous material. Both reduce light penetration, in turn affecting water column and stream bed productivity with subsequent impacts on stream biota. Fibrous and dissolved materials were detected over 1 km downstream from outfalls even after dilution by tributary streams. Evidence of discharge disperses quickly once discharge ceases because effluent materials are flushed away but the downstream fate of effluent is unknown and so problematic; it must end up somewhere else, probably in coastal ecosystems. In addition, settling pond overflows which potentially impact adjacent "clean" streams and the presence of lumps of waxy material that originated from ponds occurring well downstream from outfalls are also of concern. There is a need for investigation of the implications of the discharges relative to discharge chemistry.

Turbidity

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

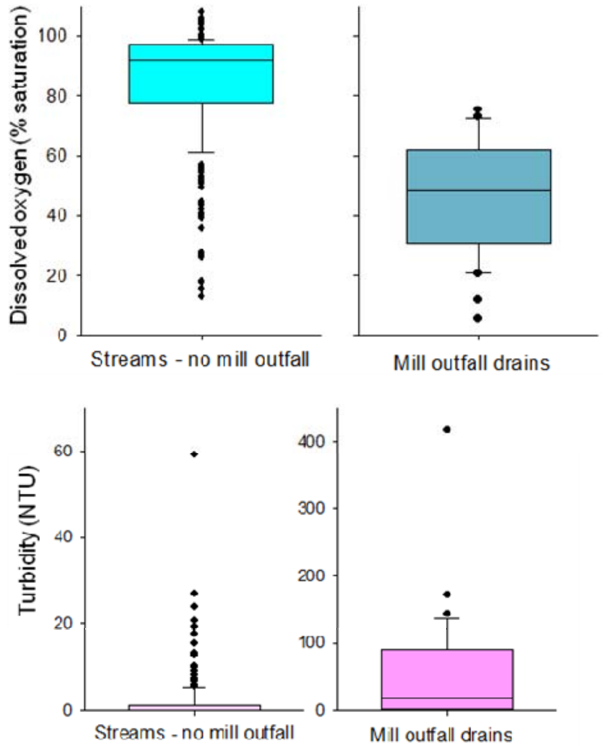


Figure 14. Comparison of physical quality of stream water as affected by mill outfall.

Aquatic faunas

We recorded 65 species of fish, 47 of which were first records for WNB estuaries or freshwaters. This demonstrates how little is known about WNB fish faunas and the situation is no better for other aquatic animals. Fish and crustacean abundances were very low and dominated by small and juvenile individuals. Distributions of many species of fish were confined to particular reaches of streams, some to particular habitats within reaches suggesting sustainability of local populations is likely dependent on continued connectivity. In addition, WNB streams are important nursery areas for many coastal species. Fish population structures in WNB streams are indicative of overfished systems and suggest there is a real problem for potential replenishment and sustainability of stocks in streams and coastal waters (Fig. 15).

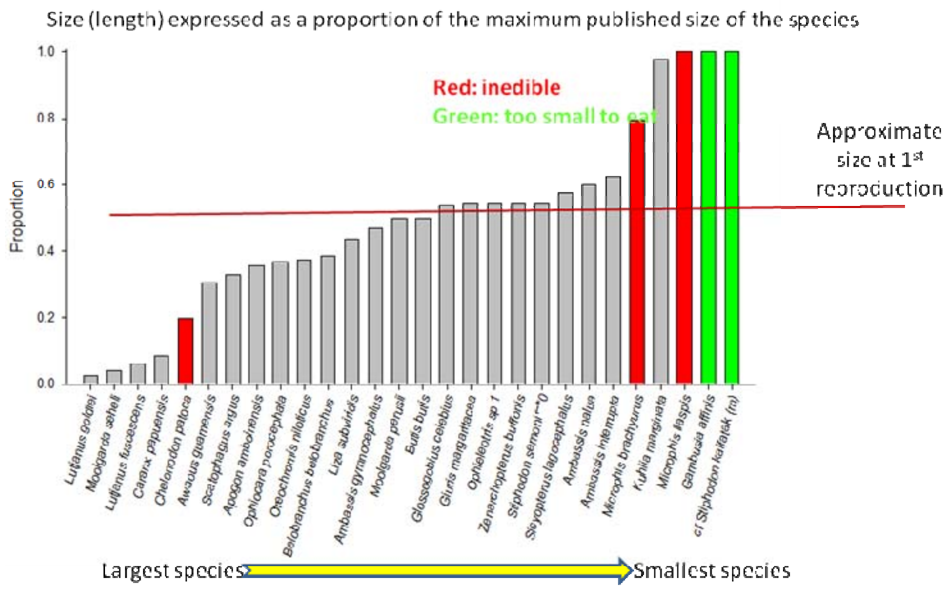


Figure 15. Maximum size of individual fish caught for a range of species, relative to the maximum size recorded for that species.

Conclusions

Key issues going into the future are:

1) Maintenance and regeneration of existing and lost riparian vegetation. This is crucial because:
   - Many rainforest aquatic organisms are temperature sensitive and natural riparian is more effective at moderating water temperatures than oil palm.
   - During natural processes of forest turn-over natural riparian contributes fallen timber to streams that provides complex habitat that many stream animals rely on for protection.
   - Delivery of large woody debris to streams also fosters improved stream hydrodynamics that enhances biodiversity of in-stream habitat.
2) Maintenance of current levels of connectivity among and within stream systems. This is important because:
   - Connectivity facilitates re-population and utilisation of streams by aquatic faunas.
   - Disruptions to connectivity may reduce or remove in some cases, opportunities to rebuild fish stocks and this is likely a crucial link in food security going into the future.
   - Disruptions may prevent life history migrations of some species and lead to localised loss of species.
3) Improvements in settling pond management. This is important because:
   - Low DO water releases are potentially harmful to system productivity and aquatic faunas and floras.
   - High turbidity releases reduce system productivity and are potentially harmful to aquatic faunas and floras.
   - The ultimate fates and potential for environmental impact of discharge materials is unknown but potentially damaging for aquatic ecosystems.
4) Identification and mitigation of sources of turbidity. This is important because:
   - Elevated turbidities reduce system productivity and are potentially harmful to aquatic faunas and floras.
   - Sedimentation reduces in-stream habitat diversity, reduces stream flow and increases flooding magnitude.
   - Sediments are ultimately distributed across coastal habitats where they have adverse effects, particularly on coastal reef ecosystems.

OBJECTIVE 5. TO DEVELOP A CROP SYSTEM MODEL

In order to model palm growth and productivity, a conceptual framework was developed to describe fluxes of light, water, carbon, and nitrogen (Fig. 16). Each of these fluxes will be represented in the model based on data from the literature or actual measurements.

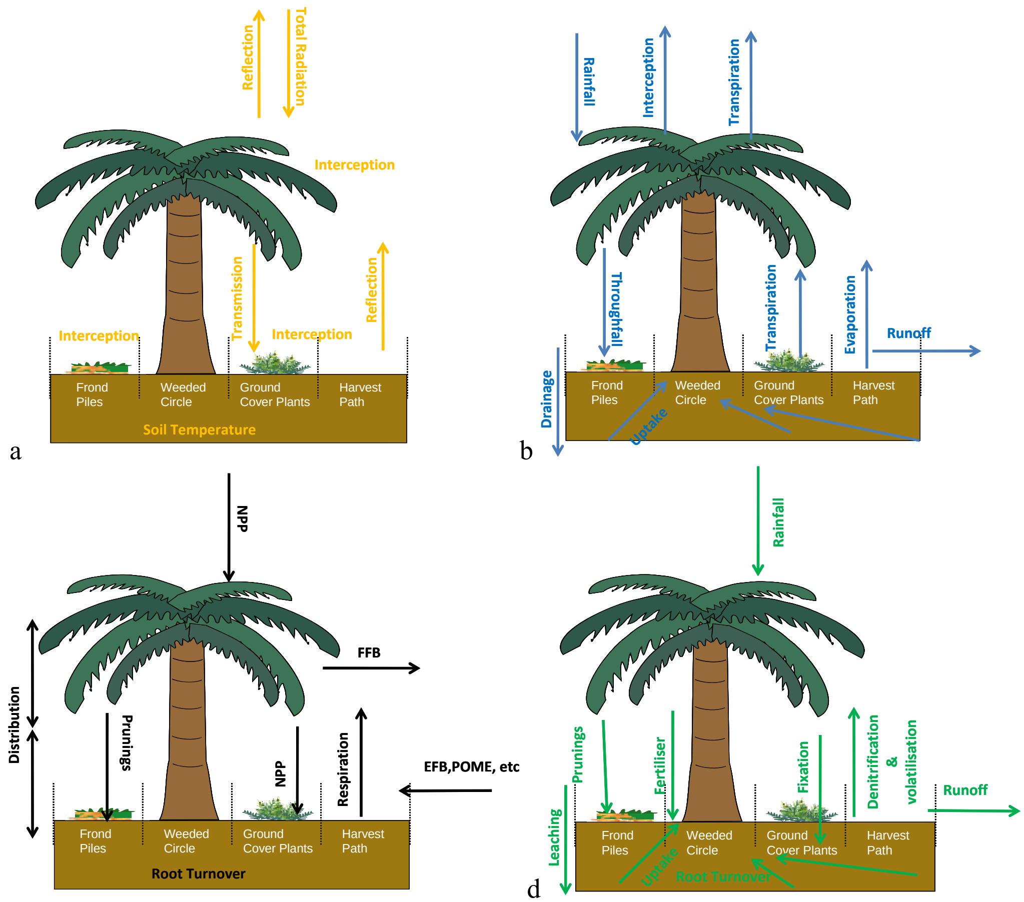


Figure 16. Conceptual framework for (a) fluxes of light and energy, (b) water, (c) carbon, and (d) nitrogen**.**

The software product, Agricultural Production Systems Simulator (APSIM) is being parameterised to model growth and FFB production of oil palm based on climate data (sunshine, rainfall, temperature) and nutrient supply. The first components to be parameterised are the canopy and roots.

Canopy

Rate of frond appearance in oil palm depends, as in other crops, on thermal time (number of days above a particular temperature). Information to parameterise this process will be determined from climate data and frond production rate available from OPRA trials. In the meantime, frond production rate has been set to a fixed value of one frond emerging each 14 days. This first estimate appears to be quite good for well fertilised (N3) palms from trial 324 (Fig. 17). This trial also shows how the frond production rate decreases as the N nutrition status decreases; most likely through a carbon constraint. Thus this data set will be highly useful in parametising the effect of N deficiency on frond production rate.

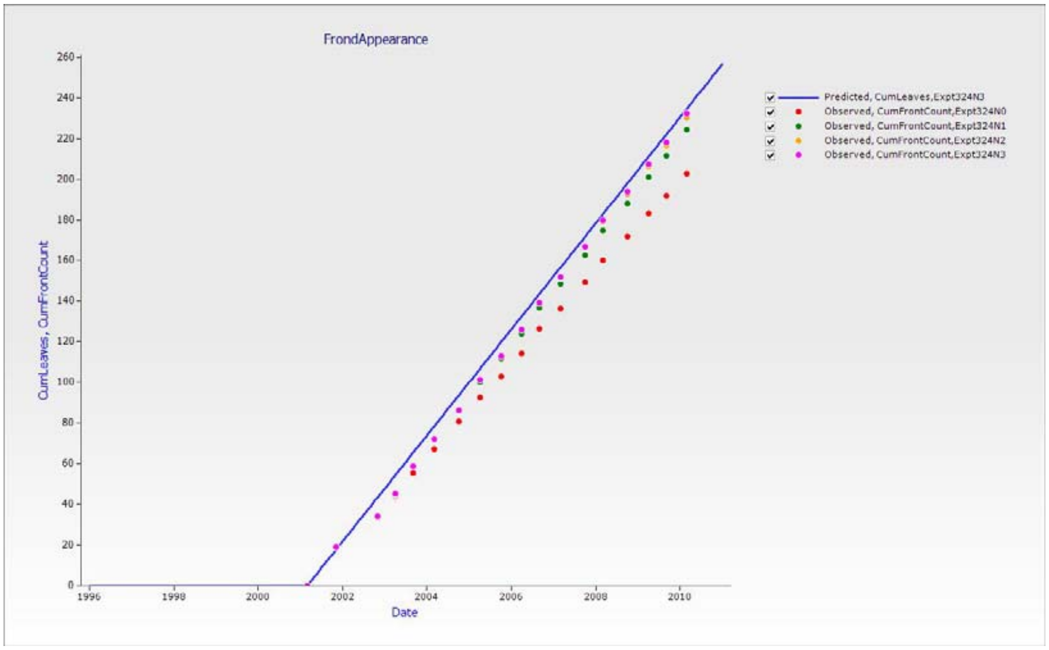


Figure 17. Cumulative frond production. The points are from observed data from trial 324; the line is modelled data.

Currently, frond production rate is determined by marking F1 and following its progression through time. However F1 is always the youngest fully expanded frond irrespective of the number of spear fronds present. Thus if there is more than 1 spear frond, the frond production rate for the previous period will be underestimated. Further enhancements will be available through number of spears present. In concert with weather data (recent rainfall), the number of spears will also provide predictive power to model frond expansion and thus leaf area. Leaf area is currently being modelled from measurements of leaflet length and leaflet width using the approach of Corley et al (1971). However, the allometric relationships recently developed (see allometrics section) will be incorporated into APSIM. Trunk density and biomass is being modelled according to Corley et al (1971) but will be replaced with relationships developed in this project.

Carbon Allocation (including roots)

DM is produced according to light use efficiency. This has been set at 1.3 g DM/MJ total short wave radiation intercepted based on data from other tree crops (Huth). This value can be revised from OPRA trial data. The energy intercepted is based on incident energy from weather records, LAI, and light extinction coefficient (Breure, 1988).

The distribution of DM is based on a number of sources:

Stem: 0.055 (van Kraalingen et al, 1989; plus assumption that 0.50 goes to bunches)
Roots: 0.20 (set higher that van Kraalingen's 0.06 to account for turnover)
Bunch: 0.50 (van Kraalingen et al, 1989)
Leaves: 0.245 (balance)

Even at this stage of development of the model, there are issues arising that will need to be addressed:

1. the above allocation of C results in a steady state root DM of 6t/ha if turnover is 0.5% DM/day, whereas measured root DM is 18t/ha in 20 yo palms at Bebere.
2. DM vs C when converting light energy in DM. APSIM uses a DM distribution because most DM in most plants is CHO, whereas in oil palm bunches much of it is as oil which has a much greater C:DM ratio than CHO - see van Kraalingen et al, (1989) and Corley et al (1971) for calculations

OBJECTIVE 6. IMPLEMENTATION

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

a) There have been OPIC field days organised across the industry and the issue of how sustainable the oil palm system is a common question. Reply has been that there is a project looking into this question of soil and water sustainability in the oil palm systems in PNG.
b) The work progress has been reported to the industry through the local planning committee which is a committee that discusses running of OPIC on project sites. The meetings are generally held on a monthly basis.
c) At one of the project sites at Popondetta, exercise books were given to the 5 selected growers to keep records of fertilisers and crop produced as a step towards trialling the indicators once outputs from the other objectives are completed.
d) The data management system is in dire need of improvement in the extension services for management, and extension purposes. OPIC have recruited IT officers under the SADP program at Hoskins and Popondetta. A small information management committee comprising PNGOPRA, Higaturu Oil Palms Smallholders Technical Services Manager and OPIC IT, field and project managers was formed at Popondetta to ensure the work is up to speed and carried out to meet the requirements.
e) There are 2 other joint projects between PNGOPRA and OPIC that have activities that relate to sustainability and are current on the ground. These are: the food security and fish pond projects. They relate to sustainable use of space between palms and water resources in oil palm blocks.

Capacity

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

- Rachael Pipai from PNGOPRA is doing her Masters on N fixing at Adelaide University.
- Murom Banabas obtained a John Dillion Fellowship for leadership training in Australia and Impact Assessment Training in Phillipines.
- Staff from OPIC and Plantation Company technical services were involved in the field sampling activities at all sampling sites.
- Vudal University of Natural Resources (Rabaul and Popondetta campuses) students on industrial training were involved in soil and plant sampling and measurements as part of their industrial training.
- PNGOPRA staff have learnt techniques for specialised sampling of soil, water and gases.

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2. ENTOMOLOGY RESEARCH

HEAD OF SECTION: CHARLES DEWHURST

SUMMARY

General operational work

There was a reduction of reported infestations in 2011 compared with 2010. Operational visits by Entomology Section to smallholder blocks and plantations continued and required Pest Recommendations were produced. The treatment teams were generally well organised and worked efficiently under Smallholder Affairs Department of NBPOL. Plantation Groups managed their own teams and operations were effectively organised in New Ireland Province. No Targeted Trunk Injection (TTI) for oil palm pest control was undertaken on mainland PNG. The insect composition of pest reports remained similar to previous years, but there were changes in abundance among the commonest taxa.

Projects

There was no activity with the Bill and Melinda Gates Foundation BREAD project, Notifiable Pest Status gazettal was not completed by NAQIA or BCS vector study; however a Concept Note on BCS research was provided to ACIAR to specifically target potential vectors. A decision will be made in 2012.

Plans for the extension and upgrade of the Entomology Section building at Dami were submitted and approved for financing by NBPOL.

Operational Research

Laboratory rearing and releases of parasitoids continued. Numbers produced and released were increased for *Doirania leefmansi (Dl)* but numbers of *Leefmansia bicolor (Lb)* released were low and the latter is being addressed. Success was achieved with the mass rearing for release of a parasitoid belonging to a previously undescribed species of Eupelmidae found in the eggs of *Eurycantha calcarata* (Giant Spiny Stick Insect) in West New Britain (WNB). Field investigations of populations of *E. calcarata* uncovered some useful new facts. Laboratory rearing studies on the life history and fecundity of the two main species sexavae from WNB have also proved very useful in helping to develop a possible modification of the methodology for the trunk injection regime. Destructive palm sampling analysis has shown that there may be a correlation between activity in the lower and upper canopy. Work on alternative insecticides did not progress during 2011 due to staff constraints, but will be pursued in 2012.

INTRODUCTION

The situation involving pest infestation reports improved significantly in 2011 with a reduction in reports from those received in 2010. This was largely due to (1), regular weekly "pest management meetings" with smallholder extension staff and (2), monthly meetings with plantation management resulting in a more effective response from the three Smallholder Affairs (SHA) treatment teams.

General issues

OPIC weekly field days were attended by staff usually in conjunction with Agronomy staff. Insect material was added to the reference collection and data added to the database. The database on oil palm insects was maintained and now contains more than 200 records. This database is not solely pests but refers to insects found on oil palms. A number of peer-reviewed scientific papers were produced during the year; they are listed at the end of this report.

OPIC Divisional Managers continued to provide specimens (adults and eggs) for research studies. Regular egg monitoring continued at Navarai Plantation, and *E.calcarata* adults were monitored regularly at Dire/Namova, although there were disruptions to the work due to weather and security issues. Weekly OPIC Pest and Disease meetings were regularly attended in WNB, but none took place in Popondetta or New Ireland. Under OPIC re-structuring, it is expected that they will start again in 2012. Integrated Pest Management Working Group (IPMWG) meetings for Hargy and Bialla OPIC were not held during 2011, however it is hoped that they will commence again in 2012. Regular monthly meetings of NBPOL Plantation management staff were attended at Mosa HQ, and information was provided for the LPC meetings as required.

Plans for upgrading the entomology section building were submitted to SADP as suggested by the Project Manager, however this was turned down by World Bank because of ownership issues, and the work will now be funded by NBPOL and begin in 2012.

Good collaboration with local and overseas research personnel continued. The project, Basic Research to Enable Agricultural Development (BREAD), did not move forward at all during the year, as it proved impossible to elicit any response from The Department of Environment and Conservation (DEC) to the request to send material to the States. This request will be re-submitted to NAQIA. Similarly there was no response received from DEC in Port Moresby for requests dealing with this project nor for Queen Alexandra Birdwing Butterfly project and nor did NAQIA take the Notifiable Pest Status further for gazettal, although a draft was sighted two years ago.

The Methamidophos Usage Database (MUD) underwent complete redesigning by the IS Officer, Charles Tringin, and was not operational by the end of 2011. It is expected to be ready in early 2012.

The shade house for culturing the Chrysomelidae, *Calligrapha pantherina*, a beetle which is an efficient biological control agent against the water weed, *Sida rhombifolia,* was rebuilt, repaired and re-stocked. The SADP/OPIC water quality invertebrate indicators monitoring project was not fully operational by the end of 2011 and much of the equipment had not arrived. Employment of an aquatic invertebrate specialist from within PNG was agreed, and the recruitment process initiated.

Staff numbers remained at 11 during 2011 (10 operational and 1 support staff). A Plant Protection Specialist and a lab technician will be employed in 2012 which will make up for the loss of three executive staff (1 terminated, 2 resigning for personal reasons) during the latter part of the year.

OIL PALM PEST REPORTS (RSPO 4.5, 8.1)
74 infestation reports were received from plantations and smallholder blocks throughout PNG during 2011 (Fig. 1). This is 45% less than were reported in 2010 (n=135), which is encouraging (Fig. 2). New Ireland (NI) reported 14 infestations of *Segestidea gracilis* (Figs. 3, 4), a drop of 39% (14/23) from 2010. There were 60 reports received from WNB, which was 81% of all reported infestations, down from 111 reported in 2010 (Figs. 5, 6). There were no pest reports received from the mainland of PNG or from GPPOL in Solomon Islands.

Where control intervention was required, this continued to be through Targeted Trunk Injection (TTI). A new report form, advising the start and completion dates for treatment operations, was introduced to encourage those responsible for control intervention (Divisional Managers from OPIC, Plantation Managers from companies) to complete this form and return it to PNGOPRA. This will be in addition to MUD, which is designed to track pesticide usage and movements only, and is provided to Management. Reports of pests and all associated data are recorded as they are received in the Pest Infestation Database (PID) maintained by Solomon Sar. All infestation reports are routinely followed up in the field by entomology staff and PestRec reports are sent as necessary electronically to OPIC and Plantations, including TSD and management.

On mainland PNG, Ambogo Estate (Higaturu) was routinely monitored for bagworm (Psychidae) and Larger Rhinoceros beetle, *Oryctes centaurus*. *O. centaurus* was causing damage to younger palms in previous years, however during 2011 numbers were very low and no damage was recorded. Although it is assumed that palms “grow-away” from the damage, this has not yet been proven conclusively.

Larvae and pupae of *O. centaurus* were still found in the remaining (standing dead) and rotting palms. The survey data are still awaiting analysis.

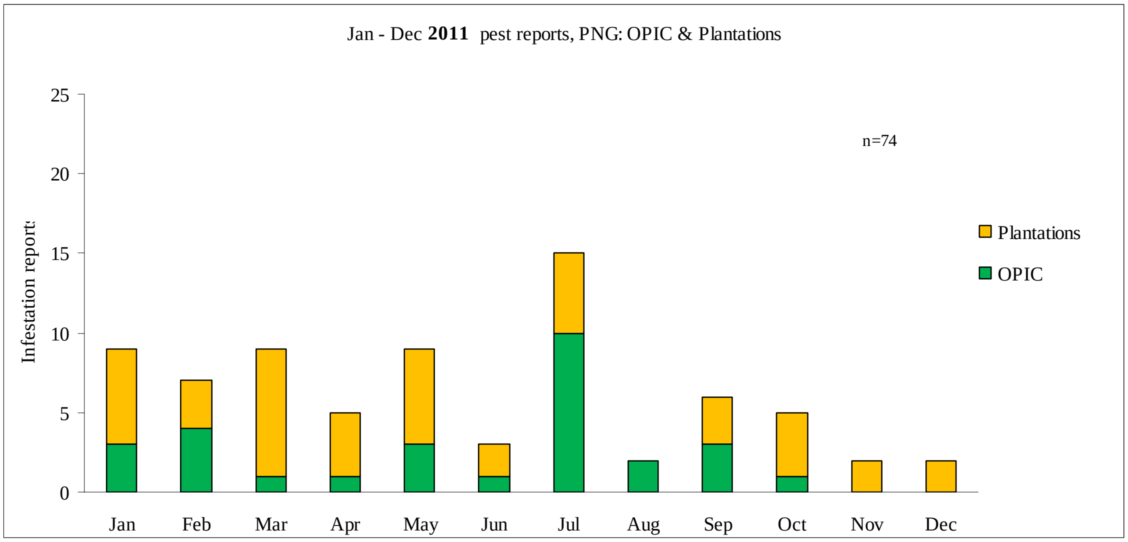


Figure 1. 2011: Pest infestation reports: PNG (smallholder blocks and Plantations).

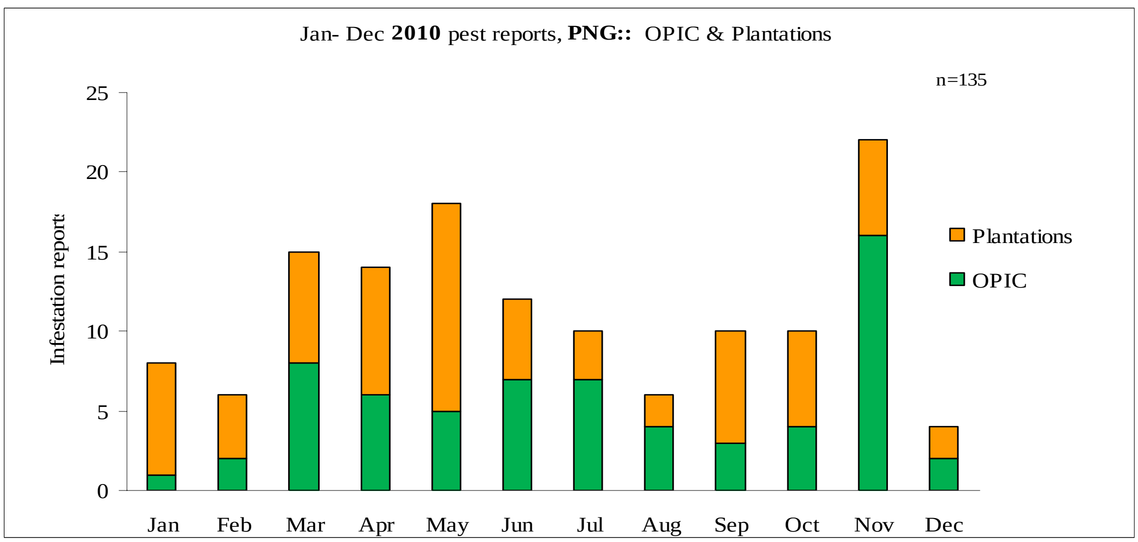


Figure 2. 2010 f*or comparison*: Pest infestation reports: (Plantations and smallholder blocks).

Mainland PNG

Although there were no pest reports from the mainland during 2011, routine monitoring of bagworms (*Manatha* sp E and *Eumeta variegata* and *Oryctes centaurus* continued at Ambogo Estate (Higaturu), Northern Province. A report of Taro beetle (*Papuana* sp.) from Mamba nursery was recorded in the 2010 Annual Report. Full data on this latter infestation are still awaited from TSD at Higaturu. A peer-reviewed paper on the recently (2010) reported weevil from Mamba Estate, previously only recorded from coconut in Madang is being prepared for publication (Dewhurst & Pilotti *in prep*.).

New Ireland

2011 was a busy period for treatment teams as, although there was a small but significant decrease in reported infestations of *S.gracilis* during the year, there was considerable TTI activity, with 14 infestations being reported as compared to 23 in 2010 (Figs 3 & 4). Areas recommended for treatment were all treated. Reports from smallholder blocks were much reduced during the year, while

Plantation activity remained low with the months of April, August, October and November with no pest reports received.

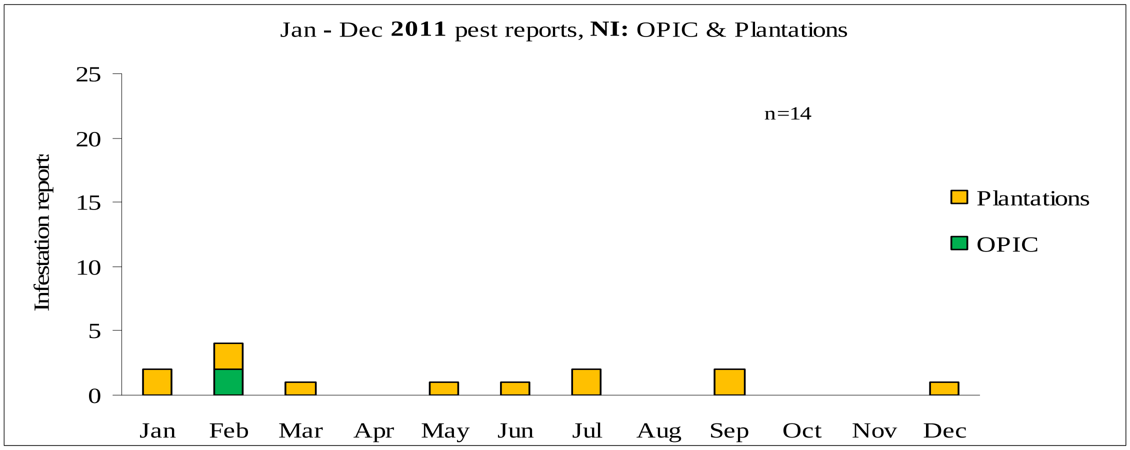


Figure 3. **2011**, Pest infestations New Ireland Province. Smallholder blocks and plantations.

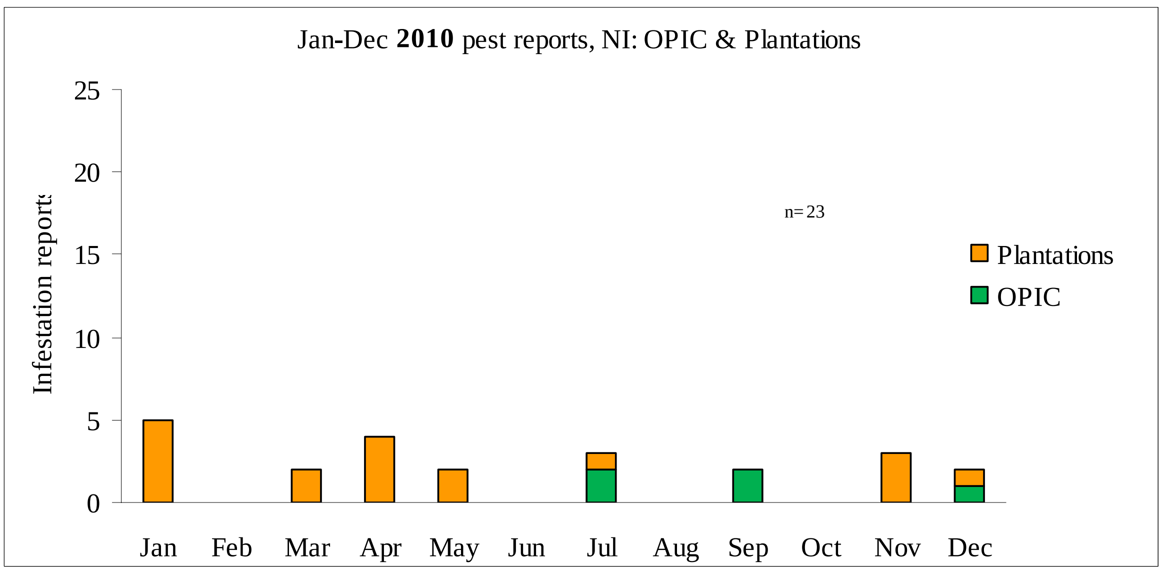


Figure 4. **2010**, *for comparison*: Pest infestations New Ireland Province. Smallholder blocks and plantation

West New Britain

Pest infestation reports from West New Britain (WNB) fell from 111 in 2010 to 60 in 2011, a decrease of 46% (Figs. 5 & 6). Of these reports, 27 (45%) were from smallholder growers and 33 (55%) were from plantations. WNB continues to report much higher levels of pest infestations than elsewhere, quite possibly due to much increased vigilance and reporting. The peak in reports during the latter part of 2010 was not expressed by increased infestations during 2011, and infestation reports reported through OPIC fell away during the latter part of the year.

Improved liaison with Smallholder Affairs department (SHA), and the regular meetings with OPIC produced a considerable improvement in the speed and efficacy of TTI.

Rainfall data for Dami showed a large peak during early 2010 (Fig. 7). Any TTI recommended during most of that period was halted and this is possibly why reported infestations were so low during this period, and fieldwork and plantation operations were severely curtailed.

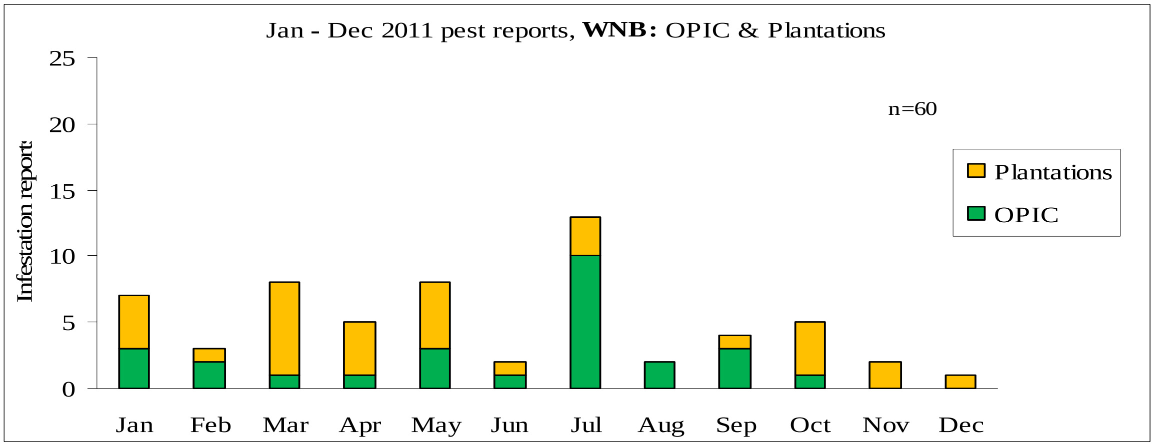


Figure 5. Pest infestations **2011**, West New Britain Province (OPIC and Plantations).

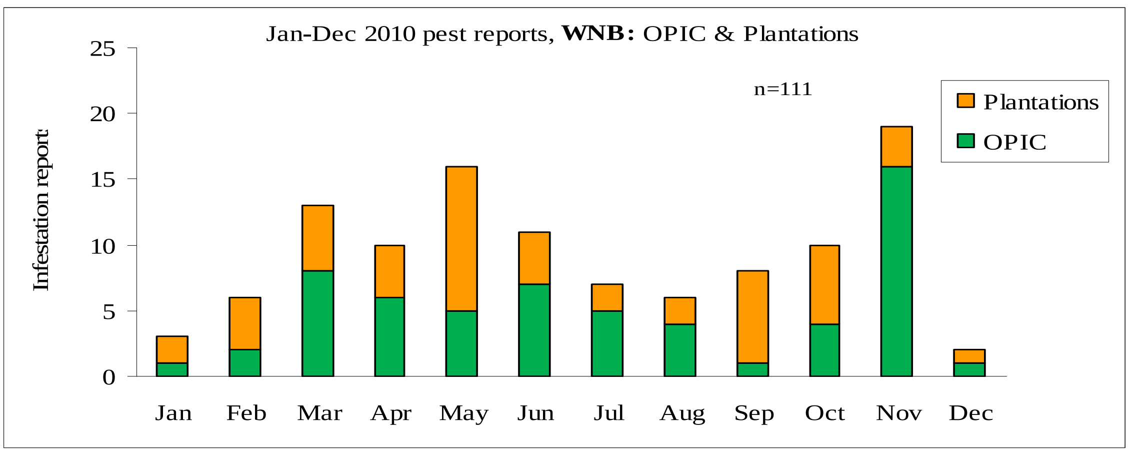


Figure 6. *For comparison*: **2010**, Pest infestations West New Britain Province (OPIC and Plantations).

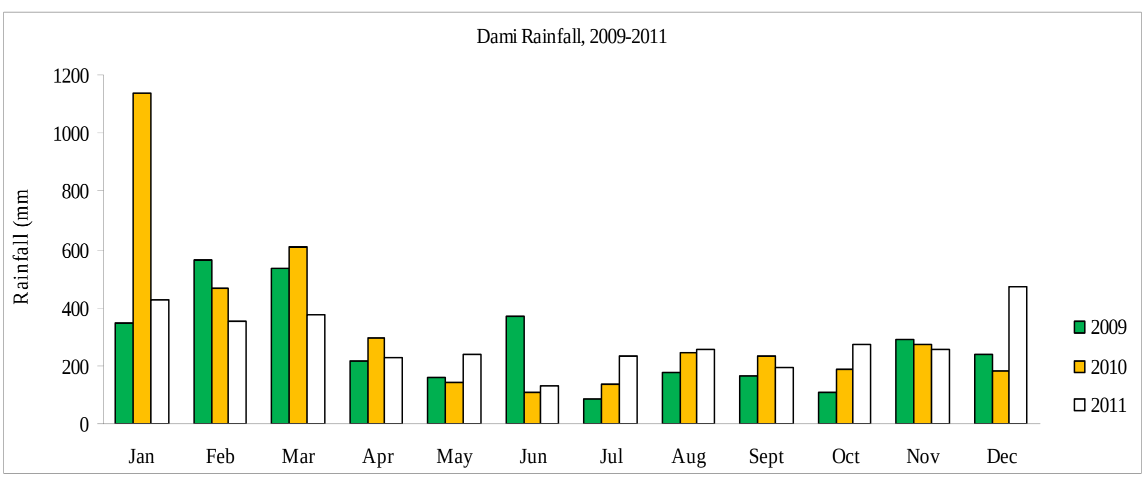


Figure 7. 2009-2011, Rainfall, Dami Research Station (WNB). Source: OPRS.

PESTRECS, TARGETED TRUNK INJECTION (TTI) AND MONITORING LEVELS IN 2011 (RSPO 4.5, 4.6, 8.1)

As plantation staff and smallholder growers have been made more aware of the need for rapid reporting (through training, field visits and field days), reports from other damage estimate categories (Moderate and Severe) should continue to be reduced with time (Fig. 8). These results reflect well on the efficiency and accuracy of reporting from across the industry.

TTI was normally only one treatment with only a few incidences where additional treatments were required. Monitoring levels show that in many cases infestations were not appropriate for TTI at least initially. Almost 73% (54/74) of infestations were recommended for a first treatment, while only 3% (2/74) were recommended for a second treatment with 65% (48/74) recommended initially for monitoring. A significant proportion of these required subsequent treatment (Fig.9). These results require careful interpretation as some initial reports may contain areas for TTI as well as for monitoring, hence the discrepancy in totals between Figs. 8, 9 and previous Figs.1-6. As reported above, there was no control required in Solomon Islands (SI) or on the Mainland of PNG during the year.

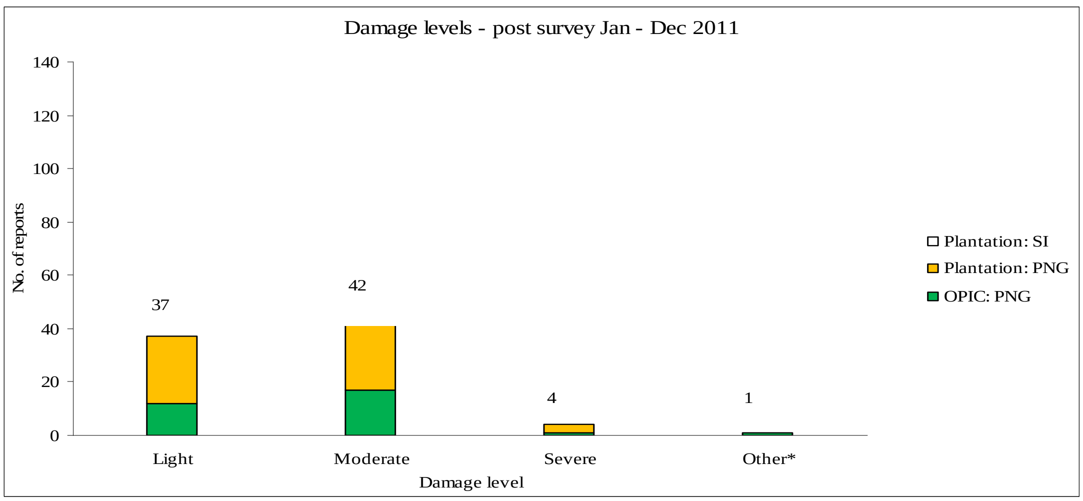


Figure 8. **2011**, Levels of reported damage before and after survey. *Numbers above histograms are total number of reports.*

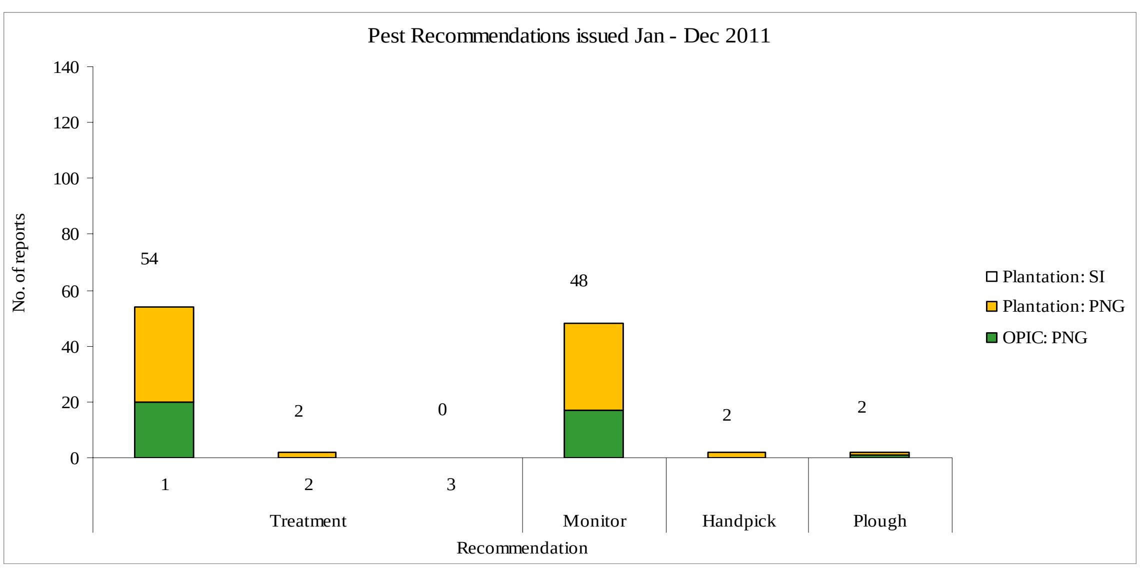


Figure 9. **2011**, TTI and Monitoring recommendations for PNG and SI. Numbers above histograms are actual number of recommendations issued (PestRecs).

All reported infestations were visited by Entomology Section staff, and an individual Pest Recommendations (PestRecs) issued, which recommends treatment or monitoring during harvests.

During the year, because of transport constraints, Plantations and OPIC assisted with transport to take entomology staff into the field and also often assisted with the pest surveys. The close liaison developed with Plantations and OPIC will continue to encourage their active involvement in pest management issues. Working so closely with producers enabled them to develop a much greater understanding of the techniques and processes involved.

