Annual Research Report

2007

PNG Oil Palm Research Association Inc.
Dami Research Station, P.O. Box 97, Kimbe, West New Britain Province, Papua New Guinea
Tel +675 9854009 • Fax +675 9854040 • enquiries@pngopra.org.pg

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Dami Research Station, P.O. Box 97, Kimbe, West New Britain Province, Papua New Guinea
Telephone +675 9854009 & 9854015 ◆ Facsimile +675 9854040

Report by the Managing Director
August 2008

The Papua New Guinea Oil Palm Research Association Inc. (PNGOPRA) is that part of PNG's National Agriculture Research System (NARS) responsible for providing research, development and technical support for the country's oil palm industry. PNGOPRA was formed in 1980 to provide research services to Papua New Guinea's relatively new expanding oil palm industry. The Association was created and resourced around the need to address specific research issues.

Since PNGOPRA's formation in 1980, PNG's oil palm industry has grown in both area and production eleven-fold (1,100%). The demands on PNGOPRA, in both scope and scale have increased in-line with the growth of the industry and the increase in technical and development issues. The original resourcing arrangements, although very efficient and appropriate for a relatively small industry, have not significantly changed and have led in recent years to an increasingly serious capacity constraint for the Association as a service provider. A recent independently-facilitated 'capacity needs assessment' identified PNGOPRA as being a highly efficient and highly competent organisation but with a significant lack of capacity. This lack of capacity is due to an inability to develop sufficient staffing levels and this is the direct result of a shortage of available housing, office and laboratory facilities.

PNGOPRA's resourcing issues are symptomatic of a lack of appropriate support to PNG's agriculture sector. Firstly, Government technical and particularly financial support to the agriculture sector has, for a very long time, been inadequate. Secondly, what public resources are allocated to the agriculture sector are poorly apportioned and do not reflect the current balance and activity within the sector; the major failing is one of prioritization when it comes to resource allocation. The Government's Medium Term Development Strategy (MTDS) wisely focuses on export driven economic recovery. The current export value of oil palm products is almost equal to the total combined value of the other major agricultural exports; however allocation of public resources to the services and infrastructure necessary to support the oil palm sub-sector are significantly less than that provided to the other major components of agriculture in PNG. In fact the balance of resource allocation to the agriculture sector has more in common with the situation in the 1970's and 80's than agriculture in the 21st century.

The oil palm industry in PNG is set to at least double in size over the next 10-years. In order to effectively support the oil palm industry and address the needs of all stakeholders, it is necessary for PNGOPRA to develop a strategic development plan for the next 10-years based on comprehensive stakeholder consultations. This process started during 2008, and it is expected that it will lead, during 2009, to significant scoping and resourcing changes that will better position PNGOPRA to support the sustainable growth of PNG's oil palm industry.

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

Table 1. PNGOPRA Members Voting Rights in 2008:

Member	FFB Production in 2006	Votes
New Britain Palm Oil Limited	744,271 tonnes	8
CTP (PNG) Ltd	525,358 tonnes	6
Hargy Oil Palms Ltd	180,122 tonnes	2
Oil Palm Industry Corporation (*smallholders*)	719,443 tonnes	8
Ramu Agri-Industries Ltd	n/a	1
Managing Director	n/a	1

PNGOPRA is very much stakeholder demand-driven. 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 2008 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 2008 is K 4.85 million. The Member's levy finances 87.3% of this expenditure and external grants 12.7%. The Member's levy is set at a rate of K1.77 per tonne of FFB for all growers. In 2008 organisation spending is distributed as 52.2.3% agronomy research, 16.3% entomology research, 9.2% plant pathology research, and 22.3% 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

The research programme of the PNGOPRA is structured to meet the needs of the oil palm industry as a whole. The Association's Scientific Advisory Committee, on which all Members are represented, 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 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 conduct 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 (*NBPOL*) about 10-years prior to the formation of PNGOPRA in 1980. NBPOL continues to run its highly successful and profitable plant breeding and seed production operation, which is producing some of the best oil palm seed material in the world.

Agronomy Programme

The bulk of the agronomy work is focused on crop nutrition related issues. Fertiliser trials comprise most of the field trials at all centres. The focus of the work is to identify realistic production targets as determined by a range of inputs which have an 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 has declined sharply again in August 2008. The combined effect of increasing cost through higher fuel and fertiliser prices and the fluctuating price for palm oil make the economic responses to fertiliser applications even more important.

Fertiliser trials

Most of PNGOPRA's fertiliser trials were established over the last decade and are large-scale factorial trials. One new N x K trial using a Central Composite Design (*see Verdooren in Fairhurst and Hardter, 2003*) was established at Milne Bay, several others are planned for 2008. These Central Composite Designs are usually smaller trials (*fewer plots*) and are designed specifically to elucidate fertiliser responses to a range of inputs. It is envisaged that most new fertiliser trials planned for 2008 and 2009 will have this design. Rob Verdooren is consulting to PNGOPRA and Dr. Verdooren's input will clarify and overcome many of the statistical issues encountered in the past.

Spacing trials

There are currently three spacing trials undertaken by the Agronomy group (*one each with 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. Discussion is taking place to investigate the opportunity for smallholders to establish food gardens or other cash crops if palms are planted on wider avenues (*increasing the width of the avenues but increasing the planting density within the row*). This work may develop into a future project.

ACIAR funded Cation project on Volcanic Soils

This project was completed in 2007 and a short extension to determine the 'leachability' of cations and anions on deep volcanic soils was carried out late 2007 into early 2008, and is now completed. The work is currently being written up as a final report to the funding agency and will be reported on fully in the 2008 PNG OPRA Annual Report.

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. The project was undertaken by Murom Banabas for his successfully completed PhD studies. A full report can be found in the PNG OPRA 2006 Annual Report.

Communication

Quarterly reports on yield achievement for selected trials were prepared for plantation managers throughout 2007/08. These reports can assist plantation managers to review plantation block yields against trial yields and make appropriate management adjustments.

Training

In 2007 training was undertaken at all plantations. Most of the training focused on oil palm agronomy; tissue test interpretation; economic return from fertiliser; and identifying Frond 17 (*used for tissue analysis*). Training was also undertaken with OPIC at Popondetta and Hoskins.

Entomology Programme

Pollinating weevils

This EU funded project was completed and the final report was submitted in August, a scientific paper is in preparation utilising part of the data sets collected.

Routine weevil monitoring on the mainland in Oro continued, and nematode populations remained relatively constant, although at Heropa there was a large peak in nematode infections in March, which continued through until July after which infection rates dropped. The effects of cyclone Guba meant that monitoring ceased after November.

The weevil stocks (*PNG and Ghana*) were being maintained in the PNGOPRA quarantine facility, and cross breeding experiments to ensure viability continued before permission can be granted by the relevant authorities in PNG to undertake release.

Integrated Pest Management (IPM)

Entomology work continued to improve pest management decisions against oil palm pests within the framework of IPM.

"PNGOPRA Entomology remains fully committed to the principles and practices of IPM for the management of pests and diseases to keep pests below their economic injury levels (EIL).

Pest monitoring is considered an essential component of PNGOPRA's strategy, and currently targeted insecticide application through trunk injection is only recommended when pest levels pose a serious threat, while other options are being explored.

IPM is utilised to provide an overall, yet continually evolving, approach to the management pest infestations, utilising options available which take fully into account human and environmental safety, and socio-economic considerations."

With regular field surveys for the presence of sexava eggs at the base of palms in areas of infestations, data on the development of field populations are being collected. Parasitoids of the sexava eggs are being reared in the laboratory. During the year, approximately 181,356 *Leefmansia bicolor* and 1,654,564 *Doirania leefmansi* were released into many locations at both plantation and smallholder growers' sites where low-levels of sexava were present.

Work to continue to encourage the spread of the internal parasitoid of sexava, *Stichotrema dallatorreanum* but this insect has continued to prove difficult to establish in the Central & West Nakanai (*although it is established at Kapiura*) areas of West New Britain. *Stichotrema* infection levels in *S. novaeguineae* were reported in all months except November and December. During June 2007, samples of *S.gracilis* collected at Lakurumai on New Ireland were found to be infested by *Stichotrema* this is a major step forward (*see Annual Research Report for 2006*).

Pest outbreaks

Visits to all reported pest infestations, and subsequent provision of control recommendations (*PestRecs*) remained a high priority during 2007. Infestation reports from the two dominant taxa (*sexava and Eurycantha*) accounted for 91.8% of all pest reports in West New Britain (*not including Ganoderma or natural causes*). Stick insects on the mainland caused serious damage, and reports of *O.centaurus* were also investigated. Small outbreaks of bagworm were also reported in West New Britain. Other pest taxa were insignificant.

The Stick insect (*Eurycantha calcarata*), still remained a serious pest, and a detailed biological study is still in progress. Although parasitoids were reared from this species, numbers were too low to be of possible use for bio-control. Other pest taxa are routinely collected during field visits, as part of the on-going addition to the inventory of insects of oil palm in PNG, as well as for training purposes. As a part of PNGOPRA's close links with smallholders and plantation, monthly meetings of the 'Pest Action Group' (*PAG*) continued to be held at Hargy Oil Palms in Bialla, and weekly meetings were held at the Nahavio OPIC offices (*Hoskins Project*).

Infestation database development was continued

Technical assistance

Routine monitoring of insect trap catches at the NBPOL seed production unit continued as part of a phyto-sanitation initiative at OPRS Dami Seed Production Unit. No potential vector taxa were identified.

Bi-monthly monitoring and sampling of oil palm nursery pests was undertaken on the mainland at Higaturu. Prophylactic spraying of the nursery palms continued in some plantation nurseries in PNG during 2007. This approach is actively discouraged by PNGOPRA.

Finschhafen Disorder (FD).

Due to delays beyond our control, this project did not start until late October 2007. A short visit was made by the newly appointed Post-doctoral research Fellow and the project Leader from Australia, field visits were made to West New Britain, and specimens of *Z.lobulata* collected for taxonomic and biochemical analysis (*bar-coding*), and parasitoid material reared.

Queen Alexandra's Birdwing Butterfly (QABB).

In conjunction with James Cook University in Australia, an interim report was produced on the early stages of the analysis of the plant chemicals relevant to QABB ecology and sent to Conservation International. At OPRS (*NBPOL*), QABB larval food vines were now being experimentally propagated by the technique of embryo rescue. Attempts to take these processes further and propagate plants from leaf cuttings will be made in 2008, when additional funding is secured, and when reliable protocols for propagation are developed.

Biological control of weed pests.

The project on the biological control of *Mikania micrantha* was agreed, and PNGOPRA took on an active collaborative role in West New Britain, a shade house was built at Rigula ME with the support of NBPOL, and was ready to receive the infected vines for propagation and release when they are cleared for importation into PNG.

Training

There was continued support by the entomology team for OPIC's farmer field days, which are expected to increase in number during the coming year. A series of radio programmes aimed at presenting extension messages were organised by OPIC in West New Britain; unfortunately none have been arranged for mainland PNG.

Pest recognition

The pest recognition display-boxes were almost completed, and those 36 remaining only need specimens of *Oryctes* before they are distributed. Outstanding requirement for *R.bilineatus* (*Black Palm Weevil*) specimens were all received.

The application to NAQIA, in March 2006, for the inclusion of sexava species and stick insects to be gazetted as Notifiable Pests is still outstanding, in spite of frequent prompts.

Plant Pathology Programme

The Plant Pathology Section is responsible for research and technical support on the control of diseases affecting oil palm in PNG. Basal stem rot caused by *Ganoderma* is still the main disease threat. Efficient management of basal stem rot (*BSR*) is the only means of ensuring that oil palm plantings are sustainable into the future. PNGOPRA's plant pathology research programme therefore continues to focus on the control of basal stem rot through the use of cultural methods, biological agents as well as exploiting the natural resistance in oil palm.

Funding for research in 2008 was provided by Member's levies as the EU Stabex Project funding ended in 2007.

Disease epidemiology

The epidemiology of basal/upper stem rot and the population structure of *Ganoderma boninense* continued to consume the bulk of resources in terms of time and funding in 2007. Sample collection for the research on the population structure of *Ganoderma* in selected study blocks in Milne Bay and West New Britain was completed in December 2007. It is expected that genetic analyses will carry over into 2008.

The collection of epidemiological data through surveys and sampling of the *Ganoderma* population has become a routine task. Collection of disease data is essential for the efficient management of stem rots in the future. The plant pathology team works closely with the plantations to ensure that survey data is collected and collated for immediate and future reference.

Temporal disease data indicated a continued steady increasing trend in disease rates in all areas where *Ganoderma* is prevalent in 2007. In Milne Bay, disease levels are approaching 14% in the oldest plantations (*1986*) in Milne Bay that are now undergoing replanting. The range for Milne Bay is 1.79-13.6%. Disease levels at Numundo in WNBP are now almost 20% in the oldest plantings (*E fields*). Disease rates did not vary significantly from the previous year and yield calculations indicate that compensation is still occurring at 18% infection levels.

Levels of infection at Poliamba in New Ireland ranged from 1.4% to 9% in 2007.

Although control of the disease through surveys and sanitation (*roguing*) is an integral part of plantation management in these areas, sanitation efficiency continues to be a concern. In 2007, most plantations did not complete sanitation rounds by the end of the surveys. Further emphasis and effort will need to be placed in this area.

The efficiency of rouging is extremely important in the biological context because of the continuous diversification of *Ganoderma* through sexual recombination of spores in the immediate environment.

Removal of inoculum sources i.e. infected palms efficiently and rapidly will reduce the probability of out-crossing and selection for more aggressive strains. Unfortunately, it is difficult to demonstrate the effects of rouging on disease levels in the short-term and hence this concept is usually ignored.

The research into the genetics of *Ganoderma* will cease in 2008 although sample will continue to be collected and stored for future reference.

Biological control

Safe and cost-effective methods are being pursued for the control of *Ganoderma*. Since 2006, research has been intensified into the systematics and behaviour of indigenous *Trichoderma* species against *Ganoderma*. The laboratory research has been completed and candidate isolates have been identified for further studies. Small-scale testing of different methods to generate *Trichoderma* spores for use as biocontrol agents has begun and the first round of field trials has been completed. The results of these trials indicated that further laboratory work on the production of biomass is required. Nursery trials will also precede field trials in the next stage of work.

Most of this work is targeted towards a low-cost method for smallholders but it is not anticipated that it will alleviate the need for roguing in heavily infected blocks.

Host resistance

The search for resistance or susceptibility to basal stem rot in the oil palm germplasm continues to be an important long-term goal. This work is carried out in collaboration with oil palm breeders from which seed of different progenies is supplied. Progress in 2007 has been slow due to the necessity of supplying specific palm populations that might allow phenotypic differences to be identified. Nursery screening is now underway and will continue as the appropriate seed lines are supplied.

Field trial sites have been identified in the Solomon Islands at GPPOL and trial designs are being finalised. Application for external funding has been made to implement and monitor the trials but at this stage no confirmation has been obtained. It is envisaged that this project will commence in January 2009. Seed for the trials is already being prepared and will be nursed in 2008 ready for planting in 2009.

Technical Services & Training

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

Training and technical services were provided to OPIC, smallholders and plantation personnel at regular intervals in 2007.

Smallholder Socio-economic Studies

Labour supply constraints are the primary cause of under-harvesting and low smallholder productivity. Constraints on the supply of labour lead to the under-utilisation of family or caretaker labour and the minimal supply of hired labour. Labour supply constraints also mean that potential yield increases from farm inputs are not realised. The absence of a market in hired labour has severely constrained the income opportunities of young men and women from highly populated blocks while at the same time limiting the productivity and incomes of labour-short blocks, with the result that approximately 25% of the crop is not harvested. The constraints on the supply of labour are due largely to the reluctance of people to provide labour because of inadequate, uncertain or disputed remuneration of their labour.

In 2003, trials were setup to investigate the 'Mobile Card' payment initiative amongst Hoskins oil palm growers, which was designed to mobilise labour on conflict-ridden and labour-short blocks. Instead of smallholders making cash payments for labour, payment was in oil palm fruit with specified proportions of the value of the harvested fruit being paid into the bank accounts of the worker and smallholder, with the transaction handled by the extension service (*OPIC*). The Hoskins trials proved very successful and in 2006 the 'Mobile Card' trials were extended to Bialla in West New Britain.

The Bialla trials are now complete and the final report has been prepared, and also included in PNGOPRA's 2007 Annual Research Report.

The 'Mobile Card' has been effective for three reasons. First, it gives confidence to workers that they will be paid in full and in a timely manner for work completed. Second, it provides a mechanism for overcoming the difficult problem that blockholders have retaining cash for the payment of labour. Third, by formalising in a contract the roles and status of both blockholder and worker, the Mobile Card helps ameliorate blockholders' fears that the recruitment of labour is a threat to their tenure rights.

Technical Services

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.

Ian Orrell
Managing Director
August 2008

1. AGRONOMY RESEARCH

Overview of Research and Communication programs

(Dr. Harm van Rees)

The key to maximising the economic return from well managed oil palm for smallholders and plantation managers is to understand the likely return from inputs such as fertilizer.

In addition to the bottom line of profitability, the industry is increasingly committing itself to protecting the environment. One of the major areas of research for minimising the impact of palm oil production on the environment is the study of nutrient loss from both fertilizer inputs and from by-products produced during the milling process. Understanding the nutrient dynamics of palm oil production, and developing appropriate management strategies is the main task of PNG OPRA Agronomy Section.

The priorities of the Agronomy research program are to:

- Determine optimum nutrient requirements for oil palm grown in different areas (where optimum is defined as the type and level of fertilizer required for greatest economic gain with the least amount of negative environmental impact);
- In those areas where fertilizer responses are not clear, to work on understanding the processes within the soil which influence and regulate plant nutrient uptake so that remedial strategies can be investigated to optimise oil palm production;
- Communication to assist small holders and plantation managers to achieve their goals in oil palm production through: (i) the provision of timely information on trial results, and (ii) training in agronomic principles and management.

MAIN TOPICS OF RESEARCH

(i) Nutrient Cycling and Soil Fertility

Five years ago several major projects commenced. The first two concentrate on the retention and loss of nitrogen and magnesium on volcanic ash soils, these projects have attracted donor funding.

1. 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 fertilizer application. The project has been completed and was carried out in collaboration with Massey University, New Zealand with financial support from the European Union. The project was undertaken by Murom Banabas his PhD studies which he successfully completed.

The results of the project were described in detail in the PNG OPRA 2006 Annual Report.

2. Cation nutrition on volcanic ash soils

The 'Magnesium nutrition' project is being carried out in collaboration with the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and James Cook University, Australia, with financial support from the Australian Centre for International Agricultural Research (ACIAR). It relates to the cation nutrition problems experienced on the volcanic ash soils that support most of PNG's oil palm crop. Widespread and serious magnesium deficiency symptoms have been identified in oil palm growing on the young, coarse-textured, volcanic ash soils in West New Britain and parts of Oro Province. The problem occurs on all types of holdings (large plantations, village oil palm and land settlement schemes). In this project, potassium deficiency is also being addressed in parts of West New Britain, Oro Province and Milne Bay Province.

This project was also completed in 2007 and a short extension was granted into early 2008. The final report is now being prepared and the complete results of this project will be presented in the PNG OPRA 2008 Annual Report.

3. Maintaining soil fertility

Our research now focuses on understanding the ways in which nutrients are retained and lost from the system, and how retention and losses are influenced by management. The ability of soils to retain and supply nutrients varies enormously within plantations and between different soil types, and is also influenced by management. From recent results it is becoming clear that soil organic matter and soil pH is the key to nutrient retention in most of our soils. For example, one of the negative impacts of using ammonium-based fertilizers is an acidification of the soil, which is significantly reducing the capacity of our soils to retain and supply cations such as potassium and magnesium. Soil pH and soil organic matter are both amenable to management - what we need to know is the critical processes and the economics of influencing them. We are continuing to seek sources of funding for this work through collaborative project proposals with Australian research bodies.

4. Nutrient budgets and nutrient use efficiency

We have started to monitor total nutrient content within palms (trunk, FFB and fronds) to estimate nutrient uptake and efficiency. Combining the information of nutrient content in the trunk and in FFB together with routine foliage nutrient level determination will allow us to calculate NUE and fertilizer recovery in our fertilizer trials and will form part of a strategy to investigate the overall management of nutrients in plantations.

(ii) Fertilizer Response Trials

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.

West New Britain Province (NBPOL)

Soils are volcanic of very recent origin, highly permeable and express a range of problems associated with cation availability (discussed above). The main fertilizer response trials with NBPOL deal with either identifying optimum and economic N inputs or developing strategies to minimise the effect of Magnesium deficiency. Over the last few years trial size has increased, and some trials now incorporate whole blocks. Some traditional factorial trials where a range of inputs can be investigated are maintained.

West New Britain Province (Hargy Oil Palm)

Most of the soils on the Hargy Oil Palm plantations (Hargy and Navo) are also volcanic of recent origin but because the mineralogy of the ash from the volcanoes is different to those where NBPOL is located and the responses to fertilizers are likely to be different. At Hargy the trials consist primarily of factorial trials where a range of nutrient inputs and rates are investigated, but we also have two N systematic trials enabling a better assessment to be made for N requirements.

Oro Province (Higaturu Oil Palm – CTP Holdings)

At Higaturu Oil Palm the soils are both alluvial and volcanic in origin. Especially on the Mamba plantation the volcanic soils are more common. The issues at Higaturu deal primarily in determining optimum fertilizer rates and there are trials with N, P and K rates as treatments. At Mamba work similar to the cation work undertaken on volcanic soils in WNB is also carried out. New trials investigating Progeny x Nutrition interactions were established in 2007/2008.

Milne Bay Province (Milne Bay Estates – CTP Holdings)

In Milne Bay the soils are primarily alluvial in origin. Some of these soils are well drained others suffer intermittently from water logging especially during the wet season. Factorial trials with N, P and K in conjunction with EFB (Empty Fruit Bunches) are the main fertilizer trials at MBE. A new trial investigating more closely the tie-up of K by alluvial soils was commenced in 2007.

New Ireland Province (Poliamba Estate – CTP Holdings)

N, P and K factorial trials were a feature at Poliamba, however the focus is now more on Boron and the need for K fertilizer. Ganoderma is a major problem at Poliamba and work has continued to reduce the impact of this disease.

RAI

New trials were established in 2004 and 2005 in newly planted plantations. Harvest of the trials commenced in mid 2007. PNG OPRA has established an office at RAI in June 2007 and has commenced a full monitoring program of the trials.

(iii) Other Factors

Most of our research is in the area of nutrition. However, we have some research on spacing and thinning for mechanical in-field collection, and research on the interaction between agronomic and socio-economic factors affecting smallholder productivity.

(iv) Predictions and Recommendations

All our research is targeted at improving predictions and recommendations for the industry. However, we also carry out some work to improve the way we can translate research results into improved recommendations.

Results are also starting to flow from our yield monitoring and prediction studies. The gross effect of annual rainfall on annual yield 2 years later has been evident in trials in all four provinces; these trends appear to be continuing. Studies in short-term prediction commenced in Oro, Milne Bay, Poliamba and RAI. This approach provides a 5 to 6 month yield estimation based on time of flowering (anthesis).

(v) Smallholder work

Smallholder samples in several provinces are being collected each year. As data is accumulated, it will be analysed in relation to fertilizer application and yield response. This information also has the potential to fine-tune the AIGF-funded Site Specific Fertilizer Recommendations project.

Together with OPIC several smallholder blocks have been used to demonstrate better management practices including timely pruning, weeding, harvest standards and fertilizer use.

COMMUNICATION ACTIVITIES

The PNG OPRA Agronomy Team is actively involved in communicating the results and knowledge gained from the trial work undertaken on behalf of the plantations and smallholders. The major communication activities are:

(i) Adoption of trial results

The primary focus for PNG OPRA Agronomy communication activities is to get the results from the trials out into the field. Both plantation managers and smallholders can benefit from the trial results by comparing trial treatments and associated FFB yield to their own fertilizer practices and yield. If there is a difference between trial yield and plantation or smallholder yield it usually means that the difference in yield can be made up by adopting the fertilizer applications as was used in the trial. The PNG OPRA Annual Report fulfils part of the requirement for making trial results available to both plantation managers and small holders (through OPIC).

In addition to the Annual Report, the Agronomy team sends a quarterly report to all plantation managers outlining the yields achieved in some of PNG OPRA's trials specific to a plantation. The quarterly report details the yield achieved over the last 3 months and the last 24 months and outlines any specific problems and interpretation. Plantation managers can easily compare trial to plantation yields using the data collected in OMP8.

(ii) Training

Detailed training notes for managing and monitoring oil palm have been prepared. Training consists of a combination of 'class room' and 'in the field' training activities which are always concluded with a test. Each participant is tested for both the theoretical and practical knowledge gained during the training activities.

Training modules include:

- Basic oil palm agronomy (eg. Nutrient cycles, soil fertility, fertilizer use and management);
- Interpretation of tissue results and calculation of fertilizer requirements and amounts;
- Nutrient deficiency symptoms (eg. Identifying nutrient deficiencies in the field);
- Identifying frond 17 (eg. Frond 17 is used for tissue sampling and the correct identification of this frond is essential for the right interpretation of tissue test results for fertilizer requirements);
- Preparing frond 17 (eg. Choosing the right frond is important but of equal importance is strict adherence to sample preparation guidelines before they are sent to the laboratory);
- Frond production counts (eg. Knowing how many new fronds are produced per year is an excellent benchmark for assessing how the palms are growing and whether they are receiving the right fertilizer mix);
- Vegetative measurements (eg. The three critical criteria for assessing vegetative growth are how many fronds are produced (see previous); the Petiole Cross Section; and the Leaf Area Index; when these three criteria are assessed on an annual basis the long term health of oil palm in a block can be monitored).
- Flower and bunch recording (eg. Yield forecasting is critical for managing operational issues and marketing of product; there is a strong link between the number of female flowers formed and FFB yield produced in the future);

Training notes for some of the above modules are also currently available in Tok Pisin, the intention is to have all the training material provided in both English and Tok Pisin.

(iii) Smallholder field days as organised by OPIC

PNG OPRA agronomists and supervisors contribute at OPIC organised smallholder field days at all the major centres. Contributions at these field days range from a description of what fertilizers do and how they should be used, to identifying nutrient deficiencies to insect control strategies (through the PNG OPRA Entomology group).

A smallholder booklet outlining best management practices has been prepared and is ready for printing. This booklet will support many of the field activities in oil palm management extension.

Agronomy Staff

I like to sincerely thank all of our hard working staff from Agronomists to Field Staff. The amount of work and the dedication you show to your work is commendable. Without your input and hard work it would be impossible to put this Research Report together. You are all making a significant contribution to the welfare and productivity of the Oil Palm Industry in Papua New Guinea.

Thank you Harm van Rees

Head of Agronomy

Dr. Harm van Rees

Senior Agronomist

Dr. Murom Banabas, Higaturu

Agronomists

Ms. Rachael Pipai, NBPOL

Mr. Winston Eremu, Hargy

Mr. Steven Nake (on study leave at JCU, Cairns, Australia)

Ms. Susan Tomda, Higaturu

Field Supervisors

Mr. Paul Simin, Poliamba

Mr. Graham Bonga, Higaturu

Mr. Wawada Kanama, Milne Bay

Mr. Kelly Naulis, RAI

Ms Pauline Hore, NBPOL

Mr Graham Dikop, NBPOL

Mr Solomon Sotman, Hargy

Mr Levi Tiriau, NBPOL

Data management and IT

Ms. Carol Cholai

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 towards the end of this year and into 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.

Hargy Oil Palm Ltd: Synopsis of 2007 PNG OPRA 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)	EFB LN 2.39 to 2.42 RK 0.98 to 1.27 TSP LP 0.141 to 0.146 RP 0.06 to 0.09 KIE LMg 0.17 to 0.19	PCS 52 to 58 FP 22 (NS) LAI 6.4 (NS)	Low in N (increased basal N rate on half of trial in 2007)
209 Hargy SOA, TSP, MOP, KIE (factorial) Soil: Volcanic	13	SOA 32 to 38 TSP 32 to 37 MOP 33 to 37 SOA x TSP high 40 KIE (NS)	B/palm 11 to 14 SBW 20 to 21	SOA LN 2.19 to 2.37 RN 0.24 to 0.26 TSP LP 0.132 to 0.141 RP 0.06 to 0.11 MOP LK 0.65 (NS) RK 0.98 to 1.44 KIE LMg 0.14 to 0.19	PCS 44 to 50 FP 22 (NS) LAI 5.5 (NS)	10 t/ha increase in yield compared to 2006 – most likely due to improved crop recovery
213 Hargy AN, TSP(factorial) Soil: Volcanic	10	AN 17 to 23 TSP 16 to 23 AN x TSP 13 to 26	B/palm 5.7 to 8.7 SBW 16 to 20	AN LN 2.36 to 2.50 RN 0.21 to 0.25 TSP LP 0.130 to 0.155 RP 0.03 to 0.05 LK 0.59; RK 0.46 LMg 0.21; LB 15ppm	PCS 36 to 40 FP 22 (NS) LAI 5.7 to 6.2	K is low in tissue (leaflet and rachis). To optimize production this site needs more MOP as a basal.
211 Navo AN (Systematic) Soil: Volcanic	9	3.0kg AN 36 to 40	B/palm 17 to 18 SBW 19.3	AN LN 2.40 to 2.60 LP 0.141; RP 0.05 LK 0.80; RK 1.60 LMg 0.17; LB 17ppm	PCS 42 (NS) FP 23.5 (NS) LAI 5.5 (NS)	Large increase in yield in 2007 compared to 2006. Response to N fertilizer increasing over time. P in rachis low (applied basal TSP)
212 Hargy AN (Systematic) Soil: Volcanic	10	AN 24.2 to 31.1	B/palm 9.1 to 10.7 SBW 19 to 21	AN LN 2.21 to 2.42 RN 0.22 to 0.24 LP 0.140; RP 0.035 LK 0.70; RK 1.15 LMg 0.18	PCS 43 to 50 FP 20 to 21.5 LAI 5.5 to 6.4	LP 0.140 RP 0.03 (very low) Applied basal TSP.

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
4. Economic return from different fertilizer strategies were calculated and presented at a workshop for Hargy management in 2008

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

SUMMARY

The application of Triple Super Phosphate (TSP), kieserite (KIE) and empty fruit bunch (EFB) has resulted in little or no yield response over the last 4 to 5 years. In some years, such as 2006 and 2007, 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. However, the overall N status of the palms at the trial site is low (mean leaflet N: 2.40; and rachis N: 0.26% dm).

If N fertility is low, crops cannot respond to other nutrients as applied by fertilizer. N deficient crops cannot reach their full productive potential.

In late 2007 the basal application of N (previously applied at AC 3kg/palm) was increased on half the number of replicates (three out of six) to 9 kg AC/palm to determine whether the palms were N deficiency. The remaining replicates received the standard 3 kg of AC/palm for the site.

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	14 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 trial was set up with two rates of each fertilizer in a 2 x 2 x 2 factorial design, replicated six times with 48 plots (Table 2). In 2007 it was decided that a possible reason for the poor response to fertilizer at this site was because the palms were N deficient. Nitrogen was applied as AC at 3kg/palm in previous years. In 2007, on half the number of replicates (ie. on three out of the six replicates) the N rate was increased to 9 kg of AC/palm (the other replicates continued to receive 3 kg AC/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 2007 was MOP at 2kg/palm and Borate at 150g/palm.

Table 2: Fertilizer and EFB treatments applied in Trial 205

Treatment	EFB (kg/palm/yr)	TSP (kg/palm/yr)	KIE (kg/palm/yr)
1	0	0	0
2	0	0	3
3	0	3	0
4	0	3	3
5	230	0	0
6	230	0	3
7	230	3	0
8	230	3	3

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 stabilised for some years, in 2007 the yield increased to above 30t/ha (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 has now stabilised at 22 kg/bunch.

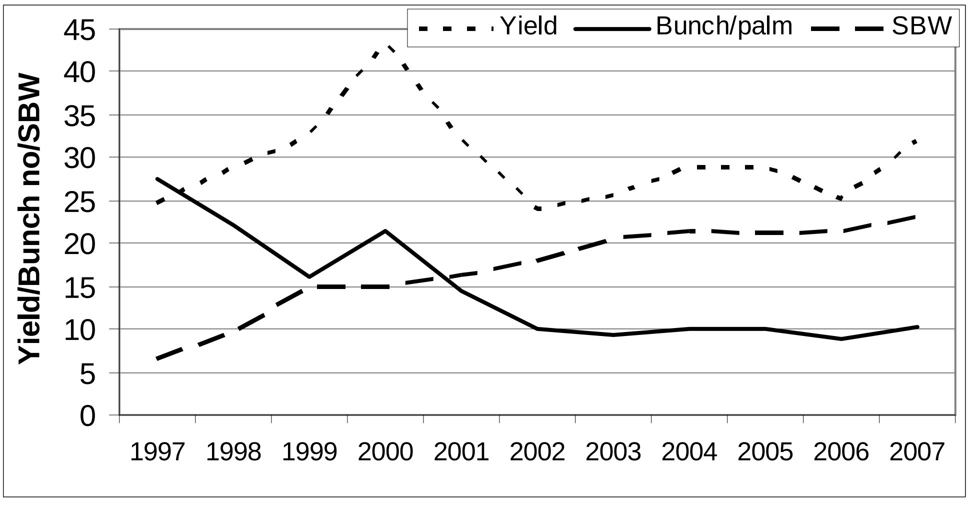


Figure1: FFB yield, Bunch no/palm and SBW from 1997 to 2007.

2007 - FFB yield and its components

The main effect of EFB application on yield was significant in 2007 (31 vs 33 t/ha for EFB 0 and 230 kg/palm respectively) (Figure 2). The effect of EFB on yield was due to a small increase in bunch number. The effects of KIE and TSP were not significant in 2007 (Figure 2) – nor were the effects of these two fertilizers significant in previous years.

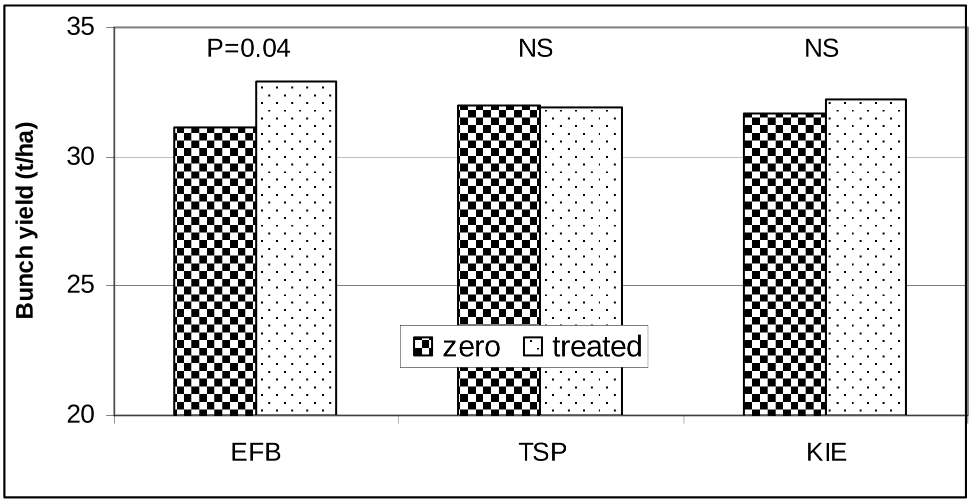


Figure 2. Main effect of EFB, Kieserite and TSP on FFB yield (t/ha) in 2007.

The interactions between fertilizer treatment (EFB x KIE; EFB x TSP; KIE x TSP; and EFB x KIE x TSP) were 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 Nitrogen deficiency is having an influence on production and optimum yields cannot be realized. In late 2007 extra N fertilizer was applied on half the number of replicates – this treatment will be included in the 2008 analysis.

2007 – 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 2007 (figures in bold are significantly different).

Fertilizer rate (kg/palm)	Leaflet (% dm)				Rachis (% dm)		
	N	P	K	Mg	N	P	K
EFB 0	**2.39**	0.143	**0.63**	**0.18**	**0.25**	**0.075**	**0.98**
EFB 230	**2.42**	0.144	**0.67**	**0.17**	**0.26**	**0.084**	**1.27**
TSP 0	2.40	**0.141**	**0.67**	0.17	0.26	**0.067**	**1.17**
TSP 3	2.41	**0.146**	**0.64**	0.18	0.26	**0.092**	**1.08**
KIE 0	2.41	**0.145**	0.65	**0.17**	0.26	0.082	1.14
KIE 3	2.40	**0.142**	0.65	**0.19**	0.25	0.077	1.12
$LSD_{0.05}$	**0.03**	**0.002**	**0.02**	**0.01**	**0.01**	**0.006**	**0.07**
CV%	**2.0**	**2.1**	**4.8**	**7.9**	**7.1**	**13.2**	**9.9**

The response seen from fertilizer treatments on tissue nutrient concentration was similar in 2005 and 2006.

The overall nutrient status of this trial is low to adequate. The main problem appears to be a lack of nitrogen fertility. Leaflet and rachis N was low for 14 year old palms (adequate levels are 2.45 and 0.32 %dm for leaflet and rachis respectively). In most agricultural production systems N drives production and if this critical nutrient is in low supply then all other nutrients supplied will not be able to increase production. In late 2007, half of the replicates in this trial received an extra 6kg AC/palm – this change to the treatment structure will continue in 2008.

Boron was also tested in the leaflets and the mean value was 15.3 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. 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 2007. 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
EFB	**0.008**	0.36	0.05	0.94	0.57	**0.002**	0.05	**<.001**	**<.001**
TSP	0.26	0.07	0.52	0.17	0.93	0.20	0.89	0.28	0.20
KIE	0.06	0.11	0.67	**0.03**	**0.01**	0.08	0.98	0.11	0.07
CV %	13.1	3.2	3.5	3.7	5.3	12.3	9.5	6.8	11.1

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).

CONCLUSIONS

Generally EFB, TSP and Kieserite treatments had no significant effect on FFB yield over the course of the trial. EFB did increase FFB yield in 2006 by 2.4 t/ha, and in 2007 by 2 t/ha. The increase in yield from EFB in 2006 and 2007 was probably due to a small increase in the available nitrogen (leaflet N increased from 2.39 to 2.42 %dm in 2007 as a result of EFB application).

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 3kg/ha (equivalent to 0.8kg N/palm) which appeared to have been too low. In late 2007, an extra 6 kg AC/palm was applied to half of the available replicates.

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. Potassium chloride (MOP) and Magnesium sulphate as kieserite (KIE) had little or no impact on yield or other growth parameters measured. When the three previous years (2004 to 2006) yield data was investigated, SOA and TSP had the largest impact on yield, with MOP playing a minor role and KIE none at all.

The overall nutrient status of frond 17 (leaflets and rachis) was still low regardless of fertilizer treatment in 2007.

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	13 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

In 2007, Borate was applied at 150g/palm as a basal fertilizer.

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).

The large increase in yield from 2006 to 2007 (25 to 35 t/ha) is probably due to improved plantation standards – crop recovery has improved greatly over 2007 (the increase in yield was due mainly to more bunches being harvested). This is a great success!

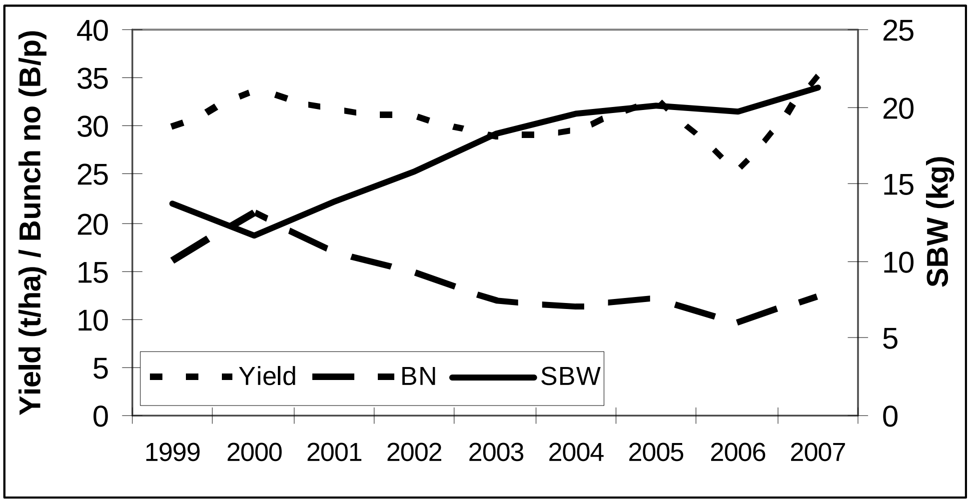


Figure 1. Yield (t/ha), Bunch number per palm (BN/palm) and SBW (Single Bunch Weight in kg/bunch) for trial 209 for the duration of the trial.

2007 – FFB yield and its components

In 2007, 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 and TSP were:

- SOA from 2kg to 8 kg/palm increased yield from 31.8 to 38.1 t/ha ($P<0.001$);
- MOP from 0 to 8 kg/palm increased yield from 33.0 to 37.0 t/ha ($P=0.006$); and
- TSP from 0kg to 8 kg/palm increased yield from 32.5 to 37.0 t/ha ($P=0.001$).

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 increased by SOA but not by TSP (Table 3), however the effect of MOP on SBW was significant (a 1.9 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 2007.

	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	30.6	32.6	32.1	11.1	11.6	11.3	20.3	20.7	21.1
4	31.6	39.0	36.6	11.3	13.7	12.5	20.7	21.2	21.6
8	35.2	39.6	39.6	12.2	13.2	13.6	20.8	21.4	21.4
Significant difference:									
SOA	**P<0.001**			**P<0.001**			**P<0.001**		
TSP	**P=0.001**			**P=0.004**			**P=0.02**		
$LSD_{0.05}$	**2.3**			**0.7**			**0.5**		

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

When the 2007 relationship between fertilizer treatment and yield and its components were compared to the average yield for 2005 to 2007 the results were similar. The analysis for the three year average data (2005 to 2007) demonstrated that SOA and TSP had the strongest effect on yield but that MOP also played a role – especially with its effect on SBW. It is possible that the effect of MOP on yield has been increasing over the last few years.

The main effects of SOA, TSP and MOP on yield using the three year average data:

- SOA from 2kg to 8kg/palm increased yield from 27.9 to 33.7 t/ha (P<0.001);
- TSP from 0kg to 8kg/pam increased yield from 28.5 to 32.5 t/ha (P<0.001); and
- MOP from 0 to 4kg/palm increased yield from 29.9 to 32.2 t/ha (P=0.04).

This increase in yield response from MOP was primarily on bunch weight (20 to 22 kg/bunch; P<0.001) rather than bunch number.

Treatments yielding greater than 30t/ha were treated with SOA at 4 to 8 kg/palm + TSP at 4 kg/palm and MOP at 2 kg/palm (Figure 2). Unfortunately the rates of TSP are such that we cannot be sure when the increase in yield, due to P, occurred – did it happen at 1, 2 or 3 kg or was it a gradual increase?

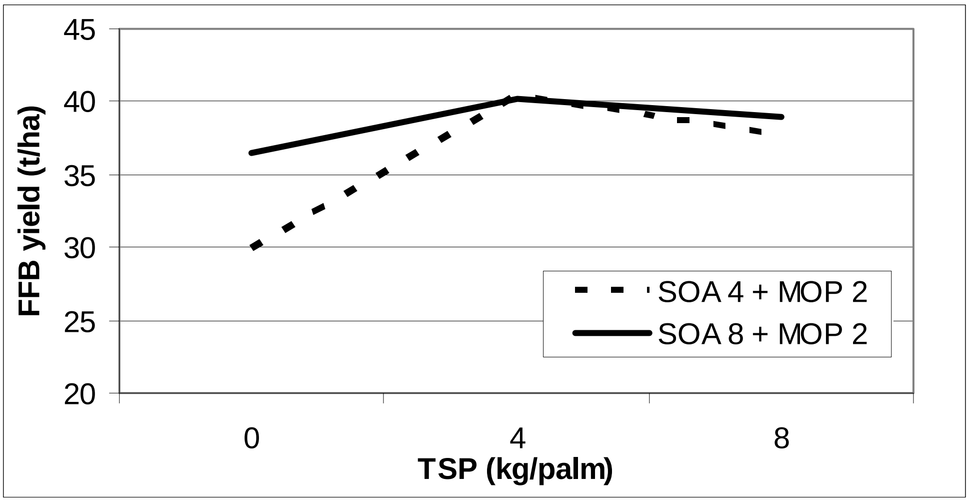


Figure 2. Yield response from P (as TSP) in 2007 (in addition to SOA + MOP).

Fertilizer effect on tissue nutrient concentrations

The effect of SOA, MOP, TSP and KIE fertilizer were significant on many of the important nutrients for palm growth (Table 4) as found in the leaflets and rachis of frond 17:

- SOA significantly increased Leaflet N – however the values even at the highest SOA rate of 8 kg/palm were still low (N – 2.37 %dm). Rachis N increased a small amount with increasing rates of N fertilizer;
- MOP had a variable and inconclusive result on leaflet K but significantly increased rachis K to adequate levels (MOP 4kg/palm: rachis K at 1.4 %dm);
- TSP significantly increased leaflet and rachis P. TSP at 4 and 8 kg/palm increased rachis P to adequate levels of above 0.8 %dm;
- KIE significantly increased leaflet Mg levels from 0.14 to 0.19 %dm (for 0 and 8 kg/palm Kieserite respectively);
- When higher rates of SOA were applied, it reduced the amount of P in the rachis – presumably this is due to the Nitrogen in SOA mobilising P out of the rachis. (This was also seen to a lesser extent with rachis K);
- Boron levels were on the low side (13.6 mg/kg) and Borate fertilizer was applied in 2007.

Table 4: Tissue nutrient concentration for Trial 209 in 2007 (figures in bold are significantly different P<0.05).

Fertilizer rate (kg/ha)	Leaflet (% dm)				Rachis (% dm)		
	N	**P**	**K**	**Mg**	**N**	**P**	**K**
SOA 2	**2.19**	0.135	0.66	**0.18**	**0.24**	**0.110**	1.31
SOA 4	**2.27**	0.138	0.66	**0.17**	**0.24**	**0.079**	1.27
SOA 8	**2.37**	0.140	0.67	**0.15**	**0.26**	**0.073**	1.21
MOP 0	2.26	0.137	**0.70**	0.17	0.25	0.072	**0.98**
MOP 2	2.29	0.138	**0.65**	0.17	0.25	0.092	**1.37**
MOP 4	2.28	0.139	**0.64**	0.16	0.25	0.098	**1.44**
TSP 0	2.24	**0.132**	0.66	0.17	0.25	**0.057**	1.33
TSP 4	2.29	**0.140**	0.66	0.16	0.25	**0.096**	1.24
TSP 8	2.29	**0.141**	0.68	0.17	0.25	**0.110**	1.22
KIE 0	2.25	0.136	0.66	**0.14**	0.25	0.088	1.27
KIE 4	2.29	0.140	0.67	**0.17**	0.25	0.084	1.25
KIE 8	2.28	0.138	0.67	**0.19**	0.25	0.091	1.27
$LSD_{0.05}$	**0.07**	**0.004**	**0.03**	**0.02**	**0.01**	**0.02**	**0.11**
CV%	**4.8**	**4.7**	**7.8**	**14.3**	**10.0**	**36.8**	**14.3**

Effects of fertilizer treatments on vegetative growth parameters

Nitrogen fertilizer, applied as SOA, had a significant effect on PCS (Petiole Cross Section) and dry matter production. K fertilizer, as MOP, only had a significant effect on rachis size (PCS). TSP and Kieserite, as the magnesium source, had little or no effect on any of the vegetative growth parameters measured or calculated (Table 5).

Main observations of fertilizer effect on vegetative growth parameters (Table 6):

- Nitrogen had the largest effect on growth parameters measured and calculated
- TSP and to some extent MOP also had an effect but Kieserite had no effect on any growth parameter
- In 2006, the number of fronds produced increased significantly by 1.4 fronds/year with the higher rates of N; however in 2007 this effect was not significant.
- The main increase in yield is from an increase in vegetative growth resulting from frond size not from an increase in frond production.

Table 5. Effect (p values) of treatments on vegetative growth parameters in 2007. P values < 0.05 are in bold.

Fertilizer	PCS	Radiation Interception				Dry Matter Production (t/ha)			
		GF	FP	FA	LAI	FDM	BDM	TDM	VDM
SOA	**0.001**	0.14	0.08	0.29	0.13	**0.005**	**0.003**	**0.004**	**<0.001**
MOP	**0.03**	0.35	0.58	0.36	0.23	0.10	0.06	0.08	**0.01**
TSP	0.06	0.49	0.07	0.49	0.36	0.05	**0.02**	**0.03**	**<0.001**
KIE	0.47	0.90	0.64	0.76	0.74	0.81	0.58	0.75	0.30
CV %	7.0	3.2	6.5	9.3	11.6	12.0	13.0	11.7	12.1

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

Table 6. Main effects of treatments on vegetative growth parameters in 2007. Significant effects (p<0.05) are shown in bold.

Fertilizer rate (kg/p)	PCS	Radiation Interception				Dry Matter Production (t/ha)			
		GF	FP	FA	LAI	FDM	BDM	TDM	VDM
SOA 2	**44.1**	33.4	21.6	12.2	5.0	**13.7**	**11.7**	**28.3**	**16.2**
SOA 4	**47.3**	33.8	22.6	12.6	5.8	**15.3**	**13.8**	**32.3**	**18.7**
SOA 8	**50.0**	34.3	23.0	13.0	6.0	**16.5**	**14.6**	**34.6**	**19.8**
MOP 0	**46.2**	33.7	22.6	12.7	5.8	15.0	13.4	31.6	**17.1**
MOP 2	**46.7**	33.6	22.0	12.4	5.6	14.8	13.2	31.1	**18.4**
MOP 4	**48.5**	34.2	22.5	12.8	5.9	15.7	13.6	32.5	**19.2**
TSP 0	45.4	33.5	21.8	12.4	5.6	14.3	**12.1**	**29.3**	**16.6**
TSP 4	47.3	33.7	22.6	12.7	5.8	15.4	**13.8**	**32.4**	**19.4**
TSP 8	48.7	34.3	22.8	12.8	5.9	15.9	**14.3**	**33.5**	**18.8**
KIE 0	47.8	33.7	22.4	12.8	5.8	15.4	13.3	31.9	17.9
KIE 4	47.1	33.9	22.4	12.6	5.8	15.1	13.8	32.1	18.8
KIE 8	46.5	33.9	22.4	12.5	5.7	15.0	13.0	31.2	18.0
$LSD_{0.05}$	***2.0***	***-***	***-***	***-***	***-***	***1.1***	***3.0***	***1.3***	***1.3***

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).

CONCLUSIONS

SOA, MOP and TSP significantly increased FFB yield (by 6, 4 and 4 t/ha respectively) while KIE had no significant effect on yield in this trial.

The highest yields, of 40 t/ha, in 2007 were obtained with the addition of SOA at 4 to 8 kg/palm plus MOP at 2 kg/palm plus TSP at 4 kg/palm. Kieserite had little or no impact on yield in 2007 or in previous years.

The general nutrient status of the palms in this trial was still low, irrespective of the treatment applied. Most of the nutrient concentrations assessed in frond 17 were low to barely adequate. This implies that there may be factors other than the nutrition supplied in this trial which are inhibiting production.

Frond production and frond size were adequate for potentially higher yielding palms.

Trial 211: Systematic N Fertilizer Trial, Navo

SUMMARY

A 2t/ha yield response resulted from the application of 3kg/ha AN, the yield response resulted from an increase in bunch weight.

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, 138 and 403 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	9 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 2007 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 2007

The yield increase from applying N fertilizer is significant (4.0 t/ha) (Table 2). This yield response was achieved at a N fertilizer rate of around 1.0 kg N/palm (equivalent to 3.0 kg AN/palm). The effect of N fertilizer was significant on bunch number; however there was no significant effect of N fertilizer on SBW (Table 2).

Table 2. T211: 2007 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	36.1	16.8	1930	18.7
0.25	0.74	37.9	17.3	1988	19.1
0.50	1.48	37.9	17.3	1991	19.0
0.75	2.22	39.8	17.9	2062	19.3
1.0	2.96	39.7	17.8	2046	19.4
1.25	3.70	41.4	18.2	2095	19.8
1.5	4.44	39.6	17.8	2045	19.3
1.75	5.18	40.9	18.3	2100	19.5
2.0	5.92	39.6	17.9	2055	19.3
	Significant difference:	**P<0.001**	**P=0.01**	**P=0.01**	**NS**
	$LSD_{0.05}$	**2.1**	**0.8**	**95**	**-**
	CV%	**5.3**	**4.6**	**4.6**	**3.5**

Yield response over time

A small but noticeable increase in yield occurred from 2003 (palm age: 5 years) to 2007 (palm age: 9 years). The response to applying N has been increasing since 2003, and in 2007 resulted in a 4 t/ha yield increase (Figure 1).

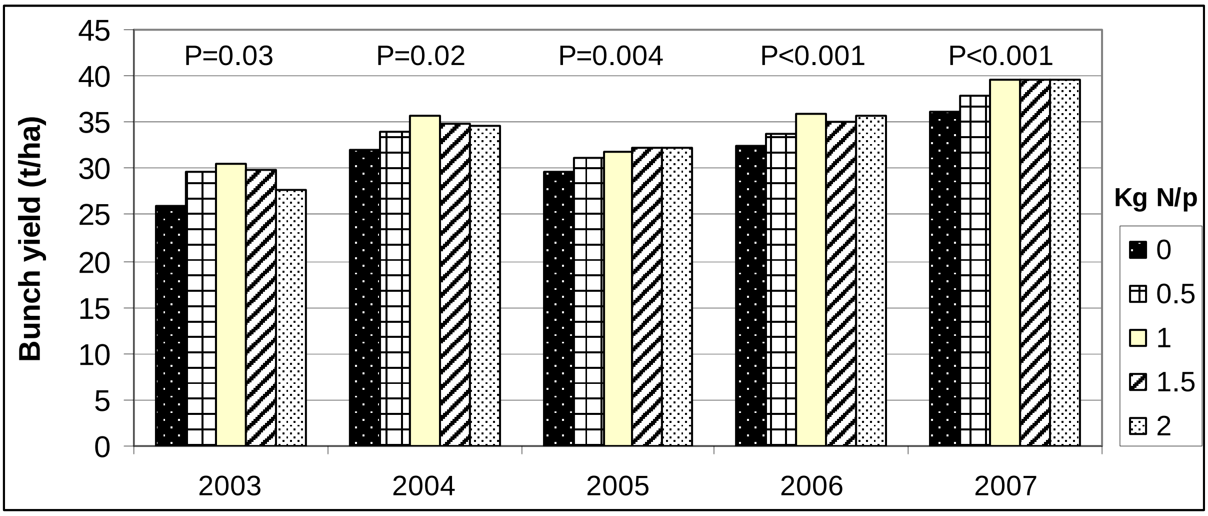


Figure 1. Yield response to 5 rates of N (kg/palm) over time (fertilizer N was first applied in late 2002).

As the palms matured from 5 to 9 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); SBW increased (Figure 2).

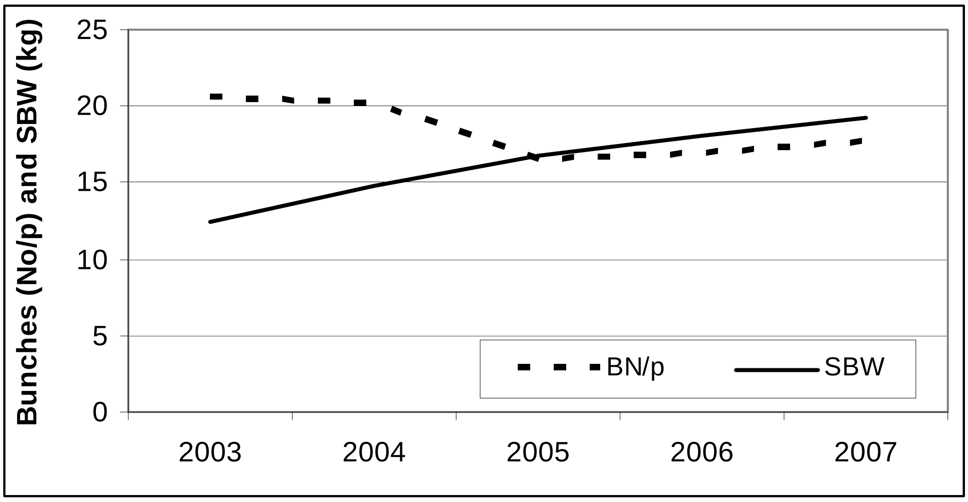


Figure 2. Mean trial Bunch Number (per palm) and SBW (kg) over time (Trial 211).

Tissue nutrient concentration for 2007

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). There were no significant effects on leaflet P or K, nor on Rachis P and K. Rachis P appears low and the site had basal P applied 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 2007.

N rate (kg/palm)	Equivalent AN rate (kg/palm)	Leaflet (% dm)			Rachis (% dm)		
		N	P	K	N	P	K
0	0	2.40	0.137	0.79	0.24	0.050	1.50
0.25	0.74	2.48	0.139	0.79	0.24	0.050	1.53
0.50	1.48	2.51	0.139	0.78	0.24	0.050	1.57
0.75	2.22	2.53	0.140	0.80	0.25	0.050	1.58
1.0	2.96	2.57	0.141	0.80	0.26	0.053	1.62
1.25	3.70	2.56	0.141	0.81	0.26	0.053	1.65
1.5	4.44	2.60	0.141	0.79	0.26	0.053	1.65
1.75	5.18	2.57	0.140	0.81	0.26	0.055	1.64
2.0	5.92	2.56	0.140	0.78	0.25	0.050	1.59
	Significant difference:	**P<0.001**	**NS**	**NS**	**0.01**	**NS**	**NS**
	$LSD_{0.05}$	**0.04**	**-**	**-**	**0.01**	**-**	**-**
	CV%	**1.5**	**1.9**	**4.9**	**5.3**	**11.1**	**7.8**

Tissue N concentration over time 2004 to 2007

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
0	0	2.66	2.60	2.44	2.40
0.5	1.48	2.72	2.65	2.53	2.51
1.0	2.96	2.72	2.68	2.55	2.57
1.5	4.44	2.74	2.69	2.58	2.60
2.0	5.92	2.72	2.65	2.56	2.56
	Significant difference:	**NS**	**P=0.02**	**P=0.03**	**P<0.001**
	$LSD_{0.05}$	**-**	**0.05**	**0.08**	**0.04**
	CV%	**2.1**	**1.9**	**2.2**	**1.5**

Fertilizer N effects on oil palm vegetative growth

Frond production and frond number

24 new fronds were produced in 2007 (one every 14 days) indicating good growing conditions during the year. Total green fronds counted per palm averaged 37 fronds which is an adequate number. 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 11.8m^2 and LAI of 5.1). 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 2007 there was no increase PCS with the application of N fertilizer. The measure of total vegetative dry matter production (TDM) increased with increasing rates of N fertilizer and reached a plateau at about 0.75 kg N fertilizer/palm.

Table 5. Effect of N treatments on vegetative growth parameters in 2007.

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	41.6	36.7	23.4	12.9	5.5	12.0	16.4	31.5	15.1
0.25	0.74	42.6	36.9	23.6	12.8	5.5	12.4	17.0	32.7	15.6
0.50	1.48	42.3	36.5	23.6	12.8	5.4	12.2	17.2	32.7	15.5
0.75	2.22	46.3	37.0	23.6	12.8	5.4	13.4	18.1	34.9	16.9
1.0	2.96	42.1	37.2	23.6	12.8	5.5	12.2	17.9	33.5	15.6
1.25	3.70	42.9	37.1	23.9	13.1	5.6	12.6	18.6	34.7	16.1
1.5	4.44	43.0	36.9	23.8	13.0	5.5	12.6	17.8	33.8	16.0
1.75	5.18	44.0	36.6	23.9	13.6	5.7	12.9	18.5	34.9	16.4
2.0	5.92	43.5	36.8	23.7	13.2	5.6	12.7	18.1	34.1	16.1
Significant difference:		**0.72**	**0.8**	**0.4**	**0.5**	**0.7**	**0.7**	**0.001**	**0.01**	**0.5**
	$LSD_{0.05}$	**-**	**-**	**-**	**-**	**-**	**-**	**1.0**	**2.0**	**-**
	CV%	**11.1**	**2.5**	**2.0**	**6.2**	**6.9**	**11.0**	**5.8**	**6.0**	**9.7**

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

A small but significant yearly increase in yield, of between 2.0 and 3.0 t/ha, has been observed since 2003 with the application of 3.0kg AN/palm (or 1.0 kg N/palm).

Tissue nutrient levels indicate there are no major deficiencies, except for possibly P. Rachis P appears to be on the low side and in time this may result in a decrease in leaflet P and have a negative impact on yield. Basal rates of P should be maintained.

Tissue P, especially in the rachis, was low and the basal rate of TSP was increased to 0.5kg/palm 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 5t/ha yield response resulted from the application of 3.7 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	11 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 2007 in Trial 212: 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 2007

Applying N fertilizer increased the FFB yield significantly. A yield increase of 6 t/ha yield was achieved with the addition of 3.7kg AN/palm (Table 2). Bunch number and SBW increased with the application of N fertilizer.

Table 2. Trial 212: 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	24.2	9.1	1276	18.9
0.25	0.74	23.2	8.7	1215	19.1
0.50	1.48	26.0	9.5	1334	19.5
0.75	2.22	27.0	9.4	1318	20.5
1.0	2.96	29.0	9.7	1359	21.4
1.25	3.70	29.1	10.3	1437	20.3
1.5	4.44	29.3	10.0	1406	20.9
1.75	5.18	30.3	10.3	1448	20.9
2.0	5.92	31.1	10.7	1503	20.7
	Significant difference:	**P<0.001**	**P<0.001**	**P<0.001**	**P<0.001**
	$LSD_{0.05}$	**2.3**	**0.8**	**111**	**0.9**
	CV%	**8.3**	**8.1**	**8.1**	**4.3**

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 7 t/ha yield difference between the control and 2.0kg N/palm (Figure 1).

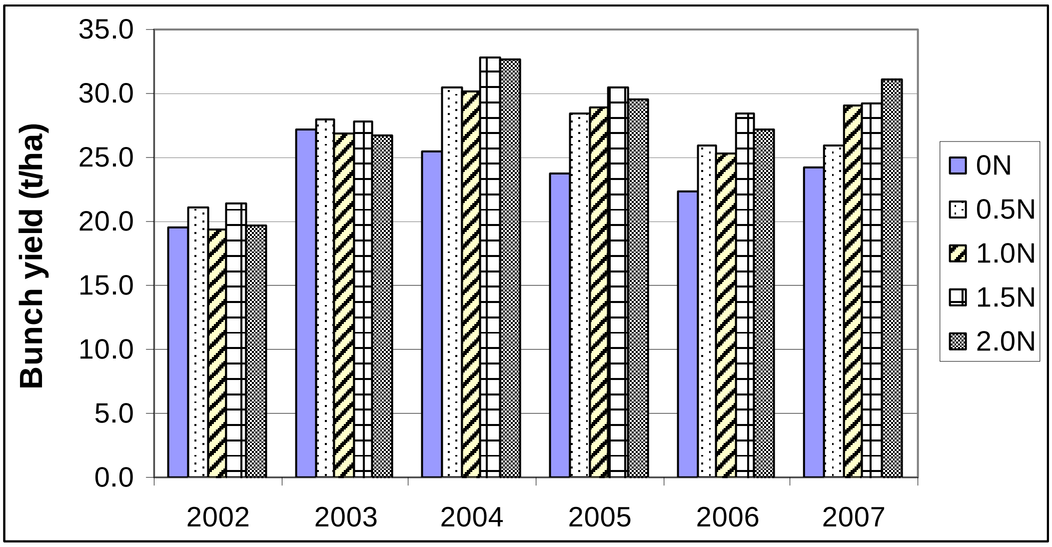


Figure 1. T212: Yield response to 5 rates of N (kg/palm) over time (fertilizer N was first applied in 2002).

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 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 2007 sampling are listed in Table 3. Increasing rates of N fertilizer significantly increased leaflet 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 2007.

N rate (kg/palm)	Equivalent AN rate (kg/palm)	Leaflet (% dm)			Rachis (% dm)		
		N	P	K	N	P	K
0	0	2.21	0.137	0.74	0.22	0.034	1.20
0.25	0.74	2.25	0.137	0.73	0.23	0.033	1.17
0.50	1.48	2.33	0.137	0.71	0.23	0.031	1.16
0.75	2.22	2.35	0.137	0.72	0.24	0.031	1.17
1.0	2.96	2.39	0.139	0.72	0.24	0.032	1.13
1.25	3.70	2.36	0.140	0.70	0.25	0.034	1.20
1.5	4.44	2.40	0.141	0.74	0.25	0.035	1.26
1.75	5.18	2.45	0.142	0.72	0.25	0.035	1.18
2.0	5.92	2.42	0.141	0.76	0.24	0.035	117
	Significant difference P:	**<0.001**	**0.009**	**0.5**	**<0.001**	**0.02**	**0.7**
	$LSD_{0.05}$	**0.05**	**0.003**	-	**0.01**	**0.002**	-
	CV%	**2.0**	**2.4**	6.7	**6.1**	**8.5**	**10.7**

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 will be applied again in 2008. Leaflet magnesium (Mg) levels were on average close to adequate (0.18 % dm), and Boron levels were near adequate (14 mg/kg).

Tissue N concentration over time 2004 to 2007

In 2004, 2005, 2006 and 2007 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
0	0	2.34	2.30	2.25	2.21
0.5	1.48	2.45	2.44	2.36	2.33
1.0	2.96	2.42	2.47	2.41	2.39
1.5	4.44	2.46	2.51	2.43	2.40
2.0	5.92	2.48	2.54	2.43	2.42
	Significant difference:	**P<0.001**	**P<0.001**	**P<0.001**	**P<0.001**
	$LSD_{0.05}$	**0.05**	**0.05**	**0.04**	**0.05**
	CV%	**2.3**	**2.1**	**1.8**	**2.0**

Fertilizer N effects on oil palm vegetative growth

Frond production and frond number

On average 20 new fronds were produced in 2007 (one every 18 days) indicating reasonably good growing conditions during the year. The addition of N fertilizer increased frond production by 1.5 fronds/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 2007.

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	43.2	32.6	19.6	12.1	5.5	12.7	13.0	28.5	15.5
0.25	0.74	44.1	33.0	19.8	12.5	5.8	13.0	12.4	28.2	15.9
0.50	1.48	47.2	32.9	20.3	13.5	6.2	14.3	13.8	31.2	17.4
0.75	2.22	48.2	33.1	20.6	13.4	6.2	14.8	14.5	32.5	18.0
1.0	2.96	47.5	34.2	20.8	13.8	6.6	14.8	15.5	33.6	18.1
1.25	3.70	49.3	33.9	20.6	13.8	6.6	15.3	15.6	34.3	18.7
1.5	4.44	50.1	34.2	21.2	13.8	6.6	15.8	15.7	34.9	19.3
1.75	5.18	48.8	33.6	21.2	13.1	6.2	15.6	16.2	32.3	19.2
2.0	5.92	50.9	33.3	21.5	13.6	6.4	16.3	16.7	36.6	20.0
Significant difference:		**<0.001**	**0.12**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**P<0.001**	**<0.001**
	$LSD_{0.05}$	**2.4**	**-**	**0.8**	**0.7**	**0.4**	**0.9**	**1.2**	**1.9**	**1.1**
	CV%	**5.1**	**3.8**	**3.9**	**5.1**	**5.8**	**6.3**	**8.4**	**6.0**	**6.0**

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 3.0kg AN/palm (or 1.0 kg N/palm). The increase in yield from N fertilizer has been steadily increasing, compared to the zero control, and in 2007 the difference was 7 t/ha.

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

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 13 t/ha vs. combined AN + P treatments > 28 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 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) appears to be lacking and in 2007 additional MOP was applied as a basal fertilizer. It is also suggested 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	9 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 2007 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.

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

RESULTS and DISCUSSION

2007 Yield and its components

Yield increased from the control plot (N 0, P 0) at 12.9 t/ha to above 25 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 and 2006).

Table 3. FFB yield (t/ha), Bunch number (bunch/palm) and SBW (kg) for trial 213 in 2007.

	Yield t/ha TSP kg/palm			**Bunch number / palm* TSP kg/palm**			**SBW kg TSP kg/palm**		
AN kg/palm	**0**	**3**	**6**	**0**	**3**	**6**	**0**	**3**	**6**
AN 0	12.9	21.3	17.5	5.9	8.0	6.7	17.0	20.5	20.1
AN 2.2	16.8	27.5	25.2	7.1	10.3	8.9	18.4	21.0	21.8
AN 4.4	18.2	23.9	26.0	7.3	8.4	9.4	19.3	22.2	21.6
Significant difference:									
N	**<0.001**			**<0.001**			**0.02**		
P	**<0.001**			**<0.001**			**<0.001**		
NxP	**0.20 (NS)**			**0.12 (NS)**			**0.82 (NS)**		
$LSD_{0.05}$	**2.4**			**0.8**			**1.2**		
CV%	**13.7**			**13.2**			**7.3**		

* 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 only increased from 17 t/ha to 21 t/ha in 2007. It reached a plateau in 2004 and yields have generally been maintained at this level. Bunch number continued to decline and bunch weight has increased every year (Figure 1).

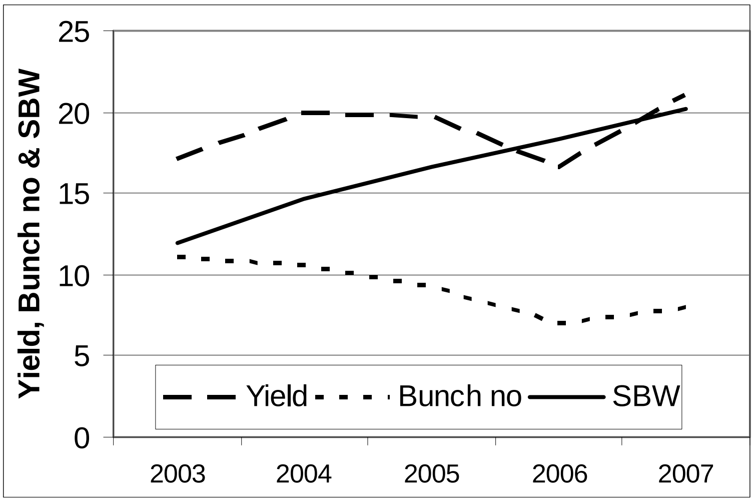


Figure 1. Long term yield, bunch number and bunch weight (average for site)

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 similarly around the 26 to 27 t/ha.

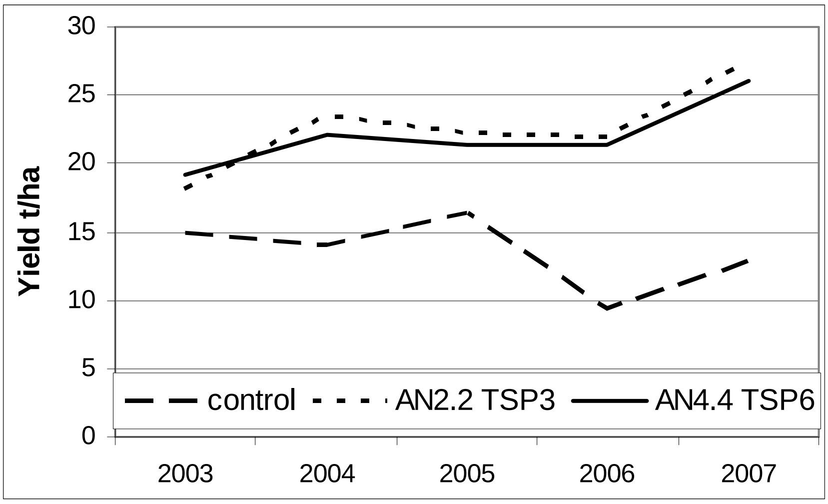


Figure 2. Yield over time for the control (no fertilizer) and combined N and P fertilizer treatments

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 2007.

	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	2.36	2.45	2.41	0.130	0.145	0.144	0.029	0.057	0.062
AN 2.2	2.50	2.58	2.59	0.138	0.150	0.149	0.030	0.046	0.056
AN 4.4	2.49	2.64	2.61	0.140	0.152	0.155	0.029	0.048	0.053
Significant difference:									
N		**<0.001**			**0.002**			**0.07 (NS)**	
P		**0.02**			**<0.001**			**<0.001**	
NxP		**0.90 (NS)**			**0.87 (NS)**			**0.40 (NS)**	
$LSD_{0.05}$		**0.08**			**0.004**			**0.006**	
CV%		**3.8**			**3.9**			**14.7**	

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: 2.58 %; Leaflet P: 0.150 % and Rachis P: 0.046%) (very similar to the results from 2006). However, other work done by PNG OPRA 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 2007.

Nutrient	**Trial mean value (% dm)**	**Accepted adequacy level (% dm)**	**Notes**
Leaflet K	0.59	0.65	Leaflet potassium is adequate but some plots are low
Leaflet Mg	0.21	0.20	Adequate levels of magnesium
Leaflet B	15 (ppm)	15 (ppm)	Leaflet boron is adequate
Rachis K	0.46	1.2	Rachis potassium is low

It appears that K (potassium) is very low in the rachis, in 2007 3kg of MOP/palm was 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.

Table 6. Trial 213, main effects (p values) of fertilizer treatments on vegetative growth parameters in 2007. 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	**<.001**	0.11	0.06	0.17	**0.02**	**<.001**	**<.001**	**<.001**	**<.001**
TSP	**<.001**	**0.003**	**<.001**	**<.001**	**<.001**	**<.001**	**<.001**	**<.001**	**<.001**
AN.TSP	0.81	0.24	0.84	0.74	0.78	0.43	0.08	0.14	0.42

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 2007.
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	**36.2**	38.5	21.9	11.5	**5.7**	**11.0**	**8.8**	**22.1**	**13.2**
AN 2.2	**37.7**	38.8	22.6	11.8	**5.9**	**11.9**	**12.1**	**26.6**	**14.5**
AN 4.4	**40.2**	39.6	22.6	12.1	**6.2**	**12.6**	**11.8**	**27.1**	**15.3**
TSP 0	**34.5**	**37.9**	**21.5**	**10.9**	**5.4**	**10.3**	**8.3**	**20.7**	**12.4**
TSP 3	**40.6**	**39**	**22.2**	**12.6**	**6.4**	**12.4**	**12.6**	**27.8**	**15.2**
TSP 6	**39.0**	**39.9**	**23.5**	**11.8**	**6.1**	**12.7**	**11.9**	**27.3**	**15.4**
$LSD_{0.05}$	***1.9***	***1.1***	***0.7***	***0.7***	***0.3***	***0.6***	***1.2***	***1.6***	***0.7***

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 young palm mature.

Leaflet N and P concentrations for plots receiving no AN and TSP were 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).

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 2007 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	6	Mg x K 26 (NS)	B/p 20 (NS) SBW 11 (NS)	LN 2.70 RN 0.31 LP 0.150 RP 0.07 +K LK 0.71 to 0.79 RK 0.9 to 1.4 + Mg LMg 0.14 to 0.19	PCS 24.5 (NS) FP 18 (NS) LAI 4.5 (NS)	Rachis P is on the low side (continue with basal P) Frond production is low Mg and K uptake in tissue, no yield response
145 Walindi Mg types Soil: Volcanic	8	No Mg 32.6 + Mg 32.7	B/p 13 (NS) SBW 20 (NS)	LN 2.52 RN 0.41 LP 0.147 RP 0.14 No Mg 0.13 + Mg 0.14 (NS)	PCS 45 (NS) FP 26 (NS) LAI 6.5 (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	8	No Mg 31.3 + Mg 32.4 (NS)	B/p 13 (NS) SBW 18 (NS)	LN 2.58 RN 0.35 LP 0.152 RP 0.10 LK 0.79 RK 1.9 No Mg 0.17 + Mg 0.17 (NS)	PCS 38 (NS) FP 25 (NS) LAI 6.4 (NS)	No Mg fertilizer response in yield or Mg tissue uptake Adequate nutrition for N, P and K
148 Kumbango Mg rates, large blocks Soil: Volcanic	6	No Mg 28.7 + Mg 29.2 (NS)	B/p 20 (NS) SBW 12 (NS)	LN 2.69 RN 0.34 LP 0.153 RP 0.07 LK 0.89 RK 1.90 No Mg 0.15 + Mg 0.18		No Mg fertilizer response in yield across large blocks. Tissue levels increased with Mg fertilizer.
137 Kumbango Systematic AN 0 to 6kg/p Soil: Volcanic	8	No response to N 30t/ha	B/p 13 (NS) SBW 18.5 (NS)	LN 2.50 (NS) RN 0.32 (NS) LP 0.144; RP 0.08 LK 0.77; RK 2.0	PCS 30 (NS) FP 25 (NS) LAI 5.7 (NS)	No response to N P on low side in rachis, increase basal TSP K adequate Mg (L Mg 0.13) is low
138 Haella Systematic AN 0 to 6kg/p Soil: Volcanic	12	AN response 27 to 32	B/p 11 (NS) SBW 21 (NS)	LN 2.24 to 2.52 RN 0.32 to 0.35 LP 0.145; RP 0.10 LK 0.75; RK 1.5		5 t/ha response to AN P now adequate (following basal TSP) K adequate
403 Kaurausu Systematic AN 0 to 6kg/p Soil: Volcanic	20	AN response 23 to 27t/ha	B/p 7.1 to 8.2 SBW 27.7 (NS)	Still with lab		2007 last year for trial. Good responses to N fertilizer (4 t/ha at 0.75kg N/palm)

Trial	Palm Age	Yield t/ha	Yield Components	Tissue % dm	Vegetative	Notes
142 Kumbango/Bebere Large Blocks (256, 260, 266) AN 0, 3, 6 Soil: Volcanic	14 12 9	AN 27 (NS)	B/p 9 (NS) SBW 23 (NS)	256 LN 2.34 to 2.43 260 LN 2.17 to 2.49 266 LN 2.47 to 2.45 256 LP 0.144; RP 0.06 260 0.147; 0.07 266 0.147; 0.06 256 LK 0.74; RK 1.7 260 0.73; 1.8 266 0.75; 1.5		There was no difference in yield between N treatments across the large treated blocks. There was an increase in leaflet N at block 260 – in this block there was also an increase in yield. Rachis P on low side.
149 Kumbango Large Blocks Borate 0, 80, 160g/p Soil: Volcanic	6	Borate 26 (NS)	B/p 17 (NS) SBW 12 (NS)	LB 13 to 16 ppm LN 2.69; RN 0.36 LP 0.153; RP 0.06 LK 0.86; RK 1.94		No effect of boron on yield, but tissue levels increased. Rachis P on low side.

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 were found at all three sites for the first time 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 very healthy 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.

Phosphorus nutrition is on the low side at these sites. Basal P will be increased at the trial sites and NBPOL is encouraged to check foliar P concentrations in adjacent blocks.

N Omission blocks

The N 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 N fertilizer. We don’t expect an N deficiency to show for at least another two years inside the omission plot.

This trial is well set up to verify if N moves through the soil from areas which receive fertilizer to areas which do not. If this is actually occurring we would expect to see changes in tissue N levels across the plot in 2009 or 2010 (depending on the inherent fertility of the site).

N fertilizer experimentation on large blocks

In 2003, in collaboration with OPRS, large blocks on breeding trial sites have been set up to study the effect of applying 0, 3 and 6 kg/palm of Ammonium Nitrate. So far there have been no yield differences between the treatments, however there is a strong indication that tissue N levels are now at or below critical levels in two of three 0 N blocks. If this persists into 2008 we would expect to see a yield response in either 2008 or 2009. When a yield response does show in the zero N or control blocks we should be able to map yield responses across the sites and see whether available N is coming into the control blocks from outside the areas which are receiving N fertilizer.

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 2007 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 2007

There was no significant increase in yield, and the other yield components; bunch number and single bunch weight from N treatments applied in 2007 (Table 2).

