Annual Research Report

2006

PNG Oil Palm Research Association Inc.
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Report by the Managing Director to the Annual General Meeting December 2007

The agriculture sector in Papua New Guinea (PNG) has in recent years been through a number of critical reviews and strategic assessments. The institutions within the sector have been challenged to account for their relevance in the face of increasing demands to deliver effective solutions to address the country's worsening social and human development indicators. It is a sad indictment that current indicators show that PNG's development ranking is comparable to the ranking of smaller neighbouring Pacific Island countries of over 20-years ago. Since the majority of Papua New Guineans depend on agriculture for their livelihoods, the lack of progress and improvement in the human social and development indicators can be subscribed to a stagnation of the agriculture sector. The only exception to this general morass is PNG's oil palm sub-sector, which has continued to grow steadily and constitutes the only substantial and effective sustainable rural development in evidence today. Why is this so? Continuing high palm oil prices are not the reason, as many would assume. The reason is fundamentally the private-sector model up on which PNG's oil palm industry is built. There are examples of similar successful private-sector-centric development models, albeit on a much smaller scale, in other tree crop sub-sectors i.e. cocoa, rubber and coffee. Why does private sector led development work? At a recent workshop in Port Moresby aimed at identifying key principles underpinning the success of extension initiatives involving the commercial sector, the common "success factors" emerged as accountability, efficiency, stakeholder involvement, benefit sharing, and an absence of inappropriate or poor governance.

The PNG Oil Palm Research Association Inc. (*PNGOPRA*) is responsible, as part of PNG's National Agriculture Research System (*NARS*), for oil palm research and development in Papua New Guinea. Unlike other NARS institutes, which were formed as statutory organisations, PNGOPRA was born from a private-sector led industry and as a consequence was formed as an 'association' in which all stakeholders in the oil palm industry (plantation companies, smallholders and community oil palm developments), are Members of that Association.

PNGOPRA is an incorporated 'not-for-profit' research Association. The current Association membership comprises New Britain Palm Oil Limited (*incorporating Guadalcanal Plains Palm Oil Limited (GPPOL)*), 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.

The Members of the PNGOPRA have full say in the direction and operation of the organization. This ensures that PNGOPRA is always 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 2007 are presented below.

PNGOPRA Members Voting Rights in 2007:

Member	FFB Production in 2006	Votes
New Britain Palm Oil Limited	692,807 tonnes	7
CTP (PNG) Ltd	506,635 tonnes	6
Hargy Oil Palms Ltd	156,276 tonnes	2
Oil Palm Industry Corporation (*smallholders*)	656,119 tonnes	7
Ramu Agri-Industries Ltd	n/a	1
Managing Director	n/a	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 research or technical 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 as an organization is small, especially when compared to the scale of the industry it serves. A recent organisational assessment has shown that PNGOPRA's workload has been increasing continuously over the last decade, however because of the severely limited availability of

accommodation, laboratory and office space, the organisation has not been able to expand to meet these increasing demands. The assessment concluded that PNGOPRA is a highly efficient organisation with a very high degree of competence; however it has insufficient capacity to reasonably meet the needs of its stakeholders. A significant capital investment in physical infrastructure is needed to address these limitations. In order to create a framework for future organisational development, a stakeholder participatory strategic planning process will be implemented in 2008.
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 2007 is K 4.85 million. The Member's levy finances 82.9% of this expenditure and external grants 17.1%. The Member's levy is set at a rate of K1.77 per tonne of FFB for all growers. In 2007 organisation spending is distributed as 44.3% agronomy research, 17.7% entomology research, 18.1% plant pathology research, and 19.9% management and centralised overheads.

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

Research

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, meets twice a year to review and establish 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 carryout oil palm plant breeding[1].

Agronomy Programme

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 fertiliser. Fertiliser costs can be as high as 70% of the total input costs and to ensure this investment is profitable, the processes that underlie the response of oil palm to fertilisers must be understood.

In addition to the bottom-line 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 fertiliser 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 PNGOPRA's Agronomy team.

[1] Oil palm plant breeding, and seed production, started in PNG long before PNGOPRA was formed by the company now known as NBPOL. NBPOL continues this work at Dami Research Station and it is the basis of the company's highly successful oil palm seed sales business.

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 fertiliser required for greatest economic gain with the least amount of negative environmental impact);
- In those areas where fertiliser 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 smallholders 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.

Agronomy Research Topics:

(i) Nutrient Cycling and Soil Fertility

Four 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 is 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, it is also the project in which Murom Banabas has undertaken, and now completed, his PhD.

Most of the oil palm in PNG is grown on coarse textured soils that are freely draining, have high hydraulic conductivity and are located in areas of high rainfall. Consequently nitrogen losses are likely to be high due to leaching, surface run-off and/or denitrification. Industry acceptance of the results from this project will have a significant impact on the oil palm industry in PNG.

The project can be divided into four areas of studies:

The characterisation of the areas under palms

The areas under palms were grouped into 5 different management zones, namely: frond piles, frond tips, between zones, weeded circle and the harvest path. The zoning of the areas under the palms was necessary for studying nitrogen formation and loss processes in detail. Soil chemical analysis done on soils from the different zones suggested that the zones were different from each other and that they reflected the different management decisions. The frond piles had the highest soil N and C content compared to the other zones while rooting distribution studies indicated that most of the roots were in the weeded circle. The implications are that the areas under the palms are non-uniform and will probably require different management strategies in terms of fertiliser applications to minimise losses and improve nutrient uptake by the palms.

The water balance or the hydrology of oil palm

Water balance is a very important component of the oil palm system because water transports nutrients into the palms and it also carries nutrients away from the system (*through leaching or runoff*). Surface runoff from the experimental sites was measured and together with collated weather data, a model was developed to predict surface runoff, evaporation and deep drainage. From the modelling, it shows that leaching is probably the major route of nutrient loss in the oil palm system.

Data from the rainfall redistribution studies under the palms showed that on average 90% of rainfall ends up as through-fall however it was highly variable. Soil infiltration studies indicated the highest rates were in the frond piles followed by the frond tips and then between zones, weeded circle and harvest path.

The formation of nitrate and losses under the palms

Nitrogen losses in the leaching and surface runoff water are mostly in the nitrate form. The location and rate of nitrate formation is crucial; when linked with a transport mechanism this will determine the most likely location for loss. The process of nitrate formation in the soils is referred to as nitrification. Experiments showed that most of the nitrates were formed in the 0 – 7.5 cm soil depth and mostly under the frond piles. There was little difference between the other 4 zones. The frond tips, between zones, weeded circle and harvest path did not differ in soil nitrification rates. The half life of ammonium was determined and will be used in modelling the nitrogen cycle and requirements by oil palm.

N loss experiments showed that surface runoff and gaseous losses were relatively small. Leaching experiments showed (*depending on where and when fertiliser was applied*) a significant amount of N to be lost through leaching. The leaching experiments also showed that ammonium ions moved to depth in soils at Dami during rain but not at Popondetta, this suggests N losses in the highly porous soils at Dami can be in the form of both NH_4-N as well as NO_3-N (*both cation and anion forms*). A leaching model was developed from the leaching experiments.

A model to assist management decisions in minimising losses in oil palm farming systems and improve N uptake by palms.

PNGOPRA is in the process of developing a computer-based model that will combine the water balance, nitrification and leaching models. The model will look at different management scenarios to decide the best option or combination of options to minimise N losses under palms.

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.

Research work carried out in 2000-2001, financed by PNGOPRA Members, found a large and general imbalance between exchangeable calcium, and exchangeable magnesium and potassium in some of the volcanic ash soils. Calcium dominates the system to at least one metre depth, frequently exceeding the soil cation exchange capacity, preventing magnesium and potassium from occupying exchange sites. This explains why topical applications of soluble amendments such as kieserite and MOP have been largely ineffective on these soils. The most likely solution will be to introduce protected 'hot spots' of magnesium and potassium compounds into the soil which allow a percentage of roots to access and take up these elements. The project will focus on the type of amendments to apply and methods of placement. Field studies in PNG will be supported by laboratory-based work in Australia aimed at: i) determining the properties of soils that will allow us to predict where various management practices should be used, and ii) identifying the processes that have caused the problem so as to determine whether it will increase or decrease in these rapidly weathering soils.

Laboratory work has seen the development of techniques to measure the selectivity of Ca and Mg by representative soils. Preliminary results have already given pointers to the origin of the cation imbalance. The soils are dominated by Ca-rich weatherable primary minerals, and they have a very low selectivity for Mg due to the nature of their cation exchange sites. Early results have already confirmed that a soil from Bialla has a high selectivity for Ca over Mg. A water/solute transport model, HYDRUS 2D has been purchased to predict the best management options under various soil, climate, palm and ameliorant conditions. Early simulations have confirmed that the heterogeneity in the hydraulic conductivity of various soil layers (*derived from airfall ash*) results in a hiatus in water movement vertically through the soil profile. This appears to result in water moving laterally in the surface layers of the soil. Although not yet modelled, it is expected that this water will also carry soluble nutrients. An understanding of this will have implications for both standard fertiliser trials and nutrient management in plantations.

Potential sources of Mg, such as sparingly soluble Mg carbonates and oxides, are being assessed for their Mg - availability to palm roots. The most promising amendments have been obtained and have been incorporated in field trials.

Four field trials with alternative amendments and placement methods have been designed and commenced in 2003 and 2004. In one of these trials, young palms that have not had any Mg added in the past, are showing responses to Mg fertiliser though a reduction in the severity of Mg deficiency symptoms. This was the first time that a direct response by palms to the addition of Mg fertiliser has been shown in West New Britain soils. These trials do not yet show a yield benefit from the application of Mg fertiliser.

An additional two trials were commenced in 2007, one at Hargy Oil Palms and one at Milne Bay Estates.

Recent intensive sampling of soil at Milne Bay Estates has shown that, while not all of the K applied is taken up, the applied K is stored within the soil profile and not lost from the system.

3. Poor responses in fertiliser trials in WNB

Over the last decade, an area of increasing concern has been the anomalous and poor responses to fertilisers in trials in West New Britain, with control plots yielding as much as fertilised plots. Over that period considerable effort has gone into ensuring that experimental designs were suitable for measuring responses. 'Systematic' trials have been re-introduced to overcome the problem, and they are expected to be successful if the problem is due to movement of nutrients through the subsoil between adjacent plots. However, if nutrient movement is occurring on a larger scale, from the surrounding plantation, systematic trials may not provide the answer. The apparent movement of nutrients has implications not just for experimental design, but also for management of nutrition in and moving out of plantations. We have commenced several experiments aimed at determining whether nutrients are moving in shallow groundwater or by other means.

We have established two large 'Omission trials', in which a large circle of palms has fertiliser with-held. Yield and tissue nutrient contents are being monitored to determine if nutrients are moving into the area and if so, how far and from what direction. The trial has been set up in two locations at Haella, one at the top edge of the plantation and one down on the floodplain, each surrounded by plantation. The first three years of results have not shown any change in yield across these sites – it will probably take a number of years for the yield to respond to the reduction in available N delivered from N fertiliser. In addition to these experiments, several fertiliser trials with very large plots have been set up.

4. 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 fertilisers 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 proposals with ARC, CSIRO and James Cook University.

5. Nutrient budgets and nutrient use efficiency

We will commence routine sampling of trunk tissue and FFB in fertiliser trials in order 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 in many of the fertiliser trials and will form part of a strategy to investigate the overall management of nutrients in plantations.

(ii) Fertiliser Response Trials

The bulk of the work undertaken by the Agronomy Team is fertiliser response work. At each of the plantations we have set up a large number of field trials in collaboration with our Members. The types of trials established vary between different areas and depend on where the gaps in knowledge are and the various 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. The main fertiliser 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 Palms)

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 the responses to fertilisers 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 of N requirements.

Oro Province (Higaturu Oil Palms – CTP Holdings)

At Higaturu Oil Palms 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 fertiliser 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.

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 fertiliser 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 fertiliser. Ganoderma is a major problem at Poliamba and work has continued to reduce the impact of this devastating disease.

Ramu Agri-Industries

New trials were established in 2004 and 2005 in newly planted plantations. Harvest and milling are expected to begin in late 2007. PNGOPRA established an office at Ramu Agri-Industries 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. In the 'Soil Resource Information' project we aim to make full use of the soil resource information that is available but not being properly utilized in the industry. In 2005, a project began to provide better fertiliser recommendations for smallholders. By combining the resource maps available and reviewing classification of soil types, we will be able to extend management recommendations from detailed experimental sites to all areas of the industry. We are in the process of incorporating all available soil maps into a GIS.

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 and Milne Bay. This approach, is similar to black bunch counts, but provides a 3-4 month yield estimation based on time of flower anthesis.

(v) Smallholder Tissue Analysis

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

Technical Services:

The PNGOPRA Agronomy Team is actively involved in communicating the results and knowledge gained from the trial work undertaken on behalf of the plantations and small holders. The major communication activities revolve around three main activities:

Adoption of trial results

The primary focus for PNGOPRA Agronomy communication activities is to get the results from the trials out into the field. Both plantation managers and small holders can benefit from the trial results by comparing trial treatments and associated FFB yield to their own fertiliser practices and yield. If there is a difference between trial yield and plantation or small holder yield it usually means that the difference in yield can be made up by adopting the fertiliser applications as was used in the trial. The PNGOPRA Annual Report fulfils part of the requirement for making trial results available to both plantation managers and smallholders (*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 PNGOPRA'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. An example of a quarterly report for MBE is provided below.

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 an exam. Each participant is tested for both the theoretical and practical knowledge gained during the training activities.

Training modules include:

- Basic oil palm agronomy (*e.g. Nutrient cycles, soil fertility, fertiliser use and management*);
- Interpretation of tissue results and calculation of fertiliser requirements and amounts
- Nutrient deficiency symptoms (*e.g. Identifying nutrient deficiencies in the field*);
- Identifying frond 17 (*e.g. 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 fertiliser requirements*);
- Preparing frond 17 (*e.g. 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 (*e.g. 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 fertiliser mix*);
- Vegetative measurements (*e.g. 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 (e.*g. 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.

Smallholder field days as organised by OPIC

PNGOPRA 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 fertilisers do and how they should be used, to identifying nutrient deficiencies to insect control strategies (*through the PNG OPRA Entomology team*).

Entomology Programme

Insect pollination

Fruitset data collected from specific palms are important and may have a direct impact on the breeding of improved oil palms. A constant yet acceptable level of fruitset is obviously a valuable trait given the high rainfall conditions experienced in the areas of PNG growing oil palm. A key factor in oil palm pollination is that there is a positive correlation between the number of male flowers and numbers of weevils. The presence of male flowers is essential for the provision of breeding sites for the *Elaeidobius* weevils.

As a part of the pollination study, additional stocks of *E. kamerunicus* were brought into the quarantine facility at Dami from Ghana, West Africa, to strengthen the current genetic diversity of the populations in PNG. This new material is being subjected to cross-breeding trials and fecundity experiments and is confined within the quarantine facility. PNGOPRA has a fully certified quarantine facility. Through the regular monitoring of male flowers using *ad hoc* collection localities, the sex ratios of weevil populations from selected sites is continuing; this is an effective method for monitoring the health of wild populations under PNG conditions.

Integrated Pest Management (IPM)

All entomology experimental work is aimed at improving pest management decision making within the framework of IPM. With regular checking for the presence of sexava eggs at the base of palms in areas of infestations, reservoirs of one of the egg parasitoids continue to be found, dominated by the minute wasp *Doirania leefmansi*. During the year, approximately 575,250 *Leefmansia bicolor* and 1.587 million *Doirania leefmansi* were released into many sites on both plantations and smallholder blocks where low levels of sexava were present. Surveys showed that populations of the abdominal parasitoid of sexava known as *Stichotrema* were well established in the East Nakanai (*Bialla area*); however this insect has continued to prove difficult to establish in the Central & West Nakanai areas of West New Britain. It was recently recovered from West Nakanai. In the Koropata area on mainland PNG, *Stichotrema* infection levels of the mainland sexava pest, *S. novaeguineae* were reported in all months except March. During June 2007, samples of *S. gracilis* collected at Lakurumau on New Ireland were found to be infested by *Stichotrema* this is a major step forward. A large male stick insect - *Eurycantha* found on the mainland was parasitised by an unknown taxon of *Tachinidae*.

The Stick insect (*Eurycantha calcarata*), is now ranking as a close second in importance to that of sexava, and a detailed biological study is in progress, as little is known about the biology of this insect in PNG. 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; this material is also used for training purposes. As a part of PNGOPRA's close links with smallholders and plantation, monthly meetings of the re-named 'pest action group' (*PAG*) continue to be held at Hargy Oil Palms in Bialla, and weekly meetings are held at the Nahavio OPIC offices (*Hoskins Project*). At these meetings, all aspects of oil palm pest and disease monitoring and control are discussed with the divisional smallholder and smallholder affairs managers and a coordinated control strategy is implemented and monitored. A major effort to document all infestation data reports from all localities and all pests from 1981 to the present is being undertaken and entered into a database; all new pest reports are entered directly into the database

Pest outbreaks

Field visits were made by PNGOPRA's Entomology team to every reported infestation, of all pests, in both plantations and smallholder blocks throughout PNG. During field visits, samples of sexava eggs are collected, dissected and the state of the egg contents identified which will help in making more precise treatment recommendations. These regular monitoring visits to all reported pest infestations, and subsequent provision of control recommendations (*PestRecs*) continue during 2007. Although a large number of visits were made to areas with reported pest damage, the total number of visits was considerably less than were visited in 2006. Infestation reports from the two dominant taxa (*sexava and Eurycantha*) accounted for 88.1% of all reports.

A pest reporting form was designed and distributed for use by all plantations and extension services to facilitate the reporting of pest outbreaks.

Technical Assistance

Routine monitoring of insect trap catches at the NBPOL seed production unit continued as part of a phyto-sanitation initiative. No potential disease vectors were identified.

PNGOPRA is also continuing the work with NBPOL on a small project to enhance the plant biodiversity in plantations and ultimately for smallholder growers to provide nectar sources and shelter for beneficial arthropods. Bi-monthly monitoring and sampling of oil palm nursery pests are being undertaken on the mainland at Higaturu. Significant effort is going into discouraging prophylactic spraying of oil palm nurseries for potential insect pests.

Finschhafen Disorder (FD).

The proposal to investigate the potential threat to the oil palm industry from the leafhopper, *Zophiuma lobulata* presented to ACIAR was accepted, a budget prepared, and staff identified. PNGOPRA will be providing logistical and technical support to this important project. Due to administrative delays the project was not able to start until October 2007.

Queen Alexandra's Birdwing Butterfly (QABB).

A joint project is being undertaken in collaboration with Conservation International and CTP (PNG) Ltd. PNGOPRA's Entomology team is providing the technical expertise on aspects of the host vine ecology in conjunction with James Cook University in Australia. An investigation is underway into possible links between food plant bio-chemistry and feeding preferences of QABB larvae. Although previous attempts to propagate the *Pararistolochia* vine from seeds failed, this issue has been solved by using the technique of embryo rescue. Further attempts to propagate plants from leaf cuttings will be made, and the development of suitable media is being pursued.

Biological control of weed pests.

The spread of the biological control agent *Heteropsylla spinulosa* (Homoptera: Psyllidae) into areas of where Mimosa (*Mimosa diplotricha*) has invaded roadsides in oil palm plantations and smallholder blocks in Oro Province continues to be complimented by the routine re-distribution of the psyllid.

The gall fly (*Ceccidochares connexa:* Diptera, Tephritidae) a parasite of the invasive Siam Weed (*Chromolaena odorata*) continues to spread with the re-distribution of galls throughout mainland and islands of PNG.

Training

There was continued emphasis on training and information dissemination, particularly through OPIC and plantation staff, concentrating on P&D recognition, management through IPM and sanitation and control. The posters depicting the main pests of oil palm in PNG are used in conjunction with the specimen boxes for illustrative purposes on all training courses.

Pest recognition

The pest recognition boxes continue to make slow but steady progress towards completion. It is very much hoped that they will be completed before the end of 2007. Posters of the main PNG oil palm pests were completed, printed and distributed; copies are still available. The application made to NAQIA for the inclusion of sexava species and stick insects to be gazetted as Notifiable Pests is still outstanding.

Our identification of a new lepidopteran pest of pre-nursery palms was confirmed as being the larvae of *Spodoptera mauritia* (Boisduval 1833) (Lepidoptera: Noctuidae).

Plant Pathology Programme

Basal stem rot, a disease caused by the fungus *Ganoderma boninense* is the only serious long-term disease threat to the oil palm industry, especially as plantations and smallholders are currently progressing to a second generation of their crop. This disease is now being found in areas where it was virtually non-existent in first generation oil palm plantings. Complete eradication of this disease is therefore unattainable for a number of reasons including the specificity of the causal fungus for palms.

Efficient management of this disease is the only means of ensuring that oil palm plantings are sustainable well 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. Almost all costs associated with the Plant Pathology research programme have been financed by the European Union under Ganoderma Stabex Project No. 4.2. This financial support will end in November 2007 and further support of this scale is very unlikely.

Disease epidemiology

Basal stem rot of oil palm is a difficult disease to control given that infection cannot be detected until symptoms appear. At this stage, treatment with fungicides is futile and further infections must be prevented by removal of diseased palms. Research on the epidemiology of basal stem rot and its causal agent, *G boninense*, is essential for improvements in the management of the disease for both smallholders and large estates.

Epidemiological studies now encompass three Provinces where environmental conditions and disease severity differ. Comparisons of disease levels between regions will provide a more reliable baseline for future predictions of disease pattern and prevalence and crop losses. Most of these studies are confined to the larger commercial plantations but will be extended to smallholders in some Provinces.

Spatial and temporal disease patterns obtained from research in 2006 indicate that there are differences appearing in both the levels of disease and the patterns of spread between regions as well as within plantations. This demonstrates the complexity of this disease and the necessity for adequate representation of all the areas affected. The plantations that have been monitored the longest (Milne Bay) are now showing some changes in the temporal disease progress. Disease rates are now apparently increasing although the disease levels in all areas are still relatively low (cf. SE Asia) and not economically significant.

The temporal disease progress in West New Britain and New Ireland, maintains steady rates of increase. This could indicate that the epidemic is still in the early stages of growth and we might expect to see an increase in disease rates (as for Milne Bay) in future years. The disease incidence is still below economic threshold levels in all provinces and crop yields are apparently unaffected. However, due to the difficulty in obtaining representative yield data in all areas for comparison, this economic threshold is difficult to quantify.

Control measures have been implemented in most plantations where the disease is prevalent although it is difficult to ascertain if the control measures at this point are having an effect on disease progress. This warrants investigation through the use of 'BMP' blocks for disease control. Blocks will be identified where efficient detection and sanitation will be carried out as a means of comparison to other blocks.

The complete eradication of basal stem rot is difficult because of the diversity in the population of *G. boninense.* Research indicates that the fungus continues to diversify despite efforts by the plantations to remove inoculum (*spore*) sources in the field through regular roguing. Evidence for vegetative spread of the fungus through the soil is still lacking and therefore spores are still considered to be the primary source of infections. New research results in 2007 reinforce this hypothesis. Despite the apparent aggregation of disease foci at trial sites in New Ireland and West New, genetic homogeneity amongst *G. boninense* isolates has still not been demonstrated. Further investigations into the genetics of this fungus are outside the scope of our current research strategy and hence the question of recombination of mating type alleles will never be fully resolved.

Environmental factors and the condition of the micro-environment will also influence spread of this basal stem rot and other diseases. As indicated in previous reports, correlations between disease levels and soil and site factors have been poor. This is largely due to the lack of accurate environmental data. We are attempting to integrate these types of studies into a multi-disciplinary research programme in order to gain a better understanding of the effect of environmental conditions on the establishment and spread of basal stem rot. This will require additional resources outside of the current project financing.

Biological control

The most appropriate means of disease (*bsr*) control for smallholder farmers is through the utilization of naturally occurring fungi. The use of toxic chemicals (*fungicides*) and mechanical sanitation equipment is not an option given the limited resources of the smallholder and therefore more safe and cost-effective methods of control are sought. Since the primary establishment of the fungus is though spores, a means of preventing spore germination and growth is required.

In previous years we reported the use of a species of fungus known as *Trichoderma* that behaves as an antagonist to *Ganoderma*. These fungi have since been tested in both our laboratory in PNG and at the University of Kent in the United Kingdom and have been shown to be effective in suppressing the growth of *Ganoderma* under laboratory conditions. Further tests indicate that the growth of *Ganoderma* spores are also inhibited by this fungus.

In 2006 a collaborative project was set up between the University of Kent to work on the identification of the isolates and investigate the mechanisms of this antagonism against *Ganoderma*. This work has recently been completed (in early 2007) and the development of a formulation for application in the field will follow on from the results of these investigations. Detailed ecological studies on *Trichoderma* and other fungi in the oil palm micro-environment are now underway. Studies have also begun on the production of biomass and potential formulations for use in small-scale field trials. It is our hope that the use of this biocontrol will greatly enhance the capacity of smallholders to control the effects of basal stem rot within their plantations.

Host resistance

The ultimate goal of selecting germplasm for resistance to basal stem rot is hampered by our lack of knowledge of the mechanisms of resistance or susceptibility of oil palm to this disease. The long-term control of basal stem rot depends upon being able to successfully identify phenotypic differences amongst commercial progeny. Our studies have concentrated on the development of a whole palm nursery screening technique that will allow partial or full resistance/susceptibility to be identified in different test progeny. Preliminary testing in 2006/2007 indicates that gross differences can be observed but the artificial nature of disease inducement may not make this test reliable. Further refinements are being made to the method of inoculum and the control of other variables in order to arrive at a more precise test. Nursery assays are a prerequisite for laboratory-based assays that will permit larger numbers of progeny to be screened in the future.

Laboratory-based assays have also been modified several times with limited success. The main difficulty remains the ability to adequately sterilise external plant parts for use in the assay. Further refinement is necessary and additional equipment for plant growth will be necessary if this assay is to be developed.

Both the nursery and laboratory assays are to be complemented by field trials to test the different progeny for resistance/susceptibility to infection by *Ganoderma* under high disease pressure. The disease pressures in PNG are relatively low (less than 20%) and hence several sites in the Solomon Islands where the disease levels are higher have been selected for the trials. These trials will determine if laboratory-based assays are a reliable indication of field resistance and also provide some insight into the influence of environmental conditions on the resistance/susceptibility of oil palm to basal stem rot.

Technical Services & Training

The plant pathology team continues to provide technical support and training to all stakeholders. In 2006/2007 all plantations were visited by pathology staff at least twice. In Milne Bay and West New Britain, where the team scientists are located, close supervision of surveys and sanitation is carried out quarterly or biannually.

Disease reporting forms were prepared and distributed in 2006 and all reports that are received from the plantations and smallholders are followed-up with recommendations for control. Training was provided to OPIC, smallholders and plantation personnel at regular intervals in 2006 and the early part of 2007.

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 plant pathology staff. This support is invaluable for PNGOPRA members as it reinforces the research advice provided through the dissemination of publications and advisory leaflets.

Technical publications continue to be produced annually in areas where a need is identified by pathology staff or stakeholders. Two such publications were produced in 2006 and another is due for distribution in 2007.

Smallholder Socio-economic Studies

In 2002 & 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 reluctance or inability of smallholders to pay cash for labour was circumvented, and the worker was guaranteed timely payment. This greatly reduced the probability of the smallholder not complying with the labour contract. Monthly production at the trial sites at Hoskins increased from 75% of the LSS average to 113% during months when Mobile Card labour was deployed. Productivity increased on 90% of trial blocks with 30% improving by more than 50 percentage points. The successful Hoskins trial was extended to Bialla in West New Britain in February 2006 and concludes in December 2007. The trial has been a collaborative effort between PNGOPRA, OPIC and Hargy Oil Palms Limited. Eighty smallholder blocks participated in the trial covering a range of low-producing smallholder blocks: VOP blocks, "caretaker" blocks; labour-short LSS blocks, and blocks where the sons were reluctant to provide labour because they were not remunerated fairly by their fathers.

Preliminary results indicate that the Mobile Card has increased production and improved block maintenance. The increased production on trial blocks reinforces that the Mobile Card has the capacity to enhance labour mobility within and across blocks, create incentives for young men to work on their father's block and to improve payment arrangements for caretakers and absentee leaseholders leading to higher and more stable production. There is also evidence to suggest that Mobile Card contracts operating on blocks with permanent "caretakers" leads to fewer disputes over block tenure and payment for work done. Finally, the trial has provided insights into the factors constraining the emergence of a market in hired labour and helped answer the difficult question of why leaseholders find it easier to pay for labour in fruit rather than cash.

Since the trial's inception there have been numerous enquiries about the trial and requests from smallholders to participate in the trial. It is anticipated that the Bialla project will be introducing the Mobile Card as an alternative smallholder payment mechanism in early 2008. Hargy's smallholder payment system has been modified to accommodate the payments of block holders and Mobile labour.

Technical Services

The staff employed by the Association represent an invaluable knowledge resource for oil palm industry. The services provided by PNGOPRA, as indicated above, 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
December 2007

1. AGRONOMY RESEARCH

Overview of Research and Communication

(Harm van Rees)

The key to maximising the economic return from well managed oil palm for small holders and plantation managers is to understand the likely return from inputs such as fertiliser. Fertiliser costs can be as high as 70% of the total input costs and to ensure this investment is profitable, the processes that underlie the response of oil palm to fertilisers must be understood.

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 fertiliser 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 PNGOPRA's 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 fertiliser required for greatest economic gain with the least amount of negative environmental impact);
- In those areas where fertiliser 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

Four 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 is 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, it is also the project in which Murom Banabas has undertaken, and now completed, his PhD.

Most of the oil palm in PNG is grown on coarse textured soils that are freely draining, have high hydraulic conductivity and are located in areas of high rainfall. Consequently nitrogen losses are likely to be high due to leaching, surface run-off and/or denitrification. Industry acceptance of the results from this project will have a significant impact on the oil palm industry in PNG.

The project can be divided into 4 groups of studies and these included:

a) The characterisation of the areas under palms

The areas under palms were grouped into 5 different management zones, namely: frond piles, frond tips, between zones, weeded circle and the harvest path. The zoning of the areas under the palms was necessary for studying nitrogen formation and loss processes in detail. Soil chemical analysis done on soils from the different zones suggested that the zones were different from each other and that they reflected the different management decisions. The frond piles had the highest soil N and C content compared to the other zones while rooting distribution studies indicated that most of the roots were in the weeded circle. The implications are that the areas under the palms are non-uniform and will probably require different management strategies in terms of fertiliser applications to minimise losses and improve nutrient uptake by the palms.

b) The water balance or the hydrology of oil palm

Water balance is a very important component of the oil palm system because water transports nutrients into the palms and it also carries nutrients away from the system (through leaching or runoff). Surface runoff from the experimental sites was measured and together with collated weather data, a model was developed to predict surface runoff, evaporation and deep drainage. From the modelling, it shows that leaching is probably the major route of nutrient loss in the oil palm system.

Data from the rainfall redistribution studies under the palms showed that on average 90% of rainfall ends up as through-fall however it was highly variable. Soil infiltration studies indicated the highest rates were in the frond piles followed by the frond tips and then between zones, weeded circle and harvest path.

c) The formation of nitrate and losses under the palms

Nitrogen losses in the leaching and surface runoff water are mostly in the nitrate form. The location and rate of nitrate formation is crucial; when linked with a transport mechanism this will determine the most likely location for loss. The process of nitrate formation in the soils is referred to as nitrification. Experiments showed that most of the nitrates were formed in the 0 – 7.5 cm soil depth and mostly under the frond piles. There was little difference between the other 4 zones. The frond tips, between zones, weeded circle and harvest path did not differ in soil nitrification rates. The half life of ammonium was determined and will be used in modelling the nitrogen cycle and requirements by oil palm.

N loss experiments showed that surface runoff and gaseous losses were relatively small. Leaching experiments showed (depending on where and when fertiliser was applied) a significant amount of N to be lost through leaching. The leaching experiments also showed that ammonium ions moved to depth in soils at Dami during rain but not at Popondetta, this suggests N losses in the highly porous soils at Dami can be in the form of both NH4-N as well as NO3-N (both cation and anion forms). A leaching model was developed from the leaching experiments.

d) A model to assist management decisions in minimising losses in oil palm farming systems and improve N uptake by palms.

PNG-OPRA is in the process of developing a model that will combine the water balance, nitrification and leaching models. The model will look at different management scenarios to decide the best option or combination of options to minimise N losses under palms.

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.

Research work carried out in 2000-2001, funded by PNG-OPRA Members, found a large and general imbalance between exchangeable calcium, and exchangeable magnesium and potassium in some of the volcanic ash soils. Calcium dominates the system to at least one metre depth, frequently exceeding the soil cation exchange capacity, preventing magnesium and potassium from occupying exchange sites. This explains why topical applications of soluble amendments such as kieserite and MOP have been largely ineffective on these soils. The most likely solution will be to introduce protected 'hot spots' of magnesium and potassium compounds into the soil which allow a percentage of roots to access and take up these elements. The project will focus on the type of amendments to apply and methods of placement. Field studies in PNG will be supported by laboratory-based work in Australia aimed at: (i) determining the properties of soils that will allow us to predict where various management practices should be used, and (ii) identifying the processes that have caused the problem so as to determine whether it will increase or decrease in these rapidly weathering soils.

Laboratory work has seen the development of techniques to measure the selectivity of Ca and Mg by representative soils. Preliminary results have already given pointers to the origin of the cation imbalance. The soils are dominated by Ca-rich weatherable primary minerals, and they have a very low selectivity for Mg due to the nature of their cation exchange sites. Early results have already confirmed that a soil from Bialla has a high selectivity for Ca over Mg. A water/solute transport model, HYDRUS 2D has been purchased to predict the best management options under various soil, climate, palm and ameliorant conditions. Early simulations have confirmed that the heterogeneity in the hydraulic conductivity of various soil layers (derived from airfall ash) results in a hiatus in water movement vertically through the soil profile. This appears to result in water moving laterally in the surface layers of the soil. Although not yet modelled, it is expected that this water will also carry soluble nutrients. An understanding of this will have implications for both standard fertiliser trials and nutrient management in plantations.

Potential sources of Mg, such as sparingly soluble Mg carbonates and oxides, are being assessed for their Mg -availability to palm roots. The most promising amendments have been obtained and have been incorporated in field trials.

Four field trials with alternative amendments and placement methods have been designed and commenced in 2003 and 2004. In one of these trials, young palms that have not had any Mg added in the past, are showing responses to Mg fertiliser though a reduction in the severity of Mg deficiency symptoms. This was the first time that a direct response by palms to the addition of Mg fertiliser has been shown in West New Britain soils. These trials do not yet show a yield benefit from the application of Mg fertiliser.

