Annual Research Report

2008

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Report by the Managing Director
September 2009

In 2008, the export value of oil palm products exceeded 1 billion Kina. This is the first time in PNG's history that an export crop has reached this level of output. The oil palm sub-sector now represents about half of the country's commercial agriculture. It is the largest employer in the country (*after the public service*) directly employing about 16,000 people. In addition to being the main driver of rural development in PNG, the oil palm industry has also made an uncompromising committed to the sustainable production of palm oil. By the early 2010 all palm oil exported from PNG is expected to be RSPO-certified sustainable palm oil. PNG aims to position itself in the global market place as being one of the few (*or only*) countries in the world that only exports certified sustainably produced palm oil.

Since PNGOPRA's formation in 1980, PNG's oil palm sub-sector has developed to a remarkable degree; it now leads the world in its development and adoption of best sustainable practices. Consequently PNGOPRA's operating landscape has changed dramatically during the last 10-15 years. It became clear that the organization needed to reassess its strategic planning to better adapt its service provision to address the current and emerging needs of its clients and stakeholders. During the last year PNGOPRA has been assessing its role within the oil palm sub-sector, and the wider requirements of the sub-sector.

A key conclusion, following analysis and extensive stakeholder consultations, was that many critical national development and policy issues were not being addressed because of the lack of an 'apex body' within the oil palm sub-sector. PNGOPRA's Managing Director's role will change during late 2009 in order to facilitate these requirements; however this will not affect the core functions of the Association.

PNGOPRA has always been stakeholder demand-driven, it is therefore not surprising that stakeholders feel that PNGOPRA's core R&D and technical services activities should not change in any dramatic way, however a number of gaps have been identified. There is a need to expand work on pests and diseases, work on socio-economic & socio-cultural constraints to smallholder productivity and livelihoods needs to be increased, and environmental research needs to be introduced to support industry sustainability initiatives.

The Association

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

Table 1. PNGOPRA Members Voting Rights in 2009:

Member	FFB Production in 2008	Votes
New Britain Palm Oil Limited	751,481 tonnes	8
CTP (PNG) Ltd	428,847 tonnes	5
Hargy Oil Palms Ltd	168,293 tonnes	2
Oil Palm Industry Corporation (*smallholders*)	731,759 tonnes	8
Ramu Agri-Industries Ltd	n/a	1
Managing Director	n/a	1

The Members of the PNGOPRA have full say in the direction and operation of the organization. This ensures that PNGOPRA is responsive & accountable to the needs of its stakeholders. The member organisations each have one representative on the PNGOPRA Board of Directors. Each Member holds voting rights within the Board that reflect the Member's financial input to the organization; this is calculated on the previous year's FFB production (*the PNGOPRA Member's Levy is charged on a FFB basis*). Voting rights in 2009 are presented in Table 1.

A sub-committee of the Board of Directors, the Scientific Advisory Committee (*SAC*), meets twice a year. It reviews and recommends to the Board the research programme for the coming year. Thus the Members can directly incorporate their services 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.

OPIC is responsible for the provision of agricultural extension for the smallholder oil palm growers. The link between PNGOPRA and smallholder extension is particularly strong with both organizations having seats on each other's planning and management meetings. Probably more important than this is a presence of a healthy and spontaneous informal communication between the officers in both organizations at both a national and local level. As part of the PNG's National Agriculture Research System (*NARS*), both PNGOPRA and OPIC included together as servicing PNG's oil palm industry.

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 2009 is K 5.18 million. The Member's levy finances 76.9% of this expenditure and external grants 14.4%. The Member's levy is set at a rate of K1.77 per tonne of FFB for all growers. In 2009 organisation spending is distributed as 55.5% agronomy research, 15.6% entomology research, 8.1% plant pathology research, and 20.9% management and centralised overheads.

PNGOPRA is self-administered and managed by a small team based at Dami Research Station, near Kimbe in West New Britain Province.

Research

PNGOPRA's research programme is developed to meet the needs of all players in PNG's oil palm sub-sector, both smallholders and plantation companies. All Association members are represented on Association's Scientific Advisory Committee (*SAC*), which reviews and establishes research priorities. To maintain PNGOPRA as a responsive and efficient research organisation, the Association addresses only the most significant constraints and threats to the sustainable production of palm oil. The PNGOPRA Agronomy team carries out research into soil fertility maintenance, crop nutrition and fertiliser management practices. The Association's Entomology team conducts research into oil palm pollination and the integrated pest management (*IPM*) of insects, weeds and other pests. The Plant Pathology team is carrying out research into the control of the Basal Stem Rot of oil palm caused by the *Ganoderma* fungus. Smallholder related socio-cultural research is carried out through a recently established team working in collaboration with researchers at Curtin University in Australia. All research teams, in addition to conducting scientific research, assist the industry by providing technical services support, recommendations and training.

PNGOPRA does not carry out any plant breeding work. Plant breeding, and the associated oil palm seed production, was started by the company now known as New Britain Palm Oil Ltd about 10-years prior to the formation of PNGOPRA. NBPOL continues to run its highly successful and profitable plant breeding and seed production operation from Dami Research Station. Dami oil palm seed is recognized as being the best commercially available oil palm seed material in the world.

Agronomy Programme

The majority of PNGOPRA's agronomy work is focused on crop nutrition issues. Fertiliser trials comprise most of the field work at all operational centres. The aim of the work is to identify realistic production targets determined by an optimised range of inputs which give the best economic return. The cost of fertiliser has increased two to three fold over the last 18-months and the current high price is unlikely to decline during 2008 and 2009. The price of palm oil increased markedly during 2007 and into 2008, however it declined sharply again in August 2008 and before starting a slow recovery. The combined effect of increasing cost through higher fuel and fertiliser prices and the fluctuating price for palm oil make the optimised use of fertiliser inputs a critical component in the management of oil palm.

Fertiliser trials

Most of PNGOPRA's fertiliser trials were established over the last decade and are large-scale factorial trials. A new N x K trial using a Central Composite Design was established at Milne Bay and a second was established in Bialla at Hargy Oil Palms; there is plan for third trial at Navo Plantation. These Central Composite Designs are usually smaller trials (fewer plots) and are designed specifically to determine fertiliser responses to a range of inputs. It is envisaged that in future more of PNGOPRA's fertiliser trials will have this design. Dr. Rob Verdooren is assisting PNGOPRA with the use of this trial design.

Spacing trials

There are currently three spacing trials undertaken by the Agronomy team (*one each at NBPOL, MBE and Higaturu*). The trial at NBPOL is the most advanced (*palms are now 8 years old*). The trial at Higaturu was thinned in 2007 and a similar trial at MBE was thinned in early 2008. Food security trials are planned using the concept of modified spacing arrangements, where food gardens or other cash crops will be planted in the wider avenues (*increasing the width of the avenues but increasing the planting density within the row*). Work has commenced on a smallholder block in Oro Province and another is planned for Bialla.

ACIAR funded Cation project on Volcanic Soils

This project was completed in 2007 and a short extension was authorised to determine the 'leachability' of cations and anions on deep volcanic soils. This additional work is now completed and has been written up (*an executive summary is included in this annual research report*).

Steven Nake has also returned from his overseas studies and an abstract of his thesis is also reported.

Minimising nitrogen losses on volcanic ash soils

The aim of the 'N losses' project was to identify the major mechanisms of nitrogen loss and to develop management practices that reduce losses and improve the benefit/cost ratio of N fertiliser application. The project has been completed and was carried out in collaboration with Massey University, New Zealand with financial support from the European Union. A full report can be found in the PNG OPRA 2006 Annual Report. There have been 2 papers published from this study. The model developed from the study is now used for developing fertiliser application guidelines concerning where and when to apply fertilisers. This information is incorporated into training programs for plantations, extension officers and smallholders.

Rachel Pipai has been awarded a JAF scholarship for a Masters degree and will be investigating the biological nitrogen fixation by legume cover crops in oil palm agro-ecosystems in PNG.

Technical communication

Quarterly reports on yield achievement for selected trials were prepared for plantation managers throughout 2008 & 2009. These reports can assist plantation managers to review plantation block yields against trial yields and make appropriate management adjustments.

There has been large increase in the use of OPIC smallholder field days to extend the message of appropriate fertiliser management.

Training

In 2008, training was given to all plantations. Most of the training focused on oil palm agronomy, tissue analysis interpretation, economic returns from fertiliser inputs and identification of Frond 17 (*used for tissue analysis*). Training was also given to smallholder extension officers in New Ireland.

Entomology Programme

Pollinating weevils

Routine weevil monitoring on the mainland in Oro continued. The weevil stocks (*Ghana pure*) were maintained in the PEQC4 quarantine facility; cross breeding experiments were completed and reported to NAQIA. Authority for release was given, however this was stopped by intervention of DEC, with whom the responsibility for release into the environment rests.

Integrated Pest Management (IPM)

Parasitoids of the sexava eggs continue to be reared in the entomology laboratory and parasitised host eggs released. We continue to encourage the spread of, *Stichotrema dallatorreanum*, but this insect has proven to be difficult to establish in the laboratory, however the collection of infested *S.decoratus* from Bilomi (*NBPOL, Kapiura Group in West New Britain*) is an encouraging sign showing that, establishment is occurring. On the PNG mainland, *Stichotrema* infection levels in *S. novaeguineae* were reported in all months until May (*last report received from R.Safitoa*). No further reports of *Stichotrema* were reported from New Ireland. A collaborative project with The University of Oxford to investigate the genome of *Stichotrema* was agreed and a Memorandum of Understanding was prepared, and is awaiting final approval.

Pest outbreaks

A continued push was made with pest infestation monitoring; nevertheless pest reports remained at unacceptable levels in West New Britain. So far this year there have been 39 infestation reports, but the areas involved were large infested in WNB. Infestation reports from the three dominant taxa (*sexava* and *Eurycantha*) accounted for 92.3% of all pest reports in WNBP, as only a single report was received of *S.novaeguineae*. The reporting and actions for *Ganoderma* monitoring and control are now the responsibility of Plant Pathology Section. Stick insects on the PNG mainland (*E.insularis*) continued to cause serious damage in smallholder blocks around Sui/Tunana, economic recovery data are being provided to us by CTP Higaturu. Reports of *O.centaurus* were also investigated, and a recommendation to remove habitat was made in the Annual Report 2008. Infestations of bagworm (*Mahasena corbetti*) were also reported in WNB. Other pest taxa were insignificant. In collaboration with an entomologist in Switzerland, a joint study to describe the bagworms attacking oil palms is being undertaken.

The entomology team is continuing to inventory insect taxa found on oil palm, and the reference collection is developing (*see 2008 Research Annual Report*). The Pest Infestation Database (*PID*) development continued, and is almost complete: once completed all infestation reports from 2000 will be entered.

Technical assistance

No potential insect threats to the Dami Seed Production Unit (SPU) were identified from light trap catches at Dami WNBP. Bi-monthly monitoring and sampling of oil palm nursery pests continued. Prophylactic spraying of the nursery palms has now totally ceased, this should permit the development of natural enemy populations.

Finschhafen Disorder (FD).

Project reporting to ACIAR was completed on time. A major review paper was accepted for publication, and two poster presentations were made. Field populations of *Z.lobulata* are routinely monitored at a new site near Dami.

Queen Alexandra's Birdwing Butterfly (QABB).

In collaboration with colleagues at NBPOL, OPRS tissue culture (Biotechnology Section), cloned culture material was produced and we expect to begin returning plants to the field nursery at Higaturu later this year. Work on a large review paper on QABB is nearing completion, and almost all "grey literature" has been scanned to DVD and will be distributed to listed recipients once completed.

Biological control of weed pests.

The project on the biological control of Mile-a-Minute vine, *Mikania micrantha* ended with the importation of the rust fungus *Puccinia spegazzinii*, however we will still be involved in the distribution of infected material during the rainy season. .

The beneficial flower report (with OPRS) was completed.

Pest Training

There was continued support by entomology for OPIC field days, which are expected to increase in number during the coming year.

Pest recognition: Notifiable Pest Status

The application for the inclusion of *sexava* species and stick insects made to NAQIA in March 2006 is being processed by NAQIA.

Plant Pathology Programme

Basal stem rot (*BSR*), continues to present a major challenge to the sustainability of oil palm, not only in areas where it is prevalent, but also in areas where it is currently at insignificant levels.

Management of this disease has proven to be extremely difficult to implement within the plantations and is not implemented in all but a few smallholder projects.

Disease epidemiology

Basal stem rot of oil palm is a difficult disease to control given that infection cannot be detected until symptoms appear. Treatment of stem rots with fungicides is discouraged, and futile, and disease spread can only be prevented by rouging of infected palms. Research continued on the epidemiology of basal stem rot and its causal agent, *G boninense* in 2008. Epidemiological work will continue until blocks under study are replanted. After this time, monitoring of disease progression into new plantings will commence.

Spatial and temporal disease patterns obtained from survey data in 2008 indicate that the epidemic is changing in older plantings where control has not been implemented sufficiently. In some areas however, temporal disease progress has not changed significantly from year to year indicating that the control measures may be having some positive effect on annual disease levels. However, further data and analysis is required to confirm this trend.

Disease incidence is approaching economic threshold levels in some provinces and crop yields appear to be affected in some areas. However, at least a further year (*or more*) of data is required to confirm the downward trend in yields in these fields.

Control measures have been implemented in most plantations where stem rots are prevalent, however removal of infected palms on an annual basis has been inadequate for a number of years in some areas, resulting in fluctuating disease rates.

In 2008, blocks were identified to be treated as Ganoderma BMP blocks as a means of comparison to other blocks within the plantation. Sanitation data collected over a 12 month period has not shown any significant effect on the disease levels in these blocks compared to other blocks where sanitation is carried out bi-annually or annually.

The diversity in the population of *G. boninense* continues to astound. Direct evidence for vegetative spread of the fungus through the soil is still elusive indicating that basisiospores are still the primary source of infections although there were a limited number of infected neighbours with identical isolates at Numundo and Poliamba, possibly indicating some secondary spread outward from infective sources within the soil. Despite the apparent aggregation of disease foci at trial sites in New Ireland and West New Britain, genetic homogeneity amongst the majority of *G. boninense* isolates has still not been demonstrated. Further investigations into the genetics of this fungus are outside the scope of our current research strategy and hence the question of recombination of mating type alleles will never be fully resolved (*in PNG at least*).

Research into other factors affecting the occurrence and persistence of basal stem rot will require external sources of funding and this avenues of investigation was not pursue in 2008.

Ganoderma biological control

Research into the use of a biological control agent against *Ganoderma* continued in 2008. Safe and cost-effective methods of disease control are sought for smallholders whose only option (currently) at replant is to poison and underplant. Since the primary establishment of the fungus is though spores, a means of preventing spore germination and growth is required.

Investigations into the use of Trichoderma, a fungus that behaves as an antagonist to Ganoderma continued in 2008. Further laboratory trials using different species and strains of Trichoderma were undertaken to determine the isolates with the best potential for propagation and field use. A number of different growth media were tested and a limited number of field trials were carried out to test the growth of the fungus on oil palm substrate in the field. Good progress has been made but there is still a substantial amount of work to be carried out on formulations and mass production before field trials can be meaningfully applied.

Host resistance to Ganoderma

The long-term control of basal stem rot depends upon being able to successfully identify phenotypic differences amongst commercial progeny. A limited number of nursery assays to assess resistance of progenies to Ganoderma were carried out in 2008 but the testing depended on seed availability.

Plans have been finalised for field trials to be established in Solomon Islands in 2009 with support from AICAR.

Technical services & training for disease control

Technical support and training to all stakeholders is an important component of the Section's programme. All plantations were visited by staff of the Section at least once in 2008. Audits of surveys and sanitation were intensified in 2008 in Milne Bay due to the replanting programme currently underway.

A number of disease reports were received and follow-up action taken by staff of the Section.

Training was provided to OPIC, smallholders and plantation personnel in 2008.

Advisory services on all aspects of disease recognition and control are provided to all stakeholders on request or through regular visits to plantation sites by staff of the Section. Technical publications (posters and notes) continue to be produced annually in areas where a need is identified by Section staff or stakeholders.

Quarantine support was provided to companies who imported seed through seed and nursery inspections.

Smallholder Socio-economic Studies

Land tenure is a major issue affecting production of smallholder oil palm planted on agricultural leasehold land (the land settlement schemes) and customary land. Land ownership and tenure is a contentious issue for large-scale plantation agriculture and development in Papua New Guinea. Land conflicts take many forms in the oil palm industry, from the large compensation claims demanded by customary landowners for land alienated for land settlement schemes (LSS) and estate plantations to land ownership disputes between and within households. Land disputes are critical production issues because they can take oil palm stands out of production thereby reducing smallholder productivity and growers' capacity for loan repayments. In addition, the types of land tenure arrangements sometimes influence smallholder productivity, attitudes to replanting and infill, investment levels in farm inputs and other assets, production strategies of smallholders, the livelihood strategies pursued by smallholders and the welfare and quality of life of smallholder families.

An ACIAR project commenced in 2008 aimed at identifying, refining and promoting effective strategies for commercial sector partnerships with smallholders that in part looks various tenancy type arrangements that condition land use.

In pursuing the objectives of the project, a pool of information has been captured through various meetings, interviews and field trips to reflect the nature of customary land transactions, dealings with the land and the laws governing the administration and use of land in Papua New Guinea. This is presented in the main report in four components as listed below.

- Types of land tenure governing smallholder oil palm.
- Land tenure conflicts on oil palm land settlement scheme blocks.
- Land tenure conflicts on customary land.
- Clan Land Usage Agreements (CLUAs).

Oil palm production decisions are also determined by the socio-cultural and economic necessities. This is supported in a desktop study assessing the obligations of oil palm growers in Oro Province. Essentially, understanding the role of different obligations in the socio-cultural settings of the oil palm growing communities is a pre-requisite to develop intervention strategies that will enhance oil palm production in the smallholder sector.

Technical Services Provision

The scientific staff employed by the Association represent an invaluable source of knowledge and expertise for PNG's oil palm industry. The services provided by PNGOPRA extend beyond research alone. The Association's scientists are committed to providing technical support to the industry through provision of advisory material, recommendations, training and direct technical inputs such as the production of biological control agents.

1. AGRONOMY RESEARCH

Overview of Research and Communication programs

(Dr. Murom Banabas)

The main task of PNG OPRA 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 is fertilizer response work. At each of the plantations we have set up a large number of trials in collaboration with our funding partners (CTP Holdings, NBPOL, Hargy Oil Palm and RAI). The types of trials established are different between 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 NBPOL plantations will be handed to OPRS (NBPOL) to manage while PNG OPRA will concentrate on simple fertiliser/demonstration trials on smallholder blocks.

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

Two important donor funded projects, N Loss and Mg/Cation, are closed and have been reported. A brief on the Mg/Cation and Steven Nake's studies are reported in this annual report. There is also going to be another donor funded project (ACIAR) looking at sustainability of oil palm production in PNG that is in the process of approval. As part of this project, an assistant agronomist will be looking at nitrogen fixation by legume cover crops.

There has also been an increased involvement in smallholder related activities. Work has commenced on 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 setting up of fertiliser demonstration blocks in Milne Bay and Poliamba. The aims here are to first increase FFB yields from 10-15 t/ha/year to >25 t/ha/year and utilising available land productivity for food production as well.

Across all sites, there is continuous involvement of training provided to the industry. There has been increased number of PNGOPRA involvement with OPIC on smallholder field days and radio broadcasts. A smallholder oil palm booklet has been completed and is yet to be printed for distribution.

A number of very important changes in staffing within the agronomy section happened during the last 12 months. Dr. Harm van Rees (Head of Agronomy) resigned at the end of May 09 and Dr. Murom Banabas was appointed to head the section, Steven Nake (Assistant Agronomist) returned from his studies and is stationed at Dami, Rachel Pipai (Assistant Agronomist) was transferred to Milne Bay, Levi Tiriau (Supervisor) was moved to Pathology Section and Abraham Puwe (Senior Recorder at Milne Bay) was promoted to a Trainee Supervisor and transferred to Hargy. I like to sincerely thank all of our hard working staff from the agronomists to all the field staff. The amount of work and the dedication you show to your work is commendable.

Nutrient cycling

Overcoming magnesium deficiency in oil palm crops on volcanic soils of PNG

(Dr. Mike Webb)

Oil palm is the most important crop in Papua New Guinea in terms of export income, earning K800 million in 2007. It is grown by plantation companies and smallholders. About 45% of the area under oil palm, but only about 32% of the production, comes from smallholders, so there is large potential to increase smallholder productivity. The main agronomic limitation to smallholder productivity is inadequate application of fertilisers.

The aims of this project were to overcome limitations to productivity caused by Mg and K deficiencies. On volcanic ash soils in West New Britain symptoms of Mg deficiency are widespread and leaf Mg concentrations are often low, but Mg fertiliser (kieserite) additions in trials had failed to significantly increase yields. It was proposed that the high Ca content of the soils, combined with high rainfall and high soil permeability, led to rapid leaching loss from the root zone of Mg. This project aimed to a) determine if Mg nutrition was limiting yield, and b) assess alternative strategies for supplying Mg to the palms. In New Ireland, Milne Bay and Morobe Provinces, productivity on alluvial and corraline soils is limited by K deficiency, and economic responses to K fertiliser (muriate of potash) had been established. However, large losses by leaching were suspected. This project aimed to determine the fate of applied K in alluvial soils and determine whether uptake efficiency could be improved.

Field trials were established on the volcanic ash soils to assess the effectiveness of fertilisers with different solubility (Mg oxide, Mg carbonate and Mg sulphate) and placement of Mg and K fertilisers on the surface or in buried 'hotspots' with or without barriers to slow leaching loss. Field trials were established on the alluvial soils to determine response to K where it was not yet known, and to assess K placement (broadcast vs concentrated in zones). Leaf nutrient concentrations have responded to treatments in some trials but there have not yet been any consistent yield responses. The trials were established 1-4 years ago and it is known that responses can take several years to develop, so the intention is for them to continue for 10 years.

The fate of Mg and K applied in fertiliser was determined by measurements in the field and laboratory. The volcanic ash soils had high ability to retain Mg (high cation exchange capacity) and there was little or no loss from the root zone by leaching, even when Mg was applied as soluble kieserite. In the alluvial soils, there was little or no loss of K and substantial fixation in non-exchangeable form due to the presence of smectite or vermiculite. The retention of K by the soil leads to low uptake efficiency. Modelling of Mg and K transport closely reflected field results, so modelling can be used to predict the fate of fertilisers in new situations.

Uptake of Mg and K, and their distribution through the canopy were strongly influenced by genotype and also by palm age. Fronds, leaflets and parts of leaflets showing deficiency symptoms (chlorosis) invariably had lower Mg concentrations than plant parts without chlorosis. The research confirmed that frond 17 is still an appropriate frond for diagnosis of Mg and K deficiencies. Maps of nutrient concentrations in smallholder palms indicate clusters of K deficiency. This information can be used to target extension.

Impacts of the research are already apparent, with plantation companies reassessing the type and manner of fertiliser applications. For smallholders it is clear that overcoming N deficiency should be the primary aim in most areas. As results from the field trials become clear, the project is expected to have a large economic impact through changed fertiliser management practices. There has been a major capacity impact due to training of Oil Palm Industry Corporation (OPIC) extension officers, PNG Oil Palm Research Association (PNGOPRA) research staff, smallholder growers and plantation managers in nutrition-related issues.

For full report see

Michael Webb, Suzanne Berthelsen, Paul Nelson, Harm van Rees, May 2009, Overcoming magnesium deficiency in oil palm crops on volcanic ash soils of Papua new Guinea, Publication Code: FR2009-11, ISBN:978 1 921531 64 4

2.0 Potassium Availability in Alluvial Clay Soils in Milne Bay Province, Papua New Guinea (PNG)

(Steven Nake)

Introduction

Potassium deficiency is very pronounced in oil palm on alluvial clay soils of Milne Bay in Papua New Guinea. These clay soils contain clay minerals that can fix K. This, coupled with large amounts of exchangeable Mg and Ca, trigger the K deficiency problem in oil palm growing in this area. Oil palm yield and other growth parameters had responded positively to K fertilizer application for the last 10 years in ongoing factorial fertiliser trials. Despite the positive response, a recent study showed that less than half of the added K was taken up by the oil palm while more than half has accumulated in the top 40 cm of the soil. There is currently limited information to explain why K accumulated in the soil and the implications for management. Fixation of K could be one of the factors contributing to K accumulation, or other factors could be restricting the palms roots from taking it up. Therefore, this study was carried out to determine fixation and release characteristics of K in alluvial clay soils under oil palm cultivation in relation to soil and management factors. All the work was carried out in two long-term fertiliser trials (Trial 502 and 504, operating since 1995 and 1994, respectively (PNG OPRA Annual Reports, 1994 to 2007) which included plots with different K fertiliser history.

Different K forms (exchangeable and non exchangeable K)

Potassium exists in the soil in four pools, each differing in its availability to plants. These forms, in increasing order of availability to the plants with their approximate amounts are: *structural or mineral* K (5000 – 25000 mg/kg); *fixed and non exchangeable* K (50 – 750 mg/kg); *exchangeable* K (40 – 600 mg/kg) and K in the *soil solution* (1-10 mg/kg) (Sparks 2000). There are equilibrium and kinetic reactions between these forms of K that affect the level of solution K at any particular time, and thus the amount of readily available K for plant uptake. The amount of K in each of these forms is determined by the type and amount of clay, uptake of K by the plants, K fertiliser application, crop and leaching losses and the relative effectiveness of K fixation and release processes that occur in the soil (Kirkman *et al*. 1994).

There is little information on the availability of other forms of K particularly, non exchangeable K, and how they are affected by K fertiliser application and management in the clay soils of Milne Bay. This study was conducted to determine the effects of management (K fertilizer history and surface management) on the amounts and forms of K in the soil. This was examined by measuring exchangeable (ammonium acetate extractable) and non exchangeable (Sodium tetraphenyl borate extractable) K. The exchangeable K contents increased considerably with K fertilizer and where it had been applied (Table 1). The concentration of exchangeable K was higher in the BZ, FT and FP zones because most of the K fertiliser is placed in these three zones. When K fertiliser is applied, it ends up in the soil solution, increasing the solution K concentration and because there is a dynamic equilibrium between the soil solution and exchangeable K, K in the soil solution moves onto the exchange complex increasing its concentration (Table 1).

The non exchangeable K contents were also affected by the K fertiliser and its placement. Within the K fertilized plots, the BZ, FT and FP zones, where most of the K fertiliser is applied, had higher contents of non exchangeable K than the HP and WC zones (Table 1). The non exchangeable K contents in all the five management zones within the non fertilized K plots were much lower.

The other soil chemical properties were also very much affected by the K fertiliser history (Table 1). The differences in the soil chemical properties as affected by the different surface management zones were only obvious in the plots or areas that received K fertiliser. Soil organic C content and pH did not differ much between the two trial sites, but the EC contents did. Exchangeable Mg and Ca levels were extremely high and can impede K uptake, and as a result large K fertiliser applications may be required to allow adequate K uptake on these soils.

Table 1. Soil chemical properties (mean of 2 replicate plots).

Trial	K fert	Zone	OC ($g\ kg^{-1}$)	pH 1:5 (water)	EC 1:5 ($\mu S\ cm^{-1}$)	Exchangeable cations (mmol (+) kg^{-1}) K	Na	Ca	Mg	Acidity	ECEC (mmol (+) kg^{-1})	K sat (%).	K_{nex} (mmol (+) kg^{-1})
502	-K	HP	13.7	6.6	44	1.5	8.4	309	149	2.0	470	0.3	1.9
	-K	WC	19.9	6.1	59	2.1	7.1	297	145	3.2	454	0.5	2.2
	-K	BZ	21.4	5.8	76	1.4	7.3	289	128	4.5	430	0.3	1.9
	-K	FT	20.8	5.7	73	1.3	6.6	286	128	8.1	430	0.3	1.6
	-K	FP	27.6	6.1	96	1.5	6.8	319	154	2.0	483	0.3	1.8
	+K	HP	15.2	6.8	57	7.3	9.3	381	161	2.0	561	1.3	5.0
	+K	WC	20.2	6.5	73	15.3	7.4	357	160	2.0	542	2.8	11.3
	+K	BZ	21.3	6.2	79	31.3	6.7	342	132	2.6	515	6.1	19.0
	+K	FT	23.2	6.0	78	64.6	4.9	318	117	3.5	508	12.7	34.8
	+K	FP	30.2	6.2	99	66.7	4.7	343	136	1.9	552	12.1	35.6
504	-K	HP	17.6	6.3	61	1.9	2.9	249	109	1.9	365	0.5	6.6
	-K	WC	20.6	5.9	119	2.5	2.7	261	109	2.9	378	0.7	7.1
	-K	BZ	24.0	5.0	131	2.0	2.6	242	82	10.6	339	0.6	6.1
	-K	FT	26.5	5.9	138	2.2	2.6	273	89	3.8	371	0.6	6.9
	-K	FP	27.7	5.8	129	2.2	2.9	270	99	2.6	377	0.6	6.6
	+K	HP	19.9	6.3	63	7.0	3.4	276	121	2.0	409	1.7	11.6
	+K	WC	24.5	6.0	145	12.0	2.6	265	120	2.0	402	3.0	18.5
	+K	BZ	25.4	5.1	194	21.5	2.4	231	92	9.2	356	6.0	21.6
	+K	FT	24.5	5.6	205	18.3	2.0	236	101	7.0	364	5.0	20.2
	+K	FP	31.4	5.4	140	26.6	1.9	226	80	5.7	340	7.8	26.9

OC – organic C content
EC – electrical conductivity of 1:5 soil:water extract
ECEC – effective cation exchange capacity
K sat – exchangeable K content as proportion of ECEC
K_{nex} – non exchangeable K

K fixation

Potassium fixation in soils is known as the transformation of available K forms (i.e. soil solution K and exchangeable K) into non exchangeable K forms. K fixation has a direct effect on the availability of K in soils and also on the degree of fertiliser K uptake by the plants (Troeh and Thompson 2005, Malavolta 1985). The degree of K fixation depends on the clay mineral type and its charge density, the degree of interlayering, soil moisture, concentration of K^+ ions with the competing cations and the pH of the soil solution (Sparks and Huang 1985). Of these factors, the soil clay (quantity and type) constitutes the most important one, because it determines the magnitude of soil fixing capacity and at the same time controls K fixation and release processes.

The soils in Trial 502B and 504 are dominated by vermiculite and smectite clay minerals that fix K in the soil. It is assumed that the presence of these two 2:1 clay minerals could have contributed to K deficiency in these two sites. However, there is limited knowledge on K fixing capacity of these soils in spite of the existence of the current K deficiency problem. This study was initiated to determine effects of trial site, K fertiliser history and surface managements on K fixation.

Different concentrations of KCl solutions (equivalent to 0, 125, 250, 375, 500, 750, 875 and 1000 mg K kg^{-1} soil) were added to the soil. Exchangeable K was then extracted from the soil with 1 M ammonium acetate. Extracted K was then analysed The decanted equilibrium solutions and NH4OAc extracts were analysed for K using an atomic absorption spectrophotometer (AAS). Fixed K was determined using the formula: Fixed K = added K – decanted equilibrium solution K - NH_4OAc extractable K.

Potassium fixation was significantly affected by trial site, K fertiliser and the management zones (Figure 1). The proportion of K fixed from the added K was higher in Trial 502B than in Trial 504, and was more related to the amount of clay at each site. Trial 502 was more clayer than 504 (41 to 37 % clay respectively). Plots with a history of no K fertiliser had considerably higher fixation than plots with a history of K fertiliser application (Figure 1). The prolonged use of soil without applying K fertiliser could have resulted in the depletion of K in the non exchangeable pool therefore when K fertiliser is added, most of it was absorbed into the non exchangeable pool to restore its low concentration, thus high fixation. Potassium fixation was lower in the 'between zones', 'frond tips' and 'frond piles' compared to the same zones in the unfertilized K plots. This is simply because K fertiliser was applied mostly in these three zones, resulting in higher concentration of exchangeable K and thus less fixation. Furthermore, the level of organic C in these zones were higher than the HP and WC zones. Organic C which contains humus have a very CEC (>150 meq/100g) and high negative surface charge and like clay minerals can hold nutrient cations such as K in easily exchangeable forms which are used by the plants.

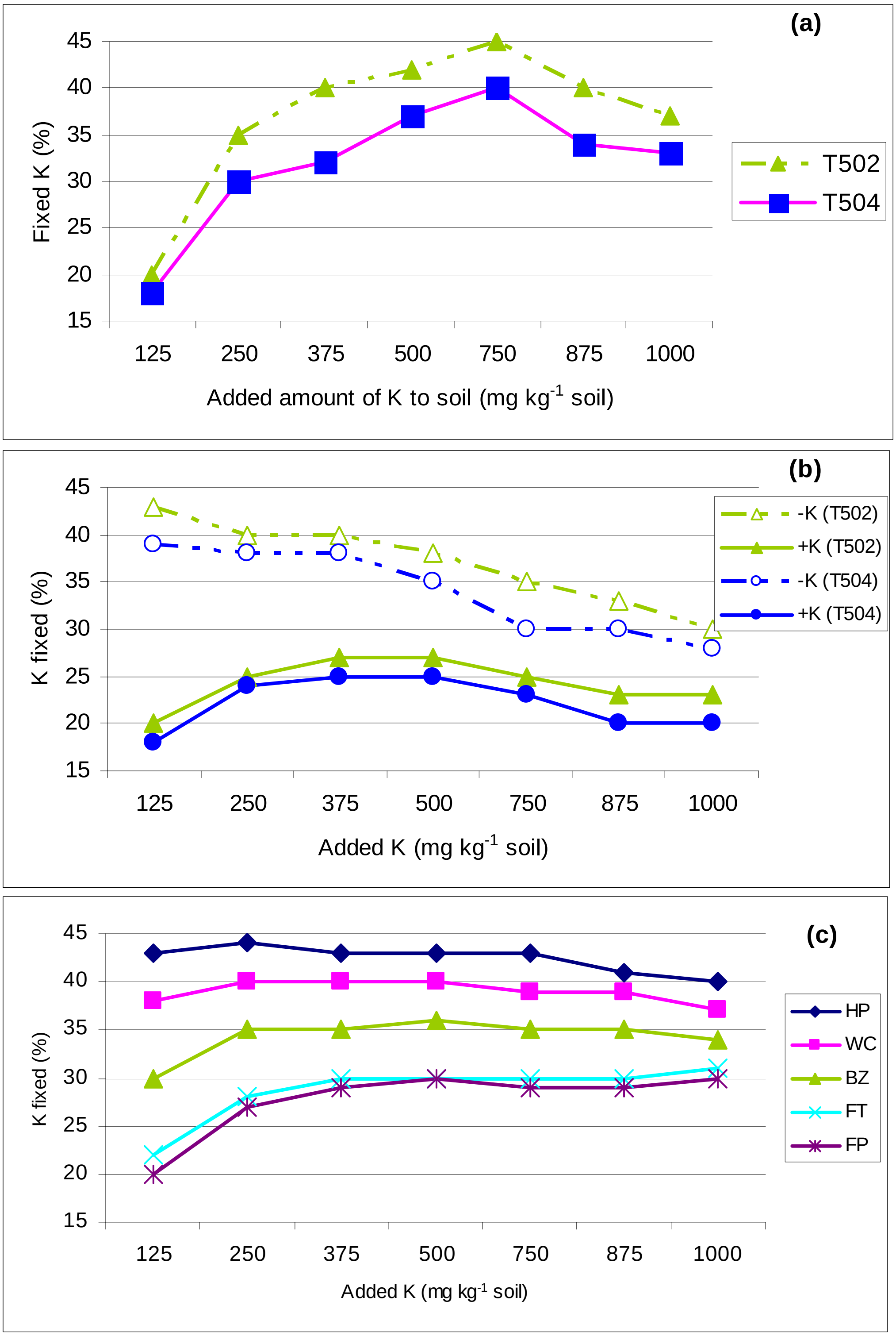


Figure 1. K fixation as affected by (a) Trial site, (b) K fertilizer history and (c) management zones.

K release

The non exchangeable K can be made available to the plants. This process is made possible when K concentration in the soil solution and exchangeable pool falls below a critical level, triggering release of K from the non exchangeable pool. The release of non exchangeable K varies greatly from soil to soil and is mainly controlled by the following factors: quantity and nature of clay, composition of associated minerals, CEC, soil reaction, organic C and the application rates of K fertiliser (Sharma and Mishra 1991). It is possible that the release of K from the non exchangeable pool is influenced by K fertiliser history and management zones. The release of K from non exchangeable forms into the K solution was studied by rinsing the soil three times with 0.25 M $CaCl_2$ to remove the exchangeable K in the soil. The soil was then equilibrated with 0.01 M $CaCl_2$ for certain time periods (1 to 480 hours). At the end of each period, K in the supernatant solution was measured using the AAS.

The initial rate of release of K from the non exchangeable K pool was much higher in Trial 502 than 504. Within the two trial sites, a lot more K was released from the 'between zones', 'frond tips' and 'frond piles' than the 'harvest path' and 'weeded circle'. The K fertiliser history also had significant effects on the initial rate of K release, with much higher amounts of K released from soils with a history of K fertiliser. The rate of release gradually declined with time. However, this declining trend was more pronounced in the soils from the K fertilised plots. The cumulative quantity of K released was well related to the initial rates of release. The cumulative release in Trial 502 was greater that observed in Trial 504. After 480 hours, the total cumulative K release in the fertilized plots at Trial 502 was 9.1 mmol kg^{-1} soil compared to 4.4 mmol kg^{-1} soil in Trial 504. The cumulative release was also higher in the surface management zones with K fertiliser history compared to the same zones in the plots without K fertiliser. The quantity of K released as a proportion of the non exchangeable K was also calculated. After 480 hours, 8 % of K in the non exchangeable pool was released in the K-fertilised plots at Trial 502B and 4.4 % of the non exchangeable K was released from soil from the equivalent plots from Trial 504. In the plots with no K fertiliser history, less than 4 % of the non-exchangeable K was released.

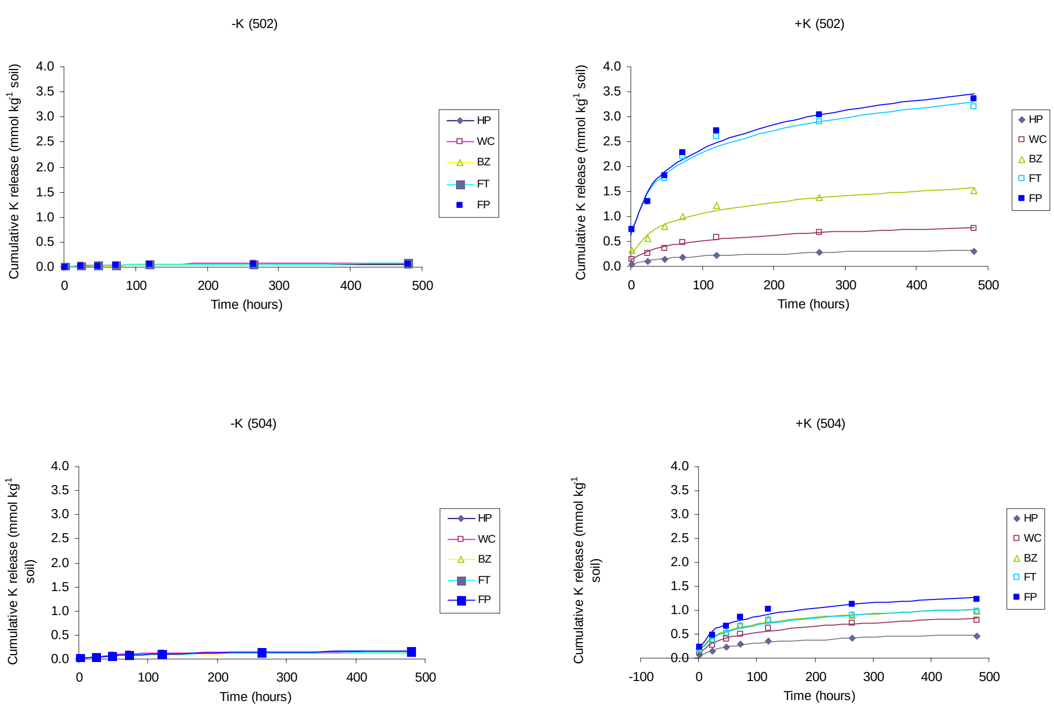


Figure 2. Release of non exchangeable K into solution. Points are data and lines are fitted curves (Equation 1).

Kinetics of K release

The kinetics of K release from non exchangeable pools into solution has been described using several functions (Cox and Joern, 1997). In this work the commonly used Elovich function (Equation 1) was fitted to the data. In Equation 1 q (mmol kg^{-1}) is the cumulative amount of non exchangeable K released into solution at time t (hours). t_0, α and β are fitted constants. Equation 1 was fitted to the data using the least squares method in Sigma Plot. If the data fit the model then the release process is assumed to be diffusion-controlled (Cox and Joern, 1997). Fitting the Elovich function enabled derivation of release-related parameters that could be used to relate K release to soil properties.

$$q = (1/\beta) \ln \alpha\beta + (1/\beta) \ln(t + t_0) \qquad \text{Equation 1}$$

The Elovich function fitted the data well. The parameter t_0 has been described as an estimate of the time beyond which release is Elovichian, and the reaction preceding t_0 cannot be described as Elovichian (Cox and Joern, 1997). In the soils examined, t_0 ranged from 6 to 28 hours. The parameter α, the inverse of parameter β, and q at any particular time, were all closely related, so only one of the parameters was needed to relate the release characteristics of the soils to their other properties. The release rate parameter 1/β, which units of mmol kg^{-1} h^{-1}, was chosen. Release rate was linearly related to the amount of non exchangeable K measured in the soils at each site. Non exchangeable K was released more rapidly from Trial 502 soil than Trial 504 soil. There was no effect of zones other than their content of non exchangeable K. The non exchangeable K content was closely related to the amount of fertiliser K that each zone had received. The release rate constants, derived from the slope of the relationships, were 0.0208 h^{-1} for Trial 502 soil and 0.0115 h^{-1} for Trial 504 soil.

The difference in release rate between the soils at the two trial sites seems to be related to differences in response to K fertiliser between the sites. The response of yield and leaf K content was larger at Trial 502 (with higher release rates) than Trial 504.

Conclusion

This work showed that management has a large effect on the fixation and release of K in alluvial soils of PNG under oil palm cultivation. Soil behaviour differed considerably between management zones, suggesting that K fertiliser placement might have a considerable effect on uptake efficiency. The ability of the soil to fix K coupled with its slow release characteristics of these soils could be the reason for the accumulated K in the top 40 cm of the soil.

References

Cox AE and Joern BC (1997) Release Kinetics of non exchangeable K in soils using sodium tetraphenylboron. *Soil Science* **162 (8)**, 588-598

Kirkman JH, Basker A, Surapaneni A, MacGregor (1994) Potassium in the soils of New Zealand – a review. *New Zealand Journal of Agricultural Research* **37**, 207-227.

Malavolta E (1985) Potassium status of tropical and subtropical region soils. In 'Potassium in Agriculture'. (Ed. RD Munson). pp 163-200. ASA and SSSA, Madison, WI USA.

Sharma VK , Mishra MK (1991) Potassium adsorption kinetics in soils differing in clay content and mineralogy. *Journal of Potassium Research* **7**, 176-181

Sparks, DL and Huang, PM (1985) Physical Chemistry of Soil Potassium. In 'Potassium in Agriculture'. (Eds RD Munson). Pp 202-265. Madison, Wisconsin USA.

Sparks DL (2000). Dynamics of K in the soils and their Role in Management of K Nutrition. Technical session I: Potassium in Soils.

Troeh RF & Thompson ML (2005) Soils and Soil Fertility (Sixth Edn). Blackwell Publishing Ltd, 9600 Garsington Road, Oxford OX4 2DQ, UK.

3.0 Biological nitrogen fixation – Sustainable management of soil and water resources for oil palm production systems

Short study on the effectiveness of nodulation on Legume cover crops (*Calapogonium caeruleum & Pueraria phaseoloides*) in four different ages of oil palm plantings in Hagita, Milne Bay Province, PNG

Rachel Pipai and Harm van Rees (May 2009)

ABSTRACT

Legume plants were sampled from four different oil palm plantings within Milne Bay Province in Papua New Guinea, to carry out a nodulation study. The study composed of nodule count along two root zones and nodule effectiveness with regard to N-fixation. 12 plants each, were collected from a new planting (1-3 years old), young mature planting (3-8 years old), mature planting (8-13 years old) and old mature planting (19-25 years old). Roots were carefully washed and nodules counted, then cut open and checked for effectiveness and recorded. Each of the plant was scored this way from 0-5 cm of the roots and then at >5 cm down the root. It was observed that the new plantings had excellent nodulation and similar potential for N-fixation. The three other plantings all had poor nodulation and possibly little to no N-fixation. Factors for poor nodulation could be highly due to shading under the mature plantings which largely affects photosynthesis in the legume plants and in turn energy production for all other cell functions including nodule formation. Also the high soil moisture under the canopy cover may affect new root formation and in turn nodule formation or some other internal and external factors. Legume plant roots were randomly selected from each planting in this case, in future study it would be recommendable to carry out nodule study on palms exposed to sunlight (e.g., where there are missing palms) in the three plantings that had poor nodulation.

INTRODUCTION

Nodulation on legume cover crops occurs in the presence of the soil bacteria rhizobium and is directly indicative of how effective the legume cover plants are fixing atmospheric nitrogen (N_2).

Rhizobia living in the root nodules of legumes plants fix atmospheric nitrogen (N) into ammonia (NH_3), which is biologically available to plants and bacteria. The amount of nitrogen fixed by legume cover plants annually can contribute significantly to crop yield. Some work was done looking at the yield of 1-3 year old palms using ^{15}N isotope in xylem sap technique on *Pueraria phaseoloides* revealed that an average of 150 kg of N/ha/yr was produced by legume cover plants (Fairhurst, Hardter, 2003).

Another technique of determining how much N is being fixed by legume cover is the xylem sap technique. N-containing compounds after being taken up by the roots travel as either nitrates and amino acids or allantoin and allantoic acid in the xylem stream. The two former compounds are usually sourced from soil N while the latter two are products of N-fixation. This technique could be used in oil palm in future studies.

In this preliminary study the level of potential N fixation by legume covers was investigated using a simple nodulation study as the basis of measuring N-fixation

There are many different species of legume cover plants but the two most common species *Pueraria phaseoloides* and *Calapogonium caeruleum* are mainly used in oil palm plantations in Papua New Guinea. *P. phaseoloides* is better suited to growing in newly established plantings with little shade while *C. caeruleum* is more shade tolerant and grows reasonably well under closed canopies of mature palms.

Nodulation could be assessed in a number of ways including how early nodules are formed on legume cover crops, root nodule number, mass and colour, distribution and longevity of the nodule population, and visual nodulation scores.

Visual nodulation scores and occurrence of nodules, where they are located on the main root or laterals are used in this particular study to see how effective N fixation may be occurring on legume cover plants. Effectiveness of nodulation was studied in new planting (1-2 year old palms), semi-matured, matured and old matured palms and a simple conclusion is made on the study.

In some cases where rhizobium does not occur naturally in some soil types, legume cover plant seed could be inoculated with rhizobia at planting time. Legume cover plants in oil palm are said to be "promiscuous" meaning they can nodulate with a wide range of rhizobium in the soil and not any special one, thus making the use of legume cover plants highly reliable. In this case inoculation was not carried out at planting.

This study aims to look at the nodulation of legume cover plants in different aged oil palm plantings. Visual nodule counts were made and observation were made on the effectiveness of nodules, where pink insides indicates active N-fixation while green or a darker colour indicated ineffective nodules and little or no N-fixation. These findings will contribute to our knowledge of nodulation effectiveness on legume cover plants and may form the basis for further N-fixation studies.

MATERIALS AND METHODS

Legume plant roots were selected from legume plants, *Calapogonium caeruleum* and/or *Pueraria phaseoloides*. The above-ground parts of the plant were carefully cut off, and legume plant roots were collected. Soil was dug to a depth of 10-15 cm all around the legume plant roots and carefully removed with the soil intact. Each plant was then placed in a bucket and brought back to the office. A total of 12 plants were sampled from four different aged oil palm plantings. At the office, each plant plus soil was soaked in water for one to two hours to loosen the soil particles. The plant plus soil was then carefully removed from the water and placed on a plastic sheet, and dirt was carefully washed off each plant root.

Once the legume plant roots were extracted successfully without breaking off nodules and roots, nodules were then removed individually from each plant, cut open with a sharp blade to reveal the insides of the nodules (pink/reddish color indicating active nodules, and green/darker color indicating ineffective nodules), and then recorded. Counts were made first for the 0-5 cm portion of the legume plant roots and recorded, and then for the deeper then 5 cm portion of the legume plant roots. From the total nodule counts, each plant was then scored according to the scoring system shown in Table 1 below. This method was repeated for four different aged oil palm plantings and a mean nodule count was calculated.

Table 1: Nodule scoring system used in this exercise as described by Unkovich, Herridge, Peoples, Cadisch, Boddey, Giller, Alves and Chalk (2008) as a guide.

0-5 cm of roots	**> 5 cm and below**		
Active nodules #	Active nodules #	Score	Score Interpretation
0		0	0-2 – indicates poor nodulation and probably little or no N_2 fixation.
<5		1	
5-10		2	2-3 – represents fair nodulation; N_2 may not be sufficient to supply the N demand of the crop
>10		3	
>10	<5	4	3-4 – indicates good nodulation; good potential for N_2 fixation
>10	>10	5	4-5 – represents excellent nodulation; excellent potential for N_2 fixation

RESULTS

Table 2 below shows the summary of the nodule counts and observations, with a score and an interpretation. A clearer pictorial summary of the work can be seen in Figures 1 and 2.

Table 2: Average nodulation score from 12 legume cover plants under different aged plantings

0-5 cm			>5 cm deep		score	interpretation
planting	Active	ineffective	active	ineffective		
1-3 yrs	64	69	40	54	**4-5**	excellent nodulation and excellent potential for N_2 fixation
3-8 yrs	0	3	0	12	**0**	poor nodulation, little to no N_2 fixation
8-13 yrs	0	3	1	10	**0**	poor nodulation, little to no N_2 fixation
19-25	0	6	0	16	**0**	poor nodulation, little to no N_2 fixation

From Table 2 and Figures 1 and 2 it can be observed that plants from the new oil palm plantings (1-3 years old) had excellent nodulation. A graphic representation of that in Figures 1 and 2 clearly shows that. Legume plants from the other planting age (young mature, mature and old mature palms) indicated poor nodulation which may mean little or no N-fixation at all.

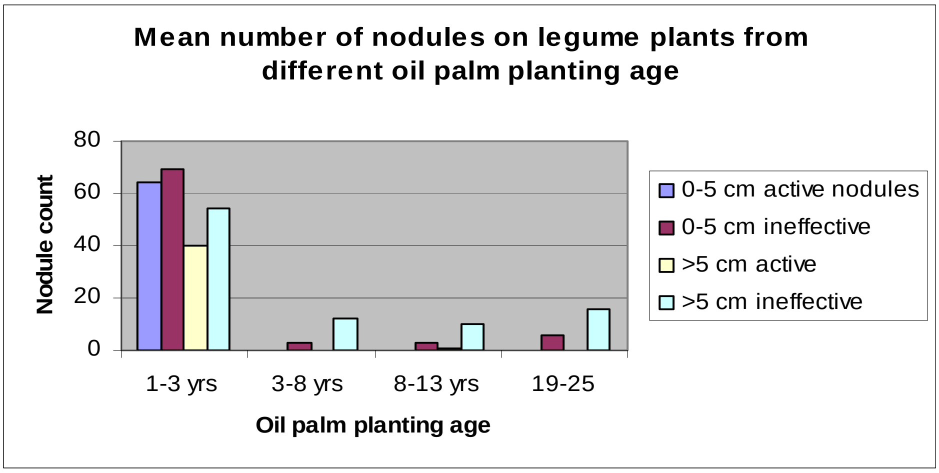


Figure 1: Graphic representation of nodulation of legume plants from different plantings

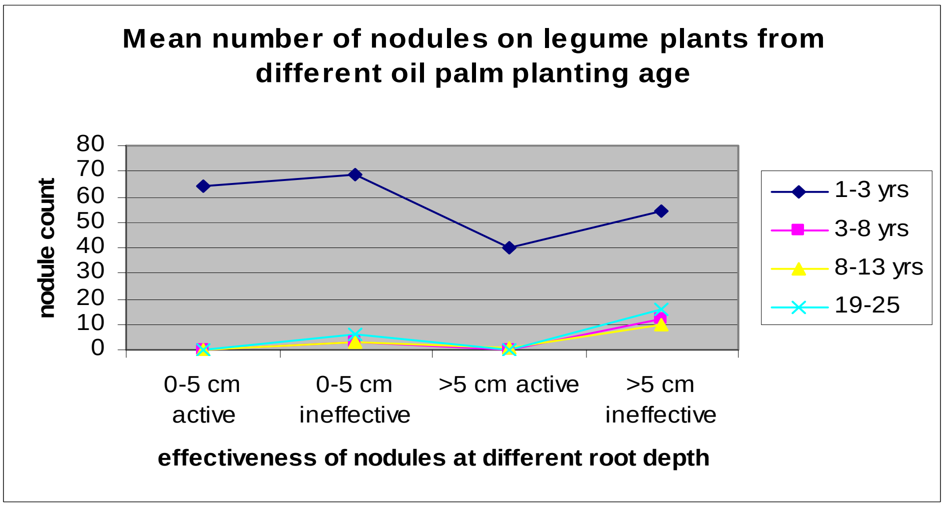


Figure 2: Line graph showing nodulation along different root depths for the different aged oil palm plantings

An example of active and ineffective nodules from the legume plants are shown in Figure 3.

Figure 3 a), b): Cross-section of nodules, pinkish red color (a) indicating active nodules that is fixing N and greenish or darker color (b) indicating ineffective nodules.

Raw data from the nodulation counts are presented in Tables 3-6. Individual legume plant nodules were counted and checked for effectiveness in N-fixation for different aged plantings.

Table 3: Nodule Scoring in 1-2 year old palms

	0-5 cm below 1st lateral root			**>5 cm and below**	
Plant #	Active nodules	Ineffective nodules		Active nodules	Ineffective nodules
1	54	61		104	100
2	84	15		20	5
3	19	49		8	56
4	25	144		11	133
5	117	99		24	35
6	18	21		10	9
7	208	102		242	152
8	67	103		5	79
9	38	64		14	6
10	40	40		20	20
11	85	83		3	1
12	12	44		16	57
Mean	**64**	**69**		**40**	**54**

SCORE: VERY HIGH (4-5)

Table 4: Nodule scoring in young matured palms (3-8 years old)

	0-5 cm below 1st lateral root			**>5 cm and below**	
Plant #	Active nodules	Ineffective nodules		Active nodules	Ineffective nodules
1	0	1		0	0
2	0	0		0	0
3	0	1		0	2
4	0	8		1	0
5	1	15		1	2
6	0	0		0	0
7	0	0		0	0
8	0	2		0	0
9	0	0		0	0
10	0	1		0	139
11	0	6		0	1
12	0	0		0	0
Mean	**0**	**3**		**0**	**12**

SCORE: 0

Table 5: Nodule scoring in matured palms (ages 8-13)

	0-5 cm below 1st lateral root			**>5 cm and below**	
Plant #	Active nodules	Ineffective nodules		Active nodules	Ineffective nodules
1	0	0		7	52
2	0	6		0	0
3	0	0		0	0
4	0	2		0	0
5	0	0		0	15
6	0	0		0	0
7	0	0		0	5
8	0	21		0	3
9	0	0		0	0
10	0	1		0	3
11	0	1		0	38
12	0	0		0	0
Mean	**0**	**3**		**1**	**10**

SCORE: 0

Table 6: Number Nodule scoring in old matured palms (ages 19-25)

	0-5 cm below 1st lateral root			**>5 cm and below**	
Plant #	Active nodules	Ineffective nodules		Active nodules	Ineffective nodules
1	0	0		0	0
2	0	3		0	0
3	0	1		0	2
4	0	0		0	0
5	0	0		0	7
6	0	6		0	2
7	0	3		0	50
8	0	5		0	46
9	0	38		0	25
10	0	14		3	49
11	0	0		0	10
12	0	0		0	0
Mean	**0**	**6**		**0**	**16**

SCORE: 0

DISCUSSION

Legume plants growing in shaded young mature, mature and old mature plantings had very low nodulation scores indicating little to no N-fixation occurring. There was obvious presence of nodules on the legume plant roots, but most to all were ineffective, with either nodules having nearly degenerated or new nodules could not be opened for being too small in size. It could be due to the legume cover plants from the plantings with closed canopies had elongated root systems or runners rather than a main tap root where possible nodulation and subsequent N-fixation could occur. Where there was a main tap root, it was quite small with little to no new root growth. These legume plants also had typically smaller main roots and fewer lateral and fibrous roots. Most part of the legume plant grew runners over the soil surface.

In the three mature plantings that had poor nodulation, most of the active or new nodules were found on fibrous roots that are more or less below 15-20 cm down the roots and nodules are typically smaller in size, and not possible to cut open to record effectiveness.

In the matured planting, most of the roots also had very few lateral roots and little to no fibrous roots, which also means the absence of nodules.

Legume plants in the new planting on the other hand had very good nodulation and possibly a very high N-fixation rate. Legume plants in the new plantings had more exposure to sunlight and photosynthetic ability, so more energy should be available for N-fixation, which could be a main contributing factor to nodulation.

Some external factors that could have contributed to poor nodulation could include high level of N in the soils, root rot, soil too dry or too wet and soil acidity.

Bacteria also infect root hairs on a legume plant to form nodules, and root hairs are formed only on new root growth. In the three plantings that had poor nodulation, there was little to no new root growth. Legume plants with nodules only showed nodules forming on new roots. An example could be seen in Figure 5 in the Figures section of this report.

Further work could be carried out to sample legume plant roots from areas under mature oil palm plantings that are exposed to sunlight (e.g. where there are missing palms) to see if nodulation could be higher than the areas that have been sampled under the canopy covered areas.

FIGURES

Figure 4 (a-d): Examples of roots from new planting (a), young mature (b), mature (c) and old plantings (d).

Figure 5: Nodules are normally formed on new root growth on legume plant roots

CONCLUSION

From this short study, nodulation on legume plants was shown to be very good in newly planted palms with the potential for good N-fixation as well. Legume plants from more mature plantings had poor nodulation and probably little to no N-fixation. This indicates that shading is a main factor affecting nodulation on legume cover plants. Further study could be carried out to do nodule counts on legume plants exposed directly to sunlight in the three plantings with poor nodulation to see whether there will be differences in nodulation due to effects of shading.

References

Eckardt, N. A., (2009), Nodulation signalling in Legumes depends on n NSP1-NSP2 complex. The Plant Cell, 21: 367.

Fairhurst, T, Hardter, R, (2003), *Oil Palm Management for Large and Sustainable Yields*. First Edition, Potash & Phosphate Institute (PPI) & Phosphate Institute of Canada (PPIC), Singapore, 382 pages.

Norhayati, M., Mohd Noor, s., Chong, K., Faizah, A. W., Herridge, D. F., Peoples, M. B., Bergersen, F. J. (1988), Adaptations of methods for evaluating N2 fixation in food legumes and legume cover crops. Plant and Soil 108: 143-150.

Unkovich, M., Herridge, D., People, M., Cadisch, G., Boddey, B., Giller, K., Alves, B., Chalk, P. (2008). *Measuring plant-associated nitrogen fixation in agricultural systems*. ACIAR, Canberra, 258 pages.

Fertilizer Response Trials

Hargy Oil Palm Ltd., WNB: Summary

(Dr. Harm van Rees and Winston Eremu)

Fertilizer response trials with Hargy comprised two main areas of interest:

1. Factorial trial responses to N, P, K and Mg: three factorial trials have been operational at Hargy for many years. One of the factorial trials (205) 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: It is possible that P uptake is not being maximised and placement of P on the frond pile should be considered. The effect of increasing N in trial 205 on half of the replicates should become evident in 2009.

2. Systematic N trials: two systematic N trials have been established (one at Hargy, 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 this report).

   Outcome: the Systematic N trials are showing N fertilizer responses of between 7 and 30% increase in yield. The responses to N fertilizer will continue to increase as the tissue N levels in the control plots are starting to decrease.

A synopsis for the trial work undertaken with Hargy Oil Palm is provided on the next page. A short recommendation for trial work, operation and plantation management based on our results is also provided.

A meeting was held with Hargy management during 2008 where the future of trial work with HOP was discussed. It was decided at that meeting:

- To stop further trial work at trials 209 and 213 (last year of trial work in 2008)
- Continue with trials 205, 211 and 212
- Start a new P rate and placement trial – this trial was established in October 2008 (trial 214)
- Start a new NxPxK trial at Barema in a new planting (trial planted in March 2009)
- Possibly start a new NxPxK trial at Navo in a replanted area in early 2010.

Hargy Oil Palm Ltd: Synopsis of 2008 PNGOPRA trial results and recommendations

Trial	Palm Age	Yield t/ha	Yield Components	Tissue (%dm)	Vegetative	Notes
205 Hargy EFB, TSP, KIE (factorial) Soil: Volcanic	14	EFB 31 to 33 TSP 32 (NS) KIE 32 (NS)	B/palm 10 (NS) SBW 23 (NS)	N LN 2.41 to 2.45 EFB LN 2.42 (NS) RK 1.42 to 1.53 TSP LP 0.141 to 0.144 RP 0.08 to 0.12 KIE LMg 0.16 to 0.18	PCS 57.5 (NS) FP 21 (NS) LAI 7.0 (NS)	An extra N treatment was introduced in late 2007, the higher treatment plots is starting to show an increase in tissue N status.
209 Hargy SOA, TSP, MOP, KIE (factorial) Soil: Volcanic	14	SOA 25 to 31 TSP 25 to 30 MOP 27 to 29 SOA x TSP 33 KIE 27 (NS)	B/palm 9 to 11 SBW 20 to 22	No tissue was sampled (last year of trial)	No vegetative measurements were taken (last year of trial)	Yield drop from 2007, fertilizer responses similar to previous years. Last year for this trial (now closed).
213 Hargy AN, TSP(factorial) Soil: Volcanic	10	AN 15 to 20 TSP 13 to 20 AN x TSP mid 20s	B/palm 4 to 8 SBW 18 to 23	AN LN 2.30 to 2.52 RN 0.25 (NS) TSP LP 0.133 to 0.150 RP 0.03 to 0.07 LK 0.64; RK 0.81 LMg 0.22; LB 15ppm	PCS 40 (NS) FP 16 to 17 LAI 5.7 to 6.2	Basal K rate increased in 2008, improvement in rachis K. This trial is now closed.
211 Navo AN (Systematic) Soil: Volcanic	10	AN 33 to 40	B/palm 16 to 17 SBW 18 to 20	AN LN 2.36 to 2.57 RN 0.24 to 0.27 LP 0.138; RP 0.07 LK 0.70; RK 1.95 LMg 0.17; LB 17ppm	PCS 41 to 48 FP 23 (NS) LAI 5.5 (NS)	Large increase in yield in 2007 and 2008 compared to 2006. Response to N fertilizer increasing over time. P in rachis low (applied more basal TSP)
212 Hargy AN (Systematic) Soil: Volcanic	11	AN 20 to 26	B/palm 8 to 9 SBW 19 to 21	AN LN 2.20 to 2.40 RN 0.24 to 0.27 LP 0.133; RP 0.045 LK 0.72; RK 1.50 LMg 0.17, LB 14ppm	PCS 43 to 51 FP 21 to 22 LAI 6.0 to 6.7	Basal P rates increased.

Apparent adequate tissue nutrient levels (for the palm age groups in the trials):

Leaflet (% dm)					Rachis (%dm)		
N	**P**	**K**	**Mg**	**B**	**N**	**P**	**K**
2.45 – 2.50	0.145	0.65	0.20	15ppm	0.32	0.08	1.2

Recommendations to Hargy Oil Palm:

1. At Hargy 30+ t/ha FFB should be attainable in mature plantations. Improved plantation standards in harvesting, pruning, weeding and overall maintenance has resulted in much higher crop recovery and there are now trials with treatment yields in excess of 35 t/ha.
2. Tissue testing and Vegetative measurement criteria will help in determining deficiencies of particular nutrients
3. Most of the focus for nutrition should be on N, followed by P and K, followed by Mg and B

Trial 205: P, Mg and EFB Fertilizer Trial, Hargy

SUMMARY

The application of Ammonium Chloride (AC), Triple Super Phosphate (TSP), Kieserite (KIE) did not result in a yield response in 2008. In 2006, 2007 and 2008 the application of EFB increased yield but only by a small amounts (less than 10% yield increase).

Leaflet N, P and Mg concentrations were significantly increased by EFB, TSP and KIE respectively. Leaflet and rachis K was also increased by EFB. With the application of a higher rate of AC as a treatment in late 2007 there has been a significant increase in leaflet N in 2008 (from 2.41 to 2.45 %dm).

METHODS

Trial Background Information

The purpose of the trial is to investigate the response of oil palm to the application of EFB, 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 Palms Ltd
Estate	Hargy	Block No.	Area 9, blocks 7 & 8
Planting Density	135 palms/ha	Soil Type	Volcanic
Pattern	Triangular	Drainage	Freely draining
Date planted	1993	Topography	Gently sloping
Age after planting	15 years	Altitude	120 m asl
Recording Started	June 1997	Previous Land-use	Oil Palm
Progeny	Known*	Area under trial soil type (ha)	Not known
Planting material	Dami D x P	Agronomist in charge	Winston Eremu

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

Experimental design and treatments

The EFB x P x Mg x N trial was set up with two rates of each fertilizer in a factorial design, replicated three times with 48 plots (Table 2). The N treatment was included in late 2007 because the palms appeared to be N deficient (based on tissue test analysis). Nitrogen was 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). Post 2008 the high AC treatment will be 6 kg/palm. Extra N fertilizer was applied on replicates 2, 4 and 6; and remained the same on replicates 1, 3 and 5.

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.

The number of bunches and bunch weights were recorded fortnightly on an individual palm basis and totalled for each plot, then totalled for each harvest and yield was expressed as tonne per ha per year.

Leaf sampling was carried out according to standard procedures and analysed for nutrient concentrations using standard analytical procedures.

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

Basal fertilizer applied in 2008 was MOP at 2kg/palm and Borate at 150g/palm.

Table 2: Fertilizer and EFB treatments applied in Trial 205 in 2008

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

* note the high AC rate will be reduced to 6 kg/palm in 2009

RESULTS and DISCUSSION

FFB yield and its components - mean trend over time

Fresh fruit bunch yield increased to a peak of about 45 t/ha in 2000 and then decreased progressively to 26 t/ha in 2002 and then stabilised for some years, in 2007 and 2008 the yield increased to 30t/ha and above (Figure 1). The increase in the FFB yield in 2000 was mainly due to an increase in number of bunches produced. Bunch number has decreased progressively from 2000 till 2002 when it began to stabilise at about 10 bunches per palm or 1300 bunches/ha. Single bunch weight SBW increased progressively until 2003, when the palms were 10 years old, and is now increasing more slowly (in 2008 the SBW was around 24 kg/bunch).

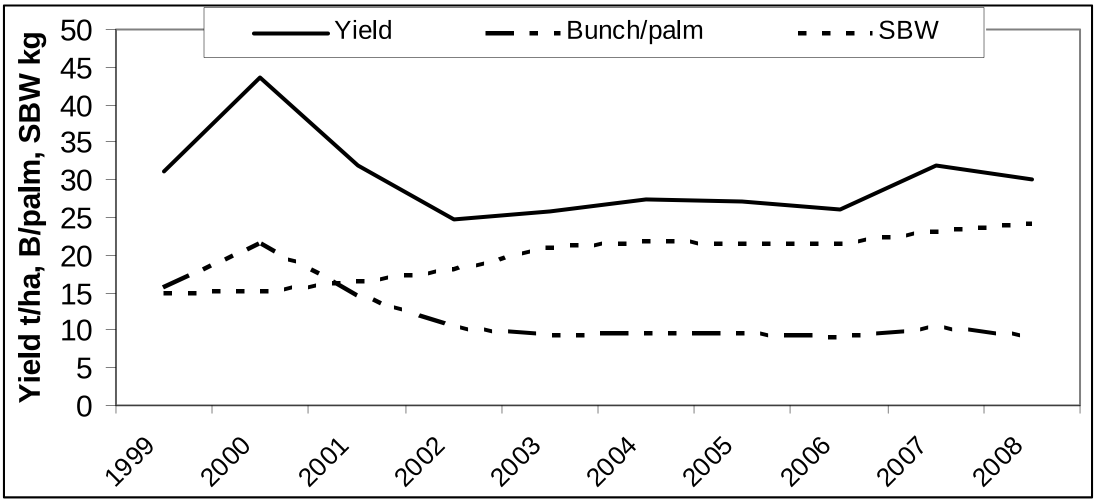


Figure1: FFB yield, Bunch no/palm and SBW from 1999 to 2008.

2008 - FFB yield and its components

The main effect of EFB application on yield was significant in 2008 (29 vs 31 t/ha for EFB 0 and 230 kg/palm respectively) (Figure 2). The effect of TSP was also significant (P=0.03) but was negative in yield response (31 vs 29 t/ha for TSP 0 and 3kg/palm respectively). The effects of N and KIE were not significant in 2008 (Figure 2).

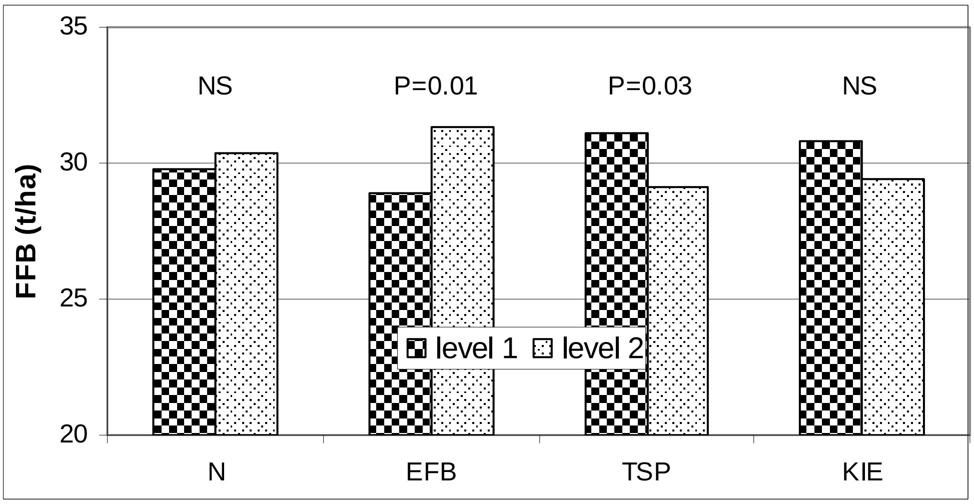


Figure 2. Main effect of EFB, Kieserite and TSP on FFB yield (t/ha) in 2008.

The interactions between fertilizer treatments were generally not significant and no trend in fertilizer effect on yield could be determined.

The overall impact of EFB, Kieserite and TSP has been minimal over the duration of this trial. It is possible that in previous years nitrogen deficiency may have been having an influence on production and optimum yields could be realized. In late 2007 extra N fertilizer was applied on half the number of replicates – it still remains to be seen whether this will increase yield.

2008 – tissue nutrient concentration

The impact of fertilizer on tissue nutrient concentration is outlined in Table 4:

- EFB increased leaflet N, K and Mg; and rachis N, P and K (EFB as a mulch breaks down and releases mineral N, P and K);
- TSP increased leaflet P and rachis P (leaflet and rachis K were reduced when TSP was applied);
- Kieserite increased leaflet Mg.

Table 4: Tissue nutrient concentration for Trial 205 in 2008 (figures in bold are significantly different).

Fertilizer rate (kg/palm)	Leaflet (% dm)				Rachis (% dm)		
	N	P	K	Mg	N	P	K
AC 3	**2.41**	0.142	0.63	0.17	0.34	0.104	1.47
AC 9	**2.45**	0.142	0.64	0.17	0.34	0.094	1.48
EFB 0	2.42	0.142	0.63	0.17	0.34	0.094	**1.42**
EFB 230	2.44	0.142	0.64	0.17	0.34	0.103	**1.53**
TSP 0	2.43	**0.141**	**0.65**	0.17	0.34	**0.078**	1.52
TSP 3	2.43	**0.144**	**0.62**	0.17	0.34	**0118**	1.43
KIE 0	2.43	**0.143**	0.63	**0.16**	0.34	0.102	1.48
KIE 3	2.43	**0.141**	0.64	**0.18**	0.34	0.094	1.47
$LSD_{0.05}$	**0.02**	**0.002**	**0.02**	**0.01**	**-**	**0.015**	**0.11**
CV%	**1.6**	**2.2**	**5.0**	**9.1**	**5.1**	**20.8**	**10.7**

The response seen from fertilizer treatments on tissue nutrient concentration was similar over the last three years. The higher rate of N increased leaflet N levels; EFB increased rachis K levels; TSP increased leaflet and rachis P but also decreased leaflet K; and Kieserite resulted in higher leaflet Mg levels and lower leaflet P levels.

The overall nutrient status of this trial is low to adequate. The main problem in previous years appeared to be a lack of nitrogen fertility. In previous years the leaflet and rachis N were low for mature palms (adequate levels are 2.45 and 0.32 %dm for leaflet and rachis respectively and these levels were not reached). In 2008 the effect of the higher rate of N was significant on leaf N (increase from 2.41 to 2.45 %dm with the higher rate of AC).

Boron was also tested in the leaflets and the mean value was 16 mg/kg – which is just adequate. B is being applied as a basal fertilizer (first application in 2007).

Effects of fertilizer treatments on vegetative growth parameters

EFB had a significant effect on PCS (Petiole Cross Section) and dry matter production. AC, TSP and Kieserite had little or no effect on any of the vegetative growth parameters measured or calculated (Table 5).

Table 5. Effect (p values) of treatments on vegetative growth parameters in 2008. P values less than 0.05 are in bold.

Fertilizer	PCS	Radiation Interception				Dry Matter Production (t/ha)			
		GF	FP	FA	LAI	FDM	BDM	TDM	VDM
AC	0.46	0.34	0.131	0.64	0.35	0.62	0.60	0.90	0.65
EFB	**0.04**	0.47	0.16	0.63	0.42	**0.01**	**0.02**	**0.002**	**0.008**
TSP	0.91	0.06	0.07	0.85	0.29	0.57	**0.03**	0.48	0.68
KIE	0.20	0.99	0.48	**0.02**	0.12	0.24	0.10	0.91	0.29
CV %	18.6	3.6	4.2	3.8	5.5	15.7	10.5	10.0	14.5

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).

CONCLUSIONS

Generally EFB, TSP and Kieserite treatments had no significant effect on FFB yield over the course of the trial. Over the last 3 years EFB has increased FFB yield (2006 by 2.4 t/ha, 2007 by 2 t/ha, and 2008 4.0 t/ha).

The general lack of a fertilizer response at this site is probably due to the overall poor N fertility status of the palms. Leaflet N and rachis N levels are both low. Nitrogen drives crop production and when in low supply the crop cannot respond to other nutrients, hence the lack of response to P and Mg applied. Ammonium Chloride was applied as a basal fertilizer at 3 kg/palm (equivalent to 0.8kg N/palm) which appeared to have been too low. In late 2007 and again in 2008, an extra 6 kg AC/palm (for a total of 9 kg/palm) was applied to half of the available replicates. In 2009, this extra AC treatment will be reduced to 6 kg/palm (the trial will then have two N treatments: 3 and 6 kg AC/palm).

Trial 209: N, P, K and Mg Factorial Fertilizer Trial, Hargy

SUMMARY

Sulphate of ammonia (SOA) and triple superphosphate (TSP) had a significant effect on yield in this trial. MOP (Potassium chloride) had a small effect on yield, whilst magnesium sulphate as kieserite (KIE) had no impact on yield.

The results in 2008 reflect the same results over the last five years:

- Strong effect of N and P
- Small effect of K
- No effect of Mg

Nitrogen (N) and phosphorus (P) and occasionally potassium (K) fertilizers should be applied – the optimum base rate for fertilizer to apply on a yearly basis is 4 to 8 kg/palm of SOA and 4 kg/palm of TSP (unfortunately the trial design does not enable the determination of a lower rate of P fertilizer on yield). The addition of MOP should be based on tissue nutrient concentration values.

METHOD

Trial Background Information

The purpose of the trial is to provide Nitrogen, Potassium, Magnesium and Phosphorus fertilizer response information necessary for determining fertilizer recommendations for palms grown on volcanic soils at Bialla. Table 1 provides background information to the trial.

Table 1. Trial 209 background information.

Trial number	**209**	Company	Hargy Oil Palms Ltd
Estate	Hargy	Block No.	Area 1, Blocks 4, 6 & 8
Planting Density	135 palms/ha	Soil Type	Volcanic
Pattern	Triangular	Drainage	Freely draining
Date planted	1994	Topography	Gently sloping
Age after planting	14 years	Altitude	68 m asl
Recording Started	June 1998	Previous Land use	Oil Palm
Progeny	Mix	Area under trial soil type (ha)	Not known
Planting material	Dami D x P	Agronomist in charge	Winston Eremu

Experimental design and treatments

The N x K x Mg x P trial was set up with three rates of each fertilizer in a 3 x 3 x 3 x 3 factorial design with 81 plots and no replication (Table 2). Each plot has 36 palms and recordings and measurements were taken on the central 16 palms. The number of bunches harvested and bunch weights were recorded fortnightly on an individual palm basis and totalled for each plot, then totalled for each harvest and yield is expressed as tonnes per ha per year. Leaf sampling, using Frond 17, was carried out according to standard procedures and analysed for nutrient concentrations using standard analytical procedures. Vegetative measurements were taken at the same time as leaf sampling.

Yield and its components, tissue nutrient concentration and vegetative parameters were analysed using General Analysis of Variance. The design was a single replicate of a 3 x 3 x 3 x 3 factorial, arranged in 9 incomplete blocks of 9 treatments such that 2 of the 4-way interactions were partly confounded within incomplete blocks. Special pseudo-factors were generated to be able to separate out the confounding in the General Analysis of Variance.

Table 2. Fertilizer levels and rates used in trial 209.

	Amount (kg/palm/year)		
Fertilizer	**Level 1**	**Level 2**	**Level 3**
SOA (Sulphate of Ammonia - N)	2	4	8
TSP (Triple Super Phosphate - P)	0	4	8
MOP (Muriate of Potash - K)	0	2	4
KIE (Kieserite - Mg)	0	4	8

Since it is the last year of this trial no basal fertilisers were applied in 2008.

RESULTS AND DISCUSSION

Fertilizer effect on FFB yield and its components

Mean trend over time – FFB yield and its components

The number of bunches (BN) harvested per palm decreased while SBW increased progressively over the course of the trial (Figure 1).

A large drop of yield (7 to 8 t/ha) occurred from 2007 to 2008, there was a large drop in the number of bunches harvested (around 300ha few bunches were harvested in 2008 compared to 2007). The same drop in yield has been observed in some other trials but interestingly did not occur at Navo (see results for trial 211).

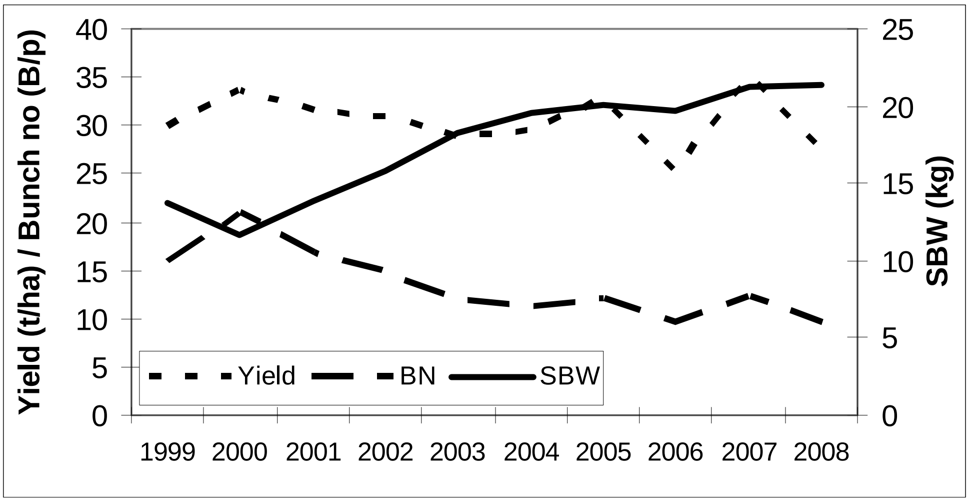


Figure 1. Yield (t/ha), Bunch number per palm (BN/palm) and SBW (Single Bunch Weight in kg/bunch) for trial 209 for the duration of the trial.

2008 – FFB yield and its components

In 2008, SOA, MOP and TSP treatments resulted in a significant increase in yield. Kieserite did not affect yield (zero increase in yield between fertilised and not fertilised with Kieserite). The main effects of SOA, MOP, TSP and Kieserite were:

- SOA from 2kg to 8 kg/palm increased yield from 25 to 31 t/ha ($P<0.001$);
- MOP from 0 to 8 kg/palm increased yield from 27 to 29 t/ha ($P=0.02$);
- TSP from 0kg to 8 kg/palm increased yield from 25 to 30 t/ha ($P=0.001$); and
- KIE from 0 to 4 kg/palm had no affect on yield (average 27 t/ha).

The combined use of SOA and TSP resulted in a significant increase in yield (Table 3). The main effect on yield was from a significant increase in bunch number. SBW was not significantly increased by SOA or by TSP (Table 3), however the effect of MOP on SBW was significant (a 1.6 kg/bunch increase in weight).

Table 3. FFB and its components of bunch number and SBW for the interaction between SOA and TSP for trial 209 in 2008.

	Yield t/ha			**Bunch no./palm***			**SBW kg/bunch**		
	TSP kg/palm			**TSP kg/palm**			**TSP kg/palm**		
SOA kg/palm	**0**	**4**	**8**	**0**	**4**	**8**	**0**	**4**	**8**
2	22.5	25.7	25.8	8.0	9.1	9.0	20.9	20.9	21.2
4	24.8	27.7	27.9	8.8	9.7	9.5	20.9	21.2	21.7
8	27.5	33.3	33.3	9.6	11.0	11.5	21.4	22.6	22.3
Significant difference:									
SOA	**P<0.001**			**P<0.001**			**NS**		
TSP	**P<0.001**			**P<0.001**			**NS**		
SOA*TSP	**NS**			**NS**			**NS**		
$LSD_{0.05}$	**2.6**			**0.9**			-		

* Bunch no/palm of 10 equates to 1350 bunches/ha.

Treatments yielding greater than 30t/ha were treated with SOA at 8 kg/palm + TSP at 4 kg/palm and MOP at 2 kg/palm (Figure 2).

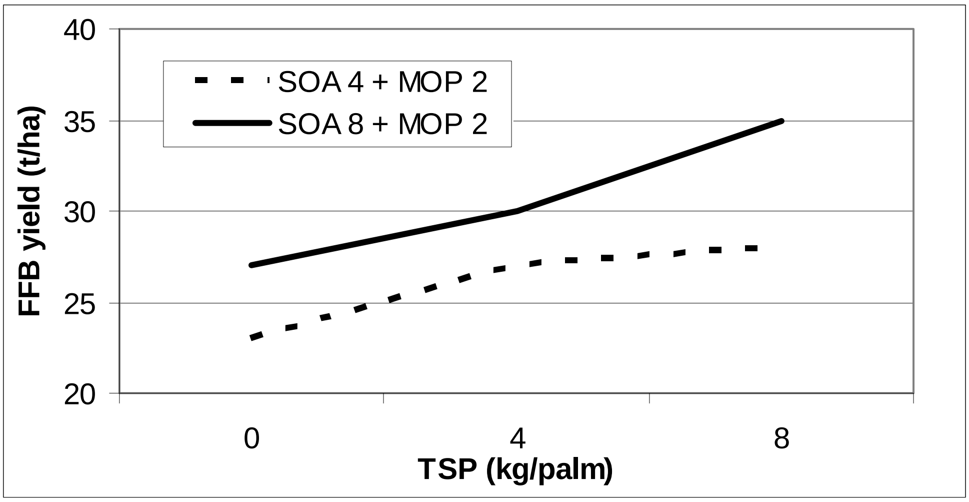


Figure 2. Yield response from P (as TSP) in 2008 (in addition to SOA + MOP).

Fertilizer effect on tissue nutrient concentrations and vegetative growth parameters

Because it was the last year for this trial no tissue samples or vegetative growth parameters were assessed for this trial in 2008.

CONCLUSION

SOA, MOP and TSP significantly increased FFB yield (by 6, 2 and 5 t/ha respectively) while KIE had no significant effect on yield in this trial.

The highest yields, of 35 t/ha, in 2008 were obtained with the addition of SOA at 8 kg/palm plus MOP at 2 kg/palm plus TSP at 4 kg/palm. Kieserite had little or no impact on yield in 2008 or in previous years.

Trial 211: Systematic N Fertilizer Trial, Navo

SUMMARY

A 6t/ha yield response resulted from the application of 4.5 kg/ha AN, the yield response resulted from an increase in bunch number and bunch weight. Some of the trial treatments achieved a yield of around 40 t/ha – a very good result.

METHODS

Two Nitrogen Systematic trials were established at Hargy in 2001/02. The nitrogen systematic trials have been designed especially for coarse textured volcanic soils to minimize the effect of fertilizer applied to one plot having an effect on an adjacent plot. The nitrogen systematic trials have 9 rates of AN (ammonium nitrate) applied in 8 replicated blocks. The rates applied increase from 0 to 2kg N/palm at 0.25kg N/palm increments (equivalent to 0 to 5.92 kg AN/palm at 0.74 kg AN/palm increments). The trials at Hargy have the same design as trials 137 and 138 with NBPOL.

Table 1. Trial 211 background information.

Trial number	**211**	Company	Hargy Oil Palm Ltd
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	10 years	Altitude	2 m asl
Treatments 1st applied	Nov 2001	Previous Land-use	Sago and forest
Progeny	unknown	Area under trial soil type (ha)	not known
Planting material	Dami D x P	Agronomist	Winston Eremu

Basal fertilizers applied in 2008 in Trial 211: MOP 2 kg, KIE 1.5 kg, TSP 0.5 kg and Borate 150 g/palm.

RESULTS and DISCUSSION

Yield and its components response to fertilizer treatment in 2008

The yield increase from applying N fertilizer is significant (6.0 t/ha) (Table 2). This yield response was achieved at a N fertilizer rate of around 1.25 kg N/palm (equivalent to 3.7 kg AN/palm). The effect of N fertilizer was significant on bunch number and SBW (Table 2).

Table 2. T211: 2008 Yield (t/ha), Bunch number (b/palm and b/ha) and SBW (kg/bunch) by N rate.

N rate (kg/palm)	Equivalent AN rate (kg/palm)	Yield (t/ha)	Bunch number (bunches/palm)	Bunch number (bunches/ha)	SBW (kg/bunch)
0	0	33.5	15.8	1818	18.4
0.25	0.74	36.1	16.4	1882	19.2
0.50	1.48	36.8	16.6	1910	19.3
0.75	2.22	37.5	16.8	1929	19.4
1.0	2.96	38.5	17.1	1969	19.5
1.25	3.70	39.5	17.1	1961	20.2
1.5	4.44	39.5	17.4	1998	19.7
1.75	5.18	40.5	17.6	2020	20.0
2.0	5.92	39.2	17.3	1992	19.7

Significant difference:	**P<0.001**	**P=0.002**	**P=0.002**	**P<0.001**
$LSD_{0.05}$	**1.9**	**0.8**	**94**	**0.7**
CV%	**4.9**	**4.8**	**4.8**	**3.3**

Yield response over time

A gradual and noticeable increase in yield occurred from 2003 (palm age: 5 years) to 2008 (palm age: 10 years). The response to applying N has been increasing since 2003, and in 2008 resulted in a 6 t/ha yield increase (Figure 1). The top producing treatments at this site have now produced 40t/ha over the last two years.

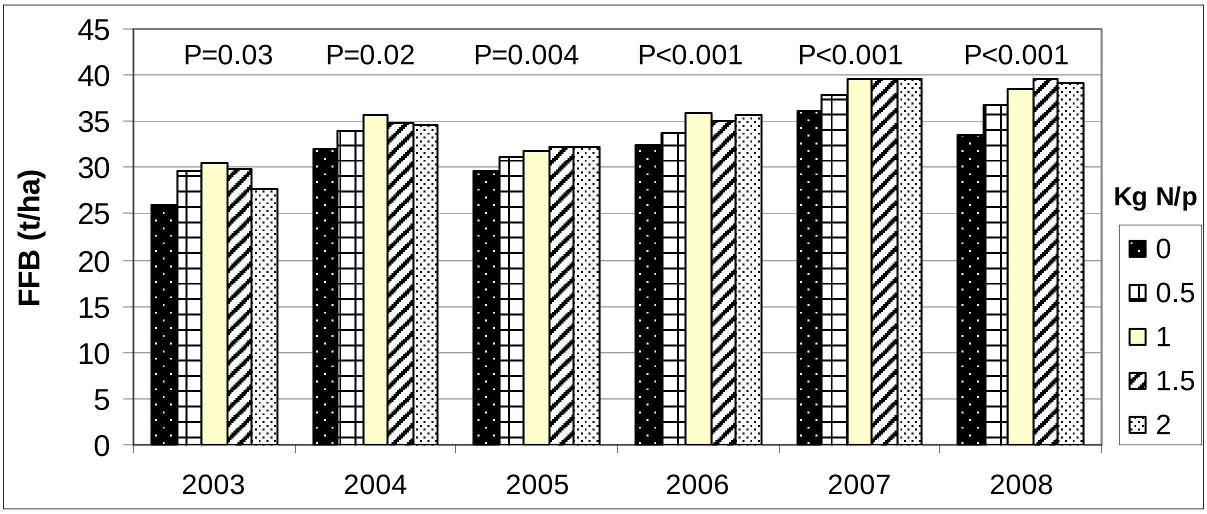


Figure 1. Yield response to 5 rates of N (kg/palm) over time (fertilizer N was first applied in late 2002).

As the palms matured from 5 to 10 years after planting the mean number of bunches per palm decreased and then maintained a constant number at (17 bunches harvested per palm per year); whilst SBW has increased from 12 kg/bunch to close to 20 kg/bunch over the last two years (Figure 2).

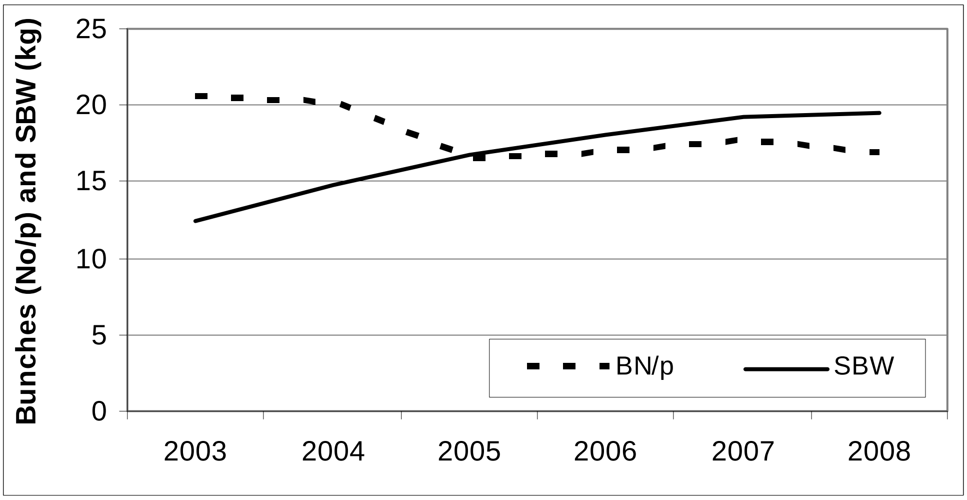


Figure 2. Mean trial Bunch Number (per palm) and SBW (kg) over time (Trial 211).