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	32.6	13.9	1782	18.3
0.25	0.74	32.4	13.5	1748	18.6
0.50	1.48	33.0	13.8	1784	18.5
0.75	2.22	32.6	13.8	1744	18.7
1.0	2.96	32.9	13.8	1778	18.5
1.25	3.70	32.8	14.0	1784	18.4
1.5	4.44	33.2	14.1	1812	18.4
1.75	5.18	33.3	13.8	1767	18.9
2.0	5.92	32.8	13.8	1763	18.6
Significant difference:		**NS**	**NS**	**NS**	**NS**
	$LSD_{0.05}$	-	-	-	-
	CV%	**3.3**	**3.9**	**3.7**	**3.7**

Yield response over time

There was an increase in the average bunch weights over time due to maturing palms, but there was no significant increase in yield according 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).

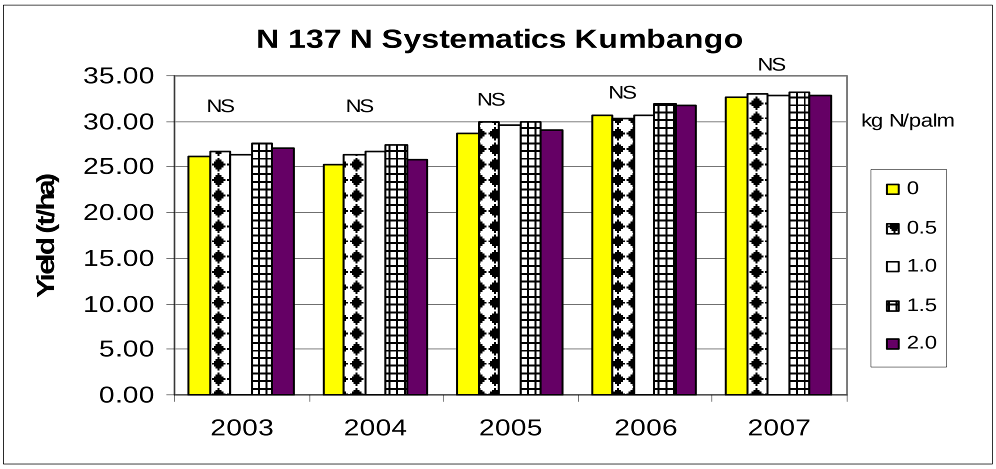


Figure 1. Yield response to 5 rates of N (kg/palm) over time (fertilizer N was first applied in March 2003).

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 and SBW is not significant for any one year.

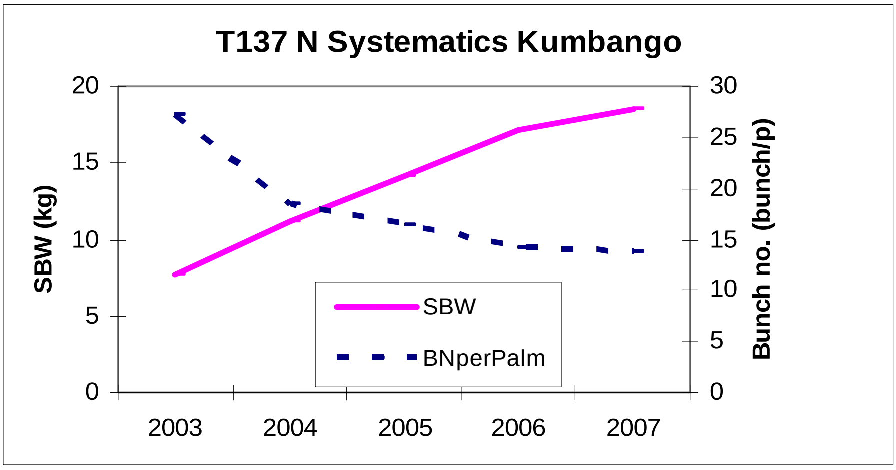


Figure 2. Mean trial bunch number per palm and SBW (kg) over time (Trial 137).

Tissue nutrient concentration

Tissue nutrient concentration was investigated for both leaflets and the rachis. There was no effect on nutrient levels listed in Table 3 by N treatment. Leaflet K decreased a small amount with the application of N fertilizer.

Table 3. leaflet and rachis nutrient content for T137 in 2007.

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	0.82	0.31	0.08	1.94
0.25	0.74	2.53	0.145	0.77	0.31	0.08	2.03
0.50	1.48	2.51	0.144	0.77	0.32	0.08	1.94
0.75	2.22	2.54	0.144	0.79	0.33	0.08	2.07
1.0	2.96	2.52	0.144	0.75	0.32	0.08	2.06
1.25	3.70	2.51	0.145	0.76	0.33	0.07	2.05
1.5	4.44	2.52	0.144	0.76	0.33	0.08	2.00
1.75	5.18	2.52	0.143	0.77	0.33	0.08	2.03
2.0	5.92	2.50	0.142	0.80	0.34	0.08	2.00
Significant difference:		**NS**	**NS**	**P=0.03**	**NS**	**NS**	**NS**
	$LSD_{0.05}$	**-**	**-**	**0.04**	**-**	**-**	**-**
	CV%	**2.1**	**2.3**	**5.6**	**8.6**	**10.3**	**9.6**

Even though leaflet Phosphorus (P) was adequate there is an indication that rachis P was on the low side. TSP was applied at a higher rate in 2007 (0.5 kg/palm), and we expect to see some increase in leaf and rachis P in 2008. Hopefully P will not be the yield limiting factor in future. All other nutrients were present at an adequate level, except for Magnesium (Mg 0.13%) and Chlorine (Cl 0.37%). Boron levels have increased in 2007 (B 16.2ppm) from a lower level in 2006.

Tissue N concentration over time 2004 to 2007

Leaflet N levels have not changed over time in relation to N fertilizer input (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
0	0	2.70	2.68	2.60	2.48
0.5	1.48	2.66	2.66	2.58	2.51
1.0	2.96	2.68	2.65	2.57	2.52
1.5	4.44	2.67	2.65	2.60	2.52
2.0	5.92	2.67	2.69	2.58	2.50
	Significant difference:	**NS**	**NS**	**NS**	**NS**
	$LSD_{0.05}$	-	-	-	-
	CV%	**2.0**	**2.8**	**2.2**	**2.1**

Fertilizer N effects on oil palm vegetative growth

There was a significant effect of N treatment on leaf area index (LAI), 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 2007. 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	0.92	0.13	0.48	0.13	**0.017**	0.99	0.99	0.99	0.99
LSD	-	-	-	-	0.32	-	-	-	-
CV %	13.1	2.9	3.2	4.9	5.5	8.7	11.9	6.5	7.5

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).

Frond production and frond number

25.7 new fronds were produced in 2007 (one frond every 14.2 days) indicating good growing conditions during the year. Total green fronds counted per palm averaged 39.5 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 within adequate limits (LAI = 5.7 and FA = 11.3 m^2). LAI as indicated in Table 5, was significantly increased by N application.

Vegetative dry matter production

Petiole cross section is a primary determinant of vegetative dry matter production. There was no effect of N observed on the measures of vegetative dry matter production; frond dry matter (FDM), total dry matter (TDM) and vegetative dry matter (VDM).

CONCLUSION

There was an increase in the average bunch weights as the palms mature, 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 2007.

Vegetative measurements indicate that AN had no effect on all 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 2007

There was a significant yield increase from applying 0 to 0.5 kg N/palm (27.1 to 29.6 t/ha). At that stage the yield increase was around 2.0 t/ha, and a higher increase of 4 t/ha was achieved at 0.75 kg N/palm (or 2.22 kg AN/palm) (Table 7). There was a significant increase in bunch number with increasing rate of N. An extra bunch was produced at 1.25 kg N/palm (or 3.70 kg AN/palm). There was no effect on SBW through the application of N fertilizer (Table7).

Table 7. Trial 138: 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	27.1	10.6	1342	20.3
0.25	0.74	28.8	10.6	1382	21.0
0.50	1.48	29.6	10.9	1402	21.1
0.75	2.22	31.0	11.4	1457	21.3
1.0	2.96	30.5	11.4	1444	21.3
1.25	3.70	32.1	11.6	1508	21.4
1.5	4.44	31.7	11.8	1509	21.1
1.75	5.18	31.9	11.9	1531	20.9
2.0	5.92	31.8	11.9	1533	20.9
Significant difference:		**P<0.001**	**P=0.026**	**P=0.004**	**NS**
	$LSD_{0.05}$	**2.0**	**0.9**	**110**	**-**
	CV%	**6.5**	**8.2**	**7.5**	**4.4**

Yield response over time

There is a small but noticeable and significant increase in yield from applying N fertilizer. 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 2007 (Figure 3). Yield in 2007 continued to show the significant increase in yield from applying N fertilizer.

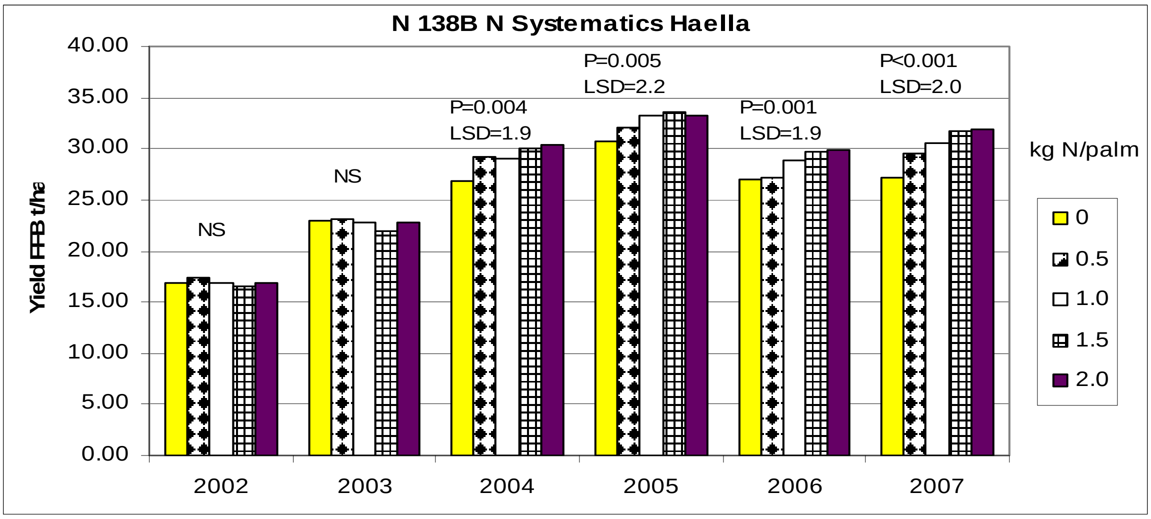


Figure 3. T138: Yield response to 5 rates of N (kg/palm) over time (fertilizer N was first applied in July 2002).

Tissue nutrient concentration

Tissue nutrient concentration was investigated for both leaflets and the rachis. The nutrient tissue levels for the 2007 sampling are listed in Table 8. Increasing rates of N fertilizer, significantly increased leaflet and rachis N concentration (also see Figure 4). Leaflet P was also increased with increasing N rates in 2007, 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 2007 from very low levels in 2006 (TSP was applied late 2006, interestingly this was picked up in the leaflets in a span of 4 months) (Figure 5). TSP was applied in 2007 as well. Leaflet K levels were not affected by fertilizer N rates, but there was a significant decrease in rachis K with increasing rate of N fertilizer.

Table 8. T138: tissue nutrient concentration for leaflets and rachis in 2007.

N rate (kg/palm)	Equivalent AN rate (kg/palm)	Leaflet (% dm)			Rachis (% dm)		
		N	P	K	N	P	K
0	0	2.24	0.139	0.75	0.32	0.14	1.84
0.25	0.74	2.30	0.139	0.71	0.33	0.13	1.62
0.50	1.48	2.37	0.141	0.71	0.31	0.11	1.51
0.75	2.22	2.41	0.142	0.73	0.31	0.10	1.45
1.0	2.96	2.45	0.144	0.75	0.33	0.10	1.45
1.25	3.70	2.48	0.145	0.75	0.34	0.11	1.46
1.5	4.44	2.51	0.146	0.73	0.35	0.10	1.49
1.75	5.18	2.51	0.145	0.76	0.35	0.10	1.59
2.0	5.92	2.52	0.145	0.73	0.38	0.10	1.55
	Significant difference:	**P<0.001**	**P<0.001**	**NS**	**P<0.001**	**P<0.001**	**P=0.001**
	$LSD_{0.05}$	**0.07**	**0.003**	**-**	**0.03**	**0.019**	**0.18**
	CV%	**3.0**	**2.1**	7.8	**9.4**	**17.4**	**11.6**

Leaflet magnesium (Mg) levels and boron (B) levels were on the low side (0.18 % dm and 13.6 mg/kg respectively), while chlorine was adequate (0.42%).

Tissue nutrient concentration over time

Leaflet N concentration reached a peak in 2004 and as palms matured had decreased since. A distinct trend in leaflet N was obvious again in 2006 and continued into 2007 (Figure 4), with the zero treatments decreasing and the higher rates (6 kg and 3 kg/p) increasing in concentration. The effect of fertilizer on leaflet N has been very marked over the duration of the trial and we expect the leaflet N values to continue to decrease in the zero N treatment relative to the N fertilizer treatments (Figure 4).

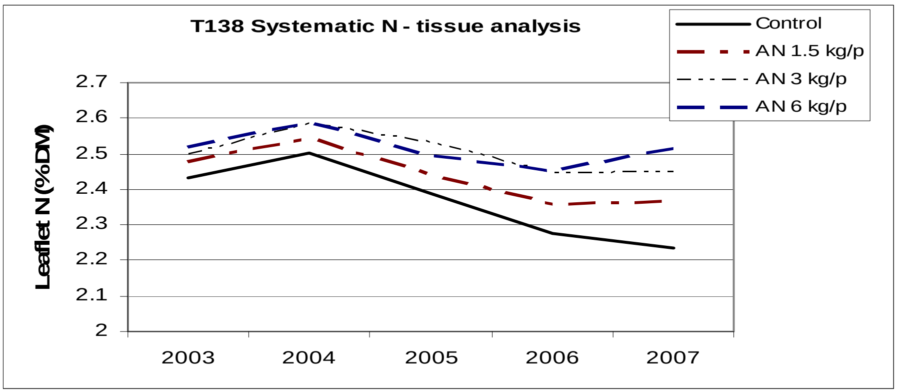


Figure 4. T138: Leaflet N concentration resulting from N fertilizer treatments over time.

Leaflet P concentration has decreased over time until 2006 when TSP fertilizer was applied at 0.5 kg/palm, since then leaflet P levels have increased (Figure 5), and was almost at adequate levels. There was sufficient P in the rachis in 2007 (most treatments above 0.1% dm), this should enable N to mobilise P out of the rachis and make it available in the leaflets – with continued application of TSP (as the P source) we expect P to become adequate in this trial in the near future.

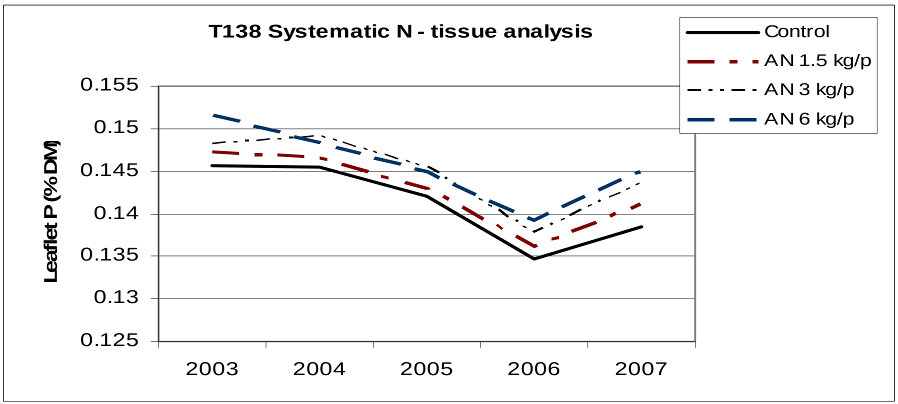


Figure 5. T138: Leaflet P concentration over time.

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, 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 403: Systematic N Fertilizer Trial, Kaurausu

Trial Background Information

Table 9. Trial 403 background information.

Trial number	**403**	Company	NBPOL
Estate	Kaurausu	Block No.	Div 1, Block I-3vand I-4.
Planting Density	120 palms/ha	Soil Type	Volcanic sand and pumice
Pattern	Triangular	Drainage	Free draining
Date planted	1987	Topography	Flat
Age after planting	20 years	Altitude	? m asl
Treatments 1st applied	2000	Previous Land-use	Forest
Progeny	unknown	Area under trial soil type (ha)	250 ha
Planting material	Dami D x P	Agronomist	Rachel Pipai

No N fertilizer and basal fertilizers applied in 2007 - site proposed to be felled in 2008.

RESULTS and DISCUSSION

Yield and its components response to fertilizer treatment in 2007

There were still responses to the fertilizer treatments even after fertilizer application had stopped in 2006. In the treatment where the fertilizer rate changed from applying 0 to 0.5 kg N/palm (or 1.5 kg AN/palm), there was a significant yield increase by 2.7 t/ha (22.9 to 25.6 t/ha). A higher yield increase of 4.3 t/ha was achieved at 0.75 kg N/palm (or 2.22 kg AN/palm) (see Table 10) which was similarly observed in Trial 138. There was a significant increase in bunch numbers as well; an extra bunch was produced at 0.75 kg N/palm. At the matured age for felling, the mean bunch numbers have evened out at 7.1-8.4 bunches/palm. There was no significant difference in single bunch weight with increasing N rate (Table 10).

Table 10. Trial 403: 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	22.9	7.1	850	27.0
0.25	0.74	23.5	7.2	862	27.4
0.50	1.48	25.6	7.7	921	27.8
0.75	2.22	27.2	8.2	984	27.7
1.0	2.96	27.6	8.3	997	27.7
1.25	3.70	28.2	8.4	1002	28.1
1.5	4.44	28.7	8.4	1005	28.6
1.75	5.18	27.9	8.4	1002	27.9
2.0	5.92	26.7	8.3	993	27.0
Significant difference:		**P<0.001**	**P<0.001**	**P<0.001**	**NS**
	$LSD_{0.05}$	**1.6**	**0.5**	**59**	**-**
	CV%	**6.2**	**6.1**	**6.1**	**5.1**

Yield response over time

There was a significant increase in yield observed between 2004 and 2007 with applied N (Figure 6). There are visible yield differences in the graph (Figure 6) between the 0 kg N/palm and the higher rates in 2005 as well, however difference are not statistically significant.

Most of the yield increase was achieved with only 0.75 kg N/palm (2.22 kg AN/palm).

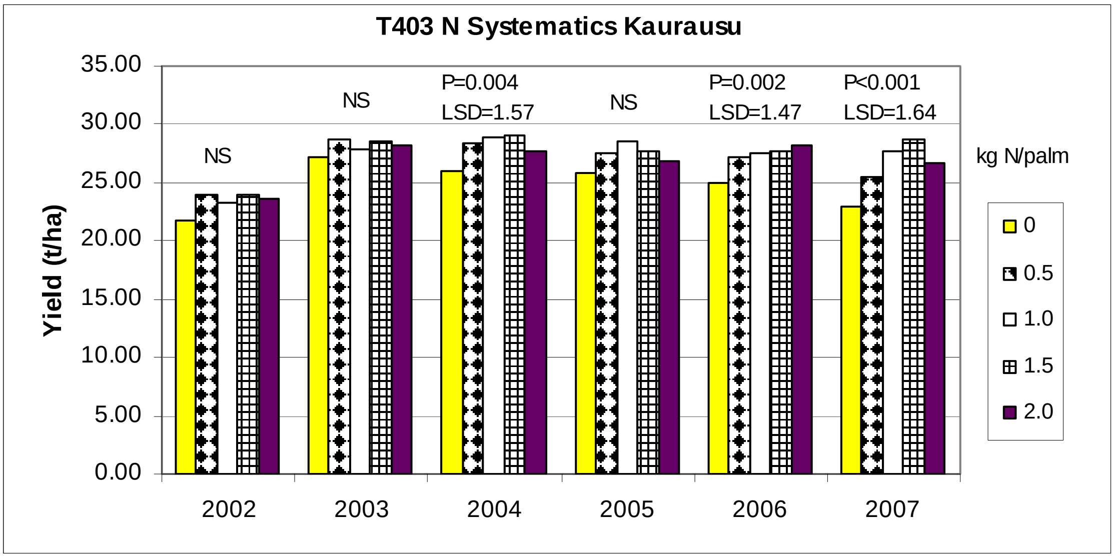


Figure 6. T403: Yield response to 5 rates of N (kg/palm) over time (fertilizer N was first applied in July 2002, and stopped in 2006 when trial was due for felling).

Compared to the other years, the difference in yield in 2007 alone is noticeable between the 0 kg N/palm up to the 1.5 kg N/palm. Nil application of N and other basal fertilizers in 2006 and 2007 may have caused the distinctive differences between the treatments. Generally the average yield in 2007 was slightly lower than the highest yield observed in 2004.

From 2004 to 2007 where the palms were at the matured age (17-20 years) the mean weight of bunches were steady at 27.0 to 27.7 kg/palm.

Tissue nutrient concentration

Leaf and rachis analysis results for 2007 are still to be received from the lab, once received the results will be reported.

CONCLUSION

There was a significant yield response when N is applied. A yield difference of 4 t/ha was achieved at 0.75 kg N/palm (or 2.22 kg AN/palm). A similar yield response was also noticed in Trial 138, Haella.

Trial 141: Large Fertilizer Omission Trial, Haella

Purpose

In addition to the N Systematic trials described previously, OPRA and NBPOL have set up large scale fertilizer omission trials in order to determine what the yield penalty will be when N fertilizer is not used, how long it takes to induce a N deficiency with an associated yield penalty, and also to determine whether nutrients flow from fertilised areas into areas that do not receive fertilizer.

Trial Background Information

Table 1. Trial 141 background information.

Trial number	**141 (Div II)**	**Downslope 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	11 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)**	**Upslope 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	10 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, to which no fertilizer has been applied since 2003. Fertilizer, following company practice, has been applied to the area outside the circle. In 2007, 2.0 kg of AN/palm was applied 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 N) and outside the circle (fertilised with N). If N fertilizer was 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 you moved into the no N 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.

	Division II Down slope		**Division III Up slope**	
	Number of palms	**Ave. FFB Yield t/ha**	**Number of palms**	**Ave. FFB Yield t/ha**
No N fertilizer*	288	21.9	251	32.2
Plus N fertilizer	84	22.0	74	28.9

* Omission plot

CONCLUSION

At this stage in the trial there is no observable impact of nutrient flow from a fertilised area into the omission plots. Two omission plots were established, one on a down slope area (relatively flat) and the other on an up-hill slope site. At neither site was there evidence that Nitrogen had come into the plot from outside the area. The trial is only in its fourth year and it is expected to see effects on the nutritional status of the palms and subsequent impact on yield.

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 2007 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 2007 is the same as the results for the first four years of experimentation (treatments were commenced in 2003).

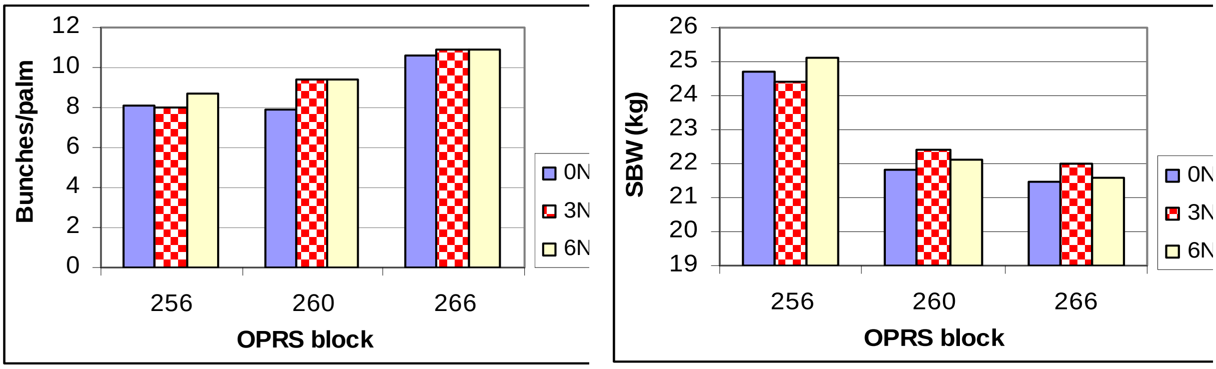


Figure 1. Bunches per palm and Single Bunch Weight (SBW) for three rates of N fertilizer at three sites in 2007 (combined project with OPRS).

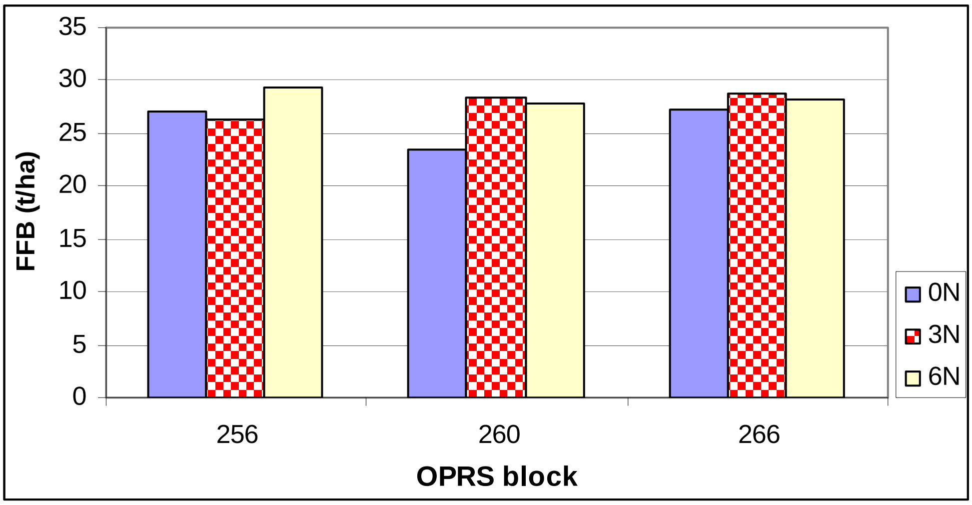


Figure 2. FFB (t/ha) for three rates of N fertilizer at three sites in 2007 (combined project with OPRS).

Progeny effect on yield

One single progeny was common across all three sites (714.814 x 742.316). 16 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).

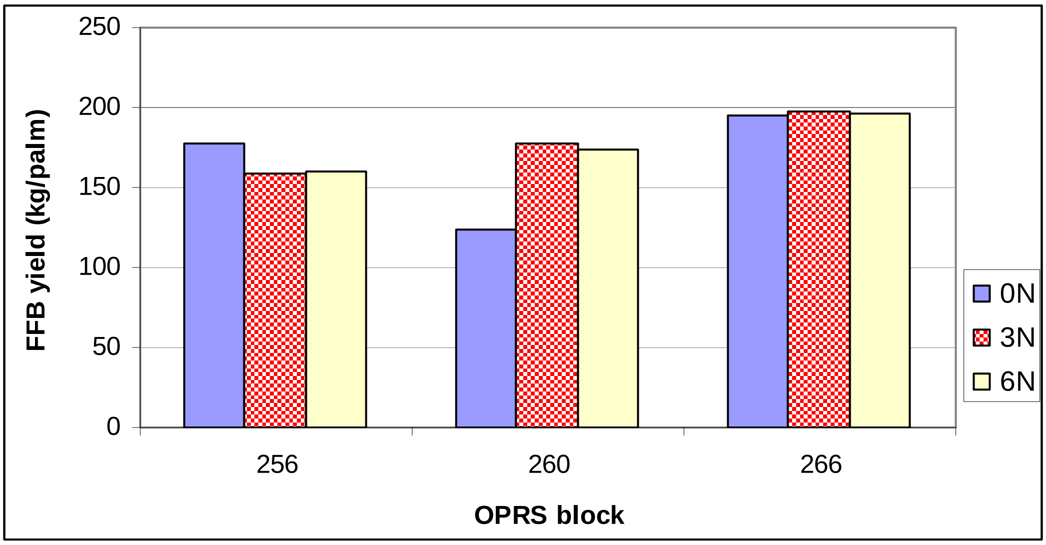


Figure 3. N treatments (kg AN per palm) on one progeny (714.814 x 742.316) on three OPRS blocks.

N impact on tissue nutrient concentration

Results for 2007

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). Leaflet N increased only at the Bebere site (260) as a result of N application (over four years). Leaflet N at this site increased from critically low levels of 2.17% to adequate levels of 2.50% (dm) with the application of N. At the two sites at Kumbango there were no differences between the treatments. This is of real concern because after four years of N treatments being applied (or in the case of 0N – no treatment being applied) there should have been a response, if not in yield, then at least in the tissue!

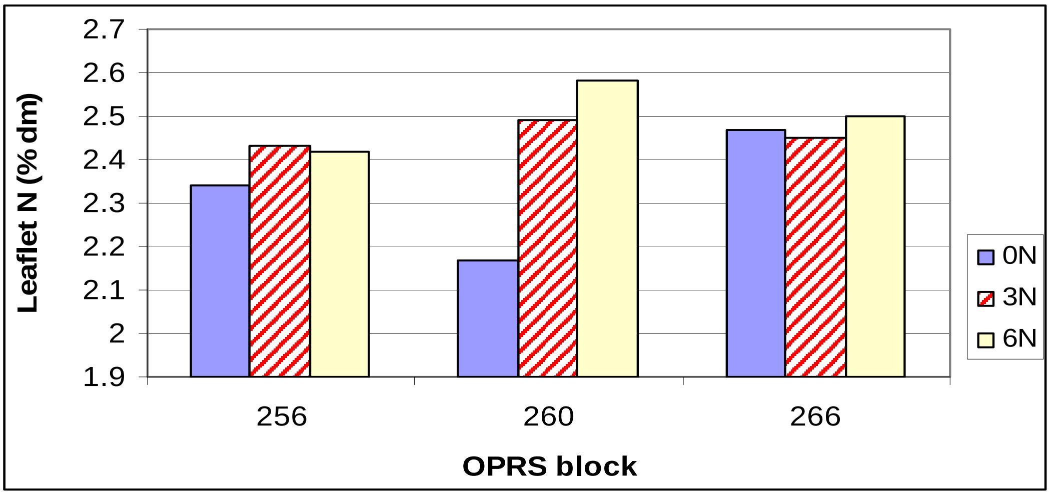


Figure 4. Leaflet N for a single progeny on three OPRS blocks.

A positive leaflet N response to the fertilizer treatments was seen at Bebere (260) this is also the site where there was a positive yield response from N fertilizer.

The other tissue nutrients are presented in Table 2. Only rachis P is on the low side but with moderate levels of fertilizer P (0.5kg/palm of TSP) this slight deficiency will be alleviated.

Table 2. Tissue nutrient concentration (% dm) for P (phosphorus), K (potassium), Mg (magnesium) and B (boron) in 2007 for progeny 714.814 x 742.316.

Block	Leaf P	Rachis P	Leaf K	Rachis K	Leaf Mg	Leaf B
256	0.144	0.057	0.74	1.69	0.13	13
260	0.147	0.069	0.73	1.80	0.15	13
266	0.147	0.062	0.75	1.54	0.15	15

CONCLUSION

The large block N trial was established in 2003 and after four years of experimentation there are still no consistent differences in yield between the 0, 3 and 6 kg/palm Ammonium Nitrate treatments. Only at the Bebere site are the tissue N levels below critical and there was a yield response of 4 t/ha from the N fertilizer.

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 PNG OPRA. 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) PNG-OPRA was successful in attracting research funds from ACIAR (Australian Centre for International Agricultural Research) to study 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.

Within this project, in addition to these trials with NBPOL, other ACIAR funded trials are located with Hargy, Higaturu and Milne Bay Estates.

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.

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

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.

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 nor in 2007 and in these years neither +Mg, +K nor +Mg+K treatments resulted in a yield difference compared to the control plots (no K nor 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.

The application of Mg and K significantly increased the levels of each respective nutrient in the leaflet (and rachis for K). However, when applied in isolation (ie either Mg alone or K alone) then the nutrient not applied was suppressed in uptake and lower values were found in the leaflet/rachis. For example, if Mg fertilizer was applied without K fertilizer then leaflet and rachis K levels were suppressed (and vice versa when K fertilizer was applied).

In the plantation, when applying Kieserite (Mg source) and MOP (K source), it is advisable to apply both fertilizers, rather than just a single one because it will result in reduced uptake of the nutrient not supplied (depending on availability in the soil).

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	6	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 2007 were Ammonium Nitrate (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 year 4 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).

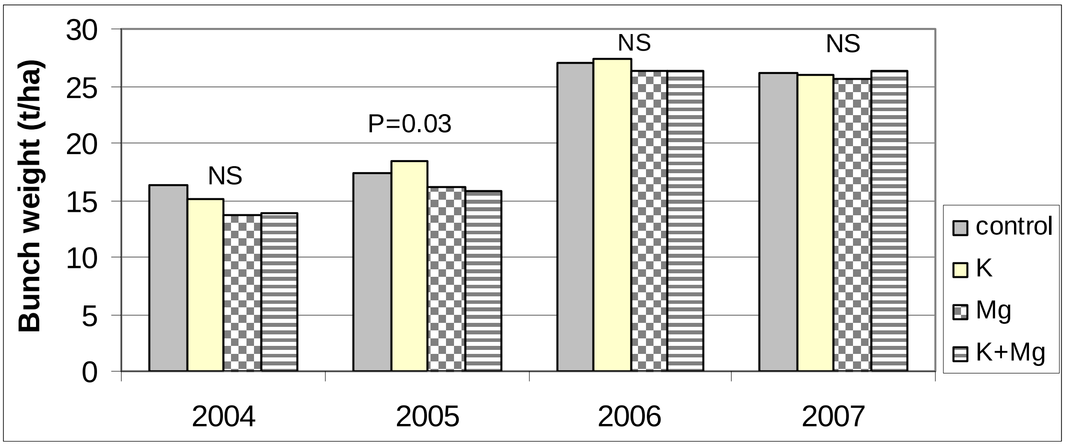


Figure 1. Trial 144 - FFB yield since inception of the trial in 2004.

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 or in 2007.

Table 3. Responses in 2007 to K and Mg fertilizer on yield (FFB Yield), single bunch weight (SBW) and number of bunches (NB/palm and 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 (B/palm)		NB (B/ha)	
Source	**Mg0**	**Mg1**	**Mg0**	**Mg1**	**Mg0**	**Mg1**	**Mg0**	**Mg1**
K0	26.2	25.6	11.0	10.6	20.0	20.3	2399	2441
K1	25.9	26.4	11.3	11.0	19.2	20.0	2300	2408
Significant difference:	**NS**		**NS**		**NS**		**NS**	

(ii) Tissue nutrient content in 2007

Potassium: K levels in the leaflets and rachis was significantly higher in the Potassium fertilizer treatment (either alone or in combination with Mg fertilizer).

Magnesium: Mg levels in the leaflets was significantly higher in the Magnesium fertilizer treatments (either alone or in combination with K fetiliser). In addition, the uptake of Mg was significantly reduced by the K treatment (in other words Mg uptake is 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 except in the Mg fertilizer treatment (Mg fertilizer in the absence of K fertilizer reduces the uptake of K)
- 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 reduces the uptake of Mg)
- Leaflet N and rachis N were adequate at 2.7% and 0.31% dm respectively; Leaflet P at 0.150% dm is adequate; whereas rachis P was on the low side with 0.97% dm. Advised to continue with basal P application.

Table 4. Leaflet K, Mg and Ca, and Rachis K levels (% dm) for four treatments in 2007.

Fertilizer treatment	Leaf K	Leaf Mg	Leaf Ca	Rachis K
Control	0.72	0.17	1.09	1.02
+ Mg	0.71	0.21	1.02	0.88
+ K	0.79	0.14	1.11	1.35
+ Mg + K	0.77	0.19	0.94	1.24
Significant difference:				
Mg	**0.50**	**<0.001**	**0.001**	**0.23**
K	**0.007**	**0.01**	**0.30**	**0.006**
MgxK	**0.69**	**1.0**	**0.09**	**0.87**
LSD	**0.04**	**0.02**	**0.06**	**0.22**
CV%	**4.8**	**9.6**	**5.0**	**17.1**

(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 and rachis; and Mg fertilizer applied alone (i.e. without K fertilizer) reduced the uptake of K (see Figures 2 and 3).

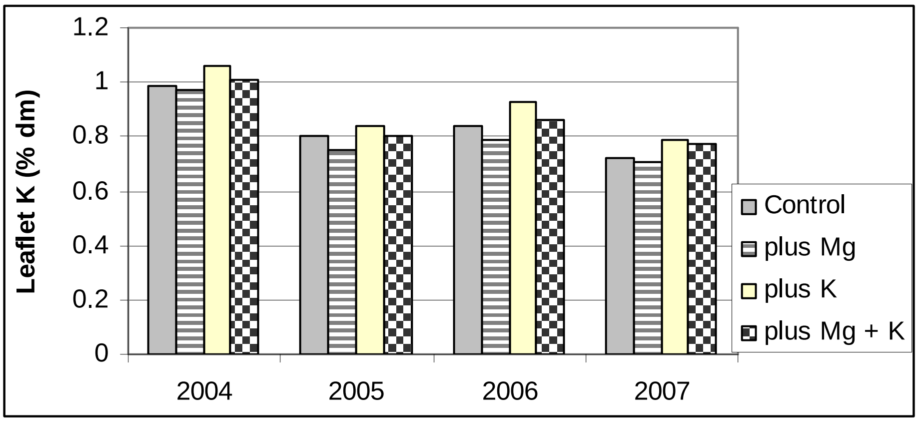


Figure 2. Leaflet K (% dm) in trial 144 over time (2004 to 2007)

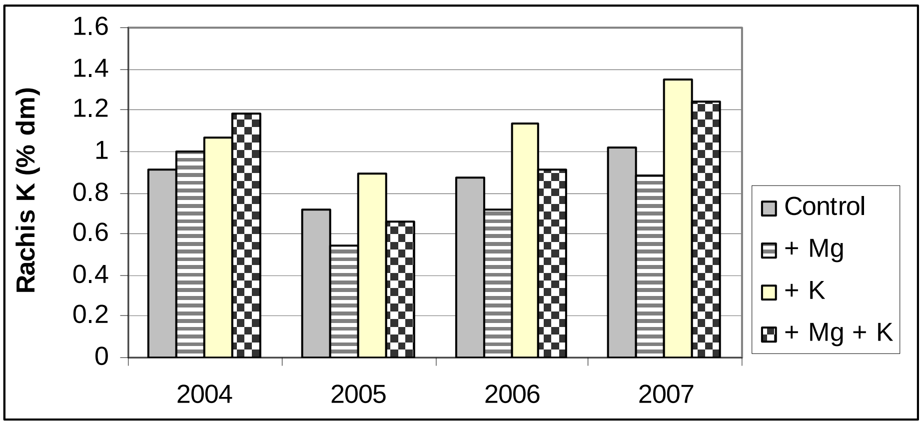


Figure 3. Rachis K (% dm) in trial 144 over time (2004 to 2007)

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).

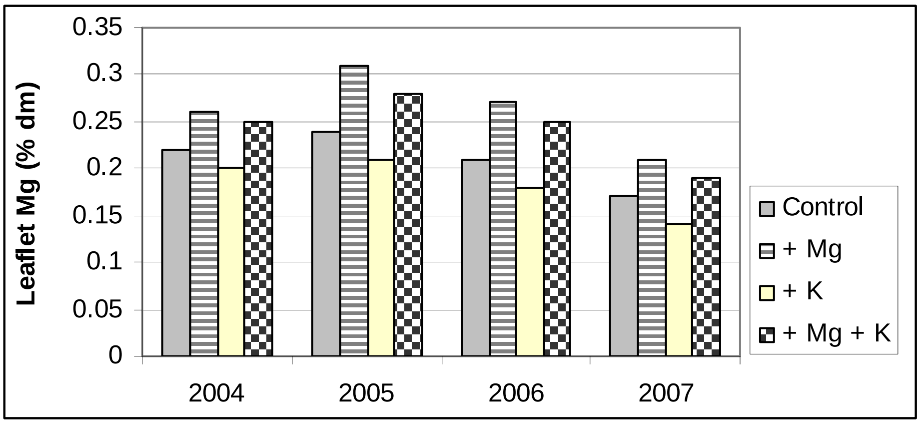


Figure 4. Leaflet Mg (% dm) in trial 144 over time (2004 to 2007).

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

17.8 new fronds were produced in 2007 (one every 20 days) – normally we would expect a new frond to form every 17 to 20 days. Total green fronds counted per palm averaged 43 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 8.8m^2 and LAI of 4.5). 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 24.5cm^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 2007.

	PCS	Radiation Interception				Dry Matter Production (t/ha)			
		GF	FP	FA	LAI	FDM	BDM	TDM	VDM
Mean	24.5	43.0	17.8	8.8	4.5	6.3	13.7	21.6	7.9
P value	0.30	0.15	0.41	0.63	0.35	0.07	0.93	0.90	0.15
CV%	7.7	3.2	2.8	8.6	9.1	6.3	9.0	7.2	6.0

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 4 of experimentation there was no impact of either Mg or K based fertilizer on production;

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

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

(iv) Leaflet K and rachis K increased in the treatments where K had been applied;

(v) Mg fertilizer suppresses the uptake of K; K fertilizer suppresses the uptake of Mg. When Mg and K fertilizer need to be applied, they have to be applied together. If only K fertilizer is applied there will be a reduction in Mg uptake and vice versa, if only Mg fertilizer is applied there will be a reduction in K uptake.

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 are below adequate levels. 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	8	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 2007: 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 2007

At this stage in the trial (third year) there are no differences between the Mg fertilizer treatments and the control (Control 32.6 t/ha and average of all Mg treatments is 32.7 t/ha). The impact of Mg fertilizer on SBW and Bunch Number was also not significant.

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

Fertilizer type	Yield (t/ha)	BN (Bunch/ha)	SBW (kg)
Control	32.6	1647	19.9
Kieserite Standard	34.3	1725	19.9
" 2 x Standard	31.6	1593	19.9
EMAG45 Standard	32.4	1625	20.0
" 2 x Standard	31.7	1588	20.0
FO1 Standard	32.3	1655	19.5
" 2 x Standard	32.8	1568	21.0
EMAG M30 Standard	33.3	1582	21.0
" 2 x Standard	33.4	1629	20.5
Significant difference:	**P=0.72**	**P=0.84**	**P=0.80**
CV%	**6.5**	**8.6**	**7.0**

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).

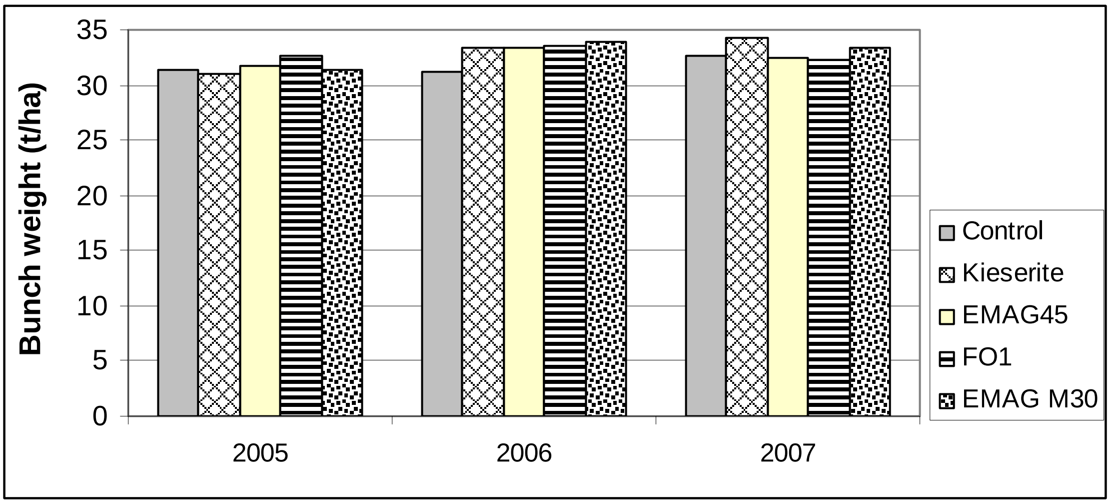


Figure 1. Yield achieved in 2005, 2006 and 2007 as a result of different Mg fertilizer treatments (including the zero Mg control)

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 (note no Rachis Mg analysed in 2007).

Mg fertilizer	Level	Leaflet Mg (%dm)					Rachis Mg (%dm)			
		2003	2004	2005	2006	2007	2003	2004	2005	2006
Control	0	0.17	0.17	0.22	0.19	0.13	0.041	0.034	0.036	0.051
Kieserite	1	0.17	0.15	0.22	0.18	0.14	0.038	0.035	0.037	0.046
Kieserite	2	0.16	0.17	0.22	0.19	0.14	0.043	0.037	0.037	0.052
EMAG45	1	0.17	0.16	0.22	0.18	0.14	0.040	0.035	0.035	0.054
EMAG45	2	0.17	0.16	0.21	0.18	0.14	0.039	0.035	0.034	0.051
FO1	1	0.18	0.17	0.23	0.19	0.15	0.044	0.032	0.037	0.047
FO1	2	0.18	0.16	0.22	0.19	0.15	0.046	0.033	0.038	0.057
EMAG M30	1	0.17	0.17	0.22	0.19	0.14	0.041	0.035	0.036	0.048
EMAG M30	2	0.16	0.15	0.21	0.18	0.14	0.041	0.034	0.038	0.046
Significant diff.: Treatment		**NS**					**NS**			

The other tissue nutrient levels are presented in Table 5. The leaflet nitrogen level in 2007 is adequate after an increase level of basal N was applied at this site in 2007. The leaflet and rachis levels for phosphorus and potassium were adequate to high (Table 5).

Table 5. Mean leaflet and Rachis nutrient levels for trial 145 (2007).

Nutrient	Leaflet (% dm)	Rachis (% dm)
Nitrogen	2.52	0.41
Phosphorus	0.147	0.14
Potassium	0.75	2.1
Calcium	0.72	-
Boron	19 ppm	

Fertilizer Mg effects on oil palm vegetative growth

Frond production and frond number

26.5 new fronds were produced in 2007 (one every 13.7 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 42 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 6.5). 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 is a primary determinant of vegetative dry matter production. Although significant (P=0.04) the PCS varied 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 2007.

Mg fertilizer	Level	PCS	Radiation Interception				Dry Matter Production (t/ha)			
			GF	FP	FA	LAI	FDM	BDM	TDM	VDM
Control	0	44.3	41.0	27.0	13.2	6.5	15.3	16.8	35.6	18.9
Kieserite	1	39.8	41.7	27.5	13.2	6.6	14.0	17.8	35.4	17.6
Kieserite	2	49.4	41.0	26.7	14.2	7.0	16.8	16.7	37.2	20.5
EMAG45	1	44.6	40.2	26.5	13.7	6.6	15.1	16.8	35.5	18.7
EMAG45	2	43.9	40.4	26.9	13.1	6.4	15.1	17.0	35.6	18.7
FO1	1	45.4	39.0	26.5	13.9	6.5	15.4	16.3	35.2	18.9
FO1	2	42.3	40.8	26.9	13.1	6.4	14.6	7.1	35.2	18.1
EMAG M30	1	44.1	41.3	26.9	13.1	6.5	15.2	17.2	36.0	18.8
EMAG M30	2	42.6	40.3	26.1	12.8	6.2	14.3	17.6	35.4	17.8
Significant diff.:		**0.04**	**0.39**	**0.48**	**0.57**	**0.59**	**0.02**	**0.57**	**0.60**	**0.03**
$LSD_{0.05}$		**4.9**	**-**	**-**	**-**	**-**	**1.4**	**-**	**-**	**1.2**
CV%		**7.8**	**3.8**	**3.0**	**7.4**	**7.7**	**6.7**	**6.3**	**4.0**	**5.1**

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

In the third 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 and rachis 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, Mg 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	8	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 2007, Ammonium Nitrate (3 kg/palm) TSP (0.5 kg/palm), MOP (0.5 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 2007.

Table 3. Significance (p values) of main effects in 2007 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 the statistical analysis.

	FFB yield	BN/ha	SBW (kg)
Fertilizer type	0.21	0.22	0.19
Placement	0.24	0.90	0.40
Source x Placement	0.18	0.18	0.47

The yield achieved in 2007 for the various treatments is presented in Table 4. Because there were no significant effects on Single Bunch Weight (mean 18.3kg), or Bunch Number (mean 1760/ha), the results for these are not presented.

Table 4. Effect of Mg source and placement on FFB yield (t/ha/yr) in 2007.

Fertilizer type	Placement					
	Zero control	**Surface**	**Open Trench**	**Covered Trench**	**Coconuts**	**Positive control**
Nil	31.3					
Kieserite		31.5	33.7	31.3	31.8	
$MgCO_3$		32.2	33.4	31.0	31.0	
MgO		34.4	31.9	31.7	34.6	
Combined						32.8

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 2007

There was no 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 2007.

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	0.16	0.17	
MgO		0.16	0.16	0.17	0.16	
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 (2007).

Nutrient	Leaflet (% dm)	Rachis (% dm)
Nitrogen	2.58	0.35
Phosphorus	0.152	0.10
Potassium	0.79	1.9
Calcium	0.8	
Boron	18 ppm	

Fertilizer Mg effects on oil palm vegetative growth

Frond production and frond number

25 new fronds were produced in 2007 (one every 14.6 days) which is indicating good growing conditions. Total green fronds counted per palm averaged 39 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 small regardless of treatment. The PCS for the Mg treatments was 37.6cm^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 2007 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	37.6	34.1	37.4	Small petiole cross section
GF	39.0	38.4	39.1	Adequate total number of fronds
FP	25.3	25.2	25.2	Good frond production (one new frond every 14.6 days)
FA	12.7	12.1	12.5	Small fronds
LAI	6.4	5.9	6.2	Adequate LAI
FDM	13.1	11.9	13.0	
BDM	16.9	16.6	17.3	
TDM	33.4	31.6	33.6	
VDM	16.4	15.7	16.3	

PCS = Petiole cross-secti1.on 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 three 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.

The trial will be continued in 2008.

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. However, when the yields of three progenies were compared across all blocks it showed that there was a yield response to Mg in two out of the three progenies. The highest yielding progeny did not respond to Mg fertilizer, however this progeny also had the highest level of leaflet Mg regardless of Mg fertilizer treatment – indicating more efficient uptake of soil Mg by this progeny.

As the Mg content in leaflets continues to differentiate between treated and untreated plots we expect to start observing differences in yield and its components.

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	6 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 2007 in Trial 148: 3.0 kg/palm DAP 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 2007 (Figure 1). There was also no effect on bunch number (average bunch number = 19 b/palm) nor on bunch weight (average SBW = 11.9kg).

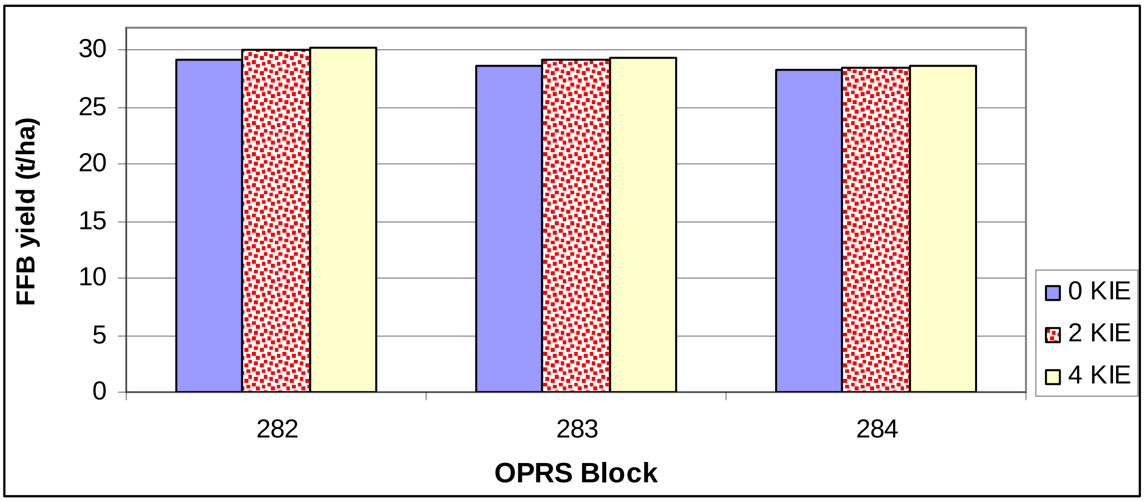


Figure 1. FFB yield of three rates of Kieserite on three large blocks.

The trial is now in its fourth 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).

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
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 a magnesium fertilizer effect on yield (P=0.03), with the control treatment (0 KIE) yielding 3 t/ha less compared to the Kieserite treatments for two of the progeny. The progeny effect was much stronger (P=0.001), and progeny 635.607 x 742.207 with a yield of 32 t/ha, out yielding the other two progeny by 2.5 to 3.0 t/ha.

Table 4. Progeny and Mg fertilizer effect on FFB yield in 2007.

	Yield t/ha		
Kieserite kg/palm	**0**	**2**	**4**
Progeny			
635.607 x 742.207	32.1	32.0	32.1
714.712 x 742.316	26.4	30.2	29.3
5035.216 x 742.316	27.8	30.5	30.7
Significant difference:			
Mg rate	**P=0.03**		
Progeny type	**P=0.001**		
Mg x Prog	**NS**		
$LSD_{0.05}$	**1.6**		
CV%	**5.4**		

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
Significant difference:			
Year	**P<0.001**		
Rate	**P<0.001**		
Year x Rate	**NS**		
$LSD_{0.05}$	**0.01**		
CV%	**7.4**		

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).

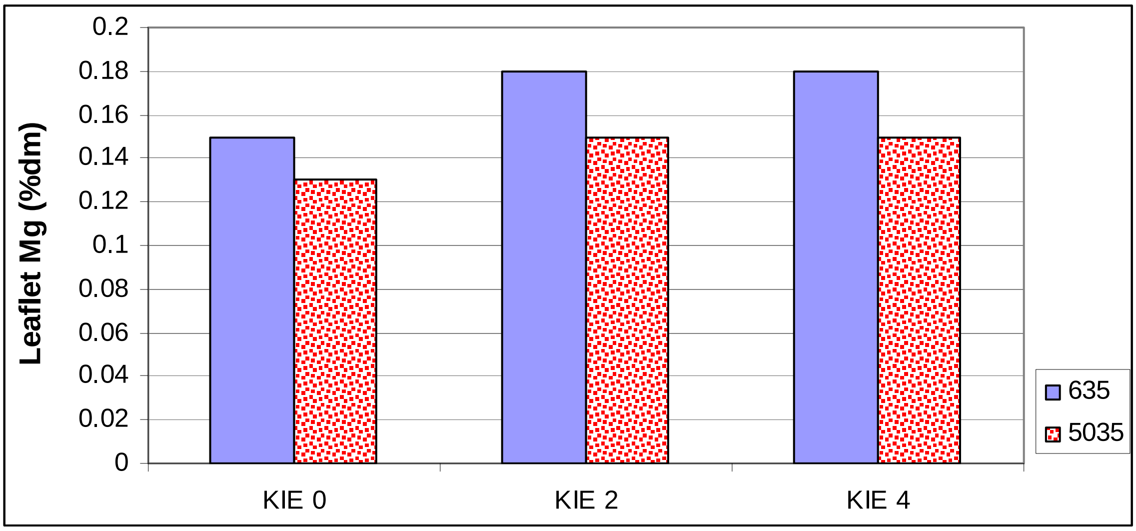


Figure2. Mg concentration in leaflets for two progeny, 2007.

Other nutrients appeared to be present in adequate amounts (Table 6). P is on the low side in the rachis and needs to be monitored over the next few years to ensure that it does not drop further.

Table 6. N, P, K and B tissue levels in 2007 (Trial 148).

	Nutrient concentration (% dm)	
	Leaflet	**Rachis**
N	2.69	0.34
P	0.153	0.07
K	0.89	1.90
B	17 ppm	

CONCLUSION

Yield
After four years of experimentation it has not been possible to demonstrate a yield response to Magnesium fertilizer (as Kieserite) over a large block. However, when progeny effect is taken into account there has been an increase in yield from the application of Kieserite. 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 had a lower yield compared to progeny 635 and 5035.

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 26 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. There was no difference between the progeny in the yield response to boron, however there was a large difference in yield between the three progeny (a difference of between 2 to 2.5 t/ha, or 10%, between progeny was observed).

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

METHODS

Boron deficiency is suspected of being involved in problems with fruit set and 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	6 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 2007

Similar to previous years, in 2007 there was no significant effect of Boron application on yield, bunch number or bunch weight (average yield 26.2 t/ha, bunch number 17.5 b/palm and SBW of 11.7 kg/bunch .

There was no difference in B response between the four breeding sites, however all three treatments yielded less at OPRS site 288 (4 to 5 t/ha less) (Figure 1).

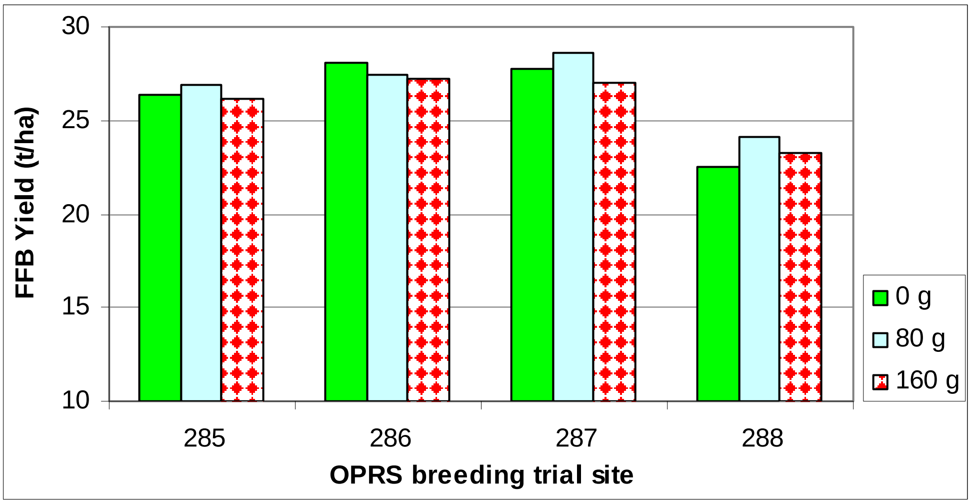


Figure 1. FFB yield for three rates of applied Boron fertilizer at four OPRS breeding sites.

Effect of boron fertilizer on the yield of different progeny in 2007

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. Progeny 635 and 5035 had a significantly higher yield compared to progeny 714 (25.0 and 24.4 vs 22.3 t/ha respectively) (Table 3). The yield response was primarily due to a heavier bunch weight for progenies 635 to 5035 compared to 714. There was no yield effect from the rate of Boron applied (Table 3).

Table 3. Yield, bunches per palm and bunch weight for three progeny in 2007.

	Yield t/ha		
Borate g/palm	**0**	**80**	**160**
Progeny			
635.607 x 742.207	24.4	26.0	24.5
714.712 x 742.316	23.1	22.7	21.1
5035.216 x 742.316	23.8	24.2	25.4
Significant difference:			
B rate		**NS**	
Progeny type		**0.002**	
B x Prog		**NS**	
$LSD_{0.05}$		**1.4**	
CV%		**7.0**	

Similar progeny effects were found in previous years.

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 five 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

Differences in the uptake of B by different progeny was not significant (Figure 2).

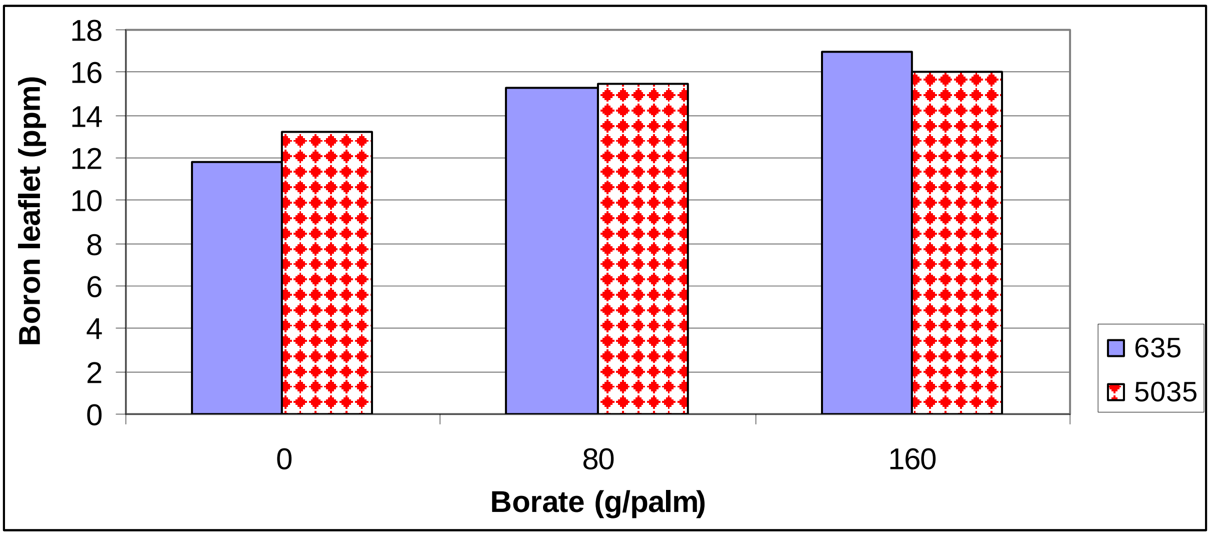


Figure 2. Leaflet boron levels (ppm) for two progeny, 635 and 5035, in 2007.

Other tissue nutrient levels were all found to be adequate or close to adequate (Rachis P is slightly on the low side) (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	2.69	0.36
Phosphorus	0.153	0.06
Potassium	0.86	1.94
Magnesium	0.19	-

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

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

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. However, 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). 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 bunch (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 these 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	8	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 2007: 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 5^{th} 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 2007

For the first time since monitoring started in this trial, in 2007 there was a small but significant effect of reduced yield with the wider avenue spacing (Table 3). The Wide avenue spacing was significantly lower in yield compared to the Standard spacing, not compared to the Intermediate spacing. The main effect was on slightly reduced bunch numbers in the Wide avenue compared to the Standard avenue spacing.

Table 3. Impact on yield, bunch number and SBW from three row spacing treatments in 2007

Spacing	Yield t/ha	Bunch No. Bunch/palm	SBW kg
Standard	33.4	14.0	18.5
Intermediate	32.3	13.5	18.6
Wide	31.2	13.2	18.4
Significant difference	**P=0.02**	**P=0.02**	**P=0.90**
LSD	**1.3**	**0.5**	**-**
CV%	**1.8**	**1.7**	**2.5**

Spacing treatment effect on yield over time

Yield increased from 16.0 t/ha in 2003 to 32 t/ha in 2007 (age of palms from 4 to 8 years). Only in 2007 has a small yield difference become evident between the Standard and the Wide avenue spacing.

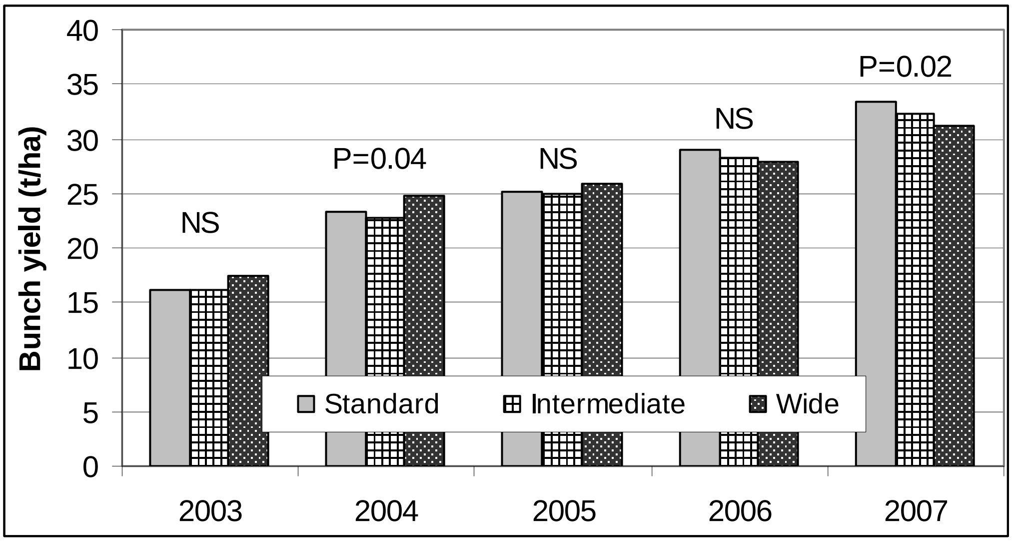


Figure 1. The impact of Avenue width on yield (keeping planting density the same) for Trial 139.

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, P and K were all adequate. P levels increased from last year's sampling following the application of basal P.

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

Avenue Width	**Leaflet nutrient concentration (% dm)**			**Rachis nutrient concentration (% dm)**		
	N	**P**	**K**	**N**	**P**	**K**
Standard	2.63	0.153	0.78	0.36	0.10	2.0
Intermediate	2.67	0.153	0.77	0.35	0.10	1.8
Wide	2.61	0.154	0.80	0.36	0.10	1.0
Significant diff:	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

Magnesium and Boron levels were near adequate (0.16 %dm and 13ppm respectively).

CONCLUSION

At this stage in the trial, as palms are reaching maturity, there are now some small differences in yield discernible 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 33.4 t/ha and the Wide avenue treatment yielded 31.2 t/ha.

Milne Bay Estates, MBE: Summary

(Dr. Harm van Rees and Wawada Kanama)

Fertilizer response trials with MBE comprised one main area of interest: the interaction between Nitrogen and Potassium based fertilizers. In addition to investigating these two nutrients we also have trials which incorporate P and EFB (Empty Fruit Bunches).

Outcome: Responses to N and K fertilizer ranged from 70 to 500% over the control (no fertilizer applied). The highest yield achieved at each of the sites was 35 t/ha. At one site (hilly country with soils which contain high levels of buckshot), higher rates of N and K were required to achieve these high yields and P fertilizer was also required to optimise yield. The trials showed the importance of balanced nutrition and the close relationship between yield and leaflet and rachis N, P and K levels.

These trials were established over a decade ago and it is now possible to determine robust adequacy levels for tissue test interpretation.

The blocks within which trials 502 and 511 are located will be replanted over the next year or two. New trial opportunities with CTP MBE should be discussed. One possible area is to investigate the nutrient requirements and potential production for different progeny. A new N x K trial was established on alluvial soils at MBE in 2007.

Based on the results of these trials, a synopsis of the trial results can be found on the next page. Also some recommendations have been made to CTP MBE based on the outcomes of the trial work.

MBE: Synopsis of 2007 trial results and recommendations

Trial	Palm Age	Yield t/ha	Yield Components	Tissue % dm	Vegetative	Notes
504 Sagarai SOA, MOP (factorial) Soil: Alluvial	17	Control 22 SOA+MOP 34	Bunch/p 7 to 10 SBW 22 to 26	SOA LN 2.40 to 2.58 MOP LK 0.55 to 0.65 RK 0.52 to 1.74	PCS 45 to 51 FP 21to 23 LAI 4.5 to 5.3	Main response to N, some response to K. P required, applied as basal.
502 Waigani SOA, MOP, TSP, EFB (factorial) Soil: Alluvial	21	Control 18 SOA+MOP+TSP+ EFB 34	Bunch/p 6 to 9 SBW 21 to 30	SOA LN 2.32 to 2.47 RN 0.32 to 0.40 MOP LK 0.53 to 0.64 RK 1.11 to 1.02 (?) TSP LP 0.149 to 0.152 RP 0.14 to 0.19 EFB LN 2.38 to 2.45 LK 0.56 to 0.64 RK 1.44 to 1.91	PCS 45 to 52 FP 22 (NS) LAI 4.7 to 5.3	Main response to N, some response to K and P (only at the highest yields).
511 Waigani SOA, MOP, TSP, EFB (factorial) Soil: Alluvial/ Hilly country	19	Control 7 SOA+MOP+TSP+ EFB 35	Bunch/p 4 to 10 SBW 15 to 26	SOA LN 2.25 to 2.47 RN 0.28 to 0.35 MOP LK 0.65 (NS) RK 1.34 to 1.79 TSP LP 0.134 to 0.147 RP 0.06 to 0.16 EFB LN 2.31 to 2.42 LK 0.61 to 0.68 RK 1.55 to 1.83	PCS 34 to 44 FP 20 to 21 LAI 4.2 to 5.3	Main response to N and P. K is also required at the higher yields.

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

Nitrogen and Potassium requirements at CTP Milne Bay Estate

Three Nitrogen (N) x Potassium (K) fertilizer trials were established in the mid 1990s, at CTP Milne Bay Estate. Two trials were established at the Waigani estate and the third at Sagarai. At all three sites the soil origin is alluvial with a clay content of between 30 and 50%. The site at Sagarai (Trial 504) and one site at Waigani (Trial 502) have relatively flat topography, the Waigani site (Trial 511) consists of inter-fluvial deposits in a terrace (hilly) formation.

Trial 504: is a fully replicated (x 4) trial with four rates of N and K (applied as SOA at 0, 2, 4 and 6 kg/palm and MOP applied at 0, 2.5, 5 and 7.5 kg/palm).

Trials 502 and 511: are non replicated factorial trials consisting of the same SOA and MOP treatments as for Trial 504, plus two additional treatments of: P (as TSP at 0 and 2kg/palm) and EFB (Empty Fruit Bunches at 0 and 0.3 t/palm).

The trials serve as an excellent example for CTP Milne Bay Estates of what yield can be achieved and what rates of fertilizers are required to achieve high and profitable yields. The tissue nutrient analysis undertaken for each of the trials demonstrates how robust this technique is in identifying optimum nutrient status. The results of the trial tissue analysis can also be used by plantation managers to identify nutrient deficiencies in the plantation and determine a fertilizer strategy to remedy these deficiencies. The economic analysis, as a gross margin of the trial results, clearly show the cost : benefit ratio of getting the fertilizer strategy right for optimum profit.

The following is a synopsis of the overall results for the three trials – the details can be found in the write up for each individual trial.

SYNOPSIS FOR N x K TRIALS AT CTP MILNE BAY ESTATES

1. Yield and its components

After more than a decade of trial treatments and monitoring it is clear that there is a great deal of similarity between the three trials in their response to fertilizer. The fertilizer treatments had an impact on bunch number (BN) produced and single bunch weight (SBW), and hence fresh fruit bunch (FFB) yield. The responses to fertilizer were consistent between the three trial sites (Table 1). Trial site 511 has lower inherent soil fertility and this site required higher inputs to achieve the same yields compared to trial sites 504 and 511.

The lowest yield, SBW and BN in each trial was always the control (no fertilizer) treatment, or other treatments without N fertilizer. SBW and BN, and hence yield, increased at each site as N was applied especially in combination with K. The two trials at Waigani included TSP and EFB as treatments and the highest yielding treatment with the heaviest SBW and highest BN, was the highest rate of N and K in combination with P and EFB (Table 1). It is clear that fertilizer treatments, especially N, had a major impact on SBW and BN at all three sites.

Table 1. Fertilizer treatments for low, average and high yield at each site (average for 2005 to 2007).

Yield level	Fertilizer treatment (product and kg/palm)	FFB yield (t/ha)	SBW (kg/bunch)	BN (bunches/palm)
Trial 504: Sagarai				
Low	SOA 0, MOP 0	21.8	22.4	7.7
Average	SOA 2, MOP 2.5	28.5	25.2	9.0
High	SOA 6, MOP 2.5	33.7	26.0	10.3
Trail 502: Waigani (flat)				
Low	SOA 0, MOP 0	17.3	21.3	6.4
Average	SOA 4, MOP 2.5	25.3	25.2	7.9
High	SOA 6, MOP5, TSP2, EFB 300	33.9	30.4	8.8
Trial 511: Waigani (hilly)				
Low	SOA 0, MOP 0	7.0	14.7	3.8
Average	SOA 6, MOP 2.5	20.8	22.2	7.3
High	SOA 6, MOP 7.5, TSP2, EFB 300	34.7	26.2	10.2

The lowest yield at Trials 504 and 502 was still quite high at 21.8 and 17.3 t/ha respectively (three year average yield), and was achieved with no fertilizer inputs. After over a decade of trial implementation the soil is still mineralising sufficient N and has sufficient access to other nutrients to keep producing these relatively high yields. Trial 511 is different, the low input treatments have very poor yields (around 7 t/ha) and the soil is unable to supply sufficient nutrients to produce similar results to trials 502 and 504. Trial 511 is situated in more hilly country and has leached soils with a large amount of buck shot down the soil profile. Interestingly, the high yield at this site (35 t/ha) was still the same as at the other two sites – indicating that it is nutrient supply which is the limiting factor not an inherent problem with soil condition or management.

The highest yield for each site was close to 35 t/ha/annum – a remarkably stable outcome. It raises the question of whether the highest yield has been attained. Could higher yields be achieved if fertilizer inputs had been even higher?

Using OMP8, these trial yield results can be compared, to the plantation blocks surrounding these trials to see how the blocks performed in relation to the trials. The fertilizer treatments in the trials can then be compared to those used on the plantation blocks to see what additional fertilizers are required to achieve higher yields (for a description of this type of comparison see at the end of this section). The trial data can also be used to compare tissue nutrient results for the trials to the plantation blocks.

Tissue nutrient status

The nutrient status of Frond 17, leaflets and rachis, was strongly correlated to production. The tissue nutrient status where high yields were achieved was very similar between the sites (Table 2).

Table 2. Adequate nutrient status for leaflets and rachis to achieve high yields for the three N x K trial sites at CTP Milne Bay Estate.

Leaflet (% dm)			**Rachis (% dm)**		
N	**P**	**K**	**N**	**P**	**K**
2.45	0.145	0.65	0.33	0.10	1.2

The analysis of tissue results is not an exact science and some interpretation is required. For example, it is clear that to achieve high yields the nutrient levels presented in Table 2 are required, however there were occasions when treatments still had high yield even when leaflet P and K levels were below adequate but in those situations the rachis P and K were always adequate.

The tissue nutrient levels increased with increasing rates of fertilizer application at each of the trial sites. It is possible to compare estate leaf sampling units (LSU) to the nutrient status of the three trial sites and devise a fertilizer program which overcomes any deficiency.

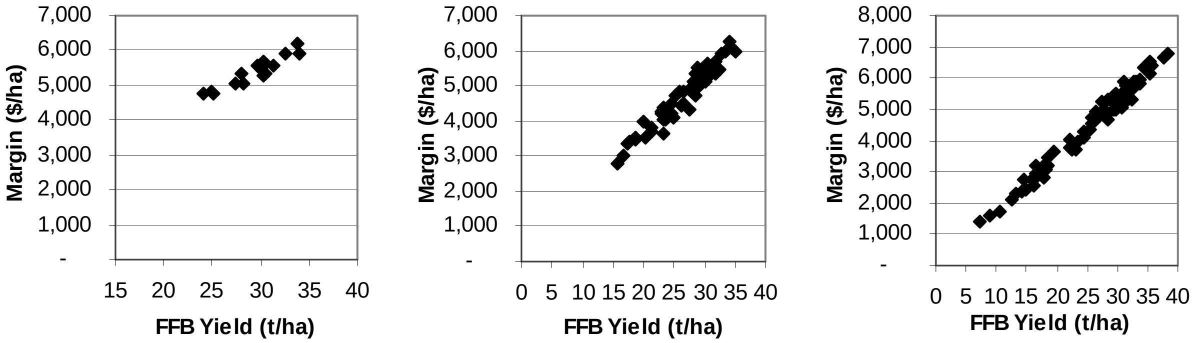
In the trial analysis for nutrient status the magnesium, Mg, status of the tissue was not considered because in all cases it was found to be above the required adequate level (most leaflet Mg levels were above 0.30% of dm).

Economic analysis

The cost : benefit ratio of applying fertilizer was calculated for each of the trial sites using the variable costs incurred in production and the income achieved from CPO (Crude Palm Oil) and kernels. The variable costs include fertilizer type and rate; transport of fertilizer from port to the mill and then to the field; the spreading of fertilizer; the harvest and transport to the mill of FFB; the processing of FFB to CPO and kernels; and the transport of CPO and kernels to port. The return was calculated from the price of CPO and kernels at port. Prices in May 2008 were used to make the calculations for variable costs and income.

Gross margin analysis (income – variable costs) is a useful method for comparing the impact of various fertilizer inputs in a trial situation. Rarely are the highest input crops the most profitable because at some stage, as inputs are increased, the variable costs become higher than the rate of return. Although useful to compare trials within a plantation, a gross margin analysis has limited suitability in comparing the performance of different plantations because major costs which are fixed or so called overhead costs are not included. Variable costs do not include the fixed costs of plantation maintenance, such as: mill maintenance, salaries, loans, road maintenance etc – these costs can easily be as high or higher than the variable costs and hence can distort the interpretation of gross margins. Never the less, a gross margin analysis of fertilizer trials is a convenient way to investigate the cost : benefit ratio for applying particular fertilizers and rate of fertilizer.

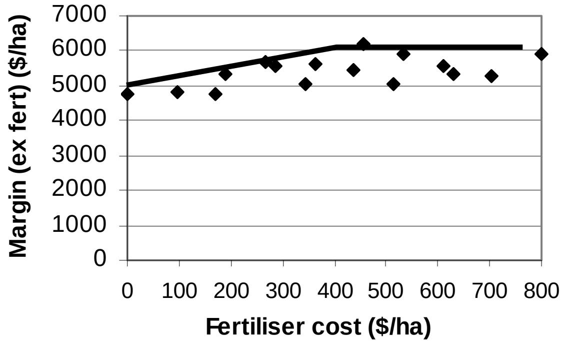
As expected there is a strong relationship between yield and the gross margin achieved – the highest yields made gross margins consistently around $6000/ha at all three trial sites (Figure 1).



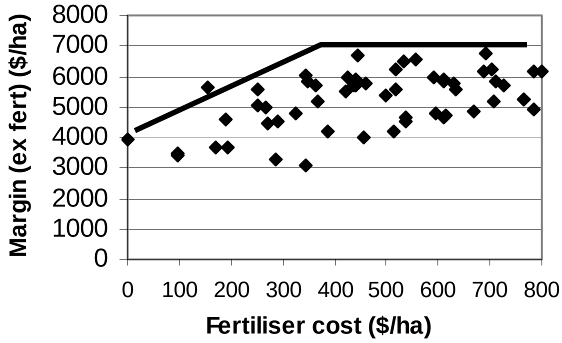
Trial 504. Trial 502. Trial 511.

Figure 1. Gross margin ($/ha) versus FFB yield (t/ha) for three trial sites at CTP Milne Bay Estate using yield data for 2007..

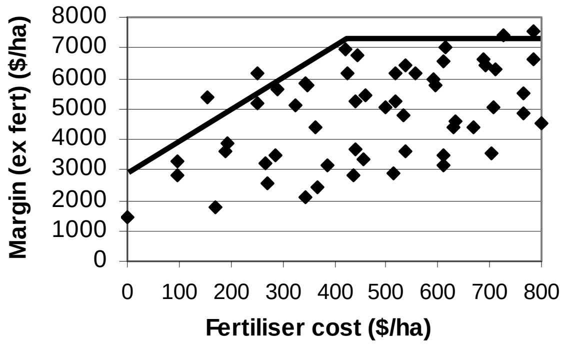
Highest inputs did not necessarily mean highest gross margin return (Figure 2). For trials 504 and 502, which have a higher inherent soil fertility compared to trial 511, the highest return was achieved with an input of around $450/ha in fertilizer. Trial 511 does not have the same inherent soil fertility as the other two sites and a higher input is required to achieve a similar return.



Trial 504:
highest return of $6200/ha achieved with SOA 6 + MOP 2.5 kg/palm
(at a cost of $458/ha in fertilizer)



Trial 502:
highest return of $6720/ha achieved with SOA 4 + TSP 2 kg/palm + EFB
(at a cost of $444/ha in fertilizer)



Trial 511:
highest return of $6900/ha achieved with SOA 2 + MOP 2.5kg/palm + EFB
(at a cost of $421/ha in fertilizer)

Figure 2. Gross margin return ($/ha) excluding fertilizer input versus fertilizer cost ($/ha) for three trial sites at CTP Milne Bay Estate in 2007.