An additional two trials were commenced in 2007, one at Hargy Oil Palms and one at Milne Bay Estates.

Recent intensive sampling of soil at Milne Bay Estates has shown that, while not all of the K applied is taken up, the applied K is stored within the soil profile and not lost from the system.

3. Poor responses in fertiliser trials in WNB

Over the last decade, an area of increasing concern has been the anomalous and poor responses to fertilisers in trials in West New Britain, with control plots yielding as much as fertilised plots. Over that period considerable effort has gone into ensuring that experimental designs were suitable for measuring responses. 'Systematic' trials have been re-introduced to overcome the problem, and they are expected to be successful if the problem is due to movement of nutrients through the subsoil between adjacent plots. The results from the systematic trials are discussed in the 'Fertiliser Response Trials' section. However, if nutrient movement is occurring on a larger scale, from the surrounding plantation, systematic trials may not provide the answer. The apparent movement of nutrients has implications not just for experimental design, but also for management of nutrition in and moving out of plantations. We have commenced several experiments aimed at determining whether nutrients are moving in shallow groundwater or by other means.

We have established two large 'Omission trials' (Trial 141), in which a large circle of palms has fertiliser with-held. Yield and tissue nutrient contents are being monitored to determine if nutrients are moving into the area and if so, how far and from what direction. The trial has been set up in two locations at Haella, one at the top edge of the plantation and one down on the floodplain, each surrounded by plantation. The first three years of results have not shown any change in yield across these sites – it will probably take a number of years for the yield to respond to the reduction in available N delivered from N fertiliser. In addition to these experiments, several fertiliser trials with very large plots have been set up (142, 148 and 149). They are described in the 'Response to Fertilisers' section.

4. 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 fertilisers 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 proposals with ARC, CSIRO and James Cook University.

5. Nutrient budgets and nutrient use efficiency

We will commence routine sampling of trunk tissue and FFB in fertiliser trials in order 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 in many of the fertiliser trials and will form part of a strategy to investigate the overall management of nutrients in plantations.

(ii) Fertiliser Response Trials

The bulk of the work undertaken by the Agronomy Team is fertiliser response work. At each of the plantations we have set up a large number of trails in collaboration with our funding partners (CTP Holdings, NBPOL, Hargy Oil Palm and Ramu Sugar). 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 fertiliser 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 the responses to fertilisers 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 of 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 fertiliser 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.

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 fertiliser 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 fertiliser. Ganoderma is a major problem at Poliamba and work has continued to reduce the impact of this devastating disease.

Ramu Sugar

New trials were established in 2004 and 2005 in newly planted plantations. Harvest and milling are expected to begin in late 2007. PNG OPRA has established an office at Ramu Sugar 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. In the 'Soil Resource Information' project we aim to make full use of the soil resource information that is available but not being properly utilized in the industry. In 2005, a project began (funded by AIGF) to provide better fertiliser recommendation for smallholders. By combining the resource maps available and reviewing classification of soil types, we will be able to extend management recommendations from detailed experimental sites to all areas of the industry. We are in the process of incorporating all available soil maps into a GIS.

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 and Milne Bay. This approach, is similar to black bunch counts, but provides a 3-4 month yield estimation based on time of flower anthesis.

(v) Smallholder Tissue Analysis

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

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 small holders. The major communication activities revolve around three main activities:

(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 small holders can benefit from the trial results by comparing trial treatments and associated FFB yield to their own fertiliser practices and yield. If there is a difference between trial yield and plantation or small holder yield it usually means that the difference in yield can be made up by adopting the fertiliser 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. An example of a quarterly report for MBE is provided below.

Quarterly update to June 1, 2007:
PNG OPRA " Trial 504: NxK fertiliser trial at Sagarai Estate, Milne Bay "

Trial description:

Date planted	1991
Treatment first applied	1995
Selected treatments	Control; SOA 6kg; MOP 7.5kg; SOA 6kg + MOP 7.5kg /palm
Replicated	4 times
Basal	TSP 0.5kg, Borate 0.2kg

Aim: to identify the optimum fertiliser rate for Sagarai estate

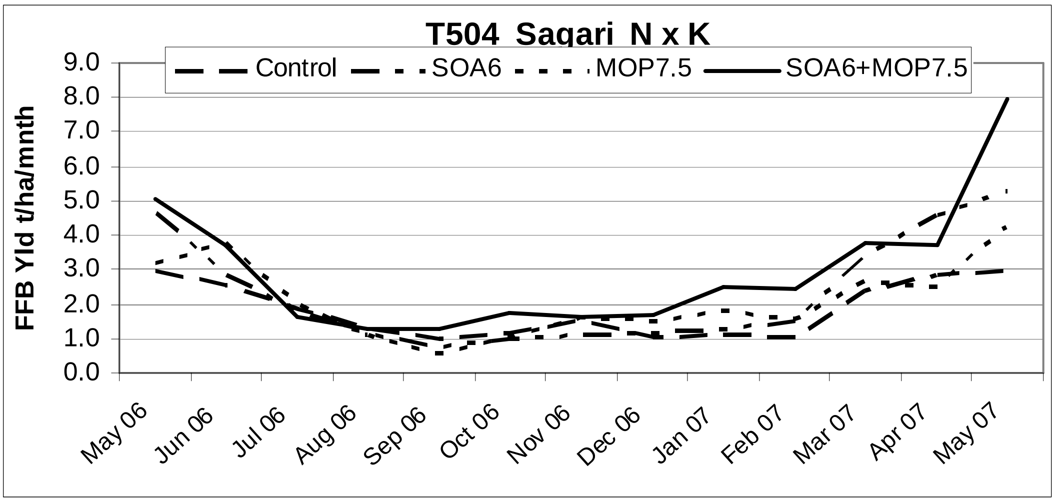

Figure 1. Monthly yield (t/ha) for each treatment over the last year.

Table 1. Monthly yield (t/ha) for each treatment over the last three months

	Control	SOA 6	MOP 7.5	SOA 6 + MOP 7.5
March 07	2.4	3.4	2.7	3.8
April 07	2.9	4.6	2.5	3.7
May 07	2.9	5.3	4.2	7.9

Table 2. Yearly yield (t/ha) for each treatment over the last 12 months.

	Control	SOA 6	MOP 7.5	SOA 6 + MOP 7.5
June 06 to May 07	18.2	23.1	20.8	29.5

Interpretation:
Significant increases in production result from the application of N fertiliser and if this is combined with K fertiliser (MOP) the yield responses are above 10 t/ha/yr.

Plantation visit reports on the state of sites inspected are available for plantation field agronomists.

(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 an exam. 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, fertiliser use and management);
- Interpretation of tissue results and calculation of fertiliser 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 fertiliser 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 fertiliser 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) Small holder field days as organised by OPIC

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

ABBREVIATIONS

AC	Ammonium chloride (NH_4Cl)
AN	Ammonium nitrate (NH_4NO_3)
ANOVA	Analysis of variance (statistical test used for factorial trials)
BA	Bunch ash (burned EFB)
BNO	Number of bunches
$cmol_c/kg$	centimoles of charge per kg, numerically equal to meq % or meq/100g
CV	Coefficient of variation
DAP	Di-ammonium phosphate (a P and N fertiliser)
DM	Dry matter
EFB	Empty fruit bunch
FA	Area of Frond
FFB	Fresh fruit bunch
GM	Grand mean (average over all treatments)
KIE	Kieserite (mostly magnesium sulphate, $MgSO_4$)
LAI	Leaf Area Index
LSD	Least significant difference (p=0.05)
mM	Millimolar (millimoles per litre)
MOP	Muriate of potash, or potassium chloride (KCl)
NS	Not Significant (in statistical analysis tables)
P	Significance (probability that treatment effect is due to chance)
SBW	Single bunch weight
s.d.	Standard deviation
s.e.	Standard error
s.e.d.	Standard error of the difference of the means
Sig.	Level of significance (* $p<0.05$, ** $p<0.01$, *** $p<0.001$)
SOA	Ammonium sulphate ($(NH_4)_2SO_4$)
SOP	Potassium sulphate (K_2SO_4)
TSP	Triple superphosphate (mostly calcium phosphate, $CaHPO_4$)

SOIL ANALYTICAL METHODS USED (Hill Laboratories, NZ)

Parameter	Method
Preparation	Air dried at 35ºC overnight, crushed through 2 mm sieve
pH	pH electrode in 1:2 (v/v) soil:water slurry
'Available' P	Olsen extraction, det. by molybdenum blue colorimetry
Anion storage capacity /P ret.	Equilibration with 0.02M K_2PO_4 followed by ICP-OES
Total P	Nitric/perchloric acid digestion, det. by ICP-OES
Exch. Ca, Mg, K & Na	1M NH_4 acetate extraction (pH 7), meas. by ICP-OES
Exch. Al	1M KCl extraction, det. by ICP-OES
CEC	Sum of exchangeable cations plus exch. acidity
Volume weight	Weight/volume of dried, ground soil
Base saturation	Calculated from exchangeable cations and CEC
'Reserve' K	1M nitric acid extraction, det. by AA
'Reserve' Mg	1M HCl extraction, det. by AA, exch. Mg subtracted
Total N	Dumas combustion
'Available' N	7 day anaerobic incubation, 2M KCl extraction of NH_4^+
Organic S	0.02 M K_2PO_4 extraction followed by ICP-OES for total S, then subtraction of sulphate-S
Sulphate-S	0.02 M K_2PO_4 extraction followed by ion chromatography
Hot water soluble B	0.01M $CaCl_2$ extraction, det. by ICP-OES
Organic matter	Dumas combustion. Calculated at 1.72 x total carbon

FERTILISER COMPOSITION

	Approximate elemental content (% mass)						
Fertiliser and abbreviation	N	P	K	S	Mg	Cl	B
Ammonium sulphate (SOA)	21			24			
Ammonium chloride (AC)	25					66	
Ammonium nitrate (AN)	35						
Urea	46						
Diammonium phosphate (DAP)	18	20					
Potassium sulphate (SOP)			14	17			
Triple superphosphate (TSP)		20		2			
Kieserite (KIE)				23	16		
Potassium chloride (MOP)			50			47	
Sodium chloride						61	
Borax							11
Ulexite							10

Agronomy Staff

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Thank you Harm van Rees

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Nitrogen Loss Pathways in Oil Palm on Volcanic Ash-Derived Soils

Stabex 4.22: End of Project Report 2002 – 2007

(Murom Banabas)

Introduction

Nitrogen (N) deficiency is the single most important yield-limiting nutrient for oil palm production in PNG. For both smallholder blocks and plantations, fertiliser inputs comprise 60 to 70 % of crop production costs. Most of the fertilisers used are nitrogenous, generally either sulphate of ammonia (SOA) or ammonium chloride (AMC). Smallholders tend to use solely N whilst >50 % of fertilisers used on plantations are nitrogenous. The use of N fertilisers on most of the oil palm soils in PNG is essential for increasing productivity and maintaining acceptable yields.

Long-term field trials conducted by PNGOPRA on different soil types and under different environmental conditions have shown variability in the patterns and magnitude of responses of oil palm to the application of N fertiliser. Reasons for these locality differences are not known but probably relate to the age of palms, soil organic matter contents, factors affecting N cycling and/or the efficiency of recovery of applied N fertiliser. However, to date, no studies have been carried out to identify the major N loss processes or the quantities of N that could be lost. Nor have there been any studies into management strategies that could be adopted to minimise losses and enhance the efficiency of use of these increasingly expensive imported fertilisers.

Most of the oil palm in PNG is grown on coarse-textured, free-draining soils that are formed on ash, alluvium or colluvium of recent volcanic origin. Characteristically these soils have high infiltration rates, high hydraulic conductivities and high erodibilities. However these same oil palm producing areas experience very high annual rainfalls with very high intensity events. This type of environment, whilst highly conducive to oil palm growth and productivity, can lead to significant losses of N from both native (soil) and added (fertiliser) sources. Losses are suspected to be high due to the combined effects of leaching, surface run-off and denitrification and could amount to >50 % of the amount of N fertiliser applied annually; a loss that would be of significant economic and environmental concern.

Based on the size of the oil palm industry and the magnitude of the N deficiency problem, this research addresses what is probably the PNG oil palm industry's most important plant nutrition problem.

To maintain high yields (22-26 tonnes FFB ha-1 yr-1), N fertilisers are applied at 520 – 850 g N palm-1 yr-1 however the actual application practices (rates, timing and placement) vary across the industry. Most fertiliser management trials done in both PNG and other oil palm producing countries have looked mostly at uptake and crop responses with no real emphasis on losses.

The project was carried out as a PhD research study by Murom Banabas and was funded by a grant from European Union (STABEX 4.22) to the Papua New Guinea Oil Palm Research Association (PNGOPRA) in collaboration with Massey University (NZ). All field experiments were done in PNG while all laboratory analyses and preliminary studies were done at Massey University. Funds were also provided by ACIAR to purchase soil water monitoring equipment (Sentek Diviner 2000®).

This study aimed to provide fundamental information about the processes that cause losses of N, and suggest remedial steps that might be taken, to allow better use and recovery of N fertilisers under the various soil and climatic conditions encountered within the oil palm growing areas of PNG. One expected outcome from this study was the development of a model that could be used to explore fertiliser management strategies to minimise N losses from any given oil palm system and to prioritise research initiatives without the need to conduct expensive trials to gain this insight.

Characterisation of Areas under Oil Palm Stands

Though oil palm plantations look uniform from above the canopy, under oil palm, the soils become non-uniform as a result of various cultural practices. There are five recognisable distinct zones; frond pile (FP) (8 % of total area), frond tip (FT) (6 %), between zone (BZ) (73 %), weeded circle (WC) (10 %) and harvest path (HP) (3 %). The characterization of different areas under the palms paved the way for detailed studies to be done under the different management zones to fully under stand the dynamics of N (or any other nutrients).

The soil pH, total C and total N values in these zones are different as a result of current and historical management. The differences in chemical characteristics are more obvious at Dami than at Sangara due to the fact that zones at Dami have been in existence for two generations of palms. The relatively high total C (6.1 %) and N (0.55 %) contents in the topsoil (0-20 cm) of the FP compared to other zones (where total C is <4 % and N <0.4 %) indicate that this zone is more biologically-active than other zones, and acts as a significant nutrient source and sink. Soil pH in the FP (0-20 cm) at Dami is >6 while in the other zones, pH ranges from 4.6 to 5.5. The relatively high pH in the FP may be due to the alkalinising effect of decomposing fronds.

Differences in soil properties between the zones affect the N transformation processes occurring in the soil, the supply of N for nitrifiers, C and N for denitrification and soil infiltrability which in turn affects the availability of N for crop uptake or loss.

Hydrology

N losses via leaching, surface runoff and denitrification (biological transformation of N in soils into gaseous N forms) are directly associated with factors affecting the soil water balance. Losses by leaching and surface water runoff usually occur when rainfall is greater than evapotranspiration after the soil has reached field capacity. Denitrification mostly occurs when the soil water content is high enough to create anaerobic conditions. By these three processes, N is lost in dissolved, particulate or gaseous forms. None to very little work has been done on this subject under oil palms and it became clear during the initial stages of the project that this had to be sorted out.

To understand the dynamics of water balance under the palms, various field experiments were done to determine (a) measurement of redistributed rainfall under the palms, (b) infiltrations rates under the different zones, (c) determining soil water holding capacity and (d) runoff water from the different management zones and from larger areas that covered all zones under the palms. Weather data including rainfall, minimum and maximum temperatures, wind run, sunshine hours from various sites were also compiled to estimate the reference crop evaporation of oil palm using FAO 56 water balance modelling. Water uptake from various depths and zones under the palms were also determined using Sentek Diviners.

At Dami, infiltrability in the FP is 8,500 mm hr-1 while in the other zones it ranges from 80 (in HP) to 1,300 mm hr-1 (in FT). At Sangara, the rates are high in FP and FT (1,000 – 1,300 mm hr-1) however they are low in BZ, WC and HP (150 – 300 mm hr-1). At both sites FP and FT soils are more permeable than those in WC and HP, presumably due to differences in organic matter content and/or compaction. The lower infiltrability in the HP and WC means that these areas are potential zones of runoff generation. At Sangara, a sandy clay subsoil horizon at 30 – 60 cm appears to slow the movement of water, and probably leads to a temporary perched water table occurring at times and greater surface runoff at this site.

The data from water holding capacity study suggested soils at Dami holds more water than at Sangara and therefore stress will be less likely at Dami than at Sangara and therefore less likely to be water stressed during low rainfall months.

Though the soils used in oil palm production are of high quality at the two sites, their porous nature coupled with high rainfalls (3,500-4,000 mm at Dami and 2,500–3,000 mm at Sangara annually), implies that nutrients such as N are highly susceptible to loss via leaching or surface runoff. Mean annual evaporation (Er), runoff and deep drainage measured as a % of annual rainfall were 39, 1 and 61 % for Dami and 55, 8 and 37 % for Sangara respectively. The significant proportion of rainfall lost as deep drainage at these two sites implies that leaching is probably the main process by which N is lost from the oil palm system. However the entry of water into the soil and downward flow in the soil profiles does not occur uniformly across the field as a result of three factors;

a) rainfall redistribution by the oil palm canopy is non-uniform (Figure 1). Average throughfall under palms increases with distance from the trunk, from about 30 % in the WC to 100 % of the rainfall in the areas which are further from the trunk. Within the different zones, throughfall is also highly variable (e.g. for FP and BZ, CVs range from 25 to 146 % with a mean of 90 %). Also approximately 11 % of total rainfall reaches the ground unevenly via stemflow. This all means that leaching is greater in some areas than others
b) placement of fronds on the FP further redistributes the rainfall. This was not measured directly in this study however the large spread in the distribution of inorganic N and Cl- ions in the in situ leaching experiments suggests that this occurred
c) soil surface characteristics can cause local ponding in some areas as evidenced by the large variation in infiltrability measurements found for different zones.

The probability of N losses is likely to be greatest where root activity is low. Root activity studies showed that water uptake was highest in the WC at both Dami and Sangara compared to other zones. Root distribution studies at Sangara also confirmed that the greatest density of roots was in the WC. However along with the high root density in the WC, a high influx of stemflow is also received by this zone so nutrients are probably more susceptible to leaching in the WC than in other zones further from the trunk.

The surface runoff data from the different zones under the palms suggested most of the runoff were occurring from the WC and HP as expected since these were 2 of the compacted areas under the palms. However, measurements under the different zones were difficult to reconcile with the rainfall because of the huge variability in the redistributed throughfall. The measurements from the areas that encompassed all the zones then provided a good picture of surface runoff. Surface runoff coefficient (proportion of rainfall occurring as surface runoff) at Dami was 0.8 % (0- 8 %) while at Sangara it was 4 % (0 – 45 %). The results suggested the soils at Dami were better drained than those at Sangara. The amount of runoff was closely related to the amount of surplus water. The relationship was used for modelling the water balance.

Using the FAO 56 and all other components of the water balance the various components long term 10 years were determined. The soils at Dami are porous and therefore have a large deep drainage but smaller runoff compared to soils at Sangara.

Nitrification

The interactions between soil and climatic factors determine the availability of N nitrate and ammonium (NO3--N and NH4+-N) for crop uptake or loss from the system by denitrification, surface runoff or leaching. Nitrification refers to the biological oxidation of NH4+-N to NO3--N that is carried out by chemoautotrophic soil bacteria. There are two major steps in the process in soils. The first step is carried out by bacteria of the genus Nitrosomonas (however Nitrosococcus, Nitrosospira, Nitrosolobus and Nitrosovibrio can also be involved) and the second step involves only one genus Nitrobacter.

$NH_4^+ + 1\frac{1}{2} O_2$ ------Nitrosomonas bacteria-----$NO_2^- + H_2O + 2H^+$ + Energy

$NO_2^- + \frac{1}{2} O_2$ -------Nitrobacter bacteria------NO_3^- + Energy

Nitrification is strictly an aerobic process. The rate at which the process is carried out is very important because it determines the availability of nitrate in the soil; which can be lost via surface runoff and leaching or biologically turned into gas (denitrification) or taken up by crops/plants. Oil palm fertilisers are applied mostly in the NH_4^+-N form which is then biologically converted to NO_3^--N. Nitrification experiments were carried out in the laboratory and in the field to determine (a) the differences in the rates of nitrification between the different zones under the palms, (b) determine if there was any indication of natural nitrification inhibitors in the soil and (c) the rate at which applied nitrogen fertilisers were converted to nitrate in the soils.

The nitrification studies done under controlled conditions in the laboratory showed that nitrates produced in the FP and FT were much higher than in soils from the other 3 zones, reflecting the differences in input of organic and inorganic N. This study though was useful in telling us that more nitrates are available in the FP and FT zones, it was not under field conditions, it did not tell us much on the conversion rates from added fertiliser which is a very important. This led to the setting up of field in situ nitrification experiments which showed that the N transformation rates were actually higher in the FP than in WC. The half life of added ammonium N fertiliser was added.

Nitrification studies showed that the rate at which half of the amount of fertiliser NH_4^+-N was changed to NO_3^--N depended on the rate at which it was applied (cause of osmotic effects), the amount of rainfall to reduce the salinity and allow nitrification to proceed) and where the fertilisers were placed under the palms (nitrification capacity of the zone). Nitrification rates were faster in the FP (half life ($t_{1/2}$) = 8-15 days) at Dami and Sangara than in the WC ($t_{1/2}$ = 70 – 80 days). However from the in situ leaching experiments, $t_{1/2}$ for NH_4^+-N in the FP was less than 3 days due to heavy rainfall diluting the fertiliser and allowing nitrification to proceed soon after fertiliser application. The Dami lysimeter study also showed that the nitrification rate was higher in the FP than in other zones. The high nitrification rates found in the FP suggest that no natural nitrification inhibitors exist in these soils. The FP appears to be an active nitrifying area as well as a N source in terms of pruned frond additions.

Losses of N – Gaseous, surface runoff and leaching

Three of the N loss processes were studied to quantify the losses and then determine the management option for minimizing the loss.

As well as being lost from farming systems in soluble and particulate forms, N is also lost in gaseous forms via the process of denitrification. It is recognised that gaseous N loss can also occur via ammonia volatilisation but this study is more concerned with denitrification from acidic soils. Denitrification is an integral part of the natural biological cycling of N between soil and the atmosphere. The gaseous loss of N from fertilisers is of economic (maintaining the supply of plant available-N) and environmental concern (build-up of N_2O in the atmosphere and its effect on the ozone layer. Denitrification is the biological respiratory reduction of NO_3^--N and NO_2^--N to gaseous N forms, N_2O, NO and N_2. The process commences when NO_3^--N replaces O_2 as an electron acceptor in soils

A simple apparatus was designed to collect gasses from the FP and samples were sent to New Zealand for analysis.

Denitrification calculated from the emissions of N_2O was minor in agronomic terms (< 1 % of fertiliser added annually) however it may be of concern for the ozone layer and could become an issue in the future given the rapid growth of the oil palm industry in PNG, the amounts of N fertiliser being used and the sensitivity of the atmosphere to receiving increased contributions of N_2O. However the full extent of denitrification was not determined in these experiments since only N_2O emissions were measured. The ratio between N_2O and N_2 is not constant and N could not be determined in this study because of the large background levels in the ambient atmosphere.

Surface runoff occurs when rainfall intensity is greater than the infiltration rate. N losses in surface runoff water can be in the particulate, dissolved inorganic N or organic forms. Water samples were collected from runoff plots from which hydrology study was done to determine nutrients loss as background as well as from applied fertilisers.

Surface runoff losses of N were also very low in these soils although they were higher at Sangara (2 kg ha^{-1} yr^{-1}) than at Dami (0.2 kg ha^{-1} yr^{-1}). Losses of N from applied fertiliser were equivalent to <1.5 % of the added fertiliser, suggesting that most of the fertiliser remained within the plots and was either taken up by the crop, immobilised by soil microorganisms or leached from the oil palm system. Losses by runoff appear to be small and agronomically insignificant but it should be noted here that the experiments were done on volcanic soils with high infiltrability and the situation may change with other oil palm soils of lower infiltrability.

The transport of solutes out of the root zone into the subsoil below, or beyond is called leaching. Because of the high rainfall and permeable soils in the oil palm growing areas of PNG, leaching of inorganic N has the potential to be an important pathway by which N is lost from the system. Although more than 90 % of soil N occurs in insoluble organic forms, mineralised N is water soluble and susceptible to loss (particularly via leaching) if not taken up by the palms.

Three quite different experimental approaches were used to determine the form and quantity of N leached from the different zones within oil palm plantations at Dami and Sangara. The approaches taken involved the use of suction cups, lysimeters, and a destructive soil sampling procedure referred to as the in situ leaching trial. The leaching experiments were conducted with the following general aims:

(i) Suction cups – to study the seasonal and spatial variability of inorganic N at 150 cm depth, where N was assumed to have passed beyond the active oil palm root system

(ii) Lysimeters – to measure the effect of added fertilisers on N leaching losses from soils taken from different zones under the palms but subjected to the same leaching conditions in an above-ground controlled leaching system

(iii) In situ leaching – to determine the rate and extent of leaching of N following fertiliser addition to selected zones, with undisturbed soil and natural rainfall.

The high infiltrability combined with high annual rainfall (2,500 – 4,000 mm vs Er of 1,350 mm) suggests that N loss via leaching is probably the major loss process in these volcanic soils. Combining the suction cup data with deep drainage estimates from the water balance produced annual N losses via leaching of 96 kg/ha at Dami and 20 kg/ha at Sangara. However the relatively small number of replicate suction cups installed, and the large variability in the data obtained from them mean that there is large uncertainty with these estimates. Also there was no attempt to partition this loss between soil and fertiliser sources.

The use of lysimeters created its own problems, however for those that worked at Dami, the retardation factor was determined for use later in the models. Results from the lysimeters showed that for Dami soils, N was leached in both NH_4^+-N and NO_3^--N forms, however NH_4^+-N moved through the soil at half the speed of NO_3^--N.

The in situ leaching studies showed that most of the N applied as AMC leached as NO_3^--N, but some NH_4^+-N also leached at Dami. Leaching was highly variable, spatially, due mainly to the variability in throughfall but also to a contribution from the “umbrella” effect caused by fronds being placed on top of the fertiliser on the FP.

Modelling

Four models were developed. The first model looks at simulating leaching of Cl- to determine the distribution parameters that are used in the two subsequent models. The second model simulates leaching of NH4+-N to obtain values for R (the retardation factor) and a (the decay constant for nitrification). The third model looks at the leaching of total inorganic N applied as NH4+-N. The fourth model combines most of the parameters used in the other models to estimate the residence time of inorganic N applied as AMC within the oil palm root zone using historical water balance data.

To develop the models, information from the various experiments were pooled together as follows;

From Hydrology

- field capacity of in situ leaching soils – 0.4 m3 m-3
- rainfall redistribution data provided the 90 % throughfall estimate and suggested that the CLT model would be more appropriate than the CDE model
- runoff data lead to runoff sub-model
- soil water balance section provided rainfall data and FAO56 evaporation estimates

From in situ nitrification

- indication of osmotic inhibition, leading to the assumption of 20 mm of rainfall to cause dilution before nitrification
- the similar recoveries for Cl- and inorganic N in AMC suggested that N losses via volatilisation and denitrification were small enough to ignore in the model
- estimates of t1/2 values for nitrification of NH4+-N.

From Denitrification losses

- further evidence that denitrification was small enough to ignore in the model

From Runoff losses

- evidence that N losses in runoff following AMC application were small enough to ignore in the model

From Dami lysimeters

- t1/2 estimates for NH4+-N nitrification
- estimates of retardation factor (R) for NH4+-N
- high recoveries of applied N in leachate provided evidence that volatilisation and denitrification were small enough to ignore in the model

From NH4+-N data for in situ leaching experiments

- more half life estimates for NH4+-N nitrification
- more estimates of retardation factor (R) for NH4+-N

From Cl- data for in situ leaching experiments

- dispersion parameters for CLT model
- value for effective evaporation of 75 % Er

From NO_3--N plus NH_4+-N ammonium data for in situ leaching experiments

- verification of detailed CLT model for fertiliser N

From Root activity paper (a paper published from this project)

- 500 mm estimate of active rooting depth

Development of a residence time model

The residence times in the root zone were estimated for fertiliser N applied as AMC on each day for which historical 10 or 12 year weather data was available at Sangara and Dami. The active root zone was assumed to be within the top 500 mm of soil. The assumptions about leaching in the model used to simulate the in situ leaching experiments were carried over into the residence time model, except for the log-normal distribution of soil water velocities and travel times. For each day a single soil water velocity was assumed, calculated as the effective Darcy flux density divided by the volumetric water content. Note that this velocity can be negative if effective evaporation is greater than rainfall. A volumetric water content at field capacity of 0.4 m3 m-3. Thus 200 mm of downward water movement was needed to move non-adsorbed solute (with R = 1) from the surface to a depth of 500 mm. The effective Darcy flux density was calculated, i.e. assuming throughfall was 90 % of rainfall, and the effective evaporation was 77 % of the FAO56 Er estimates. t½ for nitrification of NH4+-N to NO3--N was taken as 7 days. It was assumed that 20 mm of excess rainfall was needed to dilute the dissolved AMC enough for nitrification to commence. Applied N was assumed to change instantaneously, from NH4+-N to NO3--N, 7 days after the 20 mm of excess rainfall had occurred following AMC application. The retardation constant, R, was taken as 2 for NH4+-N and 1 for NO3--N. Losses of N via plant uptake, volatilisation, denitrification, immobilisation, and surface runoff have all been ignored. The computations were done in Excel spreadsheets using a Visual Basic macro. The values for each month were collected together and the monthly mean, median, and standard deviations were computed. Computed residence times can be thought of as estimates of the number of days required to leach about half of the applied N to below a depth of 500 mm.

The results are presented as the mean number of residence days for each month since annual plantation work is normally divided into monthly programs so monthly values are easy to relate to actual plantation and smallholder practices.

Table 1 gives the computed mean and median residence times for fertiliser N applied as AMC in different months over the years of available weather data. The Table also gives the residence time of fertilisers under different scenarios. Mostly the standard deviations are much smaller than the means, and the means and median values are quite similar. The exception is for January, February and March at Sangara, where the means and standard deviations are similar in magnitude and the medians are considerably lower than the means, implying a large year-to-year variation in the values. This needs to be remembered when considering the means.

The average residence time is 42 days longer at Sangara (mean = 114 days) than at Dami (mean = 72 days) (Table 1). There are also some large differences between months in the residence times at each site. For example, at Dami the average residence time is nearly six times longer for N applied in July than in February; while at Sangara the average residence time is nearly four times longer for N applied in May than in November. These findings have obvious implications for the timing of fertiliser applications.

The residence time model provides a mechanism for exploring some alternative scenarios. Some of these are shown in Table 1. These scenarios also provide some insights into the sensitivity of the model to some of the input parameters.

Table 1. Fertiliser N mean residence times in days for various scenarios.

	R	t½	Month												Ann.
		(days)	J	F	M	A	M	J	J	A	S	O	N	D	Mean
Dami															
Mean			24	21	45	87	114	111	120	103	84	74	49	32	72
SD			9	10	52	72	68	58	52	35	28	20	11	11	
CV (%)			38	48	116	83	60	52	43	34	33	27	22	34	
Median			22	18	30	67	111	110	116	97	80	73	49	32	
Standard Model	2	7	24	21	45	87	114	111	120	103	84	74	49	32	72
Scenario 1	1	-	19	15	35	72	91	90	112	94	76	68	46	28	62
Scenario 2	2	∞	32	32	82	130	155	152	150	138	112	89	66	44	99
Scenario 3	2	14	27	25	50	91	115	115	123	104	86	76	51	35	75
Sangara															
Mean			91	98	118	173	190	172	147	115	87	67	50	60	114
SD			93	95	93	81	51	41	37	37	32	19	17	23	
CV (%)			102	97	79	47	27	24	25	32	37	28	34	38	
Median			63	68	71	184	190	171	145	115	83	62	52	56	
Standard Model	2	7	91	98	118	173	190	172	147	115	87	67	50	60	114
Scenario 1	1	-	76	89	98	156	180	168	146	112	82	62	43	52	105
Scenario 2	2	∞	147	178	234	239	230	211	185	151	120	105	111	141	171
Scenario 3	2	14	95	101	120	183	191	172	147	115	89	68	54	64	117
Scenario 4	8	7	101	105	135	190	194	174	150	117	91	71	55	66	121

At each site, the first row for each (set of data) in Table 1 is the standard model with R = 2 and t½ = 7 days. The first scenario assumes R = 1 at all times. This scenario models what would happen if N was applied as NO3--N rather than as NH4+-N. The result suggests that the mean residence time would be 10 days shorter at Dami and 9 days shorter at Sangara.

The second scenario simulates what would happen if a way could be found to inhibit nitrification indefinitely (t½ = ∞). The residence times are then substantially increased, doubling in some cases (Sangara, Nov–Dec). But more interestingly is that only small effect in wetter months (Jan-Feb) at Dami. This relates to NH4+-N leaching.

The third scenario assumes a change in the NH4+-N t½ from 7 to 14 days. This results in an increased residence time of only three days on average. Thus the residence times calculated are not very sensitive to changes in t½ when R = 2.

The fourth and last scenario considered was to assume that R at Sangara was 8 rather than 2, as no reliable data for R at Sangara were obtained. An R of 8 (indicative of highly retentive soil) was the highest value found in this study. This increases the average residence time by 7 days. Thus the residence time at Sangara is not highly sensitive to the R value chosen when the NH4+-N t½ is 7 days or less.

Implications and management of fertiliser applications

This discussion of fertiliser management and recommendations is based on Table 1. However caution is required in any interpretation of this data because of the large standard deviations of residence times as shown in Table 1 for several months at both sites. Further, the averages of the 10 year historic climatic data may not hold true in future if any major changes in climate occur.

(a) When is the most suitable time for N fertiliser application and how often should fertiliser be applied in a year?

At Dami from Table 1, the model suggests that if N fertiliser is applied from May to August, on average half of it will stay within the top 50 cm depth of soil for more than 100 days. For the other months the residence time is less than 100 days. If necessary, N fertiliser could be applied in September (residence time = 84 days, CV = 33 %) or October (residence time = 74 days, CV = 27 %). But application in April is more risky even though it has the same average residence time of 87 days, because of the high (CV = 83 %). The average residence times for the period November to March are low (<50 days), so fertilisers applied during these five months are more at risk from leaching loss.

At Sangara, modelled average residence times are mostly longer than at Dami and there is a six month period (from March to August) where average residence times are >100 days. The best months to apply fertiliser would appear to be April, May and June, since all of these have residence times > 170 days. March is a more risky month with a CV of 79 %.