Handpicking is recommended when the host palms are deemed too small to be suitable for TTI. Monitoring should be carried out during the harvesting rounds, recovering any insect pests from the fallen fronds for the period stated on the PestRec form, and it is likely that a modified protocol will be required if the current research work proves sound after analysis

PEST FREQUENCY AND DISTRIBUTION (RSPO 4.5, 8.1)

During 2011, sexavae were dominated by *S. decoratus* a species which, like *S. defoliaria,* exhibits a range of colours from green to brown (Fig. 10).

Figure 10. 2011, *Segestes decoratus* females and one nymph illustrating colour morphs, Kapore VOP, WNB, on banana leaf *(note they are all females).*

In New Ireland Province (NI) only *S. gracilis* is recognised, however, because of the similarity between species occurring as pests of oil palm in PNG, the complicated taxonomy of the sexavae of WNB, NI islands and the mainland of PNG needs to be clarified. Throughout PNG and SI, there was a significant change in species complex of the 4 main species involved as causing perceived levels of economic damage with no infestations of *S.novaeguineae* having been reported in 2011 (Fig. 11). When compared with reports received in 2010, although the same major taxa were involved, there was a significant reduction in reports received, especially of *S. defoliaria* and *E. calcarata* (Fig. 12). In WNB where the majority of infestations reported were addressed, *S. decoratus* and *E. calcarata* dominated; however there was a single report of *E. calcarata* in NI and a small infestation of *M. corbetti* (Rough bagworm) also from NI in Fileba oil palm nursery, which was recommended for hand-picking (Fig. 13). As a comparison, Figure 14 illustrates reports for 2010 from plantations in WNB, NI and Mainland PNG.

The positive changes in the overall reduction of reports reflects a much more effective approach by management and treatment teams team working together in NI and in the Bialla and Hoskins areas (SHA).

Of concern, was a report of *Oryctes rhinoceros* from NI, as this insect had not been of concern since 1981-1983, when the PNG government released "*Oryctes* virus", and in "*October 1989 a visit to this development, known as Poliamba, revealed an ideal breeding ground for Oryctes, with hundreds of felled coconut logs lying exposed on the ground. Partial decay had occurred and large numbers of Oryctes larvae were found in the partially rotted logs*". *(PNGOPRA 1989, Annual Report).* Pheromone trap monitoring will continue among new plantings.

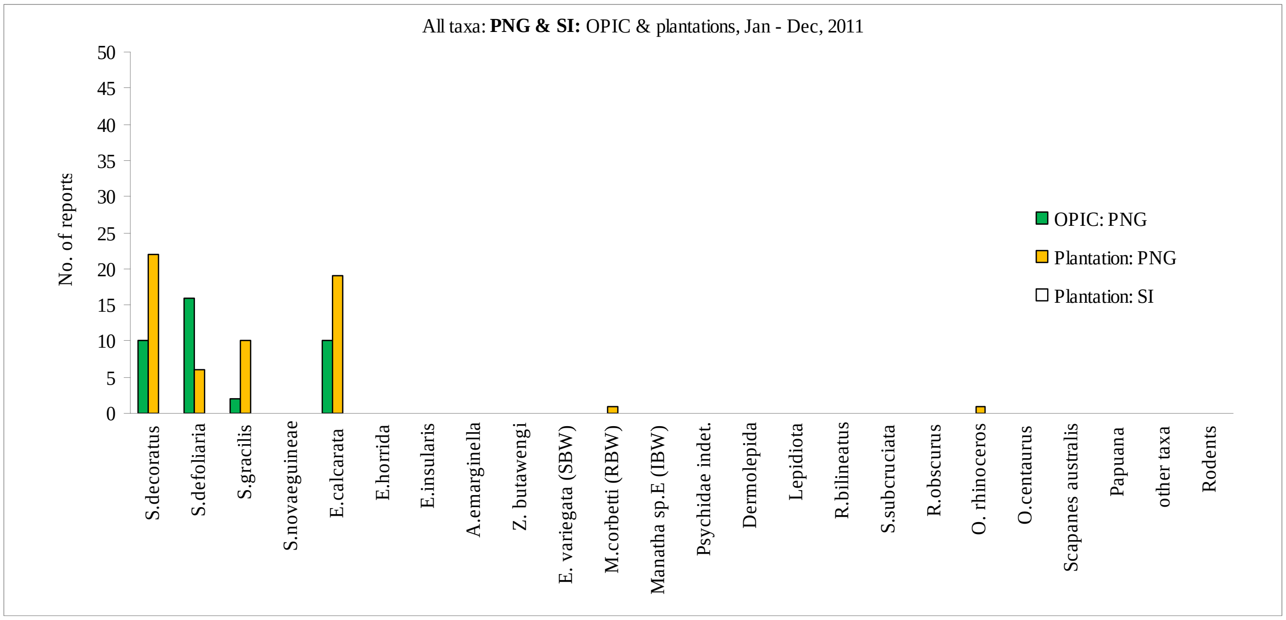


Figure 11. **2011**, Pest taxa reported: **PNG** and **SI**, from plantations and smallholder blocks (through OPIC).

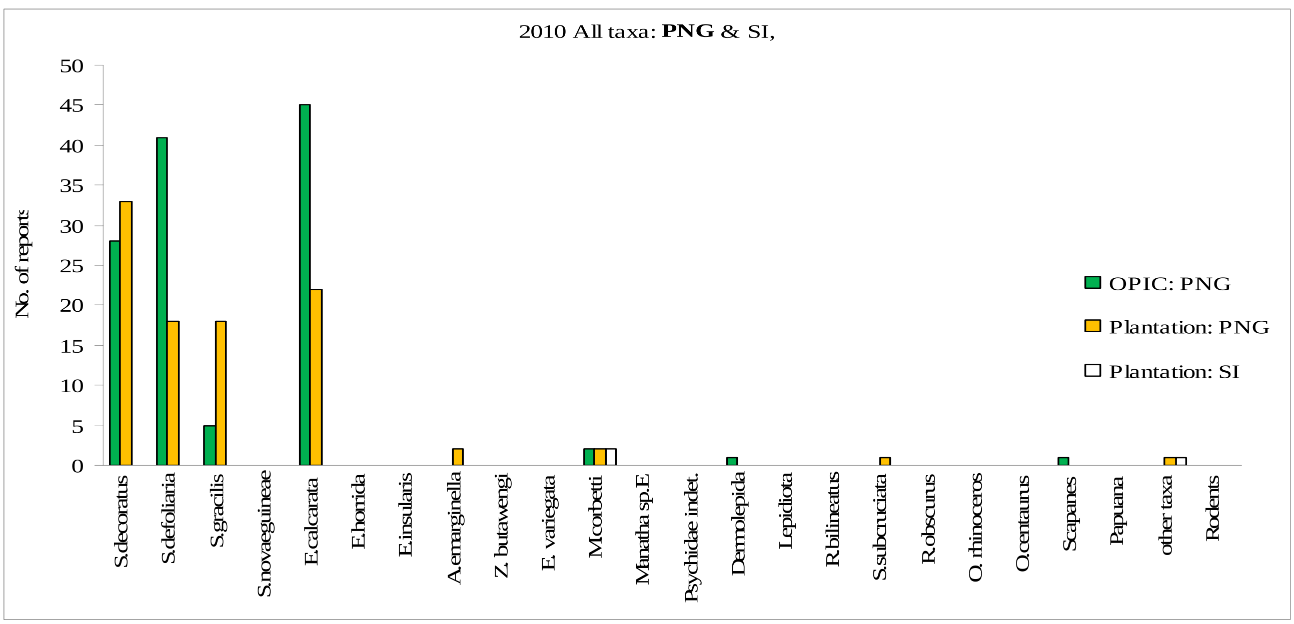


Figure 12. **2010**, *For comparison*, Pest taxa reported: **PNG** and **SI**, from plantations and Smallholder blocks (through OPIC).

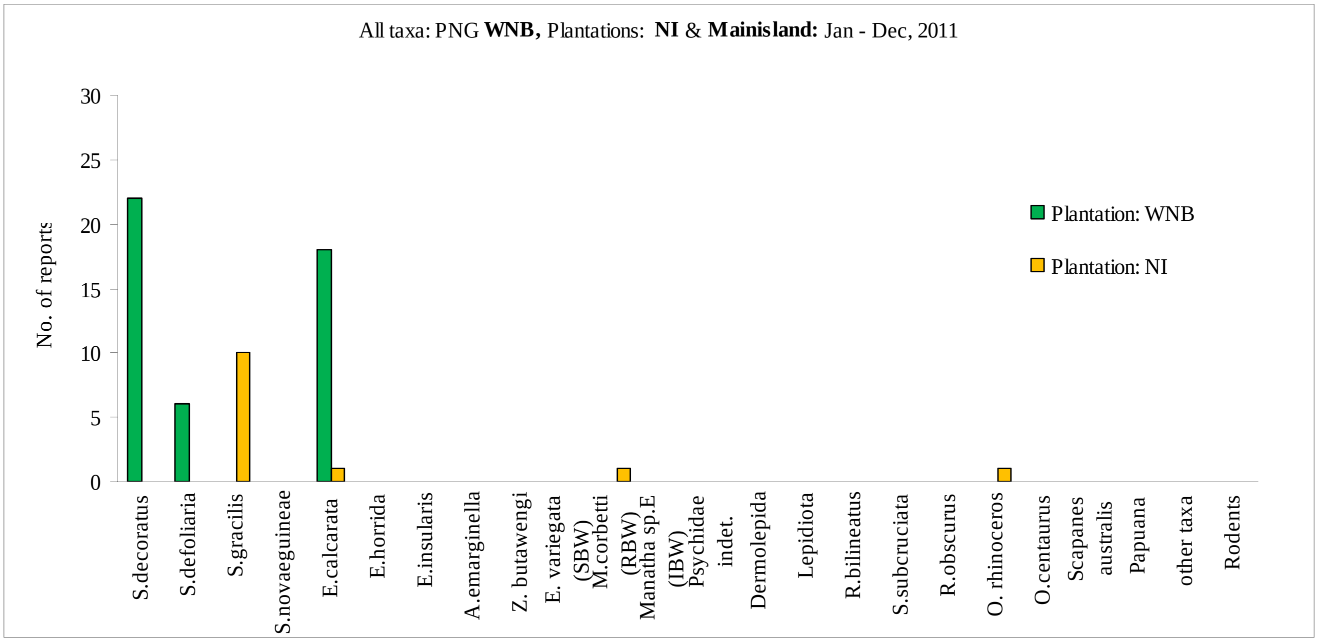


Figure 13. Pest taxa reported **2011**: (WNB, NI and mainland from plantations.

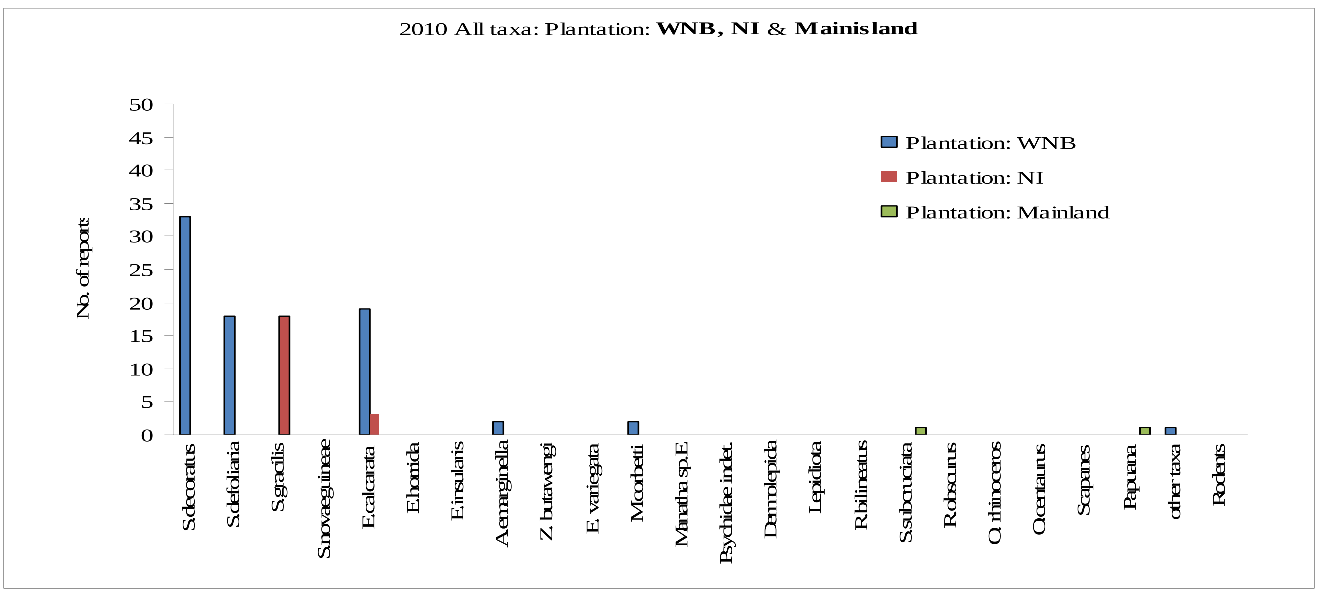


Figure 14. *For comparison*: Pest taxa reported in 2010: WNB and NI and PNG Mainland from plantations.

As a comparison between all Smallholder Groups (through OPIC), Figs. 15 & 16 contrast the differences between 2011 and 2010. The histogram (Fig. 15) illustrates the reduction in Pest infestation reports between the two years from almost double those in 2010 (Fig. 16), although the composition of the taxa involved is very similar (note the differing scales on the "Y" axis). Reported infestations were lower by more than twice in 2011, and this is likely due to the increased vigilance and speed of response to the treatment recommendations made by Plantations and SHA treatment teams.

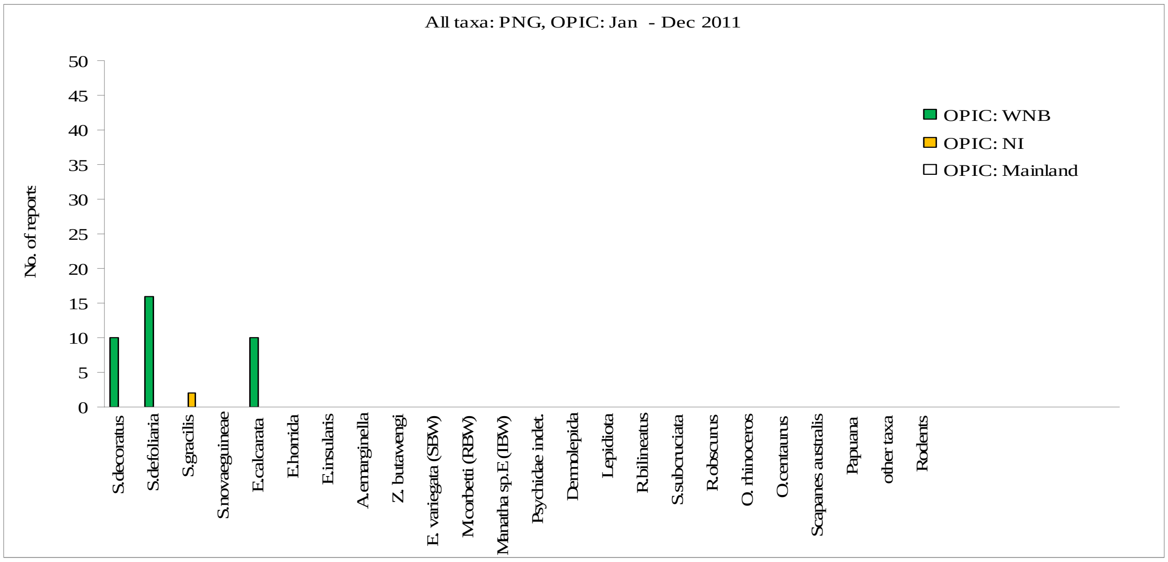


Figure 15. 2011, Pest taxa, PNG from smallholder blocks (through OPIC).

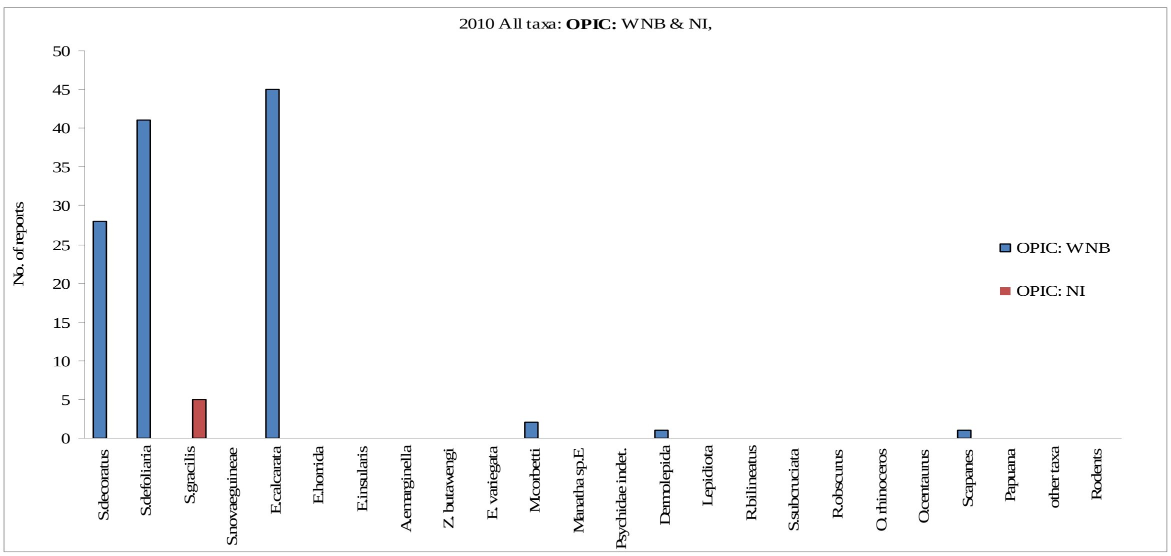


Figure 16. *For comparison*: **2010**, Pest taxa, PNG (from smallholders through OPIC). There were no reports from OPIC on the mainland.

OTHER PESTS

Lepidoptera (RSPO 4.5, 8.1)

A report of a "leaf miner" was received from Milne Bay in November, however no live material was brought back and therefore it was not identified. At the same time, there were reports of "armyworm" attacking seedlings in the nursery at Milne Bay Estates (Kula Group); however these also failed to emerge and were not identified.

Noctuidae

Infestations of larvae of the noctuid moth, *Spodoptera litura* Fabricius, known colloquially as "leafworm" or "armyworm" was recorded as attacking the leaflets of nursery palms at Fileba SE of Poliamba.. Pheromone traps and pheromone will be sourced from The Natural Resources Institute, Chatham. Kent UK and daily records will be maintained.

Lymantriidae (Tussock moths):
No reports were received, although specimens were collected at the nursery in Mamba Estate and parasitized larvae found in both Mamba and Sangara Nursery (Fig. 17)

Figure 17. Lymantriidae larva parasitized by Hymenoptera, possibly *Cotesia* sp.

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

Psychidae
There was a single report of the Rough bagworm attacking nursery palms at Fileba nursery, NI. Handpicking was recommended. (See also under Applied Research).

Hemiptera
Z. butawengi (=*lobulata*) (Lophopidae) was found in areas of Mariawatte Estate, Milne Bay Estates (Kula Group). Egg masses were collected but no parasitoids emerged. This area would be eminently suitable for the release of parasitoids if a mass rearing facility is set up at Dami.

Coleoptera (weevils, rhinoceros beetles and white grubs) **(RSPO 4.5, 8.1)**
Scarabaeidae
Dynastinae (Rhinoceros Beetles).
A single report of the Three-horned rhinoceros beetle, *Scapanes australis*, was received from New Ireland in March 2011, (Kara Estate, Baia Plantation) however there was no further information provided.

The single report of *Oryctes rhinoceros* from NI, Fileba Nursery (see above) will require careful monitoring. The island was previously dominated by coconut plantations which are a major food resource for the larvae of this pest and which may develop damaging populations rapidly even through there is a long, but variable, developmental period. Female beetles may produce an average of 51 eggs during their lives, with a developmental period of about 4 months, after which time adults are able to live for 6-9 months (Bedford 1976). The entire life cycle is also variable according to a number of published investigations (Catley 1969, Hurpin & Fresneau 1967, Gressitt 1953 and others).

O. centaurus (Larger Rhinoceros Beetle).
Routine monitoring of this insect continued at bimonthly intervals at Higaturu. Numbers recorded were well down on previous years; however collections are continuing to attempt to build up numbers to be in a position to send pupae over to The Natural Resources Institute in Kent, UK for further pheromone identification work.

Papuana sp. (*woodlarkiana or hubneri*):
One report was received during 2011 from Mamba Estate, Northern Province (Kula Group, Higaturu), where the beetles were attacking nursery seedlings. Larvae were found in the adjoining windrows where the cover crop had been sprayed off to avoid encroachment into the nursery. The lower part of the windrows was treated with *Metarhizium anisopliae* using backpack sprayers and a commercially available biopesticide (Farmset Ltd.). Monitoring reports are awaited.

Melolonthinae
Lepidiota reauleuxi, no reports were received during 2011.
Chafer beetle: (*Dermolepida* spp.): there were no reports of damaging levels of this complex of beetles during 2011, although specimens of this genus are often found on the leaflets of oil palm. It was suggested that this genus of beetles were in need of revision (J M Rowland, *pers.comm.*)

Curculionidae
No weevil pests were reported during 2011. The unidentified small weevil was identified as *Diocalandra frumenti* Marshall, which had often been reported by the late R N B Prior in previous years (Fig. 18).

Figure 18. *Rhabdoscelus obscurus* and the smaller *Diocalandra frumenti* Marshall on cut frond base. Mamba Estate, Higaturu Oil Palms, October 2010.

Rhabdoscelus obscurus
There has not been any advancement on this work at the Natural History Museum (London, UK).

Rhynchophorus bilineatus (Black Palm Weevil) (Fig 19.)
This weevil was not reported as causing any damage during 2011.

Figure 19. Female and Male *R. bilineatus* *(dead specimens).* Males can be distinguished by the slightly swollen tip of rostrum and the brushes on the fore tibiae.

Sparganobasis subcruciata
A paper describing this beetle and our work (jointly with Carmel Pilotti, Plant Pathology Section) is being prepared for submission to The Australian Entomologist and is entitled, "*A first record of the weevil, Sparganobasis subcruciata Marshall (Curculionidae: Dryopthorinae) from oil palm (Elaeis guineensis Jacq.) in Papua New Guinea and its association with decaying stem tissue*" (Dewhurst & Pilotti, *in prep*.).

Orthoptera (RSPO 4.5, 8.1)
Acrididae
A single infestation of the large Acrididae, *Austacris guttulosa*, The Australian Spur-throated Locust, at Haella Plantation (WNB) in '*overdue for planting*' nursery palms required treatment with the synthetic pyrethroid, Cypermethrin 183 e.c. This was completed over two days on 9 May and 15 May. There was no reported resurgence of this threat. Attempts to import the Australian registered bio-control product used in Australia specifically for control of this species were unsuccessful due to a lack of responses from DEC. Clearance for this product will be pursued during 2012 through NAQIA with whom we have a close working relationship.

Mollusca (RSPO 4.5, 8.1)
Achatina fulica: there were no reports of the Giant African Snail during 2010.

Rats and other vertebrates: no reports of rats were received during 2010.

Weed pests (RSPO 4.5, 8.1)
Mikania micrantha, Mile-a-minute vine (ACIAR project CP/2004/064).
Although project support has ended, we continue to liaise with colleagues involved with the project to release further pathogen-infected material. Although the fungus is found in the field, the build up to suppressing the weed has been slow.

Sida rhombifolia, Broomstick: releases of Chrysomelid beetles, (*Calligrapha pantherina*), were made during 2010, and a culture under shade was set up at Dami to enable cropping and release to be undertaken as required.

Pistia stratiotes, Water lettuce: the very small biological control weevil (*Neohydronomus affinis*) culture almost died out during the year, and the work has only involved trying to maintain and improve the culture, by the end of 2011, there were beetles present, but still in low numbers.

Eichornia crassipes, Water hyacinth: Water hyacinth is attacked by weevils of a different genus, *Neochetina bruchi* (Coleoptera: Curculionidae)-the Chevroned Water Hyacinth Beetle. Host material is collected from waterways in WNB and infested plants are returned on an *ad hoc* basis. This work continued during 2011.

Pest Treatment (RSPO 4.5, 4.6, 8.1)
Areas treated in the Bialla, Hoskins areas and New Ireland during 2011 using TTI, are shown in Table 1. There was no TTI undertaken by Hargy Oil Palms in 2011, although smallholder blocks in the Hoskins Project area required a lengthy campaign to control infestations.

Table 1.

	Total Area for TTI (Ha)	
Location	**2010**	**2011**
OPIC Bialla	245.6	471.5
Hargy Oil palms		
SHA, WNB		10,253.3
WNB, Plantation, WNB	6,956.7	5,277.5
NI, Poliamba SHA	8.6	1.6
NI, Poliamba, Plantation	1,933.5	478.9
Total hectares treated	**9,144.4**	**16,482.8**

Mainland PNG
There was no TTI control of insect pests undertaken against oil palm pests this year.

APPLIED RESEARCH

Insecticide trials (RSPO 4.5, 4.6, 8.1)
No insecticide work was carried out during 2011, because of staff constraints.

Rearing of "sexava" and stick insects (SS, TM, EK,) (RSPO 4.5, 8.1)
We are still not producing a steady or a sufficient supply of insects required for parasitoid rearing and other experimental work. Successful rearing of nymphs is crucial for increasing the number of "sexava" without the need to make collecting trips for them in the field. To improve rearing conditions, foodplant and cage covering is sprayed twice daily to maintain moisture and humidity and the cages are kept darkened (for the nymphs). Diet is supplemented with coconut palm and bananas, with additional use of *Croton* leaf for *E. calcarata*. Regularly moistened hessian sacking is provided to provide dark hiding places.

Sexavae rearing
Cage collected Sexavae eggs are used for rearing studies and parasitoid rearing from both of the main species. Previous hatching data proved unreliable because eggs of both species were mixed. Hatching records were made irregularly, although there is now a body of data from May 2011 to enable comparison to be made with the fecundity work described below (Fig. 20). Initial observations from lab rearing indicate that there is high mortality during the early instars and during the final moult into the adult stage (fledging); deformities are also observed in the field from wild collected insects.
The eggs used for this work were collected from the outside cages and placed into pots with sand and fly wire. All were maintained under ambient conditions within the confines of an outside shade cloth-covered large cage. As regards timing of emergence, *S. defoliaria* (for which many fewer eggs were available) emerged primarily during August and September, but continued to hatch in small numbers for the rest of the year. *S. decoratus* on the other hand, showed a distinct peak of hatching between October and November (Fig. 21). However for both species, hatching only amounted to just over 60% of the eggs. For *S. defoliaria* this was 61.7% and for *S. decoratus* it was 68.1%. As the eggs were all kept under the same conditions, the remaining 38.3% and 31.9% respectively are likely to have failed to develop. The remaining eggs will be dissected in the middle of 2012, and their viability or any additional hatching will be recorded. Any link between rainfall and hatching will be observed during subsequent years; however there does not at this stage appear to be any clear correlation, although there was a dry period (June) four months prior to the increased numbers of *S .decoratus* hatching

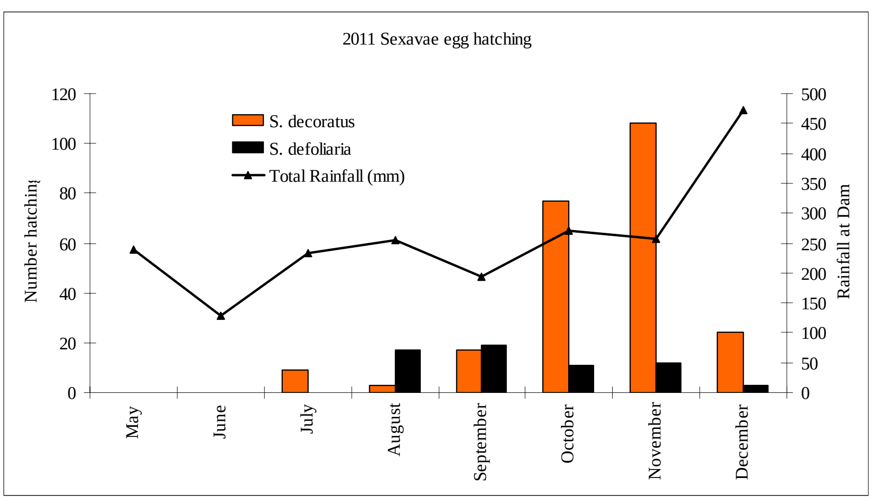


Figure 20. 2011. Hatching of eggs of *S. decoratus* and *S. defoliaria* at Dami under semi-natural conditions.

Sexava fecundity, survival and incubation periods (T Manjobie**) (RSPO 4.5, 8.1)**

Introduction

This work, using females of both species continued during the year and monitoring will continue until the middle of 2012. This study complements the work rearing eggs from the outside cages which is on-going. It will be necessary to continue this work with *S. defoliaria,* during 2012 to increase the data set.

Methods

The methods used were the same as was used during the initial experiments in 2010. Adult females of both *S. defoliaria* (n=321) and *S. decoratus* (n=1,120) were monitored daily until they died. Egg laying was monitored daily. For *S. defoliaria*, mated females were removed from the large outside cage once a spermatophore with associated spermatophalyx was seen and then individually caged with food.

Results and conclusions

These data show similarities in the fecundity and survival of the two species (*S. decoratus* (Fig. 21.) and *S. defoliaria* (Fig.22), however the Pre-oviposition Period (POP) is almost 6 times longer in *S. decoratus* than in *S. defoliaria*. Although the egg-laying period (ELP) is longer in *S. decoratus*, they lay a similar total number of eggs (TEL). Longevity after oviposition (PEL) is nearly 3 times longer in *S. defoliaria* (2.75*)*, but in the small number tested, *S. decoratus* total cycle (LIFE) was 1.8 times that of *S. defoliaria*. The inference being that although *S. decoratus* is slower to mature, it potentially lays more eggs, although these data will need to be supplemented in the case of *S. defoliaria*. *S. decoratus* has a longer egg laying period but they die off more rapidly after egg-laying is completed (PEL). As the overall period from fledging to death is longer in *S. decoratus* (LIFE), this insect is able to feed for longer consuming more photosynthetic material from palms, causing greater potential crop loss. Rapid response by SHA and Plantations to the PestRecs is therefore very important. The species specific feeding trials currently under way will provide a clear numerical background to potential damage threats.

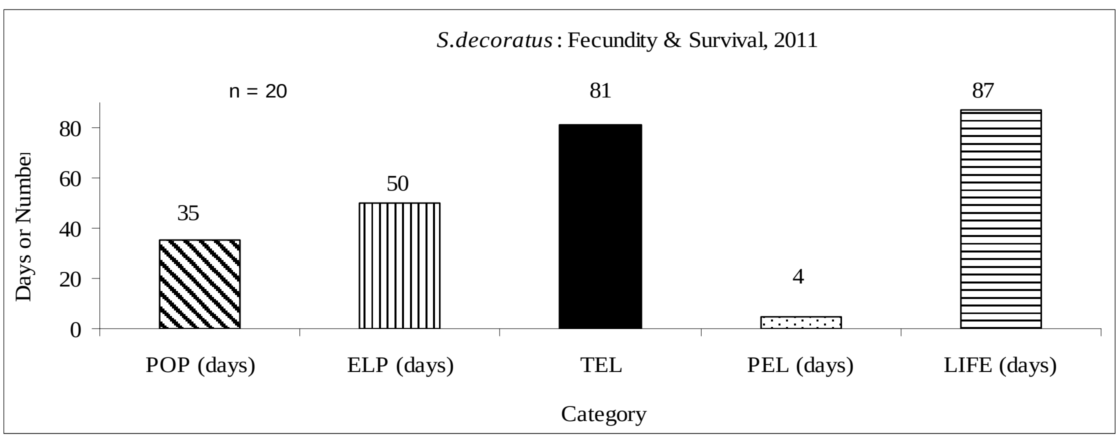


Figure 21. *S. decoratus***:** Fecundity and survival (*mean periods*).

POP = Pre-Oviposition Period (days), between fledging and oviposition ELP = the length of the egg laying period (days), TEL = total number of eggs laid by each female in the specified trial, PEL = Post Egg Laying survival (days until death), Life = Number of days the female survived from fledging until death

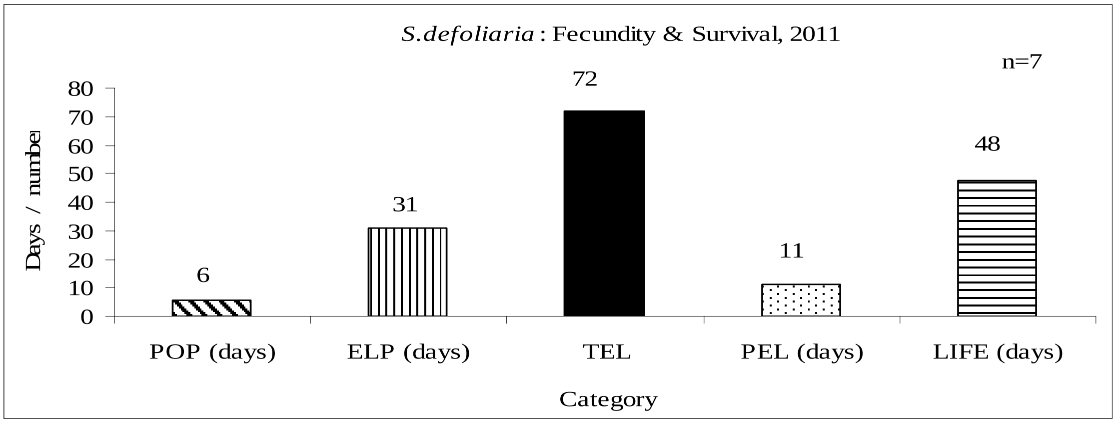


Figure 22. *S. defoliaria***:** Fecundity and survival (*mean periods*).
POP = Pre-Oviposition Period (days), between fledging and oviposition ELP = the length of the egg laying period (days), TEL = total number of eggs laid by each female in the specified trial, PEL = Post Egg Laying survival (days until death), Life = Number of days the female survived from fledging until death.

Individual monitoring for egg hatching (TM) (RSPO 4.5, 8.1)
This work was undertaken in addition to the outside cage studies illustrated above (EK, SS). Egg hatching was recorded daily from eggs held in individual pots. Figure 23 illustrates clearly the differences in initial hatching and duration of hatching period between the two species. *S. decoratus* shows how drawn out the process is over time, and the large numbers of nymphs emerging over that extended period, supporting the diapause data previously reported. Numbers of *S. decoratus* nymphs hatching after the peak were more than those hatching during the period of peak emergence. These data have shown the close similarity in the egg hatching phenology between *S. defoliaria* and *S. decoratus* but also highlight the additional threat potential of *S. decoratus* with the extended hatching period of up to almost 9 months. The results from this work may have implications for the treatment of these pests.

Segestes decoratus individual monitoring.
A total of 1,120 eggs were monitored through to hatching in the laboratory, in outside cages (as illustrated in 2010 Annual report). The hatching period of this insect continues for up to 250 days. The graph illustrates that, on average, eggs of *S. decoratus* take much longer to hatch than those of *S. defoliaria* which start hatching after a month (Fig.23). Peak hatching for this species is between 2.7 and 3.3 months (11-13 weeks), however there is a long period subsequently when hatching continues, numbers hatching after 120 days (4 months) were greater than those hatching during the peak period. After 110 days, there is a rapid decrease in numbers hatching. The first 110 days only accounts for some 40% of all hatching, the remaining 60% hatching after this time, further evidence for the diapause (Page 2005). Hatching was observed to continue for up to virtually 34 weeks (8.5 months) under ambient conditions at Dami (WNB).

Segestidea defoliaria individual monitoring.
A total of 321 eggs were monitored under similar conditions to *S. decoratus*. Peak hatching was between 2 to 3.3 months, which is between 8–13 weeks, nevertheless some hatching continued for about 5 months with about 1% continuing to hatch. In this species, 60% of the hatching takes place during the peak hatching.

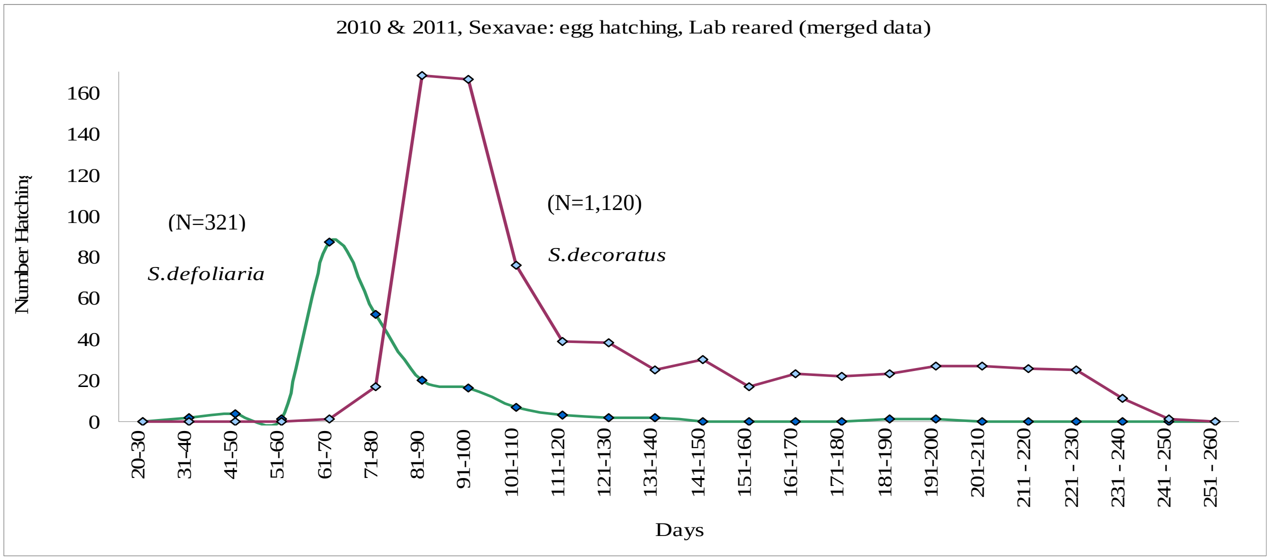


Figure 23. Numbers of *S. defoliaria* & *S. decoratus* nymphs hatching from eggs over time from Laboratory data , 2010 & 2011..

Destructive Palm Sampling (RSPO 4.5, 8.1)

Objective

This project is to develop a clearer understanding of the distribution of pest insects within the oil palm canopy, with the objective of being able to utilise the cut fronds (during harvesting/sanitation) to gain a clearer understanding of where pests, particularly sexavae are, and if there is a relationship between those found among the lower fronds and those higher up in the canopy.

Method

Palms identified for destructive palm sampling (with approval from Plantation Managers) have the fronds removed systematically by following the spiral from the base to the spear. Any specimens of sexavae, stick insects or bagworms found on the fallen fronds are recorded, placed in a pollination bag for subsequent measurement (nymphs) and colour recording.

Results

During the year two additional sites were sampled, and now all data are with OPRS Biometrician (AYalu), who is assisting with the analysis.

Pest Information Database (PID) (SS) (RSPO 4.1, 4.5, 8.1)

PID is still being used in a modified form of the original Excel spreadsheet, but now includes new parameters. Outputs can be generated to cover all aspects of infestation reports, pest taxa and infestation rates.

Methamidophos Usage Database (MUD) (SS) (RSPO 4.1, 4.5, 4.6, 8.1)

The format of the database is still incomplete and there are still sections where interrogation cannot be undertaken. It is expected to be fully operational within the 1st quarter of 2012 (C Tringin).

Biological control of insect pests of oil palm (SM) (RSPO 4.5, 8.1)

Stichotrema dallatorreanum (Strepsiptera: Myrmecolacidae).

Having been with caged and infected *S. defoliaria* in which *Stichotrema dallatorreanum* was releasing 1st instar larvae, 161 males of *S. defoliaria* were released into the field to encourage *Stichotrema* dispersal.

Specimens of *S .defoliaria* were collected from the field and infected adults were routinely mixed with *S. decoratus* to attempt to get *Stichotrema dallatorreanum* to successfully complete its development in

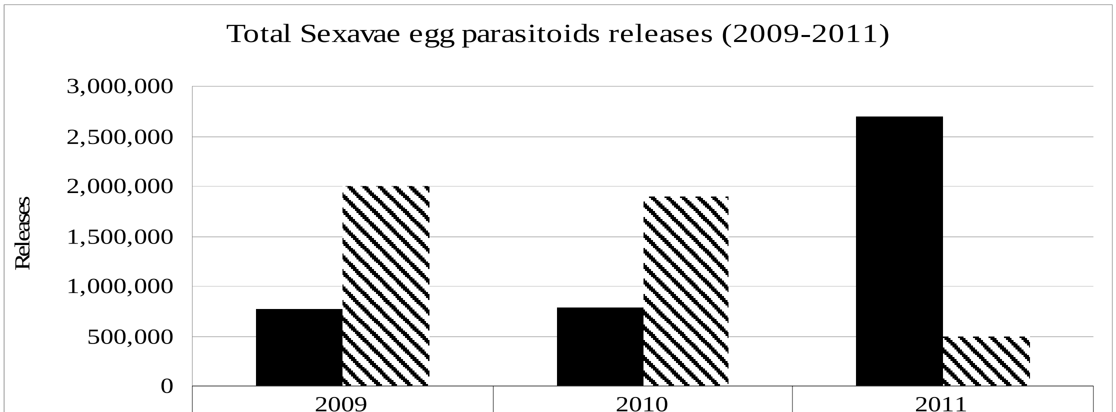
S. decoratus. These attempts to "infect" *S. decoratus* have not yet been successful, although four females, which had been in cages with infected *S. defoliaria* from which 1st instar larvae were emerging, died and were dissected on 22/9/11 and 24/9/11 and found to contain *S. dallatorreanum* larvae. Looking more closely at the correspondence and subsequent 1987 paper from G Young, this is curious as he (Young, *in litt.* 1997) pointed out that *S. decoratus* was readily parasitized by *S. dallatorreanum*. However the "*S. decoratus*" material mentioned by Young (1987) was collected from Morobe Province between February 1979 and July 1982. Recent examination of specimens of "*S. decoratus*" from near Madang (Omoru Coconut nursery), also in Morobe Province, suggest that this species is not in fact *S. decoratus*, but possibly a closely related species (D C F Rentz, *pers.comm.*). *Stichotrema* from this insect are unlikely to be parthenogenetic, as males were found (Young 1987). Males of this species are suspected to parasitize ants (Young 1987), as their family name suggests. At Dami, 497 adult female *S. decoratus* which had been caged with *S. defoliaria* that were producing 1st instars were dissected during the year. There was evidence of *S. dallatorreanum* found as immature specimens in 3 *S. decoratus*, however none had reached maturity.

The collaborative work with University of Oxford on the genome sequencing and world-wide bar-coding project will continue in 2012, as results in 2011 proved inconclusive with the technology used. New technology will be used by Dr Kathirithamby during 2012.