What can be achieved at CTP Milne Bay Estate? Comparison of block to trial data in 2007.

Comparing yields and inputs on blocks adjacent to where trials are located to actual trial data gives an excellent overview of how the commercial blocks are performing against the potential yield. Commercial block data were obtained from OMP8. The block fertilizer is presented as equivalent kg of SOA (even though other N fertilizers were used – to make comparison to the trial fertilizer easier).

Trial 504 Sagarai

Two blocks adjacent to trial 504 at Sagarai are compared to trial data. The yield is presented for the block data; the trial plot with as close to the same fertilizer as was used on the commercial blocks, and the highest yielding treatment in the trial (Figure 3).

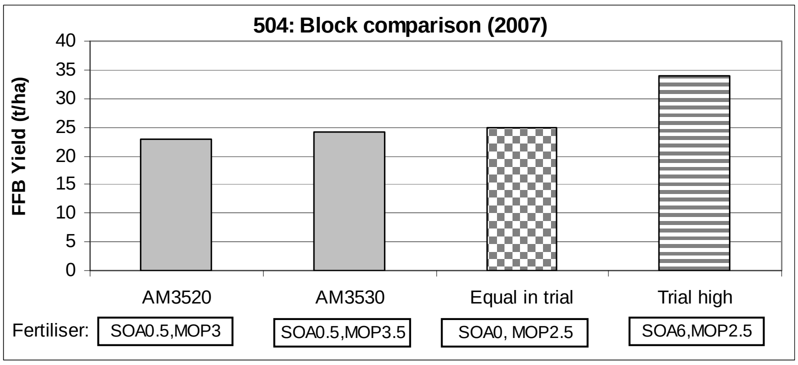


Figure 3: Block data (from OMP8) vs trial 504 yield data (2007).

The yields in blocks AM3520 and AM3530 were equal to the trial yield with a similar fertilizer input, but nearly 10 t/ha less compared to the highest yielding treatment in the trial.

Trial 502 Waigani

Two blocks (AM2150 and AM2170) adjacent to trial 502 were compared to the equivalent input treatment and the highest yielding treatment (Figure 4).

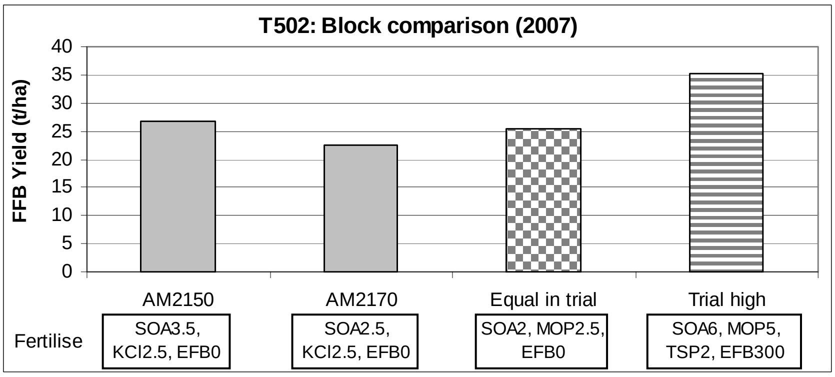


Figure 4. Commercial block data (from OMP8) vs trial 502 yield data (2007).

Equal yields were obtained in the blocks when compared to a treatment with a similar fertilizer input. However, significantly higher yields were obtained in the highest yielding treatment compared to the adjacent block data – the yield difference was close to 10 t/ha, indicating significant improvements in yield can still be made.

Trial 511Waigani

Two blocks (AO2090 and AO2100) adjacent to trial 511 were compared to the equivalent input treatment and the highest yielding treatment (Figure 5).

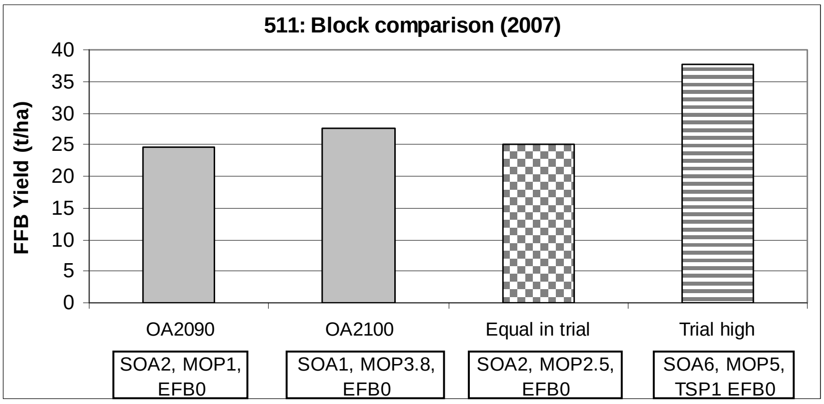


Figure 5. Commercial block data (from OMP8) vs trial 511 yield data (2007).

Similar yields were obtained in the blocks when compared to the trial treatment with a similar fertilizer input. Significantly higher yields were obtained in the highest yielding treatment compared to the adjacent block data – the yield difference was 10 t/ha, indicating significant improvements in yield can still be made.

Conclusion: significantly higher yields can be obtained with higher inputs at all three sites. If the observed yield difference was translated to all blocks on the same soil types as the trials are located (approximately 4000 ha) then the extra yield achieved would be equal to at least 30,000 t of FFB which is approximately equivalent to 6900 t CPO (or US$8M at current prices).

Where to from here at CTP Milne Bay Estate with these trials?

Both trial sites 502 and 511 will be felled and replanted in the near future. Trial 502 was maintained in 2007. However, trial site 511 was changed in late 2007. The high input plots will no longer receive fertilizer and the low input plots will be fertilised. The rationale was that:

(i) we will be able to determine how long it takes for nutrients to run down in well managed palms (this will give a better idea on how many years before felling fertilizer inputs can be reduced); and

(ii) we will know how long it takes to bring nutrient levels back up to required levels from an unfertilised state (this will give a better idea how long it takes to bring a run-down plantation back up to good nutrient levels).

In trial 511 we are monitoring tissue nutrient levels every three months and are continuing with yield recording.

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 response to N, P, K fertilizers in a factorial combination, with and without EFB. EFB was included to test whether it can be used to replace or supplement inorganic fertilizer. 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 and its components has been positive for some years and this trend continued into 2007. At both trial sites the yield gap between low and high input is widening. After more than a decade of experimentation:

- Trial 502 - the average FFB yield was 26.9 t/ha, with an average 7.7 bunches/palm and a single bunch weight of 27.4 kg;
- Trial 511 - the average FFB yield was 25.1 t/ha, 7.8 bunches/palm and a single bunch weight of 24.2 kg.

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, however Trial 511 required more fertilizer to achieve this yield.

The fertilizer treatments had a highly significant and positive effect on tissue nutrient concentration and palm dry matter production at both sites. It is clear that at both sites N drives production.

The results of each of the trials are presented individually but the conclusion is written for both trials combined.

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	21 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**		
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	19 years	Altitude	57 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 has a single plot (4 x 4 x 2 x 2 = 64 plots), the trial site has four replicate blocks within which the main effects of N and K are represented. Each plot contains 16 core palms, which are surrounded by a guard row and a trench. Trial 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) is done on a fortnightly basis (14 days).

Vegetative parameters measured included height measurements, frond measurements (total leaf length, leaflet width, leaflet length, total number of leaflets), rachis cross-section width and thickness. Vegetative measurements are normally done together with tissue sampling as all measurements are taken from Frond 17. Total frond count and marking of leaf 1 is done every six months. Leaf 1 marking is used to calculate the frond production rate.

Tissue sampling (leaflets and rachis of Frond 17) is carried out annually before the wet season starts in May. Samples are dried and processed by PNG OPRA and dispatched to AAR in Malaysia for analysis.

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 4 x 4 x 2 x 2 factorial, arranged in 4 incomplete blocks of 16 such that 2 of the 3-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.

RESULTS and DISCUSSION (Part 1 – Trial 502)

Yield and its components response to fertilizer treatments

The level of significance for different fertilizer treatments and the actual yield and its components of bunch number and bunch weight, for 2007 and the three year average for 2005 to 2007, are presented in Tables 3 and 4.

2007

N fertilizer: The trend developed in N fertilizer response continued in 2007 and the yield gap between no N and N fertilizer is approximately 4 t/ha FFB. The effect of N fertilizer was stronger on bunch weight compared to bunch number.

K fertilizer: over the last few years there has been a slow but steady increase in yield resulting from the application of K fertilizer. In 2007, the response to K was significant with a yield increase of approximately 4 t/ha from MOP. Most of the response in yield is due to bunch weight rather than bunch number.

P fertilizer: in 2005 there was a significant response to P fertilizer (as TSP) however in 2006 and 2007 the impact of this nutrient was not significant. This could be due to the slow nature of available P release from TSP and that the P becomes available over time and that one application may last several years as a supply of P.

EFB: the response to EFB was highly significant, there was a 3 t/ha increase in yield resulting from the EFB application. The yield response was due to the effect of EFB on bunch weight rather than bunch number.

2005 to 2007

The three year, 2005 to 2007, average yields and yield components were calculated to smooth out the yearly yield fluctuations resulting from different weather conditions and possible management effects.

The fertilizer response seen in the 2005 to 2007 averaged data is essentially the same as for the 2007 data indicating that the responses seen and discussed for 2007 are real.

Table 3. Trial 502, effect (p values) of treatments on FFB yield and its components in 2007 and from 2005 to 2007 (three years of averaged data). P values less than 0.05 are presented in bold.

	2007			**2005 to 2007**		
Source	**Yield**	**BN**	**SBW**	**Yield**	**BN**	**SBW**
SOA	**0.01**	0.30	**0.01**	**<0.001**	**0.01**	**<0.001**
MOP	**0.02**	0.44	**0.02**	**0.001**	**0.04**	**<0.001**
TSP	0.51	0.45	0.51	0.06	**0.02**	0.20
EFB	**0.001**	0.12	**<0.001**	**<0.001**	**0.01**	**<0.001**
SOA.MOP	0.58	0.97	0.81	0.29	0.74	0.34
SOA.TSP	0.44	0.67	0.95	0.71	0.74	0.64
MOP.TSP	0.40	0.36	0.19	0.25	0.15	0.06
SOA.EFB	0.33	0.50	0.69	0.12	0.21	0.21
MOP.EFB	0.05	0.45	**0.02**	**0.003**	0.07	**<0.001**
TSP.EFB	0.58	0.63	0.85	0.57	0.59	0.93
SOA.MOP.TSP	0.40	0.64	0.69	0.23	0.35	0.35
SOA.MOP.EFB	0.78	0.86	0.17	0.81	0.72	0.07
SOA.TSP.EFB	0.16	0.30	0.99	0.21	0.36	0.51
MOP.TSP.EFB	0.36	0.32	0.58	0.12	0.11	0.71
CV %	12.1	14.3	6.2	7.5	7.5	3.7

Table 4. Trial 502, impact on yield and its component by fertilizer treatments in 2007 and from 2005 to 2007 (three years of averaged data). P values less than 0.05 are presented in bold.

Treatments	**2007**			**2005 to 2007**		
	Yield kg/ha	**BN bunch/ha**	**SBW kg**	**Yield kg/ha**	**BN bunch/ha**	**SBW kg**
SOA0	**23.9**	932	**25.6**	**22.0**	**888**	**24.5**
SOA1	**27.4**	973	**28.1**	**26.6**	**961**	**27.7**
SOA2	**29.3**	1034	**28.3**	**28.1**	**995**	**28.1**
SOA3	**27.2**	983	**27.7**	**27.2**	**984**	**27.5**
$LSD_{0.05}$	*2.7*	-	*1.4*	*1.6*	*59*	*0.8*
MOP0	**24.2**	931	**25.9**	**23.1**	**900**	**25.4**
MOP1	**27.0**	982	**27.5**	**26.7**	**982**	**27.2**
MOP2	**28.2**	1010	**27.9**	**26.7**	**963**	**27.6**
MOP3	**28.4**	1000	**28.4**	**27.3**	**983**	**27.7**
$LSD_{0.05}$	*2.7*	-	*1.4*	*1.6*	*59*	*0.8*
TSP0	26.7	967	27.5	25.4	**932**	27.1
TSP1	27.2	994	27.3	26.5	**983**	26.8
$LSD_{0.05}$	-	-	-	-	*42*	-
EFB0	**25.0**	950	**26.2**	**23.9**	**926**	**25.6**
EFB1	**28.2**	1011	**28.6**	**28.0**	**988**	**28.3**
$LSD_{0.05}$	*1.9*	-	*1.0*	*1.1*	*42*	*0.6*

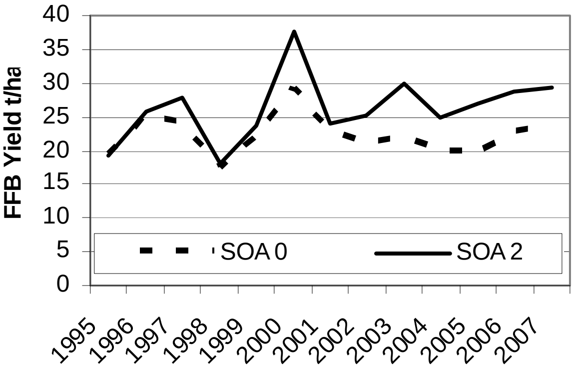
Yield trends since 1995 (commencement of trial)

In the year 2000 there was a separation in yield between N treatments (see Figure 1). In following years, except for 2001, this yield difference has continued and is now some 4 to 5 t/ha/year between the zero and middle rate of SOA application (SOA at 4kg/palm). It is likely that up to 2000 there was sufficient soil available N to produce high yields, and even now there is sufficient available N mineralized in the soil to produce 20 t/ha (as can be seen from plots not receiving N fertilizer).

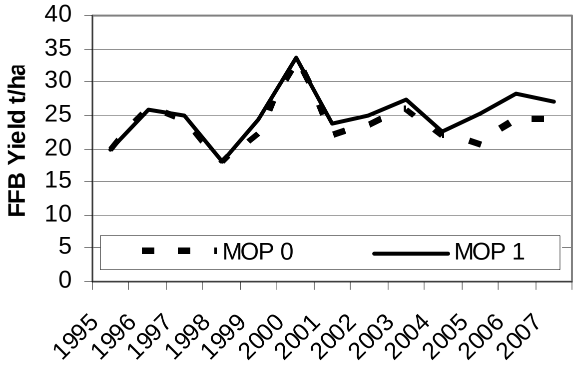
The impact of K fertilizer has only been showing over the last three years (Figure 1). K concentration is starting to decrease in the tissue (see next section) and it is expected that the K fertilized plots will see a growing yield gap from the zero K input plots. Currently the yield difference between no K and MOP at 2.5kg/palm is 2 to 3 t/ha.

There has been no response to P, except for 2005, over the years – and it is unlikely that P is required at this stage (Figure 1).

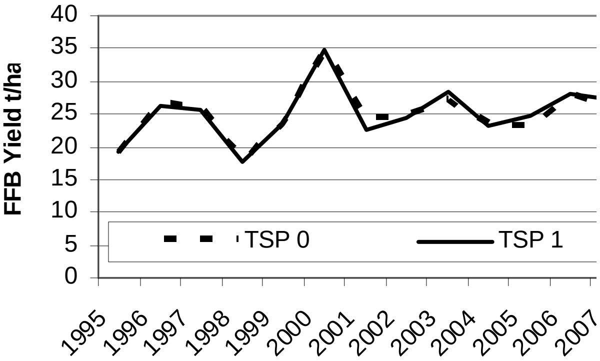
EFB started to make an impact on yield in 2002 (six years after application) and the yield response is continuing up to present (Figure 1) with a 4 to 5 t/ha difference between no EFB and EFB applied.



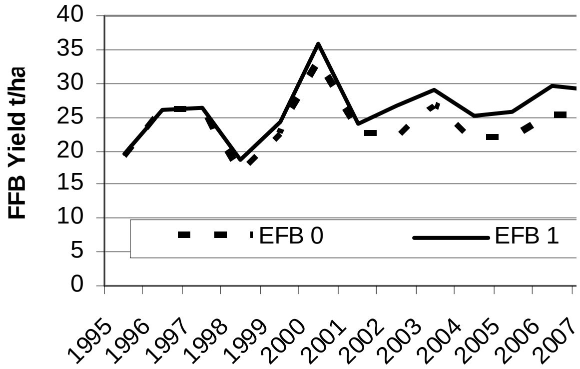
Yield (t/ha) over time for SOA level 0 and 2



Yield (t/ha) over time for MOP level 0 and 1



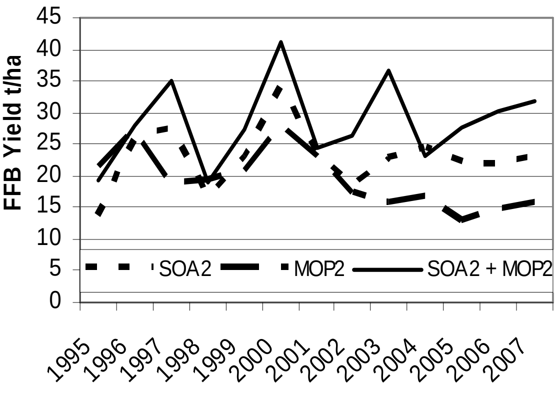
Yield (t/ha) over time for TSP level 0 and 1



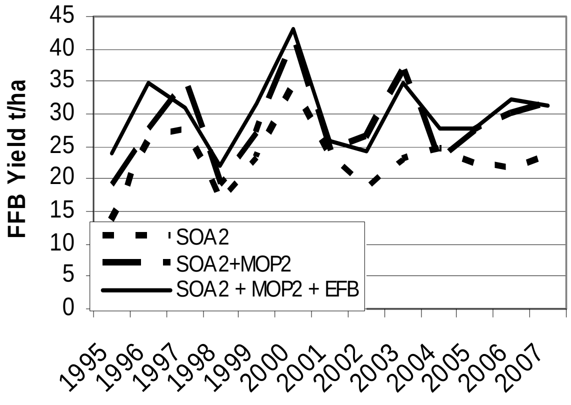
Yield (t/ha) over time for EFB level 0 and 1

Figure 1. Trial 502, FFB Yield (t/ha) since the inception of the trial in 1995.

Adding more than one fertilizer showed definite benefits (Figure 2) with the combination of N and K (as SOA + MOP) having a higher yield compared to N or K alone. The addition of P, as TSP, was of little additional benefit to yield. Adding EFB to N + K combined fertilizer is also not beneficial (Figure 2).



Treatments: SOA 2, MOP 2, SOA 2 + MOP 2



Treatments: SOA2, SOA2+MOP2, SOA2 + MOP2 + EFB

Figure 2. Trial 502, Yield over time for selected treatments illustrating the benefit of N, K, N + K and N + K + EFB.

Fertilizer effects on the leaflets and rachis nutrient concentrations

The impact of the fertilizer treatments on frond (leaflet and rachis) tissue nutrient concentration is presented in Tables 5 and 6. SOA significantly increased leaflet and rachis concentrations of N and decreased P concentration in the rachis (probably through mobilization of P out of the rachis). Leaflet concentration of N is low for those plots not receiving N fertilizer, but adequate for those plots receiving SOA.

The application of MOP significantly increased leaflet and rachis K levels.

TSP significantly increased the leaflet and rachis P concentration, whilst EFB had a positive and significant effect on leaflet N and K, and rachis K concentrations.

Tissue levels of Mg were high (0.34% of dm) and are not reported in the table. Levels of Boron were on average 14.3mg/kg and were not influenced by the current fertilizer treatments – Borate was applied in 2007 as a basal.

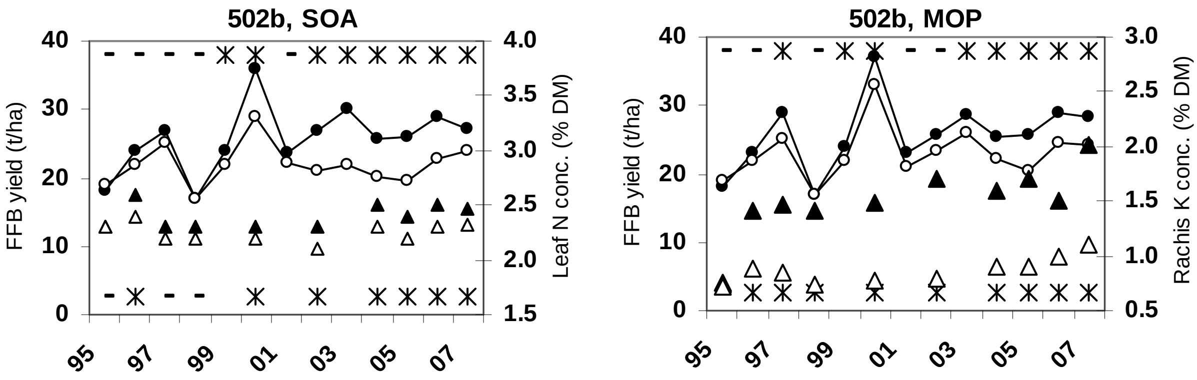
Table 5. Trial 502, effects (p values) of treatments on frond 17 nutrient concentrations in 2007**.** P values less than 0.05 are indicated in bold.

	Leaflet Nutrient Concentrations			Rachis Nutrient Concentrations		
Source	N	P	K	N	P	K
SOA	**0.01**	0.48	0.78	**0.001**	**<0.001**	0.42
MOP	0.51	0.46	**0.01**	0.99	**0.03**	**<0.001**
TSP	0.40	**0.002**	0.22	0.69	**<0.001**	0.16
EFB	**0.01**	0.16	**<0.001**	0.79	0.51	**<0.001**
CV %	4.0	2.2	10.9	10.2	15.0	11.6

Table 6. Trial 502, main effects of treatments on frond 17 nutrient concentrations in 2007, in units of dry matter %. P values less than 0.05 are indicated in bold.

	Leaflet nutrient concentration %			**Rachis nutrient concentration %**		
Source	**N**	**P**	**K**	**N**	**P**	**K**
SOA0	**2.32**	0.151	0.61	**0.32**	**0.24**	1.71
SOA1	**2.41**	0.150	0.59	**0.33**	**0.18**	1.67
SOA2	**2.46**	0.150	0.60	**0.37**	**0.13**	1.73
SOA3	**2.47**	0.149	0.59	**0.40**	**0.11**	1.61
LSD 0.05	*0.08*	-	-	*0.03*	*0.02*	-
MOP0	2.38	0.150	**0.53**	0.36	**0.15**	**1.11**
MOP1	2.44	0.152	**0.61**	0.35	**0.17**	**1.66**
MOP2	2.42	0.150	**0.62**	0.36	**0.17**	**1.93**
MOP3	2.41	0.150	**0.64**	0.35	**0.18**	**1.02**
LSD 0.05	-	-	*0.05*	-	*0.02*	*0.16*
TSP0	2.41	**0.149**	0.59	0.35	**0.14**	1.72
TSP1	2.42	**0.152**	0.61	0.36	**0.19**	1.64
LSD 0.05	-	*0.002*	-	-	*0.01*	-
EFB0	**2.38**	0.150	**0.56**	0.35	0.16	**1.44**
EFB1	**2.45**	0.151	**0.64**	0.36	0.16	**1.91**
LSD 0.05	*0.06*	-	*0.04*	-	-	*0.11*

Since 2000/2001 the application of N (as SOA), and K (as MOP) had significant impacts on yield, correspondingly the tissue concentrations of the specific nutrients were also higher with the application of these fertilizers (Figure 3). In 2000, as the leaflet N levels started to differentiate due to the application of N fertilizer a yield gap became apparent. However, this response is not as clear for K where the differences in rachis K due to MOP application have been apparent for some time (since 1996) but the yield gap has only consistently started to appear since 2003. There is little response to P at the site. The yield response due to EFB has become most apparent in 2002 and has continued since.



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

Figure 3. Trial 502, main effects of SOA and MOP on yield and tissue nutrient concentration over the duration of the trial.

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Fertilizer effects on oil palm vegetative growth

Summarized results for the vegetative growth parameters for 2007 are presented in Tables 7 and 8.

The main effect from fertilizer on vegetative growth was from an increase in frond size (Petiole Cross Section and frond area parameters). Regardless of the fertilizer regime applied, the increase in radiation interception came about from frond size not from an increase in the number of fronds produced (the effect of SOA from 0 to 6kg/palm on frond production was on average an increase of 1.6 new fronds/palm/annum).

N fertilizer had the largest impact on vegetative growth, followed by EFB. MOP and TSP had little or no impact on the growth parameters measured.

Table 7. Effect (p values) of treatments on vegetative growth parameters in 2007. P values < 0.05 are in bold.

Fertilizer Source	PCS	Radiation Interception				Dry Matter Production (t/ha)			
		GF	FP	FA	LAI	FDM	BDM	TDM	VDM
SOA	**<0.001**	0.10	0.18	**0.01**	**0.01**	**0.005**	**0.01**	**<0.001**	**0.002**
MOP	0.10	0.77	0.29	0.08	0.76	0.09	0.03	**0.006**	0.06
TSP	0.88	0.49	0.12	0.82	0.74	0.17	0.56	0.10	0.14
EFB	**0.003**	0.67	0.30	0.08	0.19	**0.01**	**0.001**	**<0.001**	**0.005**
SOA.MOP	0.86	0.93	0.24	0.65	0.99	0.39	0.61	0.31	0.36
SOA.TSP	0.63	0.86	0.65	0.20	0.72	0.80	0.53	0.27	0.72
MOP.TSP	0.29	0.23	0.55	0.23	0.92	0.99	0.45	0.62	0.99
SOA.EFB	0.09	0.79	0.31	0.67	0.66	0.20	0.31	0.11	0.17
MOP.EFB	0.29	0.98	0.78	0.25	0.60	0.59	0.05	0.07	0.57
TSP.EFB	0.92	0.43	0.54	0.05	0.46	0.56	0.49	0.27	0.49
SOA.MOP.TSP	0.90	0.55	0.23	0.85	0.56	0.28	0.37	0.04	0.20
SOA.MOP.EFB	0.45	0.91	0.88	0.60	0.71	0.57	0.74	0.24	0.49
SOA.TSP.EFB	0.97	0.74	0.20	0.71	0.96	0.33	0.14	0.07	0.28
MOP.TSP. EFB	0.61	0.44	0.16	0.21	0.35	0.11	0.37	0.45	0.11
CV %	6.5	5.7	9.1	4.8	8.3	10.9	12.2	6.4	9.6

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)*

Table 8. Main effects of treatments on vegetative growth parameters in 2007. P values <0.05) are shown in bold.

Source		Radiation Interception				Dry Matter Production (t/ha)			
	PCS	GF	FP	FA	LAI	FDM	BDM	TDM	VDM
SOA0	**45.1**	29.8	21.9	**12.5**	**4.7**	**13.4**	**12.7**	**29.0**	**16.4**
SOA1	**49.0**	30.1	22.0	**13.1**	**5.0**	**14.5**	**14.6**	**32.3**	**17.8**
SOA2	**52.6**	31.1	22.3	**13.5**	**5.3**	**15.8**	**15.6**	**34.8**	**19.2**
SOA3	**51.6**	31.3	23.5	**13.4**	**5.3**	**16.3**	**14.5**	**34.2**	**19.8**
$LSD_{0.05}$	*2.6*	-	-	*0.5*	*0.3*	*1.4*	*1.4*	*1.7*	*1.4*
MOP0	48.0	30.9	22.4	12.7	5.0	14.4	12.9	**30.3**	17.5
MOP1	49.8	30.4	23.1	13.3	5.1	15.6	14.4	**33.2**	18.9
MOP2	51.2	30.4	22.7	13.4	5.2	15.7	14.9	**34.0**	19.1
MOP3	49.3	30.6	21.7	13.1	5.1	14.4	15.1	**32.8**	17.1
$LSD_{0.05}$	-	-	-	-	-	-	-	1.7	-
TSP0	49.5	30.4	22.0	13.1	5.1	14.7	14.2	32.1	17.9
TSP1	49.6	30.7	22.9	13.1	5.1	15.3	14.5	33.1	18.6
$LSD_{0.05}$	-	-	-	-	-	-	-	-	-
EFB0	**47.9**	30.5	22.1	13.0	5.0	**14.4**	**13.3**	**30.7**	**17.4**
EFB1	**51.2**	30.7	22.7	13.3	5.2	**15.7**	**15.7**	**34.5**	**19.1**
$LSD_{0.05}$	*1.8*	-	-	-	-	*0.9*	*1.0*	*1.2*	*1.0*

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)*		

RESULTS & DISCUSSION (Part 2 – Trial 511)

Yield and other components response to fertilizer treatments

Yield and its components of bunch number and bunch weight are presented for 2007 and for the average yield from 2005 to 2007, in Tables 9 and 10.

2007

N fertilizer: Strong response to N fertilizer continued into 2007 and the yield gap between no N and N fertilizer was approximately 8 t/ha. Both the number of bunches produced and the bunch weight responded positively to N fertilizer (with the largest effect from N fertilizer being on bunch weight).

K fertilizer: In 2007, the response to K was not significant. There were no significant responses in bunch number or bunch weight from MOP.

P fertilizer: In 2007 there was a significant response to P fertilizer (as TSP) with a yield increase of 4 t/ha. Bunch weight responded positively to P fertilizer.

EFB: The response to EFB was highly significant, with a 11 t/ha increase in yield, primarily due to a large increase in bunch weight, but also in bunch number. The interaction with SOA was also significant – indicating a dual benefit from these two sources of N fertilizer.

2005 to 2007

The three year, 2005 to 2007, average yield and its components were calculated to smooth out the yearly yield fluctuations resulting from different weather conditions and possible management effects.

The fertilizer responses seen in the 2005 to 2007 averaged data is essentially the same as for the 2007 data, except that for the three year average data there was also a small response to MOP (of 2.5 t/ha).

Table 9. Trial 511, effect (p values) of treatments on FFB yield and its components in 2007 and from 2005 to 2007 (three years of averaged data). P values less than 0.05 are presented in bold.

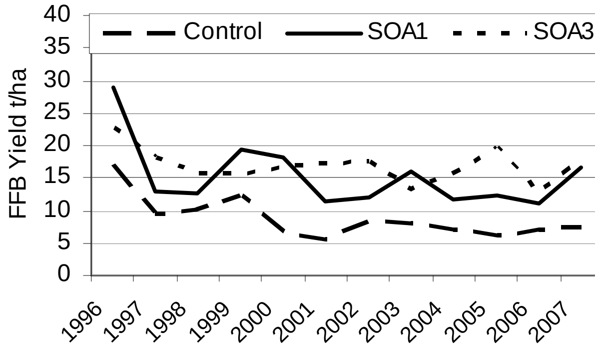
	2007			**2004 to 2007**		
Source	**Yield**	**BN**	**SBW**	**Yield**	**BN**	**SBW**
SOA	**0.004**	0.11	**<0.001**	**<0.001**	**0.004**	**<0.001**
MOP	0.44	0.51	0.07	**0.02**	0.10	0.53
TSP	**0.01**	0.14	**0.01**	**<0.001**	**0.02**	**0.001**
EFB	**<0.001**	**0.002**	**<0.001**	**<0.001**	**<0.001**	**<0.001**
SOA.MOP	0.92	0.99	0.09	0.51	0.79	0.63
SOA.TSP	0.78	0.76	**0.005**	0.36	0.55	**0.03**
MOP.TSP	0.97	0.99	0.46	0.33	0.47	0.53
SOA.EFB	0.25	0.49	**<0.001**	**0.04**	0.18	**0.01**
MOP.EFB	0.49	0.96	0.10	0.51	0.69	0.12
TSP.EFB	0.16	0.69	**0.002**	0.06	0.38	**0.02**
SOA.MOP.TSP	0.93	0.77	0.10	0.74	0.79	0.40
SOA.MOP.EFB	0.64	0.98	0.36	0.29	0.74	0.27
SOA.TSP.EFB	0.85	0.93	0.57	0.89	0.86	0.57
MOP.TSP.EFB	0.98	0.99	0.44	0.47	0.63	0.81
CV %	19.4	21.8	5.5	11.1	13.3	7.0

Table 10. Trial 511, impact on yield and its component by fertilizer treatments in 2007 and from 2005 to 2007 (three years of averaged data). P values less than 0.05 are presented in bold.

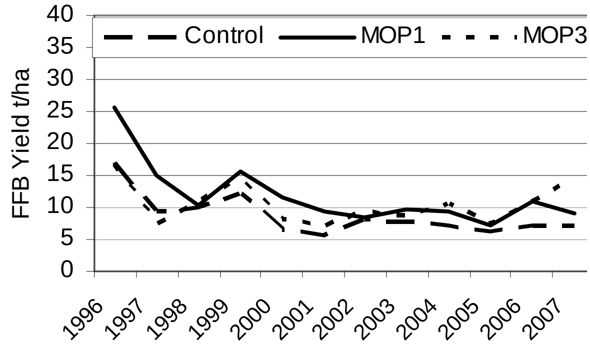
Treatments	2007			2005 to 2007		
	Yield kg/ha	BN bunch/ha	SBW kg	Yield kg/ha	BN bunch/ha	SBW kg
SOA0	**20.1**	876	**21.1**	**17.4**	**791**	**20.5**
SOA1	**24.0**	977	**23.8**	**21.1**	**876**	**23.3**
SOA2	**28.7**	1074	**26.0**	**25.4**	**963**	**25.8**
SOA3	**27.8**	1052	**25.8**	**26.9**	**1017**	**25.8**
$LSD_{0.05}$	*4.0*	-	*1.1*	*2.1*	*99*	*1.4*
MOP0	23.5	938	23.9	**20.8**	845	23.5
MOP1	25.1	1011	23.5	**22.3**	907	23.5
MOP2	26.5	1054	24.4	**24.3**	971	24.1
MOP3	25.5	976	24.9	**23.4**	914	24.2
$LSD_{0.05}$	-	-	-	*2.1*	-	-
TSP0	**23.2**	950	**23.6**	**20.8**	**864**	**22.8**
TSP1	**27.1**	1040	**24.7**	**24.7**	**954**	**24.8**
$LSD_{0.05}$	*2.8*	-	*0.8*	*1.5*	*70*	*1.0*
EFB0	**19.7**	**869**	**21.6**	**18.2**	**820**	**21.1**
EFB1	**30.6**	**1120**	**26.7**	**27.2**	**998**	**26.5**
$LSD_{0.05}$	*2.8*	*125*	*0.8*	*1.5*	*70*	*1.0*

Yield trends since 1996 (commencement of trial)

There is some response to N fertilizer at this site when applied by itself (ie without other fertilizers being applied), whereas there is no response to the application of K (as MOP) when applied by itself (Figure 4). Yield over time for N applied by itself as SOA is between 15 and 20 t/ha, whereas for K when applied alone, all treatments yielded less than 10t/ha.



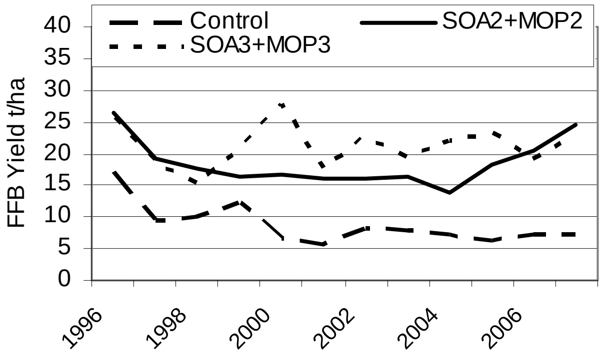
Trial 511. Response to N (as SOA)



Trial 511. Response to K (as MOP)

Figure 4. Trial 511: response to the application of N or K (as SOA and MOP) applied alone (not in combination) at three levels (0, level 1 and level 3)

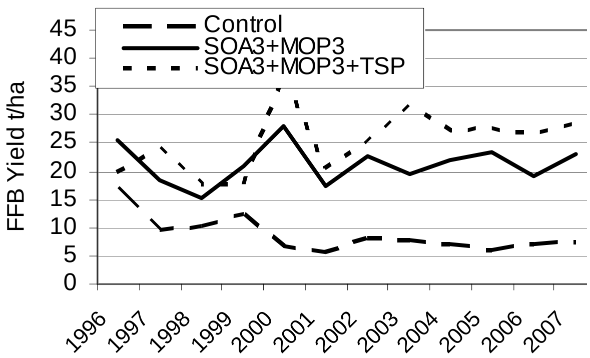
When N and K are combined (SOA + MOP) there is a significant improvement in yield. For the combined fertilizer applications yields regularly achieved around 25t/ha (for SOA and MOP both applied at level 2 and 3 see Figure 5).



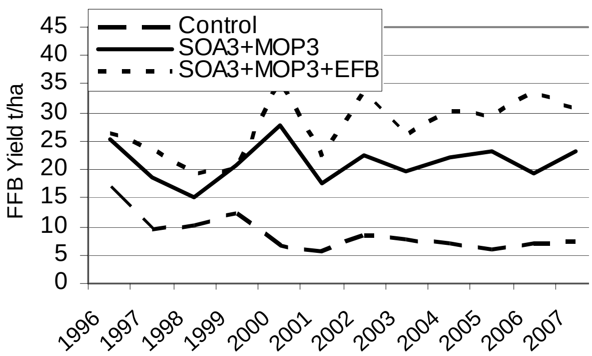
Trial 511. Response to N + K (SOA + MOP)

Figure 5. Trial 511: yield response to a combination of N + K (as SOA and MOP) at three levels (0, level 2 and level 3).

Additional benefits in yield were obtained when N and K were applied in combination with the application of either TSP (yield around 30t/ha) or with EFB (yields regularly between 30 and 35t/ha) (Figure 6).



Trial 511. Response to N + K + P (SOA + MOP + TSP)



Trial 511. Response to N + K + EFB (SOA + MOP + EFB)

Figure 6. Trial 511: yield response to a combination of N + K + P (or EFB) at the highest level of fertilizer applied in the trial.

Fertilizer effects on Frond 17 tissue nutrient concentration

The impact of the fertilizer treatments on frond (leaflet and rachis) tissue nutrient concentration is presented in Tables 11 and 12.

SOA significantly increased leaflet concentrations of N and decreased P concentration in the rachis (probably through mobilization of P out of the rachis). Leaflet concentration of N is low for those plots not receiving SOA, but adequate for those plots receiving SOA at 4 and 6 kg/palm. SOA also increased N levels in the rachis.

The application of MOP significantly increased rachis K levels, but had little effect on leaflet K levels.

TSP significantly increased leaflet and rachis P concentration, while EFB had a positive and significant effect on leaflet N, P and K concentrations. EFB also increased N and K level in the rachis.

Tissue levels of Mg were high (0.32 %dm) and are not reported in the tables of results. Levels of Boron are relatively low at 12.2 mg/kg and Borate fertilizer was applied in 2007 as a basal fertilizer.

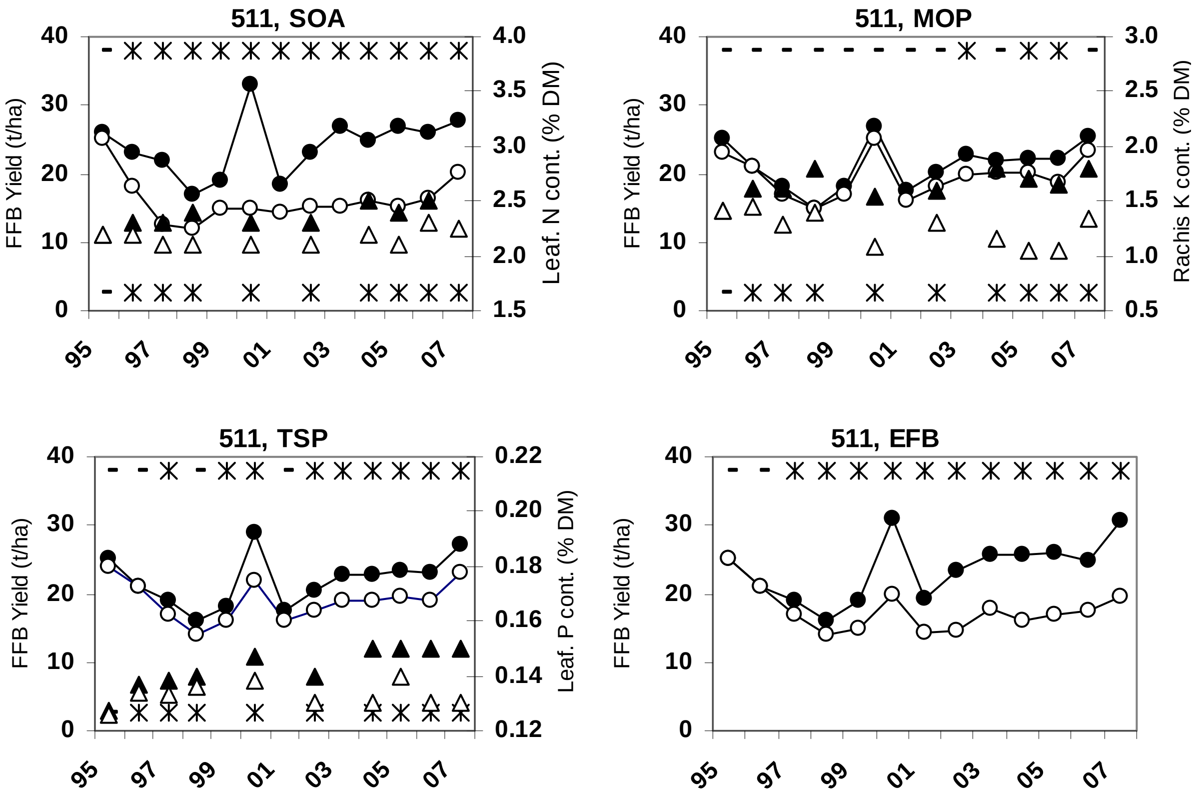
Table 11. Trial 511, effects (p values) of treatments on frond 17 nutrient concentration in 2007**.** P values less than 0.05 are indicated in bold.

	Leaflet Nutrient Concentration				Rachis Nutrient Concentration		
Source	**N**	**P**	**K**		**N**	**P**	**K**
SOA	**0.01**	0.32	0.90		**<0.001**	**0.002**	0.56
MOP	0.73	0.31	0.15		0.14	0.40	**0.01**
TSP	0.67	**<0.001**	0.44		0.17	**<0.001**	0.56
EFB	**0.02**	**<0.001**	**0.02**		**0.006**	0.98	**0.01**
CV %	6.1	3.0	13.0		7.0	40.2	11.6

Table 12. Trial 511, main effects of treatments on frond 17 nutrient concentrations in 2007, in units of dry matter %. . P values less than 0.05 are indicated in bold.

	Leaflet Nutrient Concentration %				Rachis Nutrient Concentration %		
Source	**N**	**P**	**K**		**N**	**P**	**K**
SOA0	**2.25**	0.141	0.64		**0.28**	**0.168**	1.64
SOA1	**2.34**	0.139	0.65		**0.30**	**0.114**	1.79
SOA2	**2.42**	0.141	0.66		**0.33**	**0.087**	1.62
SOA3	**2.47**	0.140	0.64		**0.35**	**0.078**	1.70
LSD 0.05	*0.12*	-	-		*0.02*	*0.04*	-
MOP0	2.37	0.140	0.60		0.32	0.099	**1.34**
MOP1	2.34	0.139	0.64		0.30	0.109	**1.76**
MOP2	2.38	0.142	0.67		0.32	0.111	**1.86**
MOP3	2.39	0.140	0.67		0.32	0.127	**1.79**
LSD 0.05	-	-	-		-	-	*0.29*
TSP0	2.36	**0.134**	0.65		0.31	**0.064**	1.66
TSP1	2.38	**0.147**	0.64		0.32	**0.159**	1.71
LSD 0.05	-	*0.002*	-		-	*0.026*	-
EFB0	**2.31**	**0.136**	**0.61**		**0.31**	0.111	**1.55**
EFB1	**2.42**	**0.144**	**0.68**		**0.33**	0.112	**1.83**
LSD 0.05	*0.08*	*0.002*	*0.05*		*0.01*	-	*0.21*

Since year 1 of the trial in 1995, the application of N (as SOA) has had a significant impact on yield, which also corresponded with higher tissue N concentration (Figure 7). The effect of MOP on yield has only been evident in the last few years and is still relatively small. Rachis K levels have been different between the zero K and high input of K since 1996 (this difference has increased over time) (Figure 7). TSP has consistently increased yield since 2002 which corresponds well with tissue P levels (Figure 7). EFB has consistently increased yield since 1998 (Figure 7).



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 7. Trial 511, main effects of SOA, MOP, TSP and EFB on yield and tissue nutrient concentration over the duration of the trial.

Fertilizer effects on oil palm vegetative growth

Summarized results for vegetative growth parameters for 2007 are presented in Tables 13 and 14.

The main effect on vegetative growth was from an increase in frond size (Petiole Cross Section and frond size parameters) rather than from a dramatic change in frond production. Nitrogen fertilizer resulted in an increase in frond production of one frond per year (19.5 to 21 new fronds produced per year).

N fertilizer as SOA and EFB had the largest impact on vegetative growth. TSP also had an effect on the PCS and frond production. MOP had little impact on the growth parameters studied.

Petiole Cross Section (PCS) is a good measure for assessing frond size without having to assess all the other growth parameters.

Table 13. Effect (p values) of treatments on vegetative growth parameters in 2007. P values < 0.05 are in bold.

Fertilizer Source	PCS	Radiation Interception				Dry Matter Production (t/ha)			
		GF	FP	FA	LAI	FDM	BDM	TDM	VDM
SOA	**<0.001**	0.41	**0.004**	**<0.001**	**<0.001**	**<0.001**	**0.007**	**<0.001**	**<0.001**
MOP	0.31	0.95	0.09	0.20	0.36	0.44	0.66	0.30	0.29
TSP	**0.007**	0.09	**0.008**	0.06	**0.009**	**0.005**	**0.02**	**0.001**	**0.001**
EFB	**<0.001**	0.35	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**
SOA.MOP	0.39	0.59	0.55	0.56	0.46	0.41	0.95	0.54	0.29
SOA.TSP	0.45	0.15	0.35	0.94	0.46	0.45	0.80	0.41	0.32
MOP.TSP	0.96	0.71	0.55	0.93	0.81	0.83	0.99	0.93	0.79
SOA.EFB	0.09	0.23	0.05	**0.01**	**0.009**	0.16	0.37	0.09	0.08
MOP.EFB	0.24	0.31	0.77	0.57	0.27	0.33	0.52	0.24	0.79
TSP.EFB	0.22	0.80	0.16	0.17	0.17	0.20	0.18	0.06	0.23
SOA.MOP.TSP	0.54	0.99	0.98	0.66	0.76	0.77	0.93	0.73	0.66
SOA.MOP.EFB	0.30	0.95	0.81	0.43	0.62	0.47	0.76	0.34	0.30
SOA.TSP.EFB	0.94	0.52	0.29	0.73	0.59	0.81	0.75	0.52	0.67
MOP.TSP. EFB	0.39	0.61	0.40	0.29	0.19	0.80	0.81	0.84	0.82
CV %	9.1	5.7	3.7	7.4	8.1	11.4	23.3	11.7	9.7

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)*

Table 14. Main effects of treatments on vegetative growth parameters in 2007. P values <0.05 are shown in bold.

Source		Radiation Interception				Dry Matter Production (t/ha)			
	PCS	**GF**	**FP**	**FA**	**LAI**	**FDM**	**BDM**	**TDM**	**VDM**
SOA0	**34.1**	31.4	**19.5**	**10.5**	**4.2**	**9.2**	**9.6**	**20.9**	**11.3**
SOA1	**38.9**	31.8	**20.2**	**11.8**	**4.8**	**10.7**	**11.9**	**25.1**	**13.2**
SOA2	**42.1**	32.0	**20.6**	**12.4**	**5.0**	**11.8**	**14.1**	**28.7**	**14.7**
SOA3	**43.8**	32.5	**20.9**	**12.8**	**5.3**	**12.5**	**13.9**	**29.3**	**15.4**
$LSD_{0.05}$	*3.0*	-	*0.6*	*0.7*	*0.3*	*1.0*	*2.3*	*2.4*	*1.1*
MOP0	38.2	32.0	20.2	11.5	4.7	10.6	11.7	24.8	13.1
MOP1	40.1	31.8	20.2	11.9	4.9	11.1	12.5	26.2	13.7
MOP2	39.8	31.7	20.8	12.2	4.9	11.3	13.0	27.0	14.0
MOP3	40.8	32.0	20.1	11.9	4.8	11.2	12.2	26.0	13.8
$LSD_{0.05}$	-	-	-	-	-	-	-	-	-
TSP0	**38.1**	31.5	**20.0**	11.7	**4.7**	**10.4**	**11.3**	**24.2**	**12.9**
TSP1	**41.4**	32.4	**20.6**	12.1	**5.0**	**11.7**	**13.4**	**27.8**	**14.4**
$LSD_{0.05}$	*2.1*	-	*0.4*	-	*0.2*	*0.7*	*1.7*	*1.8*	*0.7*
EFB0	**35.2**	31.7	**19.7**	**10.9**	**4.4**	**9.6**	**9.8**	**21.5**	**11.7**
EFB1	**44.2**	32.1	**20.9**	**12.8**	**5.2**	**12.5**	**14.9**	**30.5**	**15.6**
$LSD_{0.05}$	*2.1*	-	*0.4*	*0.5*	*0.2*	*0.7*	*1.7*	*1.8*	*0.7*

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)*

CONCLUSION Trials 502 and 511

The highest yield obtained at both sites was 34 t/ha. Due to an overall inherent lower soil fertility status in trial 511 compared to 502, the fertilizer rates required to achieve these high yields were higher in trial 511. At both sites, a combination of N and K fertilizer was required to optimize yield, in trial 511 P was also required.

The N, K and EFB fertilizer effects on FFB yield was consistent at both trial sites. P responses were higher at trial site 511 because the soil was lower in available P (1995: Soil available P was 5 to 7 mg/kg in trial 502; and only 2 to 3 mg/kg in trial 511).

To some extent EFB can replace inorganic fertilizer, however it can take five or more years before the full benefits form EFB are realized.

Frond nutrient status and vegetative parameters all responded positively to the fertilizer treatments and were good indications of potential yield. Petiole Cross Section (PCS) is a good indicator of frond size and can be used by the plantations as a measure of overall performance. It is suggested that on these mature palms a PCS of $45cm^3$ or more, is regarded an indicator of good health and production.

The yield gap between the lowest and highest yields achieved of 18 t/ha in trial 502 and 28t/ha in trial 511 continued to grow in 2007 compared to previous years. It is envisaged that the low yielding treatment plots will continue to decrease in yield as the soil can no longer supply sufficient nutrients for adequate growth and production.

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 with over 30t/ha were obtained from a combination of N and K fertilizer. In 2007 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 2.5kg/palm (1.2kg 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	16 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 2007.

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 51% K.

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

Data Collection

Yield recording (weighing of bunches) is done on a fortnightly basis (14 days).

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 six years. The yield difference between the maximum level and zero level of SOA application widened in 2005, 2006 and continued into 2007 compared to the previous years. The effect of K fertilizer on yield, although significant from 2004 to 2007, 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 2007, SOA had a significant effect on FFB yield ($p<0.001$). SOA significantly increased FFB yield above 30 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.

	2007			**2005 to 2007**		
Source	**Yield**	**BNO**	**SBW**	**Yield**	**BNO**	**SBW**
SOA	**<0.001**	**0.04**	**<0.001**	**<0.001**	**0.04**	**<0.001**
MOP	**<0.001**	**0.009**	**0.004**	**<0.001**	**0.009**	**0.004**
SOA.MOP	0.44	0.25	0.57	0.44	0.25	0.57
CV %	9.8	9.5	5.0	9.8	9.5	5.0

Table 4. Main effects of treatments on FFB yield (t/ha) and its components for 2007 and 2005 to 2007 (three years averaged data). P values less than 0.05 are presented in bold.

	2007			**2005 to 2007**		
	Yield (t/ha)	**BN (b/ha)**	**SBW (kg)**	**Yield (t/ha)**	**BN (b/ha)**	**SBW (kg)**
SOA0	**26.2**	**1182**	**22.1**	**23.0**	**1009**	**22.9**
SOA1	**29.3**	**1225**	**23.9**	**28.2**	**1143**	**24.9**
SOA2	**30.4**	**1211**	**25.1**	**31.1**	**1212**	**25.7**
SOA3	**32.1**	**1300**	**24.7**	**31.6**	**1247**	**25.6**
MOP0	**26.7**	**1155**	**23.1**	**26.3**	**1095**	**24.1**
MOP1	**29.9**	**1245**	**24.0**	**28.9**	**1162**	**24.9**
MOP2	**30.1**	**1217**	**24.8**	**29.2**	**1161**	**25.2**
MOP3	**31.0**	**1301**	**23.8**	**29.6**	**1192**	**24.9**
$LSD_{0.05}$	*2.1*	*83*	*0.8*	*1.6*	*55*	*0.7*

Combinations of both SOA and MOP produced the highest yields (Table 5). The highest FFB yield of 35.5 t/ha was obtained when 6 kg of SOA /palm was applied together with 2.5 kg of MOP/palm.

Table 5. Effect of SOA and MOP on FFB yield (t/ha) in 2007 and 2005 to 2007 (three year average data). The treatment interactions are not significant.

SOA by MOP - 2007				
	MOP0	MOP1	MOP2	MOP3
SOA0	20.8	22.5	23.7	21.7
SOA1	27.0	29.0	31.2	30.8
SOA2	30.9	32.9	35.0	33.0
SOA3	31.2	35.5	32.5	34.0

SOA by MOP – 2005 to 2007				
	MOP0	MOP1	MOP2	MOP3
SOA0	21.8	22.0	24.0	24.3
SOA1	25.2	28.5	29.8	29.4
SOA2	28.9	31.3	32.5	31.7
SOA3	29.2	33.7	30.7	33.0

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 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 (12.5ppm) were low and Mg levels (0.36 %dm) were high
- N fertilizer mobilized P and K out of the rachis
- K in the rachis was very low for the zero MOP treatment

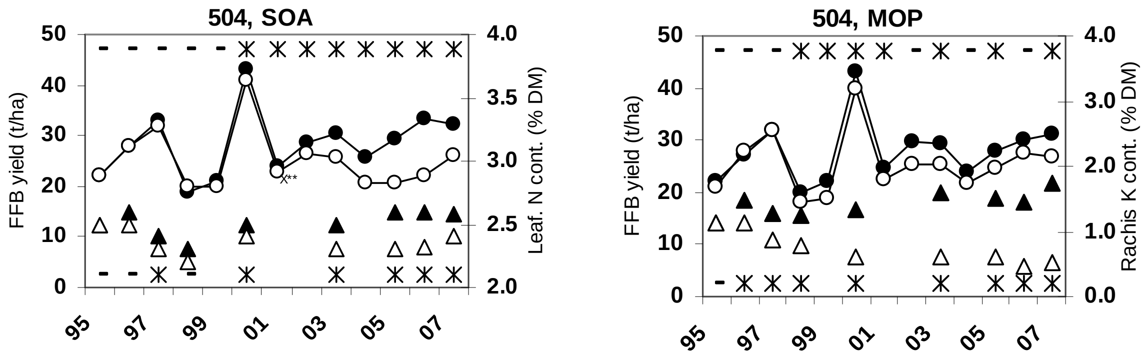
With very low values of K in the rachis for the zero MOP treatment, palms in these plots will experience increasing deficiency in K, as already exhibited in the leaflets with this treatment, and yields in this treatment are likely to fall in the near future.

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**	0.68	**0.02**	**<0.001**	**<0.001**	**0.002**
MOP	0.06	0.66	**<0.001**	0.07	**<0.001**	**<0.001**
SOA.MOP	0.15	0.05	0.57	0.85	0.80	0.39
CV %	2.2	2.4	5.8	8.4	14.1	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	**2.40**	0.161	**0.63**	**0.30**	**0.26**	**1.36**
SOA1	**2.47**	0.159	**0.62**	**0.30**	**0.22**	**1.36**
SOA2	**2.56**	0.159	**0.59**	**0.32**	**0.16**	**1.23**
SOA3	**2.58**	0.159	**0.60**	**0.34**	**0.15**	**1.20**
MOP0	2.48	0.159	**0.55**	0.31	**0.16**	**0.52**
MOP1	2.49	0.159	**0.60**	0.32	**0.19**	**1.33**
MOP2	2.53	0.159	**0.63**	0.32	**0.21**	**1.56**
MOP3	2.50	0.161	**0.65**	0.32	**0.24**	**1.74**
$LSD_{0.05}$	*0.03*	-	*0.03*	*0.02*	*0.02*	*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 2007

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 1.5 fronds/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 less an effect on frond production and frond size.

Table 8. Effect (p values) of treatments on vegetative growth parameters in trial 504, for 2007. 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**	**<0.001**	0.38	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**
MOP	**<0.001**	0.08	0.26	**0.02**	**0.007**	**<0.001**	**<0.001**	**<0.001**	**<0.001**
SOA.MOP	0.78	0.33	0.86	0.49	0.07	0.73	0.38	0.57	0.78
CV %	5.3	4.0	3.8	4.2	5.2	5.6	10.6	6.3	5.2

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 2007. 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	**45.4**	**28.7**	**20.9**	12.7	**4.6**	**12.8**	**14.0**	**29.7**	**15.8**
SOA1	**48.7**	**30.0**	**21.6**	12.9	**4.9**	**14.2**	**15.5**	**33.0**	**17.5**
SOA2	**50.8**	**31.9**	**22.6**	13.1	**5.3**	**15.4**	**16.3**	**35.2**	**18.9**
SOA3	**51.0**	**31.8**	**22.6**	12.9	**5.2**	**15.5**	**17.1**	**26.3**	**19.2**
MOP0	**47.3**	31.1	21.7	**12.7**	**5.0**	**13.9**	**14.2**	**31.2**	**17.0**
MOP1	**47.9**	30.0	21.7	**12.7**	**4.8**	**14.0**	**15.9**	**33.3**	**17.4**
MOP2	**51.4**	30.9	22.1	**13.2**	**5.2**	**15.4**	**16.1**	**34.0**	**18.8**
MOP3	**49.3**	30.5	22.1	**13.0**	**5.0**	**14.7**	**16.6**	**34.8**	**18.2**
$LSD_{0.05}$	*1.8*	*0.9*	*0.6*	*0.4*	*0.2*	*0.3*	*1.2*	*1.5*	*1.7*

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)*

NUTRIENT USE EFFICIENCY

Nutrient Use Efficiency (NUE) investigates the efficiency at which nutrients applied as fertilizer are taken up by a block of palms. It is also used to ascertain the inherent (indigenous) nutrient supply to palms without the addition of fertilizer (ie. what is supplied from the soil without any nutrient additions).

To calculate NUE the following are required:

- Nutrient analysis of bunches (on a per treatment basis because it is highly likely that different treatments will result in different levels of nutrients in bunches);
- Nutrient analysis of tissue (leaflets and rachis);
- Nutrient analysis of the trunk;
- Annual biomass increase (dry matter of FFB yield, new fronds and trunk new growth)

In 2007 for trial 504 we measured the required parameters to determine NUE. We assessed 6 treatments, including the control plots (no fertilizer). Each treatment was replicated four times. In particular we measured:

- Annual trunk incremental growth, from which core dry weight was calculated (using in situ measured core dry weight and using the core bulk density as listed in Oil Palm Management for Large and Sustainable Yields by Fairhurst and Hardter, 2003);
- FFB nutrient content (samples from whole bunches were sent to AAR for analysis), bunch dry weight was determined;
- Leaflet and rachis dry matter was calculated from vegetative measurements;
- Leaflet and rachis nutrient content were determined.

The six treatments assessed with their respective nutrients supplied are listed in table 10.

Table 10. Nutrients supplied per palm and per hectare for each of the six treatments used for NUE calculations. (note: P was applied as a basal fertilizer to all treatments).

Treatment (kg fertilizer/palm)	**Nutrients supplied per palm (kg/palm)**			**Nutrients supplied per hectare (kg/ha)**		
	N	**K**	**P**	**N**	**K**	**P**
control	0	0	0.11	0	0	13
SOA2, MOP2.5	0.41	1.28	0.11	53	162	13
SOA4, MOP2.5	0.84	1.28	0.11	107	162	13
SOA6, MOP2.5	1.26	1.28	0.11	160	162	13
SOA6, MOP5	1.89	2.56	0.11	160	324	13
SOA6, MOP7.5	1.89	3.84	0.11	160	486	13

NUE is often presented as Nutrient Recovery Efficiency (RE) which is the efficiency of uptake of an applied nutrient. The uptake of nutrients in leaflets, rachis, bunches and in the incremental growth of the core is listed in Table 11.

Table 11. N, K and P uptake in leaflets, rachis, bunches and in the core (increment growth over 2007) for six treatments in trial 504.

	kg/ha in leaflets			**kg/ha in rachis**			**kg/ha in bunches**			**kg/ha in core increment**			**Total nutrient uptake kg/ha**		
Kg fertilizer/p	**N**	**K**	**P**	**N**	**K**	**P**	**N**	**K**	**P**	**N**	**K**	**P**	**N**	**K**	**P**
control	109	26	7	23	52	17	86	93	23	5	8	2	224	180	49
SOA2,MOP2.5	131	32	9	28	125	19	109	124	27	7	15	2	275	296	57
SOA4,MOP2.5	144	37	9	29	153	22	126	128	23	12	15	3	310	334	57
SOA6,MOP2.5	139	36	9	28	165	24	134	146	23	13	14	2	313	361	58
SOA6,MOP5	160	39	10	34	179	20	114	141	20	11	15	2	318	375	52
SOA6,MOP7.5	158	39	10	34	171	19	133	154	22	12	19	2	337	382	53

Nutrients in leaflets, rachis and core are stored within the palm and become available when the fronds are pruned or after felling when the fronds and trunk decompose to organic matter. However, nutrients in bunches are exported from the plantation. In some areas on the plantation a component of these nutrients are returned as EFB, empty fruit bunches (where this trial is located, as Sagarai, EFB is not used). Table 12 lists the percentage of nutrients exported from the field as a percentage of total nutrient uptake.

Table 12. Percentage of nutrients exported (as a % of total uptake)

	Nutrients exported (as % of total uptake)		
Kg fertilizer/p	**N**	**K**	**P**
control	39	52	46
SOA2,MOP2.5	39	42	47
SOA4,MOP2.5	40	38	41
SOA6,MOP2.5	43	40	39
SOA6,MOP5	36	38	38
SOA6,MOP7.5	39	40	42

The comparison of Nutrient Recover Efficiency (RE) between treatments with different fertilizer inputs is a good way to assess the efficiency of uptake between different treatments (Table 13). The control plots (no fertilizer) provide the basis of nutrient uptake from the soil without the addition of fertilizer (indigenous fertility). For example, for the first treatment (SOA 2, MOP 2.5), 96% of the nitrogen supplied as 2kg SOA/palm has been taken up by the palm.

Table 13. Nutrient Recovery Efficiency for fertilizer applied N and K in trial 504, 2007.

	Nutrient Recovery Efficiency (as a % of applied nutrient)	
Kg fertilizer/p	**N**	**K**
SOA2,MOP2.5	96	72
SOA4,MOP2.5	81	95
SOA6,MOP2.5	56	112
SOA6,MOP5	59	60
SOA6,MOP7.5	70	42

At the highest rate of applied N (SOA 6 kg/palm) the efficiency of N uptake is decreased below 70%. Similarly at 5 and 7.5kg/palm of MOP the efficiency of uptake drops significantly compared to the low rate (2.5 kg/palm of MOP). High yields (34 t/ha) were obtained at SOA 6 kg/palm and MOP 2.5 kg/palm.

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 size of rachis 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 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).

Nutrient Use Efficiency was high for applied N and applied K (at the low rate of application).

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 densities 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.

This paper reports on the yields achieved for each of the planting densities up to the time of thinning. In next years Annual Report the results immediately post thinning will be discussed.

INTRODUCTION

The purpose of the trial was to determine the effects of spacing configuration, thinning and density on palms. The theory is that at high planting density yields will be higher compared to the lower planting density until canopy closure has been achieved (at approximately 5 years of age). Subsequent thinning of the high density plots will create wider avenues which will allow more sunlight to penetrate the remaining palm rows. It is also possible that some food or cash crops could be grown for extra income in the wider inter-rows.

This trial is a replica of the trial 331 at Higaturu Oil Palms in Oro Province.

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	4	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. There are 6 treatments initially of different planting densities with equilateral triangular spacing (Table 2). In treatments 4, 5 and 6 every third row will be 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' involves 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 row of palms in each plot. The number of bunches and bunch weights recording commenced in April 2006 and will continue on a fortnightly basis. This is being done on an individual palm basis (individual palms were not numbered pre-thinning) and totalled for each plot, then totalled for each harvest and expressed per ha per year. Single bunch weight is being calculated from these data. Post thinning (February 2008) recorded palms are numbered and bunch number and SBW are now recorded against numbered palms in each plot.

Leaf sampling will be 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 be carried out for yield component variables.

RESULTS and DISCUSSION

Density treatments had a significant effect on yield (Figure 1). The difference in yield between planting density was due only to the bunch number produced not to bunch weight (Average SBW was 5.6kg).

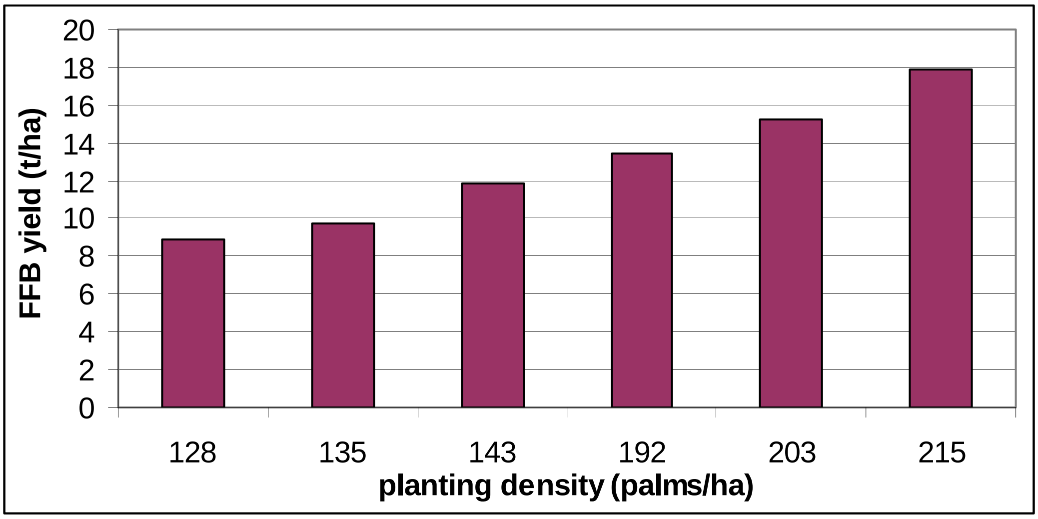


Figure 1. Trial 513: FFB yield for 2007 based on six treatments with different planting densities.

CONCLUSION

Density treatment had a significant effect on yield and number of bunches in 2007 (year prior to thinning). The significant yield increase at higher densities was due to increase in bunch numbers. It is expected that post thinning (thinning took place in February 2008) the yield in the high density plots will come back to similar weights to their corresponding planting density treatment.

Trial 515: Flowering and yield prediction

INTRODUCTION

The purpose of the flowering trials is to gain a better understanding of the factors (environmental, biological or physical) which influence the production of female flowers and bunches hence yield. These flowering trials have been established at CTP Milne Bay, Higaturu and Poliamba and with Ramu Agri-Industries. Of these flowering trials the trial at Milne Bay (Trial 515) has been running the longest running and this report highlights some of the findings and how we can use these monitoring trials to predict or estimate yield.

Table 1 provides background information on the trial site.

Table 1. Trial 515 back ground information

Trial number	**515**	Company	Milne Bay Estates
Estate	Hagita	Block No.	LI1170 (BMP block)
Planting Density	128	Soil Type	Alluvial
Pattern	Triangular	Drainage	Good
Date planted	May 1999	Topography	Flat
Age after planting	8	Altitude	Not known
Recording started	January 2006	Previous Land-use	Grassland
Planting material	Dami D x P	Area under trial soil type (ha)	Not known
Progeny	Mix	Supervisor in charge	Wawada Kanama

METHODS

Monitoring of flowering and bunch formation on 40 palms are undertaken every seven days:

- Female flower (the week number since starting this trial is painted on the frond subtending the female flower in anthesis)
- Male flower (the frond subtending the male flower is marked in anthesis)
- Youngest and the most mature black bunch are recorded
- At harvest bunch weight is recorded (plus the week number when this bunch was a female flower in anthesis)

In addition a frond production count is undertaken every three months.

The site is managed as a BMP block by Milne Bay Estates. In 2007/08, 3kg Ammonium Chloride; 3.50 kg MOP and 0.05 kg/palm Borate was applied. The leaf and rachis tissue results were:
Leaf and Rachis N – 2.42 and 0.26 %dm;
Leaf and Rachis P – 0.148 and 0.10 %dm;
Leaf and Rachis K – 0.73 and 1.34 %dm.

RESULTS and DISCUSSION

1. Female and male flowers
(i) Distribution over time
For the 12 months July 2007 to June 2008 a total of 902 female flowers/ha were formed, during the same time period 1472 male flowers/ha were also formed – for a total of 2374 flowers/ha. As a percentage of total flowers that is 38% female and 62% male flowers (Figure 1).

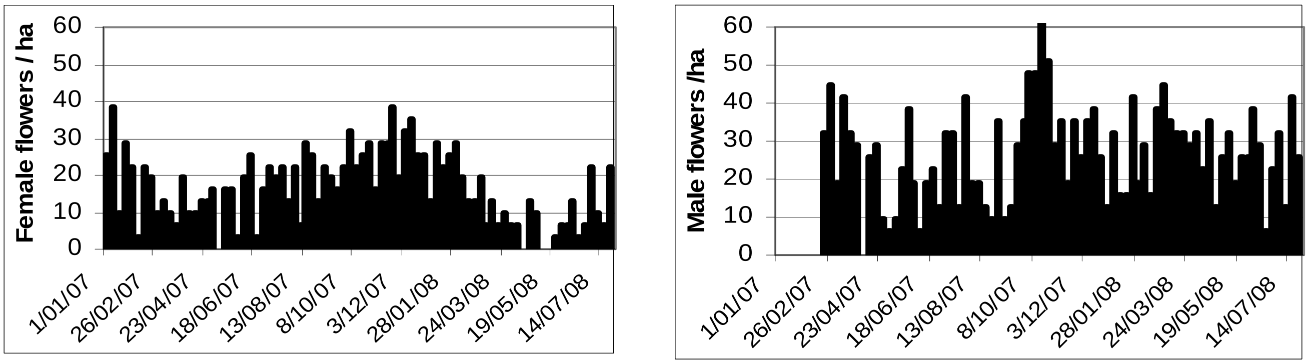


Figure 1. Female (Left) and Male (Right) flowers per hectare formed in trial 515 from January 1, 2007 to June 30, 2008 (note male flower observations were not recorded until late February 2007).

The seasonal fluctuation in female flower anthesis is clear with a peak in female flowers forming during November and December and a much lower number of female flowers forming in February and March. Male flower anthesis did not follow a seasonal pattern, however there was a large increase in male flowers during November 2007.

It was expected to see a more equal distribution of female to male flowers (from 60:40 to 50:50 female to male flowers). At this site for the 12 months July 2007 to June 2008 the ratio is closer to 40:60 female to male flowers.

The environmental and/or management factors influencing female and male flower formation is currently not known. Rainfall and sunshine patterns during the time of flower initiation (when the female or male flowers are first formed) will have to be investigated.

The number of female flowers has dropped significantly over the 2 ½ years of observations (figure 2). Some loss in female flowers as palms mature is expected but the current drop in female flowers in the second quarter (April to June) in 2008 will result in lower FFB yields during the third and fourth quarters of 2008.

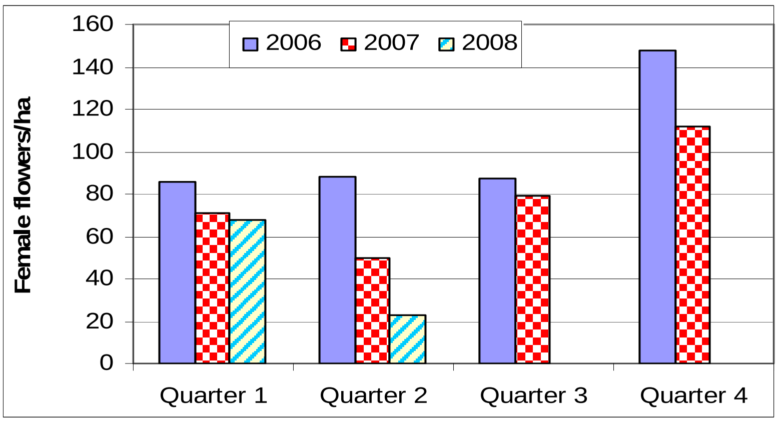


Figure 2. Female flowers produced per quarter in 2006, 2007 and 2008.

(ii) Frond production
Flowers form in the axil of a frond and each frond can support a single flower (male or female). During the twelve month period July 1 2007 to June 30 2008, 3200 fronds/ha were formed. 1300 fronds/ha equates to 25 fronds/palm forming during this twelve month period (equivalent to a new frond every 14 days).

Over this time period 2374 female and male flowers were formed (or 75% of the total number of fronds produced had a flower). This means that 25% of potential flower sites were aborted. As a percentage of total potential flowers (ie. the total number of fronds) 29% female flowers and 46% male flowers were formed.

2. Harvest
(i) Average harvest for the 40 monitored palms
In 2007, palms in the block produced 9.3 bunches per palm, or 1136 bunches per hectare with an average bunch weight of 21 kg/ha. A total of 23.2 t/ha in FFB was produced.

As a comparison, during the time period January to June in 2007, 16.3 t/ha FFB was produced. Whereas over the same time period in 2008, 18.4 t/ha was produced.

(ii) Individual palm harvests
A large variation between the 40 palms in bunch production and bunch weight was found (Figure 3). This resulted in a large variation between palms in FFB produced (Figure 4).

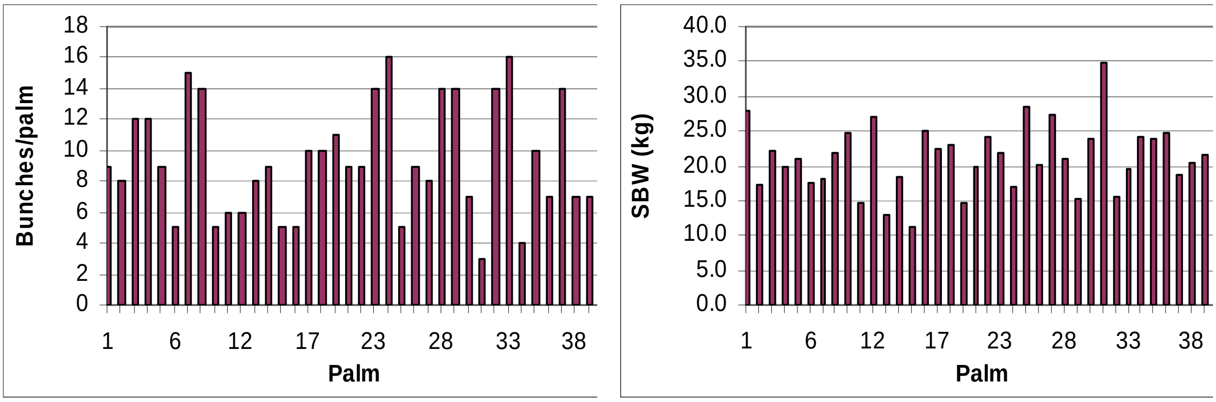


Figure 3. Bunch production per palm and average Single bunch weight produced by each of the 40 monitored palms for 2007 in trial 515 (average bunch production is 9.3 bunches/palm and average SBW is 21.1 kg/bunch).

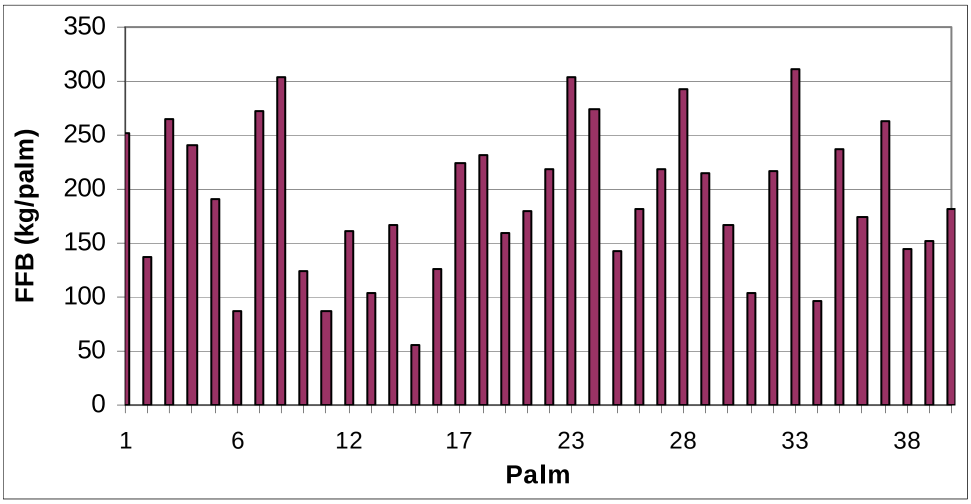


Figure 4. Bunch weight produced during 2007 for each of the monitored palms in trial 515 (average FFB produced is 191 kg/palm).

These differences in production between palms are likely to be genotype differences. The differences in yield are unlikely to be due solely to the perceived 'high and low production phases' that individual palms are thought to go through. Individual palms can yield either low or high yields over extended periods and many of the differences in yield between palms are more likely to be genetic rather than seasonal. A new trial established at Higaturu where genotype responses to fertilizer (N x P) are investigated will help in identify the role of genotype on production. As part of this genotype by fertilizer trial individual palms are also being monitored as described in this monitoring trial.

(iii) Time of flowering to harvest

For each harvest, the average time taken from flowering to bunch formation was calculated and is presented in Figure 5. Flowers in October to December 2006 took on average 20 days longer from flowering to harvest than those flowering in the April to July period. This difference was not as pronounced in 2007. The average time taken for a flower to form into a ripe and harvested bunch was 165 days or five and a half months.

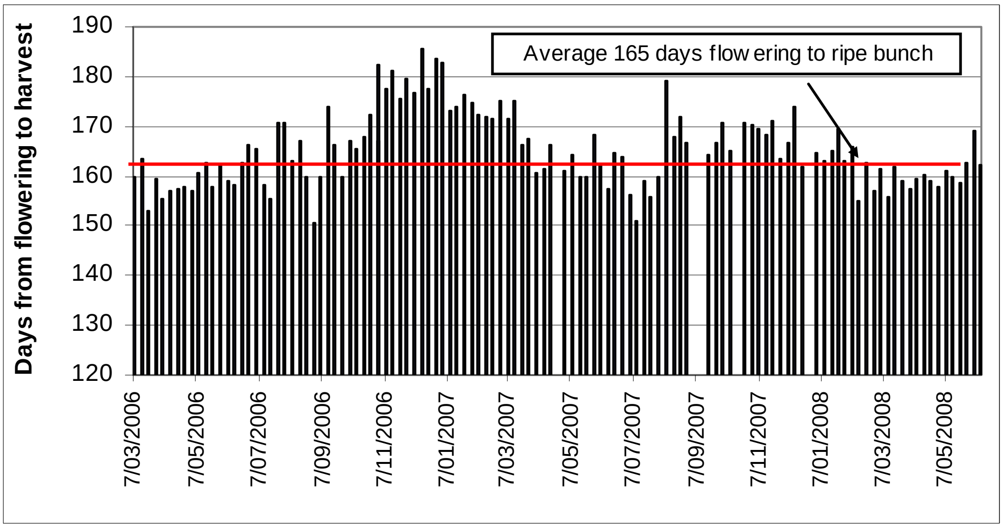


Figure 5. Days from flowering date to harvest in trial 515.