Currently applications of fertiliser have usually been avoided during high rainfall months in an attempt to minimise losses. But the model suggests that fertilisers are just as susceptible to losses via leaching if applied a couple of months prior to the main rainfall season. For example at Dami from the monthly rainfall distribution data, it might be considered reasonable to apply fertiliser in November or even December, when rainfall is lower than in January-March but expected to increase. However the residence time model shows average residence times of <50 days for November and December applications. Fertiliser applied at the end of the wet season in May would be a better option for plantations, when the residence time is >100 days.

As mentioned above, there is a wider window of opportunity for the safe application of N fertilisers at Sangara than at Dami. This has implications for the ordering of fertilisers, and for deciding whether or not to split applications. For the plantations, it is probably better to have only one or two applications per year at a site like Dami, and two or three applications at sites similar to Sangara. The first application at Dami could be in May and the second in August, while at Sangara, the first could be in March-April, a second in June, and a third in August-September. This scheduling would allow two months between applications, and avoid the months with low residence times thereby minimising leaching losses.

For smallholder blocks, where N fertiliser is normally only applied once a year, application in June-July would appear to be optimal for growers at Dami (>111 days average residence time) and May-June at Sangara (>172 days average residence time and relatively low CV).

(b) Where best to apply fertiliser?

Fertiliser placement trials in Malaysia have suggested no differences in FFB yield responses to fertiliser placement in different areas under palms. However the main interest in those trials was in what was taken up, rather than what was lost via leaching. The results from this present study show that though there were roots in the HP, water uptake was least from this zone, while the greatest water uptake occurred from WC followed by FP. In many oil palm systems, it is recommended that fertilisers be applied to WC as this is where the roots are densest. Also from the rainfall redistribution study, average throughfall was about 30 % of the rainfall within WC. This would equate to about 1,050 and 730 mm of throughfall annually at Dami and Sangara respectively, which at both sites is less than the average Er of 1,330 mm. Thus ignoring stemflow, little or no leaching would be expected from the WC. However, a significant proportion (11 %) of rainfall is also received by the WC as stemflow, which mostly infiltrates into the soil and will cause significant leaching in some parts of this zone. In addition to the large potential for leaching from the influx of stemflow soil pH was lowest in the top 20 cm in WC at both Dami and Sangara. Thus applying fertiliser in this zone would further reduce pH and so may not be good for the long-term sustainability of the soils. Hence spreading fertilisers in zones other than WC is likely to be the preferred option.

The FP zone had the next highest water uptake, and also appeared to be buffered against changes in soil pH from continuous previous fertiliser additions. The results from the leaching experiments also showed that fertilisers applied to this zone were somewhat protected from being leached by a type of "umbrella" effect of frond replacement on top of the applied fertilisers, so this would appear to be a preferred zone in which to apply fertiliser. However the umbrella effect due to fronds being placed over the fertiliser, would not apply in situations where the fertiliser is sprinkled directly over the piles as is normal practice. In such cases the umbrella effect could even enhance leaching. This suggests that the FP may not always be the ideal zone in which to apply fertiliser. It depends on the timing of frond additions in relation to the next heavy rainfall.

All things considered, a semi-circular band about 1 m wide just outside the WC, covering a mix of BZ, FT and FP zones may be the preferred option for fertiliser placement for the following reasons;

- This area receives about 50 % throughfall compared to >80% further out from the palm trunk. Application of fertilisers further from the palms in the FT and some parts of the FP would probably result in more leached N because of higher average throughfall
- This area would be unlikely to be affected by stemflow, most of which probably infiltrates within the WC, except during very heavy rain events
- This area has the second highest water uptake after WC reflecting root activity as shown from the water uptake studies
- This area is convenient for plantation workers and smallholders to enter and spread fertilisers.

(c) Form of N fertiliser

The most commonly-used fertilisers in the oil palm industry are AMC, SOA, AMN and urea. Field trials suggest that there may be no differences in yield response to any of these different N types. The in situ leaching trials indicated that within a month, and sometimes in less than a week, most of the NH4+-N was nitrified. This implies that it does not matter greatly which form of N is used, because within a relatively short time, all N will be converted to NO3--N. The residence time model (Table 1, Scenario 1) suggests that at both Dami and Sangara, the average residence time was 9 – 10 days shorter if N was applied as NO3--N rather than as NH4+-N. This difference is not large therefore while NH4+-N may be the preferred form, the residence times for NO3--N are not all that different.

If an effective economical nitrification inhibitor, suitable for use on tropical tree crops did become available sometime in the future, Scenario 2 in Table 1 suggests that the mean residence time would only be increased by 22 and 57 days at Dami and Sangara, respectively. In some of the months, the residence time would be doubled e.g. for the months of November and December at Sangara. If such an inhibitor were found, NH4+-N or urea-N would then need to be the forms used.

Many of the conventional experimental approaches used to study the fate of N from agriculture systems appear inappropriate for the type of study done here because of scale, due to the palms being large with differently managed areas under them, the unavailability of modern analytical facilities on-site for analysis, and the time taken to transfer samples and return data. Appropriate methods and approaches were designed to implement the project and they worked well. The normal 1 m x 1 m plot sizes for surface runoff studies was inappropriate and therefore 4 large palm plots were used that covered all the managed zones. The use of AMC fertiliser with Cl as an inert tracer proved useful. Use of lysimeters had its own problems so a soil coring approach was used, with extraction on-site. The soil extracts were sent off-shore for analysis.

Major Problems and suggested solutions for future work

Vandalism of field experiments and theft of equipment in the field was common at both sites, Dami and Sangara. Containers used for collecting leachates and runoff water were major targets for theft. Vandalism of field equipment in the field experiments was also common. However, these problems were minimized by providing securities in the experimental areas. Communication (phone/fax/email) problems occurred from time to time when the phone lines were down however this did not really affect the project after the experiments were on the ground and measurements and collecting of samples commenced.

The experiments involved detailed measurements, sampling and recording and mistakes were inevitable however workers were trained and were involved in all stages of the project. A lot of what could have turned out to be “disaster” was managed well by the workers.

Though there were difficulties, the patience, dedication and the spirit of team-work from PNGOPRA workers (field and office) on sites were exceptionally very good and this was the key factor in the success of this project. The corporation from OPIC, Higaturu Oil Palms and Dami Research Station (NBPOL) in terms of allowing us to use their plantations and some of their equipment for the project contributed a lot to the success of this project.

Having a qualified supervisor on site was also another import contributing factor to the success of this project. Though there were 3 specialised supervisors at Massey (NZ), the supervisor on site ensured that the experiments though simple but were relevant to the aims of this project. Visits to the experimental sites by the NZ team did not happen because Massey University was not able to release its staff for security reasons.

Extension, training and field days (dissemination of results)

The results of the project were presented to Scientific Advisory Committee (SAC) as they became available during the duration of the project. The SAC is a committee meets twice a year and looks at experiment results, reviews ongoing experiments and decides on the proposals for new projects. Results were also presented in a seminar at Massey University as part of the PhD training, to ACIAR review committee that were looking at a Mg/cation project and to the plantation and OPIC staff at various meetings. The results were also incorporated into fertiliser talks during smallholder growers field days. The model developed will be tried out in other oil palm growing areas and results will be used for fertiliser management in those areas.

A scientific paper was published from the work and two more papers are being planned.

Conclusion

The project addresses one of the oil palm industries major issue i.e. losses of nutrients which is not only of economic significance but also has important environment implications. The project though was to do with nitrogen, procedures developed and other information (e.g. zone characterization and water balance) and experience gained will be useful for other related studies/projects in future not only for oil palm but for other tropical tree crops as well.

The study showed that losses via denitrification and surface runoff were small however depending on when and where fertilisers are placed, losses via leaching can be significant. A residence time model was developed that will be used to help make practical fertiliser management decisions.

The study looked into losses only however another study looking uptake will be useful and will really help fine tune the residence time model.

Forecasting Yield, is it Possible?

(Trial 515)

(Harm van Rees)

Summary

- Large differences between palms was found in the number of bunches produced, the weight of bunches and hence the total weight of FFB produced;
- Contrary to expectations there was no correlation between bunch number produced and bunch weight;
- A monthly forecast of yield can be made using FFB/palm = 20.6 x No. of Female Flowers/palm (R2=77%);
- The number of female flowers formed during the year ranged from 0.5 to 1.5 per month (there could be a climatic trigger that plays a role here);
- Time taken from flowering to harvest ranged from 160 days for those female flowers forming in December to 190 days in February/March.
- Palm monitoring should be done on known progeny

Background

Forecasting or estimating future crop yield enables plantation management to plan for milling requirements, transport and forward selling of product. There are two ways to forecast production:

(i) through the use of sophisticated models such as APSIM (Agricultural Production Systems sIMulator) produced by CSIRO in Australia, which can model growth of a crop throughout the year and based on current conditions and climate forecasts can accurately predict a crop yield. APSIM has modules for many annual crops and sugarcane. Other modules are under development, currently there is no Oil Palm module.

(ii) predictions based on some observable growth function of a crop which is linearly related to yield.

The latter method for forecasting a future yield is being developed within PNG OPRA.

Methods

Detailed monitoring of palms at MBE and Higaturu at weekly intervals for:

- Flowering date
- Time to first black bunch
- Time to mature bunch
- Time to harvest and bunch weight
- Frond production determination (2 counts per year; in 2007 we have started doing this quarterly)

This monitoring program has been extended to other plantations (Poliamba and Ramu). In 2007 we have added to the weekly observations:

- Male flowers – to work out how many fronds do not support a male or female flower

Results

Only a small proportion of the total number of monitored palms have been analysed from Trial 515. PNG OPRA is currently entering the collected data into a database which will facilitate ease of analysis. Some initial results for the harvest period May 2006 to April 2007 are included in this report:

1. Bunch weight in relation to bunch number produced

There is a large variation between individual palms and the weight of bunches produced and the number of bunches produced (Figure 1).

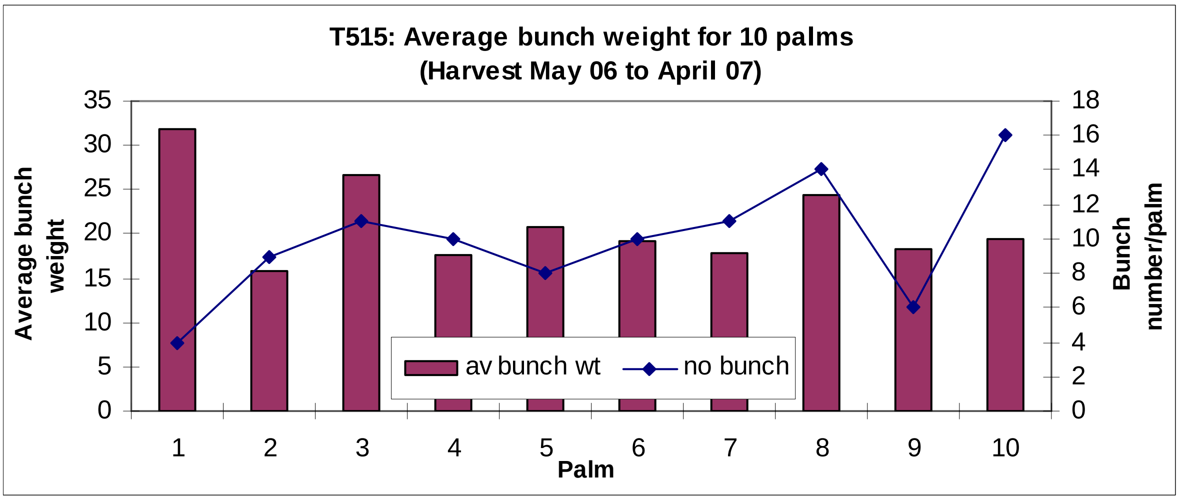

Figure 1. Average bunch weight (kg) produced by a palm with the number of bunches produced by that palm

The differences between palms in the number of bunches produced and the weight of bunches is much larger than expected. Individual palm performance will be investigated over a much longer time period to see whether these differences in bunch number and bunch weight are features of individual palms or whether the performance evens out over time.

2. Correlation between bunch weight and number of bunches produced

It would make sense to assume that bunch weight might be correlated to the number of bunches produced but that was clearly not the case. There is no correlation between the average bunch weight produced by a palm and the number of bunches produced by that palm (Figure 2). Some palms produced consistently a high number of heavy bunches (ie palm 8, see Figure 1).

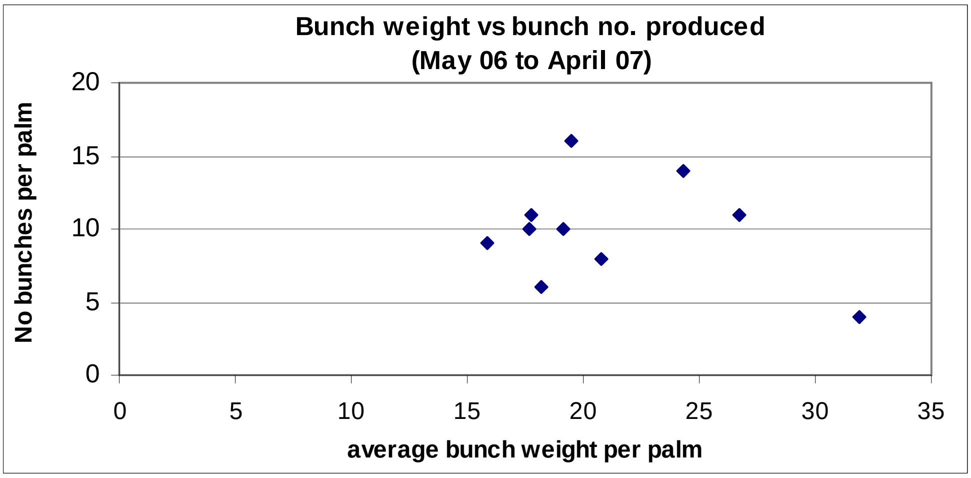

Figure 2. Average bunch weight versus the number of bunches produced per palm.

3. Total FFB produced per palm

Some palms yielded three times more FFB than other palms (Figure 3). This observation needs to be assessed over a longer time frame to see whether currently low producing palms starts producing more fruit and vice versa, when high producing palms go into a 'resting' phase.

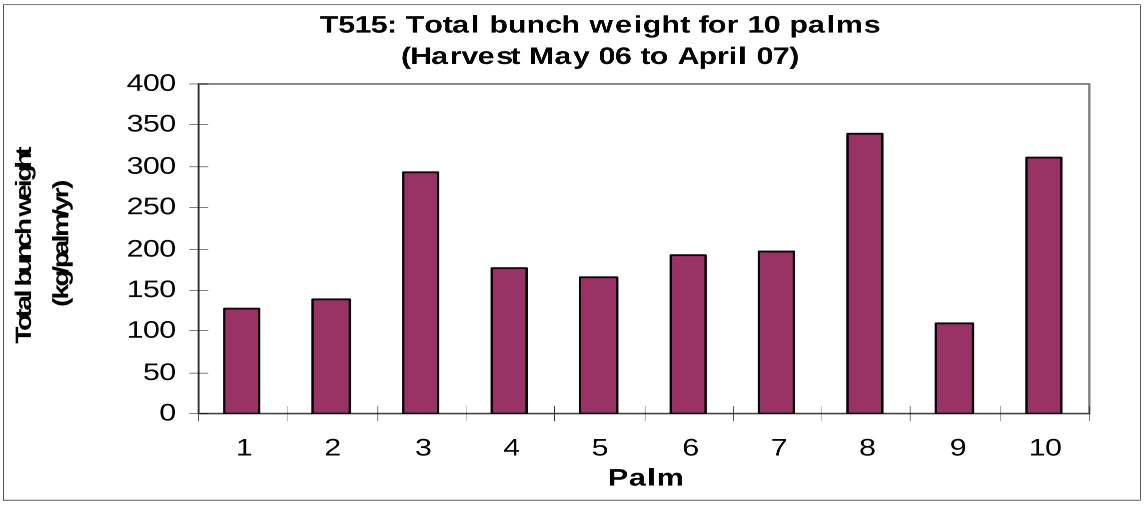

Figure 3. FFB produced (kg/palm/yr) for 10 palms in trial 515.

If this yield difference is a permanent feature of the palms then there is likely to be too much heterogeneity in the planted material.

Based on this limited data set the trial area produced 25 t/ha during the harvest period.

4. Total FFB produced versus the number of bunches produced

There is a strong correlation (R2=77%) between the total FFB produced and the number of bunches produced (Figure 4).

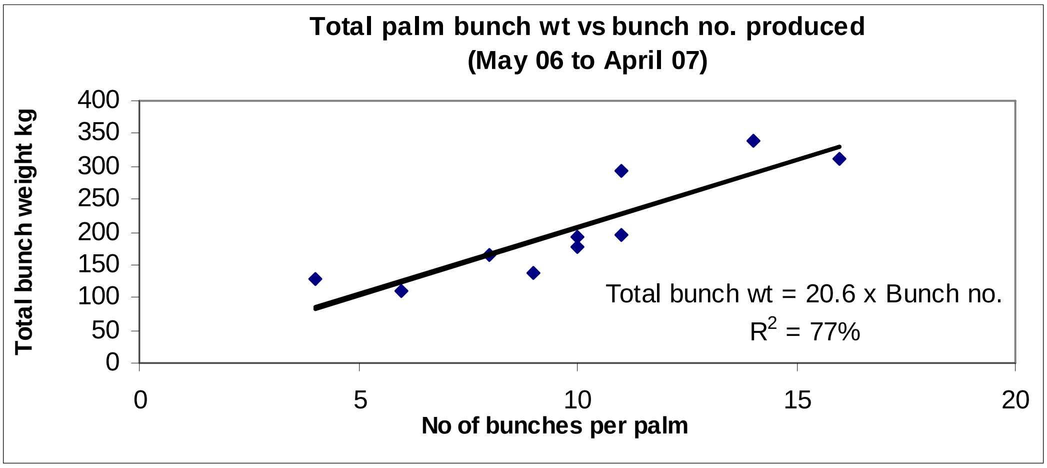

Figure 4. Correlation between FFB and bunches produced

5. Using flowering data to estimate yield

One of the reasons for setting up this observation and monitoring trial was to determine whether we can use the number of flowers produced to estimate a yield in the future. All female flowers produced a bunch (flowering and weight data for 99 flowers and bunches was recorded).

Flowering data can be used as a predictive tool to estimate a yield using the equation:

FFB = 20.6 x flower number.

6. Time frame from flowering to harvest

To estimate a yield in the future we not only need to know how many flowers have formed but also how long it takes from flowering to harvest and whether there is seasonal variation in this time frame.

(i) number of flowers produced – seasonal variation

There was seasonal variation in the number of flowers produced – with the highest number of flowers produced in the October to January period and the lowest number from February to July (figure 5).

The trigger for this variation in flower number during the year, needs to be determined, it is likely a response to some climatic condition (such as temperature, sunshine hours, rainfall or other factor).

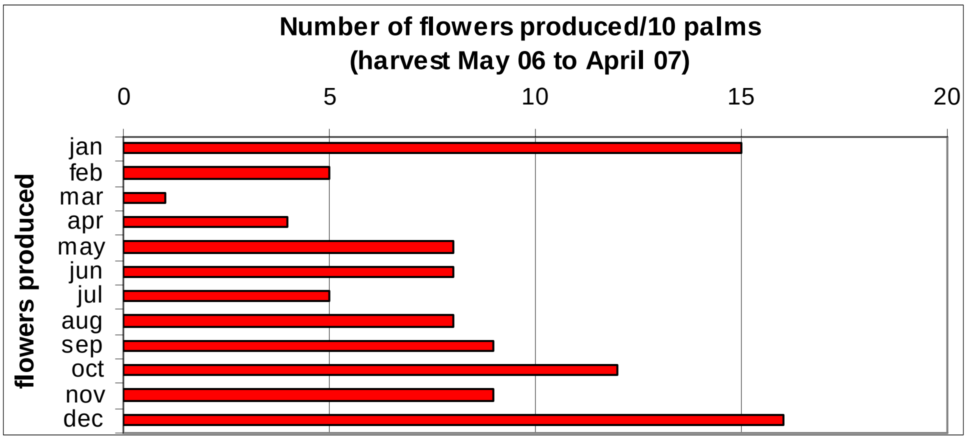

Figure 5. Seasonal variation in the number of flowers produced (for 10 palms)

(ii) time taken from flowering to harvest

There is a definite seasonal difference in the time it takes for a flower to be become a harvested bunch (Figure 6). Even though there is variation within a month in which a flower forms and when it becomes a harvested bunch (Table 1) there is on average a 20 day difference in maturation time from December to July.

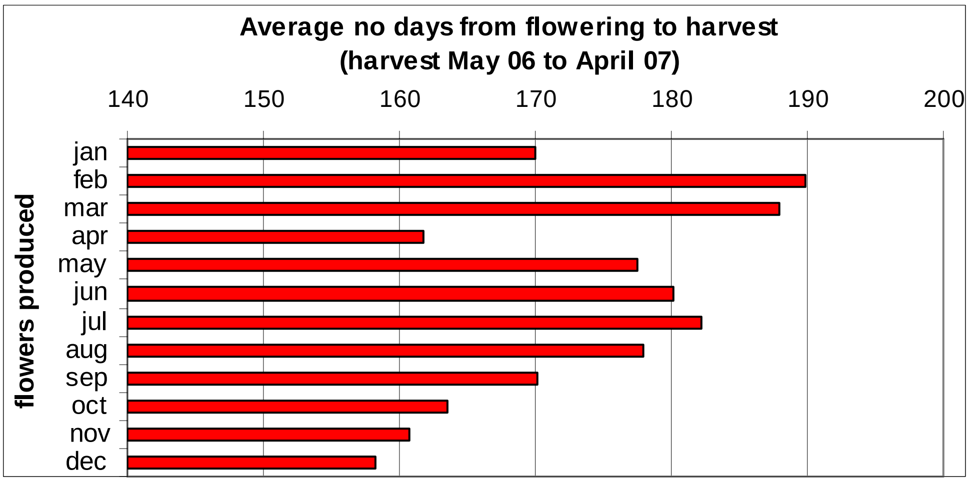

Figure 6. Average time taken (days) from flowering to harvest

Table 1. Monthly data for 10 monitored palms on number of flowers; average days from flowering to harvest; maximum and minimum days from flowering to harvest (March data are limited).

	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**		**Total**
flowers	15	5	1	4	8	8	5	8	9	12	9	16		99
average	170	190	188	162	178	180	182	178	170	164	161	158		172
Maximum	212	205	188	188	188	202	195	205	181	181	181	181		212
Minimum	153	174	188	153	160	167	173	153	160	153	145	146		145

7. Can we estimate FFB from flowering data and can we estimate when harvest will occur?

- We need to determine within palm variation over time in bunch weight and bunch number to determine how many palms we need to monitor to make a yield forecast;
- We can estimate the FFB yield from 'FFB = 20.6 x flower number' and use 160 days from flowering to harvest in December and 180 days in July (with values in between in the other months);

8. Differences between palms in time taken from flowering to harvest

There appeared to be some differences (over 20 days) between palms in the time taken from flowering to harvest (Figure 7). Some of these differences could be explained by the time of the year that the palm produced the most flowers (flowers produced in December take less time to reach harvest compared to flowers produced in July). However, when the average value of each month was subtracted for the actual time of flowering for each palm then there were still major differences. For example, comparing palm 3 and 4, palm 3 took, on average, 14 days longer to reach harvest from flowering for all flowering dates; where as palm 4 took only 1 day longer on average to reach harvest from flowering – hence it appears that there may be a palm effect in the time taken to reach maturity. This could be related to the progeny planted.

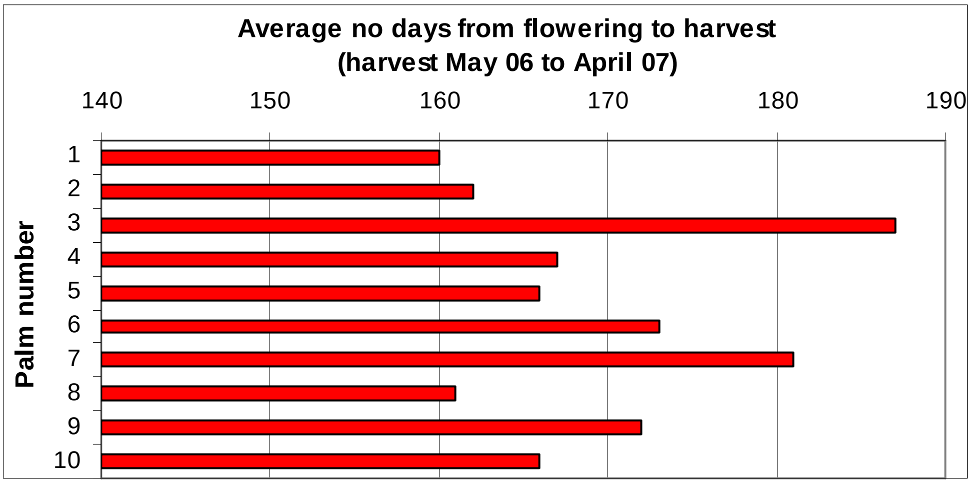

Figure 7. Average time taken from flowering to harvest for 10 palms (March data is based on only one palm).

Tissue test interpretation for fertiliser recommendations

(using trials 502, 504 and 511)

(Harm van Rees)

Summary

- Interpreting tissue nutrient test results to make a fertiliser recommendation must include both leaflet and rachis analysis;
- N fertiliser mobilises P and K out of the rachis and presumably makes these two nutrients available for growth components in the palm;
- Minimum nutrient levels for N, P and K in the leaflet and rachis can be ascertained from PNG OPRA trials and applied to plantation management.

Methods

For a number of PNG OPRA trials, tissue test results were interpreted in relation to the inputs and yields achieved. The relationship between the nutrient level in the tissue test, inputs and yield is presented in a step-wise progression from the lowest to the highest yield achieved. The methodology is similar to what was described by Hugh Foster and Noto Prabowo at the Oil Palm nutrition workshop held in Singapore (October 2006).

Results

An example of a step wise progression of inputs, tissue nutrient level and yield is described for a trial at MBE.

The information is presented as leaflet and rachis N, P and K (as %dm) in relation to the yield achieved for a specific fertiliser treatment in trial 511.

1. Tissue test result and yield for the control treatment (no fertiliser)

Fertiliser applied (kg/palm)			Leaflet (% dm)			Rachis (% dm)			Yield
N	P	K	N	P	K	N	P	K	t/ha
0	0	0	1.93	0.13	0.49	0.23	0.04	1.0	6.2

2. Tissue test result and yield with the application of 4kg/palm of SOA (Sulphate of Ammonia)

Fertiliser applied (kg/palm)			Leaflet (% dm)			Rachis (% dm)			Yield
N	P	K	N	P	K	N	P	K	t/ha
0 ↓	0	0	1.93 ↓	0.13	0.49	0.23	0.04	1.0 ↓	6.2 ↓
4	0	0	2.23	0.13	0.41	0.23	0.03	0.3	16.8

Observations (follow the arrows):

(i) Fertiliser rate increased from 0 to 4 kg/palm SOA
(ii) Leaflet N went up from 1.93% to 2.23 %dm
(iii) Rachis K went down from 1.0% to 0.3% (presumably because the extra N was able to mobilise K out of the rachis and make it available for growth)
(iv) With the application of N fertiliser the yield increased by 10.6 t/ha (6.2 to 16.8 t/ha)

3. Tissue test result and yield with the additional application of 2.5kg/palm of MOP (Muriate of Potash)

Fertiliser applied (kg/palm)			**Leaflet (% dm)**			**Rachis (% dm)**			**Yield**
N	**P**	**K**	**N**	**P**	**K**	**N**	**P**	**K**	**t/ha**
0	0	0	1.93	0.13	0.49	0.23	0.04	1.0	6.2
4	0	0	2.23	0.13	0.41	0.23	0.03	0.3	16.8
4	0	2.5	2.30	0.13	0.65	0.26	0.03	1.7	17.8

Observations (follow the arrows):

(i) Additional fertiliser applied was from 0 to 2.5 kg/palm MOP (keeping the SOA treatment rate as applied)
(ii) Leaflet K went up from 0.41 % to 0.65 %dm
(iii) Rachis K went up from 0.3% to 1.7%
(iv) With the additional application of K fertiliser the yield increased by 1 t/ha (16.8 to 17.8 t/ha)

4. Tissue test result and yield with the additional application of 2.0 kg/palm of TSP (Triple Superphosphate)

Fertiliser applied (kg/palm)			**Leaflet (% dm)**			**Rachis (% dm)**			**Yield**
N	**P**	**K**	**N**	**P**	**K**	**N**	**P**	**K**	**t/ha**
0	0	0	1.93	0.13	0.49	0.23	0.04	1.0	6.2
4	0	0	2.23	0.13	0.41	0.23	0.03	0.3	16.8
4	0	2.5	2.30	0.13	0.65	0.26	0.03	1.7	17.8
4	2	2.5	2.25	0.15	0.61	0.27	0.12	1.3	19.6

Observations (follow the arrows):

(i) Additional fertiliser applied was from 0 to 2 kg/palm of TSP (keeping the SOA and MOP rates the same).
(ii) Leaflet P increased from 0.13 to 0.15 %dm.
(iii) Rachis P increased from 0.03 to 0.12 %dm
(iv) With the addition of P fertiliser the yield increased by 1.8 t/ha (from 17.8 to 19.6 t/ha).

5. Tissue test result and yield with the additional application of another 2 kg/palm of SOA (from 4 to 6 kg/palm of SOA)

Fertiliser applied (kg/palm)			**Leaflet (% dm)**			**Rachis (% dm)**			**Yield**
N	**P**	**K**	**N**	**P**	**K**	**N**	**P**	**K**	**t/ha**
0	0	0	1.93	0.13	0.49	0.23	0.04	1.0	6.2
4	0	0	2.23	0.13	0.41	0.23	0.03	0.3	16.8
4	0	2.5	2.30	0.13	0.65	0.26	0.03	1.7	17.8
4	1	2.5	2.25	0.15	0.61	0.27	0.12	1.3	19.6
6	1	2.5	2.46	0.15	0.63	0.28	0.08	1.3	32.5

(i) Additional fertiliser applied was from 4 to 6 kg/palm of SOA (keeping the MOP and TSP rates the same).
(ii) Leaflet N increased from 2.25 to 2.46 %dm.
(iii) Rachis P decreased from 0.12 to 0.08 %dm (presumably because P was mobilised out of the rachis and made available for growth
(iv) With the addition of N fertiliser the yield increased by another 12.9 t/ha (from 19.6 to 32.5 t/ha).

Results

Minimum nutrient levels to optimise yield potential

Following a step wise progression of fertiliser inputs using different treatments from low to high yield, whilst comparing tissue nutrient concentration in the leaflet and rachis enables us to:

- Work out the optimum tissue nutrient content to achieve a particular yield;
- Determine how much fertiliser should be applied to correct a deficiency.

When this step wise progression of comparing the tissue nutrient concentrations of different treatments to palm performance was undertaken for the three NxK trials at MBE (502, 504 and 511) it was found that the minimum nutrient levels for high yielding oil palm on alluvial soils at MBE should be:

	Minimum level	
	Leaflet % dm	Rachis % dm
N	2.45	0.32
P	0.145	0.08
K	0.65	1.20

These minimum levels are roughly applicable to all areas, and more detail is provided for each specific region as detailed in this report.

Implications for a fertiliser strategy

Applying P or K without N will invariably result in a build up of P or K in the rachis without there being a yield benefit. This would occur at all sites, except for where the inherent soil supply of available N is in excess of total production. It is essential to base a fertiliser recommendation on the level of N, P and K in the leaflet AND rachis – it is impossible to recommend a fertiliser regime if for example there is no rachis tissue nutrient information. For example a low leaflet K is NOT necessarily an indication that K supply is limiting, it may mean that there is not enough N available to mobilise the nutrient out of the rachis to sites within the palm where it can be used for production. The recommendations for developing a fertiliser program based on tissue data is to:

- apply N fertiliser when leaflet N is low
- apply N fertiliser when leaflet P is low AND rachis P is high
- apply N fertiliser when leaflet K is low AND rachis K is high
- apply P fertiliser when leaflet P AND rachis P are low (usually this needs to be done in conjunction with a N fertiliser)
- apply K fertiliser when leaflet K AND rachis K are low (usually this needs to be done in conjunction with a N fertiliser)

Smallholder Research Report in 2006 – Oro Oil Palm Project

(Pauline Hore and James Kraip)

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
3. Major Field Days
4. Radio Programme for Oil Palm Growers in Oro Province.

1. Small holder Leaf Sampling

Leaf sampling was carried in selected blocks representative of the four Divisions of the Oil Palm Project; Sorovi Division, Igora Division, Aeka /Saiho Division and Ilimo Division. 41 blocks were sampled and send to AAR Laboratory in Malaysia for nutrient analysis**.** The results for each division are presented in Table 1.

Aeka Division – N, K, Cl and B are limiting production as levels are below critical values.

Recommendation – apply SOA, MOP and B.

Igora Division – Cl and B are low. The major nutrients are within their respective adequate ranges.
Recommendation – apply MOP and B. When MOP is applied it is normal to apply an N based fertilizer as well (such as SOA).

Illimo Division: K, Cl and B are low.

Recommendation – apply MOP and B. When MOP is applied it is normal to apply an N based fertilizer as well (such as SOA).

Sorovi Division: N, Cl and B are low.

Recommendation – apply SOA, MOP and B.

	Leaflet (% dm, except B ppm)						Rachis (%dm)			
Division	**N**	**P**	**K**	**Mg**	**Cl**	**B**	**N**	**P**	**K**	**Mg**
Aeka	2.18	0.141	0.68	0.26	0.10	13.0	0.27	0.060	0.76	0.05
Igora	2.32	0.143	0.72	0.22	0.19	11.9	0.29	0.069	1.10	0.64
Illimo	2.42	0.151	0.67	0.22	0.21	11.8	0.29	0.069	0.59	0.07
Sorovi	2.12	0.134	0.70	0.22	0.17	13.6	0.29	0.129	1.16	0.06
Critical value	*2.30*	*0.150*	*0.65*	*0.20*	*0.45*	*15*	*0.30*	*0.08*	*1.00*	

2. Field Visits

Field inspections were held based on reports received from OPIC Extension Officers and appropriate actions were recommended. Highlight of these were the death of young replanted seedlings caused by grubs eating the feeder roots of the palms. The Entomology section of PNG OPRA took on this work and recommended control strategies.