Tissue nutrient concentration for 2008

Tissue nutrient concentration was investigated for both leaflets and the rachis (Table 3). Leaflet N and Rachis N increased with higher rates of N application (P<0.001 and P=0.01 respectively). Leaflet P increased with higher N rates, whilst there were no significant effects on leaflet K, nor on Rachis P and K. Rachis P levels have increased since basal applications of TSP started in 2007.

Leaflet Mg is just on the low side (0.17 % dm) and Boron levels are adequate (17 ppm).

Table 3. Leaflet and rachis nutrient content for T211 in 2008.

N rate (kg/palm)	**Equivalent AN rate (kg/palm)**	**Leaflet (% dm)**			**Rachis (% dm)**		
		N	**P**	**K**	**N**	**P**	**K**
0	0	2.36	0.131	0.67	0.33	0.066	1.88
0.25	0.74	2.38	0.134	0.71	0.33	0.067	1.95
0.50	1.48	2.46	0.135	0.71	0.34	0.068	1.96
0.75	2.22	2.49	0.135	0.69	0.33	0.065	1.94
1.0	2.96	2.54	0.139	0.70	0.34	0.064	1.87
1.25	3.70	2.56	0.138	0.71	0.34	0.075	1.91
1.5	4.44	2.57	0.140	0.71	0.35	0.068	1.95
1.75	5.18	2.57	0.140	0.71	0.34	0.070	1.93
2.0	5.92	2.46	0.140	0.71	0.35	0.071	1.98
	Significant difference:	**P<0.001**	**P<0.001**	**NS**	**0.014**	**NS**	**NS**
	$LSD_{0.05}$	**0.09**	**0.004**	**-**	**0.01**	**-**	**-**
	CV%	**3.6**	**3.2**	**5.5**	**3.4**	**19.3**	**9.5**

Tissue N concentration over time 2004 to 2008

Leaflet N levels are slowly changing over time with the zero treatment now reaching low levels whereas the higher rates of N application is maintaining good leaflet N status (Table 4).

Table 4. Leaflet N (% dm) over time (trial 211).

N rate (kg/palm)	**Equivalent AN rate (kg/palm)**	**Leaflet N (% dm)**				
		2004	**2005**	**2006**	**2007**	**2008**
0	0	2.66	2.60	2.44	2.40	2.36
0.5	1.48	2.72	2.65	2.53	2.51	2.38
1.0	2.96	2.72	2.68	2.55	2.57	2.54
1.5	4.44	2.74	2.69	2.58	2.60	2.57
2.0	5.92	2.72	2.65	2.56	2.56	2.46
	Significant difference:	**NS**	**P=0.02**	**P=0.03**	**P<0.001**	**P<0.001**
	$LSD_{0.05}$	**-**	**0.05**	**0.08**	**0.04**	**0.09**
	CV%	**2.1**	**1.9**	**2.2**	**1.5**	**3.6**

Fertilizer N effects on oil palm vegetative growth

Frond production and frond number

22 new fronds were produced in 2008 (one every 16 days) indicating good growing conditions during the year. Total green fronds counted per palm averaged 35 fronds which is slightly low. AN fertilizer applications had no clear effects on either parameter measured.

Frond and canopy size

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 the expected range for 8 year old palms (average frond area $13m^2$ and LAI of 5.5). Neither, Frond Area or LAI, was affected by the rate of N fertilizer applied.

Vegetative dry matter production

Petiole cross section (PCS) is a primary determinant of vegetative dry matter production. In 2008 there was a very small increase in PCS with the application of N fertilizer.

Table 5. Effect of N treatments on vegetative growth parameters in 2008.

N rate kg/palm	Equiv. AN rate kg/palm	PCS	Radiation Interception			
			GF	FP	FA	LAI
0	0	40.6	33.7	21.6	12.6	4.9
0.25	0.74	43.3	35.1	21.8	12.8	5.2
0.50	1.48	43.8	34.8	22.1	12.9	5.2
0.75	2.22	45.0	35.0	21.7	12.7	5.1
1.0	2.96	45.5	34.9	22.6	13.3	5.3
1.25	3.70	48.0	35.1	22.4	13.2	5.3
1.5	4.44	48.5	35.7	22.4	13.1	5.4
1.75	5.18	44.9	35.1	22.3	13.1	5.3
2.0	5.92	43.5	35.3	21.9	12.8	5.2
Significant difference:		**0.05**	**0.11**	**0.51**	**0.51**	**0.12**
	$LSD_{0.05}$	**4.7**	**-**	**-**	**-**	**-**
	CV%	**10.5**	**3.2**	**4.8**	**4.8**	**5.9**

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

CONCLUSION

A significant yearly increase in yield, of 6.0 t/ha, was observed with the application of 4.5 kg AN/palm (or 1.5 kg N/palm). The response to N fertilizer has been increasing since 2003.

Tissue nutrient levels indicate there are no major deficiencies. Rachis P levels have increased since the application of basal P commenced in 2007.

N fertilizer increased the Petiole Cross Section which is a primary indicator of N fertility.

Trial 212: Systematic N Fertilizer trial, Hargy

SUMMARY

A 6 t/ha yield response resulted from the application of 4.5 kg/ha of AN. The yield response resulted from an increase in bunch number and bunch weight.

METHODS

The trial design for 212 is the same as for trial 211.

Trial Background Information

Table 1. Trial 212 background information.

Trial number	**212**	Company	Hargy Oil Palms Ltd.
Estate	Hargy	Block No.	Area 9, 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	12 years	Altitude	155 m asl
Treatments 1st applied	2002	Previous Land use	Oil palm
Progeny	unknown	Area under trial soil type (ha)	Not known
Planting material	Dami D x P	Agronomist	Winston Eremu

Basal fertilizers applied in 2008 in Trial 212: MOP 2 kg, KIE 3.0 kg, TSP 0.5 kg and Borate 150 g/palm.

RESULTS and DISCUSSION

Yield and its components response to fertilizer treatment in 2008

Applying N fertilizer increased the FFB yield significantly. A yield increase of 6 t/ha yield was achieved with the addition of 4.4 kg AN/palm (Table 2). Bunch number and SBW increased with the application of N fertilizer.

Table 2. Trial 212: 2008 Yield (t/ha), Bunch number (bunches/palm and bunches/ha) and SBW (kg/bunch) by N rate.

N rate (kg/palm)	Equivalent AN rate (kg/palm)	Yield (t/ha)	Bunch number (bunches/palm)	Bunch number (bunches/ha)	SBW (kg/bunch)
0	0	20.3	7.8	1093	18.6
0.25	0.74	20.7	7.6	1059	19.6
0.50	1.48	23.9	8.5	1189	20.1
0.75	2.22	23.9	8.2	1152	20.8
1.0	2.96	24.0	7.9	1105	21.8
1.25	3.70	25.5	8.8	1229	20.8
1.5	4.44	26.3	8.8	1236	21.4
1.75	5.18	25.4	8.5	1186	21.5

2.0	5.92	24.9	8.6	1203	20.7
Significant difference:		**P<0.001**	**P=0.04**	**P=0.04**	**P<0.001**
	$LSD_{0.05}$	**2.1**	**0.8**	**119**	**1.2**
	CV%	**8.9**	**10.2**	**10.2**	**5.9**

Yield response over time

The trial was initiated in 2002, by 2004 there was a significant effect of applying N on yield. The yearly yield response to N fertilizer has been slowly increasing (there is now a 6 t/ha yield difference between the control and 1.5 kg N/palm (Figure 1). It is also important to note that there was a large yield decline of 5 t/ha in 2008 across the whole trial compared to the previous three years – this yield decline did not occur at Navo.

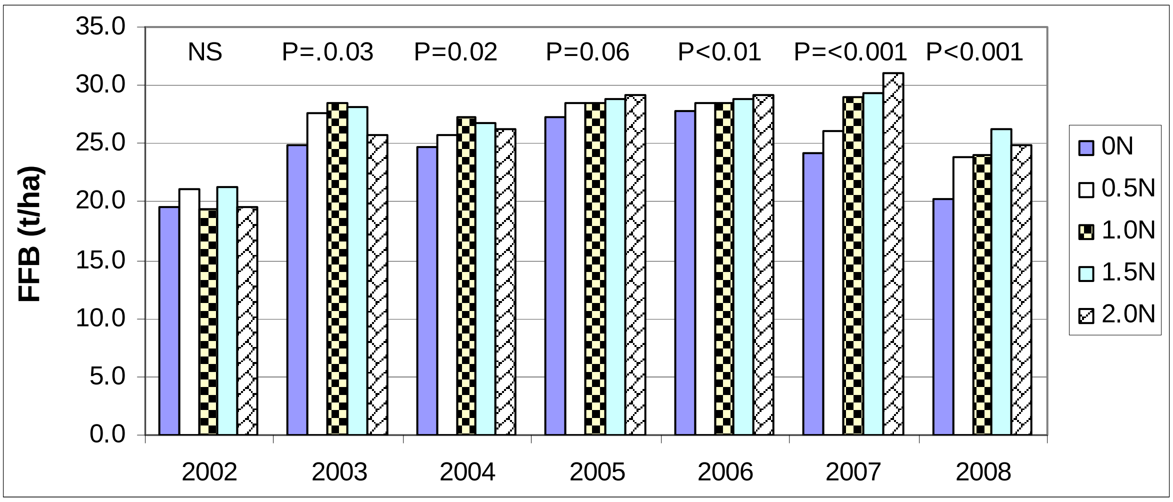


Figure 1. T212: Yield response to 5 rates of N (kg/palm) over time (fertilizer N was first applied in 2002).

Bunch number per palm and SBW increased until the palms were about 8 years old, since then the bunch number has decreased (currently around 10 bunches/palm/annum). The yield reduction seen in 2008 was due to fewer bunches being formed (down to 8.5 bunches/palm). The SBW has continued to increase and is currently on average 21 kg/bunch.

Tissue nutrient concentration

Tissue nutrient concentration was investigated for both leaflets and rachis. The values for the 2008 sampling are listed in Table 3. Increasing rates of N fertilizer significantly increased leaflet and rachis N concentration. Leaflet P increased slightly with increasing rates of N fertilizer, rachis P was variable and not related to N fertilizer input. Leaflet and rachis K levels were not affected by fertilizer N rates.

Table 3. 212: tissue nutrient concentration for leaflets and rachis in 2008.

N rate (kg/palm)	Equivalent AN rate (kg/palm)	Leaflet (% dm)			Rachis (% dm)		
		N	P	K	N	P	K
0	0	2.20	0.131	0.71	0.24	0.047	1.52
0.25	0.74	2.20	0.129	0.72	0.25	0.043	1.45
0.50	1.48	2.29	0.132	0.68	0.24	0.041	1.43
0.75	2.22	2.30	0.130	0.68	0.25	0.040	1.38
1.0	2.96	2.34	0.132	0.72	0.26	0.041	1.56
1.25	3.70	2.35	0.133	0.70	0.27	0.044	1.41
1.5	4.44	2.36	0.133	0.73	0.25	0.045	1.56
1.75	5.18	2.40	0.135	0.73	0.27	0.047	1.49
2.0	5.92	2.39	0.133	0.76	0.27	0.046	1.52
Significant difference P:		**<0.001**	**<0.001**	**0.007**	**<0.001**	**0.02**	**NS**
$LSD_{0.05}$		**0.06**	**0.002**	**0.04**	**0.02**	**0.005**	**-**
CV%		**2.4**	**1.5**	**6.0**	**7.2**	**10.6**	**9.7**

Leaflet P levels are below the accepted adequacy level (0.145 % P) and rachis P levels appear to be very low (adequate: 0.08 to 0.1% P). Basal P fertilizer was applied in 2007 and in 2008, and will be applied again in 2009. Leaflet magnesium (Mg) levels were on average close to adequate (0.17 % dm), and Boron levels were near adequate (14 mg/kg).

Tissue N concentration over time 2004 to 2008

In each year leaflet N levels increased with increasing rates of applied N (Table 4). There is a close correlation between yield and leaflet N (until adequacy levels are reached at around 2.40 to 2.45% N).

Table 4. Leaflet N (% dm) over time (trial 212).

N rate (kg/palm)	Equivalent AN rate (kg/palm)	Leaflet N (% dm)				
		2004	2005	2006	2007	2008
0	0	2.34	2.30	2.25	2.21	2.20
0.5	1.48	2.45	2.44	2.36	2.33	2.29
1.0	2.96	2.42	2.47	2.41	2.39	2.34
1.5	4.44	2.46	2.51	2.43	2.40	2.36
2.0	5.92	2.48	2.54	2.43	2.42	2.39
Significant difference:		**P<0.001**	**P<0.001**	**P<0.001**	**P<0.001**	**<0.001**
$LSD_{0.05}$		**0.05**	**0.05**	**0.04**	**0.05**	**0.06**
CV%		**2.3**	**2.1**	**1.8**	**2.0**	**2.4**

Fertilizer N effects on oil palm vegetative growth

Frond production and frond number

On average 21 new fronds were produced in 2008 (one every 17 days) indicating good growing conditions during the year. The addition of N fertilizer increased frond production by 1 frond/year. Total green fronds counted per palm averaged 34 fronds which is low and indicating possible over pruning.

Frond and canopy size

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 10 year old palms (average frond area 13m^2 and LAI of 6). Both parameters increased significantly with higher rates of N applied.

Vegetative dry matter production

Petiole cross section (PCS) is a primary determinant of vegetative dry matter production. PCS increased significantly with the higher rates of N applied. The measures of foliar vegetative dry matter production (FDM (frond dry matter production), TDM (total dry matter production) and VDM (vegetative dry matter production) all increased with higher rates of applied N.

Table 5. Effect of N treatments on vegetative growth parameters in 2008.

N rate kg/palm	Equiv. AN rate kg/palm	PCS	Radiation Interception				Dry Matter Production (t/ha)			
			GF	FP	FA	LAI	FDM	BDM	TDM	VDM
0	0	43.3	33.7	20.8	12.7	6.0	13.5	11.1	27.3	16.2
0.25	0.74	44.5	33.5	20.5	12.9	6.0	13.6	11.2	27.6	16.4
0.50	1.48	48.3	33.5	21.0	13.5	6.3	15.1	12.8	31.0	18.2
0.75	2.22	48.4	34.1	21.6	13.5	6.4	15.5	12.9	31.6	18.7
1.0	2.96	48.8	34.3	21.6	13.5	6.5	15.7	12.8	31.7	18.8
1.25	3.70	50.9	34.3	21.0	14.0	6.7	15.9	13.7	32.8	19.2
1.5	4.44	51.0	33.9	21.6	14.2	6.7	16.4	14.1	33.9	19.8
1.75	5.18	49.8	33.8	21.8	13.4	6.3	16.1	13.6	33.0	19.4
2.0	5.92	50.7	34.0	22.1	14.0	6.7	16.6	13.6	33.6	20.0
Significant difference:		**<0.001**	**0.12**	**0.004**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**P<0.001**	**<0.001**
	$LSD_{0.05}$	**2.4**	**-**	**0.8**	**0.6**	**0.4**	**0.5**	**0.6**	**1.9**	**1.1**
	CV%	**5.0**	**3.7**	**3.8**	**4.6**	**5.6**	**6.1**	**9.1**	**5.9**	**5.9**

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).

CONCLUSION

A significant yearly increase in yield has been observed since 2004 with the application of 3.0 to 4.5 kg AN/palm (or 1.0 to 1.5 kg N/palm). The increase in yield from N fertilizer steadily increased over the duration of the trial to 2007 and 2008, and has since stabilized at about 6 to 7 t/ha , compared to the zero control.

Tissue nutrient levels are indicating that there are no major deficiencies, except for P. Leaflet and rachis P were below adequacy levels, this could be having a negative impact on yield. A basal rate of TSP was applied at 0.5kg/palm in 2007 and 2008.

N fertilizer increased many of the parameters of vegetative growth, including frond production.

Trial 213: N and P Fertilizer Trial for High Ground, Hargy

SUMMARY

N and P fertilizer responses were determined for the high ground at Hargy plantation.

The control plots (no fertilizer) yielded very poorly producing 15 t/ha less than the combined N and P treatments (control 10 t/ha vs. combined AN + P treatments > 24 t/ha). The largest effect on yield from the fertilizer treatments was an increase in bunch number and a small increase in bunch weight.

The highest yield (24.3 t/ha) was achieved at 2.2 kg of AN plus 3 kg of TSP per palm.

Tissue nutrient concentration and vegetative measurements confirmed that the highest production was achieved with a combination of AN and TSP fertilizer.

However, there is a strong indication that K (potassium) appeared to be lacking in 2007 and 2008, and additional MOP was applied as a basal fertilizer. It is also recommended to test surrounding plantation blocks for leaf and rachis K to ensure that this essential nutrient is not limiting production.

METHODS

Trial Background Information

The purpose of the trial is to provide Nitrogen and Phosphorus fertilizer response information necessary for determining fertilizer recommendations for the palms on the high ground of Hargy Plantation. Table 1 provides background information to the trial.

Table 1. Trial 213 background information.

Trial number	**213**	Company	Hargy Oil Palms Ltd
Estate	Hargy	Block No.	Area 11, blocks 9 and 10
Planting Density	129 palms/ha	Soil Type	Volcanic
Pattern	Triangular	Drainage	Well drained
Date planted	1997	Topography	Rising and hilly
Age after planting	11 years	Altitude	420 m asl
Recording Started	2003	Previous Land use	Forest
Progeny	unknown	Area under trial soil type (ha)	Not known
Planting material	Dami D x P	Agronomist in charge	Winston Eremu

Basal fertilizers applied in 2008 in Trial 213: MOP 3 kg, KIE 1.5 kg and Borate 150 g/palm.

Experimental design and treatments

The N by P trial was set up as a 3 x 3 x 4 factorial design (3 N rates; 3 P rates; 4 replicates) with a total of 36 plots (Table 2). Each plot has 36 palms with recordings and measurements taken on the central 16 palms. Number of bunches and bunch weights were recorded fortnightly on an individual palm basis and totalled for each plot, then totalled for each harvest and yield was expressed as tonne per ha per year. Leaf sampling was carried out according to standard procedures and analysed for nutrient concentrations using standard analytical procedures. A two-way ANOVA (N x P) was used to analyse the main effects and interactions. Vegetative measurements were undertaken following standard procedures.

Table 2: Fertilizer rates used in trial 213.

Fertilizer	Level (kg/palm) 1	2	3
Ammonium Nitrate (AN)	0.0	2.2	4.4
Triple Superphosphate (TSP)	0.0	3.0	6.0

RESULTS and DISCUSSION

2008 Yield and its components

Yield increased from the control plot (N 0, P 0) at 10 t/ha to above 20 t/ha when N and P were applied (Table 3). The largest increase in yield was seen when N was applied in combination with P.

The response in yield was the result of a large increase in Bunch number (an increase of 50% in bunch number when N plus P were applied compared to the control) and to some extent by an increase in bunch weight (a 20% increase in bunch weight when N plus P were applied compared to the control) (Table 3).

The impact of N and P fertilizer on yield, bunch number and bunch weight was highly significant (Table 3).

The highest yields were achieved with AN 2.2kg plus TSP 3 kg/palm (similar to the results in 2005, 2006 and 2007).

Table 3. FFB yield (t/ha), Bunch number (bunch/palm) and SBW (kg) for trial 213 in 2008.

	Yield t/ha			Bunch number / palm*			SBW kg		
	TSP kg/palm			TSP kg/palm			TSP kg/palm		
AN kg/palm	**0**	**3**	**6**	**0**	**3**	**6**	**0**	**3**	**6**
AN 0	10.2	16.5	17.2	4.5	6.2	6.6	18.4	20.7	20.4
AN 2.2	13.9	24.3	23.3	5.5	8.8	8.0	19.9	21.4	22.6
AN 4.4	15.4	19.7	20.6	5.9	7.0	7.0	20.2	21.8	22.8
Significant difference:									
N	**<0.001**			**0.003**			**0.04**		
P	**<0.001**			**<0.001**			**0.005**		
NxP	**NS**			**NS**			**NS**		
$LSD_{0.05}$	**2.0**			**0.9**			**1.5**		
CV%	**13.2**			**16.2**			**8.3**		

* Bunch no/palm: 10 bunches/palm equates to 1290 bunches/ha

Long term yield and its components

Since the first year of this trial (2003) average yield has increased from 17 t/ha to 24 t/ha in 2007. Bunch number has stabilized and bunch weight has increased every year (Figure 1).

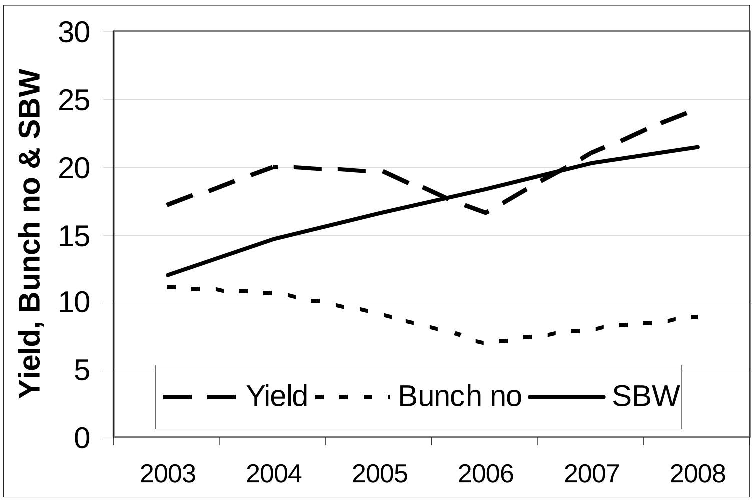


Figure 1. Long term yield, bunch number and bunch weight (AN2.2 and TSP 3)

The control treatment (no fertilizer) has continued to perform poorly relative to the fertilizer treatments (Figure 2).

With improved crop recovery practices in the field the combined fertilizer applications of N and P yielded around 25 t/ha.

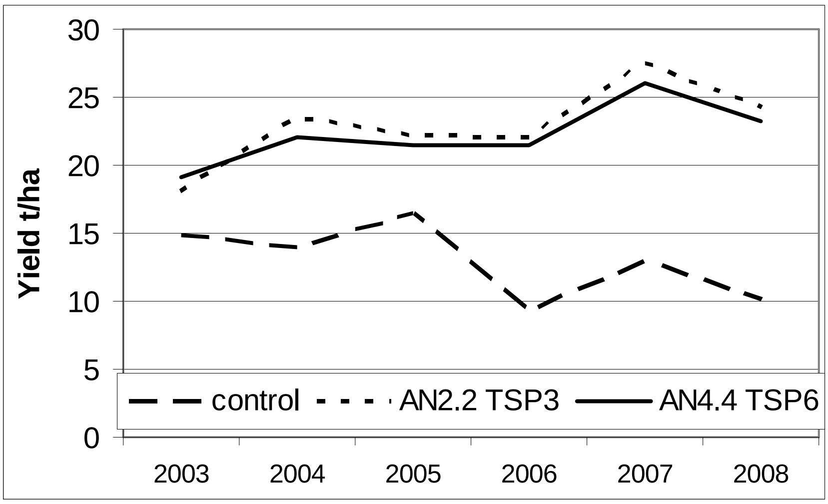


Figure 2. Yield over time for the control (no fertilizer) and combined N and P fertilizer treatments

Tissue nutrient concentrations

The treatment fertilizers N and P (as AN and TSP) had significant effects on leaflet N and P, and rachis P (Table 4).

Table 4. Tissue nutrient concentration for Leaflet N and P; and rachis P for trial 213 in 2008.

	Leaflet N (% dm) TSP kg/palm			Leaflet P (% dm) TSP kg/palm			Rachis P (% dm) TSP kg/palm		
AN kg/palm	**0**	**3**	**6**	**0**	**3**	**6**	**0**	**3**	**6**
AN 0	2.27	2.25	2.38	0.132	0.139	0.145	0.035	0.075	0.081
AN 2.2	2.39	2.45	2.54	0.135	0.144	0.153	0.034	0.057	0.069
AN 4.4	2.44	2.54	2.57	0.132	0.149	0.151	0.033	0.059	0.059
Significant difference:									
N		**<0.001**			**0.004**			**0.006**	
P		**<0.001**			**<0.001**			**<0.001**	
NxP		**NS**			**NS**			**0.04**	
$LSD_{0.05}$		**0.06**			**0.004**			**0.006**	
CV%		**2.9**			**2.9**			**12.5**	

Rachis N increased from 0.21 to 0.25 %dm from the control (no N fertilizer) to the highest rate of N used.

The highest yields were achieved at a fertilizer rate of AN 2.2 plus TSP 3 kg/palm – the tissue concentrations found for this treatment can be used to indicate optimum fertility at current conditions (ie. Leaflet N: 2.45 %; Leaflet P: 0.144 % and Rachis P: 0.057%) (very similar to the results from 2006 and 2007). However, other work done by PNGOPRA in other centres has indicated that Rachis P less than 0.08% is below adequate – this may not only be due to insufficient P, other nutrients at low levels could influence the uptake of P and hence be responsible for this low value.

Table 5 lists the other nutrients in trial 213 (other than N and P) which could be influencing the availability of other nutrients and the productive capacity of the palms.

Table 5. Mean values for leaflet and rachis K, and leaflet Mg and B for trial 213 in 2008.

Nutrient	**Trial mean value (% dm)**	**Accepted adequacy level (% dm)**	**Notes**
Leaflet K	0.64	0.65	Leaflet potassium is adequate but some plots are low
Leaflet Mg	0.22	0.20	Adequate levels of magnesium
Leaflet B	15 (ppm)	15 (ppm)	Leaflet boron is adequate
Rachis K	0.81	1.2	Rachis potassium is low

It appears that K (potassium) is low in the rachis, MOP is being applied as a basal. It would be worthwhile to investigate the K status of surrounding plantation blocks to ensure that this essential nutrient is not lacking.

Vegetative measurements

Frond size and dry matter production increased from the control plots (no fertilizer) to the AN 2.2 plus TSP 3.0 kg/palm rate (Tables 6 and 7). The main effect on frond size and dry matter production was through an increase in frond size (PCS and Frond Area) rather than through an increase in the number of fronds produced per year (frond production increased by 1 frond/yr with increased fertiliser rates).

Table 6. Trial 213, main effects (p values) of fertilizer treatments on vegetative growth parameters in 2008. P values less than 0.05 are shown in bold.

Fertilizer		**Radiation Interception**				**Dry matter production (t/ha/yr)**			
	PCS	**GF**	**FP**	**FA**	**LAI**	**FDM**	**BDM**	**TDM**	**VDM**
AN	0.09	**0.01**	**<.001**	0.30	**0.02**	**0.006**	**<.001**	**<.001**	**<.001**
TSP	**0.008**	**0.003**	**<.001**	**0.002**	**<.001**	**<.001**	**<.001**	**<.001**	**<.001**
AN.TSP	0.78	0.12	0.74	0.79	0.26	0.80	0.30	0.63	0.88

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 7. Trial 213, main effects of fertilizer treatments on the vegetative growth parameters in 2008.
P values less than 0.05 are shown in bold.

Fertilizer		**Radiation Interception**				**Dry matter production (t/ha/yr)**			
	PCS	**GF**	**FP**	**FA**	**LAI**	**FDM**	**BDM**	**TDM**	**VDM**
AN 0	38.7	**38.0**	**15.7**	11.7	**5.7**	**8.4**	**8.0**	**18.3**	**10.3**
AN 2.2	40.8	**38.8**	**16.6**	12.0	**6.0**	**9.4**	**11.0**	**22.6**	**11.6**
AN 4.4	42.0	**39.7**	**16.7**	12.1	**6.2**	**9.7**	**10.0**	**21.9**	**11.9**
TSP 0	**37.8**	**38.1**	**15.7**	**11.3**	**5.6**	**8.3**	**7.2**	**17.2**	**10.0**
TSP 3	**42.5**	**38.5**	**16.3**	**12.5**	**6.2**	**9.6**	**10.9**	**22.7**	**11.8**
TSP 6	**41.2**	**40.0**	**17.1**	**11.9**	**6.2**	**9.7**	**10.9**	**22.9**	**12.0**
$LSD_{0.05}$	***2.9***	***1.1***	***0.4***	***0.6***	***0.3***	***0.8***	***1.2***	***1.4***	***0.8***

PCS = Petiole cross-section (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).

CONCLUSION

Both N and P have had positive effects on yield over the duration of this trial. Currently the application of 2.2 kg AN plus 3 kg TSP per palm will give near maximal yield but it is expected that the requirements for N and P will change as these palms mature.

Leaflet N and P concentrations for plots receiving no AN and TSP were well below their respective critical values. However, plots that received AN and TSP increased tissue N and P levels significantly. Rachis K levels were below the critical of 1.2 %DM, thus additional K fertilizer as MOP was applied as a basal. It is recommended to test Rachis K in surrounding plantation blocks to ensure that this essential nutrient is not limiting yield potential.

Vegetative measurements of frond size and other characteristics indicate that optimum leaf area is obtained at the same level of fertilizer at which optimum yield was achieved (AN 2.2 plus TSP 3 kg/palm).

2008 was the last year of this trial, it is now closed.

Trial 214: New P fertilizer rate and placement trial, Hargy

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	14 years	Altitude	? m asl
Recording Started	2006	Previous Land use	Forest
Progeny	unknown	Area under trial soil type (ha)	Not known
Planting material	Dami D x P	Agronomist in charge	Winston Eremu

Background and Purpose:
Inherent attributes of volcanic soils in relation to fertiliser use:
- Moderate to very low CEC (Cation Exchange Capacity) with variable charge;
- CEC level is reduced as soils become more acidic (after acidifying N fertilisers are used);
- Volcanic soils contain Allophane and iron oxides which tie up phosphates (by forming complexes such as aluminium and iron phosphates). The topsoil at the site contained 6 to 8% allophane (high) and the sub-soil around 12% (very high).

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. It is important to minimise the direct contact of phosphate with the mineral soil (which is where the allophane is). In addition, the soil around the weeded circle is 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.

Aim:
To identify the best option for the placement of TSP in light of volcanic soils containing high levels of allophane.

Work done thus far:
- Pre-treatment harvest yield and tissue nutrient data (for use as co-variate in following years)
- Plot layout and first application of P fertiliser treatments in October 2008
- Soil sampling (selected sites) and samples sent to NZ for chemical analysis and allophane content determination

Results

Yield

- Average yield for all plots in 2007 was 27.8 t/ha and in 2008 19.6 t/ha.
- Bunch number declined from an average 1460 to 1130 bunches/ha from 2007 to 2008. This was the main reason for the reduced yield. (note that this yield difference between 2007 and 2008 has also been observed in some other plantations and estates but not right across the board)
- Average Single Bunch Weight was 19.0 and 17.4kg in 2007 and 2008 respectively

Tissue nutrient content

In 2008 the average nutrient content of tissue are listed in Table 1. The values for N and P are low to very low and this site should respond to P fertiliser treatments. Basal N, K, Mg and B were first applied in 2008 and will be repeated in 2009. The trial site should also provide information on the optimum rate of P to be used at Hargy.

Table 1. Tissue nutrient content in 2008 (pre-treatment)

	Leaflet %dm	Rachis %dm
N	2.13	0.20
P	0.130	0.037
K	0.66	1.13
Mg	0.18	
B	16 ppm	

Conclusion

This site should be P responsive after basal fertilisers correct basic nutrient deficiencies. It should be a good trial site to identify whether the frond pile is a better placement for TSP compared to the edge of the weeded circle.

New Britain Palm Oil Ltd., WNB: Summary

(Dr. Harm van Rees and Rachel Pipai)

Fertilizer response trials with NBPOL comprised three main areas of interest:

1. Response to Magnesium: Four trials investigated the effect of increasing rate and type of Magnesium fertilizer on production and overall growth of oil palm. Three of the trials are traditional replicated trials where a range of treatments are investigated. The fourth trial is undertaken in co-operation with OPRS and is using large blocks with and without Mg fertilizer to ascertain the effect of Mg fertilizer on production. In this latter trial the effect of some progeny on production and uptake of Mg is also being studied.

   Outcome: At this stage of the trial work it is clear that Mg, as provided by different fertilizer types, is taken up by the palm and is expressed as higher leaflet Mg levels. However, this increased level of uptake has not yet been translated into a consistent yield response.

2. Response to Nitrogen: Five trials investigated the effect of Nitrogen fertilizer on palm performance and production. It is suspected that on the coarse volcanic soils found on WNB that highly soluble nutrients such as, available nitrogen, as nitrate, move downhill through the subsoil, making the traditional method of trial layout unsuitable. Three of the N trials are Systematic Trials where nine rates of N are applied to plots where the N rates either increase or decrease consecutively as you go from plot to plot (ie. low N is never found adjacent to high N). In the second trial type, large areas of oil palm have been set up which do not receive any N fertilizer while the adjacent area receives the normal commercial N rate. Individual palm yield and tissue N levels are being monitored to see whether N is moving into these plots from adjoining uphill areas. In the third method of investigating N fertilizer requirements, large blocks receive three different rates of N and these blocks are monitored for production over time (work undertaken in co-operation with OPRS).

   Outcome: N fertilizer responses are now evident. These volcanic soils are able to provide oil palm with a high level of inherent or native N supply because it has taken 4 to 5 years to observe a distinct response to N fertilizer. The larger blocks are not responding to the different rates of applied N but tissue testing has shown that N levels in the leaflets are decreasing for the zero N input blocks, and it is expected that yield responses will be observed in the near future.

3. Response to Boron: a single trial using large blocks in co-operation with OPRS is being used to investigate the effect of different boron rate on oil palm performance and production.

   Outcome: Leaflet B levels have increased in the B treated blocks but yield has not responded as yet to the B applied.

4. Progeny: in four trials which were undertaken in co-operation with OPRS we could investigate the effect of progeny on yield and nutrient uptake. Unfortunately the way the trials were located we could only investigate progeny by nutrition interactions for three progeny.

   Outcome: there were large differences between the progeny in yield and in nutrient uptake (especially for Mg and B). This indicates there definitely is a Genotype x Nutrition interaction which needs to be investigated in more detail.

   A synopsis for the trial work undertaken with NBPOL is provided on the next two pages. A short recommendation for trial work operation and plantation management based on our results is also provided.

NBPOL: Synopsis of 2008 PNG OPRA trial results and recommendations

Trial	Palm Age	Yield t/ha	Yield Components	Tissue % dm	Vegetative	Notes
144 Waisisi Mg x K (incl. slow release) Soil: Volcanic	7	Mg x K 27 (NS)	B/p 17 (NS) SBW 14 (NS)	LN 2.64 RN 0.40 LP 0.150 RP 0.08 +K LK 0.68 to 0.74 RK 1.2 (NS) + Mg LMg 0.16 to 0.22	PCS 31 (NS) FP 26 (NS) LAI 5 (NS)	Site is looking good and there are strong indications that Mg fertiliser is being taken up by the palms (adequate tissue levels)
145 Walindi Mg types Soil: Volcanic	9	Mg 30 (NS)	B/p 14 (NS) SBW 19 (NS)	LN 2.57 RN 0.43 LP 0.148 RP 0.15 LK 0.83 RK 2.1 LMg 0.17 (NS)	PCS 48 (NS) FP 33 (NS) LAI 6 (NS)	No Mg fertilizer response in yield or Mg tissue uptake Adequate nutrition for N, P and K
146 Kumbango Mg types and K Soil: Volcanic	9	Mg 26(NS)	B/p 10 (NS) SBW 19 (NS)	LN 2.64 RN 0.35 LP 0.151 RP 0.11 LK 0.85 RK 1.8 LMg 0.16 (NS)	PCS 43 (NS) FP 25 (NS) LAI 6.3 (NS)	No Mg fertilizer response in yield or Mg tissue uptake Adequate nutrition for N, P and K
148 Kumbango Mg rates, large blocks (OPRS) Soil: Volcanic	7	Mg 23 (NS)	B/p 13 (NS) SBW 14 (NS)	LN 2.71 RN 0.43 LP 0.152 RP 0.10 LK 0.85 RK 2.1 LMg 0.15 to Mg 0.18		No Mg fertilizer response in yield across large blocks. Tissue levels increased with Mg fertilizer. Progeny 635 higher yielding cf 5035.
137 Kumbango Systematic AN 0 to 6kg/p Soil: Volcanic	9	No response to N 27 t/ha	B/p 11 (NS) SBW 9 (NS)	LN 2.52 (NS) RN 0.32 (NS) LP 0.145; RP 0.08 LK 0.79; RK 2.0 LMg 0.14	PCS 39 (NS) FP 25 (NS) LAI 6.6 (NS)	No response to N P, K adequate Mg (L Mg 0.14) is low
138 Haella Systematic AN 0 to 6kg/p Soil: Volcanic	13	AN response 25 to 30	B/p 9.5 to 11.5 SBW 20.5 (NS)	LN 2.33 to 2.50 RN 0.25 to 0.29 LP 0.142 to 0.149 RP 0.117 to 0.093 LK 0.75 (NS); RK 1.4 (NS) LMg 0.19	PCS 46 (NS) FP 23 to 25 LAI 6.5	5 t/ha response to AN P now adequate (following basal TSP) K adequate

Trial	Palm Age	Yield t/ha	Yield Components	Tissue % dm	Vegetative	Notes
141 Haella Fertiliser Omission trial Soil: Volcanic Div III Upslope Div II Downslope Large (4ha) circular area not fertilised since 2003.	DIVIII 11 DIVII 12	Response to fertiliser: Div III 24.5 (NS) Div II 20.3 (NS)		Div III LN 2.32 to 2.38; RN 0.34 LP 0.140; RP 0.07 LK 0.75; RK 1.4 LMg 0.15 Div II LN 2.30 to 2.39; RN 0.38 LP 0.131 to 0.141; RP 0.09 LK 0.74; RK 1.9 LMg 0.18		There is no yield difference between fertilised and unfertilised in either the up-hill or down-slope sites.
142 Kumbango/Bebere Large Blocks (OPRS 256, 260, 266) AN 0, 3, 6 Soil: Volcanic	15 13 10	AN 256 21 (NS) 260 22 (NS) 266 18 (NS) Note: trial only analysed for Jan to Sep (one block was part felled in Oct)	256 B/p 6 (NS) SBW 24 (NS) 256 B/p 7 (NS) SBW 22 (NS) 256 B/p 8 (NS) SBW 20.5 (NS)	256 LN 2.45 (NS) 260 LN 2.55 (NS) 266 LN 2.68 (NS) 256 LP 0.146; RP 0.08 260 0.146; 0.08 266 0.158; 0.08 256 LK 0.72; RK 2.2 260 0.70; 2.1 266 0.76; 1.9		There was no difference in yield between N treatments across the large treated blocks. Rachis P has gone up since application of basal P.
149 Kumbango Large Blocks (OPRS 285, 286, 287, 288) Borate 0, 80, 160g/p Soil: Volcanic	7	285 25 (NS) 286 25 (NS) 287 25 (NS) 288 23 (NS)	B/p 13 (NS) SBW 14 (NS)	LB 13 to 16 to 19 ppm LN 2.67; RN 0.42 LP 0.153; RP 0.08 LK 0.84; RK 1.9 LMg 0.18		No effect of boron on yield, but tissue levels increased.

Apparent adequate tissue nutrient levels:

Leaflet (% dm)					Rachis (%dm)		
N	**P**	**K**	**Mg**	**B**	**N**	**P**	**K**
2.45	0.145	0.65	0.20	15ppm	0.32	0.10	1.2

Recommendations to NBPOL:

1. On the volcanic soils at NBPOL a mature oil palm yield of 35 FFB t/ha should be attainable.
2. Some of the trial sites appear to be N limited.
3. Tissue testing and Vegetative measurement criteria will help in determining deficiencies of particular nutrients.
4. P appears to be low in some rachis measurements. The actual status of P availability and requirement needs to be determined for this soil type.
5. Most of the focus for nutrition should be on N, followed by P, then K and Mg , followed by B.
6. Plantation management (harvest time, pruning, clean weeded circles, fertilizer application and timing etc) all play a large role in the potential to optimize production. Pushing production on selected blocks would help identify what is limiting production.

Nitrogen Fertilizer Research

Nitrogen drives agricultural production systems and it is the key nutrient required when producing high yielding oil palm. Other nutrients are also important (primarily P, K, Mg and B) but if N supply is lacking it will affect the uptake and utilization of other nutrients even assuming they were available to the palm.

For oil palm to yield at its peak potential production the N Demand by the palm must equal N Supply in the field.

N Demand:

- Nitrogen required for vegetative growth
- Nitrogen exported from the field in FFB

N Supply:

- Nitrogen made available through mineralization of organic matter in the soil (by soil microbial action)
- Nitrogen made available through N fixation by the legume cover plants which then cycles through the mineralization process
- Nitrogen made available through fertilizers applied
- Nitrogen lost through leaching, volatilization (and also through water logging although that is less of a problem on volcanic soils which are freely draining).

Goh and Hardter (in Oil Palm Management for Large and Sustainable Yields, 2005) reported that the vegetative component of N uptake (Nitrogen required for growth) accounted for 33% of total requirements of N and that the nitrogen in FFB accounted for the other 66% of N uptake (together these add up to N Demand).

If approximately 3.0 kg of N is removed in every tonne of FFB then another 1.5 kg of N is required for vegetative growth. If a field produced 30 t/ha of FFB then 90 kg of N/ha is exported from the field. Another 45 kg of N/ha is required for vegetative growth. Thus a total of 135kg N/ha is required to produce 30 t/ha of oil palm (N Demand).

If it is assumed that leaching losses are minimal (Banabas, PhD thesis) then to produce high yielding oil palm N Demand must equal N Supply. An N Demand of 135 kg N/ha must be supplied (N Supply) through soil mineralization plus fertilizer applied. An estimate of soil N mineralization on volcanic soils in PNG is 60 kg/ha/yr (Banabas PhD thesis). Thus a N Demand of 135 kg N/ha – N mineralized of 60 kg N/ha = N Supply of 75 kg N/ha which has to be supplied as mineral N fertilizer.

75kg N/ha in fertilizer is equivalent to:

- 163 kg Urea/ha or 1.3 kg Urea/palm (assuming 125 palms/ha); or
- 227 kg AN/ha or 1.8 kg AN/palm; or
- 416 kg DAP/ha or 3.3 kg DAP/palm.

There are many unknowns and estimates in these equations but it is known that without fertilizer N it is impossible to grow highly productive oil palm. N deficiency is commonly observed in small holder blocks which receive little or, in some cases, no N fertilizer.

The above equations are estimates only and provide a rough guideline to how much N fertilizer is required. The aim of PNG OPRA trial work at NBPOL is to clearly identify when N needs to be applied (at what stage of the growth cycle) and how much N needs to be applied.

Applying too much N has many environmental costs through increased potential for leaching with subsequent additions of nitrate N to water tables and stream flow; and losses as N_2O with subsequent increases in greenhouse gas emissions.

Our trial work on volcanic soils with NBPOL (and in other areas in PNG with volcanic soils such as at Hargy and Popondetta) is to work out how long it takes for oil palm to lose production when N is not applied, and how much N should be applied for a certain level of potential production.

In previous work with NBPOL it has been found that on volcanic soils factorial fertilizer trials, with randomized spatial allocation of treatments, have generally been showing poor responses to fertilizers. Yield and tissue nutrient concentrations in control plots (no fertilizer) have generally been higher than would be expected. It is suspected that fertilizer may be moving through the highly permeable soils from plot to plot.

To overcome or at least to reduce the effect of this possible nutrient movement between plots, three different trials were designed with NBPOL:

1. Systematic designs where the amount of N in each plot in adjacent replicate blocks, either increases or decreases systematically (thus ensuring that high and low rates of application are never adjacent);
2. Large scale Omission plots where N is not applied over a large area and the yield and tissue N concentrations are monitored across the plot as the distance increases from the fertilized area; and
3. Large scale N trials where zero, low and high rates of fertilizer N are applied to whole blocks and these are harvested as a block to observe yield differences (the latter is joint work with OPRS).

The following section in this manual reports on the results of each of these three different trial designs to determine the optimum N fertilizer rate on volcanic soil with NBPOL.

SUMMARY of the three different approaches to study N supply at NBPOL

Systematic N trials

Significant responses to N fertilizer are now commonly observed since the commencement of these trials. The yield responses were in the range of 0 to 5 t/ha, and the higher yields resulted from moderate inputs of N fertilizer (2 to 3 kg AN/palm). Site 137 at Kumbango showed no response to N fertilizer, this site also has the highest inherent fertility (as judged by a high tissue analysis).

The yield response from N fertilizer has come from an increase in bunch number (by 1 b/palm) rather than from an increase in weight of individual bunches.

Corresponding to the positive yield response the tissue analysis also showed a strong response to N fertilizer. It is likely that a leaflet N concentration of less than **2.35 to 2.40** (as a % of dm) will result in a yield penalty.

Vegetative parameters such as PCS (Petiole Cross Section) also increased with improved nutrition, and depending on the age of the palm can also be used as an N nutrition indicator. More work will be done on this over the next year to develop the criteria for this indicator.

Basal P has been applied and P tissue levels are now approaching adequate.

N Omission blocks

The fertilizer Omission blocks were established in 2005 and are only in their third year of a monitoring program. At this stage there is no evidence that yields are declining inside the area which is not receiving any fertilizer.

This trial is well set up to verify if N moves through the soil from areas which receive fertilizer to areas which do not.

N fertilizer experimentation on large blocks

In 2003, in collaboration with OPRS, large blocks on breeding trial sites were set up to study the effect of applying 0, 3 and 6 kg/palm of Ammonium Nitrate. After five years of experimentation there has been no yield difference between the treatments. 2008 was the last year of experimentation with these large blocks, the trial is now closed.

Trial 137: Systematic N Fertilizer Trial, Kumbango

METHODS

Experimental Design and Treatments

Trials 137, 138 and 403 are N Systematic trials where 9 rates of N are applied in 8 replicated blocks. The rates applied increase from 0 to 2kg N/palm at 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 has 4 measured rows of palms with 15 palms each (60 palms/plot).

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

Figure 1. Example of two replicates for the Systematic N trial design (N rate increments are at 0.25kg N/palm)

In trial 137 the AN fertilizer is applied in two doses per year in replicate blocks 1, 3, 5 and 7; whilst blocks 2, 4, 6 and 8 receive ten doses of AN per year. Trial 138 receives AN in two doses per year on all replicate blocks.

Tissue samples, leaflet and rachis, were taken from Frond 17 following standard procedures and analysed by AAR in Malaysia for nutrient concentration. Vegetative measurements were taken at the same time as tissue sampling to calculate vegetative growth parameters. Frond production counts and total frond number were assessed twice annually.

A one-way ANOVA was used to analyse: (i) yield and its components; (ii) tissue nutrient concentrations; and (iii) vegetative parameters. Yield and nutrient levels are also presented over time (since the start of the trials).

Trial Background Information

Table 1. Trial 137 background information.

Trial number	**137**	Company	NBPOL
Estate	Kumbango	Block No.	Div 2
Planting Density	128 palms/ha	Soil Type	Volcanic sand and pumice
Pattern	Triangular	Drainage	Free draining
Date planted	Oct 1999	Topography	Flat
Age after planting	8 years	Altitude	50 m asl
Treatments 1st applied	March 2003	Previous Land use	Oil palm
Progeny	unknown	Area under trial soil type (ha)	Not known
Planting material	Dami D x P	Agronomist	Rachel Pipai

Basal fertilizers applied in 2008 in Trial 137: TSP at 0.5 kg/palm, KIE at 1.5 kg/palm and Borate at 0.15 kg/palm.

RESULTS and DISCUSSION

Yield and its components response to fertilizer treatment in 2008

There was no significant increase in yield, and the other yield components; bunch number and single bunch weight from N treatments applied in 2008 (Table 2). However, the 2008 yield was on average 7 t/ha less than in 2007. The lower yield was due to fewer bunches harvested in 2008 compared to 2007 (1420 vs 1770 bunches/ha respectively).

Table 2. T137: Yield (t/ha), Bunch number (bunches/palm and bunches/ha) and SBW (kg/bunch) by N rate.

N rate (kg/palm)	Equivalent AN rate (kg/palm)	Yield (t/ha)	Bunch number (bunches/palm)	Bunch number (bunches/ha)	SBW (kg/bunch)
0	0	26.1	10.9	1398	19.0
0.25	0.74	26.7	10.9	1394	19.5
0.50	1.48	27.5	11.6	1479	18.8
0.75	2.22	27.0	11.1	1419	19.3
1.0	2.96	26.4	11.0	1409	18.9
1.25	3.70	27.4	11.4	1461	19.0
1.5	4.44	26.1	11.0	1406	18.9
1.75	5.18	27.2	11.3	1443	19.2
2.0	5.92	26.3	10.9	1396	19.2
Significant difference:		**NS**	**NS**	**NS**	**NS**
	$LSD_{0.05}$	**-**	**-**	**-**	**-**
	CV%	**5.1**	**6.8**	**6.8**	**3.6**

Yield response over time

There has been an increase in the average bunch weights over time due to maturing palms, but there was no significant increase in yield to applied N. The lack of response to N fertilizer could be largely due to the high N status of the palms. Note: in 2003 harvest commenced in February (January data are not available). The large yield decrease in 2008 (Figure 1) was largely due to a drop in the number of bunches formed and harvested, it is not clear what caused this drop in bunches.

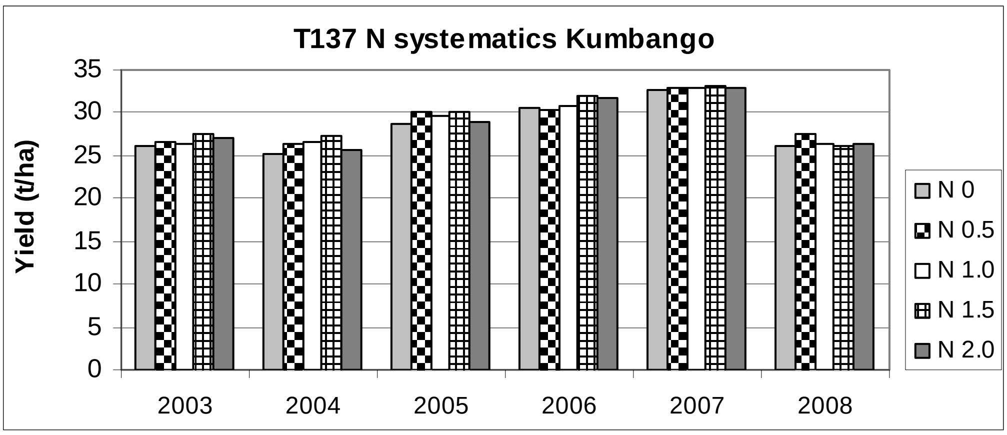


Figure 1. Yield response to 5 rates of N (kg/palm) over time (fertilizer N was first applied in March 2003).

As the palms matured from 4 to 8 years after planting the mean number of bunches per palm decreased and the SBW increased (Figure 2). The effect of N fertilizer on bunch number per palm or SBW is not significant for any one year.

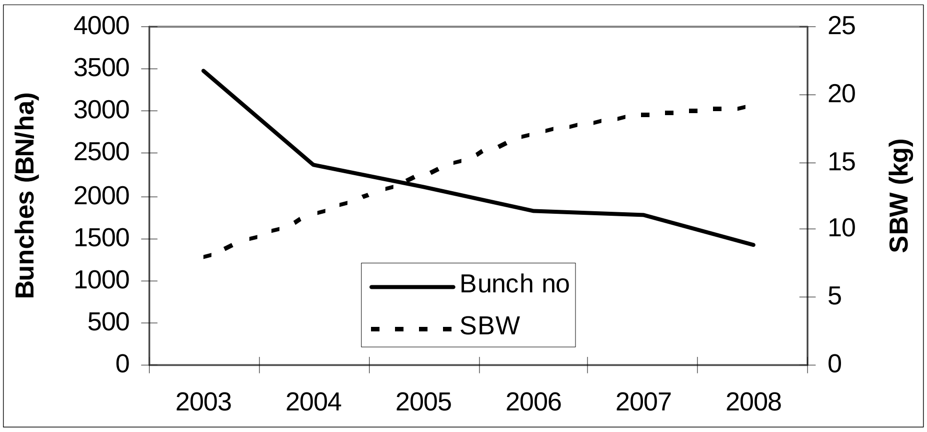


Figure 2. Mean trial bunch number per palm and SBW (kg) over time (Trial 137).

Tissue nutrient concentration
Tissue nutrient concentration was investigated for both leaflets and the rachis. There was no effect on nutrient levels by N treatment (Table 3). Leaflet K decreased a small amount with the application of N fertilizer, but is variable in its response.

Table 3. Leaflet and rachis nutrient content for T137 in 2008.

N rate (kg/palm)	Equivalent AN rate (kg/palm)	Leaflet (% dm)			Rachis (% dm)		
		N	P	K	N	P	K
0	0	2.48	0.145	0.83	0.31	0.081	1.94
0.25	0.74	2.53	0.145	0.77	0.31	0.081	2.03
0.50	1.48	2.51	0.144	0.77	0.32	0.081	1.94
0.75	2.22	2.54	0.144	0.79	0.33	0.081	2.07
1.0	2.96	2.52	0.144	0.75	0.32	0.081	2.06
1.25	3.70	2.51	0.145	0.76	0.33	0.081	2.05
1.5	4.44	2.52	0.144	0.76	0.33	0.081	2.00
1.75	5.18	2.52	0.143	0.77	0.33	0.081	2.03
2.0	5.92	2.50	0.142	0.80	0.34	0.081	2.00
Significant difference:		**NS**	**NS**	**P=0.003**	**NS**	**NS**	**NS**
	$LSD_{0.05}$	**-**	**-**	**0.03**	**-**	**-**	**-**
	CV%	**2.0**	**2.0**	**4.5**	**8.8**	**10.1**	**9.3**

Leaflet and rachis Phosphorus (P) were just adequate. TSP was again applied at a higher rate in 2008 (0.5 kg/palm). All other nutrients were present at an adequate level, except for Magnesium (Mg 0.14%) and Chlorine (Cl 0.38%). Boron levels (B 17ppm) were up from a lower level in 2006.

Tissue N concentration over time 2004 to 2008

Leaflet N levels have decreased a little over time as the palms matured. However there has been no effect of N fertilizer on N status in the leaflet (Table 4). Tissue N concentration over time also reveals the high N status of the palms, which could be the reason for a lack of yield response to applied N.

Table 4. Leaflet N (% dm) over time (trial 137).

N rate (kg/palm)	Equivalent AN rate (kg/palm)	Leaflet N (% dm) 2004	2005	2006	2007	2008
0	0	2.70	2.68	2.60	2.48	2.48
0.5	1.48	2.66	2.66	2.58	2.51	2.51
1.0	2.96	2.68	2.65	2.57	2.52	2.52
1.5	4.44	2.67	2.65	2.60	2.52	2.50
2.0	5.92	2.67	2.69	2.58	2.50	2.52
	Significant difference:	**NS**	**NS**	**NS**	**NS**	**NS**
	$LSD_{0.05}$	-	-	-	-	-
	CV%	**2.0**	**2.8**	**2.2**	**2.1**	**2.0**

Fertilizer N effects on oil palm vegetative growth

There was a significant effect of N treatment on Petiole Cross Section and Frond Dry Matter production, apart from that there was no effect of N on the vegetative growth parameters (Table 5).

Table 5. Effect (p values) of treatments on vegetative growth parameters in 2008. P values less than 0.05 are in bold.

Fertilizer	PCS	Radiation Interception				Dry Matter Production (t/ha)			
		GF	FP	FA	LAI	FDM	BDM	TDM	VDM
AN	**0.004**	0.98	0.41	0.25	0.68	**0.02**	0.91	0.26	0.86
LSD	1.8	-	-	-	-	0.69	-	-	-
CV %	4.7	4.3	4.1	4.4	6.5	5.2	7.2	4.6	4.8

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).

Frond production and frond number

25 new fronds were produced in 2008 (one frond every 14 days) indicating good growing conditions during the year. Total green fronds counted per palm averaged 42 fronds which is an adequate number.

Frond and canopy size

Frond area (FA) and Leaf Area Index (LAI) are factors used to determine canopy size. Indicating good growing conditions (LAI = 6.6 and FA = 12 m^2).

Vegetative dry matter production

Petiole cross section is a primary determinant of vegetative dry matter production. There was an effect of N observed on frond dry matter production (FDM); but not the other measures of vegetative dry matter production.

CONCLUSION

There was an increase in the average bunch weight as the palms matured, but there was no significant increase in yield according to applied N. The lack of response could be due to the high N status of the palms.

TSP was applied at 0.5 kg/palm in the hope of bringing up the tissue P, which was low in 2006, leaflet P was adequate and rachis P was near adequate levels in 2008.

Vegetative measurements indicate that AN had no effect on vegetative parameters except LAI which was increased with higher levels of N fertilizer.

Trial 138: Systematic N Fertilizer Trial, Haella

Trial Background Information

Table 6. Trial 138 background information.

Trial number	**138**	Company	NBPOL
Estate	Haella	Block No.	Div 2, Field I-95, Ave 11.
Planting Density	128 palms/ha	Soil Type	Volcanic sand and pumice
Pattern	Triangular	Drainage	Free draining
Date planted	1995	Topography	Slightly undulating
Age after planting	12 years	Altitude	? m asl
Treatments 1st applied	July 2002	Previous Land use	Forest
Progeny	unknown	Area under trial soil type (ha)	176 ha
Planting material	Dami D x P	Agronomist	Rachel Pipai

Basal fertilizers applied in 2007 in Trial 138: MOP at 0.5 kg/palm; TSP at 0.5 kg/palm; KIE 1.5 kg/palm; Borate 0.15 kg/palm.

RESULTS and DISCUSSION

Yield and its components response to fertilizer treatment in 2008

There was a significant yield increase from applying 0 to 1.0 kg N/palm (24.6 to 29.2 t/ha), a yield increase was around 4.5 t/ha. There was a significant increase in bunch number with increasing rate of N. An extra bunch was produced at 0.5 kg N/palm (or 1.5 kg AN/palm). There was no effect on SBW through the application of N fertilizer (Table 2).

Table 2. Trial 138: Yield (t/ha), Bunch number (bunches/palm and bunches/ha) and SBW (kg/bunch) by N rate in 2008.

N rate (kg/palm)	**Equivalent AN rate (kg/palm)**	**Yield (t/ha)**	**Bunch number (bunches/palm)**	**Bunch number (bunches/ha)**	**SBW (kg/bunch)**
0	0	**24.6**	9.5	1220	20.3
0.25	0.74	**26.0**	10.0	1275	20.4
0.50	1.48	**27.7**	10.5	1345	20.6
0.75	2.22	**28.5**	10.8	1377	20.8
1.0	2.96	**29.2**	11.0	1414	20.7
1.25	3.70	**29.9**	11.4	1464	20.5
1.5	4.44	**29.5**	11.2	1437	20.5
1.75	5.18	**30.0**	11.5	1469	20.5
2.0	5.92	**29.2**	11.2	1434	20.5
Significant difference:		**P<0.001**	**P<001**	**P<001**	**NS**
	$LSD_{0.05}$	**2.2**	**0.8**	**102**	**-**
	CV%	**7.8**	**7.5**	**7.4**	**4.8**

Yield response over time

There has been a significant and steady response to N in increasing yield. This was first noticeable in 2004 after the inception of this trial in 2003 (2002 was the set up year with N fertilizer first applied in July), and continued until 2008 (Figure 1). The increase in yield from N fertilizer in 2008 was the largest seen thus far in this trial (4 to 5 t/ha increase in yield from applying N fertilizer)

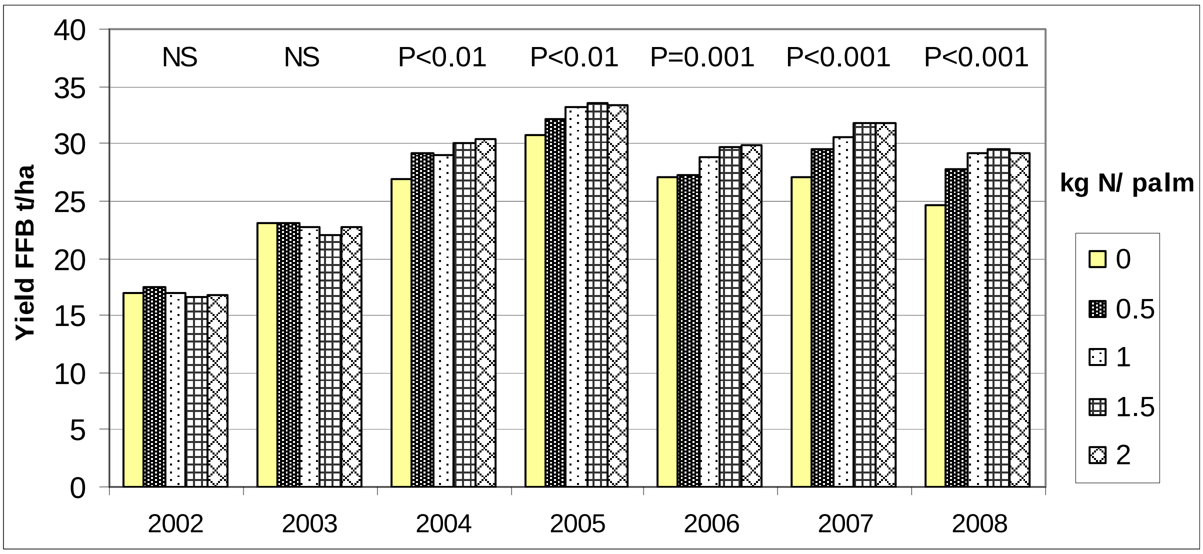


Figure 1. T138: Yield response to 5 rates of N (kg/palm) over time (fertilizer N treatments were first applied in July 2002).

Tissue nutrient concentration

Tissue nutrient concentration was investigated for both leaflets and the rachis. The nutrient tissue levels for the 2008 sampling are listed in Table 3. Increasing rates of N fertilizer, significantly increased leaflet and rachis N concentration (also see Figure 2). Leaflet P was also increased with increasing N rates in 2007 and 2008, the leaflet P levels went up as the rachis P levels went down with increasing N fertilizer rate. Rachis P levels are at adequate levels in 2008 from very low levels in 2006 (basal P was first applied in 2006). Leaflet and Rachis K levels were not affected by fertilizer N rates.

Table 3. T138: tissue nutrient concentration for leaflets and rachis in 2008.

N rate (kg/palm)	Equivalent AN rate (kg/palm)	Leaflet (% dm)			Rachis (% dm)		
		N	P	K	N	P	K
0	0	2.33	0.142	0.75	0.25	0.117	1.47
0.25	0.74	2.34	0.141	0.74	0.26	0.116	1.42
0.50	1.48	2.40	0.144	0.74	0.25	0.103	1.29
0.75	2.22	2.46	0.146	0.75	0.28	0.108	1.37
1.0	2.96	2.46	0.147	0.75	0.29	0.103	1.33
1.25	3.70	2.50	0.149	0.75	0.28	0.104	1.39
1.5	4.44	2.46	0.146	0.74	0.29	0.099	1.37
1.75	5.18	2.47	0.147	0.73	0.29	0.093	1.38
2.0	5.92	2.51	0.147	0.70	0.29	0.092	1.41
	Significant difference:	**P<0.001**	**P<0.001**	**NS**	**P<0.001**	**P=0.007**	**NS**
	$LSD_{0.05}$	**0.08**	**0.003**	**-**	**0.02**	**0.014**	**-**
	CV%	**3.4**	**2.2**	**6.7**	**8.5**	**14.0**	**9.9**

Leaflet magnesium (Mg) levels and boron (B) levels were close to adequate (0.19 % dm and 15 mg/kg respectively).

Tissue nutrient concentration over time

Leaflet N concentration reached a peak in 2004 and as palms matured had decreased since. A distinct difference in leaflet N resulting from different N rates was clear from 2004 (Figure 2), with the zero treatments decreasing and the higher rates (2 kg and 1 kg N/p) increasing in concentration.

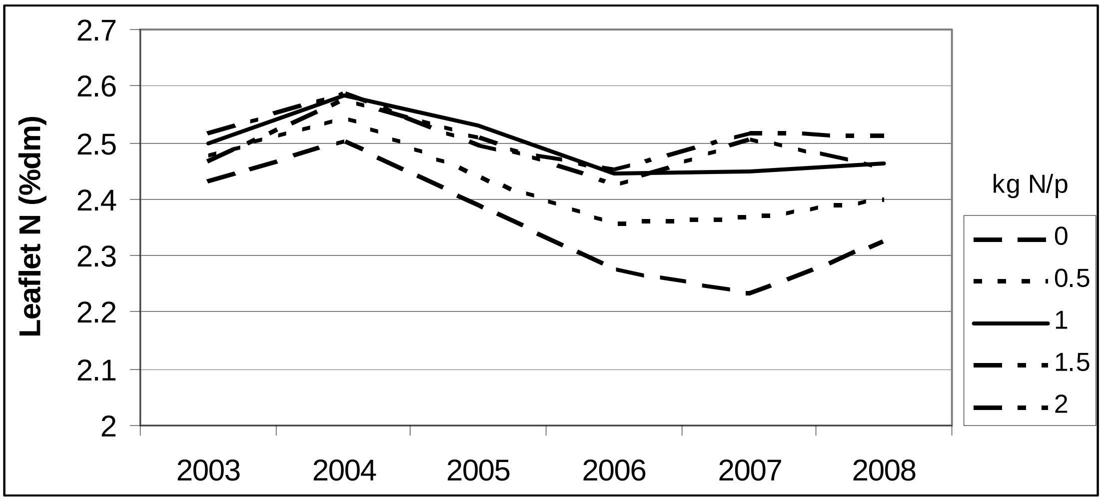


Figure 2. T138: Leaflet N concentration resulting from N fertilizer treatments over time.

Leaflet P concentration decreased from 2003 to 2006. In 2006, TSP fertilizer was applied at 0.5 kg/palm, since then leaflet P levels have increased (Figure 3), and are now at adequate levels (especially at the higher N rates). N mobilises P out of the rachis and makes it available in the leaflets – with continued application of TSP (as the P source) we expect P to remain adequate at the mid range of N inputs.

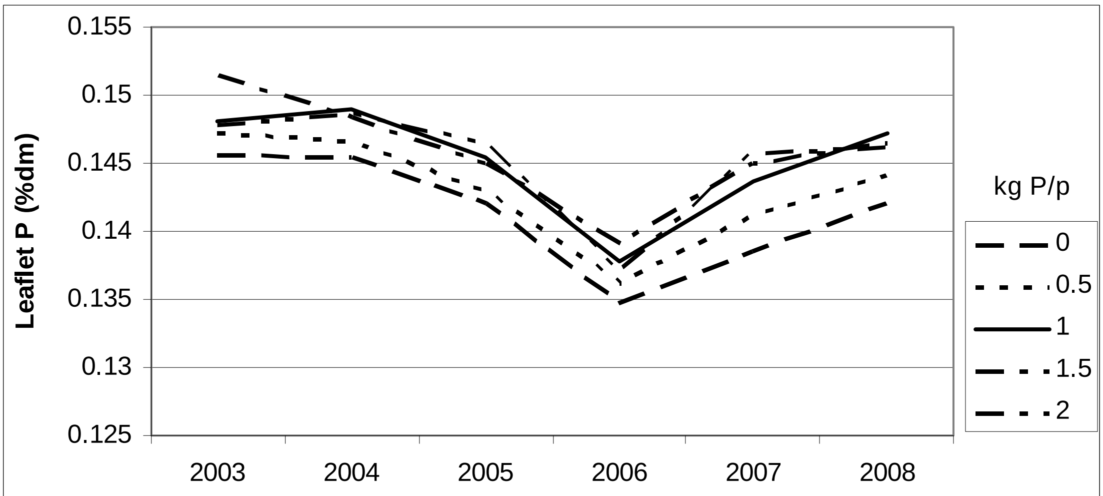


Figure 3. T138: Leaflet P concentration over time.

Fertilizer N effects on oil palm vegetative growth

There was a significant effect of N treatment on Petiole Cross Section and Frond Dry Matter production, apart from that there was no effect of N on the vegetative growth parameters (Table 4).

Table 4. Effect (p values) of treatments on vegetative growth parameters in 2008. P values less than 0.05 are in bold.

Fertilizer	PCS	Radiation Interception				Dry Matter Production (t/ha)			
		GF	FP	FA	LAI	FDM	BDM	TDM	VDM
AN	**0.05**	0.06	**<0.001**	0.65	0.26	**<0.001**	**<0.001**	**<0.001**	**<0.001**
LSD	2.4	-	0.9	-	-	0.9	1.2	1.7	1.0
CV %	5.2	3.1	3.6	6.2	6.9	5.9	8.0	4.9	5.4

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).

Frond production and frond number

Increasing N fertilizer rates increased frond production significantly from 23 to 25 fronds/year (with a resulting potential for more bunches to form). Around 25 new fronds produced per year works out to one frond every 14 days, indicating good growing conditions during the year. Total green fronds counted per palm averaged 38 fronds which is an adequate number.

Frond and canopy size

Frond area (FA) and Leaf Area Index (LAI) are factors used to determine canopy size. Both of them were high indicating good growing conditions (LAI = 6.5 and FA = 13 m^2).

Vegetative dry matter production

Petiole cross section is a primary determinant of vegetative dry matter production. There was an effect of N observed on Petiole Cross Section and the other measures of vegetative dry matter production.

CONCLUSION

A strong N fertilizer response has been found at the Haella site. At this site the first N response was seen one year after the inception of fertilizer application in the trial. It is clear from the tissue N status that this site has a lower inherent fertility compared to trial 137, at Kumbango.

In 2007 and 2008, a distinct increase in rachis and leaflet P levels was seen, after the application of TSP in late 2006, and as expected leaflet N levels has increased in the higher N rate treatments while the leaflet N levels in the zero rate treatments continued to decrease.

Trial 141: Large Fertilizer Omission Trial, Haella

SUMMARY

Two large scale (4 ha) fertiliser omission sites were established in 2003 on deep volcanic soils to test the theory that nutrient flow is occurring in down-hill water movement through the soil in shallow water tables. One site was located near the top of a slope quite close to native vegetation – this site was expected to experience little nutrient flow from up the hill and it was expected to see a gradual nutrient decline in the palms across the fertiliser omission plot. The other site was located at the bottom of a slope with a large area of fertilised palms up hill – this site was expected to experience nutrient flow from up-hill and see a gradient of nutrient content in the palms from the top to the bottom of the omission plot.

In 2008 we saw:

- No yield differences at either site – there was no response in yield to differences in applied or flow through nutrients;
- Up-slope site – leaflet N and P clearly showed higher levels in the measured palms in the top half of the omission plot. This may indicate nutrient flow from outside to inside the omission plot or it may be a natural inherent nutrient gradient across the site (if the latter is the case then over time the inherent nutrient supply will be depleted inside the omission plot and yield differences should start to appear);
- Down-slope site – leaflet N and P were higher in the measured palms in the right hand side of the omission plot. This could indicate nutrient flow into the omission plot from further up the hill or there may be a natural inherent nutrient gradient across the site.

One large concern is that the palms monitored outside the omission plots (ie in the fertilised area) also showed the same gradient in nutrient levels as explained above – the fertilised palms should generally have been showing higher tissue nutrient levels. The tissue nutrient levels outside the plot (in the fertilised area) should not follow what happened inside the omission plots. This implies that fertiliser may not have been applied to the border of the omission plots, or there is a natural nutrient gradient across the sites, or we are still not seeing a response to the expected nutrient flow from up hill to further down the slope.

Leaflet K and rachis N, P and K did not follow a gradient from high to low in the palms in the omission plots, which is still implying that nutrient flow may not be occurring.

Trial Background Information

Table 1. Trial 141 background information.

Trial number	**141 (Div II)**	**Down-slope Site**	
Estate	Haella	Company	NBPOL
Planting Density	128 palms/ha	Field No.	1322-10, Rd 6-7, Ave13-14
Pattern	Triangular	Soil Type	Volcanic sand and pumice
Date planted	1996	Drainage	Free draining
Age after planting	12 years	Topography	Lower slope
Trial established	2003	Altitude	? m asl
Progeny	unknown	Previous Land use	Forest
Planting material	Dami D x P	Area under trial soil type (ha)	176 ha
Trial number	**141 (Div III)**	**Up-slope Site**	
Estate	Haella	Field No.	1323-10, Rd 3-4, Ave1-2
Planting Density	120 palms/ha	Soil Type	Volcanic sand and pumice
Pattern	Triangular	Drainage	Free draining
Date planted	1997	Topography	Up slope
Age after planting	11 years	Altitude	? m asl
Trial established	2003	Previous Land use	Forest
Progeny	unknown	Area under trial soil type (ha)	100 ha
Planting material	Dami D x P	Agronomist	Rachel Pipai

METHODS

The trial consists of a circle, of 24 palms in diameter (approximately 4ha), to which no fertilizer has been applied since 2003. Fertilizer, following company practice, has been applied to the area outside the circle. Measurements have been carried out on palms in 12 transects (1-3 palms wide) radiating from the central palm out into the fertilised area. At this stage the analysis is based on observing the difference in yield between inside the circle (no fertiliser) and outside the circle (with fertiliser). If nutrients were coming into the omission plot from outside the plot (which is the hypothesis) one would expect to see a gradation of higher to lower yields the further one moved into the fertiliser omission plot.

RESULTS and DISCUSSION

Average FFB Yield

Even though the number of palms recorded for yield inside and outside the N omission plot were different, it is still useful to compare the yields for N fertilised palms and unfertilised palms (Table 2).

Table 2. Yield inside and immediately outside the omission plot in 2007 and 2008.

	Division III Up-slope		**Division II Down-slope**	
	FFB yield (t/ha) 2007	**FFB yield (t/ha) 2008**	**FFB yield (t/ha) 2007**	**FFB yield (t/ha) 2008**
No fertilizer*	32.2	24.7	21.0	20.2
Plus fertilizer	28.9	24.4	22.5	20.5

* Omission plot

There were no differences in yield at either the up-slope or down-slope sites between the fertilised and unfertilised areas (Table 2). The up-slope area did yield more then the down-slope area.

Spatial distribution of yield

The yield for each individual palm on the monitored transects has been recorded. The location of individual monitored palms was plotted in MapInfo enabling the plotting of yield maps for each omission plot (which can also be compared to the adjacent monitored palms in the fertilised area).

In 2008 (five years after trial establishment) there are no clear indications of a spatial yield variation across either site (see Figure 1). It was expected that the up-slope omission site, near the native vegetation with little oil palm located up-slope, would be yielding less due to a lack of nutrients being applied compared to the surrounding fertilised palms. But this has not occurred.

If the original hypothesis of nutrient flow through the sub-soil had held then it would have been expected to notice a distinct yield gradient in the down-slope site from top to bottom (as less nutrients would have been available for the palms further into the omission block), this has not occurred either (see Figure 1).

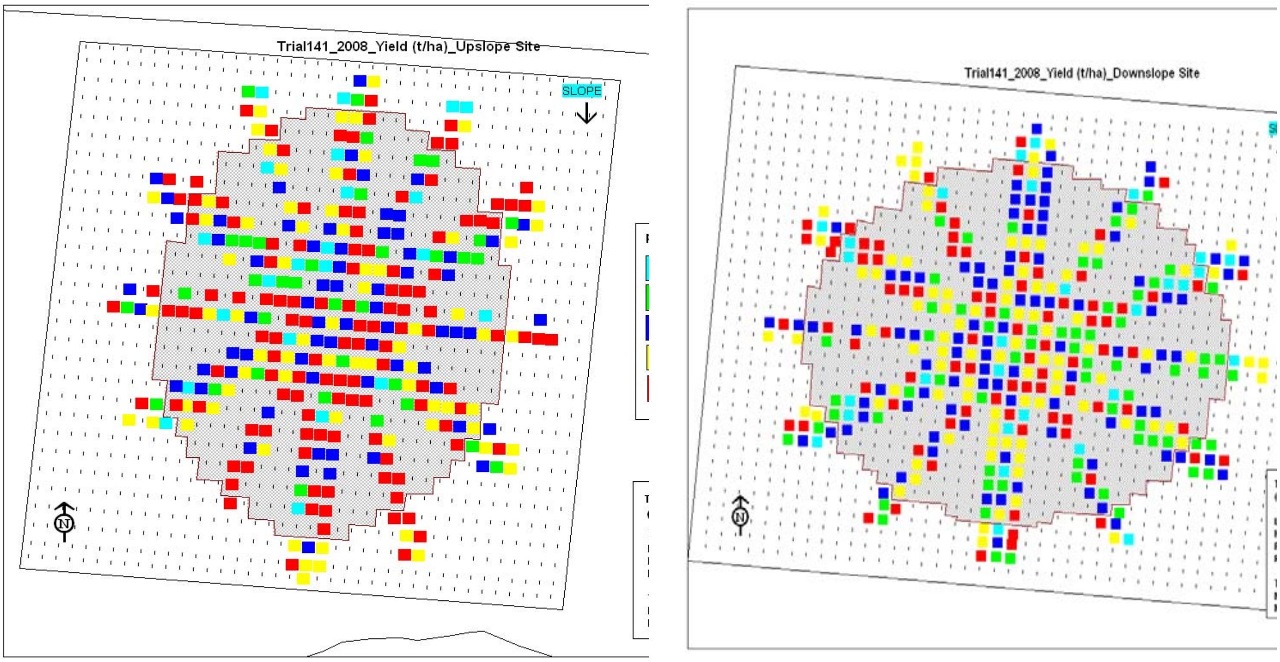


Figure 1. Yield for individual monitored palms in 2008 for the Up-slope site (Division III) (LHS) and Down-slope site (Division II) (RHS). The palms inside the shaded circle have not received fertiliser since 2003, the palms outside the shaded circle receive normal plantation fertiliser. The colour gradients go from high yield – light blue, to green, to dark blue, to yellow to red for low yield.

Tissue nutrient analysis

Palms along the monitored transects were combined into small plots for tissue testing. Tissue test results for leaflet N, P, K, Mg and B; and rachis N, P, K were investigated. Average levels for the areas fertilised and not fertilised (omission areas) are presented in Table 3 for 2008 (5 years after trial establishment).

Table 3. Leaflet and rachis nutrient concentration (% dm, except for B which is in ppm) in 2008, for the Up-slope and Down-slope sites for the fertilised and un-fertilised (omission plot) areas.

	Leaflet N	**Leaflet P**	**Leaflet K**	**Leaflet Mg**	**Leaflet B**	**Rachis N**	**Rachis P**	**Rachis K**
Div III Up-slope								
No fertiliser*	2.32	0.138	0.75	0.15	19	0.34	0.073	1.38
Plus fertiliser	2.38	0.141	0.76	0.15	18	0.34	0.070	1.34
Div II Down-slope								
No fertiliser*	2.30	0.131	0.73	0.18	17	0.37	0.077	1.92
Plus fertiliser	2.39	0.141	0.75	0.18	20	0.39	0.096	1.91

* Omission plot

When individual palm plots were plotted for nutrient content there seems to be some evidence that nutrients are moving across the landscape. Whether this is due solely to the application of nutrients outside the omission plots is not known as yet (need further verification in following years) (see Preliminary report to NBPOL on this trial).

Recommendations

- OPRA staff to be present at ALL occasions when plantation staff are spreading fertiliser to ensure that fertiliser is applied right to the edge of the omission plot and never in the plot;
- OPRA will continue monitoring this site in 2009; OPRS should consider continuing with this site post 2009 – the trial is providing some interesting data on possible nutrient flows.

Acknowledgements

Thank you to Severina Betitis and James Vuvu from OPRS in plotting the data collected from the monitored palms in Mapinfo.

Trial 142: N Response on Large Plots in OPRS Progeny Trials

Purpose

The third avenue for investigating N supply and N requirements of oil palm on volcanic soils with NBPOL was to withhold N over large blocks and compare the yield to fertilised blocks of similar size. The trials were setup in collaboration with OPRS. The trials are located on sites where progeny are known and planted in identified locations.

Trial Location

CCPT Trial 256, Reps II, III and IV, Kumbango Division II

- 110 plots (progenies) of 16 palms each, planted in 1993 at 135 palms/ha

Trial 260, Reps I, II and III, Bebere, Division I (reps I and II) and Division II (rep III)

- 155 plots (progenies) in reps I and II and 154 plots in replicate II, planted in 1995 at 135 palms/ha

Trial 266, Reps I, II and III, Kumbango Division II

- 118 plots (progenies/clones) of 16 palms each, planted in 1998 at 120 palms/ha

METHODS

The trial tests 3 levels of N fertilizer (as ammonium nitrate) at three sites (Table 1). Treatments commenced in 2003. Fertilizer application is split into 2 doses, the first applied in May and the second in October.

The trial is being analysed as a two-way ANOVA with year and N level as the variables investigated. Each level of N has 3 replicates (each progeny trial being a replicate). It will not be possible to test the interaction between N level and progeny, as only one progeny is common across all three progeny trials. Possible movement of N into zero plots from surrounding areas may be analysed spatially if the same progeny is repeated within that plot.

Table 1. Location of fertilizer treatments in Trial 142. Each progeny trial replicate is a plot of the fertilizer trial.

Trial 142 Replicate	CCPT Trial No.	Level 0 (0 kg/palm)	Level 1 (3 kg/palm)	Level 2 (6 kg/palm)
1	256 (Kumbango)	Rep III	Rep II	Rep IV
2	260 (Bebere)	Rep I	Rep II	Rep III
3	266 (Kumbango)	Rep II	Rep III	Rep I

In 2007 the basal fertilizers applied were:
256 Kumbango: MOP (1.5 kg/palm); Borate (0.15 kg/palm); TSP (0.5 kg/palm)
260 Bebere: MOP (1.5 kg/palm); TSP (0.5 kg/palm)
266 Kumbango: (MOP (1.5 kg/palm); Borate (0.15 kg/palm); TSP (0.5 kg/palm)

RESULTS and DISCUSSION

N fertilizer impact on yield

In October 2008 one replicate in Trial 260 (replicate 3) was felled – for all other blocks, yield and its components were calculated only from January to September (to achieve an even comparison between blocks). In 2008 there was no positive response in yield or its components from the application of N based fertilizer (Figures 1 and 2). This lack of response in 2008 is the same as the results for the previous four years of experimentation (treatments were commenced in 2003).

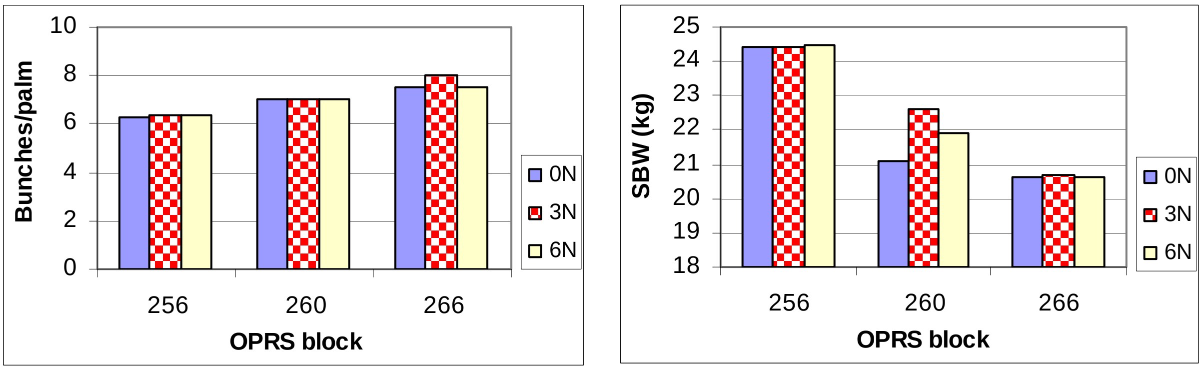


Figure 1. Bunches per palm and Single Bunch Weight (SBW) for three rates of N fertilizer at three sites in 2008 (joint project with OPRS) (all calculations performed for January to September only).

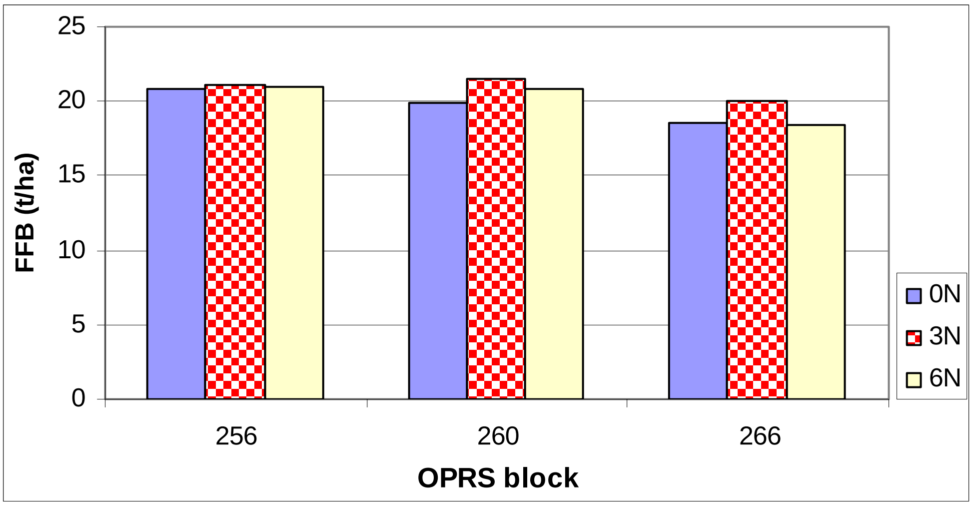


Figure 2. FFB (t/ha) for three rates of N fertilizer at three sites in 2008 (joint project with OPRS) (all calculations performed for January to September only).

Progeny effect on yield

One single progeny was common across all three sites (714.814 x 742.316). 16 palms from this progeny per replicate block were compared for N treatment across the three sites. There was no significant difference in yield between the treatments for this single progeny (Figure 3) (all calculations performed for January to September only).

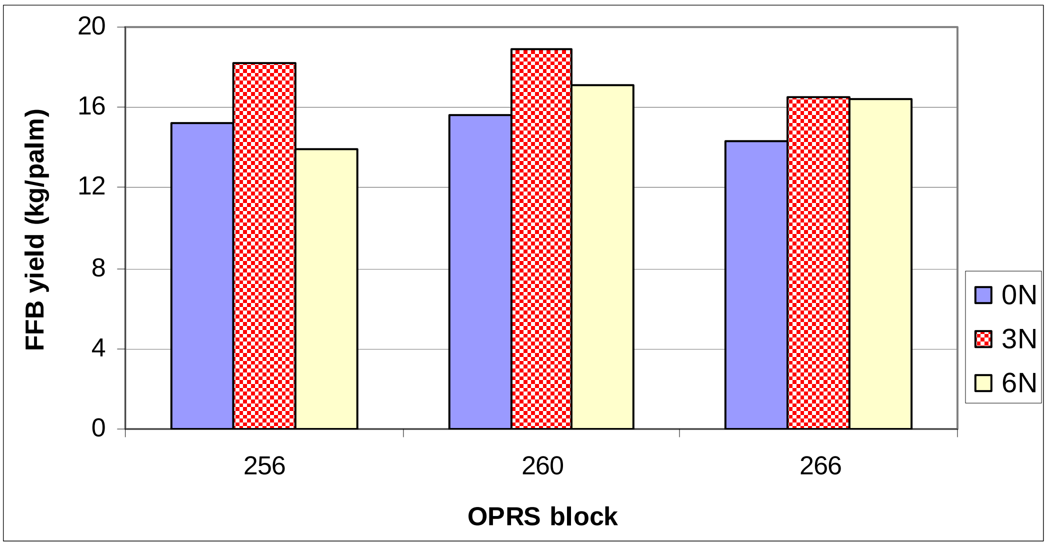


Figure 3. N treatments (kg AN per palm) on one progeny (714.814 x 742.316) (joint project with OPRS) (all calculations performed for January to September 2008 only).

N impact on tissue nutrient concentration

Results for 2008

Leaflet N differences resulting from N fertilizer treatments were investigated for a single progeny that is common across all blocks (714.814 x 742.316) (Figure 4). There was no impact on leaflet N following five years of N application, this is a surprising result as leaflet N usually responds after one or two years without any fertiliser N application (zero application). The results were similar in previous years.

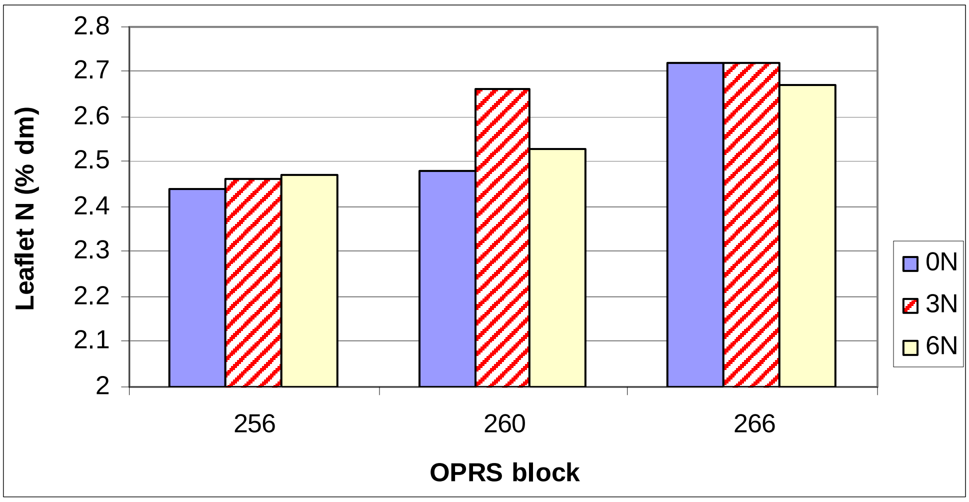


Figure 4. Leaflet N for a single progeny on three OPRS blocks.

The other tissue nutrients are presented in Table 2. Rachis P levels are higher following previous lower levels (0.5kg/palm of TSP was applied as a basal).

Table 2. Tissue nutrient concentration (% dm) for P (phosphorus), K (potassium), Mg (magnesium) and B (boron) in 2008 for progeny 714.814 x 742.316.

Block	Leaf P	Rachis P	Leaf K	Rachis K	Leaf Mg	Leaf B
256	0.146	0.08	0.72	2.18	0.14	14
260	0.147	0.08	0.70	2.10	0.15	14
266	0.158	0.08	0.76	1.91	0.16	17

CONCLUSION

The large block N trial was established in 2003 and after five years of experimentation there are still no consistent differences in yield or in tissue nutrient concentration between the 0, 3 and 6 kg/palm Ammonium Nitrate treatments. 2008 was the last year of experimentation with these large blocks, the trial is now closed.

Magnesium Fertilizer Requirements on Volcanic Soils

Magnesium deficiency symptoms in oil palm are commonly observed in plantation and small holder blocks in West New Britain, especially when grown on recently formed volcanic soils. Often the visual deficiency is associated with low Mg levels in tissue material. On WNB the yield losses associated with a deficiency of Mg are not known. Kieserite ($MgSO_4$) is applied as a remedial fertilizer however the yield response to this fertilizer has not been quantified and often the visual deficiency symptoms remain even after the application of this fertilizer.