3. Yield estimation

The relationship between flowering and bunch formation (hence yield) is reasonably good (Figure 6). The time taken for bunch formation from flowering is 165 days (or 5 ½ months) and when transposed on the monthly yield it is a reasonably good indicator of low and high yielding periods. This relationship can then be used as an estimator of yield over the next 5 months (for example if we know how many flowers were formed during July 2008 we can estimate the yield likely to be produced in 5 months time – ie. in December 2008).

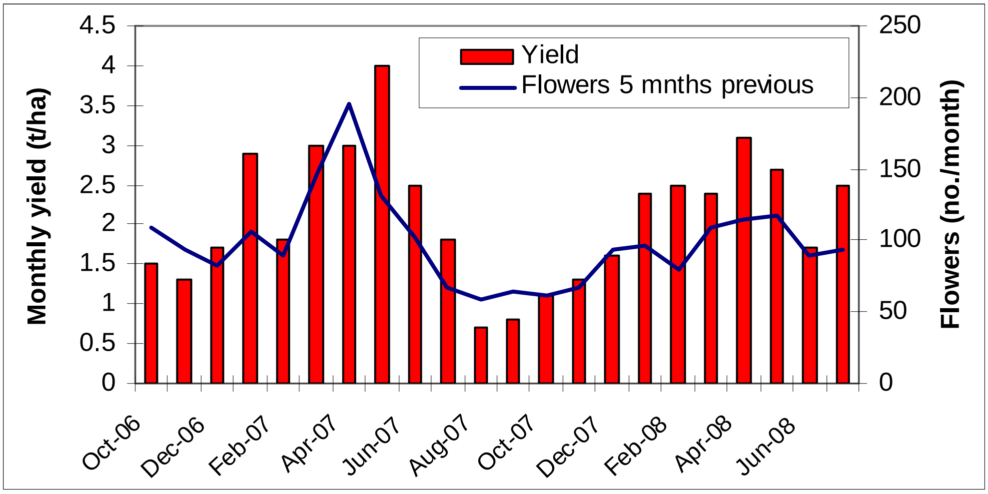


Figure 6. Relationship between monthly yield and number of flowers produced (5 month previous to the harvest month) for Trial 515.

The estimate of yield for the Bishops BMP block from August to December 2008 was calculated from the number of flowers produced during March to July, 2008 and multiplied by the average SBW (22 kg/ha).

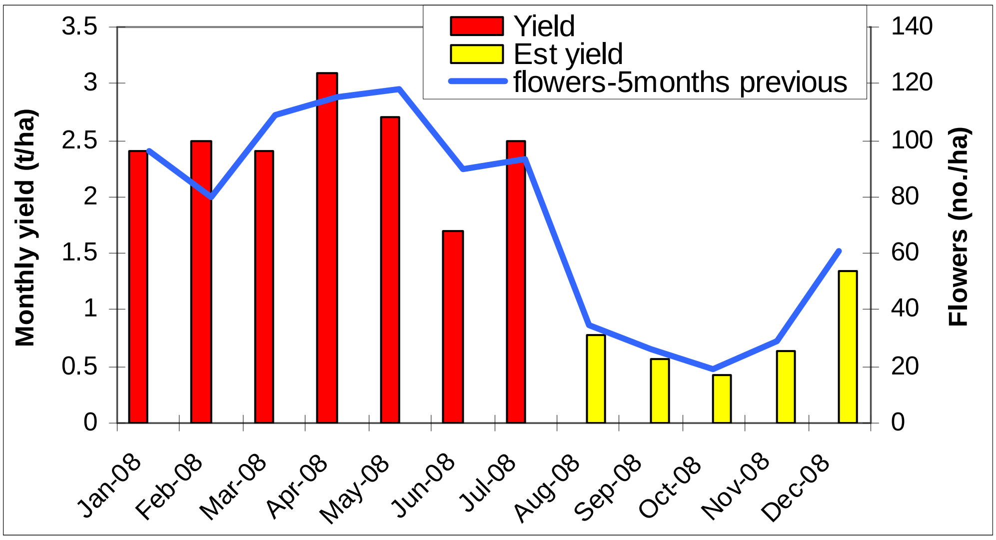


Figure 7. Estimated yield (yellow bars) against flowers formed (5 months previous to the harvest month) for Trial 515 for August to December 2008.

It is quite possible that this yield estimate can be used on similar age palms on the same soil type at MBE and can be a useful tool in planning harvesters, transport, milling capacity, and likely oil production.

CONCLUSION

1. In Milne Bay there are large seasonal differences in flower production from October to January which subsequently results in large seasonal differences in yield (peak production is from March to June).
2. In this block, for the twelve months July 07 to June 08, the ratio of female to male flowers is 4:6 which is a lower ration with fewer female flowers then expected (the expected ratio is 5:5 or 6:4 female:male flowers). The reason for the low ratio of female to male flowers is not known.
3. As a percentage of total potential flowers formed (as calculated from the total frond production) 75% of fronds carried a flower (female or male).
4. Individual palm yield (bunch number x bunch weight) varied significantly between palms and is likely to be due to genotype differences in planted progeny.
5. On average it takes 165 days from flowering to harvest – with some minor differences possible depending on the time of the year when a flower is formed to when the bunch is ripe and harvested.
6. A good relationship can be formed between flowering and yield and this relationship can be used to estimate yield five months in advance.

Trials 516 and 517: Two new trials at Maiwara Estate

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 516/517 back ground information

Trial number	**516/517**	Company	Milne Bay Estates
Estate	Hagita, Maiwara	Block No.	0020
Planting Density	143 p/ha	Soil Type	Alluvial
Pattern	Triangular	Drainage	Site is often waterlogged
Date planted	2001	Topography	Flat
Age after planting	6	Altitude	Not known
Recording started	2006	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

METHODS

Plots were marked out in 2006 and pre-treatment data are presented for the time period that data were collected. Plots consisted of 16 recorded palms surrounded by a single guard row (total 36 palms per plot). The trial site was split in two and two trials were established in May 2007.

Trial 516 – NxK: 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.

Trial 517 – K placement: Has the aim to identify the best placement option for MOP fertilizer. The trial consists of four treatments for the placement of MOP (all at 7.5kg/palm) where each treatment is replicated four times:

- spread over frond tips and frond pile
- spread over weeded circle
- spread on the edge of weeded circle
- broadcast over the whole block

(Note: one high treatment plot and two zero treatment plots were included as plots because three plots were left over in the trial design of trials 516 and 517).

RESULTS

For the 12 month prior to the application of treatment fertilizer the mean yield was 30.1t/ha, with a low of 23.1 and high of 34.3t/ha. The co-efficient of variation in yield was 9.3%.

DISCUSSION

2008 will the first full year following treatment application and the results will be presented in next years Annual Research Report.

GETTING MORE OUT OF GLYPHOSATE

The rise in commodity prices in 2007 and 2008 has seen farmers around the world planting more crop, putting pressure on the price and availability of fertilisers and herbicides. The price of glyphosate increased significantly and it is likely to be in short supply. It is a good time to review the current use of glyphosate and see if changes can be made to current practices to make the product work more effectively.

Herbicides most commonly used in PNG for spraying the weeded circle under oil palm are:
- Glyphosate CT – glyphosate 450g/L (also commonly referred to as Roundup CT);
- 2,4 D Amine 720g/L;
- Metsulfuron Methyl 200g/L (also commonly referred to as Ally);
- Paraquat 250g/L (also commonly referred to as Gramoxone).

Adjuvants most commonly used to improve the performance of glyphosate are:
- Activator 900g/L (a non-ionic surfactant – commonly referred to as a ‘wetting agent’);
- LI-700 which is a surfactant (ie wetting agent) and a pH adjuster (used in alkaline water).

Glyphosate: improving its effectiveness in killing weeds

Herbicides do not all behave the same way and each herbicide has its own set of rules on how to get the most out of the product and maximise weed control for every dollar spent.

Problem conditions for glyphosate:
- Spraying plants with a waxy leaf surface – the glyphosate molecule has a problem entering a plant which has a waxy leaf surface – it is therefore slow to act and in some situations does not act at all (in these situations glyphosate needs help from adjuvants to strip off the waxy layer and allow the active ingredient into the plant);
- Rain fastness – because glyphosate is slow to enter a plant it is susceptible to being washed off the leaves during rain. Glyphosate CT has a rain fast period of 2 hours (minimum);
- Muddy water - glyphosate will bind to clay and other sediments in water, deactivating the product;
- Alkaline water (water with a pH above 7.0) will degrade glyphosate;
- Hard water (water which has a high percentages of calcium and magnesium at levels above 250ppm) will deactivate glyphosate;
- Mixing incompatibility (glyphosate and 2,4D Amine are NOT compatible, a loss in weed control of between 10 and 20% is commonly observed when these two products are mixed).

Ameliorants (products or techniques that overcome the problem conditions for glyphosate):
1. Waxy leaf surface on the target weeds – efficacy of glyphosate maybe increased by using:
    - Petroleum based crop oils are effective in stripping off the waxy layer on the surface of the plant allowing glyphosate easier entry into the plant;
    - Product examples are DC Tron (839g/L) and Ulvapron (855g/L);
    - For glyphosate use only petroleum oils NOT vegetable oils as the preferred adjuvant.
2. Rain fastness — the only solution to this problem is to NOT spray if rain is likely. If it has rained significantly immediately after spraying then respraying may be needed
3. Muddy water — the only solution is to use clean water, preferably rain water
4. Alkaline water — use rain water instead, or add LI700 which contains a surfactant and a pH adjuster (making the water more acid)
5. Hard water – the negative effects of hard water can be over come by adding:

- Ammonium sulphate (eg. ammonium sulphate crystals at 0.8kg/100L or the product Liase (Liase is produced by Nufarm Ltd., it contains 417g/L of Ammonium Sulphate and is used at 2% solution in the spray mix);
- Ammonium sulphate will bind to the Ca and Mg ions thereby reducing the hardness of the water and improving the efficacy of glyphosate;
- Always use Technical grade ammonium sulphate because fertilizer grade could be high in aluminium and other metal cations (which will only make the problem worse because metal cations will increase the hardness of the water, not reduce it);
- Always add Ammonium sulphate to the knapsack before adding glyphosate.

6. Mixture incompatibility:
    - glyphosate and 2,4D Amine are not compatible and a loss in weed control will be observed (of between 10 and 20%) adding more of each product will reduce the loss in efficacy. The only formulation of 2,4D Amine which is compatible with glyphosate is Surpass300 (Surpass 300 is a isopropylamine salt, produced by Nufarm Ltd);
    - Under no circumstances should glyphosate be mixed with paraquat, these two products have a totally different mode of action and are biologically NOT compatible;
    - Glyphosate is compatible with Ally (metsulfuron).

Water quality in PNG

Water used for spraying glyphosate was tested during March 2008. Results are presented in Table 1.

Table 1. Water quality at different sites around PNG.

Site sampled	Hardness ppm	pH	Alkalinity ppm	Comment
Poliamba — Nalik	250-500 (high)	8.4 (high)	Above 240 (high)	Unsuitable for glyphosate without ameliorants
— Noatsi	500-1000 (very high)	8.4 (high)	Above 240 (high)	
RAMU — main workshop	500 (high)	8.4 (high)	Above 240 (high)	
Milne Bay Estates — Hagita	500-1000 (very high)	6.2-6.8 (slightly acid)	180-240 (moderate)	
Hargy — workshop	100-250 (low)	6.8-7.2 (neutral)	120-180 (low)	Suitable for glyphosate without ameliorants
NBPOL — Haella	100-250 (low)	7.2 (neutral)	120-180 (low)	
— Dami	100 (low)	6.8 (neutral)	40-80 (low)	

Legend:

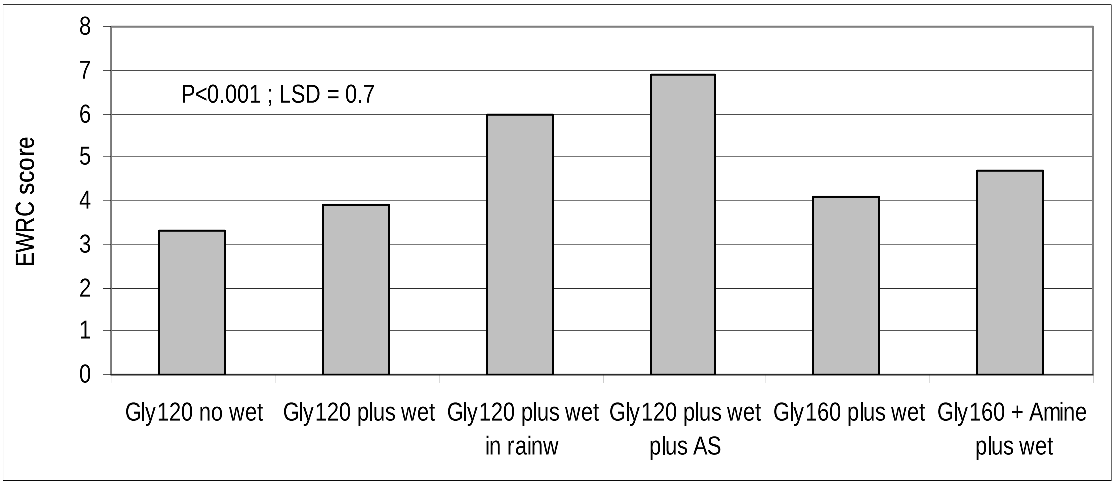
- Hardness is an estimate of the Ca++ and Mg++ ions in the solution. Glyphosate is a negatively charged molecule and water with a hardness of above 500ppm is regarded as unsuitable for glyphosate;
- pH is a measure of whether the solution is acid or alkaline. Glyphosate is a weak acid molecule and works best in a slightly acid to neutral spray solution;
- Alkalinity is a measure of bi-carbonates and carbonates in the solution. Glyphosate is generally not affected by the level of alkalinity, however 2,4D Amine does not work as effectively in a solution high in bi-carbonates.

Prelimanary results of trial work with glyphosate

A glyphosate herbicide trial using different rates of glyphosate; different water sources; and different adjuvants and ameliorants was undertaken in March 2008 at MBE. The main target weeds were grasses and some broadleaf weeds.

The treatments were (all rates per 16L knapsack):
(i) glyphosate 120ml no wetter in MBE water
(ii) glyphosate 120ml plus wetter 32ml in MBE water
(iii) glyphosate 120ml plus wetter 32 ml in rainwater
(iv) glyphosate 120ml plus wetter 32ml plus Ammonium Sulphate 120g in MBE water
(v) glyphosate 160ml plus wetter 32ml in MBE water
(vi) glyphosate 160ml + 2,4D Amine 160ml plus wetter 32ml in MBE water

Trial results:
Significant differences in grass weed control (see Figure 1) were observed:
- Glyphosate at 120ml with wetter was slightly more effective compared to glyphosate without wetter, but both treatments are not commercially acceptable
- Glyphosate in rainwater or in hard water treated with Ammonium Sulphate gave the best results
- Glyphosate at 160m was more effective then glyphosate at 120ml, but neither was commercially acceptable



Legend EWRC score:- 1=no effect; 3=visual effect; 5=strong visual effect, plants stunted; 7=commercially acceptable control; 9=dead (EWRC – European Weed Research Council)

Figure 1. Grass weed control (as assessed by EWRC score) for glyphosate with different water sources and adjuvants.

CONCLUSION

When spraying weeded circles, the effectiveness with which glyphosate kills weeds can be increased by observing some simple rules. The following recommendations assume that spraying is done by hand operators using 16L knapsacks.

1. Use rain water. If rainwater cannot be used then at least test the water for pH and hardness. Use the appropriate products listed above (LI700 for alkaline water at 80ml/knapsack; and technical grade Ammonium sulphate at 120g/knapsack). NOTE: always add these two products to the water before adding
the glyphosate);
2. Always use a wetting agent (non ionic surfactant at 30ml/knapsack) add the wetting agent after the glyphosate (if using LI700 then it is not necessary to use a wetting agent);

3. Use a petroleum based crop oil if spraying weeds with a very waxy surface (petroleum based oil at 150ml/knapsack, add the oil after the glyphosate and wetting agent);
4. Never use muddy water;
5. Do not spray if it looks like it is going to rain and do not spray wet plants;
6. If mixing glyphosate with 2,4D Amine, expect some loss in efficacy. When mixing Increase rate of glyphosate and Amine, by at least 20%.

Higaturu Oil Palm, Oro Province: Summary

(Dr. Murom Banabas and Susan Tomda)

Agronomy trials with Higaturu comprised three main areas of interest:

1. Factorial fertilizer 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) Mamba - 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) Sangara - SOA.EFB – no effect as yet because the soil has high levels of N and K.
   (iii) Heropa - Urea.Sulphur – no positive yield response as it is only the first year after treatments.
   (iv) Mamba - Mg.K source – no positive yield response since the treatment commenced in 2004 but tissue Mg and K were affected by treatments. This trial was stopped at the end of 2007.
   (v) Sangara and Ambogo Urea.TSP – established in late 2006/07 and no treatment outcomes as yet.

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 (37t/ha) and yield increased with increasing rate of N up to 1.68 kg N per palm (33 to 39 t/ha, control only 20 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 un-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 2007 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	11	N type (NS) N rate 33.2 to 39.3 Control 20.2	N B/ha 1809 (NS) N rate SBW 19-21	N type LN 2.35 (NS) N rate LN 2.26 to 2.42 RN 0.27 to 0.29 LP 0.145; RP 0.149 LK 0.75; RK 1.5 LMg 0.17, LB 12	N rate PCS 40 to 43 LAI 6.0 (NS)	Highest yield: 1.68 kg N/palm) B low
326 Sangara SOA, EFB (factorial) Soil: Volcanic ash	8	SOA 35 (NS) EFB 35 (NS)	SOA B/ha 1835 (NS) SOA SBW 19 (NS) EFB (NS)	EFB LK 0.80 to 0.82 RK 1.11 to 1.48 LN 2.40; RN 0.27 LP 0.148; RP 0.08 LMg 0.17, LB 11ppm	PCS 26 (NS) FP 26 (NS) LAI 6.2 (NS)	High levels of soil N, thus no response B low
330 Heropa (ex Grassland) Urea, Elemental S Soil: Sandy alluvium	7	Urea 22 (NS) S (NS)	B/ha 1649 (NS) SBW 13 (NS)	Urea LN 2.43 (NS) RN 0.27 (NS) Sulphur LS 0.19 (NS) LP 0.143; RP 0.08 LK 0.69; RK 1.1 LMg 0.29; LB 11ppm	PCS 26 (NS) FP 25 (NS) LAI 5.1 (NS)	High OM, high LN Low B
329 Mamba SOA, TSP, MOP, KIE (factorial) Soil: Volcanic ash	10	SOA 27 (NS) TSP 27 (NS) MOP 26 to 30 (S) KIE 27 (NS)	MOP B/ha 1195 to 1245 (S) MOP SBW 22-24 (S)	SOA LN 2.59 (NS) RN 0.27 (NS) TSP LP 0.161 to 0.167 RP 0.07 to 0.08 MOP LK 0.71 to 0.87 RK 0.44 to 1.45 KIE LMg 0.14 to 0.30 LB 13	MOP PCS 47- 59 (S) LAI 6.8-7.4 (S) Kie LAI 6.9-7.3 (S)	Tissue: K required N high B low LAI high
333 Mamba Group 1Mg sources, Group 2 K sources, Group 3 Mg & K Factorial Soil: Alluvium/volcanic	14	Mg source 23 (NS) K source 23 (NS) MgxK 23 (NS)	B/ha 864 (NS) SBW 26 (NS)	K source LK 0.64 to 0.78 (S) RK 1.39 to 1.47 Mg source LMg 0.21 (NS) RMg 0.07 LN 2.47; RN 0.23 LP 0.143; RP 0.05 LB 12ppm	PCS 50 (NS) FP 20 (NS) LAI 6.7 (NS)	Low B K response

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 the relative effects of five different nitrogen fertilizers (Urea, AC, SOA, AN and DAP) on volcanic ash soils. The trial design was a Randomised Complete Block Design (RCBD). The different sources of N were tested at 3 different levels; each treatment was replicated 4 times.

The type of N used had no significant effect on FFB yield in 2007 and for the combined 2005-2007 period. However vegetative measurements of PCS, FP, FDM and BI were significantly affected in 2007, this could be a possible indication that changes in production will be seen in 2008/09.

The rate of N had a significant effect on yield, tissue N and most physiological growth parameters. The intermediate and high rates of N applied (0.84 and 1.68 kg N/palm) yielded significantly more than the low rate of N applied (0.42 kg N/ha).

The mean yield for all treatments receiving N fertilizer was 37.2 t/ha, whereas the mean yield for palms that did not receive N fertilizer was only 20.2 t/ha in 2007. 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 fertilizers, for oil palm grown on volcanic soils at Higaturu. For plantation management N fertilizer 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 fertilizer 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 AC or urea, in these ex grassland sandy loam soils.

Whether this is the case on other soils was not known. Hence, the purpose of this trial is to test relative effectiveness of different nitrogen fertilizers 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	11	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	Dr. Murom Banabas

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

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 (AC), ammonium nitrate (AN), urea and di-ammonium phosphate (DAP). The rates applied provide equivalent amounts of N for the different N sources (Table 3). Fertilizer 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 2007, the basal fertilizers applied were kieserite (1 kg/palm), TSP (0.5 kg/palm) and Calcium borate (0.2 kg/palm).

This trial was the same design as Trial 125 in Kumbango. See the 2001 Proposals for more background information.

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
	(kg N/palm/year)		
All sources	0.42	0.84	1.68

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 on a per hectare basis. 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 fertilizer 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-fertilizer types was not statistically significant in 2007 and the combined 2005-2007 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 2007 and the combined 2005-2007 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 the 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 2007 the difference in yield between +N and –N was about 17 t/ha. The average yield for +N was 37.2 t/ha and the average yield for no N was 20.2 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 2005–2007 and in 2007. p values <0.05 are shown in bold.

	2005 – 2007			2007		
Source	**Yield**	**BNO**	**SBW**	**Yield**	**BNO**	**SBW**
Type	0.971	0.277	0.333	0.643	0.557	0.407
Rate	**<0.001**	**0.023**	**<0.001**	**<0.001**	**0.002**	**0.001**
Type. Rate	0.105	0.060	0.481	0.215	0.183	0.388
CV %	*6.5*	*6.9*	*5.5*	*9.1*	*9.0*	*6.3*

Table 5. Main effects of treatments on FFB yield (t/ha) for 2005 - 2007 and 2007. p values <0.05 are shown in bold.

	2005 - 2007			**2007**		
	FFB yield (t/ha)	**BNO/ha**	**SBW (kg)**	**FFB yield (t/ha)**	**BNO/ha**	**SBW (kg)**
Control	9.9	681	13.7	20.2	1347	14.7
SOA	35.4	1823	19.5	36.3	1750	20.7
AC	36.0	1870	19.3	38.4	1824	21.1
Urea	35.9	1887	19.1	36.9	1783	20.7
AN	36.0	1927	18.7	37.4	1838	20.3
DAP	35.9	1927	18.8	37.0	1849	20.1
Rate 1	**33.1**	**1819**	**18.3**	**33.2**	**1694**	**19.6**
Rate 2	**36.8**	**1914**	**19.3**	**39.1**	**1869**	**20.9**
Rate 3	**37.6**	**1928**	**19.6**	**39.3**	**1864**	**21.2**
l.s.d.$_{0.05}$	*1.49*	*83*	*0.7*	*2.16*	*104*	*0.8*
Mean	35.9	1887	19.1	37.2	1809	20.6

Effects of treatments on frond (F17) nutrient concentrations

The between N type differences in leaflet and rachis N was not significant but was different between the N rates applied (p<0.001 in leaflets and p = 0.036 in rachis) in 2007 (Tables 6 and 7). However, the between N type differences in the leaflets was significant for K (p = 0.001), Ca (p = 0.005), Cl (p < 0.001) and B (p = 0.017). AC appears to have a depressing effect on K and B, whilst it had a positive effect on Cl. The positive effect on Cl was mostly due to the Cl content in AC fertilizer.

The between N-rate difference in leaflet N, P, K, and Ca was significant and most nutrient concentrations increased with the N rate except Ca (Tables 6 and 7). Similarly, rachis N and K concentrations were significantly increased with higher N rates, whilst the rachis P was decreased with increasing rate of N (Tables 6 and 8). 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 fertilizer (Table 8).

Table 6. Effects (p values) of treatments on frond 17 nutrient concentrations in 2007. p values less than 0.05 are in bold.

Source	Leaflet nutrient concentrations (% DM)							
	Ash	N	P	K	Ca	Mg	Cl	B
Type	0.28	0.95	0.12	**0.001**	**0.005**	0.42	**<0.001**	**0.017**
Rate	0.9	**<0.001**	**0.02**	**0.001**	**<0.001**	0.69	0.24	0.64
Type. Rate	0.42	0.67	0.82	0.21	0.84	0.87	**0.007**	0.89
CV %	4.6	3.4	2.9	4.2	6.9	9.2	7.0	9.7

	Rachis nutrient concentrations (% DM)				
	Ash	N	P	K	Mg
Type	0.66	0.42	0.69	0.60	0.20
Rate	0.37	**0.04**	0.06	0.24	0.18
Type. Rate	0.76	0.07	0.45	0.54	0.70
CV %	6.6	10.0	23.3	7.3	13.8

Table 7. Main effects of treatments on frond 17 nutrient concentrations in 2007, 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.

Treatment	Leaflet nutrient concentrations (% DM)							
	Ash	N	P	K	Mg	Ca	Cl	B (ppm)
Control	*16.2*	*2.03*	*0.136*	*0.76*	*0.16*	*0.95*	*0.42*	*17.6*
SOA	16.0	2.36	0.144	**0.77**	0.17	**0.76**	**0.46**	**11.9**
AC	15.4	2.35	0.144	**0.72**	0.18	**0.80**	**0.59**	**10.9**
Urea	15.5	2.34	0.146	**0.74**	0.17	**0.83**	**0.46**	**12.3**
AN	15.4	2.36	0.146	**0.76**	0.17	**0.82**	**0.47**	**12.2**
DAP	15.7	2.35	0.148	**0.77**	0.17	**0.76**	**0.49**	**11.2**
l.s.d.$_{0.05}$	-	-	-	*0.03*	-	*0.05*	*0.04*	*1.1*
Rate 1	15.6	**2.26**	**0.143**	**0.73**	0.17	**0.85**	0.50	11.6
Rate 2	15.7	**2.38**	**0.146**	**0.75**	0.17	**0.80**	0.48	11.9
Rate 3	15.6	**2.42**	**0.147**	**0.77**	0.17	**0.72**	0.50	11.6
l.s.d.$_{0.05}$	-	*0.05*	*0.003*	*0.02*	-	*0.04*	-	-
GM	15.6	2.35	0.145	0.75	0.17	0.79	0.49	11.7

Table 8. Main effects of treatments on frond 17 nutrient concentrations in 2007, 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.

Treatment	Rachis nutrient concentrations (% DM)				
	Ash	N	P	K	Mg
Control	*5.75*	*0.23*	*0.326*	*1.76*	*0.06*
SOA	5.22	0.27	0.137	1.56	0.05
AMC	5.20	0.27	0.147	1.61	0.06
Urea	5.22	0.28	0.156	1.63	0.05
AMN	5.37	0.28	0.155	1.63	0.05
DAP	5.17	0.29	0.148	1.60	0.05
Rate 1	5.16	**0.27**	0.159	1.61	0.05
Rate 2	5.32	**0.28**	0.153	1.57	0.05
Rate 3	5.24	**0.29**	0.133	1.64	0.06
l.s.d.$_{0.05}$	-	*0.02*	-	-	-
Mean	5.24	0.28	0.149	1.61	0.05

Effects of fertilizer treatments on Vegetative parameters

N-type treatments had a significant effect on the Petiole Cross Section (PCS) (p=0.006), Frond Production (FP) (p=0.014), Frond Dry Matter (FDM) (p=0.001) and Bunch Index (BI) (p=0.017) (Tables 9 and 10). DAP increased PCS significantly compared to Urea and AN while the difference between DAP and either SOA or AC was not significant. However the effect of N type on the vegetative dry matter did not translate to yield.
N-rate treatments had a significant effect on all the physiological parameters except BI (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 2007. p values less than 0.05 are shown in bold.

Source	Radiation interception				Dry Matter Production (t/ha/yr)				
	PCS	FP	FA	LAI	FDM	BDM	TDM	VDM	BI
Fert. type	**0.006**	**0.01**	0.15	0.40	**0.001**	0.60	0.25	**0.002**	**0.017**
Rate	**0.003**	**<0.001**	**0.05**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	0.21
Type.Rate	0.81	**0.02**	0.08	0.12	0.36	0.34	0.16	0.22	0.92
CV %	*7.9*	*3.0*	*3.9*	*5.0*	*8.0*	*9.2*	*7.2*	*7.1*	*3.5*

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 2007. Significant effects ($p<0.05$) are shown in bold.

Treatments	Radiation interception				Dry Matter Production (t/ha/yr)				BI
	PCS	FP	FA	LAI	FDM	BDM	TDM	VDM	
Control	29.1	13.0	9.7	4.3	5.6	16.2	18.2	7.4	0.58
SOA	**41.5**	**15.7**	12.3	6.0	**9.4**	19.0	31.5	**12.5**	**0.60**
AMC	**43.5**	**15.4**	12.6	6.0	**9.7**	20.1	33.1	**13.0**	**0.61**
Urea	**39.8**	**15.0**	12.4	5.9	**8.7**	19.4	31.2	**11.8**	**0.62**
AMN	**39.9**	**15.5**	123	5.8	**9.0**	19.5	31.6	**12.1**	**0.61**
DAP	**44.1**	**15.6**	12.7	6.1	**9.9**	19.2	32.4	**13.2**	**0.59**
$lsd_{0.05}$	*2.7*	*0.4*	-	-	*0.6*	-	-	*0.7*	*0.02*
Rate 1	**39.6**	**12.2**	**12.2**	**5.7**	**8.5**	**17.5**	**28.9**	**11.4**	0.60
Rate 2	**42.4**	**12.5**	**12.5**	**6.1**	**9.5**	**20.5**	**33.4**	**12.9**	0.61
Rate 3	**43.3**	**12.6**	**12.6**	**6.1**	**9.9**	**20.3**	**33.6**	**13.3**	0.60
$lsd_{0.05}$	*2.1*	*0.3*	*0.3*	*0.2*	*0.5*	*1.1*	*1.5*	*0.6*	
GM	41.8	12.4	12.4	6.0	9.3	19.4	32.0	12.5	0.61

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 2007 and for the combined 2005-2007 period and this has been consistent since the trial started in 2001.

N-rate treatment had a significant effect on yield, tissue N and most physiological growth parameters. Increasing N rate from 0.42 kg per palm to higher rates increased yield, leaflet N and PCS, FP, FA, LAI, BDM and TDM.

Yield, leaflet N and values for physiological growth parameters for the palms that did not receive N fertilizer were comparatively lower than the palms that received N fertilizer. This indicates that without fertilizer 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 a 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 oil palm to help formulate fertilizer recommendations on volcanic plain soils of Higaturu, Popondetta.

SOA and EFB treatments had no significant effect on yield and its components in 2007 except for EFB on SBW. These results are similar to the results of the past 4 years since the trial started in 2002. Similarly, SOA treatment had no significant effect on leaf nutrient concentrations. EFB significantly increased leaflet K and Cl, and rachis P and K concentrations but not the concentration of other nutrients. However, regardless of treatments, all nutrients were above their respective critical concentrations.

SOA treatment had a significant effect on bunch index but not any other measured or calculated vegetative growth parameter. EFB treatment significantly increased 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 fertilizer 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 requirements 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, a FFB yield plateau could not be reached when increasing SOA from 0 to 6kg per palm but FFB yields did plateau with 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. Trial 326 was designed to test 3 rates of EFB 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	Agronomist in charge	Dr. Murom Banabas

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	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 a 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 the 2001 Proposals for more background information.

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 a basal application 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 on a per hectare basis. 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 fertilizer and their interactions were carried out for each of the variables of interest using the GenStat statistical program.

Table 3. Fertilizer 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 2007 except for EFB on SBW (Tables 4 and 5). Average yield and its components for the 2005 to 2007 period were also not affected by treatments. These results are similar to the past 5 years since the trial commenced in 2002.

Table 4. Effects (p values) of treatments on FFB yield and its components in 2005 – 2007 and 2007.

	2005 – 2007			2007		
Source	Yield	BNO	SBW	Yield	BNO	SBW
SOA	0.31	0.55	0.66	0.16	0.50	0.40
EFB	0.30	0.99	0.13	0.47	0.24	**0.02**
SOA.EFB	0.99	0.65	0.14	0.80	0.44	0.07
CV %	*6.3*	*6.9*	*5.3*	*8.4*	*8.9*	*5.7*

Table 5. Main effects of treatments on FFB yield (t/ha) from 2005 to 2007 and 2007.

Treatments	2005-2007			2007		
	FFB yield (t/ha)	BNO/ha	SBW (kg)	FFB yield (t/ha)	BNO/ha	SBW (kg)
SOA 0	37.3	2261	16.8	35.9	1871	19.2
SOA 2.5	37.8	2265	17.0	35.9	1842	19.6
SOA 5.0	36.3	2220	16.7	34.0	1781	19.2
SOA 7.5	36.6	2195	17.1	36.3	1841	19.8
EFB 0	36.4	2234	16.6	35.0	1862	**18.9**
EFB 130	37.2	2235	17.0	36.2	1857	**19.5**
EFB 390	37.5	2236	17.1	35.4	1783	**20.0**
$l.s.d_{0.05}$	-	-	-	-	-	*0.7*
Grand Mean	37.0	2235	16.9	35.5	1835	19.4

Effects of interaction between treatments on FFB yield

There was no significant interaction effect of SOA.EFB (Table 6).

Table 6. Effect of SOA and EFB (two-way interactions) on FFB yield (t/ha/yr) in 2007. The interaction was not significant (p=0.95).

	EFB 0	EFB 130	EFB 390
SOA 0	35.8	36.3	35.4
SOA 2.5	35.3	37.5	34.9
SOA 5.0	33.7	33.4	35.0
SOA 7.5	35.3	37.5	36.3
	Grand mean: 35.5	*sed 1.89*	

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

SOA treatment had no significant effect on leaflet and rachis nutrient concentrations in 2007 except on leaflet Ash (p=0.002), Ca (p<0.001) and rachis Mg (p=0.003) contents (Tables 7 and 8). All nutrients were above their respective critical concentrations for leaflets.

EFB treatments had a significant effect on the concentration of leaflet and rachis ash, leaflet and rachis K, leaflet Cl and rachis P, but not on other nutrients (Tables 7 and 8). Regardless of treatment effects, all the nutrients were above their respective critical concentrations. The increase in leaflet and rachis K concentrations was due to the high content of K in the EFB (approx 2.0% DM). The leaflet Cl and rachis P concentrations were significantly increased by higher rates of EFB.

Table 7: Effects (p values) of treatments on frond 17 (F17) nutrient concentrations 2007 (Trial 326). p values <0.05 are indicated in bold.

	Leaflets							
Source	**Ash**	**N**	**P**	**K**	**Mg**	**Ca**	**Cl**	**B**
SOA	**0.002**	0.19	0.45	0.98	0.20	**<0.001**	0.35	0.08
EFB	**0.001**	0.12	0.31	0.46	**0.01**	**0.002**	**<0.001**	0.36
SOA.EFB	0.71	0.67	0.95	0.51	0.92	0.98	**0.04**	0.33
CV%	*3.5*	*2.9*	*3.0*	*5.8*	*8.6*	*5.0*	*10.9*	*5.7*
	Rachis							
	Ash	**N**	**P**	**K**	**Mg**			
SOA	0.73	0.28	0.244	0.73	**0.003**			
EFB	**<0.001**	0.064	**0.008**	**<0.001**	0.65			
SOA.EFB	0.41	0.21	0.767	0.75	0.27			
CV%	*11.4*	*6.5*	*17.3*	*14.9*	*12.2*			

Table 8. Main effects of treatments on F17 nutrient concentrations in 2007, in units of % dry matter, except for B (mg/kg) (Trial 326). Effects with p<0.05 are shown in bold.

Treatments	**Leaflet nutrient concentrations (% DM)**							
	Ash	**N**	**P**	**K**	**Mg**	**Ca**	**Cl**	**B**
SOA 0	**14.6**	2.46	0.149	0.81	0.18	0.75	0.40	11
SOA 2.5	**15.3**	2.50	0.149	0.81	0.18	0.76	0.39	12
SOA 5.0	**15.1**	2.50	0.147	0.81	0.17	0.73	0.41	11
SOA 7.5	**15.4**	2.51	0.147	0.82	0.17	0.69	0.39	12
l.s.d$_{0.05}$	*0.4*	-	-	-	-	-	-	-
EFB 0	**15.5**	2.49	0.147	0.80	**0.18**	**0.72**	**0.35**	11
EFB 130	**15.0**	2.47	0.148	0.82	**0.17**	**0.72**	**0.40**	12
EFB 390	**14.8**	2.52	0.149	0.82	**0.17**	**0.76**	**0.44**	12
l.s.d$_{0.05}$	*0.4*	-	-	-	*0.01*	*0.02*	*0.03*	-
GM	15.1	2.49	0.148	0.81	0.17	0.73	0.40	12

	Rachis nutrient concentrations (% DM)				
	Ash	**N**	**P**	**K**	**Mg**
SOA 0	4.38	0.26	**0.082**	1.31	**0.05**
SOA 2.5	4.58	0.27	**0.074**	1.32	**0.05**
SOA 5.0	4.56	0.27	**0.075**	1.39	**0.05**
SOA 7.5	4.49	0.27	**0.074**	1.37	**0.04**
l.s.d$_{0.05}$	-	-	*0.010*	-	*0.004*
EFB 0	**3.40**	**0.26**	**0.069**	**1.11**	0.05
EFB 130	**4.79**	**0.27**	**0.075**	**1.45**	0.05
EFB 390	**4.75**	**0.27**	**0.083**	**1.48**	0.05
l.s.d$_{0.05}$	*0.33*	*0.01*	*0.008*	*0.13*	-
GM	4.50	0.27	0.076	1.35	0.05

Effects of fertilizer treatments on Vegetative parameters

SOA did not have any significant effect on the calculated vegetative parameters (Tables 9 and 10). However, EFB significantly increased PCS, FDM and VDM but the effects were not translated into FFB yield.

Table 9. Effect (p values) of treatments on vegetative growth parameters in 2007. p values less than 0.05 are shown in bold.

Source	Radiation interception				Dry matter production				
	PCS	FP	FA	LAI	FDM	BDM	TDM	VDM	BI
SOA	0.40	0.07	0.71	0.32	0.15	0.22	0.39	0.22	0.08
EFB	**0.02**	**0.02**	0.63	0.13	**<0.001**	0.46	0.13	**<0.001**	0.05
SOA.EFB	0.88	0.83	0.35	0.31	0.69	0.91	0.98	0.79	0.76
CV %	*6.2*	*2.8*	*6.3*	*6.2*	*5.6*	*9.0*	*5.6*	*5.0*	*4.7*

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 2007. Significant effects ($p<0.05$) are shown in bold.

Treatments	Radiation interception				Dry matter production				
	PCS	FP	FA	LAI	FDM	BDM	TDM	VDM	BI
SOA 0	35.9	25.4	11.4	6.0	13.3	18.8	35.7	16.9	0.53
SOA 2.5	35.5	26.0	11.5	6.1	13.5	18.8	35.9	17.1	0.52
SOA 5.0	36.9	25.9	11.6	6.2	13.9	17.9	35.3	17.4	0.50
SOA 7.5	36.3	26.1	11.7	6.3	13.8	19.1	36.6	17.4	0.52
EFB 0	**35.5**	**25.9**	11.6	6.1	**13.4**	18.3	35.2	**16.9**	0.52
EFB 130	**35.6**	**25.5**	11.4	6.0	**13.2**	19.0	35.8	**16.8**	0.53
EFB 390	**37.4**	**26.2**	11.7	6.3	**14.2**	18.7	36.6	**17.9**	0.51
$lsd_{0.05}$	*1.4*	*0.5*			*0.5*			*0.5*	
GM	36.2	25.9	11.6	6.2	13.6	18.7	35.9	17.2	0.52

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 treatments and all the nutrients were above their respective critical concentrations. On the other hand, EFB treatment only increased leaflet Ash, Mg, Ca and Cl, and rachis Ash, P and K concentrations.

PCS, FP, 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 fertilizer 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 fertilizer treatments included SOA (2 rates); and MOP, Kieserite and TSP, all tested at 3 rates.

Only the MOP treatment had a significant effect on yield. Increasing MOP from 0 to either 2 or 4 kg per palm increased FFB yield by 0.3 to 3.0 t/ha. Leaf and Rachis K levels were increased significantly by higher rates of MOP. For zero MOP the K level dropped below the critical level of 1.0% for 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 treatments significantly increased BDM and TDM in 2007.

One reason for other fertilizer 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 fertilizer 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 6298G1
Planting Density	135 palms/ha	Soil Type	Mamba Soils
Pattern	Triangular	Drainage	Poor
Date planted	1997	Topography	Flat
Age after planting	10	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	Agronomist in charge	Dr. Murom Banabas

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 mg/kg	P Ret. (%)	Exch. K	Exch. Ca (cmolc/kg)	Exch. Mg	CEC	Org. Matter (%)	Total N (%)	Avail. N (kg/ha)	Sulfate S (mg/kg)	B
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. Fertilizers used were ammonium sulphate (SOA), triple superphosphate (TSP), potassium chloride (MOP) and magnesium sulphate as kieserite (KIE) (Table 3). The fertilizer 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 on a per hectare basis. 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. The third dose of fertilizer in 2007 was not applied due to a lack of access to the trial site caused Cyclone Guba.

Analysis of variance of the main effects of fertilizer and their interactions were carried out for each of the variables of interest using the GenStat statistical program.

Table 3: Fertilizer levels and rates used in Trial 329

Fertilizer 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 2007 and 2005-2007 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 fertilizer 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 2007 and 2005-2007 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 3 t/ha) in 2007 and 2005-2007.

Table 4: Effects (p values) of treatments on FFB yield and its components in the combined harvest for 2005 – 2007 and for 2007 alone. p values less than 0.05 are in bold.

	2005- 2007			2007		
Source	Yield	BNO	SBW	Yield	BNO	SBW
SOA	0.69	0.50	0.55	0.50	0.89	0.35
TSP	0.63	0.53	0.97	0.08	0.15	0.73
MOP	**0.001**	0.06	**<0.001**	**<0.001**	**0.02**	**<0.001**
KIE	0.15	0.18	0.96	0.17	0.25	0.59
SOA.TSP	0.30	0.20	0.69	0.40	0.17	0.31
SOA.MOP	0.11	0.61	0.10	0.06	0.06	0.40
TSP.MOP	0.60	0.52	0.06	0.19	0.89	**0.02**
SOA.KIE	0.83	0.69	0.33	0.51	0.12	0.22
TSP.KIE	0.75	0.82	0.28	0.42	0.33	0.09
MOP.KIE	0.59	0.18	0.26	0.42	0.33	0.46
CV %	*9.3*	*9.1*	*5.0*	*9.2*	*9.4*	*5.5*

Table 5: Main effects of treatments on FFB yield (t/ha) for the combined harvest for 2005 – 2007 and 2007 alone (Yield, Bunch No and SBW in bold are significant at P<0.05).

	2005 - 2007			2007		
	FFB yield (t/ha)	**BNO/ha**	**SBW (kg)**	**FFB yield (t/ha)**	**BNO**	**SBW (kg)**
SOA 2	23.8	1044	22.9	27.7	1192	23.2
SOA 4	24.1	1061	22.7	27.2	1188	22.9
TSP 0	24.4	1071	22.7	27.7	1204	23.1
TSP 2	23.6	1035	22.8	26.3	1147	22.9
TSP 4	23.9	1052	22.8	28.2	1218	23.3
MOP 0	**22.1**	1020	**21.7**	**26.2**	**1195**	**21.9**
MOP 2	**24.1**	1041	**23.1**	**26.5**	**1128**	**23.5**
MOP 4	**25.8**	1097	**23.5**	**29.6**	**1245**	**23.8**
$Lsd_{0.05}$	*1.5*	-	*0.8*	*1.7*	*77*	0.9
KIE 0	24.7	1079	22.8	27.6	1207	22.9
KIE 2	24.1	1059	22.7	28.2	1209	23.3
KIE 4	23.2	1019	22.8	26.5	1153	23.1
GM	24.0	1053	22.7	27.4	1190	23.1

Effects of treatments on frond (F17) nutrient concentrations

SOA treatment had no significant effect on leaflet and rachis nutrient concentrations in 2007, except rachis P (Tables 6 and 7). However, all nutrients were above their respective critical concentrations for tissue except for rachis K.

TSP treatment had a significantly effect on leaflet N, P, Mg and rachis P and K concentrations (Tables 6 and 7). Increasing TSP from 0 to 4 kg per palm increased leaflet P significantly and the difference between either TSP 0 and TSP 2 or TSP 2 and TSP 4 was not statistically significant at $l.s.d_{0.05}$. Similarly, increasing TSP from 0 to 4 kg per palm increased rachis P significantly at $l.s.d_{0.05}$. Regardless of treatment differences, all leaflet P values were above the critical value of 0.14% dry mater.

MOP treatment had a significant effect on leaflet K, Mg and Cl and rachis P and K concentrations (Tables 6 and 7). MOP increased leaflet K, Cl and rachis P and K but suppresses leaflet Mg. The rachis K content at nil MOP fertilized plots was very low at 0.44 % DM. The effect of MOP on nutrient levels is also reflected in responses to yield.

Kieserite increased leaflet and rachis Mg but leaflet Ca. However, the significant positive effect on tissue Mg contents is not translated to ffb yield.

Table 6: Effects (p values) of treatments on frond 17 (F17) nutrient concentrations 2007 (Trial 329). p values <0.05 are indicated in bold.

Source	Leaflets							Rachis			
	N	P	K	Mg	Cl	Ca	B	N	P	K	Mg
SOA	0.13	0.71	0.57	0.29	0.18	0.09	0.98	0.32	**0.002**	0.70	0.24
TSP	0.02	**0.004**	0.52	**0.010**	0.71	0.67	0.12	0.1	**0.01**	**0.03**	0.91
MOP	0.06	**0.05**	**<0.001**	**<0.001**	**<0.001**	0.28	<0.001	0.67	**<0.001**	**<0.001**	**0.02**
KIE	0.02	0.34	0.06	**<0.001**	0.10	**<0.001**	0.40	0.70	0.80	0.25	**<0.001**
SOA.TSP	0.51	0.76	**0.05**	0.15	0.48	0.44	0.14	0.67	0.74	0.70	0.20
SOA.MOP	0.22	0.85	0.44	0.31	0.32	0.36	0.93	0.49	0.56	0.30	0.50
TSP.MOP	0.24	0.54	0.25	0.62	0.66	0.61	0.38	0.72	0.42	0.19	0.50
SOA.KIE	0.06	0.76	0.76	0.28	0.60	0.53	0.59	0.96	**0.005**	0.20	0.20
TSP.KIE	0.56	0.42	0.75	**0.04**	0.30	0.65	0.19	0.32	0.29	0.9	0.17
MOP.KIE	0.10	0.76	0.40	0.29	0.96	0.47	0.31	0.68	0.89	0.14	0.18
CV%	*2.9*	*3.2*	*9.1*	*7.0*	*13.2*	*804*	*7.4*	*7.7*	*13.3*	*14.4*	*18.5*

Table 7: Main effects of treatments on F17 nutrient concentrations in 2007, 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	Ca	Cl	B	Ash	N	P	K	Mg
SOA 2	8.41	2.57	0.164	0.80	0.23	0.90	0.42	13	3.6	0.27	**0.077**	1.02	0.06
SOA 4	8.49	2.61	0.164	0.81	0.23	0.87	0.40	13	3.6	0.28	**0.068**	1.00	0.06
$Lsd_{0.05}$	-	-	-	-	-	-	-	-	-	-	*0.005*	-	-
TSP 0	8.52	2.55	**0.161**	0.79	0.24	0.89	0.40	13	3.7	0.28	**0.068**	**1.06**	0.06
TSP 2	8.60	2.61	**0.164**	0.81	0.24	0.87	0.40	13	3.4	0.27	**0.071**	**0.93**	0.06
TSP 4	8.24	2.62	**0.167**	0.81	0.22	0.89	0.41	12	3.7	0.28	**0.078**	**1.03**	0.06
$l.s.d_{0.05}$	-	-	*0.003*	-	-	-	-	-	-	-	*0.006*	-	-
MOP 0	**9.57**	2.56	**0.161**	**0.71**	**0.25**	0.90	**0.20**	14	**2.4**	0.27	**0.062**	**0.44**	**0.07**
MOP 2	**7.98**	2.62	**0.165**	**0.83**	**0.23**	0.89	**0.50**	12	**3.9**	0.27	**0.075**	**1.14**	**0.06**
MOP 4	**7.81**	2.62	**0.166**	**0.87**	**0.22**	0.89	**0.52**	12	**4.5**	0.28	**0.080**	**1.45**	**0.06**
$l.s.d_{0.05}$	*0.37*	-	*0.003*	*0.05*	*0.01*	-	*0.04*	-	-	-	*0.006*	*0.10*	-
KIE 0	**9.10**	2.56	0.163	0.82	**0.14**	**1.03**	0.43	13	3.7	0.27	0.074	1.05	**0.03**
KIE 2	**8.29**	2.63	0.164	0.82	**0.26**	**0.82**	0.39	13	3.6	0.28	0.071	1.00	**0.07**
KIE 4	**7.97**	2.58	0.165	0.77	**0.30**	**0.81**	0.40	13	3.5	0.27	0.072	0.97	**0.08**
$l.s.d_{0.05}$	*0.37*	-	-	-	*0.01*	*0.05*	-	-	-	-	-	-	*0.01*
GM	8.45	2.59	0.164	0.80	0.23	0.88	0.41	13	3.6	0.27	0.072	1.01	0.06

Effects of fertilizer treatments on Vegetative parameters

SOA did not affect any of the physiological parameters. TSP affected FDM and VDM only, while kieserite affected only LAI (Tables 8 and 9).

MOP significantly affected all the vegetative parameters except FP and BI. Effect of MOP on physiological parameters was also noticed in tissue samples 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 is diverted to bunch production.

Table 8. Effect (p values) of treatments on vegetative growth parameters in 2007. p values less than 0.05 are shown in bold.

Source	**Radiation interception**				**Dry matter production (t/ha/yr)**				
	PCS	**FP**	**FA**	**LAI**	**FDM**	**BDM**	**TDM**	**VDM**	**BI**
SOA	0.43	0.97	0.93	0.33	0.53	0.85	0.85	0.54	0.72
TSP	0.06	0.55	0.47	0.38	**0.05**	0.24	0.12	**0.04**	0.20
MOP	**<0.001**	0.44	**0.006**	**0.003**	**<0.001**	**0.006**	**<0.001**	**<0.001**	0.28
KIE	0.70	0.11	0.49	**0.05**	0.12	0.62	0.32	0.11	0.50
SOA.TSP	0.34	0.54	0.87	0.80	0.52	0.52	0.46	0.50	0.65
SOA.MOP	0.53	0.46	0.70	0.85	0.57	0.32	0.37	0.57	0.39
TSP.MOP	0.65	0.58	0.49	0.87	0.53	0.66	0.29	0.42	0.94
SOA.KIE	0.37	0.17	0.94	0.23	0.06	0.50	0.83	0.08	0.14
TSP.KIE	0.14	0.85	0.63	0.55	0.42	0.09	0.08	0.36	0.25
MOP.KIE	0.61	0.19	0.43	0.34	0.16	0.60	0.19	0.12	0.71
CV%	*5.4*	*5.3*	*5.2*	*7.0*	*6.9*	*10.7*	*5.9*	*6.2*	*7.0*

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)				
	PCS	**FP**	**FA**	**LAI**	**FDM**	**BDM**	**TDM**	**VDM**	**BI**
SOA 2	49.9	21.0	13.0	7.0	15.0	15.1	33.4	18.3	0.45
SOA 4	49.3	21.0	13.0	7.2	14.8	15.2	33.3	18.1	0.45
TSP 0	48.4	20.7	12.9	7.0	**14.4**	15.3	32.9	**17.7**	0.46
TSP 2	49.9	21.1	12.9	7.1	**15.1**	14.6	33.0	**18.4**	0.44
TSP 4	50.6	21.1	13.1	7.2	**15.2**	15.5	34.2	**18.7**	0.45
l.s.d$_{0.05}$					*0.7*			*0.8*	
MOP 0	**47.2**	20.7	**12.5**	**6.8**	**14.0**	**14.2**	**31.4**	**17.2**	0.45
MOP 2	**50.7**	21.1	**13.2**	**7.4**	**15.4**	**15.0**	**33.8**	**18.7**	0.44
MOP 4	**50.9**	21.1	**13.2**	**7.2**	**15.3**	**16.1**	**34.9**	**18.8**	0.46
l.s.d$_{0.05}$	*1.8*	-	*0.5*	*0.3*	*0.7*	*1.1*	*1.3*	*0.8*	-
KIE 0	49.2	20.5	13.1	**6.9**	14.5	15.1	32.9	17.8	0.46
KIE 2	50.0	21.1	13.1	**7.3**	15.1	15.4	33.9	18.5	0.45
KIE 4	49.6	21.3	12.8	**7.2**	15.1	14.8	33.3	18.4	0.44
l.s.d$_{0.05}$	-	-	-	*0.3*	-	-	-	-	-
GM	49.6	20.9	13.0	7.1	14.9	15.1	33.4	18.2	0.45

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 fertilizer treatments only MOP had a major positive effect on FFB yield, tissue nutrient content and physiological parameters in 2007. Increasing MOP from 0 to 2 or 4 kg/palm increased yield by 1 to 3 t/ha. Leaf K levels 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 fertilizer strategy for oil palm grown on the sandy soils of the grasslands.

In the second year of treatments, there was no significant effect of fertilizer 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 fertilizer 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 in the top 30 cm of the soil (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 fertilizer 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	7	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	Dr. Murom Banabas

Table 2. Initial soil analysis results from soil samples taken in 2005

Depth	**pH in water**	**Exch K**	**Exch Ca**	**Exch Mg**	**CEC**	**OM (%)**	**Total N (%)**	**Olsen P (mg/kg)**
cm		**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 the different rates of each fertilizer tested. Fertilizer 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. Fertilizer treatments and levels in Trial 330.

Fertilizer	**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 fertilizer 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

Fertilizer treatments had no significant effect on FFB yield and yield components in 2007 and 2006-2007 combined data (Tables 4 and 5). The CV% for yield and BNO were very high and this indicates high 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 2006-2007 and 2007

Source	2006-2007			2007		
	FFB yield (t/ha)	BNO/ha	SBW (kg)	FFB yield (t/ha)	BNO/ha	SBW (kg)
Urea	0.35	0.58	0.25	0.71	0.86	0.78
El. Sulphur	0.48	0.31	0.61	0.44	0.39	0.13
Urea x El. Sulphur	0.73	0.66	0.50	0.52	0.67	0.45
CV %	*24.3*	*20.5*	*8.4*	*21.3*	*24.1*	*9.8*

Table 5. Main effects of treatments on FFB yield (t/ha) in 2006-2007 and 2007.

Fertilizer (kg/palm)	2006-2007			2007		
	FFB yield (t/ha)	BNO	SBW (kg)	FFB yield (t/ha)	BNO	SBW (kg)
Urea 0.5	16.5	1457	11.0	22.6	1657	13.6
Urea 1.5	15.5	1431	10.7	21.4	1634	13.2
Urea 2.5	16.3	1446	10.9	23.0	1718	13.5
Urea 3.5	13.5	1289	10.2	20.7	1586	13.0
El. Sulphur 0	14.8	1375	15.5	20.7	1628	12.8
El. Sulphur 0.15	14.9	1332	10.9	21.8	1568	13.9
El. Sulphur 0.30	16.6	1510	10.7	23.2	1750	13.4
Grand Mean	15.5	1406	10.7	21.9	1649	13.3

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

The fertilizers had no significant effect on leaf nutrients except for elemental sulphur which significantly reduced rachis N content (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 (Table 7).

Table 6: Effects (p values) of treatments on frond 17 (F17) nutrient concentrations 2007 (Trial 330). p values <0.05 are indicated in bold.

Source	Leaflets								Rachis			
	N	P	K	Mg	Ca	Cl	S	B	N	P	K	Mg
Urea	0.07	0.46	0.23	0.71	0.13	0.79	0.31	0.73	0.23	0.83	0.99	0.28
S	0.18	0.78	0.44	0.94	0.51	0.15	0.12	0.62	**0.01**	0.99	0.76	0.87
Urea x S	0.845	0.30	0.32	0.44	0.76	0.92	0.43	0.90	0.17	0.38	0.79	0.58
CV%	*3.2*	*3.3*	*9.8*	*16.3*	*5.9*	*9.7*	*4.1*	*10.4*	*9.7*	*25.4*	*19*	*19.6*

Table 7: Main effects of treatments on F17 nutrient concentrations in 2007, 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**	**Ca**	**Cl**	**S**	**B**	**Ash**	**N**	**P**	**K**	**Mg**
Urea 0.5	10.8	2.38	0.141	0.66	0.27	0.90	0.57	0.18	11	3.8	0.26	0.083	1.07	0.09
Urea 1.5	10.7	2.42	0.144	0.67	0.27	0.93	0.57	0.19	11	4.0	0.27	0.085	1.10	0.10
Urea 2.5	11.2	2.44	0.142	0.73	0.26	0.87	0.58	0.19	12	3.9	0.27	0.085	1.07	0.09
Urea 3.5	10.0	2.49	0.144	0.69	0.29	0.88	0.55	0.19	11	3.9	0.28	0.077	1.08	0.11
S 0.00	10.5	2.40	0.142	0.67	0.28	0.91	0.59	0.18	11	3.8	**0.29**	0.083	1.06	0.09
S 0.15	10.6	2.45	0.144	0.70	0.27	0.89	0.55	0.19	11	3.9	**0.26**	0.084	1.12	0.10
S 0.30	11.0	2.44	0.143	0.69	0.27	0.89	0.56	0.19	11	3.9	**0.26**	0.082	1.08	0.10
GM	10.7	2.43	0.143	0.69	0.27	0.90	0.57	0.19	11	3.9	0.27	0.083	1.09	0.10

Effects of fertilizer treatments on vegetative parameters

There was no significant effect of fertilizer treatment on vegetative growth parameters except for elemental sulphur on FP (Tables 8 and 9). The mean BI was 0.43 implying high VDM production in relation to BDM production.

Table 8. Effect (p values) of treatments on vegetative growth parameters in 2007. p values less than 0.05 are shown in bold.

Source	Radiation Interception				Dry Matter Production (t/ha/yr)				BI
	PCS	**FP**	**FA**	**LAI**	**FDM**	**BDM**	**TDM**	**VDM**	
Urea	0.48	0.06	0.82	0.82	0.58	0.64	0.58	0.56	0.74
S	0.87	**0.05**	0.65	0.59	0.72	0.57	0.64	0.72	0.49
Urea xEl.S	0.99	0.39	0.83	0.57	0.91	0.49	0.64	0.88	0.47
CV %	*10.5*	*3.7*	*9.0*	*10.4*	*10.3*	*21.3*	*14.3*	*10.6*	*8.5*

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)				BI
	PCS	**FP**	**FA**	**LAI**	**FDM**	**BDM**	**TDM**	**VDM**	
Urea 0.5	26.6	24.5	9.1	5.1	9.7	9.5	21.3	11.8	0.44
Urea 1.5	26.3	25.1	9.2	5.1	9.8	9.2	21.1	11.9	0.43
Urea 2.5	27.2	25.4	9.3	5.3	10.2	10.0	22.5	12.5	0.44
Urea 3.5	25.1	25.8	8.9	5.1	9.7	8.9	20.6	11.7	0.42
S 0.0	26.5	**24.6**	9.0	5.0	9.7	8.9	20.7	11.8	0.43
S 0.15	26.5	**25.6**	9.3	5.3	10.0	9.4	21.6	12.2	0.43
S 0.30	26.0	**25.5**	9.0	5.1	9.8	9.8	21.8	12.0	0.44
$l.s.d_{0.05}$		0.8							
GM	26.3	25.2	9.1	5.1	9.8	9.4	21.4	12.0	0.43

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

Fertilizer treatments had no significant effect on yield and its components. Similarly, tissue nutrients and physiological parameters were not affected by the treatments.

Trial 333: Slow Release Options for Mg and K on Acidic Soils, Mamba

SUMMARY

Trial 333 was established on the Mamba estate in Oro Province to determine if slow-release options for supplying Mg and K to palms are more effective than the current use of soluble fertilizers, on the acidic, low CEC soils of the Ilimo-Mamba area. The trial commenced in April 2004.

Since the trial commenced in 2004, there has been no significant effect of fertilizer treatments on fresh fruit bunch (FFB) yield and physiological growth parameters (petiole cross section, leaf area index, annual frond production, bunch dry matter production, bunch index and others).

Tissue Mg and K concentrations were affected by fertilizer treatments in 2007. Leaflet Mg concentrations were above the critical value of 0.20% regardless of treatments, while leaflet K concentrations were below the critical value of 0.75%. However, rachis K which is a good indicator of K nutrition in oil palm was above the critical value for all treatments except the control plot.

The trial was closed at the end of 2007 because the palms were very tall and difficult to work with to collect data.

INTRODUCTION

Soils of the Ilimo-Mamba area of Oro Province are acidic and have very low CEC. Magnesium and Potassium deficiency symptoms are common and severe. Calcium content of the soils is also low. Trials 317 and 318 showed responses to MOP and kieserite at Mamba, but the data were not of sufficient quality to be conclusive. Kieserite and MOP are applied commonly by the plantations on the basis of tissue levels. However, recommendations to smallholders currently include MOP but not kieserite due to the lesser degree of confidence in its necessity. MOP is only recommended for smallholders who are applying their N fertilizer as recommended. A factorial trial with SOA, TSP, MOP and kieserite (Trial 329) has recently commenced at Mamba. We expect that the effectiveness of soluble cation fertilizers will be limited because of the high potential for leaching losses due to high rainfall and low CEC. Therefore, this experiment was designed to test less soluble sources. Less soluble fertilizers such as $MgCO_3$, MgO and boiler ash have the added advantage of being likely to increase soil pH, which will increase CEC of these variable charged soils. Other means of increasing CEC were considered but costs and logistics tend to be prohibitive. Compost is an option, but at the moment the quantity being produced is only adequate for the nursery. EFB is included as a source of K, because of its high K content, and it has the added advantage of increasing soil organic matter content.

The objective of this trial is to determine if slow-release options for supplying Mg and K to palms are more effective than the current use of soluble fertilizers, on the acidic, low CEC soils of the Ilimo-Mamba area of Oro province. Back ground information of the trial is presented in Table 1.

Table 1. Trial 333 background

Trial number	**333**	Company	Higaturu Oil Palms
Estate	Mamba	Block No.	Ebeii – Block 6193E
Planting Density	143 palms/ha	Soil Type	Mamba Soils
Pattern	Triangular	Drainage	Poor
Date planted	1993	Topography	Flat
Age after planting	14	Altitude	350 m asl
Recording Started	2004	Previous Land-use	Ex forest/Logging
Planting material	Dami D x P	Area under trial soil type (ha)	Not known
Progeny	Not known	Agronomist in charge	Murom Banabas

METHODS

Experimental Design and Treatments

Treatments

The treatments consist of different sources of Mg and K and controls with zero or adequate Mg and K. The treatments fall into 3 groups. In Group 1, all Mg sources were tested in the presence of adequate K (4 treatments). In Group 2, all K sources were tested in the presence of adequate Mg (3 treatments). In Group 3, adequate Mg and K were tested alone and together (similar to the trial 146, WNB), a boiler ash treatment, (supplies Mg and K in approximately the correct ratio) and a control with zero Mg and K. Fertilizer rates for the various treatments are given in Table 2.

Group 1, Mg sources

The four Mg sources were added individually at an equivalent rate of Mg, and all were applied in 2 doses per year, cast over the frond pile as per standard procedure: 1) $MgSO_4$ as Kieserite, 2) $MgCO_3$ as Magnesite (QMAG FO1), 3) dolomite and 4) MgO (QMAG M45). Dolomite was included because of its generally low cost, the fact that Ca is also low in these soils (although not below critical levels in leaf tissues), and its effectiveness as a liming agent.

Group 2, K sources

The following 3 sources of K were added individually. 1) MOP (2x per year, applied on the frond pile as standard). 2) MOP in trenches covered with plastic (see Trial 146 description). Applied once at a rate equivalent to 3x the surface MOP rate. Other methods of applying nutrients in ‘hot spots’ such as in inversed coconut shells and plastic-covered trenches are being compared in Trial 146 in WNB. 3) EFB at an equivalent rate of K to the surface MOP treatment (applied in 1 dose per year). We are not aware of any other readily available sources of K in slow-release form. Boiler ash may be an alternative, but as it contains a significant amount of Mg it was included in group 3.

Group 3, Factorial of adequate Mg and K, with an extra boiler ash treatment

The adequate Mg treatment comprised of kieserite + magnesite + MgO, with each component making up 1/3 of the Mg dose, applied together in 2 doses per year. The adequate K treatment will be MOP applied to the surface 2x annually + MOP in trenches covered with plastic applied once at a rate equivalent to 3x the surface MOP rate.

The other treatment includes all K and Mg (MOP surface + MOP trenches + Kie + Magnesite + MgO) treatments in Group 3 applied together. Boiler ash was applied as a separate treatment as it provides both K and Mg in rates similar to those chosen above.

It was decided not to include EFB in this group because of other nutrients contained in it.

A single control (0 K, 0 Mg, but including standard Basal Fertilizer -see below) plot for each replicate acted as the control for each group.

Basal fertilizer

Nitrogen (Urea) was applied across the trial at 2 kg/palm; TSP at 0.5 kg/palm; and borate at 0.2 kg/palm from 2006 onwards. Previously nitrogen was applied at the same rate as for the surrounding blocks.

Statistical design

The 12 treatments were replicated 4 times, giving a total of 48 plots. The field layout is a Randomised Complete Block Design (RCBD). The trial can be analysed as 3 separate experiments by treating the treatment groups as separate experiments.

(i) 4 Mg sources in presence of K (one way ANOVA)

(ii) 3 K sources in the presence of Mg (one way ANOVA)

(iii) Factorial of +/- adequate Mg and K. The boiler ash treatment can be compared with the adequate K+Mg treatment using a simple T test.

Or the whole trial can be analysed as a single experiment comparing 12 different treatments, which allows ‘controls’ from group 3 to be compared with the various sources.

We had considered various factorial designs with Mg source by K source but discarded the idea because we are not really interested in individual interactions between source types – we are more interested in finding appropriate ways to deliver Mg or K more effectively.

Table 2. Fertilizer types and rates

Tt No	Fertilizer	Nutrient	Nutrient appl. rate (kg/palm)	Nutrient cont. of fert. (%)	Fert. appl. rate (kg/palm)	Number of appl.	Amount per applic. (kg/palm)
	Group 1 (Mg sources)						
1	Kieserite	Mg	0.425	17	2.5	2/yr	1.25
2	Magnesite (FO1)	Mg	0.425	26	1.6	2/yr	0.8
3	Dolomite[1]	Mg	0.425	10	4.3	2/yr	2.15
4	MgO (EMAG 45)	Mg	0.425	56	0.8	2/yr	0.4
	Basal (all plots)						
	MOP	K	1.25	50	2.5	2/yr	1.25
	MOP trenches & plastic	K	3.75	50	7.5	1	7.5
	Group 2 (K sources)						
5	MOP surface	K	1.25	50	2.5	2/yr	1.25
6	MOP trenches & plastic	K	3.75	50	7.5	1	7.5
7	EFB[2]	K	2.50	0.83	300	1/yr	300
	Basal (all plots)						
	Kieserite	Mg	0.14	17	0.8	2/yr	0.4
	Magnesite	Mg	0.14	26	0.5	2/yr	0.25
	MgO	Mg	0.14	56	0.3	2/yr	0.15
	Group 3 (Mg and K factorial)						
8	MOP	K	1.25	50	2.5	2/yr	1.25
	MOP trenches & plastic	K	3.75	50	7.5	1	7.5
9	Kieserite	Mg	0.14	17	0.8	2/yr	0.4
	Magnesite	Mg	0.14	26	0.5	2	0.25
	MgO	Mg	0.14	56	0.3	2	0.15
10	Tr 8 + tr 9						
11	Boiler Ash[3]	Mg & K	0.425 & 1.39	1.5 & 4.9	28.3	2	14.15
12	Control			No K & no Mg			

1. Mg:Ca ratio of 50:50
2. EFB is 2.5 % K as DM, assuming 67% water content, is 0.83% K (fresh weight); 300 kg per palm gives 2.5 kg per palm equivalent to 4.2 kg MOP.
3. In order to obtain a rate of Mg application equivalent to the kieserite, need 28.3 kg/palm @ 1.5% Mg. This results in 1.9 kg kg/palm instead of the usual 1.25.

Data Collection

Recordings and measurements were taken on the central 16 palms 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 expressed on a per hectare basis. Single bunch weight

(SBW) was calculated from these data. During 2007 this trial was harvested on a 10 day interval in line with company practice. Frond sampling was carried out once annually according to standard procedures and analysed for nutrient concentrations using standard analytical procedures.

Statistical Analysis

Analysis of variance of the main effects of fertilizer 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

The 12 treatments had no significant effects on the FFB, number of bunches nor the single bunch weight in 2007 and for the combined 2005-2007 period (Table 3 and 4).

There was no significant effect on yield from either Mg or K sources. Since the results of the One-Way ANOVA (p values and main effects) showed no significant effects of treatments, the significance levels are not presented.

Table 3. Effects (p values) of treatments on FFB yield and its components in 2005 – 2007 and 2007.

Source	**2005 – 2007**			**2007**		
	Yield	**BNO**	**SBW**	**Yield**	**BNO**	**SBW**
Treatment	0.78	0.86	0.75	0.18	0.44	0.85
CV %	*9.4*	*11.2*	*6.5*	*16.7*	*18.1*	*7.1*

Table 4. Main effects of treatments on FFB yield (t/ha) from 2005 to 2007 and 2007.

Trt no.	**Treatments**	**2005 - 2007**			**2007**		
		FFB yield (t/ha)	**BNO /ha**	**SBW (kg)**	**FFB yield (t/ha)**	**BNO /ha**	**SBW (kg)**
	Group 1						
1	Kieserite	24.3	893	27.2	23.9	895	26.7
2	Magnesite, FO1	23.2	856	27.1	23.0	851	27.0
3	Dolomite	23.7	897	26.4	23.4	898	26.0
4	MgO, EMAG45	22.4	835	26.9	26.7	1021	26.2
	Group 2						
5	MOP surface	22.5	868	25.9	21.2	840	25.5
6	MOP Trench/Plastic	23.0	833	27.6	25.0	950	27.4
7	EFB	22.6	838	27.0	22.9	863	26.6
	Group 3						
8	MOP S+T	21.9	894	24.9	19.1	778	24.9
9	Kie+Magnesite+MgO	23.6	900	26.4	22.2	872	25.8
10	Treatment 8 + 9	21.0	778	27.0	18.9	705	26.9
11	Boiler ash	22.6	846	26.9	22.7	871	26.0
12	Control	23.1	855	27.1	21.7	820	26.6
	Grand mean	22.8	858	26.7	22.6	864	26.3

Effects of fertilizer treatments on frond (F17) nutrient concentrations

Fertilizer treatments had a significant effect on leaflet and rachis K concentrations in 2007 (Table 5).

Regardless of the treatment effects, leaflet Mg level was above the critical value of 0.20% DM. Leaflet K values were below the critical level of 0.75% except for treatment 4 (MgO + adequate K) and treatment 10 (all sources Mg + all sources K treatments) (Table 6). In terms of differences between K source fertilizers, only treatment 7 (EFB) had a significant effect on rachis K at $l.s.d._{0.005}$.

Table 5: Effects (p values) of treatments on frond 17 (F17) nutrient concentrations 2007 (Trial 333). p values <0.05 are indicated in bold.

Source	**Leaflets**								**Rachis**				
	Ash	**N**	**P**	**K**	**Mg**	**Ca**	**Cl**	**B**	**Ash**	**N**	**P**	**K**	**Mg**
Trt	0.54	0.35	0.90	**0.017**	0.11	0.19	0.35	0.51	**<0.001**	0.60	0.17	**<0.001**	0.11
CV%	*9.3*	*4.4*	*5.3*	*10*	*16.7*	*8.3*	*7.7*	*10.2*	*10.2*	*7.6*	*18.0*	*15.1*	*22.6*

Table 6: Main effects of treatments on F17 nutrient concentrations in 2007, in units of % dry matter, except for B (mg/kg) (Trial 333). Effects with p<0.05 are shown in bold.

Trt no.	**Source**	**Leaflet nutrient concentrations**							**Rachis nutrient concentrations**		
		N	**P**	**K**	**Mg**	**Ca**	**Cl**	**B**	**N**	**P**	**K**
	Group 1										
1	Kieserite	2.46	0.142	**0.76**	0.21	0.82	0.50	12	0.23	0.039	**1.50**
2	Magnesite, FO1	2.52	0.142	**0.74**	0.22	0.84	0.51	11	0.24	0.045	**1.37**
3	Dolomite	2.46	0.144	**0.72**	0.20	0.85	0.53	11	0.23	0.046	**1.48**
4	MgO, EMAG	2.49	0.142	**0.67**	0.23	0.84	0.50	12	0.24	0.046	**1.42**
	Group 2										
5	MOP surface	2.48	0.144	**0.78**	0.17	0.86	0.54	11	0.22	0.049	**1.39**
6	MOP Trench/Plastic	2.43	0.142	**0.64**	0.23	0.82	0.48	12	0.24	0.046	**1.39**
7	EFB	2.58	0.149	**0.73**	0.23	0.77	0.48	12	0.24	0.057	**1.47**
	Group 3										
8	MOP S+T	2.35	0.138	**0.62**	0.22	0.89	0.50	13	0.23	0.039	**0.77**
9	Kie+Magn.+MgO	2.45	0.141	**0.77**	0.20	0.83	0.52	12	0.23	0.039	**1.40**
10	Treatment 8 + 9	2.41	0.142	**0.64**	0.23	0.92	0.49	13	0.23	0.048	**1.06**
11	Boiler ash	2.49	0.143	**0.66**	0.17	0.91	0.52	12	0.23	0.045	**0.92**
12	Control	2.52	0.144	**0.74**	0.24	0.82	0.49	11	0.25	0.047	**1.55**
	$l.s.d._{0.005}$	-	-	*0.10*	-	-	-	-	-	-	*0.28*
	Grand mean	2.47	0.143	0.71	0.21	0.85	0.50	12	0.23	0.046	1.31

Effects of fertilizer treatments on Vegetative parameters

Fertilizer treatments had no significant effect on any of the physiological growth parameters in 2007 (Tables 7 and 8). Note that mean bunch index was <0.50.

Table 7. Effect (p values) of treatments on vegetative growth parameters in 2007. p values less than 0.05 are shown in bold.

Source	**Radiation interception**				**Dry matter production**				
	PCS	**FP**	**FA**	**LAI**	**FDM**	**BDM**	**TDM**	**VDM**	**BI**
Treatment	0.79	0.72	0.69	0.65	0.95	0.60	0.91	0.97	0.26
CV %	*5.6*	*5.6*	*6.4*	*10.7*	*8.4*	*16.7*	*10.6*	*8.4*	*8.3*

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 8. Main effects of treatments on vegetative growth parameters in 2007. Significant effects (p<0.05) are shown in bold.

Treatments	**Radiation interception**				**Dry matter production (t/ha/yr)**				
	PCS	**FP**	**FA**	**LAI**	**FDM**	**BDM**	**TDM**	**VDM**	**BI**
Control	49.8	19.8	13.7	6.8	14.9	12.7	30.7	18.0	0.41
Group 1									
Dolomite	51.7	19.5	14.3	7.2	15.3	12.2	30.5	18.3	0.40
Magnesite, FO1	51.6	19.7	13.6	6.5	15.4	13.8	32.4	18.7	0.42
Kieserite	51.8	19.8	13.4	6.3	15.5	14.5	33.4	18.9	0.43
MgO, EMAG	48.8	19.7	13.1	6.3	14.6	13.2	30.9	17.7	0.42
Group 2									
MOP Trench/Plastic	49.1	20.8	13.4	6.7	15.5	14.7	33.6	18.9	0.44
EFB	52.5	19.6	13.8	6.8	15.5	13.2	32.0	18.8	0.41
MOP surface	50.8	20.9	13.3	6.8	16.1	11.1	30.2	19.1	0.36
Group 3									
MOP S+T	50.8	20.0	14.2	7.0	15.4	14.4	33.1	18.7	0.43
Kie+Magnesite+MgO	50.7	20.2	13.7	6.6	15.6	13.2	32.0	18.8	0.41
Treatment 8 + 9	50.1	20.0	13.7	6.7	15.2	12.9	31.3	18.4	0.40
Boiler ash	49.8	19.5	13.1	6.1	14.8	13.4	31.3	17.9	0.43
Grand mean	50.6	20.0	13.6	6.7	15.3	13.3	31.8	18.5	0.41

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

Fertilizer treatments had no significant effect on yield and physiological growth parameters in 2007. These results were similar to the previous years' results and since the trial commenced in 2004.

The leaflet and rachis K concentrations were affected by fertilizer treatments in 2007 but this did not translate to yield or physiological growth factors.

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 a 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 fertilizer in previous trials in Higaturu. However P tissue levels have not always been optimised and 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 the rachis to the leaflet; such that at low N supply, increasing P supply only results in an increase in 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	Agronomist in charge	Dr. Murom Banabas

METHODS

The nitrogen treatments as Urea are applied three times per year while TSP is applied twice a year. Fertilizer applications started in 2007. Every palm within the trial field receives basal applications of 1 kg Kieserite and 2 kg MOP per palm.

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 on a per hectare basis. 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 fertilizer and their interactions were carried out for each of the variables of interest using the GenStat statistical program.

Table 3. Fertilizer 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

In the first year of experimentation there was no significant yield response in 2007 (Tables 4 and 5).

Table 4. Effects (p values) of treatments on FFB yield and its components in 2007.

Source	2007		
	FFB yield	BNO	SBW
Urea	0.54	0.49	0.45
TSP	0.18	0.47	0.58
Urea.x TSP	0.38	0.60	0.91
CV %	*8.5*	*9.4*	*5.1*

Table 5. Main effects of treatments on FFB yield (t/ha) in 2007.

	2007		
Treatments (kg/palm)	FFB yield (t/ha)	BNO/ha	SBW (kg)
Urea 1	32.7	1720	19.0
Urea 2	31.8	1650	19.3
Urea 5	32.8	1688	19.5
TSP 0	33.5	1702	19.7
TSP 2	33.4	1736	19.3
TSP 4	30.6	1608	19.1
TSP 6	32.6	1717	19.0
TSP 10	31.9	1667	19.2
Grand Mean	32.4	1686	19.2

Effects of interaction between treatments on FFB yield

There was no significant interaction effect of Urea.TSP. It was not expected to see significant differences between treatments in the first year of experimentation (Table 6).

Table 6. Effect of SOA and EFB (two-way interactions) on FFB yield (t/ha/yr) in 2007. The interaction was not significant (p=0.38).

Kg/palm	TSP 0	TSP 2	TSP 4	TSP 6	TSP 10
Urea 1	35.1	33.6	28.9	33.3	32.4
Urea 2	31.2	33.3	29.2	33.1	32.0
Urea 5	34.2	33.3	33.7	31.4	31.3

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

Leaf tissue samples were taken from the trial before fertilizer treatments were given and therefore cannot be commented for responses. Mean nutrient contents of all the plots were above their respective critical levels.

Table 7: Effects (p values) of treatments on frond 17 (F17) nutrient concentrations 2007 (Trial 334). p values <0.05 are indicated in bold.

Source	**Leaflet**								**Rachis**				
	Ash	**N**	**P**	**K**	**Mg**	**Ca**	**Cl**	**B**	**Ash**	**N**	**P**	**K**	**Mg**
Urea	0.71	0.15	0.43	0.76	0.82	0.03	**0.10**	0.26	0.25	0.65	0.41	0.63	0.65
TSP	0.42	0.27	0.60	0.43	**0.001**	0.09	0.47	0.20	0.52	0.78	0.39	0.57	0.35
Urea.TSP	0.44	0.35	0.90	0.08	0.34	0.32	0.63	0.60	0.14	0.68	**0.02**	0.22	0.47
CV%	*4.3*	*2.0*	*2.4*	*4.1*	*7.1*	*4.8*	*18.3*	*9.5*	*8.7*	*8.8*	*12.5*	*9.8*	*25.7*

Table 8: Main effects of treatments on F17 nutrient concentrations in 2007, in units of % dry matter, except for B (mg/kg) (Trial 334). Effects with p<0.05are shown in bold.