3. Field Days

There were two major division field days, which PNG OPRA participated in 2006. The first one for the Sorovi Division at a LLS block and the second one at Saiho Division for all the VOP blocks that were going through replanting. PNG OPRA staff members present at Sorovi Division were Steven Nake, Seno Nyaure and Pauline Hore; and at Saiho Division staff were James Kraip, Seno Nyaure and Pauline Hore.

The main topics presented to growers

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

Pauline Hore (Smallholder Supervisor) had one radio show with Collin Benton (*HOP – SLO 1*) and Graydon Hanguru (*FM -OPIC*) on the Script she wrote in "*TOK PISIN"* on the Introduction of PNG Oil Palm Research and The Research work that it does for the Oil Palm Industry in PNG.

- The second radio show was on the Agronomy Section, specifically on the importance of fertilizer in oil palm production.(*In tok pisin version*)

Field Operations, Monitoring and Methods

Harvest

Trials were harvested on a 2 week interval, which has, in 2007, been changed to a 10 day harvesting round for all CTP plantations. Harvest is undertaken by the plantation in cooperation with PNG OPRA field staff. Before the bunches are wheeled out PNG OPRA field staff, must record the number and weight of bunches and loose fruit produced by each individual trial palm at each harvest. Each trial palm is numbered and all harvest information is entered into a database which contains all trial data collected by PNG OPRA over the last decade.

Harvest measurement and fertiliser application are THE most important operations for the trial results

Trial maintenance

PNGOPRA staff are responsible for all fertiliser applications within the trial area unless specifically arranged. Plantation staff are responsible for pruning, maintaining clear weeded circles and harvest paths and digging trenches between plots in trials where required.

Monitoring

All monitoring is the responsibility of PNGOPRA. Training notes for standardized monitoring and sampling are now available from OPRA

Tissue analysis: Frond 17 is used for tissue analysis. Each measured palm in a trial plot is sampled. 4 leaflets are collected from each side of the rachis approximately $2/3^{rd}$ down from the first leaflet towards the tip of the frond (where the two ribs meet on the rachis). Samples are combined. The middle third of the leaflets is used for tissue analysis. A sample of rachis is collected at the first leaflet, the rachis sample is mulched prior to drying. Tissue samples were dried at $65^{o}C$, ground and sent to the AAR (Applied Agricultural Resources) laboratory in Malaysia for analysis. Specifically prepared standard samples are included in the batches sent to the laboratory as a quality control check. Tissue results are entered into the OPRA database.

Vegetative measurements: the same frond used for tissue analysis sampling is used to measure frond parameters. Frond length (from first leaflet to the tip of the frond), leaflet number, leaflet length and width (for leaflets taken at $2/3^{rd}$ of the length of the frond), rachis width and thickness (at the point where first leaflets are formed) are assessed and the data are entered into the database.

Besides frond parameters the frond production rate is also assessed. Every six months the newest fully opened frond (frond 1) is identified and marked with a dab of coloured paint. At the same time the current location of the previously marked newest frond is determined (using the previously applied dab of paint) and recorded. A total frond count is also undertaken. All these data are entered in the OPRA database.

From this information vegetative parameters are calculated following the procedures of Corley and Breure (1981):

PCS = petiole cross section (cm^3), calculated as rachis width x thickness

GF = green fronds (total frond number)

FP = frond production (new fronds produced over a 12 month period)

FA = frond area (m3) calculated as 0.57 x Leaf Area (palm age > 7 years) (where Leaf Area is calculated as mean leaflet width x mean leaflet length x no. of leaflets)

LAI = leaf area index calculated as FA x N (total number of fronds) x D (density) x 10^{-4}

FDM = frond dry matter production (t/ha/yr), calculated as D (density) x FP x
Frond weight x 10^{-3} (Frond weight is calculated from the PCS as 0.102 x PCS + 0.26)

BDM = bunch dry matter production (t/ha/yr), calculated as 0.82 x FFB (fresh fruit bunch wt)

TDM = total dry matter production (t/ha/yr), calculated as ((FDM + BDM)/0.9)

VDM = vegetative dry matter production (t/ha/yr), calculated as TDM - BDM

Palm height is also monitored annually. The annual measurement of palm height allows incremental growth to be calculated. Unfortunately there were some procedural problems with measuring palm height and not all trials have an accurate palm height recorded.

Nutrient Use Efficiency (NUE): NUE (or fertiliser use efficiency might be a better term to describe this assessment) can be calculated or estimated from:

- Amount of nutrients applied (fertiliser)
- Nutrients exported in the fruit
- Nutrients stored in the fronds and trunk

Together with the measured and calculated values for the Petiole Cross Section, Frond Production and dry matter stored in trunks and fronds values for NUE can be calculated.

NUE is often presented as RE (Recovery Efficiency) which is the recovery of an applied nutrient in the biomass produced (FFB, fronds and trunk). It is calculated for each applied nutrient as:

RE = (total nutrient uptake with fertiliser – total nutrient uptake without fertiliser) / applied fertiliser

Where:

- Nutrient uptake with fertiliser is the total amount of nutrients in bunches, foliage and trunk (kg / ha);
- Nutrient uptake without fertiliser is the total amount of nutrients in bunches, foliage and trunk without the application of fertiliser (kg / ha); and
- Applied fertiliser is the kg of fertiliser nutrient applied per ha

Fertiliser Response Trials

Hargy Oil Palm Ltd., WNB: Summary and Synopsis

(Harm van Rees and Winston Eremu)

Fertiliser 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) does not include an N treatment. A new factorial Mg source trial has been established in 2007.

   Outcome: Two trials have shown a 30 to 100% increase in yield resulting from N fertiliser. The third trial (205) does not include an N treatment and it appears that this site is deficient in N. In 2007 the basal N rate applied will be increased. In two of the three factorials there have been responses to P but not in trial 205. It is possible that in this trial there was no P response because N is limiting production.

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. The Systematic trials are of similar design to those at NBPOL (see this report).

   Outcome: the Systematic N trials are showing N fertiliser responses of between 7 and 20%. The responses to N fertiliser 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 two pages. A short recommendation for trial work, operation and plantation management based on our results is also provided.

Hargy Oil Palm Ltd: Synopsis of 2006 PNG OPRA trial results and recommendations

Trial	Palm Age	Yield t/ha	Yield Components	Tissue	Vegetative	Notes
205 Hargy EFB, TSP, KIE (factorial) Soil: Volcanic	13	EFB 25 to 27 TSP (NS) KIE (NS)	B/palm 10 (NS) SBW 26 (NS)	EFB LN 2.32 to 2.39 RK 1.15 to 1.34 TSP LP 0.137 to 0.141 RP 0.05 to 0.09 KIE LMg 0.16 to 0.19		Low in N (increase basal N rate on half of trial)
209 Hargy SOA, TSP, MOP, KIE (factorial) Soil: Volcanic	12	SOA 22 to 28 TSP 23 to 27 SOA x TSP high 29 MOP (NS) KIE (NS)	B/palm 8.5 to 10.8 SBW 19 to 21	SOA LN 2.18 to 2.28 TSP LP 0.126 to 0.135 RP 0.05 to 0.10 MOP LK 0.70 (NS) RK 1.05 to 1.41 KIE LMg 0.16 to 0.21	PCS 44 to 50 FP 22 to 23 LAI 5.0 to 6.0	Highest yield SOA 4 and TSP 4 (29 t/ha)
213 Hargy AN, TSP(factorial) Soil: Volcanic	9	AN x P 10 to 21	B/palm 5.7 to 8.7 SBW 16 to 20	AN LN 2.35 to 2.62 TSP LP 0.127 to 0.146 RP 0.027 to 0.046 LK 0.65; RK 0.53 LMg 0.21; LB 15ppm	PCS 31 to 35 FP 22.8 to 24.6 LAI 5.1 to 5.5	LK 0.65 (adeq) RK 0.53 (very low) Needs MOP
211 Navo AN (Systematic) Soil: Volcanic	8	3.0kg AN 28 to 30	B/palm 15 (NS) SBW 18 to 19	AN LN 2.44 to 2.56 LP 0.145; RP 0.05 LK 0.85; RK 1.51 LMg 0.18; LB 16ppm	PCS 39 to 42 FP 26 (NS) LAI 5.0 (NS)	
212 Hargy AN (Systematic) Soil: Volcanic	10	3.7kg AN 23 to 28	B/palm 9.5 to 10.5 SBW 18 to 20	AN LN 2.25 to 2.42 LP 0.135; RP 0.03 LK 0.74; RK 1.25 LMg 0.16; LB 15ppm	PCS 45 (NS) FP 19 to 20 LAI 5.5 to 6.1	LP 0.135 (low) RP 0.03 (very low) Need 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**
2.40	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 (in current trials it is unlikely that the maximum yield has been reached and it could be significantly higher than present yields)
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 fertiliser strategies can be calculated if costs of production are provided to OPRA
5. Plantation management (harvest time, pruning, clean weeded circles, fertiliser application and timing etc) all play a large role in the potential to optimize production

Trial 205: P, Mg and EFB Fertiliser Trial, Hargy Estate

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, EFB increased yield but only by a small increment (less than 10%).

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: 2.36; and rachis N: 0.25% dm).

If N fertility is low then palms, or any other crop, cannot respond to other nutrients supplied either from the soil or from applied fertiliser and the palms cannot reach their full productive potential.

It is recommended to immediately (ie. in 2007) either increase the basal application of N (currently applied at AC 3kg/palm) or to include N as a treatment and apply it at a higher rate to half of the available replicates (currently there are six replicates; three could be treated with a higher rate of N fertiliser).

This trial was planted with sixteen different progeny in each plot. The long term analysis of progeny performance showed clear differences in yield between different progeny. In trial work it demonstrates how important it is to ensure that plots have an even distribution of mixed progeny. It also shows the importance of undertaking more progeny x fertiliser trial work to ascertain differences in nutrient uptake and performance of different progeny.

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 fertiliser in conjunction with EFB. Fertiliser responses in trials can lead to more accurate fertiliser 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	13 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 fertiliser in a 2 x 2 x 2 factorial design, replicated six times with 48 plots (Table 2). 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 16 progenies are listed in Table 3.

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 three treatments, each applied at two rates).

Basal fertiliser applied in 2006 was 3kg/palm of Ammonium Chloride.

Table 2: Fertiliser 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

Table 3: Progeny numbers and codes in Trial 205

Code	Progeny Number		Code	Progeny Number
A	9004093E		I	9009127E
B	9009030E		J	9103073E
C	9009149E		K	9103136E
D	9102109E		L	9010217E
E	9010040E		M	9010190E
F	4091		N	9009110E
G	9008022E		O	9101100E
H	5148		P	9007130E

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 thereafter (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.

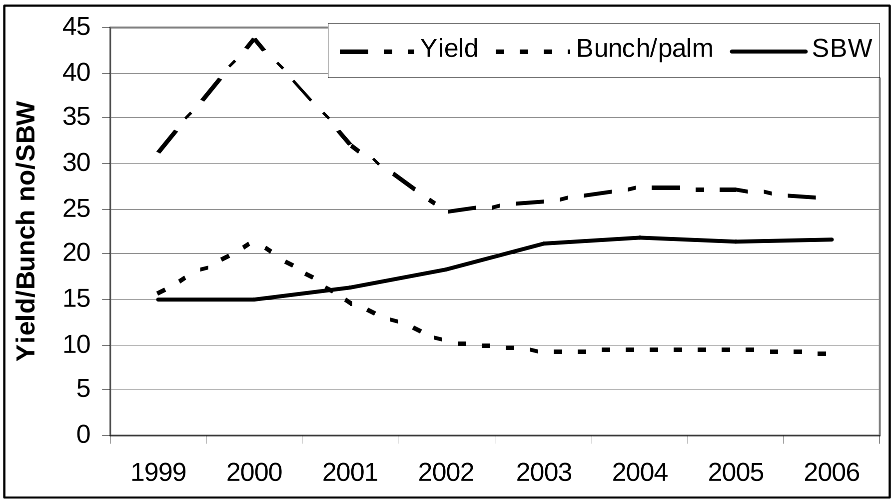

Figure1: FFB yield, Bunch no/palm and SBW from 1999 to 2006.

2006 - FFB yield and its components

The main effect of EFB application on yield was significant in 2006 (24.8 vs. 27.2 t/ha for EFB 0 and 230 kg/palm respectively) (Figure 2). The effect of EFB on yield was due to a small but significant increase in bunch weight (21.3 vs 21.9 kg/bunch) and not to bunch number. The effects of KIE and TSP were not significant in 2006 (Figure 2) – nor in 2003, 2004 and 2005.

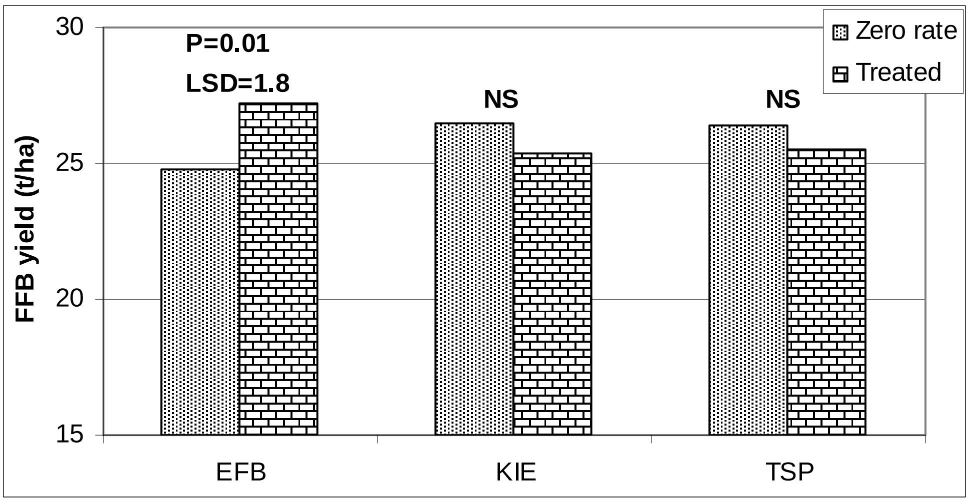

Figure 2. Main effect of EFB, Kieserite and TSP on FFB yield (t/ha) in 2006.

The interactions between fertiliser treatment (EFB x KIE; EFB x TSP; KIE x TSP; and EFB x KIE x TSP) were not significant and no trend in fertiliser effect on yield could be determined.

The overall impact of EFB, Kieserite and TSP has been minimal over the duration of this trial, the co-efficient of variation (CV %) in this trial has been high (2006: 12.2%) which indicates that within treatment plot variation is high. When the data are sorted from low to high yield it is not possible to pick a trend in the relationship between the type of fertiliser applied and yield.

It is likely that Nitrogen deficiency is having a large influence on production and optimum yields cannot be realized (see next section).

2006 – tissue nutrient concentration

The impact of fertiliser on tissue nutrient concentration was as expected (Table 4):

- EFB increased leaflet N, P and K and rachis P and K (EFB as a mulch breaks down and releases mineral N, P and K);
- TSP only had an effect on leaflet P and rachis P;
- Kieserite only had an effect on leaflet Mg.

Table 4: Tissue nutrient concentration for Trial 205 in 2006 (figures in bold are significantly different).

Fertiliser rate (kg/palm)	Leaflet (% dm)				Rachis (% dm)		
	N	P	K	Mg	N	P	K
EFB 0	**2.32**	**0.138**	**0.65**	0.18	0.25	**0.067**	**1.15**
EFB 230	**2.39**	**0.140**	**0.68**	0.17	0.25	**0.072**	**1.34**
TSP 0	2.36	**0.137**	**0.68**	0.17	0.25	**0.054**	**1.32**
TSP 3	2.36	**0.141**	**0.65**	0.18	0.25	**0.086**	**1.18**
KIE 0	2.36	0.139	0.67	**0.16**	0.25	0.070	1.25
KIE 3	2.35	0.138	0.66	**0.19**	0.25	0.070	1.24
$LSD_{0.05}$	**0.04**	**0.002**	**0.01**	**0.01**	**-**	**0.004**	**0.06**
CV%	**2.6**	**2.0**	**3.5**	**8.4**	**2.2**	**10.4**	**8.4**

The response seen from fertiliser on tissue nutrient concentration very similar to observations in 2005.

The overall nutrient status of this trial is low to adequate. The main problem appears to be a lack of nitrogen fertility. EFB increased leaflet N to barely adequate (from 2.32 to 2.39 %dm in the leaflet) and had no effect on Rachis N. 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. It is strongly recommended to apply more N fertiliser to this trial as soon as possible.

Boron was also tested in the leaflets and the mean value was 16 mg/kg – which is adequate. If higher rates of N are going to be applied then it is recommended to supply B as a basal fertiliser.

Individual Progeny performance from 1997 to 2006

Each trial plot was planted to the same 16 progeny (named A to P); this enabled the analysis of progeny performance over the duration of the trial (1997 to 2006). There were consistent statistically significant yield differences between the progenies. There were no interactions with fertiliser used in the trial and performance is assessed over all levels of fertiliser treatments.

There is a large variation in yield between the progenies for each of the years (Table 5). The mean difference between the highest and lowest yielding progenies was 5 t/ha however for the individual years, it ranged from 6 – 10 t/ha (mean 8 t/ha). Progenies E, F and G consistently performed less well compared to the average, whilst progeny A, B, H, I and J consistently performed better than average.

Table 5. Mean annual yield for 16 progeny in trial 205 (see legend below table).

Progeny	Age 4 1997	5 1998	6 1999	7 2000	8 2001	9 2002	10 2003	11 2004	12 2005	13 2006	Mean
A	29	31	34	45	31	28	26	29	28	26	32
B	27	31	30	45	32	25	27	29	28	28	31
C	25	30	31	44	31	24	26	29	26	25	30
D	24	30	30	43	31	23	26	29	26	24	29
E	22	26	31	39	30	22	23	25	23	26	27
F	22	28	29	40	29	24	26	27	28	24	28
G	24	28	27	41	30	21	20	25	24	21	27
H	25	32	30	47	36	24	27	26	29	28	31
I	28	32	34	47	34	27	28	31	28	28	32
J	24	30	32	45	34	26	27	28	29	29	31
K	25	28	26	42	30	21	24	29	28	24	28
L	26	29	32	42	33	24	25	26	27	26	30
M	24	28	34	44	31	27	30	27	30	25	31
N	21	29	32	43	31	25	25	27	27	27	29
O	25	29	31	45	33	24	26	27	27	27	30
P	23	28	35	42	35	27	24	28	26	27	30
Mean	24	29	31	43	32	24	26	27	27	26	30
Min	21	26	26	39	29	21	20	25	23	21	27
Max	29	32	35	47	36	28	30	31	30	29	32
std dev	2.1	1.7	2.5	2.3	2.0	2.2	2.3	1.7	1.8	2.1	1.5
Diff	8	6	9	8	7	7	10	7	7	8	5

Legend: Low yield | Average yield | High yield

All progenies had a high peak yield (mean 43 t/ha) in 2000 and returned to normal yields with a mean of 26 t/ha in 2002. The peak was most likely due to the low rainfall (drought) in 1997, followed by a wetter season in 1998. In the peak year the lowest yielding progeny (E) had a yield of 39 t/ha while the highest yielding progeny (H and I) had a yield of 47 t/ha.

The mean yield variation for the different progenies indicated that Progeny I had the largest difference (2.7 t/ha) above the mean while Progenies E and G yielded more than 2 t/ha below the mean (Figure 3).

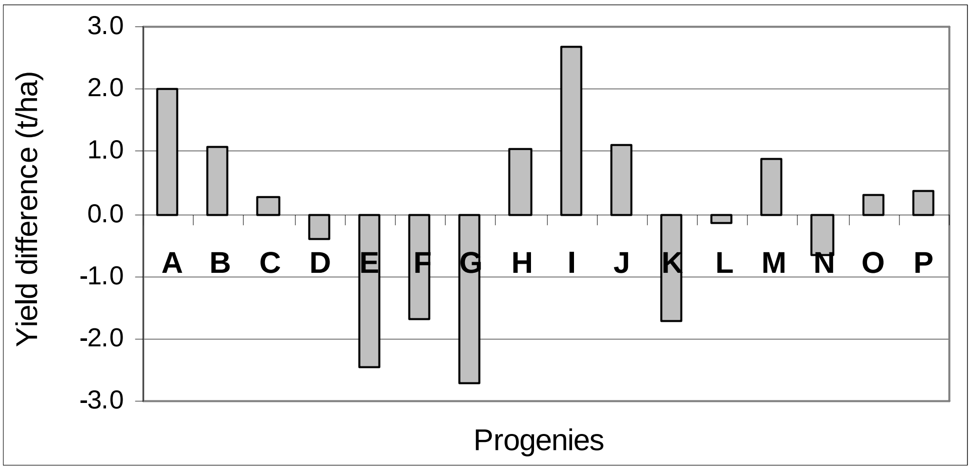

Figure 3. Deviation from mean yield for each progeny (1997 to 2006).

The implication of these results is that progeny effects can over ride fertiliser effects in plots with different? progenies in fertiliser trials. It demonstrates the importance of having mixed progenies allocated randomly in a plot for future fertiliser trials. Alternatively it could be argued that PNG OPRA should only undertake trial work where progeny are known and allocate treatments accordingly to take into account the Genotype x Nutrition interaction.

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. The increase in yield from EFB in 2006 was probably due to a small increase in the available nitrogen (leaflet N increased from 2.32 to 2.39 %dm as a result of EFB application).

The general lack of a fertiliser 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 the other nutrients applied. Ammonium Chloride is currently applied as a basal fertiliser at 3kg/ha (equivalent to 0.8kg N/palm) which appears to be too low.

It is recommended to immediately supply additional N fertiliser to the trial site. There are two options available:

1). Apply N fertiliser at a rate 3 times the current basal rate (ie AC at 9 kg/palm) for 2007 and 2008 and then review the response and decide on a N strategy for 2009; or

2). Apply N fertiliser to half of the site. There are currently six replicates, half of these replicates could continue to receive the current level of AC (3 kg/palm) and the other three replicates could receive AC at 9 kg/palm, and review this in 2009.

Trial 209: N, P, K and Mg Factorial Fertiliser Trial, Hargy Estate

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 fertiliser treatment in 2006.

Nitrogen (N) and phosphorus (P) and occasionally potassium (K) fertilisers should be applied – the optimum base rate for fertiliser to apply on a yearly basis is 4 to 8 kg/palm of SOA and 4 kg/palm of TSP. 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 fertiliser response information necessary for determining fertiliser 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	12 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 fertiliser 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. Fertiliser levels and rates used in trial 209.

	Amount (kg/palm/year)		
Fertiliser	**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

Basal fertiliser was not applied in 2006.

RESULTS AND DISCUSSION

Fertiliser effect on FFB yield and its components

Mean trend over time – FFB yield and its components

The number of bunches (BNO) harvested per palm decreased while SBW increased progressively over the course of the trial (Figure 1). FFB yield reached a peak in 2000 and has decreased since – in 2006 the average yield for the site was 25.7 t/ha.

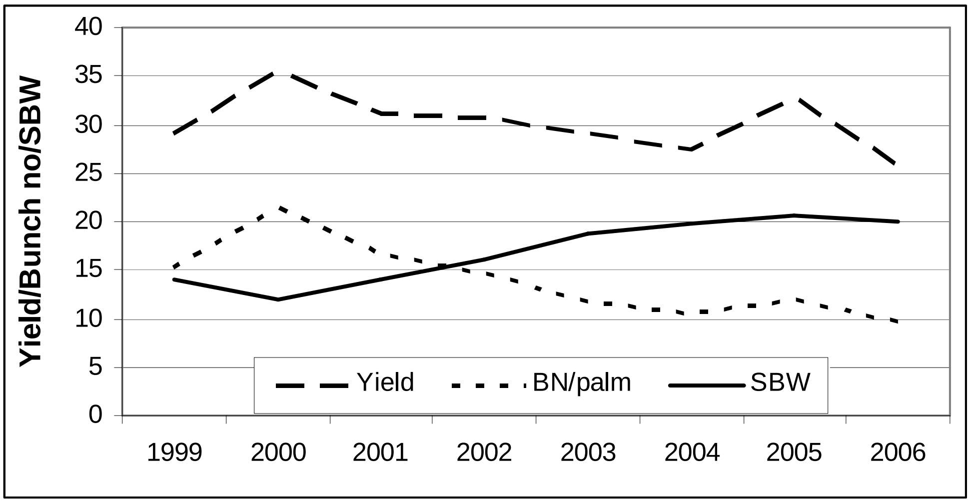

Figure 1. Yield (t/ha), Bunch number per palm (BN/palm) and SBW (Single Bunch Weight in kg/bunch) for trial 209 for the duration of the trial.

2006 – FFB yield and its components

In 2006, only the SOA and TSP treatments resulted in a significant increase in yield. MOP and Kieserite did not affect yield to any extent (less than 0.5 t/ha difference in main effects of these two treatments). The main effects of SOA and TSP were:

- SOA from 2kg to 8 kg/palm increased yield from 22.5 to 28.0 t/ha ($P<0.001$); and
- TSP from 0kg to 8 kg/palm increased yield from 23.1 to 27.4 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 2006.

	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	21.1	23.0	23.5	8.5	8.9	9.1	18.8	18.8	19.3
4	22.0	28.3	29.0	8.9	10.4	10.7	19.0	20.3	20.4
8	26.1	28.8	29.2	9.6	10.3	10.8	20.9	21.4	20.6
Significant difference:									
SOA	P<0.001			P<0.001			P<0.001		
TSP	P<0.001			P<0.001			NS		
$LSD_{0.05}$	3.1			1.0			1.4		

* Bunch no/palm of 8.5 equates to 1148 bunches/ha; and a bunch no/palm of 10.8 equates to 1458 bunches/ha.

When the strength of this one year (2006) relationship between fertiliser treatment and yield and its components was investigated on the average yield for 2004 to 2006 the results were very similar. When three year average yield and its component data are analysed it is likely that the yearly yield fluctuations within a plot are evened out. Similarly to the 2006, the analysis for the three year average data (2004 to 2006) demonstrated that SOA and TSP had the strongest effect on yield but MOP also played a role – especially with its effect on SBW.

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 25.7 to 31.1 t/ha (P<0.001);
- TSP from 0kg to 8kg/pam increased yield from 26.4 to 29.9 t/ha (P<0.001); and
- MOP from 0 to 4kg/palm increased yield from 27.7 to 29.2 t/ha (P=0.03).

This increase in yield response from MOP was primarily on bunch weight (19.3 to 20.7 kg/bunch; P<0.001) rather than bunch number which was not significant.

In general: the plots yielding 30t/ha, predominantly were treated with SOA at 4 to 8 kg/palm + TSP at 4 kg/palm. The plots yielding less than 20 t/ha generally only received the low rate of SOA (2 kg/palm) or the higher rate of SOA at 4 kg/palm but then in the absence of TSP.

The Mg based fertiliser, Kieserite, had no impact on yield or its components in 2006 or on the average data for 2004 to 2006.

Fertiliser effect on tissue nutrient concentrations

The effect of SOA, MOP, TSP and KIE fertiliser 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 – 2.28 %dm). There was no increase in Rachis N (as would have been expected);
- 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 0.16 to 0.21 %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 adequate (14.8 mg/kg).

Table 4: Tissue nutrient concentration for Trial 209 in 2006 (figures in bold are significantly different P<0.05).

Fertiliser rate (kg/ha)	Leaflet (% dm)				Rachis (% dm)		
	N	P	K	Mg	N	P	K
SOA 2	**2.18**	**0.129**	0.70	**0.21**	0.24	**0.092**	1.30
SOA 4	**2.21**	**0.132**	0.70	**0.19**	0.25	**0.071**	1.27
SOA 8	**2.28**	**0.132**	0.71	**0.17**	0.25	**0.070**	1.23
MOP 0	**2.17**	0.130	**0.72**	0.20	0.25	0.068	**1.05**
MOP 2	**2.21**	0.133	**0.68**	0.19	0.25	0.081	**1.34**
MOP 4	**2.22**	0.135	**0.70**	0.17	0.25	0.080	**1.41**
TSP 0	2.19	**0.126**	0.71	0.20	0.25	**0.046**	1.35
TSP 4	2.21	**0.133**	0.69	0.19	0.25	**0.082**	1.23
TSP 8	2.22	**0.135**	0.69	0.18	0.25	**0.102**	1.22
KIE 0	2.19	0.131	0.70	**0.16**	0.25	0.076	1.27
KIE 4	2.21	0.132	0.70	**0.19**	0.25	0.075	1.28
KIE 8	2.20	0.131	0.71	**0.21**	0.24	0.078	1.25
$LSD_{0.05}$	**0.04**	**0.003**	**0.03**	**0.01**	**-**	**0.014**	**0.18**
CV%	**3.2**	**3.9**	**4.7**	**10.0**	**5.6**	**18.8**	**15.3**

Effects of fertiliser treatments on vegetative growth parameters

Nitrogen fertiliser, applied as SOA, had significant effects on all growth parameters measured and calculated. TSP had significant effects on rachis size (PCS), fronds produced in a year and dry matter production parameters calculated from the growth and production measurements. K fertiliser, as MOP, only had a significant effect on rachis size (PCS). Kieserite, as the magnesium source, had no effect on any of the vegetative growth parameters measured or calculated (Table 5).

Main observations of fertiliser 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
- The number of fronds produced increased significantly by 1.4 fronds/year with the higher rates of N; the application of TSP increased frond number by 1.0 frond/year.
- 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 2006. P values less than 0.05 are in bold.

Fertiliser	PCS	Radiation Interception				Dry Matter Production (t/ha)			
		GF	FP	FA	LAI	FDM	BDM	TDM	VDM
SOA	**<0.001**	**0.05**	**<0.001**	**0.005**	**0.002**	**<0.001**	**<0.001**	**<0.001**	**<0.001**
MOP	**0.002**	0.16	**0.05**	0.13	0.08	**0.008**	0.70	0.15	**0.01**
TSP	**<0.001**	**0.05**	**<0.001**	0.19	0.70	**<0.001**	**<0.001**	**<0.001**	**<0.001**
KIE	0.13	0.71	0.93	0.40	0.72	0.41	0.25	0.36	0.43
SOA.MOP	0.39	0.33	0.21	0.16	0.77	0.49	0.52	0.68	0.57
SOA.TSP	0.98	0.99	0.45	0.30	0.67	0.71	0.17	0.23	0.58
MOP.TSP	0.36	0.16	0.70	0.14	0.18	0.32	0.39	0.29	0.29
SOA.KIE	0.28	0.82	0.53	0.30	0.71	0.18	0.86	0.52	0.21
MOP.KIE	1.0	0.70	0.74	0.59	0.51	0.95	0.08	0.29	0.90
TSP.KIE	**0.03**	0.83	0.63	0.59	0.89	0.39	0.09	0.10	0.29
CV %	5.0	3.7	3.7	6.6	8.6	6.5	12.2	8.0	6.5

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

Table 6. Main effects of treatments on vegetative growth parameters in 2006. Significant effects (p<0.05) are shown in bold.

Fertiliser 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**	**16.6**
SOA 4	**47.3**	**33.8**	**22.6**	**12.6**	**5.8**	**15.3**	**13.8**	**32.3**	**18.6**
SOA 8	**50.0**	**34.3**	**23.0**	**13.0**	**6.0**	**16.5**	**14.6**	**34.6**	**19.9**
$LSD_{0.05}$	*1.3*	*0.7*	*0.5*	*0.5*	*0.3*	*0.5*	*0.9*	*1.4*	*0.7*
MOP 0	**46.2**	33.7	**22.6**	12.7	5.8	**15.0**	13.4	31.6	**18.2**
MOP 2	**46.7**	33.6	**22.0**	12.4	5.6	**14.8**	13.2	31.1	**18.0**
MOP 4	**48.5**	34.2	**22.5**	12.8	5.9	**15.7**	13.6	32.5	**18.9**
$LSD_{0.05}$	*1.3*	-	0.5	-	-	0.5	-	-	0.7
TSP 0	**45.4**	**33.5**	**21.8**	12.4	5.6	**14.3**	**12.1**	**29.3**	**17.2**
TSP 4	**47.3**	**33.7**	**22.6**	12.7	5.8	**15.4**	**13.8**	**32.4**	**18.6**
TSP 8	**48.7**	**34.3**	**22.8**	12.8	5.9	**15.9**	**14.3**	**33.5**	**19.3**
$LSD_{0.05}$	*1.3*	*0.7*	*0.5*	-	-	*0.5*	*0.9*	*1.4*	*0.7*
KIE 0	47.8	33.7	22.4	12.8	5.8	15.4	13.3	31.9	18.6
KIE 4	47.1	33.9	22.4	12.6	5.8	15.1	13.8	32.1	18.4
KIE 8	46.5	33.9	22.4	12.5	5.7	15.0	13.0	31.2	18.1
$LSD_{0.05}$	-	-	-	-	-	-	-	-	-

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

The highest yields, of over 30 t/ha, in 2006 were obtained with the addition of SOA at 4 to 8 kg/palm plus TSP at 4 kg/palm. MOP and Kieserite had little or no impact on yield in 2006, and when the last three years of data was investigated then MOP only had a small additional benefit to yield.

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 is inhibiting production.

Frond production and frond size were adequate for potentially higher yielding palms. In 2007 and 2008 this trial will be investigated in more detail to ascertain what growth limiting factors could be influencing production at this site.

Trial 211: Systematic N Fertiliser Trial, Navo Estate

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 fertiliser 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	8 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 fertilisers applied in 2006 in Trial 211: none applied

RESULTS and DISCUSSION

Yield and its components response to fertiliser treatment in 2006

The yield increase from applying N fertiliser is significant but the response is only small (2.0 to 2.5 t/ha) (Table 2). The yield response of around 2 t/ha is achieved at a N fertiliser rate of around 1.0 kg N/palm (equivalent to 3.0 kg AN/palm). The affect of N fertiliser was not significant on bunch number; however SBW increased significantly by around 1kg/bunch as a result of the N applications (Table 2).

Table 2. T211: 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	27.8	14.6	1679	17.5
0.25	0.74	28.7	14.7	1691	17.5
0.50	1.48	28.7	14.8	1702	17.6
0.75	2.22	29.4	14.8	1702	18.5
1.0	2.96	30.4	15.2	1748	18.4
1.25	3.70	30.4	14.9	1714	18.7
1.5	4.44	30.0	15.1	1737	18.1
1.75	5.18	31.8	15.7	1806	18.6
2.0	5.92	30.2	15.2	1748	18.0
Significant difference:		**P<0.001**	**NS**	**NS**	**P=0.004**
$LSD_{0.05}$		**1.4**	**-**	**-**	**0.7**
CV%		**4.6**	**4.6**	**4.6**	**3.7**

Yield response over time

A small but noticeable increase in yield occurred from 2003 (palm age: 5 years) to 2006 (palm age: 8 years). Applying N fertiliser has had a yield benefit since 2003 (Figure 1), albeit a small one. In most years the benefit is between 2 and 3 t/ha and is achieved by applying 3.0 kg AN/palm (1.0 kgN/palm).