Quantifying the yield loss from Mg deficiency and how to alleviate the problem are a research priority for PNGOPRA. We expect that a Mg deficiency is often exacerbated by an associated K (Potassium) deficiency. Five years ago it was reasoned that the poor uptake of Mg and possibly K were due to:

- High solubility of both Kieserite ($MgSO_4$) and MOP (KCl). Both fertilizers could be leached out of the soil profile before plant roots were able to access the nutrients especially on the coarse textured soils in this area with high rainfall (+5000mm annually); and
- The cation exchange capacity of volcanic soils in WNB is low and the soil has relatively high levels of Ca (Calcium), preventing Mg and K from being retained.

In collaboration with CSIRO and JCU (James Cook University) PNGOPRA was successful in attracting research funds from ACIAR (Australian Centre for International Agricultural Research) to study the apparent Magnesium and Potassium deficiencies on volcanic soils in WNB and in particular devise management strategies to overcome the problem. Together with NBPOL four research trials were established in 2004/05. Three of the trials (144, 145 and 146) are replicated plot trials where specific treatments are investigated. The fourth trial is a large scale trial where the addition of Mg fertilizer is investigated on a block scale.

The focus for the three replicated plot trials was to investigate:

- Different sources of Mg fertilizer with lower solubility;
- Different application techniques, comparing fertilizer spread as per commercial practice to applying it in concentrated areas (as hot spots) to reduce leaching potential and possibly improve availability; and
- Applying a combination of Mg and K fertilizers to investigate interactions in uptake.

As part of this ACIAR funded project other studies included a detailed investigation of soil mineralogy, soil hydrological properties and potential for leaching of the different Mg fertilizers. We have now learnt that in fact the Mg in fertiliser does not leach much at all – and even several years after application most of the applied Mg is still in the top 10cm of soil.

QMAG (Queensland Magnesia Pty Ltd) kindly provided Magnesium based fertilizers with low solubility, their support is much appreciated.

The ACIAR funded project has now been completed and the final report for the project has been submitted and accepted by ACIAR.

SUMMARY for all four trials

All four trials investigated in detail the effect of Magnesium based fertilizer on palm yield and performance. In two of the trials the interaction of Mg with K (Potassium) was also investigated.

In three trials there were no significant differences in yield between the control (no fertilizer) and the Mg or K treatments (either alone or in combination). Tissue tests showed some response to Mg fertilizer but in most cases the leaflet Mg level in the trial was below the minimum recommended level of 0.2% of dm.

A strong progeny effect in Mg uptake was shown in trial 148. This demonstrates the difficulty in interpreting leaflet Mg levels (and other nutrients) based on a single adequacy level which does not incorporate progeny differences.

NBPOL apply large quantities of Kieserite across the plantation, in light of the lack of response in these trials it is recommended that Kieserite use, as it is currently applied, should be reviewed.

Trial 144: Magnesium and Potassium Fertilizer Response Trial, Waisisi

SUMMARY

The impact of K and Mg fertilizers, applied by conventional spreading and by a 'slow release' method, at rates which would ensure that both nutrients were supplied in more than adequate amounts, was tested on yield and its components of bunch number and bunch weight; tissue and vegetative parameters, on a volcanic soil in a relatively young plantation (palms were planted in 2001).

In 2005, the addition of high rates of Mg resulted in a small but significant yield penalty. This did not occur in 2006, 2007 or in 2008 and in these years neither +Mg, +K nor +Mg+K treatments resulted in a yield difference compared to the control plots (no K or Mg fertilizer).

Tissue tests in 2006 showed that all treatments (including the control) had adequate levels of Mg and K in the leaflets, however by 2007 leaflet Mg was low (at 0.17 %dm) in the control plots, and this continued into 2008 where the control plots are again low in leaflet Mg (0.16 %dm).

The application of Mg and K significantly increased the levels of each respective nutrient in the leaflet (and rachis for K).

METHODS

Trial Background Information

Table 1. Trial 144 background information.

Trial number	**144**	Company	NBPOL
Estate	Waisisi	Block No.	Waisisi mini estate – block A1
Planting Density	120 palms/ha	Soil Type	Volcanic ash and pumice
Pattern	Triangular	Drainage	Rapid
Date planted	2001	Topography	Rolling low hills
Age after planting	7	Altitude	360 m asl
Recording Started	2003	Previous Land-use	Secondary forest
Planting material	Dami D x P	Area under trial soil type (ha)	300 ha
Progeny	known	Agronomist in charge	Rachel Pipai

Magnesium (Mg) and Potassium (K) based fertilizers are applied at two rates (nil and plus Mg or K fertilizer) in a randomised design with 4 replicates (2 fertilizers x 2 rates x 4 replicates = 16 plots). For the plus fertilizer treatments, Kieserite and Potassium sulphate were used in addition to a slow release form of the nutrient.

- Magnesium: applied on the soil surface with the standard Mg fertilizer Kieserite and in a slow release form as EMAG M30
- Potassium: applied on the soil surface using Potassium sulphate (K_2SO_4) and in a slow release form as K_2SO_4 placed in inverted coconut shells to reduce leaching (see Table 2 for details of the fertilizer applications)
- Basal fertilizers applied in 2008 were Ammonium Chloride (4.0 kg/palm), MAP (3.0 kg/palm), TSP (0.5kg/palm) and Borate (0.15 kg/palm).

To minimise chances of nutrient movement between plots, each plot of 16 palms is surrounded by 2 guard rows, the inner one treated as per allocated treatment for the plot, and the outer one untreated. No Mg or K fertilizer is applied to the block surrounding the trial. Measurements focusing on uptake of Mg and K are:

(i) Single Bunch Weight (SBW) and Bunch Number to calculate yield

(ii) Tissue nutrient concentration of Frond 17

(iii) Vegetative parameters (Petiole cross section, frond length, leaflet size etc)

Table 2. Fertilizer types and rates used in Trial 144.

Nutrient	Application method	Nutrient application rate (kg/ha)	Fertilizer	Nutrient cont. of fertilizer (%)	Fertilizer application rate (kg/palm/yr)	Number of applications.
Mg	Surface	50/yr	Kieserite	17	2.45	6/yr
K	Surface	50/yr	K_2SO_4	42	0.99	6/yr
Mg	Slow-release#	150	$MgCO_3$/MgO*	46	2.72	1
K	Slow-release#	150	$K_2SO_4^+$	42	2.98	1

* QMAG M30 $^+$ K_2SO_4 in inverted half coconuts # only applied at the beginning of the trial

RESULTS and DISCUSSION

(i) Yield components

In 2008, or five years after the inception of this trial there was no response in yield to either applied Mg or K or to the combination of these two fertilizers (Figure 1 and Table 3).

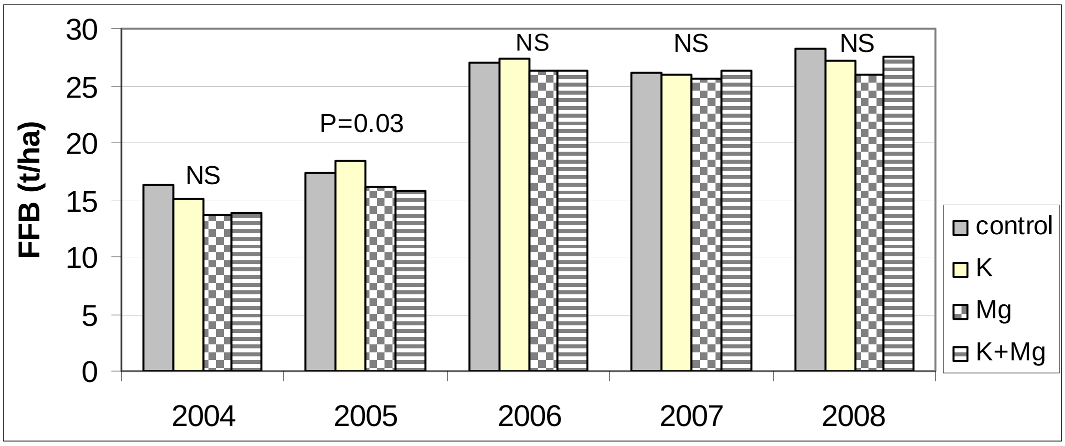


Figure 1. Trial 144 - FFB yield since inception of the trial in 2004.

In the second year of experimentation (2005) the application of Mg fertilizer significantly decreased yield by 2 t/ha (P=0.03). However, there was no difference in yield in treatments with Mg fertilizer in 2006, 2007 or in 2008.

Table 3. Responses in 2008 to K and Mg fertilizer on yield (FFB Yield), single bunch weight (SBW) and number of bunches (NB/ha). (K0 and Mg0= no K or Mg fertilizer; K1 or Mg1 = K and Mg fertilizer applied as per methods).

	FFB Yield (t/ha)		SBW (kg)		NB (/ha)	
Source	**Mg0**	**Mg1**	**Mg0**	**Mg1**	**Mg0**	**Mg1**
K0	28.2	26.0	13.8	12.7	2058	2050
K1	27.2	27.6	14.5	13.2	1885	2095
Significant difference:						

Mg	**NS**	**P=0.004 (LSD 0.7)**	**NS**
K	**NS**	**NS**	**NS**

(ii) Tissue nutrient content in 2008

Potassium: K levels in the leaflets were significantly higher in the Potassium fertilizer treatment (either alone or in combination with Mg fertilizer). There was no difference between treatments in rachis K.

Magnesium: Mg levels in the leaflets were significantly higher in the Magnesium fertilizer treatments (either alone or in combination with K fertilizer). In 2007 and 2008, there was some evidence that the Mg uptake was suppressed by K fertilizer).

Calcium: Calcium uptake is significantly reduced by the Magnesium fertilizer treatments (either alone or in combination with K fertilizer). Whether this could potentially reduce yield in the long term is unknown, currently Ca levels are high.

General comment:

- Leaflet K was adequate in all treatments (including the control)
- Rachis K was adequate in all treatments (including the control)
- Leaflet Mg was adequate in the Magnesium fertilizer treatments, but low in the control and in the K fertilizer treatment (K fertilizer in the absence of Mg fertilizer may reduce the uptake of Mg)
- Leaflet N and rachis N were adequate at 2.64% and 0.40% dm respectively; Leaflet P at 0.150% dm is adequate; whereas rachis P is close to acceptable at 0.08% dm. It is advised to continue with basal P application.

Table 4. Leaflet K, Mg and Ca, and Rachis K levels (% dm) for four treatments in 2008.

Fertilizer treatment	**Leaf K**	**Leaf Mg**	**Rachis K**
Control	0.68	0.16	1.28
+ Mg	0.68	0.22	1.18
+ K	0.74	0.14	1.29
+ Mg + K	0.74	0.20	1.13
Significant difference:			
Mg	**NS**	**<0.001**	**NS**
K	**0.003**	**NS**	**NS**
MgxK	**NS**	**NS**	**NS**
LSD	**0.04**	**0.02**	**-**
CV%	**4.4**	**11.4**	**18.9**

(iii) Tissue nutrient content over time.

Fertilizer treatments were first applied in 2003 and already by the 2004 sampling there were some changes in K and Mg nutrient contents in the leaflet and rachis. As expected, as palms matured, the leaflet K levels reduced over time. However, the trend remained the same, K fertilizer increased the level of K in the leaflet but not the rachis K in 2008 (see Figures 2 and 3).

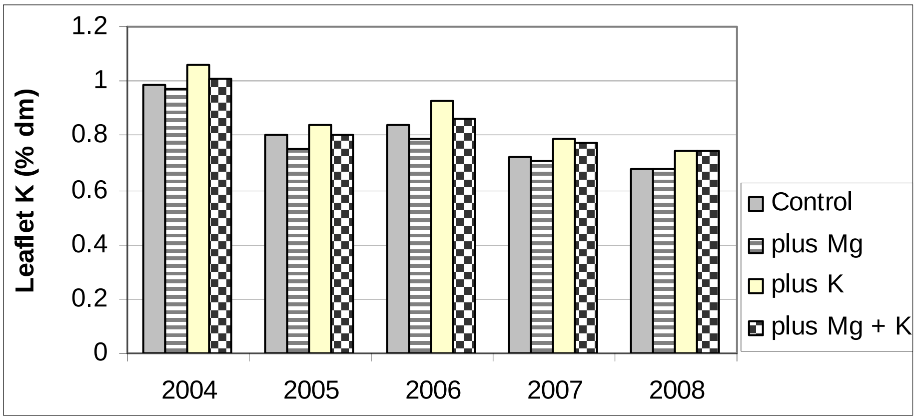


Figure 2. Leaflet K (% dm) in trial 144 over time (2004 to 2008)

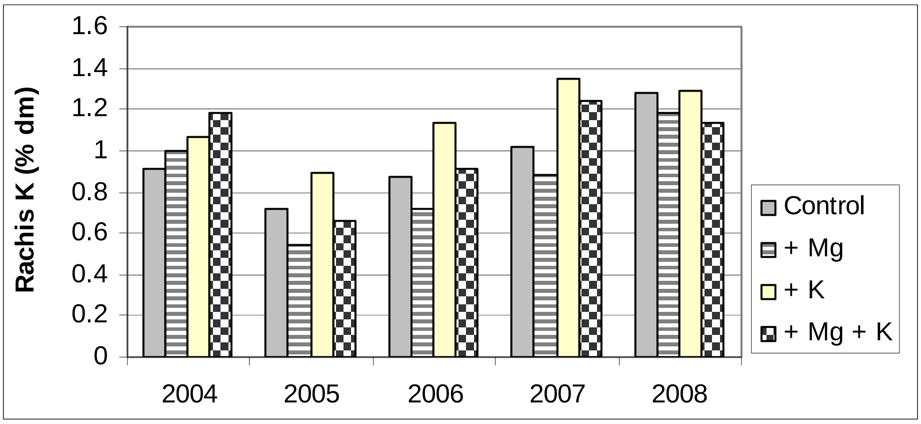


Figure 3. Rachis K (% dm) in trial 144 over time (2004 to 2008)

Marked differences in Mg uptake have resulted from the application of Mg and K fertilizer over time. In the control treatment and the K alone treatment (in the absence of Mg fertilizer) the levels of leaflet Mg have now dropped below the adequate level of 0.20 % dm. Only in the treatments where Mg fertilizer was applied were the levels adequate (above 0.20 % dm).

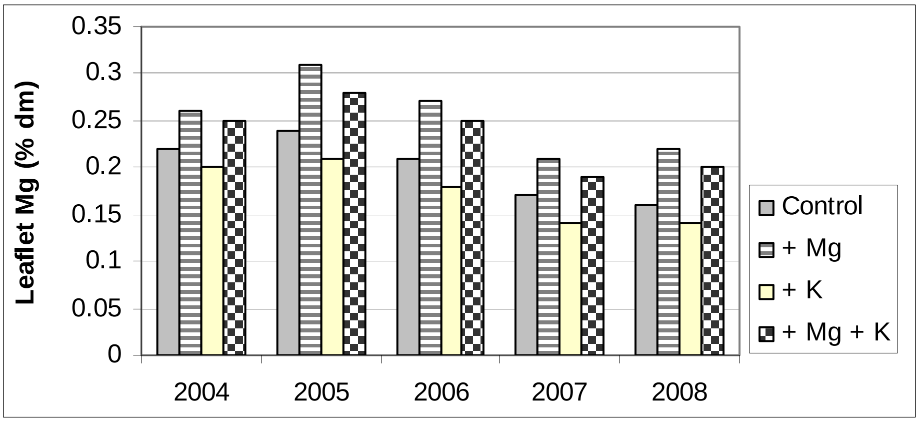


Figure 4. Leaflet Mg (% dm) in trial 144 over time (2004 to 2008).

Fertilizer Mg effects on oil palm vegetative growth

There were no significant effects of the fertilizer treatments on the growth parameters measured. The mean value for each parameter, the level of significance and the co-efficient of variation are presented in Table 5.

Frond production and frond number

26 new fronds were produced in 2008 (one every 14 days) – this is normal for this age palm. Total green fronds counted per palm averaged 42 fronds which is an adequate number. Mg and K fertilizer applications had no significant effects on either parameter measured (Table 5).

Frond and canopy size

The two assessments of canopy coverage, 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) were also within adequate limits for palms in this age group (average frond area $10m^2$ and LAI of 5). Neither, Frond Area or LAI was affected by the type and rate of Mg or K fertilizer applied (Table 5).

Vegetative dry matter production

Petiole cross section (PCS) is a primary determinant of vegetative dry matter production. PCS averaged $31cm^2$ and was not influenced by the Mg or K fertilizer treatments. 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) were also not related to the fertilizer treatments (Table 5).

Table 5. Summary of fertilizer effect on vegetative growth parameters in 2008.

	PCS	Radiation Interception				Dry Matter Production (t/ha)			
		GF	FP	FA	LAI	FDM	BDM	TDM	VDM
Mean	31.1	41.7	26.4	10.0	5.0	10.7	14.2	27.6	13.4
P value	0.44	0.24	0.69	0.52	0.33	0.25	0.93	0.77	0.30
CV%	7.7	4.5	3.1	8.2	9.7	7.6	12.2	8.3	7.1

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).

CONCLUSION

(i) In year 5 of experimentation there was no impact of either Mg or K based fertilizer on production;

(ii) Leaflet Mg levels are below adequate in the zero Mg fertilizer treatments;

(iii) Leaflet Mg levels increased in the treatments where Mg had been applied:

(iv) Leaflet K increased in the treatments where K had been applied.

Acknowledgements

- ACIAR support for funding the trial is grateful acknowledged (Project SCMN/2000/046)
- Queensland Magnesia Pty Ltd for supporting the project with the supply of Mg based fertilizers (EMAG M30)

Trial 145: Magnesium Source Trial, Walindi

SUMMARY

This trial compares four types of Magnesium fertilizer ($MgSO_4$, MgO, $MgCO_3$ and a mixture of MgO / $MgCO_3$) applied at 2 rates (standard rate and a double standard rate, where the standard rate is equivalent to 2kg/palm of $MgSO_4$). The trial was established in late 2004.

There was no increase in yield observed between the zero control and the Mg fertilizer treatments (either at the standard or double standard rate).

The application of Mg fertilizer did not result in higher leaflet Mg levels. Leaflet Mg levels remain below adequate levels (< 0.20% dm even with 4kg of Kieserite applied per palm). The application of the four different types of Mg fertilizer also had no effect on the vegetative parameters measured (such as PCS, frond production, and LAI).

METHODS

Trial Background Information

Table 1. Trial 145 background information.

Trial number	**145**	Company	NBPOL
Estate	Walindi	Block No.	MU-1311-09
Planting Density	120 palms/ha	Soil Type	Volcanic ash
Pattern	Triangular	Drainage	Rapid
Date planted	1999	Topography	Slight inclination
Age after planting	9	Altitude	30 m asl
Recording Started	2004	Previous Land-use	Replanted oil palm
Planting material	Dami D x P	Area under trial soil type (ha)	750 ha
Progeny	unknown	Agronomist in charge	Rachel Pipai

Magnesium based fertilizer is applied as four sources (Kieserite, and the QMAG products Magnesite FO1, EMAG M30 and EMAG 45), at two rates (standard and 2 times standard) and compared to a control which receives no Mg fertilizer, in a randomised design with four replicates. The current industry standard for kieserite in WNB is around 2 kg kieserite per palm per year. The other fertilizers are applied at an equivalent magnesium rate (Table 2). All treatments are applied twice annually and spread on the surface.

Basal fertilizer applied in 2008: Ammonium nitrate (3.0 kg/palm); TSP 0.5 kg/palm; MOP 0.5kg/palm; and Borate 0.15 kg/palm.

Each plot consists of 36 (6 x 6) palms with the inner 16 (4 x 4) being the recorded palms. Trenches have been dug around each plot to prevent root poaching.

Fortnightly measurements of yield are carried out. Nutrient analysis of frond 17 and standard vegetative measurements are carried out annually. The amount of magnesium in the soil and palms may be examined after several years of treatment.

Table 2. Fertilizer types and rates used in Trial 145.

Treatment number	Product	Main component	Mg content (%)	Mg application rate (kg/palm/yr)	Fertilizer rate per application (g/palm)
1	Kieserite	$MgSO_4$	17	0.34	1000
2	"	"	"	0.68	2000
3	Magnesite FO1	$MgCO_3$	26	0.34	654
4	"	"	"	0.68	1308
5	EMAG M30	$MgCO_3$ / MgO	46	0.34	370
6	"	"	"	0.68	739
7	EMAG45	MgO	56	0.34	304
8	"	"	"	0.68	607

Statistical analysis: 4 sources of Mg fertilizer by two rates plus a control equals 9 treatment plots x 4 replicates in a randomised block design was analysed using a Two Way ANOVA. One of the treatments, the nil fertilizer control, was duplicated 4 times in each block. This design has enabled the control treatment to be estimated at twice the accuracy of the other 8 treatments.

RESULTS and DISCUSSION

Yield in 2008

At this stage in the trial (fourth year) there are no differences between the Mg fertilizer treatments and the control (Control 29.1 t/ha and average of all Mg treatments is 29.6 t/ha). The impact of Mg fertilizer on Bunch Number was also not significant. There was a significant difference (at P=0.05) between treatments in bunch weights but it is not related to fertiliser type nor to Mg fertiliser in relation to the control.

Table 3. Average FFB (t/ha) for each treatment

Fertilizer type	Yield (t/ha)	BN (Bunch/ha)	SBW (kg)
Control	29.1	1612	18.0
Kieserite Standard	28.0	1564	17.5
" 2 x Standard	30.7	1692	18.2
EMAG45 Standard	30.5	1659	18.4
" 2 x Standard	29.5	1635	18.1
FO1 Standard	31.0	1725	17.9
" 2 x Standard	30.4	1544	19.7
EMAG M30 Standard	27.2	1408	19.4
" 2 x Standard	29.9	1605	18.6
Significant difference:	**NS**	**NS**	**P=0.05 (LSD 1.4)**
CV%	**8.6**	**9.4**	**5.2**

Yield over time

Treatments were first applied in 2004. Over this time there have been no trends in yield from the different Mg fertilizer treatments (Figure 1). In Figure 1, only the Standard rate of Mg fertilizer is presented (Mg equivalent to 2kg/palm of Kieserite; the double rate of Mg fertilizer had the same result).

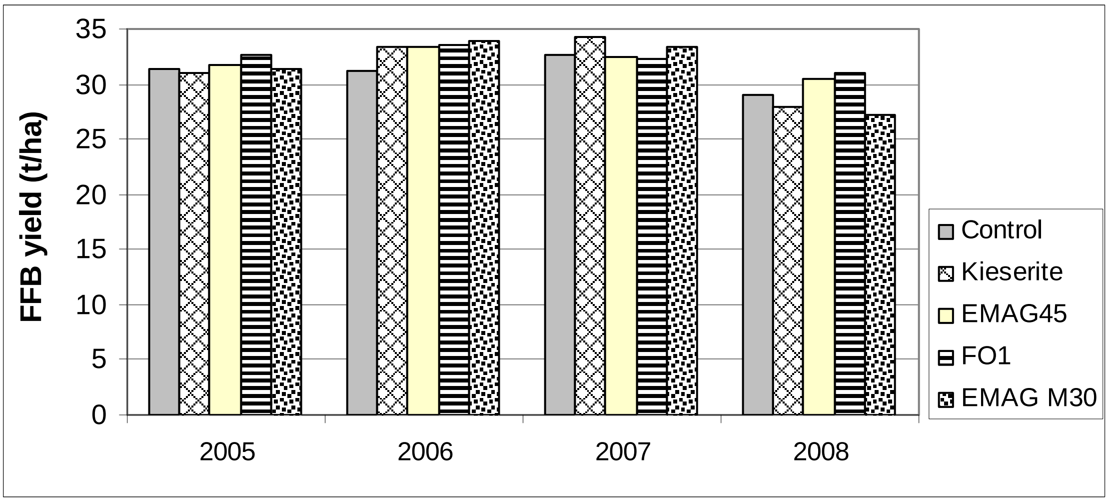


Figure 1. Yield achieved from 2005 to 2008 as a result of different Mg fertilizer treatments (including the zero Mg control)

Tissue nutrient analysis

Leaflet and rachis Mg levels have been tested in Frond 17 since 2003 (2003 was the year before treatments were applied). There has been no change in leaflet or rachis Mg levels since 2003 in any of the treatments (Table 4). However, there were large differences between years in leaflet and rachis Mg, this could be due to different timings of sampling or differences in laboratory readings between years.

Table 4. Yearly leaflet and rachis Mg levels (% dm) since 2003.

Mg fertilizer	Level	Leaflet Mg (%dm)					
		2003	2004	2005	2006	2007	2008
Control	0	0.17	0.17	0.22	0.19	0.13	0.15
Kieserite	1	0.17	0.15	0.22	0.18	0.14	0.16
Kieserite	2	0.16	0.17	0.22	0.19	0.14	0.16
EMAG45	1	0.17	0.16	0.22	0.18	0.14	0.17
EMAG45	2	0.17	0.16	0.21	0.18	0.14	0.16
FO1	1	0.18	0.17	0.23	0.19	0.15	0.17
FO1	2	0.18	0.16	0.22	0.19	0.15	0.17
EMAG M30	1	0.17	0.17	0.22	0.19	0.14	0.17
EMAG M30	2	0.16	0.15	0.21	0.18	0.14	0.17
Significant diff.: Treatment		**NS**					

Rachis Mg levels were also assessed from 2003 to 2006 and no differences in treatments were found.

The other tissue nutrient levels are presented in Table 5. All the major nutrient levels were adequate to high (Table 5).

Table 5. Mean leaflet and Rachis nutrient levels for trial 145 (2008).

Nutrient	Leaflet (% dm)	Rachis (% dm)
Nitrogen	2.57	0.43
Phosphorus	0.148	0.15
Potassium	0.83	2.1
Calcium	0.72	-
Boron	25 ppm	

Fertilizer Mg effects on oil palm vegetative growth

Frond production and frond number

33 new fronds were produced in 2008 (one every 12 days) which is indicating good growing conditions – normally we would expect a new frond to form every 17 to 20 days. Total green fronds counted per palm averaged 40 fronds which is an adequate number. Mg fertilizer (type and/or rate) applications had no significant effects on either parameter measured (Table 6).

Frond and canopy size

The two assessments of canopy coverage, Frond area (based on leaflet length and width) and LAI (Leaf Area Index, calculated from Frond area, frond number and palms per ha) were also within adequate limits for palms in this age group (average frond area 13m^2 and LAI of 6). Neither, Frond Area or LAI was affected by the type and rate of Mg fertilizer applied (Table 6).

Vegetative dry matter production

Petiole cross section (PCS) is a primary determinant of vegetative dry matter production. PCS did not vary across Mg treatments and was not significantly different from the control (no Mg fertilizer applied). 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) were also not related to Mg fertilizer type or to the control (Table 6).

Table 6. Effect of treatments on vegetative growth parameters in 2008.

Mg fertilizer	Level	PCS	Radiation Interception				Dry Matter Production (t/ha)			
			GF	**FP**	**FA**	**LAI**	**FDM**	**BDM**	**TDM**	**VDM**
Control	0	47.2	39.2	33.1	13.0	6.1	19.9	15.6	39.5	23.9
Kieserite	1	44.5	40.6	34.0	12.0	5.9	19.4	14.7	37.9	23.2
Kieserite	2	52.4	39.4	33.9	13.3	6.3	22.6	16.1	43.0	26.9
EMAG45	1	49.3	38.7	33.5	13.2	6.2	21.0	16.1	41.3	25.2
EMAG45	2	47.7	39.6	34.1	12.3	5.8	20.3	15.9	40.3	24.3
FO1	1	50.2	38.1	34.1	12.5	5.7	21.8	16.3	42.3	26.0
FO1	2	47.3	40.3	33.5	12.6	6.1	20.2	16.0	40.3	24.2
EMAG M30	1	46.9	39.9	34.6	12.9	6.2	20.7	14.6	39.2	24.6
EMAG M30	2	45.8	38.6	33.4	12.4	5.8	19.5	16.0	39.4	23.4
Significant diff.:		**0.07**	**0.14**	**0.77**	**0.21**	**0.40**	**0.03**	**0.41**	**0.009**	**0.02**
$LSD_{0.05}$		**-**	**-**	**-**	**-**	**-**	**2.0**	**-**	**2.7**	**2.2**
CV%		**7.2**	**3.3**	**4.6**	**6.0**	**6.9**	**6.9**	**7.9**	**4.8**	**6.4**

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).

CONCLUSION

In the fourth year of trial work there is no indication that there has been a positive response in yield resulting from any of Mg fertilizer applications (either as Mg type or rate applied).

It has not been possible to demonstrate a leaflet or rachis Mg level difference from the different treatments, nor an effect of the treatments on the vegetative parameters, such as Petiole Cross Section, Frond Production or Leaf Area Index.

Acknowledgements

- ACIAR support for funding the trial is grateful acknowledged (Project SCMN/2000/046)
- Queensland Magnesia Pty Ltd for supporting the project with the supply of Mg based fertilizers (FO1, EMAG M30 and EMAG 45)

Trial 146: Magnesium Fertilizer Type and Placement Trial, Kumbango

SUMMARY

In this trial the application method for three different Mg fertilizers (Kieserite, FO1 (MgCO3) and EMAG45 (MgO)) were compared to a zero control (no Mg fertilizer) and a positive control (all three Mg fertilizers). The application methods compared were: surface applied; open trench; covered trench and fertilizer placed in inverted coconuts.

There were no differences in yield (and its components of bunch number and SBW), leaflet Mg concentration, and vegetative parameters (PCS, Frond Production and LAI) from either the Mg fertilizer type or placement used.

Nutrient concentrations in the leaflet and rachis for N, P, K and Boron all indicate adequate nutrition at this stage.

METHODS

Trial Background Information

Table 1. Trial 146 background information.

Trial number	**146**	Company	NBPOL
Estate	Kumbango	Block No.	MU 1121-03A
Planting Density	135 palms/ha	Soil Type	Volcanic ash/pumice
Pattern	Triangular	Drainage	Rapid
Date planted	1999	Topography	Flat
Age after planting	9	Altitude	60 m asl
Recording Started	2004	Previous Land use	Oil palm
Planting material	Dami D x P	Area under trial soil type (ha)	460 ha
Progeny	unknown	Agronomist in charge	Rachel Pipai

Three sources of Magnesium based fertilizer (Kieserite; MgO (EMAG45); and $MgCO_3$ (Magnesite FO1)) were applied in four different placements (spread on the surface; in an Open Trench; in a Covered Trench; and in inverted coconuts). Two controls were included: the first being a zero (no fertilizer) control and the second being a positive control with all fertilizer types applied (Table 2).

Placement of fertilizer consisted of spreading twice annually on the surface; and three treatments with a high concentration, equivalent to 8 years of annual applications, applied in year 1 of the trial and applied in: (i) an open trench, (ii) a trench covered with plastic, and (iii) placed in inverted coconut shells.

Each treatment (3 sources x 4 placements + 2 controls) was replicated four times, and treatments were applied to plots in a randomised block design.

Each plot consists of 36 (6x6) palms with the inner 16 (4x4) being the recorded palms. Trenches have been dug around each plot to prevent root poaching.

In 2008, Ammonium Nitrate (3 kg/palm) TSP (0.5 kg/palm), MOP (1.0 kg/palm), and borate (0.15 kg/palm) were applied as basal fertilizers.

Table 2. Fertilizer types, rates applied and placement for Trial 146.

Treatment no.	Fertilizer type	Placement	Mg appl. rate (kg/palm)	Mg content of fert. (%)	Fert. appl. rate (kg/palm/yr)	Number of appl.
1	Kieserite	Surface	0.34	17	2	2/yr
2	Kieserite	Open Trench	2.72	17	16	Yr 1 only
3	Kieserite	Covered Trench	2.72	17	16	Yr 1 only
4	Kieserite	Coconuts	2.72	17	16	Yr 1 only
5	$MgCO_3$	Surface	0.34	26	1.3	2/yr
6	$MgCO_3$	Open Trench	2.72	26	10.5	Yr 1 only
7	$MgCO_3$	Covered Trench	2.72	26	10.5	Yr 1 only
8	$MgCO_3$	Coconuts	2.72	26	10.5	Yr 1 only
9	MgO	Surface	0.34	56	0.6	2/yr
10	MgO	Open Trench	2.72	56	4.9	Yr 1 only
11	MgO	Covered Trench	2.72	56	4.9	Yr 1 only
12	MgO	Coconuts	2.72	56	4.9	Yr 1 only
13	Zero control		0		0	
14	Positive control					
	Kieserite	Surface	0.34	17	2.0	2/yr
	M30**	Open Trench	3.40	46	7.4	Yr 1 only

* Trench with plastic cover. ** A mixture of $MgCO_3$ and MgO

RESULTS and DISCUSSION

Yield and its components

In the first three years of experimentation there were no significant responses in yield or its components to either the type of Magnesium based fertilizer applied or to the placement of the fertilizer. Table 3 presents the main effects of fertilizer type and placement for FFB yield and its components in 2008.

Table 3. Significance (p values) of main effects in 2008 for Magnesium based fertilizer type and placement on FFB yield and its components. The two controls (nil Mg, combined sources of Mg) were not included in this statistical analysis.

	FFB yield	BN/ha	SBW (kg)
Fertilizer type	0.89	0.83	0.10
Placement	0.60	0.99	0.34
Source x Placement	0.44	0.60	0.45

The average yield achieved in 2008 was 25.5 t/ha and is presented for the various treatments in Table 4. There were no significant effects on Single Bunch Weight (mean 18.7kg), or Bunch Number (mean 1390/ha), the results for these are not presented.

Table 4. Effect of Mg source and placement on FFB yield (t/ha) in 2008.

Fertilizer type	Placement					
	Zero control	Surface	Open Trench	Covered Trench	Coconuts	Positive control
Nil	27.2					
Kieserite		27.5	26.1	24.4	25.0	
$MgCO_3$		24.7	25.3	26.0	25.5	
MgO		26.1	25.1	24.3	26.3	
Combined						28.2

It is clear that there is no difference in the yield between the Zero Control (no Mg fertilizer), the Mg fertilizer treatments and the Positive Control (high rates of two sources of Mg fertilizer).

Tissue nutrient concentration in 2008

There was no consistent Mg fertilizer type or placement effect on leaflet Mg levels (Table 5). All values, including the fertilised treatments, were below the adequacy value (industry standard is 0.20 %dm) for leaflet Mg.

Table 5. Effect of Mg source and placement on leaflet Mg (% dm) in 2008.

Fertilizer type	Placement					
	Zero control	Surface	Open Trench	Covered Trench	Coconuts	Positive control
Nil	0.17					
Kieserite		0.17	0.15	0.16	0.17	
$MgCO_3$		0.17	0.16	0.15	0.16	
MgO		0.16	0.18	0.17	0.15	
Combined						0.16

Other major leaflet and rachis cations, K and Ca, were also not influenced by Mg product type or placement.

The overall nutrient status in the leaflets and rachis is presented in Table 6. The nutrient concentrations in the leaflet and rachis were all in the adequate range.

Table 6. Mean leaflet and Rachis nutrient levels for trial 146 (2008).

Nutrient	Leaflet (% dm)	Rachis (% dm)
Nitrogen	2.64	0.35
Phosphorus	0.151	0.110
Potassium	0.85	1.77
Boron	19 ppm	

Fertilizer Mg effects on oil palm vegetative growth

Frond production and frond number

25 new fronds were produced in 2008 (one every 14 days) which is indicating good growing conditions. Total green fronds counted per palm averaged 40-42 fronds which is an adequate number (Table 7). Mg fertilizer (type and/or placement) applications had no significant effects on either parameter measured.

Frond and canopy size

The two assessments of canopy coverage, Frond area (based on leaflet length and width) and LAI (Leaf Area Index calculated from Frond area, frond number and palms per ha) indicate that the canopy has good cover. Neither, Frond Area or LAI was affected by the type and placement of Mg fertilizer applied (Table 7).

Vegetative dry matter production

Petiole cross section is a primary determinant of vegetative dry matter production, for this age of palms the PCS is average. The PCS for the Mg treatments was 43 cm^2 and was not significantly different from the controls (Table 7). 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) were also not related to Mg fertilizer type or placement (Table 7).

Table 7. Mean value of vegetative parameters in 2008 as measured or calculated presented as the mean value for treatments (Mg source x placement); zero control (no Mg fertilizer) and positive control (two sources of Mg fertilizer)

	Treatment mean	**Zero Control**	**Positive control**	**Notes**
PCS	42.6	39.2	44.5	Normal petiole cross section
GF	39.2	38.8	38.5	Adequate total number of fronds
FP	24.9	25.1	25.2	Good frond production (one new frond every 14 days)
FA	12.8	12.6	12.3	
LAI	6.4	6.3	6.1	Adequate LAI
FDM	14.5	13.5	15.3	
BDM	14.0	14.8	15.0	
TDM	31.7	31.5	33.7	
VDM	17.7	16.7	18.7	

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).

CONCLUSION

After four years of experimentation, the treatments of Mg fertilizer type or application method showed no differences in yield (or in bunch number or SBW); nutrient levels in leaflets or rachis; or in vegetative parameters such as PCS, Frond Production or LAI.

Acknowledgements

- ACIAR support for funding the trial is grateful acknowledged (Project SCMN/2000/046)
- Queensland Magnesia Pty Ltd for supporting the project with the supply of Mg based fertilizers (FO1, EMAG M30 and EMAG 45)

Trial 148: Mg Response using Large Plots in OPRS Progeny Trials, Kumbango

SUMMARY

The response to magnesium fertilizer, as Kieserite, was investigated over large blocks in conjunction with OPRS breeding trials. Three replicate blocks with three levels of applied Magnesium fertilizer were set up in 2003.

An increase in Mg uptake through higher levels of leaflet Mg in treated plots compared to the nil control is evident. Yield across blocks with different rates of Mg applied were not significantly different.

Progeny 635.607 x 742.207 was the highest yielding progeny (compared to 714.712 x 742.316 and 5035.216 x 742.316) and it also had the highest leaflet Mg levels. This indicates that there are definite progeny differences in Mg uptake (as assessed by Mg levels in the tissue).

After five years there were still no observable differences in yield between the three Mg fertiliser rates applied.

METHODS

A possible explanation for the apparent lack of response to Mg in commercial blocks and some trials on WNB is the movement of nutrients into unfertilised plots from surrounding areas. This possibility has led to a change in direction for N trials in WNB. One of the approaches being used for N trials is to have very large plots and compare the yield obtained with different fertilizer rates on a block basis. This Magnesium response trial is similar to the N (Trial 142) and B (Trial 149) response trials in using large plots. It is a collaborative project between PNGOPRA and OPRS.

Background information on the trial site is described in Table 1.

Table 1. Trial 148 background information.

Trial number	**148**	Company	NBPOL
Estate	Kumbango	Block No.	Div II (OPRS breeding trials)
Planting Density	128 palms/ha	Soil Type	Volcanic
Pattern	Triangular	Drainage	Free draining
Date planted	2001	Topography	flat
Age after planting	7 years	Altitude	60 m asl
Treatments 1st applied	2003	Previous Land use	Replanted oil palm
Progeny	known	Area under trial soil type (ha)	Not known
Planting material	Dami D x P	Agronomist	Rachel Pipai

Basal fertilizer applied in 2008 in Trial 148: 3.0 kg/palm MAP, 1.5 kg/palm MOP plus 80 g/palm Borate. Fertilizer applications by PNGOPRA are being carried out in collaboration with Dami OPRS.

The large scale Mg trial utilises large blocks using three OPRS breeding trial sites located at Kumbango (OPRS trials 282, 283 and 284). The OPRS trial sites were planted to 84 progeny of 12 palms each. Each OPRS trial site was divided into three equal sized blocks of approximately 336 palms, on which three rates of Kieserite ($MgSO_4$) are applied annually (0, 2 and 4 kg/palm of Kieserite) (Table 2).

Table 2. Mg, as Kieserite, fertilizer rates (kg/palm per year) in trial 148. The replicates shown are breeding trial replicates. Each breeding trial is a replicate of the fertilizer trial.

OPRS Trial:	282			283			284		
Replicate	1	2	3	1	2	3	1	2	3
Treatment:	0	2	4	4	2	0	0	2	4

The trial is being analysed as a one-way ANOVA of kieserite level with 3 replicates (each progeny trial being a replicate). A two-way ANOVA was used to analyse the effect of kieserite (3 levels) x progeny (3 progeny: 635.607 x 742.207; 714.712 x 742.316; and 5035.216 x 742.316).

RESULTS and DISCUSSION

Mg fertilizer as Kieserite had no impact on yield in 2008 (Figure 1). There was also no effect on bunch number (average bunch number = 13 b/palm) nor on bunch weight (average SBW = 14kg).

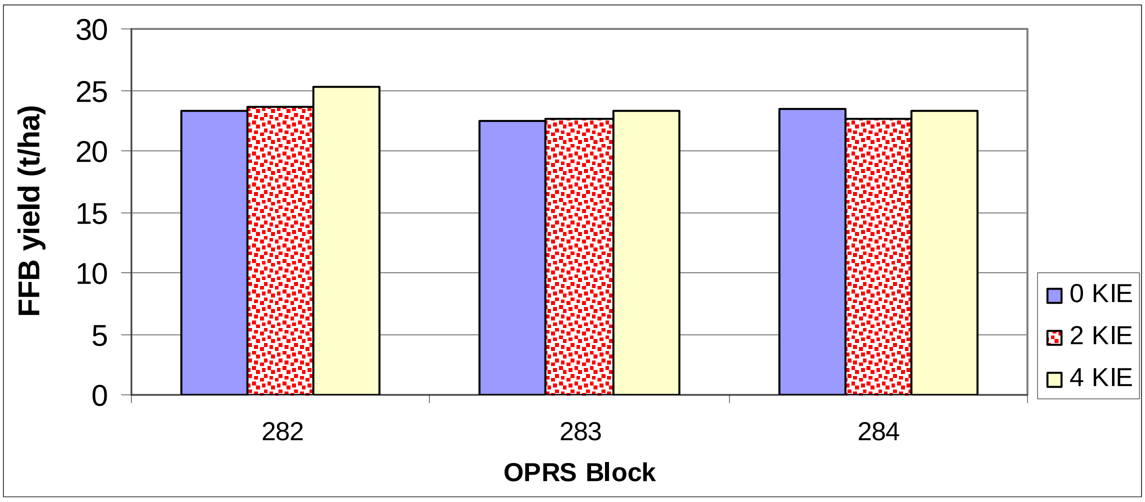


Figure 1. FFB yield of three rates of Kieserite on three large blocks.

The trial is now in its fifth year (Mg fertilizer was first applied in 2003) and over this time there has been no difference in yield from the applied fertilizer (Table 3). However, note that the yield in 2008 dropped by 5 to 6 t/ha compared to 2007.

Table 3. FFB yield for three rates of applied Kieserite.

	Rate of applied Kieserite kg/palm		
Year	**0**	**2**	**4**
2004	16.2	16.0	16.4
2005	19.0	19.0	18.7
2006	26.2	26.7	27.3
2007	28.7	29.2	29.4
2008	23.1	23.0	23.9
Significant difference:			
Year		**P<0.001**	
Rate		**NS**	
Year x Rate		**NS**	

Three progeny were common to each breeding trial, which made it possible to investigate differences in yield between progeny and also the differential yield effect of magnesium fertilizer on each progeny (Table 4). There was no magnesium fertilizer effect on yield. The progeny effect on yield was significant (P=0.01), and progeny 635.607 x 742.207 with a yield of 24.6 t/ha, out yielding the other two progeny by 2.0 t/ha.

Table 4. Progeny and Mg fertilizer effect on FFB yield in 2008.

	Yield t/ha		
Kieserite kg/palm	**0**	**2**	**4**
Progeny			
635.607 x 742.207	24.3	24.4	25.2
714.712 x 742.316	21.0	23.5	21.4
5035.216 x 742.316	22.6	23.0	22.9
Significant difference:			
Mg rate		**NS**	
Progeny type		**P=0.012**	
Mg x Prog		**NS**	
$LSD_{0.05}$		**2.9**	
CV%		**7.2**	

Effect of magnesium fertilizer on tissue nutrient concentration

Treatments were first applied in 2003 and since 2004 the leaflet concentration of magnesium has been significantly higher in the fertilizer treated blocks compared to the untreated blocks (Table 5).

Table 5. Leaflet Mg content for three rates of applied Kieserite (progeny: 635.607 x 742.207).

	Rate of applied Kieserite kg/palm		
Year	**0**	**2**	**4**
2004	0.21	0.21	0.23
2005	0.20	0.22	0.23
2006	0.16	0.18	0.18
2007	0.15	0.18	0.18
2008	0.15	0.18	0.18
Significant difference:			
Year		**P<0.001**	
Rate		**P<0.001**	
Year x Rate		**NS**	
$LSD_{0.05}$		**0.02**	
CV%		**8.1**	

There is also a strong year effect, with leaflet Mg levels in the non fertilised treatments dropping significantly in 2006. As the palms are maturing and leaf material increases in bulk the concentration levels have been decreasing (as expected).

Another complicating factor in interpreting tissue nutrient concentrations is the apparent strong progeny effect. Leaflet Mg concentration for two different progeny, 635.607 x 742.207 and 5035.216 x 742.316, was tested and a very strong progeny effect was observed ($P<0.001$) (Figure 2).

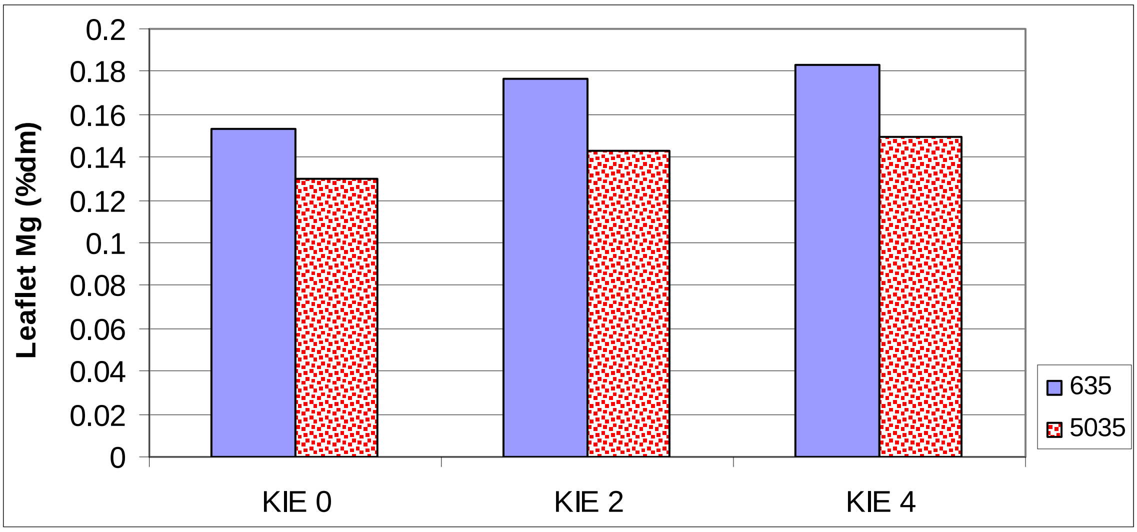


Figure2. Mg concentration in leaflets for two progeny, 2008.

Other nutrients appeared to be present in adequate amounts (Table 6). P in the rachis was on the low side in 2007 but is now adequate.

Table 6. N, P, K and B tissue levels in 2008 (Trial 148).

	Nutrient concentration (% dm)	
	Leaflet	**Rachis**
N	2.71	0.43
P	0.152	0.101
K	0.85	2.10
B	16 ppm	

CONCLUSION

Yield

After five years of experimentation it has not been possible to demonstrate a yield response to Magnesium fertilizer (as Kieserite) over a large block. There has also been increased uptake of Mg in the fertilised treatments, as measured by higher levels of leaflet Mg.

Progeny effect

Yield: a strong progeny effect was observed: progeny 714 and 5035 had a lower yield compared to progeny 635.

Tissue nutrient content: there were large differences in the uptake of Magnesium, as assessed by leaflet Mg levels, between two different progeny.

Boron Fertilizer Research

Trial 149: B Response using Large Plots in OPRS Progeny Trials, Kumbango

SUMMARY

Boron fertilizer responses in oil palm were investigated over large blocks in conjunction with OPRS breeding trials. Three replicate blocks with three levels of applied Boron fertilizer were set up in 2003.

So far it is possible to demonstrate an increase in B uptake through higher levels of leaflet B in treated plots compared to the nil controls. However, the differences in leaflet B have not been translated into a yield effect. The average yield produced in 2007 was around 24 t/ha.

Three of the planted progeny were found in all the trial blocks which made it possible to analyse a progeny effect on yield and Boron uptake (however note that the number of palms representing each progeny were not the same between blocks). There was no difference between the progeny in the yield response to boron.

Boron content in leaflets continues to differentiate between treated and untreated plots.

2008 was the last year for this trial, it is now closed.

METHODS

Boron deficiency is suspected of being involved in problems with fruit set and poor maturation in oil palm. We suspect a strong interaction between progeny and B fertilizer effects, and this trial utilises information from OPRS breeding trials in conjunction with OPRA fertilizer trials. The trial is a collaborative effort between OPRA and OPRS. This trial complements a factorial trial with boron and other nutrients set up at Poliamba.

Background information on the trial site is described in Table 1.

Table 1. Trial 149 background information.

Trial number	**149**	Company	NBPOL
Estate	Kumbango	Block No.	Div II (OPRS breeding trials)
Planting Density	128 palms/ha	Soil Type	Volcanic
Pattern	Triangular	Drainage	Free draining
Date planted	2001	Topography	Flat to gently undulating
Age after planting	7 years	Altitude	? m asl
Treatments 1st applied	July 2003	Previous Land use	Not known
Progeny	known	Area under trial soil type (ha)	Not known
Planting material	Dami D x P	Agronomist	Rachel Pipai

Basal fertilizer applied in 2007 in Trial 149: 3.0 kg/palm DAP, 2.0 kg/palm MOP and 2.0 kg/palm KIE. Fertilizer applications by OPRA are being carried out in collaboration with Dami OPRS.

The B trial utilises large blocks using four OPRS breeding trial sites located at Kumbango (OPRS trials 285, 286, 287 and 288). The OPRS trial sites were planted to 75 progeny of 9 palms each. Each OPRS trial site was divided into three equal sized blocks of approximately 225 palms, on which three rates of B are applied annually (0, 80 and 160 g/palm of Borate) (Table 2).

Table 2. B fertilizer treatments (annual rates of Borate in g/palm) in Trial 149. The 'blocks' referred to are replicates of the breeding trials and are plots for the fertilizer trial.

OPRS Trial:	**285**			**286**			**287**			**288**		
Block:	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
Treatment:	0	80	160	160	80	0	0	80	160	160	80	0

The trial is analysed as a one-way ANOVA of B level with 4 replicates (each progeny trial being a replicate). Two-way ANOVA of B (3 levels) x progeny (3 progeny) with 4 replicates will be carried out for those progeny that are found in all three trials (635.607 x 742.207, 714.712 x 742.316, and 5035.216 x 742.316).

Progeny 635 has a high OER (Oil Extraction Rate) and is being used as a parent in much of the seed produced by Dami.

RESULTS and DISCUSSION

Effect of Boron fertilizer on yield in 2008

Similar to previous years, in 2008 there was no significant effect of Boron application on yield, bunch number or bunch weight (average yield 24.2 t/ha, bunch number 13.2 b/palm and SBW of 14.1 kg/bunch .

There was no difference in B response between the four breeding sites, however all three treatments yielded less at OPRS site 288 (3 to 4 t/ha less) (Figure 1).

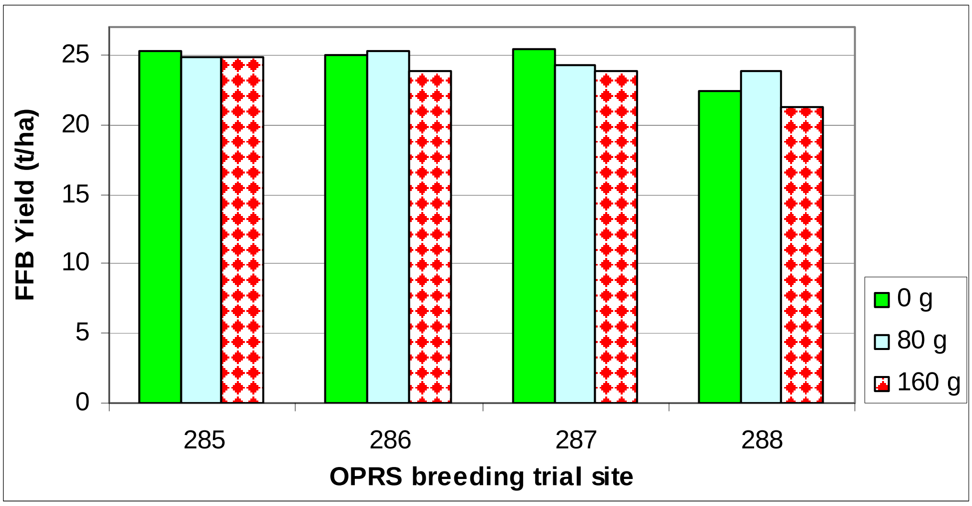


Figure 1. FFB yield for three rates of applied Boron fertilizer at four OPRS breeding sites.

Effect of boron fertilizer on the yield of different progeny in 2008

There were three progeny which were common to each breeding trial, hence it was possible to investigate a progeny effects on yield and whether there was an interaction between progeny and boron uptake. In previous years progeny 635 and 5035 had a significantly higher yield compared to progeny 714. However, in 2008 the progeny effect was not significant (Table 3). In 2008, there was a yield penalty when using 160g/palm borate compared to using zero or 80 g/palm – this has not been observed before and is likely to be an aberration.

Table 3. Yield for three progeny in 2008.

	Yield t/ha		
Borate g/palm	**0**	**80**	**160**
Progeny			
635.607 x 742.207	27.0	26.6	23.2
714.712 x 742.316	23.7	26.0	22.3
5035.216 x 742.316	25.2	27.0	22.9
Significant difference:			
B rate		**0.02**	
Progeny type		**0.42**	
B x Prog		**0.89**	
$LSD_{0.05}$		**4.4**	
CV%		**12.0**	

Effect of boron fertilizer on tissue nutrient concentration

In 2003, the year in which B fertilizer was first applied, the leaflet B levels were similar across the treatment areas. From then on the effect of B fertilizer and the rate of applied fertilizer on leaflet B levels has been significant (Table 4).

Table 4. Leaflet B levels (ppm) for three rates of applied B fertilizer for six years. Note: 2003 was the year that B fertilizer was first applied.

	Applied Borate (g/palm)		
Year	**0**	**80**	**160**
2003	14.2	13.8	13.4
2004	13.5	15.8	18.3
2005	12.7	15.5	16.8
2006	15.4	18.3	20.1
2007	12.6	15.9	16.5
2008	14.1	17.1	19.2

Leaflet B levels increased significantly with increasing B application rates ($P<0.001$). The difference in the uptake of B by different progeny was not significant ($P=0.08$) (Figure 2).

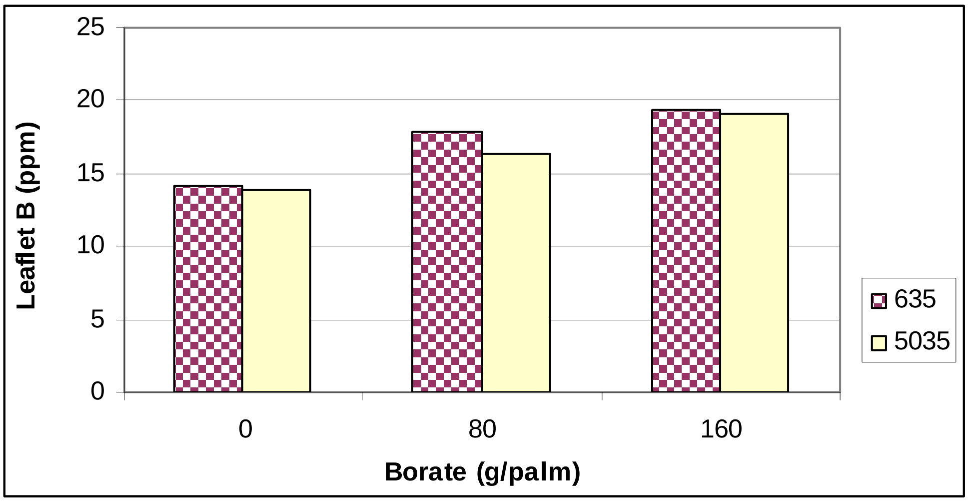


Figure 2. Leaflet boron levels (ppm) for two progeny, 635 and 5035, in 2008.

Other tissue nutrient levels were all found to be adequate (Table 5).

Table 5. Differences in tissue nutrient concentration (% dm) in the leaflet and rachis for two progeny.

	Tissue nutrient concentration (% dm)	
	Leaflet	**Rachis**
Nitrogen	2.67	0.42
Phosphorus	0.153	0.084
Potassium	0.84	1.89
Magnesium	0.18	-

CONCLUSION

Yield

After four years of experimentation it has not been possible to demonstrate a yield response to Boron fertilizer. There has been increased uptake of B in the fertilised treatments, as measured by higher levels of leaflet B.

Progeny effect

Yield: In previous years a strong progeny effect has been observed with progeny 714 having a lower yield compared to progeny 635 and 5035. However, in 2008 this was not observed and there were no significant differences in yield between the three progeny.

Tissue nutrient content: there were no differences in the uptake of Boron, as assessed by leaflet B levels, between two different progeny.

Note: this is a difficult trial to analyse and interpret because the number of palms for each of the recorded progeny is not the same in the different blocks (in some blocks there were 9 palms represented for a progeny, in another block there may have been 18). 2008 was the last year that this trial was in operation, the trial is now closed.

Trial 139: Palm Spacing Trial, Kumbango

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. From 2003 to 2006 there were no differences in yield attributed to the different plantings. In 2007 there was a small difference in yield, with the Wide avenue spacing yielding slightly less compared to the Standard avenue spacing (31.2 vs 33.4 t/ha). However, in 2008, the yields dropped by about 9 t/ha across Kumbango and there was no significant difference between the avenue spacings (23.7 vs 24.5 P=0.08). There is no difference between spacing treatments in leaflet and rachis nutrient concentrations.

INTRODUCTION

The purposes of this trial are 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 (ie 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.

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	? 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	Rachel Pipai

Basal fertilizers applied in 2008: AN 1.5kg/palm, DAP 3kg/palm, MOP 2kg/palm and Boron 0.15kg/palm.

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	128	9.5	7.8
3	8.6 x 8.6 x 8.6	128	10.6	7.5

RESULTS and DISCUSSION

Spacing treatment effect on yield in 2008

For the first time in this trial, in 2007 there was a small but significant effect of reduced yield with the wider avenue spacing, however this effect had again disappeared in 2008. The Wide avenue spacing was slightly lower in yield compared to the Standard spacing.

Table 3. Impact on yield, bunch number and SBW from three row spacing treatments in 2008

Spacing	Yield t/ha	Bunch No. Bunch/palm	SBW kg
Standard	24.5	10.3	18.9
Intermediate	24.0	10.0	19.1
Wide	23.7	10.0	18.9
Significant difference	**NS**	**NS**	**NS**
LSD	-	-	-
CV%	**1.3**	**1.6**	**1/1**

Spacing treatment effect on yield over time

Yield increased from 16.0 t/ha in 2003 to 32 t/ha in 2007 and decreased dramatically in 2008 to below 25 t/ha. The observed yield loss occurred in all trials in Kumbango. Only in 2007 has a small yield difference become evident between the Standard and the Wide avenue spacing, this difference was not evident in 2008.

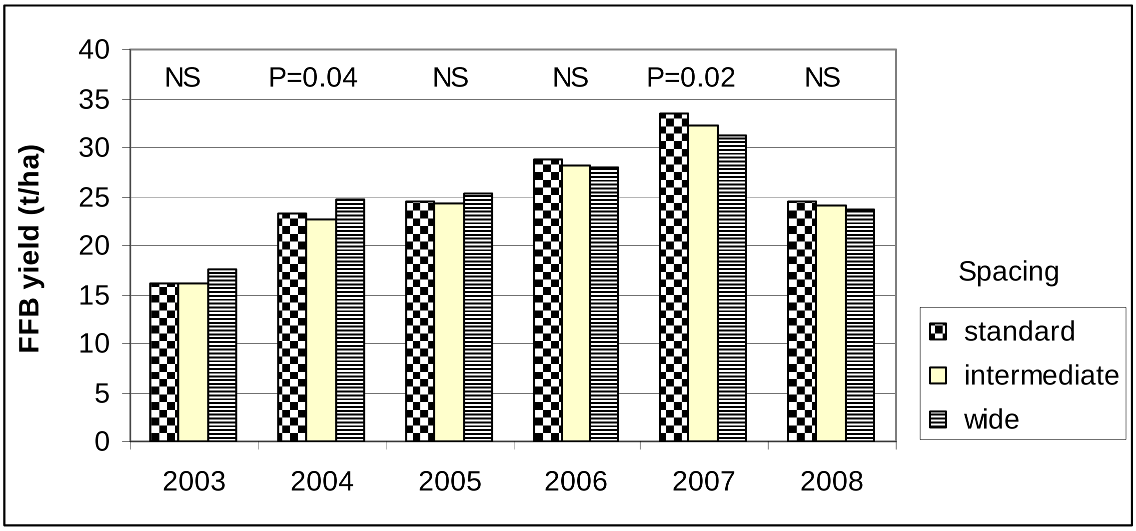


Figure 1. The impact of Avenue width on yield (keeping planting density the same) for Trial 139.

Spacing treatment effect on tissue nutrient levels

There were no differences in the nutrient status of the different spacing treatments (Table 3). Leaflet and Rachis N dropped from last year (2.60 to 2.45 for leaflet N and 0.33 to 0.25 for rachis N). P and K were both adequate. P levels increased from previous year's sampling following the application of basal P.

Table 3. Leaflet and rachis nutrient status for three different Avenue widths in 2008 (T139)

Avenue Width	**Leaflet nutrient concentration (% dm)**			**Rachis nutrient concentration (% dm)**		
	N	**P**	**K**	**N**	**P**	**K**
Standard	2.45	0.144	0.77	0.24	0.084	1.46
Intermediate	2.46	0.143	0.77	0.27	0.077	1.45
Wide	2.43	0.145	0.79	0.27	0.080	1.50
Significant diff:	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

Magnesium and Boron levels were near adequate (0.16 %dm and 15 ppm respectively).

CONCLUSION

At this stage in the trial, as palms are reaching maturity, there is still little differences in yield between planting palms at a standard avenue width of 8.2m compared to wider avenues of 9.5 and 10.6m (whilst keeping density the same). The Standard avenue treatment yielded 24.5 t/ha and the Wide avenue treatment yielded 23.7 t/ha.

Milne Bay Estates, MBE: Summary

(Dr. Harm van Rees and Wawada Kanama)

Fertilizer response trials were designed to determine the Maximum Agronomic Yield and using the marginal cost : price ratio the fertilizer rates required to achieve the Optimum Economic Yield. Two of these trials were established over a decade ago and it is now possible to determine robust fertilizer recommendations for mature palms grown on the most common soil types at MBE.

Trial 511 was closed at the end of 2007 because the site was due for replanting. It is expected that the site for trial 502 will be replanted in 2010.

New trials have been set up to further elucidate information on optimising N and K fertiliser rates, as well as finding the optimum placement for K (MOP) fertilizer.

A large yield loss was observed for trials at MBE in 2008. This yield penalty in 2008 had also been observed at some other locations other then at MBE (for example at NBPOL). It was suggested that the drop in yield may have been related to rainfall (two years pervious to the harvest year). It is unlikely that this is the reason for the drop in yield (Figure 1).

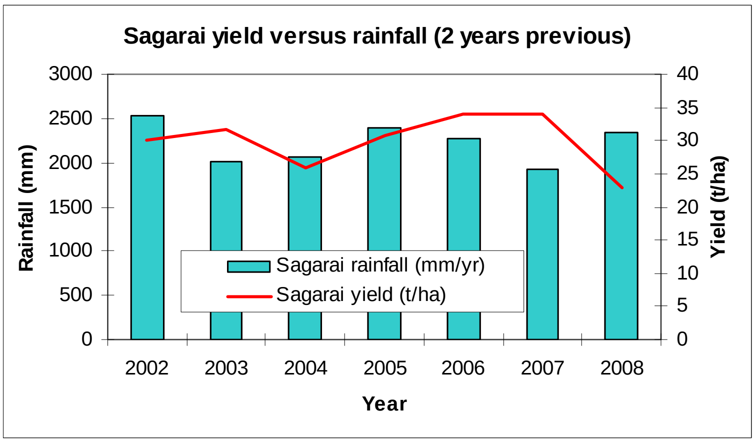


Figure 1. Annual yield achieved in Trial 504 at Sagarai plotted against rainfall (rainfall from two years previous to the harvest year).

It is not immediately clear what caused the drop in yield but it is clear that is from a reduction in bunches formed during 2008. Trial 515 is designed to elucidate the reasons for large fluctuations in oil palm yield, several more years of data are required before this trial can be used to identify the reasons for poor production.

Tissue analysis is used to identify nutrient deficiencies in plantation oil palm blocks. At Milne Bay Estates the nutrient levels which can be regarded as adequate are:

Apparent adequate tissue nutrient levels (for mature oil palm):

Leaflet (% dm)					Rachis (%dm)		
N	**P**	**K**	**Mg**	**B**	**N**	**P**	**K**
2.45	0.145	0.65	0.20	15ppm	0.33	0.10	1.2

MBE: Synopsis of 2008 trial results and recommendations

Trial	Palm Age	Yield t/ha	Yield Components	Tissue % dm	Vegetative	Notes
504 Sagarai SOA, MOP Soil: Alluvial	18	Control 14 SOA+MOP 24	Bunch/p 5.7 to 8.9 SBW 24 to 26 kg	SOA LN 2.21 to 2.41 MOP LK 0.51 to 0.61 RK 0.57 to 1.59 (LP 0.152, RP 0.180)	PCS 49 to 54 FP 25 to 26 LAI 5.3 to 5.8	Main response to N, some response to K. Large yield drop (8 t/ha) compared to 2006 and 2007.
502 Waigani SOA, MOP, TSP, EFB Soil: Alluvial	22	Control 15 SOA+MOP+TSP+ EFB 27	Bunch/p 7 SBW 22 to 30 kg	SOA LN 2.14 to 2.38 MOP LK 0.45 to 0.63 RK 0.57 to 1.91 TSP LP 0.135 to 0.150 RP 0.12 to 0.19		Main response to N, some response to K and little response to P. Large yield drop (8 t/ha) from 2006, 2007 to 2008.
516 SOA, MOP Soil: Alluvial	7	No significant difference, Ave. yield 25t/ha	Bunch/p 12 SBW 16 kg	SOA LN 2.50 RN 0.36 MOP LK 0.50 to 0.65 RK 0.75 to 1.40 LP 0.149; RP 0.14		First full year following first fertiliser treatments. No effect on yield but some tissue nutrient level effect (primarily LK and RK).
517 MOP placement Soil: Alluvial	7	No significant difference Ave. yield 24 t/ha	Bunch/p 11 SBW 16 kg	MOP placement LK 0.58; RK 1.4 (NS)		First full year following first treatment application. No effect on yield but zero MOP treatments significantly lower in Leaf and Rachis K

Tissue analysis is used to identify nutrient deficiencies in plantation oil palm blocks. At Milne Bay Estates the nutrient levels which can be regarded as adequate are:

Apparent adequate tissue nutrient levels (for mature oil palm):

Leaflet (% dm)					Rachis (%dm)		
N	**P**	**K**	**Mg**	**B**	**N**	**P**	**K**
2.45	0.145	0.65	0.20	15ppm	0.33	0.10	1.2

Recommendations to MBE:

1. On the alluvial soils at MBE an oil palm yield of 35 t/ha should be attainable. Higher rates of fertilizer are required on hilly country (soils with buck shot) compared to the lower lying alluvial soils.
2. Tissue testing and Vegetative measurement criteria will help in determining deficiencies of particular nutrients
3. Most of the focus for nutrition should be on N, followed by K and P, boron is also required (Mg is provided by the soil and is not required)
4. Plantation management (harvest time, pruning, clean weeded circles, fertilizer application and timing etc) all play a large role in the potential to optimize production

Trials 502 and 511: N, P, K and EFB factorial trials, Waigani

SUMMARY

Two trials, 502 and 511, with the same treatments, were established in 1994/95 in the Waigani estate at CTP Milne Bay. The soil type on which the trials are located are different – 502 is relatively flat and soils are alluvial in origin with a high clay content (50 to 60% clay); whilst 511 has a terraced appearance, soils contain buckshot, are also alluvial in origin but have less clay (around 30%) and a higher sand content (50 to 60%).

Both trials were set up to test the yield response to N, P, K fertilizers in a factorial combination, with and without EFB. 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).

The response of the fertilizer treatments in yield has been positive for some years and this trend continued into 2007.

Trial 502 had a higher inherent soil nutrient status at the start of the trial compared to Trial 511 and the lowest and average yields have been higher for Trial 502. At both sites, the highest yielding treatments achieved a yield of 34 t/ha in 2007, however Trial 511 required more fertilizer to achieve this yield.

Trial 511 was closed at the end of the 2007 season as the site was planned for re-planting in 2008.

This paper reports on the results for both trials of the fertilizer requirements required to achieve Maximum Agronomic Yield and Optimum Economic Yield. The full results for both of these trials are published in an OPRA final report.

METHODS

Trial Background Information

Table 1. Trial 502 and 511 background information.

Trial number	**502**		
Estate	Waigani	Company	CTP Milne Bay Estates
Planting Density	127 palms/ha	Block No.	Field 6503, 6504
Pattern	Triangular	Soil Type	recent alluvial origin
Date planted	1986	Drainage	Poor
Age after planting	22 years	Topography	Flat
Recording Started	1995	Altitude	103 m asl
Progeny	unknown	Previous Landuse	Cocoa/coconut plantings
Planting material	Dami D x P	Area under trial soil type (ha)	1067
Trial number	**511**	**NOW CLOSED**	
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

Experimental Design and Treatments

Trials 502 and 511 are factorial fertilizer trials 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 is represented by a single plot (4 x 4 x 2 x 2 = 64 plots). The trials have four replicate blocks within which the main effects of N and K are replicated. Each plot contains 16 core palms, which are surrounded by a guard row and a trench. Trial fertilizers 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 fertilizers are applied in 3 doses per year.

Table 2. Amount of fertilizer and EFB used in Trials 502 and 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	-	-

Data Collection and Analysis

Yield recording (weighing of bunches) was done on a fortnightly basis, which changed to 10 day harvest rounds in 2007 following company practice.

(i) Statistical analysis

Linear multiple regression was used to analyze the yearly influence of fertilizer N, P and K on yield. For the regression analysis the plots with EFB were separated from those plots with no EFB. EFB is an organic fertilizer high in K and through mineralization of the humus material there is also a slow but significant release of available N (as nitrate and ammonium). Hence EFB has an influence on both N and K nutrition of oil palm and the analysis was separated into 'with' and 'without' EFB, otherwise it would confuse the true response to the mineral forms of N, P and K. In this report only the response to mineral fertilizer is reported (note the effect of EFB on yield is reported in the final report for these two trials – see OPRA final reports).

In the regression equation, yield is the dependent variable, and N, P and K fertilizers are the independent variables.

The full polynomial equation (quartic) for the treatments in this trial takes the form of:

$$Yield = a + bN + cN^2 \pm dK \pm eK^2 \pm fP + gN.K + hN^2K \pm iN.K^2 \pm jN^2.K^2 + kN.P + lK.P$$

However the higher order, N^2K, NK^2 and N^2K^2, and NP, KP interactions have little effect and were not included in the final analysis, which simplified the equation to a quadratic equation:

$$Yield = a \pm bN \pm cN^2 \pm dK \pm eK^2 \pm fP + gN.K \quad \text{(equation 1)}$$

where a, b, c, d, e, f and g are the parameters to be calculated. The last term, g, represents the linear by linear interaction between N and K fertilizers.

To calculate the application rate of N and K to achieve Maximum Agronomic Yield, the derivative of equation 1 is obtained with respect to N and K fertilizer. Solving the resulting simultaneous equations gives N and K application rates at the point of Maximum Agronomic Yield (for further information see Verdooren, 2003; and Webb, 2009).

(ii) Economic analysis

The economic analysis involves finding the point at which the marginal cost of inputs equals the marginal return on income (the point at which higher fertilizer rates actually result in decreased profit). The procedure involves finding the ratio of the cost of a unit of fertilizer nutrient to the value of a unit of palm oil and equate it to the derivative of the yield with respect to the rate of fertilizer added (Verdooren, 2003).

This is a convenient method for analyzing rates of return because the plantation manager can easily calculate the ratio of fertilizer cost to the value of palm oil, and apply these ratios to the response equations. There is no need for complicated gross margin analysis and substituting these costs and returns into the quadratic equations obtained from the trial results. The manager simply calculates the current ratio (marginal cost of fertilizer / marginal value of palm oil) and finds the point on the response graph where the rate of N and K fertilizer provides the Optimum Economic Yield.

RESULTS and DISCUSSION (Trials 502 and 511)

Yield and its response to mineral fertilizer treatments

To calculate the responses to various rates of N (applied as SOA), K (applied as MOP) and P (applied as TSP) we took the three year average data for 2007 (2005 to 2007) and calculated the parameters of interest using regression analysis (see equation 1). Three year average data was used to smooth out some of the year to year fluctuations in plot yield. The estimated value of the parameters and their level of significance for 2007 (average three year yield for each year) are presented in Table 2.

Table 2. Estimated value of the regression parameters and its level of significance for trial 502 and 511 (excluding EFB) for 2007 (three year average yield data).

	T 502 2007 (2005 to 2007) yield		T 511 2007 (2005 to 2007) yield	
	parameter	**significance**	**parameter**	**significance**
constant	15.26		6.30	
N	3.245	**<0.001**	2.995	**<0.01**
N^2	2.283	**<0.01**	1.443	**<0.05**
K	-0.462	**<0.01**	-0.185	0.151
K^2	-0.247	**<0.01**	-0.154	0.067
NK	0.163	**<0.05**	0.070	0.389
P	0.380	0.38	2.653	**<0.001**
R^2	0.84		0.86	
Max N	4.6		9.4	
" K	6.1		6.8	

Note: the parameters and fertilizer rates required to reach Agronomic Maximum Yield (Max N and Max K) listed in the table refers to SOA (for N), MOP (for K) and TSP (for P)

The quadratic functions for average three year yield in 2007 were:

T502: $2007_{(3\ yr\ mean)}$ yield = 15.26 + 3.245 N – 0.462 N^2 + 2.283 K - 0.247 K^2 + 0.163 N.K + 0.38 P R^2=0.84

and

T 511: $2007_{(3\ yr\ mean)}$ yield = 6.30 + 2.995 N - 0.185 N^2 + 1.442 K - 0.154 K^2 + 0.070 N.K + 2.65 P R^2=0.86

Note in the above equations N refers to SOA, K to MOP and P to TSP.

The stationary points for maximum agronomic yield in 2007 are:

Trial 502: N (as SOA) at 4.6 kg/palm and K (as MOP) at 6.1 kg/palm, and

Trial 511: N (as SOA) at 9.4 kg/palm and K (as MOP) at 6.8 kg/palm. (Note that this stationary point for maximum yield is outside the treatment rates for N used in the trial, and therefore we need to extrapolate the optimum fertiliser use for maximum yield).

In trial 502 the effect of P is only minor and not significant (the response to P, as TSP at 2kg/palm, was only 0.76 t/ha). However, in trial 511 the response to P was large and significant (the response to P was 5.3 t/ha).

The quadratic response surfaces for yield in 2007 (three year average yield), with Maximum Agronomic Yield highlighted, are presented in Figure 1.

Figure 1. Yield response curves to SOA and MOP using three year average yield data for $2007_{(2005\text{-}2007)}$ for trials 502 and 511 (no EFB). The N and K fertiliser input for Maximum yield achieved is represented by the black half circle ◓ .

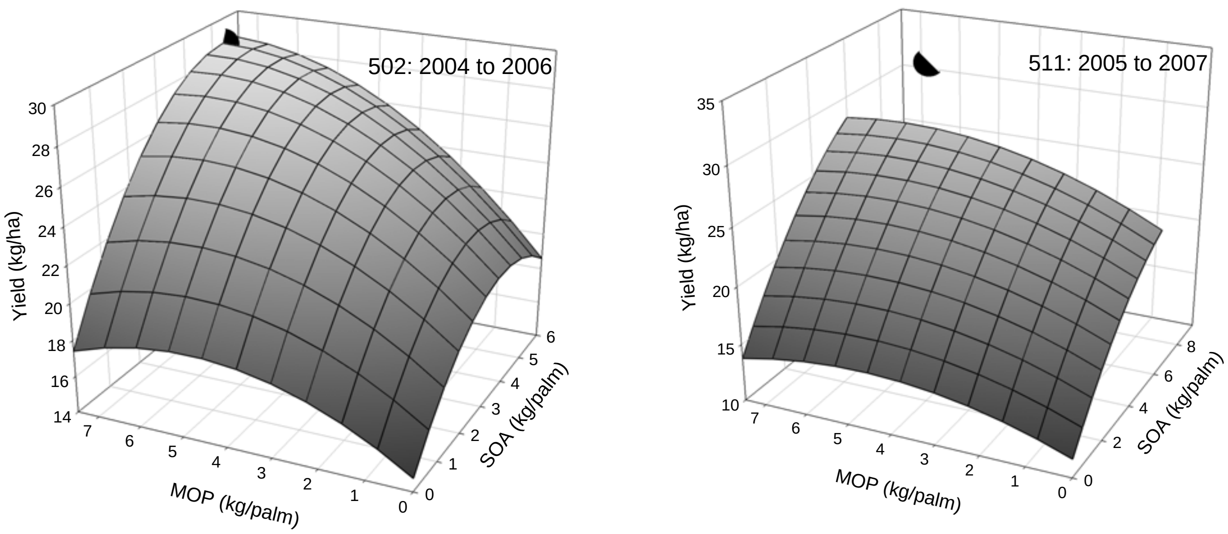


Figure 1. Yield response curves to SOA and MOP using three year average yield data for $2007_{(2005-2007)}$ for trials 502 and 511 (no EFB). The N and K fertiliser input for Maximum Agronomic Yield achieved is represented by the black half circle.

Economic analysis

The maximum agronomic yield does not always equal the optimum economic yield. At some point the cost of extra fertilizer can become greater then the return from the extra palm oil produced. A convenient way for plantation managers to evaluate the cost : price impact in relation to optimum yield is to apply the ratio of marginal cost (inputs) to marginal returns (outputs). For the case with fertilizers this is calculated as the marginal cost of an extra unit of fertilizer against the return of an extra unit of palm oil. Following this procedure is simpler than a gross margin analyses because the plantation manager just has to calculate the marginal cost : price ratio and look up the economic application rates on a graph.

This theory of economic analysis was applied to the optimum agronomic yield calculated in the previous section for 2007 (three year average yield). The economic optimum N and K fertilizer application rate, was calculated for representative marginal cost : price ratios (r_n and rk) between the values of r_n = 0.2 and 0.8, and for r_k = 0.2 to 0.8. The resulting optimum economic fertilizer rates using the 2007 (3 year mean yield) response equation for the various cost : price ratios were graphed for N (as SOA rates) and K (as MOP rates) (Figure 2).

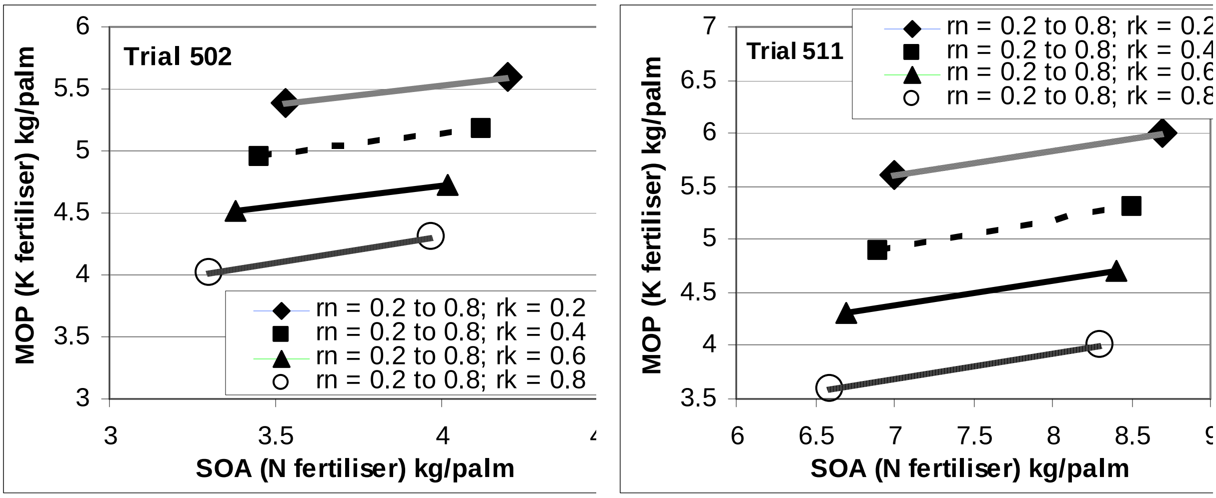


Figure 2. Marginal cost : price ratios as calculated for the Yield response equation obtained for trials 502 and 511in 2007 (3 year average yield).

A working example:

Take the cost of SOA to be US$360/t and MOP to be $380/t; and the price for CPO to be US$520/t. Assume an OER (oil extraction ratio of 0.23).

(i) The marginal cost of an extra kg/palm of SOA is:

0.36 $/kg x 1 kg/palm x 127 palms/ha = $45.72/ha

(ii) The marginal cost of an extra kg/palm of MOP is:

0.38 $/kg x 1 kg/palm x 127 palms/ha = $48.26/ha

(iii) The marginal return for an extra tonne of CPO is:

1t FFB/ha x 0.23 (OER) x 520 $/t (CPO) = $119.60

Hence the r_n = 45.72 / 119.60 = 0.38, and the r_k = 48.26 / 119.60 = 0.40

Applying this example of marginal cost : price ratios to figure 2 (only for Trial 502), we find the point on the graph where r_n = 0.38 and r_k = 0.40 and then look-up the fertilizer rates for optimum economic yield (see Figure 3 for an example). The **Optimum Economic Yield** is achieved at 3.7 kg/palm SOA and 5.1 kg/palm MOP. (Note that the **Maximum Agronomic Yield** was achieved at 4.6 kg/palm SOA and 6.1 kg/palm of MOP).

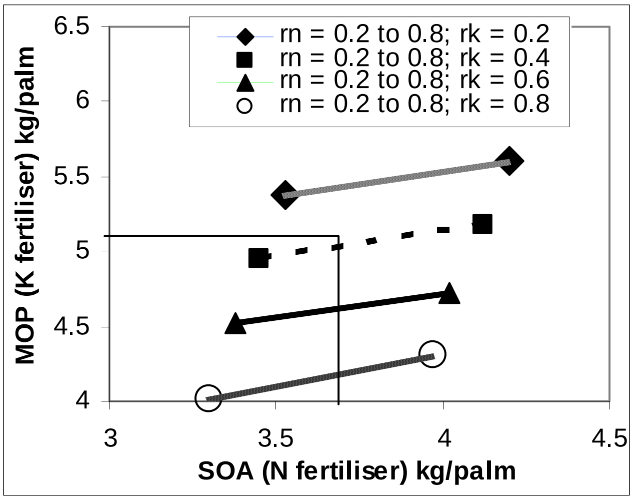


Figure 3. Point of greatest economic return (SOA and MOP fertilizer rates) for a marginal cost : price ratio of $r_n = 0.38$ and $r_k = 0.4$

CONCLUSION

Well designed and executed fertilizer trials can provide plantation managers with invaluable information on fertilizer rates to achieve (i) Maximum Agronomic Yield, and (ii) Optimum Economic Yield.

This information can be provided to plantation managers as simple graphs which outline the required information on which to base scientifically verified fertilizer recommendations.

References:

Verdooren, R (2003). Design and analysis of fertilizer experiments. In: Fairhurst, T.H and Hardter, R (eds) Oil palm: management for large and sustainable yields. Potash & Phosphate Institute/Potash, Phosphate Institute of Canada and International Potash Institute, Singapore, p 259-278

Webb, M.J. (2009). A conceptual framework for determining economically optimal fertiliser use in oil palm plantations with factorial fertiliser trials. Nutrient Cycling in Agroecosystems: Volume 83 (2): 163-178.

Trial 504. Nitrogen by Potassium trial, Sagarai

SUMMARY

Trial 504 was established in the Sagarai estate of the CTP Milne Bay Estate plantation, to test the response in oil palm to N and K fertilizer. 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 of SOA (0, 2.0, 4.0 and 6.0 kg/palm) and 4 rates of MOP (0, 2.5, 5.0 and 7.5 kg/palm).

FFB yield, frond 17 nutrient concentration and vegetative growth parameters responded well to the fertilizer treatments, especially to SOA as the N source. N drives production in this estate. Over the last few years the response to K fertilizer has been increasing.

Highest yields were significantly lower then in 2006 and 2007 (approximately 8 t/ha less) but 24 t/ha was still obtained from a combination of N and K fertilizer. In 2008 the optimum combination of N and K was 4 to 6 kg of SOA/palm (0.8 to 1.2kg N/palm) in combination with MOP at 5 kg/palm (2.25 kg K/palm).

METHODS

Trial Background Information

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	17 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	Agronomist in charge	Steven Nake

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). Fertilizer was first applied in 1994. Fertilizers are applied in 3 doses per year.

TSP at 0.5 kg/palm was applied as a basal in 2008.

Table 2. Types of treatment fertilizer 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 49% K.

Trial data was analyzed using standard two way analysis of variance procedures.

Data Collection

Yield recording (weighing of bunches) was done on a fortnightly basis, but following plantation practice changed to 10 day harvest rounds in 2007.

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.

RESULTS and DISCUSSION

Yield and other components response to fertilizer 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. The effect of the treatments, especially SOA in increasing yield has been consistent over the last seven years. The yield difference between the maximum level and zero level of SOA application widened in 2005, 2006, 2007 and continued into 2008 compared to the previous years however there was a fall in yields across all fertilizer treatments and levels. The mean FFB yield in 2007 was 29.5 t/ha and 20.2 t/ha in 2008. The effect of K fertilizer on yield, although significant from 2006 to 2008, is less marked compared to N fertilizer. The combination of both fertilizers resulted in the highest yields highlighting the importance of N and K nutrition on this soil type.

In 2008, SOA had a significant effect on FFB yield ($p<0.001$). SOA significantly increased FFB yield above 20 t/ha and this positive response resulted from a significant increase in both the number of bunches and the single bunch weight. MOP also had an impact on yield ($p<0.001$) and this was brought about by a positive effect on the number of bunches produced and the SBW.

Table 3. Effect (p values) of treatments on FFB yield and its components for 2007 and 2005 to 2007 (3 years averaged data). P values less than 0.05 are presented in bold.

	2008			**2006 to 2008**		
Source	**Yield**	**BN**	**SBW**	**Yield**	**BN**	**SBW**
SOA	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**
MOP	**0.003**	**0.02**	0.26	**<0.001**	**0.009**	**0.02**
SOA.MOP	0.12	0.20	0.14	0.61	0.27	0.36
CV %	10.7	10.5	5.5	8.0	6.9	2.0

Table 4. Main effects of treatments on FFB yield (t/ha) and its components for 2008 and 2006 to 2008 (three years averaged data). P values less than 0.05 are presented in bold.

	2008			**2006 to 2008**		
	Yield (t/ha)	**BN (b/ha)**	**SBW (kg)**	**Yield (t/ha)**	**BN (b/ha)**	**SBW (kg)**
SOA0	**16.4**	**726**	**22.5**	**21.6**	**957**	**22.6**
SOA1	**19.7**	**804**	**24.5**	**26.1**	**1066**	**24.7**
SOA2	**21.9**	**829**	**26.4**	**28.4**	**1023**	**25.9**
SOA3	**22.7**	**875**	**26.0**	**29.3**	**1158**	**25.6**
MOP0	**18.8**	**765**	24.5	**24.3**	**1016**	**24.0**
MOP1	**19.8**	**788**	25.0	**26.6**	**1074**	**24.8**
MOP2	**21.8**	**858**	25.4	**27.5**	**1089**	**25.3**
MOP3	**20.3**	**822**	24.6	**27.1**	**1105**	**24.6**
$LSD_{0.05}$	*1.5*	*83*	*1.0*	*1.5*	*53*	*0.8*

Combinations of both SOA and MOP produced the highest yields (Table 5). The highest FFB yield of 24 t/ha was obtained when 4 kg of SOA /palm was applied together with 5 kg of MOP/palm.

Table 5. Effect of SOA and MOP on FFB yield (t/ha) in 2008 and 2006 to 2008 (three year average data). The treatment interactions are not significant.

SOA by MOP – 2008				
	MOP0	MOP1	MOP2	MOP3
SOA0	14.4	14.6	19.5	17.0
SOA1	21.0	21.0	20.3	19.1
SOA2	19.1	22.3	24.0	22.0
SOA3	23.1	21.4	23.2	23.0

SOA by MOP – 2006 to 2008				
	MOP0	MOP1	MOP2	MOP3
SOA0	19.8	20.7	23.6	22.3
SOA1	23.5	26.7	27.2	27.1
SOA2	26.0	28.6	30.6	28.5
SOA3	28.0	30.2	28.7	30.3

Fertilizer effects on Frond 17 nutrient concentrations

N and K fertilizer had a significant impact on tissue nutrient concentration (Tables 6 and 7). SOA application increased the level of N in the leaflets and reduced the level of K. In the rachis, N levels increased with increasing rates of SOA, whilst P and K levels decreased.

Leaflet concentrations of K were increased by increasing rates of MOP; in the rachis both P and K levels were increased with higher MOP rates.

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 (9ppm) were low
- N fertilizer mobilized P and K out of the rachis
- K in the rachis was very low for the zero MOP treatment

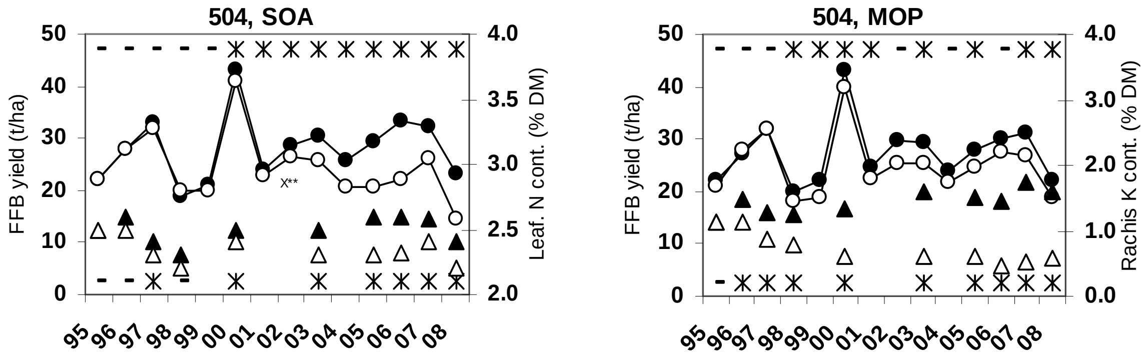
With very low values of K in the rachis for the zero MOP treatment, palms in these plots will experience increasing deficiency in K, as already exhibited in the leaflets with this treatment, and yields in this treatment are likely to fall in the near future.

Table 6. Effect (p values) of treatments of frond 17 nutrient concentration. P values < 0.05 are shown in bold.