Treatments	**Leaflet nutrient contents**								**Rachis nutrient contents**				
	Ash	**N**	**P**	**K**	**Mg**	**Ca**	**Cl**	**B**	**Ash**	**N**	**P**	**K**	**Mg**
Urea 0	13.5	2.54	0.147	0.81	0.17	0.77	0.43	12	5.2	0.27	0.113	1.57	0.08
Urea 2	13.7	2.57	0.148	0.81	0.17	0.75	0.50	12	5.5	0.28	0.116	1.63	0.08
Urea 5	13.5	2.57	0.149	0.82	0.17	0.73	0.45	12	5.4	0.28	0.110	1.59	0.08
TSP 0	13.8	2.57	0.149	0.80	0.16	0.76	0.43	0.43	5.5	0.27	0.120	1.66	0.07
TSP 2	13.8	2.58	0.146	0.83	0.18	0.72	0.44	0.44	5.2	0.28	0.106	1.55	0.07
TSP 4	13.4	2.54	0.147	0.81	0.17	0.75	0.47	0.47	5.3	0.27	0.112	1.58	0.08
TSP 6	13.4	2.54	0.148	0.80	0.18	0.76	0.48	0.48	5.3	0.27	0.111	1.56	0.09
TSP 10	13.4	2.55	0.148	0.82	0.17	0.75	0.50	0.50	5.4	0.28	0.114	1.63	0.09
Mean	13.6	2.56	0.148	0.81	0.17	0.75	0.46	0.46	5.3	0.28	0.112	1.60	0.08

CONCLUSION

The trial commenced in 2007 and there it is still early to report any true responses to fertilizer treatments.

Trial 335. N x P trial (Immature Phase) on Outwash Plains Soils, Ambogo

SUMMARY

This is a new trial, established in 2007, testing 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 trial was planted to known progeny to determine the Progeny by Nutrition interaction.

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 fertilizer in previous trials in Higaturu. The critical leaf level for P 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 an increase in 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	Agronomist in charge	Dr. Murom Banabas

METHODS

This is a new trial established in 2007, the trial is planted to known progeny. The trial was set up as a 3 N x 5 P factorial arrangement, resulting in 15 treatments. The design of the trial is a 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 fertilizer treatment applications are as scheduled (Tables 2 and 3).

Soils sampling, initial leaf tissues and vegetative measurements will be done in 2008. Yield recording will commence as soon as fruits are ready to be harvested. Recordings and measurements will be 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 on a per hectare basis. Single bunch weight (SBW) will be calculated from these data. Leaf sampling will be carried out according to standard procedures and analysed for nutrient concentrations using standard analytical procedures.

Analysis of variance of the main effects of fertilizer and their interactions will be carried out for each of the variables of interest using the GenStat statistical program.

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

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

Table 3: N Fertilizer schedule (g Urea/palm)

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

RESULTS and DISCUSSION

No results, palms planted and trial commenced towards end of 2007.

The palms were planted in 2007, palm census carried out and fertilizer dose 1 applied.

WORK PLAN FOR 2008

Continue fertilizer application as per schedule

Commence physiological measurements,

Commence leaf tissue sampling

Soil sampling and description,

Monitor flowering and commence yield recording

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. At field planting, there were six densities treatments (128, 135, 143, 192, 203 and 215 palms/ha) and 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 2007, after thinning, the original lower density plantings (128, 135 and 143 palms/ha had a significantly higher yield (average of 38.1 t/ha) compared to the original higher density plantings of 192, 203 and 215 palms/ha (average 33.1 t/ha), which have since 2006 been thinned. In the latter the spacings between palms is much less whilst the avenues are wider.

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	6	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	Agronomist in charge	Dr. Murom Banabas

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 rows 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 is now numbered.

Frond sampling was carried out once annually according to standard procedures and analysed for nutrient concentrations using standard analytical procedures. Every 5^{th} 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 2007 (Table 3). 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.

Table 3. Effects (p values) of treatments on FFB yield and its components in 2007.

	2007		
Source	**Yield**	**BNO**	**SBW**
Density treatment	**<0.001**	**<0.001**	**0.004**
CV %	*2.8*	*2.8*	*1.6*

Table 4. Main effects of treatments on FFB yield (t/ha) in 2007 (treatments which are significantly different at P<0.05 are presented in bold).

	2007		
Density Treatment	**FFB yield (t/ha)**	**BNO/ha**	**SBW (kg)**
128	**39.4**	**2791**	**14.1**
135	**37.6**	**2839**	**13.3**
143	**38.4**	**2827**	**13.6**
128 (192)	**34.4**	**2435**	**14.1**
135 (203)	**32.6**	**2382**	**13.7**
143 (215)	**32.4**	**2365**	**13.7**
$lsd_{0.05}$	*1.8*	*134*	*0.4*
Grand Mean	35.8	2606	13.8

(..) 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 2007 (Trial 331). p values <0.05 are indicated in bold.

Source	**Leaflet**								**Rachis**				
	Ash	**N**	**P**	**K**	**Mg**	**Ca**	**Cl**	**B**	**Ash**	**N**	**P**	**K**	**Mg**
Density	0.87	0.34	0.90	0.36	0.77	0.18	0.42	0.84	0.97	0.60	0.98	0.93	0.96
CV%	*7.4*	*1.9*	*4.5*	*4.3*	*6.4*	*5.5*	*7.6*	*22.2*	*7.5*	*6.4*	*12*	*5.8*	*14.0*

Table 6: Main effects of treatments on F17 nutrient concentrations in 2007, 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**	**Ca**	**Cl**	**B**	**Ash**	**N**	**P**	**K**	**Mg**
128	11.7	2.63	0.152	0.73	0.21	0.86	0.53	18	5.8	0.31	0.169	2.02	0.08
135	11.6	2.63	0.153	0.76	0.22	0.86	0.50	18	5.8	0.30	0.170	1.98	0.08
143	12.2	2.65	0.158	0.75	0.22	0.92	0.51	22	5.7	0.31	0.162	1.95	0.08
128 (192)	11.7	2.57	0.153	0.78	0.22	0.80	0.51	20	5.6	0.30	0.168	1.98	0.08
135 (203)	11.2	2.60	0.157	0.77	0.23	0.85	0.52	20	5.6	0.32	0.175	1.92	0.08
143 (215)	11.6	2.64	0.156	0.78	0.23	0.85	0.56	21	5.8	0.29	0.171	1.96	0.08
GM	11.7	2.62	0.155	0.76	0.22	0.86	0.52	20	5.7	0.30	0.169	1.97	0.08

(..) previous density

CONCLUSIONS

The density treatment had a significant effect on yield in 2007 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 2007 – Oro Oil Palm Project

(Pauline Hore, Merolyn Koia and Dr. Murom Banabas)

There were the four main areas of work for the smallholder sector in the Oro Oil Palm Project.

1. Smallholder Leaf Sampling
2. Field Inspections (Visits)
3. Field Days
4. Radio Program for Oil Palm Growers in Oro Province.

Small holder Leaf Sampling

Leaf sampling was carried out in selected blocks representative of the four Divisions of the Oil Palm Project; Sorovi Division, Igora Division, Saiho Division and Ilimo Division. 30 blocks were sampled and send to AAR Laboratory in Malaysia for nutrient analysis**.** The results for each division are presented in Table 1.

The mean nutrient contents of all the major nutrients were well below the critical levels (Table 1.0). Nitrogen, the most important nutrient is required in all blocks in the 4 divisions as suggested by the low N contents in the sampled blocks. The P, K and Cl 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.

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.

Table 1. Mean nutrient contents of 30 smallholder blocks in 2007

Division	**Leaf nutrient contents (% DM except B ppm)**						**Rachis nutrient contents (%DM)**		
	N	**P**	**K**	**Mg**	**Cl**	**B**	**N**	**P**	**K**
Aeka/Saiho	2.42	0.146	0.84	0.18	0.20	12	0.28	0.065	0.56
Igora	2.29	0.144	0.75	0.20	0.32	10	0.23	0.071	0.62
Illimo	2.23	0.142	0.67	0.21	0.29	10	0.21	0.047	0.65
Sorovi	1.98	0.130	0.75	0.21	0.26	12	0.23	0.127	1.02
Mean	2.16	0.138	0.75	0.20	0.28	11	0.23	0.092	0.80
Min	1.65	0.118	0.43	0.13	0.07	7.7	0.19	0.032	0.12
Max	2.57	0.156	0.94	0.31	0.63	14.7	0.30	0.279	1.50
Critical values	2.45	0.145	0.65	0.20	0.45	15	0.32	0.08	1.30

2. Field Visits

Field inspections were done based on reports received from OPIC Extension Officers and appropriate actions were recommended. A total of eight field visits were conducted in 2007. Seven of the eight visits were pest (stick insect) and disease (ganoderma) related problems in which the Entomology section of PNG OPRA took on the task and recommended control strategies. The eighth visit was to the Saiho division in which Pauline Hore accompanied Jerry Buhe (HOPPL) who spoke to the Extension Officers about the Growers Technical Services.

3. Field Days

There were three field days, which PNG OPRA participated in 2007. The first one was at the Sorovi Division (26/04/07) at Block No. 850115. The second one was at Saiho/Aeka Division (10/10/07) at Togoho Block No. 4200022. The third one was at Igora Division (25/10/07) at Jajau Village.

The main topics presented to growers

- The importance of fertilizer, the main type of fertilizer (SOA), main role of SOA in oil palm production, the rates of fertilizer application in immature and mature palms.
- Block sanitation- to slow down the pest population (especially sexava and stick insects in all the small holder blocks).
- 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.

4. Radio Programs

In 2007, no radio broad casts were conducted.

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

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 B and K fertilizer applications at Poliamba. Specifically, the 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 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	18 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

Boron fertilizer should have been applied as two different sources (Ca borate, Na borate) at three rates (0, 0.08 and 0.16 kg borate/palm/yr) together with Muriate Of Potash (MOP) which was applied at two rates (2.5, 7.5 kg MOP/palm/yr). In 2007, CaB was not available and no Borate fertilizer was applied.

The design has 2 B sources x 3 B rates x 2 MOP rates, with 4 replicates = 48 plots. The trial layout is a randomized block design, with pre-treatment measurements or other measurements used as covariates if necessary. 12 treatments x 4 replicates was analysed using ANOVA. Two of the treatments with no Borate applied were replicated twice in each block (NaB 0, CaB 0, MOP 2.5 and NaB 0, CaB 0, MOP 7.5) this enables the analysis of the control treatments to be more accurate than the other 8 treatments.

Na borate (borax = $Na_2B_4O_2 \cdot 10\ H_2O$) is 11%B

Ca borate (Colemanite = $Ca_2B_6O_{11} \cdot 5\ H_2O$) is 10%B

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 a significant difference in yield between the Borate and MOP treatments in 2007 (P=0.01), however it is not possible to attribute a biological difference to the treatment results. The control treatment without Borate yielded equal to plus Borate treatments, and there was no difference in yield between the low rate of applied MOP of 2.5kg/palm and the higher rate of MOP at 7.5 kg/palm. It is likely that the difference seen in 2007 was due to chance. For Bunch number and SBW see tables 3 and 4.

Table 2. Trial 254: Impact on FFB yield in 2007 from Borate fertilizer (2 types, 2 rates) and MOP (2 rates)

Borate source	Rate (B kg/p)	FFB Yield t/ha	
		MOP 2.5 kg/p	**MOP 7.5 kg/p**
No Borate (control)	0	33.0	31.0
CaB	0.08	34.1	29.2
CaB	0.16	29.4	29.4
NaB	0.073	33.9	32.2
NaB	0.146	34.4	30.1
	Significant Difference:	**P=0.01**	
	LSD	**3.7**	
	CV%	**8.1**	

Table 3. Trial 254: Impact on Number of Bunches (per ha) in 2007 from Borate fertilizer (2 types, 2 rates) and MOP (2 rates)

Borate source	Rate (B kg/p)	No. of Bunches/ha	
		MOP 2.5 kg/p	**MOP 7.5 kg/p**
No Borate (control)	0	1491	1423
CaB	0.08	1508	1325
CaB	0.16	1265	1322
NaB	0.073	1666	1537
NaB	0.146	1467	1393
	Significant Difference:	**P=0.04**	
	LSD	**230**	
	CV%	**11.0**	

Table 4. Trial 254: Impact on Single Bunch Weight (kg/bunch) in 2007 from Borate fertilizer (2 types, 2 rates) and MOP (2 rates)

Borate source	Rate (B kg/p)	Single Bunch Wt. kg/bunch	
		MOP 2.5 kg/p	**MOP 7.5 kg/p**
No Borate (control)	0	22.1	21.9
CaB	0.08	23.1	22.1
CaB	0.16	23.3	22.3
NaB	0.073	20.4	21.1
NaB	0.146	23.6	21.8
	Significant Difference:	**P=0.22 (NS)**	
	LSD	**-**	
	CV%	**1.8**	

Yield over time
Over the course of the trial (established in late 2002) 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.

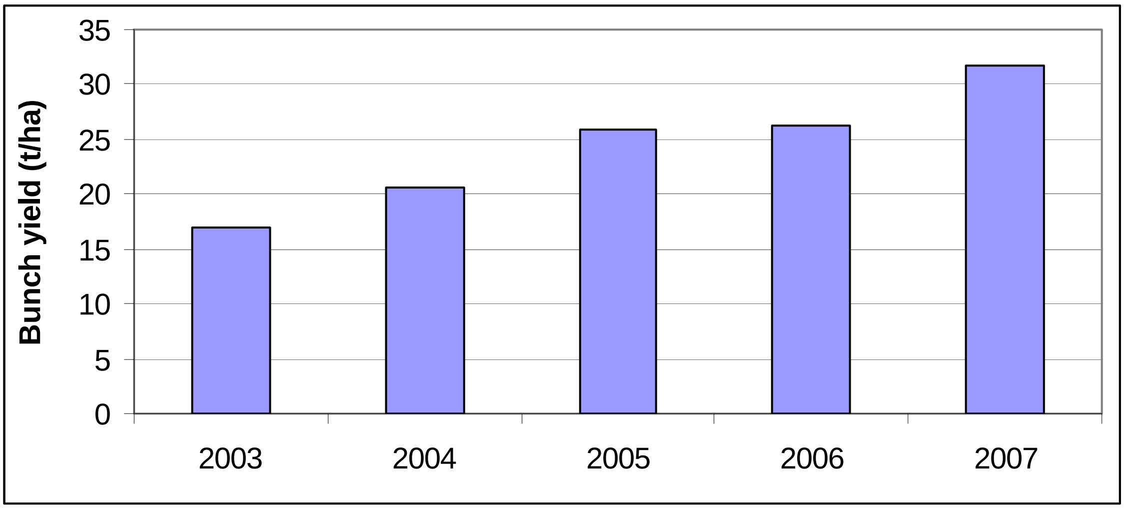


Figure 1. Trial yield since establishment in 2002.

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)

INTRODUCTION

RAI (Ramu Agricultural Industries) started planting oil palm in 2003, production has started and the mill opened in 2008. RAI have plans to expand the current plantings of 5000ha over the next few years. Three factorial fertilizer trials were established for 2003 and 2004 plantings, to assist with determining optimum fertilizer rates for oil palm in this generally dry environment with heavy soils. Harvest commenced in June 2007 and the results of one trial are discussed (harvest period June to December 2007). See Table 1 for background information on the trial.

Table 1. Trial 601 background (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	4	Altitude	? 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 NG203 (Gusap) (previously recorded as Ramu trial RM1-03). A NxKxPxS factorial design with 2 replicates was used (for details of treatments see Table 1) (3 rates of N; 3 rates of K, 2 rates of S and 2 rates of P). Sixteen identified progenies were used in each plot. All the treatments were randomised, including the progenies within plots and the fertilizer treatment plots within each replicate. Due to insolubility of elemental sulphur in 2004-05, Tiger 90 was used as source of sulphur. The half commercial rates of fertilizers that were applied to all the plots as a basal starting July 2005 was discontinued and all the plots are now receiving only the designated treatments as detailed in the trial plan.

Table 1: Details of nutrients and rates used in trial 601 (grams per palm).

	Level	Planting hole	Year 1 2004	Year 2 2005	Year 3 2006	Year 4 2007
Nitrogen	N0	0	0	0	0	0
	N1	0	140	298	595	595
	N2	0	280	595	1190	1190
Sulphur	S0	0	0	0	0	0
	S1	0	150	300	450	450
Potassium	K0	0	0	0	0	0
	K1	0	400	800	1200	1200
	K2	0	800	1600	2400	2400
Phosphorus	P0	40	0	0	0	0
	P1	80	150	300	400	400

RESULTS and DISCUSSION

Harvest commenced in June 2007. The 2007 harvest data (June to December) was analysed using ANOVA.

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 the harvest period June to December, 2008 was 5.5 t/ha, produced by 960 bunches/ha (8 bunches/palm) with a SBW of 5.5 kg. For details of treatment yield see Table 3.

Table 3. FFB yield in trial 601 (June to December, 2007)

Treatment (nutrient/rate level)	**Yield (t/ha)**
N 0	5.5
N 1	5.6
N 2	5.4
K 0	5.2
K 1	5.5
K 2	5.8
P 0	5.7
P 1	5.3
S 0	5.4
S 1	5.6

These are only preliminary results and we don’t expect to see differences between treatments until we have at least one years full data (i.e. 2008).

2. ENTOMOLOGY RESEARCH

(C. F. Dewhurst)

SUMMARY

General entomology programme related studies

The routine monitoring of oil palm pests, in particular the two main taxa (sexava and *Eurycantha*), improving the awareness of pests among growers and plantations for reporting and rapid control continued be a priority for Entomology operational research.

Ad hoc and training given at OPIC field days and company scheduled training days continued during the year, and this is expected to be at an increased intensity during 2008.

Pressure on the efficient control of all pests was maintained during the year, and this was reflected by a reduction in the numbers of reported infestations received and all of which were visited by Entomology.

The proposal for requesting Notifiable Pest Status for “sexava” and stick insects which has been with NAQIA since March 2006 was still not resolved and the gazettal process has not yet been completed, although letters were written on 11 March 2006, 29 August, 2006, 25 October 2006, 24 May 2007,

Meetings of the Sexava Working Action Group (SWAG) held at Hargy Oil Palms offices, which provide a valuable forum for discussing pest related issues were attended, although the planned monthly fora were not always completed on the scheduled dates. During these visits the opportunity was taken to visit plantations and smallholder oil palms and conduct pest surveys, and make collections for parasitoids. Weekly Sexava Action Group (SAG), part of the OPIC Divisional Managers meeting at Nahavio, was routinely attended, and was also used to keep DM’s fully informed of the current situation, and for Action Points to be put forward and followed.

Training was given through entomology section support to OPIC field days, formalised training sessions at company level and through local radio programmes organised through OPIC. No radio broadcasts were undertaken in Mainland PNG during 2007.

An issue of the OPRAtive Word Technical Note No. 11, “ *Mikania micrantha (Mile-A-Minute Vine) – current knowledge and control*”, was produced during October 2007.

Pest Infestations in West New Britain Province, New Ireland Province and Mainland PNG. Reports 2007.

The pest report database currently in use (in Excel) was updated during 2007 but was not fully utilised as further modifications were required. A detailed integration of all localities and pest taxa will be available with facilities to transfer the data across into Excel format for subsequent graphical display.

During 2007, there were 80 reports received of damage or concern about possible damage to oil palm by insect pests in WNB, 10 reports were received from New Ireland (NI and all during a single PNGOPRA visit) and six from mainland PNG. There were fewer infestation reports received in 2007 than during the previous year (2006) when 128 reports were received. In WNB during 2007, 44 reports were received from plantations, and 36 reports were received through OPIC Divisional Managers (n=80). In New Ireland, all ten reports received were from Plantations, while on mainland PNG; the six reports were received through OPIC

Five reports from the mainland were of the stick insect (*Eurycantha insularis*) and a single report was of the very large, rhinoceros beetle, *Oryctes centaurus.* White grubs of two beetle sub-families (Cetoniinae and Melolonthinae) were reported from two sites on mainland PNG at Soarovi and Igora. A report on white grubs was prepared for CTP (HOP) by our Entomologist (R Safitoa) in March 2007, and treatment recommendations made. Larvae were collected, but only one specimen was

successfully reared through to the adult stage. The identification of this insect is still awaited from CSIRO, Canberra (Dr T Weir).

All reports to PNGOPRA are followed up by visits from entomology section (either from WNB or from Mainland), however it should be noted that not every visit results in a recommendation for

chemical intervention, as some may require only time specified monitoring, while others may be of old damage.

Pest infestation reports received from WNB and NI fell during 2007 from the numbers reported during 2006, while reports from the Mainland rose slightly. It was assumed that this rise was due to the increased number of reports of *E.insularis* and *Oryctes centaurus* (Fig.1). There were no reported infestations of *S.novaeguineae* from the Mainland in 2007.

Figure 1: Oryctes centaurus (male on left).

Results from pest infestations recorded in WNB from smallholder growers show that there were two (small) peaks of infestation reports during May and October (Fig.2), while those reported from plantations remained more or less constant during the year, except for a very small increase in February (Fig. 3). Overall reports in WNB show a slight rise in infestations was reported during May with a minor rise in October (Fig.4). When compared with similar data for 2006, the two small rises are a month later in 2007 than in 2006 (Fig. 5).

The taxonomic status of bagworms remains unclear. Two reports of bagworms were received in 2007 from WNB in June and July. One infestation at Haella was treated, and a nearby (mill site) localised infestation on smaller palms was hand-picked. Bagworm infestations tend to become prevalent in the dry season, when the wind provides the 1st instar larvae with a means of dispersal.

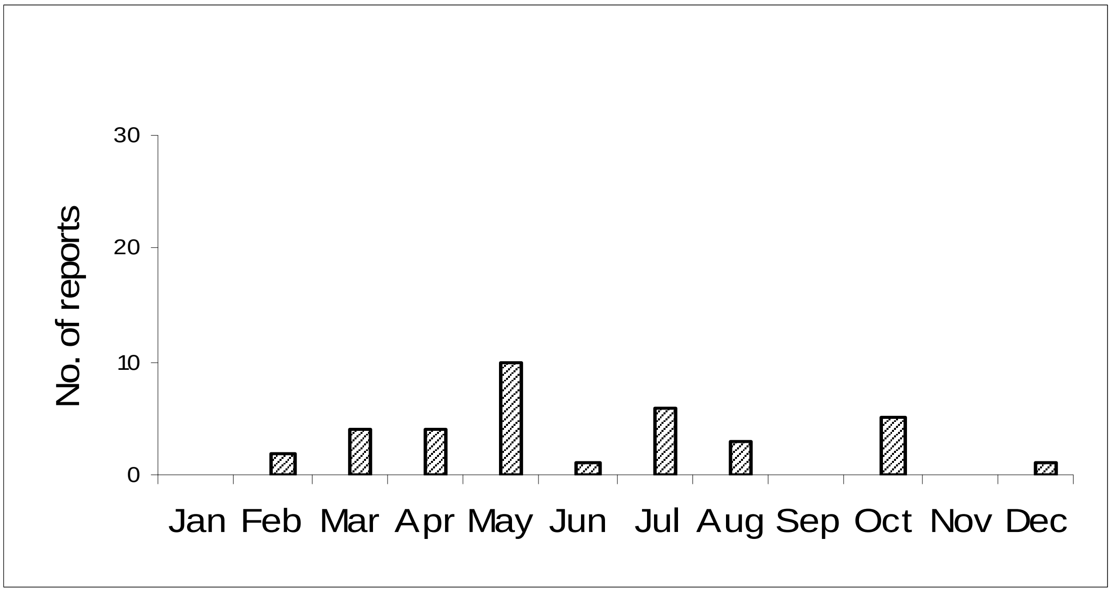


Figure 2: 2007: Pest reports from OPIC, West New Britain

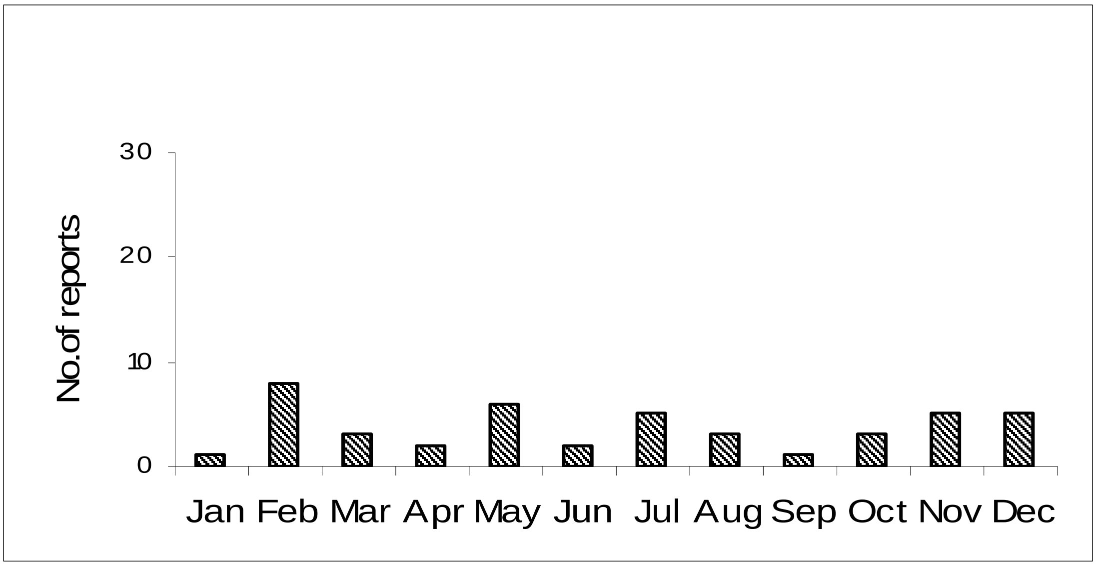


Figure 3: 2007: Pest reports from Plantations, West New Britain.

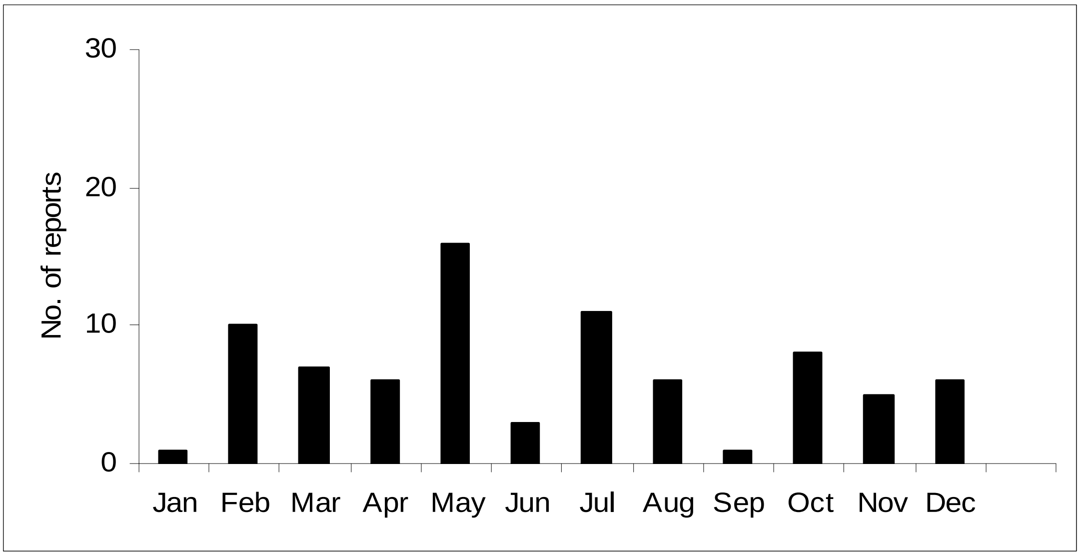


Figure 4: 2007: Pest reports OPIC and Plantations, West New Britain.

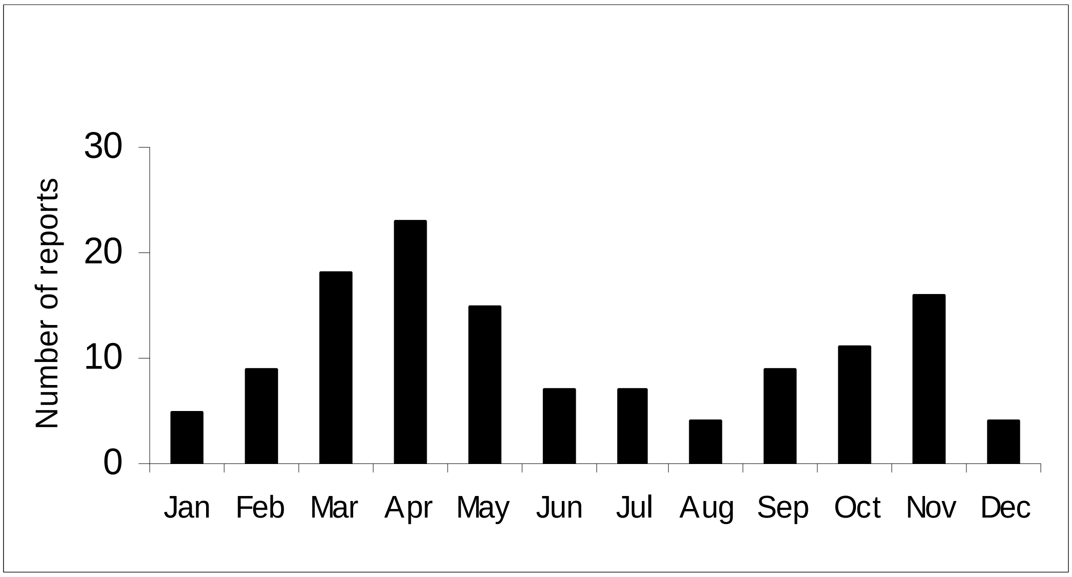


Figure 5: 2006: Pest reports OPIC and Plantations, West New Britain.

Other pest taxa were less prominent in reports (Fig.6). *Segestes decoratus*, which are still predominantly female dominated in reports, while the stick insect, *E.calcarata* followed but at lower levels than in 2006, although report numbers were similar to the number of reports as *S.defoliaria* (38 reports).

During 2007, confirmed reports of other pest taxa were insignificant, however the three-horned rhino beetle, *Scapanes australis* reported attacking young plantings was reported in low numbers in 2007 (Fig. 6), but more than in 2006 (Fig. 7). It was recorded particularly at Poliamba (5 Estates), Rigula (NBPOL) and Hargy, Navo (HOP). Insecticide treatment is rarely recommended, however manual "winkling" out of adults using a hooked sharpened wire was undertaken successfully at Rigula ME in WNB.

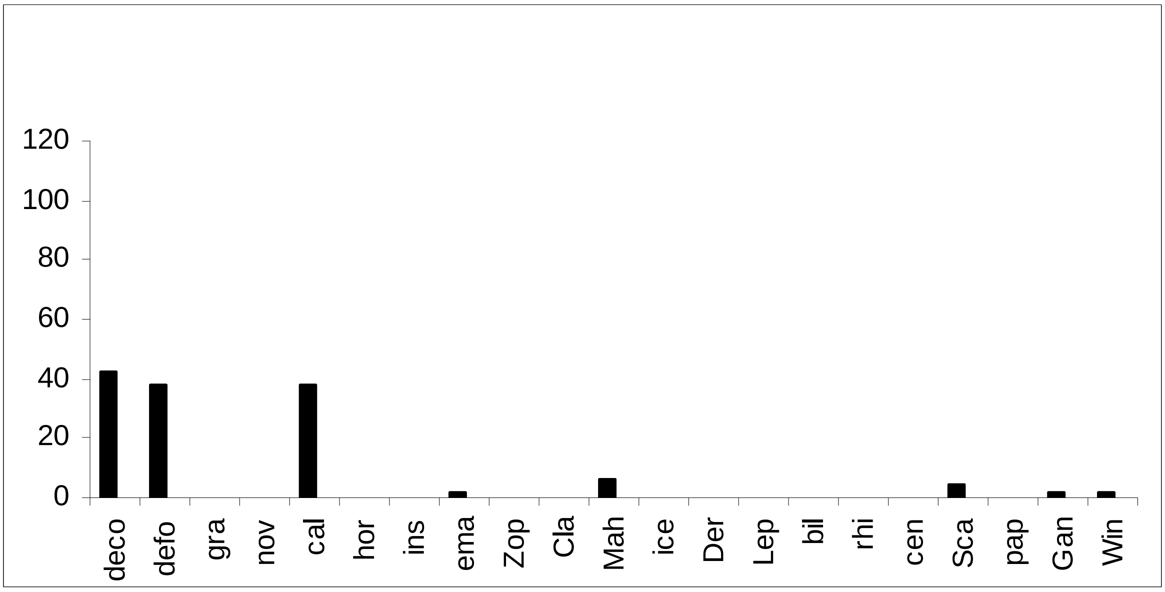


Figure 6: 2007: Pest taxa recorded for West New Britain.

These results were similar to the relative importance of the different taxa recorded in 2006 from WNB (Fig. 9), although overall report numbers were considerably less than in 2006. Pest reports did increase on mainland PNG (see above). It was again clear that in WNB pest reports were dominated by sexava, while on the Mainland by stick insects and the one report of *Oryctes centaurus*

There were no reports of Finschhafen Disorder, although, work undertaken with the new ACIAR project (see later) identified other sites that were not reported.

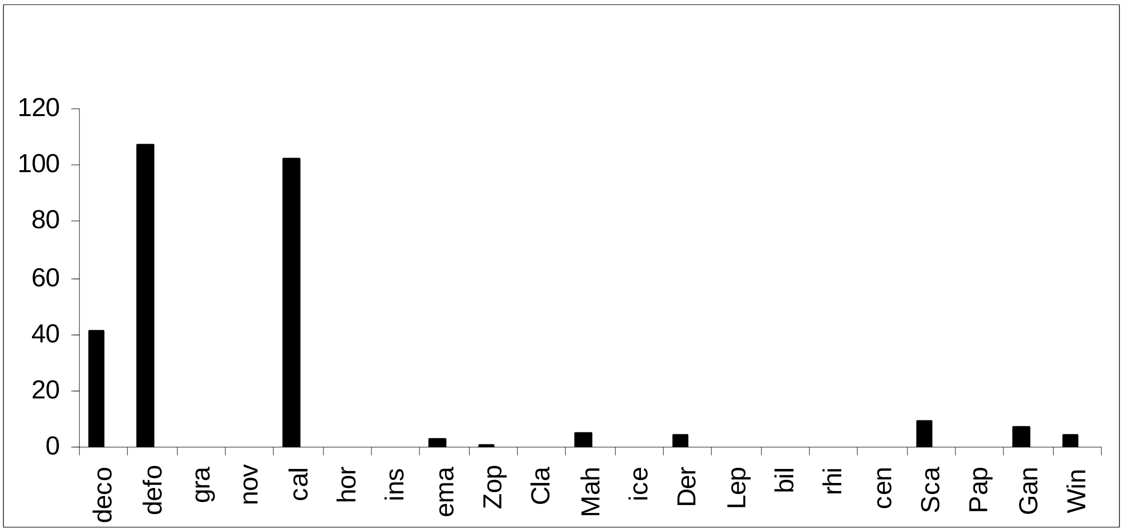


Figure 7: 2006: Pest taxa recorded for West New Britain.

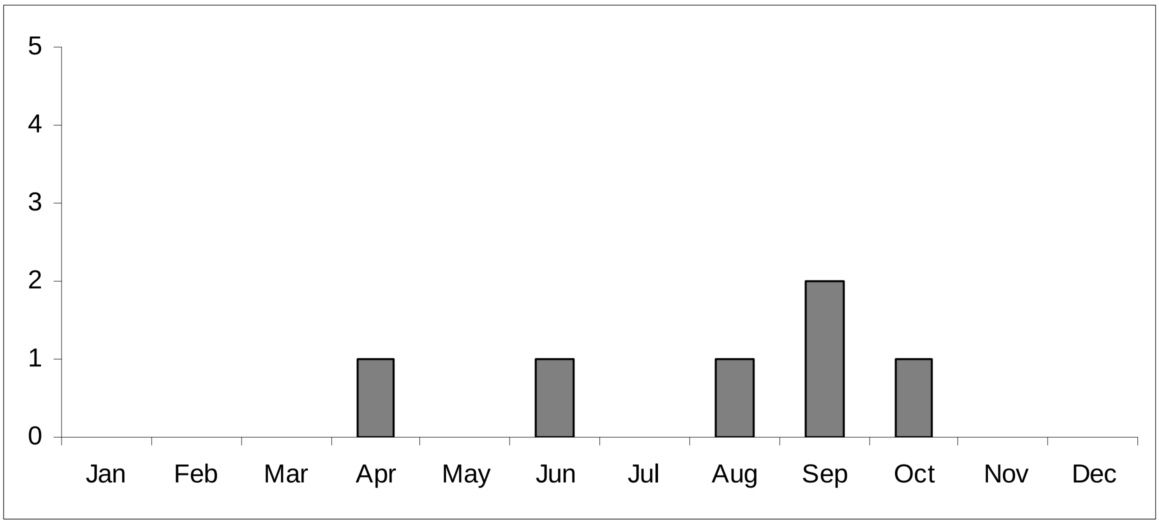


Figure 8: 2007: Pest infestations reported from mainland PNG.

Although the fungus *Ganoderma* was reported to Entomology Section, from the end of this year, these reports will be transferred to the Plant Pathology Section (PNGOPRA) for future reporting purposes.

Invasive Weeds

There were no reports received of areas with the main taxa of invasive weeds from within PNG, nevertheless the continual dispersal/redistribution of bio-control agents of the main weed pests continued. Collaboration with the ACIAR project on *Mikania micrantha* (CP/2004/064) continued (see below).

SEXAVA

As in previous years pest infestation reports in WNB were dominated by both of the pest long-horned grasshoppers (tettigoniidae, *Segestes decoratus* and *Segestidea defoliaria*) followed closely by the stick insect, *Eurycantha calcarata*.

Contrary to the situation in 2006, *S.decoratus* was reported with greater frequency than *S.defoliaria* in 2007, while there were no reports of the sexava, *Segestidea novaeguineae* from the Mainland. Reports of infestations of *S.decoratus* were only slightly higher in the pest reports received during 2007 (43 reports), in contrast with the situation in 2006 when *S.decoratus* was at similar levels, however *S.defoliaria* dominated in 2006 (107 reports).

No male specimens of *Segestes decoratus* were collected from any of the field collection sites visited on WNB during the year.

Segestidea gracilis (the endemic “sexava” species from New Ireland), was also reported at infestation levels in 2007, and targeted trunk injection was recommended.

Smallholder affairs (SHA) team undertook treatment principally for smallholders helping out in plantations when required.

Table 1: Smallholder blocks treated during 2007. (Source: SHA office).

Area/Division	Date of Report	Date Treated	No. of palms treated	Hectares	Pest Rec. No.	**Comments**
Galilo	28-February	04-March	2,400	20	0507	120 palms/ha
Rapuri	13-March	15-March	16,080	134	0607	↓
Vavua	13-March	03-April	11,760	98	0607	↓
Koimumu	13-March	15-March	3,600	30	0607	↓
Kavui	13-March	21-March	2,880	24	0707	↓
Pangalu VOP	26-April	28-April	960	8	1307	↓
Marapu	26-May	27-June	7,200	60	2507	↓
Poropora	25-July	31-July	240	2	4207	↓
Kavutu VOP	25-July	30-July	4,320	36	4307	↓
Waisisi	03-July	04-July	3,120	26	2707	↓
Lotomgam	28-August	01-September	12,356	97	4607	128 palms/ha
Natupi	28-August	11-September	17,407	136	4607	128 palms/ha
Siki	15-August	16-August	1,420	12	4607	120 palms/ha
Total			**83,743**	**450**		

The Table above shows the numbers of palms treated (83,743), however the number of hectares (rounded up), was calculated at SHA by simply multiplying number of palms treated by standard planting rates. The time between receiving the recommendation and undertaking the targeted trunk injection showed a major improvement over 2006 (Table 2), where response time averaged 93 days, and in 2007 the average response time was eight days. The expected completion of the pesticide monitoring database (MUD) will enable the production of a more accurate data set to allow closer monitoring of the actual amounts of insecticide used during treatment programmes.

Table 2: Smallholder blocks treated during 2006. (Source: SHA office).

Area/Division	Date of Report **2006**	Date Treated	No. of palms treated	Hectares	Pest Rec. No.
Ganeboku	24-February	23-March	2,097	17.47	406
Morokea	24-February		1,680	14	506
Siki	16-March	10-June	19,680	164	1306
Buvussi	20-March	07-June	229,680	1914	806
Morokea	04-March	19-April	240	2	6006
Sarakolok	13-March	24-March	73,440	612	1106
Ismin	13-March	16-March	1,820	15.16	1006
Waisisi	16-March		960	8	1406
Rikau	09-March		1,440	12	706
Kavui	13-April	15-August	33,840	282	3106
Banaule	06-April	06-July	3,840	32	2806
Kavui	06-April	09-July	38,880	324	2706
Kapore	13-May	29-August	96,480	804	4306
Kololo	26-April	27-June	480	4	3006
Kavutu	27-April	27-June	1,200	10	3406
Galilo	27-April	10-August	6,240	52	3206
Buvussi	05-April	11-April	55,440	462	2306
Sarakolok	05-April	11-July	14,400	120	2406
Silanga	05-April	11-May	28,320	236	2206
Kapore	13-May	29-August	96,480	804	4306
Buvussi	29-May	15-June	12,240	102	4506
Lavege	29-May	16-July	960	8	4906
Tarobi	16-May	29-May	5,819	48.49	4006
Sisimi	16-May	14-June	11,520	96	3806
Kae	16-May	17-May	2,640	22	3606
Silanga	13-June	14-August	5,760	48	5006
Mandopa	04-September	20-September	1,440	12	5806
Mosa	04-September	06-January	11,520	96	5906
Gule	04-September	15-October	7,200	60	5706
Mosa	11-October	03-January	14,843	123.69	
Koimumu	*07-November-2005*	*04-August-2006*	7,883	65.69	
Rapuri	*07-November-2005*	*09-August-2006*	5,160	43	
Mai	21-December-2005	17-February-2006	23,935	199.45	20051219
Buluma	21-December-2005	17-January-2006	3,431	28.59	20051219
Galai (2)	17-December-2005	18-January-2006	4,341	36.17	
Galai (1)	*07-December-2005*	*11-October-2006*	22,414	186.78	
Buluma	21-December-2005	17-February-2006	1,200	10	20051219
Totals			**859,983**	**6,212.49**	

It can be seen that there are errors in this Table particularly with treatment dates in relation to the report dates, as the maximum initial treatment period after a report is received is 16 weeks (the cycle time for sexava, in italics). These data will improve with the introduction of MUD (see above); nevertheless there was a great reduction in the number of smallholder blocks treated.

Treatment return forms from plantations were seldom received; however this should improve in 2008, although these data are however available in OMP management system.

Other sexava related studies.

Studies planned to investigate possible ovarian contamination by a bacterium planned with Dr Pilotti and the *Stichotrema* related work with Dr Kathirithamby (Oxford) were not addressed due to the pressure of pathology work at Milne Bay, and funding availability for Oxford, which was disappointing.

Analysis of the feeding data has still to be completed.

Analysis of the final series of palm circle experiments where we were looking to investigate the loss of sexava eggs from the field was entered into a database, but were not analysed.

Sexava Biological Control

Internal parasitoids

Occurrence of the internal parasitoid *Stichotrema* (Mymecolacidae) among mainland samples routinely sampled showed an increased level of parasitism towards the latter part of the year from July until; October (Fig.9). During 2007, 299 adult sexava were sampled and *Stichotrema* was found in 103 adults (Fig. 10). There were no records of *Stichotrema* in nymphal instars of sexava. From the results of *S.novaeguineae* sampled on the mainland, female *Stichotrema* were producing 1st instar larvae from January through until April, then again in October-(Fig.10). Further data collection was lost because of the cyclone affected the area.

The PNGOPRA Entomology section at Higaturu on mainland PNG maintained a small culture of *S.novaeguineae*, but they were not used for any specific research; although it is planned that feeding studies and *Stichotrema* culturing will be revisited.

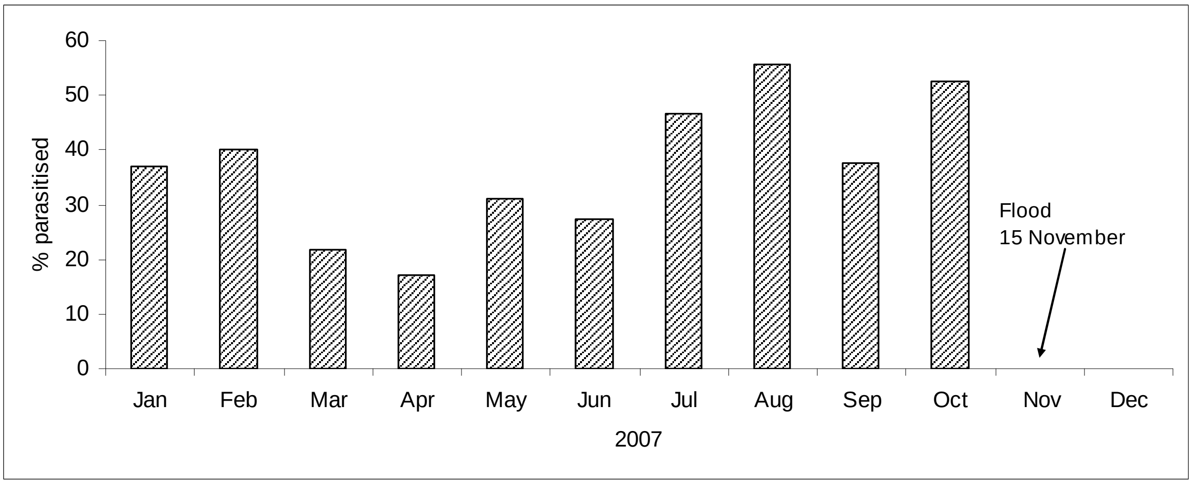


Figure 9: Stichotrema: percentage infestation of S.novaeguineae during 2007 from Koropata area on mainland PNG.

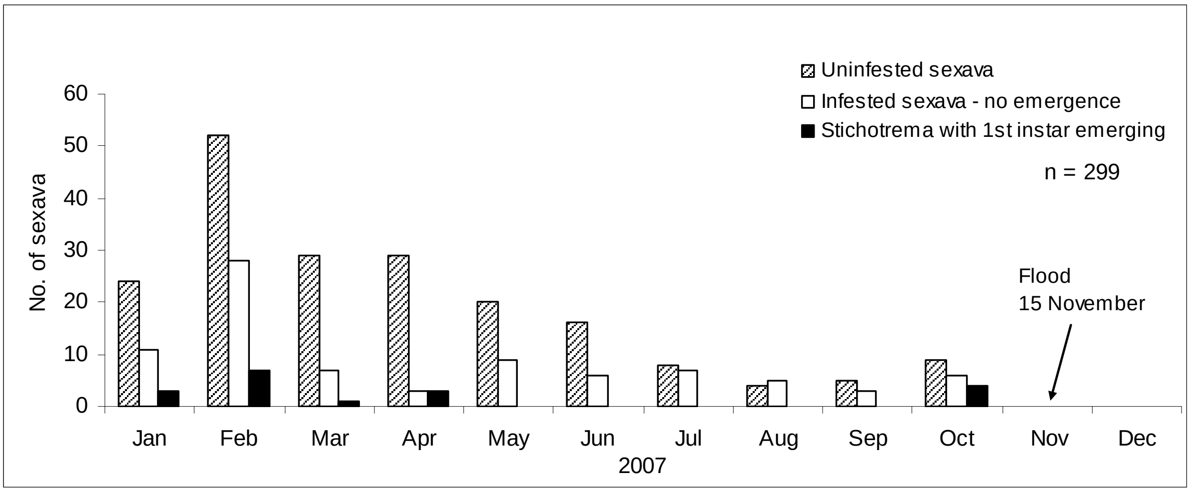


Figure 10: Infestation of S.novaeguineae from Koropata area (N.Province, mainland PNG) in 2007.

No specimens of Diptera: Tachinidae were reared from *S.novaeguineae*

Sexava egg parasitoids, (Trichogrammatidae and Encyrtidae).

Laboratory populations of (*Doirania leefmansi*- Hymenoptera: Trichogrammatidae and *Leefmansia bicolor*- Hymenoptera: Encyrtidae), were maintained but at a lower level than during 2007. As stated previously (2006), the rearing facilities are inadequate and insufficient insects were reared for successful inundative release (Figs.11 & 12).

As was reported in 2006, the importance of the availability of a nectar source is clear, not only for egg parasitoids, but many other parasitoid taxa. Work by an Honours student (Kingsten Okka) from UPNG later in 2007 was focussed on these questions. A report is expected during 2008 after he has presented his dissertation to the University. The benefit of nectar on beneficial insects was also apparent when Myrmaridae were investigated during the Finschhafen Disorder project (see below).

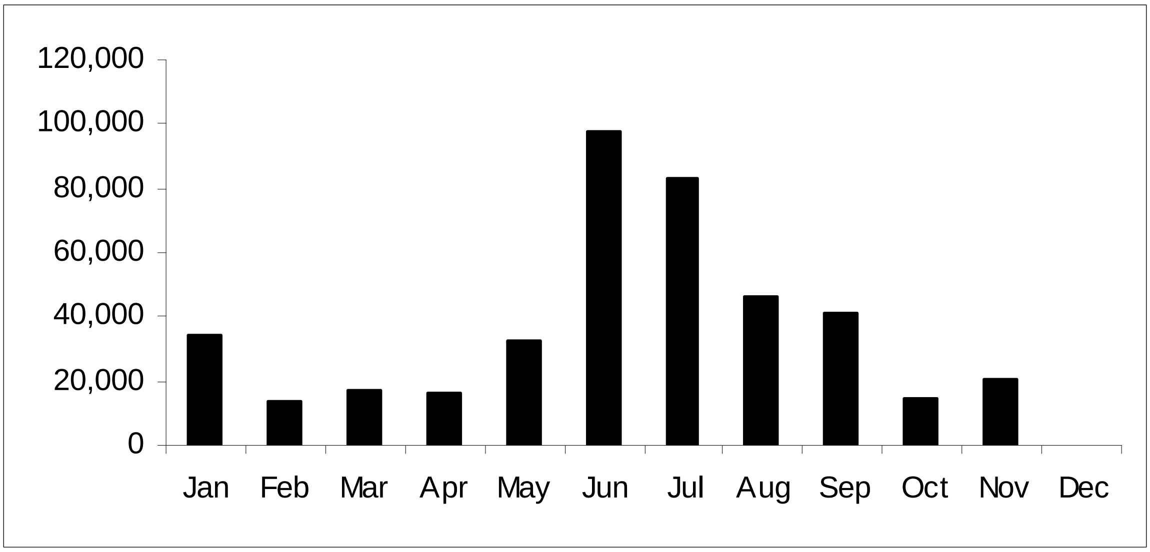


Figure 11: Leefmansia bicolor releases, West New Britain 2006.

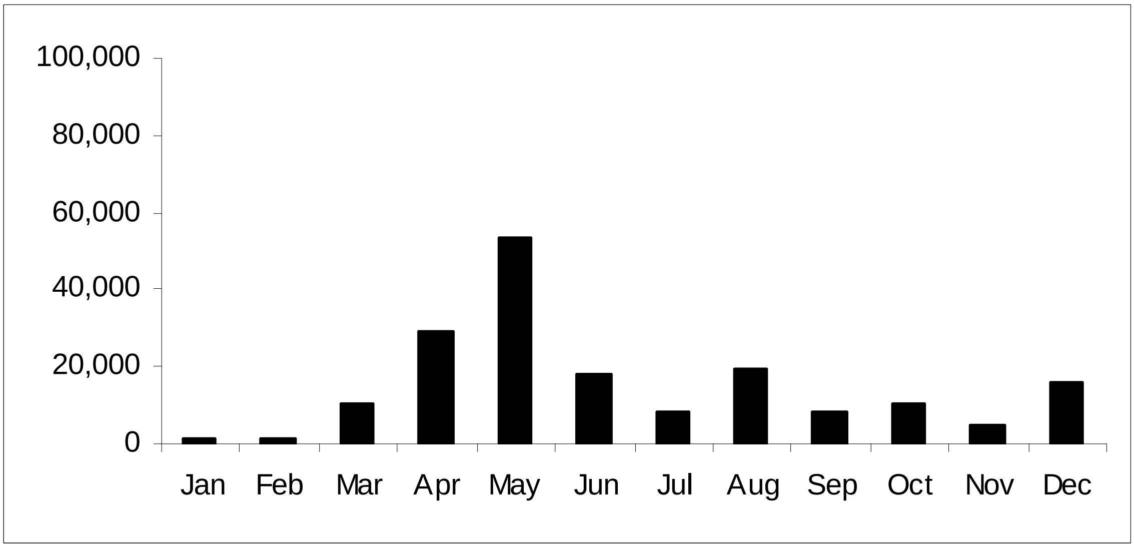


Figure 12: Leefmansia bicolor released, West New Britain during 2007.

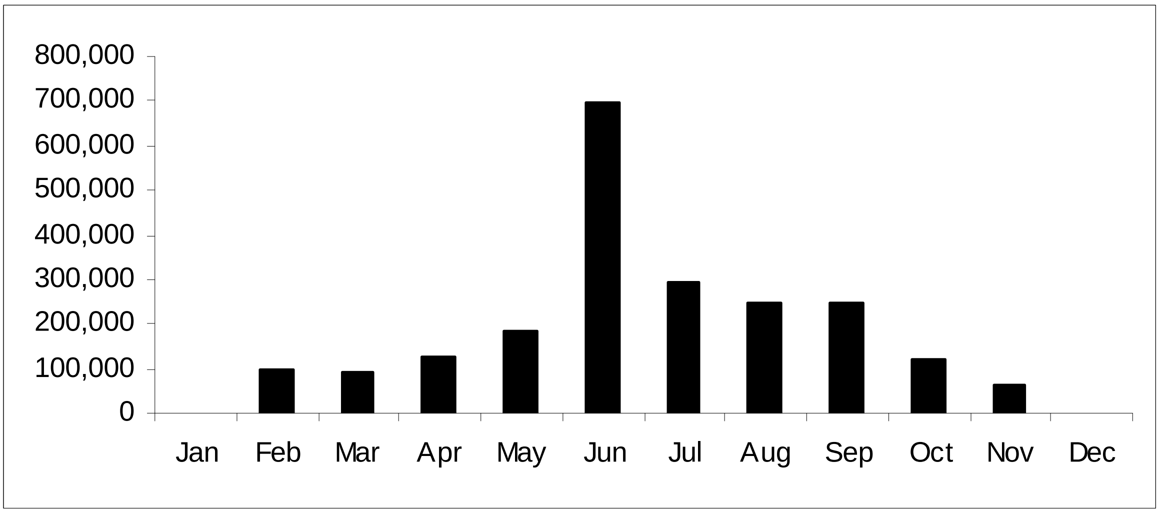


Figure 13: Doirania leefmansi released, West New Britain during 2006.

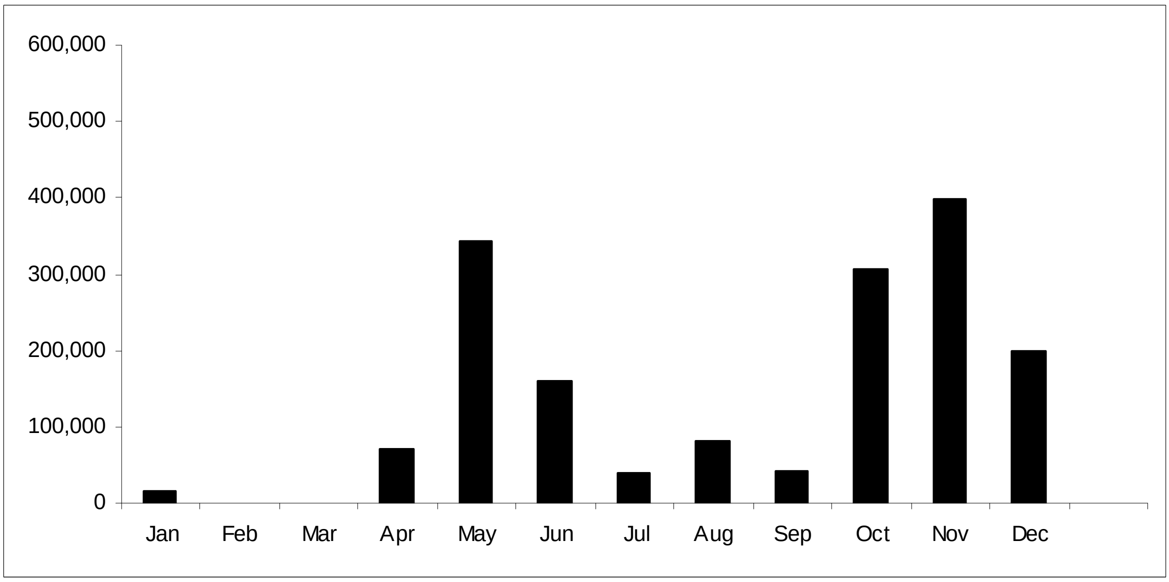


Figure 14: Doirania leefmansi released, West New Britain during 2007.

In spite of the less than satisfactory numbers produced (Figs.15 & 16), egg parasitoids were released in WNB on smallholder blocks and plantations and on New Ireland.

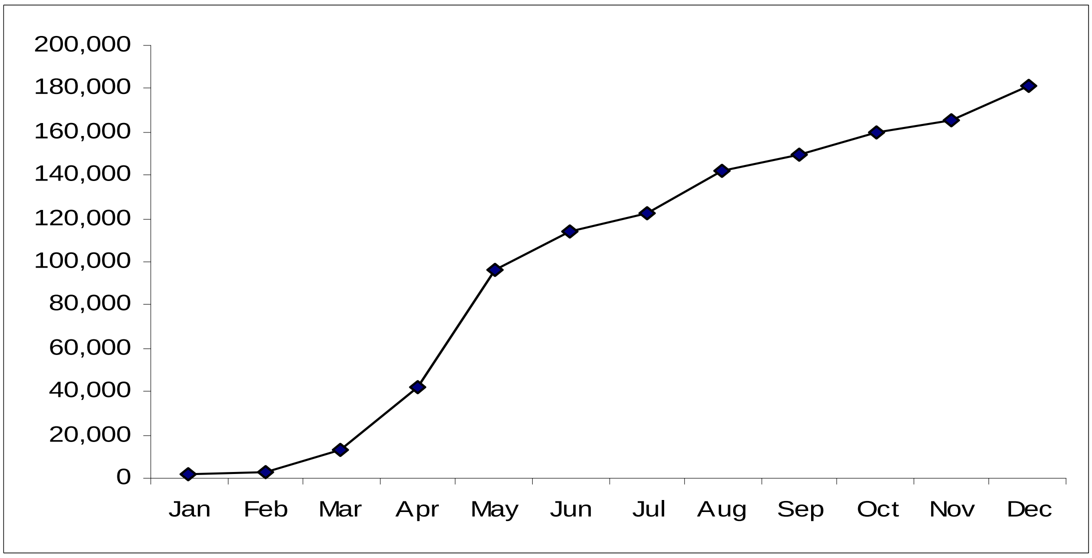


Figure 15: 2007, cumulative releases of Leefmansia bicolor in WNB & NI

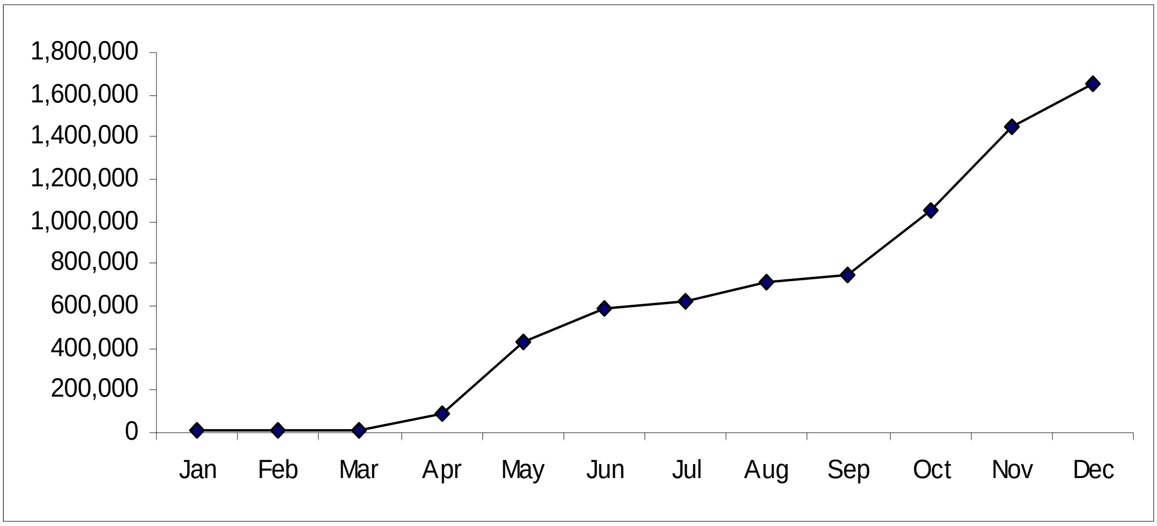


Figure 16: 2007, cumulative releases of Doirania leefmansi in WNB & NI.

Doirania were released in 54 localities on WNB and NI, and *Leefmansia* were released in 51 localities (Table 3 & Table 4).

Table 3: Dates and locations of egg parasitoid releases in WNB and NI 2007

Doirania leefmansi		*Leefmansia bicolor*	
05 January 2007	Dalom, Poliamba	**05 January 2007**	Dalom, Poliamba
06 January 2007	Kambaribia, Poliamba	06 January 2007	Kambaribia, Poliamba
06 January 2007	Madina, Poliamba	06 January 2007	Madina, Poliamba
06 January 2007	Kimadan, Poliamba	06 January 2007	Kimdan, Poliamba
06 January 2007	Lakurumau, Poliamba	06 January 2007	Lakurumai, Poliamba
07 January 2007	Sicacui, Poliamba	07 January 2007	Sicacui, Poliamba
28 March 2007	Numundo pln.	**02 February 2007**	Natupi, Lotogam
17 April 2007	Dami pln.	20 February 2007	Hargy, Area 3
18 April 2007	Wilelo LSS	26 February 2007	Numundo pln.
02 May 2007	Kumbango Div 2	**02 March 2007**	Babui, Vavua, Koimumu LSS
03 May 2007	Dami pln.	15 March 2007	Tiauru LSS
14 May 2007	Karausu pln. Div 1	28 March 2007	Numundo pln.
21 May 2007	Dami Field 5	**12 April 2007**	Malilimi pln. Div 2
24 May 2007	Karato ME	17 April 2007	Dami pln.
21 May 2007	Bebere pln.	20 April 2007	Dami pln.
21 May 2007	Bebere pln.	23 April 2007	Banaule VOP
21 May 2007	Bebere pln.	**02 May 2007**	Kumbango Div 2
25 May 2007	Marapu VOP	03 May 2007	Dami pln.
26 May 2007	Numundo pln.	14 May 2007	Kaurusu pln. Div 1
28 May 2007	Salelubu LSS	23 May 2007	Karato ME
29 May 2007	Dami seed garden	21 May 2007	Bebere pln.
05 June 2007	Haella Div 2	25 May 2007	Marapu VOP
14 June 2007	Dami pln.	26 May 2007	Numundo pln.
19 June 2007	Haella Div 2	30 May 2007	Salelubu LSS
23 June 2007	Dami pln.	30 May 2007	Buluma (Dami pln.)Field
25 June 2007	Dami pln.	29 May 2007	Dami seed garden
02 July 2007	Haella Div 2	**05 June 2007**	Haella Div 2
30 July 2007	Numundo pln.	14 June 2007	Dami pln.
01 August 2007	Dami, Buluma field	19 June 2007	Haella pln. Div 2
17 August 2007	Daliavu pln.	23 June 2007	Dami pln.
29 August 2007	Daliavu pln.	25 June 2007	Dami pln.
31 August 2007	Bialla	**30 July 2007**	Numundo pln.
16 September 2007	Haella	30 July 2007	Numundo pln.
21 September 2007	Dami pln.	**01 August 2007**	Dami, Buluma field
02 October 2007	Kavui LSS	03 August 2007	Dami, Buluma field
03 October 2007	Kavugara ME	03 August 2007	Dami pln.
05 October 2007	Malilimi pln.	06 August 2007	Dami seed garden
12 October 2007	Siki LSS	13 August 2007	Daliavu pln.
15 October 2007	Navo Estate	17 August 2007	Daliavu pln.
15 October 2007	Navo Estate	29 August 2007	Daliavu pln.
06 November 2007	Bialla	31 August 2007	Bialla
10 November 2007	Bebere, 6C	**06 September 2007**	Haella pln.
10 November 2007	Numundo	21 September 2007	Dami pln.
13 November 2007	Bialla	**12 October 2007**	Siki LSS
13 November 2007	Umbai VOP	15 October 2007	Navo Estate
23 November 2007	Natupi ME	24 October 2007	Dami pln.
23 November 2007	Kumbango	**06 November 2007**	Bialla field day
29 November 2007	Malilimi D1	23 November 2007	Kumbango Div 2
29 November 2007	Banaule VOP	**19 December 2007**	Alaba Estate
04 December 2007	Bialla	28 December 2007	Banaule VOP
04 December 2007	Bialla	31 December 2007	Numundo pln.
19 December 2007	Alaba Estate, OPIC Bialla		
28 December 2007	Banaule VOP		
31 December 2007	Numundo pln.		

The production of host (sexava) eggs was very variable during the year, which was a limiting factor on parasitoid production; furthermore hatching the eggs outside was less successful, as host eggs were being parasitized by *Doirania*, which may have escaped from the rearing room.

Lepidoptera Pests (bagworms).

Different species of Tachinidae (Diptera, Tachinidae) were reared from bagworm infestations at Hargy in January, Karausu, Kautu and Togulo in June and Haella in November. No Tachinidae were identified specifically because of lack of specialist taxonomic expertise to identify the material without payment. (The Natural History Museum, London, charges GBP 82.50 per species identified.) All material is however retained and fully labelled in the PNGOPRA reference collection. A search for a specialist will be made.

Figure 17: Rough bagworm bags

Figure 18 larval bags and damage on oil palm

The oil palm webworm, *Acria* sp. nr. *emarginella* (Lepidoptera: Oecophoridae) was not of any importance this year, although larvae, pupae and adults were found at Bebere in April and Karausu in October.

STICK INSECTS (*Eurycantha calcarata* and *E. insularis*.)

Figure 19: Male Eurycantha insularis. Higaturu, at PNGOPRA Centre 2007

Both species of stick insects were reported as pests of oil palm in WNB and on the mainland. On mainland PNG, *E.insularis* (Fig. 19) caused serious defoliation of oil palms in smallholder blocks, with the first report being received in April 2007 at Sui and Tunana (Fig.20). Light infestations were observed at Serembe in June, during August at Koropata and in September at Kanari and Jajao. No treatment was undertaken as the local people insisted that they wished to collect them for food. No infestations of this insect were observed in 2006.

Figure 20: Serious damage caused by E.insularis at Sui smallholder block 2007.

Egg parasitoids were reared from both species, and one taxon reared was similar to that found in WNB. The males are winged, but females were completely apterous (lacking wings). Specimens were taken to CSIRO-ANIC, but could only be tentatively named as: Hymenoptera: Eupelmidae, *Anastatus* sp. Another much larger parasitoid was tentatively identified as Hymenoptera: Chrysididae (J La Salle pers.comm.). A larger apterous Hymenoptera remained unidentified.

From a collection of eggs made in the field (3,140 eggs), 26 parasitoids emerged; at this low level of parasitism (0.8%) efforts to rear the parasitoid have not been pursued.

Work on clarifying the life history of *E.insularis* was completed in December at Higaturu, and the results will be analysed for publication.

There were no reports of damage caused by *E.horrida* from oil palm during the year, neither were specimens found on either WNB or NI.

No further work was undertaken with *E. calcarata* nymphal development as inferred through egg weights, due to the paucity of dense enough infestations to provide sufficient experimental material. Thirty–eight infestation reports were received from WNB involving *E.calcarata*, and although a culture of this insect was retained, sufficient numbers surviving from egg to adult were insufficient for concluding life history work.

A major mortality factor in the insectaries both inside and outside is ants.

Economic assessments

As this infestation of *E.insularis* was so serious and not controlled, a start was made to assess FFB production losses. Due to the cyclone (Guba) which struck the area in November, FFB collections were not made for a long period, and data available were erratic with some months having no fruit collected, while other months an additional collection was made.

Of the 8 blocks investigated, only two blocks indicated a very slight upward trend in FFB yield (Fig.21), whereas all the others showed a slight downward trend (Fig.22). These data will continue to be collected and any trends in FFB production identified.

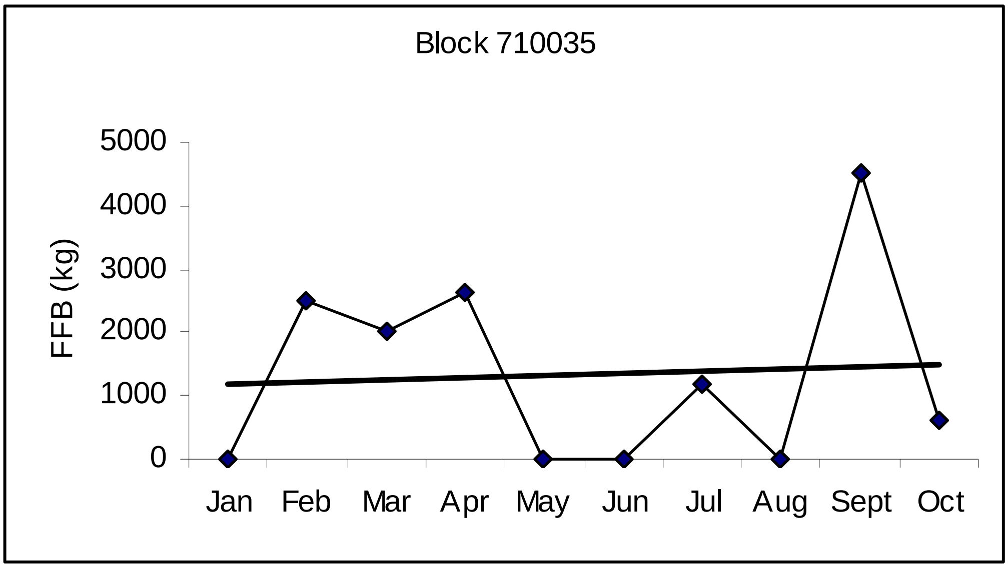


Figure 21: Northern Province, VOP Blocks at Tunana infested with E.insularis (1).

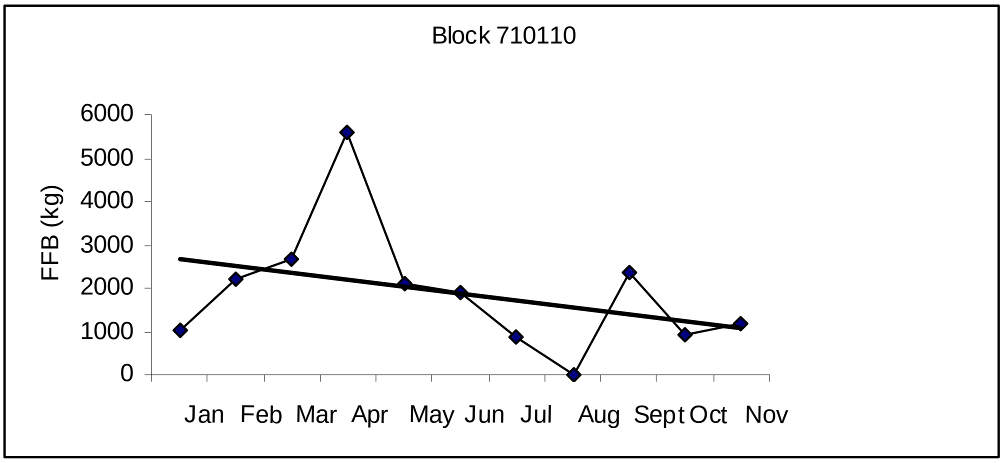


Figure 22: Northern Province, VOP Blocks at Tunana infested with E.insularis (2).

RHINOCEROS BEETLES (COLEOPTERA, SCARABAEIDAE).

Scapanes australis

There were 2 reported attacks by rhinoceros beetles (confirmed as *S.australis*) in plantations in WNB, in areas of young plantings bordering forest and typically in areas that were recently cleared (e.g. Hargy and at Ibana plantation), there were no reports through OPIC. There were no reports from New Ireland.

Oryctes rhinoceros

No reports of *Oryctes rhinoceros* from within Papua New Guinea on oil palm.

Oryctes centaurus

On mainland PNG there were further reports of the large *O. centaurus* damaging young palms. Adult beetles behave in a similar manner to *Scapanes* by boring their way into the spear cluster, causing damage to the spear base and surrounding soft tissues (Fig. 23). It is assumed that the beetles enter the tissues to feed and for the females to develop their ovarioles. The eggs and larvae are however found in rotten wood (often old poisoned palms that remain standing). A female was observed laying eggs in decaying matter in a rotten stem. Various attempts were made to rear the adults from eggs, but all have so far failed (R Safitoa, pers.comm.).

Figure 23: Damage caused by Oryctes centaurus in oil palm, Northern province, PNG.

Regular monitoring took place at Sumbiripa, Sangara and Ambogo Estates by means of counting collapsed spears. The oil palms monitored were between 3-5 years old at Sumbiripa, and 5 years old at Sangara and Ambogo. As we know so little about the life cycle of this insect, it is difficult to interpret the results of the surveys (Fig. 24), other than there appeared to be an apparent rise during the first quarter of the year. The results of our surveys showed that populations were present at Sumbiripa and Ambogo throughout the year, while at Sangara, they were not found after September, having dropped from relatively higher numbers earlier in the year. There were no reports of palms being killed by this insect; however more effort must be put into understanding the life cycle and searching for entomopathogens.

O.centaurus has not been recorded from either New Ireland or WNB; however quarantine enforcement is non-existent within PNG, that the movement of all pest taxa must be a concern. This beetle is primarily a pest of coconut, and the full grown larvae are eaten by local people.

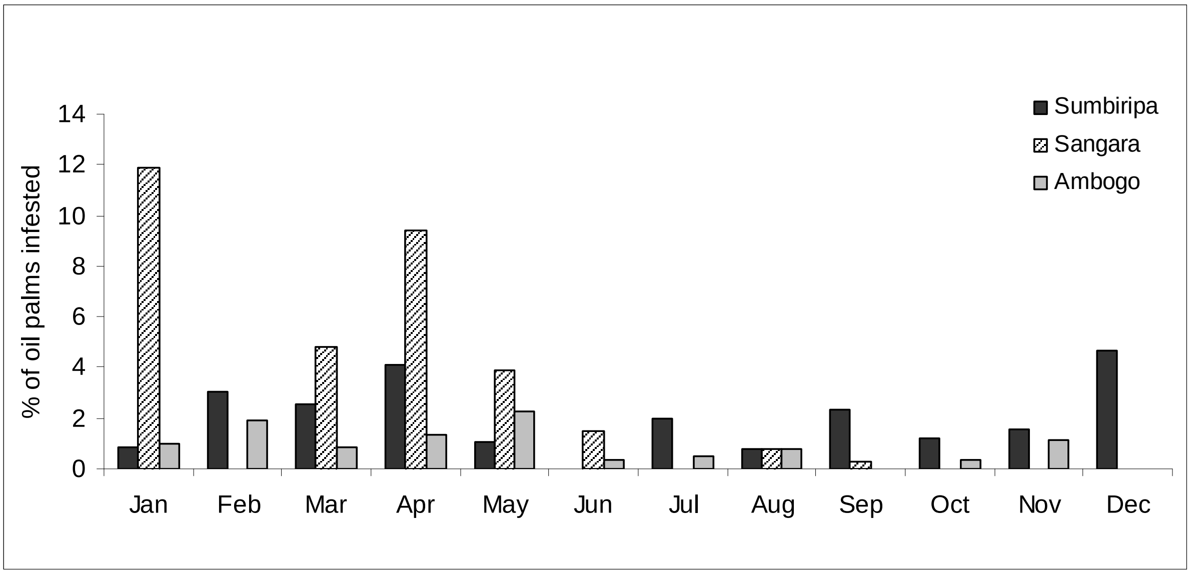


Figure 24: Damage to oil palms on mainland PNG at Higaturu Oil Palms Estates, 2007.

<u>"White Grub"</u>

The larvae of two different taxa were reported attacking the roots of oil palm from a localised area of two smallholder blocks at North Sangara. Rearing of these insects at Higaturu was not very successful, however the one adult reared successfully was not identified, and it is currently in CSIRO ANIC until a taxonomist can be found. No treatment recommendations were made.

FINSCHHAFEN DISORDER: PLANT HOPPER (*ZOPHIUMA LOBULATA*) INTEGRATED PEST MANAGEMENT (IPM)

(C. Gitau, C. F. Dewhurst et al)

Figure 25: Zophiuma lobulata egg mass on oil palm leaflet.

Figure 26: Zophiuma lobulata adult male on oil palm leaflet. (Photo: R Roe).

The proposed first phase three-year project was started in October after delays within ACIAR. A post-doctoral fellow was appointed from a very strong group of candidates from Australia, Brazil, Kenya, and Switzerland. The appointee, Dr Catherine Gitau, came from Kenya, and she was appointed to the project working principally with our collaborators at Charles Sturt University, Orange, and DPI in NSW, Australia. She visited during October with the Project Co-ordinator, Professor Geoff Gurr, to work with us to set up monitoring sites, trapping experiments and plan the major experiments for 2008 with HoE. The first report for ACIAR will be due in mid June 2008.

Three reports of Finschhafen Disorder (FD) were recorded from smallholder grower areas in WNB during 2007 (Kandori in April, Kavui in May and Galai 1 in August) (Fig. 25& 26). None of the reported infestations required treatment and there were no infestations reported from plantations.

There were no reports of FD from New Ireland. Fieldwork during the initial phase of the project also identified sites at Kavui, Walindi, Bialla, Salelubu, as well as well known sites at Kautu plantation (Kapiura Group) and Numundo plantation (on Coconut) in WNB. A visit is planned be made to Milne Bay in 2008, and it is expected that visits to Ramu and New Ireland will also be made in 2008.

Egg masses at the WNB study site at Kavui were found on frond bases or leaflet undersides of coconut or oil palm, and other plants (e.g. betel nut, taro, and banana). The eggs are typically heavily parasitized by at least two different taxa, one a Myrmaridae and the other so far unidentified (but it may be Pteromalidae). The Myrmaridae will be sent to a specialist in Canada for identification and possible description. Some initial experiments were conducted to assess the value of beneficial plants to the longevity of parasitoids.

An initial phase of the project was to confirm the identity of the suspected causal insect vector of FD. Dr Gitau, using material collected by PNGOPRA was able to confirm the identity of *Z. lobulata* by comparing specimens collected from a range of locations in West New Britain and mainland with the formal taxonomic description for specimens from various parts of mainland PNG. This project has employed morphological characters, particularly male genitalia and molecular methods using the CO1 gene. The identification of animal biological diversity by using molecular markers has recently been proposed and is demonstrated through the use of a short DNA sequence in the cytochrome *c* oxidase 1 (CO1 gene). The procedure has been conducted with *Z. lobulata*. Results indicated consistency of all morphological (Fig. 27) and molecular characters (Fig. 28). There was no evidence found for additional or cryptic species.