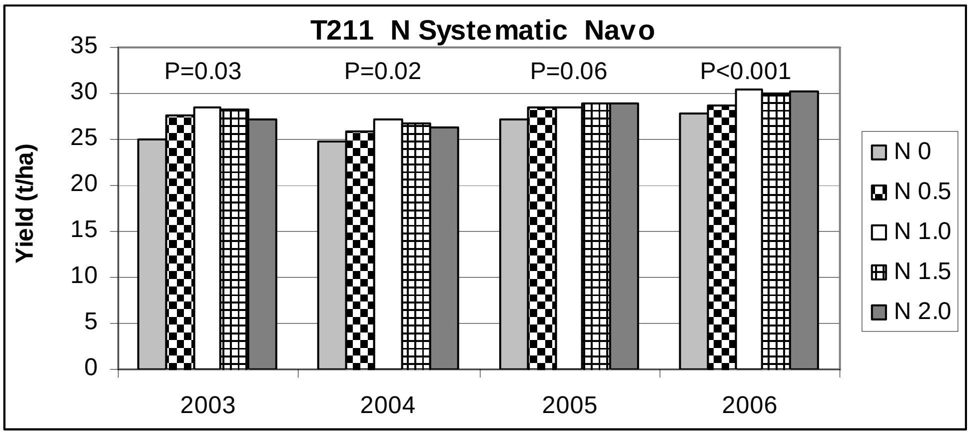

Figure 1. Yield response to 5 rates of N (kg/palm) over time (fertiliser N was first applied in late 2002).

As the palms matured from 5 to 8 years after planting the mean number of bunches per palm decreased and the SBW increased (Figure 2). The effect of N fertiliser on bunch number per palm and SBW for most years has not been significant.

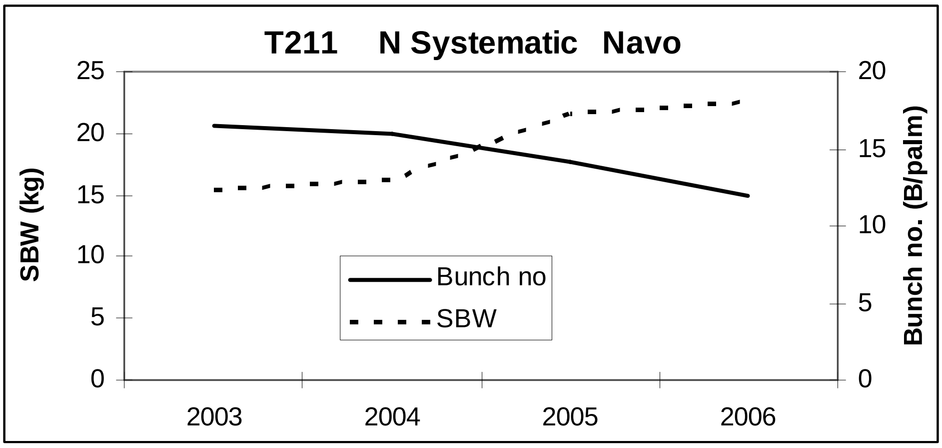

Figure 2. Mean trial bunch number per palm and SBW (kg) over time (Trial 137).

Tissue nutrient concentration for 2006

Tissue nutrient concentration was investigated for both leaflets and the rachis (Table 3). Leaflet N increased with higher rates of N application (P=0.03). There were no significant effects on leaflet P or K, nor on Rachis N, P and K. Rachis P appears low and the site should receive P fertilizer.

Leaflet Mg is just on the low side (0.18 %dm) and Boron levels are adequate (16 ppm).

Table 3. Leaflet and rachis nutrient content for T211 in 2006.

N rate (kg/palm)	Equivalent AN rate (kg/palm)	Leaflet (% dm)			Rachis (% dm)		
		N	P	K	N	P	K
0	0	2.44	0.142	0.83	0.25	0.04	1.36
0.25	0.74	2.48	0.142	0.83	0.25	0.04	1.37
0.50	1.48	2.53	0.143	0.81	0.27	0.04	1.38
0.75	2.22	2.51	0.146	0.85	0.26	0.05	1.43
1.0	2.96	2.55	0.147	0.83	0.25	0.05	1.56
1.25	3.70	2.53	0.144	0.84	0.25	0.05	1.58
1.5	4.44	2.58	0.147	0.85	0.25	0.05	1.54
1.75	5.18	2.50	0.145	0.84	0.26	0.05	1.43
2.0	5.92	2.56	0.147	0.84	0.26	0.05	1.42
Significant difference:		**P=0.03**	**NS**	**NS**	**NS**	**NS**	**NS**
$LSD_{0.05}$		**0.08**	**-**	**-**	**-**	**-**	**-**
CV%		**2.2**	**2.0**	**4.9**	**6.3**	**8.6**	**12.2**

Tissue N concentration over time 2004 to 2006

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

Fertiliser N effects on oil palm vegetative growth

Frond production and frond number

26 new fronds were produced in 2006 (one every 14 days) indicating good growing conditions during the year. Total green fronds counted per palm averaged 37.3 fronds which is an adequate number. AN fertiliser 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 fertiliser applied.

Vegetative dry matter production

Petiole cross section is a primary determinant of vegetative dry matter production. PCS increased by approximately 8% with the application of N fertiliser. The measures of foliar vegetative dry matter production (FDM (frond dry matter production), TDM (total dry matter production) and VDM (vegetative dry matter production) improved with increasing rates of N fertiliser and reached a plateau at about 1 kg N/palm.

Table 5. Effect of N treatments on vegetative growth parameters in 2006.

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	39.3	37.8	25.6	11.6	5.0	12.4	10.8	25.7	15.0
0.25	0.74	40.5	37.9	25.8	11.5	5.0	12.9	11.1	26.7	15.5
0.50	1.48	42.1	36.8	25.7	11.6	4.9	13.3	10.9	26.9	16.0
0.75	2.22	40.8	37.5	26.0	11.8	5.1	13.1	11.0	26.8	15.7
1.0	2.96	41.5	36.7	25.5	11.7	4.9	13.0	11.7	27.5	15.8
1.25	3.70	42.8	37.1	25.6	12.1	5.1	13.5	11.7	27.9	16.3
1.5	4.44	40.7	37.3	26.5	11.7	5.0	13.3	11.4	27.4	16.0
1.75	5.18	42.4	37.0	25.7	12.1	5.2	13.4	12.4	28.6	16.2
2.0	5.92	41.9	36.4	25.6	11.9	5.0	13.2	11.6	27.6	15.9
Significant difference:		0.006	0.03	0.12	0.24	0.49	0.01	0.002	0.001	0.004
	$LSD_{0.05}$	1.8	0.9	-	-	-	0.5	0.8	1.0	0.6
	CV%	4.3	2.5	2.4	4.5	4.6	4.1	6.6	3.8	3.8

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

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 should be increased to 0.5kg/palm.

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

Trial 212: Systematic N Fertiliser trial, Hargy Estate

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	10 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 fertilisers applied in 2006 in Trial 212: none applied

RESULTS and DISCUSSION

Yield and its components response to fertiliser treatment in 2006

Applying N fertiliser increased the FFB yield significantly. A yield increase of 4 to 5t/ha yield was achieved with the addition of 1.5 to 3.7kg AN/palm (Table 2). Bunch number and SBW increased with the application of N fertiliser, the largest increase was in SBW.

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	22.8	9.5	1330	17.9
0.25	0.74	22.9	9.3	1302	18.2
0.50	1.48	27.1	10.5	1470	19.2
0.75	2.22	26.6	9.8	1372	20.1
1.0	2.96	25.9	9.1	1274	21.0
1.25	3.70	28.5	10.5	1470	19.9
1.5	4.44	29.1	10.6	1484	20.2
1.75	5.18	27.3	10.2	1428	19.7
2.0	5.92	27.6	10.0	1400	19.8
Significant difference:		**P<0.001**	**P=0.02**	**P=0.02**	**P<0.001**
	$LSD_{0.05}$	**2.6**	**1.0**	**140**	**1.3**
	CV%	**9.6**	**10.2**	**10.2**	**6.6**

Yield response over time

The trial was initiated in 2002 and by 2004 there was a significant effect of applying N on yield. The yearly yield response to N fertiliser has remained at around 5t/ha (Figure 1).

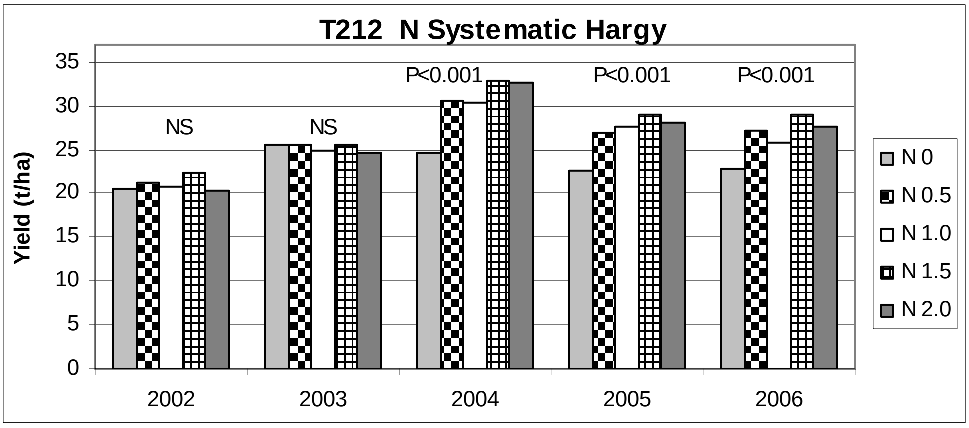

Figure 1. T212: Yield response to 5 rates of N (kg/palm) over time (fertiliser N was first applied in 2002).

Bunch number per palm and SBW increased until the palms were about 8 years old, since then the bunch number has decreased. The SBW has continued to increase and is currently on average 20 kg/bunch (Figure 2).

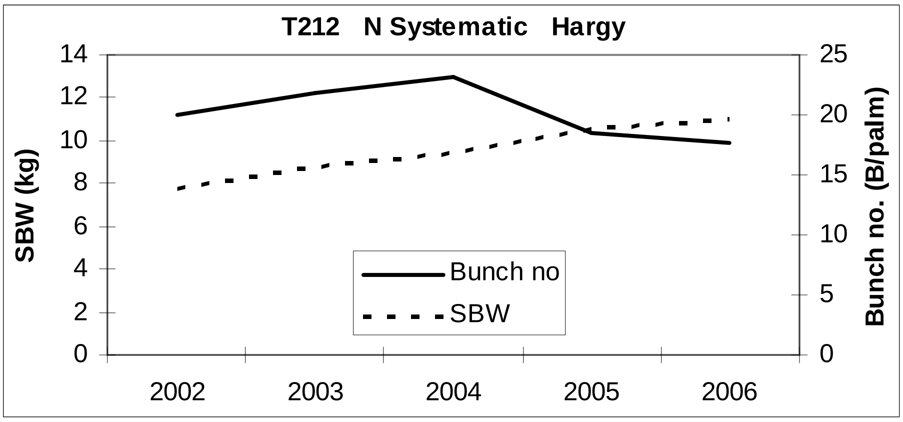

Figure 2. T212: Average bunch number and SBW since 2002.

Tissue nutrient concentration

Tissue nutrient concentration was investigated for both leaflets and rachis. The values for the 2006 sampling are listed in Table 3. Increasing rates of N fertiliser significantly increased leaflet N concentration. Leaflet and rachis P was variable and not related to N fertiliser input. Leaflet and rachis K levels were not affected by fertiliser N rates.

Table 3. 212: tissue nutrient concentration for leaflets and rachis in 2006.

N rate (kg/palm)	Equivalent AN rate (kg/palm)	Leaflet (% dm)			Rachis (% dm)		
		N	P	K	N	P	K
0	0	2.25	0.134	0.75	0.24	0.032	1.28
0.25	0.74	2.29	0.133	0.75	0.24	0.030	1.22
0.50	1.48	2.36	0.134	0.72	0.24	0.029	1.17
0.75	2.22	2.36	0.132	0.71	0.25	0.029	1.21
1.0	2.96	2.41	0.135	0.73	0.25	0.031	1.21
1.25	3.70	2.42	0.136	0.71	0.25	0.032	1.24
1.5	4.44	2.43	0.138	0.74	0.25	0.035	1.39
1.75	5.18	2.44	0.136	0.74	0.25	0.034	1.29
2.0	5.92	2.43	0.136	0.74	0.25	0.035	1.39
Significant difference:		**P<0.001**	**P=0.02**	**0.47**	**0.91**	**P<0.001**	**P=0.02**
$LSD_{0.05}$		**0.04**	**0.002**	**-**	**-**	**0.003**	**0.12**
CV%		**1.8**	**2.2**	**6.7**	**3.7**	**8.5**	**10.2**

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). It is strongly recommended to increase the rate of P fertiliser level until adequacy levels have been reached. Leaflet magnesium (Mg) levels were on average close to adequate (0.16 % dm), and Boron levels were near adequate (14.6 mg/kg).

Tissue N concentration over time 2004 to 2006

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

Fertiliser N effects on oil palm vegetative growth

Frond production and frond number

On average 20 new fronds were produced in 2006 (one every 18 days) indicating reasonably good growing conditions during the year. Total green fronds counted per palm averaged 34 fronds which is low and indicating possible over pruning. AN fertiliser applications increased frond production by about 1 frond per year.

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 is a primary determinant of vegetative dry matter production. Although not significant (P=0.06) the PCS increased from 0 to 1kg N/palm and then decreased again at the highest 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) increased between 0 to the 1.0 kg N/palm and then remained reasonably steady at higher rates of applied N.

Table 5. Effect of N treatments on vegetative growth parameters in 2006.

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	40.8	32.7	19.0	12.1	5.5	11.6	12.1	26.3	14.2
0.25	0.74	42.2	33.0	18.7	12.5	5.8	11.8	12.2	26.7	14.5
0.50	1.48	45.8	32.6	19.2	13.0	5.9	13.1	14.4	30.5	16.2
0.75	2.22	45.1	33.1	19.2	13.2	6.1	12.9	14.3	30.2	15.9
1.0	2.96	49.8	33.5	19.9	12.9	6.1	14.8	13.7	31.7	18.0
1.25	3.70	46.4	33.8	19.9	12.9	6.1	13.8	15.2	32.1	17.0
1.5	4.44	45.0	33.7	20.2	13.1	6.2	13.5	15.4	32.2	16.8
1.75	5.18	45.1	34.5	20.0	12.6	6.1	13.5	14.5	31.0	16.6
2.0	5.92	45.6	34.4	19.9	13.1	6.3	13.6	14.7	31.4	16.7
Significant difference:		0.24	0.01	<0.001	0.03	0.002	0.03	<0.001	P<0.001	P=0.02
	$LSD_{0.05}$	-	1.1	0.6	0.7	0.3	1.8	1.4	2.9	2.1
	CV%	13.7	3.4	3.3	5.3	5.8	13.9	9.9	9.6	12.8

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

CONCLUSION

A significant yearly increase in yield, of between 4.0 and 5.0 t/ha, has been observed since 2004 with the application of 3.0kg AN/palm (or 1.0 kg N/palm).

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 should be applied at 0.5kg/palm.

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

Trial 213: N and P Fertiliser Trial for High Ground, Hargy Estate

SUMMARY

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

The control plots (no fertiliser) yielded very poorly producing 10t/ha less than the combined N and P treatments (control 9.9t/ha vs. combined AN + P treatments > 20t/ha). The largest effect on yield from the fertiliser 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 fertiliser.

However, there is a strong indication that K (potassium) appears to be lacking and it is recommended to apply MOP to the trial area. 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 fertiliser response information necessary for determining fertiliser 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

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: Fertiliser rates used in trial 213.

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

Basal fertiliser was not applied in 2006.

RESULTS and DISCUSSION

2006 Yield and its components

Yield increased from the control plot (N 0, P 0) at 9.9 t/ha to above 20t/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 30% increase in bunch weight when N plus P were applied compared to the control) (Table 3).

The impact of N and P fertiliser on yield, bunch number and bunch weight was highly significant, except N fertiliser which had no effect on bunch weight (Table 3).

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

Table 3. FFB yield (t/ha), Bunch number (bunch/palm) and SBW (kg) for trial 213 in 2006.

	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	9.9	15.2	14.4	5.7	6.6	6.6	16.0	18.9	19.0
AN 2.2	11.8	21.6	22.9	5.8	9.3	9.0	16.1	20.0	21.0
AN 4.4	15.0	19.1	21.3	6.8	7.8	8.7	18.0	20.7	19.9
Significant difference:									
N	**<0.001**			**<0.001**			**NS**		
P	**<0.001**			**<0.001**			**<0.001**		
NxP	**0.05**			**0.03**			**NS**		
$LSD_{0.05}$	**1.9**			**0.7**			**1.6**		
CV%	**13.7**			**12.0**			**2.7**		

* Bunch no/palm of 5.7 equates to 735 bunches/ha; and a bunch no/palm of 9.0 equates to 1161 bunches/ha.

Long term yield and its components

Since the first data were collected in 2002 (pre-treatment data) yield has increased from 16 t/ha to 23 t/ha in 2004. It then reached a plateau and yields have been maintained at this level until now. Bunch number continued to decline and bunch weight has increased every year (Figure 1).

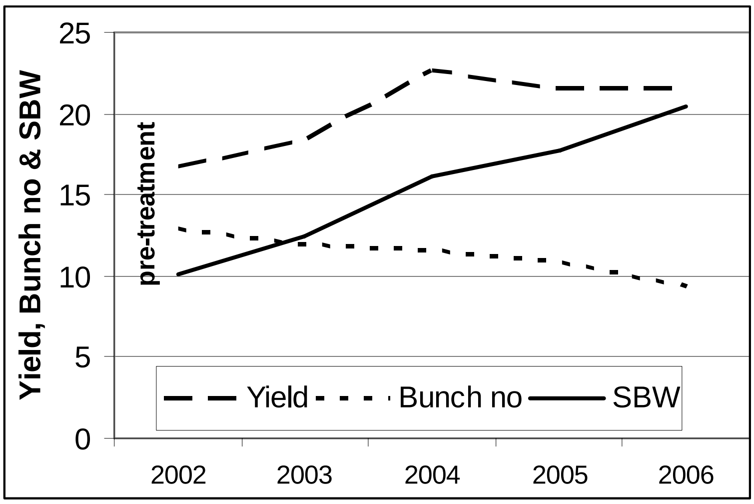

Figure 1. Long term yield, bunch number and bunch weight for AN 2.2 and TSP 3kg/palm (note 2002 was the pre-treatment year).

The control treatment (no fertiliser) has continued to perform poorly relative to the fertiliser treatments and this treatment dropped significantly in yield in 2006 (Figure 2).

The combined fertiliser applications of N and P all yielded similarly around the 22 t/ha.

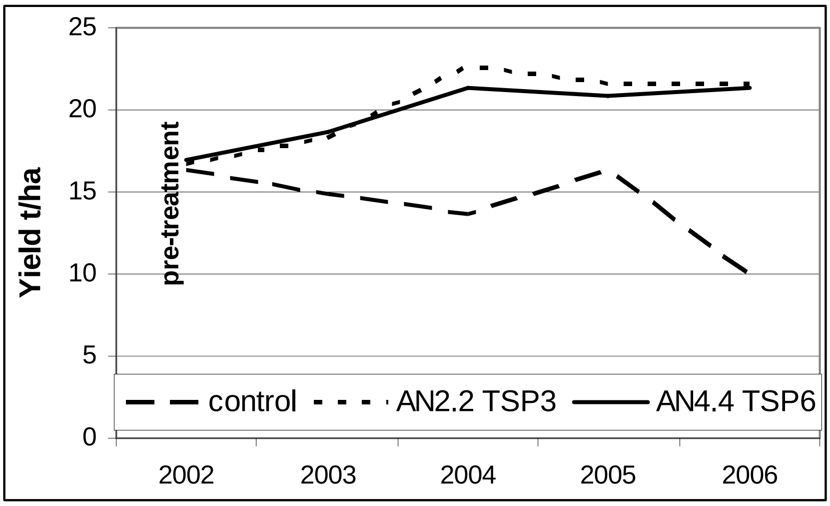

Figure 2. Yield over time for the control (no fertiliser) and combined N and P fertiliser treatments (note 2002 was the pre-treatment year).

Tissue nutrient concentrations

The treatment fertilisers 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 2006.

	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	2.35	2.41	2.50	0.127	0.138	0.142	0.027	0.047	0.048
AN 2.2	2.47	2.57	2.58	0.130	0.142	0.146	0.027	0.043	0.051
AN 4.4	2.49	2.59	2.62	0.129	0.143	0.146	0.027	0.040	0.046
Significant difference:									
N	**<0.001**			**0.02**			**0.30 (NS)**		
P	**<0.001**			**<0.001**			**<0.001**		
NxP	**0.58 (NS)**			**0.92 (NS)**			**0.54 (NS)**		
$LSD_{0.05}$	**0.05**			**0.003**			**0.005**		
CV%	**1.9**			**2.4**			**13.4**		

The highest yields were achieved at a fertiliser 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: 2.57 %; Leaflet P: 0.142 % and Rachis P: 0.04%). 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 2006.

Nutrient	Trial mean value (% dm)	Accepted adequacy level (% dm)	Notes
Leaflet K	0.65	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	0.53	1.2	Rachis potassium is low

It appears that K (potassium) is very low in the rachis and it is recommended to not only apply MOP to the trial block but also 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 fertiliser) 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 fertiliser treatments on vegetative growth parameters in 2006. P values less than 0.05 are shown in bold.

Fertiliser		**Radiation Interception**				**Dry matter production (t/ha/yr)**			
	PCS	**GF**	**FP**	**FA**	**LAI**	**FDM**	**BDM**	**TDM**	**VDM**
AN	**0.01**	0.68	0.26	**0.03**	**0.04**	**0.001**	**<0.001**	**<0.001**	**<0.001**
TSP	**0.002**	**0.02**	**<0.001**	**0.03**	**0.005**	**<0.001**	**<0.001**	**<0.001**	**<0.001**
AN.TSP	0.75	0.61	0.99	0.49	0.68	0.58	0.72	0.06	0.50
CV %	7.8	4.0	1.9	6.3	8.0	7.1	13.4	7.9	6.9

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

Table 7. Trial 213, main effects of fertiliser treatments on the vegetative growth parameters in 2006. P values less than 0.05 are shown in bold.

Fertiliser	Radiation Interception					Dry matter production (t/ha/yr)			
	PCS	GF	FP	FA	LAI	FDM	BDM	TDM	VDM
AN 0	**31.2**	40.4	23.4	**9.7**	**5.1**	**10.3**	**6.9**	**19.1**	**12.2**
AN 2.2	**33.3**	40.6	23.9	**10.4**	**5.4**	**11.1**	**9.9**	**23.4**	**13.4**
AN 4.4	**34.6**	40.9	24.0	**10.4**	**5.5**	**11.6**	**9.8**	**23.7**	**14.0**
$LSD_{0.05}$	*2.2*	-	-	*0.5*	*0.4*	*0.7*	*1.0*	*1.5*	*0.8*
TSP 0	**30.7**	**39.4**	**22.8**	**9.8**	**5.0**	**9.8**	**6.4**	**18.1**	**11.6**
TSP 3	**34.8**	**41.2**	**24.0**	**10.6**	**5.6**	**11.7**	**9.8**	**23.9**	**14.0**
TSP 6	**33.5**	**41.3**	**24.6**	**10.1**	**5.4**	**11.5**	**10.3**	**24.2**	**13.9**
$LSD_{0.05}$	*2..2*	*1.4*	*0.8*	*0.5*	*0.4*	*0.7*	*1.0*	*1.5*	*0.8*

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

CONCLUSION

Both N and P had positive effects on yield in the first four years of the 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 addition of K fertiliser as MOP is recommended in this trial. It is also 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 fertiliser at which optimum yield was achieved (AN 2.2 plus TSP 3 kg/palm).

New Britain Palm Oil Ltd., WNB: Summary and Synopsis

(Harm van Rees and Rachel Pipai)

Fertiliser 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 fertiliser on production and overall growth of oil palm. Three of the trials are traditional replicated trials where a range of treatments is investigated. The fourth trial is undertaken in co-operation with OPRS and is using large blocks with and without Mg fertiliser to ascertain the effect of Mg fertiliser on production. In this latter trial the effect of 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 fertiliser 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 fertiliser 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 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 (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 fertiliser 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 fertiliser 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 fertiliser responses are now evident. These volcanic soils must be 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 fertiliser. 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 2007 or 2008.

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 2006 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	5	Mg x K 27 (NS)	B/p 20 (NS) SBW 10 to 11 (with K fertiliser)	LN 2.49 RN 0.37 +K LK 0.79 to 0.93 RK 0.87 to 1.13 + Mg LMg 0.21 to 0.27		
145 Walindi Mg types Soil: Volcanic	7	No Mg 31.4 + Mg 33.5	B/p 15 (NS) SBW 18 (NS)	LN 2.35 RN 0.46 No Mg 0.19 + Mg 0.19 (NS)	PCS 40 (NS) FP 27 (NS) LAI 6 (NS)	Possible N deficiency
146 Kumbango Mg types and K Soil: Volcanic	7	No Mg 29.7 + Mg 31.9(NS)	B/p 13 (NS) SBW 17 (NS)	LN 2.40 RN 0.38 No Mg 0.21 + Mg 0.22 (NS)	PCS 30 (NS) FP 25 (NS) LAI 5.1 (NS)	Possible N deficiency
148 Kumbango Mg rates, large blocks Soil: Volcanic	5	No Mg 26.2 + Mg 27.2 (NS)	B/p 22 (NS) SBW 9.6 (NS)	LN 2.71 RN 0.29 No Mg 0.16 + Mg 0.19 (NS)		
137 Kumbango Systematic AN 0 to 6kg/p Soil: Volcanic	7	AN response 23 to 26	B/p 11 (NS) SBW 17.7 (NS)	AN LN 2.60 (NS) LP 0.145; RP 0.07 LK 0.77; RK 1.45	PCS 30 (NS) FP 27 (NS) LAI 5.3 (NS)	
138 Haella Systematic AN 0 to 6kg/p Soil: Volcanic	11	AN response 27 to 30	B/p 11.1 to 12.1 SBW 19.5 (NS)	AN LN 2.28 to 2.45 LP 0.138; RP 0.07 LK 0.68; RK 1.25		
403 Kaurausu Systematic AN 0 to 6kg/p Soil: Volcanic	18	AN response 26 to 28	B/p 7.6 (NS) SBW 28.3 (NS)	AN LN 2.25 to 2.38 LP 0.138; RP 0.05 LK 0.67; RK 1.40		2007 last year for trial
142 Kumbango/Bebere Large Blocks (256, 260, 266) AN 0, 3, 6 Soil: Volcanic	13 8 11	AN 25 (NS)	B/p 9 (NS) SBW 22 (NS)	256 LN 2.33 to 2.44 260 LN 2.25 to 2.49 266 LN 2.47 to 2.61 256 LP 0.142; LK 0.71 260 0.146; 0.72 266 0.146; 0.73		
149 Kumbango Large Blocks Borate 0, 80, 160g/p Soil: Volcanic	5	Borate 27 (NS)	B/p 22 (NS) SBW 9.4 (NS)	LB 15.4 to 20.1 ppm LN 2.7 LP 0.148; RP 0.05 LK 0.85; RK 1.33		

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 limiting in 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, fertiliser 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 Fertiliser 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 fertilisers 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. A total of 135kg N/ha is required to produce high yielding 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 fertiliser applied. An estimate of soil N mineralization on volcanic soils in PNG is 60 kg/ha/yr (Banabas PhD thesis). 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 fertiliser.

75kg N/ha in fertiliser 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 fertiliser 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 fertiliser.

The above equations are estimates only and provide a rough guideline to how much N fertiliser 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 fertiliser trials, with randomized spatial allocation of treatments, have generally been showing poor responses to fertilisers. Yield and tissue nutrient concentrations in control plots (no fertiliser) have generally been higher than would be expected. It is suspected that fertiliser 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 fertiliser 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 fertiliser 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 fertiliser were found at all three sites for the first time since the commencement of these trials. The yield responses were only small, in the range of 2 to 4 t/ha, and resulted from moderate inputs of N fertiliser (2 to 3 kg AN/palm). Site 137 at Kumbango showed the smallest response to N fertiliser, this site also has the highest inherent fertility (as judged by a very healthy tissue analysis).

The yield response from N fertiliser 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 fertiliser. 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 likely to be low 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 second 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 fertiliser. 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 fertiliser to areas which do not. If this is actually occurring we would expect to see changes in tissue N levels across the plot in 2008 or 2009 (depending on the inherent fertility of the site).

N fertiliser 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 2007 we would expect to see a yield response in either 2007 or 2008. 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 fertiliser.

Trial 137: Systematic N Fertiliser Trial, Kumbango

METHODS

Experimental Design and Treatments

Trials 137, 138B and 403 are N Systematic trials where 9 rates of AN 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 trials 137 and 403 the AN fertiliser 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 138B receives the 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	7 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 fertiliser applied in 2006 in Trial 137: TSP at 200g/palm and Borate at 150g/palm.

RESULTS and DISCUSSION

Yield and its components response to fertiliser treatment in 2006

Even though the yield increase from applying 0 to 2 kg N/palm is significant, the yield increase is small (Table 2). The optimum yield response of around 2 t/ha was achieved at a N fertiliser rate of around 0.75 kg N/palm (equivalent to 2.22 kg AN/palm). Neither bunch number nor SBW is significantly different between N rate treatments (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	22.9	10.8	1382	17.4
0.25	0.74	23.8	11.1	1421	17.5
0.50	1.48	24.0	11.2	1434	17.6
0.75	2.22	25.2	11.4	1459	18.0
1.0	2.96	24.2	11.4	1459	17.4
1.25	3.70	24.3	11.4	1459	17.5
1.5	4.44	25.5	11.6	1485	17.8
1.75	5.18	24.9	11.1	1421	18.3
2.0	5.92	26.6	11.7	1498	18.0
Significant difference:		**P=0.003**	**NS**	**NS**	**NS**
	$LSD_{0.05}$	**1.7**	**-**	**-**	**-**
	CV%	**6.7**	**6.4**	**6.4**	**4.5**

Yield response over time

A small but noticeable increase in yield occurred from 2003 (palm age: 4 years) to 2006 (palm age: 7 years). For the whole trial site, the yield was reduced by approximately 3 t/ha in 2006 which is probably due to climatic factors. In 2003, 2004 and 2005 there was no significant effect on yield from applying N fertiliser, however in 2006 three years after the start of the trial there was a significant effect on yield (Figure 1). Note: in 2003 harvest commenced in February (January data are not available).

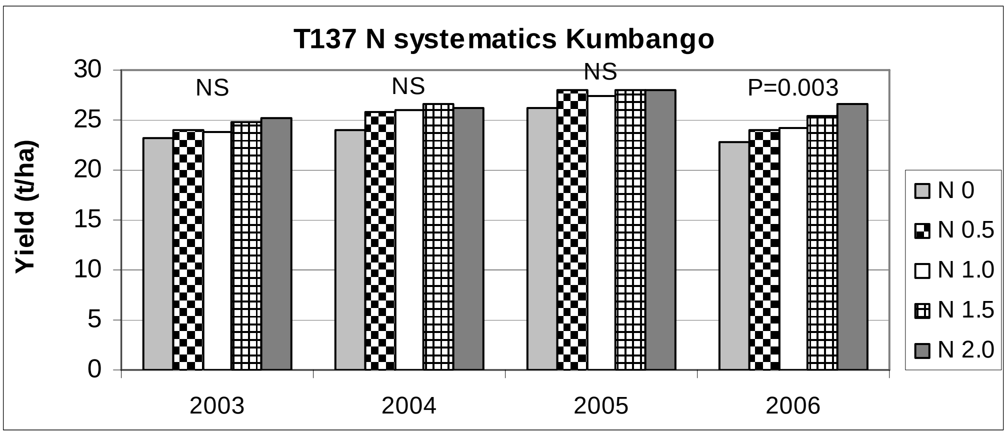

Figure 1. Yield response to 5 rates of N (kg/palm) over time (fertiliser N was first applied in March 2003).

As the palms matured from 4 to 7 years after planting the mean number of bunches per palm decreased and the SBW increased (Figure 2). The effect of N fertiliser on bunch number per palm and SBW is not significant for any one year.

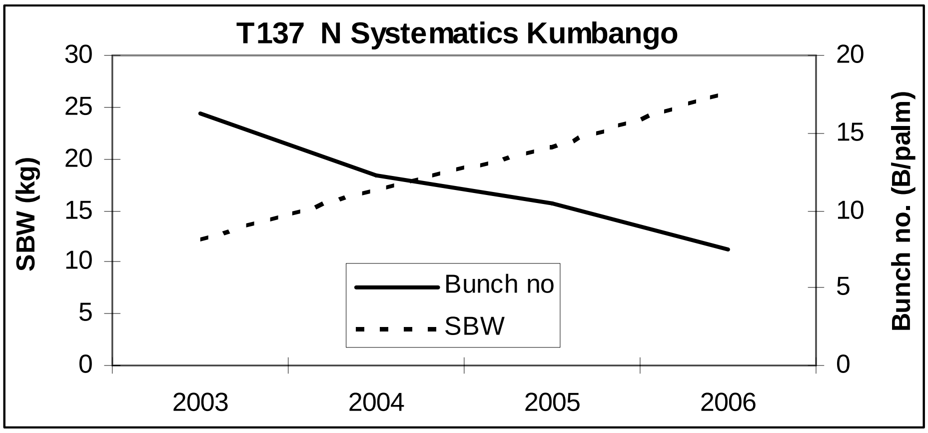

Figure 2. Mean trial bunch number per palm and SBW (kg) over time (Trial 137).

Tissue nutrient concentration

Tissue nutrient concentration was investigated for both leaflets and the rachis. N treatment had no effect on each of the nutrient levels tested (Table 3), except for leaflet K which decreased a small amount with the application of N fertiliser.

Table 3. leaflet and rachis nutrient content for T137 in 2006.