Sexava egg parasitoids (RSPO 4.5, 8.1)

Egg parasitoid rearing and releases in 2011 (HS, SK)

Work continued with the rearing and release of the two Hymenoptera egg parasitoids of "sexava", *Doirania leefmansi* (Trichogrammatidae) and *Leefmansia bicolor* (Encyrtidae). Attempts to improve rearing output were not successful, and the method using the lamp glasses will continue until a better alternative is identified. Parasitoid release data are reported below (Fig.24). Although large numbers of parasitoids of both taxa were released in the sites as indicated in Table 2 & 3, the methodology used to calculate the numbers released was found to be too variable to be meaningful. The release figures presented therefore have to be regarded as an estimate. The methodology for calculating numbers released has been refined and should prove more accurate.



	2009	2010	2011
Dl	772,520	786,184	2,686,659
Lb	1,995,059	1,898,374	486,007

Figure 24. Comparison of parasitoid releases between 2009, 2010 and **2011**.

L. bicolor parasitoids were released at 23 sites in WNB, 11 in smallholder blocks and 14 in plantations (Table 2), while *D. leefmansi* were released in 21 sites in WNB, 11 in smallholder blocks and 10 in plantations (Table 3). Although release data have been variable and to some extent unreliable in previous years, they were re-analysed (SS) and although releases of *D. leefmansi* have increased by more than three times (Figs. 24), the figures for *L. bicolor* have been disappointingly low, with a three-fold downturn. The reasons for the poor *L. bicolor* number released are unclear. Rearing techniques are being constantly reviewed and improvements will be addressed in 2012.

Monthly releases and cumulative releases for *D. leefmansi* increased later in the year (Fig. 25), with a cumulative total released of about 3.5m (Fig. 26). For *L. bicolor*, although there were good numbers released mid-year, there was a dramatic decline later in the year (Fig. 27). Numbers peaked at about 700k released (Fig. 28).

Table 2.

Doirania leefmansi : release sites

OPIC	Plantations
Banaule	Dami
Buluma	Garu
Buvussi	Haella
Daliavu	Kaurausu
Gilo	Lolokoru
Hak	Navarai
Kapore	Navo
Kavui	Numundo
Lavege	Sapuri
Siki	Volupai
Soi	

Table 3.

Leefmansia bicolor : release sites

OPIC	Plantations
Banaule	Bilomi
Buluma	Daliavu
Buvussi	Dami
Daliavu	Garu
Gilo	Haella
Hak	Kaurausu
Kapore	Lolokoru
Kavui	Lotomgam
Lavege	Navarai
Siki	Navo
Soi	Numundo
	Sapuri
	Togulo
	Volupai

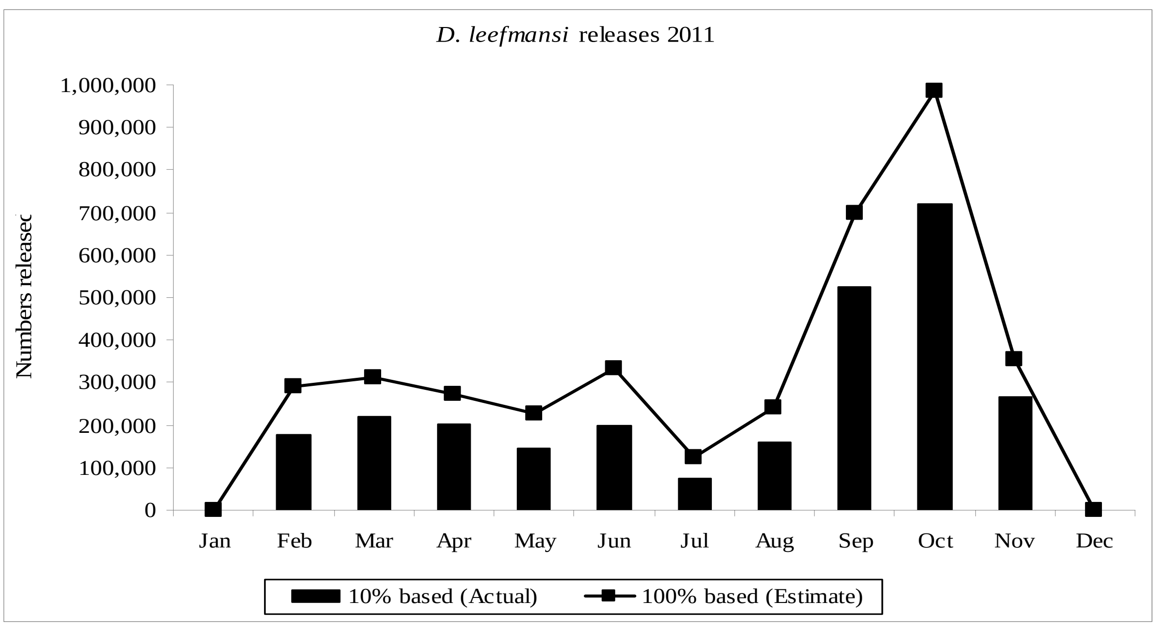


Figure 25. 2011 Monthly releases of *D. leefmansi*, all localities but mainly WNB.

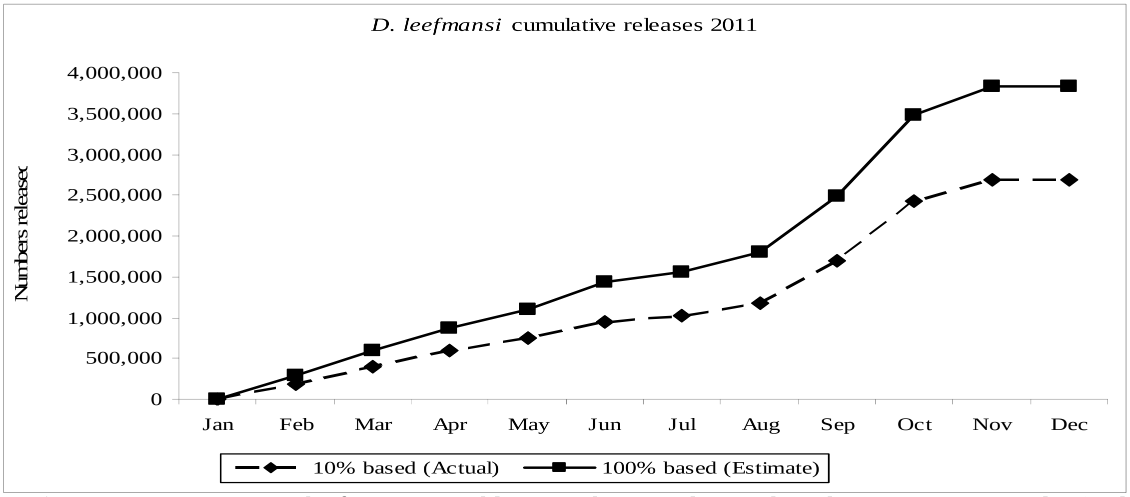


Figure 26. 2011: *D. leefmansi* monthly cumulative releases based on a 10% sample (and extrapolated).

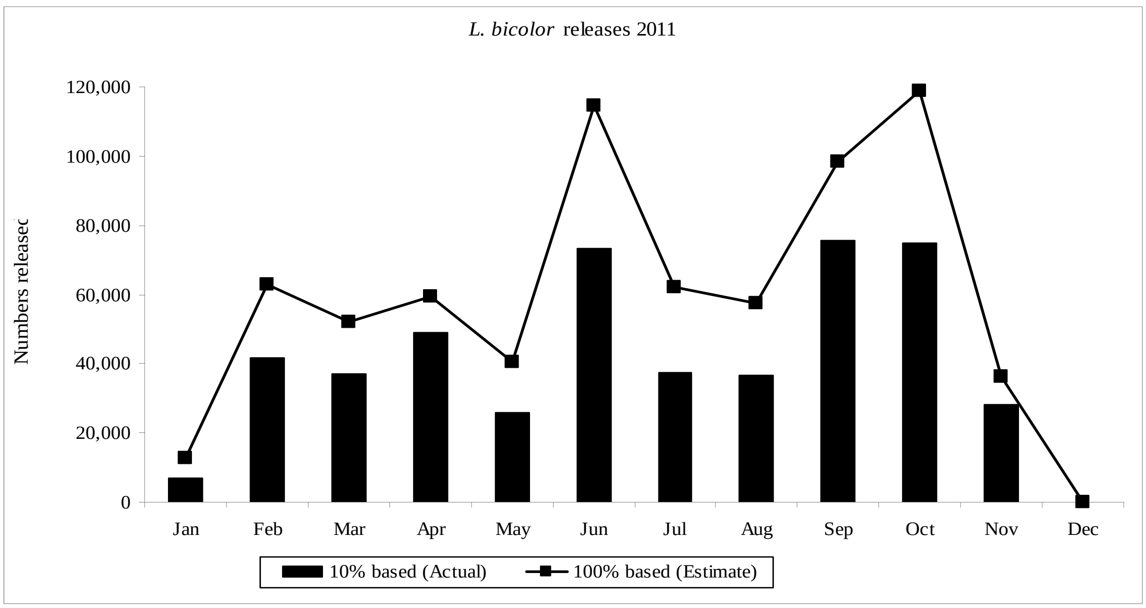


Figure 27. 2011: *L. bicolor* monthly releases based on a 10% sample (and extrapolated).

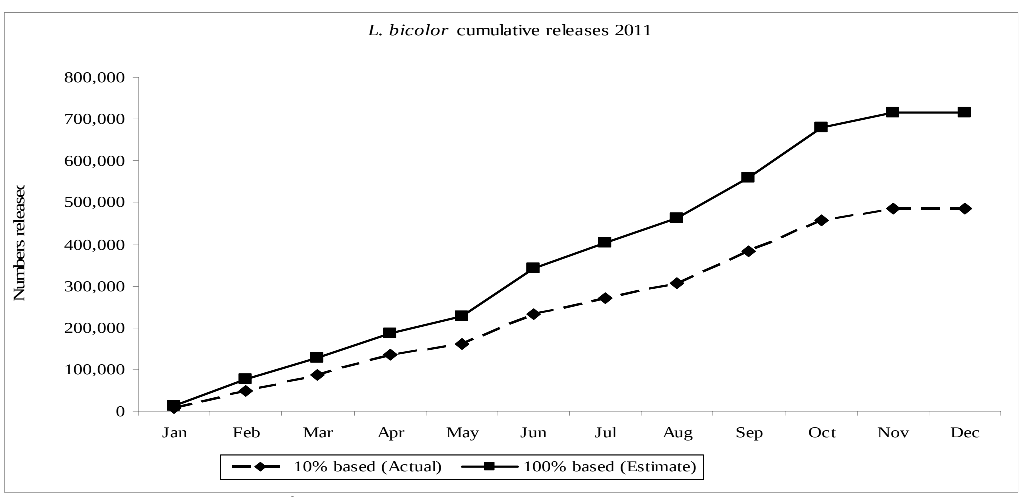


Figure 28. 2011 *Leefmansia bicolor* cumulative releases based on a 10% sample (and extrapolated).

Pollinating weevils (RSPO 8.1)

Elaeidobius monitoring in WNB.

Weevils emerging from male flower spikelets from Dami and Hoskins smallholder blocks were monitored routinely (Figs. 29, 30), and tri-annual data suggest a trend in peaks in weevil population in the July-September period (Fig. 30). In 2011, there was no correlation between rainfall and weevil numbers, although there were slight increases in numbers as overall rainfall decreased; however it should be noted that even during periods of rainfall, when the rain eases, the weevils will fly, and during these periods weevil numbers may be high (Dhileepan 1994). Overall rainfall is therefore not a good measure of weevil activity. Intermittent rainfall is not likely to affect weevil flight activity.

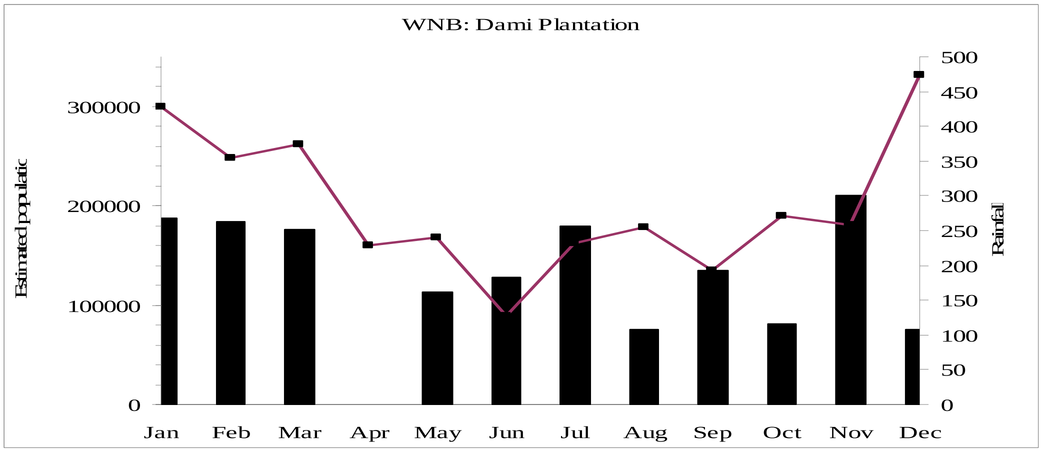


Figure 29. **2011** *Elaeidobius kamerunicus* spikelet monitoring & population estimation. Dami Plantation (WNB).

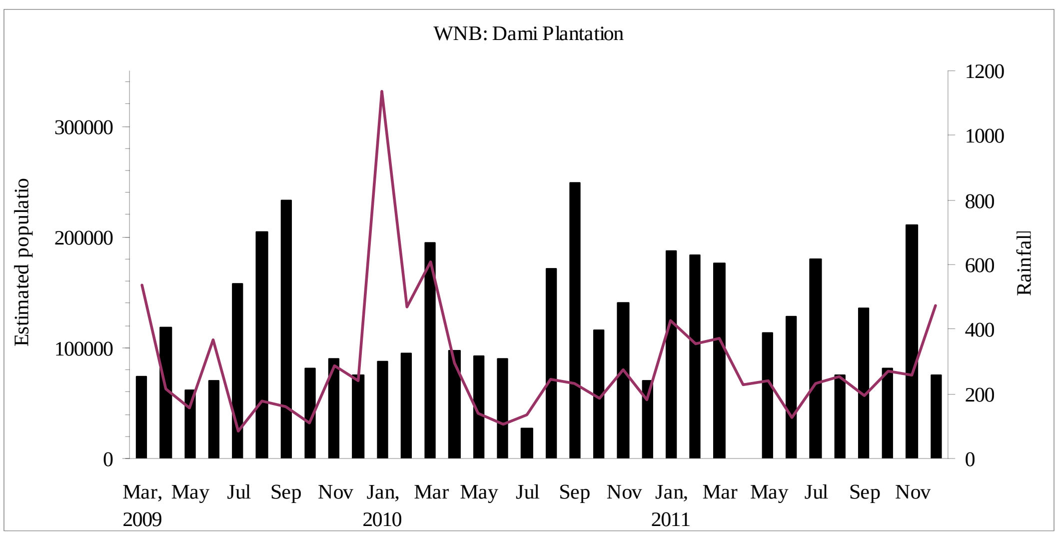


Figure 30. 2009-2011: *Elaeidobius kamerunicus* spikelet monitoring & population estimation to show three year trends. Dami Plantation.

Weevil monitoring from Hoskins suggested that with the exception of January and August (Fig. 31), numbers remained acceptable throughout most of the year.

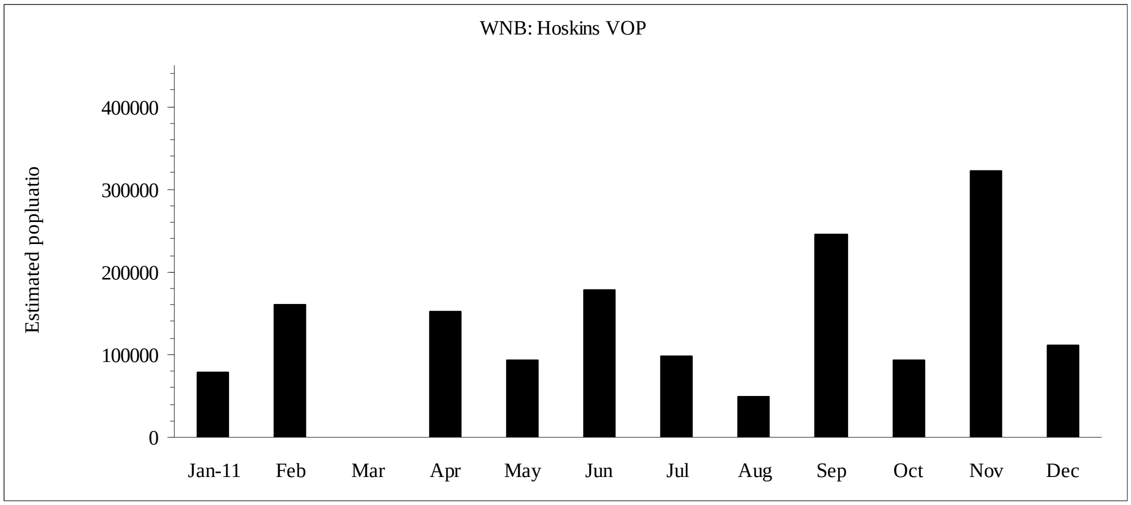


Figure 31. *Elaeidobius kamerunicus* emergence, spikelet monitoring **2011**. WNB, Hoskins VOP Block 029-0067.

We continued to monitor weevil populations at Lolokuru ME, although material was received irregularly. Mean numbers of *Elaeidobius kamerunicus* estimated from male flower rearing from all six monitoring sites at Lolokuru ME remained above 100,000/ha up until monitoring ceased (no spikelets were received), (Fig. 33).

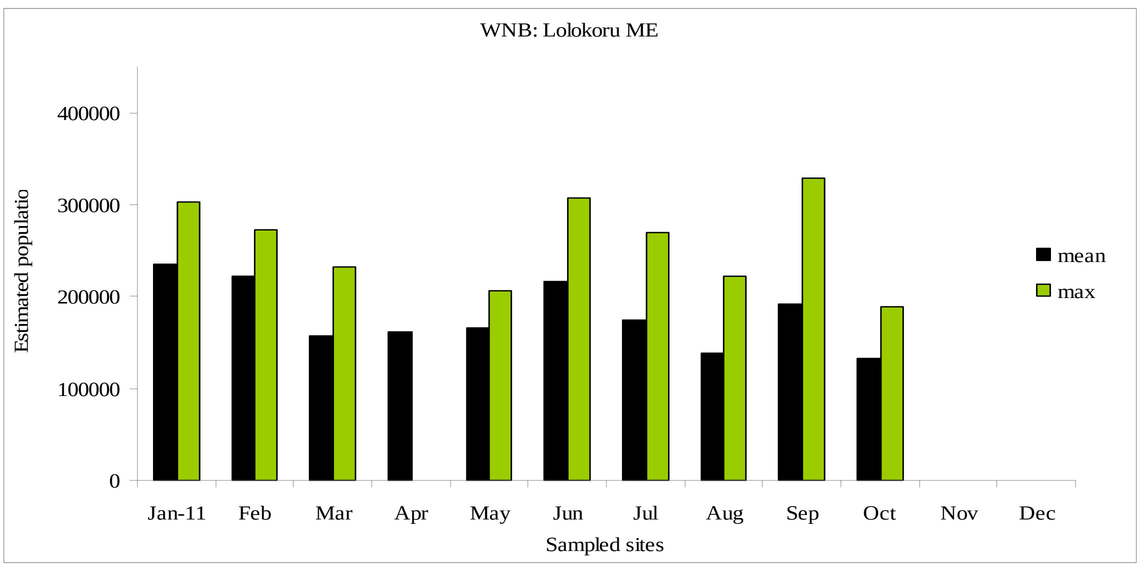


Figure 33. *Elaeidobius kamerunicus* emergence, **2011**. WNB, Lolokuru ME: estimated population numbers/ha recorded from 6 sampling sites.

Ghana origin weevils.

All areas have now received implants of the new genetic line of weevils from the quarantine reared stock originating from Ghana. The remaining stock will be released as a second group for Poliamba in early 2012. Rearing will cease having fulfilled the objective of increasing genetic heterogeneity in the *E. kamerunicus* population.

Phasmatidae (stick insects) **(RSPO 4.5, 8.1)**
In WNB the only stick insects that have been found are *Eurycantha calcarata* Lucas. During a routine visit in WNB to two smallholder areas of Dire VOP & Namova VOP, it was observed that large numbers of *E.calcarata* were to be found in fissures in a species of forest tree (Fig 34) identified as *Kleinhovia hospita* (Malvaceae, a remnant forest tree locally known as "Wulai"), and among rotten tree trunks. This habitat was identified by the characteristic odour emanating from the large "midden" of frass (insect faeces) that had accumulated at the base of the tree (Fig. 35). During two subsequent visits adults of *E.calcarata* were collected and painted with a small mark on the mesonotum using coloured "nail varnish" (with a yellow or white spot, Figs. 36, 37). On subsequent visits to Dire VOP as many *Eurycantha* as we could collect were removed and brought back to Dami (Fig. 38) even from under the remnants of bark on rotting tree stumps (Figs. 39, 40) Initial results are presented below. Marked insects were recovered after 3 days at the same site, which indicated a degree of fidelity to one site (Table 4). Heavy damage was caused to oil palm (Fig. 41), and adults were also observed feeding on Taro leaf (*Colocasia* sp.) in the same area.

Table 4. *Eurycantha calcarata*. Dire VOP, WNB. Adults marked from collection made from *K. hospita* tree #D1.

Date Marked	Number marked	Date collected	Number found	Number marked	Days after marking
07/12/2011	106	13/12/2011	218	24	6
		13/12/2011	37	10	6

Figure 34. **WNB**, Dire VOP, Wulai tree, *Kleinhovia hospita* (Malvaceae), growing among oil palm.

Figure 35. **WNB**, Dire VOP: *E.calcarata* midden ("frass pile")

Figure 36. **WNB,** Dire VOP, marked pair *E.calcarata* (*male below with white mark*).

Figure 37. WNB, Dire VOP *Solomon Sar* collecting *E. calcarata.*

Figure 38. WNB, Dire VOP, Entomology team with collection of *E.calcarata*. (l to r: TM, SK, PM, ME, AY)

Figure 39. WNB, Namova VOP, S Makai with *E.calcarata* and *K hospita* stump.

Figure 40. WNB, Namova VOP from rotten stump of *K hospita*.

Figure 41. WNB, damage to oil palm at Namova VOP, in the block where concentrations of *E.calcarata* were first found in the tree *K.hospita* in 2011.

Parasitoids of Eurycantha calcarata

An undescribed species of an egg parasitoid of the Giant Spiny stick insect (*E. calcarata*) was reared successfully from eggs collected in the field from Malilimi Plantation, WNB in the latter part of the year. A description of this insect is being prepared for publication in the on-line journal *Zootaxa*. The females are apterous (wingless) (Fig. 42) and the males, which are much smaller, are macropterous (winged) (Fig. 43).

Figure 42. Female of *Anastatus* **sp. nov**.

Figure 43. Male of *Anastatus* **sp. nov**.

Laboratory studies at Dami have shown that the numbers emerging from a single egg may be of both sexes and may range between 1-9 (mean 4) males and between 8-20 (mean 14) females. Having succeeded in rearing these parasitoids, once they emerge from the host egg after some 43 days, adult male and female parasitoids are fed with 10% honey on emergence, and are subsequently released in areas where there are stick insects to be found causing obvious damage either to palms or bananas (Fig. 44). Specific field releases began in October 2011, and approximately 2,820 have been released in WNB (Table 5).

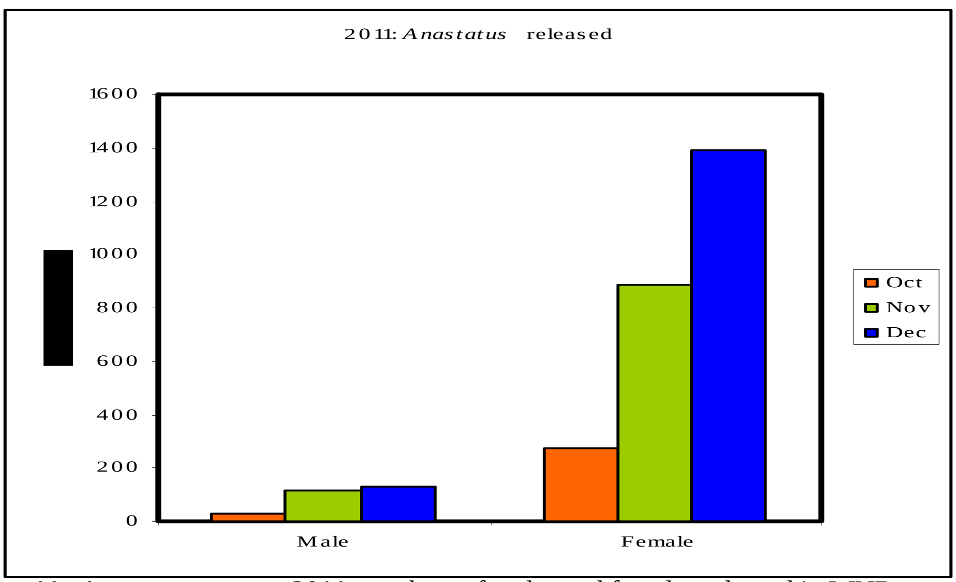


Figure 44. *Anastatus* **sp nov**. **2011,** numbers of males and females released in WNB.

Table 5. 2011. Release localities in 3 smallholder blocks and 2 plantations in WNB.

Anastatus **: release sites**

OPIC	**Plantations**
Banaule	Haella
Dire	Lotomgam
Namova	

Once the mass rearing technique had been set up and parasitoids were being produced, basic biological studies were undertaken to ascertain the effect of food, longevity, fecundity and sex ratios. These studies are still being undertaken. Although releases have been done in WNB where there are known populations of *E. calcarata* (Fig. 45, 46), releases will also be done in NI as our stocks improve.

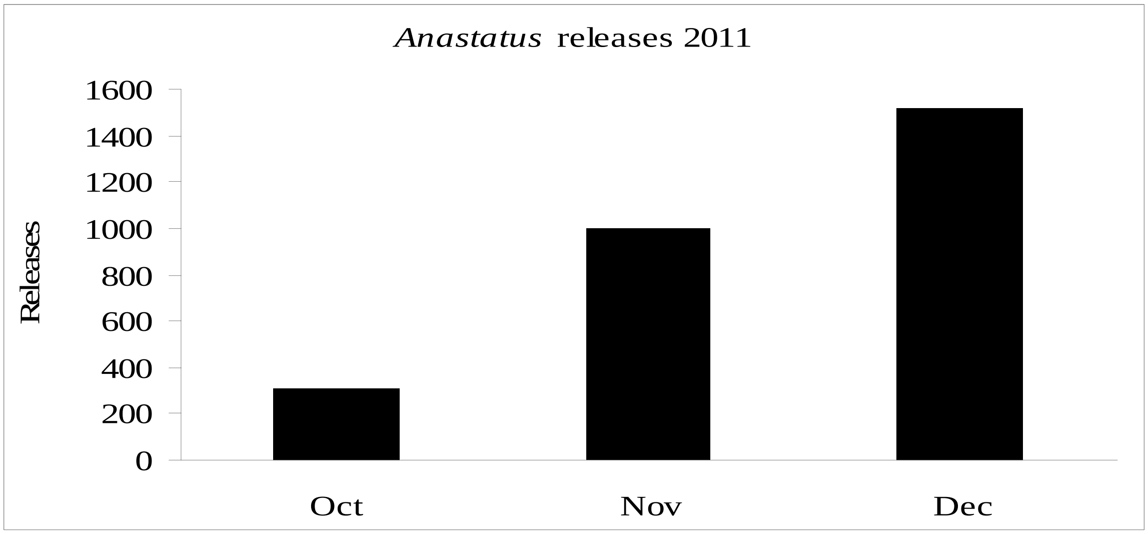


Figure 45. 2011 *Anastatus* **sp. nov**., monthly releases in selected localities in WNB.

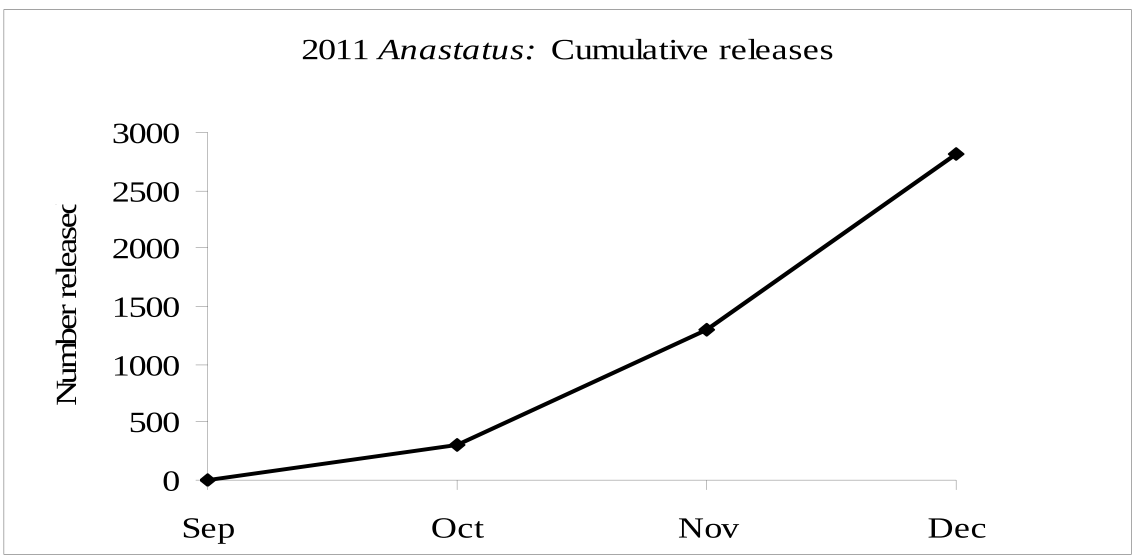


Figure 46. 2011 *Anastatus* **sp.nov**. cumulative releases at selected sites in WNB.

Feeding trials for Stick insect, Eurycantha insularis
(Diploma Student, Elizabeth Nyani-PNG University of Natural Resources and Environment).
This work was not fully completed as the student dropped out from University before submitting the final report. On preliminary analysis, approximately 0.6gm of leaf material was eaten per day for a late instar male nymph (Fig.47) and 0.96gm for female nymphs (Fig.48). There are still data that remain to be analysed, however adults will consume more of the leaf material. These results and subsequent studies will provide valuable information on biomass removal at differing pest densities.

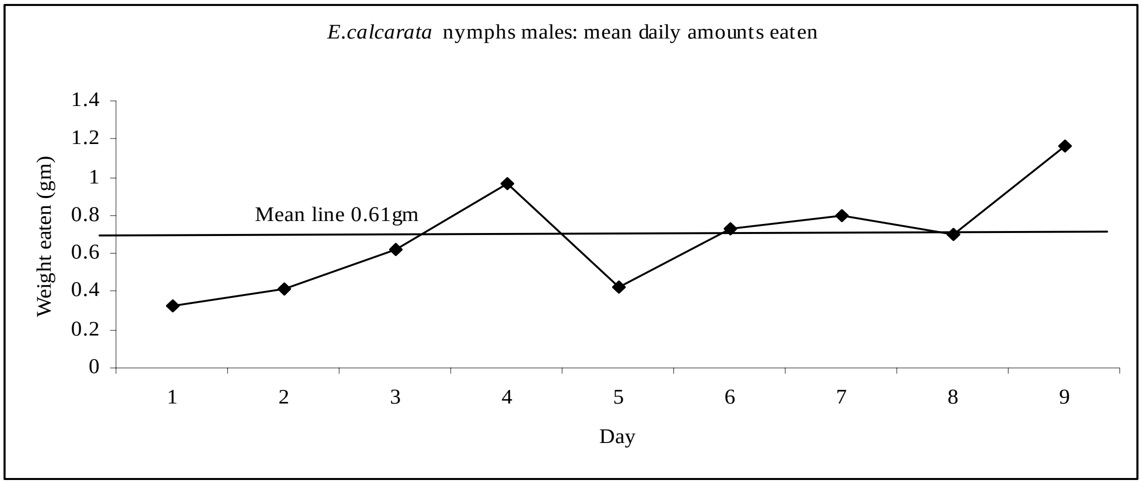


Figure 47. 2011 Leaflet weight consumed from oil palm leaflets by male *E.calcarata* nymphs.

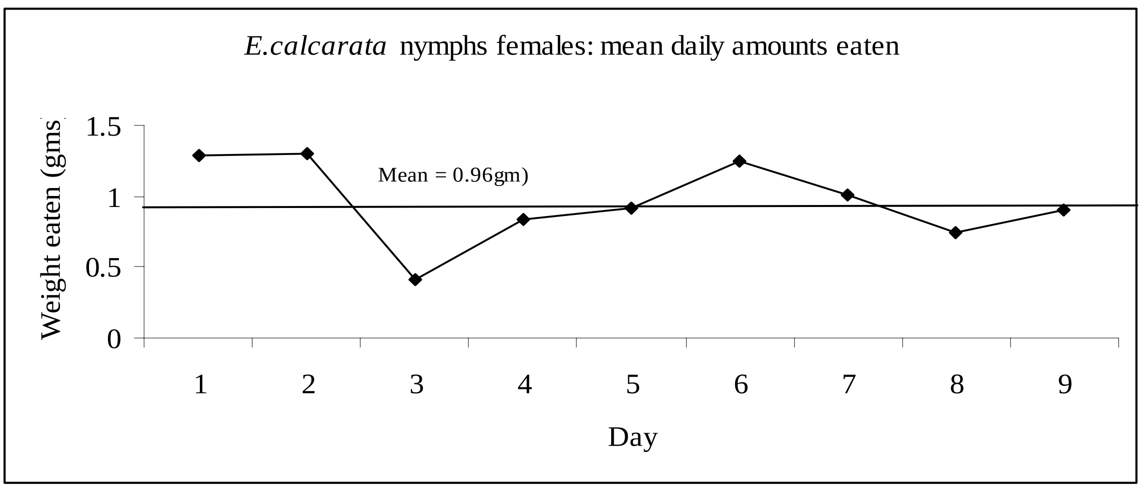


Figure 48. 2011 Leaflet weight consumed from oil palm leaflets by female *E.calcarata* nymphs.

Psychidae (Bagworm) monitoring (RSPO 4.5, 8.1)
Monthly surveys were conducted at Ambogo Estate, Northern (Oro) Province in 2010 and 2011 to estimate the level of infestations by *Manatha* sp. E (Ice Cream Cone Bagworm, Fig.49) and *Eumeta variegata* (Smooth Bagworm, Fig.50). The collections were made from fronds 17 and 25 on 9 palms on every 10^{th} row over 14 rows (n = 252). Table 6 shows that the total number of *E. variegata* decreased slightly between 2010 and 2011, whilst the number of *Manatha* sp. increased. However, the number alive increased for both pests. *Eumeta variegata* increased by about 1.2 times whilst *Manatha* sp. E increased by about 3.6 times.

In spite of the increase in the number of live insects between the two years, annual percentage mortality still remained relatively high for both pests (36% and 35% respectively). The monthly percentage (%) mortality for both species was also consistently high ranging between 30% and 70% (Fig. 6). The mortality was due to natural enemies and unknown causes which still require further investigation.

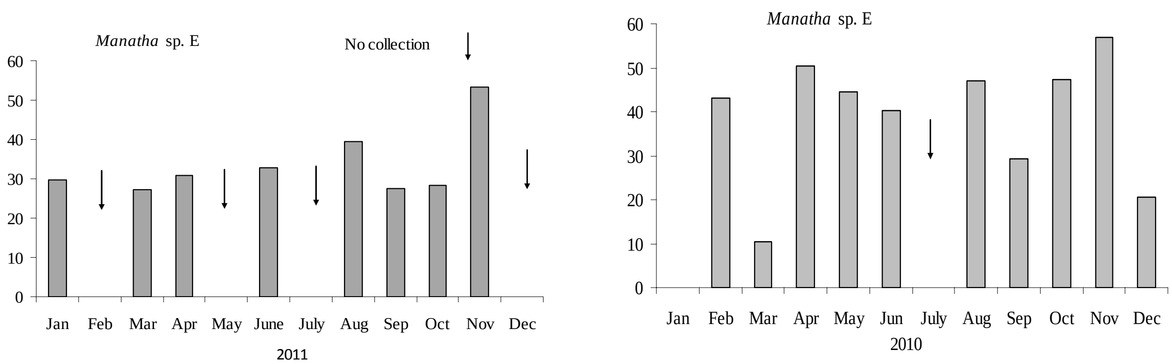


Figure 49. 2011 & 2010 for comparison, *Manatha* sp.E Northern Province, Ambogo Estate: monthly monitoring. No sampling was done in Feb, May, July & December

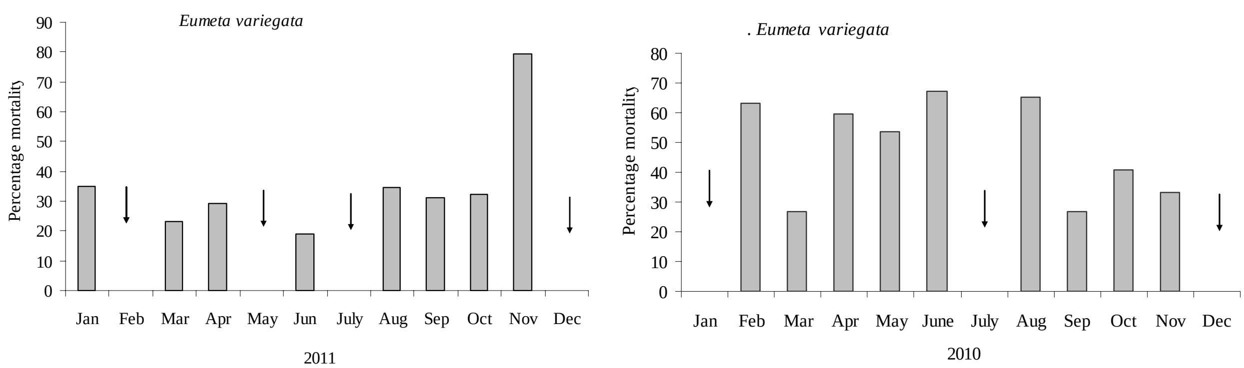


Figure 50. 2011 & 2010 for comparison, *Eumeta variegata*.E Northern Province, Ambogo Estate: monthly monitoring. No sampling was done in Feb, May, July & December

Although sampling was not regular throughout the year, number of bags never exceeded 2.5 per frond, while mortality from natural enemies and unknown sources remained high for both species (Table 6). Results showed that the incidence of bagworm attack was becoming more serious and it is likely that decisions will have to be made early in 2012 if control is required. Table 6 also shows an increase in total numbers recorded, with more than a three-fold increase of *Manatha* sp.E. This was matched by a similar rise in mortality. This increase in the population may require treatment to be undertaken in 2012. The descriptive paper for the undescribed species of bagworms (with Peter Hattenschwiler, Switzerland) is still on-going but progressing slowly, due mainly to the lack of suitable female pupae for descriptive purposes.

Table 6. Northern Province**,** Ambogo Estate, bagworm sampling: total numbers collected.

	E.variegata		*Manatha* sp. E	
	2010	***2011***	***2010***	***2011***
Number alive	199	232	678	2432
Number dead	174	129	494	1296
Total	**373**	**361**	**1172**	**3728**

Hemiptera: *Zophiuma butawengi* (=*lobulata*), and Finschhafen Disorder (RSPO 4.5, 8.1)
The proposed additional work on mass rearing of parasitoids was postponed indefinitely until there are staff and lab space available. Discussions are on-going with Charles Sturt University to begin this work in 2012 (Fig. 51).

Mycopathogens of *Z. butawengi*: M.Phil study, Deane Woruba (RSPO 4.5, 8.1)

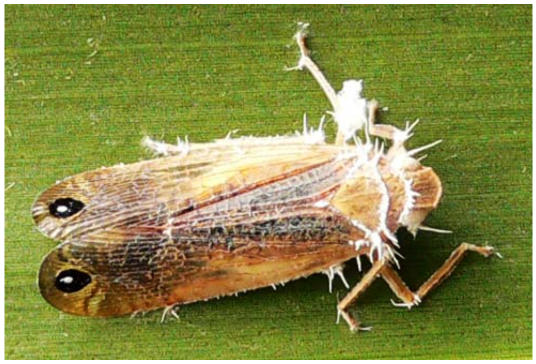


Figure 51. Adult of *Z.butawengi* attacked by entomophagous fungus.

Deane Woruba, recipient of the ACIAR John Allwright Fellowship in 2008 completed his Master of Philosophy (M.Phil.) studies in August 2011 at Charles Sturt University (CSU), Orange, New South Wales, Australia. The thesis was completed and submitted requiring only minor changes. DW resigned from PNGOPRA in December.

Queen Alexandra Birdwing butterfly (*Ornithoptera alexandrae*) (RSPO 5.2, 8.1)
Collaborative work with OPRS (Tissue culture laboratory) continued with emphasis on improving propagation techniques based on multiplication of *Pararistolochia* vine of known origin (used as food plant by QABB). Pinning-down of cuttings does work, however the multiplication rate is slow, and further attempts at bud-tissue culture techniques will be attempted using new anti-fungal materials. We have therefore continued to concentrate on propagating and using known origin vine cuttings ("authentic vines"). We are also using larvae of *O. priamus* as models for feeding study, as we still do not have authority to handle *O. alexandrae*.

The review paper co-authored by WW Page, CFD and D Mitchell is still with the third author awaiting the addition of final references.

SMALLHOLDER AGRICULTURAL DEVELOPMENT PROJECT (SADP) (RSPO 4.4, 8.1)
Aquatic ecosystem health-determination of indicators.
Although the ordering of equipment was completed by the end of the year, only a part of the order was received. SADP/OPIC agreed to fund the services of a specialist aquatic biologist, and the advertising and recruitment process was arranged later in the year. A potential candidate was identified and the process will be completed in January 2012.

REFERENCE AND REPRINT (ENDNOTE) DEVELOPMENT AND INSECT REFERENCE COLLECTIONS (RSPO 8.1)
Publication/Reprint collection
The current figure of reprints and abstracts held in the EndNote database is 875.
Specimen collection
Additional insect material was added to our reference collection and the database updated.

TRAINING AND FIELD DAYS (RSPO 1.1, 4.8, 8.1)
In-house and external training remains an important focus of our programmes. We encourage visits and are involved in both plantation and smallholder training. The field days organised by OPIC were

well attended during the year however latterly, due to the re-structuring of the OPIC Hoskins and Bialla Projects, most were postponed or cancelled (Table 7). Of those that were held, a total of 1,453 adults with children attended (705 men, 271 women and 477 children), and much interest was shown.

Training days were also held on New Ireland in VOP blocks. 14 field days were held and a total of 221 people attended (188 men and 33 women, children were not recorded) (Table 8). These field days also included input from Agronomy staff. Four radio programmes were made during the year in WNB, which were well received according to local feedback.