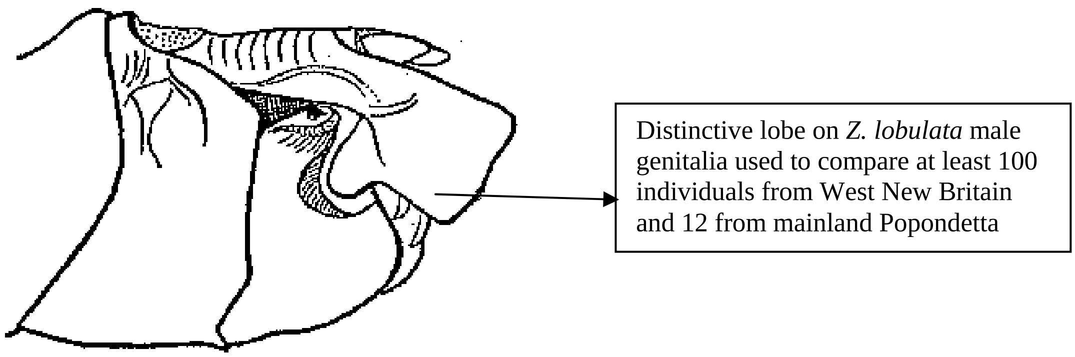


Figure 27: Shape of Zophiuma lobulata male genitalia used to confirm the identity of individuals collected from West New Britain and from mainland PNG at Popondetta.

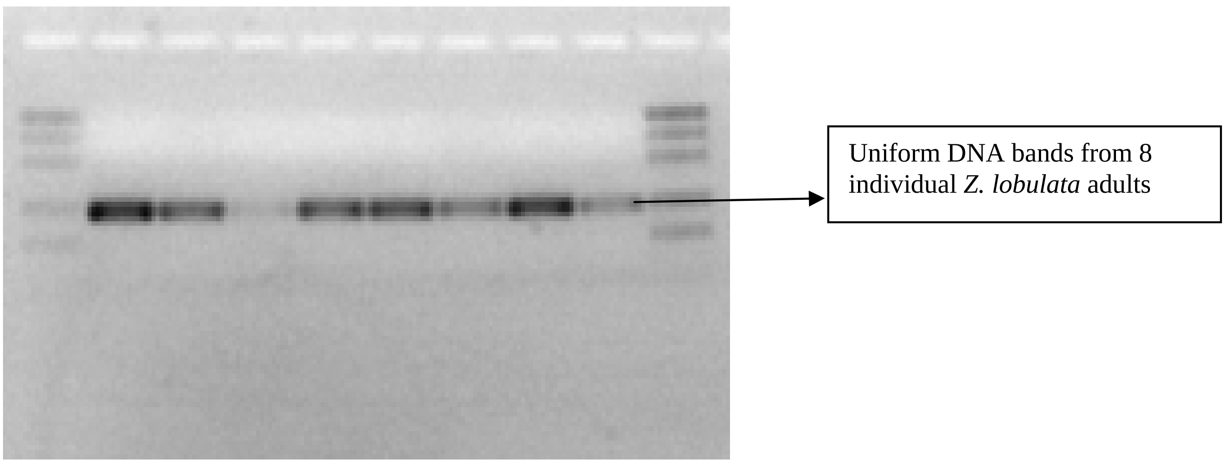


Figure 28: Diagram showing DNA bands amplified from CO1 gene of 8 Z. lobulata individuals collected from West New Britain and on the PNG mainland at Popondetta..

Laboratory experiments were undertaken to evaluate the influence of nectar rich ground cover plants on the lifespan of the mymarid parasitoids. Three cover plants were used to investigate the life span of mymarid parasitoids feeding on these plants, namely the goat weed (*Ageratum conyzoides*, Compositae)); Vernonia, (*Vernonia cinerea*) and *Tunera subulata* (Asteraceae).

Although the standard deviations were high (because of the small sample sizes used), results showed that adults lived longer with access to the flowers compared with those that were fed on water alone (Figure 29 and 30). Further work is scheduled using a variety of different cover crops and additional species of natural enemies to identify the scope for these plants to be used as a management approach that attract and support biological control agents of *Z. lobulata*.

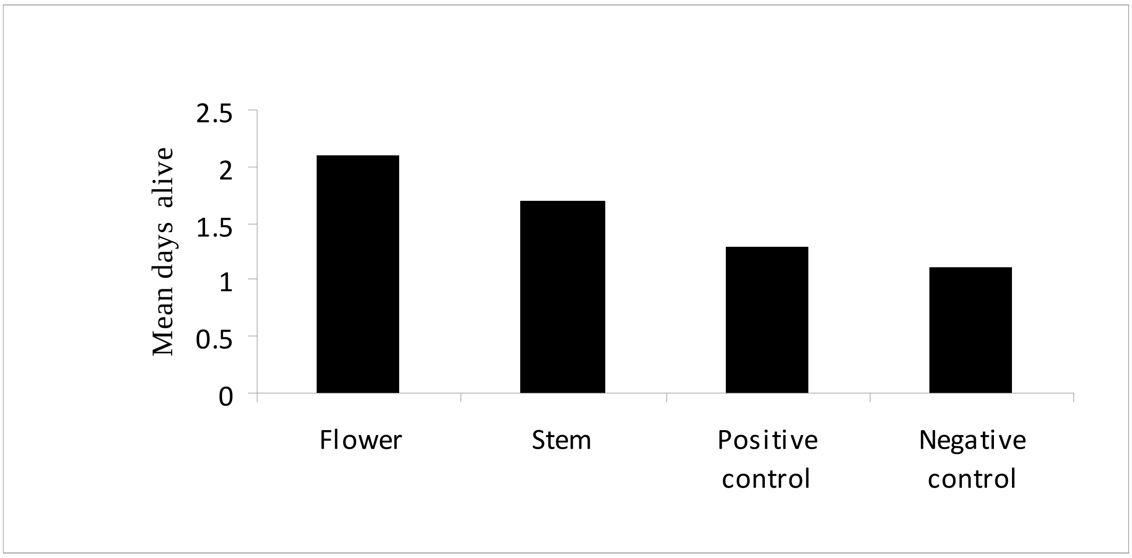


Figure 29: Effect of parts of beneficial plants, honey and water on longevity of mymarid egg parasitoids. Myrmaridae offered flowers lived longer than those that fed on water only.

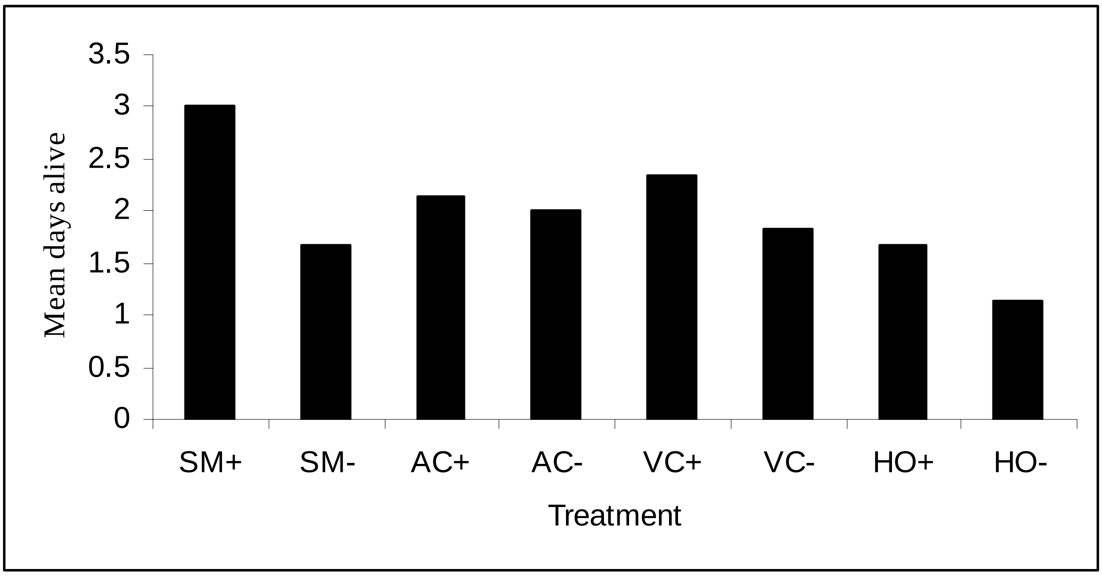


Figure 30: Mean number of days of mymarid parasitoids fed on nectar (+) and stem exudates (-) of Ageratum conyzoides (AC), Vernonia cinerea (VC) and Tunera subulata (SM). Honey (HO+) and water (HO-) were used as positive and negative controls respectively.

In the field, egg masses as well as some young stages were also found on betel nut (*Areca catechu*), Taro (Singapore), and Banana leaves at the monitoring site at Kavui (Fig.31).

Figure 31: Zophiuma egg mass on underside of Taro leaf at Kavui, WNB.

OTHER PESTS

Other typical 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.

Three reports of Oil palm webworm, *Acria* sp.nr. *emarginella* (Lepidoptera: Oecophoridae) were received from plantations on WNB but were controlled by natural enemies (parasitoids and fungi). There were no reports of this species from Mainland PNG or New Ireland.

The Powdery chafer beetle, *Dermolepida* sp. (Coleoptera: Melolonthinae) was regularly reported as it is quite large and easily seen, 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, or Black Palm Weevil, *Rhyncophorous bilineatus*.

There were no reports received by PNGOPRA of Rats received during 2006; however it is very likely that they still are not being reported as a routine to PNGOPRA. The destruction of their main predators which are all harmless snakes on WNB continues unabated. This can only lead, in the longer term, to a dramatic rise in the rat populations and damage to fruit bunches and male inflorescences.

There were no reports received by PNGOPRA of Giant African Snail (*Achatina fulica*) from any oil palm areas within PNG,

NECTAR PRODUCING BENEFICIAL FLOWERS PROJECT

Some additional photography was done with a colleague from OPRS, but no further experimental work was undertaken.

INSECTICIDE TRIALS

The only insecticidal treatment of insect pests on oil palm is undertaken through targeted trunk injection, and only when a recommendation is issued by PNGOPRA.

No aerial application of insecticides or biologicals is undertaken. On some plantations prophylactic insecticide spraying of oil palm seedlings continued to take place to kill insects however this practice was actively discouraged by PNGOPRA.

As the only insecticide currently used for controlling leaf eating pests on oil palm is the organo-phosphate, methamidophos, alternatives should be sought, that are biologically active, systemic and with a short half-life.

Three trials were conducted using a variety of possible insecticide alternatives. The standard for comparison was methamidophos, and experimental insecticides were orthene (labelled as Ortin), confidor, chlorpyrifos and dimethoate.

The first trial was set up at Kumbango (WNB), however it had to be abandoned as the field cages were either damaged by rodents or stolen and experimental insects were also destroyed by ants, consequently the data were insufficient for analysis. Laboratory bioassays were also undertaken using leaflets from the injected palms.

A report by Deane Woruba is attached as Appendix 1.

WEEVIL POLLINATION OF OIL PALM

The final report for this project was produced and submitted to the EU in August. Results from the work are being extracted for the production of scientific papers, and a first draft of a manuscript is expected to be completed during 2008. In essence, data to be presented lead to the following conclusions. To improve fruit set (and therefore yield), male flower number should not drop below 5 per ha. This is sufficient to maintain effective weevil pollination.

Fruit set is a palm character that exhibits high palm to palm variability so breeding selection for higher fruit set would seem a useful endeavour. Further, the poor fruit set response to rainy weather should be similarly amenable to influence because some individual palms are able to maintain high fruit set even in rainy weather showing that the genetic potential are already present.

Laboratory work on weevils continued at Dami with intense breeding to increase numbers of weevils from the material collected in Ghana and maintained under strict quarantine conditions. Care was taken in providing fresh uncontaminated male inflorescences and all material checked thoroughly before being used as food. Strict hygiene rules were followed, and stringent cleanliness followed. All dead and used floral material was frozen before being incinerated; dead weevils are kept, and will be sent to London to the specialist there for final confirmation that the crossed material is correct (Dr Richard Thompson).

Breeding experiments will be undertaken during 2008 to ensure the viability and fecundity of the cross mated insects.

From Mainland PNG, three sites (Sangara, Ambogo Estates and Heropa ME), were continually monitored for nematode infestation levels in the weevils (Fig.32). The procedure remained as previously described, from each site, 100 weevils were sampled every month and dissected in the laboratory. Only at Heropa did infestation levels higher than other stations, but they dropped back during the later part of the year (Fig.35). Although they are considerably smaller than males, females were more heavily infested with nematodes than males. Reasons for this are unclear, although it is possible that by spending more time on the flowers (ovipositing), they were more exposed to nematode infestation.

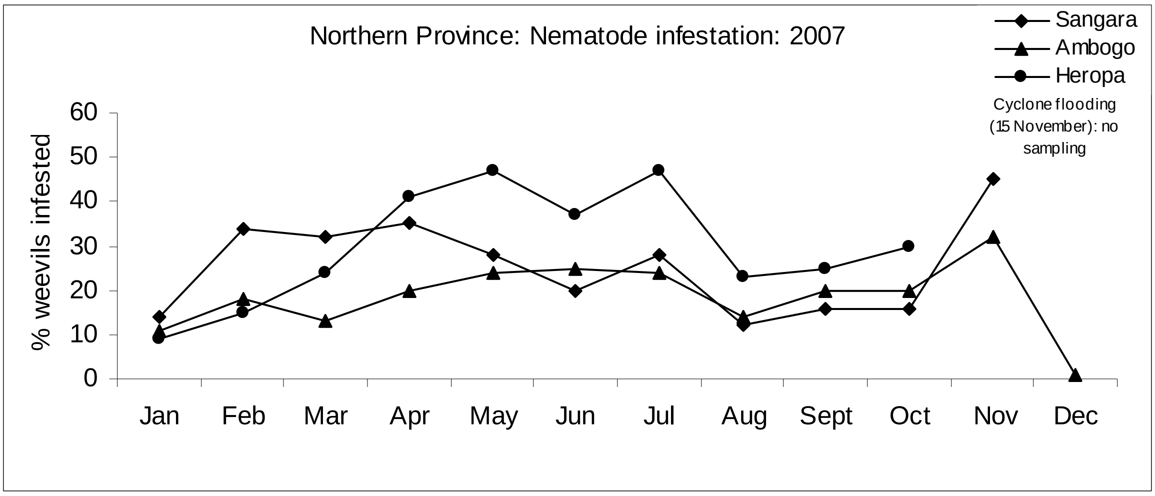


Figure 32: Nematode populations in both sexes of E. kamerunicus from three mainland sites from Higaturu Oil Palms, PNG during 2007.

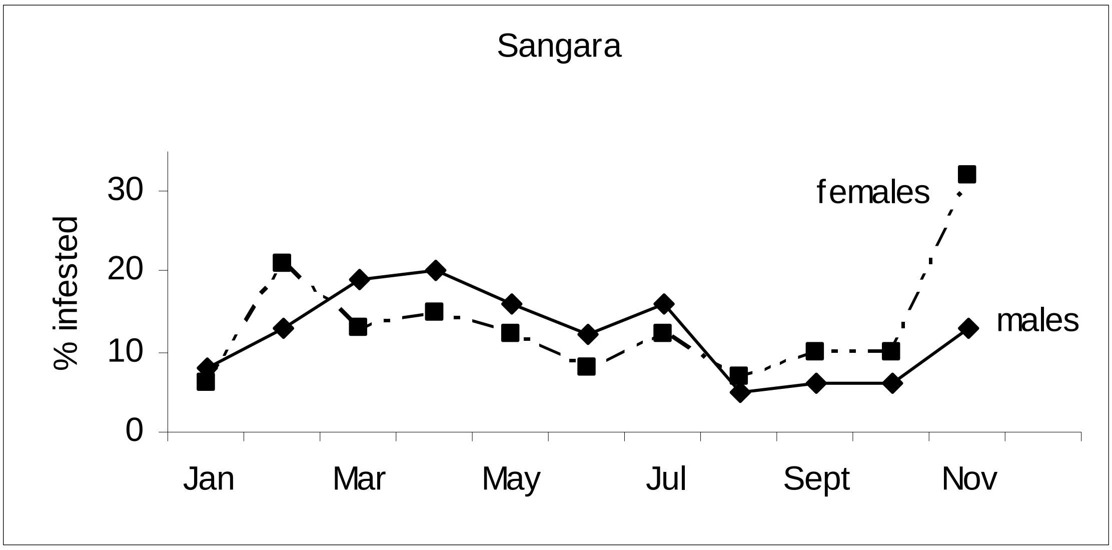


Figure 33: 2007, Nematode infestations from E. kamerunicus males and females sampled from Sangara plantation, Higaturu Oil Palms.

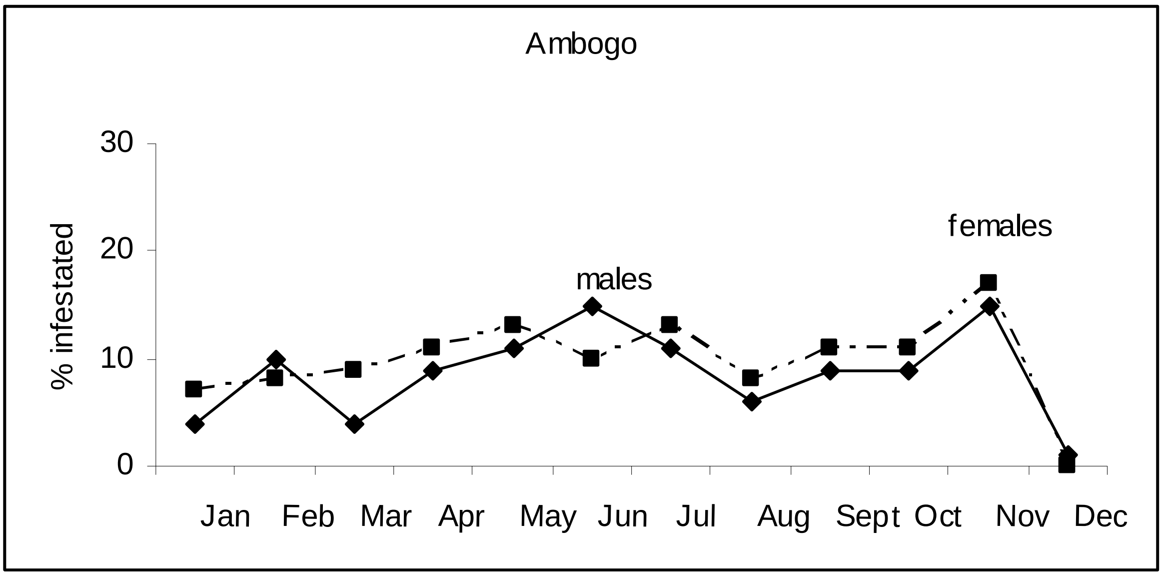


Figure 34: 2007, Nematode infestations from E. kamerunicus males and females sampled from Ambogo plantation, Higaturu Oil Palms.

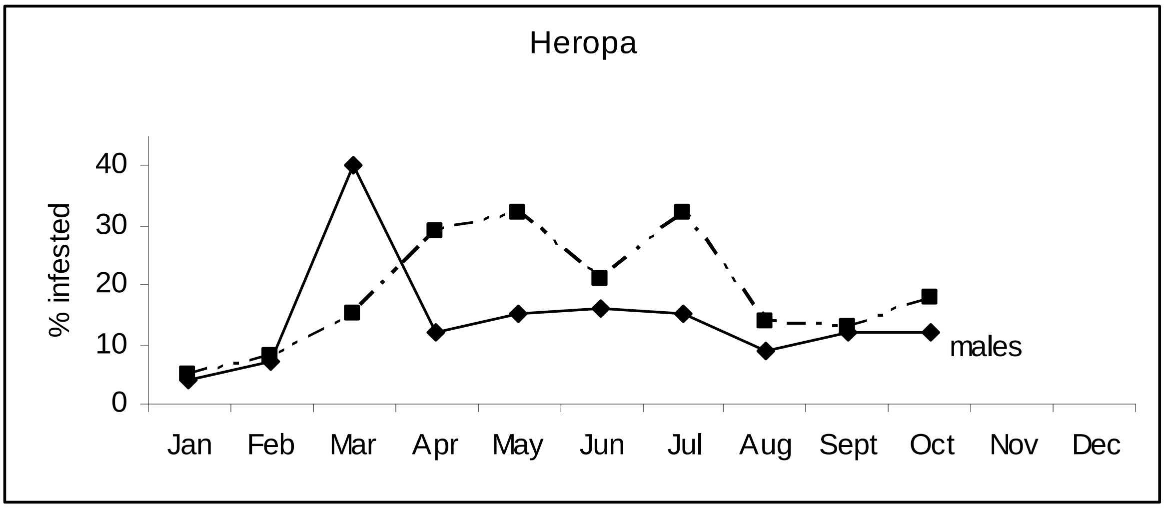


Figure 35: 2007, Nematode infestations from E. kamerunicus males and females sampled from Heropa mini estate, Higaturu Oil Palms.

No weevil monitoring was undertaken in New Ireland during 2007, but it will be started in 2008 with the anticipated posting of a PNGOPRA staff member to Poliamba.

Nursery Pest Monitoring

PNGOPRA Entomology section at Higaturu undertook regular pest monitoring at the oil palm nursery. For the majority of the year, pest infestation levels remained below 2% but there were small rises in March (5%) and October (7%). All of these infestations could have been controlled manually or through the intervention of natural enemies. Larvae of *Spodoptera litura* which are commonly found may be either manually killed or sprayed with a synthetic pyrethroid such as Karate taking great care that there is no run-off into any water courses. PNGOPRA continued to discourage the use of prophylactic spraying however it was continued monthly from October 2007 in some locations in PNG.

Table 3: 2007, Details of insect pest surveys at Higaturu oil palm nursery. (Mainland PNG).

Date	No. of seedlings in nursery	No. of seedlings sampled	No. of palms with Lymantriidae		No. of palms with Acrididae		No. of palms attacked by *S. litura* larvae		No. of palms with Bagworm		White grub
			Larvae	Cocoons	Nymphs	Adults	Batch	Individual	Rough	Smooth	
06-Jan-07	60000	14664	0	0	7	0	43	2	0	9	0
17-Jan-07	60000	3473	1	0	15	0	6	0	0	2	0
31-Jan-07	60000	14821	2	0	38	0	24	5	2	7	0
13-Feb-07	60000	12168	4	0	33	0	18	3	0	13	0
29-Mar-07	83700	6432	0	0	8	0	247	60	0	1	0
28-Apr-07	58521	7406	0	0	6	2	0	3	0	3	0
10-May-07	60000	1562	0	0	2	5	2	1	3	0	0
30-May-07	60000	1650	0	0	0	0	4	1	0	0	0
18-Jun-07	47000	5240	0	0	0	0	4	0	0	0	0
05-Jul-07	47000	5640	3	0	0	0	12	0	0	0	0
21-Jul-07	47000	4560	2	0	0	0	4	0	0	0	0
31-Aug-07	40000	2040	2	0	6	0	15	0	0	0	0
25-Sep-07	51200	8772	1	0	33	0	11	0	0	0	2
23-Oct-07	53000	1320	20	2	51	0	2	0	21	0	0
13-Nov-07	52000	2378	4	0	24	0	15	3	6	0	0
20-Dec-07	52341	9324	4	0	13	0	11	0	0	28	0
20-Dec-07	52341	9324	4	0	13	0	11	0	0	28	0
	n=	11,0774	47	2	249	7	429	78	32	91	2

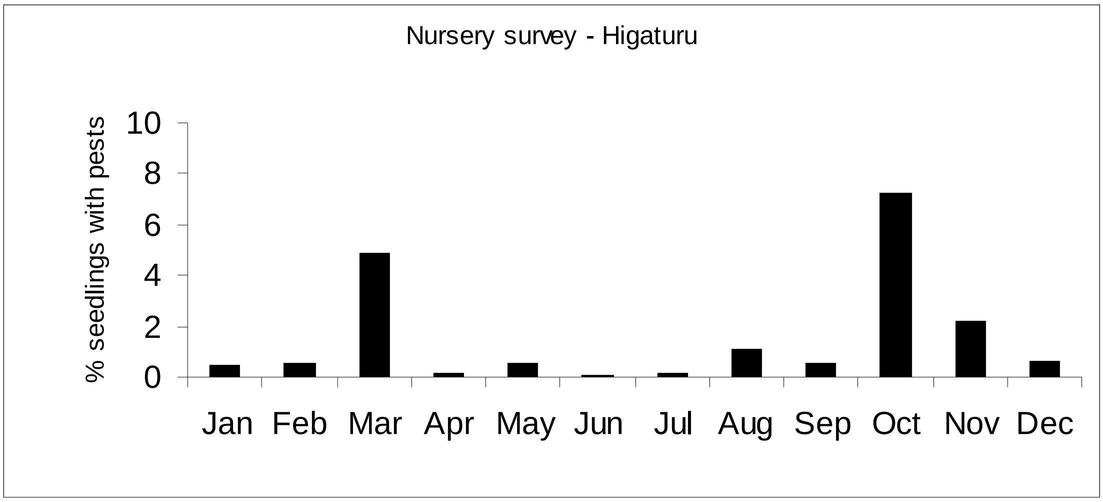


Figure 36: 2007, Percentage of seedlings recorded with pest taxa present (although not necessarily in numbers that might cause damage to the seedlings).

PNGOPRA Quarantine Facility

The quarantine facility was fully utilised during the year, with Simon Makai given responsibility for managing the weevil colony.

IPM OF WEED PESTS

Mimosa diplotricha

No additional reports were received during 2007.

Broomstick, *Sida rhombifolia*
Calligrapha penthrina (Coleoptera: Chrysomelidae) was maintained at the lab at Higaturu.

Water Hyacinth, (*Eichornia crassipes*).
Neochetina bruchi (Coleoptera: Curculionidae) was cultured at Higaturu. In WNB, at Dami, a culture was maintained but numbers were being built up for future releases.

Siam Weed, *Chromolaena odorata*
The demonstration plot was maintained at Dami; however reduced flowering at the site is not impressive, as the plants have to be controlled. The gall fly seems well established in many areas of WNB.

"*Mile*-a-minute Weed", *Mikania micrantha*

This project was agreed under ACIAR project CP/2004/064, "Biological control of "mile-a-minute" (*Mikania micrantha*) in Papua New Guinea and Fiji. PNGOPRA retains a role as the release point and multiplication centre for WNB once the required clearances are received by the project. A store was renovated (courtesy NBPOL) at Rigula ME. Shelving and shade netting were purchased and the shade-house was ready to receive infected plant material with the rust fungus *Puccinia spegazzinii*. A small 10 x 10m plot was cleared and planted near the shade house, and measurements of growth of the vine were recorded, but data were started from 22 November. A report on progress was provided to Queensland Department of Natural Resources and Mines (Dr M Day). This report will be included within the overall project report to ACIAR.

Figure 37: 2007: M.micrantha shade house at Rigula ME, WNB.

Figure 38: 2007: measuring the growth of Mikania micrantha.

CONSERVATION OF THE QUEEN ALEXANDRA'S BIRDWING BUTTERFLY (QABB).

The project agreement with Conservation International was expected during the latter part of 2006, and although a draft of the document was received in October 2006, the project started in March; however finance was not available until May 2007. Our working hypothesis for the project was that some vines from which larvae survive through to pupation contain levels of the toxic acids that are successfully sequestered by the larvae, while o0ther vines produce too much (and larvae do not survive on them or too little enabling predators to feed successfully on the larvae).

Once the project started 53 leaf samples were collected from host and non-host *Pararistolochia dielsiana* vines and sent to our collaborator at James Cook University, Australia for analysis of the content of the two main aristolochic acids. A report (see Appendix 2) was received in August with the results of the preliminary investigation.

Seed pods and seeds collected from the field were heavily contaminated by fungi, and many failed to germinate, although a procedure utilised by Dr Henderson (OPRS) using embryo rescue did show promising results.

Visits to the main butterfly localities identified by the project in Oro were undertaken as listed (Table 7), and it was very encouraging to see that and adult and larval stages were seen from February until June after which no other visits were made, as the CI project was taking over this responsibility.

Table 7: 2007: Sightings of adult QABB at Voivoro.

Date	Location	Number of sightings of life stages					
		egg	larvae	Larval stage	pupa	Adults	Sex
01-Feb-07			2	1st instars			
15-Feb-07					1		female
20-Mar-07	Voivoro		1	3rd instar			
21-Mar-07	Girigirita				1		male
31-Mar-07	Girigirita		2	4th & 6th instars			
11-Apr-07	Voivoro		1	5th instar			
18-Apr-07	Voivoro				1		male
04-May-07	Girigirita		2	1st & 6th instars			
16-May-07	Voivoro	1					
17-May-07	Voivoro					10	4 males & 6 females
23-May-07	Voivoro		1	3rd instar			
28-May-07	Voivoro					3	1 male & 2 females
08-Jun-07	Voivoro		2	3rd & 5th instars		1	female

OTHER PROJECTS

Oil Palm pest species recognition.

The majority of the boxes were distributed; however 36 remain, awaiting specimens of Black Palm weevil (*R.bilineatus*) and Rhinoceros beetle (*O.rhinoceros*).

AIGF/AIGS Proposals

The AIGS proposals will be deferred until 2008 as the AIGF structure was being revised and will be known as AIGS. One project will be re-submitted under the title, as there was no response before the end of the year.

"A pocket handbook for the identification of the main insect pests of oil palm in Papua New Guinea."

Light Trap monitoring of potential threats to seed production (with OPRS)

Daily checking of light trap samples from the Dami Seed Production Unit (SPU) continued, with a monthly report submitted to Head of Plant Breeding. No insects that might be considered a potential threat were found. Most specimens are not retained, however all catches are checked either by HoE or SM before being discarded.

INSECTICIDE TRIALS

(D. Woruba)

Introduction

Long-horned grasshoppers belonging to the family Tettigoniidae (Orthoptera) are commonly but incorrectly referred to as "sexava" in West New Britain, are the major pest of oil palm in Papua New Guinea. These insects defoliate palms resulting in lower crop yield.

In West New Britain Province, there are two species, *Segestes decoratus* and *Segestidea defoliaria*.

Figure 1: S. decoratus (female): one of the experimental insects used.

The management of these pests involves Integrated Pest Management (IPM) technologies of which targeted trunk injection of an organo-phosphate is undertaken when the damage is assessed by PNGOPRA as causing potential economic loss. The organo-phosphate (OP), methamidophos replaced the use of monocrotophos which was banned in PNG. Methamidophos has a WHO hazard rating of Category 1b, and is currently only permitted to be used in Papua New Guinea for oil palm pest control after inspection of the infestation and approval for its use given by PNG Oil Palm Research Association Inc. (PNGORPA).

A series of experiments was conducted to identify potential alternatives to this OP insecticide. The chemicals screened were Orthene 750 (labelled on the tin as Ortin), chlorpyrifos, imidacloprid, and dimethoate.

Methods

The trial palms were drilled at a 45^0 angle with a 19mm drill bit to a depth of 15cm into the trunk of the oil palm at a height of 1m (as currently recommended by PNGOPRA).

Palms used in the experiment were between 4 and 6 years old. This age group of palms was chosen because of the threat of damaging the apical meristem in younger palms and palms older than six years were too tall for practical use.

Three experiments were conducted in three locations between 15 December of 2006 and 2 October 2007.

The first two trials were conducted in New Britain Palm Oil Ltd's (NBPOL) Kumbango Plantation and the third trial was conducted in a Village Oil palm (VOP) block (#015-0075) at Banaule village, West New Britain Province.

Trial 1: Kumbango

Method

The chemicals screened in this experiment were methamidophos, acephate, chlorpyrifos and imidacloprid.

Table 1: Insecticides used

Name	Active ingredient	Concentration	Amount used per palm
Methamidophos 600ec	methamidophos	600g/L	10ml
Orthene 750	acephate	750g/L	8ml
(Chemica generic brand)	chlorpyrifos	500g/L	12ml
Mustang	imidacloprid	200g/L	30ml

The trial was set up with a randomised complete block design. Palm rows to be treated were alternated, i.e. missing one row before treating the next, (i.e. row 1, 3, 5, 7, etc).

The two guard rows of untreated palms, which act as a barrier between treatments, were ignored (edge effect). The treatments were allocated randomly to the trial palms. Treatments and one replicate were assigned to each row with one palm between each replicate.

Fronds bagged were those angled between 45° and 90° from the trunk. The frond was covered in bags 1m wide and 3m long made from nylon shade netting. Leaflets were removed from where the bag was tied for about 0.5m to prevent leaflets touching the bag and strong glue, *("Oecotak")* was put around the rachis near the area where the bag was tied to deter ants.

10 adults of a mixed population of *S. decoratus* and *S. defoliaria* were placed in each bag. The elytra on each insect were painted with white paint so the insects could be easily seen inside the bags.

Figure 2: A bagged oil palm frond.

The trial insects were introduced into the bags 3 days prior to the treatment to allow them to acclimatise. If any sexava died between the time of introduction and time of insecticide application, they were replaced with new insects.

The bags were checked every 24 hours and numbers of dead insects recorded and removed. A more detailed check of all bags was done every week.

Results (Kumbango).

Holes were discovered in the bags; it was assumed that they were damaged by crows or rats. In addition, two of the bags were stolen. These losses meant that the results were inconclusive and therefore the trial was compromised. For future work a site closer to the PNGOPRA base has been identified.

Trial 2:

Method

This trial was conducted at the same time as Trial 1. However, this trial was designed as a laboratory bioassay to investigate how long the insecticides used in Trial 1 remained active in the palms; it was not designed to test the efficacy of each insecticide.

As there were insufficient numbers of insects available, only three insects were placed per flywire cage with one cage per treatment (4 flywire cages). The flywire cages were 55cm in length and 13cm wide fitted onto pots 13cm wide and 8cm in height. The pots were filled with water-soaked shredded paper and the leaflets placed in them to prevent drying off. There was one fly wire cage for each treatment.

2 leaflets were harvested daily from each treated palm used in Trail 1 (total of 4 leaflets from each treatment), pooled together in treatment groups and fed to insects in fly wire cages. The cages were also set up 3 days prior to the introduction of leaflets from treated palms.

Every 24 hours, new batch of leaflets were added and observations made. When an insect died, a new one was added maintaining the population at 3 insects per cage.

Results and Discussion

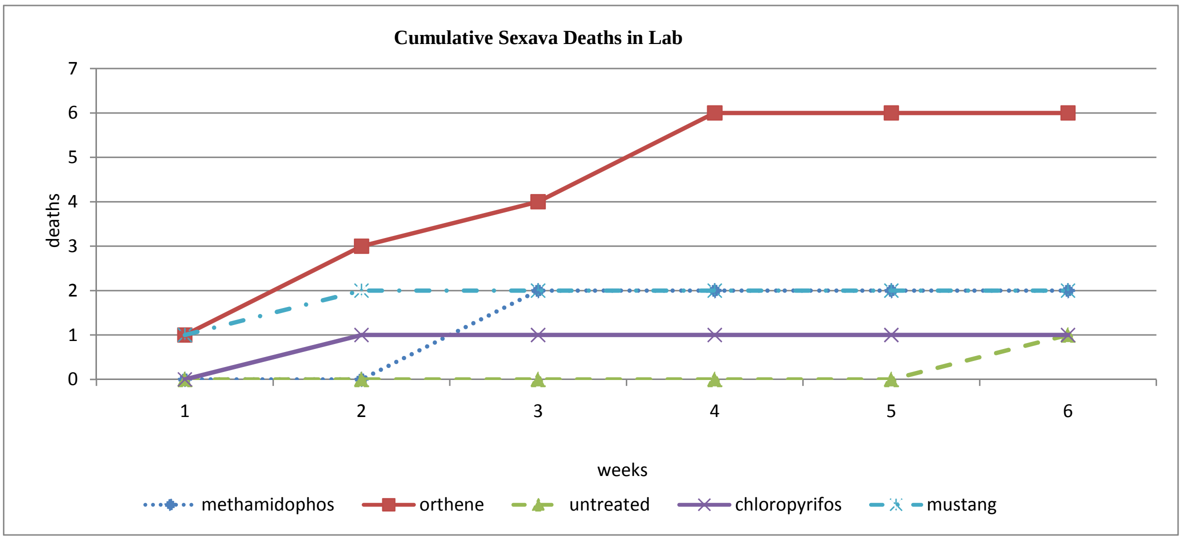


Figure 3: Cumulative sexava deaths over time.

Although insect numbers were few, orthene killed more at a consistently higher level up until the time that the untreated controls began dying. The lack of deaths expected from methamidophos until three weeks after treatment was not expected, as this insecticide results in a rapid kill after a few days under field conditions. This trial will require a repeat to investigate this anomaly.

Further trials using greater numbers of insects is required, however potentially orthene would warrant further trial, until new formulations become available.

Trial 3

Method

The trial at Banaule VOP was carried out between 20 September and 2 October 2007.

The test insects were from the all female population of S. decoratus from laboratory stocks. The insecticides tested were methamidophos (as the standard), dimethoate and confidor. As a control, untreated palms were used; thus there are 4 treatments. The insecticides and concentrations were as follows, however, it should be noted that the amounts injected were not measured proportionally but were directly compared with the current standard which meant the active ingredients were variable.

Table 2: Insecticides and concentrations

Insecticide	Concentration	Amount used per Palm
Methamidophos 600ec	600g/L	10ml
Dimethoate	750g/L	10mL
Confidor	200g/L	10mL
Untreated	-	-

Prior to treatment, the area was divided into 3 blocks. In each block there was 1 row for each treatment type (i.e. there were 4 treatment rows in a block). Between each treatment row was a guard row and at least two rows of guard row between each block. The order of treatment rows in each block was randomized (randomized block design).

In each treatment row, 7 palms were drilled and chemical injected. From these, six palms were used for the trial (one treated palm was left as a spare).

When harvested, the leaflets from each palm were placed immediately into water to prevent them wilting. To avoid any possible cross-contamination latex gloves were worn and leaflets from each treatment palm were placed in separate plastic bags. Leaflets from untreated palms were collected first to avoid contaminating other samples.

Leaflets from the first 2 palms treated with the first were bunched together and fed to one cage of bioassay insects in the lab. The holding cages for the trials were 20cm in diameter and 60cm in height made from flywire and fitted onto a black planting “polybag” filled to 20cm height with soil. Each cage contained 6 adult sexava.

From each treatment row in a block, 3 cages were set up in the lab from a single treatment to which leaflets from the 6 treatment palms were collected and provided as food.

There were 3 replicates of each treatment in 3 blocks. The wire cages were placed in blocks on raised wooden platforms for ant protection (Fig. 4). The arrangement of cages on the platform mimicked the layout in the field. Cages were set up three days before treatment to allow the insects time to acclimatize. The insects were fed daily and mortality (deaths) recorded.

Figure 4: Sexava in flywire cage on a raised platform for bioassays.

Results and Discussion.

Table 3: Cumulative mortality (expressed as percentage)

Day	methamidophos	confidor	dimethoate	untreated
0	0	0	0	0
1	0	0	0	0
4	37.6 a*	3.5 b	2.0 b	0 b
5	73.9 a	16.4 b	5.4 b	11.7 b
6	96.0 a	31.7 b	21.0 b	30.5 b
7	100 a	55.6 b	41.9 b	60.2 b
8	100 a	70.1 b	41.9 b	66.5 b
9	100 a	77.2 b	64.7 b	78.5 b
11	100 a	77.2 b	64.7 b	78.5 b
12	100a	77.2 b	64.7 b	78.5 b

Arcsin transformations applied prior to analyses, establishing significant differences between treatments, and presenting means in back-transformed percentage units.
**Means in the same row followed by a similar letter do not differ significantly (p>0.05)*

A ‘repeated measures’ analysis across days 4-12 showed significant main effect ‘treatment’ and ‘time’ effects, but no significant ‘treatment x time’ interaction. Figure 5 is a graph of the data points.

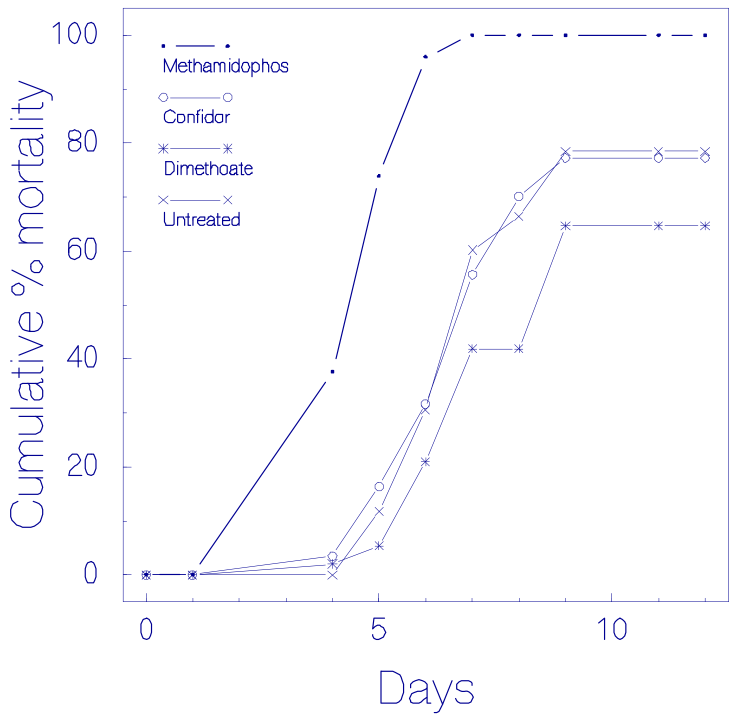


Figure 5: Analysed cumulative mortality (expressed as percentages), (Source: B.Mayer).

Confidor and dimethoate did not perform as well as methamidophos thus excluding them as potential alternatives for further screening. It was possible that the confidor had remained unused for too long, as an earlier trial had shown significant mortality. This insecticide will be repeated. The means of their mortality rate did not significantly differ ($p>0.05$) even against the Untreated “control”.

The high mortality in the Untreated asks questions of the trial methodology, and we will need review the handling methods, as S. decoratus die easily without careful handling.

During the period of investigation, the trails did not go as planned and as was shown from the first two trials where data that were produced were inconclusive. This, however, has helped us to perfect techniques that will be used for future insecticide trials e.g. an effective laboratory bioassay.

Acknowledgements

We are most grateful for analytical advice from Dr Bob Mayer of Queensland DPI. We also thank the management of NBPOL Kumbango Plantation. The NBPOL Small Holder Affairs (SHA) and Mosa Group pest treatment teams who undertook the treatment of the palms.

QUEEN ALEXANDRA BIRDWING BUTTERFLY

Report on the ecology of Queen Alexandra Birdwing Butterfly, *Ornithoptera alexandrae* in relation to its host plant *Pararistolochia dielsiana*

Pupa of QABB at Voivoro village, Oro, PNG

A collaborative project between Cargill and Temasek Plantations, Conservation International, Department of Environment and Conservation, PNG Oil Palm Research Association and Oro Provincial Government

REPORT - March to June 2007

Introduction

The Queen Alexandra Birdwing Butterfly (QABB) ecological research project was funded by Cargill and Temasek Group of Plantations (CTP) and started in March 2007 facilitated by Conservation International. The project was undertaken in collaboration with Higaturu Oil Palm (HOP), Department of Environment and Conservation (DEC), and Oro Provincial Government (OPG).

The role of PNG Oil Palm Research Association was to clarify the working hypothesis that the host vine contains chemicals that may protect the QABB larvae or act as a defence for the vine against feeding of the butterfly larvae: while too much sequestered chemical will kill the QABB larvae.

- Develop a protocol for the collection of *Pararistolochia* vine leaves for analysis.
- Identify a suitable analytical laboratory and send leaf material for analysis of chemical composition, and acid concentrations.
- Analyse and interpret leaf chemical analysis data and extrapolate lab results of leaf analysis in relation to possible effects on QABB development.

P. dielsiana Host vine tagged.

QABB larva.

Protocol for sampling *Pararistolochia* vine leaves

- Established a transect of 20m wide and 830 m long at Voivoro.
- Locate all *Pararistolochia* vines and label with the date and a unique number on an aluminium tag and fasten to the vine.
- Each vine must be checked during each visit for larval stages of *Ornithoptera alexandrae* or *Ornithoptera priamus*.
- Select the 3rd and 4th leaves, (counting down the vine, from the leaf on which the larva is currently feeding).
- Ensure as far as possible in the field, that the surface of leaves are free from contamination by fungus, algae and lichen, as this will delay processing during quarantine inspection in Australia.
- Cut leaves with a small sharp knife and place in an air-tight plastic bag and label.
- Record the date of collection, vine number and location where the leaves were sampled (e.g. in this case top of vine), and place in plastic bag with the leaf samples.
- Write down the same details on the plastic bag.
- Select two last leaves at the base of the vine.
- Number and location where the leaves were sampled (e.g. in this case bottom of vine), and place into plastic bag with the leaf samples.
- Write the same details on the plastic bag.
- In the laboratory, air-con dry the leaves for 3 days and place in the freezer (-18 degrees) awaiting packing and
- Air freight leaf samples to James Cook University in Townsville for analysis of aristolochic acid I and II.

Field visits

In conjunction with the Provincial Wildlife officer and HOP, 9 field trips were made to Voivoro and one to Indawore to sample leaves from vines, which are host of QABB and *O. priamus* larva. Leaves were sampled on 3 of the visits to Voivoro while at Indawore sampling was done on the 4th April 2007 (Table 1). Four leaves each from 13 vines were sampled. The other 3 vines sampled did not have enough leaves so only 2 or 3 leaves were sampled from these vines. In total, 53 leaves were sent to James Cook University.

Table 1: 2007, Leaf samples collected from host vines of O.alexandrae and O.priamus.

Host vine	Location	Date leaf sample collected	Vine number	Leaf sample number
O. alexandrae	Voivoro	11-Apr-07	Oa-001	1A
				1B
		11-Apr-07	Oa-002	2A
				2B
	Indawore	04-May-07	IOa-001	3A
				3B**
		04-May-07	IOa-002	4A
				4B**
	Voivoro	23-May-07	Oa-005	5A
				5B
O. priamus	Voivoro	11-Apr-07	Op-001	6A
				6B
		11-Apr-07	Op-002	7A**
				7B*
	Indawore	04-May-07	IOp-001	8A
				8B
		04-May-07	IOp-002	9A
				9B
		04-May-07	IOp-003	10A
				10B
Non host vine	Voivoro	11-Apr-07	Oa-003	11A
				11B
		11-Apr-07	Oa-004	12A
				12B
		29-May-07	Oa-006	13A
				13B
		29-May-07	Oa-007	14A
				14B
		29-May-07	Oa-008	15A
				15B

A = two younger leaves sampled from vine, B = two older leaves sampled from vine
* = one not sampled from vine, ** = two leaves not samped from vine

Analysis of concentration of Aristolochic acid 1 and 2 in *P.dielsiana* leaves

The School of Pharmacy and Molecular Science at the James Cook University undertook work on investigating Aristolochic acid I and II in leaves of *Pararistolochia dielsiana* vines.

The initial stage was to develop an accurate and appropriate method to separately identify and quantify amounts of aristolochic acids I and II in solutions of leaf extracts. This involved High Performance Liquid Chromatography (HPLC) conditions utilising a C18 reverse-phase column, elution with acetonitrile/0.01M KH_2PO_4, and diode-array ultra-violet detection.

Standard curves were constructed for aristolochic acid concentrations between 5 and 1000µg/ml, representing leaf concentrations between 1 and 200 µg/g dry weight of leaf material. This verified that aristolochic acid I or II in concentrations from leaf extracts that contained as little as 1 µgram of aristolochic acid per gram dry weight of leaf material can be separately identified and quantified.

In addition, a method to extract small quantities of aristolochic acids from leaf material was developed. This involved separating acidic components from other plant metabolites to remove interferences by other components in the quantification of aristolochic acids and minimise the volume of solvent necessary to dissolve the extract ready for analysis. This has enabled determination of aristolochic acids in leaf samples as small as 1g dry weight to the required accuracy. This is because the purified extract (i.e. the material to be analysed) can be dissolved in a small volume (200 µlitres) of solvent prior to analysis, and utilised 5µl aliquots for each analysis.

An Import Permit was obtained on 30th March, 2007 from AQIS (Australian Quarantine and Inspection Service) to import the *Pararistolochia* leaf material for analysis, and the first shipment of *P. dielsiana* leaf material (samples of 4 leaves from 15 vines) was sent on Wednesday 13th June 2007. Under the terms of the Import Permit, this material was held in Quarantine and cold treated at less than -18 degrees for 7 days.

Preliminary result of aristolochic acid I and aristolochic acid II in leaf samples are summarised in Table 2.

Table 2 Average concentrations of aristolochic acid 1 and aristolochic acid 2 in leaves of P. dielsiana which hosted QABB and O. priamus larvae.

		Aristolochic acid 1 conc'n (ug/200ml)	Aristolochic acid 2 conc'n (ug/200ml)	Total conc'n per 200ml (ug/200ml)	Total conc'n per 1ml (ug/1ml)	Average leaf mass (g)	Average aristolochic acid per g of leaf. (ug/g)
QABB host vines	Young leaves	12.68	1.33	14.01	70.07	1.42	55.64
	Older leaves	9.84	2.27	12.11	60.54	1.27	45.36
O. priamus host vines	Young leaves	14.41	1.47	15.88	79.40	.87	91.48
	Older leaves	12.43	2.52	14.95	74.76	1.25	59.37
Non host vines	Young leaves	17.38	3.29	20.67	103.36	.57	373.67
	Older leaves	29.02	2.93	31.94	159.71	1.10	164.54

The concentration of Aristolochic acid 1 is significantly higher (P = 0.05) then concentration of aristolochic acid 2 in all leaf samples. For example, average concentration of aristolochic acid 1 in young leaves sampled from a QABB host vine is 12.68ug/200ml where as the average concentration of Aristolochic acid 2 is 1.33ug/200ml of the same leaf.

Also, the concentration of aristolochic acids in the young leaves are significantly higher (P = 0.05) then the amounts in older leaves. The average concentration of aristolochic acid in younger leaves from *O. primus* food plant is 91.48 ug/200ml compared to average concentration of 59.37ug/200ml contained in older leaves.

The average concentrations of aristolochic acids in the young leaves of QABB host vine was 55.64ug/g of leaf compared to 91.48ug/g of leaf in young leaves of *O. priamus* host vine.

The concentration of aristolochic acids in leaves of vines that did not host larvae was significantly higher (P = 0.05) then that of QABB host vines or *O. priamus*. For example, average concentration of 373.67ug/g of leaf in young leaves of vines that did not host larvae compared to 55.64ug/g of leaf in young leaves of vine that hosted QABB larvae.

Propagation of QABB vines

(Collaborator: Dr W. Henderson, OPRS).

The tissue culture laboratory of New Britain Palm Oil Limited in West New Britain province under took work to develop a protocol to establish mother vines so that regular supply of quality material is available to continue with the process of developing a tissue culture based micro propagation system. Utilising stem cuttings and seeds collected from Voivoro area in the Northern Province.

P. dielsiana seedlings germinated from seeds-OPRS, West New Britain.
(photo W. Henderson)

Juvenile stem cuttings were treated with a mixture of 1.5 g/L NAA + 1.5g/L IAA and planted in coarse river sand. There were callus and weak root growth in the initial stage of development but none had successfully produced shoot. Eight matured vine cuttings were trialled and after 11 weeks only 1 vine produced shoots.

Attempts to germinate vines from seed pods contaminated by fungus were unsuccessful. Whole pods, both green and brown, were planted in coarse river sand was unsuccessful in producing vine seedlings. However, 150 seeds from a green pod were successfully initiated into an aseptic culture. After 11 weeks, 10 viable seeds were sampled from this batch, dissected and the embryo's rescued in an attempt to obtain seedlings. Two seeds have germinated on a culture media designed specifically for oil palm embryo culture. However, one is progressing better then the other.

On the 9th August 2007, 50 viable seeds that did not germinate were removed from the culture and 34 embryos were rescued. Of this 34 embryo, 14 germinated.

Movement of flight cages from Afore

Two visits were made to Afore by staff of HOP, PNGOPRA and the Provincial Wildlife Officer (PWO) to recover two flight cages which were established by the former Oro Conservation Project. The aim was to erect them at Voivoro and Hombareta Wildlife Management Area on the Popondetta plain to breed other species of butterflies for tourist attraction. On the 21st February 2006, the cages were dismantled and stock piled at Pongani Bridge which was half way down the highway. On the 28th February 2006, two Toyota landcruisers which belong to PNGOPRA and HOP were used to move the frames down to PNGOPRA office yard for safe keeping. On the 1st May 2007, the PWO purchased a roll of shade cloth measuring 100 meters in length and 4 litres of weather proof paint for the cages. The cages have not been re built at this time.

Conclusion

Methods to separately identify and quantify amounts of aristolochic acids I and II, and purifying acidic extracts from other plant metabolites was developed. This was necessary to cater for the small quantity of leaves to be analysed.

Analysis of *P. dielsiana* vines showed that in all leaf samples the concentration of Aristolochic acid 1 is significantly higher than Aristolochic acid 2. Also, the concentration of aristolochic acids in the young leaves are significantly higher than the amounts in older leaves. There was little difference in the amount of Aristolochic acids within host vines. However, the amount of Aristolochic acids in vines that did not host QABB larvae was significantly higher than those without larvae from the same plant.

A method of propagating vines from stem and seeds is being developed.

Future work

Number of points to consider when planning work for the future;

- Funding and extension of this work is required to increase leaf sampling density within the Popondetta plains to obtain quality and quantitative results.
- More time is required for the analysis work done by James Cook University and results of the parallel analysis will be available end of August 2007.
- A protocol for propagating vines from stem cuttings is vital at this stage and more seeds are required to furnish the seed propagation protocol.
- Study of the ecology and biology of the pollinating agents of *P. dielsiana* so as to obtain quality and uncontaminated seeds.
- A qualified carpenter is required to erect the two cages at Voivoro and Hombareta WMA. In the cage, food plants of other species of butterflies will be planted and butterflies bred for tourist attraction.

This work should continue, as there are tantalising pieces of information coming out of the work, and large quantities of leaf samples are required to determine amounts of Aristolochic acids within vines hosted by QABB and *O. priamus*. Leaves will be sampled from Gewoto, Hombareta, Ahora-Beuru and Afore areas.

A Report from the Investigation of Pararistolochia Leaf Samples for Aristolochic Acid Content.

(Associate-Professor Bruce F. Bowden, James Cook University, Townsville, Australia)

"To date the work carried out has centred on verification of the appropriateness and accuracy of the method to be utilised".

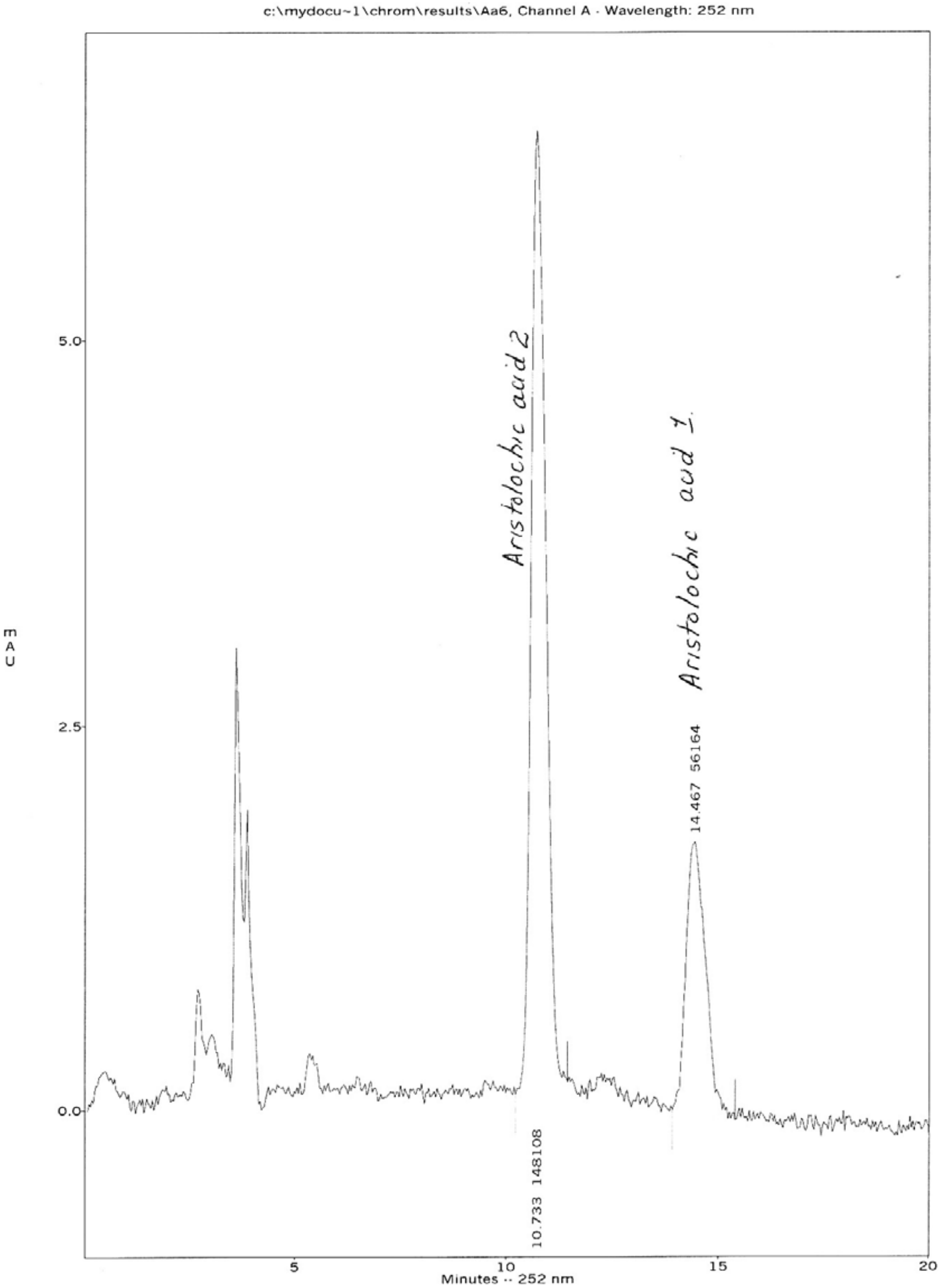
Aristolochic acid (a mixture of aristolochic acids I and II) has been purchased from Sigma and appropriate HPLC conditions have been developed to separate and quantify the aristolochic acid concentration utilising a C18 reverse-phase column, elution with acetonitrile/0.01M KH_2PO_4, and diode-array uv detection. This has enabled us to construct standard curves for aristolochic acid concentrations between 5 and 1000µg/ml, representing leaf concentrations between 1 and 200 µg/g dry weight of leaf material. This has verified that we can separately identify and quantify the amounts of either aristolochic acids aristolochic acid I or aristolochic acid II in solutions that would correspond to leaf extracts that contain as little as 1 µ gram of aristolochic acid per gram dry weight of leaf material. The ability to extract small quantities of aristolochic acids from leaf material has also been verified and a method to separate the acidic components from other plant metabolites developed (to remove interferences by other components in the quantification of aristolochic acids and minimise the volume of solvent necessary to dissolve the extract ready for analysis).

This has been demonstrated to enable determination of aristolochic acids in leaf samples as small as 1g dry weight to the required accuracy, because it allows the purified extract (i.e. the material to be analysed) to be dissolved in a small volume (200 µ litres) of solvent prior to analysis, and utilises 5µl aliquots for each analysis.

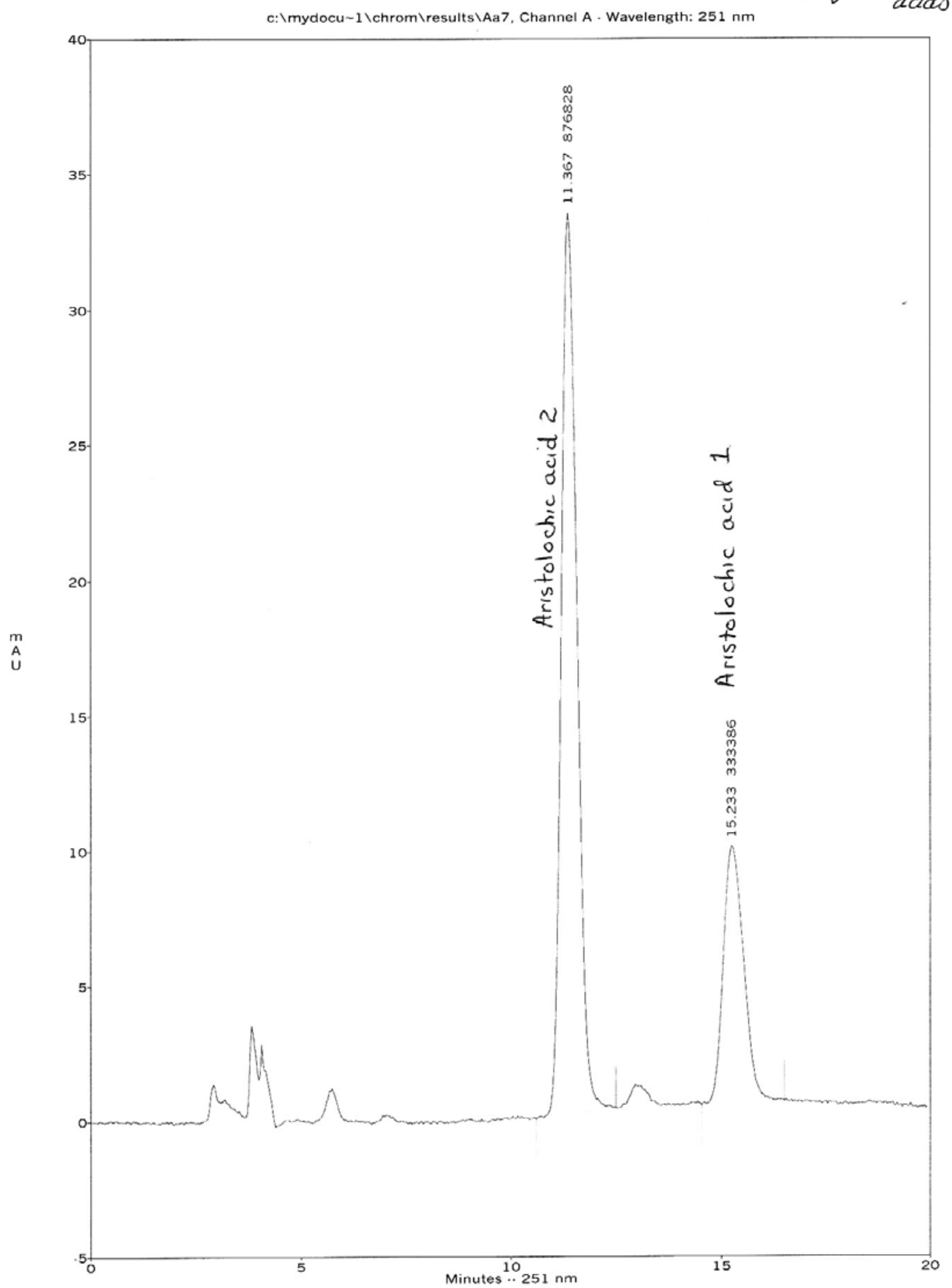
An Import Permit was obtained on 30th March, 2007 from AQIS (Australian Quarantine and Inspection Service) to import the *Pararistolochia* leaf material for analysis, and the first shipment of *P. dielsiana* leaf material (samples of 4 leaves from 15 vines) was received on Thursday 21st June. Under the terms of the Import Permit, this material was held in a Quarantine-approved PC2 premises at less than -18 degrees for 7 days after arrival.

The leaf material is currently undergoing extraction and preparation of the extracts (isolation of the acidic components as described above) prior to analysis. We expect to complete the analysis of aristolochic acids in these initial leaf samples within the next week. Examples are attached below, where the two clear peaks of activity can be clearly seen".

Solution concentration (total aristolochic acids) = 20 μg/5 ml.
5 μl injection = TOTAL of 0·02 μg aristolochic acids.



Solution concentration (total aristolochic acids) = 100µg/5ml.
5µl volume used = TOTAL of 0.1µg Aristolochic acids.



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3. PLANT PATHOLOGY RESEARCH

(Dr. C. A. Pilotti)

INTRODUCTION

The Ganoderma project and the sub-projects contained within it have been funded under the European Union Stabex over 2 phases since 1995 and the final phase of the project ended in November 2007. A separate final report has been prepared for the second phase from 2003 to 2007.

The epidemiology of basal/upper stem rot and the population structure of *Ganoderma boninense* continued to consume the bulk of resources in terms of time and funding in 2007. Sample collection for the research on the population structure of *Ganoderma* in selected study blocks in Milne Bay was completed in December 2007. It is expected that genetic analyses will carry over into 2008. Survey data will continue to be collected and analysed for future reference.

A large proportion of the research in 2007 was also spent on assessing the suitability of a technique for screening of resistance of oil palm to attack by *G. boninense*. The technique has been refined and mass screenings can now be carried out.

Research on the biocontrol agent *Trichoderma* also continued in 2007 with part of this work being carried out at the University of Kent in Canterbury.

Training and technical services in the form of site visits and publications also constituted a significant part of the work of this section in 2007.

THE EPIDEMIOLOGY OF BASAL STEM ROT

Objectives: *(1) To determine the mechanisms of primary and 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.*

Introduction

Studies on the progression of Ganoderma stem rots over several years provide means through which predictions of crop losses may be made in future generations of oil palm plantings. The characteristics of the Ganoderma disease epidemic are studied through the use of disease survey data provided by commercial plantations as well as data collected from surveys carried out by PNGOPRA personnel in designated study blocks in Milne Bay and West New Britain.

Short-term control strategies have been implemented in for 12 years in mature plantings in Milne Bay but the effectiveness of this strategy is difficult to measure in the absence of ‘control’ blocks. In plantations where the disease is prevalent, recommended sanitation procedures may not always be practiced. This presents a challenge to quantify the effects of the current control programme.

1.2 Methodology

All data presented here has been obtained from Milne Bay Estates Ltd., Poliamba Ltd. and New Britain Palm Oil Ltd. Where possible, survey data has been corrected by comparison to the previous year’s survey data. Data has also been filtered to exclude inadequately sanitized stumps, sterile and standing dead palms. Hence, only 2007 infections have been reported here. Surveys were carried out only once in the majority of blocks in Milne Bay and hence disease incidence may be underestimated for some Divisions and Blocks.

Disease survey data for PNGOPRA study blocks has been collected by PNGOPRA personnel bi-annually (Milne Bay) or quarterly (West New Britain).

1.3 Disease progress in first generation oil palm

1.3.1 Milne Bay

A summary of the total number of infected palms in each Division in Milne Bay is shown in Figure 1.1.

Naura Division recorded 2531 palms with symptoms and 637 palms containing brackets to give a total of 3168 palms detected with Ganoderma in 2007. Tamonau Division recorded a total of 1953 infections in 2007. Kwea Division recorded the lowest infections in 2007 with 188 diseased palms but this was due to a number of heavily infected blocks undergoing replant.

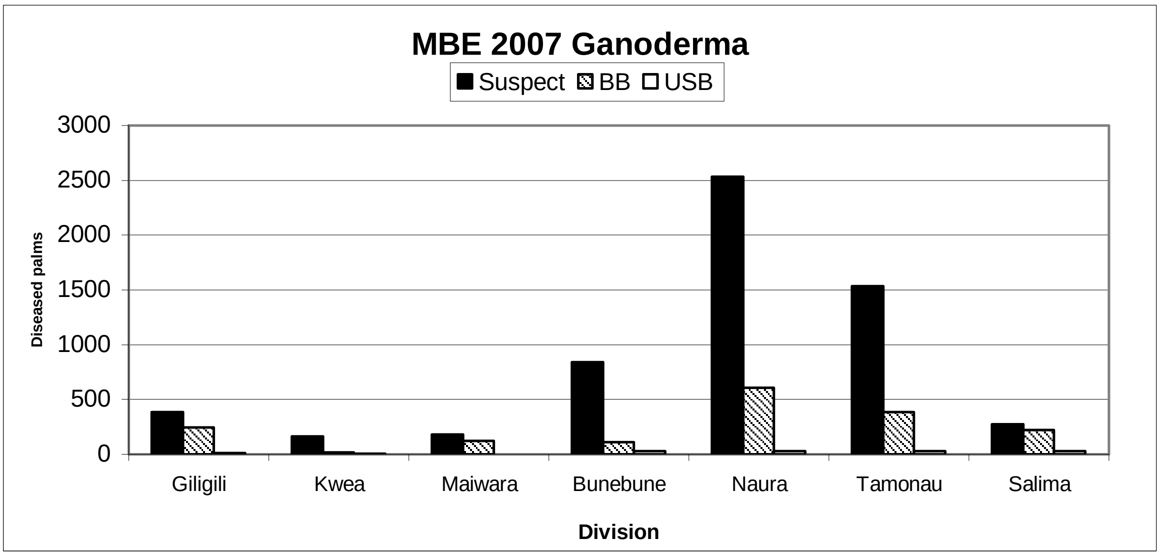

Figure 1.1. Number of diseased palms detected in all Divisions in Milne Bay in 2007.

On the basis of area, this translates recorded losses of 5.52 palms/ha in Naura Division with Bunebune recording 3.23 and Tamonau 1.86 palms/ha (Figure 1.2). Salima Division recorded the lowest losses with 0.42 palms/ha being infected in 2007.

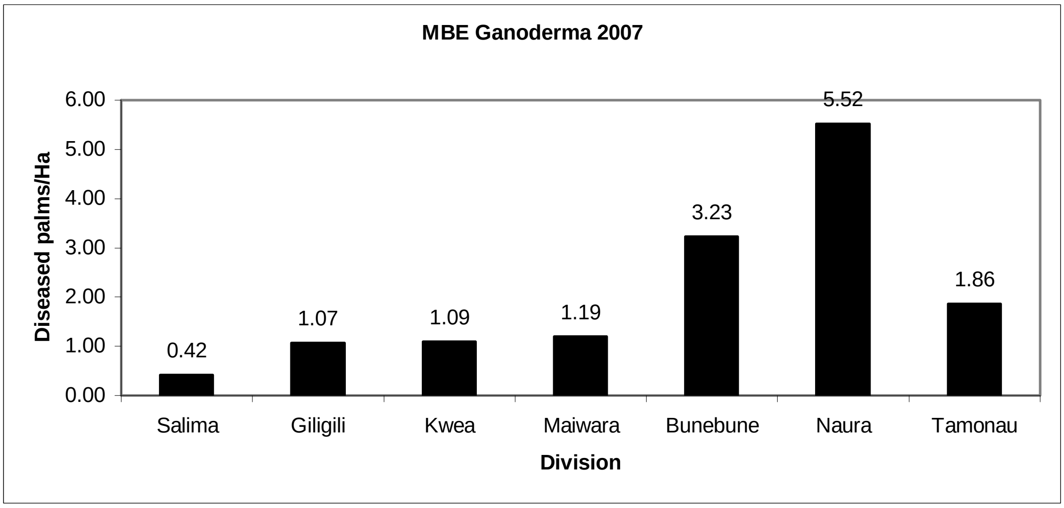

Figure 1.2 Losses due to Ganoderma in each Division in Milne Bay in 2007.

Figure 1.3 shows the total disease incidence for all blocks surveyed in Giligili Division. Only 86% of blocks were surveyed in 2007. Blocks with the highest disease levels were 7205 and 7214 with just under 2.5 palms/ha.

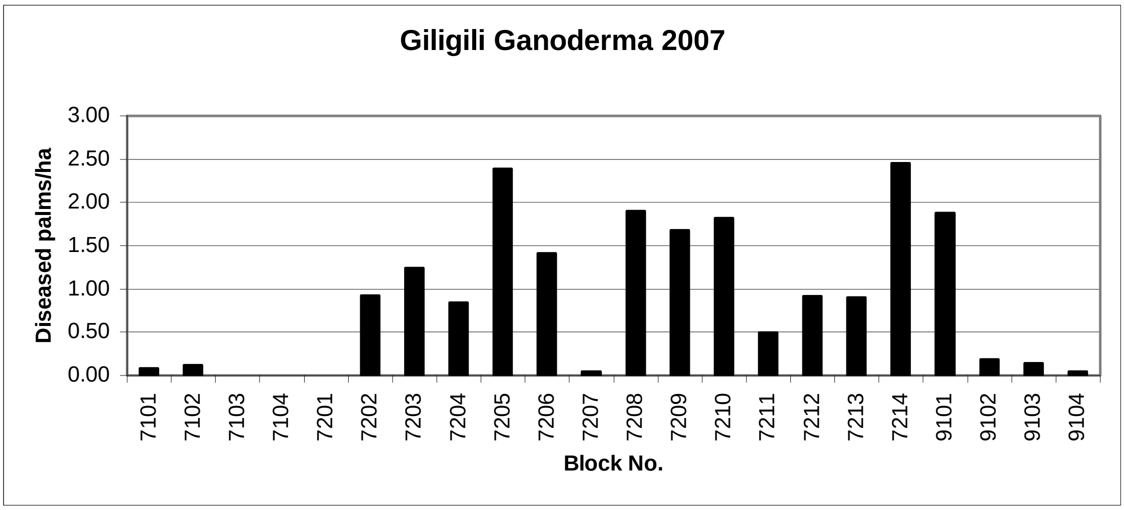

Figure 1.3 Disease incidence expressed as total number of diseased palms per hectare includingpalms with basal and upper stem rot and suspects, for Giligili Division, Milne Bay in 2007.

In Kwea Division 47% of blocks were surveyed in 2007 and most of these only once.

The blocks that received mill effluent in the past (6303, 6304, 6305 and 6306) were replanted in 2007 and survey data was not collected prior to replant (Figure 1.4) this lowered the total disease rate for Kwea to 1 palm/ha down from 3-5 palms/ha being infected in 2006. Block 6104 recorded the highest disease with 2.05 palms/ha.

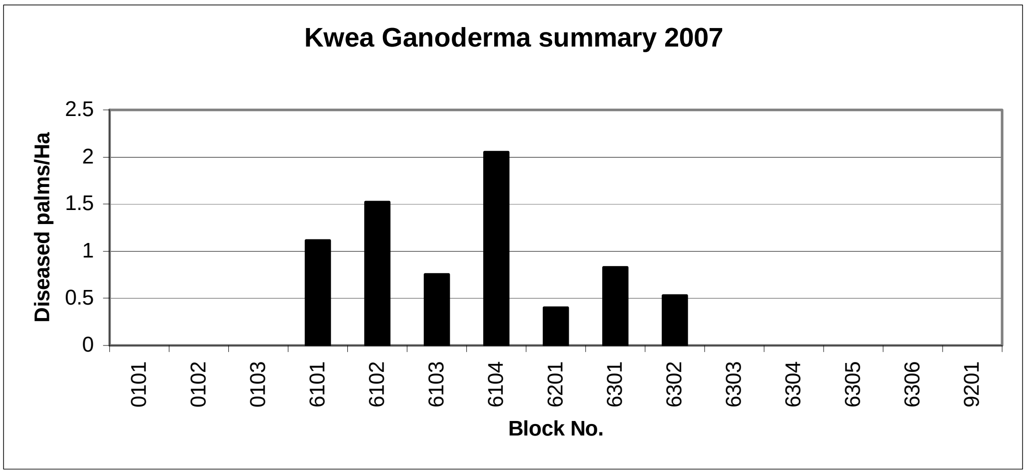

Figure 1.4 Disease incidence expressed as number of diseased palms per hectare for Kwea Division, Milne Bay in 2007. Total number of palms includes basal stem rot, upper stem rot and suspect palms.

Only 74% of blocks within Naura Division were surveyed in 2007 (Figure 1.5). The highest recorded incidence of Ganoderma was 6.31 palms/ha for Block 6605. The majority of blocks in Naura recorded higher disease levels than blocks in other Divisions and this may be a reflection of the low number of removals carried out on an annual basis

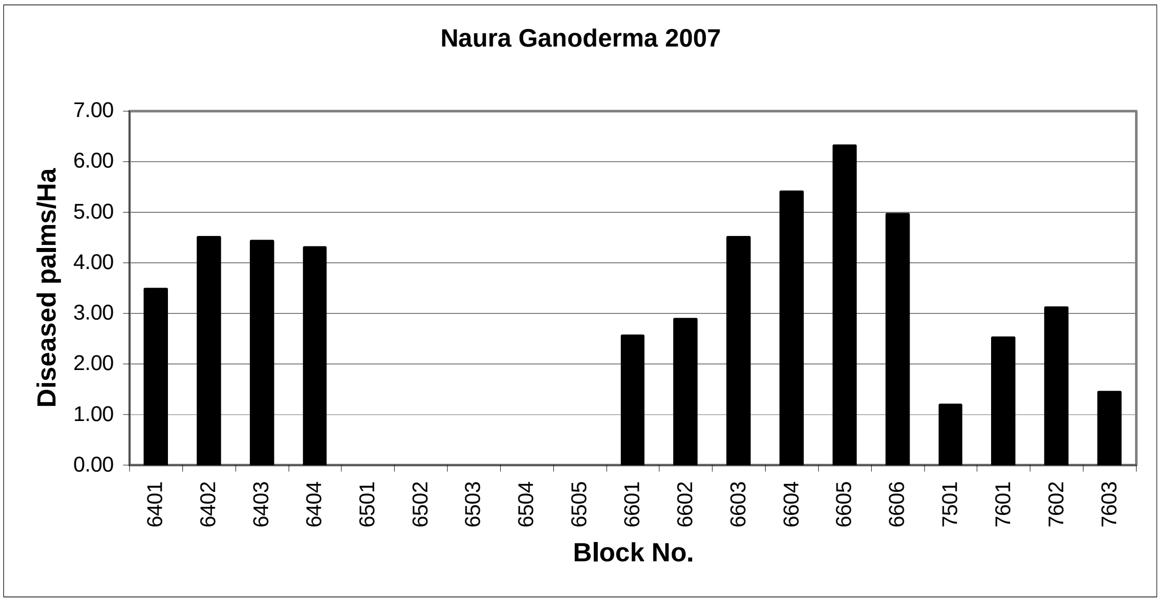

Figure 1.5 Disease incidence expressed as number of diseased palms per hectare for Naura Division, Milne Bay in 2007. The total includes palms with basal stem rot, upper stem rot and suspect palms.

Forty-five percent of blocks in Buebune Division were surveyed in 2007 (Figure 1.6). The block with the highest infection levels was Block 7301 with 2.09 palms/ha becoming infected in 2007.

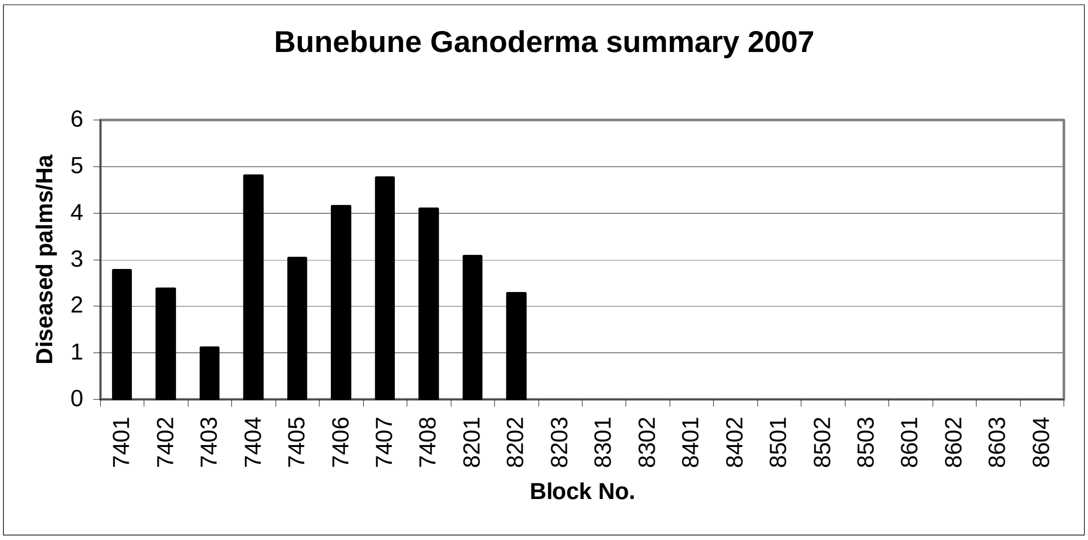

Figure 1.6 Disease incidence expressed as number of diseased palms per hectare for Bunebune Division blocks, Milne Bay in 2006. Total includes palms with basal stem rot, upper stem rot and suspect palms. Blocks without bars were not surveyed.