N rate (kg/palm)	Equivalent AN rate (kg/palm)	Leaflet (% dm)			Rachis (% dm)		
		N	P	K	N	P	K
0	0	2.60	0.145	0.82	0.33	0.07	1.35
0.25	0.74	2.59	0.145	0.79	0.31	0.07	1.45
0.50	1.48	2.58	0.144	0.78	0.32	0.07	1.39
0.75	2.22	2.57	0.144	0.78	0.32	0.06	1.37
1.0	2.96	2.57	0.144	0.77	0.32	0.07	1.47
1.25	3.70	2.61	0.144	0.76	0.32	0.06	1.45
1.5	4.44	2.60	0.143	0.77	0.31	0.07	1.49
1.75	5.18	2.60	0.144	0.76	0.33	0.07	1.37
2.0	5.92	2.58	0.146	0.77	0.32	0.07	1.40
Significant difference:		**NS**	**NS**	**P=0.03**	**NS**	**NS**	**NS**
	$LSD_{0.05}$	**-**	**-**	**0.03**	**-**	**-**	**-**
	CV%	**1.9**	**1.7**	**4.1**	**5.6**	**7.1**	**7.1**

Even though leaflet Phosphorus (P) is adequate there is a strong indication that rachis P is low. More than likely this will result in P becoming yield limiting in the near future and it is recommended that TSP be applied at a higher rate than the 2006 basal application. All other nutrients were present at an adequate level, except for Magnesium (Mg) and Boron which were on the low side.

The lack of a strong N fertiliser response on tissue nutrient levels is probably due to the high N nutrient status of these palms.

Fertiliser N effects on oil palm vegetative growth

Frond production and frond number

26.5 new fronds were produced in 2006 (one every 13.8 days) indicating good growing conditions during the year. Total green fronds counted per palm averaged 40.7 fronds which is an adequate number. AN fertiliser 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) as based on Frond area, frond number and palms per ha, were also within adequate limits for 7 year old palms (average frond area 10.1m^2 and LAI of 5.3). Neither Frond Area nor LAI was affected by the rate of N fertiliser applied.

Vegetative dry matter production

Petiole cross section is a primary determinant of vegetative dry matter production. Although not significant (P=0.06) the PCS increased from the 0 to 1kg N/palm and then decreased again at the highest rates of N applied (average 30cm^2). The measures of foliar vegetative dry matter production (FDM (frond dry matter production), TDM (total dry matter production) and VDM (vegetative dry matter production) increased from the 0 to the 1.0 kg N/palm and then decreased again at the 2.0kg N/ha. There is some evidence that at the highest rate of N (2.0 kg N/palm) the vegetative growth actually decreases a little compared to the middle rate of N used (1.0 kg N/palm). It is possible that at the highest rate of fertiliser N that growth has been limited – this will be watched closely in subsequent years.

CONCLUSION

A small but significant increase in yield of 2.0 t/ha was observed with using AN fertiliser at about 3.0kg AN/palm (or 1.0 kg N/palm).

Tissue P, especially in the rachis, was low and the basal rate of TSP should be increased to 0.5kg/palm. It would be worthwhile to check adjacent NBPOL blocks for tissue P to ensure that levels are maintained.

Vegetative measurements indicate that AN had no effect on Frond Production or Frond / Canopy size. However, there was some effect on total vegetative dry matter production with increasing N rates, at the highest rates the dry matter production actually decreased again. This observation will be checked again during the 2006 season.

Trial 138: Systematic N Fertiliser Trial, Haella

Trial Background Information

Table 4. Trial 138B background information.

Trial number	**138B**	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	11 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 fertiliser applied in 2006 in Trial 138B: MOP at 0.5 kg/palm and TSP at 0.5 kg/palm.

RESULTS and DISCUSSION

Yield and its components response to fertiliser treatment in 2006

The yield increase from applying 0 to 2 kg N/palm is significant (26.9 to 30.0 t/ha). At this stage the yield increase is small and is achieved with 1 to 1.25kg N/palm (or 3 to 3.7kg AN/palm) (Table 5). The increase in bunch number with increasing N rate was significant and at the 1.25kg N/palm rate an extra bunch per palm was produced. There was no effect on SBW through the application of N fertiliser (Table 5).

Table 5. 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	26.9	11.1	1421	19.5
0.25	0.74	27.2	10.8	1382	19.7
0.50	1.48	27.2	10.8	1382	20.0
0.75	2.22	28.4	11.4	1459	20.0
1.0	2.96	29.4	11.6	1485	19.7
1.25	3.70	30.0	12.0	1536	19.9
1.5	4.44	30.1	12.1	1549	19.5
1.75	5.18	31.1	12.1	1549	19.9
2.0	5.92	30.0	12.1	1549	19.5
Significant difference:		**P<0.001**	**P<0.001**	**P<0.001**	**NS**
	$LSD_{0.05}$	**2.1**	**0.7**	**90**	**-**
	CV%	**7.2**	**6.4**	**6.4**	**3.8**

Yield response over time

A small but noticeable and significant increase in yield from applying N fertiliser has been observed since the inception of this trial in 2003 (2002 was the set up year with N fertiliser first applied in July) (Figure 2).

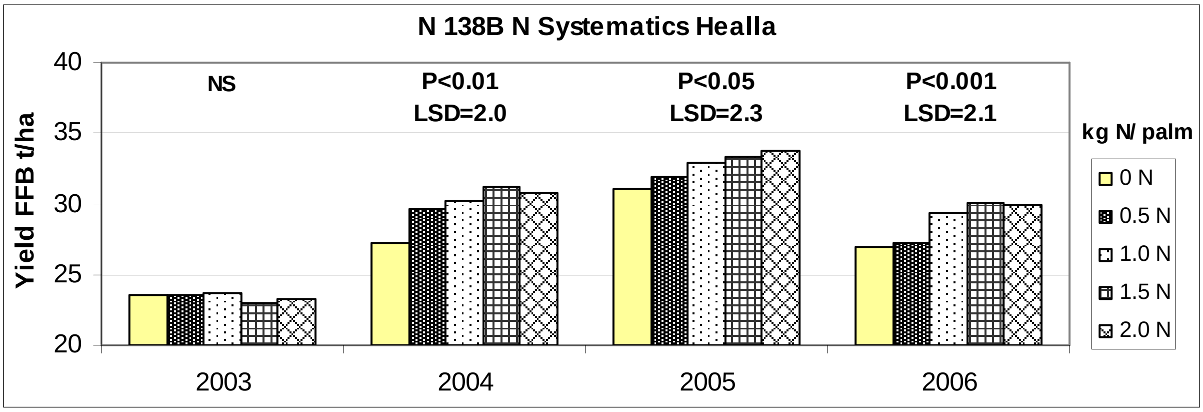

Figure 3. T138B: Yield response to 5 rates of N (kg/palm) over time (fertiliser N was first applied in July 2002).

Tissue nutrient concentration

Tissue nutrient concentration was investigated for both leaflets and the rachis. The values for the 2006 sampling are listed in Table 6. Increasing rates of N fertiliser, significantly increased leaflet and rachis N concentration. Leaflet P was also increased with increasing N rates and it appears that this was due to a mobilization of P out of the rachis (Table 6). The rachis P levels were low and TSP will have to be applied again in 2007 as a basal fertiliser. Leaflet and rachis K levels were not affected by fertiliser N rates.

Table 6. T138B: tissue nutrient concentration for leaflets and rachis in 2006.

N rate (kg/palm)	Equivalent AN rate (kg/palm)	Leaflet (% dm)			Rachis (% dm)		
		N	P	K	N	P	K
0	0	2.28	0.135	0.72	0.30	0.09	1.24
0.25	0.74	2.35	0.136	0.69	0.30	0.08	1.16
0.50	1.48	2.36	0.136	0.70	0.31	0.07	1.18
0.75	2.22	2.41	0.138	0.68	0.32	0.08	1.22
1.0	2.96	2.45	0.138	0.70	0.32	0.07	1.24
1.25	3.70	2.42	0.139	0.68	0.32	0.07	1.29
1.5	4.44	2.42	0.137	0.68	0.32	0.07	1.28
1.75	5.18	2.48	0.140	0.67	0.33	0.08	1.30
2.0	5.92	2.45	0.139	0.67	0.33	0.07	1.25
Significant difference:		**P<0.001**	**P=0.002**	**NS**	**P=0.009**	**0.009**	**NS**
$LSD_{0.05}$		**0.09**	**0.002**	**-**	**0.02**	**0.01**	**-**
CV%		**3.8**	**1.7**	**5.9**	**5.9**	**14.4**	**8.7**

Leaflet magnesium (Mg) levels were on average adequate (0.19 % dm), and Boron levels were on the low side (13.4 mg/kg).

Tissue nutrient concentration over time

Leaflet N concentration reached a peak in 2004 and as palms matured has decreased since. The effect of fertiliser 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 application treatment relative to the N fertiliser treatments (Figure 4).

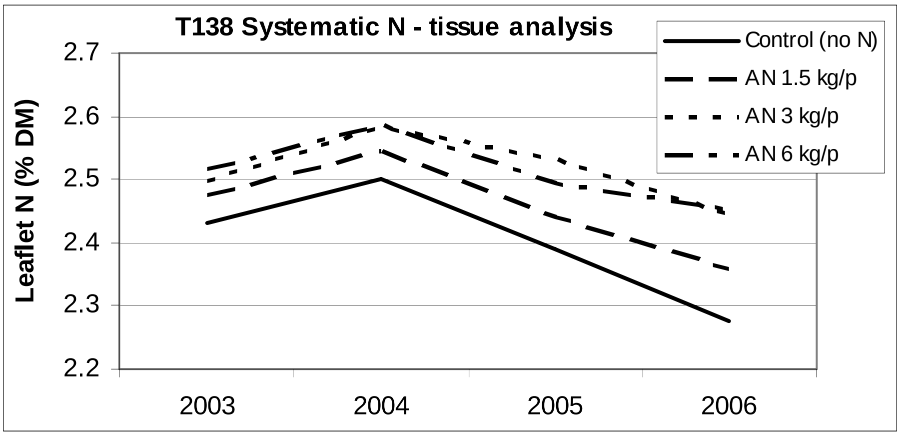

Figure 4. T138: Leaflet N concentration resulting from N fertiliser treatments over time.

Leaflet P concentration has decreased over time and is now below adequate levels (Figure 5). There is insufficient P in the rachis (average of 0.08%) to enable N to mobilise P out of the rachis to make it available in the leaflets – we expect that P will become limiting in this trial in the near future.

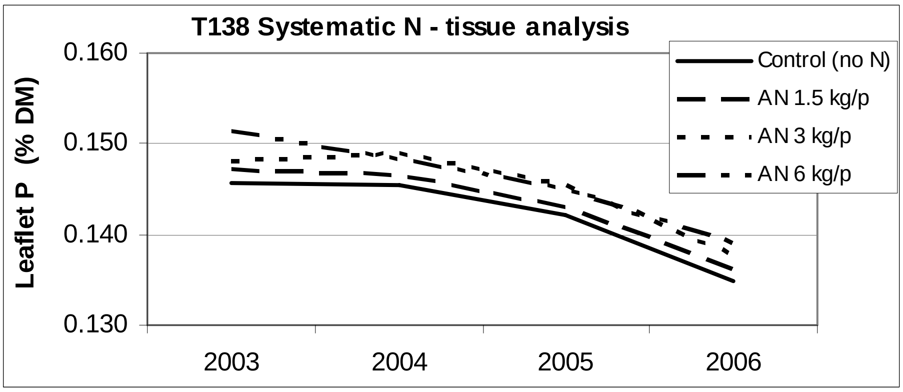

Figure 5. T138: Leaflet P concentration over time.

Fertiliser N effects on oil palm vegetative growth

No vegetative measurements were measured for T138 in 2006. A full measurement and monitoring program has re-commenced in 2007.

CONCLUSION

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

Trial 403: Systematic N Fertiliser Trial, Kaurausu

Trial Background Information

Table 7. 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	18 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

Basal fertilisers applied in 2006 in Trial 403: none – site is to be felled in 2007

RESULTS and DISCUSSION

Yield and its components response to fertiliser treatment in 2006

The yield increase from applying 0 to 2 kg N/palm is small but significant (26.4 to 28.0 t/ha). The yield increase is only small and is achieved with 0.5kg N/palm (or 1.5kg AN/palm) (Table 8). There was no significant change in bunch number or single bunch weight with increasing N rate (Table 8).

Table 8. 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	26.4	7.6	912	27.8
0.25	0.74	26.0	7.6	912	28.2
0.50	1.48	28.0	7.8	936	28.8
0.75	2.22	27.5	7.9	948	28.6
1.0	2.96	28.4	8.2	984	28.2
1.25	3.70	28.2	8.0	960	28.7
1.5	4.44	28.3	8.0	960	29.2
1.75	5.18	28.2	8.1	972	28.3
2.0	5.92	28.0	8.2	984	28.3
Significant difference:		**P=0.04**	**NS**	**NS**	**NS**
	$LSD_{0.05}$	**1.7**	**-**	**-**	**-**
	CV%	**6.0**	**6.2**	**6.2**	**4.8**

Yield response over time

A small but noticeable and significant increase in yield from applying N fertiliser has been observed since 2004 (Figure 6). Most of the yield increase is achieved with only 0.5 kg N/palm (1.5 kg AN/palm).

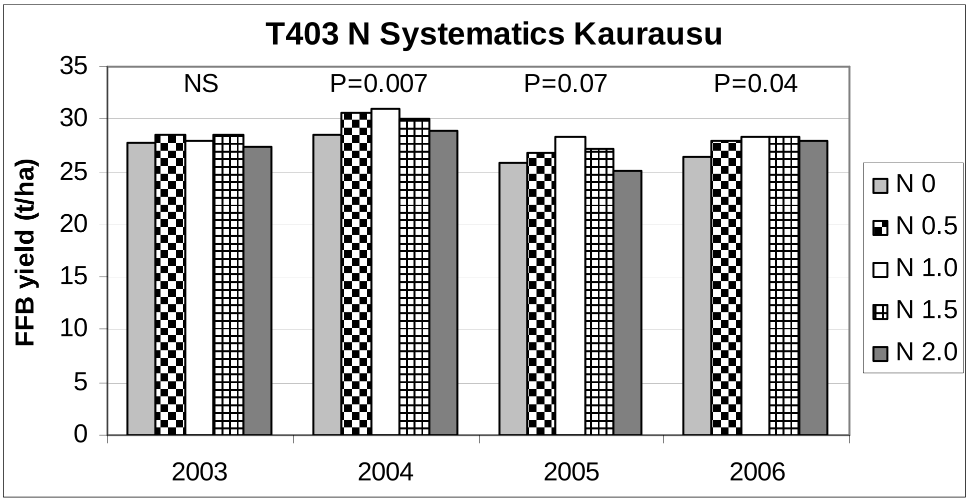

Figure 6. T403: Yield response to 5 rates of N (kg/palm) over time (fertiliser N was first applied in July 2002).

In this mature plantation (palms are currently 18 years old) the bunch number was steady at between 7.8 and 8.7 bunches/palm and the bunch weight steady at between 27.3 and 28.5 kg/bunch (as mean number and weight for all measured palms).

Tissue nutrient concentration

Tissue nutrient concentration was investigated for both leaflets and the rachis. The values for the 2006 sampling are listed in Table 9. Increasing rates of N fertiliser, significantly increased leaflet N levels, rachis N did not change. Leaflet P and K were not affected by N fertiliser rate and both nutrient levels were in the adequate range. The rachis P levels were low to very low and TSP will have to be applied again in 2007 as a basal fertiliser. Rachis K levels were adequate.

Table 9. T403: tissue nutrient concentration for leaflets and rachis in 2006.

N rate (kg/palm)	Equivalent AN rate (kg/palm)	Leaflet (% dm)			Rachis (% dm)		
		N	P	K	N	P	K
0	0	2.25	0.135	0.67	0.24	0.06	1.38
0.25	0.74	2.28	0.135	0.68	0.24	0.05	1.38
0.50	1.48	2.31	0.139	0.68	0.24	0.05	1.42
0.75	2.22	2.35	0.140	0.67	0.24	0.05	1.37
1.0	2.96	2.33	0.139	0.68	0.24	0.05	1.36
1.25	3.70	2.34	0.140	0.70	0.25	0.05	1.39
1.5	4.44	2.38	0.140	0.68	0.24	0.05	1.33
1.75	5.18	2.37	0.140	0.70	0.24	0.05	1.44
2.0	5.92	2.37	0.140	0.70	0.24	0.05	1.41
Significant difference:		**P=0.005**	**NS**	**NS**	**NS**	**NS**	**NS**
$LSD_{0.05}$		**0.07**	**-**	**-**	**-**	**-**	**-**
CV%		**3.1**	**4.3**	**5.6**	**3.6**	**18.7**	**9.2**

Leaflet magnesium (Mg) levels were on average low to adequate (0.17 % dm) and Boron levels were on the low side (14.1 mg/kg).

Vegetative parameters

Due to some missing data it is not possible to analyse the vegetative parameters for 2006.

CONCLUSION

A small but significant yield response resulted from the application of N fertiliser. Leaflet N values appeared to be low and below adequacy values even at the high rate of N applied.

Trial 141: Large Fertiliser Omission Trial, Haella

Purpose

In addition to the N Systematic trials described previously, OPRA and NBPOL have set up large scale fertiliser omission trials in order to determine what the yield penalty will be when N fertiliser 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 fertiliser.

Trial Background Information

Table 10. 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	10 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	9 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

Basal fertilisers applied in 2006 in Trial 141: None applied.

METHODS

The trial consists of a circle, of 24 palms in diameter, to which no fertiliser has been applied since 2003. Fertiliser, following company practice, has been applied to the area outside the circle. In 2006, 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 from the mean yield for each individual palm. If N fertiliser was coming into the omission plot from outside the plot (which is the hypothesis) you 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 11).

Table 11. Yield inside and immediately outside the omission plot in 2006.

	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 fertiliser*	290	25.7	252	29.1
Plus N fertiliser	84	25.3	77	26.9

* Omission plot

Yield within the N omission plot

The hypothesis is that N is moving downhill in subsurface water flow and becomes available to palms down the slope. There is evidence that this is occurring in other trials on the highly permeable volcanic soils on WNB. At this early stage in the life of the trial (only the second year of operation) there is no evidence as yet that the fertilised palms are receiving nutrients from outside the area through movement of nutrients in subsurface water flow (Figures 7 and 8). If nutrient flow of nitrogen had an impact on palm yield in the unfertilised plot one would have expected the palms closest to the top edge (top half of the circular plot) to have a higher yield compared to the bottom half.

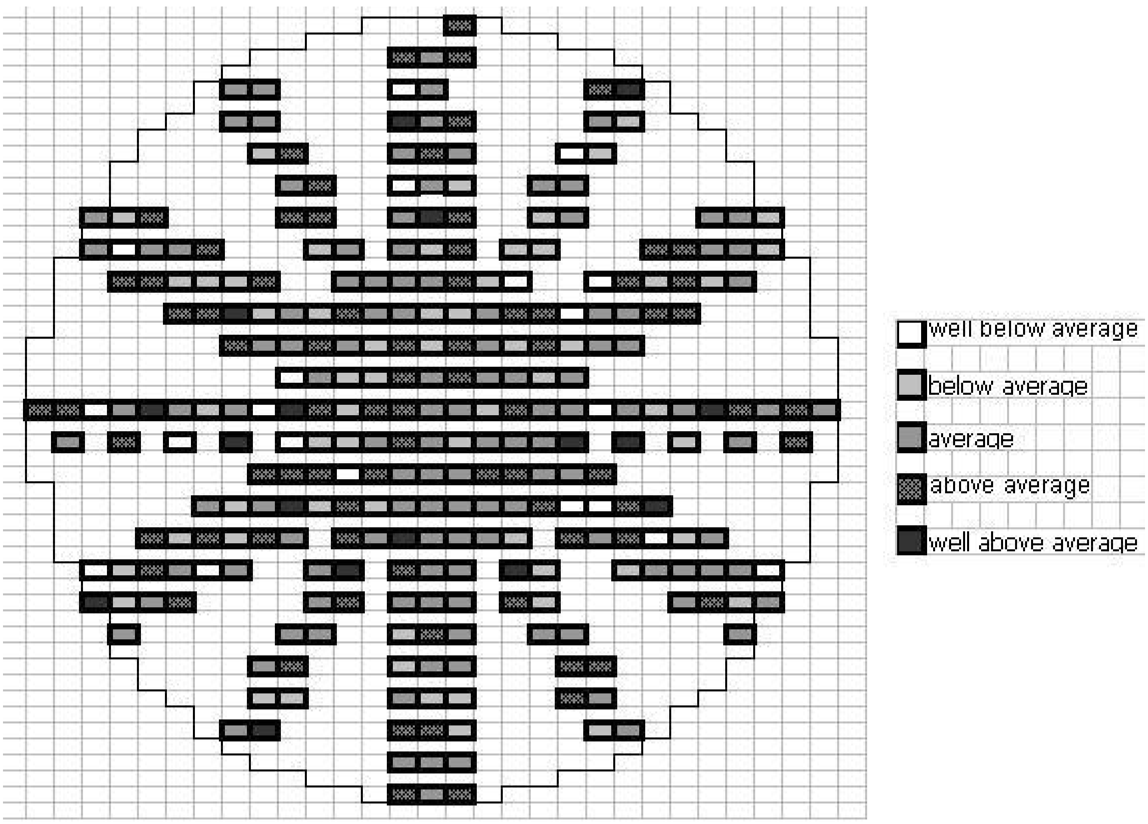

Figure 7. Down slope plot – Div II. Effect of position in the plot on palm yield. Each square denotes the location of a measured palm and the deviation from the mean yield in the plot.

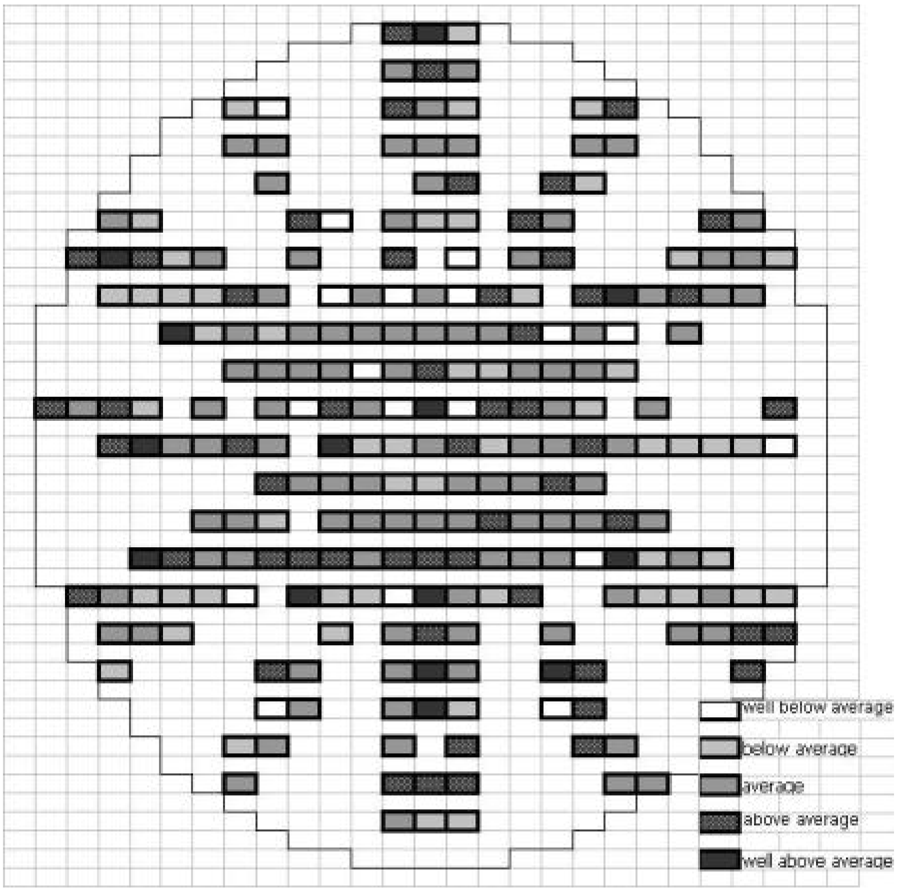

Figure 8. Upslope plot – Div III. Effect of position in the plot on palm yield. Each square denotes the location of a measured palm and the deviation from the mean yield in the plot.

At this stage it is likely that the unfertilised palms in the omission plots still have enough Nitrogen available in the soil, as residual mineral N and from the breakdown of organic matter, for the palms to not require any additional N from fertiliser. As indicated by the N systematic trials, yield penalties from not applying fertiliser occur only 3 to 4 years after the palms have become nutrient deficient for nitrogen (and possibly other nutrients).

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 second year of operation and it is expected that it will take 3 to 4 years before any effects are seen on the nutritional status of the palms and subsequent impact on yield. In 2007, tissue samples were taken from the same measured palms and the results of these tests will be discussed in the 2008 Annual Report.

Trial 142: N Response using Large Plots in OPRS Progeny Trials, Kumbango and Bebere

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 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 fertiliser (as ammonium nitrate) at three sites (Table 1). Treatments commenced in 2003. Fertiliser 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 12. Location of fertiliser treatments in Trial 142. Each progeny trial replicate is a plot of the fertiliser 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 2006 the basal fertilisers applied at Bebere, Trial 260, were: KIE, 1.5 kg/palm; MOP, 1.5 kg/palm; and Borate (NaBorate) 0.15 kg/palm. No basals were applied at Kumbango (256 and 266).

RESULTS and DISCUSSION

N fertiliser impact on yield

In 2006 there was no positive response in yield or its components from the application of N based fertiliser (Table 13). This lack of response in 2006 is the same as the findings in the first three years of experimentation (Figure 8). Since 2004 bunch number have decreased (from 1330 in 2004 to 1171 b/ha in 2006) (or 11.1 in 2004 to 9.0 b/palm in 2006) and SBW has increased (from 19.8 in 2004 to 22.1 kg/bunch in 2006).

Table 13. Effect of N level on FFB and its components in 2006.

N Level (kg AN/palm)	FFB (t/ha)	Number of Bunches (bunches/palm)	Number of Bunches (bunches/ha)	Bunch Weight (kg/bunch)
0	24.7	8.8	1138	22.0
3	26.0	9.0	1173	22.3
6	26.1	9.3	1202	21.9
Significant difference:	**NS**	**NS**	**NS**	**NS**
LSD0.05	**-**	**-**	**-**	**-**
CV%	**4.8**	**4.7**	**4.7**	**2.4**

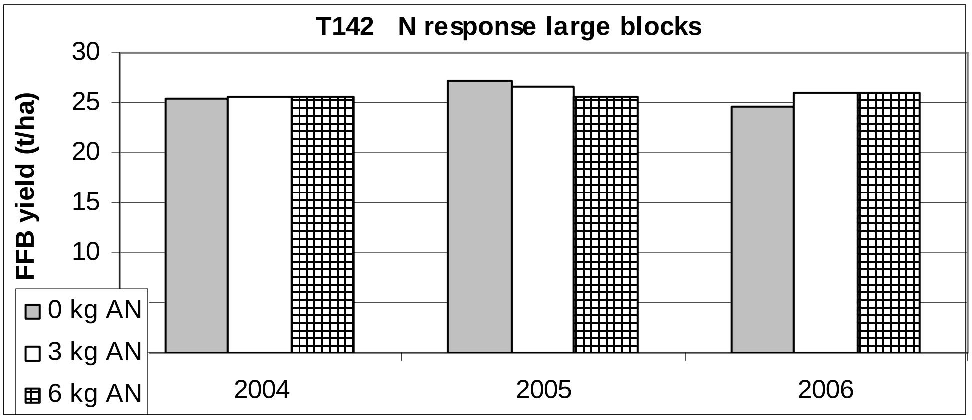

Figure 8. N response in trial 142 in 2004, 2005 and 2006.

Progeny effect on yield

The effect of progeny on yield could not be investigated for the 2006 data because progeny 714 had a very low yield for one treatment (3 kg AN). The yield was almost half of the other treatments for the same progeny. Progeny 635 did not show this drop in yield. We expect this is experimental error and will check the yield in 2007.

N impact on tissue nutrient concentration

Results for 2006

Leaflet N increased with the application of Ammonium Nitrate (Figure 9). The level at 266 Kumbango is still above the critical level but at 256 Kumbango and 260 Berbere the N tissue levels are now below or are approaching the critical level. Leaflet P and K appear to be relatively stable regardless of the amount of N applied as fertiliser (except for leaflet P at 260 Berbere which spiked with the application of 6kg AN – this result is not easily explainable and could be experimental error) (Figure 9).

There did not appear to be large differences in the other nutrients between the sites. The level of leaflet Mg and B were generally low (0.14 % dm and 13 mg/kg). Rachis P was low at 0.05% dm, whilst rachis K at 1.30 % dm was adequate. Even though leaflet P levels were adequate or near adequate the indication is that with low rachis P levels that the sites will be P deficient in future years which could impact on yield in the longer term.

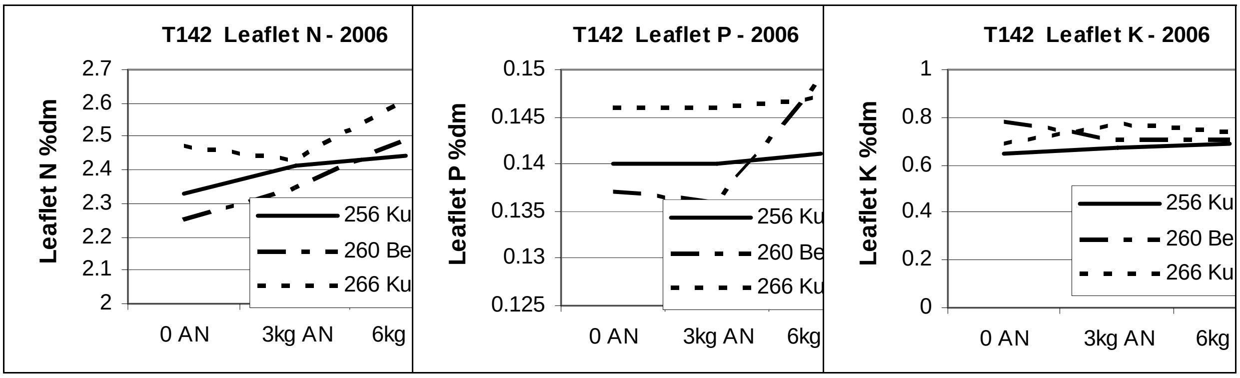

Figure 9. Leaflet N, P and K (% dm) for three AN rates (0, 3 and 6 kg N/palm) at three locations.

Leaflet N over time

At 260 Berbere and 266 Kumbango the 0 AN treatment had a decreasing level of leaflet N over time. Site 256 Kumbango did not follow this trend – however this site is quite low in tissue N and at the 0 N input rate is deficient in tissue N (Figure 10).

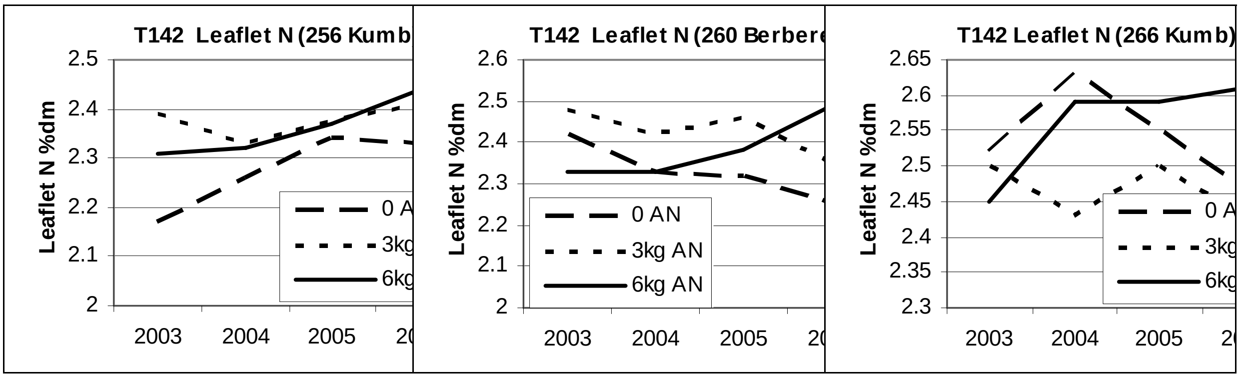

Figure 10. Leaflet N since the inception of the trial at three locations.

Leaflet N in relation to FFB yield

At sites 256 Kumbango and 260 Bebere the 0 N blocks had low leaflet N values, at both sites as N was applied the yield also increased (albeit only a small increase). At site 266 Kumbango the leaflet N levels were quite high (above 2.40 % dm) and there was no yield increase with 3kg AN applied compared to the zero control (Table 14). Because of low and dropping leaflet N levels at 256 Kumbango and 260 Bebere it is expected that a yield response to N will be seen in the near future (2007 or 2008).

Table 14. Trial 142, Individual block yield (t/ha) with associated leaflet N levels (% dm)

	0 kg/p AN		3 kg/p AN		6 kg/p AN	
	Yield	**Leaflet N**	**Yield**	**Leaflet N**	**Yield**	**Leaflet N**
256 Kumbango	24.3	2.33	27.3	2.41	26.8	2.44
260 Bebere	25.6	2.25	26.0	2.35	24.9	2.49
266 Kumbango	24.1	2.47	24.5	2.43	26.5	2.61

CONCLUSION

The large block N trial was established in 2003 and after three years of experimentation there are still no differences in yield between the 0, 3 and 6 kg/palm Ammonium Nitrate treatments. However, leaflet N levels are now dropping for the 0 N treatments and are at or below the critical level. It is expected that a yield response to N fertiliser will become evident over the next year.

Magnesium Fertiliser 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 fertiliser however the yield response to this fertiliser has not been quantified and often the visual deficiency symptoms remain even after the application of this fertiliser.

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 fertilisers 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 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 fertiliser is investigated on a block scale.

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

- Different sources of Mg fertiliser with lower solubility;
- Different application techniques, comparing fertiliser 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 fertilisers 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 investigations of soil mineralogy, soil hydrological properties and potential for leaching of the different Mg fertilisers, the results of this work will be reported in the 2007 Annual Report.

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

SUMMARY for all four trials

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

In one of the four trials a significant yield benefit from Mg fertiliser was demonstrated (Trial 144). In the other three trials there were no significant differences between the control (no fertiliser) and the Mg or K treatments (either alone or in combination). Tissue tests showed some response to Mg fertiliser but in most cases the leaflet Mg level in the trial was close to 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 Fertiliser Response Trial at Waisisi

SUMMARY

The impact of K and Mg fertilisers, applied by conventional spreading and by a 'slow release' method, at rates which would ensure that neither nutrient could be in deficient amounts, was tested on yield and its components of bunch number and bunch weight; tissue and bunch nutrient content and oil content (as oil:bunch ratio) on a volcanic soil in a relatively young plantation (palms were planted in 2001).