Source	Leaflet nutrient concentration			Rachis nutrient concentration		
	N	P	K	N	P	K
SOA	**<0.001**	0.12	**<0.001**	**0.04**	**<0.001**	**<0.001**
MOP	0.85	0.51	**<0.001**	0.43	**<0.001**	**<0.001**
SOA.MOP	0.19	0.32	0.86	0.22	0.07	0.64
CV %	3.5	2.2	6.1	5.8	10.6	10.8

Table 7. Main effects of treatments on frond 17 nutrient concentration. P values < 0.05 are shown in bold. All units expressed in % dry matter..

Source	Leaflet nutrient concentration			Rachis nutrient concentration		
	N	P	K	N	P	K
SOA0	**2.21**	0.153	**0.60**	**0.36**	**0.261**	**1.40**
SOA1	**2.25**	0.153	**0.59**	**0.36**	**0.215**	**1.29**
SOA2	**2.34**	0.150	**0.56**	**0.37**	**0.163**	**1.19**
SOA3	**2.41**	0.152	**0.55**	**0.38**	**0.132**	**1.12**
MOP0	2.31	0.153	**0.51**	0.37	**0.160**	**0.57**
MOP1	2.31	0.152	**0.57**	0.36	**0.197**	**1.27**
MOP2	2.29	0.151	**0.61**	0.36	**0.211**	**1.56**
MOP3	2.31	0.152	**0.61**	0.36	**0.208**	**1.59**
$LSD_{0.05}$	*0.06*	-	*0.02*	*0.02*	*0.015*	*0.10*



Legend:
Lines = FFB yields — Triangles = tissue concentrations
Full symbols = maximum level of application — Empty symbols = zero application
Symbols at top (yield) and bottom (nutrient) of the graph indicate significance of the main effects
Stars indicate significance (p<0.05) — Dashes= non-significance

Figure 1. Main effects of SOA and MOP on yield and tissue nutrient concentration over the duration of Trial 504.

Fertilizer effects on vegetative growth parameters in 2008

Tables 8 and 9 present the fertilizer effects on vegetative growth parameters. Increasing rates of SOA had a positive and significant effect on the petiole cross section, frond production (by 1.0 frond/year), Leaf Area Index (LAI) by 0.5 units, and dry matter production. The addition of K also had beneficial impact on increasing the petiole cross section and dry matter production, however K fertilizer had little effect on frond production and frond size.

Table 8. Effect (p values) of treatments on vegetative growth parameters in trial 504, for 2008. Significant effects (p<0.05) are shown in bold.

Source	PCS	Radiation Interception				Dry Matter Production (t/ha)			
		GF	FP	FA	LAI	FDM	BDM	TDM	VDM
SOA	**<0.001**	**<0.001**	**0.02**	0.07	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**
MOP	**0.002**	0.44	0.09	0.23	0.44	**0.002**	**0.002**	**<0.001**	**<0.001**
SOA.MOP	0.13	0.66	0.07	0.04	0.07	0.07	0.09	**0.05**	0.06
CV %	5.9	3.9	6.6	4.9	6.4	9.5	10.2	6.8	8.9

Legend:

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)*	*Height*	*Height of palms (m)*

Table 9. Main effects of treatments on vegetative growth parameters in trial 504, for 2008. Significant effects ($p<0.05$) are shown in bold.

Source		Radiation Interception				Dry Matter Production (t/ha)			
	PCS	GF	FP	FA	LAI	FDM	BDM	TDM	VDM
SOA0	**49.1**	**31.8**	**24.6**	13.0	**5.3**	**16.3**	**8.9**	**28.1**	**19.1**
SOA1	**52.8**	**32.8**	**24.0**	13.0	**5.4**	**17.1**	**10.7**	**30.0**	**20.2**
SOA2	**55.1**	**33.6**	**25.6**	13.5	**5.7**	**18.9**	**11.7**	**34.1**	**22.3**
SOA3	**54.1**	**33.8**	**25.6**	13.5	**5.8**	**18.7**	**12.2**	**34.3**	**22.1**
MOP0	**50.0**	33.4	24.2	13.0	5.5	**16.6**	**10.1**	**29.4**	**19.3**
MOP1	**53.2**	32.7	25.0	13.1	5.5	**18.0**	**10.7**	**31.9**	**21.1**
MOP2	**54.1**	33.1	25.8	13.5	5.7	**18.7**	**11.8**	**33.9**	**22.1**
MOP3	**53.8**	32.8	24.8	13.3	5.5	**18.0**	**11.0**	**32.1**	**21.2**
$LSD_{0.05}$	*2.2*	*0.9*	*1.2*	*0.5*	*0.3*	*1.2*	*0.8*	*1.5*	*1.3*

Legend:

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)*	*Height*	*Height of palms (m)*

CONCLUSION

N fertilizer, applied as SOA, was the main driver of production in this trial. N treatments resulted in higher concentrations of N in the rachis and leaflets, increased the size of the PCS (petiole cross section), higher dry matter production of fronds and subsequent higher yields. The higher yield of palms in the N treatments was brought about by more and heavier bunches.

K fertilizer, applied as MOP, is becoming more important over time as K levels are dropping in the zero MOP plots. Palms in these plots now have low rachis and leaflet K levels.

Highest yield were 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 a low rate of MOP (2.5kg MOP/palm or 1.2kg K/palm).

Trial 513: Spacing and Thinning Trial, Padipadi

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.

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	5	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.

Fertilizer application will follow normal plantation practice for an immature fertilizer 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 between the treatments post-thinning in 2008 (Figure 1).

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 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 ($P=0.11$)

The difference in yield between planting density treatments was due only to the bunch number produced per hectare not to bunch weight (all treatments produced similar bunch weights).

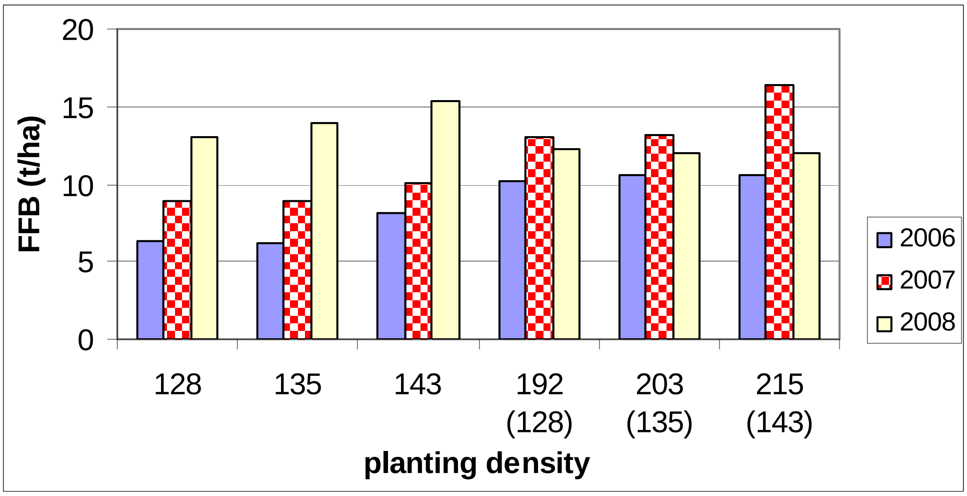


Figure 1. Trial 513: FFB yield for the pre-thinning years (2006 and 2007) and the post-thinning year (2008).
Note 1. the planting density in brackets refers to post-thinning
Note 2. in 2006 harvest commenced in April (yield only for April to December)
Note 3. post-thinning (in February 2008) harvest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

Of greatest interest is whether any one treatment had a higher yield over the period pre-thinning plus post-thinning. Treatments 1 and 2 (planted at 128 and 135 palms/ha) had a significantly lower yield compared to treatments 3, 4 and 5 (respectively planted at 143; 192 and thinned to 128; and planted at 203 and thinned to 135 palms/ha) compared to treatment 6 (planted at 215 and thinned to 143 palms/ha) (Figure 2).

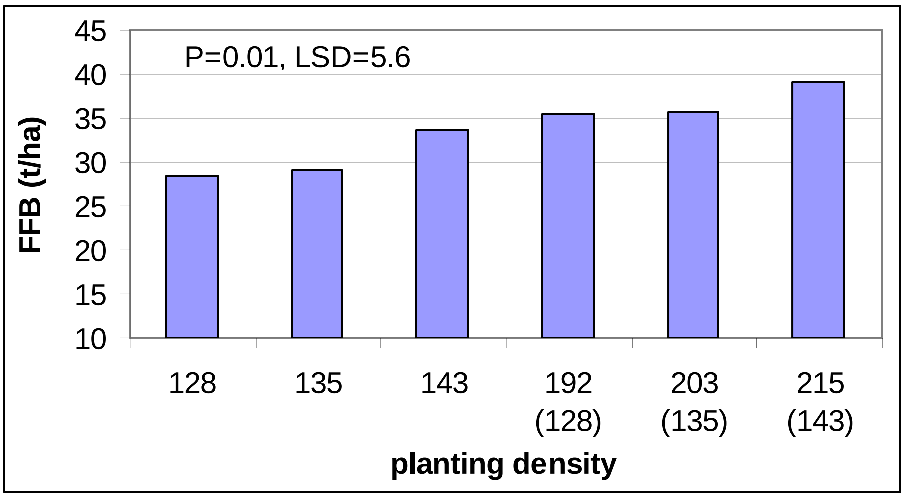


Figure 2. Total yield for six planting density treatments commencing pre-thinning (April 2006) to the end of 2008 (thinning took place in February 2008).
Note 1. the planting density in brackets refers to post-thinning

The trial should continue until full maturity to determine whether the yield in the high planting density plots (original planting at 143 palms/ha and the treatment planted at 215 and then thinned to 143 palms/ha) can maintain their current yield advantage compared to the lower density plantings.

CONCLUSION

Density treatment had a significant effect on yield and number of bunches produced in the pre-thinning and post-thinning phases. The highest yielding treatment over the three years of trial work, 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.

Trial 515: Flower monitoring trial, Hagita Estate

Trial 515 is a flowering monitoring trial (similar trials have been set up at Higaturu, Ramu and Poliamba) and can be used to estimate yield (4 to 6 months ahead of harvest). The real value of the monitoring trials will become apparent over time when sufficient data have been collected on female/male flower formation, frond production and harvest yield to model the effect of weather/climate on production.

In order to understand and manage the factors affecting oil palm yield we need to be able to identify specific stressors during the critical production phases:

- Number of flowers set (primordia) (38 months prior to harvest);
- Sex differentiation (23 months prior);
- Flower abortion (10 months prior); and
- Flowering (anthesis) (5 to 6 months prior),

and then determine the impact of these stress periods on future production potential.

These trials are an integral step towards providing this information.

Currently the information on yield forecasting is provided to plantation management, an example of such a report is provided below.

Quarterly Yield Estimate for January to May, 2009 (report to MBE management)

Trial description:

Location	Block LI1170 (Bishops Best Management Block), Hagita Estate
Date planted	1 May 1999
Current age of palms	10 years
Soil type	Alluvial
Monitoring commenced	2006
Fertiliser applied	3kg AC; 3.5 kg MOP and 0.05 kg/palm Borate (2007/08)

Aim: to provide the Estate with a monthly yield estimate (five months in advance) for this age palm on this soil type.

Number of flowers at mid-flowering over the last twelve months:

Month	Female flws/ha	Month	Female flws/ha	Month	Female flws/ha
Jan 08	107	May 08	28	Sep 08	116
Feb 08	80	June 08	31	Oct 08	163
Mar 08	38	July 08	66	Nov 08	173
Apr 08	37	Aug 08	111	Dec 08	159

Yield Estimation:

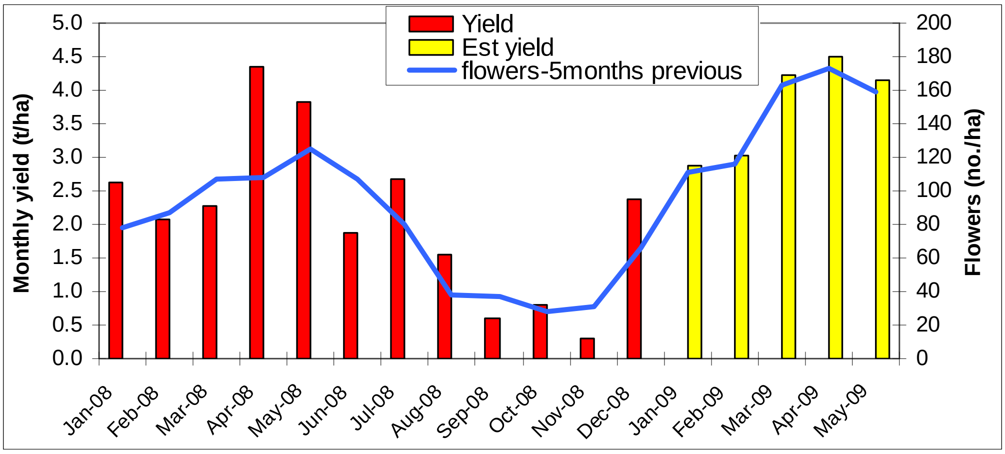


Figure 1. Monthly actual (red bars) and estimated (yellow bars) yield (t/ha) based on flowers formed per hectare in monitoring trial 515.

Interpretation:
The number of female flowers at flowering during July/August 2008 increased significantly from the previous four months (from around 30 flowers to over 100 flowers per month per hectare). As a result of the increase in flowering from July/August period yields have started to increase in December and will remain high to at least May 09.

Trial 516: New NxK trial at Maiwara Estate

SUMMARY

Treatments for a new NxK trial at Maiwara were first applied in May 2007. There were no differences in yield resulting from the application of different rates of N and K fertiliser, however there are some apparent differences showing in the tissue analysis (K fertiliser increased the rachis K level).

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 fertilizer treatments were applied in May 2007. Site details are presented in Table 1.

Table 1. Trial 516 back ground information

Trial number	**516**	Company	Milne Bay Estates
Estate	Hagita, Maiwara	Block No.	AJ 1290
Planting Density	143 p/ha	Soil Type	Alluvial
Pattern	Triangular	Drainage	Site is often waterlogged
Date planted	2001	Topography	Flat
Age after planting	7	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 2008: 0.5 kg TSP

METHODS

Plots were marked out in 2005 and pre-treatment data were collected throughout 2006 and 2007. First treatments were applied in May 2007 and hence 2008 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).

Trial 516 has the aim to identify the optimum economic return for N and K fertilizer application on alluvial soils at MBE. The trial consists of 13 plots with 5 treatment rates of both N and K (N range: SOA from 0 to 9 kg/palm and MOP from 0 to 7 kg/palm). A uniform precision rotatable central composite trial design was established, this design is standard for generating fertilizer response surfaces. For a 2-factor (k = 2) central composite design, the treatments consist of (a) 2^k (= 4 treatments) factorial, (b) 2k (= 4) star or axial points and (c) 5 centre points.

Linear multiple regression was used to analyze the yearly influence of fertilizer N and K on yield. In the regression equation, yield is the dependent variable, and N and K fertilizers are the independent variables.

The equation used is:

$Yield = a \pm bN \pm cN^2 \pm dK \pm eK^2 \pm fN.K$ (equation 1)

where a, b, c, d, e, f and g are the parameters to be calculated. The last term, f, represents the linear by linear interaction between N and K fertilizers.

Tissue samples (Frond 17) were also collected and the results of nutrient analysis are presented.

RESULTS

Yield

Two analyses were undertaken for 2008 – the first one was for the 2008 data alone and secondly we used 2006 yield as the co-variate for the 2008 analysis (we cannot use 2007 as the co-variate year because treatments were imposed half way during the year).

The regression equation for Yield in 2008 was:

$Yield_{2008} = 16.1 + 9.5\ N – 1.6\ N^2 + 4.1\ K – 0.2\ K^2 – 2.3\ N.K \quad R^2=0.44$

(note in the above equation N and K refer to units of nutrient applied in kg/palm)

The only parameter which was significant was the intercept (parameter a) at P=0.009. All other parameters were not significant indicating that at this stage in the trial there is no impact of the fertilisers on yield.

It was hoped to use the pre-treatment data as a co-variate to improve the relationship for the effect of fertiliser on yield. The use of co-variates means that the differences across the field in the pre-treatment data can be allowed for in the 2008 treatment data.

The regression equation for Yield in 2008 whilst using Yield 2006 as a co-variate was:

$Yield_{2008} = 11.4 + 7.8\ N – 1.7\ N^2 + 3.1\ K – 0.3\ K^2 – 1.5\ N.K \quad R^2=0.45$

(note in the above equation N and K refer to units of nutrient applied in kg/palm)

In this case none of the parameters were significant (all had a $P > 0.05$) and the R^2 (coefficient of variation) had not improved indicating that using 2006 yield data as a co-variate did not improve the explanation of yield outcomes in 2008.

Tissue nutrients

The same regression procedures as for yield were applied to the tissue data and in this first full year of treatments there were few significant effects. Only Rachis K was influenced by the fertiliser treatments ($R^2 = 0.80$) with the parameter for K having a P value of 0.03. Certainly the zero input K treatment had a low Rachis K content (RK = 0.78 %dm) and much lower then the K fertiliser treatments (RK > 1.2 %dm).

We expect that these results will continue to differentiate between no or low fertiliser inputs and the higher fertiliser treatments in future years.

DISCUSSION

There were no fertiliser effects (N or K) on yield in 2008. However, even though barely significant, there were some differences observable in the tissue data. We expect that the tissue data differences will increase in future years to be followed by yield differences.

Trial 517: New K placement trial at Maiwara Estate

SUMMARY

A new K placement trial was set up at Maiwara, MBE. Treatments were first applied in May 2007.

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

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 fertilizer treatments were applied in May 2007. Site details are presented in Table 1.

Table 1. Trial 517 back ground 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	7	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 2008: 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).

Trial 517 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 poor uptake from 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) broad-cast. Three additional plots were available and two of these did not receive any K fertiliser, and the third plot has a higher rate of 12k g/palm MOP. These three plots are not part of the analysis but are used to provide additional information especially when interpreting tissue K levels.

One way Anova is used for trial analysis.

RESULTS

Yield

There were no differences resulting from the different MOP placements on yield (P>>0.05) and the average yield was 23.4 t/ha (Table 2) (with an average of 1496 bunches/ha and a SBW of 15.7 kg).

Tissue nutrients

There were no differences in Leaf K and Rachis K resulting from the different MOP placements (Table 2).

Table 2. FFB yield (t/ha) and tissue K levels (%dm) for 2008

Placement	Yield (FFB t/ha)	Leaflet K (% dm)	Rachis K (% dm)
Weeded Circle	23.8	0.57	1.29
Edge Weeded Circle	23.5	0.58	1.28
Frond tips/pile	23.5	0.57	1.44
Broadcast	23.0	0.58	1.41
Significant difference:	**NS**	**NS**	**NS**

The two zero MOP control plots had a similar yield but a much lower Rachis K level of 0.77 %dm (leaflet K was similar to the treatments plots).

Leaflet and Rachis N (2.57 and 0.36 %dm); Leaflet and Rachis P (0.144 and 0.130 %dm) were adequate. Leaflet boron at 11 ppm was on the low side.

DISCUSSION

There were no K placement effects on yield or in tissue K content in 2008. However, the zero controls had much lower rachis K content indicating that the treatments are having an impact.

Higaturu Oil Palm, Oro Province: Summary

(Dr. Murom Banabas and Susan Tomda)

Agronomy trials with Higaturu comprised three main areas of interest:

1. Factorial fertiliser trials: (i) N.P.K.Mg at Mamba Estate; (ii) SOA.EFB at Sangara; (iii) Urea.S at Heropa; (iv) Mg.K source at Mamba; and (v) N.P at Sangara and Ambogo.

   Outcome:
   (i) N.P.K.Mg trial – only K increased yield as rachis K level of 0.44 for the control indicates that K is limiting yield production in this area.
   (ii) SOA.EFB – no effect as yet because the soil has high levels of N and K.
   (iii) Urea.Sulphur – no positive yield response as it is only the first year after treatments.
   (v) Urea.TSP (matured and immatured)– established in late 2006 and 2007 respectively, no treatment outcomes as yet in the matured trial however there are responses to urea in the leaf tissues in the immture trial.

2. N source trial: N source trial established at Sangara Estate to determine the relative effect of different N sources and the optimum N rate for the volcanic soils at Higaturu.

   Outcome: Yield of different types of N are similar (35 t/ha) and yield increased with increasing rate of N up to 1.68 kg N per palm (31 to 38 t/ha, control only 15 t/ha).

3. Spacing, thinning and density trial: one trial has been established at Ambogo Estate to determine the effect spacing configuration, thinning and density will have on oil palm.

   Outcome: After thinning, the un-thinned densities yields were higher than the thinned densities

A synopsis for the trial work undertaken with Higaturu Oil Palms Limited is provided on the next two pages. A short recommendation for trial work operation and plantation management based on our results is also provided.

Higaturu Oil Palms Ltd: Synopsis of 2008 PNG OPRA trial results and recommendations

Trial	Palm Age	Yield t/ha	Yield Components	Tissue (% dm)	Vegetative	Notes
324 Sangara N type x rate Soil: Volcanic ash	12	N type (NS) N rate 30.7 to 37.7 Control 15.3	N rate B/ha 1539-1754 N rate SBW 20-21.5	N type LN 2.48 (NS) N rate LN 2.41 to 2.57 RN 0.30 to 0.34 LP 0.144; RP 0.169 LK 0.74; RK 1.76 LMg 0.19, LB 11	N rate PCS 40. to 44 LAI 5.5-5.9	Highest yield: 1.68 kg N/palm) B low
326 Sangara SOA, EFB (factorial) Soil: Volcanic ash	10	SOA 31 (NS) EFB 31 (NS)	SOA B/ha 1508 (NS) SOA SBW 20.8 (NS) EFB (NS)	EFB LK 0.79 to 0.82 RK 1.13 to 1.42 LN 2.50; RN 0.29 LP 0.146; RP 0.08 LMg 0.20, LB 14 ppm	PCS 41 (NS) FP 23 (NS) LAI 6.1 (NS)	High levels of soil N, thus no response B low
330 Heropa (ex Grassland) Urea, Elemental S Soil: Sandy alluvium	8	Urea 17 (NS) S (NS)	B/ha 1287 (NS) SBW 13 (NS)	Urea LN 2.35 (NS) RN 0.27 (NS) Sulphur LS 0.21 (NS) LP 0.143; RP 0.08 LK 0.65; RK 1.12 LMg 0.25; LB 11ppm	PCS 28.3 (NS) FP 20 (NS) LAI 5.6 (NS)	High OM, high LN Low B Low K
334 Sangara Urea, TSP (factorial) Soil: Volcanic ash	8	Urea 35.1 (NS) TSP 35.1 (NS)	Urea and TSP (NS) B/ha 1709 SBW 20.5	Urea LN 2.50 – 2.56 (NS) RN 0.31-0.32 (NS) TSP LP 0.155-0.156 RP 0.117 to 0.137 LK 0.82 RK 1.47 LMg 0.19 LB 13	MOP PCS 50- 54 (S) LAI 6.3–6.6 (S) Kie LAI 6.4-6.8 (S)	Tissue: K required N high B low LAI high
335 Ambogo Urea, TSP (factorial) Soil: Outwash plain, sandy soils	1	Urea NR TSP NR	Urea and TSP NR	Urea LN 2.64 – 2.85 (S) RN 0.35-0.36 (NS) TSP LP 0.170 (NS) RP 0.169 to 0.184 LK 0.0.99 RK 1.06 LMg 0.41 LB 18	Urea & TSP PCS 2.85 (NS)	All nutrients ok.

Apparent adequate tissue nutrient levels:

Leaflet (% DM)					Rachis (% DM)		
N	P	K	Mg	B	N	P	K
2.45	0.145	0.65	0.20	15 (ppm)	0.32	0.08	1.3

Recommendations to Higaturu Oil Palm:

1. On the volcanic soils in Oro Province an oil palm yield of 35 t/ha should be attainable. Some of the soils have very high inherent N fertility and these soils require less N input. Monitoring of available N is essential to ensure that soil supply keeps up with demand.
2. N source trial suggests no difference between products in yield response; purchase on price and ease of handling
3. Tissue testing and vegetative measurement criteria will help in determining deficiencies of particular nutrients
4. Most of the focus for nutrition should be on N, followed by K and P. Tissue Mg levels appear to be adequate. Boron is low in all trials and needs to be applied as a basal.
5. Plantation management (harvest time, pruning, clean weeded circles, fertilizer application and timing etc) all play a large role in the potential to optimize production

Trial 324: Nitrogen Source Trial on Volcanic soils, Sangara

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.

N-type treatment had no significant effect on FFB yield in 2008 and for the combined 2006-2008 period however PCS, FP,FDM and BI were significantly affected in 2008.

N-rate treatment had a significant effect on yield, tissue N and most physiological growth parameters. For most variables, the between N-rate difference was significant for 0.42 kg N per palm and either 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 35.1 t/ha for palms that received N fertiliser, mean yield for the palms that did not receive N fertiliser was only 15.3 t/ha in 2008. 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	Higaturu Oil Palms
Estate	Sangara	Block No.	Blocks 2102 & 2103
Planting Density	135 palms/ha	Soil Type	Higaturu Soils
Pattern	Triangular	Drainage	Good
Date planted	1996	Topography	Flat
Age after planting	12	Altitude	130 m asl
Recording Started	2001	Previous Land-use	Replanted oil palm
Planting material	Dami D x P	Area under trial soil type (ha)	3000
Progeny	Not known	Agronomist in charge	Susan Tomda

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 2006, 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 difference in FFB yield between different N-fertiliser types was not statistically significant in 2008 and the combined 2006-2008 period (Tables 4 and 5). Since the trial commenced in 2001, N-type had no significant effect on yield. However, yield response to N-rate has been significant since 2003. In 2008 and the combined 2006-2008 period, the significant effect on yield was mainly due to a combined increase in number of bunches (BNO) and single bunch weight (SBW). The yield difference between annual N-rate of 0.84 and 1.68 kg per palm was not significant at $l.s.d._{0.05}$ but the differences between either 0.42 and 0.84, and 0.42 and 1.68 kg per palm were significant at $l.s.d._{0.05}$.

In 2008 the difference in yield between +N and –N was about 17 t/ha. The average yield for +N was 35.1 t/ha and the average yield for –N was 15.3 t/ha. This indicates the importance of N in oil palm FFB production.

Table 4. Effects (p values) of treatments on FFB yield and its components in 2006–2008 and in 2008. p values <0.05 are shown in bold.

	2006 – 2008			2008		
Source	**Yield**	**BNO**	**SBW**	**Yield**	**BNO**	**SBW**
Type	0.946	0.528	0.345	0.968	0.821	0.568
Rate	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**0.002**
Type. Rate	0.436	0.405	0.752	0.895	0.870	0.838
CV %	*6.7*	*7.2*	*5.4*	*8.1*	*8.1*	*5.9*

Table 5. Main effects of treatments on FFB yield (t/ha) for 2006 - 2008 and 2008. p values <0.05 are shown in bold.

	2006 - 2008			2008		
	FFB yield (t/ha)	**BNO/ha**	**SBW (kg)**	**FFB yield (t/ha)**	**BNO/ha**	**SBW (kg)**
Control	16.9	1046	14.3	15.3	1179	14.3
SOA	34.6	1702	20.4	35.2	1674	21.1
AMC	35.1	1728	20.3	35.3	1674	21.0
Urea	34.4	1708	20.1	35.0	1661	21.0
AMN	34.9	1775	19.7	35.4	1724	20.4
DAP	34.5	1763	19.7	34.6	1689	20.5
l.s.d.$_{0.05}$						
Rate 1	**31.0**	**1625**	**19.1**	**30.7**	**1539**	**20.0**
Rate 2	**36.3**	**1790**	**20.2**	**36.8**	**1760**	**20.9**
Rate 3	**36.9**	**1789**	**20.7**	**37.7**	**1754**	**21.5**
l.s.d.$_{0.05}$	*1.485*	*80.1*		*1.825*	*87*	*0.79*
Grand Mean	34.7	1735	20.0	35.1	1684	20.8

Effects of treatments on leaf (F17) nutrient concentrations

The differences in N contents between the N-types in the leaflet and rachis were not significant but were different between the rates (p<0.001 in leaflets and rachis) in 2008 (Tables 6 and 7). The between N types difference in the leaflets was significant for K (p = 0.008) and rachis P (p < 0.001). AMC appears to be suppressing K content in the leaflets.

The between N-rates differences in leaflet and rachis N and P contents were significant (p<0.001). Leaflets N and P and rachis N contents increased with N fertiliser rates however rachis P was lowered (Tables 6 and 7). This suggests a loss of P from the rachis and gain of P in the leaflet, which was probably triggered by improved N nutrition of the palms.

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, 2.06 and 2.48 % DM respectively (Table 7).

Table 6. Effects (p values) of treatments on frond 17 nutrient concentrations in 2008. p values less than 0.05 are in bold.

Source	Leaflet contents						Rachis contents			
	Ash	N	P	K	Mg	B	Ash	N	P	K
Type	0.203	0.560	0.096	**0.008**	0.577	0.426	0.056	0.359	**<0.001**	0.530
Rate	**0.002**	**<0.001**	**<0.001**	0.061	0.395	0.163	0.626	**<0.001**	**<0.001**	0.326
Type. Rate	0.226	0.475	0.283	0.242	0.645	0.380	0.300	0.231	0.164	0.538
CV %	3.4	4.3	2.0	4.9	8.5	8.6	7.6	7.9	13.4	10.1

Table 7. Main effects of treatments on frond 17 nutrient concentrations in 2008, in units of % dry matter. p values less than 0.05 are shown in bold. Values for plots receiving zero N (control) were not included in the analysis of variance.

Source	Leaflet nutrient contents (% DM)						Rachis nutrient contents (% DM)			
	Ash	N	P	K	Mg	B (ppm)	Ash	N	P	K
Control	*15.3*	*2.06*	*0.130*	*0.68*	*0.23*	*13.0*	*6.27*	*0.27*	*0.340*	*1.84*
SOA	14.9	2.50	0.143	**0.74**	0.19	10.9	5.89	0.32	**0.159**	1.78
AMC	15.0	2.49	0.145	**0.71**	0.20	10.3	6.00	0.32	**0.163**	1.82
Urea	14.3	2.44	0.143	**0.76**	0.20	10.5	5.48	0.31	**0.160**	1.72
AMN	14.6	2.48	0.146	**0.75**	0.19	10.9	5.78	0.33	**0.166**	1.71
DAP	15.0	2.51	0.144	**0.75**	0.19	10.6	5.69	0.32	**0.198**	1.78
l.s.d.$_{0.05}$	*0.414*			*0.0298*					*0.0187*	
Rate 1	14.5	**2.41**	**0.142**	0.73	0.19	10.7	5.83	**0.30**	**0.206**	1.77
Rate 2	14.8	**2.47**	**0.145**	0.73	0.19	10.8	5.70	**0.32**	**0.164**	1.71
Rate 3	15.1	**2.57**	**0.145**	0.76	0.19	10.3	5.78	**0.34**	**0.136**	1.80
l.s.d.$_{0.05}$	*0.3205*	*0.0678*	*0.0018*					*0.0162*	*0.0145*	
GM	14.8	2.48		0.74	0.19	10.6	5.8	0.32	0.169	1.76

Effects of fertiliser treatments on Vegetative parameters

N-type treatment had a significant effect on PCS (p=0.042), FP (p=0.002), FDM (p=<0.001), VDM (p=0.001) and BI (p=0.050) (Tables 9 and 10). DAP and AMC increased PCS significantly compared to Urea, SOA and AMN while the difference between DAP and either SOA or AMC was not significant. However, the effect of N type on the vegetative dry matter did not translate to yield.

N-rate treatment had a significant effect on all the physiological parameters (Table 9 and 10). The differences between 0.42 and either 0.84 or 1.68 kg of N per palm were significant but not between 0.84 or 1.68 kg of N per palm (l.s.d.$_{0.05}$.).

Generally, physiological parameters in the control plots were lower than in the N fertilized plots. These results correspond well with yield and tissue results.

Table 9. Effect (p values) of treatments on vegetative growth parameters in 2008. p values less than 0.05 are shown in bold.

Source				Radiation interception			Dry matter production				
	FL	HI	PCS	FP	FA	LAI	FDM	BDM	TDM	VDM	BI
Fert. type	0.693	0.062	**0.042**	**0.002**	0.433	0.137	**<0.001**	0.967	0.204	**0.001**	**0.050**
Rate	**<0.001**	**<0.001**	**<0.001**	**<0.001**	0.068	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**0.004**
Type.Rate	0.998	0.242	0.991	0.372	0.338	0.263	0.749	0.854	0.689	0.700	0.983
CV %	3.0	16.7	6.5	3.2	5.1	5.6	6.3	7.6	5.6	5.7	3.8

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 2008. Significant effects ($p<0.05$) are shown in bold.

Source	**FL**	**HI**	**PCS**	Radiation interception			Dry matter production (t/ha/yr)				
				FP	**FA**	**LAI**	**FDM**	**BDM**	**TDM**	**VDM**	**BI**
Control	532.0	43.0	28.7	19.8	10.0	4.21	8.5	8.6	19.0	10.4	**0.44**
SOA	628.7	73.6	**41.7**	**23.1**	12.7	6.06	**13.9**	19.4	37.0	**17.6**	**0.52**
AMC	628.2	62.6	**43.7**	**23.5**	13.0	6.12	**14.8**	19.5	38.2	**18.6**	**0.51**
Urea	619.0	68.8	**41.6**	**22.9**	12.5	5.82	**13.8**	19.1	36.5	**17.4**	**0.52**
AMN	626.9	68.9	**40.8**	**23.7**	12.6	5.89	**14.0**	19.4	37.1	**17.7**	**0.52**
DAP	623.9	76.4	**43.6**	**24.2**	12.6	5.99	**15.2**	19.2	38.3	**19.0**	**0.50**
$lsd_{0.05}$			*2.261*	*0.626*			*0.739*			*0.862*	*0.0163*
Rate 1	**612.5**	**62.2**	**40.5**	**22.6**	**12.4**	**5.68**	**13.3**	**16.9**	**33.5**	**16.6**	**0.50**
Rate 2	**627.3**	**67.9**	**41.9**	**23.7**	**12.9**	**6.16**	**14.3**	**20.1**	**38.3**	**18.2**	**0.52**
Rate 3	**636.2**	**80.2**	**44.4**	**24.1**	**12.7**	**6.09**	**15.4**	**21.0**	**40.5**	**19.4**	**0.52**
$lsd_{0.05}$	*11.8*	*7.47*	*1.751*	*0.485*	*0.4103*	*0.214*	*0.572*	*0.944*	*1.346*	*0.668*	*0.0126*
GM	625.3	70.1	42.3	23.5	12.7	5.98	14.3	19.3	37.4	18.1	0.52

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 yield and SBW in 2008 and for the combined 2006-2008 period and this was consistent since the trial started in 2001.

N-rate treatment had a significant effect on yield, tissue N and P and most physiological growth parameters. Increasing N rate from 0.42 kg per palm to higher rates increased yield, leaflet N and PCS, FP, FA, LAI, BDM, TDM and BI.

Yield, leaflet N and values for 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 can not be sustained or increased.

Trial 326: Nitrogen x EFB Trial on Volcanic Soils, Sangara

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 and EFB treatments had no significant effect on yield and its components in 2008 except for EFB on SBW. These results are similar to the results of the past 6 years since the trial started in 2002. However, SOA treatment had significant effects on leaf ash, B and rachis P contents. EFB significantly affected leaflet ash, Mg and B, and rachis ash, P and K. Regardless of the fertilizer treatments, all nutrients were above their respective critical concentrations.

SOA did not affect the measured and calculated vegetative growth parameter. EFB treatment significantly increased height increment, frond and vegetative dry matter production but not bunch dry matter, and this resulted in a significant increase in total dry matter production.

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 PNG OPRA 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	Higaturu Oil Palms
Estate	Sangara	Block No.	23CAS1
Planting Density	135 palms/ha	Soil Type	Volcanic ash
Pattern	Triangular	Drainage	Good
Date planted	1999	Topography	Slightly undulating
Age after planting	8	Altitude	150 m asl
Recording Started	2002	Previous Land-use	Oil palm
Planting material	Dami D x P	Area under trial soil type (ha)	Not known
Progeny	Not known	Assistant agronomist in charge	Susan Tomda

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

Depth (cm)	**pH**	**Exch K**	**Exch Ca**	**Exch Mg (cmol/kg)**	**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 design of the trial is Randomised Complete Block Design (RCBD). The 12 treatments were 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 every year.

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

SOA and EFB treatments had no significant effect on yield and its components in 2006-2008 and 2008 except for EFB on SBW (Tables 4 and 5). Average yield and its components for the 2006 to 2008 period were also not affected by treatments. These results are similar to the past 6 years since the trial commenced in 2002.

Table 4. Effects (p values) of treatments on FFB yield and its components in 2006 – 2008 and 2008.

	2006 – 2008			2008		
Source	Yield	BNO	SBW	Yield	BNO	SBW
SOA	0.157	0.401	0.485	0.454	0.590	0.521
EFB	0.097	0.913	**0.020**	0.176	0.774	**0.021**
SOA.EFB	0.943	0.512	**0.042**	0.333	0.743	0.063
CV %	*6.6*	*7.7*	*5.0*	*9.3*	*10.4*	*5.6*

Table 5. Main effects of treatments on FFB yield (t/ha) from 2006 to 2008 and 2008.

Treatments	2006-2008			2008		
	FFB yield (t/ha)	BNO/ha	SBW (kg)	FFB yield (t/ha)	BNO/ha	SBW (kg)
SOA 0	34.4	1863	18.7	31.2	1530	20.4
SOA 2.5	35.2	1881	19.1	32.0	1536	20.9
SOA 5.0	33.3	1815	18.8	30.0	1464	20.8
SOA 7.5	34.1	1805	19.2	31.5	1503	21.0
EFB 0	33.3	1837	**18.4**	30.3	1502	**20.2**
EFB 130	34.7	1850	**19.1**	31.8	1529	**20.9**
EFB 390	34.7	1836	**19.3**	31.7	1495	**21.3**
$l.s.d_{0.05}$			*0.609*			*0.744*
Grand Mean	34.3	1841	18.9	31.3	1508	20.8

Effects of interaction between treatments on FFB yield

There was no significant interaction effect of SOA.EFB but the highest yield of 34.3 t/ha was achieved 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 2008. The interaction was not significant (p=0.946).

	EFB 0	EFB 130	EFB 390
SOA 0	30.3	30.5	32.8
SOA 2.5	29.3	**34.3**	32.6
SOA 5.0	30.5	30.1	30.4

SOA 7.5	30.9	32.4	31.1
	Grand mean: 31.3	*sed 1.830*	

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

SOA treatment had no significant effect on leaflet and rachis nutrient concentrations in 2008 except on leaflet Ash (p=0.001), B (p=0.046) and rachis P (p=0.005) contents (Tables 7 and 8).

EFB treatment had a significant effect on the concentration of leaflet and rachis ash, leaflet Mg (p=0.018) and B (p=0.009), and rachis P (p<0.001) and K (p<0.001) contents (Tables 7 and 8). The rachis P and K concentrations were significantly increased with EFB rates. The increase in rachis K concentrations was due to the high content of K in the EFB (approx 2.0% DM). Regardless of treatment effects, all the nutrients were above their respective critical concentrations.

All nutrients were above their respective critical concentrations for leaflet.

Table 7: Effects (p values) of treatments on frond 17 (F17) nutrient concentrations 2008 (Trial 326). p values <0.05 are indicated in bold.

Source	Ash	N	P	K	Mg	B	Ash	N	P	K
SOA	**0.001**	0.562	0.202	0.621	0.127	**0.046**	0.542	0.844	**0.005**	0.465
EFB	**<0.001**	0.605	0.089	0.300	**0.018**	**0.009**	**<0.001**	0.114	**<0.001**	**<0.001**
SOA.EFB	0.463	0.125	0.515	0.958	0.448	0.993	0.405	0.979	0.787	0.282
CV%	*3.4*	*2.7*	*2.0*	*5.9*	*7.6*	*7.2*	*10.6*	*8.2*	*15.5*	*12.1*

Table 8: Main effects of treatments on F17 nutrient concentrations in 2008, in units of % dry matter, except for B (mg/kg) (Trial 326). Effects with p<0.05are shown in bold.

Source		Leaflet nutrient contents (% DM)							Rachis nutrient contents (% DM)			
		Ash	N	P	K	Mg	B (ppm)		Ash	N	P	K
SOA 0		**14.7**	2.48	0.146	0.81	0.21	**14.2**		4.84	0.293	**0.089**	1.43
SOA 2.5		**15.2**	2.51	0.146	0.80	0.20	**15.0**		4.72	0.287	**0.074**	1.37
SOA 5.0		**15.1**	2.50	0.146	0.82	0.20	**14.1**		4.84	0.294	**0.077**	1.43
SOA 7.5		**15.4**	2.51	0.144	0.80	0.19	**14.8**		4.99	0.290	**0.075**	1.47
$l.s.d_{0.05}$		*0.377*									*0.0089*	
EFB 0		**15.7**	2.49	0.144	0.79	**0.21**	15.1		**4.05**	0.281	**0.071**	**1.13**
EFB 130		**15.0**	2.49	0.145	0.81	**0.19**	14.4		**5.07**	0.295	**0.077**	**1.52**
EFB 390		**14.6**	2.51	0.147	0.82	**0.20**	14.1		**5.38**	0.296	**0.088**	**1.62**
$l.s.d_{0.05}$		*0.327*				*0.010*	*0.67*		*0.328*		*0.0077*	*0.110*
GM		15.1	2.50	0.146	0.81	0.20	14.5		4.84	0.291	0.079	1.42

Effects of fertiliser treatments on vegetative parameters

SOA did not have any effect on the calculated vegetative parameters (Tables 9 and 10). However, EFB significantly increased HI (p=0.020), FDM (p=0.041), VDM (p=0.029) and TDM (p=0.027) but the effects were not translated to FFB yield.

Table 9. Effect (p values) of treatments on vegetative growth parameters in 2008. p values less than 0.05 are shown in bold.

Source				Radiation interception			Dry matter production (t/ha/yr)				
	FL	HI	PCS	FP	FA	LAI	FDM	BDM	TDM	VDM	BI
SOA	0.948	0.308	0.233	0.171	0.458	0.913	0.177	0.487	0.424	0.201	0.234
EFB	0.321	**0.020**	0.235	0.242	0.995	0.370	**0.041**	0.109	**0.027**	**0.029**	0.601
SOA.EFB	0.116	0.189	0.577	**0.032**	0.059	0.175	0.143	0.709	0.420	0.152	0.434
CV %	4.6	8.1	6.7	4.2	5.1	5.6	7.0	9.1	6.5	6.5	4.6

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 2008. Significant effects (p<0.05) are shown in bold.

Source				Radiation interception			Dry matter production (t/ha/yr)				
	FL	**HI**	**PCS**	**FP**	**FA**	**LAI**	**FDM**	**BDM**	**TDM**	**VDM**	**BI**
SOA 0	638.2	122.9	40.0	22.9	12.1	6.09	13.3	17.0	33.7	16.7	0.50
SOA 2.5	639.4	123.2	40.2	23.8	12.1	6.14	13.8	17.4	34.7	17.3	0.50
SOA 5.0	636.3	124.1	41.5	23.3	11.8	6.05	14.0	16.6	34.0	17.4	0.49
SOA 7.5	642.7	129.2	41.8	23.3	12.1	6.08	14.0	17.3	34.8	17.5	0.50
EFB 0	647.3	**122.3**	40.2	23.1	12.0	6.08	**13.4**	16.5	**33.2**	**16.7**	0.50
EFB 130	633.8	**122.0**	40.7	23.3	12.0	6.02	**13.7**	17.3	**34.5**	**17.2**	0.50
EFB 390	636.3	**130.3**	41.7	23.6	12.0	6.18	**14.2**	17.4	**35.1**	**17.7**	0.49
$Lsd_{0.05}$		*6.48*					*0.617*		*1.415*	*0.718*	
GM	639.1	124.9	40.9	23.3	12.0	6.10	13.8	17.1	34.3	17.2	0.50

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

There was no significant effect of SOA and EFB treatments on yield and its components since the trial commenced in 2002.

Leaf nutrient concentrations were not affected by SOA treatment and all the nutrients were above their respective critical concentrations. On the other hand, EFB treatment only increased leaflet Ash and Mg, and rachis Ash, P and K concentrations.FDM and VDM production were significantly increased by EFB treatment.

Trial 329: Nitrogen, Potassium, Phosphorus and Magnesium Trial, Mamba

SUMMARY

The N.P.K.Mg trial was established on Mamba soils in Oro Province to provide a guide to fertiliser recommendations to estates and oil palm smallholder growers in this area. The trial block was planted in 1997 and the trial commenced in September 2002. The fertiliser treatments included SOA (2 rates); and MOP, Kieserite and TSP, all tested at 3 rates.

Only MOP treatment had a significant effect on yield. Increasing MOP from 0 to either 2 or 4 kg per palm increased FFB yield by up to 3.0 t/ha. Leaf K levels were increased significantly by higher rates of MOP treatment but for MOP 0, K level dropped below the critical of 1.0% (rachis K). This indicates that K is limiting FFB production in this area. The effect of MOP on bunch dry matter (BDM), total dry matter (TDM) and bunch index (BI) corresponded well to its effects on yield and leaf K. Higher rates of MOP treatment significantly increased DM production in 2008.

One reason for other fertiliser treatments having no significantly effect on variables measured is that soil N, P, Mg levels are high in the trial area, thus any response to N, P and Mg treatments are unlikely in the short to intermediate term.

INTRODUCTION

The trial was established with the intention to provide information for fertiliser recommendations for estates and smallholders in the Kokoda Valley, and Ilimo/Papaki and Mamba areas. Some back ground information about this trial is presented in Table 1.

Table 1: Trial 329 back ground information.

Trial number	**329**	Company	Higaturu Oil Palms
Estate	Mamba	Block No.	Komo Div. Blocks 298G1
Planting Density	135 palms/ha	Soil Type	Mamba Soils
Pattern	Triangular	Drainage	Poor
Date planted	1997	Topography	Flat
Age after planting	9	Altitude	350 m
Recording Started	Sep 2001	Previous Land-use	Cocoa Plantation
Planting material	Dami D x P	Area under trial soil type (ha)	Not known
Progeny	Not known	Assistant agronomist in charge	Susan Tomda

Soils of Ilimo/Kokoda and Mamba areas are different from soils of the Popondetta plains. The soils at Mamba are generally acidic (pH in water), are intermediate in cation exchange capacity (CEC) and have high P retention (Table 2). The soils are susceptible to frequent water-logging. Total N, OM%, total P, exchangeable K and exchangeable Mg are high in the top 10 cm of the soil and decrease progressively down the soil profile down to 60 cm.

Table 2: Soil chemical characteristics for bulked samples taken from each of the three experimental blocks in 2001.

Depth (cm)	pH	Olsen P	P Ret.	Exch. K	Exch. Ca	Exch. Mg	CEC	Org. Matter	Total N	Avail. N	Sulfate S	B
		mg/kg	(%)	(cmolc/kg)				(%)	(%)	(kg/ha)	(mg/kg)	
0-10	5.6	22	98	0.37	7.5	1.62	25.5	15.6	0.84	137	16	0.4
10-20	5.3	8	100	0.16	0.6	0.22	16.2	9.4	0.51	51	98	0.2
20-30	5.3	5	100	0.13	<0.5	0.11	11.6	6.3	0.36	23	184	0.1
30-60	5.4	7	92	0.14	<0.5	0.11	8.1	3.0	0.19	<10	176	0.1
0-10	5.6	17	99	0.43	6.3	1.41	24.2	14.4	0.81	130	23	0.4
10-20	5.3	6	100	0.16	0.9	0.24	14.9	8.9	0.52	55	133	0.2
20-30	5.4	5	100	0.17	0.6	0.19	12.9	7.5	0.38	38	202	0.1
30-60	5.5	7	95	0.18	<0.5	0.11	8.4	3.5	0.20	<10	201	<0.1
0-10	5.8	14	96	0.37	9.3	1.94	25.1	13.9	0.81	128	16	0.3
10-20	5.6	5	100	0.22	1.3	0.33	14.5	9.1	0.52	58	75	0.2
20-30	5.6	5	100	0.18	0.7	0.19	11.0	6.8	0.40	23	155	0.1
30-60	5.6	7	97	0.17	<0.5	0.14	8.5	4.0	0.23	<10	182	0.1
						Mean values						
0-10	5.7	17	98	0.39	7.7	1.66	24.9	14.6	0.82	132	18.3	0.4
10-20	5.4	6	100	0.18	0.9	0.26	15.2	9.1	0.52	55	102	0.2
20-30	5.4	5	100	0.16	<0.5	0.16	11.8	6.9	0.38	34	180	0.1
30-60	5.5	7	95	0.17	<0.5	0.12	8.3	3.5	0.21	<10	186	0.1

METHODS

The N P K Mg trial was set up as a 2 x 3x 3 x 3 factorial arrangement, resulting in 54 treatments with 36 palms per plot (Table 3). The 54 treatments were not replicated, and were arranged in 3 blocks of 18 plots. Fertilisers used were ammonium sulphate (SOA), triple superphosphate (TSP), potassium chloride (MOP) and kieserite (KIE) (Table 3). The fertiliser treatments were applied in 3 doses per year. The plots were surrounded by a trench to prevent plot-to-plot nutrient poaching. 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 were recorded on 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 per ha per year. Single bunch weight (SBW) was calculated from these data. Leaf sampling was carried out according to standard procedures and analysed for nutrient concentrations using standard analytical procedures. Third dose of fertiliser was not applied due to disturbance caused Cyclone Guba.

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 levels and rates used in Trial 329

Fertiliser treatments	Amount (kg/palm/year)		
	Level 1	Level 2	Level 3
SOA	2	4	
TSP	0	2	4
MOP	0	2	4
KIE	0	2	4

RESULTS and DISCUSSION

Main effects of treatments on FFB yield over the trial period

SOA did not affect yield in 2008 and 2006-2008 period, and this was consistent since the trial started (Tables 4 and 5). One possible explanation for the lack of N response is that leaflet N concentrations were in the adequate range, indicating that N nutrition is not limiting yield. The reason for the high inherent N nutrient status is that soil organic matter and total N are high. High levels of soil organic matter and total N result in high levels of mineralisation and available N, thus responses to N fertiliser are unlikely until soil N reserves are depleted over time.

Similar to the effects of SOA treatment, TSP and KIE treatments had no significant effect on FFB yield in 2008 and 2006-2008 and during the course of the trial.

On the other hand, increasing MOP from 0 to 4 kg per palm resulted in a substantial yield increase (by up to 2 t/ha) in 2008 and 2006-2008. The increase in FFB yield was due to increase in BNO (though not significant) and increase in SBW ($p<0.001$).

Table 4: Effects (p values) of treatments on FFB yield and its components in the combined harvest for 2006 – 2008 and for 2008 alone. p values less than 0.05 are in bold.

	2006 - 2008			2008		
Source	Yield	BNO	SBW	Yield	BNO	SBW
SOA	0.228	0.389	0.478	0.090	0.334	0.068
TSP	0.534	0.538	0.983	0.417	0.202	0.644
MOP	**<0.001**	0.061	**<0.001**	**0.006**	0.135	**<0.001**
KIE	0.427	0.447	0.981	0.607	0.678	0.806
SOA.TSP	0.568	0.224	0.227	0.996	0.772	0.253
SOA.MOP	0.134	0.585	0.123	0.261	0.498	0.265
TSP.MOP	0.919	0.232	0.143	0.871	0.562	0.629
SOA.KIE	0.367	0.335	0.186	0.276	0.668	0.104
TSP.KIE	0.550	0.550	0.246	0.385	0.361	0.132
MOP.KIE	0.778	0.536	0.274	0.709	0.257	0.124
CV %	*9.3*	*9.7*	*5.0*	*15.8*	*15.1*	*6.2*

Table 5: Main effects of treatments on FFB yield (t/ha) for the combined harvest for 2006 – 2008 and 2008 alone (Yield, Bunch No and SBW in bold are significant at P<0.05).

	2006 – 2008			2008		
	FFB yield (t/ha)	**BNO/ha**	**SBW (kg)**	**FFB yield (t/ha)**	**BNO/ha**	**SBW (kg)**
SOA 2	23.7	1010	23.5	20.5	859	23.9
SOA 4	24.4	1032	23.7	22.1	895	24.7
TSP 0	24.4	1035	23.7	21.6	885	24.4
TSP 2	23.6	1001	23.6	20.4	833	24.5
TSP 4	24.1	1027	23.6	21.9	913	24.0
MOP 0	**22.1**	990	**22.4**	**19.0**	831	**23.0**
MOP 2	**24.3**	1008	**24.2**	**22.1**	878	**25.3**
MOP 4	**25.8**	1065	**24.3**	**22.8**	923	**24.7**
$Lsd_{0.05}$	*1.532*		*0.815*	*2.306*		*1.037*
KIE 0	24.3	1035	23.6	21.5	879	24.5
KIE 2	24.3	1030	23.6	12.7	896	24.2
KIE 4	23.5	998	23.7	20.7	857	24.2
GM	24.0	1021	23.6	21.3	877	24.3

Effects of treatments on leaf (F17) nutrient concentrations

SOA treatment had no significant effect on leaflet and rachis nutrient concentrations in 2008, except leaflet Mg, and rachis ash and P (Tables 6 and 7).

TSP treatment had a significantly effect on rachis P only (Tables 6 and 7). Rachis P increased with TSP rates but only up to 2 kg TSP/palm. Leaflet P values were above the critical value of 0.140 % dry matter.

MOP treatment had a significant effect on leaflet Ash, K, Mg and B, and rachis Ash, N, P and K concentrations (Tables 6 and 7). MOP increased leaflet K, and rachis Ash, P and K ($p<0.001$) but suppressed leaflet Ash, Mg and B at $p<0.001$and rachis N at $p=0.045$. The rachis K content at nil MOP fertilized plots was very low at 0.43 % DM. The effect of MOP on nutrient levels is also reflected in responses to yield.

Kieserite significantly increased leaflet Mg ($p<0.001$) but lowered leaflet ($p<0.001$) and rachis ash ($p=0.003$) and K ($p=0.028$ and $p=0.004$). However, the significant positive effect on tissue Mg contents is not translated to ffb yield.

All nutrient contents were above their respective critical concentrations for leaflet except for rachis K.

Table 6: Effects (p values) of treatments on frond 17 (F17) nutrient concentrations 2008 (Trial 329). p values <0.05 are indicated in bold.

Source	Leaflets						Rachis			
	Ash	**N**	**P**	**K**	**Mg**	**B (ppm)**	**Ash**	**N**	**P**	**K**
SOA	0.873	0.703	0.189	0.122	**0.033**	0.195	**0.042**	0.550	**<0.001**	0.070
TSP	0.710	0.848	0.116	0.808	0.522	0.751	0.431	0.969	**<0.001**	0.319
MOP	**<0.001**	0.959	0.414	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**0.045**	**<0.001**	**<0.001**
KIE	**<0.001**	0.051	0.199	**0.028**	**<0.001**	0.136	**0.003**	0.402	0.958	**0.004**
SOA.TSP	0.859	0.509	0.831	0.333	0.384	0.386	0.823	**0.028**	0.467	0.819
SOA.MOP	0.915	0.741	0.679	0.473	0.145	0.489	0.131	0.156	0.973	0.093
TSP.MOP	0.258	0.609	0.430	0.986	0.792	0.592	0.311	0.618	0.064	0.981
SOA.KIE	0.277	0.877	0.749	0.427	0.252	0.199	0.585	0.947	0.936	0.395
TSP.KIE	0.945	0.794	0.399	0.768	0.210	0.299	0.685	0.407	0.809	0.118
MOP.KIE	0.098	0.082	0.111	0.286	0.221	0.196	0.258	0990	0.375	0.110
CV%	*7.2*	*4.2*	*2.5*	*9.5*	*10.0*	*8.8*	*7.7*	*7.1*	*12.1*	*9.6*

Table 7: Main effects of treatments on F17 nutrient concentrations in 2008, in units of % dry matter, except for B (mg/kg) (Trial 329). Effects with p<0.05are shown in bold.

Source	Leaflet nutrient contents						Rachis nutrient contents			
	Ash	**N**	**P**	**K**	**Mg**	**B**	**Ash**	**N**	**P**	**K**
SOA 2	8.87	2.57	0.168	0.75	**0.27**	13.8	**3.61**	0.284	**0.087**	0.92
SOA 4	8.86	2.58	0.168	0.79	**0.25**	13.4	**3.45**	0.287	**0.077**	0.87
$Lsd_{0.05}$							*0.152*		*0.0056*	
TSP 0	8.80	2.57	0.166	0.78	0.26	13.6	3.55	0.284	**0.072**	0.88
TSP 2	8.95	2.57	0.167	0.77	0.27	13.4	3.58	0.286	**0.087**	0.92
TSP 4	8.79	2.59	0.169	0.76	0.26	13.7	3.46	0.286	**0.087**	0.89
$l.s.d_{0.05}$									*0.0068*	
MOP 0	**9.80**	2.57	0.168	**0.68**	**0.29**	**15.5**	**2.62**	**0.296**	**0.072**	**0.43**
MOP 2	**8.36**	2.58	0.168	**0.80**	**0.25**	**12.9**	**3.70**	**0.279**	**0.084**	**0.99**
MOP 4	**8.39**	2.58	0.167	**0.83**	**0.25**	**12.4**	**4.26**	**0.282**	**0.090**	**1.27**
$l.s.d_{0.05}$	*0.438*			*0.0502*	*0.0178*	*0.820*	*0.186*	*0.0138*	*0.0068*	*0.0593*
KIE 0	**9.40**	2.53	0.166	**0.78**	**0.16**	14.0	**3.69**	0.284	0.082	**0.93**
KIE 2	**8.64**	2.63	0.169	**0.80**	**0.28**	13.1	**3.55**	0.291	0.082	**0.92**
KIE 4	**8.51**	2.57	0.168	**0.73**	**0.33**	13.6	**3.34**	0.282	0.083	**0.84**
$l.s.d_{0.05}$	*0.438*			*0.0502*	*0.0178*		*0.186*			*0.0593*
GM	8.85	2.57	0.168	0.77	0.26	13.6	3.50	0.285	0.082	0.90

Effects of fertiliser treatments on Vegetative parameters

SOA did not affect any of the physiological parameters. TSP affected LAI (p=0.019) only while kieserite affected height increment (p=0.009) and LAI (p=0.026) (Tables 8 and 9).

MOP significantly affected all the vegetative parameters except FL, FP and BI. Effect of MOP on physiological parameters was also noticed in leaf tissue nutrient contents and ffb yield responses.

The mean BI was 0.45 suggesting more than 50% of the DM is diverted VDM compared to trials on the Popondetta Plains (BI>0.50) where >50% DM was diverted to bunch production.

Table 8. Effect (p values) of treatments on vegetative growth parameters in 2008. p values less than 0.05 are shown in bold.

Source				Radiation interception			Dry matter production				
	FL	HI	PCS	FP	FA	LAI	FDM	BDM	TDM	VDM	BI
SOA	0.912	0.179	0.522	0.139	0.169	0.616	0.168	0.100	0.059	0.129	0.368
TSP	0.893	0.636	0.480	0.948	0.071	**0.019**	0.571	0.440	0.798	0.653	0.230
MOP	0.508	**0.002**	**0.002**	0.812	**<0.001**	**0.004**	**0.013**	**0.006**	**0.001**	**0.006**	0.133
KIE	0.884	**0.009**	0.214	0.901	0.524	**0.026**	0.327	0.639	0.335	0.302	0.978
SOA.TSP	0.011	0.474	0.367	0.985	**0.008**	**0.004**	0.634	0.983	0.835	0.650	0.827
SOA.MOP	0.828	0.283	0.395	0.066	**0.018**	**0.035**	0.076	0.220	0.081	0.068	0.451
TSP.MOP	0.302	**0.032**	0.418	0.457	**0.004**	**0.014**	0.301	0.896	0.777	0.348	0.485
SOA.KIE	0.104	0.563	0.854	0.567	0.550	0.620	0.916	0.270	0.400	0.838	0.390
TSP.KIE	0.763	0.078	0.783	0.913	0.120	0.064	0.844	0.439	0.560	0.815	0.553
MOP.KIE	0.111	**0.002**	0.652	0.506	**0.001**	**0.001**	0.587	0.769	0.755	0.612	0.711
CV%	4.6	5.6	5.8	4.4	4.5	5.4	7.7	16.0	8.6	7.5	9.9

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 2008. Significant effects ($p<0.05$) are shown in bold.

Source				Radiation interception			Dry matter production (t/ha/yr)				
	FL	**HI**	**PCS**	**FP**	**FA**	**LAI**	**FDM**	**BDM**	**TDM**	**VDM**	**BI**
SOA 2	684.2	84.2	51.8	24.7	13.2	6.62	18.3	10.0	32.4	21.6	0.33
SOA 4	683.2	86.0	52.4	25.2	13.0	6.57	18.9	11.6	33.9	22.3	0.34
TSP 0	681.8	84.6	51.4	24.9	13.3	**6.70**	18.3	11.4	33.0	21.6	0.34
TSP 2	686.5	84.6	52.6	25.0	12.8	**6.38**	18.8	10.7	32.9	22.1	0.32
TSP 4	682.7	85.9	52.2	25.0	13.2	**6.70**	18.7	11.4	33.5	22.1	0.34
l.s.d$_{0.05}$											
MOP 0	680.4	**87.0**	**50.0**	24.8	**12.6**	**6.34**	**17.8**	**10.0**	**30.9**	**20.9**	0.32
MOP 2	679.8	**86.8**	**52.4**	25.0	**13.4**	**6.75**	**18.7**	**11.5**	**33.6**	**22.1**	0.34
MOP 4	690.8	**81.4**	**53.9**	25.1	**13.3**	**6.69**	**19.3**	**12.1**	**34.9**	**22.8**	0.34
l.s.d$_{0.05}$		*3.254*	*2.083*		*0.404*		*0.982*	*1.228*	*1.961*	*1.135*	
KIE 0	683.8	**82.0**	51.9	25.0	13.1	**6.42**	18.6	11.2	33.1	21.9	0.34
KIE 2	686.2	**86.5**	53.1	25.0	13.0	**6.60**	19.0	11.5	33.9	22.4	0.34
KIE 4	681.0	**86.7**	51.3	24.9	13.2	**6.77**	18.3	10.9	32.4	21.5	0.33
l.s.d$_{0.05}$		*3.254*									
GM	683.7	85.1	52.1	25.0	13.1	6.59	18.6	11.2	33.1	21.9	0.34

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

Of all the fertiliser treatments only MOP had a major positive effect on FFB yield, leaf tissues and physiological parameters in 2008. Increasing MOP from 0 kg/palm/year to any other rate increased yield by 1 to 3 t/ha. Leaf K contents and dry matter production, specifically BDM and TDM were also increased by higher rates of MOP.

We expect that the lack of N response is due to high inherent N soil nutrient status. The high levels of soil organic matter and total N results in high levels of N mineralization making nitrate and ammonium freely available.

These results were similar to the previous year's results.

Trial 330: Grassland Sulphur Trial on Outwash Plains, Heropa Mini Estate

SUMMARY

The Nitrogen (N) x Sulphur (S) trial was established on the grasslands of Popondetta for the purpose of developing a fertiliser strategy for oil palm grown on the sandy soils of the grasslands.

In the second year treatment, there was no significant effect of fertilisers on yield, tissue nutrients and the physiological growth parameters.

INTRODUCTION

With increased oil palm plantings in the Popondetta grassland areas, both by smallholders and the mini-estate schemes, this trial was initiated purposely to provide information for fertiliser recommendations. In the grassland areas, N and S are expected to be the major limiting nutrients. The soils in the grassland areas are sandy with very low organic matter content. These areas also experience periods of water deficit during low rainfall months. Due to the porous nature of the sandy soils, leaching of nutrients can be a problem during periods of heavy rainfall. Soil results indicate low levels of K and P levels in the top 30 cm of the soil layer (Table 2). However, N and organic matter levels are high within the top 30 cm of the soil, possibly as products of mineralization of decaying plant debris within the oil palm establishment. With frequent burning during the dry season, soil C (OM) is not expected to accumulate in the surrounding grassland areas.

The objective of the trial is to provide information for fertiliser recommendations (especially for N and S) to the Estate, mini estates and the smallholder growers in the grassland areas of Popondetta.

Background information of the trial is presented in Table 1.

Table 1. Trial 330 background information.

Trial number	**330**	Company	Higaturu Oil Palms
Estate	Embi	Block No.	Heropa (9HE01)
Planting Density	135 palms/ha	Soil Type	Ambogo/Penderretta
Pattern	Triangular	Drainage	Moderate
Date planted	2000	Topography	Flat
Age after planting	8	Altitude	?? m asl
Recording Started	May 2005	Previous Land-use	Grassland
Planting material	Dami D x P	Area under trial soil type (ha)	Not know
Progeny	Not known	Agronomist in charge	Susan Tomda

Table 2. Initial soil analysis results from soil samples taken in 2005

Depth	**pH in**	**Exch K**	**Exch Ca**	**Exch Mg**	**CEC**	**OM (%)**	**Total N (%)**	**Olsen P (mg/kg)**
cm	**water**	**cmol/kg**						
0-10	5.6	0.14	3.3	1.2	18.0	13.0	0.50	6.1
10-20	5.9	0.06	1.4	0.6	9.6	6.6	0.24	3.4
20-30	6.0	0.04	0.7	0.1	3.5	1.9	0.12	7.6
30-60	6.8	0.34	10.0	1.88	15.7	1.1	0.05	13.3

METHODS

Experimental Design and Treatments

The trial design was a Randomised Complete Block Design (RCBD). The treatment structure was a factorial arrangement of 4 rates of N (urea) x 3 rates of S (elemental Sulphur) x 4 replicates, resulting in 36 plots. Each replicate had 12 plots and the treatments were randomly allocated within each replicate block. Each plot consisted of 36 palms, the central 16 were recorded and the outer 20 were guard palms.

The initial plan was to test out 4 rates of ammonium nitrate (AN) and 3 rates of elemental sulphur (S). However, AN was replaced with urea, which is the source of N that the plantation (HOP) was using. Table 3 shows different rates of each fertiliser tested. Fertiliser treatments commenced in 2006 and treatments were applied in two applications per year. There was no nil N treatment because it was felt landowners might not want very low crop yields in the mini estates. The trial received an annual blanket application of MOP (2.0 kg/palm/yr), Borate (0.2 kg/palm/yr), FO1 magnesite (0.66 kg/palm/yr) and TSP (0.5 kg/palm/yr).

Table 3. Fertiliser treatments and levels in Trial 330.

Fertiliser	Amount (kg/palm/year)			
	Level 1	Level 2	Level 3	Level 4
Urea	0.5	1.5	2.5	3.5
Elemental Sulphur	0	0.15	0.30	-

Data Collection

Recordings and measurements were taken on the central 16 palms in each plot. The number of bunches and bunch weights were recorded on 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 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.

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.

RESULTS and DISCUSSION

Effects of treatment on FFB yield and its components

Fertiliser treatments had no significant effect on FFB yield and yield components in 2008 and 2006-2008 (Tables 4 and 5). The CV% for yield and BNO were very high and this indicates huge variability between plots in terms of bunch number and subsequently yield. One possible explanation for this is because of the substantial moisture difference observed within the trial block, mainly due to the difference in the soil's physical properties.

Table 4. Effects (p values) of treatments on FFB yield and its components in 2006 – 2008 and 2008

Source	2006-2008			2008		
	FFB yield (t/ha)	BNO/ha	SBW (kg)	FFB yield (t/ha)	BNO/ha	SBW (kg)
Urea	0.305	0.493	0.591	0.330	0.200	0.781

El. Sulphur	0.324	0.288	0.222	0.103	0.379	0.134
Urea x El. Sulphur	0.544	0.496	0.731	0.625	0.329	0.961
CV %	*21.5*	*21.1*	*8.4*	*17.3*	*12.6*	*11.4*

Table 5. Main effects of treatments on FFB yield (t/ha) in 2006 – 2008 and 2008.

Fertiliser (kg/palm)	**2006-2008**			**2008**		
	FFB yield (t/ha)	**BNO/ha**	**SBW (kg)**	**FFB yield (t/ha)**	**BNO/ha**	**SBW (kg)**
Urea 0.5	19.7	1599	12.3	18.0	1354	13.3
Urea 1.5	18.7	1553	12.2	17.9	1331	13.5
Urea 2.5	19.9	1601	12.5	17.4	1266	13.6
Urea 3.5	16.6	1392	11.8	15.6	1198	12.9
El. sulphur 0	17.6	1490	11.8	15.7	1233	12.7
El. sulphur 0.15	18.4	1460	12.6	18.4	1311	14.0
El. Sulphur 0.30	20.1	1659	12.2	17.6	1318	13.3
Grand Mean	18.7	1536	12.2	17.2	1287	13.3

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

The fertilizers had no significant effect on leaf nutrient contents (Tables 6 and 7). Though not statistically significant, there is a trend developing in leaflet N concentration with urea rates (Table 7). All the nutrients were in the adequate range except leaflet and rachis K contents (Table 7).

Table 6: Effects (p values) of treatments on frond 17 (F17) nutrient concentrations 2008 (Trial 330). p values <0.05 are indicated in bold.

Source	**Leaflets**							**Rachis**			
	Ash	**N**	**P**	**K**	**Mg**	**S**	**B**	**Ash**	**N**	**P**	**K**
Urea	0.250	0.503	0.675	0.992	0.638	0.847	0.685	0.389	0.125	0.235	0.840
S	0.936	0.749	0.776	0.021	0.691	0.813	0.914	0.773	0.875	0.609	0.570
Urea x S	0.391	0.981	0.941	0.445	0.404	0.915	0.396	0.081	0.384	0.607	0.446
CV%	*9.8*	*5.1*	*4.3*	*5.6*	*15.9*	*4.6*	*13.9*	*14.0*	*9.2*	*26.6*	*17.8*

S= elemental sulphur

Table 7: Main effects of treatments on F17 nutrient concentrations in 2008, in units of % dry matter, except for B (mg/kg) (Trial 330). Effects with p<0.05 are shown in bold.

Source	**Leaflet nutrient contents**							**Rachis nutrient contents**			
	Ash	**N**	**P**	**K**	**Mg**	**S**	**B**	**Ash**	**N**	**P**	**K**
Urea 0.5	11.8	2.32	0.142	0.65	0.25	0.21	11.6	4.31	0.261	0.089	1.12
Urea 1.5	11.3	2.32	0.143	0.64	0.25	0.21	11.1	4.07	0.269	0.079	1.15

Urea 2.5	11.7	2.38	0.142	0.65	0.24	0.21	11.9	4.11	0.284	0.070	1.15
Urea 3.5	10.8	2.39	0.145	0.65	0.26	0.21	11.1	3.83	0.287	0.072	1.07
S 0.00	11.3	2.36	0.144	0.62	0.25	0.21	11.3	3.99	0.273	0.082	1.07
S 0.15	11.4	2.37	0.144	0.65	0.24	0.21	11.4	4.08	0.278	0.075	1.16
S 0.30	11.5	2.33	0.142	0.67	0.26	0.21	11.6	4.16	0.274	0.075	1.14
$l.s.d_{0.05}$				*0.0307*							
GM	11.4	2.35	0.143	0.65	0.25	0.21	11.4	4.08	0.275	0.077	1.12

S= elemental sulphur

Effects of fertiliser treatments on vegetative parameters

There was no significant effect of fertiliser treatment on vegetative growth parameters except for elemental sulphur on FP (Tables 8 and 9).

Table 8. Effect (p values) of treatments on vegetative growth parameters in 2008. p values less than 0.05 are shown in bold.

Source				Radiation interception			Dry matter production				
	FL	**HT**	**PCS**	**FP**	**FA**	**LAI**	**FDM**	**BDM**	**TDM**	**VDM**	**BI**
Urea	0.197	0.275	0.477	0.312	0.464	0.960	0.580	0.333	0.448	0.576	0.134
S	0.518	0.932	0.559	0.179	0.232	0.084	0.350	0.075	0.096	0.255	0.112
Urea x S	0.824	0.634	0.837	0.868	0.833	0.761	0.784	0.719	0.729	0.771	0.873
CV%	5.2	7.3	10.5	4.7	9.0	9.2	11.4	15.9	12.6	11.3	5.6

FL = Frond length (cm); HT = Height (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 2007. Significant effects ($p<0.05$) are shown in bold.

Source				Radiation interception			Dry matter production (t/ha/yr)				
	FL	**HT**	**PCS**	**FP**	**FA**	**LAI**	**FDM**	**BDM**	**TDM**	**VDM**	**BI**
Urea 0.5	570.0	395.9	28.8	19.1	10.0	5.59	8.1	11.9	21.3	10.2	0.52
Urea 1.5	565.2	394.6	28.3	19.6	9.9	5.57	8.2	10.8	21.1	10.3	0.51
Urea 2.5	560.4	401.1	29.2	19.9	9.8	5.64	8.6	10.7	21.4	10.7	0.50
Urea 3.5	541.3	375.6	27.1	19.8	9.4	5.51	8.0	9.7	19.6	9.9	0.49
S 0.00	555.5	389.4	27.8	19.2	9.4	5.33	7.9	9.6	19.4	9.8	0.49
S 0.15	567.1	393.5	29.1	19.7	10.0	5.82	8.4	11.1	21.7	10.6	0.51
S 0.30	555.0	392.6	28.1	19.9	9.8	5.59	8.3	10.9	21.4	10.4	0.51
GM	559.2	391.8	28.3	19.6	9.8	5.58	8.2	10.6	20.8	10.3	0.50

FL = Frond length (cm); HT = Height (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

Fertiliser treatments had no significant effect on yield and its components. Similarly, leaf nutrients and physiological parameters were not affected by the treatments.

Trial 334: N x P Trial (Mature Phase) on Volcanic Ash Soils, Sangara

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.

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) while 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	Higaturu Oil Palms
Estate	Sangara	Block No.	2212A, 2213A & 22124A
Planting Density	135 palms/ha	Soil Type	Volcanic ash
Pattern	Triangular	Drainage	Good
Date planted	1999	Topography	Flat
Age after planting	8	Altitude	150 m asl
Recording Started	2006	Previous Land-use	Oil palm replant
Planting material	Dami D x P	Area under trial soil type (ha)	Not known
Progeny	Not known	Asst. Agronomist in charge	Susan Tomda

METHODS

Urea treatment is to be applied three times per year while TSP will be applied twice a year. 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 3. 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 were no significant yield and yield components responses in 2008 (Tables 4 and 5). Mean ffb yield in 2008 was 35.1 t/ha. Ffb yield response to TSP were unusual and cannot be explained.

Table 4. Effects (p values) of treatments on FFB yield and its components in 2007 to 2008 and 2008.

Treatments	2007-2008			2008		
	FFB yield	**BNO**	**SBW**	**FFB yield**	**BNO**	**SBW**
Urea	0.598	0.949	0.307	0.176	0.667	0.325
TSP	**0.031**	0.188	0.870	**0.018**	0.079	0.601
Urea.x TSP	0.113	0.314	0.911	0.061	0.145	0.808
CV %	*6.1*	*7.8*	*4.4*	*6.9*	*8.3*	*4.7*

Table 5. Main effects of treatments on FFB yield (t/ha) and yield components in 2007 to 2008 and 2008.

	2007-2008			2008		
Treatment levels	**FFB yield (t/ha)**	**BNO/ha**	**SBW (kg)**	**FFB yield (t/ha)**	**BNO/ha**	**SBW (kg)**
Urea-1	35.4	1810	19.6	34.1	1684	20.3
Urea-2	35.6	1794	19.9	35.6	1731	20.6
Urea-3	36.2	1805	20.1	35.5	1712	20.8
TSP-1	**36.7**	1827	20.1	**35.7**	1739	20.5
TSP-2	**36.6**	1859	19.7	**35.5**	1765	20.2
TSP-3	**34.2**	1737	19.8	**34.0**	1664	20.5
TSP-4	**36.8**	1852	20.0	**36.9**	1772	20.9
TSP-5	**34.5**	1739	19.9	**33.0**	1604	20.6
Grand Mean	35.7	1803		35.1	1709	20.5

Effects of interaction between treatments on FFB yield

There was no significant interaction effect of Urea.TSP but the highest yield of 38.8 t/ha was obtained at urea-1 and TSP-2 levels. It is still very early to report actual responses (Table 6).

Table 6. Effect of Urea and EFB (two-way interactions) on FFB yield (t/ha/yr) in 2008. The interaction was not significant (p=0.378).

	TSP-1	**TSP-2**	**TSP-3**	**TSP-4**	**TSP-5**
Urea-1	37.3	32.9	33.8	34.9	31.5
Urea-2	33.3	**38.8**	32.9	38.5	34.2
Urea-3	36.4	34.9	35.4	37.4	33.4
Grand mean	35.0	*Sed = 1.974*			

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

This was the first leaf sampling results analysed after fertilizer treatments were given to the plots. Urea significantly lowered rachis P contents (p=0.009) in the rachis while TSP affected Mg contents (p=0.034) in the leaflets and P contents (p=0.027) in the rachis. However, mean nutrient contents of all the plots were above their respective critical levels except leaflet Mg which was at 0.19 % DM.

Table 7: Effects (p values) of treatments on frond 17 (F17) nutrient concentrations 2008 (Trial 334). p values <0.05 are indicated in bold.

Source	Leaflet						Rachis			
	Ash	N	P	K	Mg	B	Ash	N	P	K
Urea	0.550	0.125	0.406	0.710	0.564	0.179	0.562	0.274	**0.009**	0.359
TSP	0.116	0.760	0.862	0.446	**0.034**	0.685	0.442	0.669	**0.027**	0.598
Urea.TSP	0.288	0.333	0.077	0.447	0.111	0.859	0.261	0.938	0.061	0.235
CV%	*3.8*	*3.1*	*2.0*	*5.9*	*8.3*	*11.9*	*10.4*	*7.9*	*10.9*	*9.5*

Table 8: Main effects of treatments on F17 nutrient concentrations in 2008, in units of % dry matter, except for B (mg/kg) (Trial 334). Effects with p<0.05 are shown in bold.

Treatments	Leaflet nutrient contents						Rachis nutrient contents			
	Ash	N	P	K	Mg	B	Ash	N	P	K
Urea-1	14.1	2.50	0.155	0.81	0.19	13.7	4.7	0.308	**0.135**	1.42
Urea-2	14.1	2.53	0.156	0.82	0.19	13.0	4.9	0.321	**0.127**	1.49
Urea-3	13.9	2.56	0.156	0.82	0.19	12.7	4.9	0.321	**0.119**	1.48
$l.s.d_{0.05}$									*0.0103*	
TSP-1	14.2	2.55	0.155	0.80	**0.18**	13.5	4.7	0.314	**0.117**	1.43
TSP-2	14.4	2.55	0.155	0.81	**0.20**	13.5	4.7	0.318	**0.120**	1.45
TSP-3	13.8	2.51	0.156	0.83	**0.19**	13.2	5.0	0.308	**0.130**	1.49
TSP-4	14.0	2.52	0.156	0.81	**0.19**	12.7	4.8	0.318	**0.132**	1.44
TSP-5	13.9	2.53	0.156	0.84	**0.19**	12.7	5.0	0.326	**0.137**	1.52
$l.s.d_{0.05}$									*0.0133*	
Grand mean	14.1	2.53	0.155	0.82	0.19	13.1	4.8	0.317	0.127	1.47

Effects of fertiliser treatments on vegetative parameters

Urea only affected TDM and VDM while TSP did not have any effect on the physiological parameters (Tables 9 and 10).

Table 9. Effect (p values) of treatments on vegetative growth parameters in 2008. p values less than 0.05 are shown in bold.

Source				Radiation interception			Dry matter production				
	FL	HT	PCS	FP	FA	LAI	FDM	BDM	TDM	VDM	BI
Urea	0.599	0.615	0.238	0.130	0.641	0.404	0.064	0.195	**0.018**	**0.041**	0.785
TSP	0.711	0.463	0.761	0.599	0.819	0.216	0.884	0.058	0.308	0.937	0.166
Urea.TSP	0.542	0.804	0.763	0.181	0.790	0.382	0.275	0.106	0.073	0.232	0.324
CV%	3.4	7.4	7.7	2.6	4.9	5.5	7.1	7.2	4.9	6.3	4.8

FL = Frond length (cm); HT = Height (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 2008. Significant effects ($p<0.05$) are shown in bold.

Source				Radiation interception			Dry matter production (t/ha/yr)				
	FL	**HT**	**PCS**	**FP**	**FA**	**LAI**	**FDM**	**BDM**	**TDM**	**VDM**	**BI**
Urea-1	631.2	519.5	43.5	24.9	12.5	6.52	15.6	18.7	**38.2**	**19.5**	0.49
Urea-2	626.7	533.8	45.3	25.0	12.4	6.49	16.3	19.6	**39.9**	**20.3**	0.49
Urea-3	623.2	526.6	45.6	25.4	12.6	6.66	16.6	19.5	**40.2**	**20.7**	0.48
TSP-1	632.8	534.4	46.0	24.8	12.6	6.43	16.4	19.6	40.0	20.4	0.49
TSP-2	618.5	539.2	44.2	25.2	12.3	6.37	16.1	19.6	39.6	20.0	0.49
TSP-3	627.4	525.0	44.8	25.3	12.5	6.64	16.3	18.8	39.0	20.2	0.48
TSP-4	629.2	506.4	44.1	25.1	12.5	6.61	15.9	20.2	40.1	19.9	0.50
TSP-5	627.3	528.1	45.0	25.2	12.5	6.73	16.6	18.3	38.4	20.1	0.47
GM	627.1	526.6	44.8	25.1	12.5	6.55	16.2	19.3	39.4	20.1	0.49

FL = Frond length (cm); HT = Height (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

The trial commenced in 2007 and there it was still early to report any true responses to fertiliser treatments.

Trial 335. N x P trial (Immature Phase) on Outwash Plains Soils, Ambogo

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) while 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 resect to leaf and rachis nutrient levels.

Table 1. Trial 335 background information.

Trial number	335	Company	Higaturu Oil Palms
Estate	Ambogo	Block No.	Block 4280H2
Planting Density	135 palms/ha	Soil Type	Volcanic outwash plains
Pattern	Triangular	Drainage	Good
Date planted	Oct/Nov 2007	Topography	Flat
Age after planting	0	Altitude	m asl
Recording Started	2008	Previous Land-use	Oil palm replant
Planting material	Dami D x P	Area under trial soil type (ha)	Not known
Progeny	4 Progenies	Asst. Agronomist in charge	Susan Tomda

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 tissue sampling and vegetative measurements were done in 2008. Yield recording will commence as soon as fruits are ready to be harvested. Recordings and measurements are taken on the central 16 palms in each plot. The number of bunches and bunch weights will be 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 will be carried out for each of the variables of interest using the GenStat statistical program.

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

Year	Age	TSP rate (kg/palm/year)				
		0	2	4	6	10
		g TSP/palm				
Planting	Hole	200	200	200	200	200
1st	6 m	0	300	600	900	1,500
	12 m	0	300	600	900	1,500
	Year 1 Total	**0**	**600**	**1,200**	**1,800**	**3,000**
2nd	18 m	0	450	900	1,350	2,250
	24 m	0	450	900	1,350	2,250
	Year 2 Total	**0**	**900**	**1,800**	**2,700**	**4,500**
3rd	30 m	0	500	1,000	1,500	2,500
	36 m	0	500	1,000	1,500	2,500
	Year 3 Total	**0**	**1,000**	**2,000**	**3,000**	**5,000**
4th	42 m	0	750	1,500	2,250	3,750
	48 m	0	750	1,500	2,250	3,750
	Year 4 total	**0**	**1,500**	**3,000**	**4,500**	**7,500**
5^{th} 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/year)		
		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

Table 4. Initial soil analysis results from soil samples taken in 2008

Reps	Depth (cm)	pH (H_2O)	Cations (cmol/kg) K	Ca	Mg	Na	CEC (cmol/kg)	OM (%)	Total N (%)	Olsen P (mg/kg)	Total P (mg/kg)	P ret. (%)
1	0-20	6.0	0.9	16.8	9.5	0.1	34.0	4.9	0.31	15.4	900	19
2	0-20	5.8	1.1	18.7	8.6	0.1	36.6	5.7	0.34	21.1	923	25
3	0-20	5.7	1.0	16.8	7.7	0.1	35.2	7.0	0.36	22.0	921	33
4	0-20	5.3	1.0	10.9	4.8	0.1	28.5	7.8	0.37	21.6	940	45
1	40-60	6.6	0.3	10.1	8.9	0.2	22.8	1.3	0.15	5.3	941	12
2	40-60	6.6	0.4	13.5	9.1	0.2	26.9	1.3	0.10	7.3	864	14
3	40-60	6.4	0.3	13.4	8.2	0.2	26.0	1.6	0.11	6.9	806	18
4	40-60	6.2	0.3	9.3	5.2	0.2	18.5	1.4	0.08	7.8	788	20
Mean	0-20	5.7	1.0	15.8	7.7	0.1	33.6	6.3	0.3	20.0	921.2	30.4
	40-60	6.4	0.3	11.6	7.9	0.2	23.5	1.4	0.1	6.8	849.8	15.9

Initial measurements, Bunches, PCS and FL

A survey was carried out in 2008 to determine the number of bunches that passed anthesis for all the palms in the trial. Survey was done to determine the number of black bunches, ripe bunches and hermaphrodites. The results are presented in Table.5. The data suggested Progeny D had the highest number of bunches for the 3 categories; ripe, black and hermaphrodite, followed by C, B and then A, implying differences in the 4 progenies.

Table. 5 Number of bunches for the four different progenies

Progeny	Bunch categories: Ripe bunches	Black bunches	Hermaphrodites	Total
A	2	127	46	129
B	0	369	105	369
C	12	325	95	337
D	17	397	116	414

The number of bunches were also analysed on the basis of treatments. Initial measurements on physiological growth parameters were also done in the trial and analysed. The analysed data are presented in Tables 6 and 7. There were significant responses in frond length to fertilizer treatments but cannot be interpreted sensibly because it is still very early to see any fertilizer effects on the parameters measured. The CV % were also very high, >10%, implying large interpalm and interplot variances.

Table 6 P values of BNO/plot petiole cross section and frond length.

Treatments	Measured parameters BNO/plot	PCS	FL
Urea	0.449	0.718	**0.012**
TSP	0.051	0.531	**0.013**
Urea.TSP	0.833	0.743	0.522
CV%	*49.5*	*16.2*	*11.5*

PCS = petiole cross section, FL = frond length

Table 7 Initial bunch number, petiole cross section and frond lengths

Treatments	**Measured parameters**		
	BNO/plot	**PCS (cm^2)**	**FL (cm)**
Urea-1	21.0	2.78	**123.8**
Urea-2	22.0	2.88	**111.2**
Urea-3	18.6	2.88	**114.0**
$l.s.d_{0.05}$			*8.54*
TSP-1	21.5	3.01	120.4
TSP-2	28.3	2.83	110.8
TSP-3	15.4	2.92	107.9
TSP-4	18.6	2.71	126.2
TSP-5	20.2	2.76	116.7
Grand mean	20.8	2.85	116.4

Effects of Urea and TSP treatments on leaf (F09) nutrient concentrations

Though leaf tissues were taken from the palms after only 6 months of receiving fertilizer treatments, significant responses were seen in leaf tissue nutrients. Urea had a significant effect on leaflet N ($p<0.001$), P ($p=0.034$) and B ($p<0.001$), and rachis ash ($p<0.001$), P ($p<0.001$) and K ($p<0.001$) (Tables 8 and 9). Urea increased leaflets N and P contents but lowered rachis ash, P and K contents.

In the leaflets, TSP increased the ash contents ($p=0.032$). TSP also affected B ($p=0.013$) contents but the trend was not clear.

Table 8: Effects (p values) of treatments on frond 09 nutrient concentrations 2008 (Trial 335). p values <0.05 are indicated in bold.

Source	Leaflet						Rachis			
	Ash	N	P	K	Mg	B	Ash	N	P	K
Urea	0.085	**<0.001**	**0.034**	0.103	0.967	**<0.001**	**<0.001**	0.541	**<0.001**	**<0.001**
TSP	**0.032**	0.171	0.518	0.375	0.720	**0.013**	0.439	0.180	0.176	0.933
Urea.TSP	0.211	0.768	0.111	0.237	0.181	0.522	0.084	0.441	0.789	0.130
CV%	*5.0*	*3.9*	*2.4*	*9.2*	*5.9*	*11.5*	*16.3*	*7.7*	*19.5*	*15.6*

Table 9: Main effects of treatments on frond 9 nutrient concentrations in 2008, in units of % dry matter, except for B (mg/kg) (Trial 335). Effects with p<0.05 are shown in bold.

Treatments	Leaflet nutrient contents						Rachis nutrient contents			
	Ash	N	P	K	Mg	B	Ash	N	P	K
Urea-1	10.1	**2.64**	**0.168**	1.00	0.41	**16.8**	**4.32**	0.350	**0.231**	**1.21**
Urea-2	9.8	**2.74**	**0.171**	1.02	0.41	**20.4**	**4.04**	0.359	**0.177**	**1.10**
Urea-3	10.0	**2.85**	**0.171**	0.96	0.41	**16.8**	**3.47**	0.357	**0.154**	**0.87**
l.s.d$_{0.05}$		*0.068*					*0.241*		*0.0233*	*0.106*
TSP-1	**9.5**	2.69	0.169	1.03	0.41	**18.0**	3.94	0.364	0.169	1.06
TSP-2	**10.0**	2.73	0.169	1.00	0.42	**17.5**	3.91	0.342	0.194	1.07
TSP-3	**10.1**	2.78	0.171	1.00	0.41	**19.4**	3.96	0.367	0.184	1.05
TSP-4	**10.1**	2.78	0.171	0.96	0.42	**17.6**	4.05	0.353	0.206	1.09
TSP-5	**10.1**	2.75	0.168	0.97	0.41	**17.4**	3.87	0.352	0.184	1.03
Grand mean	10.0	2.75	0.170	0.99	0.41	18.0	3.94	0.355	0.188	1.06

Conclusion

The bunch survey suggests there were differences in the progenies coming into flowering and fruiting.

The palms were responding to urea treatments as shown by differences in N contents in the leaf tissues.

Work progress todate.

- Yield recording commenced in 2009.
- Full vegetative measurement done in 2009
- Leaf tissue sampling done in frond 17 in 2009
- Fertilizer treatments on schedule.

Trial 331: Spacing and Thinning Trial, Ambogo

SUMMARY

The trial was designed to test the effects of spacing configuration, thinning and planting density on fresh fruit bunch (FFB) yield and other variables of interest. From field planting, there were six densities treatments (128, 135, 143, 192, 203 and 215 palms/ha) but at 5 years of age (May 2006), the densities 192, 203 and 215 were thinned to 128, 135 and 143, respectively, which now become the replicate of the three originally lower densities but with different spacing configurations.

Prior to thinning, a significantly high number of bunches (BNO) were produced at densities 192, 203 and 215 compared to the three lower densities. In 2006, the increase in the BNO resulted in significantly higher FFB yields. At lower densities, single bunch weight (SBW) was significantly higher.

INTRODUCTION

The purpose of the trial was to determine the effects of spacing configuration, thinning and density on palms, cover crops and soils, with a view to facilitating mechanical in-field collection. Mechanical removal of FFB from the field after harvest was and issue when the trial when the trial started. Mechanical removal is intended to reduce harvesting costs. Little is known about the impact that machine traffic has on the physical properties and long-term sustainability of the soils. Wider avenue spacings may allow more sunlight, better cover crop growth and less soil damage in the trafficked inter-rows.