Maiwara Division generally recorded low levels of Ganoderma although these blocks were not surveyed properly in 2006. In 2007, only 57% of the blocks in this Division were surveyed (Figure 1.7). Block 7301 recorded the highest disease incidence with 2.09 palms/ha being diseased.

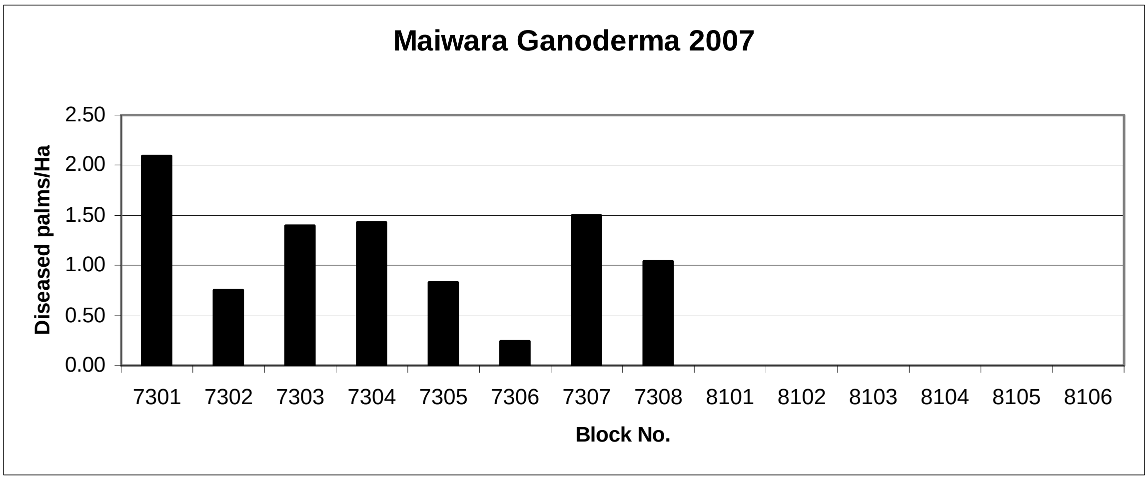

Figure 1.7 Disease incidence expressed as diseased palms/ha for Maiwara Division, Milne Bay in 2007. Total includes palms with basal and upper stem rot and suspect palms.

As for the other Divisions, not all blocks were surveyed in Tamonau and Salima Divisions. In Tamonau only 47% of blocks were surveyed with 89% of blocks being surveyed in Salima Division in 2007 (Figures 1.8 and 1.9).

Salima Division generally recorded the lowest levels of disease in 2007.

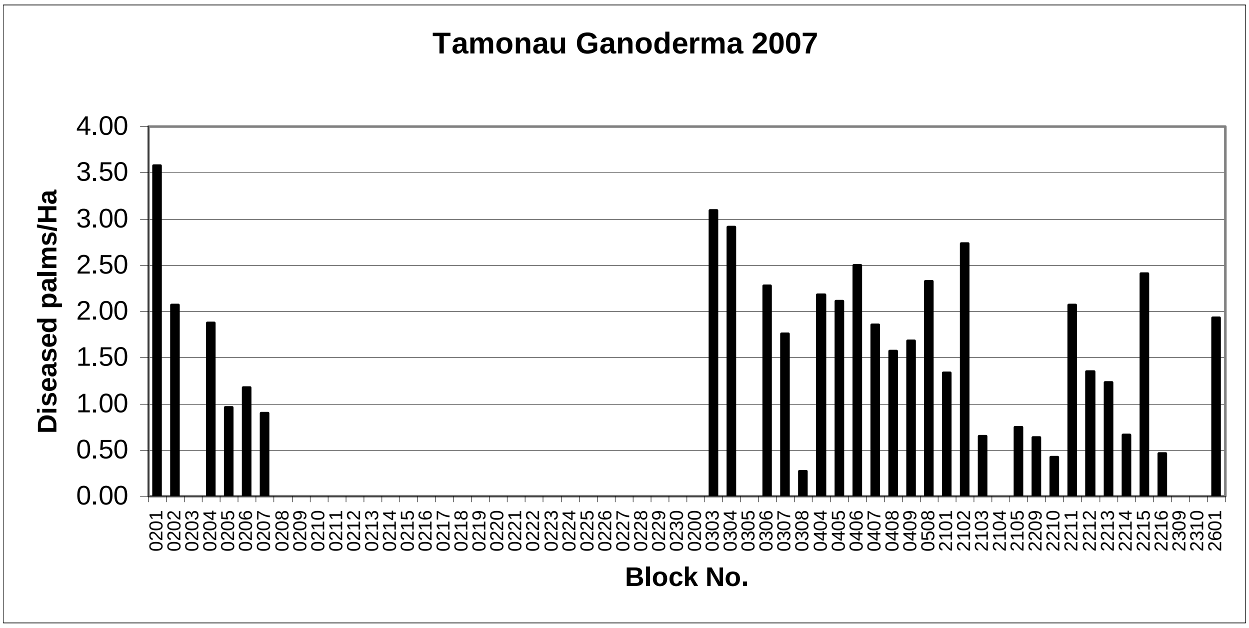

Figure 1.8 Disease incidence expressed as number of diseased palms per hectare for Tamonau Division, Milne Bay in 2007. Total includes palms with basal stem rot, upper stem rot and suspect palms.

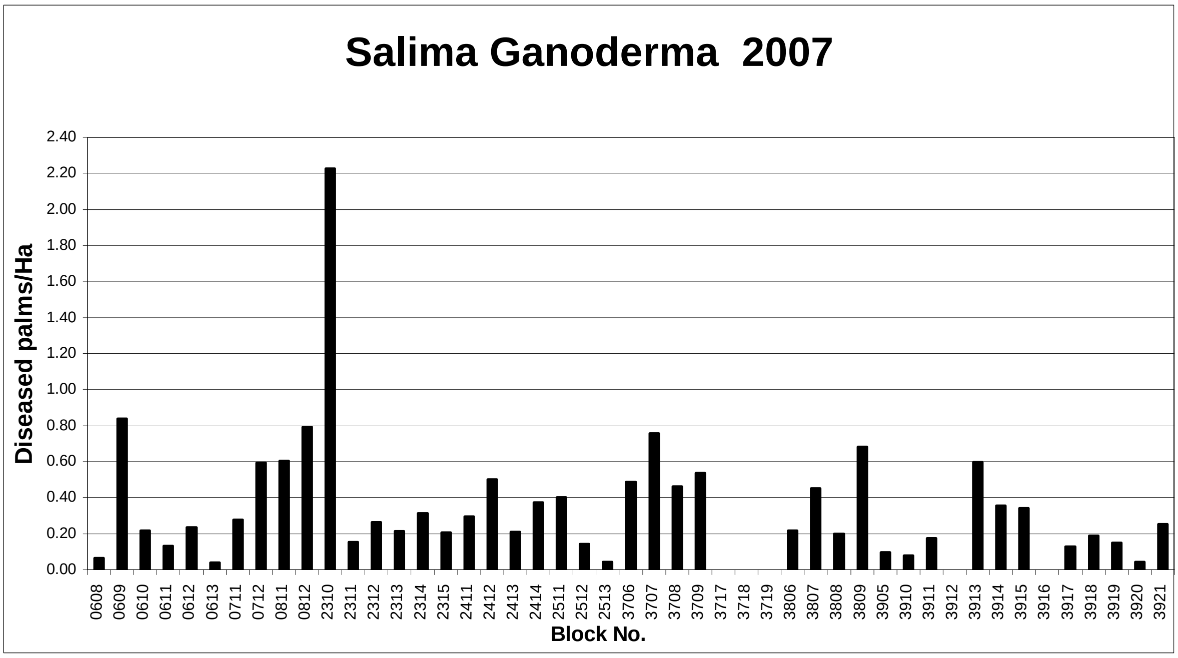

Figure 1.9 Disease incidence expressed as number of diseased palms per hectare for Salima Division, Milne Bay in 2007. Total includes palms with basal stem rot, upper stem rot and suspect palms.

Annual disease rates expressed as a percentage of the total stand are shown in Figure1.10. Disease rates were variable but generally decreased for all Estates in 2007 (from 2006) except Waigani Estate (Naura and Bunebune Divisions) where an increase in the absolute disease rate was observed. This is attributed to an incomplete survey in 2006. The decrease in disease incidence in Kwea Estate (Kwea and Maiwara Divisions) in 2007 is attributed to surveys being omitted from some blocks undergoing replant that in previous years had recorded high incidences of Ganoderma.

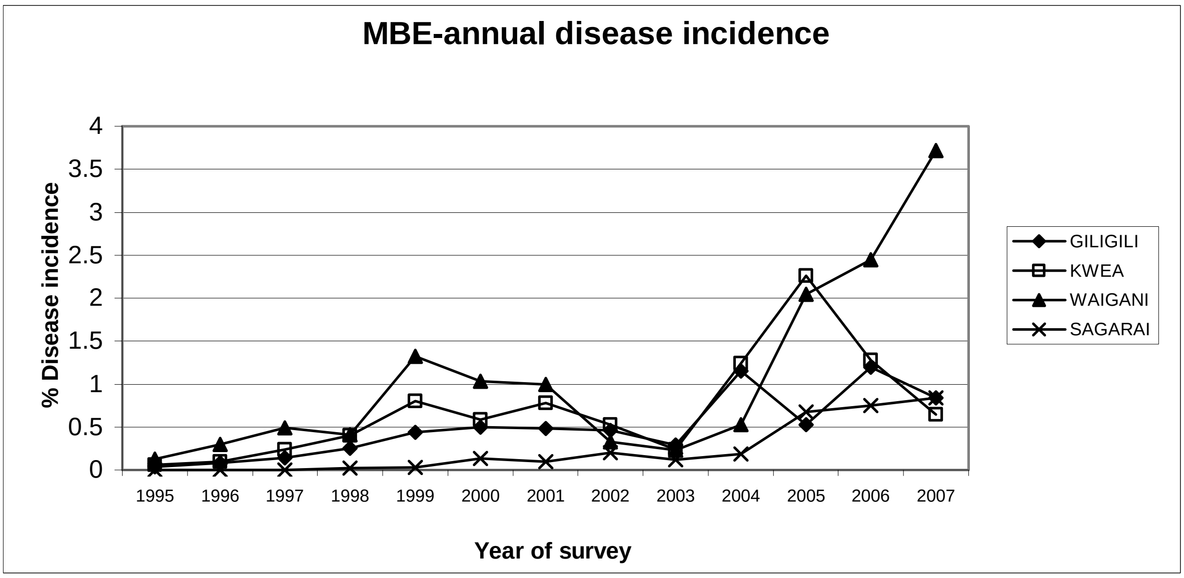

Figure 1.10 Annual disease incidence from 1995-2007 for all Estates in Milne Bay.

Disease progress curves for each Estate are shown in Figure 1.11. Disease progress is a reflection of the annual rate curves which remained steady for most Estates except Waigani in 2007. Waigani

Estate now has an average disease incidence of 13.8% followed by Kwea with 9.12%, Giligili with 6.41% and Sagarai with 3.08%.

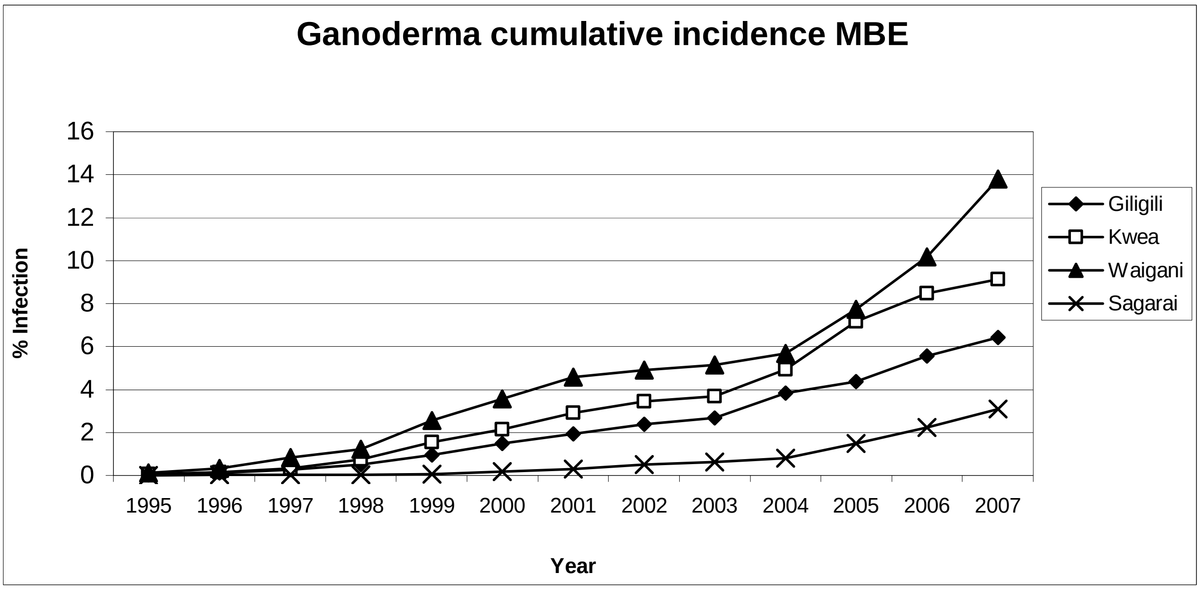

Figure 1.11 Cumulative disease incidence for all Estates in Milne Bay from 1995-2007.

Annual rate curves (Figure 1.12) for palms of different ages show that disease rates for the 1986 plantings which form the majority of blocks in Waigani and Kwea Estate actually decreased in 2007. Similarly for the 1989 plantings. The reason for the decrease is unknown but could be due to only a single survey being done in some blocks in 2007. Disease rates for plantings in other years (1987-1993) generally remained steady or increased.

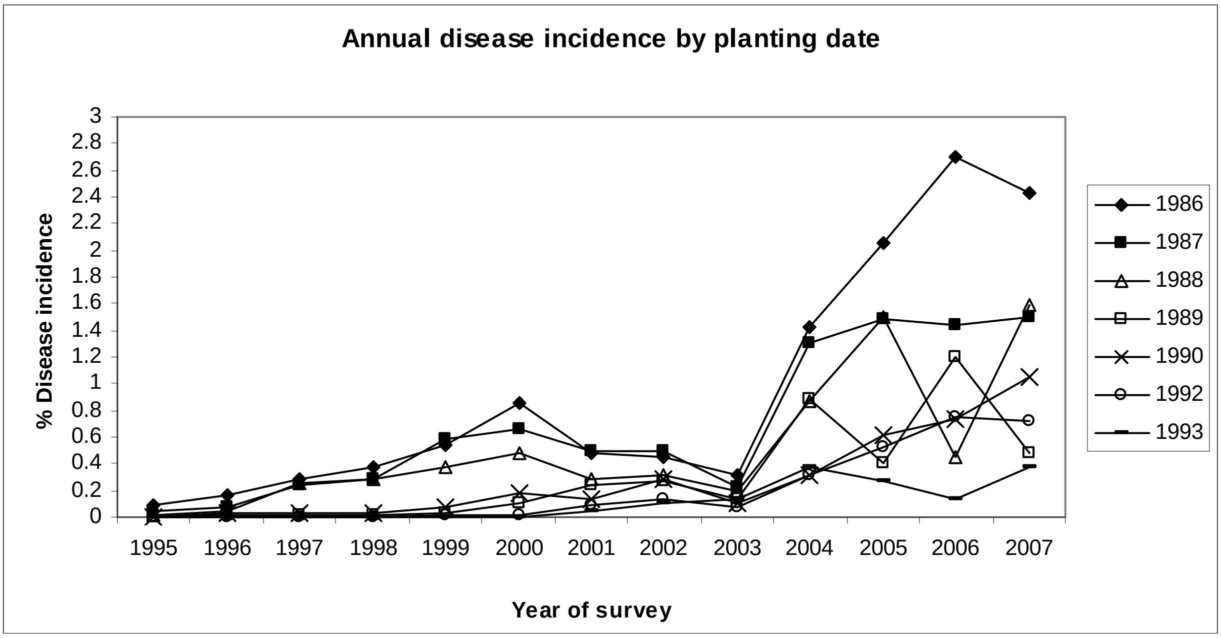

Figure 1.12 Annual disease rates from 1995-2007 for palms of different age groups (planting date) at Milne Bay.

Age curves indicate that the disease progress is changing in the older plantings (1986, 1987, 1988) with a non-linear trend in the last few years (Figure 1.13). This may be a reflection of the normal epidemiology of the disease in the absence of strong control measures (roguing). The level of infection in 22 year old palms is 13.63%, slightly lower than the total for Waigani Division.

The disease level in the 1989 plantings is nearly 3% lower than the 1986 plantings at the same age (19 years). It is expected that this trend will continue until replant. In contrast, the disease incidence in the 1992 plantings is similar to the 1987 plantings at 15 years of age indicating the complexities of basal stem rot.

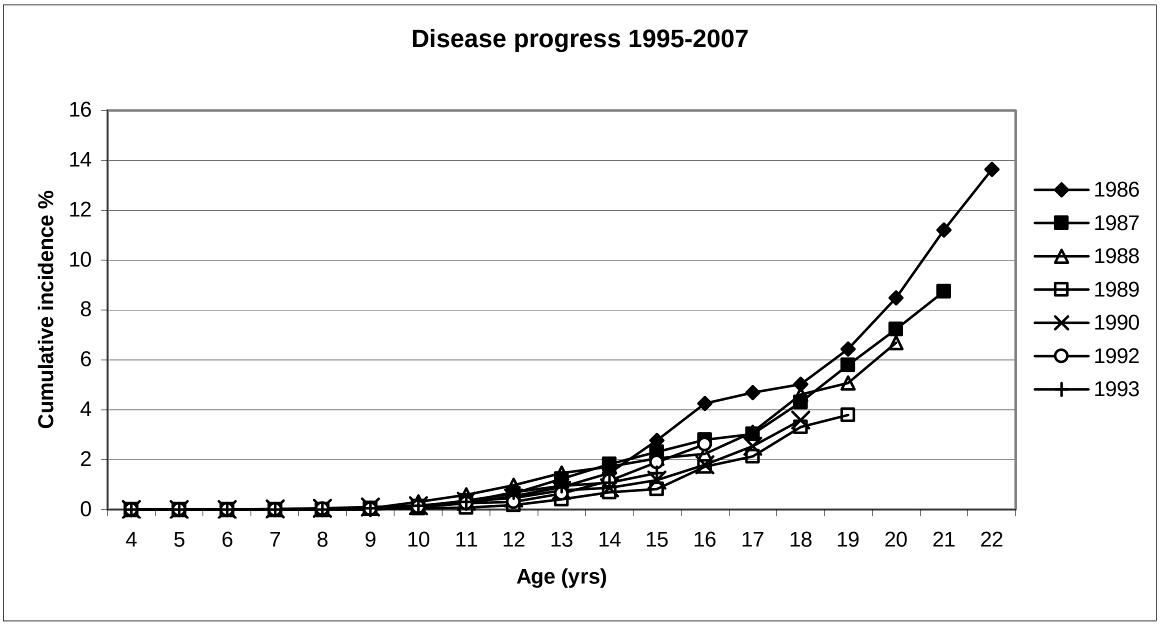

Figure 1.13 Disease progress for palms of different ages from 1995-2007 in Milne Bay.

1.3.2 Disease progress in PNGOPRA study blocks

Disease progress curves for the six blocks used to model disease progress are shown in Figure 1.14. Block 6504 recorded the highest disease levels in 2007 and the cumulative incidence is now 15.4%. Blocks 6404, 6503 and 7501 had similar levels of disease around 13%. Blocks 7213 and 7214 recorded steady rates in 2007 with the cumulative disease incidences now being 10.8% and 9.8% respectively.

When viewed according to age (Figure 1.15), Block 7501 has the highest disease incidence at 21 years of age and Block 7213 the lowest. This could be a reflection of the relative rate of removals in each of these blocks.

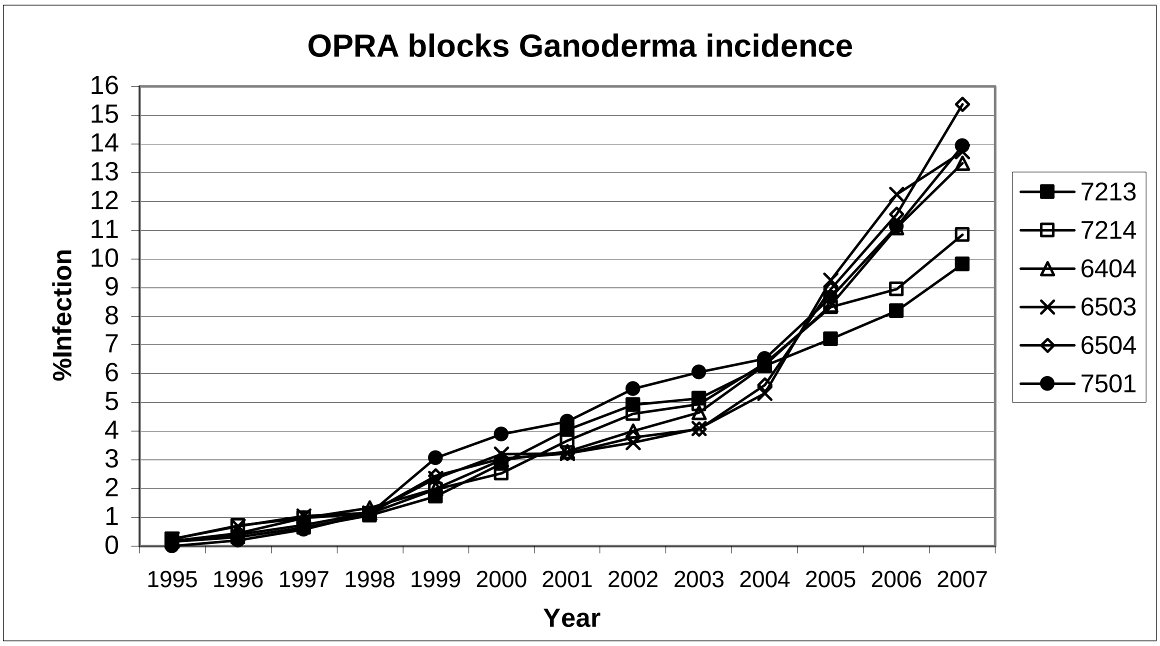

Figure 1.14 Disease progress curves from 1995 to 2007 for the six 'OPRA' blocks under study.

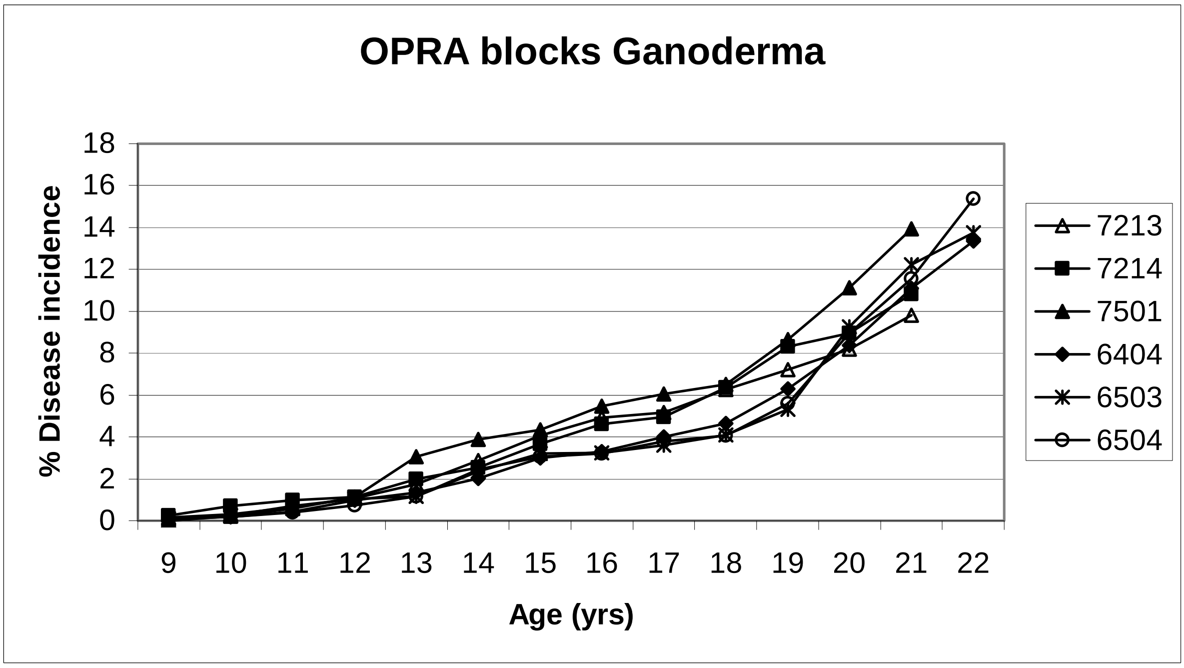

Figure 1.15 Disease progress with age in PNGOPRA study blocks in Milne Bay.

1.3.3 New Ireland

Disease progress curves for plantations established in 1989 in New Ireland are shown in Figure 1.16. Disease levels ranged from 1.44% at Lugagon to 5.33% at Maramakas. Data was not collected from Bolegila and Medina in 2007 but based on the DPCs, the levels in these plantations are around 9% for Medina and 8% for Bolegila.

Data for other plantations in 2007 was not reliable and this is not shown.

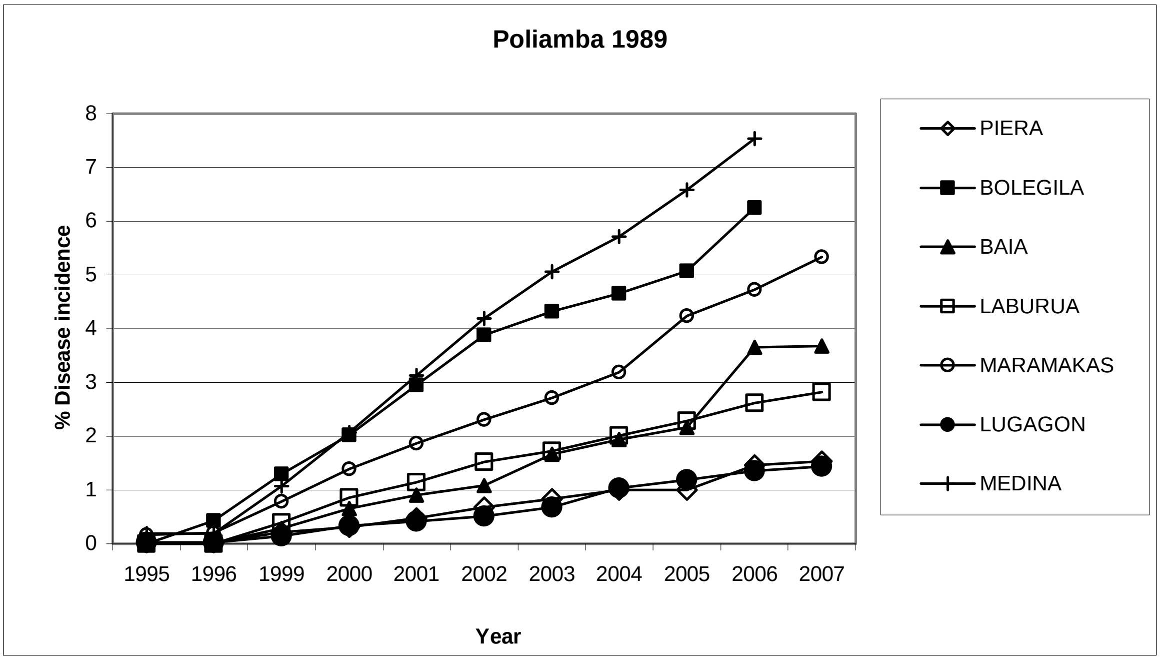

Figure 1.16 Cumulative disease incidences from 1995 to 2007 for the 1989 plantings in New Ireland. Data was not collected in 2007 for Bolegila and Medina.

1.3.4 West New Britain

Annual disease rates in 2007 for the E fields at Numundo remained steady with no significant increases (Figure 1.17).

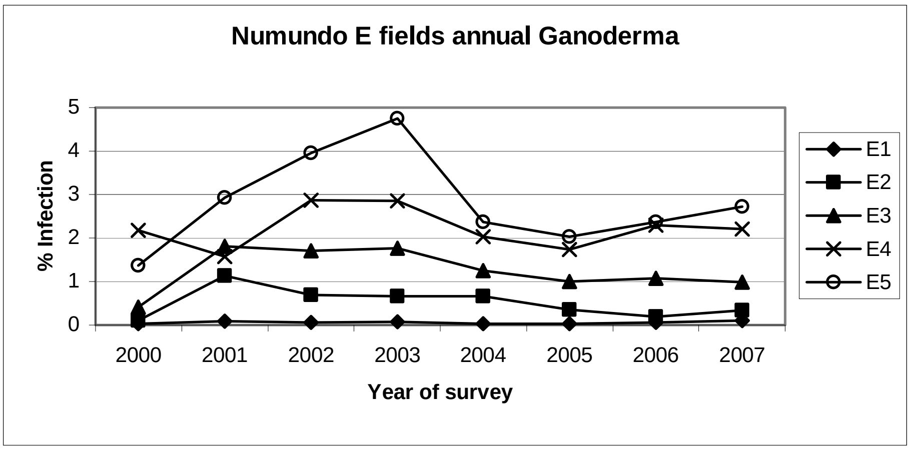

Figure 1.17 Annual disease incidence in Numundo E Fields from 2000-2007.

Disease progress curves for the period 2000-2007 show the continuing linear trend in infections levels in the E Fields (Figure 1.18). The highest recorded incidence is for Field E5 with 22.5%, followed by E4 with 17.7%. Levels of infection in Field E1 remain low at 0.47%.

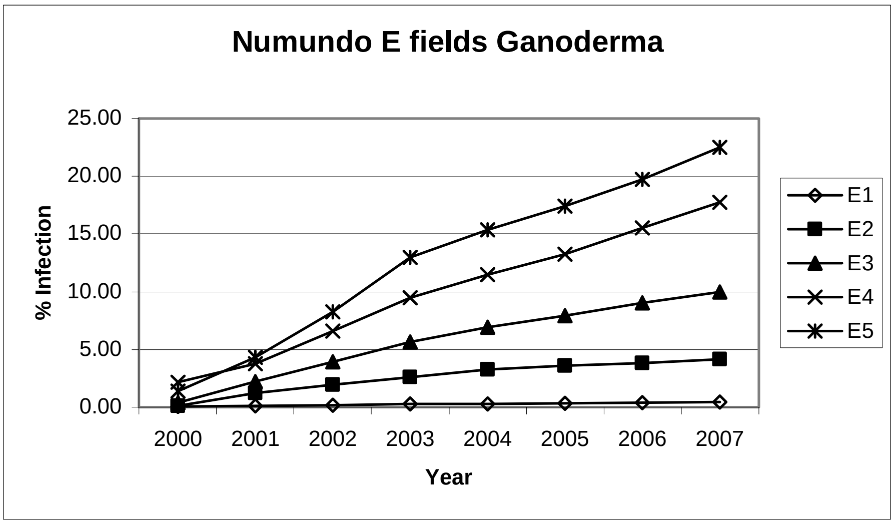

Figure 1.18 Disease progress curves for the 1994 E fields at Numundo, West New Britain Province from 2000-2007.

Disease rates in the F fields remained steady or increased in 2007 except for Field F1 where an increase was recorded (Figure 1.19) and Field F3 where the disease rate decreased significantly in 2007. This is attributed to survey error or reduced sanitation rates in 2006.

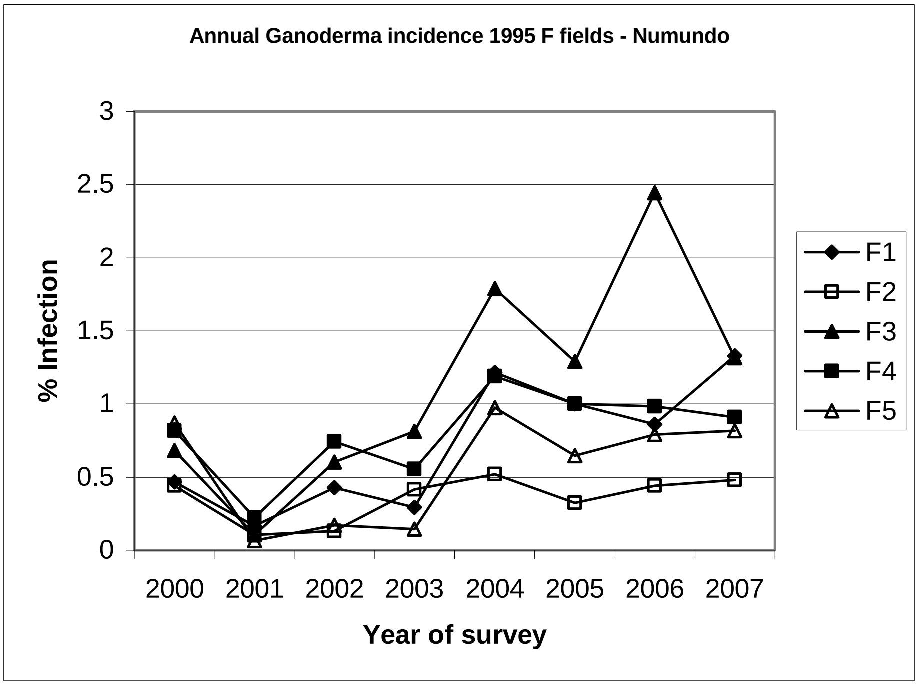

Figure 1.19 Annual disease losses for 1995 F Fields at Numundo, West New Britain Province from 2000-2006.

As for the E fields, the disease progress curves continue to follow a linear trend for all F Fields although a change may be occurring for Field F3 due to the large increase in recorded infections in 2006 (Figure 1.20). The disparity between the disease incidences amongst the F fields is not as large as in the E Fields. This highest recorded infection levels are 9.0% for Field F3 and the lowest is 2.8% for Field F2.

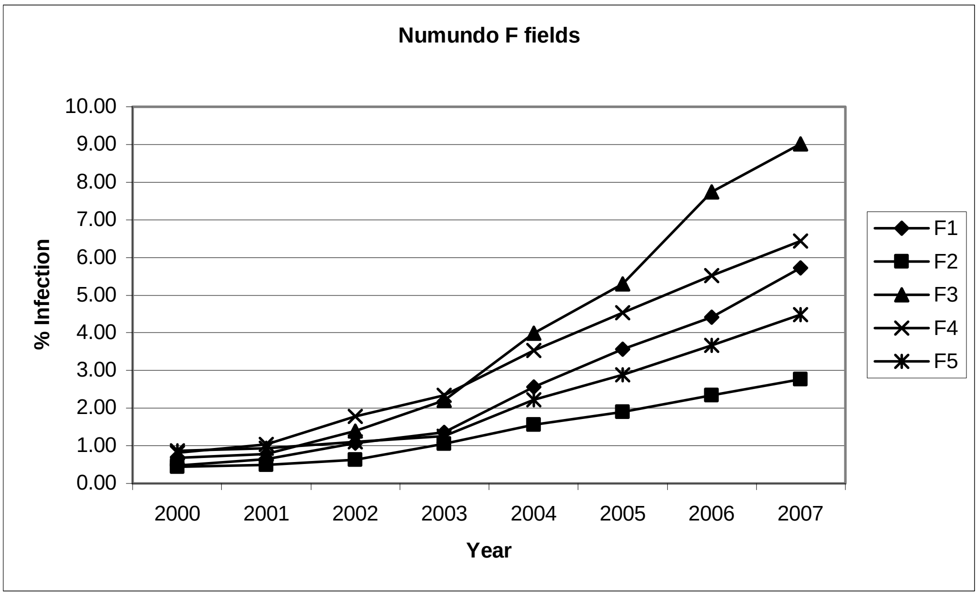

Figure 1.20 Disease progress for the period 2000-2007 for 1995 F fields at Numundo, West New Britain Province.

1.3.5 Monitoring the effects of disease on production in selected blocks

It is recognised that the economic threshold will be dependent on a number of factors including planting density, nutrition 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 Milne Bay and West New Britain are shown in Figures 1.21 and 1.22. Only the blocks with the highest levels of disease are shown.

Palm yields are not affected in Block 6504 at the level of 14.5% infection in 2007.

Similarly for Fields E4 and E5 that comprise MU3 at Numundo. At an average of 18% disease incidence, individual palm yields continue to rise, indicating compensation from surrounding palms. Unfortunately, yield data is not available for Field E5 which has a disease incidence over 20%, the theoretical threshold level.

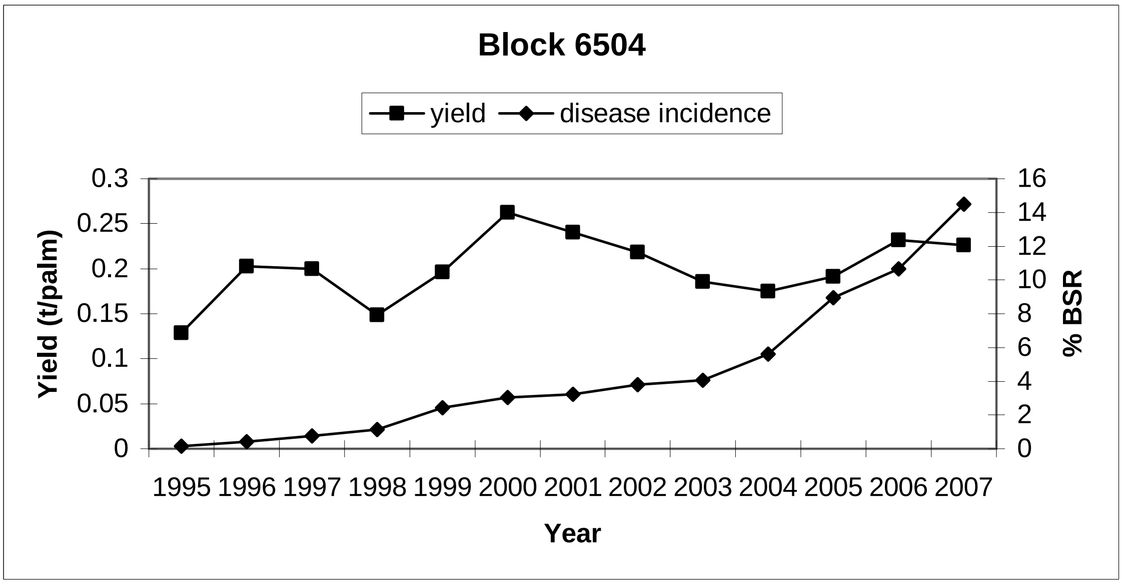

Figure 1.21 Average palm yields (plantation data) with disease progress from 1995-2007 in Block 6504, Milne Bay.

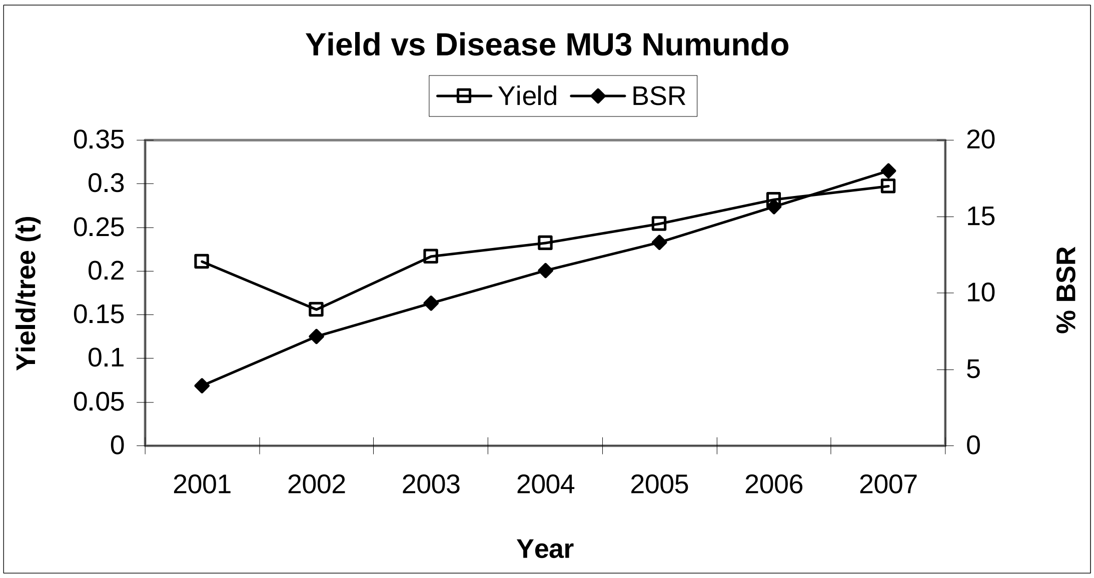

Figure 1.22 Effects of basal stem rot (BSR) on palm production in fields with the highest infection levels (MU3) at Numundo, West New Britain from 2000-2005.

THE POPULATION DYNAMICS OF *G. BONINENSE* ON OIL PALM

Objectives: (1) To determine temporal changes in the population of G. boninense on oil palm

(2) To determine the main mode(s) of disease spread

2.0 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. It is envisaged that the *Ganoderma* population studies in Milne Bay will cease in 2007 as adequate data has been collected from this area and most of these blocks will be replanted in 2007/2008.

2.1 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 and from selected isolates in Numundo Field E5. Individual spores are isolated and mating types determined after reciprocal crosses of sibling spores.

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.

2.2 Results

2.2.1 The population in Milne Bay

As in previous years, bi-annual surveys of the six designated PNGOPRA blocks were completed in 2007 and samples were collected for laboratory studies. A summary of 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 2007 is shown in Table 2.2.

Table 2.1. Areas surveyed and number of Ganoderma isolates collected in the 2007 surveys at Milne Bay (OPRA blocks only).

Block #	Ha surveyed	No. isolates collected
7213	29	21
7214	16.7	18
7501	69	15
6404	63.9	14
6503	76	8
6504	36	17

Crosses amongst isolates from Block 7213 continue to confirm that the isolates are of different genetic origin. However, a small number of isolates share common alleles indicating some recombination within the population. Direct hereditary relationships are still elusive however and their rarity indicates some other factors may be contributing to disease spread.

Table 2.2. Shaded portions represent the mating type crosses completed in 2007 for isolates collected from Block 7213, Giligili in 2006 and 2007.

	Isolate number										
	2074	2075	2077	2078	2079	2081	2084	2085	2086	2087	2088
2074											
2075											
2077											
2078											
2079											
2081											
2084											
2085											
2086											
2087											
	Isolate number										
	1674	1675	1676	1677	1678	1679	1681	1682	1875	1877	1878
1674											
1675											
1676											
1677											
1678											
1679											
1681											
1682											
1875											
1877											
1879											

2.2.2 The population in New Ireland

Specimen collections were made as usual in Trial 252 in New Ireland. These isolates were processed and stored and have not been tested as yet.

Table 2.3 Number of isolates of Ganoderma collected from Trial 252(New Ireland) in 2007.

Location	**No. of isolates collected**
Trial 252	23

2.2.3 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 2007. The results of these tests are presented in Table 2.5 and show that all isolates obtained from adjacent palms are genetically distinct except for isolates 2224 and 2176. This result indicates a direct relationship between isolates from the two palms and possibly a common source of infection.

Table 2.4 Ganoderma isolates collected from infected palms at Numundo, West New Britain Province in 2007.

Location	Ha surveyed	No. of isolates collected
Field E4	59.05	55
Field E5	28.10	112

Table 2.5 Vegetative compatibility tests amongst isolates from Ganoderma brackets collected from neighbour palms in Fields E4 and E5, Numundo, West New Britain Province in 2007.

Ganoderma brackets from neighbouring palms		
Isolate number	**Isolate number**	**Test result**
1908	1909	incompatible
2068	2067	incompatible
2111	2169	incompatible
1191	1604	incompatible
2062	2063	incompatible
2195	2175	incompatible
2008	2009	incompatible
2222	2223	incompatible
2189	2185	incompatible
1985	1986	incompatible
2219	1901	incompatible
2144	2229	incompatible
1808	1809	incompatible
1904	1903	incompatible
2224	2176	compatible
1944	1945	incompatible
1989	1988	incompatible
1918	1919	incompatible
1760	1761	incompatible
1738	1737	incompatible
1792	1791	incompatible
2006	2009	incompatible
1804	1805	incompatible
1912	1913	incompatible
1971	1970	incompatible
1794	1796	incompatible
1935	1934	incompatible
2005	2004	incompatible
1927	1928	incompatible

DETERMINATION OF LATENT INFECTION LEVELS IN PLOTS WITH RELATIVELY HIGH INCIDENCES OF BASAL STEM ROT

Objective: To assess the levels of latent infection in apparently healthy palms in fertilizer plots

3.0 Introduction

Trial 251 is a factorial fertilizer trial with 3 levels of N and K and 2 levels of P and Mg. There are 36 plots each with 16 palms whose yields are recorded (recorded palms) and a single guard row around each plot of 20 palms in total. Guard row palms were given the same dosage of fertilizer as the recorded palms throughout the life of the trial. Ganoderma infections have been recorded in these plots since 1995 but accurate disease data has only been collected since 2000. The levels of basal stem rot recorded in some of the plots has been quite high compared to other planted areas in New Ireland and it was assumed that the levels of fertilizer in the different plots was having some effect on the levels of disease. Early analyses (Nelson & Pilotti, OPRAtive Word # 2, 2002) indicated that there was some correlation with K levels but further analyses have not been carried out to confirm this finding.

The high levels of Ganoderma in the majority of plots presented an opportunity to investigate the degree of latent infection in the remaining palm stand.

In 2006 and the early part of 2007, the recorded palms remaining in all of the 36 plots were felled and assessed to determine if Ganoderma was present in the bole tissue of apparently healthy palms. The hypothesis being tested was that there would be a high level of infection in the boles of the remaining palms in plots that exhibited high levels of Ganoderma infection.

This report provides a summary of the work completed in 2006 and early 2007.

A detailed report of this investigation will be produced separately.

3.1 Methodology

3.2 Results

These methodology and results for Trial 251 have been previously described in the 2006 Annual Report. The finals results are presented here as the felling of the plots was completed in 2007.

Table 3.1 Summary of observations on recorded palms destructively sampled in fertilizer Trial 251, New Ireland.

	# Standing palms	# Palms with symptoms	# Palms with other basal rot	# Palms with Gano rot and no BSB	# BSB palms	#USR	Total latent infection	Total # infected standing	% Latent
Plot 1	13	1	2		1		2	3	15.4
Plot 2	16	0	3				3	3	18.8
Plot 3	10	0					0	0	0.0
Plot 4	13	0			1		0	1	0.0
Plot 5	13	0					0	0	0.0
Plot 6	15	0		3			3	3	20.0
Plot 7	15	0					0	0	0.0
Plot 8	15	0		1			1	1	6.7
Plot 9	12	2			2		0	2	0.0
Plot 10	11	0					0	0	0.0
Plot 11	11	2	2		2		2	4	18.2
Plot 12	10	2	1		1		1	2	10.0
Plot 13	13	2		1	1		1	2	7.7
Plot 14	15	0		2			2	2	13.3
Plot 15	13	1	1	1			2	2	15.4
Plot 16	15	0					0	0	0.0
Plot 17	15	3		1	2		1	3	6.7
Plot 18	11	3			2	1	0	3	0.0
Plot 19	16	0					0	0	0.0
Plot 20	14	2		2	2		2	4	14.3
Plot 21	14	0	1				1	1	7.1
Plot 22	11	3	3		3		3	6	27.3
Plot 23	14	0	1	1			1	2	7.1
Plot 24	12	1	2	1	2		2	5	16.7
Plot 25	16	0	2				3	2	18.8
Plot 26	10	3			3		0	3	0.0
Plot 27	15	0					0	0	0.0
Plot 28	16	1	1		1		1	2	6.3
Plot 29	12	1	3	1			4	4	33.3
Plot 30	12	3			2		0	2	0.0
Plot 31	16	2	1		1		1	2	6.3
Plot 32	11	1	1		1		1	3	9.1
Plot 33	14	1	1		3		1	4	7.1
Plot 34	13	2				1	0	1	0.0
Plot 35	14	1			1		0	1	0.0
Plot 36	15	0	1		1		1	2	6.7
All Plots	**481**	**37**	**26**	**14**	**32**	**2**	**40**	**74**	**8.3**

BSB= basal stem bracket; USR = upper stem rot

GANODERMA INOCULUM IN-FIELD: PERSISTENCE AND SPREAD INTO NEW PLANTINGS

Objective: To determine if Ganoderma infection can be induced by planting in close proximity to infected stumps.

4.1 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 infections of the palms in this area.

Mapping of the disease in certain fields (E4 and E5) showed that small clusters were apparently developing in contrast to the other areas of PNG where the disease is prevalent.

In 2006, a trial was set up to investigate the possibility of root transmission as a mode of disease spread that might explain the apparent ‘clustering’ of diseased palms. It should be emphasized that analyses were not carried out to confirm the apparent aggregation.

The hypothesis being tested was that basal stem rot could be transmitted from diseased oil palm stumps to young seedlings through root contact.

4.2 Methodology

As previously described in the 2006 Annual Report.

4.2 Results

Table 1 shows the results of the monthly inspections over a 21-month period to December 2007.

Soon after the trials were established, damage by taro beetle was reported in several plots. Most of the palms recovered in the majority of plots but a few died as a result and were not replaced. Some remain stunted.

After 21 months of recording, the majority of palms are healthy despite having active Ganoderma fruiting bodies on the stumps and therefore a high level of inoculum within the stump itself. Monitoring will continue until March 2008 when the plots will be destructively sampled.

Table 4.1 Status of oil palm seedlings in Ganoderma experimental plots at Numundo, 21 months after planting. There are 24 seedlings per plot.

Plot No.	Condition of seedlings
1	All healthy
2	#17 died at 6 months, remainder healthy
3	#11 dying, remainder healthy
4	All healthy
5	All healthy
6	#23 died at 13 months, remainder healthy
7	#3 died at 17 months, remainder healthy
8	#15 died at 15months, remainder healthy
9	All healthy
10	All healthy
11	#4 dying from 11 months, remainder healthy
12	#21 died at 5 months, remainder healthy
13	#6, died at 19 months, remainder healthy
14	#13 died at 13 months, remainder healthy
15	#13 died at 14 months, remainder healthy
16	All healthy
17	All healthy
18	All healthy
19	All healthy
20	#6 dying at 17 months, remainder healthy
21	All healthy
22	#4 dying at 11 months, remainder healthy
23	All healthy
24	#6 dying at 17 months, remainder healthy
25	All healthy
26	All healthy
27	#14 dead at 13 months, remainder healthy
28	All healthy
29	#15 died at 10 months, remainder healthy
30	#21 died at 8 months, remainder healthy
31	All healthy
32	All healthy
33	#4 dead at 13 months, remainder healthy
34	All healthy
35	#15 dying at 15 months, remainder healthy
36	All healthy
37	#2 dying, #15 died at 7 months, #24 died at 6 months, remainder healthy
38	All healthy
39	#4 dead at 4 months, remainder healthy
40	All healthy

**Deaths were not due to Ganoderma infection but to attack by taro beetle in the first 2 months after planting. Most seedlings attacked by taro beetle recovered.*

SCREENING OF OIL PALM SEED LINES FOR RESISTANCE OR SUSCEPTIBILITY TO GANODERMA

5.0 Introduction

A satisfactory method for inducing disease in young oil palm seedlings has been developed and this report is on the initial screening tests carried out in 2007.

Most seed obtained were standard commercial crosses as palm populations were still being developed.

5.1 Methodology

Nursery assays were carried out as described in previous reports.

5.2 Results

Nursery screening

Several sets of nursery tests were carried out in 2007 using seed supplied from Dami OPRS. There were no significant differences amongst different progenies, however there was some evidence of differences within progeny (Figure 5.1). Seedling within a progeny responded to the inoculum differently indicating partial resistance. Further testing is underway.

Figure 5.1. Young palms from a single progeny inoculated at 1 week of age with Ganoderma on rubber wood. Results after 4 months in the nursery.

BIOLOGICAL CONTROL OF GANODERMA USING INDIGENOUS ISOLATES OF *TRICHODERMA* SPP.

Objective: (1) To utilize Trichoderma as a natural antagonist of Ganoderma to prevent Ganoderma infection on cut frond bases.

6.0 Introduction

Several species of the fungus *Trichoderma* are worldwide for biocontrol in a number of crops. Biocontrol is based on the ability of the *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 hyphae of other fungi.

In 2006 a collaborative project was set up between staff from the University of Kent and PNGOPRA to investigate the possibility of using indigenous isolates as biocontrol agents for Ganoderma on oil palm. This study will be completed in 2007.

6.1 Methodology

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.

6.2 Results

6.2.1 Systematics

Traditional morphological characterisation of all isolates was used to give indicative species designations. The species identified are given in Table 6.1 along with the grouping according to their SSCP profiles with various primers.

Isolates 41b12, 41r2, Vert-like 3 and Hop10g are not *Trichoderma* species and are not being included in biocontrol tests.

Initial SSCP profiles have been completed (Figure 6.1 and Table 6.1) summarises the draft analysis. As expected, the mtSSU gene is the least discriminatory with 3 profiles that come from *Trichoderma* strains and 2 from non-*Trichoderma* isolates. ITS patterns are more variable with 10 different profiles (7 *Trichoderma*; 3 non-*Trichoderma*). There is good correlation between mtSSU groups and those of ITS profiles, but the ITS patterns split the largest mtSSU group into 4 sub-groups. Representative sequences have now been obtained for all groups.

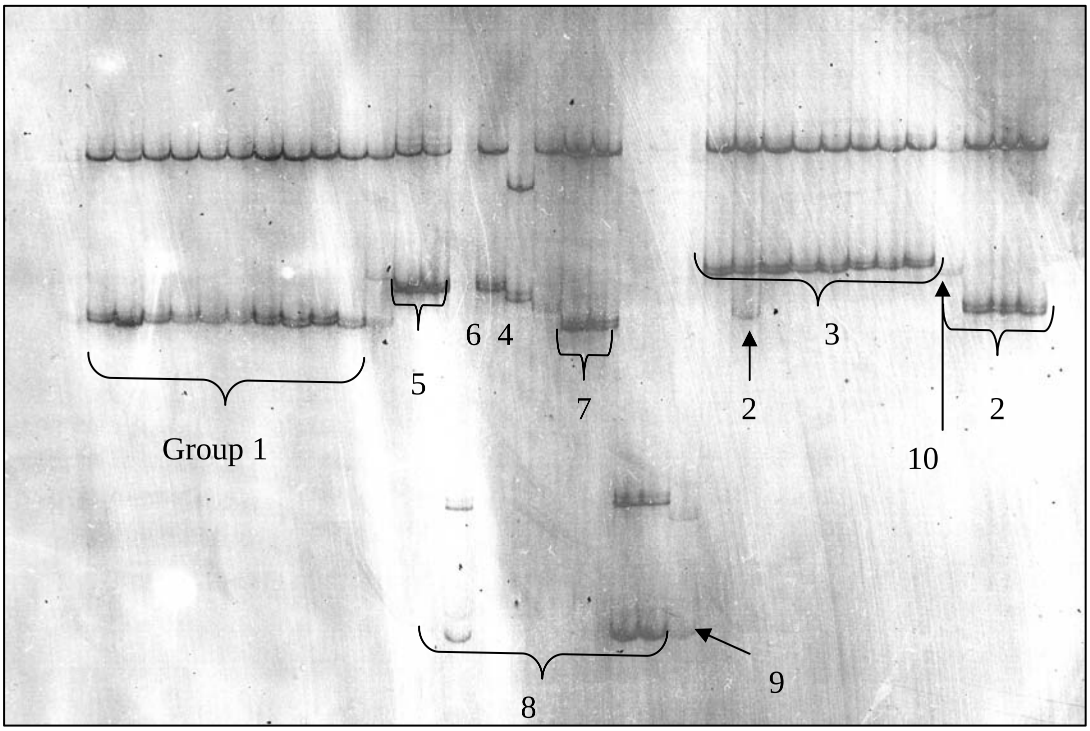

Figure 6.1. SSCP profiles of the ITS regions of several Trichoderma isolates showing polymorphisms in this region. Numbers denote the isolate groups derived from these profiles.

Table 6.1 Comparison of SSCP patterns for primers isolates with identical SSCP profiles share the same colour code.

Isolate	Mtssu primer	ITS primer	Ech42 Primer
M	G1	G1	NEGATIVE
SP6B	G1	G1	NEGATIVE
SP5A	G1	G1	NEGATIVE
WFB1	G1	G1	G1
BQ	G6	G1	G1
BX	G1	G1	G1
BP	G1	G1	G1
SP4C	G1	G1	G1
BV	G1	G1	G1
BW	G1	G1	G2
R	G1	G1	G2
P	G1	G1	G2
Y	G1	G1	G2
SP5B	G1	G1	G2
B1	G1	G1	G3
#2	G1	G1	G3
A1	G1	G1	G4
G	G1	G3	G4
BN	G1	G3	G5
H1	G1	G3	G5
E	G1	G3	G6
K	G1	G3	G6
42brl	G1	G3	G6
40r	G1	G3	G7
SP4B	G1	G4	NEGATIVE
C	G1	G5	G2
Q	G1	G5	NEGATIVE
41b12	G2	G6	G8
BU	G3	G7	G9
72126P3	G3	G7	G9
41r2	G4	G8	G10
L	G4	G8	G10
Vert-like 3	G4	G8	G10
Hop 10g	G4	G9	G11
# 3	G5	G10	G12

ITS sequences.

Figure 6.2 shows the phylogram constructed from the ITS sequence information for each of the PNG isolate groups and selected reference sequences from GenBank including the relevant ex-types. Groups 1 and 4 appear to be subclades of *Trichoderma asperellum*. There are only ~10 base (98%) differences between these two groups which is within the sequencing error range. Group 10 is also close to this clade but shares similarity with *T. hamatum*. Group 3 clusters with the *T. virens/Hypocrea virens* clade 87% (~63 bp different to group 1), whilst group 5 clusters with *T. atroviride*. Group 7 falls within the *T. harzianum/Hypocrea lixii* clade 86% (~73 bp) different from group 1. Sequences from Groups 6, 8 and 9 cluster well outside the *Trichoderma* clades confirming their different taxonomy.

SSUmitDNA, ech*42 sequences*

The mitochondrial gene sequences had little variation (~15bp difference between the major groups) and were not useful for making discriminative phylograms. The *ech*42 data confirmed the ITS results showing groups 1, 2, 3 and 4 clustering with *T. asperellum*, and groups 5, 6, 7 and 12 grouping with the *T. virens/T. hamatum* branches. A lack of discrimination between these two species reflects the lack of sequences available in the databases for meaningful comparisons. Group 9 fell between *T. asperellum* and *T. harzianum*, whilst groups 10 and 11 were clearly not related to *Trichoderma* spp. Group 8 sequences were not obtained.

In summary, the 28 species of *Trichoderma* are classified as follows:

T. asperellum group 1	17 isolates
T. asperellum group 2	1 isolate
T. virens	7 isolates
T. atroviride	2 isolates
T. hamatum	1 isolate
H. lixii/ T. harzianum	2 isolates

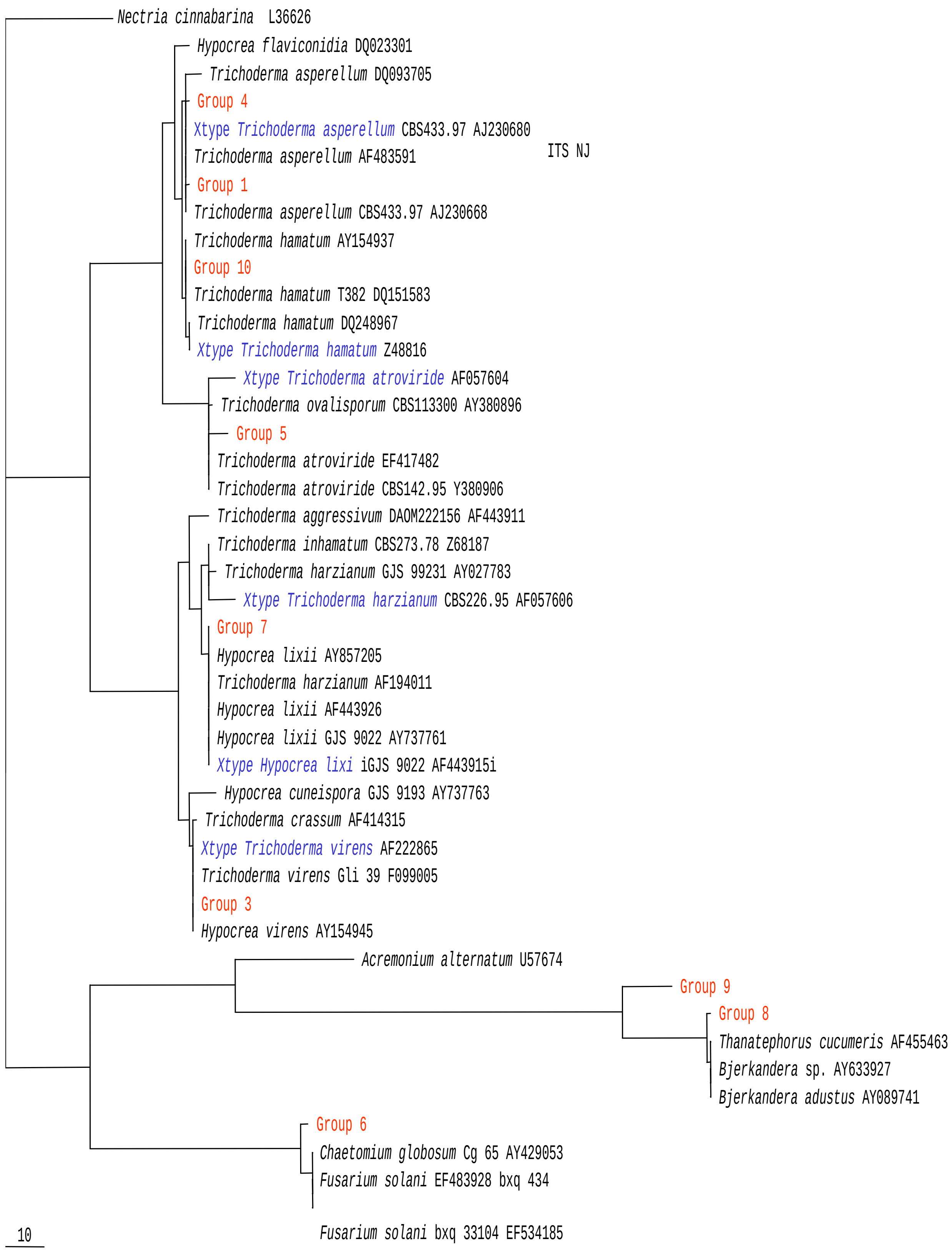

Figure 6.2 Dendogram of relationships of SSCP groups to verified and type sequences of Trichoderma strains from GENBANK

6.2.2 In-vitro screening

All 33 isolates were screened for general aggressiveness against 3 strains of *Ganoderma boninense* by growing opposed cultures on 1/10 strength PDA. The most aggressive strains are #2, #3, BN, H1, E, G, A1, K, 42br1, 40r, C, BU and 72126p3. There was some correlation of aggressiveness with molecular grouping (e.g. E, G, K and 42br all belong to same small group, as do BN and H1) but this is still being analysed in detail.

6.2.3 Determination of mechanisms of antagonism

All isolates were tested for methods for initial determination of mechanisms of antagonism using a single isolate of *G.boninense* (1301).

Direct interaction:

Isolates of *Trichoderma* and *Ganoderma* were inoculated at opposite sides of Petri dishes containing Potato Dextrose Agar (Difco, USA). The *Ganoderma* was inoculated 3 days in advance of the *Trichoderma* to enable it to begin to advance across the agar surface prior to inoculation with the much-faster growing *Trichoderma* isolates. Plates were then incubated in the dark at 25^{o}C, and examined daily after inoculation with *Trichoderma* to record the relative radii of the two opposed colonies. Antagonism was scored as negative where no effect was noted and the *Trichoderma* did not apparently inhibit growth of *Ganoderma*; + when at least 2/4 isolates of *Ganoderma* were inhibited and the degree of inhibition averaged between 0-20mm radial growth; ++ when at all 4 isolates of *Ganoderma* were inhibited and the degree of inhibition averaged between 20-40mm radial growth; and +++ when at all 4 isolates of *Ganoderma* were inhibited and the degree of inhibition averaged over 40mm.

Production of volatiles: The method of Dennis & Webster (1971) was used. The lids of Petri-dishes containing PDA inoculated centrally with either the test *Trichoderma* or the test *Ganoderma* were removed and the edges taped together. This created a sealed chamber with both cultures exposed to volatiles produced within the intervening space. Controls comprised two cultures of *Ganoderma*. Antagonism was scored as negative if no inhibition was noted; + if the growth rate was slowed but the *Ganoderma* still reached the edge of the plate within 4 days; ++ if the growth rate was slowed but the radius of the *Ganoderma* colony exceeded 40mm within 7 days; and +++ if the *Ganoderma* did not exceed 40mm within 4 days

Production of diffusible inhibitors (enzymes, antibiotics): PDA plates were overlain with sterile cellophane (PT300 grade) disks (90mm diam). They were centrally inoculated with the test *Trichoderma* isolates and incubated at 25^{o}C until the cultures had neared the edge of the cellophane. The cellophane and culture was then stripped off the agar and the agar inoculated centrally with the test *Ganoderma*. Growth of Ganoderma was then measured daily and the degree of inhibition noted after 5 days relative to *Ganoderma/Ganoderma* controls. Antagonism was scored as negative if no inhibition was noted; + if the growth rate was slowed but the radius of the *Ganoderma* colony exceeded 40mm; ++ if the growth rate was slowed but the radius of the *Ganoderma* colony exceeded 30mm; and +++ if the *Ganoderma* did not exceed 30mm.

Production of chitinases: A rapid screen was required and so the method of Rodgers-Gray & Shaw (2001) using Chitin Azure as substrate was adapted for use with *Trichoderma* in microtitre plates. Technical problems meant that drying out of culture prevented meaningful results being obtained within the timeframe available so no results are reported here.

6.3 Results

Direct interaction: Isolates BP, SP4C, #2, G, E, 42br1, SP4B, C, 72126P3 and #3 all showed significant inhibition or dissolution of *Ganoderma* growth on plates. Direct observation of interactions showed a variety of morphological effects in these cultures ranging from no obvious effects to hyphal coiling by *Trichoderma*, vacuolation and disorganisation of cytoplasm and lysis in the *Ganoderma* hyphae. Results from the first experiment are graphed in Figure 6.3.

Production of volatiles: Volatiles from isolates WFB1, BX, BP, SP4C, P, #2, A1, BN, E, SP4B, C, and BU all showed significant inhibition of *Ganoderma* growth. Replicate experiments showed that results were variable but some isolates such as BP and A1 were consistently inhibitory. Results from the first experiment are graphed in Figure 6.4.

Production of diffusible inhibitors (enzymes, antibiotics): Growth of *Ganoderma* was significantly inhibited on plates previously pre-colonised by isolates SP5A, WFB1, SP4C, BV, Y, BN, E, C and Q. The lack of results from the enzyme assay experiments means that the nature of this diffusible inhibition was attributable to either one of enzyme activity or antibiotics. Highlighted isolates appear in all three lists. Results from the first experiment are graphed in Figure 6.5.

Once the methodology was finalised, these experiments were then repeated using all 4 isolates of *Ganoderma*. There was considerable variation in results and some isolates of *Trichoderma* inhibited the growth of only some isolates of *Ganoderma*. In order to choose the most effective antagonists, a composite value of inhibition across all 4 isolates of *Ganoderma* was used (Table 6.2).

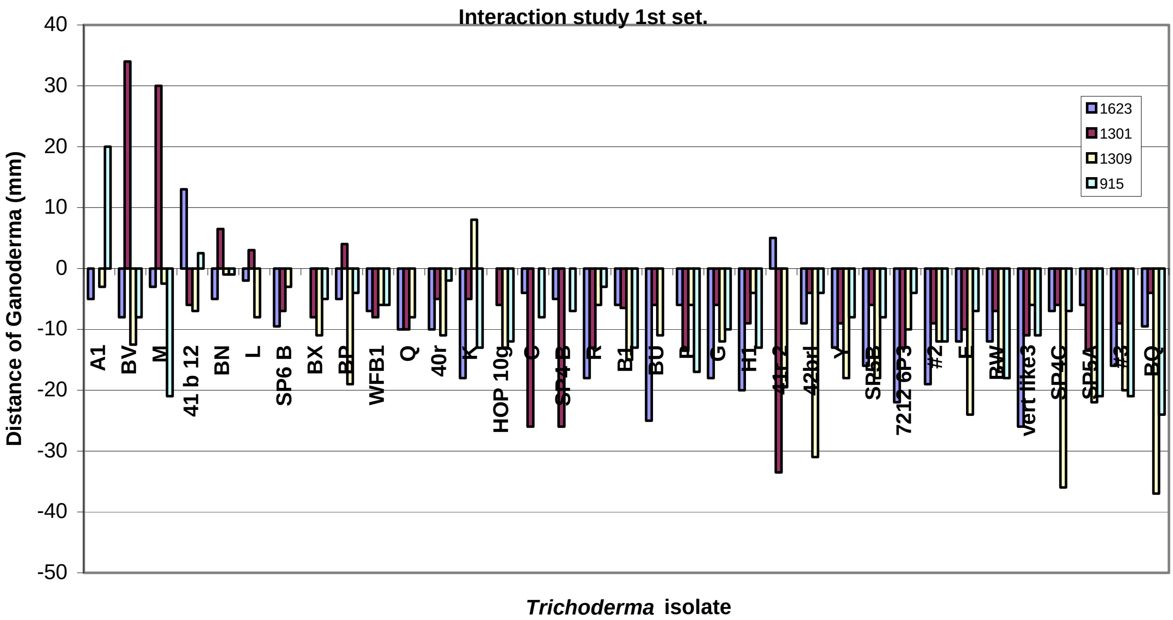

Figure 6.3 Direct interaction study of Trichoderma and Ganoderma in vitro.

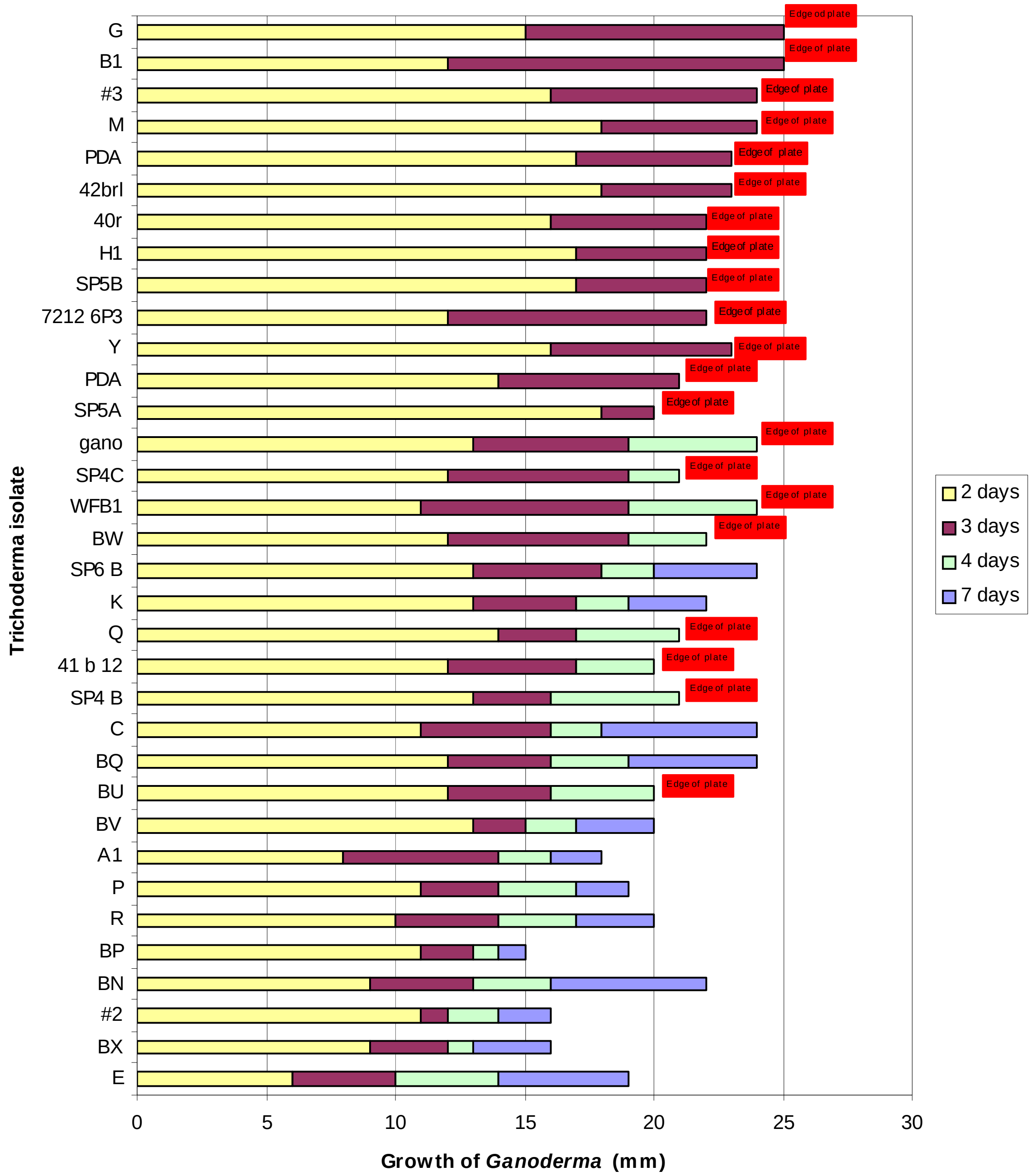

Figure 6.4 Graph showing the degree of inhibition of Ganoderma in the presence of volatile compounds of Trichoderma strains.

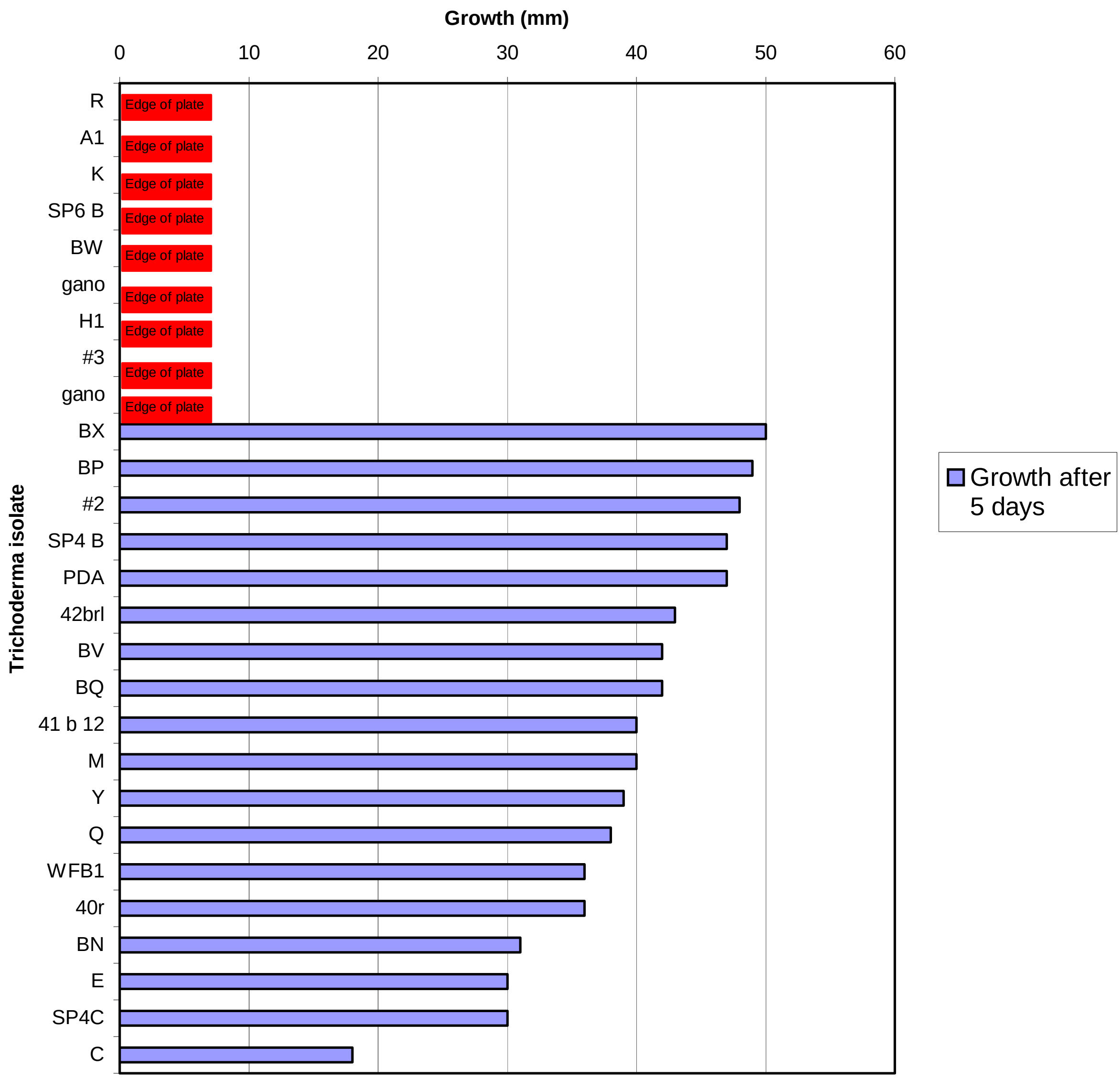

Figure 6.5 Graph showing the degree of inhibition on growth of Ganoderma by diffusible compounds of Trichoderma strains.

Selection of three isolates with complementary activities for possible combination in mixed inocula for field use

The following three isolates scored highly and consistently in all three tests for antagonism: *T. asperellum* SP4C; *T. virens* E, *T. atroviride*, C. Further trials will be necessary to prove their efficacy in the field.

Table 6.2 (on next page) Summary of the various test of antagonism of Trichoderma against Ganoderma.

Isolate	Degree of inhibition of *Ganoderma* via volatiles	Degree of inhibition of *Ganoderma* via diffusable inhibitors	Degree of inhibition of *Ganoderma* by direct contact on plate	Comments on direct contact	Total score (no.of +)
T.asperellum1 M	-/+	+/-	-/+	Pronounced disorganisation on contact	3
SP6B	++/+	+/-	+/+	Disorganisation of older hyphae.	6
SP5A	-/+++	NA/+++	+++/-	NA	9*
WFB1	+/+++	++/NA	+/+	Disorganisation/lysis of mature hyphae	8*
BQ	++/+	+/++	+++/-	No obvious effect	9
BX	+++/+	-/-	+/+	Some disorganisation of BX cytoplasm	6
BP	+++/+++	+/NA	+/+++	Some disorganisation in both	11
SP4C	+/+++	++/NA	+++/++	No obvious effects	11*
BV	++/-	+/+++	-/++	Hyphal collapse/coiling/disorganisation	8
SP5B	-/+	NA	++/+	Lysis of hyphal tips on contact	4**
BW	+/+	-/-	++/-	Some disorganisation of BW cytoplasm	4
R	++/+	+/++	++/-	Lysis/disorganisation at hyphal tips	8
P	+++/++	NA/-	++/-	Marked coiling/disorganisation/some lysis	7*
Y	-/-	++/++	++/-	NA	6
B1	-/+	NA/-	++/-	Some disorganisation of B1 cytoplasm	3*
#2	+++/+	+/++	++/++	No obvious effects	11
A1	+++/+++	-/-	-/+	NA	7
T.virens G	-/+	NA/-	++/++	Hyphal collapse/coiling/disorganisation	5*
BN	++/++	++/++	-/-	Coiling; destruction of cytoplasm	8
H1	-/+	-/+	++/-	Marked coiling/disorganisation	4
E	+++/++	++/++	+++/+	Vacuolisation at tips	13
K	++/+	-/-	++/-	No obvious effects	5
42br1	+/+	+/NA	+++/NA	Vacuolisation/browning/disorganisation	6**
40r	-/+++	++/-	+/-	Pronounced lysis tips from distance	6
T.asperellum2 SP4B	+/+++	+/NA	++/++	NA	9*
T.atroviride C	++/+++	+++/NA	++/++	Limited disorganisation/lysis	12*
Q	+/++	++/NA	+/++	Lysis/disorganisation/some coiling	8*
T.harzianum BU	NA/++	+/-	++/-	Limited disorganisation	5*
72126P3	-/-	NA/-	+++/+	No obvious effect	4*
T.hamatum #3	-/+	-/++	+++/+	NA	7

Key: +++ strong inhibition, ++ medium inhibition, + weak inhibition, - no inhibition; *missing data point

6.4 In-vitro testing of Trichoderma isolates in PNG

Further testing was carried out in PNG (Plant Pathology Laboratory Milne Bay), to assess the effect of the Trichoderma isolates on basidiospore germination and growth of *G. boninense* on oil palm rachis tissue.