In the first two years of experimentation, 2004 and 2005, the addition of high rates of Mg resulted in a small but significant yield penalty. This did not occur in 2006 and neither +Mg, +K nor +Mg+K treatments resulted in a lower yield compared to the control plots (no K nor Mg fertiliser).

Tissue tests showed that even the control plots still had adequate levels of Mg and K in the leaflets. Leaflet Mg levels were raised in those treatments receiving Mg treatments. There was no effect by treatments on leaflet K. Rachis K levels were maintained at recommended adequacy levels in those treatments where K had been applied and dropped below those levels where K was not applied. Rachis Mg levels increased for those treatments where Mg fertilizer was applied but there is some indication that the uptake of Mg into the rachis was reduced when K was applied together with the Mg fertilizer.

Bunch nutrient analysis showed similar nutrient contents compared to published values and none of the Mg or K treatments had an apparent effect on bunch nutrient content.

Oil to bunch ratio was higher for two out of the eight progeny tested but was not influenced by fertiliser Mg or K treatments.

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	5	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 fertilisers are applied at two rates (nil and plus Mg or K fertiliser) in a randomised design with 4 replicates (2 fertilisers x 2 rates x 4 replicates = 16 plots). For the plus fertiliser 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 fertiliser Kieserite and as 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 fertiliser applications)
- Basal fertilisers applied in 2006 were Di-ammonium Phosphate (3.0 kg/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 fertiliser 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) Bunch nutrient analysis over 6 consecutive harvests (up to 5 bunches per harvest) (from selected plots related to progeny)

(iv) Oil : Bunch ratio for 6 consecutive harvests on 72 bunches (from selected plots related to progeny)
The trial was established on a site with many different progeny. The different progeny were planted in two or three adjacent rows and trial treatment plots were not allocated to specific progeny, hence a progeny effect could occur at the site. The nutrient and oil:bunch ratio work did include progeny type where bunches were collected only from known progeny.

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

Nutrient	Application method	Nutrient application rate (kg/ha)	Fertiliser	Nutrient cont. of fertiliser (%)	Fertiliser 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

RESULTS and DISCUSSION

(i) Yield components

After three years of experimentation there has been no response in yield to either applied Mg or K or to the combination of these two fertilisers (Figure 1).

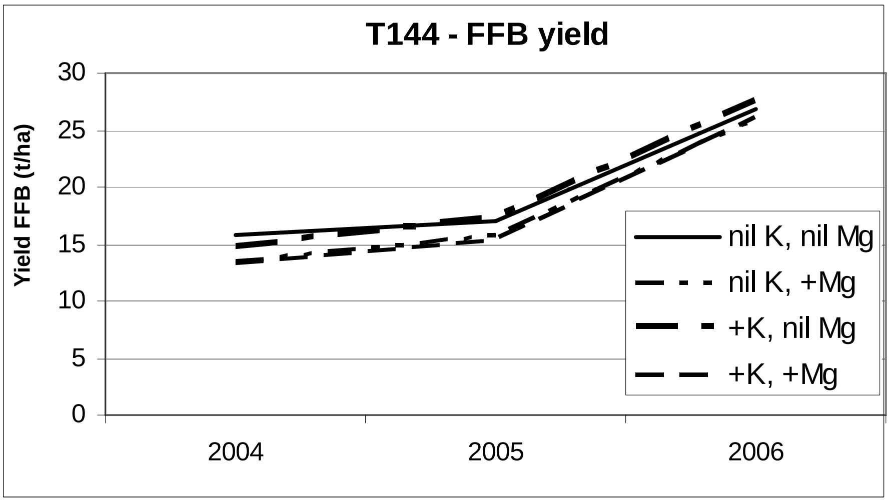

Figure 1. Trial 144 - FFB yield since inception of the trial in 2004.

In the first two years of experimentation (2004 and 2005) Mg fertiliser significantly decreased yield. However, there was no difference in yield in treatments with Mg fertiliser in 2006 (Table 3).

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

Source	**FFB Yield (t/ha)**		**SBW (kg)**		**NoB (B/palm)**		**NoB (B/ha)**	
	Mg0	**Mg1**	**Mg0**	**Mg1**	**Mg0**	**Mg1**	**Mg0**	**Mg1**
K0	26.9	26.0	10.9	10.2	20.6	21.5	2472	2580
K1	27.6	26.1	11.7	10.8	19.7	20.1	2364	2412
Significant difference:	**NS**		**P<0.05, LSD=0.6**		**NS**		**NS**	

(ii) Tissue nutrient content

The first fertiliser treatments were applied in 2003 and already by 2004 there had been uptake of Mg into the leaflets. The Mg content in leaflets continued to be higher in Mg treated plots compared to the control and K only plots in 2005 and 2006 (Table 4). Even though the K fertiliser treatment was also significant on leaflet K content the differences between K treatments and control plots were not consistent, for example the leaflet K level in the Control was 0.84 %dm and only 0.86 %dm in the +Mg+K treatment, this difference is not statistically significant it could be that the Mg is inhibiting the uptake of K. Certainly without the Mg (+K only) the uptake of K was much higher (0.93 %dm) and different to the control.

Table 4. Leaflet K and Mg levels (% dm) for four treatments in 2004, 2005 and 2006.

Treatments	**Leaflet K (% dm)**			**Leaflet Mg (% dm)**		
	2004	**2005**	**2006**	**2004**	**2005**	**2006**
Control	0.99	0.80	0.84	0.22	0.24	0.21
+ Mg	0.97	0.75	0.79	0.26	0.31	0.27
+ K	1.06	0.84	0.93	0.20	0.21	0.18
+ Mg + K	1.01	0.80	0.86	0.25	0.28	0.25
Significant difference:						
Year	**P<0.001**			**P=0.004**		
Treatment	**P<0.001**			**P<0.001**		
Year x Treatment	**NS**			**NS**		
LSD0.05	**0.07**			**0.04**		
CV%	**5.7**			**10.8**		

It also appears that Calcium levels in the leaflets was suppressed by the availability of Mg fertiliser but not by K fertiliser (1.22, 1.25, 1.13 and 1.12 % dm for the Control, +K, +Mg, +Mg+K treatments, P<0.001, $LSD_{0.05}$ 0.04).

In 2004 (time of first application of fertiliser) there was no difference between treatments in the rachis level of K and Mg. However, by 2005 this had changed and the same was found in 2006 (Table 5). Rachis K dropped in the control and +Mg only treatment whilst it was maintained in the +K and +Mg+K treatments. A similar result was found for Mg treatments where the control and +K treatments had a significantly lower Mg level compared to the +Mg treatment, there is some evidence that K fertiliser applied in combination with Mg suppressed uptake of Mg in the rachis (Table 5).

Table 5. Rachis K and Mg levels (% dm) for four treatments over three years.

	Rachis K (% dm)			**Rachis Mg (% dm)**		
Treatments	**2004**	**2005**	**2006**	**2004**	**2005**	**2006**
Control	0.91	0.72	0.87	0.058	0.058	0.058
+ Mg	1.00	0.54	0.72	0.060	0.091	0.085
+ K	1.07	0.89	1.13	0.055	0.049	0.048
+ Mg + K	1.18	0.66	0.91	0.053	0.074	0.065
Significant difference:						
Year	**P<0.001**			**P=0.04**		
Treatment	**P=0.004**			**P<0.001**		
Year x Treatment	**NS**			**0.05**		
LSD0.05	**0.25**			**0.017**		
CV%	**19.8**			**19.0**		

(iii) Bunch nutrient analysis and nutrient export in FFB

Bunch nutrient analysis was determined over a 3 month period (February to April 2007) on 33 bunches. Bunches were collected from known progeny from each of the treatments and also including from palms outside the study area which had not received any Mg or K fertiliser (the latter was done to try to ensure that for each progeny a zero control was obtained for each treatment).

The mean dry matter (%) of the 33 measured bunches was 55.1%. The nutrient content of bunches collected in trial 144 is presented in Table 6, the calculated kg of each nutrient exported in FFB is also presented.

Table 6. Bunch nutrient content and nutrient export in bunches for trial 144.

Nutrient	**% dm**	**kg per tonne of FFB**	**Nutrient**	**% dm**	**kg per tonne of FFB**
Ash	*3.47*		Mg	0.14	0.77
N	0.63	3.46	Cl	0.20	1.1
P	0.095	0.52	S	0.12	0.66
K	0.73	4.0	B	5.5 ppm	3.0g
Ca	0.33	1.82	Na	237 ppm	130g

The average FFB yield for the trial site in 2006 was 26.7 t/ha, which equates to 14.7 t/ha of dry matter (at 55% dm content of fresh FFB). Which means the average nutrient export for N was 92.6 kg/ha; P 14.0 kg/ha; K 107.3 kg/ha; Ca 48.5 kg/ha and Mg 20.6 kg/ha.

There did not appear to be a progeny effect in the nutrient content of bunches. However, only 33 bunches were collected for 8 progeny lines and hence there could have been an undetected progeny effect. The variability in nutrient content between bunches appeared higher than the variation in nutrient content between progeny.

(iv) Oil to Bunch ratio

Together with OPRS, bunch characteristics were determined over the same time period as for bunch nutrient analysis and 72 bunches were characterised in detail including measures of Oil:Bunch ratio (expressed as a %). Bunches were collected from the trial treatment plots (Control, +Mg, +K and +Mg+K) and also from an outside area (OUT) which was located just outside the trial area, this was done to ensure that bunches were collected from a control area for each progeny. Because of the nature of the trial and experimental procedures for collecting bunches from allocated progeny it is not possible to statistically analyse the data. However, if trends in oil:bunch ratio resulting from different

Mg or K treatments were present they should be apparent from the data (Table 7). What is apparent is that two progeny have a higher OB ratio (W4 and W17) compared to the other six progenies.

Table 7. Oil:Bunch ratio (OB %) for eight progeny and 5 treatments

Progeny	Treatment	OB %	Mean OB %	Progeny	Treatment	OB %	Mean OB %
W2	C	27.2		W14	+K	28.5	
	+K	27.4			+Mg+K	27.9	
	OUT	26.1	27.0		OUT	26.2	27.6
W4	+Mg	30.8		W17	C	30.3	
	+Mg+K	27.4			+Mg	31.7	
	OUT	32.5	29.9		OUT	30.8	30.8
W9	C	27.6		W19	C	27.4	
	+K	27			+Mg	27.8	
	OUT	29.3	27.9		OUT	26.5	27.1
W13	+Mg	28.5		W20	+K	27.3	
	+Mg+K	25.5			+Mg+K	30.2	
	OUT	26.7	27		OUT	29.3	27.9

To investigate whether the OB ratio is influenced by nutrient supply it is recommended to utilise a smaller number of progeny, undertake bunch analysis throughout the year, and include nutrients with a known effect on oil content and possibly quality.

CONCLUSION

(i) In year 3 of experimentation there was no impact of either Mg or K based fertiliser on production;

(ii) Leaflet Mg levels are still above critical in the zero Mg fertiliser treatments;

(iii) Leaflet Mg levels have increased in the treatments where Mg has been supplied:

(iv) Leaflet K levels are above critical and K fertiliser had no impact on K levels in the leaflet;

(v) Rachis K levels dropped over time for the control and Mg treatments and is now below recommended adequacy levels. Rachis Mg levels increased when Mg fertiliser was applied above the control and K only treatments.

(vi) Bunch nutrient levels were not influenced by fertiliser treatment, nor did progeny have an effect on nutrient content of bunches produced;

(vi) Oil to Bunch ratio was not influenced by fertiliser treatment, however two progeny tested had an apparent higher OB compared to six other progeny tested.

Acknowledgements

- ACIAR support for funding the trial is grateful acknowledged (Project SCMN/2000/046)
- OPRS for their significant input in undertaking the detailed bunch analysis including oil;bunch ratio determination
- Queensland Magnesia Pty Ltd for supporting the project with the supply of Mg based fertilisers (EMAG M30)

Trial 145: Magnesium Source Trial at Walindi

SUMMARY

This trial compares four types of Magnesium fertiliser (MgSO4, MgO, MgCO3 and a mixture of MgO / MgCO3) applied at 2 rates (standard rate and a double standard rate, where the standard rate is equivalent to 2kg/palm of MgSO4). The trial was established in late 2004.

In the second year of the trial it appears that there is a significant effect of Magnesium fertiliser on yield (by approximately 2.5t/ha). However, there is no difference in yield between the different types of Magnesium fertiliser used in the trial.

The application of Mg fertiliser did not result in higher leaflet and rachis Mg levels. Leaflet Mg levels are at or just below adequate levels. The application of the four different types of Mg fertiliser also had no effect on the vegetative parameters measured (such as PCS, frond production, LAI etc).

In this trial there are indications that the addition of Mg fertiliser is having an impact on yield but at this stage there are no vegetative measurements (such as tissue nutrient content or vegetative parameters) which can be used as a guide to assessing and hence addressing an Mg deficiency.

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	7	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 fertiliser 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 fertiliser, 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 fertilisers are applied at an equivalent magnesium rate (Table 2). All treatments are applied twice annually and spread on the surface.

Basal fertiliser applied in 2006: Ammonium nitrate (2.0 kg/palm); TSP 0.5 kg/palm; MOP 0.5kg/palm; and Borate 150 g/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. Fertiliser types and rates used in Trial 145.

Treatment number	Product	Main component	Mg content (%)	Mg application rate (kg/palm/yr)	Fertiliser 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 fertiliser 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 fertiliser 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

FFB Yield

At this early stage in the trial (second year) the results are not conclusive in relation to Mg source (Table 2) but there is an indication that the Mg treatments are yielding higher (by 7% or 2.1 t/ha) than the control (P=0.01). The increase in yield above the control is consistent for all Mg treatments.

Table 3. Average FFB (t/ha) for each treatment (yield of the control with no Mg fertiliser = 31.4 t/ha).

Fertiliser type	Standard rate	Double rate
Kieserite	33.7	32.9
FO1	33.5	34.2
EMAG M 30	34.7	32.3
EMAG 45	34.0	33.1
Mean	34.0	33.1

The impact of Mg fertiliser on SBW and Bunch Number was not significant. SBW was not affected by the treatments (average SBW for the control was 18.0 and for the Mg treatments it was 18.1 kg/bunch). The bunch number was slightly higher for the Mg treatments (average bunch number per palm for the control was 15.0 and for the Mg treatments 15.6 bunches/palm/year; or 1800 to 1872 bunches/ha/year).

Tissue nutrient analysis

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

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

Mg fertiliser	Level	Leaflet Mg (%dm)				Rachis Mg (%dm)			
		2003	2004	2005	2006	2003	2004	2005	2006
Control	0	0.17	0.17	0.22	0.19	0.041	0.034	0.036	0.051
Kieserite	1	0.17	0.15	0.22	0.18	0.038	0.035	0.037	0.046
Kieserite	2	0.16	0.17	0.22	0.19	0.043	0.037	0.037	0.052
EMAG45	1	0.17	0.16	0.22	0.18	0.040	0.035	0.035	0.054
EMAG45	2	0.17	0.16	0.21	0.18	0.039	0.035	0.034	0.051
FO1	1	0.18	0.17	0.23	0.19	0.044	0.032	0.037	0.047
FO1	2	0.18	0.16	0.22	0.19	0.046	0.033	0.038	0.057
EMAG M30	1	0.17	0.17	0.22	0.19	0.041	0.035	0.036	0.048
EMAG M30	2	0.16	0.15	0.21	0.18	0.041	0.034	0.038	0.046
Significant diff.:									
Treatment		**NS**				**NS**			
Year		**P<0.001**				**P<0.001**			
$LSD_{0.05}$		**-**				**-**			
CV%		**8.6**							

The other tissue nutrient levels are presented in table 5. The leaflet nitrogen level is barely adequate and it is recommended to increase the basal application of Ammonium Nitrate (however it is unusually high in the rachis). 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 (2006).

Nutrient	Leaflet (% dm)	Rachis (% dm)
Nitrogen	2.35	0.46
Phosphorus	0.160	0.13
Potassium	1.01	1.8
Calcium	0.79	0.4
Boron	22 ppm	

Fertiliser Mg effects on oil palm vegetative growth

Frond production and frond number

26.8 new fronds were produced in 2006 (one every 13.6 days) which is indicating good growing conditions – normally we would expect a new frond to form every 13 to 17 days. Total green fronds counted per palm averaged 43 fronds which is an adequate number. Mg fertiliser (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 $12m^2$ and LAI of 5.9). Neither, Frond Area or LAI was affected by the type and rate of Mg fertiliser applied (Table 6).

Vegetative dry matter production

Petiole cross section is a primary determinant of vegetative dry matter production. Although significant (P=0.03) the PCS varied across Mg treatments and rates and there was no consistency in treatment. 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 fertiliser type or rate (Table 6).

Table 6. Effect of treatments on vegetative growth parameters in 2006.

Mg fertiliser	level	PCS	Radiation Interception				Dry Matter Production (t/ha)			
			GF	FP	FA	LAI	FDM	BDM	TDM	VDM
Control	0	40.8	43.4	27.0	12.0	5.9	14.2	16.4	34.0	17.6
Kieserite	1	38.8	43.4	27.5	11.6	5.8	13.7	17.0	34.1	17.1
Kieserite	2	45.2	43.4	26.7	12.5	6.2	15.5	17.5	36.6	19.1
EMAG45	1	42.6	42.7	26.1	12.4	6.0	14.2	17.7	35.5	17.8
EMAG45	2	40.2	42.9	26.9	12.0	5.8	13.9	17.2	34.6	17.3
FO1	1	42.6	41.3	26.5	12.4	5.8	14.5	16.9	34.9	17.9
FO1	2	38.9	43.8	26.9	11.8	5.8	13.5	17.8	34.8	16.9
EMAG M30	1	40.9	43.8	26.9	12.1	6.0	14.1	17.8	35.5	17.7
EMAG M30	2	40.4	42.4	26.1	11.5	5.6	13.5	17.1	34.0	16.9
Significant diff.:		0.03	0.22	0.36	0.12	0.25	0.05	0.51	0.26	0.05
$LSD_{0.05}$		1.8	-	-	-	-	1.1	-	-	1.2
CV%		6.4	3.2	3.2	4.6	5.0	5.7	8.0	4.9	5.1

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

In this second year of trial work there is an indication that there has been a positive response in yield (of about 2.5 t/ha) resulting from Mg fertiliser application. However, there was no difference in the type of fertiliser used (Kieserite, FO1, EMAG45 or EMAG30) or in the rate applied (equivalent to a standard rate or double the standard rate).

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

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- Queensland Magnesia Pty Ltd for supporting the project with the supply of Mg based fertilisers (FO1, EMAG M30 and EMAG 45)

Trial 146: Magnesium Fertiliser Type and Placement Trial at Kumbango

SUMMARY

In this trial the application method for three different Mg fertilisers (Kieserite, FO1 (MgCO3) and EMAG45 (MgO)) were compared to a zero control (no Mg fertiliser) and a positive control (all three Mg fertilisers). The application methods compared were: surface applied; open trench; covered trench and fertiliser 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 fertiliser 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	7	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 fertiliser (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 fertiliser) control and the second being a positive control with all fertiliser types applied (Table 2).

Placement of fertiliser 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 2006, Ammonium Nitrate (2 kg/palm) TSP (0.5 kg/palm), MOP (0.5 kg/palm), and calcium borate (0.15 kg/palm) were applied as basal fertilisers.

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

Treatment no.	Fertiliser 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 two years of experimentation there were no significant responses in yield or its components to either the type of Magnesium based fertiliser applied or to the placement of the fertiliser. Table 3 presents the main effects of fertiliser type and placement for FFB yield and its components in 2006.

Table 3. Significance (p values) of main effects in 2006 for Magnesium based fertiliser 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	BNO/ha	SBW (kg)
Fertiliser type	0.26	0.15	0.24
Placement	0.52	0.45	0.15
Source x Placement	0.14	0.47	0.34

The yield achieved by the various treatments is presented for interest in table 4. Because there were no significant effects on Single Bunch Weight, or Bunch Number, the results for these are not presented.

Table 4. Effect of Mg source and placement on FFB yield (t/ha/yr) in 2006.

Fertiliser type	Placement					
	Zero control	Surface	Open Trench	Covered Trench	Coconuts	Positive control
Nil	29.7					
Kieserite		31.5	29.0	27.6	26.0	
$MgCO_3$		26.7	28.4	28.9	28.7	
MgO		31.0	28.3	29.8	29.7	
Combined						31.9

There is an apparent difference between the Zero Control yield of 29.7 t/ha and the Positive Control of 31.9 t/ha but these values lie within the yield range of the other treatments – there is variability in the yield data (as there is in all trials) and it may take more time before any differences between treatments start to statistically differentiate from each other.

Tissue nutrient concentration in 2006

There was no Mg fertiliser type or placement effect on leaflet or rachis Mg levels (Tables 5 and 6). All values were above 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 2006.

Fertiliser type	Placement					
	Zero control	Surface	Open Trench	Covered Trench	Coconuts	Positive control
Nil	0.21					
Kieserite		0.23	0.21	0.20	0.22	
$MgCO_3$		0.21	0.21	0.21	0.21	
MgO		0.23	0.21	0.22	0.21	
Combined						0.23

Table 6. Effect of Mg source and placement on rachis Mg (% dm) in 2006.

Fertiliser type	Placement					
	Zero control	Surface	Open Trench	Covered Trench	Coconuts	Positive control
Nil	0.038					
Kieserite		0.040	0.039	0.035	0.037	
$MgCO_3$		0.036	0.038	0.039	0.037	
MgO		0.035	0.035	0.040	0.037	
Combined						0.040

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 7. The nutrient concentrations in the leaflet and rachis were all in the adequate range.

Table 7. Mean leaflet and Rachis nutrient levels for trial 146 (2006).

Nutrient	Leaflet (% dm)	Rachis (% dm)
Nitrogen	2.40	0.38
Phosphorus	0.156	0.09
Potassium	0.92	0.38
Calcium	0.90	0.26
Boron	14 ppm	

Fertiliser Mg effects on oil palm vegetative growth

Frond production and frond number

30.2 new fronds were produced in 2006 (one every 14.6 days) which is indicating good growing conditions. Total green fronds counted per palm averaged 40 fronds which is an adequate number (Table 8). Mg fertiliser (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 fronds in this trial are on the small size (average frond area 9.9 m^2 and LAI of 5.1). Neither, Frond Area or LAI was affected by the type and placement of Mg fertiliser applied (Table 8).

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. Although placement of Mg fertiliser was significant (P=0.01) the PCS response was not significant for the source of Mg fertiliser. The PCS for the zero control was 28.7cm^2 and for the positive control 31.6cm^2 but these values lie within the range of the other treatments and are not different to each other (Table 8). 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 fertiliser type or placement (Table 8).

Table 8. Mean value of vegetative parameters as measured or calculated presented as the mean value for treatments (Mg source x placement); zero control (no Mg fertiliser) and positive control (two sources of Mg fertiliser)

	Treatment mean	**Zero Control**	**Positive control**	**Notes**
PCS	30.2	28.7	31.6	Small petiole cross section
GF	40.1	38.7	39.3	Adequate total number of fronds
FP	25.0	24.4	24.7	Good frond production (one new frond every 14.6 days)
FA	9.9	10.3	10.0	Small fronds
LAI	5.1	5.1	5.1	Low LAI
FDM	10.5	9.8	10.8	
BDM	15.2	16.6	15.8	
TDM	28.6	29.3	29.6	
VDM	13.4	12.7	13.8	

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

At this stage of the trial, the treatments of Mg fertiliser 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 2007.

Acknowledgements

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- Queensland Magnesia Pty Ltd for supporting the project with the supply of Mg based fertilisers (FO1, EMAG M30 and EMAG 45)

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

SUMMARY

Magnesium fertiliser, as Kieserite, response in oil palm was investigated over large blocks in conjunction with OPRS breeding trials. Three replicate blocks with three levels of applied Magnesium fertiliser 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. However, the differences in leaflet Mg have not translated into a yield effect. The average yield produced in 2006 was around 26.5 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 Magnesium uptake. There was no difference between the progeny in the yield response to Mg fertiliser, however there was a large difference in yield between the three progeny (a difference of between 2 to 3 t/ha, or 10% yield difference, between progeny was observed).

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 fertiliser 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	5 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 fertiliser applied in 2006 in Trial 149: DAP 3.0 kg/palm plus Borate at 80 g/palm. Fertiliser 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 fertiliser rates (kg/palm per year) in trial 148. The replicates shown are breeding trial replicates. Each breeding trial is a replicate of the fertiliser 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 will be 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). Progeny 714 has a low oil extraction rate (OER) and 635 have a high OER and are being used as a parent in much of Dami seed production.

RESULTS and DISCUSSION

There was no effect of Mg fertiliser on yield or its components in 2006 (Table 3).

Table 3. Effect of Mg fertiliser (as Kieserite) on FFB yield, bunch number and bunch weight in 2006.

Kieserite (kg/palm)	FFB (t/ha)	Number of Bunches (bunches/palm)	Number of Bunches (bunches/ha)	Single Bunch Weight (kg/bunch)
0	26.2	21.8	2790	9.6
2	26.7	22.4	2867	9.6
4	27.2	22.6	2893	9.7
Significant difference:	**NS**	**NS**	**NS**	**NS**
LSD0.05	**-**	**-**	**-**	**-**
CV%	**5.4**	**4.4**	**4.4**	**1.9**

The trial is now in its third year (Mg fertiliser was first applied in 2003) and over this time there has been no difference in yield from the applied fertiliser (Table 4).

Table 4. 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
Significant difference:			
Year	**P<0.001**		
Rate	**NS**		
Year x Rate	**NS**		
$LSD_{0.05}$	**1.9**		
CV%	**5.3**		

Three progeny were common to each breeding trial, which made it possible to investigate differences in yield between progeny (Table 5) and also the differential yield effect of magnesium fertiliser on each progeny. There was no Magnesium fertiliser effect on yield but there was a strong progeny effect (Table 5). The number of bunches produced and bunch weights were also significantly different between the three progeny. Similar to the results obtained in Trial 149, progeny 635 and 5035 had a significantly higher yield compared to progeny 714.

Table 5. Progeny effect on FFB and its components.

	Yield t/ha			Bunches/palm			SBW (kg/bunch)		
Kieserite kg/palm	**0**	**2**	**4**	**0**	**2**	**4**	**0**	**2**	**4**
Progeny									
635.607 x 742.207	28.3	30.0	30.9	23.6	24.5	24.7	9.2	9.4	9.6
714.712 x 742.316	27.1	27.0	27.0	20.5	19.9	21.1	10.2	10.7	10.0
5035.216 x 742.316	29.3	28.7	31.2	21.3	21.6	21.1	10.8	10.5	11.1
Significant difference:									
Mg rate	**NS**			**NS**			**NS**		
Progeny type	**0.03**			**0.003**			**<0.001**		
Mg x Prog	**NS**			**NS**			**NS**		
$LSD_{0.05}$	**3.9**			**3.4**			**1.0**		
CV%	**7.6**			**8.8**			**5.7**		

Effect of magnesium fertiliser on tissue nutrient concentration

Treatments were first applied in 2003 and since 2004 the leaflet concentration of magnesium has been significantly higher in the fertiliser treated blocks compared to the untreated blocks (Table 6).

Table 6. 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**
2003	0.21	0.21	0.22
2004	0.21	0.21	0.23
2005	0.20	0.22	0.23
2006	0.16	0.18	0.18
Significant difference:			
Year	**P<0.001**		
Rate	**P=0.003**		
Year x Rate	**NS**		
$LSD_{0.05}$	**0.02**		
CV%	**6.7**		

There is also a strong year effect, with leaflet Mg levels dropping significantly in 2006. This makes interpretation of commercial tissue data more complicated because, the question arises of whether the level is low because of a nutrient deficiency exhibited by the palms or is it due to a laboratory issue where the results for a particular batch are lower compared to previous results?

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 ($P<0.001$, $LSD_{0.05}$ 0.02) (Figure 1). The same result in progeny differences in nutrient content was observed in this trial in 2005, and also for boron in trial 149.

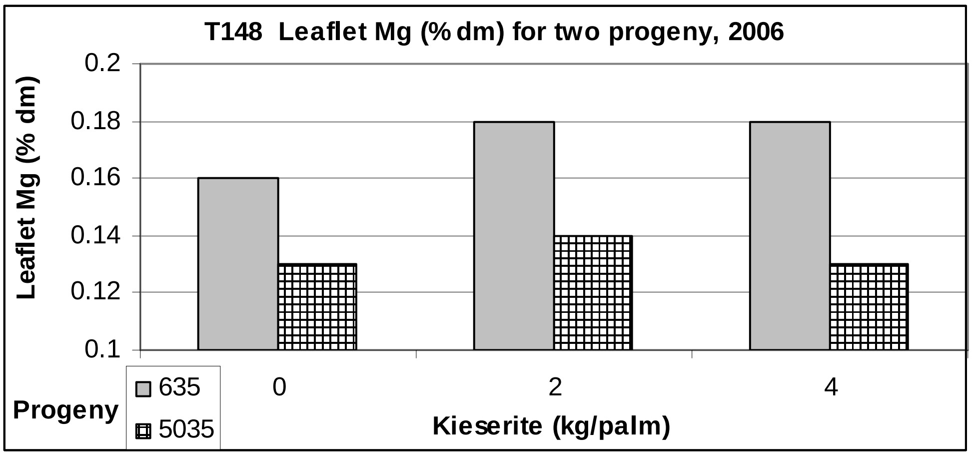


Figure 1. Mg concentration in leaflets for two progeny, 2006.

Other nutrients appeared to be present in adequate amounts (Table 7). 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 7. N, P, K and B tissue levels in 2006 (Trial 148).

	Nutrient concentration (% dm)	
	Leaflet	**Rachis**
N	2.71	0.29
P	0.149	0.06
K	0.84	1.33
B	19.5 ppm	

CONCLUSION

After three years of experimentation it has not been possible to demonstrate a yield response to Magnesium fertiliser (as Kieserite). There has 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. Interestingly both the progeny tested for nutrient levels had similar yields but very different Mg levels in the leaflets.

Boron Fertiliser Research

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

SUMMARY

Boron fertiliser responses in oil palm were investigated over large blocks in conjunction with OPRS breeding trials. Three replicate blocks with three levels of applied Boron fertiliser 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 2006 was around 27 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 3 t/ha, or 10%, between progeny was observed).

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

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 fertiliser effects, and this trial utilises information from OPRS breeding trials in conjunction with OPRA fertiliser 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	5 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 fertilisers applied in 2006 in Trial 149: DAP 3 kg/palm and Kieserite at 2 kg/palm. Fertiliser 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 Ca borate) (Table 2).

Table 2. B fertiliser treatments (annual rates of Ca borate in g/palm) in Trial 149. The 'blocks' referred to are replicates of the breeding trials and are plots for the fertiliser 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 whole trial will be 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 fertiliser on yield in 2006

In 2006, there was no significant effect of Boron application on yield, bunch number or bunch weight (Table 3).

Table 3: Effect of B fertiliser on FFB, bunch number and SBW in 2006.

CaB rate (g/palm)	FFB (t/ha)	Number of Bunches (bunches/palm)	Number of Bunches (bunches/ha)	SBW (kg/bunch)
0	26.8	22.5	2880	9.3
80	27.1	22.5	2880	9.4
160	26.9	22.5	2880	9.4
Significant diff.:	**NS**	**NS**	**NS**	**NS**
$LSD_{0.05}$	-	-	-	-
CV%	**2.3**	**2.4**	**2.4**	**0.8**

There was no yield difference in B response between the four breeding sites (Figure 1).

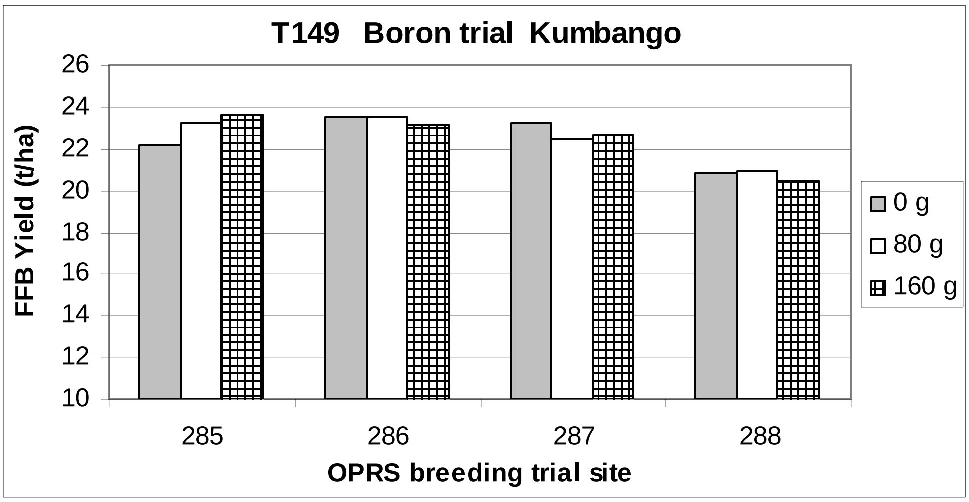


Figure 1. FFB yield for three rates of applied Boron fertiliser at four OPRS breeding sites (note trial 288 has one month of missing yield data).

Effect of boron fertiliser on the yield of different progeny in 2006

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 (Table 4). 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 4).

Table 4. Yield, bunches per palm and bunch weight for three progeny in 2006.

	Yield t/ha			**Bunches/palm**			**SBW (kg/bunch)**		
CaB g/palm	**0**	**80**	**160**	**0**	**80**	**160**	**0**	**80**	**160**
Progeny									
635.607 x 742.207	30.6	32.2	31.8	27.0	26.9	27.7	10.1	8.9	10.0
714.712 x 742.316	27.8	29.4	27.1	21.6	22.9	20.2	10.1	10.2	10.4
5035.216 x 742.316	30.0	31.1	34.5	23.3	23.5	25.5	10.1	10.4	10.7
Significant difference:									
B rate	**NS**			**NS**			**NS**		
Progeny type	**0.001**			**<0.001**			**<0.001**		
B x Prog	**NS**			**NS**			**NS**		
$LSD_{0.05}$	**3.7**			**2.4**			**0.6**		
CV%	**8.2**			**6.7**			**4.1**		

Similar progeny effects as found in 2006, were recorded in 2005.

Effect of boron fertiliser on tissue nutrient concentration

In 2003, the year in which B fertiliser was first applied, the leaflet B levels were similar across the treatment areas. From then on the effect of B fertiliser and the rate of applied fertiliser on leaflet B levels has been highly significant (Table 5).

Table 5. Leaflet B levels (ppm) for three rates of applied B fertiliser for four years. Note: 2003 was the year that B fertiliser was first applied.