Soils of the trial area belong to the Ambogo/Penderetta families, which are of recent alluvially re-deposited volcanic ash, with loamy topsoil and sandy loam subsoil, and seasonally high water tables. Other back ground information of the trial is presented in Table 1.

Table 1. Trial 331 back ground information

Trial number	**331**	Company	Higaturu Oil Palms
Estate	Ambogo	Block No.	4971A2
Planting Density	See Table 2	Soil Type	Alluvial flood plain
Pattern	Triangular	Drainage	Good
Date planted	2001	Topography	Flat
Age after planting	7	Altitude	m asl
Recording Started	Jan 2002	Previous Land-use	Oil Palm plantation
Planting material	Dami D x P	Area under trial soil type (ha)	Not known
Progeny	Mixed Dami DxP	Asst. Agronomist in charge	Susan Tomda

METHODS

Design and treatments

Initially there were 6 treatments 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 (May 2006) and treatments 1, 2 and 3 remained as planted. The final densities of treatments 4, 5 and 6 were the same as treatments 1, 2 and 3 but they have closely spaced pairs of rows with wide avenues between the pairs. There were 3 replicates of the 6 spacing treatments, giving a total of 18 plots. Each plot had 4 rows of recorded palms and these plots were surrounded by guard palms.

In 2002, about a year after the palms were planted, 7 cover crops were sown in small plots throughout replicate 2 of the spacing trial in order to assess their performance under the different light and traffic conditions of the different spacing treatments. The cover crops were Pueraria, Calapogonium, Mucuna, Vigna, Desmodium, Centrosema and Stylo. The cover crop trial was discontinued as there was poor germination and establishment.

Table 2. Treatment allocations in Trial 331. 'Thinning' involves the removal of every third row 5 years after planting in treatments 4, 5 and 6.

Treatment No	Initial density (palms/ha)	Triangular spacing (m)	Initial number of rows/plot	Density after thinning (palms/ha)	Inter-row width after thinning (m)
1	128	9.50	7	128	8.2
2	135	9.25	7	135	8.0
3	143	9.00	7	143	7.8
4	192	7.75	8	128	13.4 & 6.7
5	203	7.55	9	135	13.1 & 6.5
6	215	7.33	9	143	12.7 & 6.4

Data Collection

Recordings and measurements were taken on the 4 row of palms in each plot. The number of bunches and bunch weights were recorded fortnightly on an individual palm basis (individual palms not numbered) and totalled for each plot, then totalled for each harvest and expressed per ha per year. Single bunch weight was calculated from these data. During 2007, every recorded palm in each plot and record data against each numbered palm in the computer database system.

Leaf sampling was carried out once annually according to standard procedures and analysed for nutrient concentrations using standard analytical procedures. Every 5th palm in every recorded row of palms was leaf sampled and vegetative measurements were also taken from same palms.

Statistical Analysis

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

RESULTS and DISCUSSION

Effects of density treatment on yield and yield components

Density treatments had a significant effect on yield and it components in 2008 and 2007-2008 (Tables 3 and 4). Treatments 1, 2 and 3 (un-thinned) produced yield which were significantly higher than the thinned densities. This was due to significantly higher number of bunches from the un-thinned densities. In 2008, yield from palms planted at 128 palms/ha (un-thinned) recorded the highest with 37 t/ha however this was not statistically different from densities 135 and 143 (un-thinned).

Table 3. Effects (p values) of treatments on FFB yield and its components in 2008.

	2007-2008			2008		
Source	**Yield**	**BNO**	**SBW**	**Yield**	**BNO**	**SBW**
Density treatment	**<0.001**	**<0.001**	**0.009**	**0.035**	**0.051**	**0.058**
CV %	*2.4*	*3.0*	*1.7*	*5.1*	*5.9*	*2.0*

Table 4. Main effects of treatments on FFB yield (t/ha) in 2008 (treatments which are significantly different at P<0.05 are presented in bold).

	2007-2008			2008		
Density Treatment	**FFB yield (t/ha)**	**BNO/ha**	**SBW (kg)**	**FFB yield (t/ha)**	**BNO/ha**	**SBW (kg)**
128	**38.2**	**2540**	**15.1**	**37.0**	2288	16.2
135	**36.6**	**2574**	**14.3**	**35.6**	2308	15.4
143	**37.0**	**2535**	**14.7**	**35.6**	2243	15.9
128 (192)	**34.0**	**2243**	**15.2**	**33.5**	2050	16.3
135 (203)	**32.5**	**2203**	**14.8**	**32.3**	2025	15.9
143 (215)	**32.3**	**2206**	**14.7**	**32.3**	2047	15.8
$lsd_{0.05}$	*1.526*	*127.3*	*0.447*	*3.207*		
Grand Mean	35.1	2383	14.8	34.4	2160	15.9

(..) previous density

Leaf tissue nutrient concentrations

There was no difference in leaf tissue nutrient contents and all nutrient concentrations were above their respective critical values for oil palm (Table 5 and 6).

Table 5: P values of frond 17 nutrient concentrations 2008 (Trial 331). p values <0.05 are indicated in bold.

Source	**Leaflet**						**Rachis**			
	Ash	**N**	**P**	**K**	**Mg**	**B**	**Ash**	**N**	**P**	**K**
Density	0.273	0.921	0.216	0.595	0.299	0.615	0.106	0.478	0.070	0.277
CV%	*2.8*	*1.7*	*1.4*	*3.8*	*4.7*	*20.7*	*4.3*	*8.7*	*7.7*	*5.6*

Table 6: Main effects of treatments on F17 nutrient concentrations in 2008, in units of % dry matter, except for B (mg/kg) (Trial 331). Effects with $p<0.05$ are shown in bold.

Density	**Leaflet nutrient contents**						**Rachis nutrient content**			
	Ash	**N**	**P**	**K**	**Mg**	**B**	**Ash**	**N**	**P**	**K**
128	12.2	2.61	0.158	0.737	0.233	24.8	5.2	0.350	0.154	1.93
135	11.8	2.59	0.159	0.723	0.247	31.3	5.5	0.323	0.164	2.02
143	12.3	2.62	0.157	0.743	0.250	33.9	5.4	0.327	0.148	1.96
128 (192)	12.2	2.63	0.160	0.743	0.250	30.9	5.3	0.323	0.170	1.90
135 (203)	11.9	2.62	0.156	0.763	0.240	28.6	4.9	0.307	0.148	1.80
143 (215)	11.8	2.61	0.159	0.757	0.233	29.4	5.2	0.307	0.138	1.88
GM	12.0	2.61	0.158	0.744	0.242	29.8	5.3	0.323	0.153	1.91

(..) previous density

CONCLUSIONS

The density treatment had a significant effect on yield in 2008 with the higher yields achieved by un-thinned planting densities of treatments 1, 2 and 3 (compared to treatments 4, 5 and 6). The number of bunches were significantly higher for the three un-thinned densities

Leaf tissue nutrient levels were generally at an adequate level.

Smallholder Research Report in 2008 – Oro Oil Palm Project

(Merolyn Koia and Dr. Murom Banabas)

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 2008.

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

1. Small holder Leaf Sampling

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 50 blocks and sent to AAR Laboratory in Malaysia for nutrient analysis**.** The results for each division are presented in Table 1.0.

The mean nutrient contents of all the major nutrient elements were well below the critical levels (Table 1.0). 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 P, K and B contents 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 value although it is not prominent.

There are a range of reasons or a possible combinations of reasons for the large range of values and they include; lack of fertilizer application, differences in palm age, negligence of block upkeep and very old palms due for replanting. In essence, the palms are nutritionally very low in nutrients and need inorganic fertilizer inputs especially nitrogen and potassium fertilisers.

Table 1.0 Mean nutrient contents of 60 smallholder blocks in 2008

Division	**Leaflet (% DM, except B ppm)**					**Rachis (% DM)**		
	N	**P**	**K**	**Mg**	**B**	**N**	**P**	**K**
Aeka (6)	1.99	0.138	0.76	0.25	10.6	0.257	0.094	0.89
Saiho (7)	2.30	0.144	0.74	0.25	13.6	0.259	0.050	0.62
Igora (10)	2.24	0.138	0.73	0.22	12.2	0.280	0.071	0.95
Illimo (9)	2.17	0.144	0.62	0.23	11.1	0.260	0.074	0.64
Sorovi (18)	2.21	0.135	0.76	0.27	13.5	0.279	0.106	1.11
Range	*1.81-2.96*	*0.124-0.157*	*0.61-0.93*	*0.14-0.40*	*8.5-20.4*	*0.200-0.330*	*0.030-0.260*	*0.20-1.69*
Critical value	*2.45*	*0.145*	*0.65*	*0.20*	*15*	*0.32*	*0.08*	*1.30*

(..) = number of blocks

2.0 Smallholder Block Assessments

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 Appendix… for criterias used for assessment). The summarised scores are presented in Table 2

The mean nutrient deficiency score was 1.8 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 1.0.

General block upkeep (weeded circles, harvest paths and general weeds) were low in all the divisions. However, pruning standards in many of the blocks were above average (2.2-2.7) due to harvesting done (FFB Harvest = 2.7). Note here that not all blocks do regular harvests, however blocks selected for sampling were blocks that harvest though not necessarily regular.

Insects pests and diseases scored very high (2.9-3.0) implying no major problems with pests and diseases in the blocks.

The scoring assessments indicate that there is average and above average scores in agronomic upkeep standards and pests and disease free blocks, nutrient deficiency is common across all the divisions. Harvesting at various frequencies is mostly likely leading to more nutrients leaving the blocks than going in and this could affect the long term sustainability of smallholder oil palm productivity.

Table 2.0 Smallholder block assessments scores in 2008

Criteria used for scoring block assessment	Divisions					Average score
	Aeka (6)	Igora (10)	Ilimo (9)	Saiho (7)	Sorovi (18)	
Nutrient deficiency (palms)	2.1	1.7	1.6	1.9	1.7	**1.8**
Nutrient deficiency (LCP)	2.6	2.5	2.5	2.9	2.3	**2.5**
Block Standard	1.9	2.3	2.5	2.9	2.0	**2.3**
Frond stacking	2.0	2.2	2.1	2.2	2.1	**2.1**
Legume cover plants	2.7	2.5	2.7	2.6	2.1	**2.5**
Harvest paths	1.9	2.0	1.8	2.0	1.9	**1.9**
FFB Harvest	3.0	2.6	2.6	2.8	2.3	**2.7**
Trunk ferns	2.6	2.6	2.5	3.0	2.6	**2.7**
Trunk wood/vines	2.1	2.3	2.1	2.1	2.1	**2.2**
Weeded circle	2.6	2.1	1.9	2.1	1.9	**2.1**
Weed-ground cover	1.7	1.8	1.7	1.9	2.1	**1.9**
Pruning <7years	3.0	2.5	2.5	2.8	2.4	**2.7**
Pruning >7years	2.3	2.5	2.0	2.1	2.1	**2.2**
Ganoderma	3.0	3.0	3.0	3.0	2.9	**3.0**
Insect damage	3.0	2.8	3.0	2.9	3.0	**2.9**
Rat damage	3.0	2.9	3.0	3.0	2.9	**3.0**

See Appendix…. assessment form used
(..) = number of blocks

3.0 Field Visits

Only three field inspections were done in 2008. All visits were pest (stick insect) and disease (ganoderma) related problems within the Igora Division. The Entomology section took the task in recommending control strategies.

4.0 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 fertilizer trials and shown around the trials plots and third was radio broadcasts.

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

Table 3.0 Number of field days and radio broadcasts in 2008

Extension mode	Section		Total
	Agronomy and Entomology	Agronomy alone	
Field days (Major)	7		7
Field days (Minor)	2	8	10
Radio broadcasts	3	3	6

Common questions asked by the growers were;

- difference between the 1st and 2nd planting materials
- why the company applying MOP (red marasin) & SOA (white marasin) while the growers only SOA
- can the fertilizer application be divided into smaller potions
- what is the orange spots/colour on the palm leaves
- production, when and why is the company not giving fertilizers

The main topics presented to growers during field days and radio broadcasts were;

- What is PNG OPRA and its functions
- The Importance of fertilizer, the main type of fertilizer (SOA), main role of SOA in the oil palm production, the rates to apply in immature and mature palms.
- 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.
- Impacts of HIV-AIDS on oil palm production

Forecasting Yield, is it Possible?
(Trial 332)

Dr. Murom Banabas

Background

Forecasting or estimating future crop yield enables plantation management to plan for milling requirements, transport and forward selling of product. There are two ways to forecast production:

(i) through the use of sophisticated models such as APSIM (Agricultural Production Systems sIMulator) produced by CSIRO in Australia, which can model growth of a crop throughout the year and based on current conditions and climate forecasts can accurately predict a crop yield. APSIM has modules for many annual crops and sugarcane. Other modules are under development, currently there is no Oil Palm module.

(ii) predictions based on some observable growth function of a crop which is linearly related to yield.

The latter method for forecasting a future yield is being developed within PNG OPRA.

Methods

Detailed monitoring of palms at MBE and Higaturu at weekly intervals for:

- Flowering date
- Time to first black bunch
- Time to mature bunch
- Time to harvest and bunch weight
- Frond production determination (2 counts per year; in 2007 we have started doing this quarterly)

Results and work progress

Towards the end of 2007, we started monitoring newly planted Dami materials (4 progenies of 5 palms each randomly allocated in plot) and three ASD materials (20 palms each per progeny) at Ambogo Estate. The idea here is to monitor the palms from the very early age to maturity.

Data from monitoring sites at Mamba, T324, OPRA Base and the new additional sites at Ambogo will be looked for 2009 Annual Report. The data from Higaturu on this trial was supposed to be looked at in 2008 however, data from similar trials at Milne Bay and Ramu were looked at and data need sorting into the computer system.

Poliamba Ltd, New Ireland Province: Summary and Synopsis

(Dr. Harm van Rees and Paul Simin)

A single fertilizer response trial was undertaken with Poliamba Estates in 2007:

1. Factorial trial response to B and K: two types of Boron fertilizer (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 fertilizer, but K levels have not changed (and this nutrient is present at an adequate level).

CTP Poliamba Estates: Synopsis of 2007 PNG OPRA trial results and recommendations

Trial	Palm Age	Yield t/ha	Yield Components	Tissue %dm	Notes
254 Poliamba B, MOP (factorial) Soil: Clay over coral	18	B x MOP 32 (NS)	B/palm 11.3 (NS) SBW 22.1 (NS)	MOP LK 0.68 (NS) RK 1.60 (NS) B LB 13 to 16 mg/kg LN 2.54, RN 0.26: LP 0.154, RP 0.11; LMg 0.25	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:

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

CTP Poliamba and PNG OPRA should develop a program for new trials at Poliamba. There is scope to develop new fertilizer trials on the shallow coral based soils on New Ireland. A phenology monitoring trial (similar to trial 515 at MBE) was initiated in mid 2007.

Trial 254: Boron Requirement Trial at Poliamba

SUMMARY

There were no differences in yield or tissue nutrient concentration from Borate and MOP fertilizer treatments in 2007. The trial is in its third year of full monitoring and assessment. 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 CTP Poliamba. This trial is designed to provide information that will help make recommendations for N, K and B fertilizer 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 a 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	19 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 fertilizers applied to all plots: TSP 1 kg / palm, Kieserite 1 kg / palm and Urea 2kg / palm

RESULTS and DISCUSSION

Yield and its components

There was no significant difference in yield between the three treatments (AC, MOP and Borate) in 2008 (see Table 2). The full effect of the extra nitrogen fertiliser, first applied in March 2008), was not expected to be measurable until at least the end of 2009.

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 2. Impact of FFB yield in 2008 from N (AC), K (MOP) and B (borate)

AC (kg/p)	**MOP (kg/p)**	**Borate (kg/p)**		
		0	**0.08**	**0.16**
4	2.5	30.2	30.9	28.1
4	7.5	28.3	30.0	29.4
8	2.5	30.5	29.6	30.0
8	7.5	28.1	28.5	29.7
Significant difference:				
	AC		**NS**	
	MOP		**NS**	
	B		**NS**	

There also were no significant effects of the different fertiliser treatments on bunch number (1264 b/ha) and bunch weight (23.4 kg). Note that the number of bunches recorded in 2008 was around 200/ha fewer compared to 2007, which resulted in a reduction in yield of around 2 to 3 t/ha between the two years.

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 (Figure 1). A 5 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, primarily due to fewer bunches being harvested.

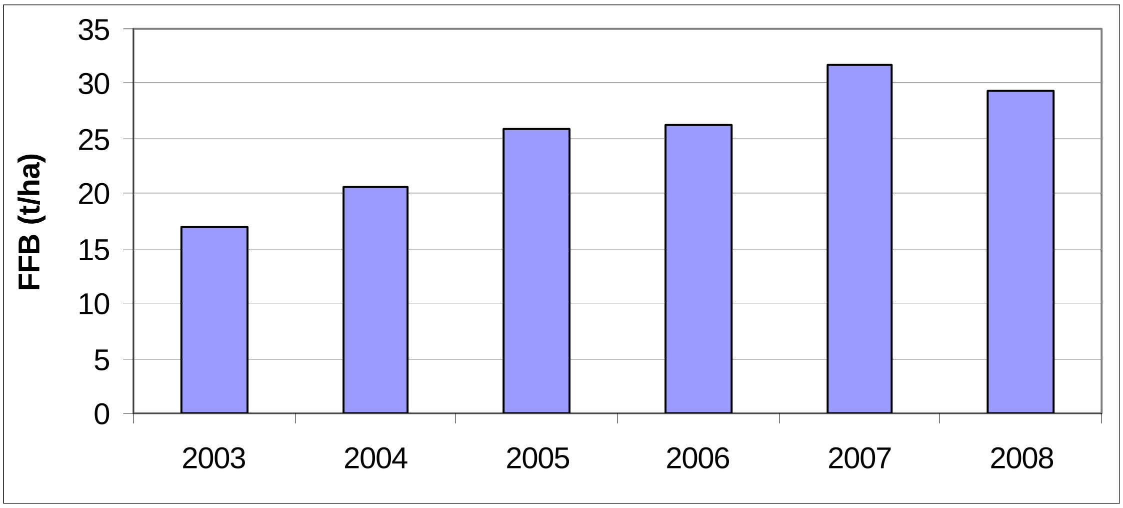


Figure 1. Trial yield since establishment in 2002.

Tissue nutrient concentration

Tissue (leaflet and rachis) nutrient concentrations were highly variable with co-efficients of variation above 10%, indicating that within treatment variability is high.

There was no significant effect of MOP rate on either leaflet or rachis K content. The application of Borate (either as Ca or Na borate) was significant on leaf B content (control with no Borate fertilizer had significantly lower B content compared to the Borate fertilizer treatments) (Table 5). However, there was no difference in leaflet B content between the two sources of Borate – Ca or Na borate.

Table 5. Trial 254: Tissue leaflet and rachis nutrient concentration in 2007 resulting from Borate fertilizer (2 types, 2 rates) and MOP (2 rates) application.

		Muriate of Potash kg/p					
	Boron	**2.5**	**7.5**	**2.5**	**7.5**	**2.5**	**7.5**
Borate source	**kg/p**	**Leaflet K (%)**		**Rachis K (%)**		**Boron (mg/kg)**	
No Borate (control)	0	0.67	0.73	1.51	1.66	13.0	13.3
CaB	0.08	0.70	0.69	1.56	1.75	16.1	16.0
CaB	0.16	0.64	0.65	1.51	1.72	17.6	16.1
NaB	0.073	0.67	0.70	1.62	1.77	16.5	16.1
NaB	0.146	0.66	0.69	1.47	1.53	16.8	17.6
	Significant Difference:	**P=0.25 (NS)**		**P=0.27 (NS)**		**P<0.001**	
	$LSD_{0.05}$	**-**		**-**		**2.7**	
	CV%	**8.7**		**12.5**		**12.2**	

The levels of leaflet N (mean 2.5%) and rachis N (mean 0.26); leaflet P (mean 0.154%) and rachis P (mean 0.11%); and leaflet Mg (mean 0.25%) were all adequate.

Effects of fertilizer treatments on vegetative growth parameters

The fertilizer treatments had no significant effect on Petiole Cross Section (P=0.25, mean 41.5cm^2); Frond Production (P=0.65, mean 22.3 new fronds/year); and Leaf Area Index (P=0.49, mean 5.3).

CONCLUSION

Muriate of Potash (MOP) and Borate fertilizer had no impact on yield or on tissue nutrient concentration. The trial treatments were first applied in 2005 and this was the third 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.

At the end of 2007 there were still no differences in yield between treatments. B uptake in the leaflet was higher in the treated plots compared to the nil controls (however there was no difference in rate or product type in leaflet B uptake).

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).

New trial layout (April 2008)

Trial	Plot	Rep	AC	MOP	NaB		Trial	Plot	Rep	AC	MOP	NaB
254	1	2	4	2.5	0		254	25	2	4	2.5	0.08
254	2	2	8	2.5	0		254	26	3	8	2.5	0.08
254	3	4	4	2.5	0		254	27	3	8	7.5	0.08
254	4	3	4	2.5	0.08		254	28	3	4	7.5	0
254	5	4	8	2.5	0.08		254	29	3	8	7.5	0.16
254	6	2	4	2.5	0.16		254	30	1	4	7.5	0
254	7	3	4	7.5	0.16		254	31	1	4	7.5	0.08
254	8	2	8	7.5	0.16		254	32	3	8	7.5	0
254	9	4	8	2.5	0.16		254	33	2	4	7.5	0.08
254	10	1	4	2.5	0		254	34	4	8	7.5	0
254	11	4	8	7.5	0.16		254	35	2	8	7.5	0.08
254	12	3	4	2.5	0.16		254	36	4	8	2.5	0
254	13	4	4	7.5	0		254	37	1	8	2.5	0.08
254	14	1	4	2.5	0.08		254	38	3	8	2.5	0.16
254	15	1	8	7.5	0.16		254	39	4	4	2.5	0.16
254	16	1	8	2.5	0		254	40	4	4	2.5	0.08
254	17	1	4	7.5	0.16		254	41	4	4	7.5	0.16
254	18	2	4	7.5	0		254	42	1	8	7.5	0.08
254	19	1	4	2.5	0.16		254	43	4	4	7.5	0.08
254	20	2	4	7.5	0.16		254	44	1	8	2.5	0.16
254	21	2	8	2.5	0.08		254	45	2	8	7.5	0
254	22	4	8	7.5	0.08		254	46	3	4	7.5	0.08
254	23	3	4	2.5	0		254	47	2	8	2.5	0.16
254	24	3	8	2.5	0		254	48	1	8	7.5	0

Treatment fertilizers
The treatment fertilizers 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 fertilizer: TSP at 1kg/p and Kieserite at 1kg/palm, both once per year

Ramu Agri-Industries (RAI)

Trial 601: N x P x K x S fertilizer trial on Immature palms, Gusap

(Dr. Harm van Rees and Nelly Naulis)

SUMMARY

The trial was planted in 2003, and 2008 was the first year of full data collection. The trial received reduced rates of treatment fertilizers from 2003 to 2007. In 2008 the trial received the full dose of treatment fertilizers.

No significant effects or trends of fertilizer treatments could be determined on yield or tissue nutrient contents. Tissue nutrient content appears to be adequate however the level of zinc in the leaflets could be low and should be further investigated.

INTRODUCTION

Oil palm planting started at RAMU in 2003, production has started and the mill opened in 2008. Three factorial fertilizer trials were established for 2003 and 2004 plantings, to assist with determining optimum fertilizer rates for oil palm in this generally drier environment with heavier clay soils. Harvest commenced in June 2007 and the results of two trials (601 and 602), both planted in 2003, are discussed. See Table 1 for background information on the first trial.

Table 1. Trial 601 background information (trial 601 was RAI trial RM1-03)

Trial number	**601**	Company	Ramu Oil Palm
Estate	Gusap	Block No.	GN203
Planting Density	120 palms/ha	Soil Type	Ramu clay
Pattern	Triangular	Drainage	Intermediate
Date planted	2003	Topography	Flat
Age after planting	5	Altitude	450 m asl
Recording Started	2007	Previous Land-use	Grassland
Planting material	Dami D x P	Area under trial soil type (ha)	Not known
Progeny	Known	Supervisor in charge	Kelly Naulis

METHODS

This trial was planted in November 2003 in block GN203 (Gusap) (previously recorded as Ramu trial RM1-03). A NxKxPxS factorial design with 2 replicates was used (for details of treatments see Table 2) (the trial treatments had 3 rates of N; 3 rates of K, 2 rates of S and 2 rates of P). Sixteen identified progenies were planted in each plot. All the treatments were randomised, including the progenies within plots and the fertilizer treatment plots within each replicate. During the immature phase following planting all treatment plots were fertilised with reduced treatment rates (see PNGOPRA Annual Report 2007). 2008 was the first year with a full application of treatment fertilisers (see Table 2).

Table 2. Details treatment fertiliser application in trial 601 (kg per palm) in 2008.

Fertiliser	Nutrient	Level 1	Level 2	Level 3	Schedule for application
Urea	N	0	1.5	3.0	(3) March, June, November
MOP	K	0	2.4	4.8	(2) April, November
TSP	P	0	1		(1) April
Tiger90	S	0	0.5		(2) April, November

RESULTS and DISCUSSION

Harvest commenced in June 2007. The 2008 yield data were analysed using ANOVA and Regression.

Yield - Analyis of Variance

At this early stage of the trial there are no significant differences between treatments, nor were any of the interactions between different fertilizers significant. The average yield for the trial site for 2008 was 16.4 t/ha, made up of 1982 bunches/ha (17 bunches/palm) with a SBW of 7.7 kg. For details of treatment yield see Table 3.

Table 3. FFB Yield, Bunch number and Single Bunch Weight for 2008 in trial 601

Treatments (kg/palm)	Yield (t/ha)	Bunch number (/ha)	SBW (kg)
Urea 0	15.5	1979	7.3
1.5	16.2	1929	7.8
3.0	17.4	2037	7.9
MOP 0	15.7	1978	7.3
2.4	16.4	1981	7.8
4.8	17.0	1986	8.0
TSP 0	15.8	1934	7.6
1	16.9	2029	7.8
Tiger S 0	15.7	1975	7.4
0.5	17.0	1988	7.9
Significant difference	NS	NS	NS
CV %	20.5	16.6	13.5

Yield – regression analysis

Linear multiple regression was used to investigate further the yearly influence of fertilizer N, P, K and S on yield. In the regression equation, yield is the dependent variable, and the N, P, K and S fertilizers the independent variables.

The interactions N.S, K.S, K.P and S.P had little effect and were not included in the final analysis, which simplified the quadratic equation:

$$Yield = a \dotplus bN \dotplus cK + dS + eP \dotplus fN^2 + gK^2 + hN.K + jN.P \qquad \text{(equation 1)}$$

where a, b, c, d, e, f, g, h and j are the parameters to be calculated. The last two terms, h and j, represent the linear by linear interaction between N and K; and N and P fertilizers.

The values for the parameters (with the associated standard error and t statistic) for the effect of fertilizer N, P, K and S on yield in 2008 are presented in Table 4. The multiple linear regression has a Co-efficient of Determination (R^2) of 0.30.

Table 4. Calculated parameters for the multiple linear regression for trial 601 in 2008.

	Calculated parameter	**Standard error**	**t statistic**	**Probability**
a Intercept	14.21	1.38	10.40	<0.001
b N	-0.34	1.13	-0.30	0.77
c K	-0.04	0.68	-0.06	0.96
d S	2.63	1.40	1.88	0.07
e P	1.11	1.11	1.0	0.32
f N^2	0.13	0.33	0.40	0.69
g K^2	-0.01	0.13	-0.07	0.94
h N.K	0.24	0.16	1.55	0.13
j N.P	-0.001	0.57	-0.02	0.98

For 2008 yield the only parameter which was significant was parameter 'a' for the Intercept, none of the other parameters were significant (see Table 4). The linear multiple regression confirmed the findings of the ANOVA (see above) in that none of the fertilisers had a significant effect on yield in 2008.

Fertiliser effect on tissue nutrient content

Leaflet and rachis samples were collected in April/May 2008 from each monitored palm and combined for each plot. The samples were analysed by AAR in Malaysia. The effects of fertilisers on tissue nutrient content are presented in table 5.

Table 5. Leaflet and Rachis nutrient levels for 2008 in trial 601 (significant effects are denoted in bold)

Treatments (kg/palm)	**Leaflet (% dm)**				**Rachis (%dm)**		
	N	**P**	**K**	**S**	**N**	**P**	**K**
Urea 0	2.61	0.152	0.63	0.21	0.38	**0.152**	1.77
1.5	2.63	0.153	0.66	0.21	0.37	**0.141**	1.71
3.0	2.66	0.154	0.67	0.22	0.38	**0.133**	1.79
MOP 0	2.62	0.154	**0.69**	0.21	0.37	**0.129**	1.70
2.4	2.64	0.153	**0.63**	0.21	0.38	**0.145**	1.78
4.8	2.64	0.153	**0.63**	0.21	0.38	**0.153**	1.79
TSP 0	2.63	0.153	0.65	0.21	0.38	0.141	1.78
1	2.64	0.154	0.65	0.21	0.37	0.143	1.73
Tiger S 0	2.64	0.153	0.65	0.21	0.38	0.147	1.75
0.5	2.63	0.153	0.66	0.21	0.37	0.138	1.76
CV %	2.7	2.1	7.8	4.2	11.1	16.1	10.8

As expected rachis P content decreased significantly with increasing application of N fertiliser; however it is not clear why increasing rates of MOP decreased both leaflet and rachis K.

The mean values for nutrient levels in the leaflet and rachis (Table 6) show that the overall nutrient status for the palms is satisfactory, no deficiencies, other then possibly for Zn, were noted. The level of Zinc could be low and should be further investigated (see Reuter and Robinson, Plant Analysis, an interpretation manual, CSIRO 1997).

Table 6. Mean values for nutrients in the leaflet and rachis (trial 601, 2008)

	Leaflet	**Rachis**
N %dm	2.63	0.38
P %dm	0.153	0.142
K %dm	0.65	1.76
Ca %dm	1.07	0.50
Mg %dm	0.32	0.13
Cl %dm	0.27	0.39
B ppm	0.21	0.06
Mn ppm	13	6
Cu ppm	31.5	7.3
Zn ppm	3.4	1.9
Fe ppm	8.9	4.0

DISCUSSION

In the first year after full fertiliser application there are no significant differences in yield from the different fertiliser treatments in this trial.

Trial 602: N x P x K x S fertilizer trial on Immature palms, Gusap

SUMMARY

The trial was planted in 2003, and 2008 was the first year of full data collection. The trial received reduced rates of treatment fertilizers from 2003 to 2007. In 2008 the trial received the full dose of treatment fertilizers.

No significant effects or trends of fertilizer treatments could be determined on yield or tissue nutrient contents. Tissue nutrient content appears to be adequate however the level of zinc in the leaflets could be low and should be further investigated.

INTRODUCTION

Oil palm planting started at RAMU in 2003, production has started and the mill opened in 2008. Three factorial fertilizer trials were established for 2003 and 2004 plantings, to assist with determining optimum fertilizer rates for oil palm in this generally drier environment with heavier clay soils. Harvest commenced in June 2007 and the results of two trials (601 and 602), both planted in 2003, are discussed. See Table 1 for background information on the second trial.

Table 1. Trial 602 background information (trial 602 was RAI trial RM2-03)

Trial number	**601**	Company	Ramu Oil Palm
Estate	Gusap	Block No.	GN106
Planting Density	120 palms/ha	Soil Type	Ramu clay
Pattern	Triangular	Drainage	Intermediate
Date planted	2003	Topography	Flat
Age after planting	5	Altitude	475 m asl
Recording Started	2007	Previous Land-use	Grassland
Planting material	Dami D x P	Area under trial soil type (ha)	Not known
Progeny	Known	Supervisor in charge	Kelly Naulis

METHODS

This trial was planted in November 2003 in block GN106 (Gusap) (previously recorded as Ramu trial RM2-03). A NxKxPxS factorial design with 2 replicates was used (for details of treatments see Table 2) (the trial treatments had 3 rates of N; 3 rates of K, 2 rates of S and 2 rates of P). Sixteen identified progenies were planted in each plot. All the treatments were randomised, including the progenies within plots and the fertilizer treatment plots within each replicate. During the immature phase following planting all treatment plots were fertilised with reduced treatment rates (see PNGOPRA Annual Report 2007). 2008 was the first year with a full application of treatment fertilisers (see Table 2).

Table 2. Details treatment fertiliser application in trial 601 (kg per palm) in 2008.

Fertiliser	Nutrient	Level 1	Level 2	Level 3	Schedule for application
Urea	N	0	1.5	3.0	(3) March, June, November
MOP	K	0	2.4	4.8	(2) April, November
TSP	P	0	1		(1) April
Tiger90	S	0	0.5		(2) April, November

RESULTS and DISCUSSION

Harvest commenced in June 2007. The 2008 yield data were analysed using ANOVA and Regression.

Yield - Analyis of Variance
At this early stage of the trial there are no significant differences between treatments, nor were any of the interactions between different fertilizers significant. The average yield for the trial site for 2008 was 8.4 t/ha, made up of 1028 bunches/ha (8.3 bunches/palm) with a SBW of 6.9 kg. For details of treatment yield see Table 3.

Table 3. FFB Yield, Bunch number and Single Bunch Weight for 2008 in trial 602

Treatments (kg/palm)	Yield (t/ha)	Bunch number (/ha)	SBW (kg)
Urea 0	9.1	1054	7.2
1.5	8.0	997	6.9
3.0	8.1	1034	6.5
MOP 0	8.5	1029	6.9
2.4	8.0	1008	6.8
4.8	8.6	1048	7.0
TSP 0	8.1	1014	6.6
1	8.7	1043	7.2
Tiger S 0	8.9	1076	7.1
0.5	7.9	980	6.7
Significant difference	NS	NS	NS
CV %	32.1	23.1	16.4

It is not clear why the yield is about half the yield in this trial (602) compared to trial 601. Both trials were planted at the same time. The co-efficient of variation of both trials is very high, and generally much higher compared to other PNGOPRA trials.

Yield – regression analysis
Linear multiple regression was used to investigate further the yearly influence of fertilizer N, P, K and S on yield. In the regression equation, yield is the dependent variable, and the N, P, K and S fertilizers the independent variables.

The interactions N.S, K.S, K.P and S.P had little effect and were not included in the final analysis, which simplified the quadratic equation:

$$\text{Yield} = a \pm bN \pm cK + dS + eP \pm fN^2 + gK^2 + hN.K + jN.P \qquad \text{(equation 1)}$$

where a, b, c, d, e, f, g, h and j are the parameters to be calculated. The last two terms, h and j, represent the linear by linear interaction between N and K; and N and P fertilizers.

The values for the parameters (with the associated standard error and t statistic) for the effect of fertilizer N, P, K and S on yield in 2008 are presented in Table 4. The multiple linear regression has a Co-efficient of Determination (R^2) of 0.15.

Table 4. Calculated parameters for the multiple linear regression for trial 602 in 2008.

	Calculated parameter	Standard error	t statistic	Probability
a Intercept	11.33	1.24	9.16	<0.001
b N	-1.77	1.02	-1.73	0.09
c K	-0.77	0.62	-1.25	0.22
d S	-2.04	1.27	-1.61	0.11
e P	0.60	1.0	0.60	0.55
f N^2	0.29	0.30	0.98	0.33
g K^2	0.09	0.12	0.80	0.43
h N.K	0.23	0.14	1.64	0.11
j N.P	0.04	0.52	0.07	0.94

For 2008 yield the only parameter which was significant was parameter 'a' for the Intercept, none of the other parameters were significant (see Table 4). The linear multiple regression confirmed the findings of the ANOVA (see above) in that none of the fertilisers had a significant effect on yield in 2008.

Fertiliser effect on tissue nutrient content

Leaflet and rachis samples were collected in April/May 2008 from each monitored palm and combined for each plot. The samples were analysed by AAR in Malaysia. The effects of fertilisers on tissue nutrient content are presented in Table 5.

Table 5. Leaflet and Rachis nutrient levels for 2008 in trial 602 (significant effects are denoted in bold)

Treatments	Leaflet (% dm)				Rachis (%dm)		
(kg/palm)	N	P	K	S	N	P	K
Urea 0	2.54	0.152	0.58	0.21	0.36	**0.164**	1.42
1.5	2.54	0.151	0.59	0.21	0.36	**0.139**	1.36
3.0	2.58	0.152	0.59	0.22	0.36	**0.134**	1.41
MOP 0	2.56	0.152	0.60	0.21	0.36	0.145	1.38
2.4	2.54	0.151	0.58	0.21	0.36	0.144	1.41
4.8	2.56	0.152	0.59	0.21	0.36	0.149	1.40
TSP 0	2.55	0.152	0.59	0.21	0.36	0.145	1.39
1	2.56	0.151	0.58	0.21	0.36	0.147	1.41
Tiger S 0	2.56	0.152	0.59	0.22	0.36	0.148	1.38
0.5	2.55	0.152	0.58	0.21	0.35	0.144	1.41
CV %	2.6	2.3	5.2	3.5	8.5	11.4	8.7

As expected rachis P content decreased significantly with increasing application of N fertiliser.

The mean values for nutrient levels in the leaflet and rachis (Table 6) show that the overall nutrient status for the palms is satisfactory, no deficiencies, other then possibly for Zn, were noted. The level of Zinc could be low and should be further investigated (see Reuter and Robinson, Plant Analysis, an interpretation manual, CSIRO 1997).

Table 6. Mean values for nutrients in the leaflet and rachis (trial 602, 2008)

	Leaflet	**Rachis**
N %dm	2.55	0.36
P %dm	0.152	0.146
K %dm	0.59	1.40
Ca %dm	1.04	0.53
Mg %dm	0.34	0.16
Cl %dm	0.49	0.92
S %dm	0.21	0.06
B ppm	15	6
Mn ppm	61.9	11.5
Cu ppm	3.8	1.6
Zn ppm	7.8	2.6
Fe ppm	66.7	38.0

DISCUSSION

In the first year after full fertiliser application there are no significant differences in yield from the different fertiliser treatments in this trial.

Trial 603: N x P x K x S fertilizer trial on Immature palms, Gusap

SUMMARY

The trial was planted in 2003, and 2009 was the first year of full data collection. The trial received reduced rates of treatment fertilizers from 2003 to 2008. In 2009 the trial received the full dose of treatment fertilizers.

No significant effects or trends of fertilizer treatments could be determined on yield or tissue nutrient contents. Tissue nutrient content appears to be adequate however the level of zinc in the leaflets could be low and should be further investigated.

INTRODUCTION

Oil palm planting started at RAMU in 2003, production has started and the mill opened in 2008. Three factorial fertilizer trials were established for 2003 and 2004 plantings, to assist with determining optimum fertilizer rates for oil palm in this generally drier environment with heavier clay soils. Harvest commenced in June 2007 and the results of two trials (601 and 602), both planted in 2003, are discussed. See Table 1 for background information on the second trial.

Table 1. Trial 602 background information (trial 602 was RAI trial RM2-03)

Trial number	**603**	Company	Ramu Oil Palm
Estate	Gusap	Block No.	GN106
Planting Density	120 palms/ha	Soil Type	Ramu clay
Pattern	Triangular	Drainage	Intermediate
Date planted	2003	Topography	Flat
Age after planting	6	Altitude	475 m asl
Recording Started	2008	Previous Land-use	Grassland
Planting material	Dami D x P	Area under trial soil type (ha)	Not known
Progeny	Known	Supervisor in charge	Kelly Naulis

METHODS

This trial was planted in November 2003 in block GN106 (Gusap) (previously recorded as Ramu trial RM2-03). A NxKxPxS factorial design with 2 replicates was used (for details of treatments see Table 2) (the trial treatments had 3 rates of N; 3 rates of K, 2 rates of S and 2 rates of P). Sixteen identified progenies were planted in each plot. All the treatments were randomised, including the progenies within plots and the fertilizer treatment plots within each replicate. During the immature phase following planting all treatment plots were fertilised with reduced treatment rates (see PNGOPRA Annual Report 2007). 2008 was the first year with a full application of treatment fertilisers (see Table 2).

Table 2. Details treatment fertiliser application in trial 603 (kg per palm) in 2009.

Fertiliser	Nutrient	Level 1	Level 2	Level 3	Schedule for application
Urea	N	0	1.5	3.0	(3) March, June, November
MOP	K	0	2.4	4.8	(2) April, November
TSP	P	0	1		(1) April
Tiger90	S	0	0.5		(2) April, November

RESULTS AND DISCUSSION.

Data from this trial will be analysed and discussed in 2009 Annual Report because full recording was done in 2009.

ANNEXURE A

Small holder block – hygiene and block management assessment

Block: Division:	Date:	Inspected by:

No	Insect/Nutrient deficiency	Score	Insect/Nutrient deficiency	Score
1	**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	
2	**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
3	**Block Standard – assess evenness (distance from road side pickup)** 1. 100m – rotten fruit on ground 2. 200m – rotten fruit on ground 3. no rotten fruit across block		10	**Trunk weeds – woody or vines:** 1. more than 20% trunk covered 2. 1 to 20% 3. none	
4	**Harvest - Fruit on the ground:** 1. more than 30 fruit on ground 2. 5 to 30 3. less than 5		11	**Trunk weeds – ferns:** 1. more than 80% (crown hidden) 2. 50 to 80% 3. less than 50%	
5	**Weeded Circle:** 1. more than 50% ground cover 2. 10 to 50% 3. less than 10%		12	**Pruning – less than 7 years old:** 1. 4 or more below lowest bunch 2. three to four 3. two fronds	
6	**Legume cover plants (LCP):** 1. more than 50% ground cover 2. 10 to 50% 3. less than 10%			**Pruning – more than 7 years old:** 1. 2 or more below lowest bunch 2. two fronds 3. one frond	
7	**Undesirable weed ground cover:** 1. more than 50% ground cover 2. 10 to 50% 3. less than 10%		13	**Insect damage (% defoliation):** 1. more than 25% damage 2. between 1 and 25% damage 3. no insect damage	
8	**Frond stacks:** 1. fronds not stacked 2. some stacked 3. stacked properly		14	**Ganoderma:** 1. more than 1 palm with brackets 2. one palm 3. none	
9.	**Harvest paths:** 1. no harvest paths 2. harvest paths with obstructions 3. good access		15	**Rat damage on bunches/male flow:** 1. more than 5 bunches/male flowers 2. 1 to 5 bunches/male flowers 3. no damage on bunches/male flow	

Procedures for under taking assessment:

- Small holder blocks may be uneven in management across the block – it is important to get an idea of unevenness across the block (see question 3).
- For the other assessments: as you walk through the block 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	**Nutrient deficient palms** • Write in which nutrient is deficient and record number of palms (out of six) with the visual deficiency
2	**Ground cover deficiency** • Write in nutrient deficiency and record % of plants with the visual deficiency
3	**Assess standard of maintenance across whole block** • Make assessment from the point where fruit is picked up on the road side • Assess how far into the block (in metres) fruit is harvested and collected
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	**Insects** • Record level of foliage damage for the six palms at each palm site
14	**Ganoderma** • How many of the six palms at each palm site have Ganoderma brackets
15	**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

2. ENTOMOLOGY RESEARCH

(C. F. Dewhurst)

SUMMARY

General entomology programme related studies

2008 was another busy year for Entomology Section, with our work being targeted primarily at continuing to improve pest monitoring and reporting, providing hands-on training for smallholders and continuing to address pest-related practical issues affecting all growers and the industry. During this year a more detailed reporting system for monitoring potential pest infestations was being developed. A change to the monitoring methods currently used was designed to enable a better understanding of pest populations before any serious situations arise by involving plantation and OPIC staff to a much greater extent than is currently the case (see below).

Extensive maintenance work was required to the entomology office and laboratory at Dami. The “insectary" laboratory” downstairs was modified; the wire mesh partitions were removed to give a better working environment for staff and provide more space for the rearing and sorting of both pest and beneficial insects. The surrounding compound was fully fenced to secure the experimental cages which were to be built for the Finschhafen Disorder project experimental work (CP/2006/063), and to comply with quarantine requirements. There was, as a consequence, a great deal of disruption on our staff and facilities.

Elaeidobius weevil rearing was maintained in our quarantine facility, and a full report on the rearing results was submitted to NAQIA for a decision to be made by them and DEC on the release procedures.

Pressure on the effective control of all pests was maintained during the year, although the number of reported pest infestation reports received increased from 80 in 2007 to 106 in 2008. Every infestation was visited by a member of the Entomology section.

No new pest taxa were recorded as oil palm pests during this year.

Updating of the pest infestation database (PID and PestRecs outputs) continued. Modifications to the Access database were required, which will delay full implementation, and data will continue to be entered into Excel until the updating is completed.

Since March 2006, six letters were written to NAQIA (on 11 March 2006, 29 August, 2006, 25 October 2006, and 24 May 2007) requesting Notifiable Pest Status (NPS) for “sexava” and stick insects, however they elicited no response and the gazettal process has not been completed. NPS status urgently requires gazetting to enable OPIC to deal more effectively with pest incidences and to inform growers of their responsibilities for pest reporting. It is therefore suggested that NPS should also be extended to cover *Ganoderma*; however there will be legal implications for this process which will require clarification from NAQIA/DEC.

Three meetings of the “Pest Management Working Group” (PMWG) were held at Hargy Oil Palms offices during the year (13/2, 14/8 & 19/10/08). During these visits, opportunities were taken to visit plantation fields and smallholder oil palm blocks and conduct pest surveys, as well as to make collections of *S.defoliaria* for *Stichotrema* (internal “sexava” parasitoid).

Weekly Pest Action Group Meetings, which form part of the OPIC Divisional Managers (DM) meeting at Nahavio, were routinely attended, and actively participated in to keep DM’s fully informed of the current situation, and for Action Points to be produced and acted upon before the following meeting. Up until the end of 2008, 156 such meetings chaired by SPM and latterly Ag/SPM OPIC had been attended by entomology personnel (HoE, DW or SM), since inception in 2006. Minutes are maintained and form the basis for discussion.

Through the regular weekly meetings, close contacts were maintained with OPIC and SHA in West New Britain, however there are obvious communication problems which must be addressed particularly when pest treatment issues are concerned.

Pest recognition training was given to plantation groups in WNB during August with 55 attendees attending at three separate sessions. OPIC field days were supported with some 360 smallholder growers attending during the year.

No radio broadcasts arranged by OPIC were undertaken on Mainland PNG during 2008, due to lack of available funding, however they continued undertaken in WNB.

Trials for alternative insecticides were undertaken and reports prepared, data were insufficient due to logistical and practical problems encountered. The reports that were prepared are however stored electronically on the server at PNGOPRA.

Pest Infestations in West New Britain Province, New Ireland Province and Mainland PNG in 2008.

<u>Plantation and smallholder pest monitoring</u>.

In 2008, there were 106 reports received of damage or concern about possible damage to oil palm by insect pests in PNG. Fifty eight-(55%) reports were received from plantations, and 48 (45%) reports were received through OPIC (WNB and mainland) (Fig.1). This was an increase of 32% from the previous year (80) in spite of maintaining pressure on issuing recommendations to treatment teams for dealing as quickly as possible with those infestations requiring treatment. There were however logistical issues with a lack of functional treatment equipment and team complements.

Due to the increases in infestations, and as a part of the need to improve on pest reporting, during the latter part of 2008, a plantation-wide monitoring plan for the major pests was proposed for trial in WNB. Once tested successfully, it will be rolled out to the other milling companies and growers; however with current staff levels, we do not have sufficient manpower and we find it difficult to effectively keep abreast of infestations reports coming in from the field. Developing this technique will continue until a simple and reliable method is identified.

For the reporting of pest infestations, PNGOPRA entomology section is relied upon to visit and survey all pest infestation reports, and provide recommendations for action for all such reports in PNG. This put a strain on staff resources, and infestations were often visited at a late stage, although in 2008, the majority of infestations (84%) were visited when infestations were light, 31% when we estimated damage to be medium and only 2% that were deemed severe. Lack of transport is a compounding issue.

We will soon be in a position to undertake an analysis of all reported infestations from 2000 once the new Access database is running. Results will be linked with meteorological data, as we require a sound bio geographical study of infestation developments in PNG.

Pest reports.

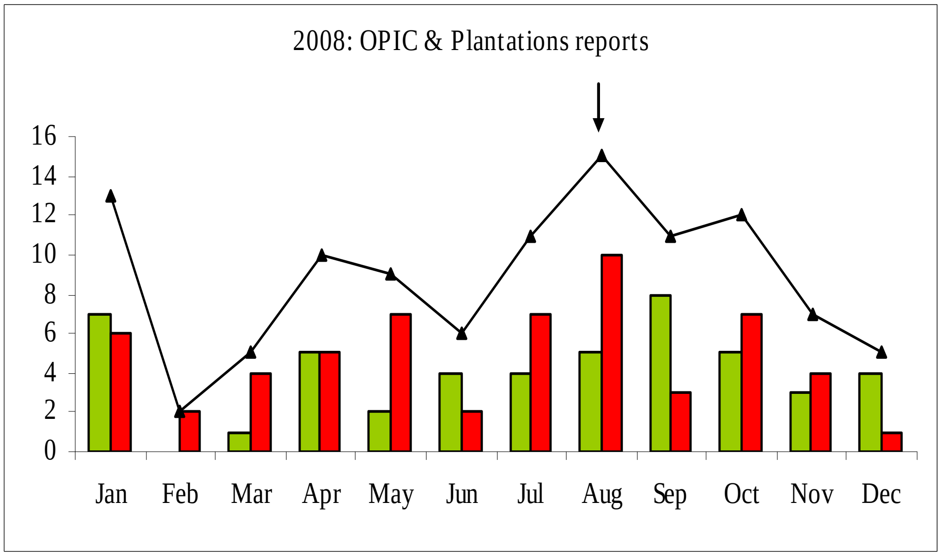


Figure 1: 2008: OPIC and Plantation infestation reports from **PNG**,

(OPIC GREEN, Plantations RED).

It can be seen from Figure 1 above, that there were some obvious difference in infestation reports between OPIC (Smallholders) and plantations, particularly during March, May and in the middle of the year (July-September) & again in December. There are peaks at approximately four month intervals (January, April, August, an approximate equivalent to the life cycle (not taking into account the effect of diapause eggs).

In **West New Britain,** there were 95 pest reports (OPIC 43, Plantation 52).

WNB reported the highest number of infestations in 2008 (Fig. 2), the figures appear similar as 75 of the reports were of *S.decoratus*, while 28 were of *S.defoliaria*, 33 also involved *E.calcarata*, although they were not mutually exclusive, and exclusivity depended upon locality, as there was considerable species overlap in some areas (especially on the north coast of WNB), while in the Bialla area, only *S.defoliaria* is found. There was a single report of *Zophiuma* was on coconuts in the Seaview compound at Numundo plantation (NBPOL)**,** although there were other local populations that were being used for experimental work at Kavui and near Dami [for 2009] (smallholder blocks). Rough bagworm (*Mahasena corbetti*) was the only other pest of significance with 9 reports in 2008.

Although there is no oil palm grown on the south coast of WNB, it would be very useful to know if any sexava spp. occurs there feeding on coconuts, as parasitoids were released there in the Kilenge area of Cape Gloucester in 1989 (Table 2).

Results of reports from West New Britain (Fig.2) also show, from the combined data, a series of peaks coinciding more clearly with the approximate life cycle; however the additional small peak in October cannot be explained, although it may be part of an extended population rise and fall towards the end of the year. Infestation numbers are, for the oil palm industry, not as relevant as areas attacked, and this change will be addressed in subsequent reports.

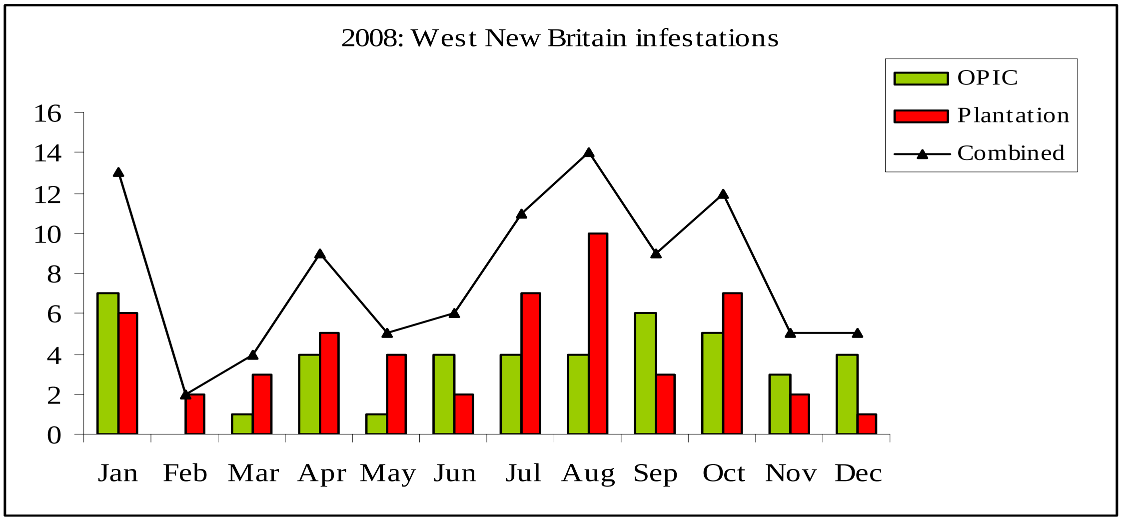


Figure**:** 2. 2008 infestation reports in **West New Britain**.

Pest taxa identified from field visits in reported infestations show that during 2008, *Segestes decoratus* dominated (in WNB) with more than double the number of infestations of *Segestidea defoliaria* and also more than double the number of reports of *Eurycantha calcarata.* Populations of *S.decoratus* in the north coastal areas of WNB were characterised by the all female populations of this insect (reproducing parthenogenetically), although occasional male specimens were collected. *S.decoratus* was first reported as attacking oil palm in 1986, and recognised as reproducing parthenogenetically.

Pest infestations treated during 2008.

Insecticide treatments in WNB

In the Bialla area HOPP treated 1,387.6ha in their plantations and a further 40ha (2 treatments) in a smallholder area (Alaba), against *Segestidea defoliaria*, the only species in that area.

In plantations 6,455.3 ha were treated, and Smallholder Affairs (SHA), part of NBPOL, managed treatment teams treated approximately 2,400ha of smallholder grower oil palms in all five divisions of the of "sexava" found in that area (Table 1).

Table 1: Smallholder blocks treated during 2008. (Source: NBPOL SHA office).

Smallholders		
Division	**No. of Palms**	**ha**
Buvussi Division	55,958	466
Nahavio Division	104,253	863
Kavui Division	2,473	21
Siki Division	120,205	997
Salelubu Division	6,734	56
Total	**289,623**	**2,403**

In **New Ireland** (Fig.3)**,** there were five reports of infestations, and those confirmed were in the second and last quarters of the year. There were no reports of *E.calcarata*, but only *S.gracilis*, with a single report which turned out to be wind damage. Of 5 pest reports received, 4 of them were from CTP plantations, and 1 was reported through OPIC.

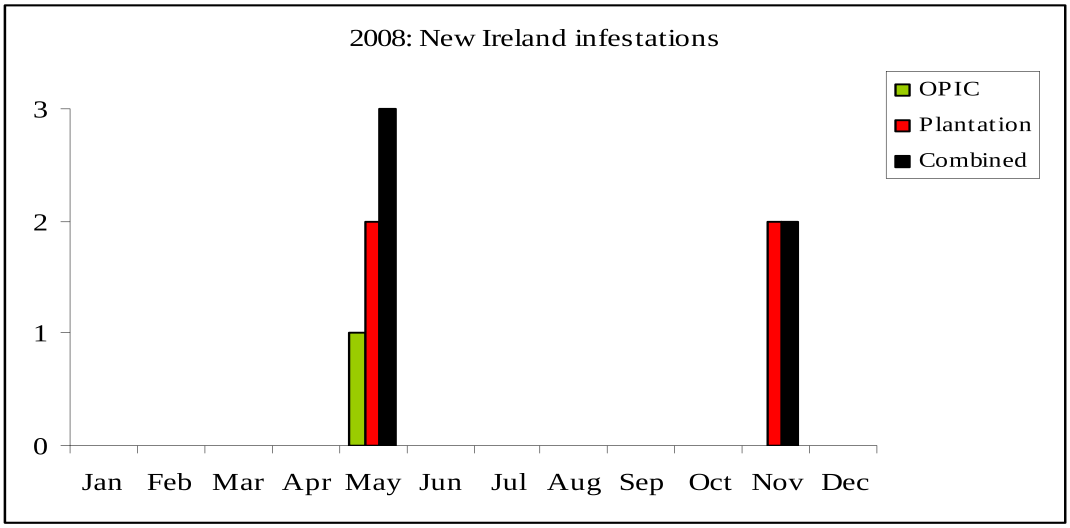


Figure: 3: 2008 infestation reports in New Ireland.

<u>Insecticide treatments in NI</u>

Interestingly *S.gracilis* was not known from oil palm in 1992, but only on coconuts at this stage, however in 2000, 70ha of oil palm was treated at Wanup Estate on the island. Infestations have subsequently been reported regularly ever since.

Insecticide treatment (TTI) was carried out in two blocks in December 2008 at Dalom and part of Kamarika-fields (AE0130 and AE 0140), both on Madak Estate. 18ha at Dalom and 33.9 & 43.2ha (77.1ha) respectively for the two blocks at Kamerika.

Six pest infestation reports were received from **Mainland PNG** (two of *S.novaeguineae*) (Fig.4). Four reports were received through OPIC, with 1 from Higaturu and 1 from Milne Bay Estates (MBE) who reported an as yet undescribed bagworm (Lepidoptera, Psychidae) which was found on 8-10yo palms near the mill (Block 1190). The initial report received from here related to a small dark Cassid (Coleoptera: Cassidae), which has still to be identified. This insect does not feed on oil palm, but was roosting on the underside of the leaflets during the day.

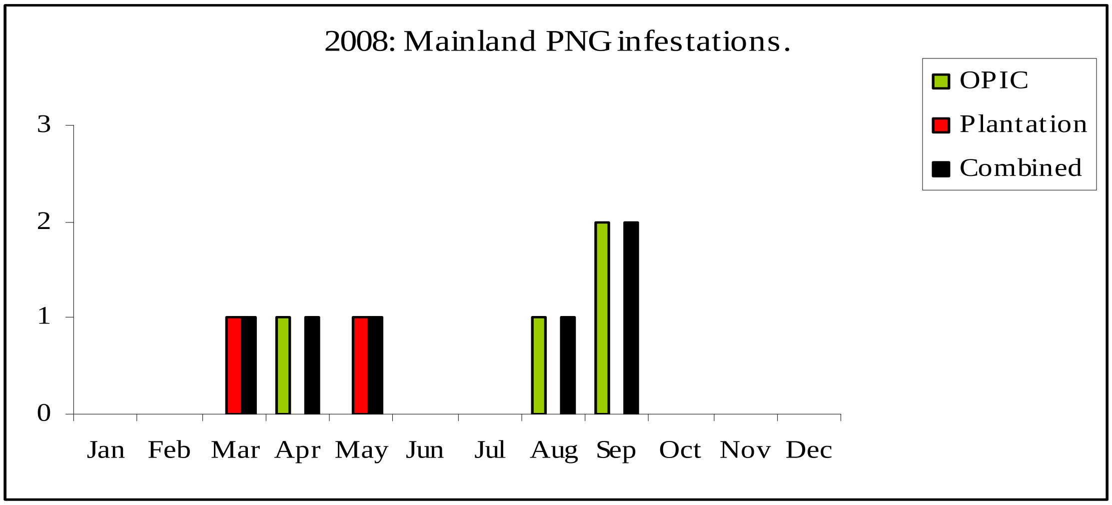


Figure 4: 2008. Infestation reports from mainland PNG.

Insecticide treatments on the mainland

There was no insecticide treatment (TTI) undertaken on the mainland this year.

Five other mainland reports were of the stick insect *E.insularis* (2 sites), *Segestidea novaeguineae* (2 sites) and *Oryctes centaurus* (2 sites, 1 on coconut also with *Z.lobulata* on coconut in the staff residential area at Mamba only). These data are stored on the pest information database held at Dami and as individual records in .pdf and Excel format at Entomology section (Higaturu Research Centre).

Eurycantha insularis (stick insect) which was first reported as an oil palm pest in 1986 through until 1990, however there were subsequently no reports until 2007. This insect was reported on three occasions in 2008, and continued to cause damage in the Igora and at Boru-Sorape area of Northern (Oro) Province. As they are eaten by local inhabitants, treatment could not be recommended (see section on Economic monitoring).

Other insects.

There were no reported infestations of "white grubs", and there were no pest reports received from Ramu, although *Lepidiota* was responsible for damage to new plantings on the grass plains new planting areas where the infestations were treated by NBPOL/RAI.

We are still awaiting identification of the melolonthine beetle (Coleoptera: Scarabaeidae) collected near Higaturu [North Sangara smallholder block] (mainland PNG), which was damaging young plantings [ca. 12months old] (roots), and killing the affected seedlings. The specimen was sent to CSIRO, Canberra Australia for identification; however it is with Dr P Allsopp at BSES Ltd, Brisbane. It appeared similar to *Lepidiota*.

On the mainland, *Oryctes centaurus* (larger rhinoceros beetle) was reported from two plantations, Sangara and Ambogo (see below). *Oryctes rhinoceros* (Asian rhinoceros beetle) was reported twice, both reports of this insect were from West New Britain (WNB), and both in smallholder blocks (Figs. 5, 6 & 7).

O.rhinoceros was not recorded in New Ireland until 1989 and in East New Britain in 1992. It will be monitored in WNB using pheromone traps, as there were infestations of this beetle in WNB plantations during 1996-1997.

Scapanes australis which was first reported from Kapiura in 1991 was only reported from a single smallholder block locality in WNB in 2008.

No treatment for the control of any of these three pests was recommended.

Rough-bagworm (Rbw) infestations were reported from 9 plantations in three areas of WNB. Comparisons with 2007 are given in Fig.8

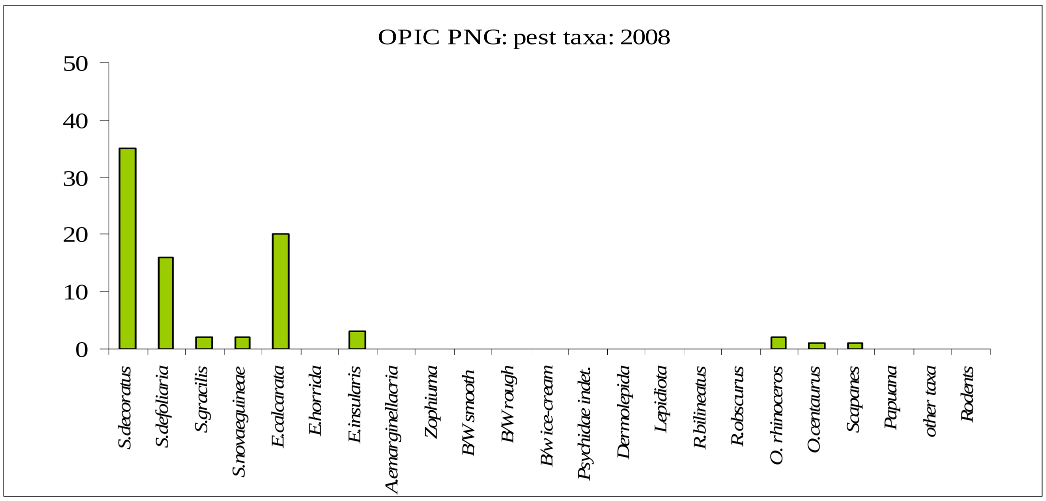


Figure 5: 2008: OPIC pest taxa records from within PNG

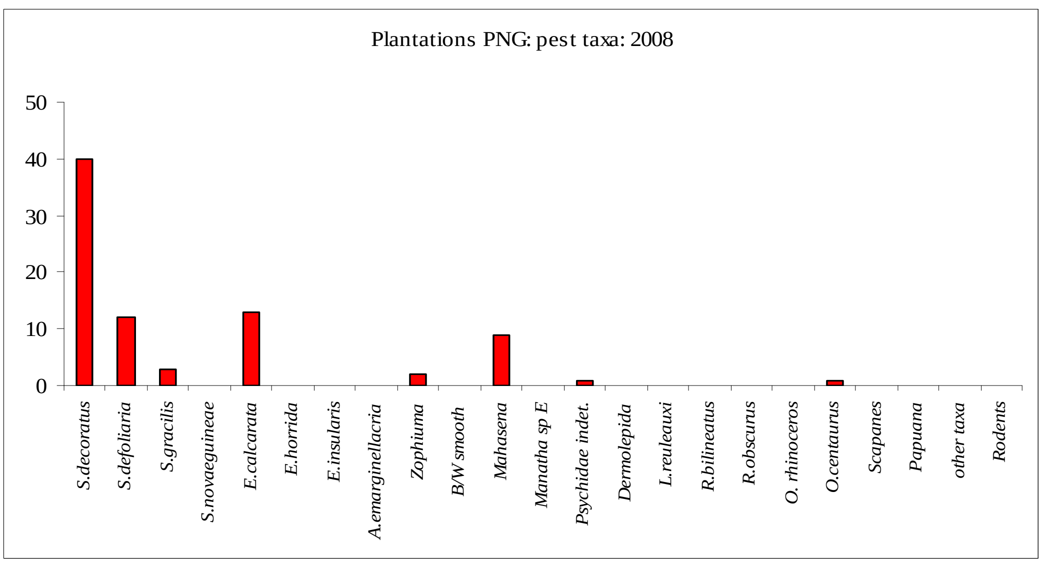


Figure 6: 2008: Plantation pest records from within PNG.

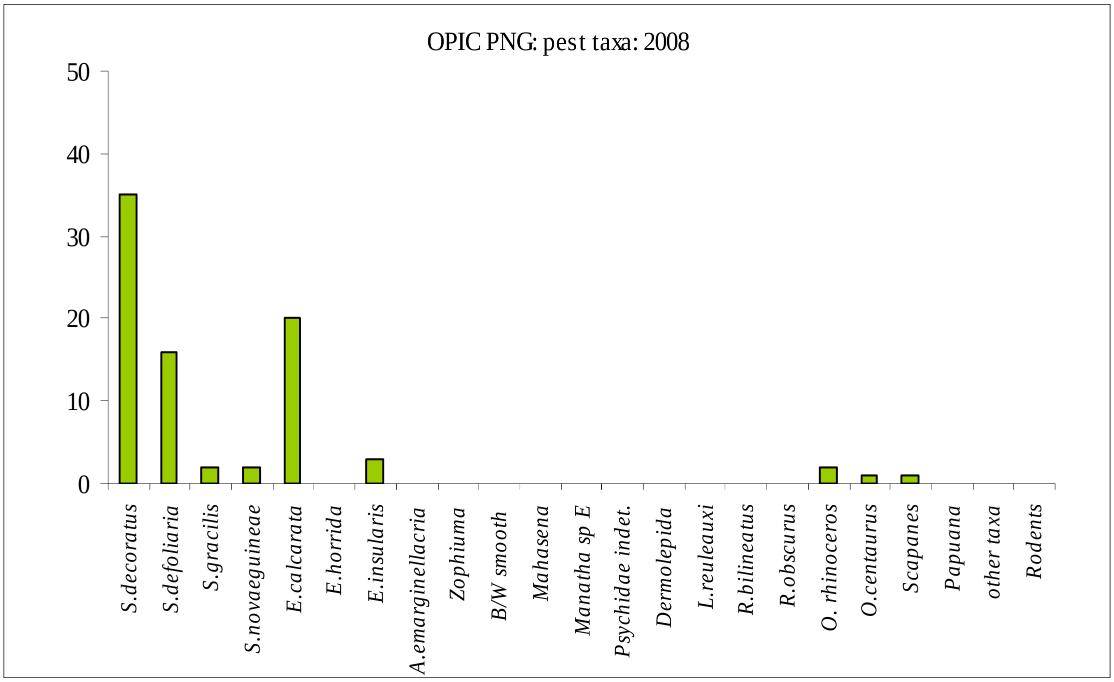


Figure 7: 2008: OPIC & Plantations: pest records, all areas in PNG.

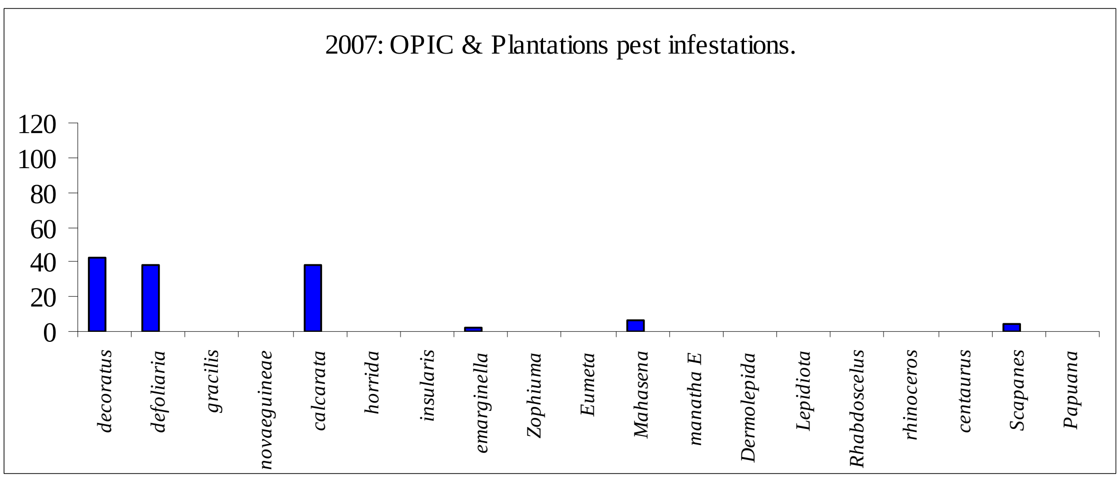


Figure 8: infestations of “sexava” and *Eurycantha* from 2007 (for comparison with 2008).

Table 2: PID spreadsheet. [Report dates are the date of infestation confirmation by ento. team].

	A	B	C	D	E	F	G	H	I	J	K	L
1	Report No.	OPIC (O) or Plantation (P)	Location details	Group	Plantation Division	OPIC Division	Where in PNG	Reference (report date)	Date of visit	Days after report received @ PNGOPRA	Reports/month (date visited & confirmed)	Date report issued by PNGOPRA
2	0108	O	Siki LSS			Siki	WNB	12-December-2007	**11-January-2008**	30		18-January-2008
3	0308	O	Sarakolok LSS			Nahavio	WNB	07-January-2008	14-January-2008	7		18-January-2008
4	0408	O	Pangalu VOP			Nahavio	WNB	15-January-2008	15-January-2008	0		18-January-2008
5	0508	P	Lotomgam ME	Mosa	1		WNB	08-January-2008	15-January-2008	7		18-January-2008
6	0608	P	Natupi ME	Mosa	1		WNB	08-January-2008	15-January-2008	7		18-January-2008
7	0708	P	Daliavu plantation	Numundo	2		WNB	15-January-2008	15-January-2008	0		18-January-2008
8	0808	P	Lotomgam ME	Mosa	1		WNB	20-January-2008	23-January-2008	3		24-January-2008
9	0908	P	Numundo plantation	Numundo	1, 2		WNB	23-January-2008	23-January-2008	0		24-January-2008
10	1008	P	Waisisi CP	Mosa	1		WNB	23-January-2008	28-January-2008	5		06-February-2008
11	1108	O	Waisisi VOP	OPIC		Siki	WNB	23-January-2008	28-January-2008	5		06-February-2008
12	1208	O	Siki LSS	OPIC		Siki	WNB	27-January-2008	28-January-2008	1		06-February-2008
13	1308	O	Siki LSS	OPIC		Siki	WNB	27-January-2008	28-January-2008	1		06-February-2008
14	1408	O	Buvussi LSS	OPIC		Buvussi	WNB	14-January-2008	29-January-2008	15		06-February-2008
15									Monthly summary		13	
16	1508	P	Haella plantation	Numundo	1		WNB	19-February-2008	**19-February-2008**	0	2	27-February-2008
17	1608	P	Bebere plantation	Mosa	1		WNB	18-February-2008	19-February-2008	1		27-February-2008
18	1708	O	Porapora VOP			Siki	WNB	09-March-2008	**17-March-2008**	8	5	26-March-2008
19	1808	P	Garu plantation	Numundo	2		WNB	17-March-2008	17-March-2008	0		26-March-2008
20	1908	P	Garu plantation	Numundo	1		WNB	17-March-2008	18-March-2008	1		26-March-2008
21	2008	P	Hargy	SIPEF			WNB	14-March-2008	19-March-2008	5		26-March-2008
22	2108	P	Milne Bay Estates	CTP	Field 1190		Mainland	20-January-2008	14-March-2008	54		31-March-2008
23	2208	P	Togulo plantation	Mosa	1		WNB	07-April-2008	**10-April-2008**	3	10	11-April-2008
24	2308	O	Tiauru LSS	Bialla		Bialla	WNB	17-March-2008	07-April-2008	21		12-April-2008
25	2408	O	Boru-Sorape	OPIC	2		Mainland	31-March-2008	02-April-2008	2		16-April-2008
26	9908	P	Kumbango plantation	Mosa	2		WNB	09-April-2008	10-April-2008	1		11-April-2008
27	2508	P	Bebere plantation	Mosa	2		WNB	09-April-2008	10-April-2008	1		11-April-2008
28	2608	O	Kaus LSS			Kavui	WNB	10-April-2008	13-April-2008	3		16-April-2008
29	2708	O	Ismin VOP			Nahavio	WNB	23-April-2008	23-April-2008	0		24-April-2008
30	2808	O	Pangalu VOP			Nahavio	WNB	17-March-2008	23-April-2008	37		25-April-2008
31	2908	P	Volupai plantation	Mosa	2		WNB	24-April-2008	28-April-2008	4		29-April-2008
32	3008	P	Haella plantation	Numundo	1		WNB	21-April-2008	23-April-2008	4		29-April-2008
33	3108	O	Sarakolok LSS			Nahavio	WNB	07-May-2008	**07-May-2008**	0	9	22-May-2008
34	3208	P	Daliavu plantation	Numundo	2		WNB	28-April-2008	02-May-2008	4		02-May-2008

Table 2b: Second page is a continuation from the previous screen shot, which continues still further across the page (to the right) and covers all pest taxa.

The spreadsheet is currently at: My Documents/Pests&Weeds/OPIC Plantation Pest Reports.xls.

Date report issued by PNGOPRA	Days from visit to report issued	Treatment no. monitor = 5, or Hand pick =6	Palms treated	Map info. Code	MU	Field number	Section	No. infested blocks	Avenue	Road	Pests found on visit: 1=Yes, 2=No, 3= eggs	Parasitoids released (1=DI 2=Lb, 3=both 4=Sticho, 5=Tachi	S.decoratus	S.defoliaria	S.gracilis	S.novaeguineae
18-January-2008	7	1		009				14			1	1	1	1		
18-January-2008	4	5		003				8			1		1			
18-January-2008	3	1						adjacent to Lotomgam			1		1			
18-January-2008	3	2							1,2,3		2		1			
18-January-2008	3	2							2,3,4		1		1			
18-January-2008	3	2									1		1			
24-January-2008	1	1			1, 2						1		1			
24-January-2008	1	1			1-5						1		1			
06-February-2008	9	1			6,7,8,9,10		7				1		1			
06-February-2008	9	2									1		1			
06-February-2008	9	1									1		1			
06-February-2008	9	2									1		1			
06-February-2008	8	5					7-10				1		1			
27-February-2008	8	1			3, 4						1		1			
27-February-2008	8	5			6B, 6C, 7G				12 - 18		1		1			
26-March-2008	9	1				003-'005					1		1			
26-March-2008	9	2			7, 10						0		1			
26-March-2008	8	1			2, 3						1		1			
26-March-2008	7	5				7					1			1		
31-March-2008	17	5				432		1			1					
11-April-2008	1	6			1B, 3A						1	0				
12-April-2008	5	5					4	7			1	1		1		
16-April-2008	14	5						690003			1	0				
11-April-2008	1	5						E8-E10			1	0	1			
11-April-2008	1	6			4A		isolated scattered palms		8B, D1, D2	BC, nahav	1	0				
16-April-2008	3	1		008							1	0	1			
24-April-2008	1	1		037						0-1A	1	0	1			
25-April-2008	2	1		063		31, 34, 16, 66		4			1	0	1			
29-April-2008	1	1			5, 7						1	0	1			
29-April-2008	6	1			3						1	0	1			
22-May-2008	15	1		003							1	0	1			
02-May-2008	0	1								6-10	1	0	1			

Smallholder Affairs (SHA), part of NBPOL, managed treatment teams treated approximately 2400ha of smallholder grower oil palms in all five divisions of the Hoskins Project. Plantation teams were required to treat 6,455.3 ha during the year. In the Bialla area HOPP treated 1,387.6ha in their plantations and a further 40ha (2 treatments) in a smallholder area (Alaba), against *Segestidea defoliaria*, the only sexava found in that area.

<u>Nursery surveys</u>

Nursery surveys were carried out monthly at CTP Higaturu (Mainland only), to monitor pest populations, as prophylactic spraying is no longer permitted under RSPO.

Only incidences of the common potential pests were monitored (Acrididae, Lymantriidae, Noctuidae and Psychidae) (Table 3 & Fig. 9).

Table 3: 2008 results of nursery pest surveys at CTP Higaturu oil palm nursery.

Month	No. of seedlings in nursery (sample area)	No. of seedlings sampled	% sampled	No. of palms with Lymantriidae (Tussock moths)		No. of palms with Acrididae (short-horned grasshoppers)		No. of palms attacked by *Spodoptera* spp. larvae (Noctuidae)		No. of palms with Bagworms (Psychidae)	
				Larvae	Cocoons	Nymphs	Adults	Bat ch	Individual	Rbw	Sbw
Jan	52341	5441	10.4	2	1	15	0	16	0	5	15
Feb	50000	4400	8.8	0	0	24	0	0	0	0	0
Mar	50000	4900	9.8	0	0	13	0	2	0	2	0
Apr	50000	7280	14.6	2	0	21	0	7	0	0	4
May	57112	8372	14.7	0	0	25	0	14	6	1	11
Jun	37361	11610	31.1	2	0	150	5	6	3	2	58
Jul	37361	10993	29.4	0	0	16	0	11	0	6	6
Aug	20120	6792	33.8	1	0	4	1	0	0	14	72
Sep	20120	7192	35.7	0	0	4	1	0	0	9	40
Oct	12383	1152	9.3	0	0	1	0	0	0	1	45
Nov	12383	2023	16.3	0	0	2	0	0	0	6	21
Dec	Seedlings overgrown and too dense to walk through the rows										

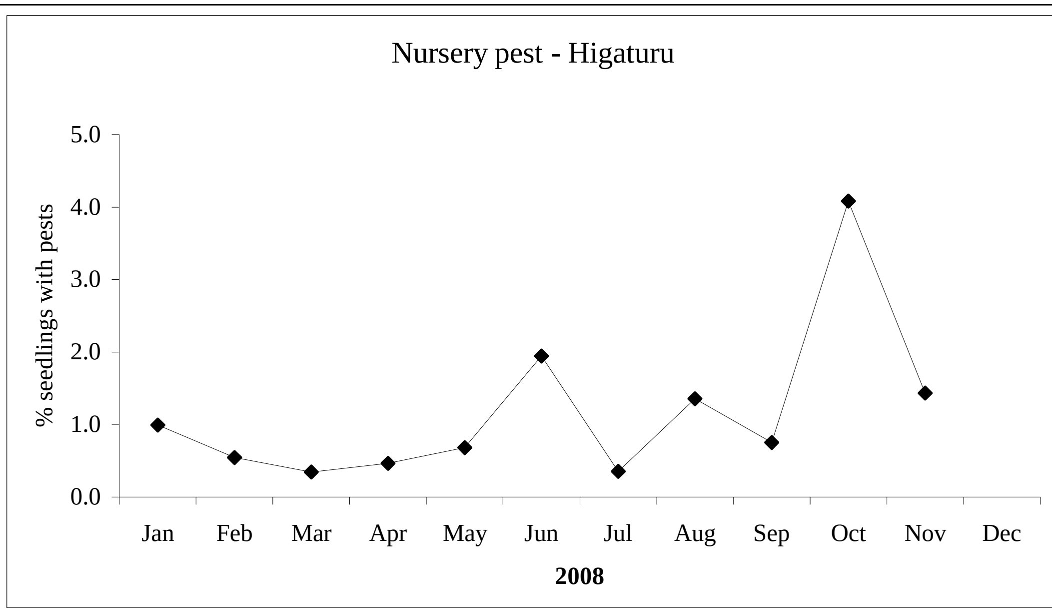


Figure 9**:** Nursery pest surveys monthly data; Higaturu (mainland).

The surveys (which did not include Acarina -mites), indicated the presence of low pest numbers from the nursery surveys, except for an increased percentage in October. Nevertheless numbers remained below 5% infestation (R.Safitoa pers.comm.). Any insects found such as Lepidoptera larvae or eggs were destroyed. The form of these surveys will require changing as the data are not adequately providing the statistics required by CTP, and a new record form will be prepared.

A common grasshopper found among nursery palms is from the family Acrididae: Oxyinae (*Oxya japonica* probably (ssp. *viticollis*) which was reared out from egg pods laid inside rolled oil palm leaflets. This is a very unusual oviposition site. If these egg pods are found in a nursery, they are easily destroyed manually by nursery staff (Figures 10, 11).

Figure 10: O.japonica egg case in leaflet

Figure 11: O.japonica (2 males above & female). Note the obvious markings especially on the dorsal surface.

Destructive Oil palm sampling (DPS)

The main pests of oil palm are nocturnal, which makes the process of monitoring during sampling very difficult. In plantations, when replanting is due to take place, the old palms are felled mechanically and the fallen palms are windrowed before being overgrown with planted cover crop.

To investigate other sampling options it was decided to remove all fronds from a sample of palms before they were felled, and to record the presence of all important pest taxa found on those fronds.

On 13 occasions the team went into plantations (Table 4) that were due for felling and preceded the mechanical felling teams by randomly taking 6 palms and systematically removing all fronds one by one following the spiral from the oldest frond up to the spear. Six palms were chosen as we found that six palms could be accurately sampled and data recorded during a mornings' work. As each frond was cut down, any pest specimens seen on them were removed and recorded. Specimens were sorted back in the lab in the afternoon.

Standardisation of frond number cut from each palm was essential so as to be able compare each palm from each site and compare the results obtained from different sites.

Figure 12: 2008: Spear about to be removed during DPS, Dami WNB.

Table 4. Localities where palms were sampled in 2007 and 2008.

Date sampled	*Location*	*No. of palms sampled*
14 April 2007	Malilimi Div. 2	6
05 June 2007	Navarai plantation	6
27 September 2007	Bebere plantation	6
12 November 2007	Dami plantation	6
21 February 2008	Malilimi plantation	6
26 September 2008	Bilomi plantation	6
30 September 2008	Garu plantation	6
2 October 2008	Daliavu plantation	6
8 October 2008	Haella plantation	6
20 October 2008	Sapuri plantation	6
21 October 2008	Waisisi Mini Estate	6
22 October 2008	Kumbango plantation	6
30 November 2008	Dami plantation (Buluma field)	6

These studies will be continued until there are sufficient data to enable a satisfactory estimation of the relationship between pest numbers on the lower (pruned) fronds with what is actually living within the oil palm canopy.

Data were collected from 78 palms and approximately 2,730 fronds were sampled (assuming about 35 fronds sampled per palm). There was a good correlation found between numbers of insects found on the older (lower) fronds and those among the younger fronds (towards the crown). There was an apparent relationship between numbers of insects occurring on the lower fronds which relate back to the numbers occurring higher up in the palm (Fig. 13). A regression on these data could not be undertaken, as fronds having no insects on them were not included in the analysis. Number and positioning of nymphs and adults was plotted (Fig.14) for all samples. The drop in numbers of insects collected from the older fronds is seen clearly in Fig.14, and this may provide the link between harvested fronds and the sexava “load” within the palm canopy. Additional work is still required, as it was also possible that those insects higher in the canopy migrated upwards as the lower fronds were removed. A **provisional** analysis has been undertaken (D.Woruba, personal communication), and more work is required before any applied use can be made of the data, as the data, however, the results suggest that the use of harvested (pruned) fronds may provide information for the further development of a sampling protocol. All data are retained on the PNGOPRA server.

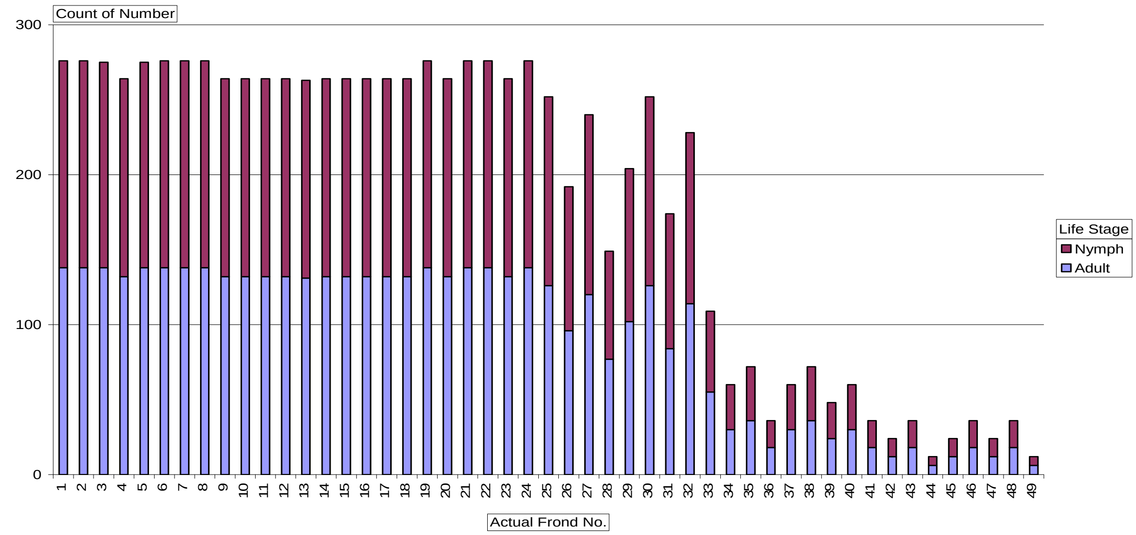


Figure 13: 2008. Nymphs of “sexava” and adults recorded from oil palm fronds at two localities in WNB (Dami and Malilimi plantations).

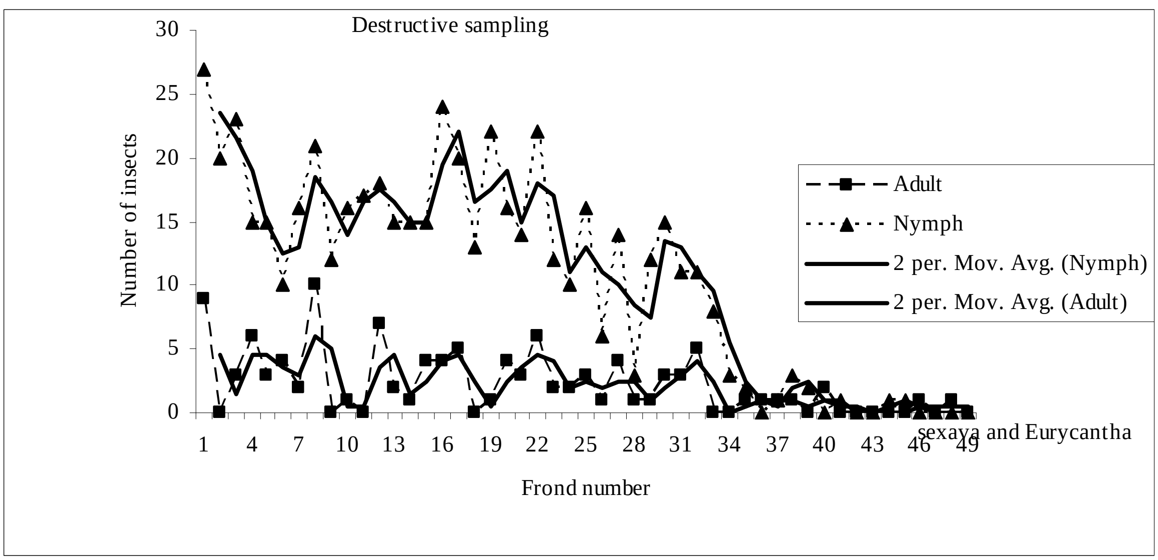


Figure 14: Variability of sexava numbers within the frond canopy. (Darker lines indicate 2 sample moving average).

Palm circle investigations

The data collected from these investigations were insufficient to be included in this report, however because of the relevance of these investigations, this work will continue when opportunities arise. We feel that clean "weeded" palm circles may help in reducing the survival of nymphs, either by unearthing the eggs making them available to predators or desiccation, and the nymphs more susceptible to predation by arthropods and vertebrates.

"Sexava" IPM

Figure 15: 2008: *Segestidea novaeguineae* Higaturu, Mainland PNG on oil palm. (lab photo).

"sexava" feeding trials.

Adults and nymphs of S.*decoratus, S.gracilis, S.defoliaria, and E.calcarata* were fed with palm leaflet material and the amounts eaten were calculated over a period of time. As a weight loss coefficient was not included in the original calculations, the amount eaten was not a true representation and these experiments will need to be repeated. All data currently available are stored on PNGOPRA server (Entomology drive on PNGOPRA server).

Economic assessment of sexava damage in a plantation in WNB

Figure 16: Pest damage to oil palm, notice the amount of light passing through the canopy.

A severe infestation of *S.decoratus* affected an oil palm plantation (Lotomgam ME) on the Talasea peninsular and, in conjunction with Thomas Betitis, Senior Agronomist at NBPOL/OPRS it was decided to monitor the effect of the infestation on FFB (fresh fruit bunch) productivity as a long term study, to ascertain when full productivity would be regained (Figure 17). Data showed an overall drop in FFB production from all Management Units (MU) monitored. This monitoring will continue until pre-infestation productivity is reached, which will provide economic data on the effects of severe damage to crop loss ($).

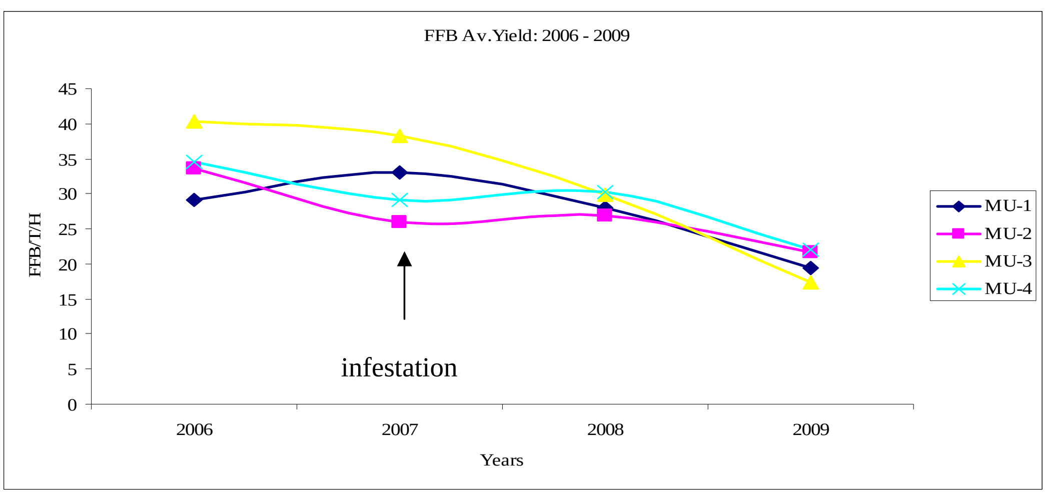


Figure 17: Lotomgam yield changes with time. (Results courtesy T. Betitis OPRS).