Table7. OPIC field days (including those attended by entomology staff).

Date	Division	Event	Location	Attendees	Number of attendees			
15-Mar-11	OPIC Radio	Radio	WNB	WNB	**Male**	**Female**	**Child**	WNB OPIC Radio
04-Apr-11	NBPOL		OPRS					**Total**
04-Apr-11	NBPOL		SHA TTI (Kapiura & Mosa)					
04-Apr-11	NBPOL	Pesticide Safety	OPRS					
05-Apr-11	NBPOL	Treatment team	OPRS					
05-Apr-11	Nahavio	Field Day	Hak					89
12-Apr-11	Maututu	Field Day	Barema					149
12-Apr-11	Nahavio	Ismin						80
13-Apr-11	OPIC	Treatment team	Soi					7
19-Apr-11	OPIC	Field Day	Dami					63
26-Apr-11	OPIC	Field Day	Buluwara					29
03-May-11	OPIC	Field Day	Waisisi					
10-May-11	OPIC	Field Day	Valoka					54
24-May-11	OPIC	Field Day	Koimumu OPRA Trial	150	42	2	1	45
31-May-11	OPIC	Field Day	Karapi ME	150	17	0	0	17
07-Jun-11	OPIC	Field Day	Buvussi Sect 9 Block 1312	200	75	19	19	113
14-Jun-11	OPIC	Field Day	Buvussi community	200	95	10	250	355
20-Jun-11	OPIC	Field Day	Galai 2	70	17	45	14	76
28-Jun-11	OPIC	Field Day	Galai 1	100	140	34	30	204
28-Jun-11	OPIC	Radio WNB	WNB	WNB				
12-Jul-11	OPIC	Field Day	Laeri		45	12	10	67
19-Jul-11	OPIC	Field Day	Kavui Section 11		129	67	75	271
26-Jul-11	OPIC	Field Day	Buluma VOP		88	74	59	221
09-Aug-11	OPIC	Field Day	Kae VOP		38	6	5	49
10-Aug-11	NBPOL	Pest ID & Monitoring	Kapiura Division					1
05-Sep-11	OPIC	Pest Monitoring	Buvussi		4			
06-Sep-11	OPIC Radio	Radio WNB		WNB				
09-Sep-11	OPIC	Pest Monitoring	Kavui		5			
12-Sep-11	OPIC	Pest Monitoring	Siki LSS		2	1		
14-Sep-11	OPIC	Pest Monitoring	Nahavio		4			
21-Sep-11	OPIC	Pest Monitoring	Salelubu		5	1		
04-Oct-11	OPIC	Radio WNB	Radio WNB	WNB				
07-Nov-11	ARDSF	Workshop						

Table 8.

New Ireland: Field days summary2011

Date	Location	Type	Men	Women
28/06/2011	Bura	VOP	53	20
03/08/2011	Katedan	VOP	8	0
06/09/2011	Lavolai	VOP	10	3
20/09/2011	Amba	VOP	11	0
27/09/2011	Kafkaf	VOP	23	8
10/10/2011	Lossu	VOP	17	0
29/11/2011	Putput 2	VOP	31	1
01/12/2011	Maranawai	VOP	8	1
13/12/2011	Lakurumau	VOP	27	0
		Totals	**188**	**33**
		All attendees	**221**	

IPM Working Group held at Hargy Oil Palms offices (RSPO 8.1)
One IPM Working Group (IPMWG) meeting were held during 2011.

SEED PRODUCTION UNIT (SPU) (RSPO 5.1, 8.1)
Routine monitoring of traps was erratic during the year due to major refurbishment of the seed production facility, however on the occasions when material was checked, no insect taxa of quarantine concern were identified. Routine monitoring will continue once refurbishment has been completed.

DATABASE OF INSECTS ON OIL PALM (RSPO 4.5, 8.1)
To date some 205 different species have been added to the database, which is maintained in Entomology Section. Many of these are not recognised as pests but for which mention has been made in the literature, even if vaguely. There is a large amount of information on many of the Homoptera (scale and mealy bugs) which has not been included, as they are still so complicated taxonomically. The information will be added to as and when new information is available.

VISITORS TO ENTOMOLOGY SECTION IN 2011
More than 121 official visitors were addressed by entomology staff during 2011. Representatives visited from:

ACIAR, POM
Agropalma, Brazil
Bishop Museum, Hawai'i
CIC, Aiyura, PNG
Conservation International, Alotau, PNG
Curtin University, Australia
DAL, Kimbe, PNG
Hargy Oil Palms, Bialla, PNG
Kula Group, NBPOL
NBPOL
NARI World Bank
OPIC, Hoskins Project, OPIC Bialla, PNG
NAQIA, POM
UCAL, Malaysia
UK visitors
Unitech, Lae

PUBLICATIONS.
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Day, M. D., Kawi, A.P., Fidelis, J., Tunabuna, A., Orapa, W., Swamy, B., Ratutini, J., Saul-Maora, J., Dewhurst, C.F. (2011). **Biology, field release and monitoring of the rust *Puccinia spegazzinii*, de Toni (Pucciniales: Pucciniaceae), a biocontrol agent of *Mikania micrantha* Kunth (Asteraceae) in Papua New Guinea and Fiji.** *13th International Symposium for Biological Control of Weeds, held in Hawaii from 11-16th September 2010.*

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3. PLANT PATHOLOGY SECTION

HEAD OF SECTION: CARMEL PILOTTI

THE EPIDEMIOLOGY OF BASAL STEM ROT (RSPO 4.1, 4.5, 8.1)

Introduction

Disease levels in all plantations continue to be monitored and 2011 was an important year as a lot of areas in Poliamba and Milne Bay were due for replant. Knowledge of disease levels at replant may assist in disease management in future plantings.

Methodology

Survey data presented here has been obtained from Milne Bay Estates Ltd., Poliamba Ltd., Higaturu Oil Palms Ltd. and New Britain Palm Oil Ltd. All data has been corrected where possible and only infections for 2011are included. Ganoderma survey data for Blocks 6404, 6503, 6504, 7213 and 7214 and Fields E4 and E5 were collected by OPRA personnel in biannual (Milne Bay) or monthly (West New Britain) surveys. Blocks 6404, 6503, and 6504 were replanted this year.

Disease progress in first generation oil palm

Milne Bay Estates

A summary of 2011 Ganoderma (total of confirmed and suspect palms) disease levels for Divisions in Milne Bay is shown in Figure 1 Bunebune and Tamonau recorded the highest disease incidences of 2.3 and 2.5% respectively. Most other Divisions recorded below 1.5%. Most of Bunebune was replanted in 2011.

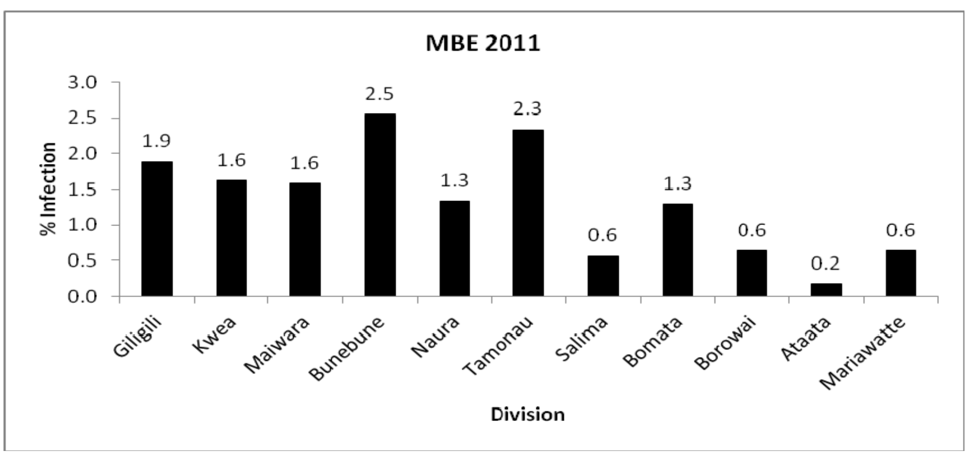


Figure 1. Disease incidences in Milne Bay Estates plantations in 2011.

Figures 2 to 10 show the disease incidence for all blocks in 9 Divisions in Milne Bay. Data for Padipadi Division is not presented. The highest recorded incidence in Giligili Division was Block AC1140 (Figure 2) with a reported incidence of 4.4 %. This is unusually high. Kwea Division also reported blocks with disease incidences higher than normal (3-5.8%) (Figure 3). This may be a reflection of the greater vigilance during surveys in 2011 as these blocks were to undergo replant in 2011/2012. High disease incidences were also recorded for a large percentage of blocks at Maiwara (Figure 4) and Tamonau (Figure 5). Blocks in all other Divisions generally had disease incidences below 1.5%.

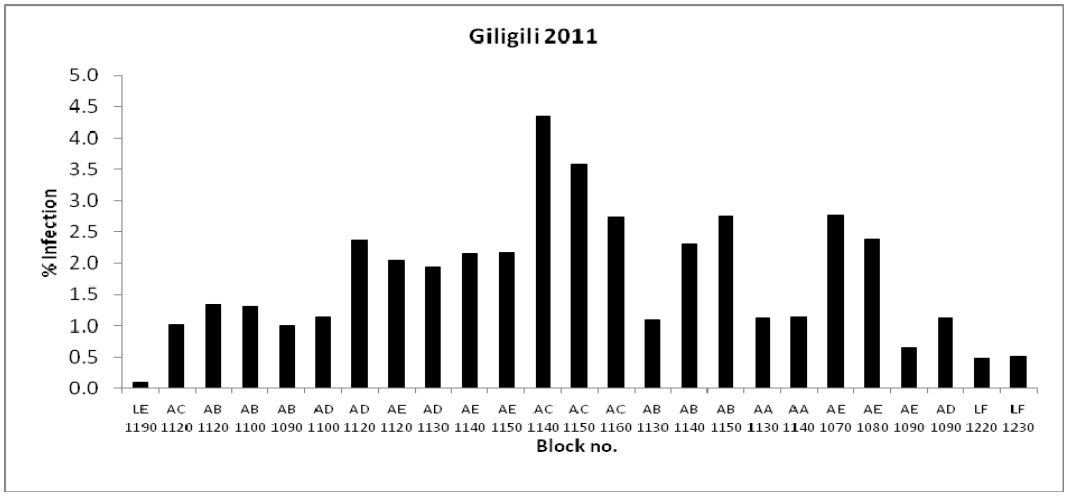


Figure 2 Disease incidences for block in Giligili Division in 2011.

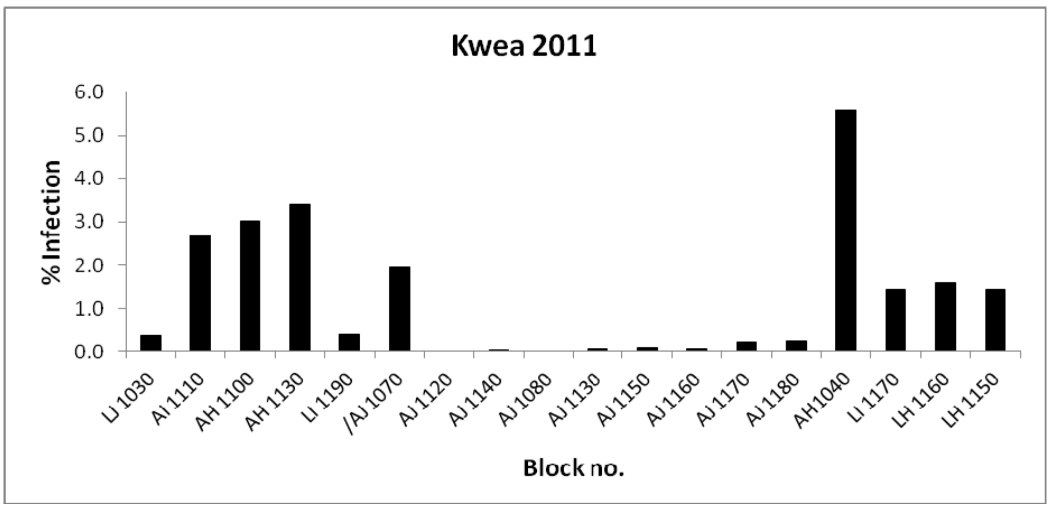


Figure 3 Disease incidences for blocks in Kwea Division,Milne Bay Estates in 2011.

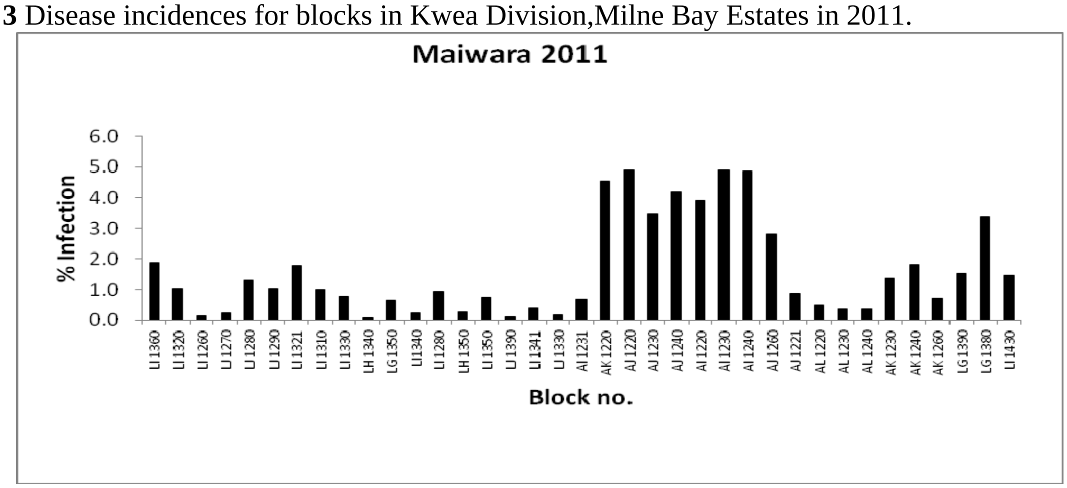


Figure 4 Disease incidences for blocks in Maiwara Division, Milne Bay Estates, in 2011.

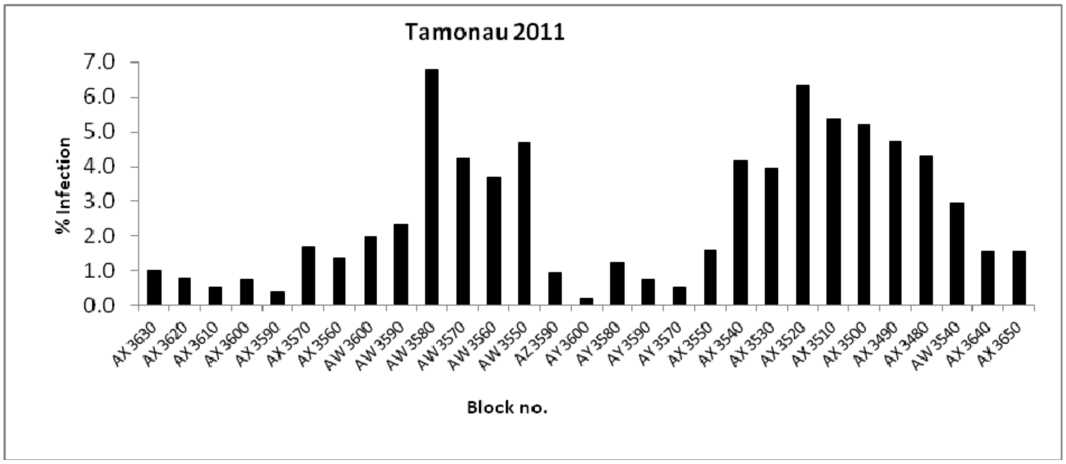


Figure 5 Disease incidences for blocks in Tamonau Division, Milne Bay Estates, in 2011.

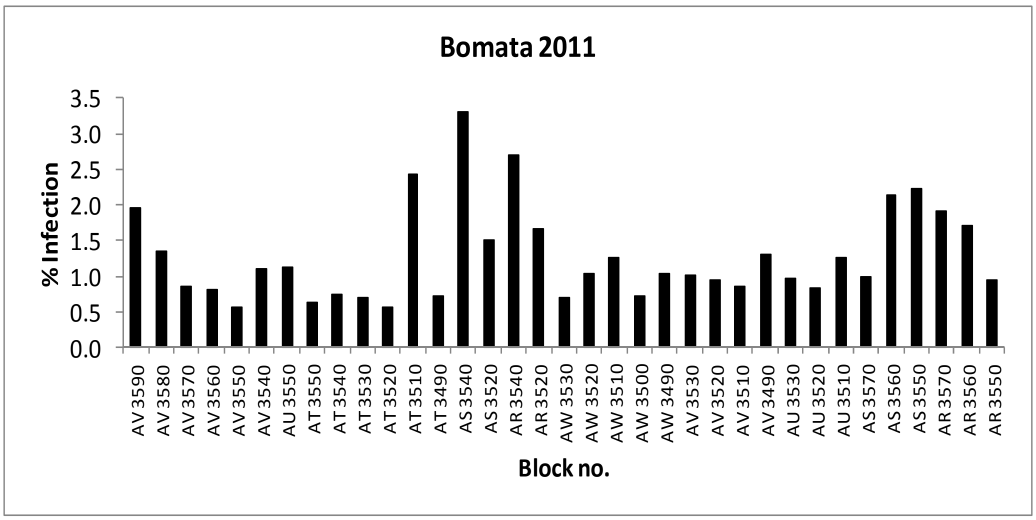


Figure 6 Disease incidences for blocks in Bomata Division, Milne Bay Estates, in 2011.

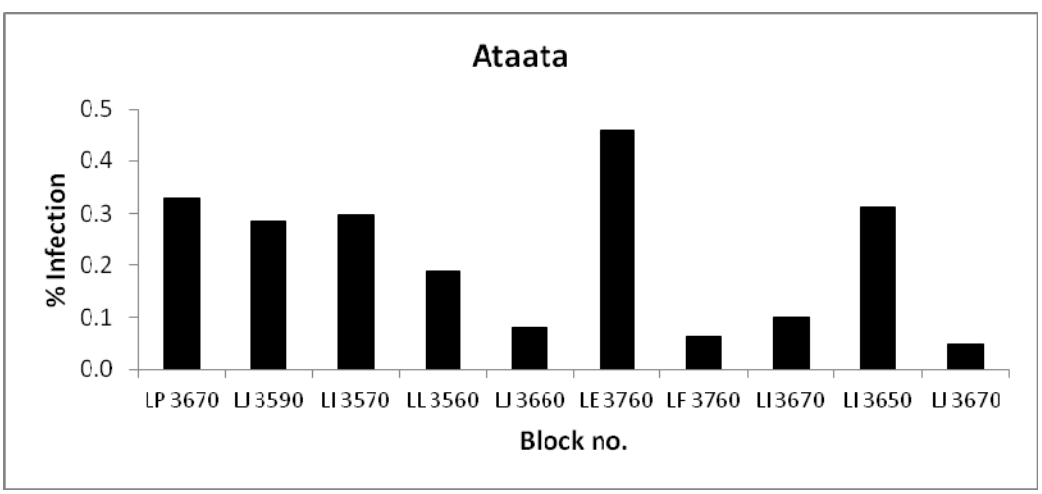


Figure 7 Disease incidences for blocks in Ata'ata Division, Milne Bay Estates, in 2011.

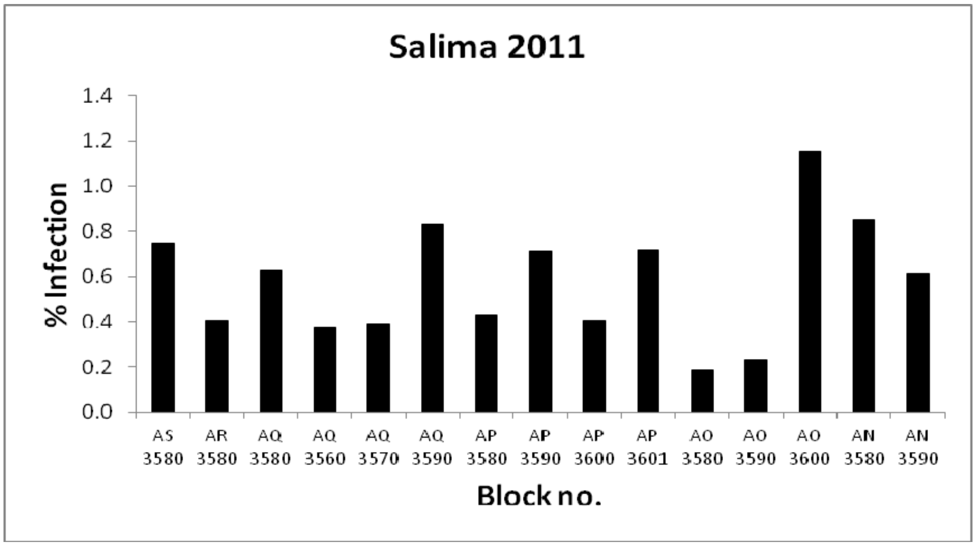


Figure 8 Disease incidences for blocks in Salima Division, Milne Bay Estates, in 2011.

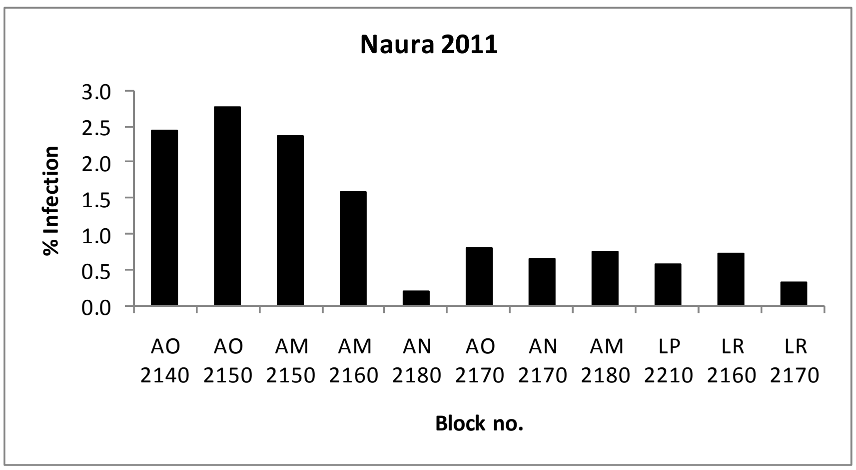


Figure 9 Disease incidences for blocks in Tamonau Division, Milne Bay Estates, in 2011.

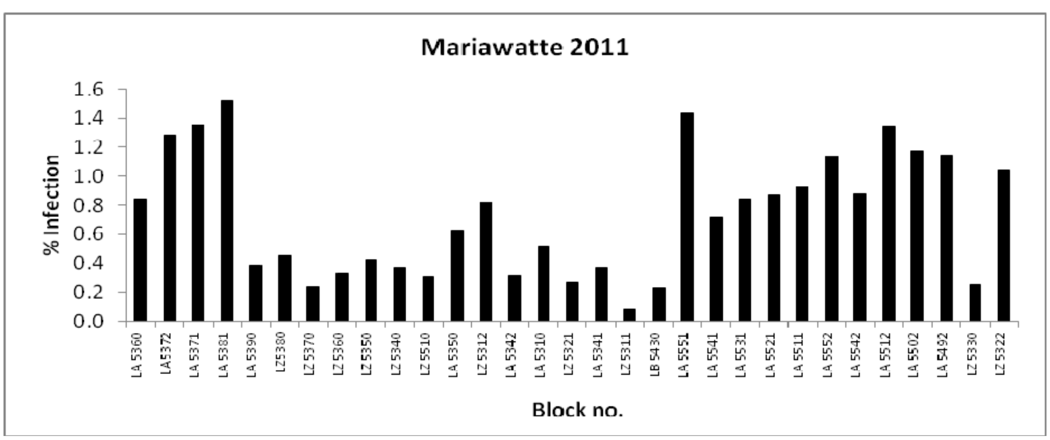


Figure 10 Disease incidences for blocks in Mariawatte Division, Milne Bay Estates, in 2011.

Disease progress in Ganoderma study blocks

Disease incidence in Blocks 7213, 7214, 7501, 6404, 6503 and 6504 for 2011 are shown in Figure 1.11. Block 7214 which recorded the highest disease incidence in 2010 also recorded one of the highest in 2011. The low disease levels recorded for Blocks 6503 and 6504 were due to replanting of these blocks mid-year. Block 7501 was replanted in 2010. The remaining blocks are due for eplant in 2012.

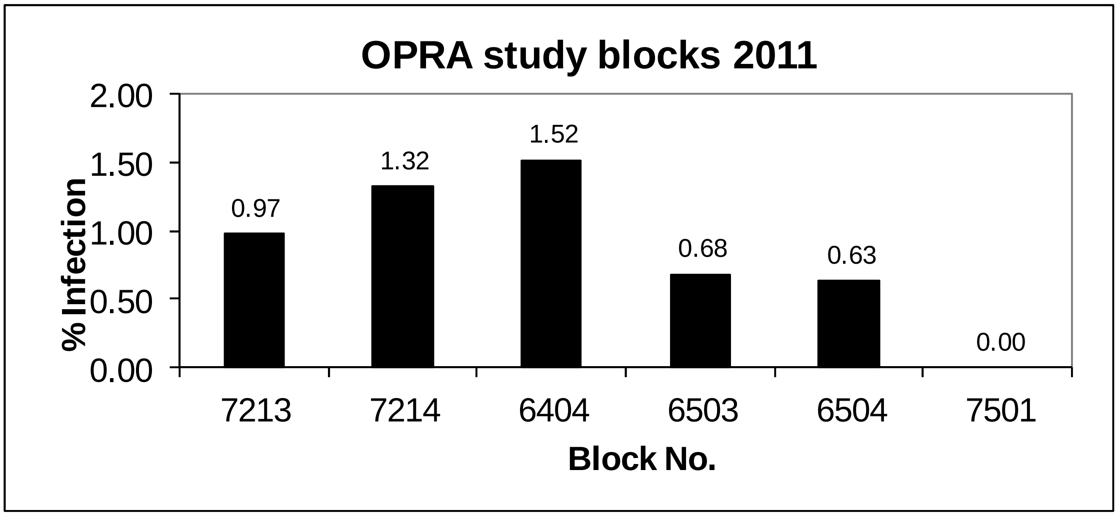


Figure 11 Incidences of Ganoderma in OPRA study blocks in Milne Bay in 2011.

Updated disease progress curves for these six blocks are shown in Figure 1.12. Block 6504 had the highest disease levels with 30.7% and Block 7213 has the lowest incidence of 16.7 %. Incidences of Ganoderma in the remaining blocks are in the range 20.5-22.7%. Blocks 6503 and 6504 and 6504 were replanted in 2011 and disease data was only collected in January 2011. Most of the blocks were/will be replanted with disease levels in excess of 20% and careful monitoring of disease progress in the new plantings will be required.

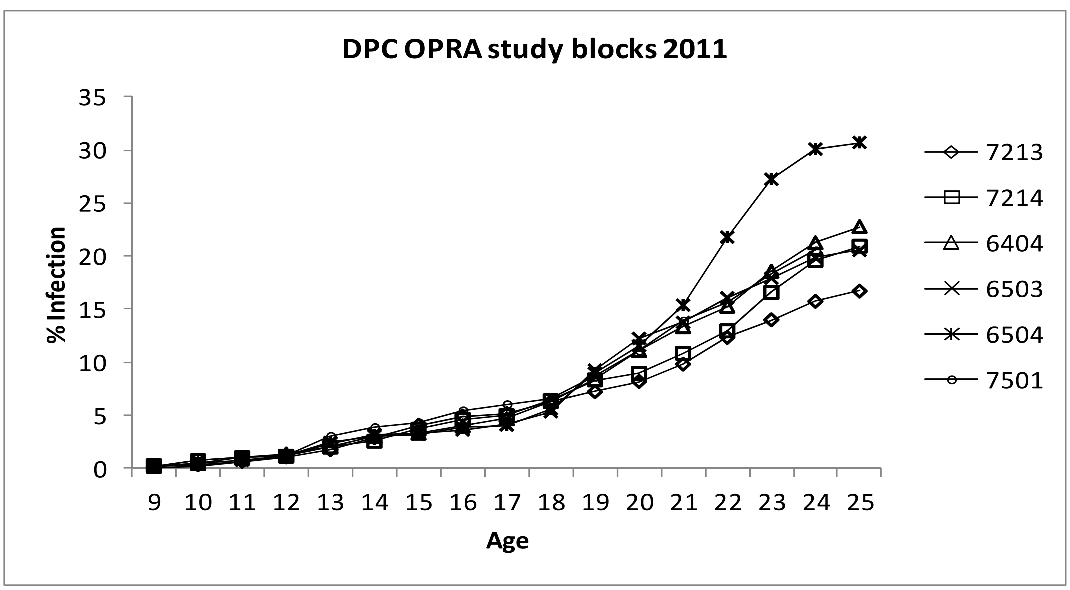


Figure 12 Disease progress curves from 1995 to 2010 for the six blocks selected for study in Milne Bay.

Smallholder Ganoderma – Milne Bay

Disease surveys in VOP blocks continued in 2011 with all accessible blocks with mature (>10yo) oil palm being completed. Surveys were started in blocks with palms less than 10 years old. Table 1.1 shows the number of blocks surveyed and Figures 1.13 to 1.18 depict the survey results for all blocks surveyed in the different Divisions.

In addition to surveys, blocks were also manually mapped in order to prepare the blocks for replanting. GPS data collection in these blocks has commenced but has not yet been completed.

Table 1 Status of Ganoderma surveys and mapping in VOP blocks in Milne Bay Province at the end of 2011.

AREA	TOTAL BLOCKS	SURVEYED	ISO MAP	GPS
LAVIAM/KEKERINA	36	28	28	9
GABUGABUNA	34	18	17	0
LAUTEWATEWA	25	19	19	6
KERAKERA	25	17	17	0
RABE	34	32	32	11
WAEMA	45	35	35	0
LEASEHOLD	6	6	6	0
YANEYANENE	46	46	46	0
KAPURIKA	25	12	12	2
KILAKILANA	24	17	0	0
DELAMA	19	19	19	0
NAURA	39	31	31	0
GUMINI	28	5	0	0
LAUHABA	23	19	19	0
MARAYANENE	21	17	17	0
DIUDIU	11	11	11	3
IPOULI	42	21	0	0
SIASIADA	57	40	0	0
TAMONAU	39	26	12	3
MILA	31	26	0	0
WELLA	10	10	0	0
IWAME	24	15	0	0
FIGO	30	14	5	0
ATA ATA	37	14	0	0
BOROWAI	65	29	9	0

The level of infection in some blocks was very high (e.g. Figure 1.14, Block 10008) but the majority of those recorded were suspect palms and their status could be attributed to other factors besides disease such as poor nutrition and water-logging. There was a very large range in infection levels amongst the blocks surveyed. Accurate historical data on these blocks is lacking and hence it would be difficult to ascertain the causes of this wide variability.

Mapping of blocks that are undergoing replant in 2012 has been completed and a decision is now pending on the best procedures to replant these blocks.

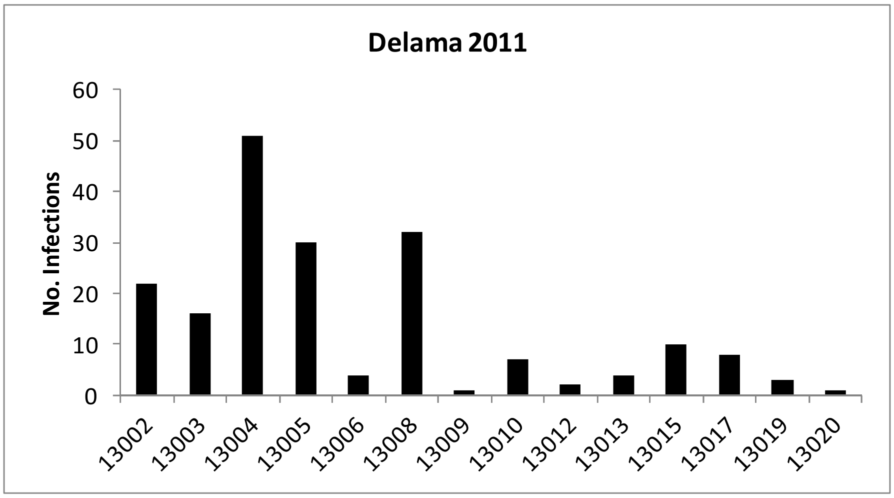


Figure 13 Ganoderma infections recorded for VOP blocks at Delama in 2011.

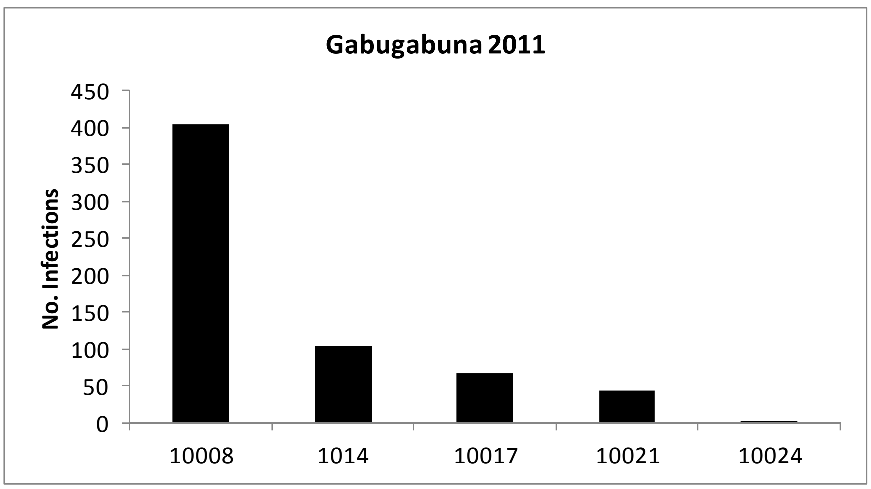


Figure 14 Ganoderma infections recorded for VOP blocks at Gabugabuna in 2011.

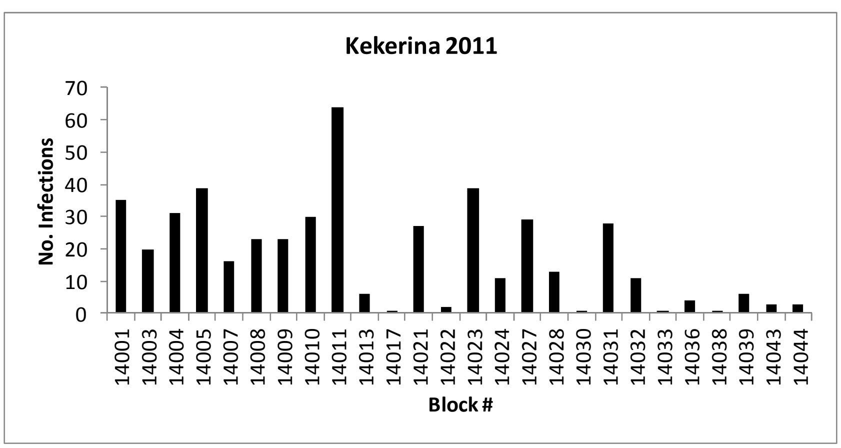


Figure 15 Ganoderma infections recorded for VOP blocks at Kekerina in 2011.

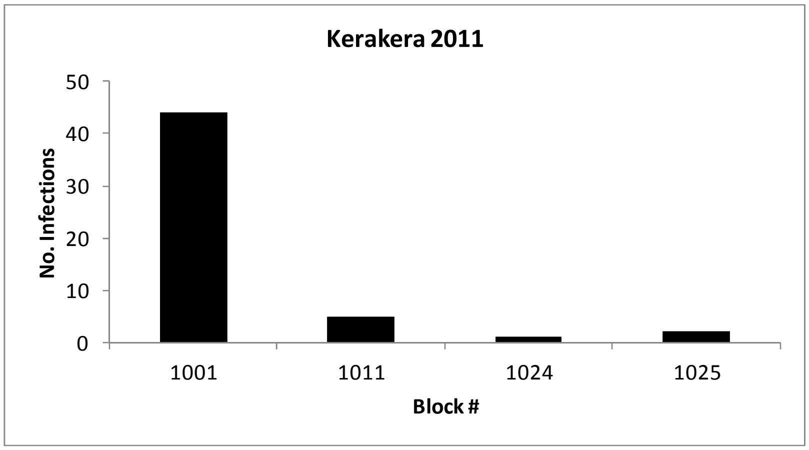


Figure 16 Ganoderma infections recorded for VOP blocks at Kerakera in 2011.

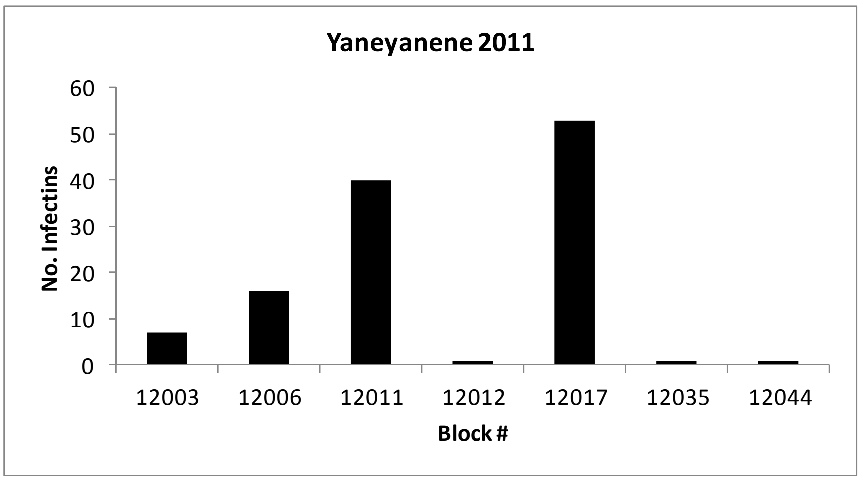


Figure 17 Ganoderma infected palms in VOP blocks surveyed in 2011 at Yaneyanene.

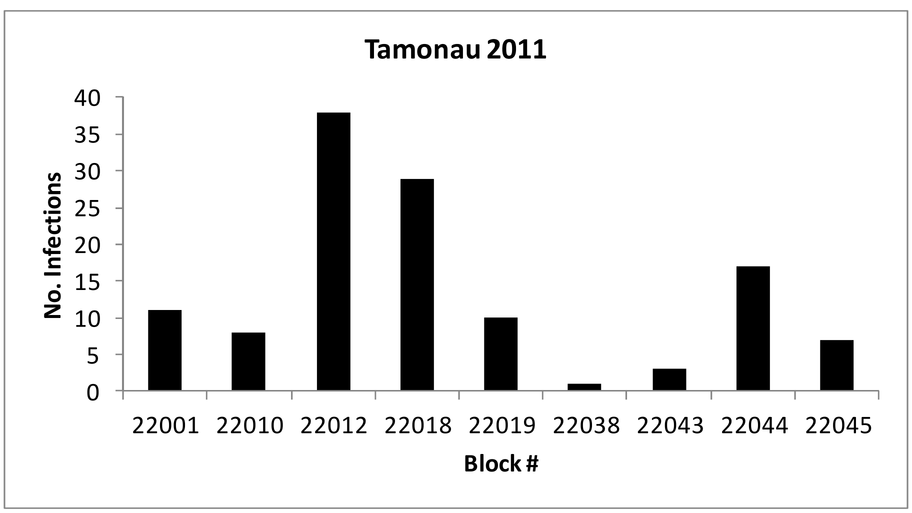


Figure 18 Ganoderma infected palms in VOP blocks in Tamonau,

Poliamba Ganoderma
Ganoderma infection levels recorded for each Estate at Poliamba in 2011are shown in Figure 1.19. In 2011, the highest average disease levels.were recorded for West Coast (Nalik West), followed by Noatsi. These figures are for confirmed Ganoderma (bracket) palms only.

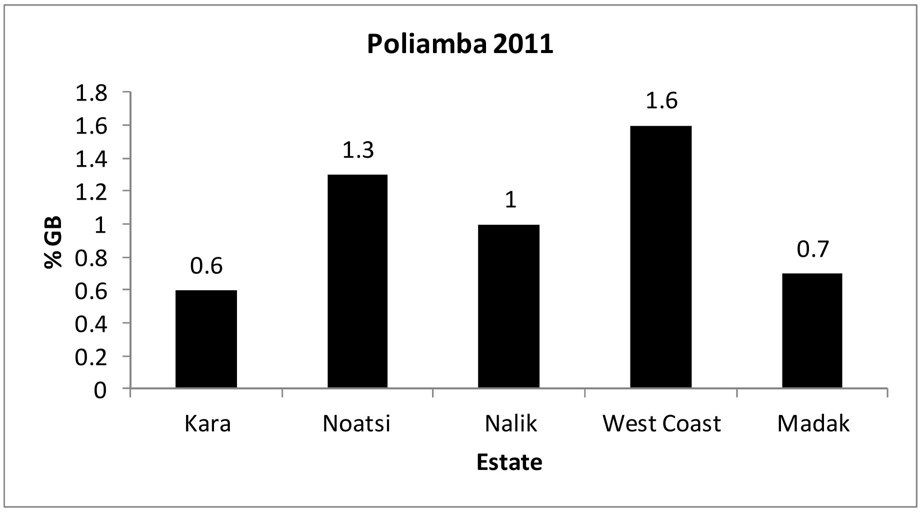
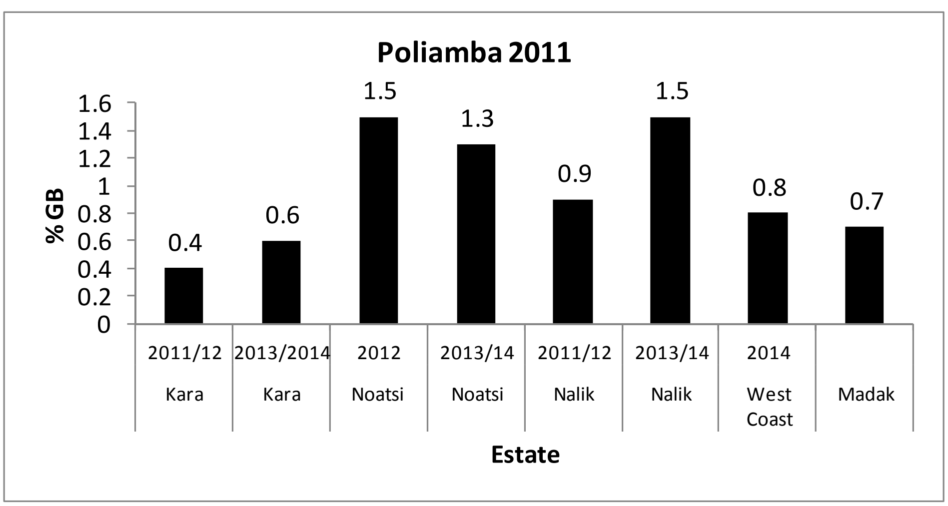
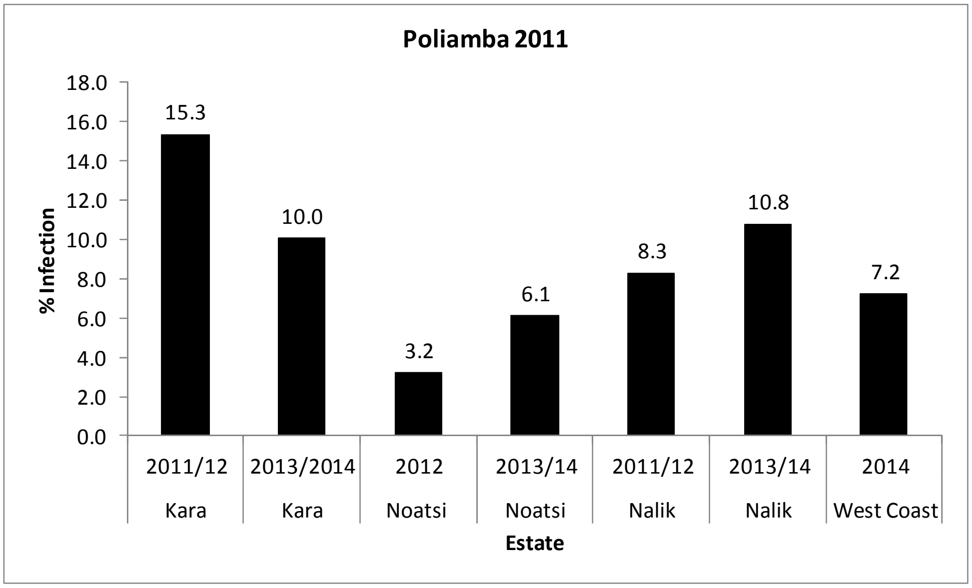


Figure 19 Disease incidences (confirmed Ganoderma only) for each Estate at Poliamba Ltd. in 2011.