6.4.1 Results

Ganoderma spore viability tests against Ceratocystis, Theilaviopsis and Trichoderma spp.

A single isolate of *Ceratocystis* (C10), *Thielaviopsis* (HT8) and two different isolates of *Trichoderma* (28b4 & 31b2) were challenged against isolates of germinating *Ganoderma* spores.

Ganoderma spores were streaked and left to germinate. Once germinated, the spores were subcultured onto the centre of 9 PDA plates (1 Control and 4 duplicates) and then an agar disc of each of the different fungi was placed 2cm away from the germinating *Ganoderma* spore. The length of *Ganoderma* mycelia was measured for ten days or until growth was complete to the edge of the plates. The results of these challenges are shown in Table 6.3.

Table 6.3. Ganoderma spore germination and growth tests in the presence of fungal antagonists.

		Length of *Ganoderma* isolate/ Length of challenging fungi (mm)							
Day #	**Control (mm)**	C10	C10	HT8	HT8	28b4	28b4	31b2	31b2
1	0	0/2	0/2	0/3	0/2	0/6	0/7	0/7	0/6
2	2	1/30	1/29	1/30	1/30	1/20	2/20	2/22	1/20
3	10	3/44	2/40	2/43	3/edge	-	-	-	-
4	16	8/edge	7/edge	7/edge	10/edge	-	-	-	-
5	21	15/edge	9/edge	9/edge	11/egde	-	-	-	-
6	34	21/edge	10/edge	15/edge	17/edge	-	-	-	-
7	40	25/edge	17/edge	15/edge	21/edge	-	-	-	-
8	40	27/edge	19/edge	17/edge	23/edge	-	-	-	-
9	40	30/edge	20/edge	20/edge	25/edge	-	-	-	-
10	**←Growth complete; all fungi have reached the edge of the plate→**								

The results above show the length of *Ganoderma* and corresponding length of the challenging fungi for the period of measurement. From days 1 to 3, *Ganoderma* could still be distinguished and was measured. However for all the plates of *Ganoderma* spores challenged with the *Trichoderma* isolates, measurements did not continue after day 2 as *Trichoderma* had completely suppressed further growth of the spore.

In contrast the *Ceratocystsis* isolates reached the edge of the plates after day 3 but *Ganoderma* mycelia was still visible superimposed on the *Ceratocystis* mycelia and thus growth measurements were continued until day 10. Hence, this fungus is not an effective inhibitor of *Ganoderma*.

Further testing was carried out using *Trichoderma* cultures only and oil palm rachis tissue to assess if the antagonism by *Trichoderma in-vitro* could be translated to oil palm tissue. The results of these tests are presented in Table 6.4 and pictorially in Figure 6.5.

Table 6.4 The effects of different isolates of Trichoderma on Ganoderma growth on oil palm rachis tissue.

***Trichoderma* Isolate**	**Observations/ Comments**	***Ganoderma* Indicator (GSM)**
SP5A	- Trichoderma completely covered the rachis with dense spore growth	Nil
J	- Same as the above with no signs of Ganoderma.	Orange (yes)
BF	- White mycelium along the rachis, not sure if Ganoderma or Trichoderma; the duplicate shows a partially green mycelium all over the rachis.	Nil
BV	- Ganoderma mycelium is evident on the surface of the rachis to only about 10- 11 cm, then Trichoderma sporulated on all over but not on the Ganoderma mycelium.	Nil
B	- Dense greenish-white mycelium; the duplicate has only a thick white mycelium thus not sure of Trichoderma or Ganoderma	Nil
BN	- Nice healthy Trichoderma growth on all sides of the block in both duplicates,	Nil
E	- Slightly green mycelium on the rachis but no indication of any Ganoderma.	Nil
W	- Slightly greenish mycelium on the block but not as thick or evident as the others	Nil
40r	- Very healthy Trichoderma growth on all sides of the rachis; duplicate shows the same	Nil
28b4	- The same as 40r.	Nil

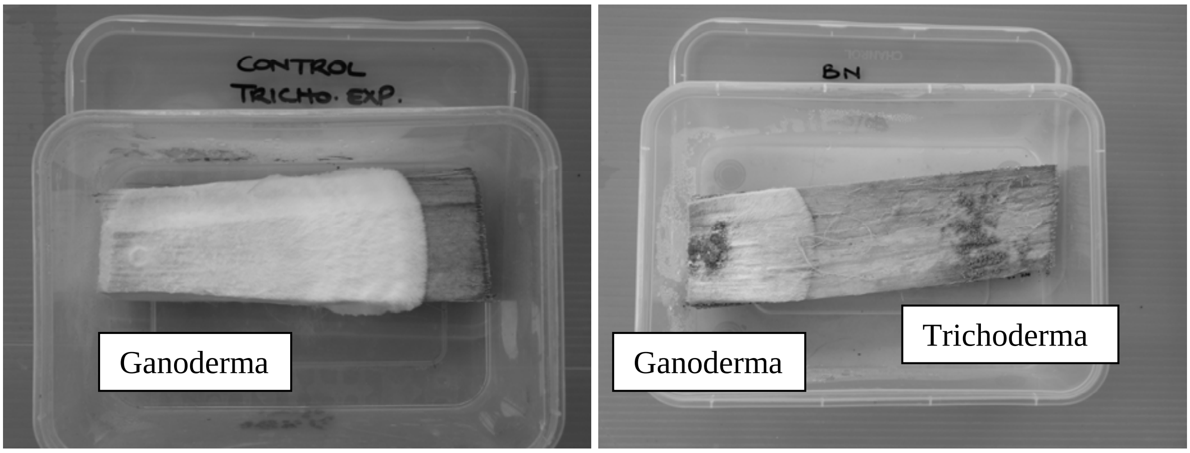

Figure 6.5 Growth of Ganoderma in-vitro on rachis tissue (left- Control) and right, in the presence of Trichoderma isolate BN showing suppression of growth of Ganoderma.

7.0 Technical services

Training

Formal and field training sessions were held in all plantations and smallholders projects in 2007.

Disease reports

Forty-five reports of diseases in all plantations and smallholders were received in 2007. The majority of these were Ganoderma but some included spear rot, crown disease and other unknown diseases. All reports were attended to and recommendations were made.

4. SMALLHOLDER STUDIES

(G. Curry & G. Koczberski, Curtin University of Technology, Perth, Australia)

MOBILE CARD TRIAL BIALLA[1]

1. INTRODUCTION

This report presents the results of a trial of a new payment initiative to improve the income and production levels of smallholders by mobilising labour for oil palm production in the Bialla Oil Palm Scheme in West New Britain Province. The payment initiative known as the 'Mobile Card' was trialled for 20 months on 71 smallholder blocks across three smallholder divisions. The Card was used on smallholder blocks alongside the two existing payment mechanisms: the 'Papa' and 'Mama' payments. Each smallholder block sells their oil palm fruit to Hargy Oil Palms Ltd. (HOPL) and presently has access to two payments per month. One payment is made to the registered blockholder (the Papa payment) and the other payment (the Mama payment) is specifically for women for the collection of the oil palm fruitlets (*lus frut*) that scatter on the ground during the harvesting of fresh fruit bunches (FFB). Both payments are linked to a specific block. Unlike the two existing payment mechanisms, the Mobile Card is not tied to work on the block where the worker resides; it can be used as a payment mechanism on any block requiring labour where a 'labour contract' has been signed by the blockholder and Mobile Card worker. This payment initiative is designed to facilitate labour mobility both between and within blocks.

Unlike existing payment arrangements, the Mobile Card labourer is paid a proportion of the oil palm fruit he harvests which is weighed on a separate docket from the Papa and Mama dockets. Thus, rather than being paid in cash by the blockholder, the company pays the labourer directly according to the percentage split agreed to by the blockholder and Mobile Card worker. The payment of labour in fruit (a share of the fruit harvested by the worker) overcomes the reluctance or inability of blockholders to fulfil their part of the labour contract, i.e., the full and timely payment of labour. By guaranteeing payment for work undertaken by hired or family labour there is an incentive for young men to contribute labour to oil palm production whether on their family block or as hired labour on other blocks.

A percentage split of the harvested crop for payment for work done by the Mobile Card worker was the preferred and most effective method of payment for harvesting and block maintenance labour, with the fruit weighed and recorded on a single docket. If there were two separate weighings for each share of the crop there would be potential for conflict over the amount of fruit allocated to each weighing. Further, a proportional payment mechanism was preferred rather than a specified amount of fruit for work done (e.g. 2 nets) because the latter may reduce the Mobile Card labourer's incentive to fully harvest a block. A ratio method maintains an incentive to fully harvest a phase/block.

Before a labourer is employed on another's block as a Mobile Card worker a contract agreement (Appendix 1) is signed by the blockholder and the Mobile Card worker and this is witnessed and approved by an OPIC extension officer. Designed by OPIC, the contract specifies:

- the agreed percentage split of FFB weighed on the Mobile Card docket.
- The work to be done by the Mobile Card worker (e.g., harvesting, net stacking, pruning, fertiliser application, etc).

[1] This report is included with the kind permission of the authors. The original report can be found at http://espace.lis.curtin.edu.au/archive/00002985/01/Bialla_MobileCardReport_FINAL_23July08.pdf

- Where the work will be carried out (Phase 1, 2, or 3).
- The period of the contract.

Once the contract has been signed and the details entered into the HOPL smallholder payment computer program, the labourer can begin work and be paid directly by the company. Contracts are renewable and the terms of the contract (e.g., percentage split of harvested fruit) can be renegotiated at the end of each contract period. Contracts can be cancelled if either party to the contract does not fulfil the terms of the contract.

Why the need for a Mobile Card?

Low harvesting rates

Research among Bialla oil palm smallholders revealed that a major determinant of low smallholder productivity is the considerable level of under-harvesting (Koczberski & Curry 2003). Under-harvesting leads to substantial production losses amongst smallholders and is a major cause of low productivity among growers. Analysis of five years of production data from the Hoskins scheme reveals growers on the land settlement schemes (LSSs) achieved 60% of plantation levels of production (tonnes/ha) while Village Oil Palm (VOP) growers achieved 38% of plantation levels. While some of the smallholder-plantation deficit is explained by lower farm inputs in the smallholder sector (e.g., less fertiliser inputs, delayed replanting and low levels of block maintenance), a substantial proportion of the difference is attributable to high rates of under-harvesting, particularly amongst VOP producers and towards the rear of the 6 ha LSS block furthest from harvest roads. At the time of the 2003 Bialla smallholder study, the extent of under-harvesting was gauged by using two sets of data: an OPIC 'late pickup' survey; and, a post-harvest survey of 57 blocks in the four LSS subdivisions: of Wilelo, Barema, Soi and Kabaiya.

The late pickup survey gathered data on the numbers of extra nets of fruit stacked for collection when the fruit collection truck was delayed for 24 hours or more. In 2002, HOPL was concerned that the tonnage of fruit harvested by smallholders for collection by company or contractor trucks was frequently underestimated by OPIC. This meant that extra trucks had to be redirected by HOPL to collect the additional fruit thus disrupting transport schedules. OPIC attributed the disparity between predicted and actual tonnages to the delayed pickups allowing smallholders more time to harvest fruit. In November 2002, OPIC counted the nets in those sections of Wilelo (one of the oldest LSS subdivisions) and Soi (a recent LSS subdivision) and Pakisi VOP where the truck was one or more days later than the scheduled pickup day. The results are shown in Table 1.1.

Table 1.1. Expected and actual numbers of nets of fruit collected in a harvest pickup round in November 2002 when the harvest truck was more than 24 hours late for the scheduled pickup.

Bialla subdivision	Expected number of nets	Actual number of nets	Increase (%)
Wilelo (older LSS)	231	362	57
Soi (recent LSS)	362	456	26
Pakisi (VOP)	133	169	27
Totals	726	987	36

Source: data supplied by OPIC-Bialla.

Across the three subdivisions, late pickups resulted in an increase in production of 36%. Soi LSS subdivision and Pakisi VOP had similar increases of 26% and 27% respectively, but the most significant increase was in the older subdivision of Wilelo where production increased by 57%. Wilelo subdivision has many elderly growers and at the time of the survey in 2002 many had delayed replanting, resulting in extensive areas of tall palms which are more difficult and time consuming to harvest. Delayed pickups thus allowed more time for harvesting, suggesting labour shortages are a factor explaining low harvesting rates.

Data on under-harvesting were also collected from post-harvest surveys. Surveys were conducted within two days following a harvest pickup and recorded harvesting rates from Phase 1 at the roadside edge of the block through to Phase 3 at the rear of the block. The surveys were conducted with OPIC officers in June 2002 in the older LSS subdivisions of Wilelo and Barema (33 blocks) and the more recent LSS subdivisions of Soi and Kabaiya (24 blocks). The results presented in Figure 1.1 demonstrate a considerable level of under-harvesting and also a very marked edge-effect in which harvesting rates decline from Phase 1 through to Phase 3 plantings at the rear of the block. The results are compared with post-harvest survey data collected among smallholders in the Hoskins scheme in May-June 2002.

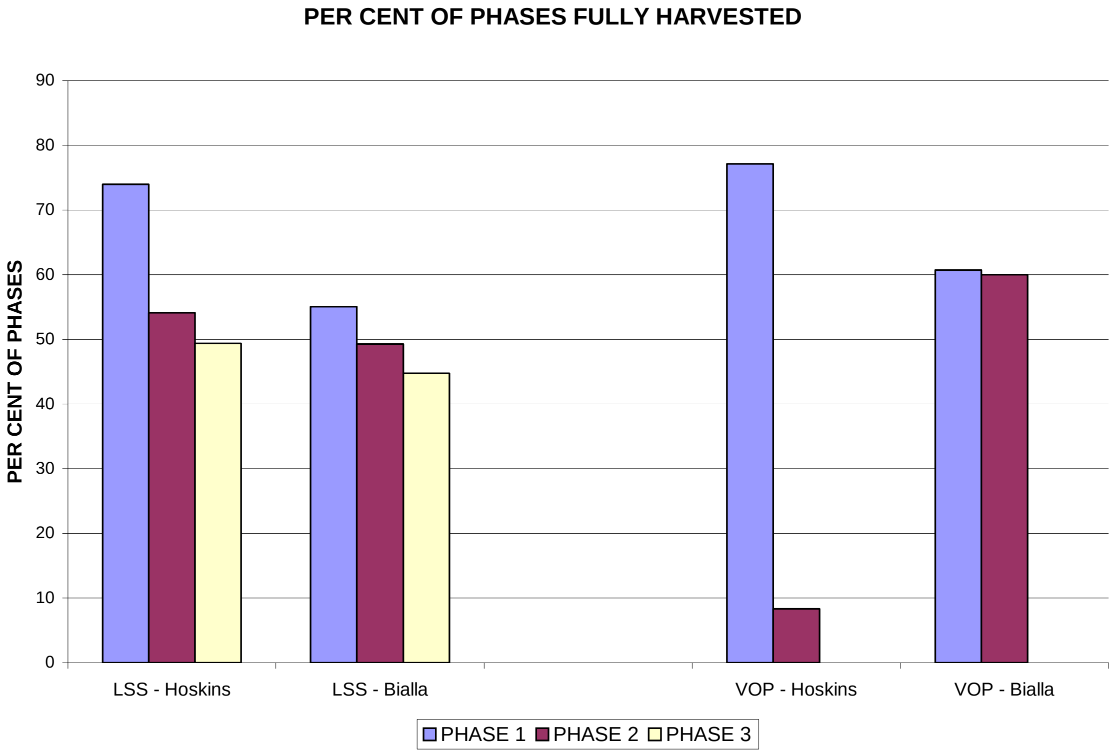

Figure 1.1. Per cent of phases fully harvested for Bialla and Hoskins LSSs and VOPs.

Harvesting rates tend to be higher at Hoskins for all three planting phases on the LSS and Phase 1 of VOP blocks. The lower harvesting rates recorded in 2002 at Bialla LSS may reflect the greater average age of plantings on the older subdivisions, thus lowering labour efficiency in harvesting. Because of the small number of VOP blocks in the survey with a Phase 2 planting, it is not possible to draw any conclusions about differences in the harvesting propensities of VOP smallholders on the two schemes. The harvesting surveys were undertaken when smallholders were receiving between K120 and K130 per tonne.

The harvesting edge-effect across the two LSSs reveals the impact of distance from the road on harvesting practices. On the LSSs at both Bialla and Hoskins less than half of Phase 3 plantings were fully harvested, compared with 55% and 74% of Phase 1 plantings at Bialla and Hoskins respectively. The greater distance which fruit must be carted by wheelbarrow from the rear of the block may serve as a disincentive to harvesting. However, a combination of factors is also likely to compound the effect of distance. This may include insufficient labour or time to evacuate fruit from Phase 3 plantings, age of blockowner, difficult terrain (e.g., slopes, gullies, swampy ground), and minimal maintenance of oil palm stands at the rear of the block.

The Bialla survey was not large enough to estimate the annual losses of smallholder fruit, although some indication of potential losses can be gained by examining data from the nearby Hoskins scheme where a larger post-harvest survey was undertaken in May-June 2002. At Hoskins, total annual losses of smallholder fruit were conservatively estimated at over 60,000 tonnes per year, or around 25% of production for 2001. If we assume that smallholder under-harvesting rates at Bialla are similar to those at Hoskins (a likely assumption), then in 2002, over 33,000 tonnes of smallholder fruit were not processed by the HOPL mill. *In 2007 prices (average price K254.68/tonne), the cash losses to Bialla smallholders were K8.4 million or K2,429 per smallholder block.* Whilst it is likely that harvesting rates in 2007 have improved with the record high oil palm prices since April 2007, there remains considerable potential to increase smallholder productivity and incomes through raising harvesting rates.

Labour constraints

The Bialla smallholder study concluded that the primary determinants of under-harvesting and low productivity were household labour shortages and the under-utilisation of labour (Koczberski & Curry 2003) (Figure 1.2). Addressing household labour supply is therefore one approach for lifting harvesting rates.

As illustrated in Figure 1.2, the main factors constraining labour supply relate to household labour shortages, the under-utilisation of available labour, and the minimal use of hired labour — all of which are outcomes of various structural barriers and individual household circumstances that prevent labour from being deployed and adequately remunerated. Such labour constraints can result in incomplete harvesting, skip harvesting, abandonment of blocks or the semi-abandonment of a portion of an oil palm block (usually at the rear of the block, or an old stand of oil palm awaiting replanting).

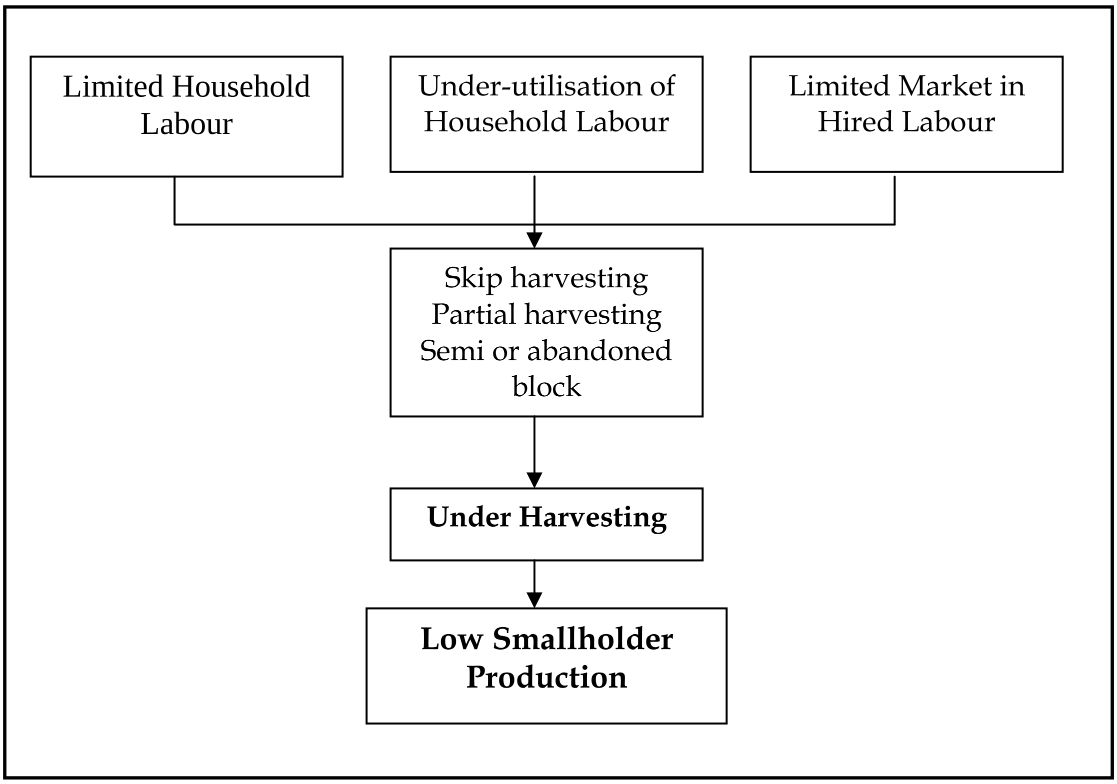

Figure 1.2. Flow chart of factors contributing to low smallholder productivity.

Limited household labour

Household labour shortages can be either long-term or short-term and tend to be experienced by the following types of households:

Long-term

- Elderly blockholders or widow households with one or no adult sons residing on the block. Elderly blockholders experiencing labour shortages tend to be concentrated in the older subdivisions of Wilelo, Barema and Tiaru.
- Young married couples with young dependants. Younger families are typically found in the newer subdivisions of Kabaiya and Soi.
- Female-headed households without adult sons.

Temporary

- Households with members incapacitated by illness.
- Customary or religious obligations that draw significantly on household members' time.
- Short-term absences from the block (e.g., visiting relatives in another province or temporary employment).
- Households where labour is temporarily diverted to other livelihood activities. This is more common on VOP blocks where some family members may shift their labour from oil palm to other more profitable or physically less demanding economic activities, such as cocoa production during seasonal flush periods or fishing when fish are abundant.

For various reasons labour-short blocks have limited access to off-block labour due for example to their restricted kinship ties or social networks (more of a factor on the LSS) and because they are often unable or reluctant to overcome labour shortages by hiring labour. They may not address labour deficits by hiring labour because of their low incomes and a perception that hired labourers are not reliable and may make claims on the block through their labour input (see Section 3). Another important reason is that blockholders are reluctant to pay cash for labour. Labour shortages can lead to consistently low productivity and incomes. Typically, there is also a reduced capacity to invest in block maintenance and replanting, hence the impact of labour shortages on productivity is cumulative through time.

Under-utilisation of available labour

Labour is under-utilised in oil palm production on the LSSs and VOPs for different reasons. On the LSS blocks under-utilised labour is commonly associated with highly populated blocks practicing the *markim mun* production strategy, where harvesting work and oil palm income are rotated on a monthly basis among co-resident households. As described in earlier studies among Bialla and Hoskins oil palm smallholders (see Koczberski *et al*. 2001; Koczberski & Curry 2003), the growing numbers of people and households per block often lead to social stresses that can result in disputes over labour allocations and income distribution. Conflicts commonly arise between fathers and sons over payments for oil palm work. When disputes are on-going, these densely populated blocks tend to switch from the co-operative *wok bung* production strategy where all block residents work together in oil palm production to the *markim mun* production strategy.

To some extent these disputes reflect inter-generational conflicts over the control and management of block where young men challenge the leadership of their father by disputing levels and types of remuneration. Young men, particularly on the LSSs, want to be paid well for their work (many are married with dependent children), rather than let their father manage the block finances on their behalf (e.g., pay the school fees of children residing on the block). Many sons are therefore challenging their father's authority and the traditional cultural norms surrounding labour and in-kind payment of labour by refusing to work on the block unless they are paid in cash and receive what they consider to be a fair return on their labour. Such disputes serve to undermine the labour cooperation among co-resident households and can lead to a situation whereby a complete harvest of a block is not possible due to a 'shortage' of labour during the fortnightly three-day harvest period.

The shift to the *markim mun* production strategy also involves an erosion of the father's (the leaseholder) authority to organise, manage and remunerate labour because production decisions become the responsibility of the household head allocated that month's production (usually one of the married sons). This has implications for the ability of the leaseholder to mobilise labour, make block management decisions and repay farm debts. Also, as observed on several *markim mun* blocks there is a reduced incentive to undertake block maintenance as no single household is willing to take responsibility for block maintenance when the benefits of such work accrue to other households.

The under-utilisation of labour sometimes reflects a low commitment level to oil palm. For many customary landowners with VOP or leasehold blocks, oil palm may not be their primary income source or interest, and therefore they may harvest their blocks irregularly (once a month or less) and only when additional cash is required. Also, many customary landowners do not reside on their oil palm blocks preferring instead to live in the village. Such growers could be described as 'hobby' or part-time growers/semi-retirees who tend to produce to a target income, above which their motivation to produce oil palm declines rapidly.

A further reason for the under-utilisation of labour is the reluctance of people to provide labour because of payment uncertainty. Because of incomplete, deferred or non-payment of family labour (e.g., to brothers, wives, children), caretaker labour or hired labour (e.g., youth groups), the supply of labour for oil palm harvesting and block maintenance is constrained. This results in a great deal of under-utilised labour. In the case of family labour, women prior to the introduction of the *Lus Frut Mama* scheme (see below) contributed minimally to household oil palm production because returns to labour were greater in the production and sale of food at local markets where they had more control over the income earned from their labour.

Another important group whose labour is often under-utilised is caretakers. Long-term caretakers are often confronted with uncertain and under-payment of their labour by blockholders who are residing elsewhere. Because oil palm payments are made directly to the blockholder, the caretaker is wholly dependent on the blockholder for his or her income. If the blockholder lives at a distance from the block, then opportunities for remuneration may be limited and very irregular. Poor and irregular remuneration creates few incentives for caretakers to maintain high production levels or to undertake block maintenance, resulting in very low production for months or years. There may also be some shifting of crop to other blocks which can exacerbate debt levels on the block. Importantly, major investments like replanting and fertiliser inputs can be neglected. Thus, the payment arrangements between blockholders and caretakers have a considerable bearing on block productivity.

Minimal use of hired labour

Labour shortages are rarely overcome through the use of hired labour. Only two of 103 smallholder blocks surveyed in 2002 at Bialla reported the regular use of hired labour (Koczberski & Curry 2003). There are several reasons why a market in labour has not developed in the smallholder sector, despite the large numbers of under-employed youth. Like the case of caretakers described above (and women before the *Lus Frut Mama* Scheme), young men are reluctant to provide hired labour because of concerns over payment uncertainty for their labour. Often when blockholders receive their oil palm payment, they have not budgeted for the payment of hired labour resulting in partial, deferred or non-payment for work done by labourers. The employment of youth and youth groups for contract harvesting and block maintenance has been very limited and many groups have failed as a result of the 'labour contract' not being fulfilled by the blockholder.

2. MOBILE CARD TRIAL

Mobilising labour

Taking into consideration the factors described in Section 1 that explain the constraints on labour in oil palm production, a strategy for mobilising labour within and across smallholder blocks must incorporate a mechanism that guarantees timely and 'fair' payment of family, caretaker and hired labour. Payment mechanisms that guarantee timely payment of labour should instil confidence that the labour contract will be fulfilled, thereby increasing the incentives and motivations to commit labour to oil palm production.

In developing an appropriate initiative to mobilise labour we first examined the principles underlying the success of the *Lus Frut Mama* Scheme. The evaluation of the *Lus Frut Mama* Scheme revealed that low rates of loose fruit collection by smallholder women prior to the scheme were the result of limited and/or uncertain remuneration of their labour by their husbands (Lewis 2000; Koczberski *et al.* 2001). Before the *Lus Frut Mama* Scheme, the company paid only the household head for oil palm harvested on the block. This was a cause of frequent domestic disputes and led many women to redirect their labour to income activities where they had greater control over the income earned (e.g., production and sale of food at local markets). By paying women directly for loose fruit collection the scheme removed much of the payment uncertainty when women relied on their husbands to remunerate them for this work. Thus the under-utilisation of women's labour was the result of an ineffective (uncertain) payment mechanism for their labour.

Another important finding explaining the success of the *Mama Lus Frut* Scheme was that cashless transactions proved to be a suitable form of payment for labour (Koczberski *et al.* 2001). Prior to the introduction of the *Lus Frut Mama* Scheme many men were unwilling or unable to hand over a share of the oil palm income to their wives because of the many demands on the income and the weak bargaining position of women in the distribution of the household oil palm income. Since the introduction of the *Mama Lus Frut* Scheme, most men are willing to place a few fruit bunches in the Mama net as their financial contribution to the household budget. Also, block maintenance tasks performed by women, such as maintaining paths and palm circles, are now often 'paid' for at harvest time by placing some fruit bunches in the Mama net. *It is much easier for men to give fruit bunches than cash to their wives because a cashless transaction circumvents the competing claims on cash, thereby effectively guaranteeing a contribution by the male household head to the household budget.* Thus, by opening up a channel whereby men could 'pay' their wives in fruit rather than cash, it was much easier for husbands to fulfil their economic obligations to their wives and families. It was considered that a similar payment system for caretakers and hired labourers which used 'fruit' rather than cash would overcome the labour constraints associated with uncertain and incomplete remuneration of labour.

The trial

The Mobile Card trial began in 2006 following interest from OPIC, the Growers Association and HOPL. The trial incorporated the key principles underpinning the success of the *Lus Frut Mama* Scheme, in particular the guaranteed, timely and direct payment of the labourer by the company. The design principles and concept of the Mobile Card also built on the successful OPRA trial of the Mobile Card payment initiative amongst Hoskins oil palm growers in 2002-2003 which aimed at mobilising labour on conflict-ridden and labour-short blocks (Curry & Koczberski 2004). The Bialla trial made some minor operational changes to improve the running of the new payment system, and the final design was based on numerous meetings and discussions with senior OPIC managers and extension officers, and with key personnel from HOPL. The overall aim of the Mobile Card was to enable greater labour and payment flexibility as a way to enhance incentives for increasing smallholder production and incomes.

Two OPIC Mobile Card extension officers were employed full-time (funded by ACIAR) during the trial period from February 2006 to December 2007. One Mobile Card officer was responsible for Divisions 1 and 2, and the other was responsible for Division 3. The Mobile Card officers' main tasks were to promote, supervise and monitor the trial, and explain and organise contracts between blockholders and Mobile Card workers.

Immediately following the signing of a Mobile Card contract the Mobile Card officer conducted an inspection of the trial block. For each trial block, data were collected on levels of pruning, ring weeding, cover crop and general maintenance. This information provided a baseline to monitor changes in block condition. On each trial block the Mobile Card extension officers also maintained monthly production and income records and dealt with any problems as they arose (e.g., late payments, payment inaccuracies or late renewal of contracts).

Plate 2.1. OPIC Mobile Card awareness meeting at Uasilau LSS subdivision.

Throughout the trial the officers were also responsible for conducting awareness among smallholders of the Mobile Card which they did in association with the OPIC Divisional managers and extension officers (Plate 2.1). They also reported regularly on the progress of the Mobile Card trial at OPIC staff meetings and Local Planning Committee meetings.

Prior to the trial's commencement HOPL modified their computer smallholder payment system to accommodate the trial. This involved programming the computer to accommodate the agreed percentage split between the blockholder and the Mobile Card labourer of the value of the fruit bunches weighed on the Mobile Card docket, and entering the dates of the contract period. During the trial, Mobile Card labourers were paid by cheque directly. The fortnightly production and income data recorded by HOPL for the Mobile Card, Papa and Mama production provided the data to assess the impact of the Mobile Card on block production and incomes.

To assist blockholders and Mobile Card workers with understanding the concept of a percentage split of the production and to arrive at a decision

Table 2.1. Ready Reckoner

	PERCENTAGE SPLITS																	
	Split 1		Split 2		Split 3		Split 4		Split 5		Split 6		Split 7		Split 8		Split 9	
	Papa	Mobile	Papa	Mobile	Papa	Mobile	Papa	Mobile	Papa	Mobile	Papa	Mobile	Papa	Mobile	Papa	Mobile	Papa	Mobile
	10%	**90%**	**20%**	**80%**	**30%**	**70%**	**40%**	**60%**	**50%**	**50%**	**60%**	**40%**	**70%**	**30%**	**80%**	**20%**	**90%**	**10%**
Kg harvested																		
50	5	45	10	40	15	35	20	30	25	25	30	20	35	15	40	10	45	5
100	10	90	20	80	30	70	40	60	50	50	60	40	70	30	80	20	90	10
200	20	180	40	160	60	140	80	120	100	100	120	80	140	60	160	40	180	20
300	30	270	60	240	90	210	120	180	150	150	180	120	210	90	240	60	270	30
400	40	360	80	320	120	280	160	240	200	200	240	160	280	120	320	80	360	40
500	50	450	100	400	150	350	200	300	250	250	300	200	350	150	400	100	450	50
600	60	540	120	480	180	420	240	360	300	300	360	240	420	180	480	120	540	60
700	70	630	140	560	210	490	280	420	350	350	420	280	490	210	560	140	630	70
800	80	720	160	640	240	560	320	480	400	400	480	320	560	240	640	160	720	80
900	90	810	180	720	270	630	360	540	450	450	540	360	630	270	720	180	810	90
Tonnes harvested																		
1	100	900	200	800	300	700	400	600	500	500	600	400	700	300	800	200	900	100
2	200	1800	400	1600	600	1400	800	1200	1000	1000	1200	800	1400	600	1600	400	1800	200
3	300	2700	600	2400	900	2100	1200	1800	1500	1500	1800	1200	2100	900	2400	600	2700	300
4	400	3600	800	3200	1200	2800	1600	2400	2000	2000	2400	1600	2800	1200	3200	800	3600	400
5	500	4500	1000	4000	1500	3500	2000	3000	2500	2500	3000	2000	3500	1500	4000	1000	4500	500
6	600	5400	1200	4800	1800	4200	2400	3600	3000	3000	3600	2400	4200	1800	4800	1200	5400	600
7	700	6300	1400	5600	2100	4900	2800	4200	3500	3500	4200	2800	4900	2100	5600	1400	6300	700
8	800	7200	1600	6400	2400	5600	3200	4800	4000	4000	4800	3200	5600	2400	6400	1600	7200	800
9	900	8100	1800	7200	2700	6300	3600	5400	4500	4500	5400	3600	6300	2700	7200	1800	8100	900
10	1000	9000	2000	8000	3000	7000	4000	6000	5000	5000	6000	4000	7000	3000	8000	2000	9000	1000
11	1100	9900	2200	8800	3300	7700	4400	6600	5500	5500	6600	4400	7700	3300	8800	2200	9900	1100
12	1200	10800	2400	9600	3600	8400	4800	7200	6000	6000	7200	4800	8400	3600	9600	2400	10800	1200
13	1300	11700	2600	10400	3900	9100	5200	7800	6500	6500	7800	5200	9100	3900	10400	2600	11700	1300
14	1400	12600	2800	11200	4200	9800	5600	8400	7000	7000	8400	5600	9800	4200	11200	2800	12600	1400

on the proportion of the crop to 'pay' a Mobile Card labourer (and hence their anticipated earnings), a ready reckoner was developed (Table 2.1). This was used by the Mobile Card extension officers when explaining to smallholders how the Mobile Card operated and for negotiating contract agreements. Although, initially the concept of a percentage split was difficult to grasp for many blockholders, they gradually developed an understanding of how it worked as the trial progressed. Some blockholders changed the percentage split at the contract renewal stage when they understood more about how the split determined the amounts of money paid to the Mobile Card worker and themselves.

Selection of trial participants

A total of 71 smallholder blocks were involved in the trial for varying periods. The selection of blocks for the trial focused on the following types of low producers:

- VOP growers with poorly maintained blocks.
- Caretakers receiving poor and/or irregular payment of their labour.
- Labour-short blocks of elderly or 'semi-retired' growers in the older LSS subdivisions.
- Labour-short blocks among recently married couples with young children on the new LSS subdivisions of Soi and Kabaiya.

While OPIC identified low producing blocks for inclusion in the trial, many blockholders themselves approached OPIC to be involved in the trial because they identified the potential benefits of the Mobile Card for overcoming production constraints on their block and/or solving conflicts between family members over the distribution of oil palm income. Prior to inclusion in the trial the blockholders were interviewed by the Mobile Card officers to assess their suitability for the trial. The assessment was forwarded to the OPIC Field Manager and the HOPL Smallholder Manager for final approval.

Originally, 40 blocks were to be included in the trial. However, because of the high level of interest among smallholders it was decided to progressively expand the number of trial blocks. In addition, there were 15 blocks at Uasilau LSS included in the trial. These blocks are six to ten hectares and have been informally subdivided by leaseholders to allow their children to plant and harvest oil palm. Because the block is under one agricultural lease, there are only two payments made to the block (Papa and Mama payments), which creates difficulties when allocating income amongst the family members managing these informally subdivided blocks. The Mobile Card was introduced on these blocks to solve this particular problem, and hence production data for these blocks were excluded from the analysis and are not reported here.

As shown in Table 2.2, the trial participants can be categorised into four main groups based on the relationship between the blockholder and the Mobile Card labourer. The most common contract arrangement was between fathers and sons (Table 2.2). The typical contract period was for three months with 68% of contracts being renewed one or more times. The average number of contracts per trial block was 2.28 (Table 2.3). The most common Mobile Card contract percentage split was 50:50, although the percentage split varied greatly depending on the relationship between the blockholder and the Mobile Card worker (Table 2.3) (see Section 3 for further discussion).

Table 2.2. Relationships of blockholders to Mobile Card workers.

Relationship	Number	Percentage
Son	23	32
Other co-resident relative	17	24
Caretaker	16	23
Hired labourer	13	18
Not identified	2	3
Total	71	100

Table 2.3. Mobile Card contract details by relationship of Mobile Card worker to blockholder.

Relationship	Average number of contracts	Most common percentage split Papa: Mobile Card worker
Son	2.17	40:60
Other co-resident relative	2.35	50:50
Caretaker	2.56	40:60
Hired labourer	2.23	50:50
Not identified		
Total	2.28	50:50

1. Father-son blocks. These blocks are found on the older LSS subdivisions and are heavily populated blocks with several co-resident married sons or daughters and other relatives. They often experience conflicts over the distribution of oil palm income. Typically, these blocks have a *markim mun* production strategy in place which means that the family whose month it is to harvest and collect the income is unable to harvest all available crop in each fortnightly harvest round. Block maintenance is often poor. The most common percentage split on father-son Mobile Card contracts was 40:60 (father:son), followed by the 10:90 (father:son) percentage split. The latter was largely restricted to blocks where the father was elderly/retired or where the contract was for only one phase.
2. Other co-resident relative-blockholder blocks. Other co-resident relative is someone from outside the immediate family such as an in-law, adult brother or other relative, often someone visiting the LSS block from ‘home’. They often reside on the block for relatively long periods with their residency typically dependent on their labour contribution to oil palm production. These relatives are mostly found on labour-short blocks and in some cases have been ‘adopted’ by the blockowner. The most common Mobile Card contract percentage split on these blocks was 50:50.
3. Caretaker blocks. Caretakers are often disadvantaged by irregular and under-payment of their labour by the blockholder. Payment uncertainty and irregular payments are disincentives to production, resulting in low production and poor block maintenance. Most of these blocks are in the LSS subdivisions of Soi, Kabaiya and Lalopo where some of the leaseholders are customary landowners from nearby villages. These leaseholders tend to spend most of their time in their villages or do not have ready access to labour. These blocks are generally very poorly maintained

with high levels of under-harvesting. The most common percentage split on caretaker blocks was 40:60 (blockholder:caretaker), followed by the 60:40 percentage split.

4. Hired labourers. Hired labourers were mostly engaged by aged or widowed blockholders with few adult sons living on the block, or by young families with dependant children. Production on blocks owned by elderly leaseholders is low and variable because they experience regular labour shortages. These types of blocks are common in the older LSS subdivisions in Division 2. The most common percentage split for contracts with hired labourers was 50:50, followed by the 10:90 (blockholder:hired labourer) percentage split. The latter split was used on semi-abandoned and abandoned blocks where yields were very poor and enormous effort was required by the hired labourer to rehabilitate the blocks before production levels could be improved. On these blocks there was an understanding that the percentage split would eventually move in favour of the blockholder once the production of the block improved.

Whilst it was anticipated that VOP blocks would be a target group for the trial, recruitment of young men as Mobile Card workers was limited because many of them in Division 2 and 3 were employed with logging companies at Barema and further east along the coast near Ulamona. Also, the record high oil palm prices from April 2007 meant that many young village men with their own oil palm holdings were unwilling to form youth groups to work on other people's blocks.

The trial results are discussed in the next section.

3. TRIAL RESULTS AND DISCUSSION

Productivity improved significantly on Mobile Card blocks as measured against average monthly LSS and VOP production. Monthly production increased from 6% above the LSS/VOP average without the Mobile Card to 40.45% above the LSS/VOP average during months when Mobile Card labour was deployed. This gave a productivity improvement of 34.4 percentage points, just less than the 38 percentage point gain recorded for the Mobile Card trial at Hoskins (Curry & Koczberski 2004). The success of the Mobile Card trial can also be gauged by the fact that 68% of contracts were renewed once or more, with the average number of contracts per block being 2.28 (Table 2.3).

Factors affecting the trial results

Productivity improvements were documented for 72% of trial blocks with 28% improving by more than 50 percentage points (Table 3.1). At the earlier Hoskins trial, productivity improvements were recorded on 90% of trial blocks. The difference between Bialla and Hoskins in the proportions of trial blocks showing an improvement in productivity relates to the relatively large proportion of blocks in the Bialla trial that were already high producers. Indeed, 30% of trial blocks were achieving productivity levels of more than 50% above average productivity ***before*** entering the trial (Table 3.2). These blocks were concentrated in Soi and Kabaiya. Prior to joining the trial they were achieving productivity rates of 43% and 28% respectively above average LSS productivity. Understandably, from such a strong starting position scope for further improvement was limited (Table 3.3). Consequently, only 50% of Soi trial blocks (69% of Kabaiya blocks) experienced productivity increases with the deployment of Mobile Card labour.

The intention during the trial was to recruit low-producing ‘problem’ blocks. High producing blocks at Soi and Kabaiya were recruited to the trial for two main reasons. First, some were self-identified blocks which sought to enrol in the trial because they saw the Mobile Card as providing some additional benefit for themselves, not because they were low producers, *per se*. These high producers viewed the Mobile Card as potentially assisting with financial and labour management on their blocks through providing an additional mechanism for allocating labour and income. Second, early in the trial the Mobile Card extension officer tended to recruit better producing blocks (the usual practice in on-farm research trials). As the trial progressed, a higher proportion of ‘difficult’ blocks that were often conflicted, were recruited.

Table 3.1. Improvement in production on trial blocks using the Mobile Card.

	Improvement in Percentage Points*				
	No gain	>0-10	>10-50	>50	Total
No. of blocks	20	7	24	20	71
Per cent of trial blocks	28	10	34	28	100

*0 represents mean productivity.

Table 3.2. Productivity of trial blocks in relation to the smallholder average before the introduction of the Mobile Card.

	Starting Point in Relation to Average LSS/VOP Productivity*				
	<-50	>-50 to <0	0 to <+50	50+	Total
No. of blocks	10	22	18	21	71
Per cent of trial blocks	14	31	25	30	100

*0 represents mean productivity.

While the results of the trial indicate positive production and socio-economic gains (see below), productivity improvements have probably been under-estimated for several reasons.

- There were occasional delays in the renewal of Mobile Card contracts leading to the company computer payroll system rejecting Mobile Card weigh dockets. These weights were thus recorded as production on the Papa dockets. Because payroll and production data for the trial were obtained from the smallholder payment system, these months would have been analysed as 'months without Mobile Card labour'. Although efforts were made to correct these data through checking individual weigh dockets, it is likely that some errors slipped through.
- Many instances were identified of Mobile Card fruit being recorded as Papa or Mama production in the smallholder payment database. These errors arose because of incorrect labelling of dockets at the fruit pickup point, or errors in data entry on the payroll system resulting in Mobile Card payments being coded as Papa or Mama payments.
- On some blocks the fruit bunches harvested by the Mobile Card worker were weighed on both the Mobile Card and Papa docket. That is, after harvesting the Mobile Card worker and the blockholder mutually agreed to divide the Mobile Card fruit between the two payment dockets, indicating that some trial participants had difficulty with the concept of a percentage split — see Section 2.
- The sharp rise in oil palm prices since April 2007 may have masked some of the productivity improvement because of the rise in average productivity across the scheme as growers in general increased production in response to the sharp rise in prices.

Finally, unlike most on-farm research or extension trials that target innovative and progressive farmers, the Mobile Card trial targeted 'problem' blocks, often characterised by very low production, a history of disruptive family conflict and debt avoidance. The likelihood of success of the trial on such problem blocks was potentially low. Whilst the Mobile Card was able to overcome conflict and payment problems on most blocks, sometimes the problems were just too great for the Mobile Card alone to resolve.

Productivity improvements

Despite the presence of these confounding factors, marked increases in productivity were recorded with the largest improvements in productivity being associated with the most poorly performing blocks prior to the trial (Table 3.3). For example, blocks that started at worse than 50% below average productivity improved their position to above average productivity with the Mobile Card. Blocks that were in the range of average to 50% above average productivity managed to improve by 20 percentage points. However, as pointed out above, blocks that were high performing to begin with (more than 50% above average productivity), improved their productivity only minimally (Table 3.3).

Further, all trial blocks that were below average productivity on entering the trial showed some improvement in productivity with the Mobile Card (Table 3.3). In the range of average to 50% above average productivity, the proportion of blocks that improved was still high at 67%. Even in the most productive group entering the trial, one-third of blocks showed an improvement in productivity (Table 3.3).

Table 3.3. Mean productivity improvements by initial starting position in relation to the smallholder average.

	Starting Position in Relation to Smallholder Average				
Position before Mobile Card	<-50	>-50 to <0	0 to <+50	50+	Total
No. of blocks	10	22	18	21	71
Improvement in percentage points	84	54	20	3	
Per cent of blocks showing improvement	100	100	67	33	72

Productivity gains by relationship between blockholder and Mobile Card labourer

Improvements in productivity by type of relationship between blockholder and Mobile Card worker were similar to those observed at Hoskins (Table 3.4). 'Hired labourer' and 'other co-resident relative' showed greatest improvement at Bialla followed by 'caretaker' and then 'son'.

Table 3.4. Average productivity improvement in percentage points by relationship between blockholder and Mobile Card labourer for Bialla and Hoskins.

	Improvement in Percentage Points	
	Bialla	Hoskins*
Hired labourer-blockholder	45	58
Caretaker- blockholder	40	37
Son-father	17	18
Other co-resident relative- blockholder	44	n.a.

*Hoskins data reported in Curry & Koczberski (2004, 21).

Hired labour

As stated above, blockholders employing 'hired labourer' showed the largest improvement in productivity following adoption of the Mobile Card (Table 3.4). Eighty-five per cent of blocks employing hired labour experienced an improvement in productivity, which was the highest proportion of blocks to show an improvement amongst the different relationship categories (Table 3.5). These findings are not surprising given that those blocks recruiting off-block labour are usually faced with long-term labour shortages. That is, they tend to have low numbers of able-bodied workers (e.g., elderly blockholders with few co-resident adult sons or blocks occupied by young families with dependant children).

Table 3.5. Per cent of blocks showing an improvement in productivity by relationship between blockholder and Mobile Card labourer.

Relationship	Per cent of Blocks
Hired labourer	85
Caretaker	81
Son	52
Other co-resident relative	76

Also, the use of Mobile Card contracts for hired labour addresses one of the key disincentives to employing hired labour in the smallholder sector — the risk that labourers recruited from off the block will accumulate tenure rights through expending their labour in oil palm production. Some blockholders are reluctant to address labour shortages by employing hired labour because they are fearful that the labour 'investments' of hired labour might lead to compensation demands being made on them by the worker, especially when the work is for an extended period. As discussed further below in relation to caretaker blocks where these issues are more significant, the existence of a Mobile Card contract for hired labour formalises the relationship between blockholder and worker and makes such claims less likely. Thus the Mobile Card overcomes not only payment uncertainty for workers, but also eases the concerns of blockholders that the recruitment of outside labour might ultimately be a threat to their tenure rights. The easing of such fears and the effectiveness of the Mobile Card in overcoming long-term labour shortages are reflected in the high proportion of contracts that were renewed during the trial (68%). Some blockholders were into their seventh Mobile Card contract by the end of the trial.

Other reasons for the success of Mobile Card contracts for hired labour included:

- Improved access to labour for elderly and widowed growers with long-term labour shortages. By offering hired workers guaranteed 'employment' of at least three months with regular fortnightly pay, it was much easier for elderly and widowed growers to recruit young men.
- It offered a solution to short-term labour shortages when blockholders were ill or had temporary off-block commitments such as visits to the home village or short-term work commitments elsewhere. It is therefore very useful for addressing temporary labour shortages of up to two or three months.
- Improved working environment for hired labourers. Mobile Card labourers and blockholders had much praise for the Mobile Card. For Mobile Card labourers there were increased opportunities for work with much lower risks of delayed payment or under-payment. As one Mobile Card worker pointed out, he no longer had to hound the blockholder for payment. For blockholders the payment of labour in fruit with the transaction handled by the company circumvented the difficulty of trying to retain cash for the payment of labour.

Caretakers

The impact of the Mobile Card was significant on caretaker blocks where 81% of blocks showed an improvement in productivity (Tables 3.4 and 3.5). The payment initiative was very acceptable to caretakers and absentee blockholders, as demonstrated by the high proportion (75%) of contracts renewed during the trial and the large number of requests to the Mobile Card officers for 'permanent' Mobile Card contracts. The production data show that the Mobile Card is very effective for overcoming the problems of uncertain and unfair payments that create disincentives for caretakers to harvest regularly and invest labour in block maintenance. Also, it is likely that the practice of some caretakers to weigh their fruit using a neighbouring block's number on the weigh docket (to ensure adequate and timely payment) may cease with the adoption of Mobile Cards on caretaker blocks.

It is also probable that in the long-term the use of Mobile Cards on caretaker blocks will reduce the incidence of tenure disputes and compensation claims that commonly arise on these blocks, a problem that also deters the recruitment of hired labour as highlighted above. Tenure disputes often arise after a caretaker has resided and worked on a block for several years or more while the blockholder has resided elsewhere and has taken scant interest in the day-to-day management of the block. Such disputes are more likely to arise in cases where the caretaker has undertaken poisoning and replanting, and repaid loans. In these situations, the caretaker often views such labour and capital investments as building an ownership claim to the block in the same way that tenure rights to land and crops in subsistence production are reinforced by working the land (see Curry *et al.* 2007). Such investments by caretakers often mean that they will strongly contest attempts by the original blockholder or his descendants to reclaim or sell the block and the caretaker will often demand monetary compensation if forced to vacate the block. Such disputes can be protracted and result in reduced oil palm productivity for extended periods as the conflict plays out through the various dispute resolution channels such as OPIC mediation or local courts.

Mobile Card contracts on caretaker blocks can reduce the likelihood of these disputes in four interrelated ways. First, Mobile Card contracts signed by the blockholder, the Mobile Card labourer and witnessed by an OPIC extension officer specify the contract period, the percentage split of the income, the work tasks to be completed, and the phases to be harvested and maintained. The Mobile Card is in effect a contract between an employer (the blockholder) and an employee (the caretaker). By defining their respective positions and roles, dispute rates are likely to be lower as Mobile Card contracts become increasingly accepted as evidence of the respective tenure rights of blockholders and caretakers. Second, the tenure security of the absentee leaseholder is strengthened because claims of ownership by the caretaker are diminished by the regular fortnightly payments received by the caretaker as specified in the Mobile Card contract. Third, loan repayments for company or bank credit are deducted from the blockholder's payments (the Papa payment), not the Mobile Card, leaving less scope for caretakers to assert ownership claims based on their capital investments in the block. Fourth, the smallholder payment system of the company provides a permanent record of payments to caretakers. These records are a source of evidence for resolving disputes over tenure or compensation claims by caretakers.

Thus, the Mobile Card has the potential to overcome some of the long-standing production problems on caretaker blocks and turn these blocks into stable high producing blocks that benefit both caretakers and blockholders. Given the large number of low-producing caretaker blocks in the newer LSS subdivisions of Soi and Kabaiya it may be useful to suspend the Papa docket and replace it with a long-term Mobile Card, where there is an automatic rollover of contracts every six months (see recommendations in Section 4 for further discussion).

Family labour

Soon after the commencement of the trial there were numerous requests for Mobile Cards from blockholders with married, co-resident sons. These growers saw the Mobile Card as a way to better manage the distribution of work and income on their blocks and to reduce the competing demands on the Papa payments. Despite the marked interest in the Mobile Card, productivity gains were lower for this relationship category than other categories (Table 3.4). This was also observed in the earlier Hoskins trial. Further, almost half those blocks where a son was using a Mobile Card showed no improvement in productivity (Table 3.5).

The lower productivity gain for sons with Mobile Cards was not surprising because typically these blocks were not confronted with absolute labour shortages. Rather, as indicated above, the blockholder used the Mobile Card as a way to improve financial and labour management on the block. Therefore, the Card may be valued more as a social innovation because of its capacity to reduce conflict amongst family members, especially between fathers and sons on the more heavily populated LSS blocks. Some of these leaseholders had already tried other avenues to reduce conflict on their blocks such as rotating monthly production and oil palm payments amongst co-resident sons (the *markim mun* production strategy), but for various reasons these efforts were relatively unsuccessful. As previous research among Bialla and Hoskins smallholders has demonstrated, social conflict among co-resident households is a major factor explaining long-term low production and poor block management (Koczberski *et al*. 2001; Koczberski & Curry 2003). The Mobile Card, and its proportional split of the harvest, was attractive to the residents of highly populated blocks because it added flexibility to how income and labour could be allocated among co-resident households.

The enhanced social stability, especially on densely populated LSS blocks following the Card's introduction, is likely to lead to more stable production over the longer term, and may facilitate a smoother inter-generational transfer of block management from father to son. For leaseholders whose authority and leadership are increasingly being challenged by a younger generation of males, the Mobile Card provides the father with a means to maintain his control over production and income through assisting with the retention of the *wok bung* production strategy. For some blockholders, the rationale for acquiring Mobile Cards was to sustain the *wok bung* production strategy that was under increasing pressure from co-resident adult sons seeking to adopt the *markim mun* production strategy. The main feature of the *wok bung* strategy is its highly centralised control of production, with the leaseholder responsible for organising labour and distributing income.

The switch to a *markim mun* production strategy may be a less efficient production strategy than the *wok bung* strategy. There is evidence to suggest that oil palm productivity is lower on highly populated blocks employing a *markim mun* production strategy than on highly populated blocks that continue to practice the *wok bung* production strategy where all adult males participate in block maintenance and harvesting (Koczberski *et al*. 2001). Because there is less inter-household cooperation with a *markim mun* production strategy, the family whose month it is to harvest often runs into labour shortages and is unable to complete a full harvest in each fortnightly harvest round of three days. The total income and production for the block may therefore be less than it would be under a *wok bung* strategy. Other implications arising from the switch to a *markim mun* production strategy which the introduction of Mobile Cards on highly populated blocks may avoid or postpone, include:

- Greatly reduced motivation to invest in farm inputs, such as fertiliser — the costs of such inputs are disproportionately borne by one or two households (those households whose turn it is to harvest when loan repayments are being made) while the benefits accrue to other households.
- Reduced incentives to undertake block maintenance as no single household is willing to take responsibility for block maintenance — most of the benefits of such expenditures of labour accrue to other households.
- Limited capacity for individual households to accumulate savings to invest in other businesses or material improvements on the block (e.g., water tanks, housing improvements, poultry projects, etc.). Under a *markim mun* production strategy, co-resident households might receive only three or four oil palm payments per year making it very difficult to save.
- Greater desire of co-resident households to avoid loan repayments when households face long periods between oil palm payments and have limited opportunity to save. On some blocks, when it is a household's allocated month to collect the oil palm income they will attempt to maximise household income by avoiding the monthly deductions for loan repayments by weighing fruit on the Mama docket or on the Papa docket of a neighbouring block.

If the Mobile Card is effective in either delaying or preventing the shift from the *wok bung* to the *markim mun* production strategy on highly populated blocks, then it would be worthwhile promoting its use on densely populated LSS blocks contemplating abandoning the *wok bung wantaim* production strategy in favour of more individualised forms of production. Further, whilst the production gains were lower on father-son blocks than other categories (e.g., hired labour) the improvements in social relations among family members and the more equitable distribution of the oil palm income were of considerable benefit to block residents.

Block management

Alongside the increases in productivity and incomes resulting from the reorganisation and increased deployment of labour, improvements in block management were also noted (Table 3.6). On average, general block condition improved by 20% (Table 3.6).

Table 3.6. Impact of Mobile Card on block management.

Activity	Before Mobile Card (June 2006)		After Mobile Card (June 2007)		% Improve-ment
	Score	Average	Score	Average	
Paths	162/310	5.22	199/310	6.42	23
Pruning	157/310	5.06	187/310	6.03	19
Ring Weeding	136/310	4.39	187/310	5.68	29
Maintenance	163/310	5.26	198/310	6.39	21
Loose fruit	161/310	5.19	179/310	5.77	11
Cover Crop	146/310	4.71	177/310	5.71	21
Management	163/310	5.26	193/310	6.23	18
Fertiliser	115/310	3.71	135/310	4.35	17
Total	1203/2480	4.85	1444/2480	5.82	20

Table adapted from Henry Turuo's October, 2007 report to OPIC Field Manager. Data based on 31 trial blocks.

The most marked improvements in block condition following the introduction of the Mobile Card were on semi-abandoned blocks. The leaseholder of the LSS block pictured in Plate 3.1 and Plate 3.2 resided in a nearby village and only occasionally visited the block. This grower was invited to join the trial because the block was semi-abandoned and had consistently low production over several years. Whilst there had been a resident caretaker for a period of time, production was well below average because of irregular and under-payment of the caretaker. The Mobile Card caretaker and his wife moved onto the block after the contract was signed and together rehabilitated the block.

Plate 3.1. An LSS block at Wilelo before the deployment of Mobile Card labour.

Plate 3.2. An LSS block at Wilelo after the deployment of Mobile Card labour.

In summary, the range of socio-economic benefits for smallholders from adoption of the Mobile Card included the following:

- Utilisation of under-employed labour on LSS blocks.
- Greater capacity of growers to overcome long and short-term labour shortages and thus generate higher incomes for themselves.
- Improved access to labour for elderly and disabled growers.
- Greater financial security for long-term caretakers and increased tenure security for absentee leaseholders.
- Greater opportunities for work as hired labourers with full and timely payment assured.
- More equitable distribution of oil palm income amongst household members.
- Less social conflict on highly populated blocks (fewer disruptions to oil palm production).

4. RECOMMENDATIONS

The primary objective of the Mobile Card initiative was to overcome labour supply constraints by eliminating payment uncertainty and reducing disputes over labour remuneration through guaranteeing timely and full payment of labour. The trial results demonstrate that the payment of labour in fruit (a share of the fruit harvested by the worker) overcomes the reluctance or inability of blockholders to pay cash for family or hired labour, thereby improving the supply of labour for oil palm production. Further, by reducing intra- and inter-household conflicts over work and income and facilitating a more equitable distribution of income among household members, the Mobile Card is one way for the industry to address some of major socio-demographic and economic pressures now affecting the smallholder sector.

Based on the successful results of the trial and the support for the Mobile Card by all key stakeholders (smallholders, OPIC and the Company), we recommend that HOPL introduce the Mobile Card as a payment option for smallholders. We make the following recommendations to assist the company and OPIC with introducing this payment initiative.

Mobile Card payment mechanism and contracts

It is recommended that the Company re-programmes the smallholder payment system to incorporate a Mobile Card payment that enables a percentage split of the value of the crop harvested by the Mobile Card worker to be made between the blockholder and the Mobile Card worker. By enabling the Mobile Card to operate on a percentage split of the harvest, it will accommodate the broadest possible range of situations under which the Mobile Card is likely to be used for the payment of labour. The percentage split payment method with the fruit weighed and recorded on a single docket is preferred to a set payment for labour for the following reasons:

- Payment for labour with a specified fixed rate of pay (e.g., kina per task per hectare) may reduce the Mobile Card labourer's incentive to fully harvest a block. For example, difficult to harvest fruit bunches on very tall palms or on palms at the rear of the block may not be harvested once a perceived value of work (e.g., K200/4 hectares) has been completed. The ratio method maintains an incentive to fully harvest a phase/block — the more one harvests the more one earns.

- A proportional split seems to be more suitable for the payment of family labour as there is no 'fixed' rate of payment operating among family members and payments for oil palm work have little relationship to formal market rates for hired labour. Instead, 'payment' rates are often determined by a range of factors such as age of the father, marital status of co-resident sons and daughters, other income sources of family members, individual family needs and other socio-economic circumstances on the block. Also, how the Papa payments are distributed among other co-resident households may determine the proportional split agreed to by the father and the son holding the Mobile Card. In deciding upon a percentage split, such factors in addition to current oil palm prices and the amount of work to be done are taken into consideration. By allowing blockholders to choose the pay rate for family labour (the percentage split) the Mobile Card will be flexible enough to accommodate the diverse socio-economic circumstances of families, especially those on highly populated blocks.

- Related to the previous point, a proportional split of the harvest among family members may facilitate the inter-generational transfer of block management from elderly fathers to their sons. In such situations a 10:90 or 20:80 split with 10% or 20% of the value of the crop being paid to the father may provide him with a 'retirement' income, earned from his son's labour.

- With an 'appropriate' percentage split on caretaker blocks, where payment is above the average rate for hired labour, it is likely that generous pay rates will reduce incentives to weigh fruit on the weigh dockets of neighbouring blocks.

- A proportional split seems to be favoured by Mobile Card workers because they feel that they too are sharing in the benefits of the current high prices. In PNG, pay rates for family and hired labour are influenced by cash crop prices. During high prices, pay rates tend to rise and conversely they tend to fall during low price periods. When there is a perception of a growing divergence between pay rates for labour and cash crop prices (the returns to blockholders), family labour, caretakers and, to a lesser extent, hired labour become dissatisfied.

How the percentage split would work

Initially, many growers had difficulty understanding the concept of a percentage split between the blockholder and the Mobile Card worker. Generally, when payments commenced (and with the aid of a ready reckoner — Table 2.1), growers and workers came to understand the proportional payment system. In some cases blockholders adjusted the percentage split after the first contract expired.

It is suggested that to facilitate understanding of the concept of the percentage split, each blockholder and potential worker interested in the payment scheme be given a copy of a ready reckoner incorporating the prevailing FFB price (see for example Table 4.1). This will help extension officers explain the concept of a percentage split, and blockholders and potential workers will see their respective potential incomes under different percentage splits and FFB prices. It is important for extension officers to explain to smallholders that the prevailing oil palm price, the condition of the block, and the amount of work to be done should be key determinants of the percentage split. Mr Graham King of HOPL is presently developing a ready reckoner that incorporates the daily labour market rate of different tasks likely to be undertaken by Mobile Card workers. This will help guide blockholders and hired labourers to arrive at an appropriate percentage split (G. King pers. comm., April, 2008). While some types of Mobile Card blocks like the father-son blocks discussed above, will include other considerations in deciding the percentage split (e.g., individual family and household needs on the block), prices, block condition and the amount of work to be done should be central to determining the percentage split.

Some percentage splits might not be used very often. For instance, during the trial the 10:90 split (blockholder:Mobile Card worker) was largely restricted to Mobile Card contracts between fathers and sons where the father was effectively retired and the son had taken over management of the block, and between blockholders and hired labourers employed to rehabilitate ‘bush’ blocks that had been abandoned for many years. On abandoned blocks the percentage split on the succeeding contracts tended to move more in favour of the blockholder as the block came back into production and the amount of maintenance work declined. Another example is the well-maintained high producing block where the palms are not too tall and the fruit is harvested easily by chisel. If the blockholder were to miss a single harvest round because of a short absence from the block and the work required is limited to harvesting, the split might be 90:10 in favour of the blockholder. Most splits would typically be in favour of the blockholder especially when prices are high. As a general rule, the blockholder must always see an increase in his/her income from employing Mobile Card labour.

Table 4.1. Ready Reckoner for income by percentage split, using an FFB price of K254.68/tonne.*

	FFB PRICE PER TONNE																	
													254.68					
	INCOME IN KINA UNDER DIFFERENT PERCENTAGE SPLITS																	
	Split 1		Split 2		Split 3		Split 4		Split 5		Split 6		Split 7		Split 8		Split 9	
	Papa	Mobile	Papa	Mobile	Papa	Mobile	Papa	Mobile	Papa	Mobile	Papa	Mobile	Papa	Mobile	Papa	Mobile	Papa	Mobile
	10%	**90%**	**20%**	**80%**	**30%**	**70%**	**40%**	**60%**	**50%**	**50%**	**60%**	**40%**	**70%**	**30%**	**80%**	**20%**	**90%**	**10%**
Kg harvested																		
50	1.27	11.46	2.55	10.19	3.82	8.91	5.09	7.64	6.37	6.37	7.64	5.09	8.91	3.82	10.19	2.55	11.46	1.27
100	2.55	22.92	5.09	20.37	7.64	17.83	10.19	15.28	12.73	12.73	15.28	10.19	17.83	7.64	20.37	5.09	22.92	2.55
200	5.09	45.84	10.19	40.75	15.28	35.66	20.37	30.56	25.47	25.47	30.56	20.37	35.66	15.28	40.75	10.19	45.84	5.09
300	7.64	68.76	15.28	61.12	22.92	53.48	30.56	45.84	38.20	38.20	45.84	30.56	53.48	22.92	61.12	15.28	68.76	7.64
400	10.19	91.68	20.37	81.50	30.56	71.31	40.75	61.12	50.94	50.94	61.12	40.75	71.31	30.56	81.50	20.37	91.68	10.19
500	12.73	114.61	25.47	101.87	38.20	89.14	50.94	76.40	63.67	63.67	76.40	50.94	89.14	38.20	101.87	25.47	114.61	12.73
600	15.28	137.53	30.56	122.25	45.84	106.97	61.12	91.68	76.40	76.40	91.68	61.12	106.97	45.84	122.25	30.56	137.53	15.28
700	17.83	160.45	35.66	142.62	53.48	124.79	71.31	106.97	89.14	89.14	106.97	71.31	124.79	53.48	142.62	35.66	160.45	17.83
800	20.37	183.37	40.75	163.00	61.12	142.62	81.50	122.25	101.87	101.87	122.25	81.50	142.62	61.12	163.00	40.75	183.37	20.37
900	22.92	206.29	45.84	183.37	68.76	160.45	91.68	137.53	114.61	114.61	137.53	91.68	160.45	68.76	183.37	45.84	206.29	22.92
Tonnes harvested																		
1	25.47	229.21	50.94	203.74	76.40	178.28	101.87	152.81	127.34	127.34	152.81	101.87	178.28	76.40	203.74	50.94	229.21	25.47
2	50.94	458.42	101.87	407.49	152.81	356.55	203.74	305.62	254.68	254.68	305.62	203.74	356.55	152.81	407.49	101.87	458.42	50.94
3	76.40	687.64	152.81	611.23	229.21	534.83	305.62	458.42	382.02	382.02	458.42	305.62	534.83	229.21	611.23	152.81	687.64	76.40
4	101.87	916.85	203.74	814.98	305.62	713.10	407.49	611.23	509.36	509.36	611.23	407.49	713.10	305.62	814.98	203.74	916.85	101.87
5	127.34	1146.06	254.68	1018.72	382.02	891.38	509.36	764.04	636.70	636.70	764.04	509.36	891.38	382.02	1018.72	254.68	1146.06	127.34
6	152.81	1375.27	305.62	1222.46	458.42	1069.66	611.23	916.85	764.04	764.04	916.85	611.23	1069.66	458.42	1222.46	305.62	1375.27	152.81
7	178.28	1604.48	356.55	1426.21	534.83	1247.93	713.10	1069.66	891.38	891.38	1069.66	713.10	1247.93	534.83	1426.21	356.55	1604.48	178.28
8	203.74	1833.70	407.49	1629.95	611.23	1426.21	814.98	1222.46	1018.72	1018.72	1222.46	814.98	1426.21	611.23	1629.95	407.49	1833.70	203.74
9	229.21	2062.91	458.42	1833.70	687.64	1604.48	916.85	1375.27	1146.06	1146.06	1375.27	916.85	1604.48	687.64	1833.70	458.42	2062.91	229.21
10	254.68	2292.12	509.36	2037.44	764.04	1782.76	1018.72	1528.08	1273.40	1273.40	1528.08	1018.72	1782.76	764.04	2037.44	509.36	2292.12	254.68
11	280.15	2521.33	560.30	2241.18	840.44	1961.04	1120.59	1680.89	1400.74	1400.74	1680.89	1120.59	1961.04	840.44	2241.18	560.30	2521.33	280.15
12	305.62	2750.54	611.23	2444.93	916.85	2139.31	1222.46	1833.70	1528.08	1528.08	1833.70	1222.46	2139.31	916.85	2444.93	611.23	2750.54	305.62
13	331.08	2979.76	662.17	2648.67	993.25	2317.59	1324.34	1986.50	1655.42	1655.42	1986.50	1324.34	2317.59	993.25	2648.67	662.17	2979.76	331.08
14	356.55	3208.97	713.10	2852.42	1069.66	2495.86	1426.21	2139.31	1782.76	1782.76	2139.31	1426.21	2495.86	1069.66	2852.42	713.10	3208.97	356.55

* In 2007 average price of FFB price paid to smallholders was K254.68/tonne.

Implementation of the Mobile Card

Other aspects to be taken into consideration when implementing the Mobile Card include:

- The erection of signs at the fruit collection point of blocks where Mobile Card workers are engaged. This will signal to truck drivers to be alert for fruit to be weighed on the Mobile Card.
- Design an easily recognisable weigh docket for Mobile Card fruit to reduce the probability of data entry errors in the smallholder payment office. A coloured docket might offer the simplest solution (green or yellow). The company may also wish at the same time to introduce a coloured docket for loose fruit weighings so that the three types of payments for fruit are easily distinguished from each other (white docket for Papa payments, red for loose fruit and green for Mobile Card fruit).
- Automatic rollover of contracts where the Mobile Card is working successfully on a long-term basis, such as on caretaker or father-son blocks.
- Direct credit to bank accounts for payments to Mobile Card workers on contracts of at least one month. Most caretaker and father-son blocks are likely to fall into this category as well as a significant proportion of hired labour blocks. This will ensure timely payments of workers.
- Loan repayments for farm inputs should **not** normally be deducted from Mobile Card payments. This will reinforce the employee status of Mobile Card labour and help prevent the build-up of ownership claims in the block resulting from capital investments (see Section 3). Conversely, deductions for farm inputs from the payments to the blockholder will reinforce his or her employer status and tenure rights to the block. One exception is where the Mobile Card contracts have been made between fathers and sons in transitional arrangements where block management is in the process of being passed from an elderly father to a son. In such cases, the son may be receiving the larger share of the income and be responsible for most of the work on the block, and therefore should also be responsible for loan repayments for farm inputs (see below).
- OPIC to adjudicate any disputes between blockholders and Mobile Card workers.

We make several recommendations for specific types of blocks.

Low producing VOP blocks

Low producing VOP blocks should be a priority for uptake of the Mobile Card given their very low productivity relative to LSS growers. Indeed, *promotion of fertiliser among low producing VOP growers should be suspended until harvesting rates are raised* because loan deductions can further undermine the motivation to harvest on low producing blocks (see Curry *et al.* 2007). With regular and full harvesting with the Mobile Card, the purchase of farm inputs such as fertiliser becomes more attractive to growers because they are able to realise the income gains from yield increases.

We recommend that one or two low producing VOP villages be targeted for the introduction of the Mobile Card. The promotion and introduction of the Mobile Card by OPIC should be undertaken in collaboration with village leaders for two main reasons. First, the support of village leaders may allay some of the concerns VOP growers have about recruiting off-block labour (concerns also found among some elderly LSS growers). Like the ownership claims that can arise from labour and capital investments by caretakers, some VOP growers fear that employing outside labourers may lead these labourers to make ownership claims on the block or to demand compensation based on their labour investments in the block. However, village leaders working with OPIC should emphasise to blockholders that employing a Mobile Card worker does not undermine their 'ownership' of the block because the Mobile Card contract reinforces the worker's status as a labourer (*olsem fotnait man*). In effect, the tenure rights of the blockholder *vis-à-vis* the Mobile card worker are strengthened by the existence of the contract.

Second, village leaders could identify trustworthy and conscientious village youth to be employed as Mobile Card workers, or identify church, sports or youth groups to be employed as Mobile Card groups of labourers. The use of village work groups does not appear to undermine the tenure rights of growers employing these groups. This is probably because such work groups are modelled on traditional labour exchange practices that are still used for large-scale subsistence tasks such as clearing bush for new gardens.

A related recommendation for low producing VOP villages is that village sporting clubs, church groups and schools should also have access to Mobile Cards for fund raising. These groups could be used as harvesting or block maintenance teams employed on Mobile Card contracts with work focused on blocks with consistently low production. Income earned by such village/community groups could fund projects that strengthen the community while creating awareness among the smallholder population that the company is interested in supporting community and village development activities.

Caretaker blocks

On caretaker blocks where the Mobile Card contract has been renewed several times and is working well (i.e., stable production, good block maintenance and the absence of conflict between the blockholder and the Mobile Card worker), the blockholder should be encouraged to sign a 'rollover' contract form that allows automatic renewal of contracts after their expiry. This will lead to less disruption in payments to caretakers and ease the administrative burden of OPIC and the company. When long-term roll-over contracts are in place, caretakers should be encouraged to open bank accounts for direct payments, and the company, with the blockholder's consent, should suspend separate weighings on the Papa docket.

Again, the existence of a contract specifying the roles and responsibilities of the blockholder and caretaker will reinforce their respective positions and interests in the block and preclude caretakers from building up ownership claims. Also, loan repayments for farm inputs (e.g., for fertiliser and replanting) should be deducted from the blockholder's portion of the payment, not from the caretaker's payment. This too will reinforce their respective positions as blockholder and caretaker and reduce the probability that caretakers will assert ownership claims on the block or make demands for additional compensation. This is critical if caretaker Mobile Cards are to receive widespread acceptance amongst blockholders.

Father-son blocks

The Mobile Card should be encouraged on blocks where there is emerging or prolonged conflict between blockholders and their sons over the allocation of oil palm labour and income. As discussed in Section 3, production gains following the introduction of the Mobile Card were not as great as those recorded on caretaker or hired-labour blocks. However, it is likely that the reduction in social conflict and the more equitable distribution of oil palm income among households on these blocks will lead to long-term benefits through creating a more stable and harmonious social environment for oil palm production.

Also, as mentioned earlier, the presence of a Mobile Card may facilitate the transition in block management from ageing blockholders to their sons because the fathers are still able to derive an income from the block. Thus, because the Mobile Card guarantees the blockholder an income in 'retirement', ageing blockholders are more likely to relinquish block management to a son thereby avoiding the often protracted disputes and disruption of production that can afflict these blocks.

Further, it is recommended that HOPL consider introducing multiple Mobile Cards on the more populated blocks, with each contract specifying the work tasks to be completed, and the phases to be harvested and maintained by the Mobile Card worker. This may assist households on these more populated blocks to better distribute income and oil palm work among the various households and family members. On these blocks Mobile Card contracts should not be applied to an area of less than 2 ha of oil palm. The above average size of blocks (10 ha +) at Uasilau LSS would be an appropriate situation to test multiple Mobile Cards on blocks.

Hired labour

There is scope for the market in hired labour to be expanded with the introduction of the Mobile Card thereby making it easier for blockholders with long-standing or short-term labour shortages to recruit young men, either as individuals or as youth, sports or church groups. Productivity gains are likely to be greatest for this category of worker as evidenced by the trial results at both Bialla and Hoskins. Further, as revealed in the Hoskins Mobile Card trial, the most successful blockholder-Mobile Card labourer relationships were those where the blockholder identified the worker (Curry & Koczberski 2004). Thus, blockholders should be given every opportunity to identify their own workers.

Like the caretaker category of Mobile Card worker, the existence of a Mobile Card contract formalises the work relationship and makes claims of tenure or for compensation by Mobile Card hired labourers less likely. This should be highlighted by OPIC when the Mobile Card is being promoted amongst blockholders as a way to recruit hired labour.

A final recommendation in relation to the hired labour category is that OPIC hold several Mobile Cards for short-term work activities, such as the one-off harvest round where there may be a temporary production problem (e.g., illness), or a block requires some additional maintenance labour to maintain stable production (e.g., weeding palm circles and maintaining access paths for harvesting).

Conclusion

To conclude, labour supply constraints are the primary cause of under-harvesting and low smallholder productivity. Constraints on the supply of labour lead to the under-utilisation of family or caretaker labour and the minimal supply of hired labour. Labour supply constraints also mean that potential yield increases from farm inputs are not realised. The absence of a market in hired labour has severely constrained the income opportunities of young men and women from highly populated blocks while at the same time limiting the productivity and incomes of labour-short blocks, with the result that approximately 25% of the crop is not harvested. The constraints on the supply of labour are due largely to the reluctance of people to provide labour because of inadequate, uncertain or disputed remuneration of their labour. The Mobile Card addresses these long-standing problems of poor and uncertain remuneration of caretakers and hired labourer by guaranteeing timely payment of labour. The trial demonstrated that the Mobile Card was effective in overcoming constraints on the supply of family, caretaker and hired labour. It has also generated social benefits for smallholders by enabling them to tailor their household labour and payment strategies to better accommodate their varying socio-demographic situations on their blocks.

In summary, the Mobile Card is effective for three reasons. First, it gives confidence to workers that they will be paid in full and in a timely manner for work completed. Second, it provides a mechanism for overcoming the difficult problem that blockholders have retaining cash for the payment of labour. Third, by formalising in a contract the roles and status of both blockholder and worker, the Mobile Card helps ameliorate blockholders' fears that the recruitment of labour is a threat to their tenure rights.

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Appendix 1. Mobile Card Contract.

MOBILE CARD CONTRACT
BIALLA SCHEME

This contract agreement is between the registered blockowner (*papa bilong blok*) and the Mobile Card holder whose names and signatures appear below.

NAME OF BLOCKOWNER:	NAME OF MOBILE CARD HOLDER:

Block where work is to be carried out:

Division: __ Subdivision: ________________ Section: __ Block Number: ______

CONTRACT PERIOD:
Start Date: ___/________/200_ Finish Date: ___/________/200_

Work contract applies to the following phases (please tick **-** √**)**:

Phase 1 ☐ Phase 2 ☐ ase 3 ☐

Agreed Tasks (Tick √ if applicable):

- Under Brush ☐
- Pruning ☐
- Loose Fruit Collection ☐
- Circle Weed ☐
- Harvesting ☐
- Other (specify task): ________________

For the duration of this contract the agreed split between the blockowner (papa bilong block) and the Mobile Card Holder is:

Papa	☐	% Split
Mobile Card	☐	% Split

The Mobile Card holder agrees to perform the following work tasks to the satisfaction of the blockowner. Any disputes will be mediated by the OPIC Mobile Card Officer. The Mobile Card will be cancelled if the agreed work tasks are not carried out satisfactorily.

Signature Blockowner: _________________ Name: ____________________

Signature Mobile Card Holder: _________________Name: ____________________

Witnessed and Approved By OPIC Mobile Card Officer: _______________________

Date of Signing: ___/________/200_