"sexava" Biological Control

Internal parasitoids

Occurrence of the internal parasitoid *Stichotrema* (Mymecolacidae) among mainland samples routinely sampled monthly varied between 20-40% (mean of 29%) throughout the year with noticeably fewer parasitoids recovered during May to July (Figs. 18 & 19). None were found in nymphs of mainland sexava (*S.novaeguineae*), as they are rarely found. In 1999 parasitism reported in Northern (Oro) Province to *S.novaeguineae* was 30-40%, which may be regarded as high.

Stichotrema genome studies in collaboration with Dr Jeya Kathirithamby (Oxford University, UK) were re-visited this year (see 2007 report) as funding for this work will become available in 2009. A Letter of Agreement will be prepared with Oxford University to ensure that any issues involving IPR are covered. MD will be the authorised signatory. This parasitoid is the largest known member of this order, it has a very small genome and a unique immune system, and as we use it in our biocontrol programme, understanding more about its genetic make up will clarify some of the issues surrounding its parthenogenetic reproduction with regards to the mechanism for maintenance of sufficient genetic variation without resorting to recombination.

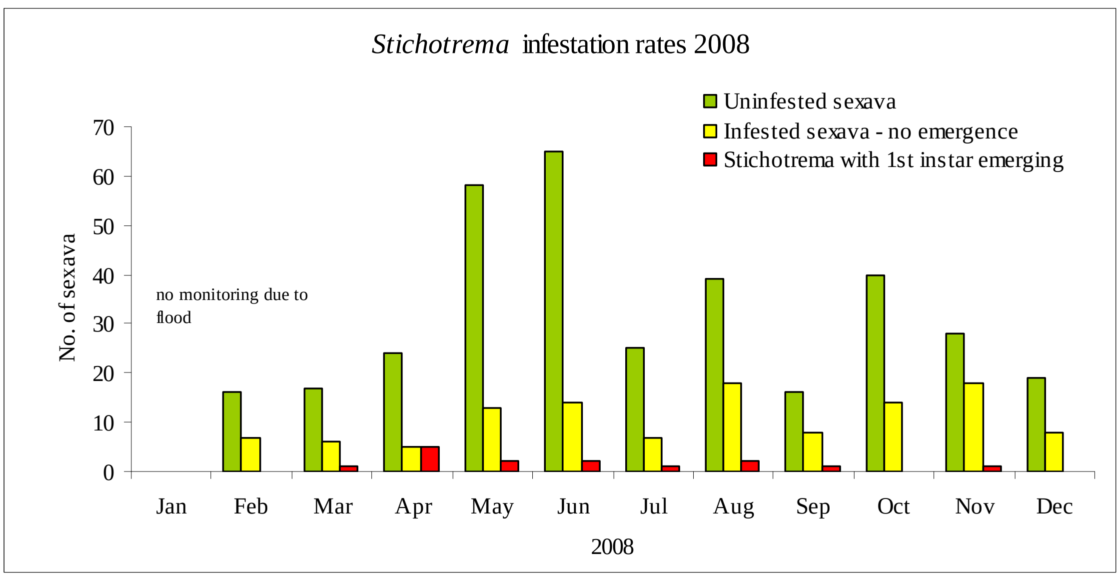


Figure 18: 2008: Mainland PNG *S.novaeguineae* showing monthly *Stichotrema* infestation rates.

During 2008, 480 adult "sexava" (*Segestidea novaeguineae*) were sampled. Infected adult *S.novaeguineae* were recorded during each month (Fig. 17), however there were no records of *Stichotrema* in nymphal instars of *Segestidea novaeguineae*, while from 133 adults (27.7%), of which only 15 were producing instar *i* larvae(11.3%) there was a distinct peak during April (Fig. 19). Female *Stichotrema* were recorded producing instar *i* larvae from March through until September, and again in November; however parasitized *S.novaeguineae* were recorded in all months (excluding January when flooding prevented sampling). Apart from the peak in April, parasitism remained between 20-40% (Mean 29%) throughout the year (Fig.20), in spite of noticeable fluctuations in October and December, and a mid-year trough.

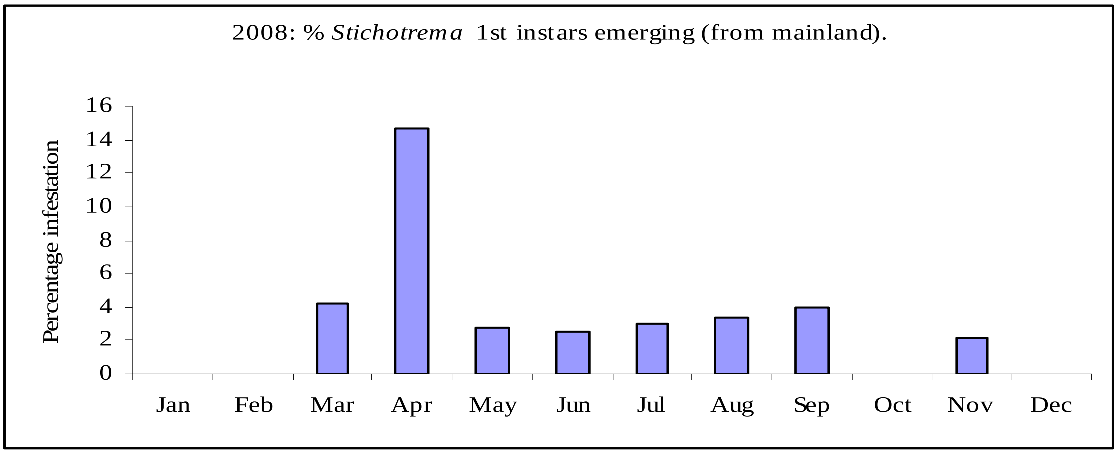


Figure 19: 2008: *S.novaeguineae* months with 1st instar *Stichotrema* emerging. Northern (Oro) Province PNG.

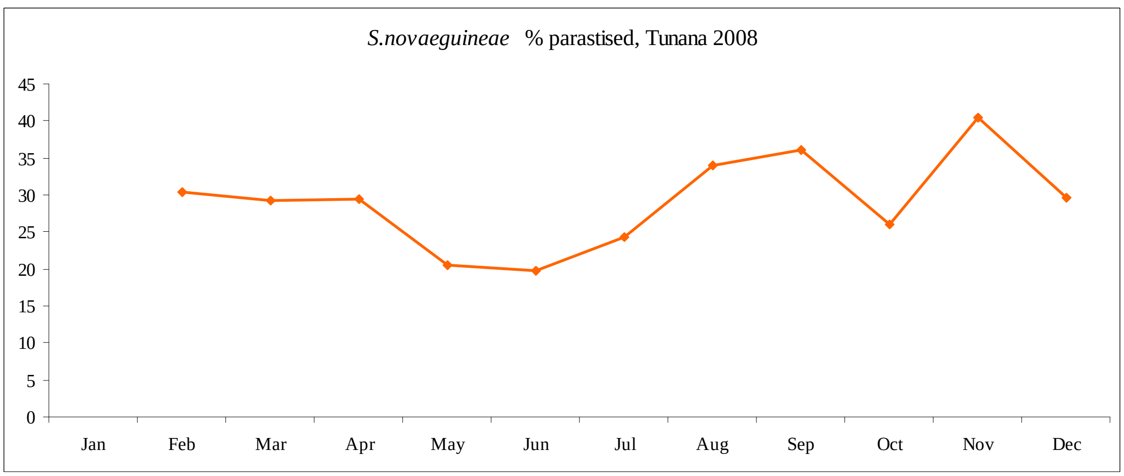


Figure 20: 2008, monthly percentage parasitism. Northern (Oro) Province.

Stichotrema in WNB:

The highlight in 2008 was the recovery of a female *S.decoratus* infested with *Stichotrema* from which instar *i* larvae were emerging. The host was collected on Dami plantation (Buluma field) on 23 April 2008. 10 *S.defoliaria* males and 10 *S.decoratus* infested with *Stichotrema* had been previously released into that area in 2005 from laboratory reared stock (Table 5). Males are released to reduce the possibility that females, although affected by reduced fecundity of 52% (Solulu 1996), may be able to lay eggs before being killed by the *Stichotrema* they are harbouring (Fig.21).

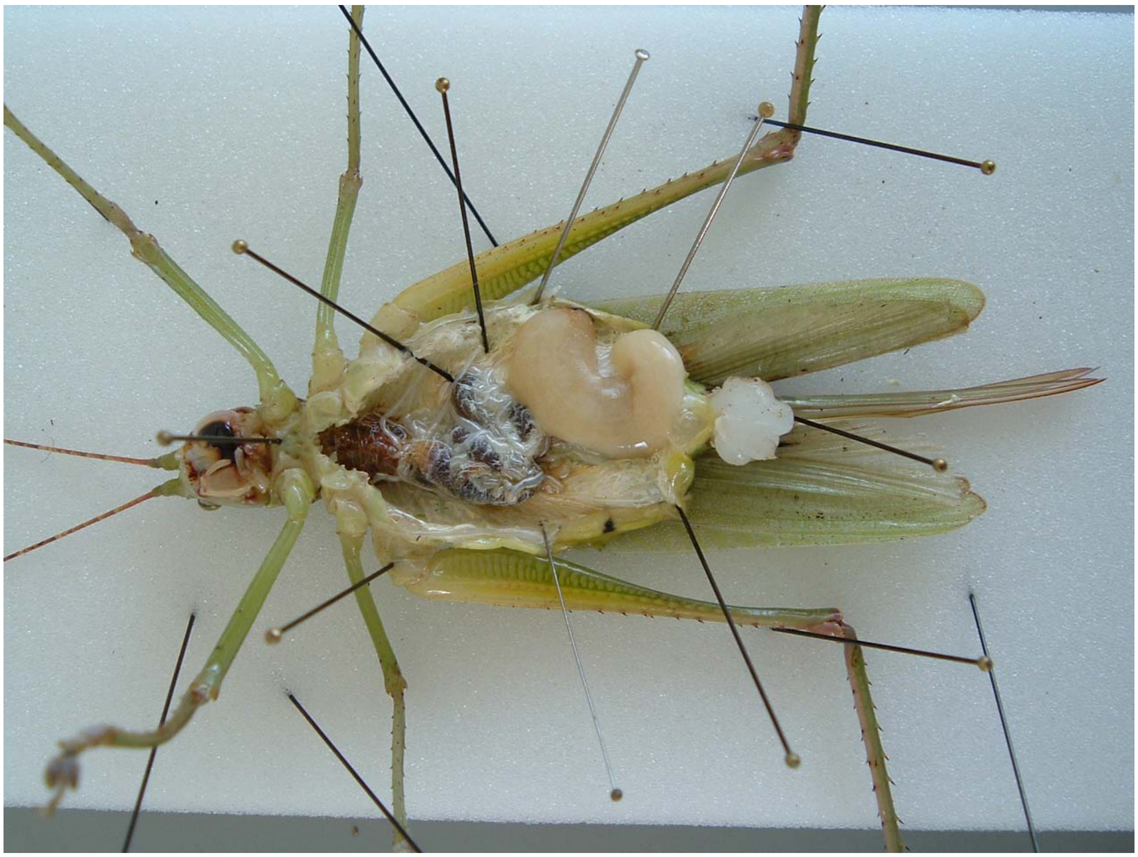


Figure 21:
Recently mated female *S.defoliaria* (note white spermatophalyx) with two developing female *Stichotrema* (arrowed). Note the complete absence of developing eggs.

Table 5. Records of *Stichotrema* activities at Dami 2008.

Date	**Locality**	**Host** *S.decoratus* (Sd) *S.defoliaria* (S def)	**1st instars emerging**	**Fate**	**Notes**
9 Jan 08	Karausu	S.def (4m 5f)	No	To Dami	
10 Jan 08	Dami	S.def (9m)	No	All released at Buluma field	
8 Feb 08	Dami	S.def	No	Dead in cage	
11 Feb 08	Dami	Sd	No		Nymph V instar
15 Feb 08	Dami	S def (3 m)	No	Cage 4	Ex. Kapiura
23 April 08	Buluma Field	Sd (f)	Yes	10 S def and 10 Sd also released	**1st record of wild capture in Sd**
25 April 08	Dami	Sd (f)	Yes	Into cage with Sd and S.def nymphs	
7 May 08	Dami	Sd 2 nymphs dead			Dissected, but no sign of *Stichotrema*
5 June 08	Dami	Sd	Yes	Was in cage with nymphs	
8 July 08	Buluma field	6 S.def released	No		Ex lab stock
25 July 08	Dami	S.def (7th nymph)	No	From Sticho infested cage	Ex lab stock
3 Sept 08	Dami	Sd 20 nymphs Sd			Into cage with emerging 1st instars from nymph of 25/7
6 Sept 08	Dami	Sd (nymph)	Yes		Died before all larvae dispersed

"sexava" egg parasitoids, (Trichogrammatidae and Encyrtidae).

Laboratory populations of (*Doirania leefmansi*- Hymenoptera: Trichogrammatidae and *Leefmansia bicolor*- Hymenoptera: Encyrtidae), that were from material collected from New Hanover in 1985 and brought to Dami which had been introduced into New Hanover from the Moluccas Islands in 1933 (Frogatt 1935), were maintained at a higher level than during previous years. They are mass reared for inundative release throughout areas of WNB and NI in our laboratory at Dami in WNB. As stated in previous reports (2006 & 2007), the rearing facilities are inadequate and must be improved if the mass release programme is to be of full benefit to growers. Egg parasitoid releases during 2008 were made in West New Britain and New Ireland (Table 6 & 7). Using estimated emergence figures which will have to be revised for *Doirania*, as they are consistently high, 240,388 *Leefmansia bicolor* were released and 3,061,468 *Doirania leefmansi* were released at 120 sites between them (65 sites for *D.leefmansi* and 55 sites for *L.bicolor*) covering plantations and OPIC divisions, but only for WNB and NI. (Fig. 22 & 23). This latter figure for *Doirania* will be considerably reduced, when revised estimated are included. Rearing studies made through the observation of host eggs and numbers of parasitoids produced enabled us to revise the numbers of parasitoids emerging from the host eggs. Trials using gelatine capsules and Eppendorf tubes as individual host egg rearing vessels will be undertaken in 2009 to refine these estimates further; nevertheless the ambient high humidity might pose a constraint to using capsules as they are hygroscopic.

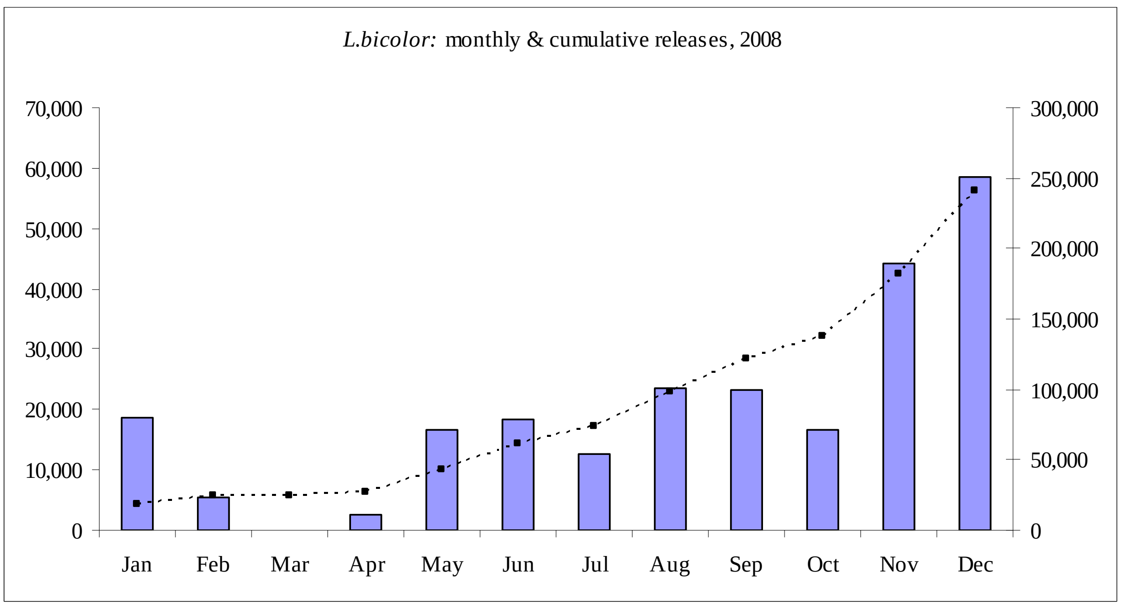


Figure 22: 2008: Releases of *Leefmansia bicolor* (Encyrtidae): actual (solid), cumulative (dashed).

Table 6: 2008: *Leefmansia bicolor* releases all sites.

10 January 2008	Siki LSS	O	70	1,960
15 January 2008	Haella plantation	P	107	2,996
23 January 2008	Lotomgam ME	P	330	9,240
29 January 2008	Dami plantation Buluma Field	P	160	4,480
05 February 2008	Kumbango plantation Div 2	P	70	1,960
22 February 2008	Bebere plantation Div 1	P		100
22 February 2008	Haella plantation Div 2	P		100
25 February 2008	Kumbango plantation	P	110	3,080
29 February 2008	Dami plantation: Buluma Field	P		200
02 April 2008	Dami plantation: Buluma Field	P	30	840
09 April 2008	Dami plantation: Buluma Field	P	40	1,120
10 April 2008	Bereme VOP	O	20	560
06 May 2008	Tarobi VOP	O	40	1,120
09 May 2008	Sarakolok LSS	O	161	4,508
10 May 2008	Dami plantation(Buluma Field)	P	120	3,360
20 May 2008	Sarakolok LSS	O	95	2,660
22 May 2008	Sarakolok LSS	O	105	2,940
27 May 2008	Tamabu VOP	O	30	840
29 May 2008	Patanga VOP	O	40	1,120
21 June 2008	Dami plantation: Buluma Field	P	290	8,120
24 June 2008	Numundo plantation	P	70	1,960
25 June 2008	Siki LSS & Waisisi CP	P	150	4,200
30 June 2008	Siki LSS	O	148	4,144
03 July 2008	Alaba Estate	P	300	8,400
09 July 2008	Bebere Di v 1 & 2	P	100	2,800
24 July 2008	Banaule VOP blk 51	O	55	1,540
04 August 2008	Banaule VOP blk 51	O	210	5,880
05 August 2008	Numundo plantation	P	70	1,960
07 August 2008	Haella plantation	P	70	1,960
13 August 2008	Salelubu LSS	O	70	1,960
13 August 2008	Kumbango plantation	P	70	1,960
19 August 2008	Morokea LSS	O	70	1,960
21 August 2008	Kapiura: Bilomi	P	130	3,640
27 August 2008	Garu plantation	P	150	4,200
02 September 2008	Garu plantation	P	220	6,160
04 September 2008	Buvussi , sect 4	O	60	1,680
04 September 2008	Buvussi, sect 3	O	130	3,640
25 September 2008	Galai sect 17 (=Galai 1)	O	140	3,920
29 September 2008	Numundo plantation	P	140	3,920
30 September 2008	Garu division 1	P	140	3,920
11 October 2008	Dami plantation seed garden	P	90	2,520
11 October 2008	Waisisi ME	P	140	3,920
12 October 2008	Daliavu plantation division 2	P	140	3,920
13 October 2008	Banaule VOP blk 51 sect 1	O	70	1,960
27 October 2008	Likuranga VOP Nuao	O	80	2,240
28 October 2008	Lavege VOP	O	70	1,960
06 November 2008	Banaule VOP sect 1 blk 0206	O	140	3,920
11 November 2008	Kiawa VOP	O	280	7,840
13 November 2008	Kavieng (with DW)	P	280	7,840
13 November 2008	Sarakolok LSS blk 953	O	280	7,840
19 November 2008	Banaule VOP Blk 108 Sect 1	O	140	3,920
20 November 2008	Volupai plantation	P	280	7,840
26 November 2008	Banaule VOP blk 15-51	O	140	3,920
28 November 2008	Banaule VOP 015-0010	O	40	1,120
01 December 2008	Banaule VOP blk 15-108	O	140	3,920
09 December 2008	Kapore LSS blk 0310	O	210	5,880
09 December 2008	Kavui LSS	O	210	5,880
16 December 2008	Banaule VOP blk 0105	O	240	6,720
22 December 2008	Banule VOP 0100	O	280	7,840
23 December 2008	Kumbango plantation Div 2	P	160	4,480
29 December 2008	Kavui LSS	O	80	2,240
29 December 2008	Kumbango plantation Div 2	P	150	4,200
29 December 2008	Banaule VOP blk 0010	O	380	10,640
30 December 2008	Dami plantation: Buluma field	P	240	6,720

Table 7: 2008 *Doirania leefmansi* releases, all locations.

10 January 2008	Siki LSS	O	150	36,600
14 January 2008	Kavui LSS	O	150	36,600
15 January 2008	Haella plantation	P	205	50,020
23 January 2008	Lotomgam ME	P	270	65,880
23 January 2008	Numundo plantation	P	210	51,240
29 January 2008	Buluma VOP	O	120	29,280
05 February 2008	Kumbango plantation (Div 2)	P	175	42,700
13 February 2008	Hargy Area 12	P	130	31,720
25 February 2008	Kumbango plantation	P	130	31,720
11 March 2008	Kavui LSS	O	53	12,932
19 March 2008	Garu plantation (Div 2)	P	40	9,760
19 March 2008	Haella plantation	P	30	7,320
27 March 2008	Dami plantation	P	60	14,640
27 March 2008	Buluma VOP	O	60	14,640
02 April 2008	Sarakolok LSS	O	60	14,640
08 April 2008	Silanga VOP	O	50	12,200
10 April 2008	Tiauru LSS	O	20	4,880
02 May 2008	Garu Div 2	P	250	61,000
05 May 2008	Lavege VOP	O	250	61,000
13 May 2008	Dami plantation	P	52	12,688
13 May 2008	Kamarimba: Poliamba	P	200	48,800
16 May 2008	Banaule VOP	O	95	23,180
02 June 2008	Garu plantation Div 1 & 2	P	120	29,280
22 June 2008	Numundo plantation	P	650	158,600
24 June 2008	Numundo plantation	P	450	109,800
30 June 2008	Siki LSS	O	80	19,520
25 June 2008	Siki LSS & Waisisi CP	O	144	35,136
04 July 2008	Lotomgam ME	P	360	87,840
09 July 2008	Bebere plantation Div 1&2	P	180	43,920
10 July 2008	Buvussi LSS	O	120	29,280
24 July 2008	Banaule VOP	O	370	90,280
25 July 2008	Waisisi CP	P	143	34,892
04 August 2008	Banaule VOP	O	70	17,080
05 August 2008	Numundo plantation	P	180	43,920
07 August 2008	Haella plantation plantation	P	230	56,120
13 August 2008	Salelubu LSS	O	220	53,680
13 August 2008	Kumbango plantation	P	85	20,740
13 August 2008	Volupai ME	P	150	36,600
19 August 2008	Morokea LSS	O	140	34,160
21 August 2008	Kapiura: Bilomi plantation	P	150	36,600
27 August 2008	Haella plantation plantation	P	60	14,640
27 August 2008	Garu plantation	P	65	15,860
04 September 2008	Buvussi sect 4	O	70	17,080
04 September 2008	Lavege VOP	O	140	34,160
25 September 2008	Galai sect 1	O	150	36,600
29 September 2008	Numundo plantation	P	140	34,160
30 September 2008	Garu plantation Division 1	P	150	36,600
02 October 2008	Daliavu division 2	P	70	17,080
03 October 2008	Banaule VOP blk 51	O	140	34,160
11 October 2008	Waisisi ME	P	70	17,080
11 October 2008	Dami plantation (seed garden)	P	140	34,160
16 October 2008	Siki LSS section 3	O	140	34,160
23 October 2008	Sarakolok LSS, sect 5 blk.0915	O	210	51,240
27 October 2008	Likuranga VOP Nuao, blk 077151	O	80	19,520
28 October 2008	Lavege VOP	O	290	70,760
11 November 2008	Kiawa VOP	O	280	68,320
11 November 2008	Kumbango Division 2	P	140	34,160
13 November 2008	Sarakolok Blk 953	O	280	68,320
13 November 2008	Kavieng (with DW)	P	190	46,360
19 November 2008	Banaule VOP Blk 206 Sect 1	O	150	36,600
20 November 2008	Volupai plantation	P	265	64,660
26 November 2008	Banaule VOP	O	140	34,160
28 November 2008	Banaule VOP 015-0010	O	140	34,160
01 December 2008	Banaule VOP Blk 108 Sect 1	O	140	34,160
09 December 2008	Banaule VOP blk 015-0108	O	325	79,300
22 December 2008	Banaule VOP blk 0100	O	290	70,760
23 December 2008	Kumbango plantation D2	P	140	34,160
29 December 2008	Kavui LSS	O	80	19,520
29 December 2008	Kumbango plantation D2	P	80	19,520
29 December 2008	Banaule VOP blk 0010	O	280	68,320
30 December 2008	Dami plantation Buluma field	P	280	68,320
30 December 2008	Kapore LSS blk 0310	O	280	68,320
30 December 2008	Kapore LSS blk 0306	O	280	68,320

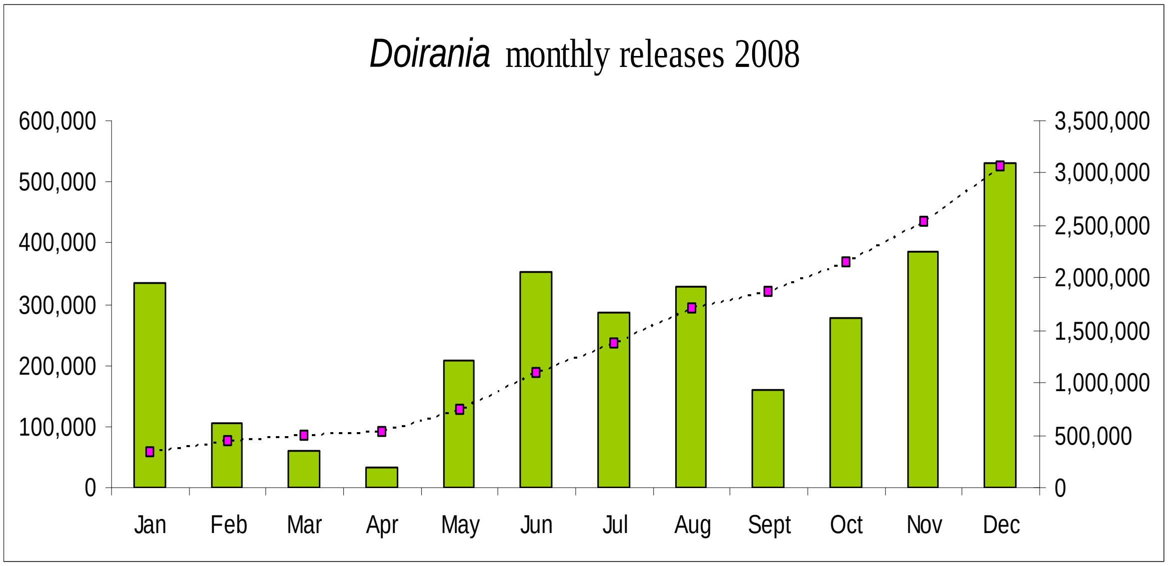


Figure 23: 2008: Releases of *Doirania leefmansi* (Trichogrammatidae) –before revision

Parasitoid feeding & longevity.

It was found that by feeding the parasitoids with honey, their longevity could be considerably prolonged, and this is routinely done as a food additive during the rearing process. *Doirania* surviving for up to 6 days (mean 3.8 days) with food (honey) and *Leefmansia* surviving for up to 25 days (mean 16 days) with honey as food. UPNG student (Kingsten Okka) worked with entomology section for 6 weeks to investigate the effect of feeding parasitoids on their longevity, and confirmed our results. His final report is awaited.

Stick insects.

Figure 24: *Eurycantha insularis* last instar female nymph on a wild fern Tunana (Northern Province).

Eurycantha insularis feeding trials

The results of this work will be reported on next year (2009), as the student assisting with this work removed the original data sheets from Higaturu Centre, and they have not yet been returned (Dec 2008). The Dami data were insufficient.

Economic assessment of stick insect damage in Northern (Oro) Province.

A severe infestation of *E.insularis* (Fig. 24) continued in the Sui/Tunana area on a number of smallholder blocks. As the local people in the area utilise the stick insects for food, no treatment could be carried out. It was earlier decided to monitor the defoliation effects of the stick insects on the production of fruit (FFB) weights from the palms in these blocks over a long period (until productivity reaches expected levels again) (Fig 25).

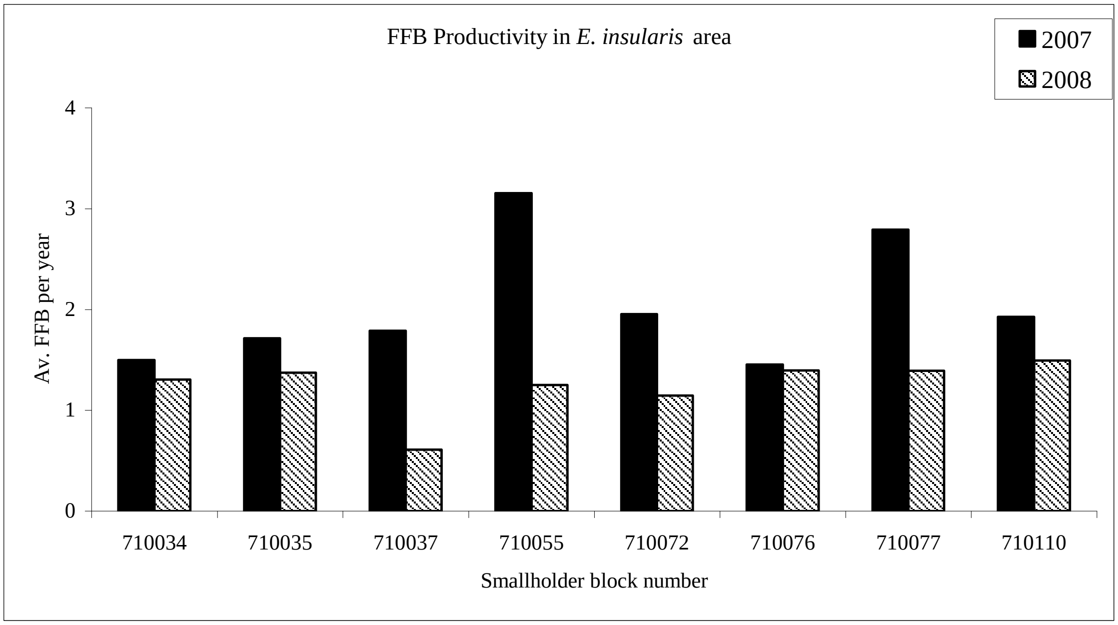


Figure 25: 2007/2008: Sui Tunana FFB productivity in infestation of *E.insularis*: comparative production of FFB from smallholder blocks in N. Province

The fruit harvested from eight smallholder blocks was monitored from January 2007 (black bars) through December 2008 (diagonal stripes) (Fig. 25), and the monitoring will continue in future years until crop production is back to expected levels. The data show that there was a distinct drop in fruit production between both years in almost all the blocks except one (#710076) which was apparently a well kept block (R Safitoa, personal communication). Harvesting was somewhat erratic during 2007/8, and therefore mean monthly values were utilised to counter times when harvest was not undertaken (Table 8). The main problems were as a result of hurricane Guba, and vehicular access for fruit trucks to collect the fruit. Stick insect (*E.insularis* on mainland) damage is very characteristic, and on the mainland it is the commonest insect causing damage to oil palms (Fig. 26).

The data are with PNGOPRA. (We are grateful to Higaturu Oil Palms for continuing to assist us with the provision of data).

Figure 26: Typical feeding damage *by E.calcarata* to a frond. This would be classed as severe damage.

Table 8. Harvested fruit from area with *E.insularis* Sui/Tunana, Northern (Oro) Province

Block number	**2007 weight (average monthly)**	**2008 weight (average monthly)**	**Difference**	**% change**
710034	1.5	1.3	0.2	- 13.3
710035	1.72	1.37	0.35	- 20.3
710037	1.79	0.61	1.18	- 65.9
710055	3.15	1.25	1.9	- 60.3
710072	1.95	1.15	0.8	- 41
710076	*1.45*	*1.40*	*0.05*	*- 3.4*
710077	2.79	1.39	1.40	- 50.2
71110	1.93	1.49	0.44	- 22.8

Eurycantha biological control

No parasitoids were reared from the eggs of *E.calcarata* during 2008; however one of the parasitoids reared from the eggs of *E.calcarata* during 2007/08 was identified as Hymenoptera: Eupelmidae? *Anastatus*, while from *E. insularis*, from Northern (Oro) Province: Hymenoptera: Chrysididae: Amiseginae were commonly reared. There is still a great deal of parasitoid material to be sorted and labelled from the specimens reared by R Safitoa/S Nyaure at PNGOPRA Higaturu Research Centre.

Rhinoceros Beetles (Coleoptera, Scarabaeidae).

Scapanes australis

There was 1 reported attack by the three-horned rhinoceros beetle (confirmed by visit as *S.australis*) in a smallholder block at Mingae in WNB, there were no reports received through OPIC, and there were no reports from New Ireland or mainland PNG.

Oryctes rhinoceros

A single report of the Asian rhinoceros beetle, *Oryctes rhinoceros* from within PNG on oil palm was recorded from Kilu at the southern end of the Talasea peninsular (WNB) in oil palms. Pheromone trapping was undertaken there, but beetles were collected on a few nights only. No further action was required, but further monitoring will take place.

Oryctes centaurus

On mainland PNG there were two reports of the larger rhinoceros beetle, *O. centaurus* damaging young palms from Igora in September (#8008) and Mamba in May (#3308), although populations are constantly present. However populations were being regularly monitored, and specimens collected for life history studies from Ambogo plantation where the poisoned palms provide a perfect food source for the young stages and the young palms themselves are a food source for adult beetles. Adult beetles behave in a similar manner to *Scapanes* by boring their way into the spear cluster, then burrowing vertically down into the heart causing damage to the developing spear base and surrounding soft tissues, although the hole they make and the damage caused is much more severe (Fig.27).

Figure 27: *O.centaurus* adult beetle in feeding hole.

Figure 28: *O.centaurus* larvae in rotting oil palm.

Recommendation:

We recommend that all poisoned palms are felled and, if possible either broken up, buried or cover crop is planted as soon as possible to eliminate breeding sites for the beetles. In plantations, after mechanical felling and windrowing, rapid encouragement of cover crop is essential.

Monitoring of *O.centaurus* populations in the field.

As in 2007, monitoring palm frond collapse was undertaken monthly, but only until July at Sumbiripa, Ambogo and Sangara (Figs.29-31). At all localities a rise in numbers of new collapsed fronds was observed between March and May, however all ended up at between 20-35% of fronds 0-4 being damaged. It should be noted that monitoring palm frond collapse will only indicate attack from a maximum 2.5 months previously (for frond 4), as it was fronds 0-4 that were monitored. There was a marked increase in damage recorded from Sangara, for reasons as yet not understood, while damage increase was less obvious, but still noticeable at Ambogo and Sumbiripa.

Life history

Work started on investigating the life history of this insect, and some data were available for larva and adult emergence. Only single beetles have been recovered from one hole, unlike *O.rhinoceros*, where a male and female are often found together.

From the rearing studies undertaken at Higaturu, only a part of the life cycle was evaluated as:

Males: Prepupa to adult emergence = 37 days

Females: Prepupa to adult emergence = 37 days. No information was obtained on the duration of earlier stages.

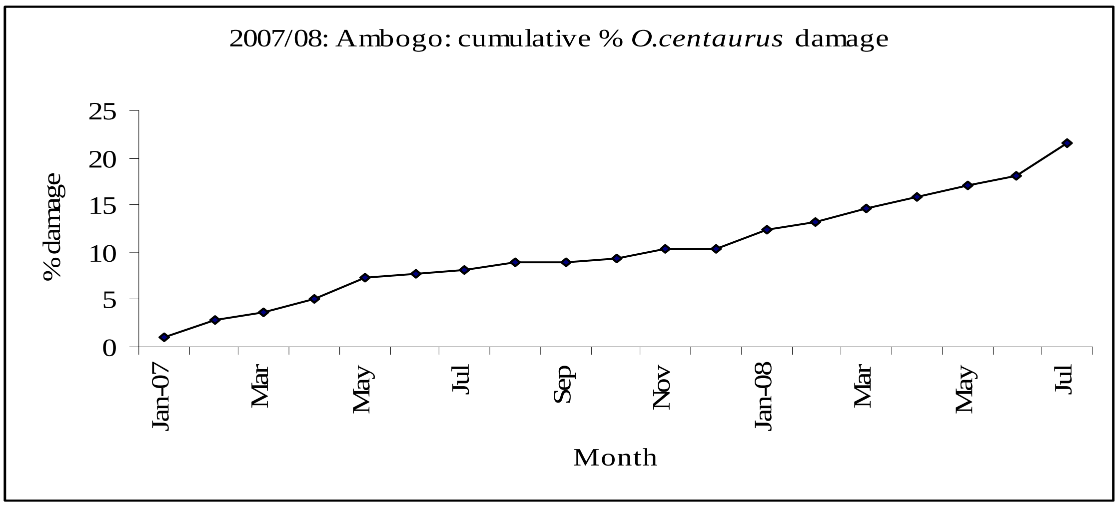


Figure 29: 2007/8 *O.centaurus* damage to fronds 0-4 at Ambogo plantation (cumulative).

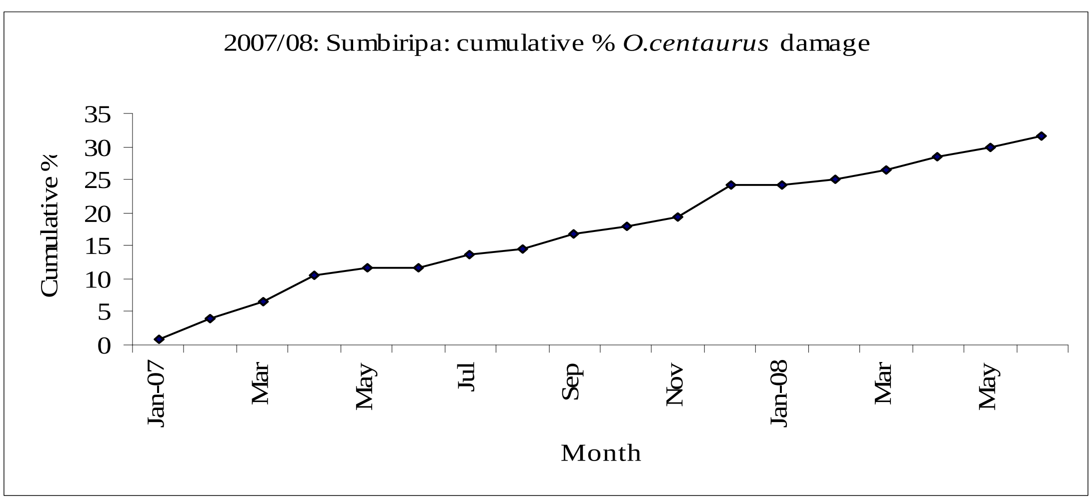


Figure 30: 2007/8, O.*centaurus* damage to fronds 0-4 at Sumbiripa plantation (cumulative).

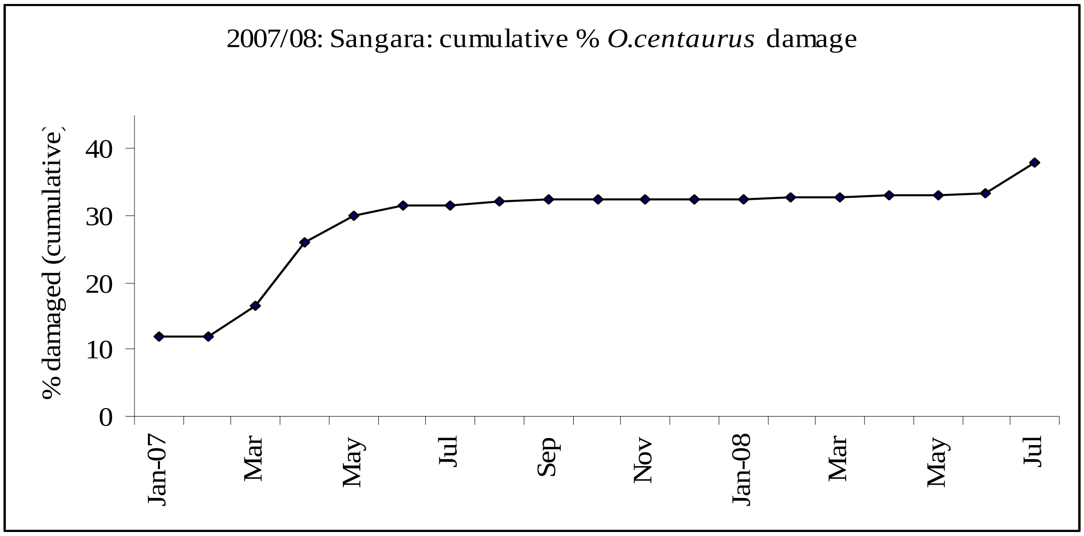


Figure 31: 2007/8: O.*centaurus* damage to fronds 0-4 at Sangara plantation (cumulative).

<u>White grubs (Melolonthinae)</u>

There were no reports of white grubs during the year, although they are a constant feature at Ramu, where pest management issues are handled by Dr Kuniata and his team at RAI.

Lepidoptera pests on oil palm.

Bagworms

Bagworm infestations were reported from Haella plantation (WNB) in February [#1508], Togulo plantation (WNB) in April [#2208] Bebere plantation (WNB) in April and September [#2508, #8108] and Haella plantation again in October [#8308]. There were no other reports from PNG plantations or through OPIC.

In some plantations in WNB there were repeated infestations, and treatment (TTI) was recommended on 5 occasions where the populations were causing extensive defoliation. This amounted to 72.26ha (Source: SHA). Prior to any oil palm treatment, extensive larval and pupal "bag" collections were organised, parasitoids (Diptera: Tachinidae) were reared out, provided with food, and those that were not required for taxonomic or reference purposes were fed and returned to the areas they were collected. Any non-parasitized material was incinerated. There were no reports of Rbw from smallholder blocks.

There were no reports of infestations of smooth bagworm (*Eumeta variegata* - Sbw), anywhere in oil palm in PNG, although specimens were found during Nursery surveys at Higaturu (Northern Province) in June and August-October (see Nursery Pest section). Smooth bagworms (Sbw) were not recorded from smallholder blocks during 2008.

The taxonomic status of bagworms remains unresolved with some undescribed species recorded as feeding on oil palm; however during the year contact was made with a specialist on this family (Lepidoptera: Psychidae) in Switzerland (Dr P Hättenschwiler), and a joint paper will be prepared for publication, when sufficient material is available. Specimens of all five taxa reared from oil palm were prepared and sent to him for further study. A joint paper is being prepared for publication in which the three new species will be described (Fig. 32). One of the undescribed species, the "ice-cream cone" bagworm (ICC), (*Manatha* sp.E) currently only found by PNGOPRA in Northern (Oro) Province at Ambogo and Igora, causes localised but obvious damage to oil palm leaflets. It has not, however occurred in large enough numbers to necessitate palm treatment (TTI), however it is very likely to spread through oil palm plantations. Parasitoids were reared from the pupal material, fed with honey and released back into the areas from where they were collected. Parasitoids were principally two species of parasitic flies (Diptera: Tachinidae), although Hymenoptera (unidentified) were also reared. The Tachinidae themselves are commonly parasitized by a hyperparasitoid, Chalcididae *Brachymeria* sp. The number of parasitoids reared and subsequently released was not recorded, but samples of parasitoids released were retained for the collection, and some were hand delivered to the Natural History Museum (London) for identification.

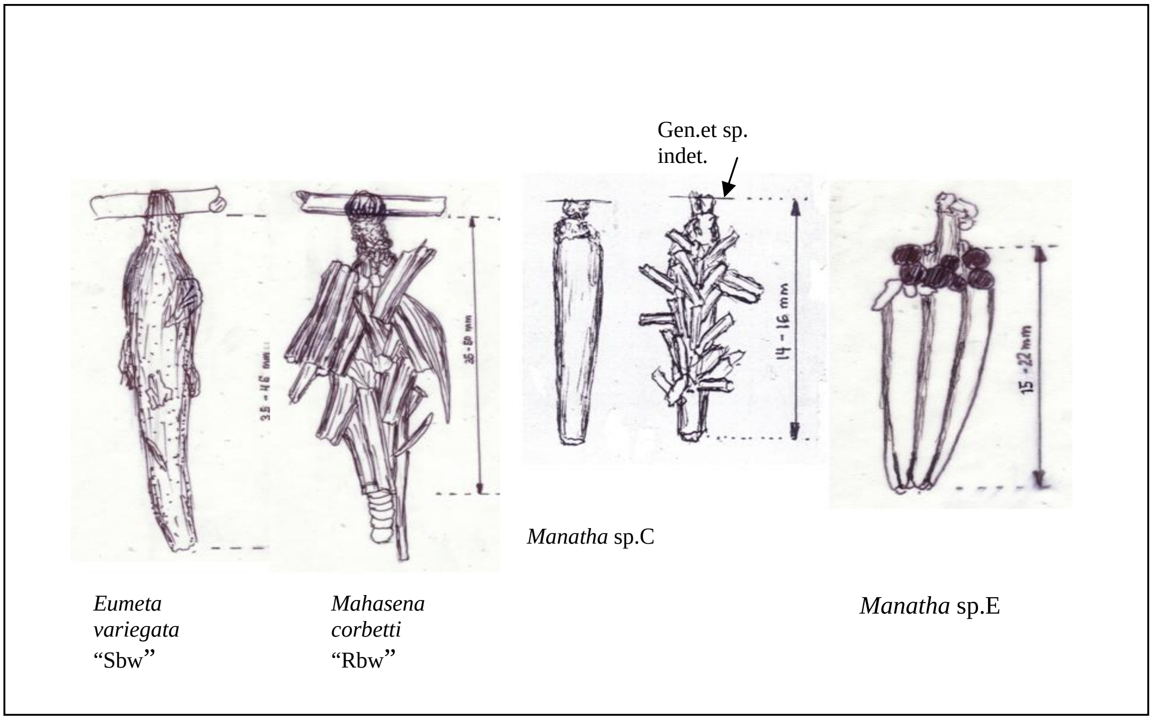


Figure 32: Bagworms from oil palm in Papua New Guinea : (*from left to right*): Smooth bagworm (Sbw) (*Eumeta variegata*), Rough bagworm (Rbw) (*Mahasena corbetti*), and undescribed species of *Manatha* with an undescribed Genus & species (Hättenschwiler & Dewhurst *in prep*.)

Hesperiidae (skipper butterflies). There were no reports during 2008, although the occasional specimens were collected from the field. Two species commonly found on oil palm, are *Cephrenes moseleyi* and *C.augiades* (Lycaenidae), an OPRAtive Snippet will be prepared in 2009, as we now have good photographs.

The oil palm webworm, *Acria* sp. nr. *emarginella* (Lepidoptera: Oecophoridae) was not reported as a threat during 2008 from Mainland PNG or New Ireland. In WNB, at Dami Research Station, there was a heavy infestation on Royal Palms (*Roystonea*), which was controlled by pruning off affected fronds. Many of the cocoons collected contained pupae that had been attacked by parasitic hymenoptera (parasitic wasps), and were therefore dead.

Other Pests

Other pest taxa were present in plantations and smallholder blocks, but as very minor components and in very small numbers, and could not be considered as pests.

The Powdery chafer beetle, *Dermolepida* sp. (Coleoptera: Melolonthinae) was regularly reported as it is quite large and easily seen resting on the leaflets , however it was (as in 2006) in such low numbers as to be insignificant, as can not be regarded as an important pest on oil palm.

There were no reports received by PNGOPRA of the Taro beetle, *Papuana* spp., (Coleoptera: Dynastinae) Black Palm Weevil, *Rynchophorous bilineatus* (Coleoptera: Curculionidae) or Sugar-cane Weevil (*Rhabdoscelus obscurus* – Coleoptera: Curculionidae) from oil palm in PNG.

There were no reports received by PNGOPRA of Giant African Snail (*Achatina fulica*) from any oil palm areas within PNG,

There were no reports received by PNGOPRA of Rats. A work experience student worked on a rat monitoring project at Dami during October 2008 and a summary of his report is attached (see below).

Rodents

There were no reports of **rodents** received from any plantation or smallholder growers, probably still due to under-reporting, as Milne Bay (CTP) and Ramu (NBPOL) are areas where rodents have been reported in the past and will continue to be a problem. Verbal reports were received from both areas, but there was no follow-up. Although there is a rat problem in some plantations and certainly among smallholder growing areas, there has been little systematic study of the rat complex or potential threat.

The principal and major predator on rats are snakes, especially Amethystine Python, however these reptiles are always all killed on sight. This activity should be actively discouraged in WNB (different scenario on mainland where there are many very poisonous snakes to be found).

During October/November, a work experience student visited and undertook a trapping study of rats in oil palm of different ages on Dami (NBPOL).

His full report is expected during 2009, however a summary follows:

"A Report on the Relative Abundances of Rats within an Oil Palm Plantation in West New Britain, PNG"

"The genus *Rattus* is highly adaptable and capable of prolific reproduction (Sumangil, 1990). As a result many *Rattus* species have become a common pest of crops on a global scale (Pimentel, 2002). Studies in oil palm plantations show rats may be responsible for losses as great as 5% of annual crop (Wood, 2001). The species most commonly effecting oil palm are *Rattus* tiomanicus (Miller 1900) and a sub species of the *Rattus rattus* Complex, *Rattus rattus diardii* (Jentink 1879, Chasen, 1933, Wood 2001). The impact of these species on oil palm productivity is two-fold. Rats feed on immature and mature fruits, damaging both the mesocarp and the kernels. This directly reduces available CPO (crude palm oil) and the valuable KPO (kernel oil) extraction rates. Secondly rats prey upon the larvae of the pollinating weevil, *Elaeidobius kamerunicus* as they are developing in the male flowers. Shortly after male flower anthesis weevils lay eggs in the male flower (inflorescence) where the larvae develop. Rats shred the inflorescence to get to the larvae (Liau, 1985), which are an important source of protein in their diet (Caudwell, unpublished). Excessive damage by rats to male flowers may result in reduced pollination if the infestation of rats is very severe; however there are little supporting data to indicate at what level rat infestations become critical (Fig. 33).

Figure 33: Rodent damage to male spikelet

Papua New Guinea currently has about 132,176 hectares of oil palm in both plantation and smallholder areas and is rapidly expanding. Currently (2008), 63.2% of oil palm is grown on the island of New Britain, specifically in West New Britain (PNGOPRA, 2007).

At present, rat damage is considered to be negligible on West New Britain, however as the sector continues to expand, so does the potential for an established pest species. The low level of damage may be related to the lack of *Rattus tiomanicus* on New Britain (Aplin *et al*. 2003), the primary *Rattus* pest recorded in oil palm. Potential pest species known to be present on New Britain are *R. exulans*, the Pacific rat (Peale, 1848), a form of R. r*attus* Complex, the Black rat (Aplin *et al.*, 2003) and *R. preator* (Thomas, 1888), a New Guinean spiny rat (Aplin *et al.*, 2003, Flannery, 1995). These species are all known to thrive in disturbed habitat and each has been recorded as crop pests in other locations (Nass 1977; Wood *et al*., 1988; Aplin *et al*., 2003; Flannery 1995). However there has been no extensive trapping carried out in oil palm on New Britain and consequently knowledge of species and their relative abundances is unavailable. Without a better understanding of the potential pest species found within a crop it is difficult to implement cost effective management".

(NB: There is no bibliography presented here, as this will be in the full report).

Bird pests.

Although birds are not recognised as important pests of oil palm, Head of Entomology assisted the Plantation Agronomist at Hargy with fieldwork and writing up for his Masters degree in Agricultural studies (MAg.St.) in Australia on the effects of bird damage to oil palm FFB.

A summary of that work which is expected to be published follows:

*"An investigation into the effects of bird damage on fruit bunches of Oil palm (*Elaeis guineensis*) at Hargy Oil Palms plantation, West New Britain, Papua New Guinea".* by P. Taramurray, Hargy Oil Palms, Bialla, West New Britain, Papua New Guinea.

"The Eclectus parrot (*Eclectus roratus*) and the New Britain White cockatoo (*Cacatua opthalmica*) are confirmed as feeding on oil palm fruits at Hargy Oil Palm plantations. Other birds commonly seen around the plantation but not feeding on oil palm fruit included the Blyth's hornbill (*Aceros plicatus*), the Torresian crow (*Corvus orru*) and the Brahminy kite (*Haliastur indus*). Eclectus parrot and New Britain White cockatoo were observed feeding on the fleshy mesocarp of the oil palm fruits resulting in individual bunch fruit loss, which in turn contributed to loss of crop. Observations on 255 fruit bunches carried out from the 1st April – 13th May 2008 showed 5.5% of ripe bunches, 14.9% of tight bunches (those almost ripe) and 6.5% of black bunches (immature) were damaged by birds. The damage caused was either partial at only 1 - 2% of bunches or complete resulting in 3 - 4% of the fruit weight lost. Fruit loss due to bird damage was higher among the border palms than those in the interior (Fig.34)".

Figure 34: 2008: Bird damage to oil palm fruit bunch, Hargy Oil palms, Bialla, WNB.

Finschhafen Disorder: The Leafhopper (*Zophiuma lobulata*) Integrated Pest Management.

Figure 35: Adult *Z.lobulata* on palm rachis

Figure 36: *Zophiuma lobulata* egg mass on male spikelet of oil palm.

Two reports of Finschhafen Disorder (FD) were recorded from plantations, one in WNB (Numundo on coconuts in the compound) in August [#6008], and one at Mamba (Northern Province), also on coconuts and in the compound during May [#3308]. Following many collections of adult and nymphal *Zophiuma* material from Numundo Seaview compound, treatment was recommended and carried out due to the close proximity of these coconuts to plantation oil palms. There were no reports of FD from New Ireland (NI). A full survey visit was planned to survey NI for 2009.

The ACIAR project collaboration with Charles Sturt University and DPI, Queensland continued into the second year. The main focus involves FD, a problem which originated from coconut palms near Finschhafen, Morobe Province, Papua New Guinea (PNG) in 1960, and is now a potential threat to palm oil production. The objective of this project is to protect the viability of oil palm industry in Papua New Guinea, and aims at enhancing the social and economic benefits that emanate from production of the oil palm in plantations and nucleus estates (smallholdings). Research conducted in the 1980's implicated a native PNG planthopper *Zophiuma lobulata* Ghauri (Hemiptera: Lophopidae).

Methods used to study causality pre-dated the availability of molecular biology tools that enable detection of possible plant pathogens. The project has so far used these tools to screen a variety of pathogens known to be vectored in other crops by a group of insects in which *Z. lobulata* belongs. Transmission experiments in large cages and small sleeves have also been used to study FD causality.

The first objective of this project is to develop a comprehensive biological understanding of the causes of FD. The second objective is to develop preliminary control measures for FD.

In pursuit of the first objective, bibliographic information on FD and *Z. lobulata* as well as similar disorders and pests of palms has been sourced from various scientific databases and an electronic library has been compiled using the EndNote bibliographic software package. Copies of all relevant publications have been collected and complemented by a significant volume of personal communication material that has been obtained from liaison with palm health researchers around the world.

All of this information has been synthesised into a comprehensive review article that has recently been accepted for publication in The Australian Journal of Entomology.

The identity of *Z. lobulata* has been confirmed by comparing specimens collected from four locations in PNG (Fig. 35). A formal taxonomic description for specimens from mainland PNG and West New Britain has been made using morphological characters, particularly male genitalia and molecular methods using the CO1 gene. Results so far indicate consistency in all morphological and molecular characters and there is no evidence for additional or cryptic species. In addition, another congeneric planthopper to *Z. lobulata* namely *Z. pupillata* collected by HoE from coconut and sugarcane on mainland PNG has been compared with *Z. lobulata* using both morphological taxonomy and bar coding. Currently, the CO1 sequence data is being analysed and a formal article to be submitted to a taxonomic journal is in preparation.

A comprehensive screening for possible microbial pathogens in *Z. lobulata* and oil palm material has been conducted extensively. Pathogens particularly phytoplasmas and bacteria-like organisms (BLO's) were thoroughly screened using current molecular biology tools. The pathogens were also screened from saliva samples that were collected in 5% sucrose solution. The saliva was collected by presenting sucrose solution, contained in an Eppendorf tube which was covered with a semi-permeable membrane, to enable the plant hoppers to feed.

Large insect-proof cages (1.8m x 1.8m x 2.5m) were constructed at Dami and used in a study that aimed at elucidating the role of *Z. lobulata* in FD. *Z. lobulata* that were raised from egg masses collected in the laboratory and those collected from the field (Fig.36) were released into the cages in an additive process over a period of 8 months. Both the laboratory-reared and field collected *Z. lobulata* induced FD symptoms to healthy coconut and oil palms. Small sleeve experiments were set up to corroborate the large cage experiments after the netting cages deteriorated and broke down before full blown symptoms were observed in most of the cages.

Field work aiming at identifying natural enemies of *Z. lobulata* that could be used as biocontrol agents resulted in the collection of several taxa of parasitic wasps belonging to the family Mymaridae and Encyrtidae. These were the common parasitoids of *Z. lobulata* egg masses on West New Britain and Milne Bay in PNG mainland. Samples of the Mymaridae were sent to Canada and UK for identification by specialists as a result of which it was revealed that they are new species. The mymarids are *Parastethynium* sp. near *P. mayeri*, and the encyrtids are *Ooencyrtus* near *minor* or *major* Perkins.

The results of feeding studies and parasitoid longevity using nectar producing weeds and honey were presented as a poster display on behalf of the team at a conference of international scientists by Dr Catherine Gitau.

Samples of *Z. lobulata* that had been killed by insect diseases especially fungus have been collected from various sites in West New Britain and preserved material delivered to Australia. With the help of Dr. Michael Priest, DPI Orange and Dr. Hywel-Jones in Thailand; preliminary identifications suggest most are a species of *Sporothrix* whilst others are from *Gliomatix* or similar genus. The identity of *Sporothrix* seems to be *Hirsutella citriformis*, an entomopathogenic fungus with a pan-tropical distribution, although it could be a complex of related species.

The second objective to develop preliminary control methods for FD is contingent on the findings of the first objective. However, monthly monitoring of *Z. lobulata* numbers and FD symptoms on betel nut, coconut and oil palm was conducted between January 2008 and February 2009 on a small holder oil palm block in West New Britain. Another site at Dami Research Station has been identified and monthly monitoring will be conducted in a similarly manner in 2009/2010. Results indicate that egg masses and other *Z. lobulata* life stages may be used as a monitoring tool for FD incursions in oil palm habitats.

A variety of coloured sticky traps were evaluated in the field to assess trapping as a monitoring tool for *Z. lobulata*. Eight different bright colours were evaluated. Results did not reveal significant differences in attractiveness, based on colour. Moreover the catches on numbers of *Z. lobulata* adults and nymphs were dismally low. Future experiments using trap and kill approaches will be planned.

Laboratory experiments evaluating the influence of nectar rich ground cover plants on the lifespan of mymarid and encyrtid parasitoids were conducted. Results showed that adults lived longer when they had access to flowers compared with those that were fed on water alone. Further work on the biology and applicability of these parasitoids in oil palm habitats is planned in the next phase of the project.

In the last year, the project leader (Prof Geoff Gurr) and the Postdoctoral Fellow (Dr Catherine Gitau) visited PNG once and four times respectively, to conduct, follow up experiments and work with PNG Oil Palm Research Association (Entomology Section) in the last year. Molecular biology and taxonomic expertise have been contributed by Drs Andrew Mitchell and Murray Fletcher, respectively, of NSW Department of Primary Industries.

<u>Methamidophos Usage Database</u> (MUD)

The development of this software was completed on time with support from PNGOPRA IS section, and being used during 2008. The data may be submitted electronically or by fax to PNGOPRA. Results, based solely on the information received are provided to NBPOL on a monthly basis. There were some difficulties experienced by some plantation groups in completing the forms, and alternative formats for MUD will be investigated. Treatment completion return forms from plantations were seldom received, and this did situation not improve during 2008, although indirectly these data were available through MUD.

<u>Insecticide trials</u>

Trials were undertaken to investigate alternative insecticides to replace methamidophos. Initially we used large mesh sleeve bags made from green shade netting (25%) into which 20 sexava adults were placed. Palms were then injected with the insecticides to be tested using targeted trunk injection (TTI) techniques; however none of the three trials were conclusive for the alternative insecticides, due mainly to unforeseen losses of either the caged insects or by the theft of the sleeve bags (Fig.. 37). Shade-netting sleeves will not be used for future trials, and laboratory bioassays will be used to test efficacy (Fig. 38), however the palms will be treated using TTI. As a result it was felt that the results obtained would be retained on the PNGOPRA server, but not included in this report.

Figure 37: Shade netting sleeved fronds at Waisisi, WNB

Bioassays were carried out by collecting leaflets from the treated palms, carefully labelling them and feeding the insects in cages at the laboratory while monitoring mortality over time.

Figure 38: Setup used for laboratory bio-assays at Dami. (WNB).

Mycoinsecticides

With support from ACIAR we were able to undertake trials using mycoinsecticides against sexava.

The spraying of broad spectrum chemical pesticides, as is undertaken for many pests is not an option in the PNG oil palm industry, because it is both difficult and unacceptable under the strict environmental standards imposed. Trunk injection with OP insecticides works well and is not persistent, but from a pest management point of view, reliance on a single mode-of-action to control a major pest is highly unsatisfactory in the long-term.

Three entomopathogenic fungus isolates in the genera *Metarhizium*, *Beauveria* and *Paecilomyces* were obtained, mass produced and tested against the important oil palm pest *Segestes decoratus*. Previous work had been marred by high control mortality in bioassays, but in the experiments described here, control mortality (using blank oil formulation) was reduced to an acceptable level. Two experiments were carried out: (a) a bioassay in which 5µL topically applied oil-based formulation was applied directly to the insects and (b) an arena/cage test in which the formulation was sprayed onto palm seedlings which were subsequently introduced to insects placed in large cages. We established that the spores of all three fungal isolates were still viable in the formulation after application, but there were no significant (or even noticeable) differences in insect mortality between these and control treatments: in either experiment. Although disappointing, scientifically these results are interesting as they highlight the extreme specificity of the fungal pathogens and illustrates the need to expand our field searches for diseased sexava.

Insecticide compounds that are used against sexava must be applied under the strict conditions, since they are hazardous to handle (belonging to WHO/EPA class I). The standard method of insecticide application is targeted trunk injection (TTI) of a systemic organophosphate (OP) methamidophos; at 10ml per palm trunk. Many OP insecticides have been withdrawn in OECD countries, and the future for the availability of remaining permitted compounds is a matter of spirited debate.

There has been much enthusiasm and acceptance for the use and encouragement of natural enemies which is currently undertaken by PNGOPRA, however these interventions are time consuming and difficult to rear and release in the quantities that are required. One option appears to be the use of mycoinsecticides as an inundative biological control method. Entomopathogenic fungi are part of the naturally occurring microbial biodiversity in tropical and temperate agro-ecosystems. These fungi are important members of natural enemy communities regulating arthropod populations typically by the action of many isolates of a particular species infecting and killing a small proportion of the population. Occasionally, epizootics of highly virulent isolates, cause population crashes of insect pests. Previous work has shown that the *Metarhizium anisopliae* isolates which successfully infect Orthoptera belong to a specialised clade of *M. anisopliae*: var. *acridum*.

Entomopathogenic fungi in the genera: *Metarhizium*, *Beauveria* and *Paecilomyces* have been found on sexava in West New Britain (R. Caudwell, pers. comm., & Fig.39). Caudwell carried out preliminary experiments to evaluate locally-obtained isolates (41 *Metarhizium*, 8 *Paecilomyces*) against sexavae, but results were marred by high control mortality (60% at day 5, 100% at day 7).

Figure 39: *S. defoliaria* infected with *B. bassiana. Photo at Dami from outside cages.*

A short-term project was commissioned by ACIAR under its country sub-programme: Enhancement of smallholder incomes from agriculture through the focus on an environmentally more acceptable method for controlling a major and constant threat to oil palm growing, and palm oil production.

Objective 1: - To identify suitable isolates, and to produce a formulation suitable to fulfil the requirements for second objective.

The tettigoniid specific isolates will be sourced from USDA where they are stored and infected specimens will be collected from the field in PNG.

The potential entomophagous fungus will be cultured and formulated into a gradated suspension, suitable for testing on living insects.

Objective 2: To undertake caged experiments in PNG to assess the virulence of the mycopesticides against sexava.

The formulated mycopesticide will be field tested in cage based statistically secure experiments to evaluate its potential for further development.

Three Tettigoniidae isolates were tested, belonging to different entomopathogenic fungal species that may be found naturally in PNG:

1. *Beauveria bassiana* ARSEF 6234
2. *Metarhizium anisopliae* ARSEF 0727
3. *Paecilomyces reniformis* Samson & Evans ARSEF 0484

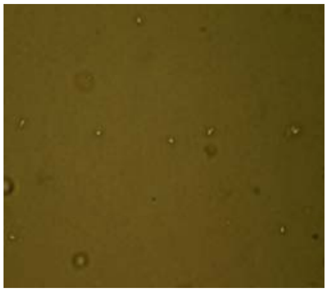
Mass spore production

a. Mass Production: First Stage

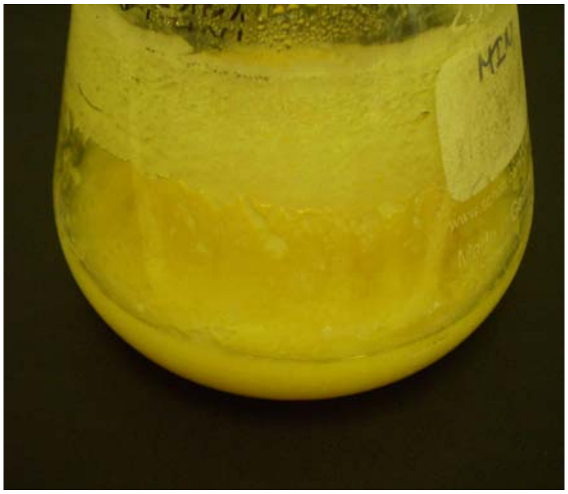
A two phase production took place at CABI Europe-UK, starting with liquid medium, composed of sterile water, 2% yeast extract and 2% sucrose, which was inoculated with the lyophilised cultures (as above). Flasks were placed on a rotary shaker (approx. 175 rpm) for 4 days.

In the early stages of growth distinct clumps of mycelium may be formed within an otherwise clear broth. This form of growth is less productive than a homogenous colonisation of the culture broth by evenly dispersed mycelium and hyphal fragments.

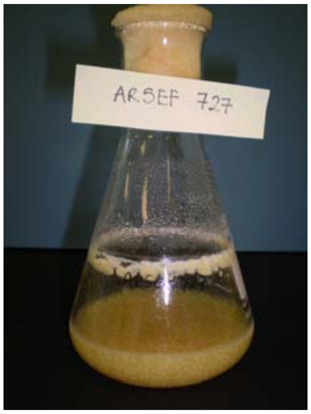
P. reniformis (ARSEF 0484) after 4 days showing no germination



P. reniformis (ARSEF 0484) after 4 days showing no germination growth



P. reniformis (ARSEF 0484) after 14 days showing mycelial growth



M. anisopliae
(ARSEF 0727):
showing pelleting

B. bassiana
(ARSEF 6234):
showing metabolite
production

Both *M. anisopliae* and *B. bassiana* were taken to the secondary stage; however the 1st run of *P. reniformis* showed no growth. As only one ampoule was supplied it was decided to leave two flasks on the shaker to see if any growth did occur and after 14 days a useable mycelial broth was produced.

b. Spore Production: Second stage

Dry, unpolished rice was placed in an automatic rice cooker with a measured amount of water (300ml/Kg *B. bassiana*; 600ml/Kg *M. anisopliae & P. reniformis*) and cooked. The rice was then divided into autoclave bags (600 x 700 mm - 500 g rice per bag), autoclaved for 30mins at 121°C, 103kPa (15psi), and placed in a laminar flow cabinet to cool.

Each 500 g bag of rice was inoculated with 75 ml of inoculum. Prior to inoculation the flasks containing *M. anisopliae* & *P. reniformis* were diluted with 75ml sterile water. The *B. bassiana* was not diluted due to the pelleting.

Once inoculated the tops of the bags were loosely folded once and the contents massaged to evenly distribute the inoculum. The bags were then transferred to an incubator room containing multi-tiered shelves, separated by 300 mm.

Bags of *M. anisopliae* & *B. bassiana* in mass production suite at CABI Europe-UK.

c. Spore separation

With the *B. bassiana* and *M. anisopliae* bags especially, it was necessary to re-massage the substrate to break up mycelial clumps. All bags were opened up for 2 days, to surface dry the substrate (and encourage further conidiation) before extraction using the MycoHarvester (version 5 prototype) at IPARC. Following extraction, the conidial powder was further dried in a dessicator, using indicating silica gel, before sealing in tri-laminate aluminium sachets for shipment. During the drying - spore extraction process, there was also a strong odour (similar to souring milk) with the *P. reniformis* isolate.

The production and extraction processes has not been optimised for any of the isolates, but to indicate the considerable differences in productivity, Table 1 shows the weights of conidia obtained from the primary cyclone cylinder of the MycoHarvester.

Table 1: Fungal productivity.

	ARSEF	Production (g. per 1 kg rice)
B. bassiana	6234	1.6 (2 kg)
M. anisopliae	727	32.4 (2 kg)
P. reniformis	484	5.5 (large quantity of mycelium in secondary)

Application and testing

A simple formulation technique in oil, for spraying at ultra-low volume (ULV) rates is described below. Formulated isolates were plated out on PDA shortly after application; all three samples of conidia were >95% viable (*B. bassiana* illustrated below) and went on to produce characteristic growths of the respective fungal species. The *P. reniformis* again showed secondary metabolite formation, with purple colouration of the agar.

Treatment and assessment of cage tests, supplemented with a bioassay, was carried out in the Quarantine Facility of the PNG-OPRA Entomology Department. The term 'sexava' describes a complex of species of Tettigoniidae that attack palms in PNG. In these experiments, target populations consisted almost exclusively of parthenogenetic females of Segestes decoratus. Two experiments were performed according to the following protocol:

A. Sprayed seedlings cage test

1. Prepared 10 large cages (1805 x 1050 x 1100 mm) and introduce 30 sexava into each - the day before introducing treated seedlings (replace any moribund insects before spraying).
2. Randomised treatments in 2 blocks and assigned labels to cages.
3. During the run-up to the experiments, captured bush cricket populations were decimated by rodent attack, so brodifacoum BB was placed under each walk-in cage.
4. Sprayer calibrated "mini-Ulva lite" 9000 rpm, 65 ml/min (red restrictor).
5. Formulations were prepared as follows:
   - 50% groundnut oil / kerosene mixture stock carrier.
6. 2.5g spores in 125ml for each isolate; control was blank oil with UV tracer.
7. Isolates have not been characterised, but formulation were approx. 10^9 conidia/ml.
8. Spray 2 seedlings for each replicate: i.e. total of 4 trees for each randomly selected - approximately 10 seconds for each plant, both sides, in 2 pairs. With a 25% estimated droplet capture, delivery was expected to be in the order of 3×10^9 conidia/seedling.
9. Seedlings sprayed with UV tracer (astral pink) were examined in the dark: >1 droplet/mm$^{-2.}$
10. Insects checked in cages for handling mortality and numbers adjusted if necessary, before carefully introducing fronds into the correctly labelled cage.
11. New seedling placed in each cage after 7 days to maintain insect welfare.
12. Assess at 24 hour intervals - checking ground, crevices and foliage carefully for cadavers.
13. Place any cadavers on moist tissue paper in 80 x 70 x 40 mm plastic boxes for assessment of mycosis (keep for 4-5 days at room temperature for checking then dispose).

14. Sheet provided for data recording; at the end of the trial enter data to computer spreadsheet (Excel).

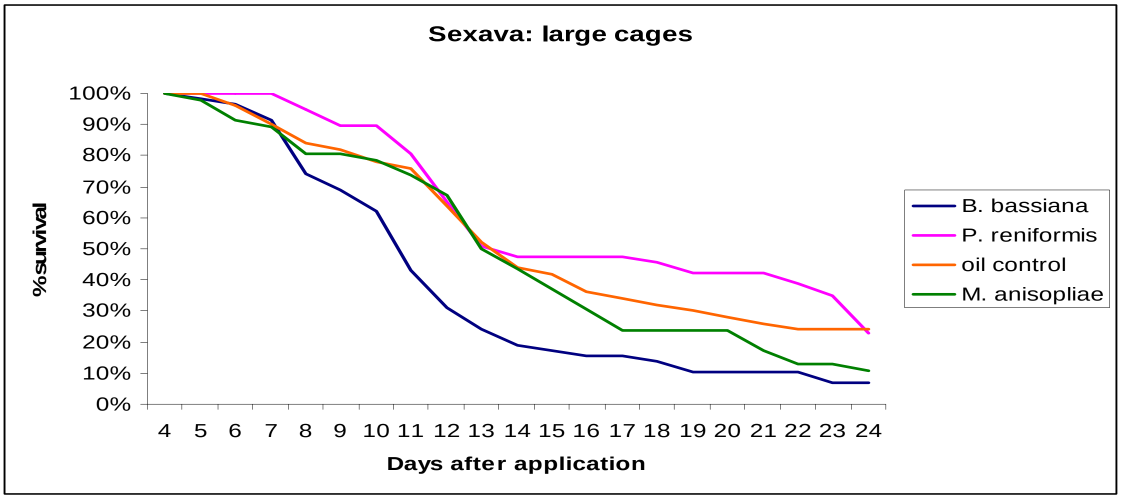
15. Continue recording if necessary, until control mortality was >50%.

B. Topical application bioassay

1. Insects were randomly selected from stock and placed, 12 in each of five 300 x 300 x 600mm cages.
2. Inoculated with 5 µL suspension using ‘Drumond Microcaps’ (Broomall, PA USA). The five treatments consisted of: 3 formulations (as above), blank oil control and untreated control. Estimated delivery was approximately 2.0 x 10^5 conidia/insect.
3. Oil palm leaflets were introduced into cages, which were placed on wooden laths to minimise ant attack.
4. Replace leaves approximately every 5 days.
5. Assess at 24 hour intervals - checking ground, crevices and foliage carefully for cadavers.
6. Place any cadavers on moist tissue paper in 80 x 70 x 40 mm plastic boxes for assessment of mycosis (keep for 4-5 days at room temperature for checking then disposal).
7. Record data on sheet provided.

Recording mortality in one of the walk-in cages.

In the cage tests, control mortality was reduced to 10% at the end of the first week and some 50% by the end of the second; this compares with 100% mortality by day 7 in Caudwell's experiment. However, there were no significant (or even noticeable) differences in insect mortality between these and control treatments: in either topical bioassay or sprayed seedling/cage experiments (illustrated).



Survival of sexavae in large cages using a "base line" of survivors at day 3, to allow for handling mortality and initial escapes. The final mortality with the four treatments was 76%, 65%, 70% (oil control) and 72% respectively

Although we were unable to locate any of the original 49 isolates obtained in Caudwell's original study, so isolates obtained from other Tettigoniids were used. From LUBILOSA experience, the apparent complete absence of any biological activity with all 3 isolates was surprising. Although operationally very disappointing, from a biological perspective this is an interesting "negative result" and raises important questions about disease resistance by insects living in humid environments. The results have been discussed with authorities on the fungal infection process, including Ray St Ledger, and may be the subject of future investigation. However, the question of medium-long term control techniques for sexava remains.

On the positive side, control mortality was greatly reduced and a protocol and infrastructure has been put in place for assessing other fungal isolates relatively cheaply. It would be appropriate to continue monitoring for local isolates - preferably epizootics of diseased sexava, which might be co-evolved. Other micro-organisms that appeared to show promise for biological control of locusts included *Nosema locustae* and Entomopox viruses (see Table 2), but rely on expensive *in vivo* production processes and showed variable efficacy in the field. We do not know of any reports of these occurring in sexava and for the reasons given in the table, anamorphic, entomopathogenic fungi have been by far the most successful biological control technique for locusts and grasshoppers. However, it is of course important not to pre-judge any potentially promising control agents (including chemicals). A further course of action would be to consider the technique for trials against *Eurycantha calcarata*, (Phasmatidae: Eurycanthinae) which is also an important pest of New Britain palms. PNG-OPRA scientists have specimens that have been found in the field dead from fungal infection (probably by *Beauveria* sp.).

Table 2:

Biological Control Agents for Acrididae: summary

Agent	Mode of action	Suitability
Deuteromycetes: *Metarhizium* & *Beauveria*	Contact	History of effective products, with known production systems
Entomophaga grylli	Contact: epizootics	*In vivo* production
Protozoa: *Nosema* & *Malamoeba*	Ingestion	Ditto; laboratory but not field efficacy
Entomopox viruses	Ingestion	*In vivo* production
Nematodes: *Mermis*	Ingestion	Ditto, v. low mortality
Bacteria: *Serratia*	Ingestion	Low efficacy, safety?
Arthropods, vertebrates	Predators, parasitoids	Typically <10% mortality in Africa

From an operational point of view, there is obviously an urgent need to identify substitute control measures for the organophosphates (OP) such as methamidophos. Possible alternative compounds for trunk injection were discussed and a draft field trial protocol was prepared. Table 3 includes compounds from differing mode of action (MoA) groups selected for systemic action, based on low partition coefficient {log P} and high solubility (see:http://www.dropdata.org/RPU/pesticide_activity.htm#mode-transfer). Although fipronil conforms only poorly to these properties, it has an extremely high biological activity and is known to show limited xylem systemicity in some monocotyledonous crops.

Table 3: MoA and a.i. of selected groups.

MoA group (IRAC code)	active ingredient	product	formulation	product/tree*
OP standard (1B)	methamidophos		60% SL	10
Neonicatinoid (4A)	thiamethoxam	Actara	25% WG	24
Neristoxin analogue (4C)	cartap	Padan	50% SP	12
Phenylpyrazole (2B)	fipronil	Regent	80% WG	7.5
Neonicatinoid (4A)	imidacloprid	Confidor	20% SC	30

* to achieve 6 g.a.i. / tree

Beneficial insects

Monitoring of pollinating weevils, *Elaeidobius kamerunicus* in PNG.

Although externally funded project- work with *Elaeidobius* has now ended, regular monitoring of male flowers is undertaken through the field collection of male inflorescences with routine recording male and female weevil emergence from spikelets in the lab. At Higaturu Research Centre we also monitor nematode incidences from routine dissection of weevils sampled in the field. Because weevil field collected data are now becoming more regularised, these data will be incorporated into a running database and routinely updated to include estimated numbers of weevils per hectare based on 10 anthesing male palms per hectare (Prior & Solulu 1991). Results presented in this way will be much more useful in monitoring field based weevil populations.

Laboratory work on new-genetic stocks of the same species of weevils from Ghana (West Africa) continued at Dami with intense breeding to increase numbers of weevils from the material maintained under strict quarantine conditions. Four large cages were used during the year. Care was taken to provide fresh, uncontaminated male inflorescences, and all male spikelet material was checked thoroughly before being introduced to the cages as food and breeding substrate. Breeding experiments undertaken during 2008 demonstrated the stability of the weevil crosses, and a report will be finalised in 2009 to request NAQIA for the authority to release the out crossed *Elaeidobius* weevils.

A paper on ecological aspects of *Elaeidobius* dynamics in WNB is in preparation (W W Page and C F Dewhurst). From Mainland PNG, three sites (Sangara, Ambogo Estates and Heropa ME), were continually monitored for nematode infestation levels in the weevils during the year (Fig.40). A sample of 100 weevils was dissected from each of three sites on a regular monthly basis. While infestation rates followed a similar pattern at Sangara and Ambogo, there were consistently higher rates of nematode infestation of weevils from Heropa for reasons that are unclear, although this area of Kunai grassland is almost sea level whereas the other two sites are about 200m asl.

There was however no clear link to rainfall, although Heropa is regarded as being “wetter”. (R.Safitoa, personal communication) (Fig. 41).

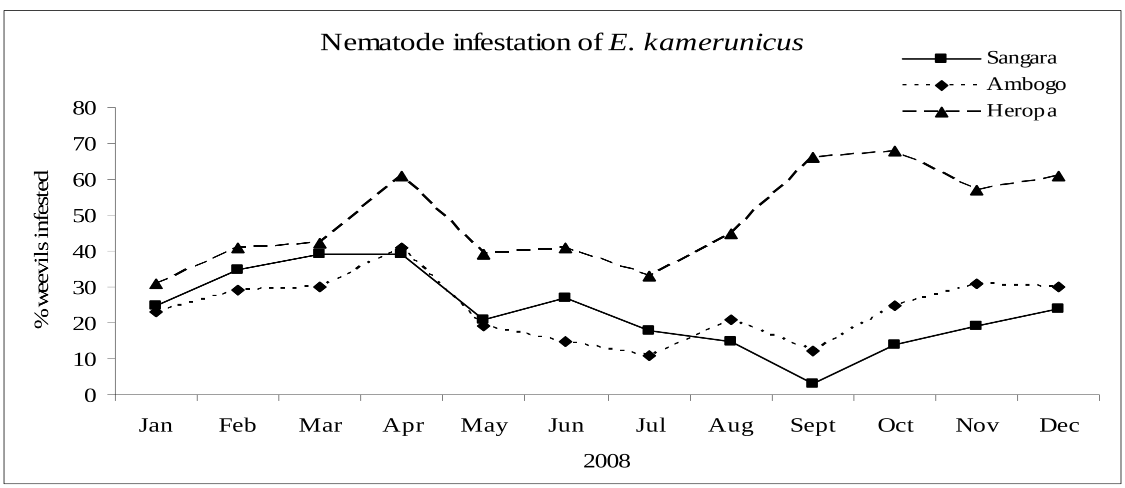


Figure 40 Nematode infestations in both sexes of *E. kamerunicus* from three mainland sites from Higaturu Oil Palms, PNG during 2008.

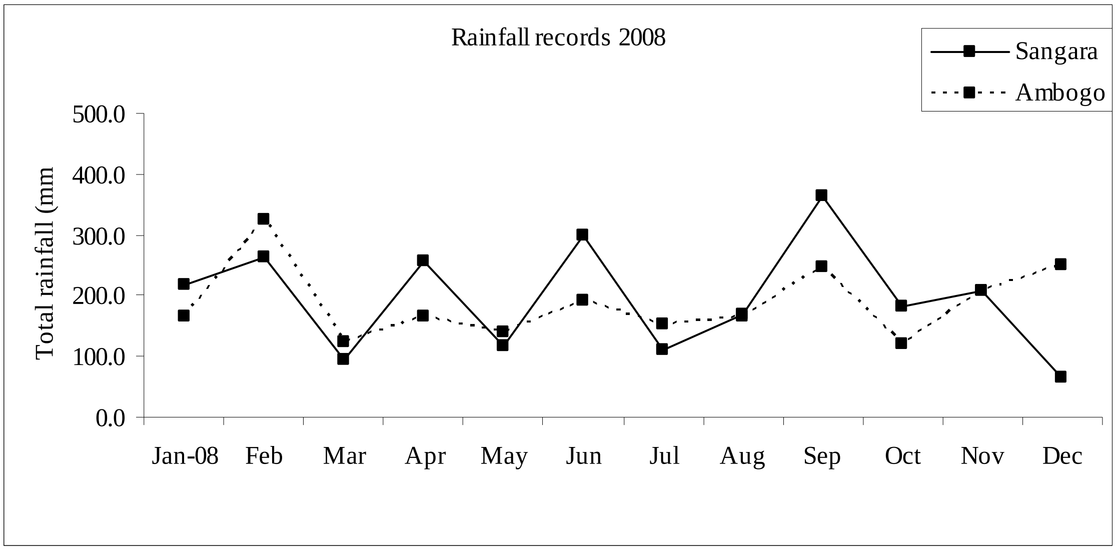


Figure 41 2008: Rainfall records from Sangara and Ambogo plantations.

West New Britain

Although the results do show that overall there are more females than males, data from Bialla indicate that, in October 2007, there were more males than females, while in October 2008, at Rigula, there were equal numbers of both sexes (Fig.42). Interestingly, and for unknown reasons, the sex ratio also reversed dramatically at Dami in September with more males than females; however this was for only one month. Typically one expects more of the smaller females. These data will continue to be collected over a long period of time, and will be similarly followed in Northern (Oro) Province.

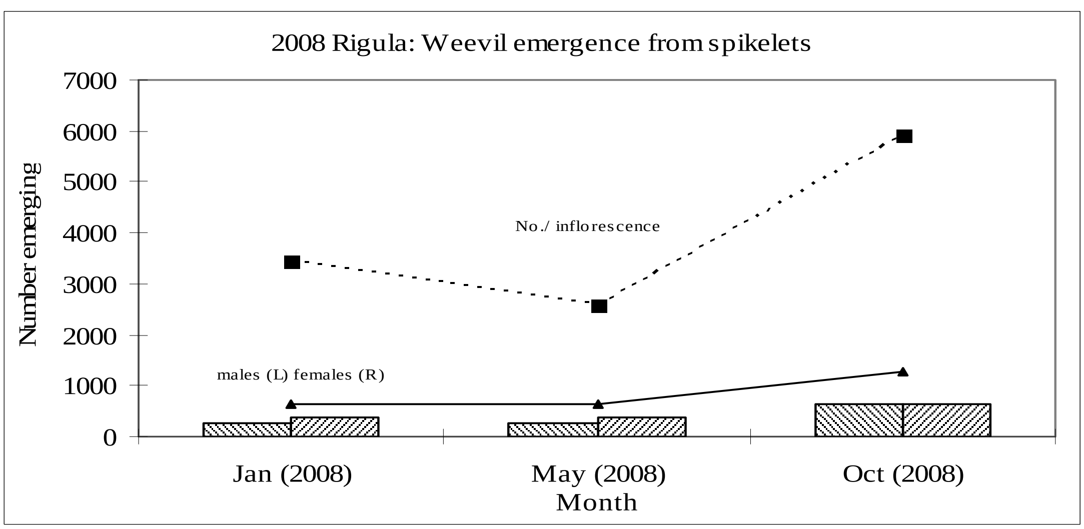


Figure 42. Weevil sex ratios recorded from Rigula, West New Britain 2008.

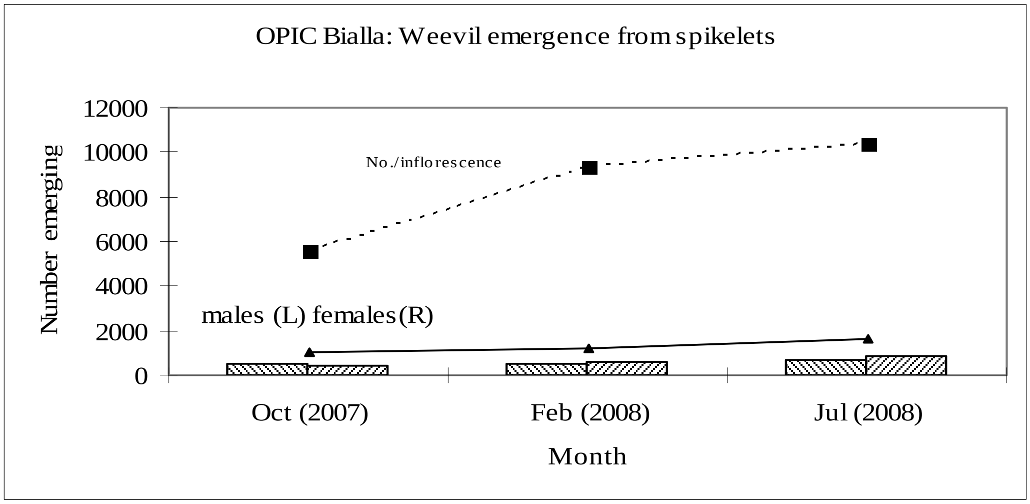


Figure 43: Weevil sex ratios recorded from OPIC Bialla, West New Britain 2008.

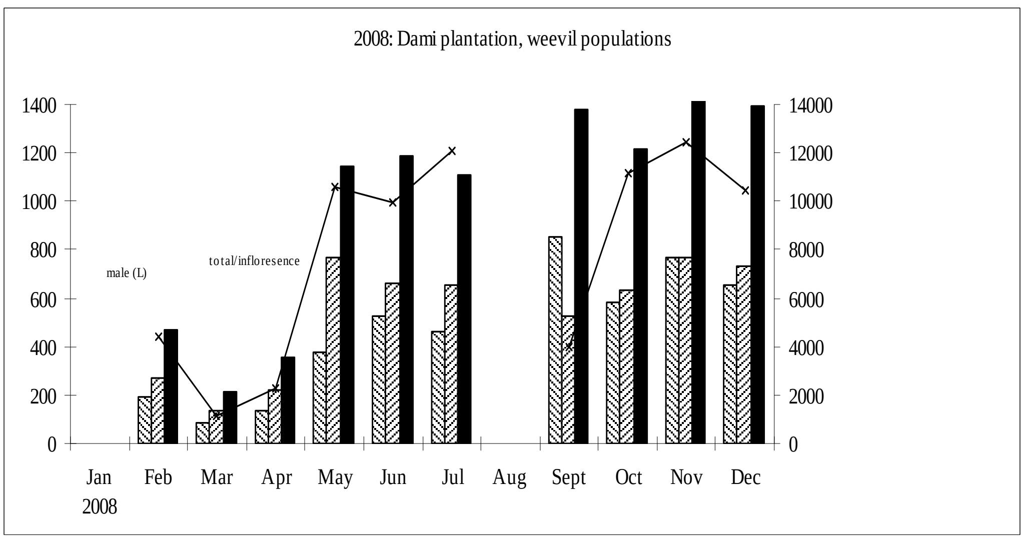


Figure 44: Weevil sex ratios recorded from Dami, West New Britain 2008.

New Ireland

This year we also started regular monitoring of weevil numbers from Agronomy trial plots in New Ireland where previously we were only recording them on an *ad hoc* basis. Twenty (20) spikelets were collected and cut into 10cm lengths and all weevils reared out from them. Estimates of numbers per spikelet and hence per male inflorescence may then be calculated. Female *Elaeidobius* consistently outnumbered males except from Lakurumau in November (Fig. 45) Maramakas in August and November (Fig. 48), and Leinaru in August and December (Fig.47).

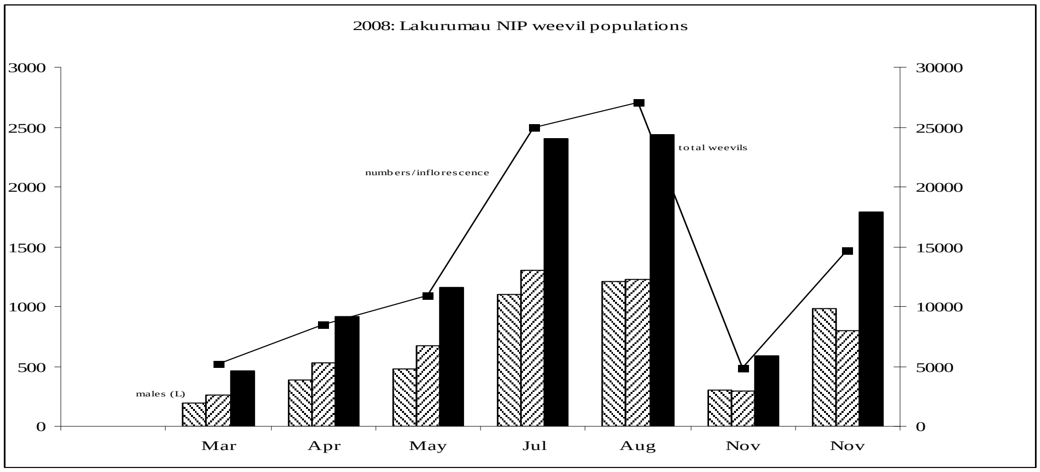


Figure 45: Weevil sex ratios recorded from Lakurumau, New Ireland 2008.