As shown in Figure 1.20, levels of infection in replant blocks is highly variable (a) and more so when suspect palms are included in the analyses (b). Blocks in Kara Estate reported very low levels of palms with brackets but increased markedly when suspect palm data was included. These high numbers may be due to palms with deficiency symptoms being recorded as diseased 'suspect' palms. This data should be viewed with caution until further verification can be made.
Similarly, the data for the other Estates. Noatsi 2012 replant blocks recorded approximately 50:50 Ganoderma:suspect palms which is reasonable at this age of the palms.



(a)



(b)

Figure 20 (a) and (b) Ganoderma infection levels for all Estates at Poliamba Ltd., New Ireland in 2011 expressed as the percentage of total (original) palm count. (a) Confirmed Ganoderma only; (b) Confirmed plus suspect palms.

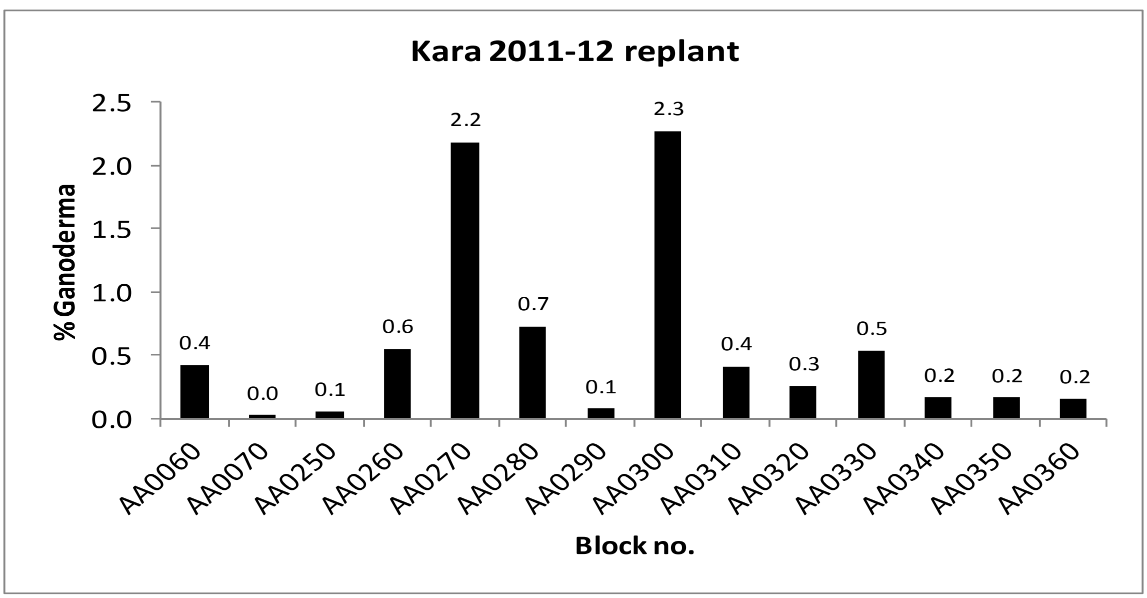


Figure 21 Ganoderma infection levels in 2011 for blocks within Kara Estate undergoing replant in 2011-12.

Disease levels in individual blocks within each estate, grouped according to scheduled planting dates, are shown in Figures 1.21 through 1.28. Data for Madak is for the whole Estate as there are no blocks due for replant within the next 2 years. Again, infection levels were highly variable however there are a significant number of blocks to be replanted that have disease levels above 2% for 2011 alone. These blocks will likely have a history of elevated (>1%) annual incidences and removals therefore need to be thorough. Block ABO590 (Figure 1.25) in Nalik Estate requires further investigation as do blocks with over 4% infection recorded for 2011 in Noatsi 2103-14 replants (Figure 1.27).

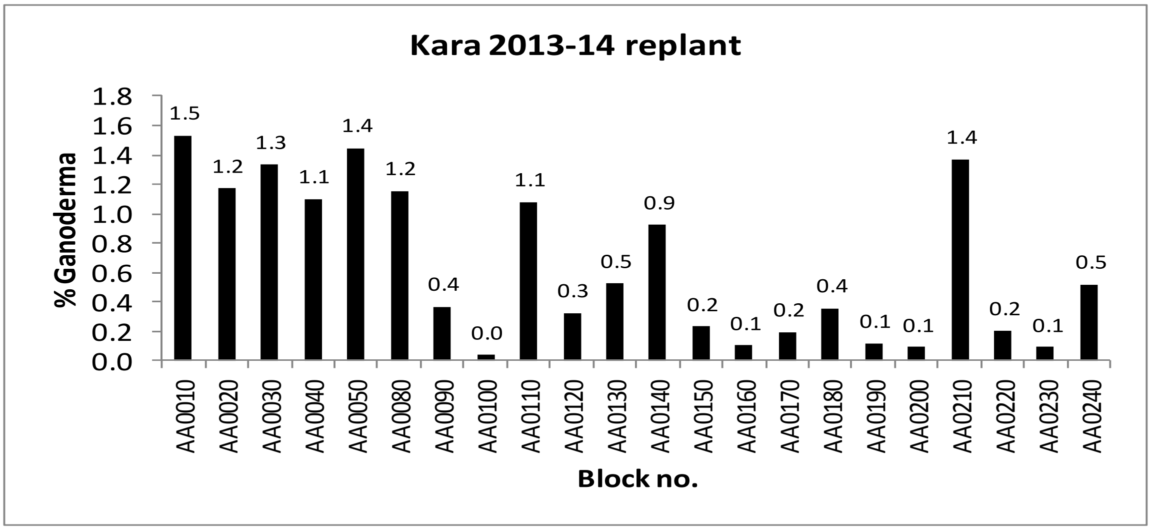


Figure 22 Ganoderma infection levels in 2011 for blocks within Kara Estate due to undergo replant in 2013-14.

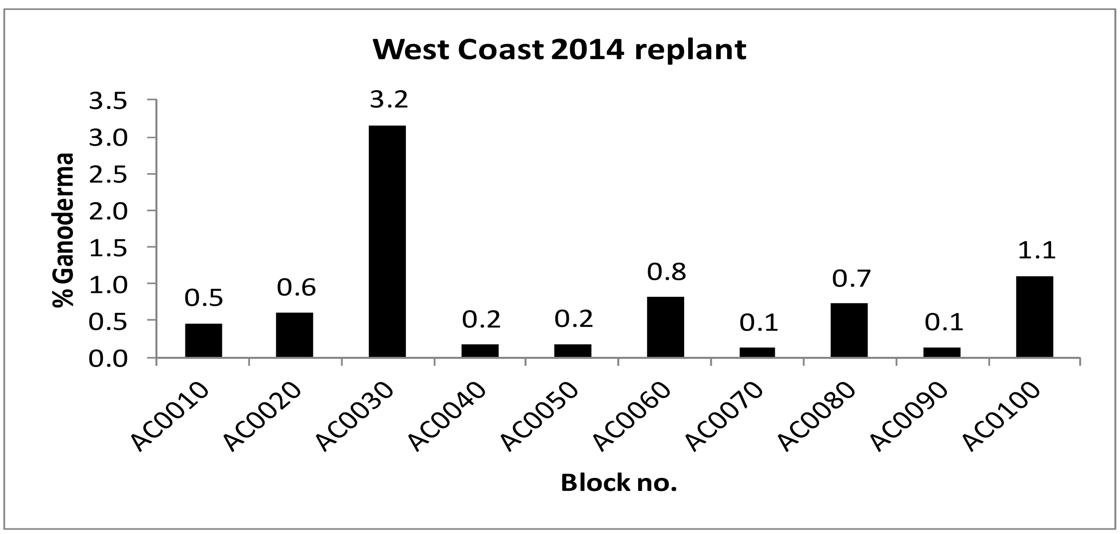


Figure 23 Ganoderma infection levels in 2011 for blocks in West Coast Division due for replant in 2014.

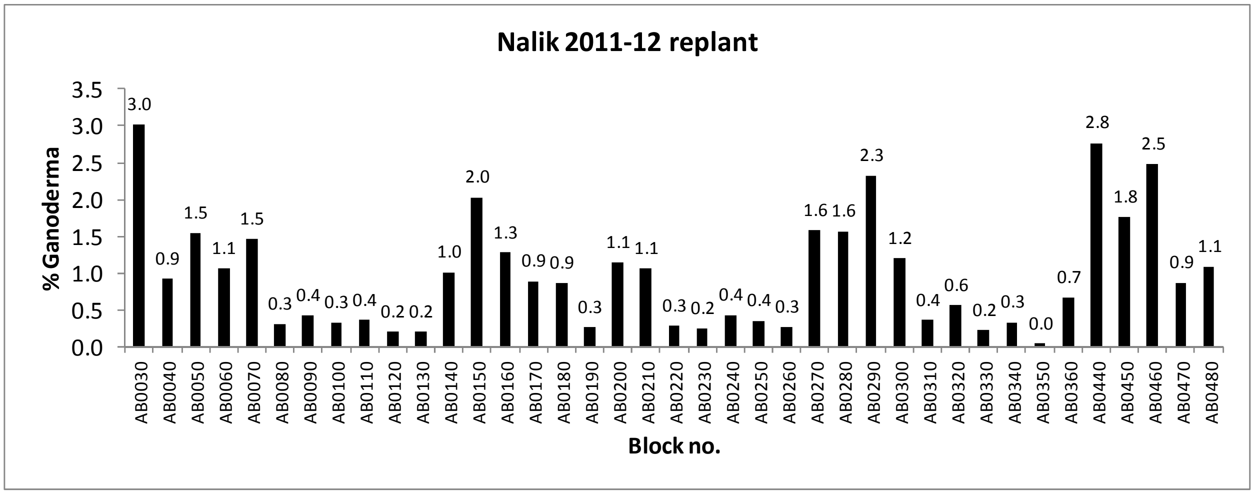


Figure 24 Ganoderma infection levels in 2011 for blocks in Nalik Estate undergoing replant in 2011-12.

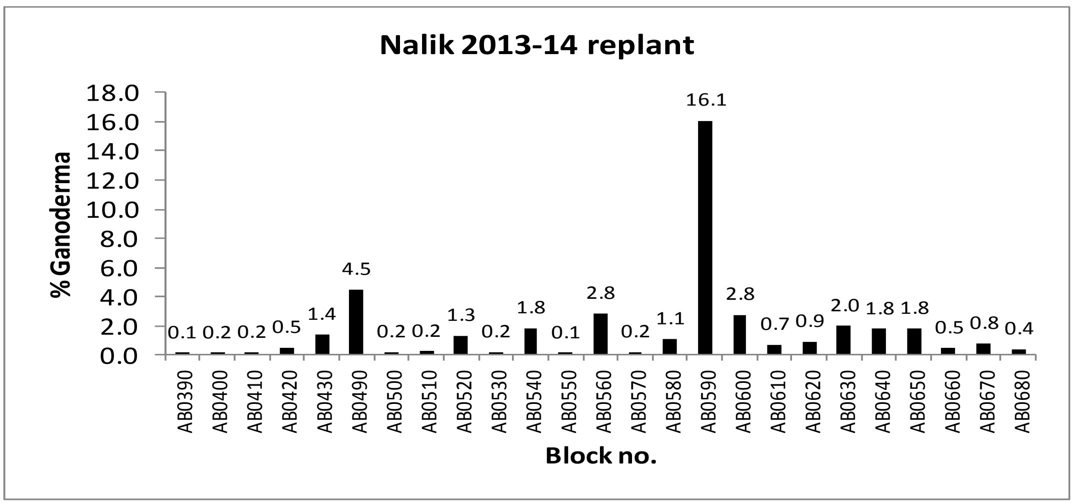


Figure 25 Ganoderma infection levels in 2011 for blocks in Nalik Estate due for replant in 2013-14.

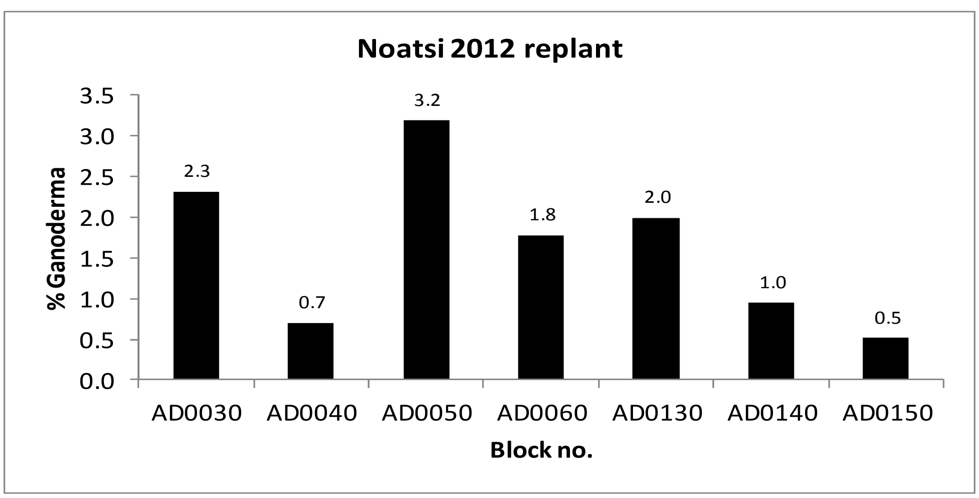


Figure 26 Ganoderma infection levels in 2011 for blocks in Noatsi Estate due for replant in 2012.

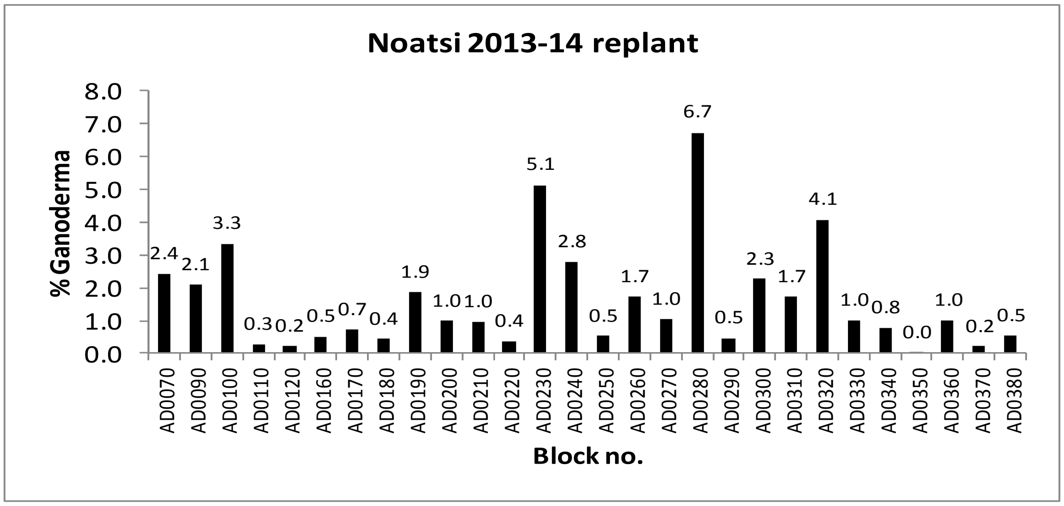


Figure 27 Ganoderma infection levels in 2011 for Blocks in Noatsi Estate due for replant in 2013-14.

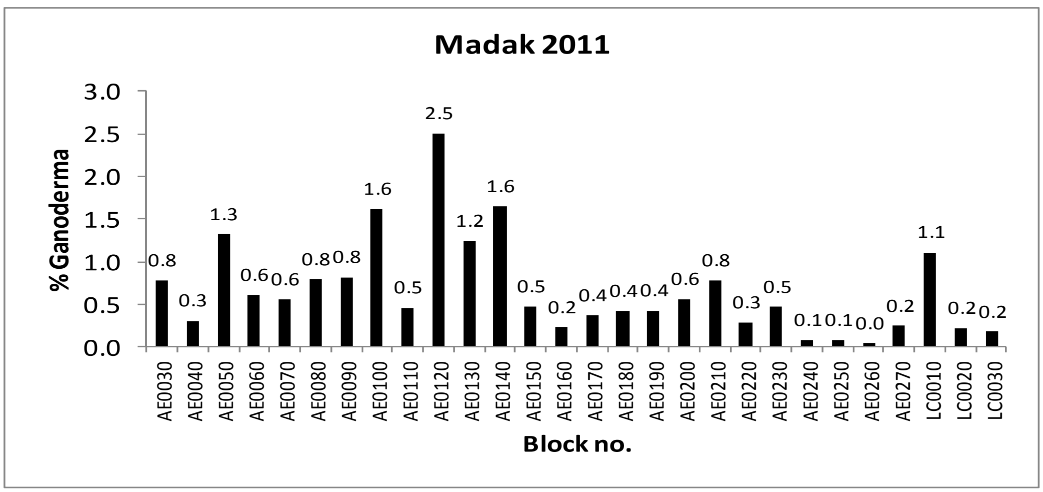


Figure 28 Ganoderma infection levels recorded for blocks in Madak Estate in 2011.

Madak Estate generally recorded low levels of disease (majority under 0.5%) for 2011 which is is expected as some of the youngest plantings are in this Estate (Figure 1.28).

HOPL Ganoderma

Mean disease levels in all Estates at Higaturu Oil Palms Ltd. are shown in Figure 1.29. Ganoderma disease incidences were below 1% in 2011 (lower than in 2010) with the highest recordings at Sangara followed closely by Sumberipa.

Disease incidences at Embi and Ambogo were slightly lower possible due to blocks undergoing replant or a high percentage of immature (<10yrs) blocks.

Disease levels for individual blocks in each of the Estates are shown according to planting dates (Figures 1.30-1.48).

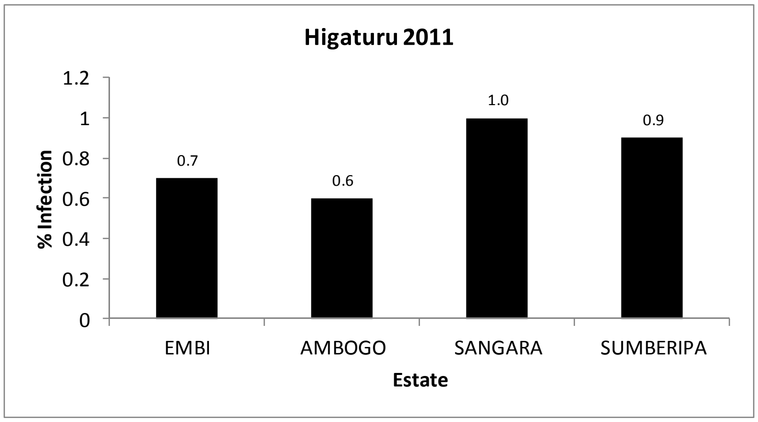


Figure 29 Mean Ganoderma infection levels recorded for each Estate at Higaturu Ltd., Oro Province in 2011.

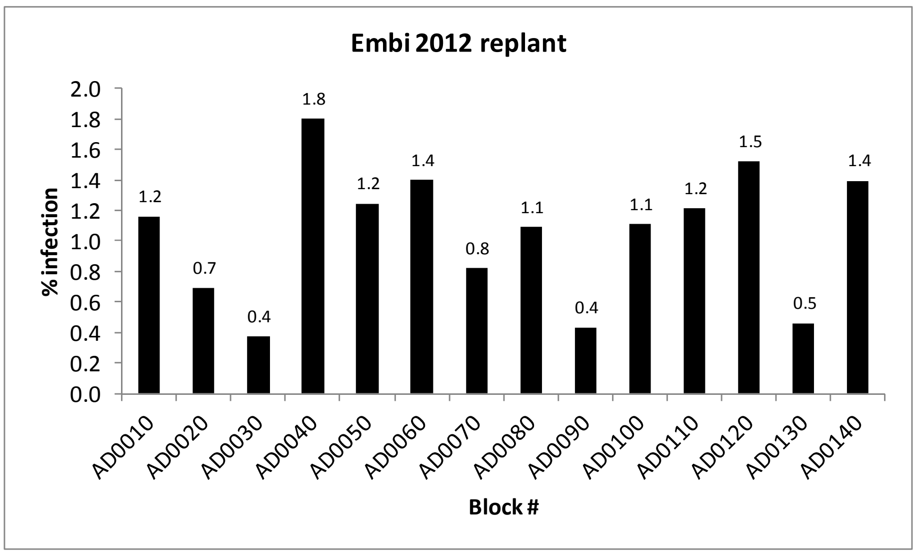


Figure 30 Ganoderma infection levels (total) for 2011 in blocks at Embi Estate due for replant in 2012.

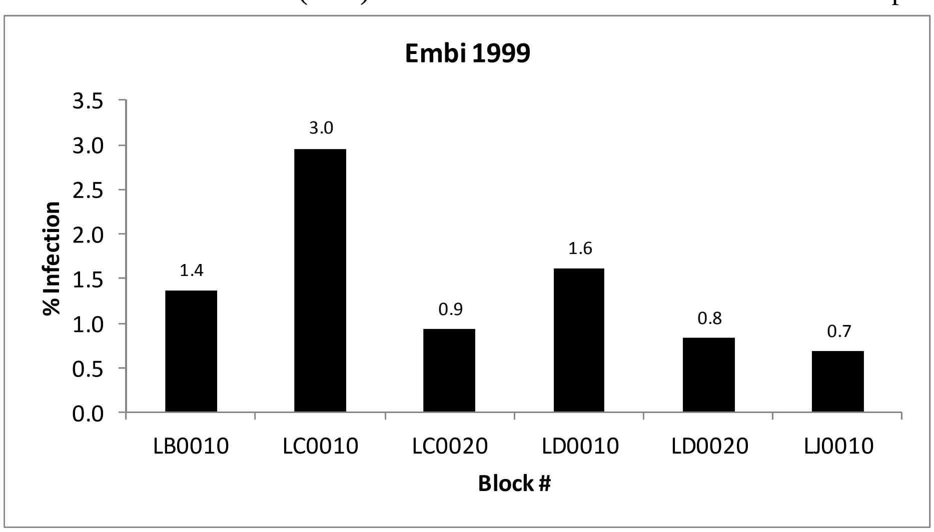


Figure 31 Ganoderma infection levels (total) in Embi 1999 plantings in 2011.

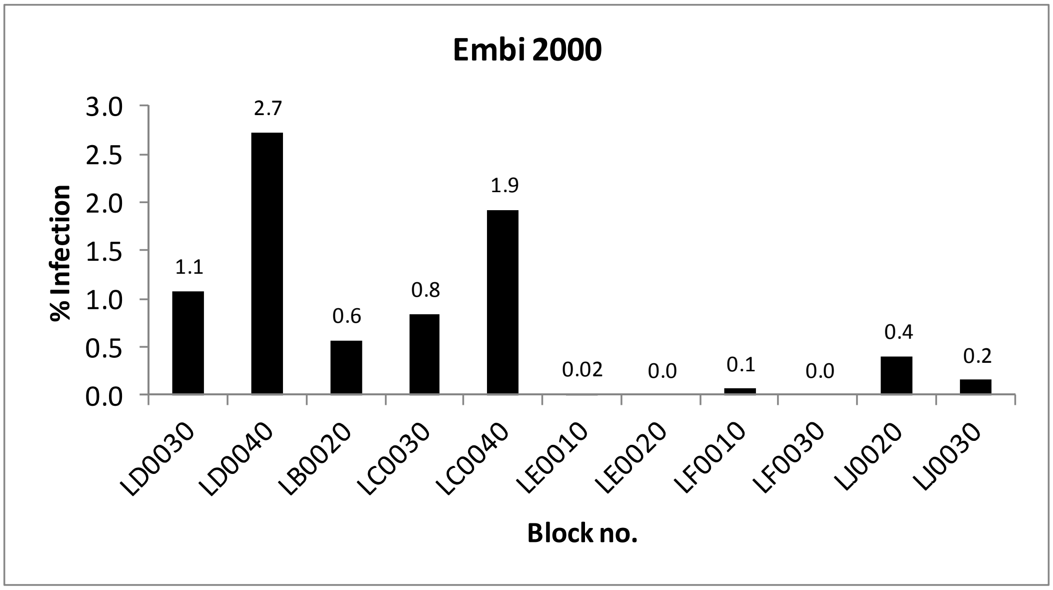


Figure 32 Ganoderma infection levels in Embi 2000 plantings in 2011.

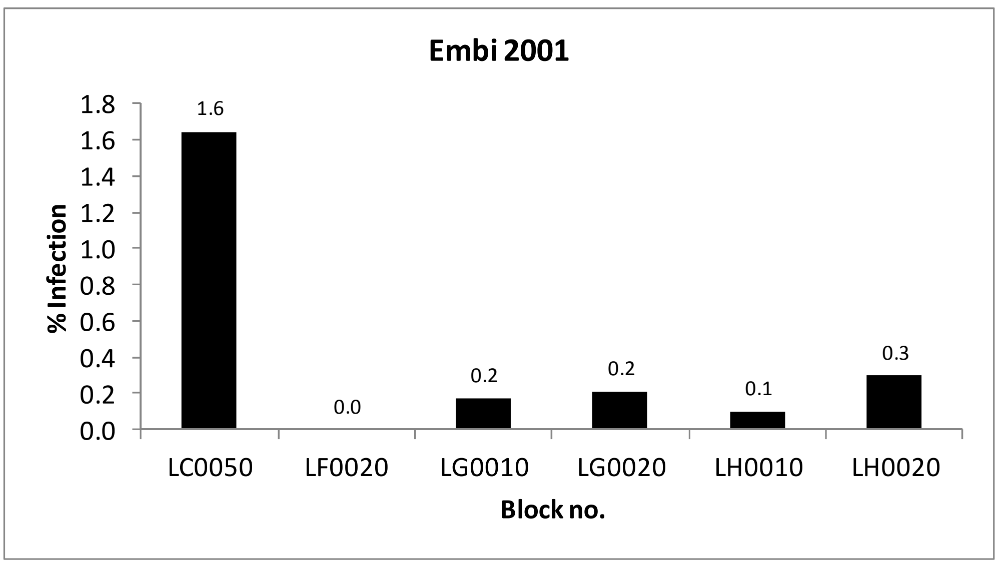


Figure 33 Ganoderma infection levels in Embi 2001 plantings in 2011.

There is a large variability in the reported infection levels for all blocks (Figures 1.34 to 1.47). Of concern are the younger plantings at Embi, Ambogo and Sumberipa which are showing annual incidences of above 0.5% in 7-10 year-old palms and in excess of 2% in 12 year-old palms. Sanitation in these blocks will need to be thorough.

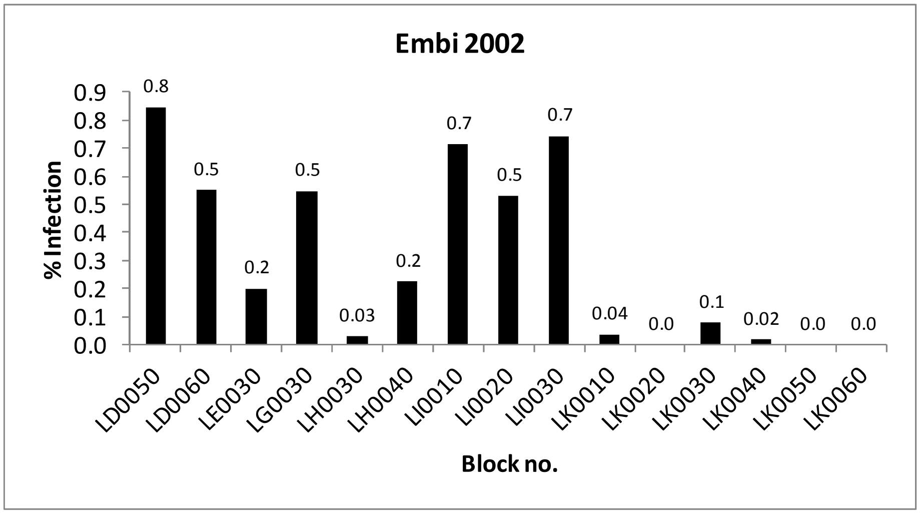


Figure 34 Ganoderma infection levels in Embi 2001 plantings in 2011.

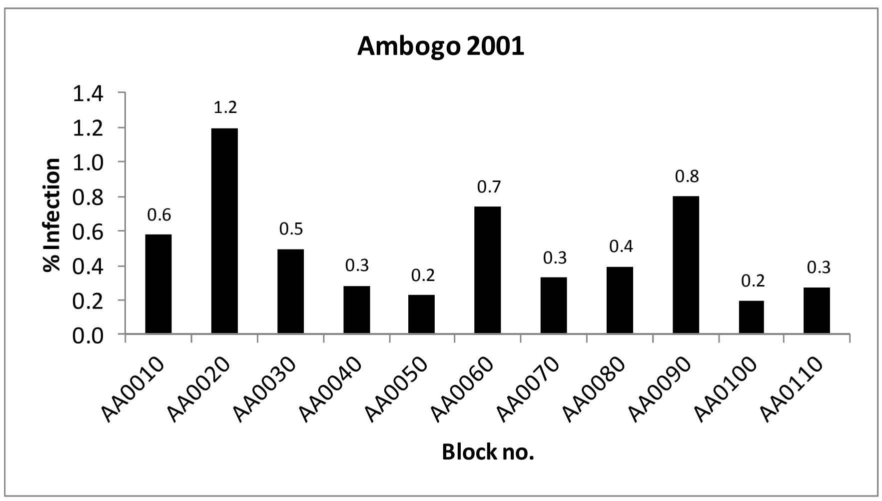


Figure 35 Ganoderma infection levels in Ambogo 2001 plantings in 2011.

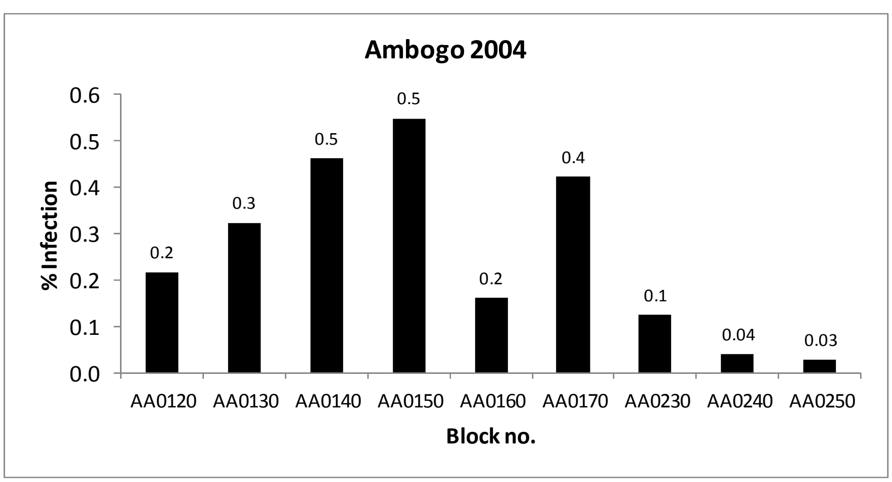


Figure 36 Ganoderma infection levels in Ambogo 2004 plantings in 2011.

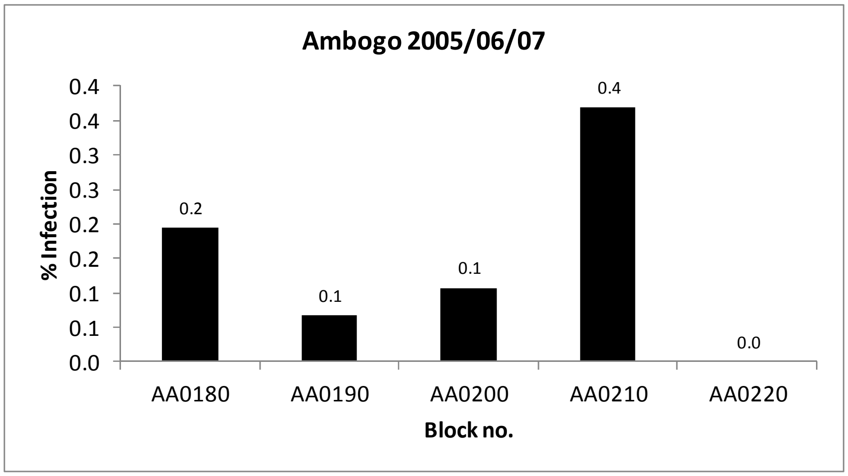


Figure 37 Ganoderma infection levels in Ambogo 2005-7 plantings in 2011.

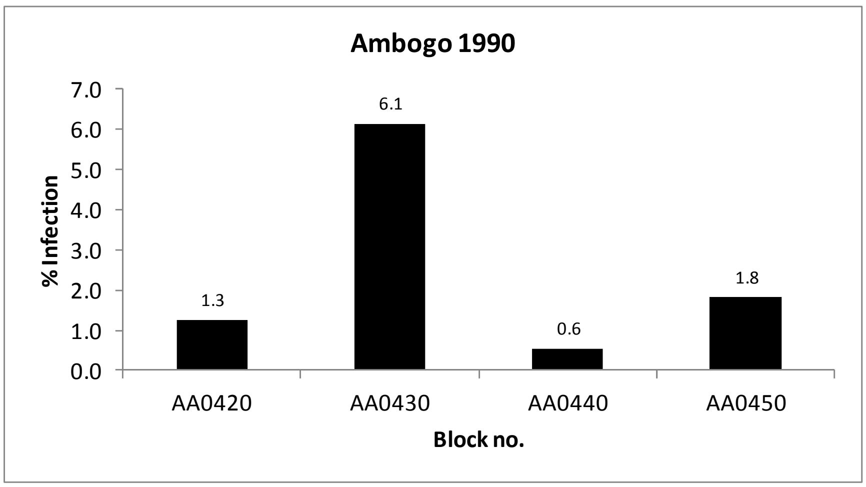


Figure 38 Ganoderma infection levels in Ambogo 1990 plantings in 2011.

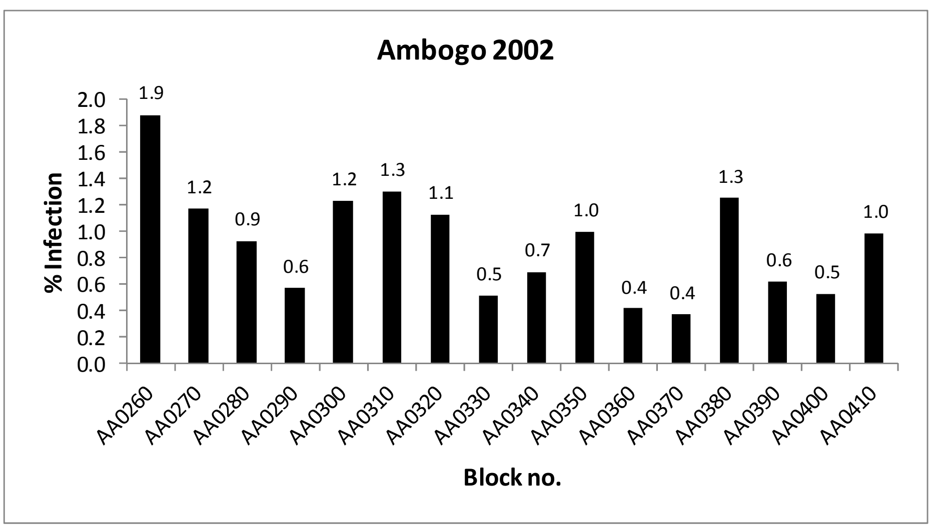


Figure 39 Ganoderma infection levels in Ambogo 2002 plantings for 2011.

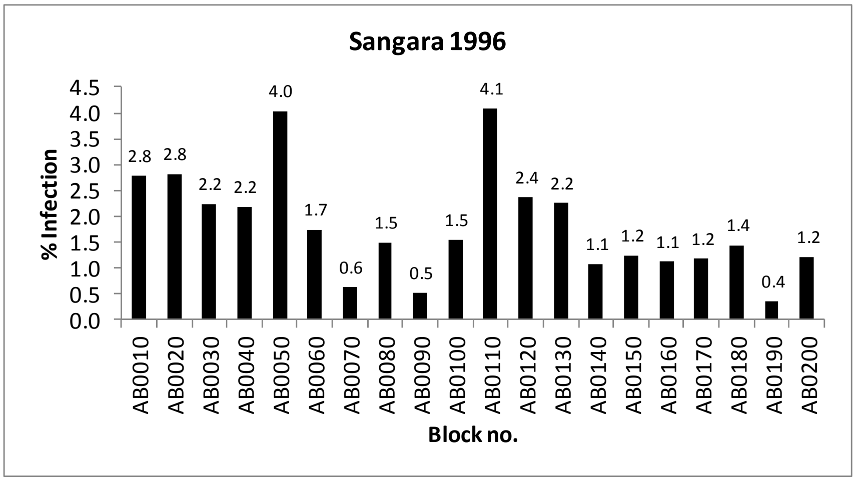


Figure 40 2011 Ganoderma infection levels in Sangara 1996 plantings.

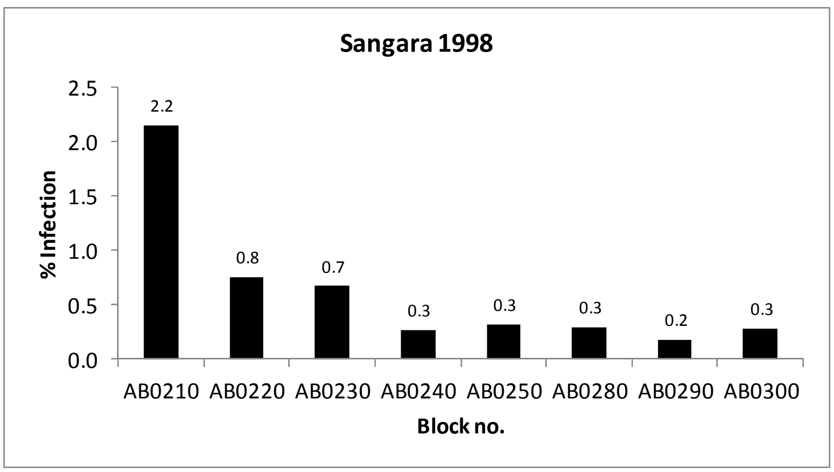


Figure 41 2011 Ganoderma infection levels in Sangara 1998 plantings.

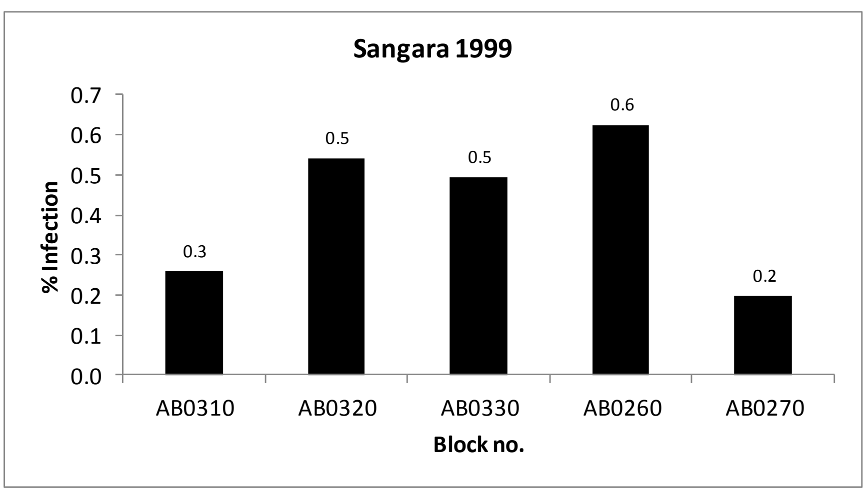


Figure 42 2011 Ganoderma infection levels in Sangara 1999 plantings.

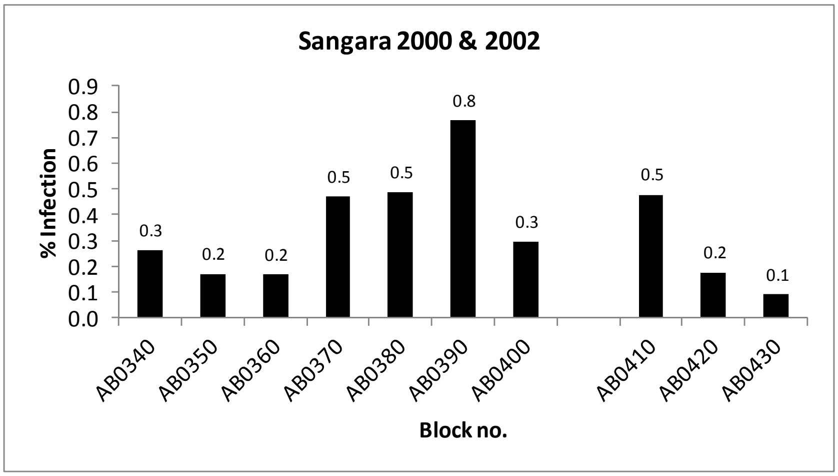


Figure 43 2011 Ganoderma infection levels in Sangara 2000-2 plantings.

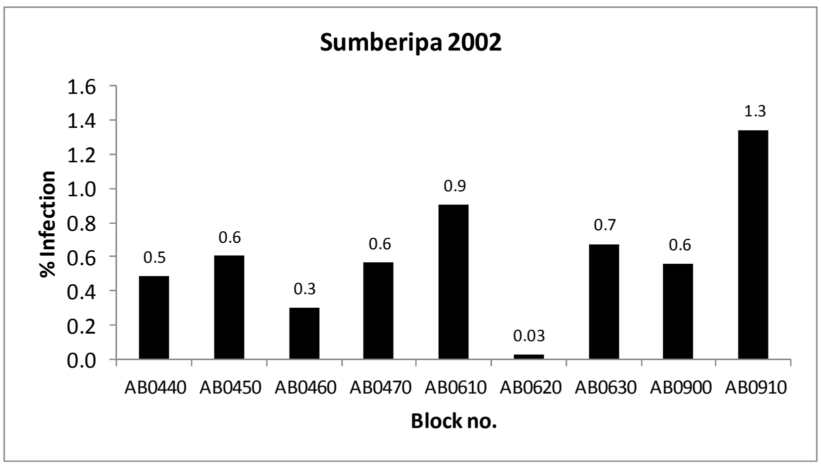


Figure 44 2011 Ganoderma infection levels in Sumberipa 2002 plantings.

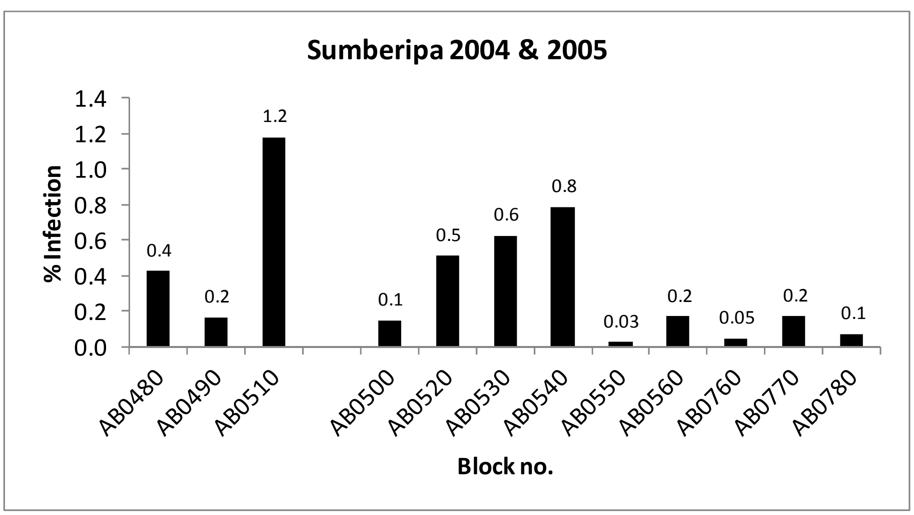


Figure 45 2011 Ganoderma infection levels in Sumberipa 2004-5 plantings.

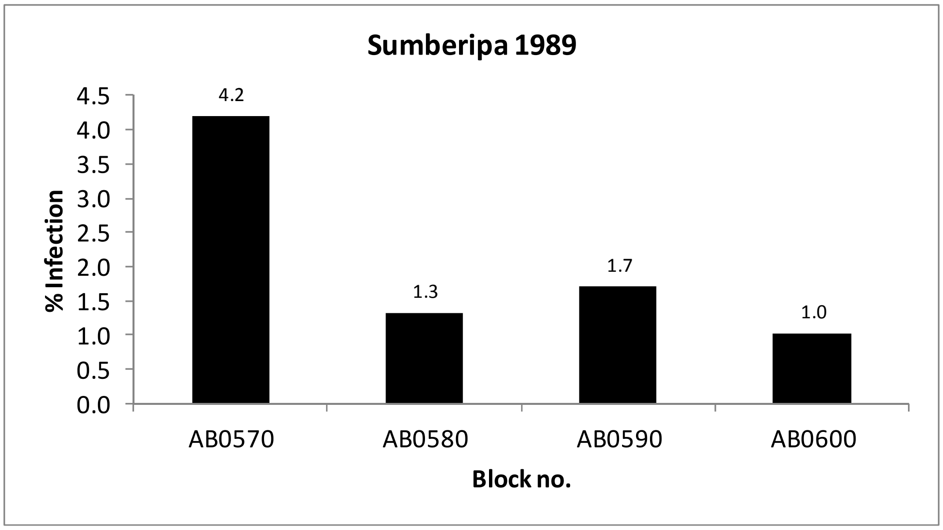


Figure 46 2011 Ganoderma infection levels in Sumberipa 1989 plantings.

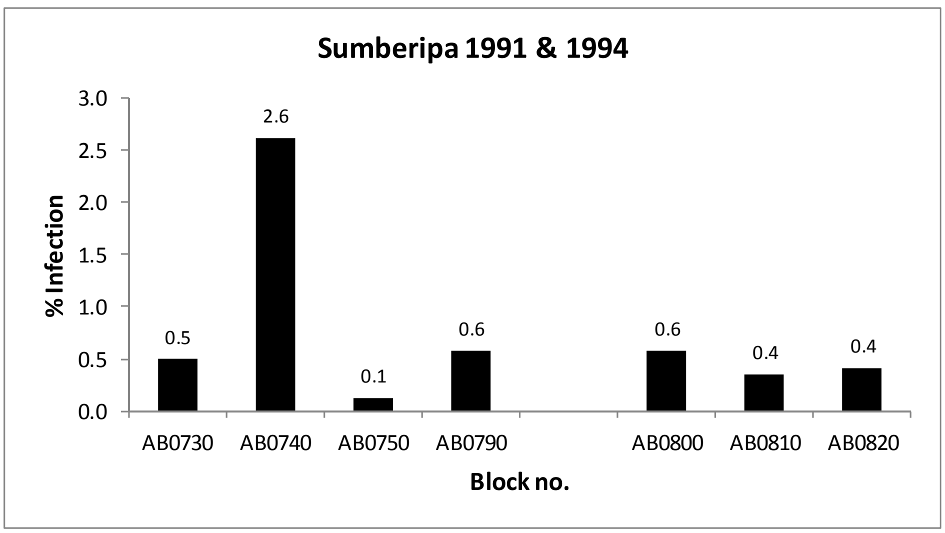


Figure 47 2011 Ganoderma infection levels Sumberipa 1991 and 1994 plantings.

NBPOL

Monthly monitoring of disease levels in Fields E4 and E5 continued in 2011 (Figure 48). Field E5 averaged about 15 new infections per month with Field E4 recording higher than average levels of infections for most months.

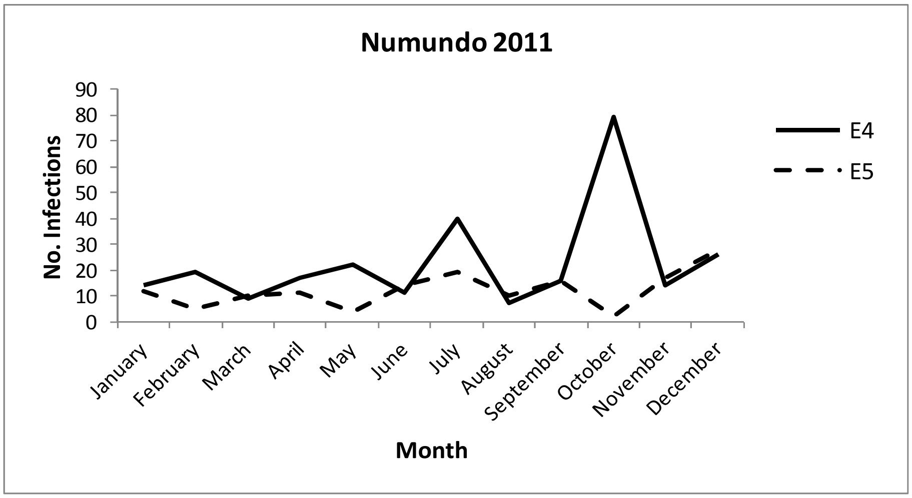


Figure 48 Monthly infections recorded in Fields E4 and E5, Numundo, West New Britain in 2011.

Disease progress curves for the period 2000-2011 show the continuing linear trend in infection rates in the E Fields (Figure 49). Disease rates did not increase from 2010. Disease incidence in Field E5 is now 35.2%. Field E4 now has a cumulative disease incidence of 27.3%.

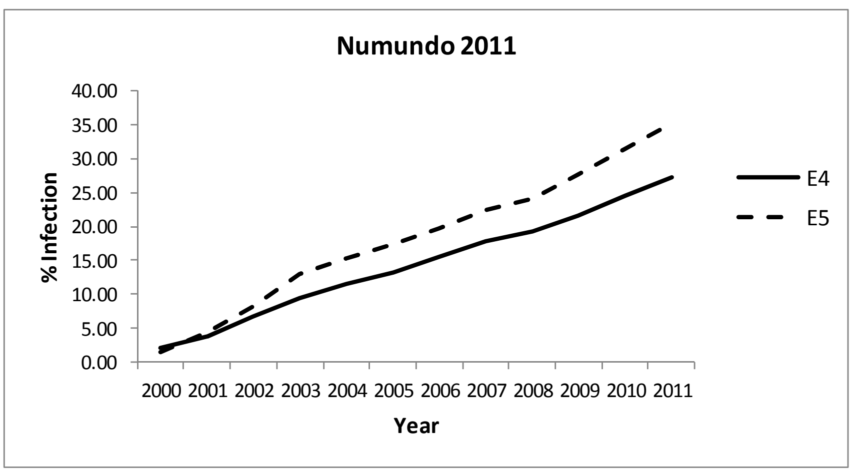


Figure 49 Disease progress curves for the fields E4 and E5 at Numundo, West New Britain Province from 2000-2011.

Monitoring the effects of disease on production in selected blocks

A further decline in yield was observed in 2011 from 2010 for Numundo MU3 (Figure 1.50). Yields dropped 25kg/palm from 2010 values and since 2009, yields have declined by approximately 50kg/palm. This is significant and clearly shows that any compensation by healthy palms is not adequate to fill the yield gap produced by non-yielding (diseased) palms. The critical point after which compensation fails to make a difference, in this instance, is at a disease level of approximately, 22%.

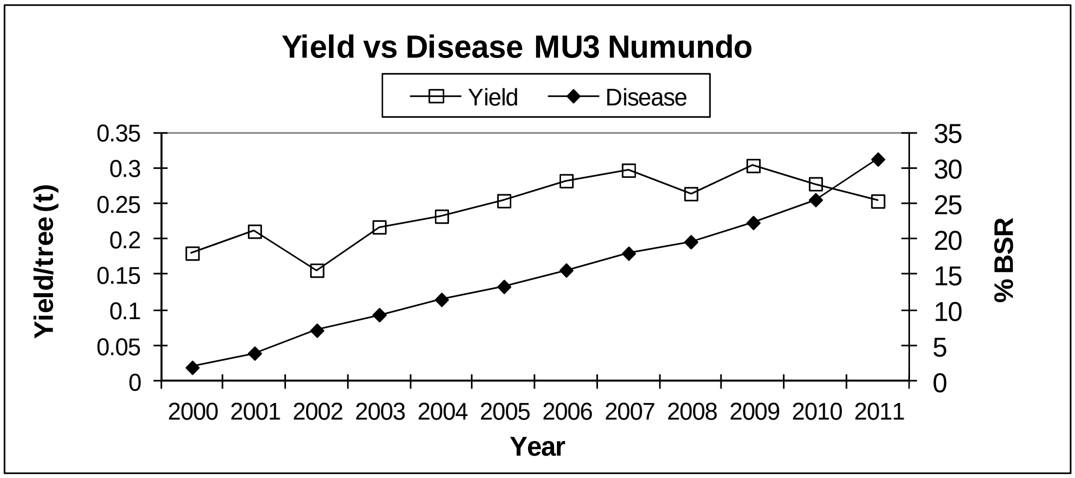


Figure 50 Effect of Ganoderma disease on palm production in fields with the highest infection levels (MU3) at Numundo, West New Britain from 2000-2010. The yield curve is derived from plantation data (provided by Dami OPRS).

Data for Blocks 7213 and 7214 in Milne Bay is not shown.

Ganoderma BMP blocks

Monitoring of disease levels in Blocks 7213 and 7214 and monthly disease surveys ceased in December 2011. After 2.5 years, disease levels in Block 7214 were 20.9% compared to Block 7213 (BMP) with a disease incidence of 16.7% (Figure 1.51). Blocks are to be replanted in 2012.

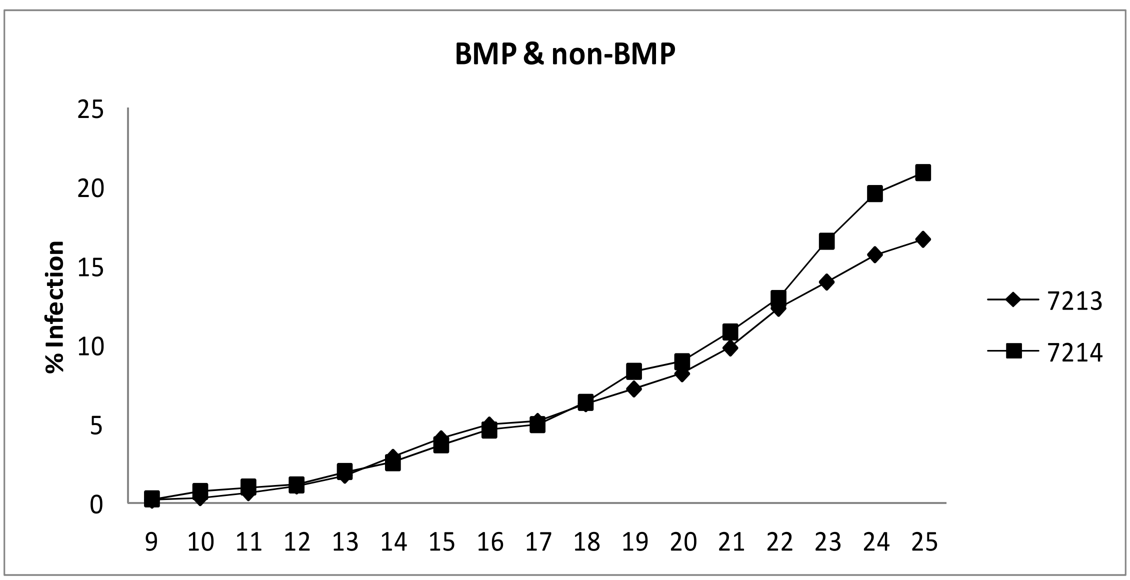


Figure 51 Disease progress curves for Ganoderma Block 7213 (BMP) and Block 7214 after 2.5 years of monthly removals in Block 7213.

YIELD STUDIES ON GANODERMA-AFFECTED PALMS (RSPO 4.5, 8.1)

Yield recording for this trial commenced in December 2010 and continued throughout 2011. The data below is for two periods: December 2010 to July 2011 and December 2010 to January 2012.

Figure 1 shows trial yields (t/ha) of palms with Ganoderma detected in Harvest 1 compared to apparently healthy palms after a period of 13 harvests. Clearly, the combined yield of the Ganoderma palms is lower than that of the healthy palms. However, when the yields of all palms are combined, the depression in the total yield appears insignificant. Obviously, because the percentage of Ganoderma-infected palms compared to healthy palms in the trial is initially low.

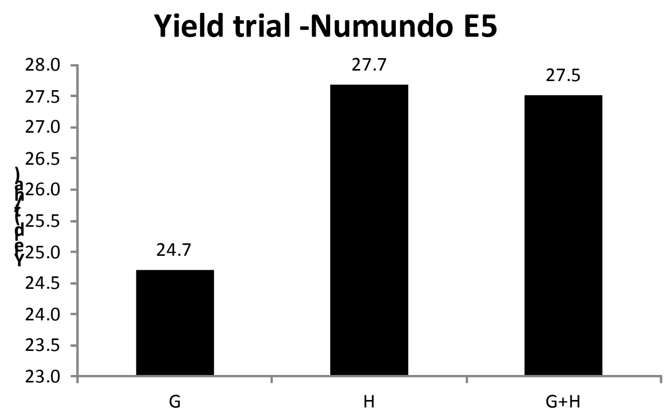


Figure 1 Yield (t/ha) of palms in OPRA trial, Field E5, Numundo. G=Ganoderma infected palms, H= healthy palms; G+H = Ganoderma infected pus healthy palm yields combined.

The yield profile of the same group of palms over 13 harvests is depicted in Figure 2. Here, the production trend of both categories of palms mimics each other although the yield from Ganoderma-affected palms is (in most cases), significantly lower than that of palms categorised as healthy. Again, the depressed yields from the Ganoderma palms do not affect the overall yields obtained per ha over the harvest periods.
The average bunch weights were calculated over the same period and bunch weights of healthy palms are consistently higher for healthy palms although not always significantly (Figure 3). This indicates that Ganoderma-infected palms are responding with some variability with regard to the infection. Admittedly, palms at Harvest 1 were not scored for their symptoms. It could be that some palms have the disease at a more advanced stage and this could account for the variability in bunch weights. These are preliminary results and further data analysis is required.

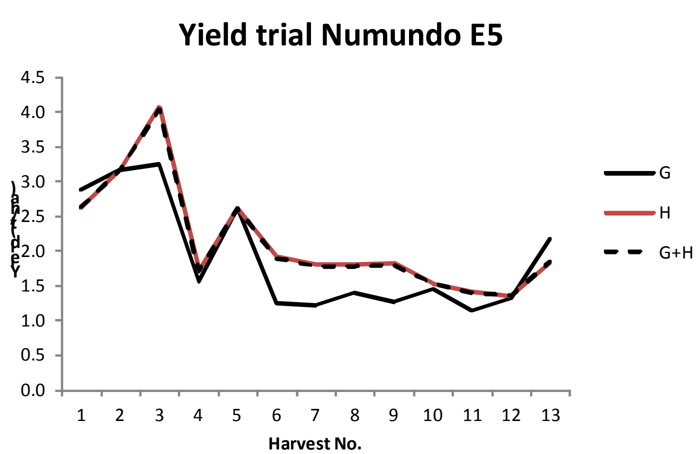


Figure 2 Yield (t./ha) of trial palms in Field E5, Numundo over 13 harvests. G=Ganoderma infected palms; H=healthy palms; G+H = Infected plus healthy palms combined.

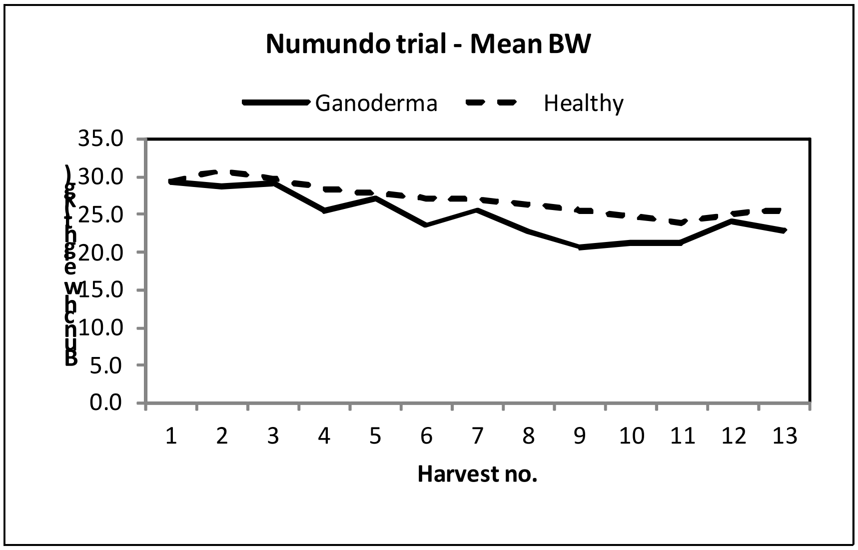


Figure 3 Mean bunch weights of diseased and healthy palms in Field E5, Numundo over 13 fortnightly harvests.

The mean bunch weight for all palms combined over 27 harvests is shown in Figure 4. The range is from 23.8 to 29.4.

The total bunch number and corresponding yield/ha are shown in Figures 5 and 6. There appears to be a temporal decline in yield however further analysis will be required in order to quantify this.
Figure 7 gives an indication of the variability in bunch weight recorded for Ganoderma-infected palms with advanced (Stage 4) symptoms.

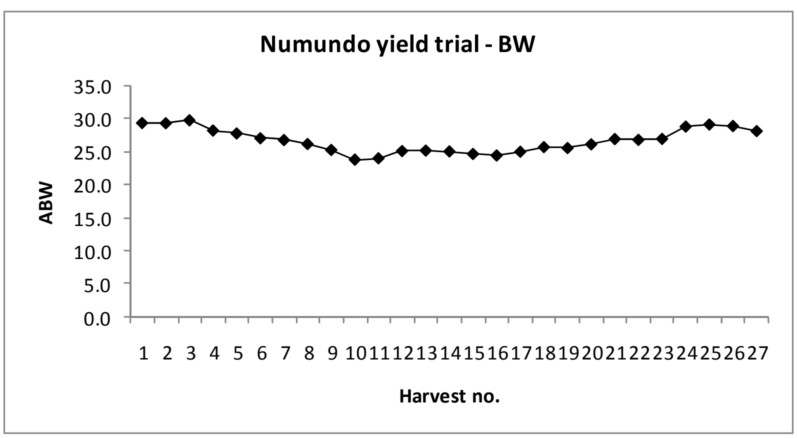


Figure 4 Mean bunch weights of diseased and healthy palms in Field E5, Numundo over 27 fortnightly harvests.

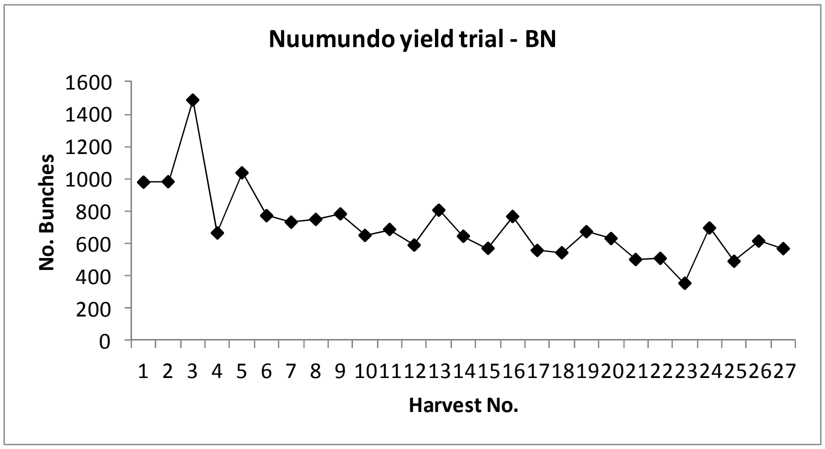


Figure 5 Bunch numbers of recorded trial palms at Numundo Field E5 over 27 harvests.

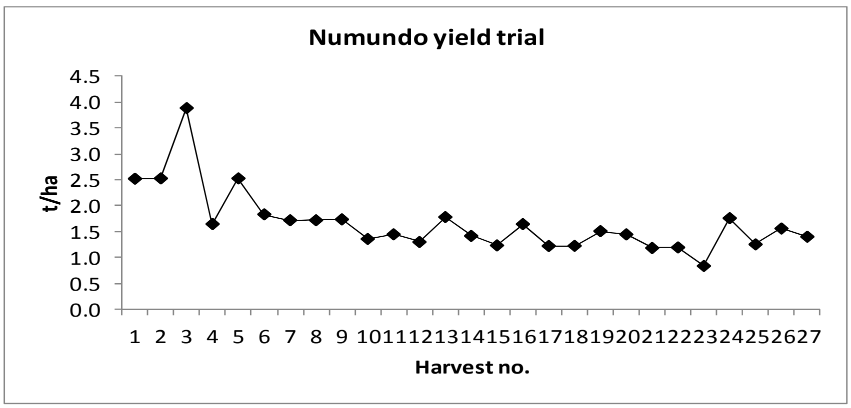


Figure 6 Yield (t/ha) of recorded trial palms at Numundo Field E5 over 27 harvests.

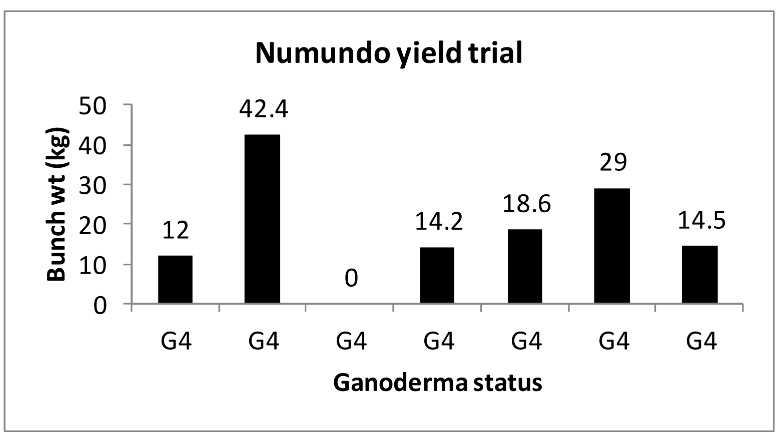


Figure 7 Bunch weights of Ganoderma-infected palms at an advanced sage of the disease at Numundo, Field E5.

A large number of data sets and analyses are required in order to make sense of the trial data and further analyses are underway. In the meantime, the trial will continue for an additional 12 months.

BIOLOGICAL CONTROL OF GANODERMA USING INDIGENOUS ISOLATES OF *TRICHODERMA* SPP. (RSPO 1.1, 4.1, 4.5, 4.6, 4.8, 8.1)

FINAL REPORT
This project was completed in January 2012 and the final report is reproduced below.

Further work
Field trials are currently underway in VOP blocks undergoing replant in Milne Bay. It is hoped that this can be extended to other Provinces. *Trichoderma* inoculum continues to be processed and stored for later use.

GANODERMA: AN APPROPRIATE CONTROL MEASURE FOR OIL PALM GROWERS

Final Report prepared by C. A. Pilotti Project Leader

ABSTRACT
A large proportion of smallholder replanting costs will be associated with the control of disease caused by *Ganoderma.* This project was initiated to support the research and development of a biological control agent that could alleviate some of the costs of disease control at replant for oil palm growers. The project has successfully delivered a product that can be used in the field for the control of basal stem rot and minimize future disease risk. The dissemination of information between project partners (PNGOPRA and OPIC) and growers was initiated and will continue despite completion of the work under this project. The results from this project have set the basis for further development of the research that will assist in minimizing the impact of disease on incomes in rural households in the oil palm sector.

RATIONALE
The oil palm industry supports a large population of out-growers in four Provinces, namely Milne Bay, Oro, New Ireland and West New Britain. These growers are dependent on research and development and extension through the PNG Oil Palm Research Association (PNGOPRA) and the Oil Palm Industry Corporation (OPIC) to improve their productivity and incomes. Both the PNGOPRA and the OPIC work closely together to research the constraints to increasing smallholder production by minimizing pest and disease risk as well as overcoming agronomic constraints. Basal stem rot (BSR) is a disease of oil palm caused by the fungus *Ganoderma*. The disease is present in both smallholder and commercial blocks and is the major threat to oil palm sustainability. The disease spreads mainly by spore produced by *Ganoderma* fruiting bodies. Disease control using fungicides is both costly and hazardous and is not an option for smallholders. Current control methods include the manual removal of infected palms with disposal of rotten trunk tissue. A major danger to the spread of BSR is the dissemination and germination of fungal spores on oil palm trunks at replant. A method was required to minimize the risk of fungal spore germination on trunk debris at replant for smallholder growers in all Provinces. PNGOPRA had begun investigating the use of naturally occurring biological control agents to prevent the growth of *Ganoderma.* This project was devised in order to further develop potentially useful fungi into a biological control agent that was safe and easy to use by smallholder growers. The fungi identified were in the genus *Trichoderma*. It was envisaged that a pilot scale project could be set up with funding under the AIGS project in order to begin trials with smallholders, with further commercial expansion at a later date. This report encompasses the background and research activities carried out on this project.

PARTNERSHIPS IN THE PROJECT
The partners in this project are PNGOPRA and OPIC. A large constraint in the implementation of a

disease control programme within the smallholder sector is financial in nature. Many growers are unwilling or unable to meet the costs of replant using mechanization. The partnership arrangements include PNGOPRA, OPIC and the smallholder Farmers Association. Dissemination of information and training will be initiated by the PNGOPRA through a series of field training sessions initially in Milne Bay and then in the other Provinces as replanting progresses. Without the support of OPIC, the information cannot be disseminated successfully as there are a large number of smallholder households to visit and a coordinated effort must be made to bring the growers together for training sessions.

RESPONSIBILITY OF EACH PARTNER

The project partners have a long and strong association and the responsibilities of each partner are clearly delineated. PNGOPRAs role is that of research and development and they will be responsible for the development of a viable product that can be used by smallholder oil palm growers. The role of OPIC is in extension and its responsibility will lie solely in training farmers in the utilization of the product produced. OPRA will also be responsible for disseminating the information through training to OPIC officers and VOP growers during field days organized by OPIC. Thus, OPIC will set field training schedules and be present during demonstrations initially in order to gain capacity in delivering the information required for farmers to utilize the product. At a later stage, OPIC will be solely responsible for the education of their farmers with monitoring of product use by PNGOPRA as a means of verification that technology transfer is being achieved.

ESTABLISHING THE PILOT BIOCONTROL PRODUCTION CENTRE

A production facility to house processing and packaging equipment will be based in Milne Bay adjoined to the PNG OPRA laboratory. A centralized facility will enable quality control to be maintained throughout the process. Without quality control, the product effectiveness cannot be guaranteed.

FUTURE EXPANSION TO COMMERCIAL STAGE PRODUCTION

The development of a commercially viable biological control process will depend on the adoption of the new technology by the farmers.

THE PROJECT

OUTPUT 1

Baseline study –VOP farmer disease assessment

The project baseline study included the survey of VOP farmer blocks in Milne Bay to determine the number of blocks undergoing replant in the next 2 years and to determine the level of *Ganoderma* infestation in these blocks. Because of the large area to cover, the baseline study only encompassed bocks going into replant in the ear following. Following this survey and during the research part of the project, the study continued to include all accessible VOP blocks in Milne Bay. Due to a lack of resources, baseline studies were not carried out in the other Provinces however, given presence of *Ganoderma* in these areas, the data is not expected to differ significant from the results in Milne Bay. That is, there is large variability in the disease incidence amongst blocks and blocks undergoing replant in other Provinces will require an assessment of their disease levels to determine the most appropriate means of control.

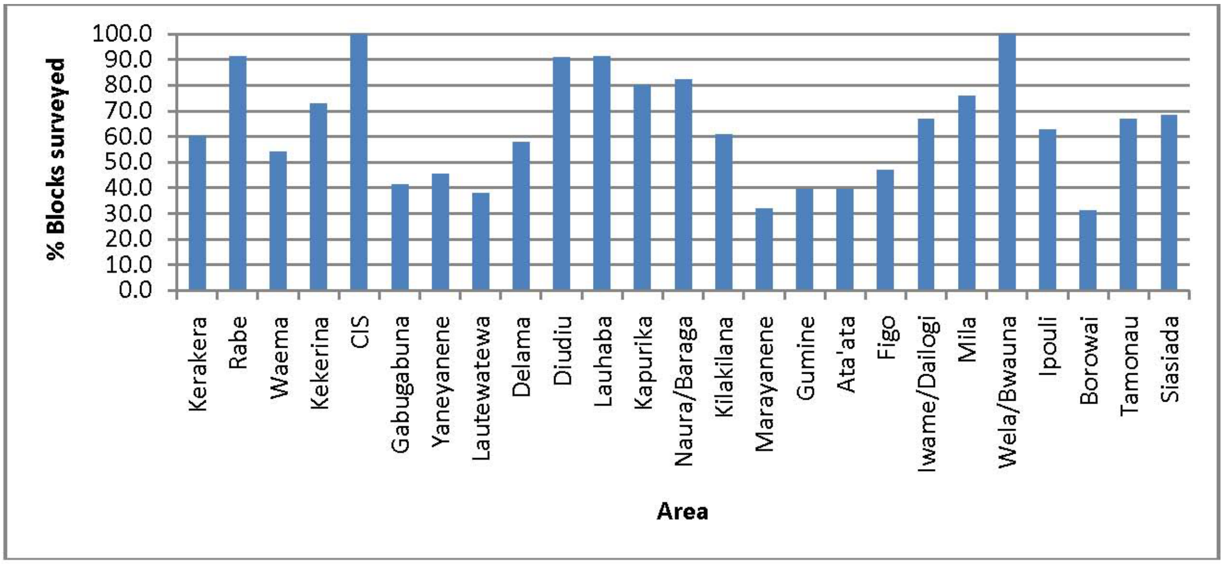


Figure 1. VOP blocks surveyed in different areas in Milne Bay.

Table 1.1 Disease levels in VOP Blocks in Milne Bay *DATA EXCLUDES STERILE PALMS

AREA	*TOTAL GANODERMA	BRACKET PALMS	SUSPECT PALMS	AREA SURVEYED	INFECTION PER HA	% INFECTION
Kerakera	1075	18	1057	40	26.9	21.0
Rabe	246	25	170	69	3.6	2.8
Waema	264	34	230	45	5.9	4.6
Kekerina	465	28	389	43	10.8	8.4
CIS	226	6	208	23	9.8	7.7
Gabugabuna	1067	39	1028	34	31.4	24.5
Yaneyanene	216	2	214	50	4.3	3.4
Lautewatewa	394	92	291	32	12.3	9.6
Delama	200	5	198	27	7.4	5.8
Diudiu	19	17	1	18	1.1	0.8
Lauhaba	483	6	466	58	8.3	6.5
Kapurika	659	678	1	65	10.1	7.9
Naura/Baraga	907	2	904	101	9.0	7.0
Kilakilana	215	0	215	39	5.5	4.3
Marayanene	136	1	135	28	4.9	3.8
Gumine	77	2	75	18	4.3	3.3
Ata’ata	125	0	125	35	3.6	2.8
Figo	241	0	241	51	4.7	3.7
Iwame/Dailogi	136	0	136	40	3.4	2.7
Mila	267	0	267	61	4.4	3.4
Wela/Bwauna	69	0	69	18	3.8	3.0
Ipouli	143	10	133	59	2.4	1.9
Borowai	322	3	319	32	10.1	7.9
Tamonau	518	3	515	68	7.6	6.0
Siasiada	182	19	163	89	2.0	1.6

Table 1.2 VOP replant blocks 2011/2012

AREA	BLOCK #	HA	GANODERMA	REC. REPLANT
LAUHABA	3012	4	46	2
	3017	4	48	2
NAURA/BARAGA	4011	4	51	2
	4012	4	55	2
	4017	5	54	2
LEASEHOLD	5005	3	66	2
LAUTEWATEWA	6005	4	60	2
	6006	4	62	2
	6007	3	45	2
GABUGABUNA	10001	2	58	2
	10002	3	75	2
	10004	2	80	2
	10006	4	264	2
	10007	2	75	2
	10009	4	131	2
	10011	2	95	1
	10013	3	113	2
	10017	2	83	2
YANEYANENE	12001	4	48	2
LAVIAM/KEKERINA	14010	3	90	2
	14011	2	60	2
MARAYANENE	15003	5	56	2
TAMONAU	22002	3	44	2
	22003	4	41	2
	22004	4	42	2
	22010	2	40	2
	22017	3	40	2
KERAKERA	1003	2	63	2
	1004	4	78	2
	1007	5	88	2
	1010	2	84	2
	1012	2	91	1
	1017	4	74	2
	1021	2	51	2
	1022	4	95	2
DELAMA	13007	4	85	2
				70

Issues identified

The main issue identified in Milne Bay was the reluctance of the farmers to implement a control programme for *Ganoderma* within their blocks. They considered that the manual method of palm removal was difficult and time-consuming and would not benefit them. The issue of replanting is a major difficulty with the current recommendation involving the felling of all palms in block undergoing replant. This exercise requires mechanization to be efficient and the cost of this is prohibitive for smallholder and VOP growers. In addition, due to the shortage of land in some areas (especially in the LSS areas in WNB), the option of fallow is not practical as all the planted area needs to be utilized in order to provide an adequate source of income for the growers. The need for an alternative means of control to minimize disease risk was evident.

Baseline study – Review of biological control production methods

Introduction
Fungi of the genus *Trichoderma* are known for their antagonistic properties to other fungi and have been used extensively as biological control agents against pathogens on a variety of crops (Dennis & Webster 1971; Imtiaj & Lee, 2008; Wells et al. 1972). The effectiveness of biological control agents is dependent on the field conditions as well as the formulation of the fungus or bacteria. Different conditions require different formulations of biofungicides in order to maximize the benefits imparted by the biological agent.

Rationale
This literature review was undertaken specifically to assess the production methods available for *Trichoderma* spp. (and other biocontrol fungi) and their suitability and application to local conditions.

Culture methods for fungi
Numerous reports have been published on the growth and application of *Trichoderma* species as biological control agents for control plant pathogens. A brief review of the literature is presented here. Liquid media, Czapek-Dox broth has been used to grow *Trichoderma koningii, T.harzianum* and *T. viride*. Cultures were grown in 250ml conical flasks and shaken on a rotary shaker at 26C and 100rpm for 6 days. After 6 days the hyphal mat was removed aseptically and dried at 60C for 2 days to obtain the weight of the mycelium. No details of conidia production were given as the species were grown to assess cellulose production. In another method, *Trichoderma harzianum, T. pseudokonigii* and *T. virens* were cultured in potato dextrose broth for 20 days at 25C on a rotary shaker at 140-150rpm. Filtrates were collected after filtration with 2 layers of Whatman No. 1 filter paper followed by filtration through a 0.22 micron membrane filter. The liquid culture filtrates were used against the pathogen *A. pori* in *in-vitro* tests. An unreferenced method for the mass production of *T. harzianum* as a biocontrol agent for *Sclerotium rolfsii* on both solid and liquid substrates was cited. For the liquid culture

T. harzianum was grown in a liquid fermentation process using 15% molasses, 0.3% ammonium choride, 0.1% yeast extract, 0.05% magnesium sulphate, 0.1% potassium phosphate (pH 4.5). Thirteen days after culturing the highest biomass was obtained. Powder formulations were prepared from the liquid fermentation biomass with diatomite. Four percent boiled tapioca starch was used as an adhesive agent for conidia or chlamydospores. Solid state fermentation used sorghum seeds and spent barley grain for production of spores. A liquid-solid fermentation process was used for the production of large numbers of conidia of *Trichoderma viride*. Liquid culture consisted of a 5% maize starch in water solution. This was seeded with sterile conidia (containing 1,000,000condia/ml) and flasks shaken at 180rpm at 28C. After 24 hours cultures were added to solid rice bran of different water contents ranging from 50-66% in flasks. Media with 60% moisture content produced the highest amount of conidia and most conidia was produced in the period between 30 -36h in the liquid medium. Conidia production had ceased in all cultures approximately 40 hours after inoculation. The effectiveness of formulations of *Trichoderma* species against *Macrophomina phaseolina* were also investigated in one study. *Trichoderma koningii*, *T. harzianum* and *T. sp.* Were grown in liquid culture (modified Richard's medium). The medium consisted of potassium nitrate, potassium phosphate, anhydrous magnesium sulphate, sucrose, iron chloride and 150ml tomato juice in water. The liquid medium (100ml) was put into 250ml flasks and inoculated with a 1cm sq. sterile agar plug of the *T. koningii* culture and incubated at 28C for 21 days. The mycelia were harvested and dried at 30C for 24-48hr and stored at 4C before testing. The mycelia were used in formulations for treatment of seeds. A suspension of ground mycelium of each *Trichoderma* species (6.8-2.0 x 10^7 cfu/ml) with and without cassava starch as adhesive agent was used in the trials. An anonymous article was found that described a simple method for the preparation of *Trichoderma* inoculum for treating durian against *Phytopthora*. A liquid medium was used which contained rice bran in 1 litre water. The medium was boiled until the rice was cooked and then strained through cheesecloth. Calcium nitrate was added to the broth collected and autoclaved. The medium was seeded with *Trichoderma* and grown as a stationary culture for 10 days. The liquid biomass was diluted 1/10 and used directly as a spray on trees. Wheat bran was also used as medium to culture *T. harzianum*. The fungus was grown in a 2% liquid culture in a 250ml flask at 30C on a shaker at 50rpm for 5 days. Conidial suspensions were harvested through four layers of cheesecloth and used directly as a spray on turfgrass. An evaluation of solid substrates for growth of *T. harzianum* and *T. viride* tested sorghum grain, neem cake, coir pith, cow dung and wheat flour in various combinations for their ability to produce conidia. Sorghum grains showed the highest growth rates for both *T. harzianum* and *T. viride.*

T. harzianum strains were grown in a liquid medium containing potassium phosphate, magnesium sulphate, potassium chloride, iron sulphate, zinc sulphate, sac arose, yeast extract in distilled water. The pH was adjusted to 6.2 and the cultures were shaken in flasks at 250rpm for 48h at 26C. Two carriers were used (peat and vermiculite) with the homogenized culture suspensions in trials on radish seeds.

Conclusion

For a summary of the methods see Table 1.3

Table 1.3 Summary of available published methods for inoculum production of biological control agents *Trichoderma*, *Beauvaria* and *Metarhizium*.

Liquid medium	**Solid medium**	**Formulation**
(Trichoderma) Czapek-Dox broth, 100rpm, 6 days	Nil	Nil
(Trichoderma) PD broth, 140 150rpm, 20days	Nil	Filtrate
(Trichoderma) 15% molasses, 0.3% NH4Cl, 0.1% yeast extract, 0.05% MgSO4.7H2O, 0.1% KH2PO4 (pH 4.5),	Nil	Conidia/chlamydospores with 4% tapioca starch
(Metarhizium) 2% yeast extract and 4% glucose (or sucrose), 150rpm, 2-4 days	Unpolished (brown) rice 600g/500ml water/25ml (1:40) liquid culture to bags, 14 days incubation	Conidia suspended in oil and sprayed directly
(Trichoderma) 5% maize starch in water, 180rpm	24hr liquid culture added to solid rice bran 60% moisture content	Nil
(Trichoderma) KNO3, KH2PO4,	Nil	Dried, ground

MgSO4, sucrose, FeCl3 and 150ml tomato juice, 28C, 21 days, stationary.		mycelium with and without cassava starch
(Trichoderma) Sucrose-yeast extract medium (conc. unknown), with minerals, 5 days	Nil	Nil
(Beauvaria) -Nil	Granulated rice	Suspension in oil of 5 x 107 conidia/ml
(Trichoderma) rice bran/1 litre calcium nitrate, 10days, stationary	Wheat dough	Liquid culture diluted 1/10 with water
(Trichoderma) KH2PO4; MgSO4.7H2O; KCl; FeSo4.7H2O; ZnSO4.7H2O; ZnSO4; sac arose; yeast extract: in water	nil	Liquid culture mixed with peat or vermiculite

Generally, liquid culture methods appeared superior to solid state culture. Liquid cultures resulted in higher biomass when compared to biomass produced on solid media. The separation of fungal biomass from solid media is also seen as a limiting factor in a production system. In addition, many of the solid media used such as sorghum grains are unavailable in PNG. It was concluded that the production system adopted in this project would be a liquid culture method so that total biomass could be utilized and to minimize the contamination from external sources.

Selection of a production system
The selection of a production system was based on several criteria namely:
(1) Ease of production
(2) Minimisation of waste
(3) Ease of use
(4) Safety and environmental issues
(5) Minimisation of contamination

The final process selected was a liquid culture and freeze-drying procedure that would utilize all available biomass of the fungus rather than just spores. In addition, the liquid medium was formulated to utilize locally available materials where possible, in order to minimise the costs of microbial culture and also eliminate the need to order supplies from overseas. The freeze-drying procedure allowed eh mycelia to remain viable and reduced the amount of contamination of the dried product. This is an essential requirement for long term storage of the product.