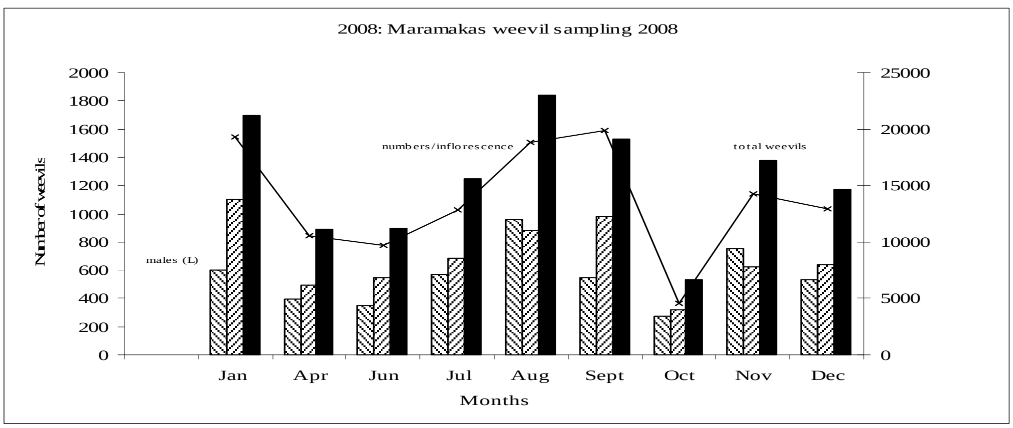


Figure 46: Weevil sex ratios recorded from Marmaras, New Ireland 2008

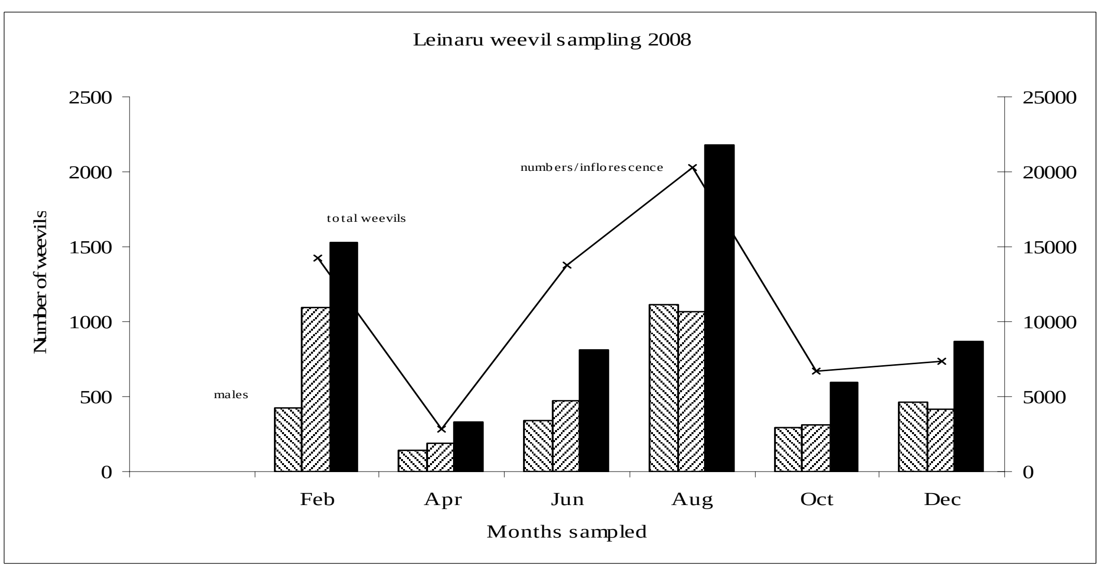


Figure 47: Weevil sex ratios recorded from Leinaru, New Ireland 2008.

Beneficial plants (nectar production)

This continues to be an on-going project in conjunction with NBPOL (OPRS). It will be completed during 2009.

Aspects of beneficial plant use were also investigated under the Finschhafen (FD) project (described above) and are reported on below. A scientific poster describing this work is available as a .pdf.

Invasive Weeds IPM

Siam Weed, *Chromolaena odorata*

The demonstration and harvesting plot was maintained at Dami; however it will have to be relocated in 2009, as NBPOL requires the site. Galls were harvested from this site for relocation to areas in WNB and on the mainland (Northern). The gall fly seems well established in many areas of WNB and mainland, although the weakening of the weed and its thinning out is not as dramatically obvious as in other areas where the fly has been released. It is planned to survey New Ireland in 2009.

Mile-a-minute weed, *Mikania micrantha*

Collaboration with the ACIAR project on *Mikania micrantha* (Project # CP/2004/064) continued (see below), however there were delays with approval from NAQIA for the importation of the rust fungus (*Puccinia*) which is now not expected until 2009 (Fig.48). Field and laboratory measurements were made with Mikania plants which showed that growth of up to 1m/month was typical. Growing tips of the plants were very sensitive to touch, and die rapidly if handled. At Dami, the plants were heavily attacked by aphids (Homoptera: Aphidoidea). An edited summary follows (Source: ACIAR report June 07-May 2008, M Day):

There has been steady progress on the project in some areas; however, there have been some obstacles encountered which have severely impacted on the project. There have been some changes to project staff with key personnel leaving. This has resulted in a reduction of momentum and capacity. Staff has now been appointed but some training is required. Most infrastructure work has been completed. Quarantine upgrades have been conducted in Fiji and PNG. However, minor work is still required at NARI, Kerevat, PNG before approval of the facility is granted by NAQIA. The approval for the importation and field release of the rust in PNG is dependent on the satisfactory upgrade of the quarantine. Shade houses have been constructed in WNB by PNGOPRA and at SPC in Fiji.

Growth studies have been conducted in Fiji and PNG, showing Mikania can grow over 1 m per month. Impact studies have been completed in Fiji and in some parts of PNG. Communication problems with the regions have impacted on this activity. There is good data on its distribution in PNG in two provinces but little is known of its distribution elsewhere. Host testing of the rust *Puccinia spegazzinii* was completed by CABI Europe-UK under contract. The rust is host specific and an application to import the rust into quarantine in PNG has been submitted and approval is pending the satisfactory upgrade of the quarantine facility at NARI, Kerevat, PNG.

Future meetings will need to be held to assist new staff with project activities.

Figure 48: *Mikania micrantha*, leaves and flowers showing leaf form & flowers.

Giant Sensitive plant, *Mimosa diplotricha* (= *invinsa*)

The infestation of *Mimosa diplotricha* (= *invinsa)* that was found on WNB near Wandoro in 2007 was cut back again on 15th February and treated with herbicide (Fig. 46). This process will have to be repeated annually, as seeds can remain for many years in the soil, and new plants continue to develop.

Figure 49: With OPIC at Wandoro WNB, Mimosa destruction, stumps were then

A request for financial assistance to purchase a back-pack sprayer, some herbicide (Glyphosate) and bush knives was submitted to SPC in Fiji. The request was authorised in December, and equipment was purchased to enable us to organise regular control operations against this noxious weed, and to prevent it from becoming established in WNB. Support from SPC is gratefully acknowledged.

Water hyacinth, *Eichornia crassipes*

Water hyacinth weevil (Coleoptera: Curculionidae) (*Neochetina bruchi* Hustache, 1926)) was released on two occasions into an area in WNB where the weed was present ("Klin wara" & Kumbango stream) (Fig.50). Cultures of the weed and weevil are maintained in half section 200l drums. No releases were made on mainland PNG.

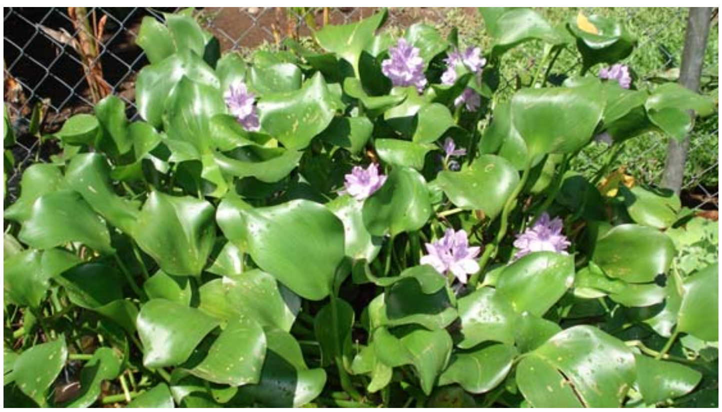


Figure 50: Water hyacinth, *Eichornia crassipes* in drum at Dami, WNB.

Conservation: Queen Alexandra Birdwing Butterfly (QABB).

The close collaboration with NBPOL (OPRS) and James Cook University (JCU), continued. There were difficulties in collecting and receiving sufficient "clean" plant material for culture, and the heavy fungal load meant that a great many samples were lost. Delays in the receipt of samples from the field, both in Australia and WNB were also an issue which were overcome.

QABB *Summary of NBPOL/OPRS involvement provided by Dr Dale Smith)*.

"Seed pods and seeds collected from the field were heavily contaminated by fungi, which proved impossible to remove and which severely hampered mass production attempts. Effort will be put into solving this problem during 2009.

During the year a Bachelor of Agricultural Science student, Ms. Lydia Tasi, began a 6 months industrial placement in the Biotechnology group of New Britain Palm Oil Ltd (NBPOL) Dami Oil Palm Research Station (OPRS). Ms. Tasi undertook a project on micro-propagation (tissue culture) of *Pararistolochia dielsiana*, the sole food source of the endangered Queen Alexandra Birdwing Butterfly (QABB), *Ornithoptera alexandrae*. Her report was not published.

Three lines of research were carried out:

1) Sample decontamination and callus induction on *Pararistolochia* leaf samples from Popondetta using a De Fossard matrix of 81 different media.

2) Decontamination and germination of *Pararistolochia* seed pods from a preferred food plant, and sterile culture of resulting seedlings.

3) Use of seedling material to optimize callus and plant growth in sterile culture.

All *Pararistolochia* leaf samples contained internal fungal contamination and from several thousand “explant” pieces only one callus sample was observed.

Seed germination however was successful and 31 clones were established by subsequent axillary shoot multiplication in sterile culture. Although these 31 individual genotypes have been untested as food plants, they are all the progeny of a “verified” QABB food plant. Thus they will contain some of the genetic features that constitute a food plant and are a valuable plant genetic resource. These plants are also a useful resource for ongoing tissue culture experiments to optimize plant production”.

Although principal monitoring of QABB sites and life stages continued to be undertaken by the Popondetta based Conservation International (CI) project (Eddie Malaisa, see 2007 Annual Report), visits to the main butterfly localities (Voivoro and Girigirita) were undertaken, for the collection of leaf material for additional biochemical study and propagation (31/1, Voivoro, 5/6 Girigirita and Voivoro (Fig.51).

Figure 51: Pre-pupa of QABB in natural habitat, Voivoro, Northern Province.

Other projects

Silavuti New Development [for Douglas Environmental Services] environmental assessment.

Arthropod material collected by consultants working on this project was delivered (some in a poor state) to entomology section in December, and approximately 50 specimens have been mounted and labelled so far. An equivalent number remain to be prepared, and identified.

PNGOPRA Quarantine Facility

The facility (PECQ4) is in constant use and will continue to be maintained until authority for weevil release is received from NAQIA in 2009, after the detailed breeding report is delivered for NAQIA and DEC for them to decide on when the *Elaeidobius kamerunicus* can be released.

Insect pest monitoring at Dami seed production unit (SPU).

Light trap samples were sent weekly to entomology laboratory to check for the presence of any known vector insects that might have been trapped. None was found during the year. Reports were provided to HoPB.

Insect reference collection.

Having a comprehensive reference collection is essential for a good understanding of oil palm pests in PNG. Reference material is also used for training.

During the period 2006/8, more than 500 specimens were individually prepared, mounted, labelled sorted, and stored. All specimens are from known hosts, and are directly or indirectly (parasitoids) related to oil palm. They were mounted with relevant host material if parasitoids, or cocoons/pupae.

Examples were sent to specialists around the world for specific identification. As this is now very expensive, examples of duplicate specimens identified were donated to the Natural History Museum in exchange for specimen identification. Duplicate examples are also to be made available to the National Insect collection in Port Moresby. Any material sent for study or identification is accompanied by the "*Approved Institution*" status form issued by Department of Environment and Conservation.

Every specimen is accompanied by a data label on which is contained all basic data information.

The data recorded on these labels will be retrieved and a database prepared, as many specimens contain valuable rearing data (possible student project).

The insect storage cabinet from Higaturu Research Centre was returned to Dami, and is being used to store the insect reference collection specifically for oil palm pests and their natural enemies.

An example of a data label which are printed in Times New Roman font size 4 or 5 and attached to every specimen or are inserted in every tube/bottle:

Papua New Guinea West New Britain

Bebere Div 2 ex. oil palm as larvae

em 29.viii.2008 C F Dewhurst

Spirit collection

There is also a large spirit collection, this has not yet been documented, and it continues to grow, as it consists of many specimens of "sexava", all stages of *Eurycantha* and *Stichotrema,* as well as *Doirania leefmansi* and *Leefmansia bicolor*. All are preserved in alcohol and are fully labelled.

All these data require entry into a database.

Scientific reprint collection database

Entomology has an extensive reprint collection of more than 600 reprints and additional "grey" publications (reports) and books. They are currently only partially labelled and referenced by Head of Entomology, but a complete inventory and abstracted set of references will be started in early 2009 which will be accessible to all within PNGOPRA (initially).

Head of Entomology has donated a number of his own publications to the entomology library.

Training (and **Radio broadcasts)**

Three work experience students visited PNGOPRA entomology during the year, two were based at Dami. One finished his study period in early February, and one at Higaturu Research Centre. Two of the reports are outstanding and have not yet been made available to PNGOPRA.

Regular attendance was made to OPIC field days. Two display boards and specimen box are taken to every field day, and brief summaries provided to growers with an emphasis of what they require to know. Two staff members attend these field days.

Five radio broadcasts were made in WNB during the year, providing information on oil palm pest related topics for the general public. None were made on the mainland due to lack of available funding through OPIC

IS training was also made available to a staff member during the year.

Staff, travel visits to other areas.

- Susan Pipai, laboratory technician resigned and left on 7 March (to work with her family in POM).
- HoE to Milne Bay on 13-17 March, to investigate pest report.
- HoE to Popondetta 17-21 March to Higaturu Research Centre.
- HoE to Hargy Oil Palms 4-7 April, with Dr C Pilotti.
- Professor G Gurr visited 3-8 June (Zophiuma project).
- Dr Catherine Gitau visited 3-18 June (Zophiuma project).
- Dr Roy Bateman visited 20 June-3 July (Mycoinsecticides trial).
- Dr Mark O'Shea visited PNGOPRA 23-27 June. (Reptile specialist).
- Dr M Day (Mikania project) visited 4-5 August.
- HoE and Simon Makai to Hargy Oil Palms 13-15 August.
- D Woruba and Simon Makai to Bialla 26-28 October.
- Dr C Gitau visited 6 November – 4 December (Zophiuma project).
- All staff took their annual leave during the year.

3. PLANT PATHOLOGY RESEARCH

(Dr. C. A. Pilotti)

INTRODUCTION

There were no external sources of funding for projects under the Plant Pathology Section in 2008 as all donor projects ended in 2007.

The epidemiology of basal/upper stem rot and the population structure of *Ganoderma boninense* continued 2008 with sample collection for the research on the population structure of *Ganoderma* in selected study blocks in Milne Bay and at Numundo in West New Britain. As usual, survey data was collected from the plantations and audits were carried out on the implementation of the control in the plantations.

Research on the biocontrol agent *Trichoderma* also continued in 2008 with additional *in-vitro* testing against *Ganoderma*. A proposal was prepared this year for external funding to allow research leading to a commercially available product in 2011.

Screening of seed lines for resistance to Ganoderma in the nursery continued and work on a project document for field trials to be established in Solomon Islands in 2009 was finalized.

Training and technical services in the form of site visits, training and publications also constituted a significant part of the work of this section in 2008.

Some constraints in staffing levels and duty changes impacted on the research programme but generally, short-term projects were completed and new projects implemented in 2008 as proposed.

THE EPIDEMIOLOGY OF BASAL STEM ROT

Objectives: *(1) To determine the mechanism(s) secondary spread of Ganoderma within plantations in PNG and to apply this data to refine control methods.*
(2) To generate epidemiological models from survey data that will allow growers to make predictions of crop loss and economic thresholds in future plantings.

1.1 Introduction

Both qualitative and quantitative disease data from current plantings are required in order to assess the effects of disease on future generations of oil palm on the same sites. Data is collected on an annual basis through surveys carried out by plantation personnel and /or data submitted after rouging rounds.

1.2 Methodology

All data presented here has been obtained from Milne Bay Estates Ltd., Poliamba Ltd. and New Britain Palm Oil Ltd. Survey data has been corrected where possible and only disease incidence data detected in the 2008 surveys are reported here. Data has also been filtered to exclude inadequately sanitized stumps, sterile and standing dead palms. Some blocks in Milne Bay were not surveyed in 2007 and therefore the 2008 data also includes palms that became symptomatic in 2007 but were not recorded.
Disease survey data for OPRA study blocks has been collected by OPRA personnel bi-annually (Milne Bay) or quarterly (West New Britain).

1.3 Disease progress in first generation oil palm

1.3.1 Milne Bay Surveys

The percentage of blocks surveyed in Milne Bay in 2008 is shown in Figure 1.1. Data was not received for Ataata and Borowai Divisions and indications are that they were not surveyed in 2008. A high percentage of blocks in Giligili, Sagarai and Padipadi were surveyed at least once in 2008 but only 50% of the blocks in Waigani were surveyed.

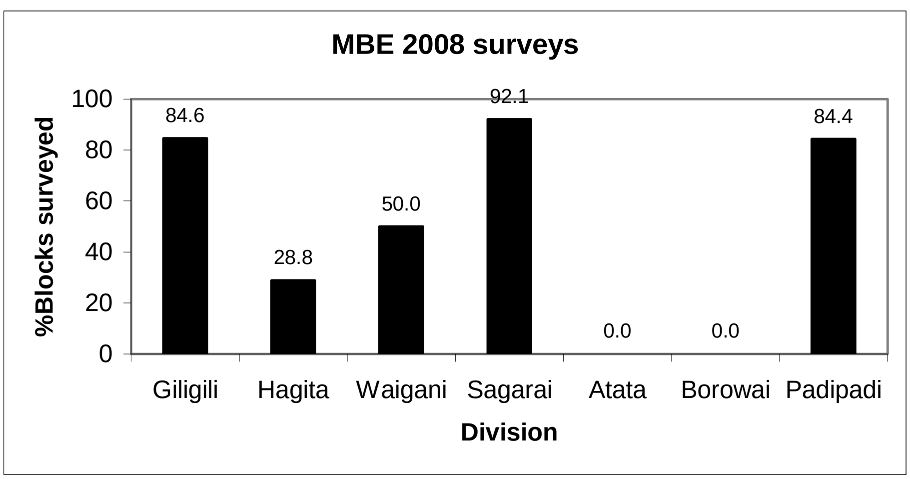


Figure 1.1. Percentage of blocks surveyed in 2008 for all Divisions in Milne Bay in 2008.

The total disease incidence for 2008 expressed as the number of diseased palms per hectare for all Divisons in Milne Bay is shown in Figure 1.2. Naura and Kwea Divisions were undergoing or preparing for replant in 2008 and this resulted in survey data not being collected for many of the blocks and therefore data for infection levels in these three Divisions are underestimated.
The highest incidence was recorded for Giligili Division with 5.6palms/ha being identified as infected in 2008. On an individual block basis, block 7209 recorded the highest disease levels with

12.6palms/ha (Figure 1.2). This block was amongst those not surveyed in 2007. The disease levels in the majority of the blocks increased in 2008 compared to 2007.

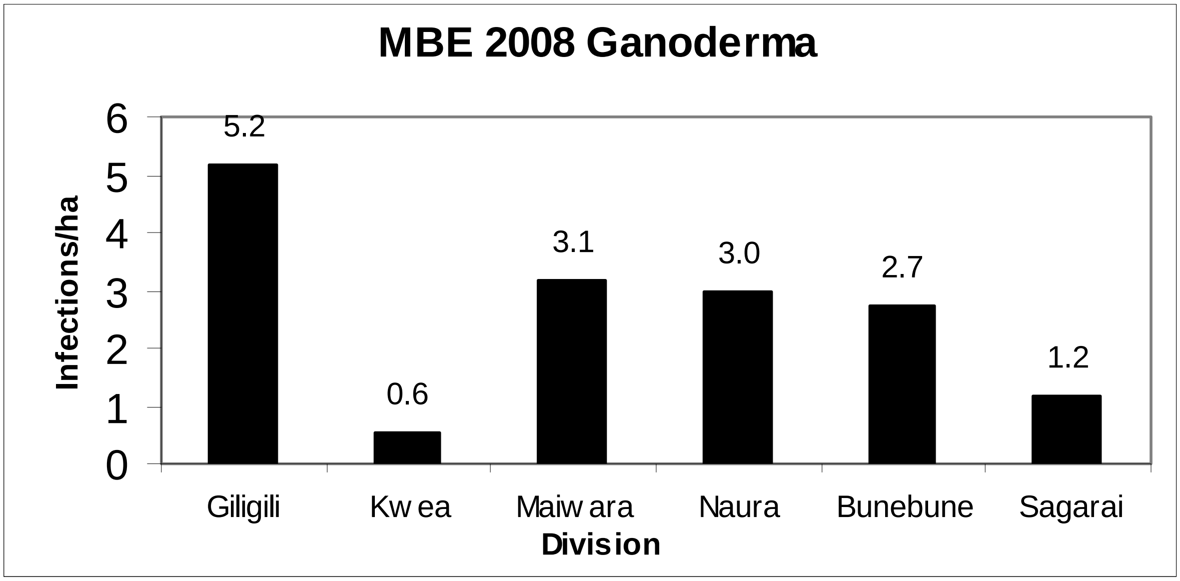


Figure 1.2 Number of diseased palms (per ha) detected in all Divisions in Milne Bay in 2008. Figures are corrected for 2007 palms.

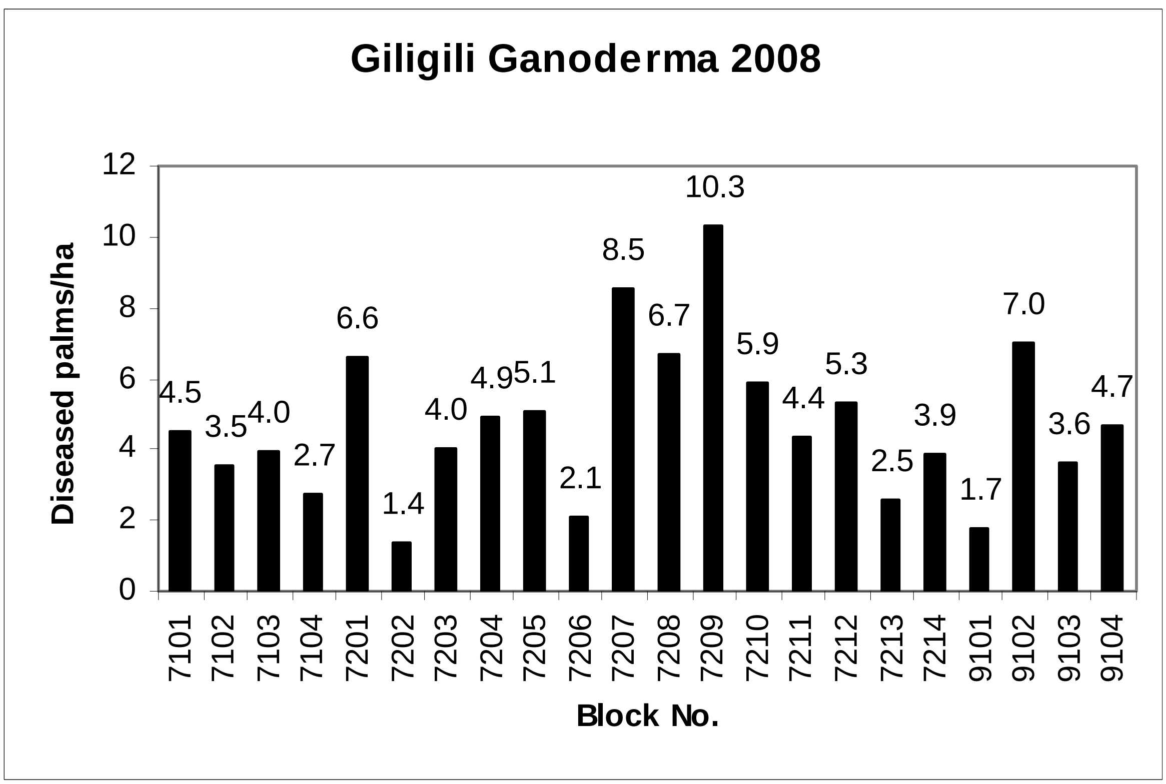


Figure 1.3 Disease incidence expressed as the total number of diseased palms per hectare including palms with basal and upper stem rot and suspect palms for Giligili Division, Milne Bay in 2008.

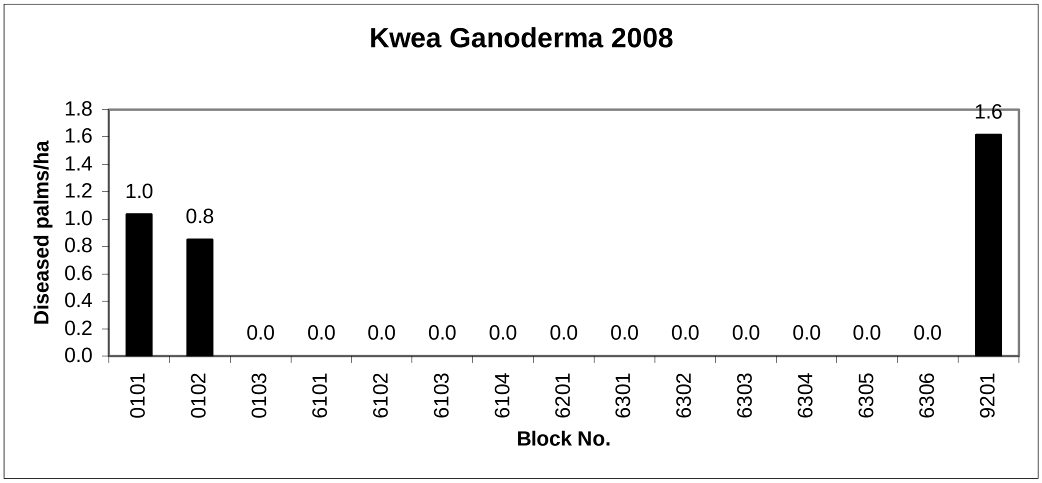


Figure 1.4 Disease incidence expressed as number of diseased palms per hectare for Kwea Division, Milne Bay in 2008. Total number of palms includes basal stem rot, upper stem rot and suspect palms. Blocks without bars were replanted in 2008.

Disease data for Kwea is shown in Figure 1.4. Infection levels were low and the majority of the blocks were not surveyed prior to replant.

Only 50% of blocks within Naura Division were surveyed in 2008 (Figure 1.5). The highest incidence was obtained for Block 6606 with 9.9 palms per hectare recorded as infected. This block was not surveyed in 2007 and therefore the data represent 2 years of infections. Most of the blocks in this Division are due for replant in 2009 and it is important that sanitation is carried out efficiently prior to planting.

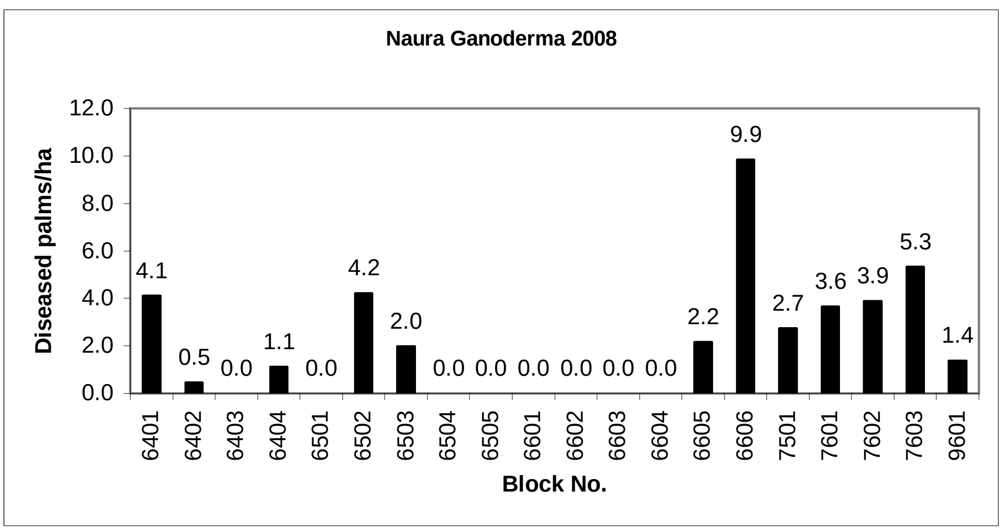


Figure 1.5 Disease incidence expressed as number of diseased palms per hectare for Naura Division, Milne Bay in 2008. The total includes palms with basal stem rot, upper stem rot and suspect palms. Blocks without bars were not surveyed in 2008.

The highest recorded disease incidences for Bunebune and Maiwara Divisions in 2008 were in the vicinity of 7 palms/ha (Figures 1.6 and 1.7). It is suspected that surveys were not completed within these blocks in 2007 resulting in high detection levels in the 2008 surveys.
The majority of other blocks in these Divisions recorded below 3 palms/ha infected in 2008.

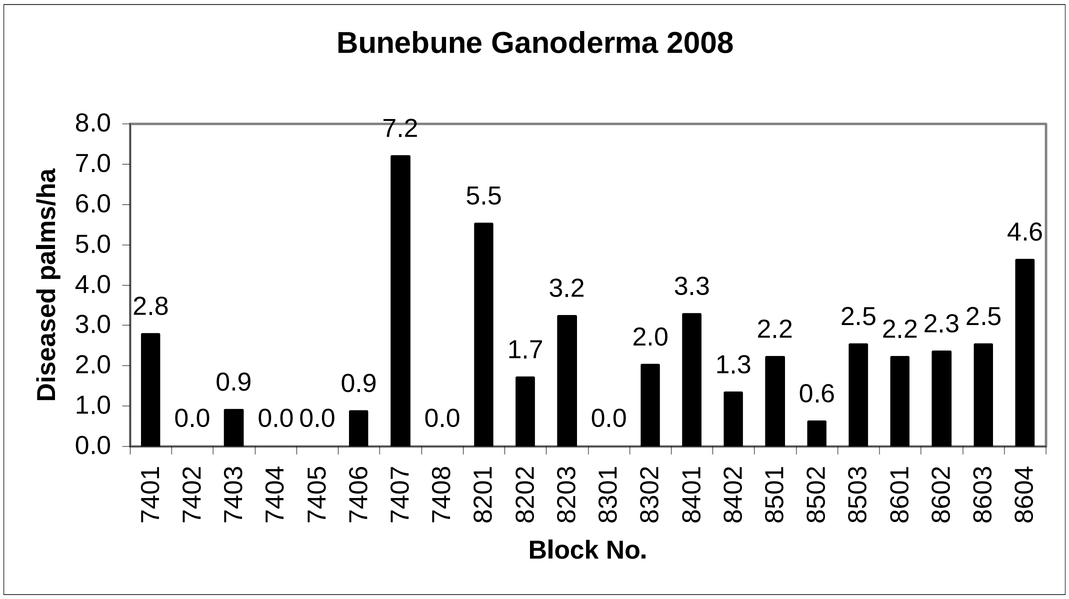


Figure 1.6 Disease incidence expressed as number of diseased palms per hectare for blocks in Bunebune Division, Milne Bay in 2008. Total includes palms with basal stem rot, upper stem rot and suspect palms. Blocks without bars were not surveyed in 2008.

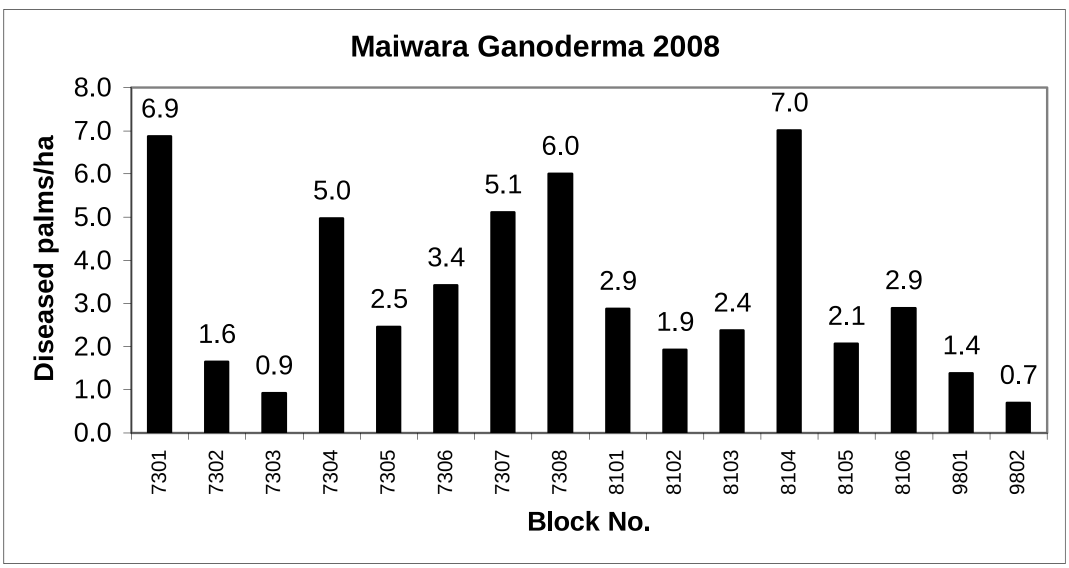


Figure 1.7 Disease incidence expressed as diseased palms/ha for Maiwara Division, Milne Bay in 2008. Total includes palms with basal and upper stem rot and suspect palms.

Disease progress curves for palms of different age groups in Milne Bay are shown in Figure 1.8. The disease incidences for the different age groups appear to be following the same trend. Disease progress appears to be linear in the first 15 years and then increases in a non-linear fashion after this time. This is likely due to the poor control being undertaken by the plantations. The average level of infection in 24 year old palms is 16% and increase of 2.3% from 2007.

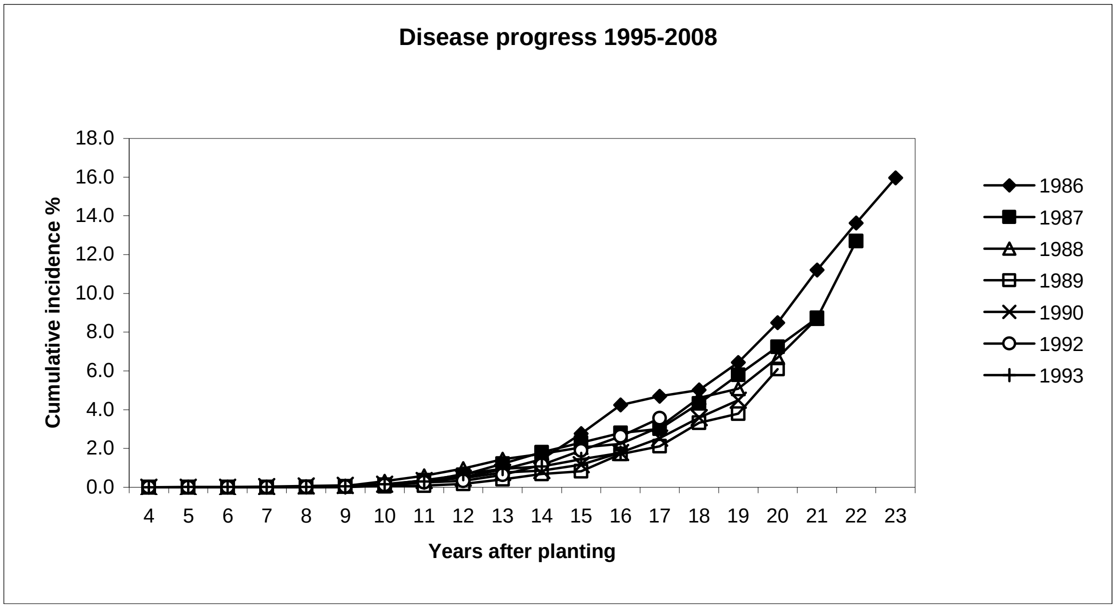


Figure 1.8 Cumulative disease incidence (1995-2008) for palms of different age groups (planting date) in Milne Bay.

1.3.2 Disease progress in Ganoderma study blocks

Updated disease progress curves for the six blocks that are monitored by OPRA in Milne Bay are shown in Figure 1.9. Block 6504 recorded the highest disease levels in 2008 (perhaps because it was not surveyed in 2007) and the cumulative incidence is now 21.8%, an increase of 6.4% from 2007. For most of the other blocks, the increase from 2007 was lower (range 1.7% to 2.8%) and this could be a reflection of the higher efficiency of the control programmes within these blocks in previous years. The disease incidence for Block 6404 is now at 15.3%, 6503 at 16.1% and 7501at 15.7%. Blocks 7213 and 7214 recorded steady rates in 2008 with the cumulative disease incidences now being 12.3% and 13%respectively.

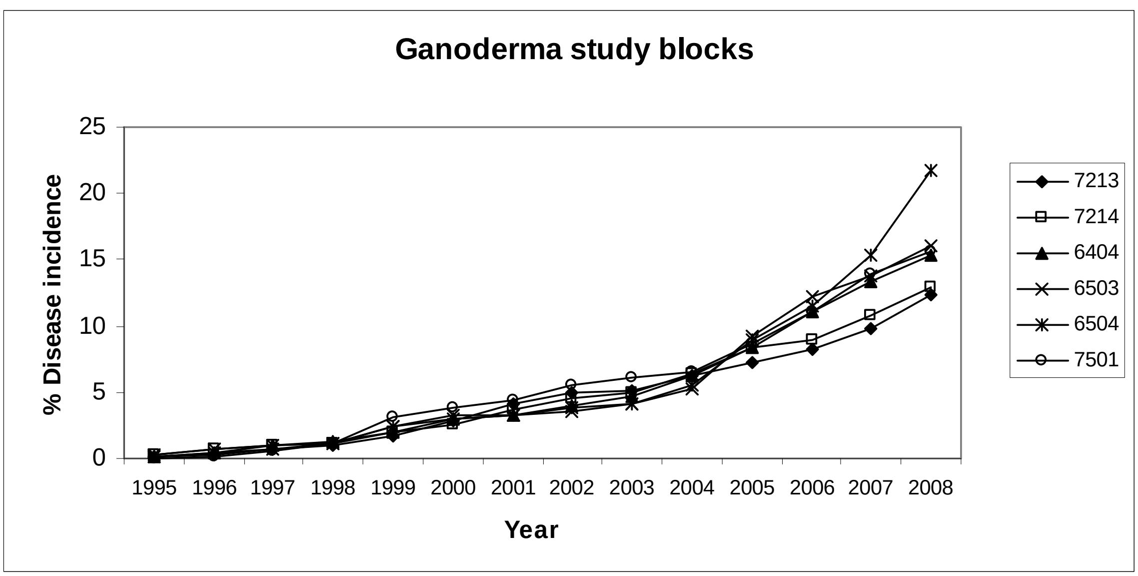


Figure 1.9 Disease progress curves from 1995 to 2008 for the six blocks selected for study in Milne Bay.

1.3.3 New Ireland

Surveys and Ganoderma infection levels for each Division at Poliamba in 2008 are shown in Figures 1.10 to 1.17.

Surveys for all blocks were not completed for any of the Divisions in 2008 however Madak Division, had the highest completion rate with all blocks being surveyed in all 4 plantations (Figure 1.17).

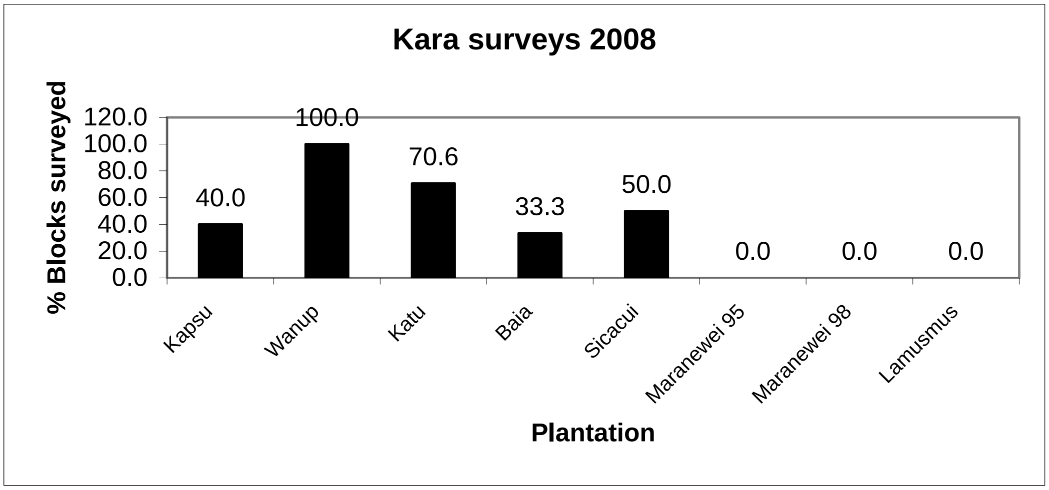


Figure 1.10. Number of blocks surveyed 2008 in Kara Division, New Ireland.

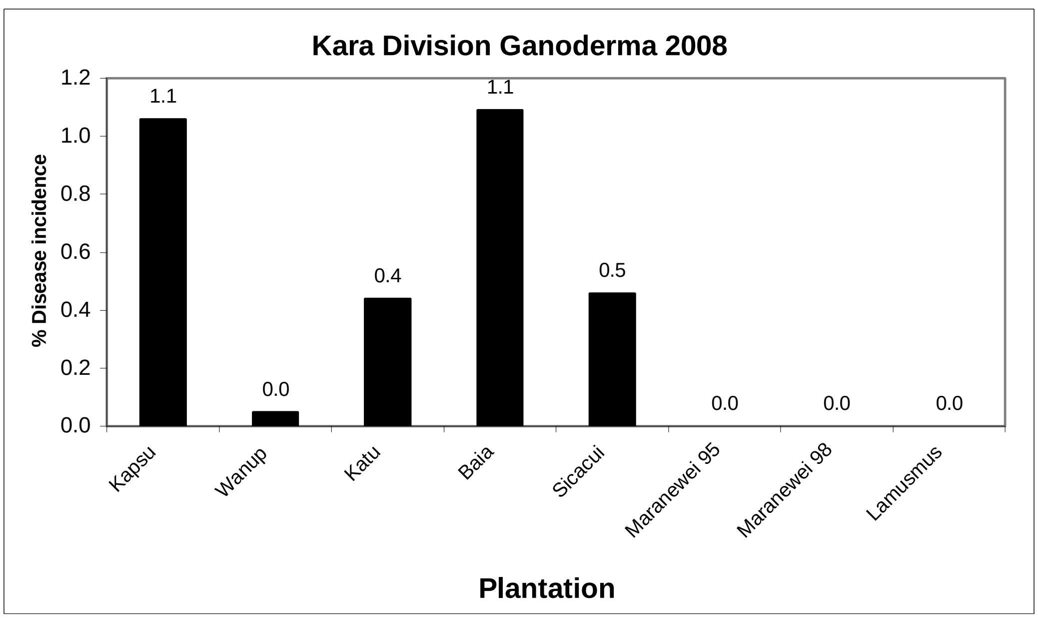


Figure 1.11.Ganoderma infection levels for 2008 in Kara Division, New Ireland.

The highest Ganoderma levels for Poliamba in 2008 (3.5palms/ha) were recorded at Kafkaf in Notsi Division. All other divisions recorded less than 2 palms/ha infected in 2008.

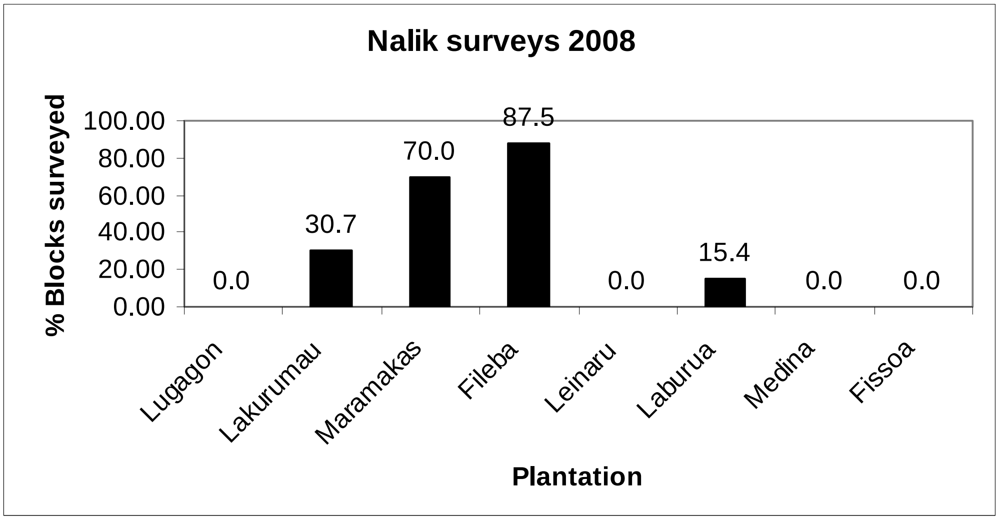


Figure 1.12 Blocks surveyed in 2008 for Nalik Division, New Ireland.

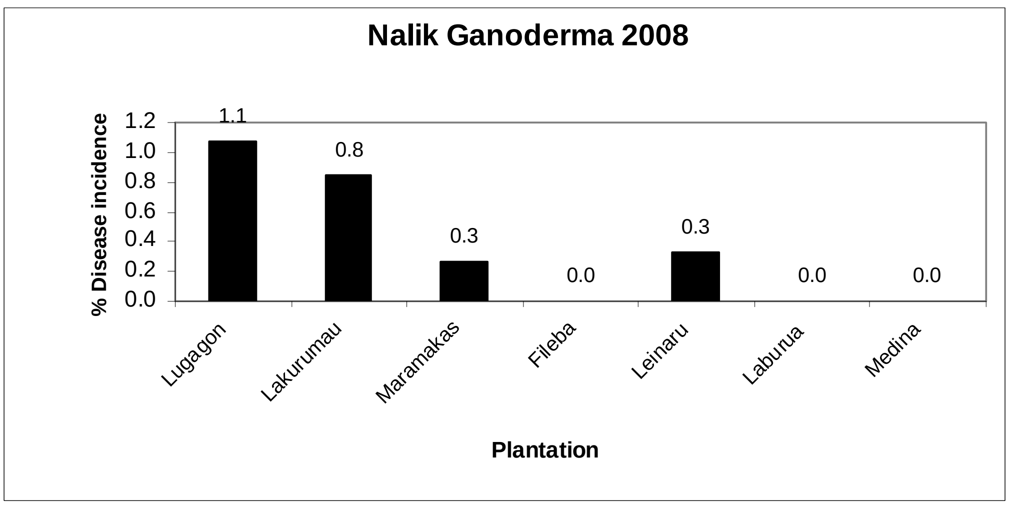


Figure 1.13 Ganoderma incidence for Nalik Divisio, New Ireland in 2008.

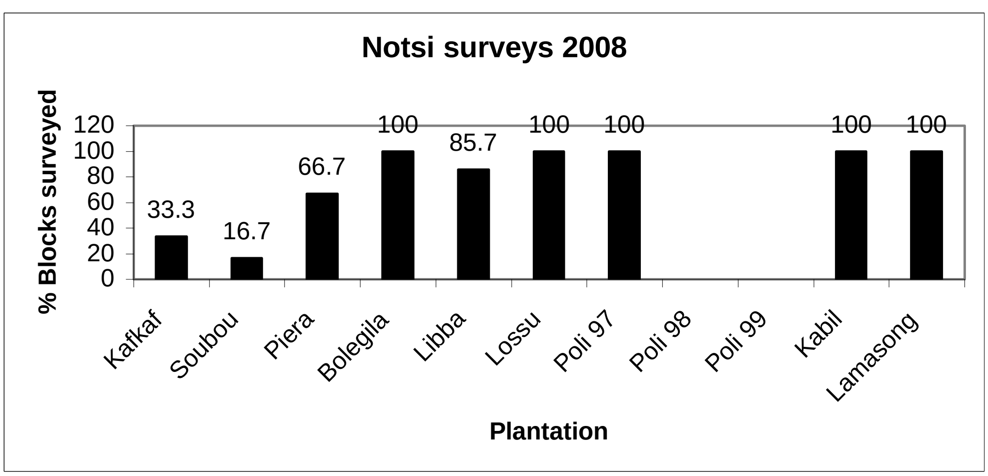


Figure 1.14. Number of blocks surveyed in Notsi Division, New Ireland in 2008.Blocks without bars were included in the surveys for Poli.

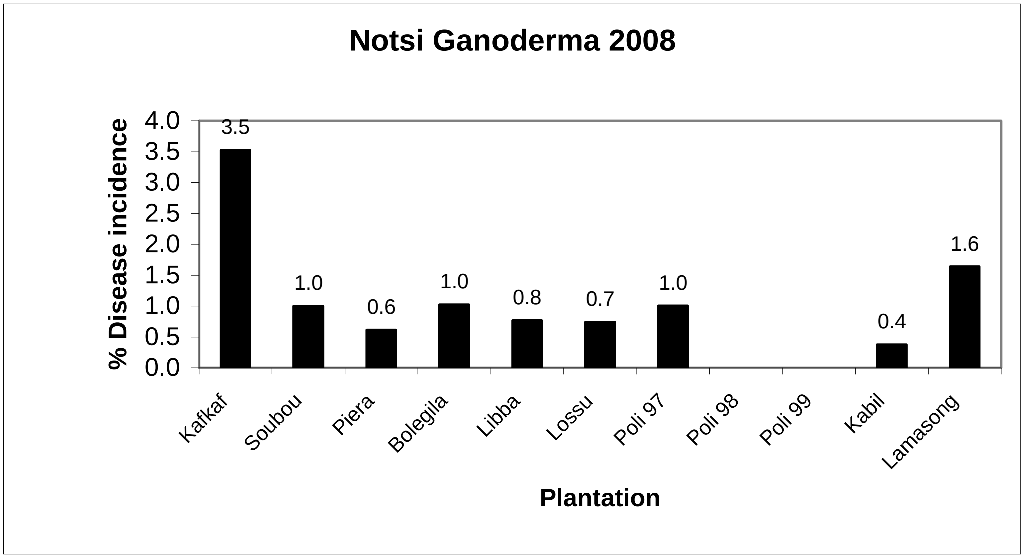


Figure 1.15. Ganoderma incidence for Notsi Divisio, New Ireland in 2008.

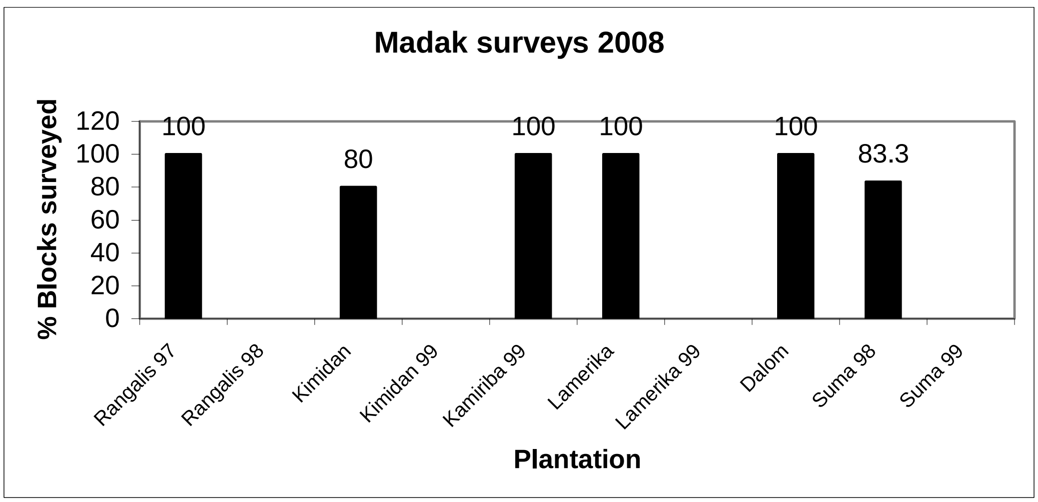


Figure 1.16. Surveys completed at Madak Division (Poliamba, New Ireland) in 2008.

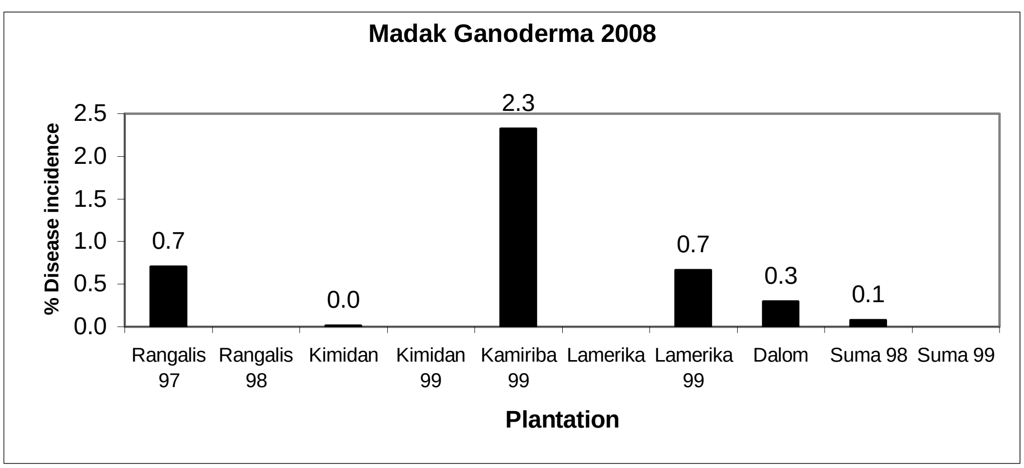


Figure .1.17 Levels of Ganoderma infection ((palms/ha) at Madak Division (Poliamba) in 2008.

1.3.4 West New Britain

Annual disease rates in 2008 for the E fields at Numundo increased from 2007 for all E fields except E2 and E3. (Figure 1.18). However, since data is based on removals rather than surveys, the increase in these two fields may be due to an increase in removals due to a backlog from the previous year. Data for Fields E4 and E5 is based on surveys (not removals) and the disease rate in these two fields decreased in 2008. It is speculated that this is due to the higher rate of removals in 2007 compared to 2006 but further analysis will need to be done to confirm this observation.

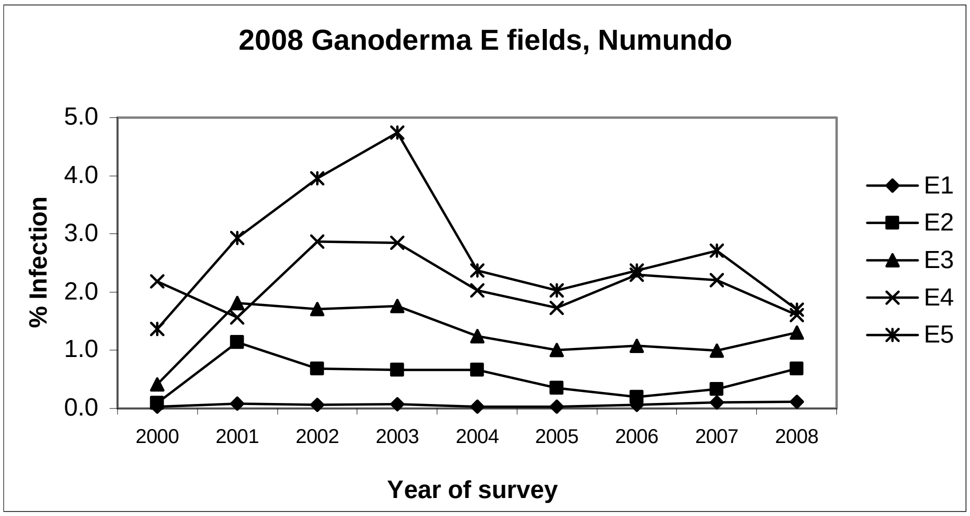


Figure 1.18 Annual disease incidence in 1994 Numundo E Fields, Wes New Britain from 2000-2008.

Disease progress curves for the period 2000-2008 show the continuing linear trend in infection levels in the E Fields (Figure 1.19). Field E5 continues to have the highest incidence with 24.2%, followed by E4 with 19.3%. Levels of infection in Field E1 remain very low at 0.6%.

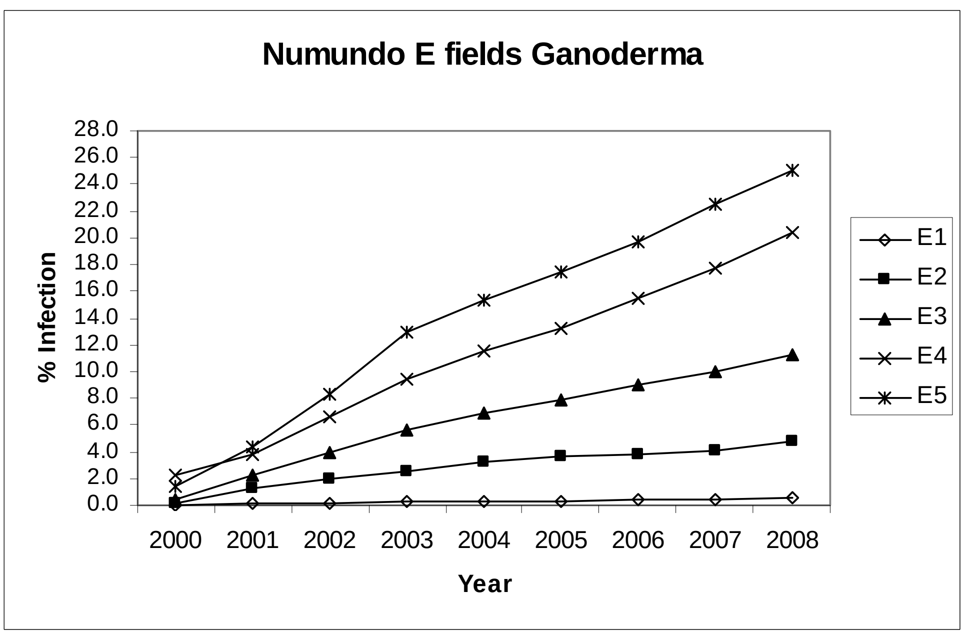


Figure 1.19 Disease progress curves for the 1994 E fields at Numundo, West New Britain Province from 2000-2008.

In terms of management units (MUs), as expected the highest cumulative disease incidence (19.6%) was recorded in MU3 which comprises the worst affected Fields E4 and E5. This figure is approaching the theoretical threshold level of 20% and it will be interesting to determine if any yield loss has started to occur. Certainly for Field E5, with a cumulative disease incidence of over 24% the yield should have started decreasing in 2008 if not in 2008. Unfortunately, it is not possible to quantify the yield loss for this field alone since yield data is no longer recorded on a block basis.

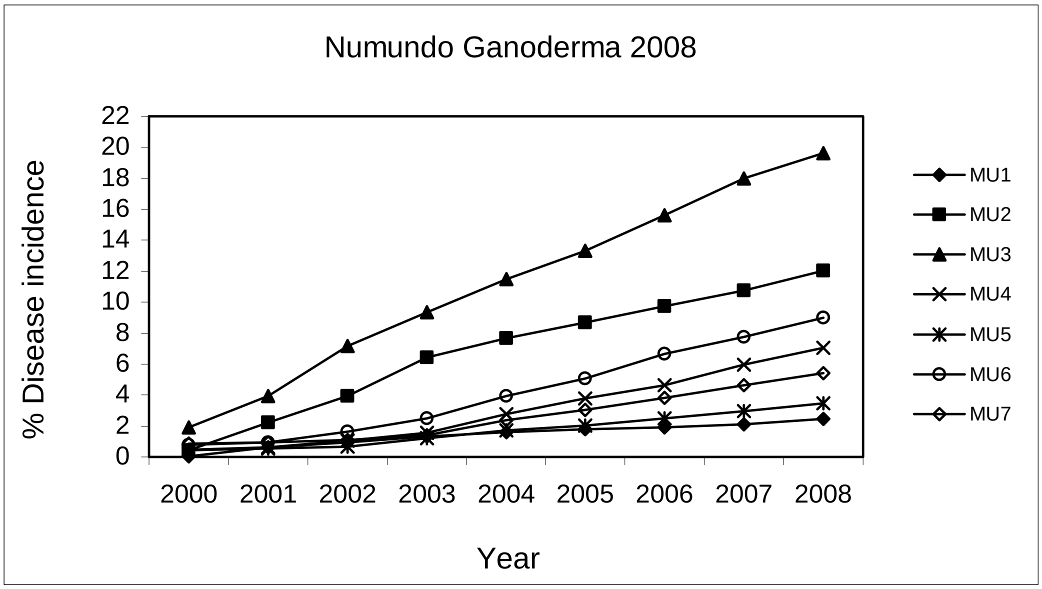


Figure 1.20. Disease progress curves for the period 2000-2008 for Numund, West New Britain by Management Unit (MU). MU3 is comprised of Fields E4 and E5.

In contrast, the adjacent F fields recorded a steady disease rate in 2008 except for Field F3 where disease levels increased (Figure 1.21). Disease levels are well below that of the worst affected E fields and range from 2% in Field F2 to 10.4% in Field F3 (Figure 1.22).

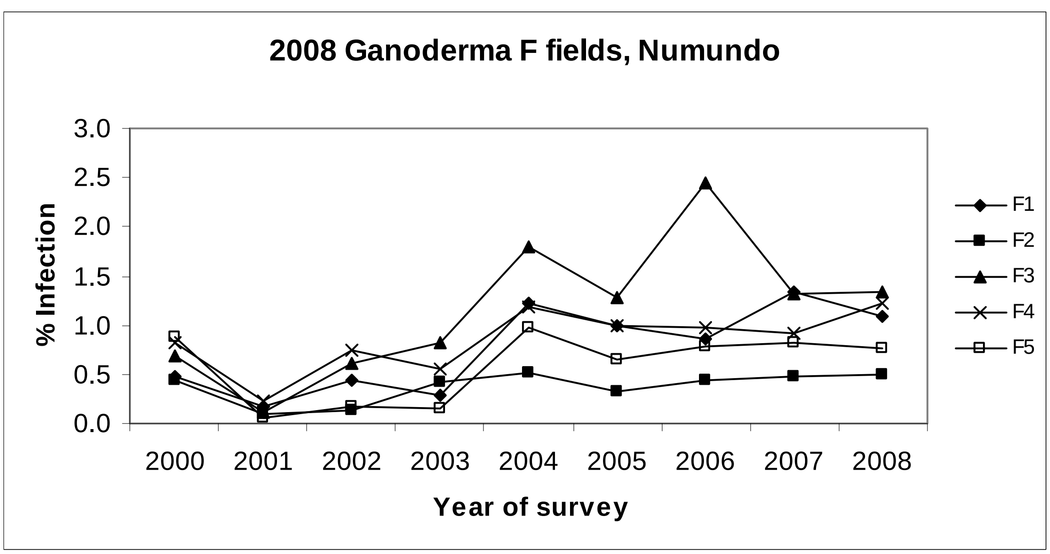


Figure 1.21 Annual disease losses for 1995 F Fields at Numundo, West New Britain Province from 2000-2006.

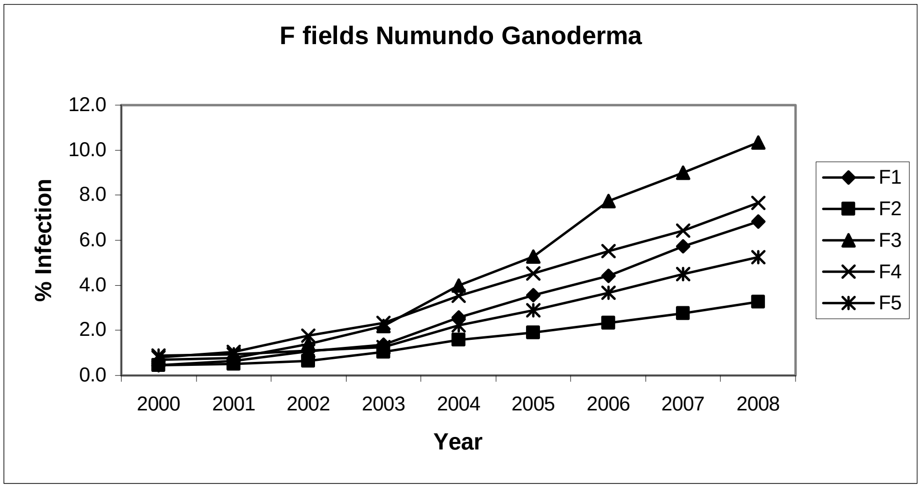


Figure 1.22 Disease progress for the period 2000-2008 for 1995 F fields at Numundo, West New Britain.

1.3.5 Monitoring the effects of disease on production in selected blocks

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.

The disease progress curves and corresponding yield levels expressed as yield per palm for selected study blocks in West New Britain and Milne Bay are shown in Figures 1.23 and 1.24. Only the blocks with the highest levels of disease are shown.

It is unfortunate that yield data is not available for Field E5 which has a disease incidence over 24%.

There appears to be a decrease in the yield in tonnes per tree for MU3 at Numundo. The disease incidence in MU3 is 19.6% in 2008 and yields dropped by approximately 33kg/tree from 2007 (Figure 1.24). This is a drop of approximately 298 tonnes in 2008 for this MU. However, this is the first year that a decrease has been observed and yield data for 2009 will need to be assessed to see if the downward trend continues. In addition, data for 'natural' yields have not been obtained for comparison to assess if the reduction is real or simply within the normal annual fluctuation levels.

The yield reduction in Block 6504 is more dramatic with a decrease of about 70kg per tree from 2007 (Figure 1.24). Again, confirmation of the downward trend will be required with another year of data. This block will undergo replant in 2009 and another year of yield data should be available to make an assessment.

There is some error in the yield trend in Block 6504 given that many of the palms have not been removed and hence the assumption that all diseased palms are non-productive may not apply.

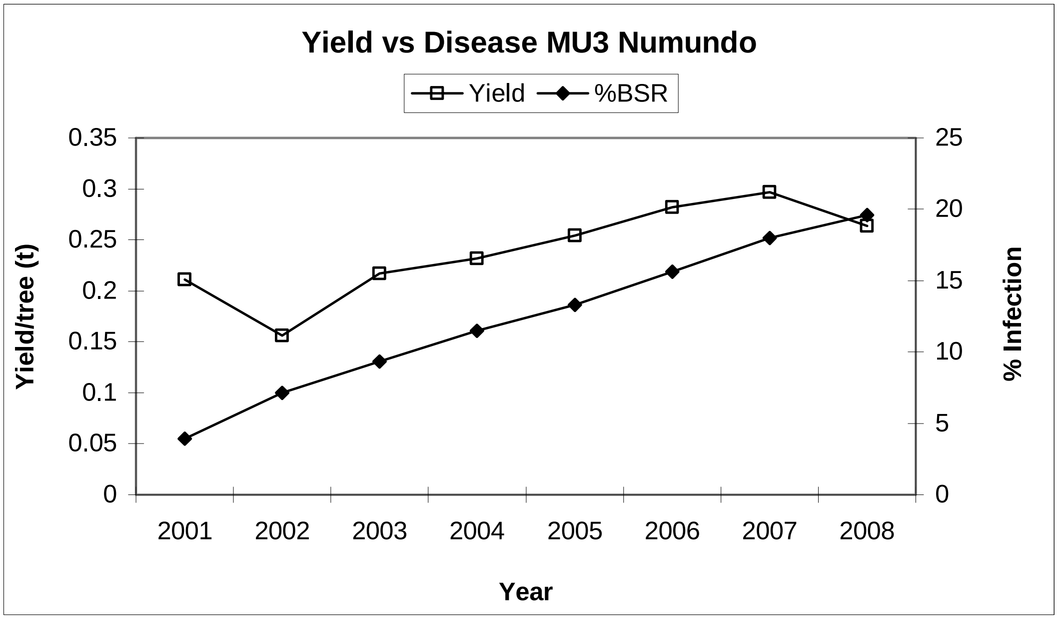


Figure 1.23 Effects ofGanoderma disease on palm production in fields with the highest infection levels (MU3) at Numundo, West New Britain from 2000-2008. Yield trend is derived from plantation data.

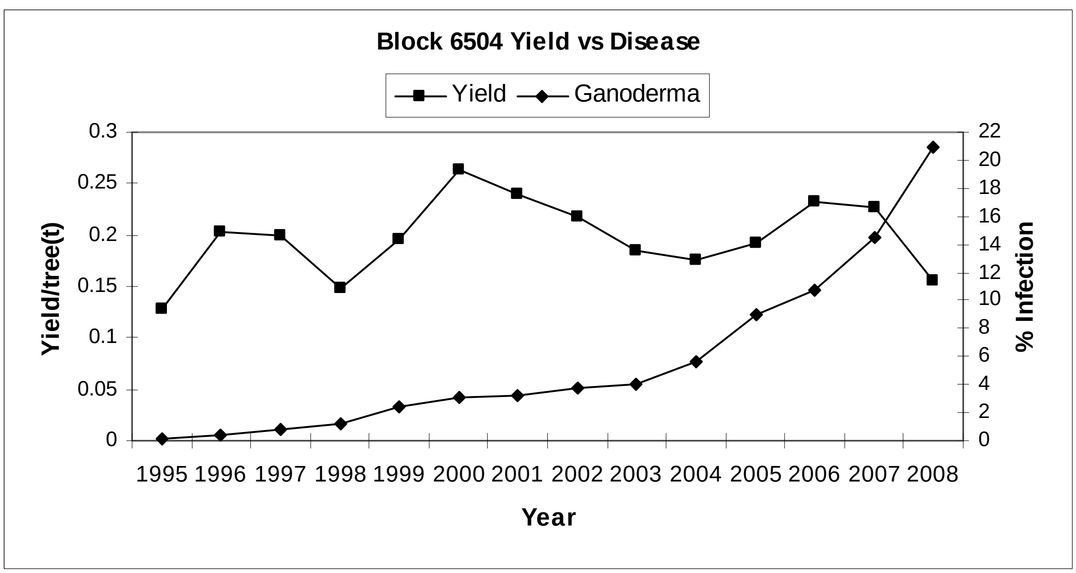


Figure 1.24 Average palm yields (plantation data) with disease progress from 1995-2008 in Block 6504, Milne Bay.

1.4 Disease control

Control of disease caused by *Ganoderma* can only be achieved through regular surveys followed by roguing of infected palms. Unfortunately, apart from a few blocks in some areas, most plantations have not been able to successfully implement a rigid sanitation programme. Data for 2008 indicates this.

In 2008, the highest rate of removals achieved in Milne Bay was 68% in Bunebune Division (Figure 1.25). This was for the removal of bracket palms only. Many of the blocks where surveys and sanitation have not been completed are due for replant in 2009 or 2010 and the level of sanitation within these blocks needs to be improved significantly in order to maintain disease levels at a manageable rate in the replanted crop.

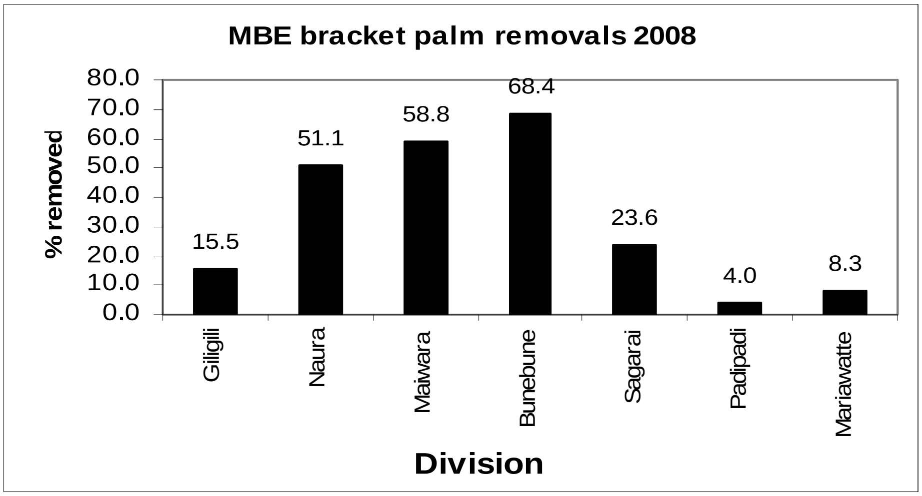


Figure 1.25. Removal of infected palms with Ganoderma brackets in 2008 in all Divisions in Milne Bay.

Removals of infected palms in the *Ganoderma* study blocks in Milne Bay were less efficient with the highest level of only 31% in blocks 7213 and 6404 (Figure 1.26).

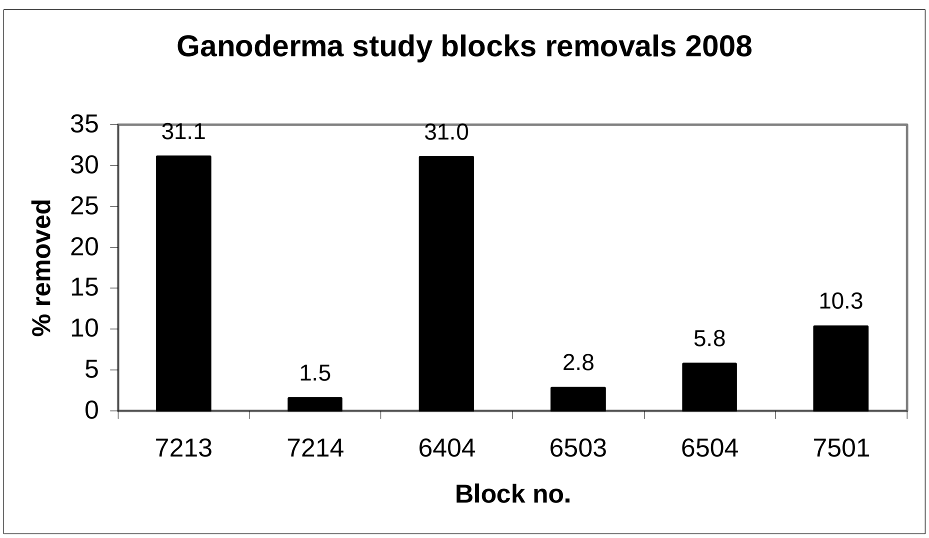


Figure 1.26. Removal of Ganoderma infected palms (percentage of infected palms) from Ganoderma study blocks in Milne Bay in 2008.

1.5 Ganoderma BMP blocks

In 2008, blocks were selected in Milne Bay for treatment as *Ganoderma* BMP blocks. It was anticipated that if the efficiency of removal could be increased in selected blocks, the disease incidence data should provide some means of comparison against blocks in which removals were low and irregular. After 12 months, there does not appear to be a significant difference in the levels of disease between BMP blocks and other blocks within the plantation (data not shown). This is partly because the removals in the BMP blocks have not been satisfactory. A further year of data may be required to assess the effectiveness of regular removals.

THE POPULATION DYNAMICS OF *G. BONINENSE* ON OIL PALM

Objectives: (1) To determine temporal changes in the population structure of G. boninense on oil palm
(2) To determine the secondary mode(s) of disease spread

2.1 Introduction

Knowledge of the structure of the *Ganoderma* population and changes in this structure over time are an important part of understanding the epidemiology of basal and upper stem rot. The study of the population has been conducted over a ten-year period in selected blocks in Milne Bay to determine the primary agents of disease spread. More recently, study areas in New Ireland (Poliamba) and West New Britain (Numundo) have been added to this study as a means of comparison.

2.2 Methodology

Surveys are conducted bi-annually by the plantations in Milne Bay and New Ireland and quarterly in West New Britain.
Ganoderma specimens are collected from infected palms in the selected fields and mycelium is isolated from these in the laboratory. Spore prints are also obtained from all Ganoderma brackets in Blocks 7213 and 7214 in Milne Bay.
Mating tests are then carried out between spore isolates from different fruiting bodies. Where spores are not collected, vegetative compatibility tests are carried out between selected isolates collected from different palms.

2.3 Results

2.3.1 The population in Milne Bay

As in previous years, bi-annual surveys of the six designated Ganoderma study blocks in Milne Bay were completed in 2008 and samples were collected for laboratory studies only from blocks 7213 and 7214. The number of isolates collected from each block is shown in Table 2.1. The number of isolates tested for compatibility through mating studies in 2008 is shown in Table 2.2.

Table 2.1. Areas surveyed and number of Ganoderma isolates collected in the 2008 surveys at Milne Bay (OPRA blocks only).

Block #	Ha surveyed	No. isolates collected
7213	29.9	29
7214	16.7	6
7501	69	Nil
6404	63.9	Nil
6503	76	Nil
6504	36	Nil

Crosses amongst isolates from Block 7213 continue to confirm that the isolates are of different genetic origin. However, the number of isolates sharing common alleles (incompatibility) is apparently increasing (Table 2.2) indicating some recombination within the population. Direct hereditary relationships are still rare.

Table 2.2. Mating type crosses completed in 2008 for isolates collected from Block 7213, Giligili in 2007. +=compatible isolate;, - = incompatible isolate; ND=no data

	Isolate number																	
	2198	1875	1877	1878	1879	2074	2075	2076	2078	2079	2080	2081	2083	2084	2085	2086	2087	2088
2198		ND	+	+	+	-	-	+	+	-	+	+	+	ND	-	+	+	+
1875			+	-	+	+	+	+	+	+	+	-	ND	+	+	+	+	+
1877				+	+	ND	ND	+	+	+	+	+	+	+	+	+	+	+
1878					+	+	+	+	+	+	+	-	+	+	-	+	+	+
1879						+	+	+	+	+	+	+	+	+	+	-	+	-
2074							+	+	+	+	+	+	+	+	+	+	+	+
2075								+	+	+	+	-	+	+	+	+	+	+
2076									+	-	+	+	+	+	+	+	+	+
2078										+	+	+	+	+	+	+	+	+
2079											+	+	+	+	+	+	+	+
2080												+	+	ND	ND	ND	ND	ND
2081													+	-	-	+	+	+
2083														+	+	+	+	+
2084															-	+	-	+
2085																+	+	+
2086																	+	+
2087																		+

2.3.2 The population in New Ireland

The remaining samples collected from Trial 251 prior to felling in 2006/2007 were tested in 2008. The majority of isolates were found to be incompatible (Table 2.3). Five isolates demonstrated compatibility indicating the same genetic origin. Three of these were from Plot 20 and 2 were obtained from Plot 13. The other compatible isolates were from multiple brackets on the same infected palm where compatibility is expected.

Table 2.3. Vegetative compatibility testing of isolates of Ganoderma from Trial 251(New Ireland) in 2008.

PLOT #	SAMPLE # CROSSES	RESULTS	PLOT #	SAMPLE # CROSSES	RESULTS
3	1302 x 1329	incompatible	**17**	923 x 1016	incompatible
6	1304 (917) x 2034	incompatible	**18**	1314 x 1014	incompatible
7	1646 x 1647	incompatible		1461 x 1314	incompatible
9	1305 x 1306	incompatible		1461 x 1014	incompatible
11	1307 x 919	incompatible	**20**	1015 x 1317	incompatible
	1307 x 1308	incompatible		1015 x 1318	incompatible
	1307 x 1451	incompatible		1015 x 1319	incompatible
	1307 x 1649	incompatible		1015 x 1652	incompatible
	1308 x 919	incompatible		1317 x 1319	incompatible
	1308 x 1649	incompatible		1317 x 1318 (1020)	incompatible
	1451 x 919	incompatible		1317 x 1652	**compatible**
	1451 x 1308	incompatible		1318 x 1652	incompatible
	1451 x 1649	incompatible		1319 x 1318 (1020)	incompatible
	1649 x 919	incompatible		1319 x 1652	**compatible**
12	1452 x 2035	incompatible	**24**	1653 (1) x 1465	incompatible
	1454 x 2035	incompatible		1653 (2) x 1645	incompatible
	1454 x 1452	incompatible		1653 (1) x 1653 (2)	**compatible**
13	1013 x 1019	incompatible	**26**	1008 x 1323	incompatible
	1013 x 1114	incompatible	**30**	1324 x 1657	incompatible
	1013 x 1310	incompatible		1324 (1115) x 1658	incompatible
	1013 x 1311	incompatible		1657 x 1658	incompatible
	1019 x 1114	incompatible	**31**	1325 (1021) x 1659 (1)	incompatible
	1019 x 1310	incompatible		1325 (1021) x 1659 (2)	incompatible
	1019 x 1311	**compatible**		1659 (1) x 1659 (2)	**compatible**
	1310 x 1114	incompatible	**32**	1326 x 1660 (1)	incompatible
	1310 x 1311	incompatible		1326 x 1660 (2)	incompatible
	1114 x 1311	incompatible		1327 x 1660 (3)	incompatible
15	1651 x 1650 (1)	incompatible		1660 (1) x 1660 (2)	**compatible**
	1650 (1) x 1650 (2)	**compatible**		1660 (1) x 1660 (3)	**compatible**
	1652 x 1650 (2)	incompatible		1660 (2) x 1660 (3)	**compatible**

2.3.3 The population in West New Britain

The number of isolates collected in 2007 from Fields E4 and E5 at Numundo are given in Table 2.4. Due to the large number of infected palms at Numundo, only the isolates obtained from neighbouring, infected palms were tested for mycelial compatibility in 2008. The results of these tests are presented in Table 2.5 and show that all isolates are genetically distinct except for isolates 2267 and 2268 and 2278 and 1805 from two pairs of adjacent palms. This result indicates a direct relationship between isolates from the two pairs of palms and possibly a common source of infection.

Table 2.4 Ganoderma isolates collected from infected palms at Numundo, West New Britain Province in 2008.

Location	**Ha surveyed**	**No. of isolates collected**
Field E4	59.05	46
Field E5	28.10	49

Table 2.5 Vegetative compatibility tests amongst isolates from Ganoderma brackets collected from neighbour palms in Field E4, Numundo, West New Britain Province in 2008.

Isolates	Result	Isolates	Result	Isolates	Result
2265:1891	*incompatible*	2267:2268	*compatible*	2226:2069	*incompatible*
2274:1913	*incompatible*	2271:2105	*incompatible*	2266:1894	*incompatible*
1938:1939	*incompatible*	2271:1778	*incompatible*	2266:1628	*incompatible*
2275:1977	*incompatible*	2105:1778	*incompatible*	2266:1746	*incompatible*
2276:1788	*incompatible*	2272:1779	*incompatible*	2266:1629	*incompatible*
2269:2238	*incompatible*	2272:1780	*incompatible*	2069:1894	*incompatible*
2275:2242	*incompatible*	2273:1910	*incompatible*	2069:1628	*incompatible*
2278:1804	*incompatible*	2279:2192	*incompatible*	2069:1746	*incompatible*
1804:1805	*incompatible*	2288:2289	*incompatible*	2069:1629	*incompatible*
2276:1915	*incompatible*	2288:2269	*incompatible*	1894:1628	*incompatible*
1621:1784	*incompatible*	2289:2269	*incompatible*	1894:1746	*incompatible*
1622:1579	*incompatible*	2289:2238	*incompatible*	1894:1629	*incompatible*
1623:1576:2173	*incompatible*	2283:2103	*incompatible*	2287:1630	*incompatible*
1625:1826:2220	*incompatible*	2285:2286	*incompatible*	2287:1895	*incompatible*
1634:2177	*incompatible*	2285:1615	*incompatible*	1630:1895	*incompatible*
1639:1827:1791:1604	*incompatible*	2285:1750	*incompatible*	2290:2174	*incompatible*
1643:2232:2233	*incompatible*	2285:1749	*incompatible*	2290:1623	*incompatible*
1645:1917	*incompatible*	1615:1750	*incompatible*	2290:1576	*incompatible*
2234:2064:1609	*incompatible*	1615:2286	*incompatible*	2174:1623	*incompatible*
2238:1752	*incompatible*	1615:1749	*incompatible*	2174;1576	*incompatible*
2239:2060:1754	*incompatible*	2286:1749	*incompatible*	1623:1576	*incompatible*
2240:1757:1900	*incompatible*	2286:1750	*incompatible*	2291:1912	*incompatible*
2241:1971	*incompatible*	2280:1888	*incompatible*	2291:1913	*incompatible*
2277:1863	*incompatible*	2280:1737	*incompatible*	2291:1616	*incompatible*
2279:2192	*incompatible*	2281:2282	*incompatible*	2291:2274	*incompatible*
2274:1912	*incompatible*	2281:1742	*incompatible*	1912:1913	*incompatible*
2242:1977	*incompatible*	2282:1742	*incompatible*	1912:1616	*incompatible*
2278:1805	*compatible*	2284:2266	*incompatible*	1912:2274	*incompatible*
2266:1746	*incompatible*	2284:2069	*incompatible*	1913:1616	*incompatible*
1616:2274	*incompatible*	2284:1894	*incompatible*	1913:2274	*incompatible*
2292:1977	*incompatible*	2182:1978	*incompatible*	2275:1875	*incompatible*
2292:2275	*incompatible*	2182:1914	*incompatible*	2293:2182	*incompatible*
2292:1785	*incompatible*	1978:1914	*incompatible*	2293:1978	*incompatible*

1977:2275	*incompatible*	1628:1746	*incompatible*	2293:1914	*incompatible*
1977:1785	*incompatible*	1628:1629	*incompatible*		

GANODERMA INOCULUM IN-FIELD: PERSISTENCE AND SPREAD INTO NEW PLANTINGS

Objective: To determine if Ganoderma infection can be induced in young seedlings by planting in close proximity to infected stumps.

3.1 Introduction

West New Britain is relatively free of basal stem rots caused by *G. boninense*. However, there are several fields in the 1994 and 1995 plantings at Numundo that demonstrate significantly higher levels of disease than other areas. It is considered that this is largely due to the previous crop being coconut. In addition, the areas were not cleared adequately before planting and many of the young palms were exposed to high inoculum levels before sanitation of these blocks was carried out. Of further relevance is the fact that these blocks were severely affected by *Oryctes* attack at planting and subsequent, recurring attacks by *Sexava* has compounded the stress on the growing palms. It is thought that the effects of all of these factors have contributed to the early and continuing infections of the palms in this area.

In 2006, a trial was set up to investigate the root transmission as a mode of disease spread that might explain the apparent 'clustering' of diseased palms.

The hypothesis being tested was that basal stem rot could be transmitted from diseased oil palm stumps to young seedlings through root contact.

3.2 Methodology

Oil palm seedlings (5 months old) were planted around 40 diseased (BSR) stumps at distances of 50cm, 100cm and 150cm from the base. Four progenies were used, numbered 7, 11, 15 and 16. Two seedlings per progeny per distance were planted i.e. a total of 24 seedlings around each stump. Seedling condition was checked on a monthly basis over a 24 month period. The condition of the stump and Ganoderma were also recorded during this period.

In early 2008, after observations for 24 months palms were destructively sampled and dissected to assess the condition of the bole and roots. Samples of rotting tissue (including frond bases close to the ground) were taken from all palms in each plot. Prior to sampling, seedling health (external appearance) was assessed in each of the plots.

Only obviously rotting tissue from dying palms was plated to Ganoderma selective medium. The other tissue from frond bases and roots of apparently healthy palms was processed for DNA extraction. This work is still in progress.

3.2 Results

Table 4.1 provides a summary of the trial results.

Generally, there was a low mortality of seedlings in all plots. Onmy 2.5% of seedlings succumbed to disease and some of these deaths were not due to Ganoderma but to taro beetle attack soon after planting.

Table 3.1. Seedling mortality in forty trial plots at Numundo after 24 months growing in close proximity to Ganoderma-infected stumps. Each plot comprised 24 seedlings.

#Healthy plots	# Plots with 1 seedling dead	# Plots with 2 seedlings dead	#Plots with 3 seedlings dead	% Mortality (all plots)
20	17	2	1	2.5%

Fifty percent of plots remained healthy after 2 years and the majority of the remaining plots (42.5%) had only a single seedling death. Only one plot had 3 seedlings which had died at various stages over the 2 year period.
Of the 4 progenies used in each trial, the largest number of deaths was of progeny #7, closely followed by progeny #11 (Table 4.2). However, the difference between progenies 7 and 11 did not appear to be significant. The number of deaths was too low to provide a good comparison between the performances of the different progenies. It could be surmised however that all of the progenies tested demonstrated good resistance to *Ganoderma* infection.
Surprisingly, the number of progenies infected was highest furthest from the stump (Table 4.3). Nearly 46% of all mortalities were at a distance of 1.5m from the oil palm stump. The remainder was roughly evenly distributed between 0.5m and 1.0m. Unfortunately, *Ganoderma* was not recovered from the majority of infected seedlings at 1.5m and hence, infection by *Ganoderma* through the roots is assumed but cannot be confirmed.

Table 3.2. Frequencies of progenies infected in forty trial plots at Numundo after 24 months.

Progeny number	**Frequency**	**% Mortality**
7	7	2.92
11	5	2.08
15	3	1.25
16	3	1.25

Table 3.3. Frequencies of seedling infections at various distances from infected stumps in forty trial plots at Numundo after 24 months.

	Distance from stump		
	0.5m	**1.0m**	**1.5m**
Frequency	6	7	11

Compatibility tests on Ganoderma isolates from within the trial plots and between palms adjacent to the trial plots are presented in Table 4.4. Compatible isolates are highlighted in grey. Isolate numbers 1622(1) – (5) were multiple isolates from a trial stump and isolate numbers 1570 (1) – (4) were from obtained from an infected palm adjacent to the trial plot. Some isolates from each of these palms were compatible (i.e. identical) and some were incompatible. This is unusual because all of the isolates from each palm were identical to each other. These results will need to be verified by repeated testing of the isolates from within the same tree. Other isolates that were identical (compatible) were 2234 (plot isolate) and 2064 (adjacent infected palm) and 1623 (plot isolate) and 1576 (adjacent infected palm). Testing of DNA of these compatible isolates will be required in order to conclude if they are indeed identical and root transmission may have occurred.

SCREENING OF OIL PALM SEED LINES FOR RESISTANCE OR SUSCEPTIBILITY TO GANODERMA

4.1 Introduction

A satisfactory method for inducing disease in young oil palm seedlings has been developed.
Testing in the nursery will allow quicker screening of seed lines and provide the basis of molecular screening which will later be tested on progeny screened in the field.