OUTPUT 2

Laboratory evaluations
Liquid media testing. It was necessary to test the growth of *Trichoderma* species in different liquid media. Seven (7) different culture media were evaluated (Table 2.1). Trials were carried out in order to assess the most suitable medium for conidial and mycelial development. In the first experiment, selected *Trichoderma* isolates were grown in 3 different media and the weights of conidia produced in each of the media were determined (data for one isolate is shown, Table 2.2).

Table 2.1 Production of mycelia and conidia of *Trichoderma* isolate SP5A in seven different liquid media after 7 days incubation.\.

Media	**Observations**
CDB	Poor mycelial growth; nil conidia production
PDB	Fair mycelial growth; nil conidia production
YEM	Fair mycelial growth; fair conidia production
YG	Fair mycelial growth; nil conidia production
SW	Poor growth; some conidia production
RBB	Good mycelial production; fair conidia production
TJB	Good mycelial and conidia production

In the second experiment, additional media were tested against selected fast-growing isolates of *Trichoderma* (Table 2.2).

Table 2.2 Yield of spores obtained for *Trichoderma* isolate SP5A under both stationary and shaking culture.

SP5A		
Stationary		
Media solution	Shaker culture	culture/NUV
TJB	9mg/100ml	9mg/100ml
RBB	9mg/100ml	20mg/100ml
YEM	5mg/100ml	No result

A higher number of conidia were produced with RBB media during stationary culture. This is probably due to the fact that stationary cultures were also exposed to light to enhance the production of conidia. TJB was the medium of choice when cultures were grown with shaking. Good conidial production was observed after 7 days incubation at 150rpm (Table 2.3).

Table 2.3: Conidia production in two *Trichoderma* isolates B and BN in different media after 7 days with shaking @ 150rpm B

	B		BN	
	mycelia	conidia	mycelia	conidia
TJB1	+	+	+	+
TJB2	+	+	+	+
TJB3	+	+	+	+
RBB1	+	-	+	-
RBB2	+	-	+	-
RBB3	+	-	+	-
YEM1	<+	-	+	-
YEM2	<+	-	+	-
YEM3	+	-	+	-

From the results of the testing, TJB media was selected as the ideal media for mass production of *Trichoderma*. In addition, agitation of cultures was deemed necessary to enhance growth.

Assessing the antagonistic ability of Trichoderma isolates against Ganoderma An assessment of the ability of Trichoderma isolates to hinder the growth of *Ganoderma* was made for several isolates of each fungus. Some results are reported here.

Experiment 1
Trichoderma isolates SP5A, BU and C were each challenged with *Ganoderma* dikaryons #1026, #1301, #1326 and #1320 for 2 weeks. After 1 week and 2 weeks of incubation an agar plug was removed 1 cm away from the original *Ganoderma* mycelia and subcultured to selective medium (GSM) for 1 week.

Results
In all the agar challenges with the four different dikaryotic isolates, SP5A consistently inhibited the growth of each *Ganoderma* dikaryon to an average length of 0.1 cm. The maximum growth of the *Ganoderma* culture was less than 0.5 cm. After 1 week of incubation together with the *Trichoderma* cultures, the *Ganoderma* had lost viability. After 2 weeks, however, cultures removed from the plates containing #1301 vs C, #1320 vs BU and #1326 vs C tested positive for *Ganoderma* on GSM indicating that the *Ganoderma* had not been killed during the testing. The remaining *Ganoderma* isolates had all been killed (Table 2.4).

Table 2.4 Growth rates of different isolates of *Ganoderma* after 1 week incubation on agar with different isolates of *Trichoderma*.

Trichoderma vs Ganoderma	Length of Ganoderma (cm) (Mean of triplicate plates)	GSM after 1 wk	GSM after 2 wk
#1026 vs Bu	0.3		
#1026 vs C	0.3	---	---
#1026 vs SP5A	0.1	---	---
#1301 vs Bu	0.3	---	---
#1301 vs C	0.1	---	---
#1301 vs SP5A	0.1	---	- + +
#1320 vs C	0.2	---	---
#1320 vs SP5A	0.1	---	---
#1320 vs Bu	0.2	---	---
#1326 vs Bu	0.1	---	+++
#1326 vs C	0.4	---	---
#1326 vs SP5A	0.1	---	- - +

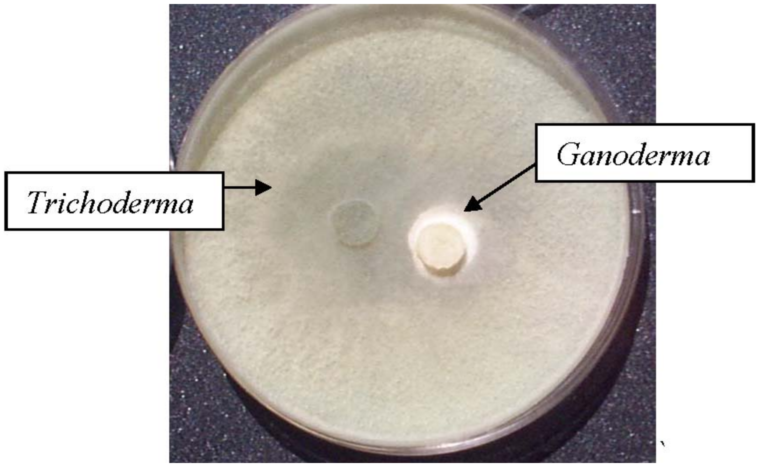


Figure 2.1 Suppression of *Ganoderma* in culture by *Trichoderma* on potato dextrose agar.

Experiment 2
The growth of *Ganoderma* dikaryon #1026 on oil palm rachis tissue was tested against *Trichoderma* isolates SP5A, BU and C. Rachis blocks (x12) were autoclaved and allowed to cool to room temperature. Agar plugs of a *Ganoderma* and a *Trichoderma* culture were placed at each end of the rachis blocks. Cultures were incubated for 2 weeks before final measurement were made. Assays were done in triplicate. Examples are shown in Figure 2.1. Growth of *Ganoderma* isolate #1301 was severely restricted with over 80% inhibition. However, after 2 weeks, the *Ganoderma* culture was still viable (Table 2.5).

Table 2.5 Growth of *Ganoderma* isolate #1301 after 2 weeks incubation on rachis blocks with different cultures of *Trichoderma.*

Treatment	Mean length (cm) of Ganoderma isolate # 1301	Inhibition *Effectiveness (%)	GSM Result #1301
SP5A	1.1	87.4	- + +
Bu	1.4	83.9	+ + +
C	1	88.5	- + +
Control	8.7	0.0	+ + + +

*Data are expressed as % of control colonies without antagonist and values are average of 3 replicates.

Experiment 3
Trichoderma isolates SP5A, Bu and C were each tested against *Ganoderma* isolate # 1326 on rachis blocks for two weeks. At the end of the challenge, measurements were taken on the length of the *Ganoderma* culture. The *Ganoderma* culture from each of the blocks was later sub-cultured onto selective medium to ascertain if it was still viable. After 2 weeks incubation with *Trichoderma* cultures SP5A, BU and C, the *Ganoderma* culture was killed and no longer viable. The *Trichoderma* cultures effectively prevented the growth of *Ganoderma* with over 90% inhibition (Table 2.6).

Table 2.6 Growth and viability of *Ganoderma* isolate #1326 incubated with selected *Trichoderma* cultures on oil palm rachis tissue for 2 weeks.

Treatment	Length (cm) of Ganoderma isolate # 1326 Two weeks growth	Inhibition Effectiveness (%)	GSM Result #1326
SP5A	0.13	93.16	---
Bu	0.10	94.74	---
C	0.10	94.74	---
Control	1.90	0.00	

- = nil growth of the Ganoderma isolate

The experiment was repeated using spores of *Ganoderma* inoculated onto the surface of the rachis followed by inoculation of *Trichoderma* (Figure 2.3).

Figure 2.2 Suppression of the growth of a *Ganoderma* mycelial culture by *Trichoderma* culture SP5A on oil palm rachis. On the left is the control.

Figure 2.3 Suppression of the growth of *Ganoderma* spores by *Trichoderma* isolate SP5A on oil palm rachis. On the left is the *Ganoderma* control.

Selection of Trichoderma species for formulation testing. During the trials, nine (9) different species and strains of *Trichoderma* were tested. From these **5 different species were selected** on the basis of good growth of both mycelia and conidia on liquid media. These were B, BN, BU, C and SP5A. Four of the cultures on agar are shown in Figure 2.4.

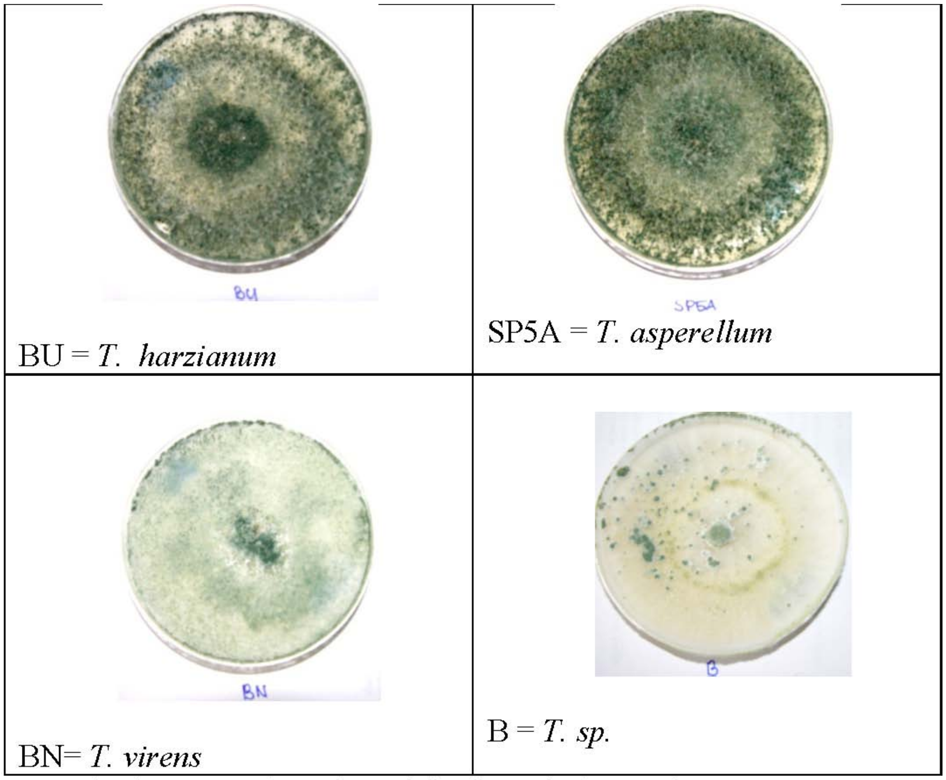


Figure 2.4 *Trichoderma* species selected for formulation testing.

From the results of the *in-vitro* antagonism tests, 5 species/strains of *Trichoderma*with good antagonistic ability were selected for use in formulation testing. These species will be used in a mixture in all formulation work.

Laboratory and field formulation trials

Several sets of field trials to test different formulations were undertaken in 2009 and 2010. Some results of these trials are presented below. Generally, variability due to weather conditions is an inhibiting factor. A large number of different formulations were made up with different dispersants and adjuvants and different amounts of *Trichoderma* inoculum. Each of these had to be tested in the field for effectiveness of application and adhesion to the substrate. Numerous field trials were undertaken in Milne Bay. Trials produced variable results and growth was dependent on the weather, mainly rainfall and humidity (Table 2.7).

Table 2.7 Some results of the formulation (small-scale) field trials in 2010.

Trial #	Type of spray	Substrate	Results
Trial #1	Trichoderma (mixed cultures) and Formulation A	5x sanitized bases 4x logs	Trichoderma growth established but washed off by rain after 1 wk. Growth ceased after 1 week
Trial #2	Trichoderma (mixed culture)s and Formulation A	2x BB 5x sanitized bases	40% established on 2x brackets 5x base had growth, washed off by rain after 1 week
Trial #3	Field spray at 7213 with Formulation B (mixed cultures). Sprayed on logs with brackets.	6x BB on logs	*Trichoderma* growth on 2x brackets, 4x brackets no colonisation. After 1wk nil results i.e. washed off by rain
Trial #4	Field sprays at 7204 with Formulation A (singles, SP5A).	6x sanitized bases	*Trichoderma* growth established on 6x base but not abundant
Trial #5	Field spray with; 1). Formulation A (mixed cultures) 2). and Formulation C (singles) on sanitized bases and brackets on logs.	4x base with gelatin 4x base with flour 3x brackets w. gelatin 3x brackets w. flour	¾ sprayed had growth 1%-40% 2/4 bases sprayed had growth 2%-10% All brackets sprayed had no colonisation
Trial #6	Formulation D Sprayed on sanitized base and bracket palms	6x bases	All 6x base established *Trichoderma* growth (80%-100%)
Trial #7	Field spray with Formulation E (mixed cultures). Sprayed on sanitized base and bracket palms.	6x base 5x brackets	5x brackets no colonisation 6x bases established growth (40%-60% coverage)
Trial #8	Field spray at 8502 with *Trichoderma* (SP5A) Formulation F on sanitized bases/brackets on logs.	6x bases 5x brackets	2x bases with 100% coverage. 4x bases had 40%-60% coverage 2/5 BB had spore growth but were washed off by rain
Trial #9	Field spray at 7213 with *Trichoderma* (Freeze dried-mixed cultures) and Formulation G. Sprayed on sanitized bases & brackets on logs.	5x bases 5x brackets	Brackets no colonization Unsatisfactory results for 5x bases with 1%-10% coverage of *Trichoderma*
Trial #10	Field spray at 7213 with *Trichoderma* (mixed cultures) and Formulation G. Sprayed on sanitized bases	7x base	80% - 90% coverage
Trial #11	*Trichoderma* (mixed cultures) and Formulation G	57 x brackets	3.5% of brackets had *Trichoderma* spores mostly on the edges.
Trial #12	*Trichoderma* mixed cultures (concentrated by oven drying) and Formulation G	8 x sanitized bases	Inconsistency in results and *Trichoderma* coverage ranging from 10% to 90%
Trial #13	*Trichoderma* mixed cultures and Formulation F	6 x sanitized bases	All 6x bases had 100% *Trichoderma* growth by day 7
		25 x interfaces	*Trichoderma* established growth on 40% of the interfaces by day 3, nothing observed after day 6 due to bad weather
		24 x brackets	Only 1 bracket had *Trichoderma* spores growing on it but was washed off by rain

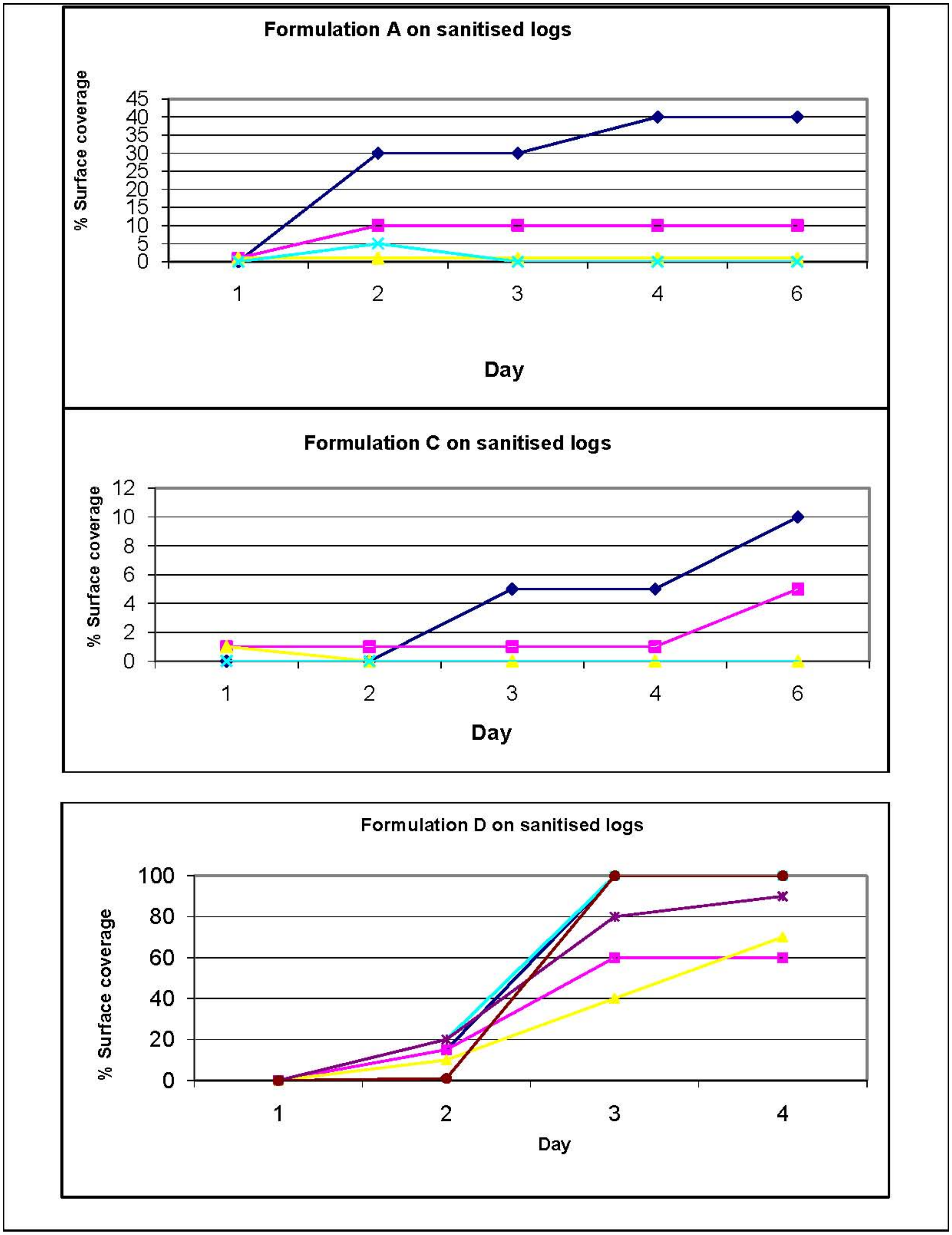


Figure 2.5 Field testing of three *Trichoderma* formulations showing the progress of growth of *Trichoderma* on the substrate with time.

<table>
<tr><td></td><td>Formulation A Sprayed onto sanitised trunk of oil palm. Growth was adequate (70% coverage) after 5 days.</td></tr>
<tr><td></td><td>Formulation B Sprayed onto a sanitised trunk of oil palm. Growth was satisfactory (50% coverage) after 5 days.</td></tr>
<tr><td></td><td>Formulation C Sprayed onto a sanitised trunk of oil palm. Growth was excellent (100% coverage) after 5 days.</td></tr>
</table>

Fig 2.6 Field testing of Trichoderma species on sanitised logs in the field.

From the results of the small-scale field trials, a single formulation has been selected and this will be used in larger scale replant trials in Milne Bay and elsewhere.

OUTPUT 3

Pilot scale production and processing equipment
Biomass production of *Trichoderma* involved the liquid culture of the fungus and therefore equipment such as culture vessels and stirrers were required to maintain a continuous batch process. The costs of larger fermentation systems were prohibitive so a smaller processing system using 3 litre culture vessels had to be adopted. This is not a constraint as adequate levels of inoculum can be produced for smallholder blocks undergoing replanting. At the time of this report, one order for processing equipment still had not arrived however the equipment already procured was being used to bulk up inoculum for storage and later use. Equipment for processing will be set up in the area allocated for processing of the biocontrol product.

Figure 3.1 Some of the processing equipment used to produce Trichoderma biomass.

Figure 3.2 Different product formulations produced for field testing with equipment purchased.

Construction of production & storage facility
The production storage facility is currently under construction and when completed will house the pilot

production and processing equipment. This will enable the production of adequate amounts of the biocontrol agent for use by smallholders in areas to be replanted. It is anticipated that there will be continued refinement and modification of processes, depending on the availability of reagents and the scale of product required. Further expansion of the laboratory area will depend on the scale of future production. Quality control procedures will be put incorporated in order to minimize contamination of the product and deliver a clean and highly active ingredient.

Figure 3.3 Laboratory extension work underway to house the equipment purchased for the production of the biological control agent

OUTPUT 4

VOP farmer training

Training sessions were initiated in the last quarter of 2012. The objective of the training sessions was to firstly introduce farmers to the concept of biological control and explain the rationale behind the use of living material as a control agent. The field days also demonstrated the use of the use of the sprayer and the application of the liquid to palms that had been felled and treated for *Ganoderma* rot. Growers were very attentive but not entirely convinced that the product was harmless and it will take more intensive training with additional background information before farmers are comfortable with the product. For the time being, the product will continue to be introduced during multi-topic field days as a general awareness on the impending widespread application of the product.

Figure 4.1 OPRA/OPIC field day training introducing the biological control agent to VOP growers.

Figure 4.2 OPRA staff demonstrating the application of the biological control agent during an OPRA/OPIC field day.

OPIC training

Training of OPIC officers from the other centres was not able to be held on schedule and will be held at a later date. The plan is to train OPIC extension officers from the different regions in the theory, mixing and application of the biocontrol agent and these officers will have the responsibility of disseminating the information to growers during farmer field days and grower community days. At least one field day will be held in Oro Province with OPIC WNB extension staff in attendance.

Cross-cutting issues

There are a number of issues which impact on productivity and sustainability of the agricultural sector. These issues are common to all commodities and awareness on these issues should be mainstreamed into training and development programmes. Where possible, the project attempted to incorporate these issues in field training but in some cases, lack of resources lead to omission of specific activities to address them.

HIV/AIDS
No direct training on HIV/Aids was provided to growers in this project. However, this important issue is part of an ongoing awareness and research programme under the PNGOPRAs Socio-Economic Section. OPIC and OPRA recognize the potential of the HIV/Aids epidemic to adversely impact on the income of smallholders by reducing their productivity as a direct result of a lack of human resources. This topic will continue to be addressed in future training of growers.

Gender
Whilst gender equity severely impacts on women in some Provinces, in Milne Bay this is not as serious and issue although improvements can be made to the general perception and welfare of women in the agricultural environment. Training sessions did not specifically target women. However, the number of women attending training sessions was noted in order to improve on this in subsequent training programmes.

Safety & Environment
From the outset, the development of this project was strongly influenced by safety and environmental concerns. The impact of fungicides on the health of growers and consequences of environmental damage eliminated this option as a long term solution to disease control. A natural product with majority organic additives has provided a safe and environmentally friendly solution to the dilemma facing growers when replanting their blocks. Adverse impacts on the health and safety of users and the environment are not expected.

Conclusions and recommendations
The project achieved its objective of development of a suitable biological control for field use by farmers. Despite early setbacks in funding and later with procurement of supplies, all outputs were eventually achieved. A standard operating procedure will be drawn up for use of the product and OPIC extension staff will be trained to deliver the appropriate information to the growers.

RECOMMENDED PRACTICE TO BE USED IN LARGE SCALE SMALLHOLDER REPLANT TRIALS

Production and storage of biocontrol agent
The biological control agent will continue to be produced at the laboratory facility in Milne Bay. The cultures will be grown in liquid media (as shown) for 1 week and then spores and mycelia will be harvested. The total solution (3 litres) will be homogenized and then dispersants and adjuvants added. The liquid will then be poured into plastic bags and frozen. After freezing, the liquid will be dried and packed in sealed bags ready for distribution. It is envisaged that advance orders for the biocontrol product will be provided by OPIC according to their replant requirements and the laboratory will produce the required amounts. This is in order to ensure that the product is not stored for too long and will remain viable prior to use. Once prepared, the product will be provided to OPIC for use as needed and its use monitored by PNGOPRA. The product can be stored within the OPIC offices as long as 6 months provided it is not exposed to excessive heat. Packages will be small (50-100g) in order to minimize handling problems.

Mixing
Instructions for mixing will be provided with the product. The mixing will be simplified to involve only addition of water to a bucket of water or directly into a sprayer and the addition of the product directly from the packet. Agitation of the solution is adequate to mix the contents. No further additives will be required except for a small amount of adjuvant that will be packaged separately.

Application
Solutions of the biocontrol agent will be delivered by 15 litre backpack sprayers with approximately 100 ml per trunk base being used (more if the chipped area is extensive). Thus, up to 150 palm trunks can be

sprayed with a single batch of 15 litres of product mixture. Application will be required at least 3 times per year and more if rain events are frequent. Product should not be applied during rainfall.

Target
Smallholder blocks undergoing replant will be identified and the product used as above. All sanitized palms will be treated as well as poisoned, standing palms. Application will be to the base of the palm and chipped tissue or to the base and up to 3m on standing poisoned palms.

Safety
Although the product contains a naturally occurring fungus as well as organic additives, it is advisable to wear a dust mask when mixing the product in case small particles are picked up by wind. Safety data sheets will also be provide with the product.

Acknowledgements
The following organizations and persons are gratefully acknowledged for their contribution, encouragement and guidance of throughout this project: AIGS management and staff, OPIC extension officers, OPRA staff, VOP farmers.

PNGOPRA also gratefully acknowledges the ARDSF and AusAid for their support of this work which could not have been undertaken without their assistance with funding.

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SCREENING FOR GANODERMA RESISTANCE (RSPO 4.5, 8.1)
Incorporating ACIAR Ganoderma Project PC-2007/039: The control of basal stem rot caused by Ganoderma in Solomon Islands

INTRODUCTION
Laboratory and nursery assays also continued in 2011. The results of some of this work are presented below. Monitoring of the field trial at GPPOL continued in 2011.

RESULTS
Nursery assays
Three sets of nursery trials were established in 2010 and final assessment was made in 2011. Three more trials were set up in 2011.

Trial 1 tested the hypothesis that E.o x g hybrids are resistant to Ganoderma. As shown in Figure 1, high levels of infection were obtained in both progenies after 8 months of testing.

Trials 2 and 3 tested selfed progenies against a single Ganoderma isolate (Figures 2, 3 and 4). Some progenies showed consistency in results against Ganoderma. None of the progenies were totally resistant with each sowing degrees of partial resistance. Disease progress curves for Trial 2 (Figure 3) indicate that the progeny ranking was also consistent over time.

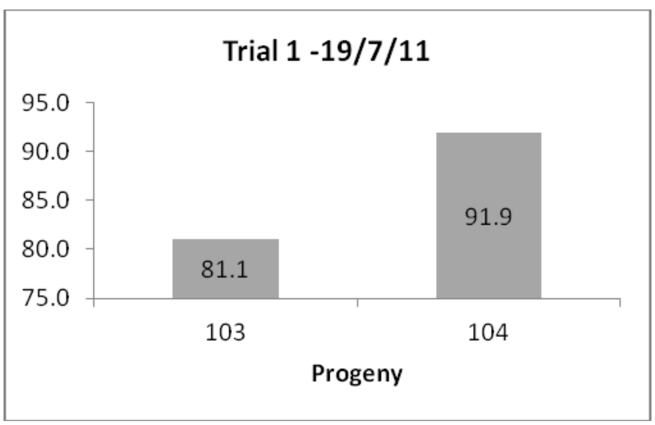

Figure 1 Seeding mortality 10 months after inoculation with Ganoderma on rubber wood blocks.

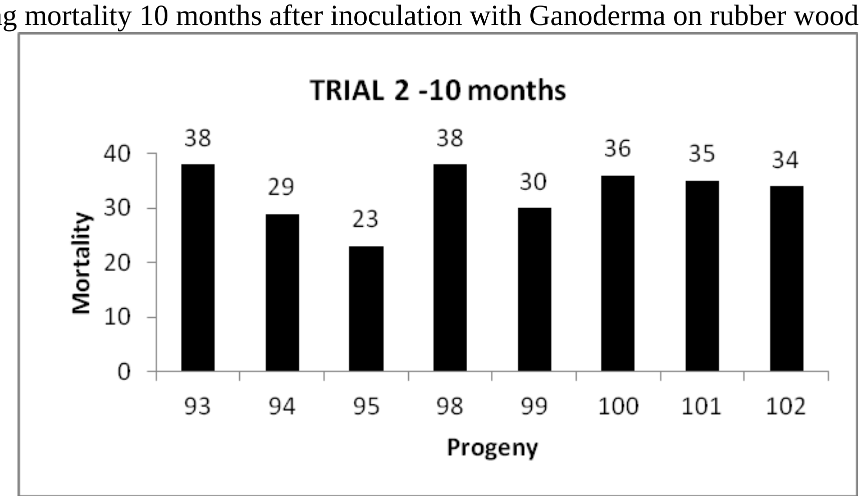

Figure 2 Seedling mortality 10 months after inoculation with Ganoderma on rubber wood blocks.

Trial 4 demonstrated the effectiveness of the *Trichoderma* formulation developed for use as a biological control agent (above) (Figure 5). After 4 months, the disease levels in *Trichoderma*-treated plants were significantly different from the control palms which had distilled water treatment. Further trials are to be implemented to confirm this initial work.

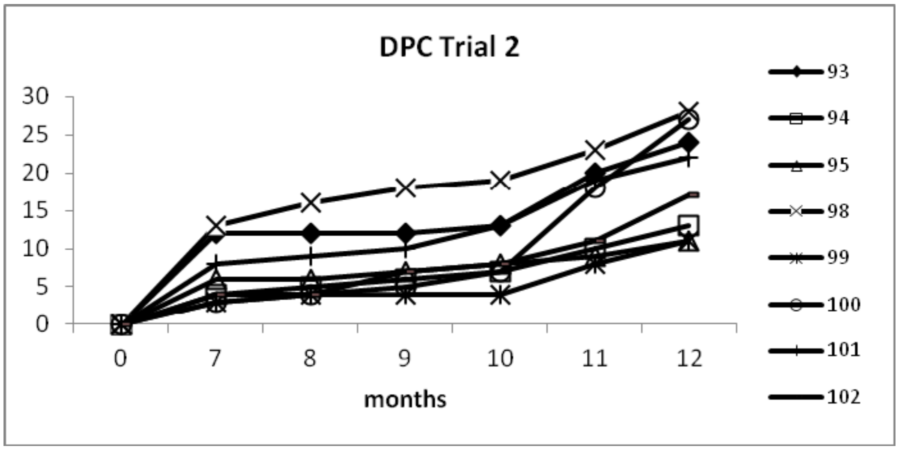

Figure 3 Disease progress amongst different progenies over 12 months under nursery conditions.

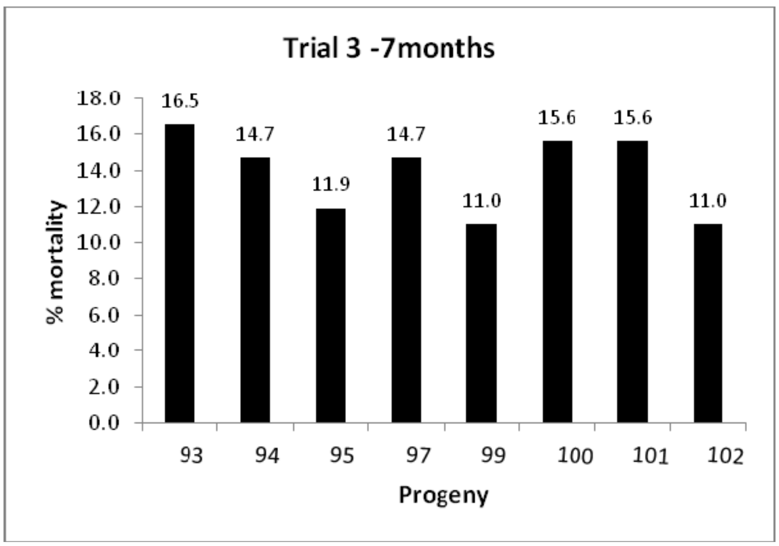

Figure 4 Seedling mortality 7 months after inoculation with Ganoderma inoculum on rubber wood blocks under nursery conditions.

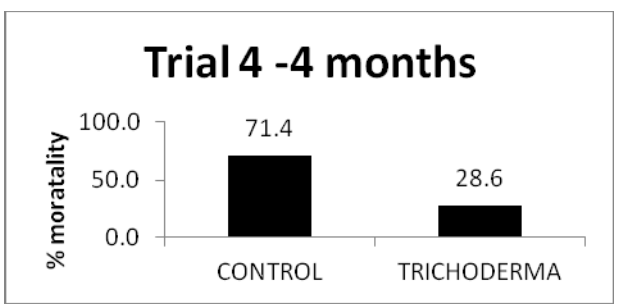

Figure 5 Mortality of seedlings inoculated with Ganoderma, with and without (Control) Trichoderma treatment. (Single progeny).

Field trials- Solomon Islands

Field trials were established at Ngalimbiu Plantation, GPPOL, Solomon Islands in March and April 2010. Trial design is a randomized complete block design with 14 replicates (blocks) and a single progeny per block. Eighty one progenies provided by Dami OPRS are being tested.

Sampling of seedlings and genetic testing

In 2011, all trial palms were sampled as well as all remaining seedlings in the nursery. All samples were delivered to the University of Queensland. An assay to screen large numbers of samples is being developed by UQ collaborators and should be ready for further testing of the trial palms in early 2012.

Sampling of Ganoderma in trial blocks

Surveys of stumps and logs remaining in the field after planting have indicated a large number of Ganoderma brackets remaining in the trial block areas. Brackets have been collected and isolations made so that these isolates can be stored in case of new infections in trial palms. Not all isolations have been successful owing to poor conditions at the laboratory in SI but this situation should improve with the procurement of new equipment late 2011.

Phenotypic data collection

Bunch counts commenced in August 2011 and will continue until harvesting begins. Some preliminary data is presented below (Figures 6 and 7). Although variability is high, some progenies are performing consistently in both trials. Other traits such as crown disease are also being monitored.

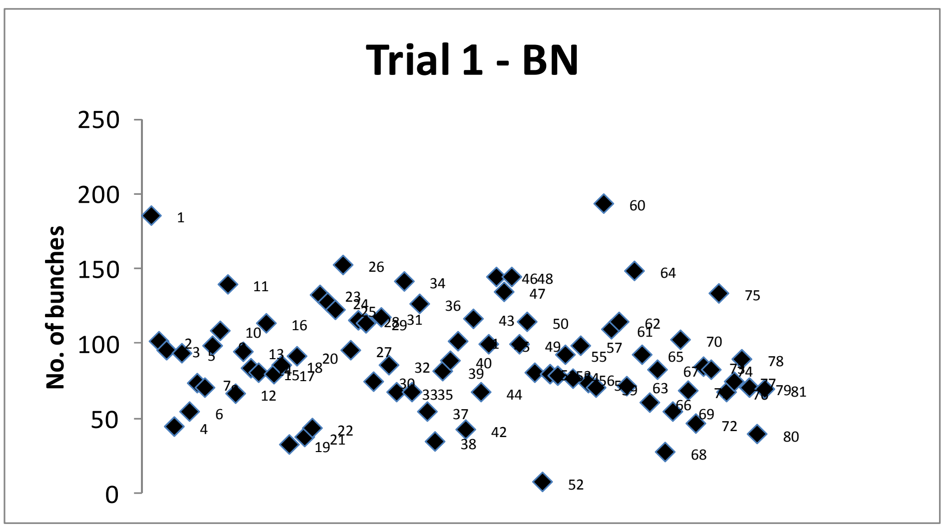

Figure 6 Total bunch numbers produced by progenies in Trial 1 Field 12 Ngalimbiu Plantation, GPPOL over an 8 month period.

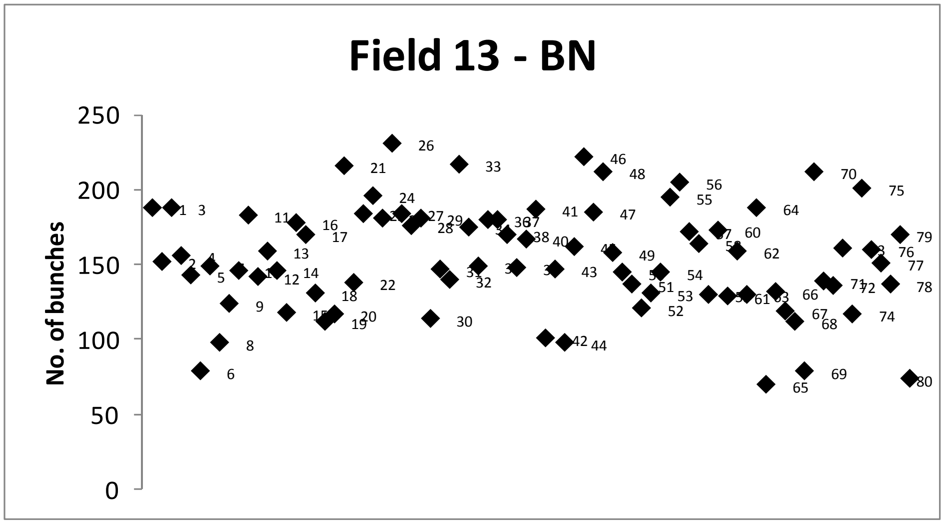

Figure 7 Total bunch numbers produced by progenies in Trial 2 Field 13 Ngalimbiu Plantation, GPPOL over an 8 month period.

QUARANTINE (RSPO 4.5, 8.1)

Nursery inspections

All ASD material has now been moved to the field and no further inspections for quarantine were required after a final inspection in February 2011.

Bogia Coconut Syndrome

Samples colleced by CCI and Entomolgy Section were processed and tested for phytoplasma. All samples were negative however, most of the insects were degraded and good quality DNA could not be obtained for PCR analysis.

PUBLICATIONS, CONFERENCES AND TRAVEL (RSPO 8.1)

Publications

The APPS Conferences was attended by C. Pilotti in May 2011 and a joint Poster with UQ collaborators was presented**.**

Travel

Travel was undertaken by the Head of Plant Pathology (HoPP) for normal plantation site visits and project work.

Table 1 Travel undertaken by HoPP and APP during 2011.

Month	**Plantation/Visit**
January	NBPOL
February	Higaturu OPL
March-April (E. Gorea)	GPPOL
May	GPPOL/UQ
May	Madang-BCS meeting
June-July	Poliamba Ltd.
August	Kokopo – ACIAR workshop
June	NBPOL, Hargy OPL
October	GPPOL, UQ

OTHER ACTIVITIES

Project administration

General administration and quarterly and annual reporting for the AIGS and ACIAR Projects was accomplished throughout the year.

LPC MEETINGS

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

DISEASE REPORTS (RSPO 4.5, 8.1)

A list of disease reports received and attended to in 2011 by staff in West New Britain and Milne Bay is shown in Tables 1 and 2.

Table 1 Disease reports received and attended to by the Plant Pathology Section – Milne Bay in 2011.

Date	Location	Details
February	Hagita- ASD nursery	Leaf spots
February	Higaturu –Sangara & Mamba nurseries	Leaf spots
February	Mamba Estate	Weevil damaged palms
February	Sagarai Estate	Dead palms
March	Sagarai -Tamonau	Orange spotting
March	Mariawatte	Basal rot & wet rot
May	Hagita -Nawae nursery	Leaf spots
May	Hagita - nursery	Army worm
June	Hagita nursery	Leaf spots
July	Padipadi	Wet rot & basal rot
December	Hagita-BMP block	Basal rot & weevil damage

Table 2 Disease reports attended to in West New Britain, in 2011.

	Report Received	From	Reported By	Area	Block #	Description
1		OPIC Nahavio		Tamba	002-0501	Sanitised
2				Tamba	002-0503	Sanitised
3				Tamba	002-0522	1 suspect palm
4				Tamba	002-0523	2 collapsed (basal stem rot)
5				Tamba	002-0464	1 palm suspected with wet stem rot
6				Kilu Patanga	026-0021	3 collapsed palms
7				Morokea 2	?-0068	Not located
8				Dagi	010-0033	1 collapsed palm
9				Dagi	010-0038	1 collapsed palm
10				Dagi	010-0071	2 dead, 1 collapsed, 1 suspect & 1 with brackets
11				Dagi	010-0291	4 collapsed palms
12				Sarakolok Sec. 6	003-0941	1 palm infected - light
13				Sarakolok	003-0975	1 palm infected - light
14		OPIC Buvussi		Buvussi	004-1403	2 palms infected - light
15				Buvussi	004-1488	1 collapsed palm
16		OPIC Siki		Waisisi	023-0135	1 palm infected - light
17		OPIC Kavui		Kapore Sec. 1	001-0270	1 palm infected - light

18				Kapore Sec. 8	001-0356	1 upper stem rot
19				Kapore Sec. 8	001-0522	1 palm dead - Gb brackets
20				Kavui/Waramari	006-1768	7 palms infected - severe
21				Kavui Sec. 1	006-1755	1 palm infected - light
22				Kavui Sec. 1	006-1798	1 palm infected - light
23				Gaongo Sec. 2	017-0152	2 palms infected - light
24				Gaongo Sec. 5	017-0251	2 palms infected - light
25				Gaongo Sec. 5	017-0117	1 palm infected - light
26				Banaule VOP	015-0045	1 collapsed palm
27				Banaule VOP	015-0047	1 palm infected - light
28				Kwalakessi VOP	013-0039	5 sterile palms
29				Kwalakessi VOP	013-0060	5 wind damage
30				Kwalakessi VOP	013-0066	4 wind damage
31				Kwalakessi VOP	013-0068	4 wind damage
32	15/02/11	OPIC Kavui	D Daure	Mandopa VOP	1-085-0020	Crown damage & 1 suspect palm
33	03/03/11	OPIC Siki	J Gemes	Siki Sec. 4	009-0094	1 suspect palm
34	03/03/11	OPIC Siki	J Gemes	Siki Sec. 2	009-1055	1 suspect palm
35	03/03/11	OPIC Siki	J Gemes	Siki Sec. 1	009-2264	1 suspect palm
36	03/03/11	OPIC Siki	J Gemes	Siki Sec. 1	009-0165	1 suspect palm
37	07/03/11	OPIC Kavui	J Jackba	Kapore Sec. 7	001-0352	Brackts present
38	07/07/11	OPIC Siki	D Yangum	Siki	009-0022	Confirmed Gb
39	21/07/11	OPIC Kavui	D Mataio	Kavui Sec. 2	006-1778	Wet stem rot
40	10/08/11	OPIC Nahavio	Z Wenga	Rerengi VOP	062-0220	suspect palm
41	10/08/11	OPIC Kavui	D Daure	Kwalakessi VOP	013-0023	4 wind damage
42	10/08/11	OPIC Kavui	D Daure	Kwalakessi VOP	013-0049	2 crown disease
43	10/08/11	OPIC Kavui	D Daure	Kwalakessi VOP	013-0052	4 wind damage
44	10/08/11	OPIC Kavui	D Daure	Kwalakessi VOP	013-0061	3 wind damage
45	10/08/11	OPIC Kavui	D Daure	Kwalakessi VOP	013-0065	5 wind damage
46	10/08/11	OPIC Kavui	D Daure	Kwalakessi VOP	013-0069	2 wind damage
47	10/08/11	OPIC Kavui	D Daure	Kwalakessi VOP	013-0078	6 wind damage
48	29/09/11	OPIC Nahavio	J Selvin	Sarakolok Sec. 2	003-0806	1 palm with brckts & 2 suspects
49	29/09/11	OPIC Nahavio	C Hidalgo	Sarakolok Sec. 2	003-0850	2 palms with brckts & 3 suspects
50	07/10/11	Bebere Pltn	A Wamahama	Division 1	MU 07B	1 palm with brckts & 1 upper stem rot
51	13/10/11	OPIC Buvussi	M Henao	Galai 1 Sec. 15	005-1529	Wilting fronds (suspect disorder (?))
52	28/10/11	OPIC Kavui	J Jackba	Banaule VOP	015-0045	Brcks on 4 palms
53	01/11/11	OPIC Siki	P Poka	Siki Sec. 4	009-0097	1 suspect
54	01/11/11	OPIC Siki	P Poka	Siki Sec. 4	009-2243	Basal stem rot on 1 palm
55	01/11/11	OPIC Siki	P Poka	Siki Sec. 6	009-2208	1 suspect palm
56	01/11/11	OPIC Siki	P Poka	Siki Sec. 6	009-2216	1 suspect palm
57	04/11/11	OPIC Salelubu	D Mataio	Silanga VOP	242-0443	Suspect spear rot (?) on 6 palms
58	16/11/11	OPIC Nahavio	Z Wenga	Dagi	010-0071	Brckts presence
59	16/11/11	OPIC Nahavio	Z Wenga	Dagi	010-0072	Brckts presence
60	22/11/11	OPIC Buvussi	M Henao	Galai 1 Sec. 15	005-1513	Unproductive palms (suspect disorder (?))
61	22/11/11	OPIC Buvussi	M Henao	Galai 1 Sec. 15	005-1510	Unproductive palms (suspect disorder (?))

62	22/11/11	OPIC Buvussi	M Henao	Galai 1 Sec. 16	005-1558	1 palm with Gb brckts
63	02/12/11	OPIC Kavui	T Poglo	Kavui Sec. 11	006-1635	Suspect maganesium deficiency on 3 palms
64	13/12/11	OPIC Nahavio	P Side	Dagi	010-2061	Brcks on dead palm

TRAINING (RSPO 1.1, 4.8, 8.1)

Table 1 Training and awareness sessions held throughout the year for OPIC and plantations in West New Britain Province.

Month	Date	Type	Location	Comments
March	15th	Field Day	Barema LSS [Bialla Project]	
April	05th	Field Day	Hak VOP [OPIC Nahavio]	
	12th	Field Day	Ismin VOP [OPIC Nahavio]	
May	03rd	Field Day	Waisis VOP [OPIC Siki}	
June	14th	Field Day	Buvussi Community [OPIC Buvussi]	
	21st	Field Day	Bubu VOP [Bialla Project]	
	28th	Field Day	Galai 1 [OPIC Galai]	
	28th	Radio Talk	Radio WNB - Kimbe	Aired on Radio WNB
September	28th	Training/Demo	Numundo E4 field	Ganoderma sanitation demo for OPIC & SMA officers
November	18th	Training	OPIC conference room [Nahavio]	PowerPoint presentation for new infield farmers
	23rd	Demonstration	Numundo E4 field	Ganoderma sanitation demonstarion for ACIAR team visit

Table 2 Summary of field training sessions held for VOP growers in Milne Bay in 2011.

DATE	AREA	# ATTENDEES	TRAINERS
6/6/2011	Waema	19	Emmanuel, Ura, Arthur, Moses
1/8/2011	Rabe	25	Ura/Emmanuel
8/8/2011	Borowai	22	Ura/Emmanuel
15/8/2011	Borowai (Yaneyanene)	7	Emmanuel/Willie
17/8/2011	Kerakera	7	Emmanuel/Willie/Terry
21/08/2011	Siasiada	15	Emmanuel/Ura
24/8/2011	Ipouli	12	Emmanuel/Ura/Arthur
21/9/2011	Iwame	12	Emmanuel/Ura
12/10/2011	Marayanene	9	Emmanuel/Ura/Terry
9/11/201	Kilakilana	9	Emmanuel/Terry
11/9/2011	Figo	5	Crawley,James,Ronald, Rodney
16/11/2011	Mila	18	Emmanuel. Gorea
21/12/2011	Kapurika	9	Emmanuel/Terry

(shaded) Introduced biocontrol

Additional training was held for plantation staff.

4. SOCIO ECONOMICS RESEARCH

HEAD OF SECTION: VACANT
Written by Gina Koczberski, George Curry and Emmanuel Germis

SMALLHOLDER ENGAGEMENT STRATEGY (RSPO 4.8, 6.2, 8.1)

In 2011 the socio-economic section began work on a research project, within the support framework of the Smallholder Agricultural Development Project (SADP), to determine the most effective and appropriate extension methodologies to apply in SADP project areas. The overall aim of the project is to produce a Smallholder Engagement Strategy for OPIC that will lead to more effective and efficient delivery of extension services.

In 2003 LSS smallholders achieved about 60% of the production per hectare of the company plantations, while VOP producers achieved only 38% of plantation production (Curry *et al*, 2007). Currently, average smallholder productivity is approximately 17 tonnes/ha (OPIC data). Over the past fifteen years efforts by OPIC to increase smallholder productivity have included the introduction of additional harvesting cards to benefit women and to promote hired labour, as well as interventions to increase fertiliser use, and the promotion of better farm management techniques, including pest and disease control.

Despite financial and staffing limitations, OPIC generally performs well in meeting its annual smallholder production and replanting targets. OPIC appears to outperform other export commodity crop extension organisations in PNG, and the introduction of the Mama Loose Fruit Scheme is recognised nationally as amongst the most innovative and successful extension interventions introduced across all the extension agencies in PNG. Similarly, the promotion of fertiliser and good oil palm management practices amongst growers has shown good results. The use of fertiliser amongst growers has increased considerably over the last decade, with around 80-90% of growers regularly applying fertiliser. Recent research conducted at Hoskins also shows that smallholders have very good knowledge of the yield benefits of fertiliser and good block management practices (Mendano, 2012). Thus awareness campaigns by OPIC and PNGOPRA among smallholders on the benefits of fertiliser have been very effective.

Despite these achievements, smallholder productivity remains low and it appears that the knowledge of good management practices held by smallholders is not translated into everyday farming practices. For example, whilst most smallholders purchase fertiliser, it is often not applied regularly or at the correct rate, and maintenance on numerous blocks remains poor. To develop a Smallholder Engagement Strategy for OPIC which contains a set of guidelines and recommendations for more effective extension delivery, the socio-economic section is examining the main reasons why many smallholders are not adopting current OPIC extension messages and what problems OPIC experiences in aiming to improve smallholder production.

The aims of the Smallholder Engagement Strategy are to provide OPIC with:

(i) a set of guidelines and recommendations that will assist the organisation to develop more effective and efficient forms of extension delivery; and

(ii) a strategy that will work to improve smallholder production and household well-being. The Strategy and its key recommendations will be informed by information collected in workshops and interviews with OPIC and from questionnaire surveys and interviews with smallholder households.

The project will involve conducting two workshops with OPIC officers in each of the project areas. The aims of the first workshop are to:

1. Inform OPIC of the study.
2. Identify relevant local issues and concerns related to extension and education.

3. Seek opinions on the types of extension methods that could be introduced or improved to increase the uptake of extension messages by smallholders.
4. Gather information to inform the design of the smallholder household surveys and the final smallholder engagement strategy for OPIC.

In 2011 the first set of workshops was completed and information was gathered from discussions around the following broad questions:

- Why are many smallholders not adopting OPIC extension messages/advice?
- What problems do OPIC officers face in trying to improve smallholder production?
- What are the main extension methods used by OPIC and what new methods could OPIC use to improve the likelihood that their extension advice will be adopted?

The purpose of the second set of workshops will be to gain feedback from key stakeholders on the draft OPIC smallholder engagement strategy. The draft report will be distributed prior to the second workshop.

The information gathered at the first set of workshops will be supplemented by data collected from smallholder household surveys which will be conducted among 90 families residing on LSS, CRP and VOP blocks in each project area. The survey will collect the following information: the education levels of the smallholder population and the range of education strategies employed within and between co-resident households on smallholder blocks; livelihood and income strategies pursued by different co-resident households; population density; land tenure security; and production strategies pursued by multiple household blocks. Smallholders will also be asked to evaluate the effectiveness of OPIC extension messages and training and the value of channelling extension messages through existing and new media such as: audio-visual material, SMS messages, etc. A final Smallholder Engagement Strategy will be available at the end of 2012.

CUSTOMARY LAND USAGE AGREEMENTS (RSPO 1.1, 2.1, 2.2, 2.3, 5.1, 6.1, 6.2, 6.4, 7.5, 7.6, 8.1)

Work continued with OPIC and the World Bank to standardise and introduce a new Clan Land Usage Agreement for use on Customary Rights Purchase Blocks. As outlined in earlier annual reports, the majority of CRPB land transactions are informal and land surveys are rarely undertaken. Written agreements often do not specify the agreed 'sale' price of the land, the amount and timing of payment instalments, and the specific rights of the purchaser. Seldom is there any written evidence that the land 'sale' has the approval of the clan. This can lead to much misunderstanding and disputes between the 'purchaser' and the customary landowners.

Current procedures for dealing with new oil palm plantings on CRPBs and the commonly used Clan Land Usage Agreement (CLUA) form do not provide adequate land tenure security for the outsider 'purchasing' or leasing land; nor do they ensure that all members of the landowning clan agree to or benefit from these land 'sales'. In most cases, the sales are not in accordance with customary law. Section 81 of the Land Act prohibits the sale of customary land except to citizens of PNG in accordance with customary law. Thus, unless the sale of the land can be shown to be in accordance with customary law then the sale is illegal. An illegal sale is not compliant with RSPO criteria. The new Clan Land Usage Agreement template aims to address these legal issues.

In mid 2011 PNGOPRA organised a meeting in Port Moresby with OPIC Project and Field Managers and Lands Officers to discuss the draft CLUA template and to reach agreement on a standard CLUA to be introduced at each project site. The template includes comprehensive guidelines and instructions. At the meeting it was agreed that further legal advice be sought before the CLUA was standardised and introduced at all project sites.

FOOD SECURITY PROJECTS (4.2, 4.8, 5.1, 6.1, 8.1)

Improving food security and marketing opportunities for women in smallholder cash crop production.

Work continued on the smallholder project "Improving food security and marketing opportunities for women in smallholder cash crop production". Funding for the project was received from the Agricultural Innovation Grant Scheme (AIGS), an initiative of the Australian Government through the Agricultural Research and Development Support Facility (ARDSF). Food and income security among oil palm smallholders in Papua New Guinea is central to the long term sustainability of the oil palm sub-sector.

Food gardening is a primary focus in the lives of smallholders, particularly for women, and most smallholder households remain heavily dependent on subsistence food production for their daily needs. Most LSS and VOP smallholders grow sufficient food to meet most of their food requirements, and garden food production for sale at local markets provides LSS women with an important source of income. Koczberski *et al.,* (2001) found that smallholders spend considerably more time in gardening than they do in oil palm related work. In 2000 women allocated almost 2.5 times as much of their labour to gardening than to oil palm, whereas, for men, gardening and oil palm were of about equal importance in terms of the time allocated to each activity. Research conducted by the socio-economic section also has demonstrated the importance of food gardens for maintaining food security, especially on the LSSs where households were much more dependent on food gardens than VOP producers. Dietary recall studies on one LSS subdivision at Hoskins revealed that almost 80% of meals consisted entirely of ingredients from food gardens compared with about 50% of meals on a nearby VOP subdivision. This survey was during a period of depressed oil palm prices, when the price fell to around K50/tonne. On the LSS subdivision, the consumption of store foods tended to be concentrated within the first few days of receiving the oil palm cheque. For the following three weeks, households were heavily dependent on garden foods. Thus, food gardens are central to maintaining food security. Their importance to families increases as the number of people on the block increases. They also provide a buffer against low oil palm prices as occurred in 2000.

However, rising population pressures and recent high oil palm prices have encouraged smallholders to fully plant their 6 ha blocks to oil palm. This practice has displaced food gardens to environmentally sensitive lands such as buffer zones, riparian habitats or on to nearby state land or land belonging to customary landowners or the company. In the context of rising population and land shortages on the LSS, there is a need to develop sustainable production and farming systems to overcome these problems. One option is to look at innovative ways of utilising the limited amount of land available by intercropping oil palm with food crops.

This project is currently investigating the optimal planting arrangements for oil palm to facilitate intercropping of food crops and fuel wood species for home consumption and sale at local markets while sustaining oil palm incomes. Intercropping of oil palm and food crops will help ameliorate the land pressures from food gardening on marginal and environmentally sensitive areas like buffer zones. At the same time it would greatly improve women's access to land for food production, thereby contributing to food security and enhancing income opportunities.

Intercropping trials are being conducted at Popondetta, Bialla and Hoskins. The socio-economic team is working closely with the agronomy section to monitor the trials. The socio-economic section has also conducted focus group discussions on food security issues with smallholders in Uasilua and Vainemasile, Cenaka Division.

Oil palm, food security and adaptation among smallholder households

This project forms the basis of an ACIAR-funded PhD scholarship conducted by Veronica Bue (Unitech) in collaboration with Curtin University and PNGOPRA. The four year study is located on the LSS blocks at Hoskins and Bialla and examines: i) how household food security and access to land for food gardening have changed over the past three decades; and ii) how smallholders are maintaining household food security in the context of growing demand for land for oil palm production and rapid population growth.

Given that most blocks are now fully planted to oil palm, yet most smallholders continue to maintain food gardens, the study has focused on identifying the various ways smallholders are adapting to shortages of gardening land. Preliminary results indicate that smallholders are responding to shortages of garden land through the:

- intensification of land-use;
- intercropping immature oil palm with food crops;
- seeking access to land beyond the LSS block.

Table 1 shows the changes in food gardening systems from 1975 to 2010 and the impact on land pressures on shortening fallow periods and extended cultivation periods. In 1975 when population densities were much lower and just over half of the 6 ha leasehold block was planted to oil palm, almost 3 ha per block were available for food gardening, which was more than sufficient to meet the average needs for garden area per block of 0.402 ha (Table 1). Gardens were cultivated for 12-18 months, with a fallow period of 6-9 years, which allowed seven years without crops before returning to the original plot (Benjamin, 1977). In 2010, mean garden area required per block has risen to 0.6 ha, while the effective area of gardening land had contracted to a mean of 0.61 ha per block across the LSS as smallholders converted their 2 ha of 'reserve land' to oil palm. Thus there is barely adequate land for food gardening now, with virtually no scope for fallowing. Over the same period, through intensification, smallholders have reduced the mean garden area cropped per head from 0.058 to 0.04 ha (Table 1) and many have begun utilising land during the oil palm replanting stage to intercrop immature palms with food crops.

Table 1. Changes in food gardening systems from 1975 to 2010.

Gardens	1975[1]	2010[2]
Size of leasehold block	6.07	6.07
Persons per block	7.24	14.72
Area of leasehold block planted to oil palm	3.24 ha	6.00
Garden land available on block per year (i.e. land not planted to oil palm)	2.83	0.61
Mean garden area cropped per head	0.058	0.0405
Required cultivated garden area per block to meet needs of resident population	0.402 ha	0.5964 (0.6)
Fallow period	6-9 years	Assumes permanent cultivation
Intercropping of immature oil palm with food crops	Non-existent	35% of the total area of food gardens

(Source: Koczberski, Curry & Bue, in press).

1. Data for 1975 are drawn from Benjamin (1977). Her study surveyed 140 gardens at Kapore, Tamba, Sarakolok, Buvussi, Galai, Kavui and Kavugara subdivisions. 2. Data for 2010 are drawn from Bue (unpublished data). Her study surveyed 118 gardens at Kapore subdivision.

Land use pressure has led to shorter fallow periods, extended cultivation periods, greater reliance on short-maturing food crops that are more tolerant of less fertile soils, and the increased use of fertilisers and pesticides. Preliminary results also indicate that smallholders are maintaining food production by favouring staple food crop types that are more tolerant of poorer soils, quick maturing and less prone to pest attack. Compared with food crop garden data from 1975 (Benjamin, 1977), smallholders are planting less yams and taro, and relying more on bananas and cassava: crops that are higher yielding and can tolerate less fertile soils. Smallholders are also adopting quick maturing food crop varieties and these are becoming more common in the suite of food crops cultivated by smallholders. For example, *wan mun kaukau* (*Ipomoea batatas*) which matures in less than three months was displacing older varieties of sweet potato that take four or five months to mature.

With the reduction of garden 'reserve land' on LSS blocks, settlers have responded by cultivating gardens in new locations on and off the block (Figure 1). Garden surveys on two of the earliest LSS subdivisions established at Hoskins and Bialla revealed that while almost a quarter of the total cultivated garden area was at the rear of the block on land remaining after planting 6 ha of oil palm, smallholders were bringing small patches of land previously considered unsuitable for food gardens into production. These included hilly sections of the block unsuitable for oil palm and land around house sites. Also, some smallholders were not replanting the full number of palms after poisoning senile palms and were leaving out an edge row of palms to make more land available for food gardening. Gardens cultivated on this 'converted land' accounted for just over 10% of the total area of smallholder food gardens (Figure 1).

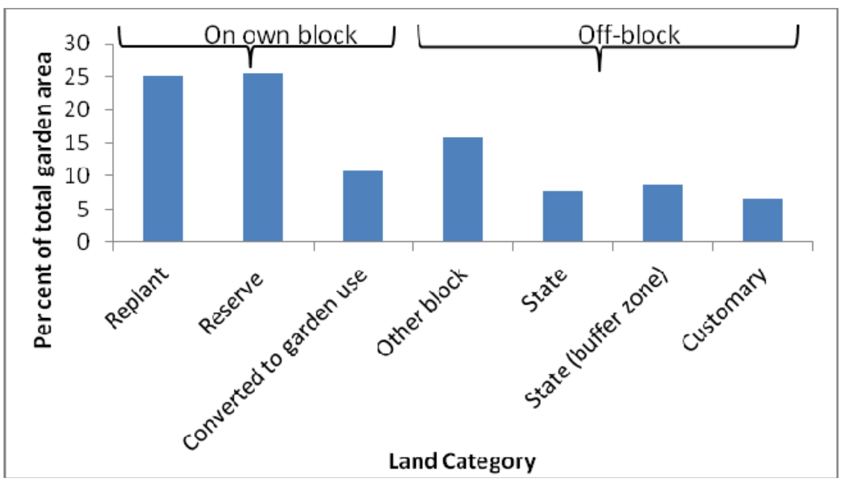

Figure 1. Proportions of garden area located on different land types and tenures.
(Source: Koczberski, Curry & Bue, in press).

Replant sections on smallholder blocks were providing the only substantial area for food gardening on a smallholder block (Figure 1). Thirty-five per cent of the total area of food gardens was in replant sections, either on smallholders' own blocks (25%) or in the replant sections belonging to other growers, usually a relative (10%). Smallholders practice rotational replanting of 2 ha stands of oil palm every 22 years, which means 2 ha are available for food gardening for 6 of every 22 year cultivation round on a block with 6 ha of oil palm. When there was insufficient land for food gardens on their own blocks, smallholders sought the assistance of friends and relatives living on nearby blocks for access to gardening land: 16% of the total garden area was located on other blocks, which indicated the growing importance of social networks for accessing land. Smallholders were also cultivating food gardens illegally on State land surrounding the LSS, some of which was categorised as 'buffer zone' land in environmentally sensitive areas along creek lines (Figure 1). In some cases, smallholders were making informal arrangements with neighbouring customary landowners for access to gardening land. Thus, as the land available for food gardening on the block contracts, smallholders are becoming more dependent on off-block access to gardening land with almost 40% of the total garden area now being off-block (Figure 1).

Work will continue in 2012 on understanding ways smallholders are adapting to shortages of gardening land.

SMALLHOLDER HOUSEHOLD SURVEYS (RSPO 6.1, 6.2, 8.1)
Changing Production Strategies among Smallholders
Data from the household survey collected by the socio-economic section among smallholders at Hoskins, Popondetta and Bialla found that almost 55% of households are adopting new labour and payment arrangements on their block, which they term *skelim hecta.* The types of labour and payment arrangements operating on smallholder blocks have a significant impact on harvesting rates and block maintenance. Earlier studies conducted by the socio-economic section revealed that a major determinant of low smallholder productivity was the considerable level of under-harvesting (Koczberski & Curry, 2003; Koczberski & Curry, 2008). Under-harvesting leads to substantial production losses amongst smallholders and is a major cause of low productivity. Whilst low productivity is explained by low farm inputs in the smallholder sector (e.g. low rates of fertiliser application, delayed replanting, poor block maintenance, etc) and range of other socio-cultural factors, a key factor is high rates of under-harvesting. The types of labour and payment arrangements operating on a smallholder block are linked closely with smallholder harvesting strategies. Before describing *skelim hecta,* a short discussion of smallholder production strategies and block production is necessary.

Background
As the smallholder sector develops over time, different smallholder household types are emerging, and these influence the ways in which labour is organised and remunerated. Single household blocks, caretaker households and multiple co-resident households are the three main types of smallholder blocks on the LSS.

As the smallholder sector develops over time diverse household types are emerging to include:

- Single household blocks – usually consist of one household made up of household head, spouse, children and relatives attached to the household such as an elderly parent of the husband or wife, and/or short-term visitors.
- Caretaker household blocks – many caretaker households are single households consisting of the household head, spouse, children and relatives attached to the household, such as a brother or a temporary visitor. The type of relationship between the blockowner and caretaker varies. Caretakers can be close or distant relatives, friends or an unrelated person from the same ethnic group as the blockowner.
- Multiple household blocks – often consist of the elderly original owner, his wife, their married sons (and sometimes married daughters) and their families. On the older LSS schemes many of the original owners are deceased and the married sons/daughters now share and manage the block.

Smallholders have developed different ways of organising and remunerating family labour, which we term smallholder production strategies. There are three main production strategies operating on the LSS blocks: *wok bung wantaim*, *markim mun* and recently *skelim hecta*.

The type of production strategy used on a block can have a considerable impact on block productivity, through influencing:

- Access to labour
- Management decisions on the block
- Harvesting frequency and intensity
- Block maintenance
- Willingness to invest in farm inputs (e.g. fertiliser and replanting)

- Income distribution
- Incentives to repay or not repay loans for farm inputs
- Skip harvesting

How each of the production strategy influences each of the above points is discussed next.

Household production strategies

Wok Bung Wantaim

On most VOP blocks and on LSS blocks where one or two families reside on the block, the most common oil palm management and production strategy is *wok-bung wantaim*, where all family members harvest together and share the income. The *wok bung wantaim* production strategy has 'traditionally' been the dominant form of harvesting strategy among smallholders. The *wok bung wantaim* production strategy is a centralised form of production, where the male head of the block (typically the male leaseholder/VOP owner) takes full responsibility for mobilising and organising household harvesting labour and distributing income. The '*papa bilong blok*' also takes control of labour for the upkeep of the block and makes all the farm management decisions. Loose fruit collection, and its income, is under the control of the female head of the block. The *wok bung wantaim* production strategy used in oil palm emerged from the labour strategies underpinning subsistence production. Generally, for heavy, labour intensive subsistence tasks such as the cutting, clearing and fencing of new food gardens, the planting and harvesting of root crops, house building or the preparation of communal feasts, the lineage and often other members of the broader kinship group contribute labour. These large co-operative work groups in which the labour of the extended family and kinship group is mobilised to perform intensive agricultural or community work are commonly used by rural households in PNG. On smallholder blocks that still practice the *wok bung wantaim* production strategy it is typical to find families where all or most of the family members are involved in harvesting and block maintenance and share the resultant income. Generally, household relations are harmonious and there are few disagreements over the distribution of the oil palm income.

Makim mun

In the mid 1990s, on LSS blocks where several families were co-residing, *the wok bung wantaim* production strategy began to be replaced by a rotation harvesting system where the harvesting and oil palm income are rotated among the co-resident households on a block. The rotation system is referred to by smallholders as *markim mun*. A rotation *markim mun* system is characterised by the allocation of a month's harvest and the monthly oil palm cheque to one of the households residing on a block on a rotating basis. The following month a different household will perform most of the harvesting and collect the cheque. Thus, for example, if there are four households sharing the oil palm income, each household receives three cheques per year with four months between each payment. The household that has been allocated the harvest may or may not receive assistance with harvesting from other households on the block. Both the FFB harvest and the loose fruit collection are rotated on a monthly basis. Typically, one household is allocated FFB and another household is allocated loose fruit collection in any given month.

Many smallholders from heavily populated blocks moved from co-operative family harvesting (*wok bung wantaim*) to a rotation (*markim mun*) system following continual disputes over the allocation of labour and distribution of oil palm income. It appears that when the number of household units became too great for the sharing of oil palm income under a *wok bung* system or when disputes over the disbursement of income threatened social harmony on the block, a rotation system was adopted. Thus, when the numbers of household units becomes too great for the sharing of oil palm income they begin to act as separate production units. Co-resident households begin to operate as individual production units with limited inter-household labour co-operation in oil palm. During the lengthy period without oil palm income, households rely on alternative income sources or the generosity of the brother whose turn it is to receive the oil palm income.

There is some evidence to suggest that oil palm productivity is higher on highly populated blocks that have not moved to the rotation (*markim mun*) system, that is, those blocks that continue to practice *wok bung wantaim*. Families that harvest together tend to have more people involved with the harvest and therefore can harvest more of the crop. In a rotation system fewer block members may participate in a harvest round so harvesting is more likely to be incomplete. Apart from the potentially lower smallholder productivity associated with *markim mun* production systems, there is also an erosion of the father's (the leaseholder) authority to organise, manage and remunerate block labour as production decisions become the responsibility of the household head allocated that month's production (usually one of the married sons). This has implications for the ability of the leaseholder to mobilise labour, make block management decisions and repay farm debts. The implications arising from the switch to a *markim mun* harvesting system include:

- Greatly reduced motivation to invest in farm inputs, such as fertiliser.
- Where economic pressure exists, there will be a reluctance to poison old palms and replant. The loss of income may be considered, in the short-term, too great.
- Reduced incentives to undertake block maintenance as no single household is willing to take responsibility for block maintenance. For an individual household wishing to minimise its labour expenditure while maximising its income, it makes more sense not to engage in block maintenance as the benefits from such labour (higher yields) accrue to all resident households including those that did not contribute to block maintenance.
- Limited capacity for individual households to accumulate savings to invest in other businesses or material improvements on the block (e.g. water tanks, housing improvements, poultry projects, etc.). Under a *markim mun* production strategy, co-resident households may receive only three or four oil palm payments per year making it very difficult to save.
- Greater desire of co-resident households to avoid loan repayments when households face long periods between oil palm payments and have limited opportunity to save. Under a rotation (*markim mun*) system there is an incentive to abuse industry credit schemes as individual households seek to maximise their oil palm income during their allocated payment month through avoiding loan repayments by shifting fruit to a nearby debt-free block. On blocks where each household is receiving only three or four oil palm cheques a year, then the temptation to avoid loan repayments or to place a significant quantity of fruit on the mama card can be irresistible, especially since the costs of such a decision (e.g., loan repayments) are shared amongst all block households. Incentives to avoid loan repayments appear to increase under credit systems where repayment rates are high (e.g., 50% or more of monthly income) and/or during low oil palm prices and high cash demands periods (e.g. when school fees are due, or to fulfil customary obligations like brideprice payments).
- Likelihood that higher loan repayment rates will create a greater disincentive to repay loans because the impact of loan repayments falls disproportionately on one or two families. Also disproportional loan repayments among households raise the risk of disputes arising over the programming of the *markim mun* calendar, thereby disrupting production.

Skelim hecta

In the last five years a new smallholder production system has emerged and has spread rapidly among highly populated LSS blocks where three or more second-generation households are co-residing on the block, and most often where the original leaseholder is deceased or his authority on the block has been undermined by his married sons. Smallholders refer to this new system as *skelim hecta* and under this system each of the three 2 ha phases (total 6 ha) is allocated to a household on the block, usually the married sons. The main household responsible for the phase will make decisions regarding harvesting, block maintenance and fertiliser application, thus each 2 ha phase is the sole responsibility of one household. This is fine when there are only three households residing on the block and each has a mature 2 ha stand of oil palm. However, on blocks where four or more households reside, other variations of *skelim hecta* are being practiced as these highly populated blocks try to develop systems to distribute the oil palm income more fairly among all households on the block to reduce disputes on pay-days. Some variations on *skelim hecta* found operating on smallholder blocks include:

- A 2 ha phase is shared between two households and *markim mun* is practiced.
- Sometimes, an agreement is made between two phase 'managers' to practice *markim mun* on the two phases so each household receives a larger payment when it is their month to harvest.
- The occasional agreement between the three phase managers to allow one block resident to be given a harvest round of the whole block and harvest from all three phases.
- During low crop periods, households will shift to *markim mun* production strategies and return to *skelim hecta* during high crop periods.

On *skelim hecta* blocks, typically the Papa Card is used on one 2 ha phase, the Mama Card on another 2 ha phase, and if a Mobile Card (Bialla) or a C Card (Hoskins) is registered on the block, the FFB and loose fruit from the third phase will be weighed on the additional card. If a block does not have a third card for the weighing of fruit, the FFB and loose fruit from the third 2 ha phase will be weighed on the Papa Card or Mama Card with the income distribution calculated by the number of nets and tonnage recorded on the docket. However, there are several variations on how FFB and loose fruit from each of the three 2 ha phases is weighed, recorded and the income distributed to the 'manager' of the phase. For example, on some blocks the Papa Card and Mama Card are used to weigh FFB and loose fruit, respectively, on all three 2 ha phases, with the expected income from each of the three phases calculated by the number of nets and tonnage from each phase.

The subdividing of the phases among second generation families is an attempt to address the increasing population pressures on the block and to more evenly distribute the oil palm income among the co-resident households. The majority of blocks adopting *skelim hecta* previously practised *markim mun*, but because of continual disputes over labour and income distribution or the death of the original leaseholder, the block switched to *skelim hecta*. Whilst there are no data to comment on the productivity of *skelim hecta* blocks, observations indicate that many have good upkeep and sanitation. Smallholder interviews indicate that *skelim hecta* has reduced disagreements among block residents over the distribution of the oil palm income. However, there are several worrying trends regarding the practice of *skelim hecta* which have implications for productivity levels, and these include:

- Mama Card is used for weighing bunches and not only loose fruit. Thus, the advantages of the Mama Card in assisting women to have access to their own oil palm income separate from their husband has the potential to be lost on *skelim hecta* blocks, thereby reducing incentives for the harvesting of loose fruit.
- Reluctance to replant by the manager of the 2 ha phase, as they are left without an income.
- Due to the limited income derived from a 2 ha phase, there is reluctance by the phase manager to take out company loans for farm inputs such as fertilser.
- Shortages of tools at harvest time because of the difficulties associated with purchasing items through the company credit system under a *skelim hecta* production system.
- Three or more households are withdrawing their oil palm income from the one or two bank accounts in which the oil palm income is deposited on payday. There is no opportunity under this system for a phase manager to accumulate funds to improve housing or living standards. The lack of savings acts as a disincentive to harvest at high levels.

- Skip harvesting is more likely to be practised on *skelim hecta* blocks where production on each phase is rotated amongst two or more households. Because each phase is only 2 ha and therefore easily harvested, all of the crop can be taken off in single a harvest round. In this situation there are very strong incentives for the person whose month it is to harvest to cut not only ripe bunches, but also black bunches not yet ready for harvesting. This means that the person harvesting in the next round will find very little mature fruit to harvest and so will "skip" the first fortnightly harvest round in his month. In this situation, the typical harvesting pattern to emerge is one where each brother harvests in the second fortnight of his monthly rotation because so little ripe fruit is available to harvest in the first fortnightly harvesting round. This problem is less likely to emerge on *markim mun* blocks where an individual's harvesting round is for the whole block, that is, a full 6 ha. This is simply because labour constraints make it unlikely that the harvester is able to harvest all ripe bunches AND immature black bunches in a single harvest round.

In 2012 the socio-economic section aims to conduct further research into the different production strategies and how they affect harvesting rates, fruit quality, incentive to make farm investments and loan repayments.

TRAINING WORKSHOP IN SOCIAL SCIENCE TECHNIQUES (RSPO 1.1, 4.8, 8.1)
The socio-economics section hosted a three-day training workshop in Social Science Methods, titled "Qualitative, Quantitative and Mixed Methods Approaches" conducted by Gina Koczberski, George Curry and Sean Ryan from Curtin University, Perth. The training workshop was part of a larger training course on Social Science Methods for Smallholder Agricultural Research. Part 1 "Introduction to Socio-Economic Research" was conducted at CCIL, Kerevat in 2009. The final workshop will be conducted at CIC, Aiyura, at the end of 2012.

The training aims to improve the social science research skills of junior and middle-level research staff at PNG Oil Palm Research Association (PNGOPRA), the Cocoa and Coconut Institute (CCIL), the Coffee Industry Corporation (CIC) and the National Agricultural Research Institute (NARI). Each of the research staff attending the workshops is involved in collecting socio-economic data associated with ACIAR projects; however, none has had any formal training in social science research methods apart from the first introductory training workshop in 2009. The training was based on the tenet that through a better understanding of the socio-cultural and economic factors influencing smallholder farming practices, research will better reflect the needs and priorities of smallholders, and, therefore, be more successful in developing appropriate interventions to increase smallholder production. The three-day training workshop provided instruction on appropriate social science research design, qualitative and quantitative data analysis and interpretation, and the collection of reliable and valid data. The training placed a heavy emphasis on a farmer-oriented approach which values spending time with famers and their families, involving agricultural extension officers in the research design and data collection and encouraging a more 'bottom-up' methodology that facilitates an understanding of the socio-cultural factors influencing smallholder production. The three-day program included:

Day 1: Introduction to qualitative and quantitative research methods. The training addressed the various data collection techniques and procedures in qualitative and quantitative approaches. Mixed methods research and participatory/farmer-orientated research methods were covered, as well as sampling, interview and survey design.

Day 2: Analysing qualitative and quantitative data. Ethical issues in conducting fieldwork. Introduction to designing and managing data bases.

Day 3. Field trip. A visit to the oil palm smallholder blocks to showcase to participants from CIC, CCI and NARI the socio-economic research currently being undertaken by PNGOPRA.

APPENDIX 1 – RSPO PRINCIPALS AND CRITERIA

The Roundtable on Sustainable Palm Oil (RSPO)
PNG National Implementation Working Group (PNG NIWG)
Principles and Criteria

PRINCIPLE 1: Commitment to transparency

Criterion 1.1
Oil palm growers and millers provide adequate information to other stakeholders on environmental, social and legal issues relevant to RSPO Criteria, in appropriate languages & forms to allow for effective participation in decision making.
Criterion 1.2
Management documents are publicly available, except where this is prevented by commercial confidentiality or where disclosure of information would result in negative environmental or social outcomes.

PRINCIPLE 2: Compliance with applicable laws and regulations

Criterion 2.1
There is compliance with all applicable local, national and ratified international laws and regulations.
Criterion 2.2
The right to use the land can be demonstrated, and is not legitimately contested by local communities with demonstrable rights.
Criterion 2.3
Use of the land for oil palm does not diminish the legal rights, or customary rights, of other users, without their free, prior and informed consent.

PRINCIPLE 3: Commitment to long-term economic and financial viability

Criterion 3.1
There is an implemented management plan that aims to achieve long-term economic and financial viability.

PRINCIPLE 4: Use of appropriate best practices by growers and millers

Criterion 4.1
Operating procedures are appropriately documented and consistently implemented and monitored.
Criterion 4.2
Practices maintain soil fertility at, or where possible improve soil fertility to, a level that ensures optimal and sustained yield.
Criterion 4.3
Practices minimise and control erosion and degradation of soils.
Criterion 4.4
Practices maintain the quality and availability of surface and ground water.
Criterion 4.5
Pests, diseases, weeds and invasive introduced species are effectively managed using appropriate Integrated Pest Management (IPM) techniques.
Criterion 4.6
Agrochemicals are used in a way that does not endanger health or the environment. There is no prophylactic use of pesticides, except in specific situations identified in national Best Practice guidelines. Where agrochemicals are used that are categorised as World Health Organisation Type 1A

or 1B, or are listed by the Stockholm or Rotterdam Conventions, growers are actively seeking to identify alternatives, and this is documented.

Criterion 4.7

An occupational health and safety plan is documented, effectively communicated and implemented.

Criterion 4.8

All staff, workers, smallholders and contractors are appropriately trained.

PRINCIPLE 5: Environmental responsibility and conservation of natural resources and biodiversity

Criterion 5.1

Aspects of plantation and mill management, including replanting, that have environmental impacts are identified, and plans to mitigate the negative impacts and promote the positive ones are made, implemented and monitored, to demonstrate continuous improvement.

Criterion 5.2

The status of rare, threatened or endangered species and high conservation value habitats, if any, that exist in the plantation or that could be affected by plantation or mill management, shall be identified and their conservation taken into account in management plans and operations.

Criterion 5.3

Waste is reduced, recycled, re-used and disposed of in an environmentally and socially responsible manner.

Criterion 5.4

Efficiency of energy use and use of renewable energy is maximised.

Criterion 5.5

Use of fire for waste disposal and for preparing land for replanting is avoided except in specific situations, as identified in the ASEAN guidelines or other regional best practice.

Criterion 5.6

Plans to reduce pollution and emissions, including greenhouse gases, are developed, implemented and monitored.

PRINCIPLE 6: Responsible consideration of employees and of individuals and communities affected by growers and mills

Criterion 6.1

Aspects of plantation and mill management, including replanting, that have social impacts are identified in a participatory way, and plans to mitigate the negative impacts and promote the positive ones are made, implemented and monitored, to demonstrate continuous improvement.

Criterion 6.2

There are open and transparent methods for communication and consultation between growers and/or millers, local communities and other affected or interested parties.

Criterion 6.3

There is a mutually agreed and documented system for dealing with complaints and grievances, which is implemented and accepted by all parties.

Note PNG NIWG sees 6.2 and 6.3 as linked

Criterion 6.4

Any negotiations concerning compensation for loss of legal or customary rights are dealt with through a documented system that enables indigenous peoples, local communities and other stakeholders to express their views through their own representative institutions.

Criterion 6.5

Pay and conditions for employees and for employees of contractors always meet at least legal or industry minimum standards and are sufficient to provide decent living wages.

Criterion 6.6

The employer respects the right of all personnel to form and join trade unions of their choice and to bargain collectively. Where the right to freedom of association and collective bargaining are restricted under law, the employer facilitates parallel means of independent and free association and bargaining for all such personnel.

Criterion 6.7

Children are not employed or exploited. Work by children is acceptable on family farms, under adult supervision, and when not interfering with education programmes. Children are not exposed to hazardous working conditions.

Criterion 6.8

Any form of discrimination based on race, caste, national origin, religion, disability, gender, sexual orientation, union membership, political affiliation, or age is prohibited.

Criterion 6.9

A policy to prevent sexual harassment and all other forms of violence against women and to protect their reproductive rights is developed and applied.

Criterion 6.10

Growers and mills deal fairly and transparently with smallholders and other local businesses.

Criterion 6.11

Growers and millers contribute to local sustainable development wherever appropriate.

PRINCIPLE 7: Responsible development of new plantings

Criterion 7.1

A comprehensive and participatory independent social and environmental impact assessment is undertaken prior to establishing new plantings or operations, or expanding existing ones, and the results incorporated into planning, management and operations.

Criterion 7.2

Soil surveys and topographic information are used for site planning in the establishment of new plantings, and the results are incorporated into plans and operations.

Criterion 7.3

New plantings since November 2005 have not replaced primary forest or any area required to maintain or enhance one or more High Conservation Values.

Criterion 7.4

Extensive planting on steep terrain, and/or on marginal and fragile soils, is avoided.

Criterion 7.5

No new plantings are established on local peoples' land without their free, prior and informed consent, dealt with through a documented system that enables indigenous peoples, local communities and other stakeholders to express their views through their own representative institutions.

Criterion 7.6

Local people are compensated for any agreed land acquisitions and relinquishment of rights, subject to their free, prior and informed consent and negotiated agreements.

Criterion 7.7

Use of fire in the preparation of new plantings is avoided other than in specific as identified in the ASEAN guidelines or other regional best practice.

PRINCIPLE 8: Commitment to continuous improvement in key areas of activity

Criterion 8.1

Growers and millers regularly monitor and review their activities and develop and implement action plans that allow demonstrable continuous improvement in key operations.

RSPO Principles and criteria addressed by each PNGOPRA study during 2011

NB: Principle 3 is not included below as it is not directly covered by PNGOPRA research although results may contribute to the production of management plans

Principle	**1**		**2**			**4**								**5**						**6**											**7**							**8**
Criteria	1	2	1	2	3	1	2	3	4	5	6	7	8	1	2	3	4	5	6	1	2	3	4	5	6	7	8	9	10	11	1	2	3	4	5	6	7	1
AGRONOMY RESEARCH																																						
Fertiliser response trials							x	x			x																											x
Palm spacing trial							x	x																														x
Spacing/Thinning Trials							x	x																														x
Smallholder palm/food crop intercropping							x	x					x	x						x																		x
Smallholder leaf sampling							x	x																														x
Smallholder block assessments						x	x	x	x	x	x		x	x																								x
Smallholder BMP demo blocks							x	x		x	x		x																									x
Sustainability Project	x						x	x	x				x	x					x																			x
Agronomy training	x												x																									x
ENTOMOLOGY RESEARCH																																						
Oil Palm Pest Reports										x																												x
PestRecs and TTI levels in 2010										x	x																											x
Pest frequency and distribution										x																												x
Other pests										x																												x
Pest treatment										x	x																											x
Insecticide trials										x	x																											x
Rearing of "sexava" and stick insects										x																												x
Sexava fecundity survival and										x																												x
Individual monitoring for egg hatching										x																												x
Destructive Palm Sampling										x																												x
Pest Information Database (PID)						x				x																												x
Methamidophos Usage Database (MUD).						x				x	x																											x
Biological control of insect pests										x																												x
Sexava egg parasitoids.										x																												x
Phasmatidae (stick insects)										x																												x
Psychidae (bagworm) monitoring										x																												x
Finschhafen disorder										x																												x
QABB studies															x																							x
Evironmental monitoring project									x																													x
Reference and reprints and insect																																						x
Training and field days	x												x																									x
Seed production unit														x																								x
Database of insects on oil palm										x																												x
PLANT PATHOLOGY RESEARCH																																						
Epidemiology of basal stem rot						x				x																												x
Yields of Ganoderma-affected palms										x																												x
Biological control using Trichoderma	x					x				x	x		x																									x
Screening for Ganoderma resistance										x																												x
Quarantine										x																												x
Publications, conferences and travel																																						x
Disease reports										x																												x
Training	x												x																									x
SOCIO-ECONOMICS RESEARCH																																						
Smallholder engagement strategy													x								x																	x
Clan Land Usage Agreement (CLUA)	x		x	x	x									x						x	x		x												x	x		x
Smallholder food security projects							x						x	x						x																		x
Smallholder household surveys																				x	x																	x
Training workshop in Social Science	x												x																									x
Totals	**7**	**0**	**1**	**1**	**1**	**5**	**9**	**8**	**3**	**26**	**8**	**0**	**11**	**6**	**1**	**0**	**0**	**0**	**1**	**4**	**3**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**1**	**0**	**45**