4.2 Methodology

Nursery assays were carried out as described in previous reports.
Two lots of seed were received in 2008. A total of 2600 seeds were sown ready for testing. The majority of seed were attacked and destroyed by rats and therefore only a limited number could be tested.
One trial was set up to test different progeny in a completely randomized block design with an equal number of control seedlings to test seedlings. Seedlings were inoculated with rubber wood blocks colonized with *Ganoderma*.

4.3 Results

Nursery screening

Because of the limited number of seed, only one set of trials was set up in 2008. Results of this trial after 12 months are presented in Table.5.1.
Progenies 9 and 11 demonstrated the highest mortality with 4.5 and 3.9% respectively. Only 2 other progenies number 13 and number 10 differed significantly from the controls. The remaining progenies could be considered to be resistant.

Table 4.1. Mortality of seedlings inoculated with a single isolate of Ganoderma (#915) after 8 months under controlled nursery conditions.

Progeny number	% Mortality
2	0.5
6	1.0
8	1.0
9	4.5
10	2.8
11	3.9
12	1.7
13	2.2
14	1.0
control	1.0

BIOLOGICAL CONTROL OF GANODERMA USING INDIGENOUS ISOLATES OF *TRICHODERMA* SPP.

Objective: (1) To utilize Trichoderma spp. as natural antagonist of Ganoderma to prevent Ganoderma infection through pruned frond bases and other oil palms substrates.

5.1 Introduction

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.

In 2006 a collaborative project was set up between staff from the University of Kent and PNG OPRA to investigate the possibility of using indigenous isolates as biocontrol agents for Ganoderma on oil palm. This study was completed in 2007.

The research in PNG continued in 2008 and in the same year, a research proposal was submitted for funding to the ARDSF Agricultural Innovations Grant Scheme (AIGS) to further this research. This project will commence in 2009.

This report presents the research completed in 2008 as a lead up to the new AIGS project.

5.2 Methodology

As described in previous reports, *Trichoderma* isolates were obtained in from Milne Bay in 2004 from soil samples by baiting or direct isolation. Some isolates were obtained from pieces of oil palm wood in the field.

Species identifications based on traditional morphological characterization and groupings based on molecular genomics were carried out at Kent University as well as the *in-vitro* tests against Ganoderma.

DNA was extracted from all 33 isolates and products obtained from PCR runs using primers for ITS, mtSSU and ech42 genomic regions. SSCP profiles were documented after amplification of the ITS regions of all isolates. These results were presented in the 2007 annual report.

In 2008, further *in-vitro* testing was carried out by PNG OPRA on selected isolates that showed good potential in the tests carried out in 2007.

5.3 Results

6.3.1 In-vitro Testing

Liquid culture trials

Trials were carried out using different culture media. In order to assess the most suitable medium for conidia development, selected *Trichoderma* isolates were grown in 3 different media and the weights of conidia produced in each of the media were determined. A single medium was chosen for liquid production of conidia for initial testing, pending further supplies to test other media.

There was some contamination during filtration and freeze-drying of spores. Different methods of filtration including using cloth, cotton wool, filter paper and paper towel were tried in order to separate the conidia from the mycelia. Paper towel was the best filtration medium as it allowed the spore to be quickly and easily separated from the mycelia.

The conidia from one set of cultures were separated and freeze-fried in 2007 and the viability of the dried conidia was tested in 2008 as in the previous year. As shown in Table 6.1, the conidia still remained viable after 18 months after refrigerated storage. Conidia stored under room temperature (air-conditioned) were not viable after 3 months due to contamination.

Table 5.1. Viability of lyophilized conidia and mycelia of Trichoderma spp. after 18 months of storage at both ambient temperature and under refrigeration. NT = not tested.

***Trichoderma* isolate**	**Ambient temperature**		**Refrigeration**	
	conidia	mycelia	conidia	mycelia
J	x	NT	√	NT
BF	x	NT	√	NT
BV (rice)	x	NT	x	√
BV (tomato)	x	x	√	√
B	x	x	√	√
BN	NT	x	NT	√
E	NT	x	NT	√
28b4	NT	x	NT	√
SP5A	NT	x	NT	√
40r	NT	x	NT	√
W	NT	x	NT	√

x = non-viable; √= viable; NT = not tested

5.3.2 Field trials

Four sets of trials were carried out to assess the effectiveness of conidial suspensions against *Ganoderma* brackets and frond bases *in-situ*.

All results were negative after periods up to 3 weeks and spraying intervals of 3 days. This work is continuing.

Spraying of frond bases did result in the colonisation by *Trichoderma* on frond bases and this work will be extended in 2009.

Table 5.2 Field trials with Trichoderma conidial suspensions.

***Trichoderma* isolate**	**Growth on palm rachis tissue**			**Replicate**
	Spore concentration /100ml			
	0.25	**0.5g**	**1g**	
B	Positive	Positive	Positive	50
BN	Positive	Positive	Positive	50
SP5A	Positive	Positive	Positive	50

MOISTURE LOSS STUDY IN COCONUT PALMS

Objective: To determine the rate at which moisture is lost from poisoned coconut palms subjected to various treatments.

6.1 Introduction

A growing number of small block owners who have coconut planted are interested in making the transition to oil palm. This brings forth a potential problem since dead or poisoned coconut palms are a source of *Ganoderma* that will likely transmit the fungus to young oil palm.
It is hypothesised that by reducing the moisture content of the coconut palms rapidly after poisoning, this will also minimise the risk of colonisation of the dead coconut by *Ganoderma*.
A trial was set up in 2008 to test this hypothesis by subjecting poisoned coconuts to various practically applicable treatments. This information will be used to determine the best practice for smallholders replacing coconut with oil palm.

6.2 Methodology

The moisture content of forty (40) coconut palms of roughly the same age was determined at four points on the trunk: at the base (above the root mass), at 50cm, at 100cm and at 2m using a moisture meter. A minimum of 2 measurements at each height were made, one on either side of the trunk.

All 40 coconuts were then poisoned on the same day and treated as described below on the following day.
The moisture content was measured at one (1) week, at two (2) weeks, at 1 month, at 2 months and thereafter every 3 months after treatment up to 24 months. The presence of *Ganoderma* on the trunks was also recorded over the same time period.
Weather conditions were also monitored at the time of the treatments and moisture recordings.

Treatments applied

Treatment A: 10 x coconuts – no treatment – CONTROLS
Treatment B: 10 x coconuts – remove the outer 'bark' from the base up to a height of 1m all around the trunk. A depth of 2.5cm should be sufficient.
Treatment C: 10 x coconuts – drill holes to a depth of 10cm from the base at 50cm intervals up to 2m i.e. 5 holes are to be drilled into the trunk on three sides = 10 holes in total. (a manual drill can be used for this).
Treatment D: 10 x coconuts – slash the trunk with a bush knife from the base up to 1.5m all around the trunk. At least 15 cuts should be made in the trunk.

6.3. Results

Treatments B and D showed the most rapid decline in moisture content of poisoned coconut trunks. After 28 weeks, equilibrium moisture content was reached (Treatment D) or almost reached (Treatment B) whereas for Treatments A (control) and C, the moisture contents remained high (Figure 7.1). It was not possible to carry out statistical analysis because of the large variation within single treatments. Also, during the wet season, moisture contents readings were unreliable and so recordings after 28 weeks were discarded.
Treatments B and D also had the least number of *Ganoderma* brackets on the poisoned trunks after 72 weeks and this differed significantly from the control treatment which had the highest number of *Ganoderma* brackets present (Figure 7.2). Overall, the number of Ganoderma brackets on al the palms was reasonable low but this number may increase with time.
The results indicate that a reduction in moisture content does in fact help to reduce the *Ganoderma* inoculum present on poisoned trunks which in turn will reduce the risk of newly planted palms becoming infected.

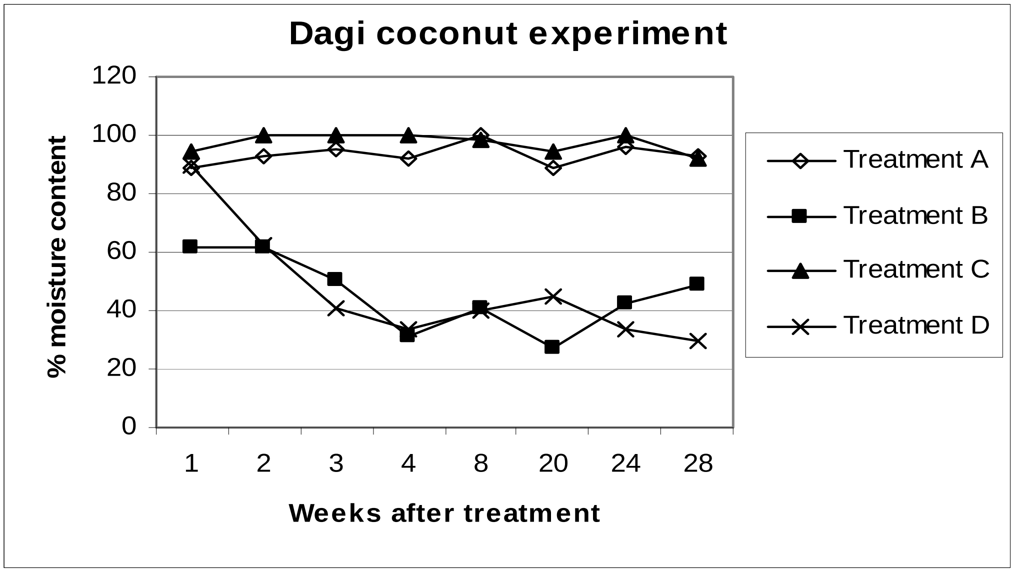


Figure 6.1. Moisture contents of coconut trunks subjected to different treatments from 1 to 28 weeks after treatment.

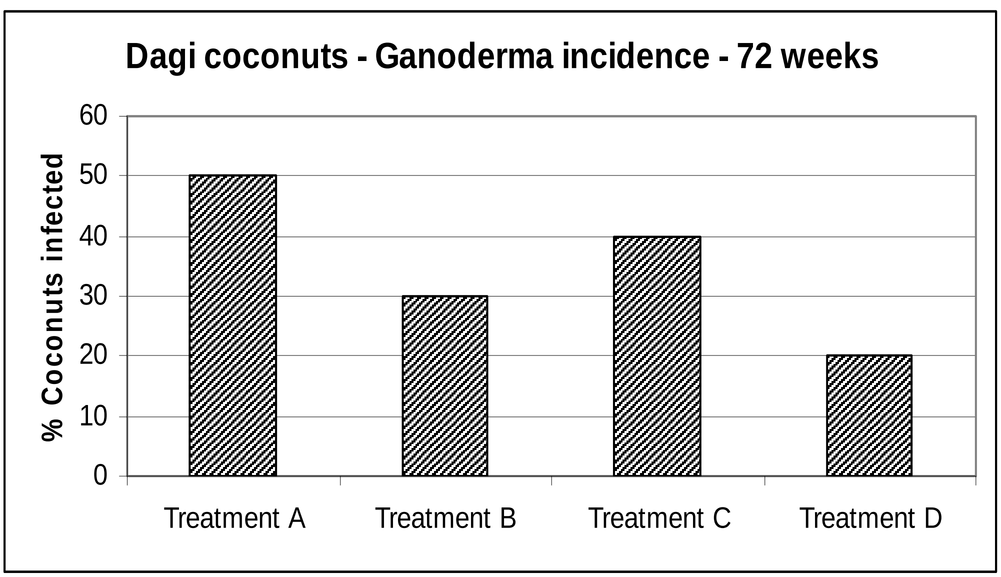


Figure 6.2. Incidence of Ganoderma brackets on poisoned coconut trunks subjected to various treatments 72 weeks after treatment.

Technical services

7.1 Training

Formal and field training sessions were held at all plantations and smallholders project areas in 2008.

7.2 Disease reports

A total of 37 formal reports of disease were received from West New Britain and 5 from Oro. All of these reports were followed-up by staff at these centres and recommendations made. In some cases, Ganoderma removals were supervised. There is still room for improvement in reporting problems on palms in each of the Provinces.

Disease	**Number of reports WNBP**	**Number of reports Oro**
Basal stem rot	22	5
Upper stem rot	5	
Crown disease	2	
Spear rot	1	
Other	2	
Total	**32**	**5**

7.3 Quarantine
The two quarantine nurseries at Milne Bay were inspected on a regular basis in 2008 and no major problems were reported.
In 2008, a disorder affecting coconuts in Bogia, Madang Province was reported by CCI and in November 2008, PNG OPRA staff were invited to the first meeting of a Technical Committee to investigate the matter as a precaution against any movement of biotic agents to oil palm.

8. Publications, conferences and travel
Travel
Visits were made to the following locations during 2008 by C. Pilotti:
(1) Poliamba Ltd., New Ireland for training and Ganoderma records audits
(2) Ramu Agri-Industries Ltd., Morobe Province - for quarantine matters
(3) Higaturu Oil Palms Ltd., Oro Province - for training
(4) Hargy Oil Palms Ltd., West New Britain Province - for general disease surveillance
(5) NBPOL - Dami/Numundo West New Britain Province - for trial sampling
(6) GPPOL, Solomon Islands - for site selection of trials
(7) CCI Stewart Research Station and Bogia, Madang Province - for discussions on Bogia Coconut Syndrome (BCS)

Publications
Smallholder OPRAtive

9. Other activities
9.1 AIGS Ganoderma Project
Preparation of a research proposal for funding from AIGS (ARDSF) for the development of *Trichoderma* as a biological control for *Ganoderma*. This proposal was successful and the project will commence in January 2009.

9.2 ACIAR Ganoderma Project
Finalisation of the ACIAR project proposal for funding for field trials of different oil palm progenies in Solomon Islands.

4. SMALLHOLDER STUDIES

(G. Curry & G. Koczberski, Curtin University of Technology, Perth, Australia & Jesse Anjen, PNGOPRA)

Commercial sector/smallholder partnerships for improving incomes in the oil palm and cocoa industries in Papua New Guinea. ACIAR Project ASEM/2006/127

1. INTRODUCTION

The aim of this project is to raise smallholder productivity and incomes in the oil palm and cocoa sectors through identifying, refining and promoting effective strategies for commercial sector partnerships with smallholders. Commercial sector engagement can range from the provision of farm management advice/sale of inputs to smallholders, to joint venture companies between the commercial sector and customary landowner groups, involving various tenancy type arrangements that condition land use.

As part of this project, attention has been given to identifying the main land tenure issues affecting production of smallholder oil palm planted on agricultural leasehold land (the land settlement schemes) and customary land. Land ownership and tenure is a contentious issue for large-scale plantation agriculture and development in Papua New Guinea. Land conflicts take many forms in the oil palm industry, from the large compensation claims demanded by customary landowners for land alienated for land settlement schemes (LSS) and estate plantations to land ownership disputes between and within households. Land disputes are critical production issues because they can take oil palm stands out of production thereby reducing smallholder productivity and growers' capacity for loan repayments. In addition, the types of land tenure arrangements sometimes influence smallholder productivity, attitudes to replanting and infill, investment levels in farm inputs and other assets, production strategies of smallholders, the livelihood strategies pursued by smallholders and the welfare and quality of life of smallholder families.

This report provides a brief overview of the main land tenure issues in the smallholder sector and covers the following four areas:

- Types of land tenure governing smallholder oil palm.
- Land tenure conflicts on oil palm land settlement scheme blocks.
- Land tenure conflicts on customary land.
- Clan Land Usage Agreements (CLUAs).

Customary Land Tenure

To understand why conflicts over land and oil palm (they are two separate issues) sometimes arise amongst smallholder growers, it is useful to begin with a brief summary of customary land tenure principles in relation to subsistence production because it is these principles that have been modified to accommodate cash cropping .

In PNG, customary land generally refers to land that is under the communal ownership of traditional social and kinship groupings like tribes, clans, subclans and lineages. Traditionally, customary land tenure regimes in PNG were characterised by two general sets of principles. First, exclusive individual land ownership and inheritance were almost unknown as all land was vested in land-holding groups, usually kinship groupings such as clans and subclans. Typically, membership in landholding groups was loosely based on common descent, residence and participation in social and ceremonial activities (Crocombe, 1971), and, ideally, group members had usufruct rights to land for cultivation of food crops and access rights for hunting and gathering forest products (Ward, 1997). This meant that an individual's gardening rights in an area of land waned as the garden reverted to fallow and the fallow period lengthened — there was a gradual reversion of rights to the group (Ward & Kingdon, 1995). This system of communal tenure limited the extent to which land could be inherited directly and so prevented individuals from acquiring exclusive control over large tracts of land.

The second set of principles related to the flexible and pragmatic nature of customary land tenure. Rights to land were often modified to accommodate changing socio-political, demographic and environmental situations (Crocombe & Hide, 1971; Ward, 1997). The relative importance in land rights of descent, residency and participation in social/ceremonial and political activities varied so that no single criterion, such as descent, was sufficient in itself to provide unconditional tenure rights. Thus flexible tenure arrangements sustained a system whereby all households had access to land for their daily sustenance as well as access to a range of ecological zones to meet different household subsistence needs. In summary, traditional principles of customary land tenure created a balance between group and individual rights and obligations, with ownership of land vested in the group and access and land use rights operating at the individual or household level.

With the emergence of new land uses such as cash cropping, customary rules of land tenure are tightening and being modified. This is because land planted to cash crops is under individual control for much longer periods than for communal subsistence food gardens where short cultivation periods are interspersed with much longer fallow periodsA different situation pertains with long-term assets such as oil palm that have a productive life of over twenty years. Thus, as more land is devoted to commercial agriculture and comes under semi-permanent commercial production, usufruct rights are now vested in the same family or individual for much longer periods.

This long-term alienation of land for cash cropping is leading people to claim exclusive rights of access to, and inheritance of, these resources. For example, usually, the individual or household managing the crop wishes their children to inherit it rather than letting the land revert to communal ownership. Similarly, most oil palm growers prefer to replant their oil palms rather than let the land move back into the pool of common clan lands. The most significant modifications to customary tenure for cash cropping have therefore occurred in relation to the greatly extended period of individual tenure and the increased emphasis on individual inheritance of land used for cash cropping. The outcome is that customary tenure is gradually coming to resemble more individualised forms of land tenure. These shifts have been accompanied by a change in peoples' views and attitudes to land such that land is increasingly being seen by some clan members as a commodity that can be sold to people outside the land-holding group. The increased dependence on cash together with changing attitudes to land and land tenure principles are potential sources of conflict in smallholder oil palm production (see below).

The modifications made to customary land tenure can be seen in the range of land tenure arrangements found in the smallholder sector. The principal forms of land tenure governing smallholder oil palm are:

- Agricultural State leasehold land on Land Settlement Schemes (LSS);
- Village oil palm (VOP) holdings on customary land by major and minor clans;
- Land Tenure Conversion blocks;
- Customary Purchase Blocks (CPBs) or Customary Rights Purchase Blocks (CRPs) on customary land.

<u>Agricultural State leases on Land Settlement Schemes (LSS)</u>

The oil palm blocks on the Land Settlement Schemes (LSS) at Bialla, Hoskins and Popondetta are on State land which was acquired by the State from the original customary landowners. The LSS blocks operate on individual 99-year State agricultural leases that were initially allocated to settlers, the majority of whom were from other provinces. Leasehold blocks average 6 to 6.5 ha. Approximately 45% of the total area of smallholder oil palm in PNG is planted on agricultural State leasehold land (Table 1).

Village Oil Palm (VOP) Holdings on Customary Land

VOP holdings are cultivated on village land and are subject to the rules and regulations of customary law and land tenure principles which are recognised in the PNG constitution and in the *Underlying Law Act 2000*. VOP growers are not all customary landowners — they are a diverse group made up of close and distant relatives of the core landowning clan or subclan, members of minor village clans or subclans without full customary rights to the land on which they are cultivating oil palm, or they are members or friends of an extended family network or clan.

Typically, clan leaders control the allocation of land for export cash crops. Clan agreements for the planting of individual oil palm holdings are either informal social contracts or are outlined in Clan Land Usage Agreements (CLUA). Across the oil palm growing regions, approximately 49% of the total area of smallholder oil palm is classified as VOP plantings (Table 1).

Table 1. The numbers and areas of LSS, VOP and CRP oil palm blocks*.

	BIALLA	HOSKINS	POPON-DETTA	MILNE BAY	NEW IRELAND
No. of LSS blocks	1,866	2,370	1,128	-	-
LSS area (ha)	8,481	12,576	4,215		
LSS area as a % of total smallholder area	66%	52%	30%		
No. of VOP blocks	1,782	3,793	4,554	773	1,256
VOP area (ha)	4,068	8,914	10,020	1,837	2,478
VOP area as a % of total smallholder area	32%	37%	70%	100%	98%
No. of CRP blocks	70	953	25	-	26
CRP area (ha)	200	2,721	50		55
CRP area as a % of total smallholder area	2%	11%	0.4%		2%

*(OPIC data for 2007/8).

Customary Purchase Blocks / Customary Rights Purchase Blocks

Customary Purchase Blocks / Customary Rights Purchase Blocks are cultivated on village customary land by people from outside the village who have 'purchased' the land from the clan. The sale of land by customary landowners is a recent trend, first emerging at Hoskins in the mid 1980s and later, around the mid 1990s to 2000, at Bialla and Popondetta. These oil palm blocks were called "Customary Purchase Blocks" (CPBs), though at Hoskins they are now called "Customary Rights Purchase (CRP) Blocks" to reflect the fact that they are not permanent purchases.

Several different land transaction procedures may occur once an area of land has been identified and a 'purchase' price has been negotiated. Often land transactions are undocumented relying only on verbal agreements between the clan leader and 'purchaser'. Other 'purchases' may be recorded on an official Transfer or Lease of Customary Land Form, a Customary Land Transaction Form, and/or a Notice of Change of Ownership Form, and then executed and registered at the Provincial Lands Office. These officially executed forms lack a formal land survey and payment details.

Another procedure used in land transactions involves the signing of a Clan Land Usage Agreement by the 'purchaser' and a clan leader. The agreement acknowledges that the landowning clan endorses the transfer of the customary land to the 'purchaser' for the cultivation of oil palm. In other words, the clan acknowledges that the land has been taken out of the clan 'commons' and use rights have been granted to an individual. Under a CLUA only the access and use rights have been individuated, not the land itself.

Most CRP blocks are cultivated by migrants from the mainland, especially second generation settlers from highly populated LSS blocks and those who have spent much of their working lives in the oil palm project areas. The high cost of LSS blocks puts these blocks beyond the reach of most LSS growers and other potential oil palm growers (prices for a 6 ha LSS block at Bialla and Hoskins range from K30,000 to K70,000 compared with K2,000 to K5,000 per ha for a CRP block). There has been a rapid expansion of CRP blocks at Hoskins over the past 10 years; nearly 2,721 ha of customary land (953 blocks) have been developed as CRP blocks, representing 23% of the total area of VOP plantings. Approximately 200 ha and 50 ha of land have been 'sold' at Bialla and Popondetta respectively to 'outsiders' for oil palm development. Not all VOP villages are selling land and the amount of land sold varies greatly amongst villages

Land Tenure Conversion (LTC) Blocks (Popondetta)

In the early 1960s, in an attempt to individualise land tenure and encourage export cash crop production, the Australian administration introduced the *Land (Tenure Conversion) Act 1963*. This allowed for customary tenure to be transferred to individual freehold title. LTC designated land was removed from customary control and registered in the name of an individual, with provisions to allow up to six co-owners to be registered. LTC was based on the assumption that the individualisation of land holdings through titling would encourage the emergence of family farms and thus promote commercial agricultural development in PNG.

LTC land must meet two requirements to be classified as private freehold land. First, it must have an LTC declaration on the land, which identifies the person who owns that piece of land by customary law. The second requirement is that LTC declared land must be surveyed, registered and a freehold title issued. An area of land declared as LTC without a freehold title therefore remains customary land. Legally, customary law continues to apply to such land. Where freehold title is issued, customary law ceases to apply.

The early LTC land tenure blocks were first trialled in Popondetta. They were planted to coffee, cocoa, or rubber, and many were later replanted with oil palm. Approximately 450 ha of VOP oil palm at Popondetta are classified as Land Tenure Conversion (LTC) blocks. However, most of the land holdings did not proceed to full title registration in the name of an individual, including the majority of the oil palm blocks in Popondetta presently referred to as 'LTC blocks'.

Land Tenure Conflicts on Oil Palm Land Settlement Scheme Blocks

This section outlines some of the key factors contributing to conflicts on leasehold blocks on the LSS in West New Britain and Oro provinces.

The main concerns regarding land tenure for LSS growers relate to:

- Transmission of leasehold titles (e.g., disputes over inheritance).
- Rising population pressure leading to conflicts between co-resident households over block management and ownership.
- Disputes between long-term caretakers and leaseholders over ownership of blocks.
- Arrears in land rentals undermining the security of state leases.

Transmission of Land Titles

Most LSS growers follow informal mechanisms of transferring tenure rights in leasehold blocks. These are typically modelled on traditional systems of land tenure from settlers' home communities. For example, settlers from matrilineal societies such as parts of ENB, recognise that the sisters' sons of the leaseholder have a claim to the leasehold block based on principles of matrilineal tenure. To validate the inheritance rights of the leaseholder's own children, compensation is sometimes paid to the leaseholder's nephews, that is, to his sisters' children. Generally, for settlers from patrilineal societies (the majority of settlers), all the sons are thought to have some rights in the block after the death of the leaseholder, with overall responsibility for managing the block usually recognised as passing to the eldest son. Problems can emerge when the eldest brother attempts to assert absolute control over the block (especially in relation to income), thereby alienating his younger brothers. These inheritance disputes sometimes result in blocks being locked out of production or under-harvested for extended periods.

Furthermore, when leasehold blocks change hands, the leasehold titles are rarely updated, and the lease remains under the name of the original leaseholder. There are numerous cases where lease titles that have not been updated are used to challenge informal tenure arrangements that have been in place for many years. For example, when an original leaseholder who sold his block many years ago passes away, sometimes his sons will challenge the tenure rights of the current residents citing the evidence of the existing lease which is still in their father's name. Thus the current residents become classified as 'caretakers' without security of tenure despite having purchased the block at some time in the past.

Whilst most leaseholders recognise that their blocks are under agricultural leases, with individual leasehold title, there is still a general acceptance amongst leaseholders that the planting of a crop confers ownership of it on the person planting the crop. This is a principle of most systems of customary tenure in PNG. This principle means that in cases where the lease title is disputed, replanting is postponed indefinitely because the ownership claim of the person replanting would be strengthened at the expense of the other party to the dispute.

Rising Population Pressure on Leasehold Blocks

Most LSS blocks are 6.0-6.5 ha, an area deemed sufficient to support a nuclear family when the LSS schemes were first established. Today, however, the single household has been supplemented by co-resident households as sons and sometimes daughters marry and raise their own children on the block. It is not uncommon for three or more families spanning three generations to be sharing the resources of a single, 6 ha block. Population pressures are greatest at Hoskins (the oldest LSS scheme), followed by Bialla and then Popondetta.

The LSSs, especially in WNBP, have experienced considerable population growth since the late 1960s/early 1970s. Population density on the Hoskins LSS has risen from 5.9 persons per block in the early 1970s (Ploeg, 1972) to 13.3 persons per block (222 persons km^{-2}) in 2000, and in 2002 the Bialla LSS averaged 11.1 persons per block (187 persons km^{-2}) (Table 2). These population densities are extremely high given the area of the average LSS oil palm block of 6 ha.

High population density on LSS blocks is placing significant social and economic stresses on block residents. These pressures are reflected in conflicts over block ownership (especially following the death of the leaseholder), disputed management decisions amongst family members concerning the allocation of oil palm work and income, attempts to avoid loan repayments and efforts to delay replanting. At Hoskins there are many instances of the sons of elderly or deceased leaseholders stalling replanting because one or more sons are reluctant to forego oil palm income during replanting. Their reluctance to replant and ability to delay replanting is aided by the fact that leadership and responsibility for the block have not been clearly vested in one son. Thus, population pressures can exacerbate tenure disputes amongst male siblings in deceased estates or in cases where the father is too old to exercise effective authority over the block.

Table 2. Numbers of persons per block from the early 1990s projected through to 2011 for LSS blocks at Bialla, Hoskins and Popondetta.

LSS	YEAR	POPULATION PER LSS BLOCK
BIALLA	**1994**	**8.52**
	2002	**11.1**
	2011	**14.88**
HOSKINS	**1990**	**8.6**
	2001	**13.3**
	2011	**19.91**
POPONDETTA	**1990**	**n.d.**
	2001	**8.2**
	2011	**10.2**

Source: Curry *et al.,* 2006. Hoskins: Annual growth rate per LSS block 1990-2001=4.968. This growth rate used to calculate projected 2011 population. Bialla: 1994 population obtained from OPIC census survey of all blocks at Wilelo subdivision. 1994-2002 annual population growth rate per LSS block=3.78. The slower growth rate on blocks at Bialla compared to Hoskins may be due to the opening up of Soi and Kabayia subdivisions in the early 1990s. The 3.78% growth rate was used to calculate projected 2011 population per block. Popondetta: 2011 population projection based on census data for annual population growth rate for Oro province between 1990-2000=3.2%. (Sources: Landells Mills, 1991, OPIC, 1994, Koczberski *et al*., 2001, Koczberski & Curry, 2003, National Statistical Office, 2000).

*2011 figures do not take account of the impact of HIV/AIDS related deaths on population growth rates.

<u>Disputes Between Long-term Caretakers and Leaseholders</u>

Disputes often arise when a caretaker for many years has taken primary responsibility for managing the block while the lessee has resided elsewhere. A caretaker's sense of ownership of an LSS block is heightened if he has undertaken replanting, loan repayments and the planting of fruit trees, coconuts and betel nut palms on the block. The caretaker often views such investments (including labour) as validating his ownership claim on the block and will strongly resist any attempts by the original leaseholder or his sons to reclaim or sell the block. This view accords with traditional principles of land tenure whereby the tenure rights of villagers cultivating land are strengthened the longer they use the land. Monetary compensation is often demanded by caretakers if they cannot remain on the block.

When ownership disputes arise between caretakers and leaseholders, or between caretakers and customary landowners, production and productivity can drop sharply as harvesting rates fall and major investments like replanting and fertiliser inputs are deferred. Also, the insecurity generated by these disputes often means that the current occupants of the block are less inclined to repay loans because there is a relatively high probability of eviction and therefore not benefiting from such investments. Such disputes can result in reduced smallholder production and productivity for extended periods.

Arrears in Land Rentals

The State land rental fees on many LSS blocks have been in arrears for more than a decade, though determining the amount of arrears is difficult because of poor record keeping in land administration. The Organic Law on Provincial and Local Level Government decentralised land functions to the provinces, but land rents on State leasehold land remain a source of revenue for the National Government and are paid directly into national consolidated revenue.

Arrears in land rentals are a breach of lease conditions which could result in the forfeiture of the lease. Also, it can sometimes be difficult for growers to qualify for commercial loans when their land rentals are in arrears. For instance, the progress of the replanting program under the Oro Expansion project was initially delayed by the Lands Department's refusal to grant approval for replanting of blocks that were in arrears.

Key problems that have emerged concerning land rentals on LSS blocks include:

- Large differences in the land rental charges between LSS blocks. Rentals are based on an assessment of the value of the land by a valuer from the Lands Department. Blocks that have been valued recently have significantly higher land rental fees than those that have not been re-valued for more than a decade (valuations of LSS blocks are supposed to be made every 10 years).

- Many leaseholders lack confidence or trust in the record-keeping capacity of the Lands Department (both provincial and national) which they use to justify non-payment of annual land rentals.

- Many growers claim to have paid land rentals without receiving official receipts. They claim that these payments were never recorded by the Lands Department, and therefore are considered by the Lands Department to be outstanding.

The two most pressing land issues that are likely to present major challenges to the industry over the next decade relate to the growing population pressures on the leasehold blocks and the rising number of tenure disputes associated with the ageing and death of the original leaseholders. OPIC has begun to address the latter issue through the promotion of Wills among leaseholders to facilitate the orderly transfer of leases between generations.

Land Tenure Conflicts on Customary Land

Tenure disputes over oil palm planted on customary land can arise between customary landowners and two distinct groups: 1) other village lineages who were granted land for oil palm in the past; and 2) 'outsiders', often from other provinces, who were granted access to land for oil palm production usually under a financial arrangement with a leader from the customary landowning group. Each group is discussed below.

Land Tenure Disputes Between Customary Landowners and Other VOP Growers

With the initial introduction of village oil palm, clans, subclans and lineages that were land-short or lacked land for oil palm cultivation near a harvest road, were usually allocated land belonging to the major landholding group to plant oil palm, in the same way they were granted access to land for subsistence gardens. Because oil palm locks up land for 20+ years, this meant in some villages there was a redistribution of land from primary landholding groups to minor clan groups. The effect was to reduce potential income inequalities amongst village families by allowing most households access to land for oil palm.

Now, 20 or more years on, the redistribution of landholdings that occurred when oil palm was first introduced is increasingly being questioned by the present generation of members of the primary landowning group who oppose replanting by other villagers who are not part of the primary landowning group. This is to forestall long-term claims on the land by people outside the primary landowning group. Also, members of many customary landowning groups are becoming more resistant to non-clan/subclan villagers developing new blocks on their customary land. The reasons for this shift in attitude are varied, but relate largely to increased demographic pressures, functional land shortages for oil palm production (e.g., the need for oil palm holdings to border a harvest road), increased reliance on cash, and a growing recognition of the potential of land to generate wealth.

Although VOP tenure disputes between customary landowning clans/subclans and land-short village clans/subclans are beginning to emerge in some VOP subdivisions in Bialla and Hoskins, these problems have been present in Popondetta for a longer period and are a major cause of tension in some villages. Individuals from minor clans who were granted access to land to plant oil palm are now seen by some members of the primary landowner group to be enjoying better lifestyles and living standards than the 'true' landowners (*papa graun tru*). These growers are envied by members of the primary landowning group, partly because the wealth generated from these VOP blocks is viewed by customary landowners as being derived from 'their' land and, as such, is wealth being siphoned from the clan. Typically, the customary landowning group tends to emphasise the role of the land in wealth generation over the role of labour or capital in generating that wealth. Replanting senile palms can be a trigger for customary landowners to reclaim their land or to demand compensation and/or the imposition of landowner 'rental' fees on 'tenants' before replanting can proceed.

The functional land shortage for oil palm relates largely to the uneven distribution of village landholdings amongst village clans/subclans, and the requirement that oil palm blocks be located along feeder roads. The road requirement means that landowner groups without a feeder road on their land are dependent on the generosity of other landowner groups for access to land for oil palm. OPIC, rightly, does not approve applications for new VOP blocks if the proposed site is not located along an existing road. The road network is therefore an important determinant of the income potential of different landowning groups within villages.

Whilst absolute and functional land shortages may be the root cause of disputes over planting (and replanting) of VOP blocks, other social variables are at play too that may serve as triggers for these disputes. These include: 1) the death of the clan leader who allocated land to a non-clan/subclan member; and 2) the death of the blockholder who was first granted the land to plant oil palm. Thus the children of the blockholder who was the recipient of the land, may face an uncertain future with regard to oil palm production. The moral basis of customary landowner demands for the return of the land is strengthened if two important conditions are not met. These are the perception amongst customary landowners that the:

1. blockholder did not contribute adequately to the mortuary payments (or participate sufficiently in mortuary-related activities) of the deceased clan leader who allocated the land; and/or
2. blockholder or deceased blockholder did not fulfil customary obligations to the 'host' landowning group to an appropriate level, or failed to share a sufficient amount of his oil palm wealth with the 'host' landowning clan members.

Customary obligations include contributions to the brideprices and mortuary payments of the host group and often, nowadays, contributions to the school fees of children of the landowning group. In the case of a deceased blockholder, moves by his sons or other male relatives to take control of the block will be resisted vigorously by the landowning group, which can result in the block being locked out of production for a prolonged period with replanting postponed indefinitely. These grievances reveal the continuing influence of traditional socio-cultural values in relation to land access.

<u>Land Tenure Disputes Between Customary Landowners and 'Outsiders' Acquiring Land</u>

As mentioned above, the acquisition of customary land by 'outsiders' from other regions of PNG is a recent trend. At Bialla and Popondetta these oil palm blocks are not classified separately from VOP blocks and at Hoskins, where the majority of these blocks exist, a new category has been created, termed "Customary Rights Purchase Blocks" (CRP) in recognition that the land is not alienated permanently from the customary landowning group.

Most CRP land transactions are informal and are often not in accordance with customary law. Seldom is there written evidence that the transaction has the approval of the clan. Land surveys are rarely undertaken, and written agreements typically do not specify the agreed 'sale' price of the land, the amount and timing of payment instalments, and the specific rights of the purchaser. This can lead to much misunderstanding and disputes between the 'purchaser' and the customary landowners.
Many of those acquiring land believe that:

- Their children can inherit the land. This is not the case in law as the land remains customary land with the potential for the block to be reclaimed by the customary landowners on the death of the 'purchaser'.
- They possess the right to sell the land to a third party without consulting the customary landowners. This is also a frequent cause of disputes.
- They have the freedom to invite anyone to reside on block such as their wantoks from their home villages. The customary landowners often do not agree and think that it is only the 'purchaser' and his immediate family who have residency rights.

Customary landowners often believe that they:

- Have the right to evict those who cause law and order issues. Many 'purchasers' think this is none of the business of the customary landowners.
- Are entitled to be paid the difference in land value between the price of a block 'sold' in the past and its current value. For example, a CRP grower who paid K1,000 for a 2 ha block 10 years ago, might now be faced with a demand for an additional payment of K2,000 because the current value of his block has risen.
- Are being denied rightful income when the price of oil palm rises sharply like it did in early 2008. They feel that the 'purchaser' is benefiting unfairly from the higher prices because the block was 'sold' when prices were lower. This can lead customary landowners to demand extra money from the CRP blocks.
- Should share a portion of the wealth coming from the land purchased by migrants and therefore anticipate that migrants will contribute to village bride prices, mortuary payments and to other form of ceremonial exchange or village fund raising. It is also expected that migrants will contribute labour to community events like church building, sports events, etc.
- Have the right to reclaim the land, or at least be compensated financially if the 'purchaser' wishes to sell the land or transfer the block to his immediate or extended family.
- Have control over who is allowed to reside on a CRP.

The views outlined above arise largely from two conflicting interpretation of the land transactions between migrants and customary landowners.

One interpretation of the land transaction, adopted by many migrants purchasing land, views land as a commodity where rights to land are alienable and where the land transaction is seen as largely a commercial transaction. In this view, the purchase of the land confers 'individual' and permanent ownership (similar to freehold title), and from this perspective the land is held in perpetuity by the migrant and can be inherited by his children or sold to a third party. Those migrants associating the land transaction with principles of freehold title also feel that there should be no obligations on them to share the wealth from the purchased land with the customary landowners or to maintain a social relationship with customary landowners by participating in their ceremonial and social activities.

The other interpretation of land transactions held by customary landowners draws on customary principles that view land as an inalienable resource held by the kinship group – this perspective is held by most members of the customary land-owning group. For customary LOs, land rights granted to outsiders are not permanent and exclusive despite the land being 'paid' in full as a 'purchase' block. Instead, a less exclusive set of rights pertain that are conditional on the migrant's continued participation in customary exchange and fulfilling other obligations – expectations similar to more traditional concepts of land tenure where access rights to land are not based solely on descent, but also on residence and participation in communal economic and social activities. Hence, if the migrant does not share some of the wealth from the land with the customary landowners or fails to participate in customary activities then the validity of the migrants' tenure rights begins to erode with a gradual reversal of the rights back to the host lineage.

Robert Cooter's (1991) conceptualisation of the differences between freehold and customary tenure in PNG (Figure 1) can be applied to the two different interpretations of land transactions described above. Cooter described freehold transactions as those that occur largely between strangers whose only relationship with each other is commercial and the obligations and commitments to each other are minimal. Whilst buyers and sellers have some obligations to each other, the transaction choices they make are not constrained by social obligations to each other. Both parties can act to their own best advantage and the relationship between them is short-term and concludes with completion of the sale. Cooter conceives freehold tenure as "property law for stranger relations" (Cooter, 1991: 41). In contrast, customary land tenure transactions occur between relatives and are based on long-term relationships of reciprocal obligations, cooperation and commitment to members of the kinship group (Figure 1). Such obligations and commitments affect customary rights to land and constrain a person's freedom to act to their own best advantage in land transactions. Thus, customary land law is described as "property law for kin relations". Under customary land law, the concept of property is relational and ownership rights are dispersed among the kinship group. This is in contrast to freehold title where ownership is unitary and absolute, and land transactions are grounded in market relationships.

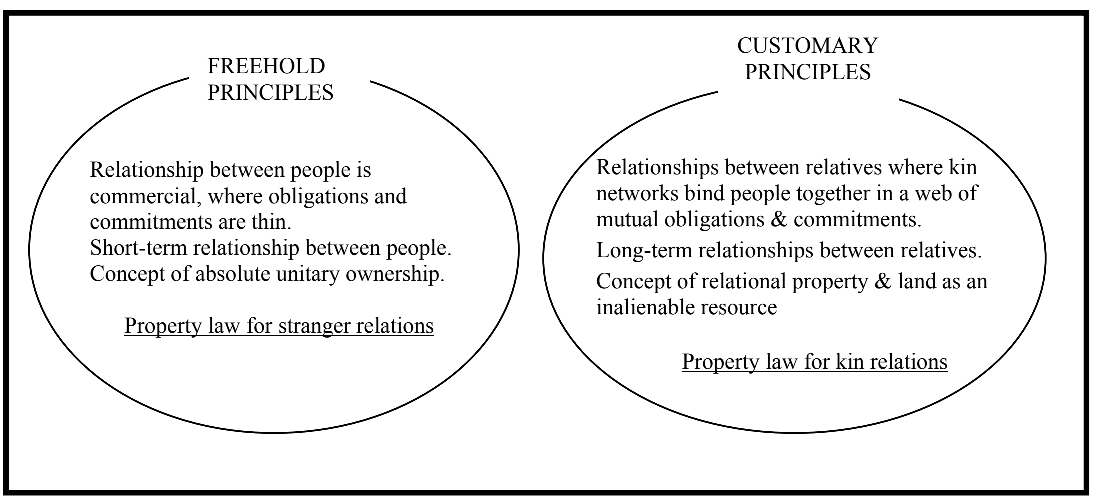


Figure 1. adapted from Cooter's concept of property law in PNG

Many settlers purchasing land are attempting to place the land transaction in the realm of commodity exchange thereby associating the transaction with principles of freehold title (stranger relations), whereas the landowners' view continues to be based on customary law (property law for kin relations) and the mutual obligations that are required to maintain access rights to the land. Any attempt to address the conflicts occurring on customary rights purchase blocks need to first acknowledge these differing interpretations of the land transaction.

Towards a Solution: A New Clan Usage Agreement

There are potential solutions to address the concerns of both customary landowners and 'outsiders' acquiring land, and which should contribute to more stable relationships and more productive relationships between customary landowning 'hosts' and 'outsiders' producing oil palm on their land.

Current procedures for dealing with new oil palm plantings on CRPs and existing Clan Land Usage Agreements (CLUA) 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 transactions. Therefore, there is a need to review current practices relating to the establishment of CRPs. As part of the ACIAR research project, OPRA and OPIC are closely working together and consulting widely with customary landowners and migrants acquiring land to develop a new Clan Land Usage Land Agreement (CLUA).

A set of preliminary guidelines that should be considered in the design of a new and suitable land administrative system for oil palm planted by 'outsiders' on customary land is provided below. There are two main elements:

1. The design of a new CLUA.
2. Completion of a Land Investigation Report.

1. Clan Land Usage Agreement (CLUA)

A CLUA should be designed specifically for each project area and be endorsed by local landowners before being promoted by OPIC. It should include the following elements:

a) Clarification that the person is not purchasing the land outright as in freehold title, but rather is *leasing* the land for a specified period of time (25-50 years – one or two planting cycles).
b) Three party signatory process comprising landowning clan members (at least four senior clan members, including women leaders), individuals from the clan who have use rights on the land under customary law and the proposed tenant. These signatures should be witnessed by the OPIC Lands Officer and a senior staff member of the Provincial Lands Mediation Committee.
c) Agreement that the customary landowners will relinquish any use rights or management rights to the land for the duration of the lease period.
d) Land boundaries are clearly defined (preferably surveyed and marked with Cordyline '*tanget*' or palms).
e) A description of the rights and obligations of the clan leaders disposing of the land and the tenant. For example, the rights of the tenant to plant other cash crops and food crops, and to establish businesses, houses and other assets should be specified. The transfer rights of the tenant should also be defined, as should the rights of the clan leaders to repossess the land due to breaches of the terms of the CLUA. OPIC could act as referee in such disputes. Similarly, all covenants on the lease should be specified, such as restrictions on the transfer or sub-leasing of all or part of the block to another person during the lease period, or any conditions on the disposal of the lease payments by clan leaders. Conditions may also be imposed on certain behaviours of tenant and family (e.g., illegal activities) or on clan members (e.g., intimidation of tenant or demands for money beyond specified lease payments).
f) Payment details. This should include details of any up-front payments made or owing, the annual rental fees and when due, any royalty component based on production and the penalties incurred in cases of default. All payments and payment arrangements should be transparent and accountable. Ideally, payments should be deducted through the smallholder payment system with payments paid directly into an account of the landowning group, so that there is a permanent record of payments.
g) A component of the fee should be similar to a royalty based on the value of production, so that as the value of production from the block increases through time, landowners will feel they are also benefiting from the rise in the value of the production (e.g., when oil palm prices rise).

h) Provisions for future contingencies. For example, consideration should be given to what provisions should be made for dealing with lease renewal, the death of the tenant, or if the lease were to be revoked for some reason (compensation of the tenant).
i) Inclusion of a Land Investigation Report (see below).

Based on the above, a draft CLUA has been designed by OPRA and OPIC (Annexure A) which is currently under discussion and awaiting feedback from the various stakeholders.

2. Land Investigation Report

Before a CLUA is signed, the OPIC Lands Officer and a member of the Provincial Lands Mediation Committee should, in the company of representatives from the landowning group and the proposed tenant, inspect the designated land and complete a Land Investigation Report to verify ownership claims of the land and that the land portion is not under dispute. The boundaries of the designated land should be clearly defined. Investigations should be conducted to determine what other forms of secondary rights, if any, exist over the land. Also, land availability should be assessed to ensure that the leasing of land to the 'outsider' will not lead to land shortages for members of the landowning group during the lease period.

As part of the Land Inspection Report a community meeting should be held with a sizable representation from the landowning group (including women) and/or those individuals or families identified by the community to deal in land. The community meeting should in the first instance:

1. Record the individual/family unit identified and supported by the landowning group to have the rights, under customary law, to deal in the designated land for lease.
2. Give members of the landowning group an opportunity to object/support the proposed land agreement.
3. Define the conditions under which that portion of land be released on a lease basis.

The meeting should also be used as a forum to determine/alter the following: use rights of the lessor; appropriate levels of rentals/royalty payments and how they will be distributed to members of the landowning group; and dispute resolution mechanisms. Whilst there will be standard rights, obligations and restrictions written into all agreements (e.g., rights of tenant to plant oil palm and prohibitions on clan members transferring the land to another party during the lease period), the customary landowners of the designated land should be given the opportunity to impose additional conditions on the land during the lease period (e.g., thoroughfare right of way). This meeting should be announced publicly several weeks in advance. The meeting should be deemed invalid if a sizable proportion of the landowning group is not present.

The Land Investigation Report must be approved by OPIC, the Provincial Lands Mediation Committee and the customary landowners prior to the signing of a CLUA and delivery of seedlings. Approval of the Land Investigation Report should be given only if all of the following conditions are verified:

- The landowners have the right to dispose of the land for lease.
- Land boundaries are clearly defined.
- The land is not under dispute.
- Secondary rights to the land are acknowledged.
- Leasing the land will not negatively impact on clan members' access to land or undermine their livelihoods and everyday needs.
- Attendance at the publicised community meeting to discuss the Land Investigation Report was representative of the landowning group (e.g., women, youth and elderly clan members).
- The landowning group agree that the land be leased and are aware of their rights and restrictions on the land under the lease agreement.

- The landowning group have in place or are preparing a system for the collection of rentals/royalties and its fair distribution to clan members.
- That RSPO criteria for oil palm cultivation are met.

Conclusion

Land tenure disputes on State agricultural leasehold land and customary land are one of the many complex factors influencing smallholder production. The design of a modified CLUA agreement together with the Land Investigation Report incorporating the principles described above is one way to address disputes on customary land. The modified CLUA aims to lead to more stable tenure arrangements for both 'outsiders' acquiring land and customary landowners who continue to retain the underlying customary ownership of the land. This will help ameliorate many of the present frustrations of both landowners and 'outsiders' thereby creating a more stable environment for oil palm production.

Feedback on the draft Customary Land Usage Agreement (Annexure A) can be sent to Jesse Anjen at: jesse.anjen@pngopra.org.pg

<u>References:</u>

Cooter, R. 1991. Kin Groups and the Common Law Process. In: Customary Land Tenure: Registration and Decentralisation in Papua New Guinea. P. Lamour (Ed.). IASER Monograph 29. National Research Institute, Boroko, Papua New Guinea.

Crocombe R (ed) 1971 *Land tenure in the Pacific* Oxford University Press, Melbourne

Crocombe R and Hide R 1971 New Guinea: unity in diversity in Crocombe R ed *Land tenure in the Pacific* Oxford University Press, Melbourne 292-333

Curry, G.N., G. Koczberski, E. Omuru, J. Duigu, C. Yala and B. Imbun 2006. Social Assessment of the Smallholder Agriculture Development Project. Report prepared for World Bank.

Ward R G 1997 Changing forms of communal tenure. In: *The Governance of Common Property in the Pacific Region.* P. Larmour (Ed.). National Centre for Development Studies, Research School of Pacific and Asian Studies, and Resource Management in Asia-Pacific, Research, School of Pacific and Asian Studies, The Australia National University, Canberra, 19-32.

Ward R G and Kingdon E (eds) 1995 *Land, custom and practice in the South Pacific* Cambridge Asia-Pacific Studies, Cambridge University Press, Cambridge

ANNEXURE A

Drafted by OPRA & OPIC (Bialla, Hoskins & Popondetta)

22 December, 2009

DRAFT
(for comment and feedback)
OPIC Customary Land Use Agreement — Hoskins

Section 1. Land Use Agreement

We the undersigned, being representatives of __________________ Clan (the lessor), agree that ____________________________ (the lessee) who is ***not*** a member of the recognised landowning group or land custodian has/have the right under customary law to use, occupy and develop __ hectare of customary land known as _________________ situated in ____________________ VOP, ____________ District, ____________ Province for a period of:

- ☐ One oil palm planting cycle (25 years)
- ☐ Two oil palm planting cycles (50 years)
- ☐ The lifetime of the lessee
- ☐ For a period of ____ years
- ☐ Other: Specify ___________________

This agreement takes effect from the ___ day of ________ Two thousand and ________.

The GPS co-ordinates of the land are ______________________________

<u>Lessor (customary landowning group) accepts and declares</u>:
By signing this CLUA, __________________ the landowning group accepts and declares that:

1. They are the rightful owners of the land known as ______________ situated in _________________ VOP, and have the right to deal in the land.
2. The land is not disputed and is clearly demarcated.
3. For the duration of this CLUA, customary tenure will cease to apply to the land and clan members' management and use rights to the land are relinquished.
4. The boundaries of the CRPB are demarcated and marked with tanget, coconut or other markers. Specify: _____________
5. This CLUA will not negatively impact on clan members' access to land or undermine their livelihoods and everyday needs.
6. The lessee has the right to terminate the lease and seek compensation if ___________________ members of the landowning group do not abide by the terms and conditions of the CLUA outlined in Section 2.

7. A Block Inspection Report has been conducted and endorsed by the landowning group and OPIC. Appendix 1.
8. The landowning group has in place or are preparing a system to ensure all scheduled payments are properly receipted and recorded.
9. The landowning group has in place or are preparing a system for the fair distribution of payments to group members.
10. A signed copy of the CLUA will be given to the LLG land mediator and lodged with OPIC and the Lands Department within 21 days of signing.

We certify that all members of ____________________ clan accept this Customary Land Use Agreement between _________________ clan and _________________ (lessee) and that we are the four persons authorised by the clan and accepted and recognised by OPIC to sign on the clan's behalf.

___________________________ ________________________../../….
a) Full name of female Clan Leader Signature/Mark Date

Signed in the presence of ___________________ OPIC Representative

___________________________ ________________________../../….
b) Full name of female Clan Leader Signature/Mark Date

Signed in the presence of ___________________ OPIC Representative

___________________________ ________________________../../….
c) Full name of male Clan Leader Signature/Mark Date

Signed in the presence of ___________________ OPIC Representative

___________________________ ________________________../../….
d) Full name of male Clan Leader Signature/Mark Date

Signed in the presence of ___________________ OPIC Representative

Witnesses:

___________________________ ________________________../../….
Full name of LLG Land Mediator Signature/Mark Date

___________________________ ________________________../../….
Full name of Ward Councillor Signature/Mark Date

___________________________ ________________________../../….
Full name of local Church Leader Signature/Mark Date

___________________________ ________________________../../….
Full name of Clan Leader from Neighbouring Clan Group Signature/Mark Date

Lessee accepts:

By signing this Customary Land Use Agreement, I ___________ accept that under this agreement:

1. The parcel of land will be released to me for ____ years from the ___ day of _____, 20____ and upon the expiry of the CLUA the land will revert to customary ownership.
2. The land will not be used for any purpose other than those uses listed in Section 2, clause 1 of this agreement.
3. ___________________ clan has the right to terminate this CLUA if I do not abide by the terms and conditions specified in Section 2.
4. This CLUA will become invalid if the schedule of payments listed in Section 3 are not made in full on or before the due dates referred to in Section 3 of this agreement.

___________________________ ________________________../../….

Full name of Lessee Signature/Mark Date

Signed in the presence of ____________________ OPIC Representative

Section 2. Terms and conditions of the land use agreement

1. Under the terms of CLUA, the lessee is entitled to make the following uses of the land:
   i) Cultivate oil palm.
   ii) Cultivate other commodity crops (e.g., cocoa, vanilla, spices). Specify: ______________
   iii) Cultivate betel nut, coconuts, fruit trees for sale. Specify: _________
   iv) Cultivate garden crops for home use and for sale at local markets.
   v) Raise livestock.
   vi) Operate small business enterprises (e.g., tradestores or PMV). Specify: ______________
2. Burials cannot take place on the CRPB (burial permitted on prescribed village cemetery free of charge).
3. Only the lessee and his/her immediate family to reside permanently on the block.
4. The lessee shall be entitled to occupy and begin developing the CRPB on payment of the deposit sum of ______Kina referred to in Section 3 of this agreement.
5. No member of ______________________clan can interfere with or hinder the progress of any income earning activities that are permitted under the terms of this agreement specified in Section 3, clause 1.
6. The lessee cannot sub-lease the CRPB or any part thereof without the prior consent of the lessor.
7. The lessee cannot transfer the CRPB to another person during the period of the CLUA without the prior consent of the lessor and in accordance with Section 3, clause 8.
8. Should the lessee die before the expiry of the CLUA, the CRPB will automatically be transferred to the deceased's spouse __________________ or _____________________, the person named in the Will of the lessee, for the remaining period of the CLUA.

9. The lessor holds the right to terminate the CLUA if illegal activities or anti-social behaviour (e.g. garden theft, drugs, homebrew) by the lessee or his/her family occur on the CRPB.
10. The lessor can terminate the CLUA if the lessee or a member of his/her family is responsible for violent or threatening behaviour to the residents of ____________ VOP.
11. The CLUA will become invalid if the land designated for oil palm is not planted within ___ years of the signing of this agreement.
12. It is illegal for members of ______________clan to make monetary or other demands on the lessee beyond the specified payments listed in the payment schedules of Section 3 of this agreement.
13. No changes can be made during the period of this agreement by __________ clan to the payment schedules specified in Section 3 of the agreement.
14. The lessee has the right to terminate the CLUA if members of ___________ clan breach the terms and conditions described in Section 2, clauses 4, 5, 12, 13 and may seek compensation from _______________ clan for lost income earnings for the remaining period of the CLUA.
15. The lessor has the right to terminate the CLUA if the lessee breaches the terms and conditions described in Section 2, clauses 1, 2, 3, 4, 6, 7, 9, 10, 11 and Section 3. The lessee is not entitled to compensation apart from property from _______________ clan if the terms and conditions of the CLUA are breached.
16. Upon expiry or termination of the CLUA, the lessee is free to sell or remove his/her house, cash crops, garden or other assets before vacating the block.
17. In the final year of the CLUA, oil palms over 25 years of age must be poisoned by OPIC.
18. All aspects of block development and management by the lessee must comply with RSPO principles and criteria for smallholder blocks.

Section 3. Payment Schedules

The lessee who is from __________ Village, _______ Province has agreed to meet the following payment schedules to ___________________ Clan for occupation and exclusive land usage rights over the said portion of land for the period of _____ years:

☐ Customary Rights Purchase fee: The total sum of __________ Kina in full by Two thousand and _________. A deposit of _____ Kina has been paid on the signing of this CLUA and the lessee agrees to pay the outstanding balance of K________ in full as annual instalments of _______ Kina by _____day of _______ Two thousand and _________.

☐ Oil Palm Production Fee (Option 1): The lessee agrees to a monthly payment of a proportion of the value of oil palm production from the block at the rate of ___ per cent of the total value of monthly production from the CRPB. Payment will commence when the palms come into production and will cease at 20 years from the signing of this CLUA. The production fee will continue to be deducted for the remaining period of the CLUA and be held in trust by the financial institution managing the payments. On renewal of the lease, monies accumulated in the fund will be paid to the customary landowners (lessor) as a lump sum. If the lease is not renewed, the monies accumulated in the fund will be paid as a lump sum to the lessee at the end of the lease period (25 years) as compensation for improvements that cannot be removed from the block.

☐ Oil Palm Production Fee (Option 2): The lessee agrees to a monthly payment of a proportion of the value of oil palm production from the block at the rate of ___ per cent of the total value of monthly production from the CRPB. Payment will commence when the palms come into production and will cease at 20 years from the signing of this CLUA. On signing the lease renewal for another planting round (25 years plus number of years remaining on existing lease) the oil palm production fee paid to the lessor will resume. If the existing lease is *not* to be renewed, the suspension of the oil palm production fee for the remaining period of the lease (5 years) will compensate the lessee for improvements that cannot be removed from the block.

☐ No payment: The lessee is not required to make any payments for access to this land for the period specified in this CLUA.

Section 4. Dispute Resolution Procedures

1. Disputes relating to the terms and conditions of the CLUA agreement should be referred to the OPIC Lands Officer in the first instance.

2. Disputes amongst the customary landowning groups relating to ownership of the land should be referred to the land mediation process. If a resolution is not achieved through the LLG land mediator, the matter should be referred to the district court. During such disputes, the lessee will be allowed to continue production without interference from either of the disputing parties. Payments to the customary landowners may be held in a trust account by the bank until the dispute amongst customary landowners is resolved.

Where mediation by the village land mediator or district court magistrate succeeds in a resolution of the dispute, a record of the terms of the agreed resolution should be forwarded by the mediator to the local land magistrate and OPIC.

Section 5. Validation of Agreement by District Land Court

Signature of District Land Court Magistrate ______________________________

Date: ______________

Stamp of Local District Land Court:

SKETCH PLAN BLOCK NUMBER

Mark the locations of any natural or man-made boundary markers (e.g. tanget and coconuts)

OPRA-Curtin University ACIAR project. Land Access and Tenure Security: Customary Purchase/Customary Rights Purchase Blocks

The "purchase" of customary land by non-clan members for oil palm development is occurring at Hoskins and to a lesser extent at Bialla and Popondetta. These oil palm blocks were called "Customary Purchase Blocks" (CPBs), though at Hoskins they are now called "Customary Rights Purchase (CRP) Blocks" to reflect the fact that they are not permanent purchases.

The sale of land by customary landowners is a recent trend, first emerging at Hoskins in the mid 1980s and later, around the mid 1990s to 2000, at Bialla and Popondetta. Approximately 200 ha and 50 ha of land have been "sold" at Bialla and Popondetta respectively to "outsiders" for oil palm development. At Hoskins, there has been a rapid expansion of CPBs over the past 10 years. Presently at Hoskins, 2,721 ha of customary land (953 oil palm blocks) have been developed as CPBs, representing about 23.4% of the total area of VOP plantings. Not all VOP villages are selling land and the amount of land sold varies greatly amongst villages.

At Hoskins and Bialla, there is enormous demand for land by migrants attempting to secure a future for themselves and their families in the relatively prosperous oil palm belt bordering Kimbe Bay. For LSS settlers, especially from highly populated blocks, the acquisition of a CPB offers a way to reduce population pressure on their existing LSS blocks. The high cost of LSS blocks puts these blocks beyond the reach of most LSS growers (prices for a 6 ha LSS block at Bialla and Hoskins range from K30,000 to K60,000 compared with K2,000 to K3,000 per ha for a CPB). Also, the acquisition of a CPB is even more critical for second generation LSS settlers who have lost access to land in their home villages. Similarly, company and government employees who have spent much of their working lives in WNB and raised their children in WNB, see the "purchase" of a CPB as a way to secure a livelihood in retirement and/or a future for their children.

The main difficulties relating to land tenure for CPB growers are undocumented land transactions and insecure land tenure rights, both of which increase a CPB grower's vulnerability.

<u>Undocumented Land Transactions</u>
The majority of CPB land transactions are informal and not in accordance with customary law. Land surveys are rarely undertaken, and 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. Disputes can arise over the following:

- Many "purchasers" believe they own the block outright, and therefore their children should be able to inherit the land. This is not the case in law as the land remains customary land with the potential for the block to be reclaimed by the customary landowners on the death of the "purchaser".

- Many "purchasers" believe they have permanent ownership of the block, and therefore they have the right to poison and replant their senile palms without the consent of the customary landowners. Many customary landowners argue that the initial grant of land for oil palm was for a single planting round and the land can now be resumed by the customary landowners. Disputes over replanting are emerging as a major problem in all three project areas.

- Many "purchasers" believe that they have the right to sell the land to someone else without consulting the customary landowners. This is also a frequent cause of disputes.

- Many "purchasers" believe that they have the right to invite anyone to reside on block such as their *wantoks* from their home villages. The customary landowners often do not agree and think that it is only the "purchaser" and his immediate family who have residence rights.

- Many customary landowners think they have the right to evict troublemakers who cause law and order issues. The "purchasers" sometimes think this is none of the business of the customary landowners.

- Many customary landowners believe that if land sold to outsiders is not planted to oil palm within a couple of years, the transaction is invalidated and they have the right to resell the land to another "outsider" without compensating the original "purchaser". This often occurs when a 4 ha block is sold with the first phase of 2 ha being planted to oil palm and second phase delayed until the first phase is in production. Sometimes the customary landowners will resell the unplanted second phase to a third party.

- When blocks were "sold" in the past at a lower price than they are selling now, customary landowners often believe they have the right to be paid the difference in the value between the earlier "sale" price and the value today. For example, a CPB/CRP grower who paid K1,000 for a 2 ha block 10 years ago, might now be faced with a demand for an additional payment of K4,000 because the current price of a 2 ha plot is K5,000.

- When the price of oil palm rises sharply, like it did in early 2008, customary landowners often feel that they have been cheated because they "sold" the land when oil palm prices were lower. They think that the "purchaser" is receiving benefits unfairly from the higher prices. This can lead customary landowners to demand additional cash payments from CPB/CRP blockholders.

What to do?

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". Therefore, there is a need to review current practices relating to the establishment of CPBs/CRPs.

A set of preliminary guidelines that should be considered in the design of a new and suitable land administrative system for oil palm planted on CPBs is provided below. The recommended system contains two main elements:

1. The design of a new Clan Land Usage Land Agreement (CLUA).
2. Completion of a Block Inspection Report.

1. Clan Land Usage Agreement (CLUA)
It is recommended that a new CLUA be designed and trialled for each oil palm project area. The new CLUA must be endorsed by local landowners in each project area before being promoted by OPIC.

The new CLUA should cover the following elements:

i) Clarification that the person is not purchasing the land outright as in freehold title, but rather **leasing** the land for a specified period of time (25 years).

ii) Three party signatory process comprising landowning clan members (at least four senior clan members, including women leaders), individuals from the clan who have user rights on the land under customary law and the proposed lessee. These signatures must be witnessed by the OPIC Officer, LLG Land Mediator, the Ward Councillor, a local church leader and a clan leader from a neighbouring landowning group. The age of clan leaders should be noted on the CLUA to help with identification of signatories in the future. At least one clan leader should be relatively young to ensure some clan leaders will be alive at the end of the CLUA.

iii) Agreement that the customary owners relinquish any use rights or management rights to the land for the duration of the CLUA.

iv) Land boundaries are clearly defined (preferably surveyed with GPS and marked with Cordyline '*tanget*' or coconut/betel nut palms).

v) A description of the rights and obligations of the clan leaders disposing of the land, other clan members and the lessee. For example, the rights of the lessee to plant other cash crops and food crops, and to establish businesses, houses and other assets should be specified. The transfer rights of the lessee should also be made clear, as should the rights of the clan leaders to repossess the land due to breaches of the terms of the CLUA. OPIC could act as referee in such disputes. Similarly, all covenants on the land should be specified in the CLUA, such as restrictions on the transfer or sub-leasing of all or part of the block to another person during the period of the CLUA, or any restrictions on the disposal of the payments by clan leaders. Restrictions may also be imposed on certain behaviours of lessee and family (e.g., illegal activities) or on clan members (e.g., intimidation of lessee or demands for money beyond those specified in the CLUA).

vi) Payment details. This should include details of any up-front payments made or owing to maintain ongoing access rights to the land, and any payments based on the value of production and the penalties incurred in cases of default. All payments and payment arrangements should be transparent and accountable. Ideally, payments should be deducted through the smallholder payment system with payments paid directly into an account of the landowning group, so that there is a permanent record of payments.

vii) A component of the fee (the Oil Palm Production Fee) should be similar to a royalty based on the value of production, so that as production from the block increases through time and/or FFB prices rise, landowners will feel they are also sharing the benefits of the increase in the value of production (growers and landowners have suggested the name "*hamamas pei*" to describe this fee). Discussions with customary landowners in all three project areas suggest that a production fee of 5% of the value of production would be an appropriate level of payment.

Also, FFB shifting (to avoid loan deductions) would be less of a problem with a fee paid to customary landowners based on the value of production. This is because it would be against the financial interests of customary landowners if CRP growers were to shift fruit. Therefore, customary landowners would be anticipated to prevent the shifting of fruit.

viii) Provisions for future contingencies. Consideration should be given to what provisions should be made for dealing with renewal of the CLUA, the death of the lessee, or if the CLUA were to be revoked for some reason (compensation of the lessee). For example, on the expiry of CLUAs that are not being renewed, compensation for non-removable assets (e.g., coconut palms, water tanks, etc) of lessees vacating their blocks was raised in discussions by CRP growers in all project areas. Two ways of handling the compensation of lessees for assets that cannot be removed from the block at the expiry of CLUAs are proposed. Both involve the suspension of the oil palm production fee for the last five years of the lease as compensation of those vacating their blocks when CLUAs expire. The first is the preferred option because it involves a lump sum payment as compensation to the lessee vacating his block or as a lump sum paid to the lessor for lease renewal.

Option 1: It is recommended that for all CLUAs, the 5% oil palm production fee cease being paid to customary landowners five years before the expiry date of the CLUA. The production fee would continue to be deducted for the remaining five years of the CLUA and be held in trust by the financial institution managing payment transactions. On renewal of the lease, monies accumulated in the fund would be paid to the customary landowners (lessor) as a lump sum. If the lease were not to be renewed, the monies accumulated in the fund would be paid as a lump sum to the lessee at the end of the lease period (25 years) as compensation for improvements that cannot be removed from the block.

Option 2: The 5% oil palm production fee cease being paid to customary landowners five years before the expiry date of the CLUA. Ideally, lease renewals would occur 20 years into the existing lease with lease renewal for 25 years plus the number of years (5 years) remaining on the existing lease. On signing the lease renewal, the oil palm production fee would resume. If the existing lease is not to be removed, the suspension of the oil palm production fee at 20 years into the lease will serve as compensation to the lessee for any improvements that cannot be removed from the block at the expiry of the lease at 25 years.

ix) Inclusion of a Block Inspection Report (see below).

2. Block Inspection Report

Before a CLUA is signed, the OPIC Lands Officer, the LLG land mediator should inspect the designated land and complete a Block Inspection Report, together with representatives from the landowning group and the proposed lessee, to verify ownership claims of the land and that the land portion is not under dispute. The boundaries of the designated land should be clearly defined. Investigations should be conducted to determine what other forms of ‘secondary’ rights, if any, exist over the land. Also, land availability should be assessed to ensure that the leasing of land to an “outsider” is not going to lead to future land shortages for members of the landowning group.

As part of the Block Inspection Report a community meeting should be held with a sizable representation from the landowning group (including women) and/or those individuals or families identified by the community to deal in land. The community meeting should in the first instance:

1. Record the individual/family unit identified and supported by the landowning group to have the rights, under customary law, to deal in the designated land.
2. Give members of the landowning group an opportunity to object/support the proposed CLUA.
3. Define the conditions under which that portion of land be subject to a CLUA.

The meeting should also be used as a forum to determine the following:

- use rights of the lessor;
- appropriate levels and schedules of payments and how payments will be disbursed amongst members of the landowning group; and
- dispute resolution mechanisms.

Whilst there will be standard rights, obligations and restrictions written into all agreements (e.g., rights of lessee to plant oil palm and prohibitions on customary landowners transferring the land to another party during the period of the CLUA), the customary landowners of the designated land should be given the opportunity to impose additional conditions on the land during the CLUA (e.g., thoroughfare right of way). This meeting should be announced publicly several weeks in advance. The meeting should be deemed invalid if a sizable proportion of the landowning group is not present.

The Block Inspection Report must be approved by OPIC, the village land mediator and the customary landowners prior to the signing of a CLUA and the supply of seedlings. Approval of the Block Inspection Report should only be given if all of the following are verified:

- The landowners have the right to deal in the land.
- Boundaries are clearly marked.
- Ownership of the land is not disputed.
- Secondary rights to the land are acknowledged.
- Leasing the land will not negatively impact on clan members’ access to land or undermine their livelihoods and everyday needs.

- Attendance at the publicised community meeting to discuss the Block Inspection Report was representative of the landowning group (e.g., women, youth and elderly clan members).
- The landowning group agree that the land be released according to the terms and conditions of the CLUA and are aware of their rights and restrictions on the land under the CLUA.
- The landowning group have in place or are preparing a system for the collection of payments and their fair distribution amongst the customary landowning group.
- Must meet the RSPO principles and criteria for smallholder oil palm blocks (refer to Oil Palm Approval Form).

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BLOCK INSPECTION REPORT FOR SMALLHOLDER CUSTOMARY RIGHTS PURCHASE BLOCKS — Hoskins

This Block Inspection Report is for the __ ha portion of land in ________________ VOP, GPS co-ordinates ______ _______ _________ ________

OPIC Officer, ___________________________ together with ___________________, ______________________, ___________________ and _______________________ the four authorised representatives from ______________________ clan have completed an inspection of the proposed leased land which verifies the following:

1. The boundaries of the land have been clearly marked (e.g. with tanget, coconuts or betel nut).
2. _____________________________ clan has the right to deal in the land for lease.
3. The land is not under dispute.
4. Leasing the land will not negatively impact on clan members' access to land or undermine their livelihoods and everyday needs.
5. The land is suitable for oil palm production (e.g. suitable topography and road access is available — refer to conditions in Oil Palm Planting Approval Form) and complies with RSPO principles and criteria for smallholder blocks.

It is recommended that the land be leased for a period of ___________ years and that a community meeting be held to verify the clan's approval of leasing the land under a Customary Land Use Agreement (CLUA).

We certify that we are the four persons authorised by _________________ clan and OPIC to sign on the clan's behalf to endorse the above recommendation.

__________________________ ________________________../../….
a) Full name of female Clan Leader Signature/Mark Date

Signed in the presence of ___________________ OPIC Representative

__________________________ ________________________../../….

b) Full name of female Clan Leader Signature/Mark Date

Signed in the presence of ____________________ OPIC Representative

____________________________ ____________________________../../….
c) Full name of male Clan Leader Signature/Mark Date

Signed in the presence of ____________________ OPIC Representative

____________________________ ____________________________../../….
d) Full name of male Clan Leader Signature/Mark Date

Signed in the presence of ____________________ OPIC Representative

Witnesses:

____________________________ ____________________________../../….
Full name of LLG Land Mediator Signature/Mark Date

____________________________ ____________________________../../….
Full name of Clan Leader from Neighbouring Clan Group Signature/Mark Date

It is **NOT** recommended that the land be leased for the following reasons:

____
____
____
____
____
____
____
____

OPIC Representative: ____________________________ date __________________

STEP-BY-STEP GUIDELINES FOR DEALING WITH SMALLHOLDER CUSTOMARY RIGHTS PURCHASE BLOCKS

This document provides a step-by-step guide to assist OPIC to develop a formal system for dealing with smallholder Customary Rights Purchase Blocks (CRPB) to ensure all land dealings are fair and equitable for both customary landowners and lessees. Central to this process is the concept of Free, Prior and Informed Consent (FPIC) amongst all parties to the transaction in accordance with RSPO principles. This means that each party (customary landowning group and the person seeking to acquire a specified parcel of land parcel) must be fully informed about all aspects of the transaction ***prior to*** making a decision as to whether or not to proceed with the land transaction. In other words, the process must be fully transparent to all people with an interest in the land.

The term Customary Rights Purchase Block (CRPB) is preferred to Customary Purchase Block because CRPB more accurately describes the land transaction, in that rights to the use of the land are being purchased for a period of time, not the land itself.

When an enquiry is made to OPIC regarding a proposed CRPB transaction, the following SEVEN steps should be taken.

Step 1. It must be made clear to the customary landowners and the proposed lessee that the process towards formalising a Customary Land Usage Agreement (CLUA) will cease if various criteria are not met. At all stages the process must be transparent, public and all parties must be fully informed about all aspects of the proposed land transaction in order to be able to make Free, Prior and Informed Consent (FPIC) in accordance with RSPO principles and the PNG national interpretation and guidance documents.
Step 2. Confirm that there is agreement from the majority of the members of the landowning group for the proposed land transaction to go ahead. Confirmation to be obtained at a community meeting – see below.
Step 3. Complete a Block Inspection Report (see attached Block Inspection Report Form).
Step 4. Conduct public signing of the CLUA.
Step 5. Assist landowners to open a bank account.
Step 6. CLUA to be stamped by the Local District Lands Court and copies of the signed CLUA to be lodged with LLG Land Mediator, Lands Department and OPIC within 21 days.
Step 7. Complete an OPIC Planting Approval Form.

Each step is outlined below.

STEPS 1 and 2

OPIC Lands Officer to visit the village and conduct a community meeting with a majority representation from the landowning group with interest in the land proposed as a CRPB. At least 50% of members should be present at the meeting, including those individuals or families identified by the community with rights to deal in the land. The meeting should also have a good representation of women and younger members of the landowning group. At least one or two representatives from neighbouring landowning groups should be present. The community meeting should in the first instance:

1. Confirm that a majority of landowners with an interest in the land support the proposed CLUA. If a majority oppose the proposed CLUA, *no further steps should be followed and the land transaction should not proceed*.
2. Identify and record the individuals/families acknowledged and supported by the landowning group to have the rights, under customary law, to deal in the land proposed for a CLUA.
3. Confirm that the landowning group has the right to deal in the land and the land is not under dispute. If the land is under dispute, *no further steps should be followed and the land transaction should not proceed*.
4. Identify and record the names of members of the landowning group who have been authorised by the clan to be signatories to the CLUA. At least four members of the landowning group to be nominated signatories and should include the following: those recognised by the landowning group to be clan leaders and have an interest in the land; two male and two female clan leaders; the son or daughter of a clan leader, and; a representative from each of the sub-clans that has an interest in the land. A copy of the signatures of the four nominated signatories should be filed at OPIC.
5. Outline the terms and conditions of the proposed CLUA (these are listed in the standard CLUA form). Customary landowners with an interest in the land should be in a position to give Free, Prior and Informed Consent (FPIC) in accordance with RSPO principles. They should be made fully aware of their rights and restrictions on the land under the CLUA.

STEP 3

OPIC Lands Officer to inspect the proposed CRPB and complete a Block Inspection Report with the LLG Land Mediator, the proposed lessee and representatives from the landowning group and neighbouring landowning group. The GPS co-ordinates of the boundary should be recorded on the Block Inspection Report Form and a sketch plan of the land attached to the CLUA. If the Block Inspection Report is not approved by OPIC, *no further steps should be followed and the land transaction should not proceed*.

STEP 4

OPIC Lands Officer to hold a community meeting for the public witnessing of the signing of the CLUA (see attached CLUA). Signing the agreement should not proceed if less than 50% of clan members are present, including those individuals or families authorised and identified by the community to deal in land matters. Prior to signing the CLUA confirmation must be made that a majority of landowners with an interest in the land included in the CRPB have FPIC and support the proposed CLUA. If a majority oppose the transaction, the CLUA should not be signed and *no further steps should be followed and the land transaction should not proceed*.

If the CLUA is signed, five signed copies of the signed CLUA to be held by the customary landowning group, lessee, LLG Land Mediator, Lands Department and OPIC.

STEP 5

OPIC Lands Officer to assist the landowning group to open a bank account for depositing payments. Landowners should also be encouraged to nominate six members to a committee (termed Village Development Committee) who will oversee the disbursement of monies received from leased land in a way that benefits all members of the landowning group.

STEPS 6 & 7

CLUA to be stamped by the Local District Lands Court and copies of the signed CLUA to be lodged with LLG Land Mediator, Lands Department and OPIC with 21 days. An Oil Palm Planting Approval Form can now be completed.

OBLIGATIONS OF OIL PALM GROWERS IN ORO PROVINCE

Pauline Hore and Merolyn Koia
PNGOPRA Smallholders Supervisors, Dami and Popondetta
July 2009

Background

Oil palm smallholders follow a farming system that also involves a range of socio-cultural and economic strategies that influence the production of oil palm crop and hence the livelihood of the growers and their families. One such factor is cultural obligations (expectation or duty that must be met) of the growers, their families and the communities in which they live. Obligations are a very important part of the lifestyle of people and have a great influence on oil palm production.

Obligations can have a positive or negative or even a neutral effect on oil palm production. A positive effect can be to increase production to meet obligations such as church donations, bride price payments, funeral costs and compensation. The negative impacts happen when obligations lead to situations where block maintenance and harvesting are neglected. These can include families shifting labour from normal family routine activities and getting more involved in other non-oil palm activities. This results in less available time to do basic upkeep activities such as applying fertilizer at the right months or harvesting regularly. Meeting cultural obligations ensures that in times of hardship all the good deeds, especially cash and in-kind contributions, made to help each other will be reciprocated to benefit them and their children when they are in need. An understanding and appreciation of the different obligations in the cultural settings of the oil palm growing communities is a pre-requisite to develop intervention strategies that will enhance oil palm production in the smallholder sector.

The main objectives of this desk study were to:

a) Understand some of the obligations of oil palm growers in Oro Province.
b) Suggest intervention measures that can improve oil palm production and the livelihood of growers.
c) Predict likely changes in growers' livelihoods and the sustainability of the oil palm farming systems in the future
d) Suggest possible socioeconomic studies to improve oil palm production in the smallholdings

Procedures of doing the study

The writers are originally from Oro Province who come from families with oil palm blocks and have spent much time in the blocks with their families. Much of what is discussed here is drawn from their family background, personal experience and discussions with other working colleagues (OPIC, PNGOPRA and CTP) who also have similar backgrounds in smallholdings. The officers' involvement in OPIC field days, talking with smallholders during leaf and soil sampling activities, smallholders' pests and disease surveys and involvement of one of the officers in ACIAR-funded smallholder studies since 2000 are also important sources of information. Another important source of information is from listening and over hearing discussions amongst growers while standing in the queue at the ATM machines, in the shop and or at the bus stops waiting for PMVs. The discussion points were informally discussed with various OPIC extension officers and smallholders to clarify certain points.

Discussion

Growers' obligations are complex and are intertwined with their socio-cultural-economic livelihoods. To discuss this subject, and its effects on oil palm production, the obligations are grouped in seven categories (many overlap and are interrelated) and they include:

1.0 Individual obligations.

2.0 Family obligations (whole block).
3.0 Originality/ethnicity (LSS) obligations.
4.0 Block owners in a road and neighbours' obligations.
5.0 Family ties and inter-marriage obligations.
6.0 Church and religious obligations, including church and youth groups, mothers' union, etc.
7.0 Social groups e.g. sports groups, or just peer groups living along a road, etc.

1.0 Individual Obligation.

An individual obligation can be defined as an obligation that an individual in a block has to others. The individual can be the head of the family, his wife, his sons, his daughters and other relatives living with them on the block. In many cases the individual obligation can become a family/block obligation, such as bride prices and compensation payments.

An example is when a *Tambu* (son-in-law) is obliged to help his wife's immediate family to pay for one of his wife's younger brother's or sister's school fees as part of his contribution to assist his in-laws. This is common in Oro Province where the man has to help his in-laws contribute to school fees before the school year begins. He is obliged to do that so that the in-laws will have trust in him and also for him to prove to the family that he is capable of taking care of his in-laws. This will mean harvesting regularly before the school year begins. He also applies fertiliser on his block and does other up-keep activities before the next harvest is due. He probably will pay youth groups to help him during harvesting to make sure all the ripe bunches on all the palms are harvested. His wife will also assist by cooking food for those who help with harvesting and other tasks. She will also collect loose fruit, sell food crops and cooked food at the markets to purchase the basic household item. , The assistance the couple provides to the wife's family strengthens the relationship between this individual and his family with his in-laws. This often leads to "desperate" harvesting during the month before the school year begins, and parts of the block that are usually not harvested are also harvested at this time, resulting in more crop going to the mill. On the negative side, unripe black bunch harvesting can happen. Avoiding debt repayments is also common during this month when growers sell their fruit through debt-free block numbers.

Another common example of individual obligation is *dinau* (credit made from trade stores, beer sold in black markets, cash from money markets and chicken from broiler farmers, etc) which an individual is obliged to pay back in cash. A grower or a family member gets *dinau* on the condition that after the harvest he will pay back the *dinau*. This makes him harvest his block to meet the obligation, in addition to meeting his other normal requirements. In oil palm blocks with many adult family members and where harvesting is rotated between them, the individual will most likely avoid contributing to pay for inputs into the block (e.g. purchase of tools and fertilizer), because he wants sufficient cash to repay his *dinau* and meet his or her other needs. If the block has a company loan for tools, fertilizers or seedlings, the individual will sell the crop under somebody else's block number who does not have a company loan to avoid loan repayment. Here, none of the family members takes full responsibility for the block upkeep requirements and this affects production and loan repayments over the long term.

2.0 Family (whole block) Obligation

Family obligation is when the whole family or the block is required to meet certain obligations. The whole family/block is obliged to pay land fees to the Lands Department (LSS), company debts for tools, nets and fertilizers, replanting costs, funeral costs, bride price payments and compensation claims if it affects the whole family. Bride price and compensation payments can be seen as individual obligations but because of the cultural way of life, the whole family becomes involved and shares the responsibility.

For the land fees, the grower is responsible to pay at the lands office while the company debts (tools, fertilizers and replanting costs) are deducted from the Papa Card when the crop is sold to the milling company. For large families, irrespective of whose turn it is to harvest (where there is rotational harvesting), company debts will still be deducted from the Papa Card. This has created situations where members of the family sell crop under other *wantoks'* block numbers who do not have debts or under the Mama Card. This also means that none of the family member takes responsibility of inputs into the block and this affects the block productivity in the long term.

On many blocks, the families also work together to carry out crop husbandry practices and harvesting. However, when income from the crop is not shared fairly among family members this affects relationships within the family and can reduce co-operation in oil palm production. In many cases, family members have developed their own ways earning an income from non–oil palm activities to meet their obligations. Male members in the family often go to the plantations to look for jobs, seek employment as hired labourers on other people's blocks or become involved in other activities such as making home brew beer to sell and or putting up *dabarere* (dance/disco) in the village to make ends meet. Other family members will resort to food crop gardening to grow crops for sale at local markets. Sometimes this will lead to labour shortages for block upkeep, harvesting and collecting loose fruit. Labour shortages can also occur when hired labourers are not compensated adequately for their labour by the family/block owners, which can result in low labour inputs leading to poor maintenance and under-harvesting, thus lowering productivity in the long term.
Bride price payment is another non-oil palm activity where most of the growers co-operate to meet the bride price demand from the bride's parents. In Oro there are two types of bride price payments. The first payment is called *soupe or bel kol pei.* This happens when the man takes the woman to his parent's place and to show the bride's parents that he will get married to the bride. The man's family and friends will contribute cash and food stuff and two pigs and give them to the bride's parents. During the *soupei,* the family will also announce the real *davana* (bride price) which includes store goods and specifies the number of pigs to be given so that the man's family can prepare for the actual pride price ceremony. Oil palm harvesting will increase and saving will accumulate for the ceremonies. However, payments for farm inputs may be deferred and loan and debts repayments avoided: both of which will affect the long term productivity of these blocks.

Block owners and their families also have an obligation to assist neigbouring blocks when someone from the neighbouring block dies. The family/block and all the other growers and their families within the area contribute cash and food to support the *haus krai* (shelter for mourning). The *Haus krai* is typically built with coconut leaves or a plastic canvas and is erected in front of the deceased person's home where friends and relatives come to mourn the death. The *haus krai* will last for approximately a month or more, and during that time the block will not be harvested in respect of the deceased. Neighbouring growers will also miss harvest rounds as a sign of respect. At the *haus krai* food will be served to people who attend the mourning. Food preparation, chopping and collecting of fire wood, and fetching water will be done by the family members of the deceased and by people from neigbouring blocks.

After the burial, a date will be set to remove the *haus krai* and at the same time host a *pondo* (feast) to show appreciation to those who supported the family of the deceased through the mourning period. The family members of the deceased person will normally allocate a task to every member of their family to buy certain items for the feast, which will include pigs, chickens, bags of rice, canned fish, sugar, and garden food such as taro, bananas and yams. Each family member will be allocated a harvesting round to earn sufficient income to buy the items which they need to contribute to the feast. This often means that some of their friends from neighboring blocks will "Sunday" or allow the relatives of the deceased to harvest ripe bunches from their block. This assistance often extends to offering for the feast a pig a 5/10kg bag of rice, taro and bananas as part of their contribution and also as insurance for the future if they happen to be in a similar situation.

At the time of the feast, the family members of the deceased person will remove the *haus krai* and burn it, distribute the cooked sweet potato and pigs and packets of rice, tinned fish, bananas and taro to everyone who supported them during the mourning period. Persons involved in the actual burial (if he is from another family) will be given a pig as a sign of appreciation for his help. When the son of the deceased buries the body he will be repaid with pigs, yam and taro as sign of friendship. Once all the debts have been repaid, the immediate family of the deceased will host a small appreciation meal to thank everyone for making the *pondo* (feast) a success.

The whole series of activities have many implications for oil palm production ranging from the temporary abandonment of a block (no harvesting) to delayed harvesting, skip harvesting to 'desperate' harvesting. In many situations because of the pressure on the need for cash, crop is sold under the neigbours' block numbers who do not have company debts to avoid loan repayments and by doing so, very little or no savings for investments are made. Implications here are that in the long term, yields drop or are low and worsen the pressure for cash in future.

3.0 The Originality /Ethnicity (LSS) Obligation

Growers from the same ethnic group or home areas will tend to assist each other when there is a need, even if they live in different parts of the LSS. Assistance ranges from bride price payments to mourning for a death and helping a family to meet compensation claims.

Growers on the LSS blocks, despite being from different parts of PNG and from different ethnic backgrounds, have adopted the culture and lifestyle of local Orokaiva people. Many of the families are now in the 3rd and 4th generations. There is a lot of intermarriage with the Oro people and this has influenced the cultural values of settlers. Many of the LSS blocks are located close to the traditional landowners and many growers have friends in the neighbouring villages. The settlers, by taking part in the village activities receive support from their friends in the surrounding villages when there is a problem in the LSS blocks.. Children from the LSS blocks also attend the same schools as the children from the neighbouring villages. All these factors have influenced settlers to adopt Orokaiva culture and customs. For example, a grower or descendent of a Sepik migrant on a LSS block who beats his wife over some argument and she runs away to her parents' house, he is obliged to settle the problem by taking some cash, a live chicken or pig to the wife's family. In this way, he apologies and only then is he able to take his wife and children back to his house. This is an Orokaivan custom.

Therefore many customary obligations that apply to the local people and the factors that affect block productivity also apply to the settlers. Most of the hard-earned cash from oil palm is spent on such related obligations besides meeting basic household needs.

4.0 Block Owners in a Road and Neighbors' Obligations

Over the years irrespective of ethnic origin, LSS settlers living along a road or from neighbouring blocks have formed social groupings that bind them together in a network of reciprocal obligations. This is more common amongst 2nd and 3rd generations of oil palm growers. For example, a block owner in a road and the neighboring blocks are obliged to settle a compensation claim where youths stoned a PMV bus after consumption of home brew. The growers, as discussed earlier, also contribute to help other families on the road for bride price payments and funeral costs. The effects on production are similar to those mentioned under the same section above.

5.0 Family Ties and Inter-Marriage Obligation

Inter-marriage is bringing many families together. Family ties and groups related through marriage are obliged to contribute cash and food for bride price payments for a son of a LSS grower who marries a woman from the customary landowning group where their blocks are situated. They also come together to contribute to *haus krai* and assist in other issues. Such obligations place a certain pressure on how income earned from the palms is distributed.

6.0 Church and Related Religious Obligations.

Christianity is a very important part of the life of oil palm growers both in the LSS and VOP schemes. There are many different religious groupings within the communities, each with various structures including youth groups, women's union, Sunday Schools, Ministry groups, etc. Each group expects its members to contribute to normal Sunday offerings and other special offerings such as the construction of a new church, donations to youth groups and/or the mothers union, and attend conferences and crusades. Each of these groups has expectations that church members will contribute towards their costs.. The youth and ministry group may require funds to purchase sporting equipment or musical instruments for the church. This requires church members who are block holders or their dependants to contribute towards the costs. Church members at times also mobilize labour for hire so that funds can be raised, and organise exchange baskets where members buy gifts for others and exchange. There are also church days where church members are divided into groups and expected to raise funds to meet the costs of a particular project such as the construction of a new church building or a *Sande Skul* classroom. These expectations place a lot of pressure on the church followers to meet these costs and the pressures are transferred to the oil palm blocks. There are also opportunities for labour-short blocks to utilise labour from church groups for block maintenance.

7.0 Social Groups such as Youths and Sports Groups

There are also organised sports in the smallholder oil palm settings. Teams can be from a division or made up of growers living along the same road. Teams require uniforms, club registrations, etc, and team members need to raise funds, usually by contributions from the team members. These financial pressures can therefore stimulate oil palm production.

General discussion

An appreciation of the various obligations described above is very important for enhancing crop production in the smallholder blocks and improving growers' livelihoods. Identifying the groups within the community is important for fully utilizing their labour for labour-short blocks. Also, through understanding these obligations, extension services can be better targeted to meet the needs of identified groups.

Flexibility within the payment system to allow for credit facilities for fertilizers and costs of tools will ease many of the growers' burden. Savings facilities for customary obligations will also be very useful to pay for funeral costs, etc. There is little or no savings or investing back into the blocks because in many situations, spending income earned from the oil palm on socio-cultural obligations takes precedence.

Improving food farming activities for food security is important to meet other requirements in terms of food contributions and cash earnings so that less pressure is placed on cash earned from oil palm.