	Applied CaB (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
Significant difference:			
Year	**P<0.001**		
Rate	**P<0.001**		
Year x Rate	**P=0.003**		
LSD0.05	**2.1**		
CV%	**13.2**		

The uptake of B by different progeny was highly significant (Figure 2). With applied B fertiliser, progeny 635 had a significantly higher level of B in the leaflets.

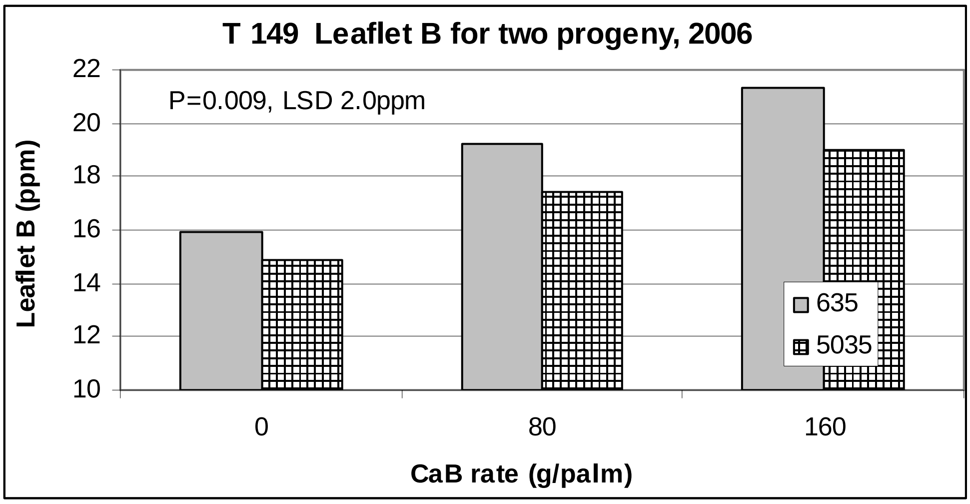


Figure 2. Leaflet boron levels (ppm) for two progeny, 635 and 5035, in 2006.

Because two progeny were found in each block it was also possible to investigate the uptake of other nutrients in the leaflets and rachis (Table 6)

Table 6. Differences in tissue nutrient concentration (% dm) in the leaflet and rachis for two progeny.

	Tissue nutrient concentration (% dm)	
	Leaflet	**Rachis**
Nitrogen	NS	NS
Phosphorus	NS	P=0.04 (Prog. 635 highest level)
Potassium	P=0.02 (Prog. 635 highest level)	P=0.02 (Prog. 5035 highest level)
Magnesium	NS	-

The actual level of leaflet N, P, K and Mg appear to be adequate (2.7, 0.149, 0.85 and 0.15 % dm respectively), except the Mg level is on the low side. Rachis, N and K are adequate (0.29 and 1.33 %dm) with rachis P on the low side (0.05% dm).

CONCLUSION

Yield

After three years of experimentation it has not been possible to demonstrate a yield response to Boron fertiliser (as CaB). 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 large differences in the uptake of Boron, as assessed by leaflet B levels, between two different progeny. Interestingly both the progeny tested for nutrient levels had similar yields but very different B levels in the leaflets.

Milne Bay Estates, MBP: Summary and Synopsis

(Harm van Rees, Steven Nake and Wawada Kanama)

Fertiliser response trials with MBE comprised one main area of interest: the interaction between Nitrogen and Potassium based fertilisers. In two of the trials besides N and K treatments, there were also treatments with P and EFB.

Outcome: Responses to N and K fertiliser ranged from 70 to 500% over the control (no fertiliser applied). The highest yield achieved at each of the sites was 36 t/ha. At one site, on interfluvial deposits (these soils contain also contain buckshot), higher rates of N and K were required to achieve these high yields and P fertiliser 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.

For these trials it was possible to determine robust adequacy levels of 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 2006 trial results and recommendations

Trial	Palm Age	Yield t/ha	Yield Components	Tissue % dm	Vegetative	Notes
504 Sagarai SOA, MOP (factorial) Soil: Alluvial	16	Control 21 SOA+MOP 36	Bunch/p 7 to 11 SBW 22 to 26	SOA LN 2.32 to 2.60 MOP LK 0.59 to 0.72 RK 0.45 to 1.45	PCS 51 to 59 FP NS (22) LAI NS (5.5)	Main response to N, some response to K. Some P required as basal.
502 Waigani SOA, MOP, TSP, EFB (factorial) Soil: Alluvial	20	Control 18 SOA+MOP+TSP+ EFB 36	Bunch/p 7 to 10 SBW 22 to 28	SOA LN 2.26 to 2.48 MOP LK 0.51 to 0.62 RK 1.04 to 1.54 TSP LP 0.144 to 0.148 RP 0.11 to 0.16 EFB LN 2.32 to 2.42 LK 0.54 to 0.61 RK 1.25 to 1.50	PCS 44 to 51 FP 19 to 20 LAI 5.6 to 6.1	Main response to N, some response to K and P (only at the highest yields).
511 Waigani SOA, MOP, TSP, EFB (factorial) Soil: Alluvial/ interfluvial	18	Control 7 SOA+MOP+TSP+ EFB 36	Bunch/p 4 to 12 SBW 15 to 25	SOA LN 2.15 to 2.45 MOP LK 0.62 to 0.72 RK 1.05 to 1.65 TSP LP 0.134 to 0.148 RP 0.04 to 0.12 EFB LN 2.24 to 2.40 LK 0.63 to 0.73 RK 1.38 to 1.60	PCS 40 to 52 FP 21 to 22 LAI 4.3 to 5.8	Main response to N, P is also important. Some response to K.

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

Leaflet (% dm)					Rachis (%dm)		
N	**P**	**K**	**Mg**	**B**	**N**	**P**	**K**
2.40	0.145	0.65	0.20	15ppm	0.32	0.10	1.2

Recommendations to MBE:

1. On the alluvial soils at MBE an oil palm yield of 36 t/ha should be attainable. Higher rates of fertiliser are required on the inter-fluvial soils compared to the better drained 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 not required)
4. Plantation management (harvest time, pruning, clean weeded circles, fertiliser application and timing etc) all play a large role in the potential to optimize production

Nitrogen and Potassium Requirements at MBE: a summary

Three Nitrogen (N) x Potassium (K) fertiliser 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 interfluvial 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 6kg/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 fertilisers 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 fertiliser 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 fertiliser 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 trials in their response to fertiliser. The fertiliser treatments had an impact on bunch number (BNO) produced and single bunch weight (SBW), and hence fresh fruit bunch (FFB) yield. The responses to fertiliser 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 BNO in each trial was always the control treatment (no fertiliser) or other treatments without N fertiliser. SBW and BNO, 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 BNO, was the highest rate of N and K in combination with P and EFB (Table 1). It is clear that fertiliser treatments, especially N, had a major impact on SBW and BNO at all three sites.

Table 1. Fertiliser treatments for low, average and high yield at each site in 2006.

Yield level	Fertiliser treatment (product and kg/palm)	FFB yield (t/ha)	SBW (kg/bunch)	BNO (bunches/palm)
Trial 504: Sagarai				
Low	SOA 0, MOP 0	20.8	22.2	7.3
Average	SOA 2, MOP 2.5	29.0	25.7	9.1
High	SOA 6, MOP 2.5	35.5	26.2	10.8
Trail 502: Waigani (flat)				
Low	SOA 0, MOP 0 *	18.0	21.7	6.8
Average	SOA 4, MOP 2.5	27.8	28.7	7.6
High	SOA 6, MOP 7.5, TSP2, EFB 300	36.2	28.4	10.1
Trial 511: Waigani (hilly)				
Low	SOA 0, MOP 0 *	7.2	15.2	3.9
Average	SOA 6, MOP 2.5	21.0	22.2	7.4
High	SOA 6, MOP 7.5, TSP2, EFB 300	35.8	25.0	11.6

* treatments at the low range of yields had no SOA

The lowest yield at Trials 504 and 502 was still quite high at 20.8 and 18.0 t/ha respectively, and was achieved with no fertiliser 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 and the soil is unable to supply sufficient nutrients to produce similar results to trials 502 and 504. However, the high yield at this site (36 t/ha) was still the same as at the other two sites – indicating that it is nutrient supply which is the issue not an inherent problem with soil condition or management.

The highest yield for each site was 36 t/ha – a remarkably stable outcome. It raises the question of whether the highest yield had been achieved? Could higher yields be achieved if fertiliser inputs had been even higher?

Using OMP8, these trial yield results (Table 1) can be compared, to the plantation blocks surrounding these trials to see how the blocks performed in relation to the trials. The fertiliser treatments in the trials can then be compared to those used on the plantation blocks to see what additional fertilisers 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	0.100	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 fertiliser 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 fertiliser program which overcomes any deficiency.

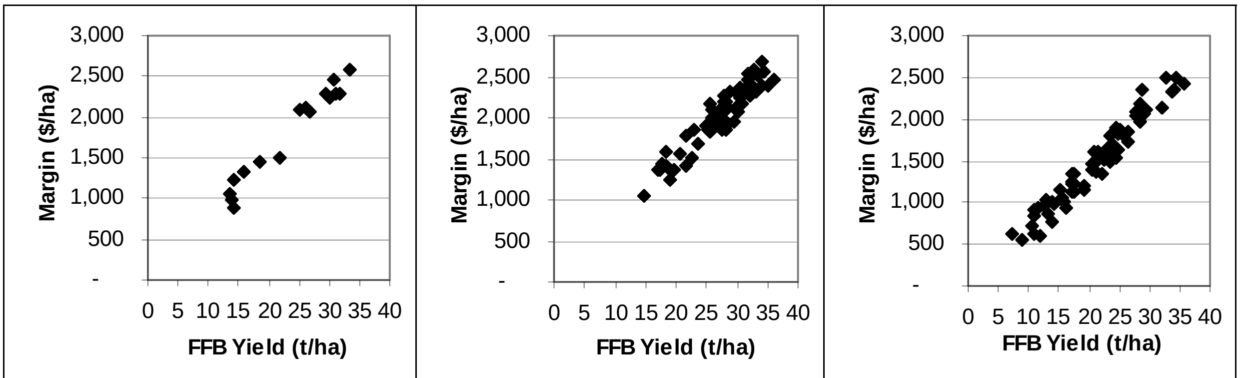
In the trial analysis for nutrient status the magnesium, Mg, status of the tissue was not considered because in all cases it was found to be above the required adequate level (most leaflet Mg levels were above 0.30% of dm).

Economic analysis

The cost : benefit ratio of applying fertiliser 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 fertiliser type and rate; transport of fertiliser from port to the mill and then to the field; the spreading of fertiliser; 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 for CPO and kernels at port.

Gross margin analysis (income – variable costs) is a useful method to compare the impact of various fertiliser 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. However, 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, mill maintenance, salaries, bank interest 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 fertiliser trials is a convenient way to investigate the cost : benefit ratio for applying particular fertilisers and rate of fertiliser.

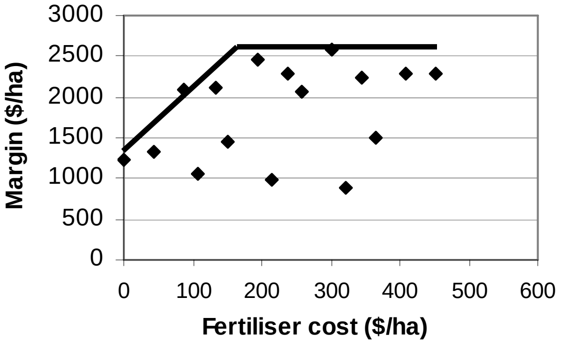
As expected there is a strong relationship between yield and the gross margin achieved – the highest yields made gross margins consistently around \$2500/ha at all three trial sites (Figure 1).



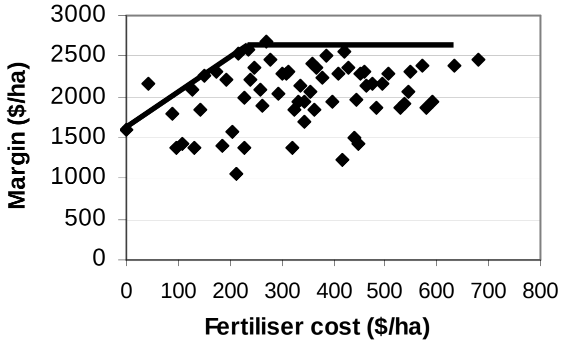
Trial 504.	Trial 502.	Trial 511.

Figure 1. Gross margin (\$/ha) versus FFB yield (t/ha) for three trial sites at CTP Milne Bay Estate in 2006.

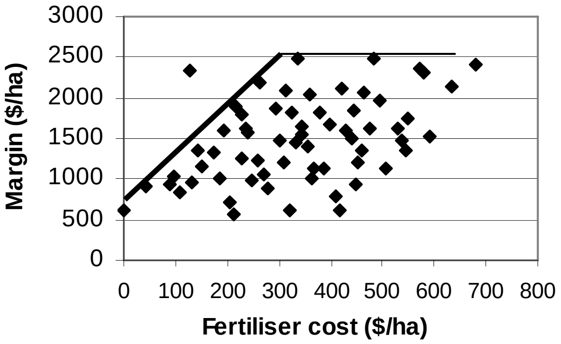
Highest inputs did not necessarily mean highest gross margin return (Figure 2). For trials 504 and 502, which have a higher inherent soil fertility compared to trial 511, the highest return was achieved with an input of around \$200/ha in fertiliser. The highest return was achieved, at both sites, with SOA at 4kg/palm plus either MOP at 2.5kg/palm or EFB at 0.3t/palm (EFB contains a high level of K). 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. At this site an input of around \$340/ha (consisting of SOA 6 + MOP 2.5 + TSP 2kg/palm) was required to achieve a gross margin of \$2500/ha.



Trial 504:
highest return of $2500/ha achieved with SOA 4 + MOP 2.5 kg/palm
(at a cost of $195/ha in fertiliser)



Trial 502:
highest return of $2600/ha achieved with SOA 4 kg/palm + EFB
(at a cost of $217/ha in fertiliser)



Trial 511:
highest return of $2500/ha achieved with SOA 6 + MOP 2.5 + TSP 2 kg/palm
(at a cost of $336/ha in fertiliser)

Figure 2. Gross margin return ($/ha) versus fertiliser cost ($/ha) for three trial sites at CTP Milne Bay Estate in 2006.

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

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.

Trial 504 Sagarai

Three 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 fertiliser as was used on the commercial blocks, and the highest yielding treatment in the trial (Figure 3).

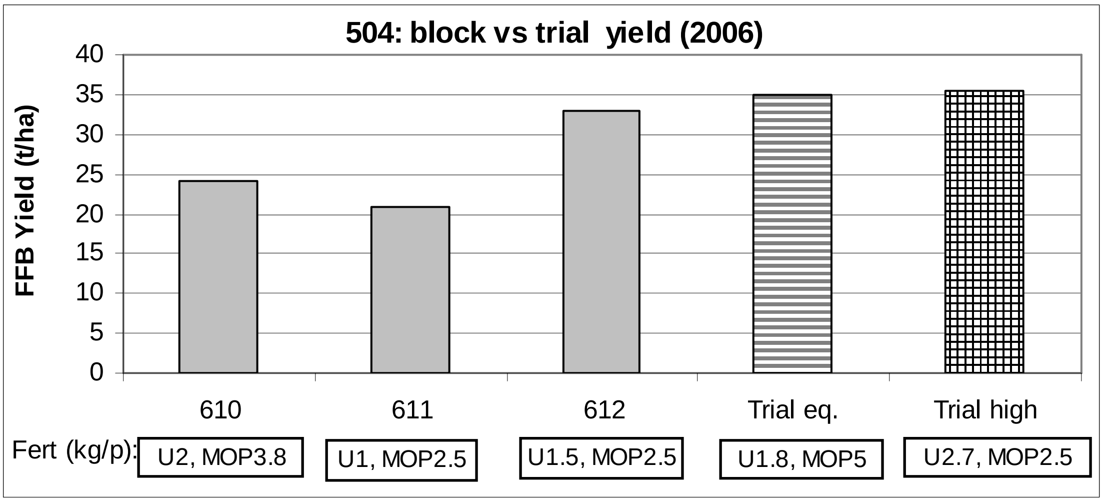


Figure 3: Block data (from OMP8) vs trial 504 yield data (2006).

The yields in blocks 610 and 611 were much lower compared to trial treatments with either a similar fertiliser input or the highest yield treatment This indicates that significant yield improvements can be made through the judicious use of fertiliser.

Trial 502 Waigani

Two blocks (6503 and 6504) adjacent to trial 502 were compared to the equivalent input treatment and the highest yielding treatment (Figure 4).

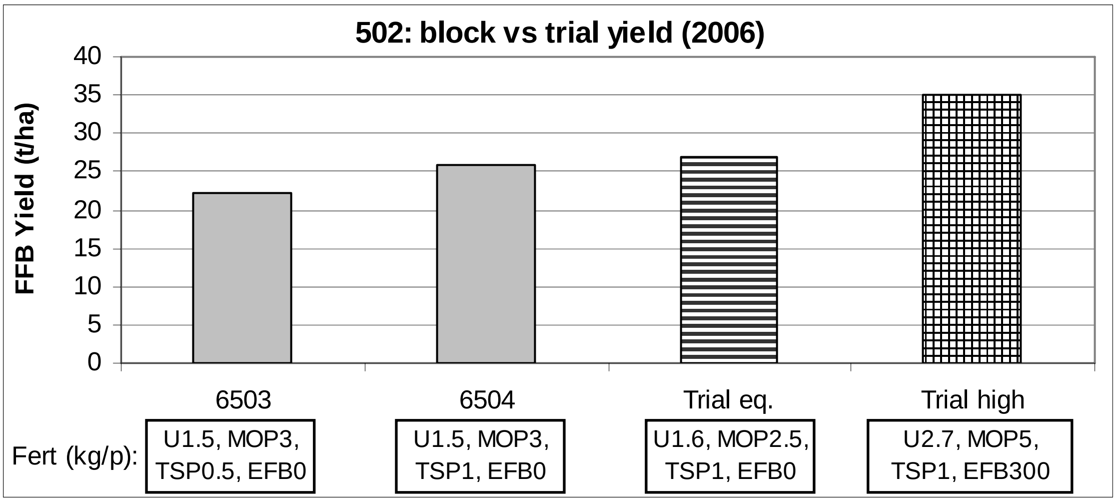


Figure 4. Commercial block data (from OMP8) vs trial 502 yield data (2006).

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.

Trial 511Waigani

Two blocks (8501 and 8502) adjacent to trial 511 were compared to the equivalent input treatment and the highest yielding treatment (Figure 5).

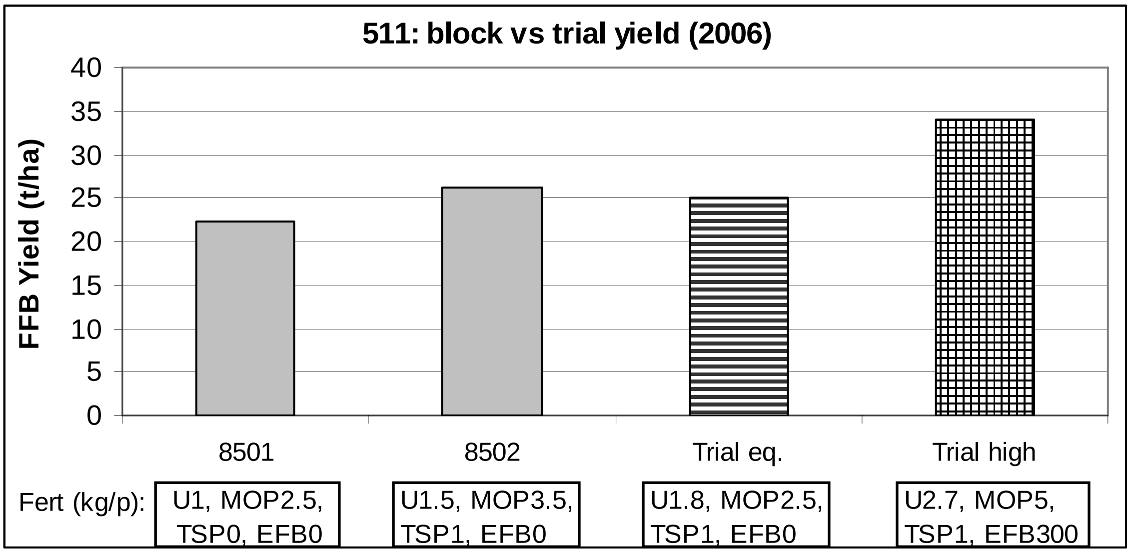


Figure 5. Commercial block data (from OMP8) vs trial 511 yield data (2006).

Significantly higher yields were obtained in the highest yielding treatment compared to the adjacent block data – the yield difference was between 8 and 12 t/ha.

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 32,000 t of FFB which is approximately equivalent to 7300 t CPO.

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

Both trial sites 502 and 511 will be felled and replanted in 2009/2010. 2007 could be the last year of experimentation at both sites. The trends in fertiliser response have been consistent at both sites for a number of years now and it is unlikely that much more benefit can be gained from these sites if they are continued in their present format.

However, there is possibly a side benefit to maintaining some input into these trials over the next two years. The lowest yielding plots are severely deficient in N and K (and for 511 also in P). It is proposed to apply these nutrients to the lowest yielding plots and observe how quickly the palms respond with a higher nutrient status in Frond 17 and in yield and its components. The rate of recovery can be assessed against the average and top yielding plots. This will have benefit for when small holders or plantation managers are considering re-establishing neglected palms. If the true time lag can be determined the cost : benefit ratio of re-establishing a plantation to full production can be determined.

Trials 502 and 511: Nitrogen, Phosphorus, Potassium and EFB Trials at Waigani

SUMMARY

Two trials, 502 and 511, with the same treatments, were established in 1994/95 in the Waigani estate at CTP Milne Bay Estate. 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 fertilisers in a factorial combination, with and without EFB. EFB was included to test whether it can be used to replace or supplement inorganic fertiliser. Treatments consisted of four rates of SOA (0, 2.0, 4.0 and 6.0 kg/palm), 4 rates of MOP (0, 2.5, 5.0 and 7.5 kg/palm), two rates of TSP (0 and 2.0 kg/palm) and two rates of EFB (0 and 0.3 t/palm).

The response of the fertiliser treatments in yield and its components has been positive for some years and this trend continued into 2006. At both trial sites the yield gap between low and high input is widening. After a decade of experimentation:

- Trial 502 - the average FFB yield was 27.4 t/ha, with an average 7.9 bunches/palm and a single bunch weight of 27.6 kg;
- Trial 511 - the average FFB yield was 21.0 t/ha, 6.8 bunches/palm and a single bunch weight of 24.3 kg.

Trial 502 had a higher inherent soil nutrient status at the start of the trial than Trial 511 and the low and average yields have been higher for Trial 502. At both sites, the highest yielding treatments achieved a yield of 35 t/ha, however Trial 511 required more fertiliser to achieve this yield.

The fertiliser 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

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	20 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	18 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	Agronomist in charge	Steven Nake

Experimental Design and Treatments

Trials 502 and 511 are factorial fertiliser 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 replicate plot (4 x 4 x 2 x 2 = 64 plots), the trial site has four replicate blocks within which the main effects of N and K are represented. Each plot contains 16 core palms, which are surrounded by a guard row and a trench. Trial fertilisers were first applied in late 1994 and EFB was first applied in 1995. EFB is applied by hand as mulch between palm circles once per year. Other fertilisers are applied in 3 doses per year.

Table 2. Amount of fertiliser 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

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 fertiliser treatments

The level of significance and the actual yield and its components of bunch number and bunch weight, for 2006 and the three year average for 2004 to 2006, are presented in Tables 3 and 4.

2006

N fertiliser: The trend developed in N fertiliser response continued in 2006 and the yield gap between no N and N fertiliser is approximately 5 t/ha FFB. The effect of N fertiliser was stronger on bunch weight compared to bunch number.

K fertiliser: over the last few years there has been a slow but steady increase in yield resulting from the application of K fertiliser. In 2006, the response to K was significant with a yield increase of approximately 3 t/ha from MOP. Most of the response in yield is due to bunch weight rather than bunch number.

P fertiliser: in 2005 there was a significant response to P fertiliser (as TSP) however in 2006 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 5 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.

2004 to 2006

The three year, 2004 to 2006, average yields and yield components were calculated to smooth out the yearly yield fluctuations resulting from different weather conditions and possible management effects.

The fertiliser response seen in the 2004 to 2006 averaged data is essentially the same as for the 2006 data indicating that the responses seen and discussed for 2006 are real.

Table 3. Trial 502, effect (p values) of treatments on FFB yield and its components in 2006 and from 2004 to 2006 (three years of averaged data). P values less than 0.05 are presented in bold.

	2006			**2004 to 2006**		
Source	**Yield**	**BNO**	**SBW**	**Yield**	**BNO**	**SBW**
SOA	**<0.003**	0.07	**<0.001**	**<0.001**	**0.001**	**<0.001**
MOP	**0.04**	0.18	**<0.001**	**<0.001**	**0.02**	**0.001**
TSP	0.14	0.06	0.35	0.28	0.09	0.19
EFB	**<0.001**	0.06	**<0.001**	**<0.001**	**0.002**	**<0.001**
SOA.MOP	0.57	0.85	0.02	0.09	0.41	0.51
SOA.TSP	0.74	0.67	0.14	0.53	0.67	0.20
MOP.TSP	0.54	0.50	**0.04**	0.08	**0.03**	0.06
SOA.EFB	0.62	0.40	0.10	**0.005**	**0.01**	0.16
MOP.EFB	0.07	0.43	**<0.001**	**<0.001**	**0.02**	**0.002**
TSP.EFB	0.92	0.69	0.07	0.89	0.93	0.54
SOA.MOP.TSP	0.49	0.42	**0.04**	0.19	0.27	0.46
SOA.MOP.EFB	0.65	0.67	0.01	0.37	0.28	0.34
SOA.TSP.EFB	0.35	0.16	0.07	0.16	0.24	0.55
MOP.TSP.EFB	0.26	0.17	0.38	0.05	0.08	0.58
CV %	13.0	12.1	2.9	6.1	5.8	4.0

Table 4. Trial 502, impact on yield and its component by fertiliser treatments in 2006 and from 2004 to 2006 (three years of averaged data). P values less than 0.05 are presented in bold.

Treatments	**2006**			**2004 to 2006**		
	Yield kg/ha	**BNO bunch/palm**	**SBW kg**	**Yield kg/ha**	**BNO bunch/palm**	**SBW kg**
SOA0	**22.9**	7.3	**24.8**	**20.0**	**6.6**	**23.6**
SOA1	**29.1**	8.3	**28.2**	**24.5**	**7.2**	**27.1**
SOA2	**28.8**	8.0	**29.1**	**26.1**	**7.4**	**28.1**
SOA3	**28.8**	8.2	**28.0**	**26.1**	**7.6**	**27.3**
$LSD_{0.05}$	2.9	-	0.6	1.2	0.3	0.9
MOP0	**24.6**	7.5	**26.2**	**22.1**	**7.0**	**25.0**
MOP1	**28.2**	8.2	**27.5**	**24.9**	**7.4**	**26.8**
MOP2	**27.7**	7.9	**28.2**	**24.2**	**7.1**	**27.0**
MOP3	**29.0**	8.2	**28.4**	**25.7**	**7.5**	**27.3**
$LSD_{0.05}$	2.9	-	0.6	1.2	0.3	0.9
TSP0	26.7	7.7	27.7	24.0	7.1	26.7
TSP1	28.1	8.2	27.5	24.4	7.3	26.3
$LSD_{0.05}$	-	-	-	-	-	-
EFB0	**25.2**	7.7	**26.0**	**22.3**	**7.0**	**25.1**
EFB1	**29.6**	8.2	**29.0**	**26.0**	**7.4**	**27.9**
$LSD_{0.05}$	2.0	-	0.5	0.85	0.2	0.6

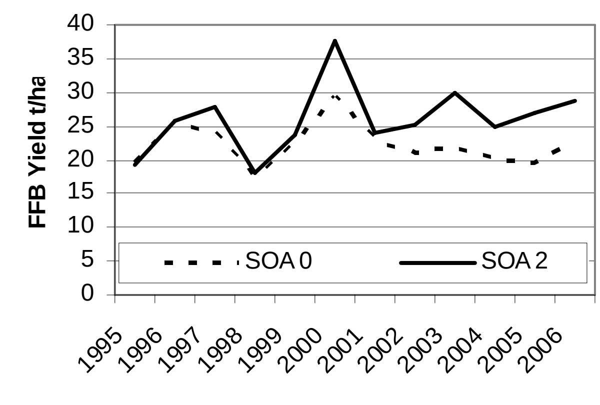
Yield trends since 1995 (commencement of trial)

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 5 t/ha/year between the zero and high rate of SOA application. 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 fertiliser).

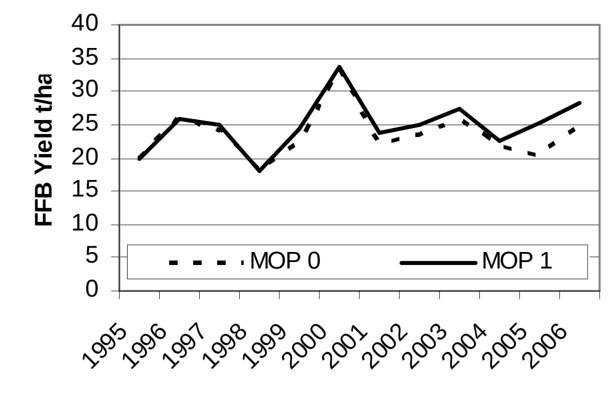
The impact of K fertiliser has only been showing over the last two years (Figure 1). K concentration is starting to decrease in the tissue (see next section) and it is expected that the K fertilized plots will see a growing yield gap from the zero K input plots.

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).

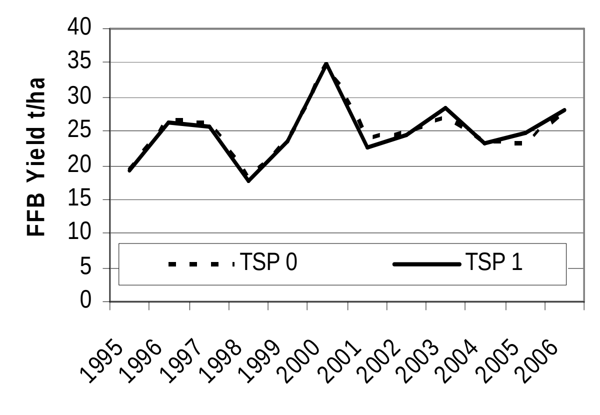
EFB started to make an impact on yield in 2002 (six years after application) and the yield response is continuing up to present (Figure 1).



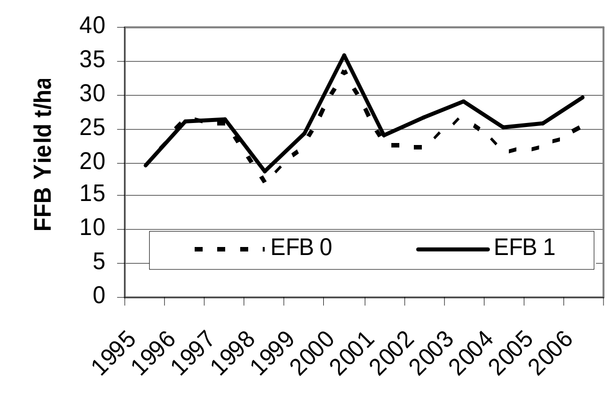
Yield (t/ha) over time for SOA level 0 and 2



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



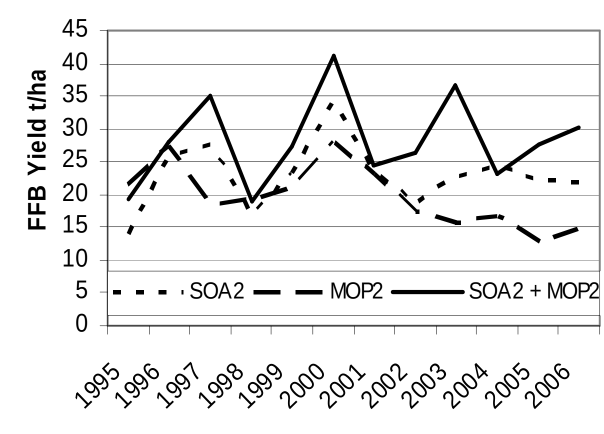
Yield (t/ha) over time for TSP level 0 and 1



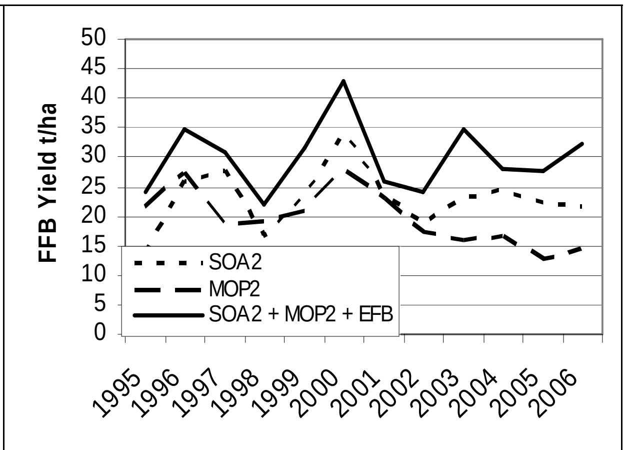
Yield (t/ha) over time for EFB level 0 and 1

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

Adding more than one fertiliser showed definite benefits (Figure 2) with the combination of N and K (as SOA + MOP) having a higher yield (8 to 20 t/ha more) 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 fertiliser was beneficial by adding another 3 to 4 t/ha to the yield (Figure 2).



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



Treatments: SOA2, MOP2, SOA2 + MOP2 + EFB

Figure 2. Trial 502, Yields of selected treatments illustrating the benefit of N + K and N + K + EFB.

Fertiliser effects on the leaflets and rachis nutrient concentrations

The impact of the fertiliser treatments on frond (leaflet and rachis) tissue nutrient concentration is presented in Tables 5 and 6.

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 N fertiliser, but adequate for those plots receiving SOA. N levels in the rachis averaged 0.27 (% dm) with very little variation in this level between treatments, in previous years there has been a significant effect of N fertiliser on rachis N levels. The results were rechecked by the laboratory and the values returned were similar to the original sample sent indicating the results are real.

The application of MOP significantly increased leaflet and rachis K to adequate 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 P and K concentrations.

Tissue levels of Mg were high and are not reported in the table. Levels of Boron were on average 15.5mg/kg and were not influenced by the current fertiliser treatments – Borate will be applied in 2007 as a basal.

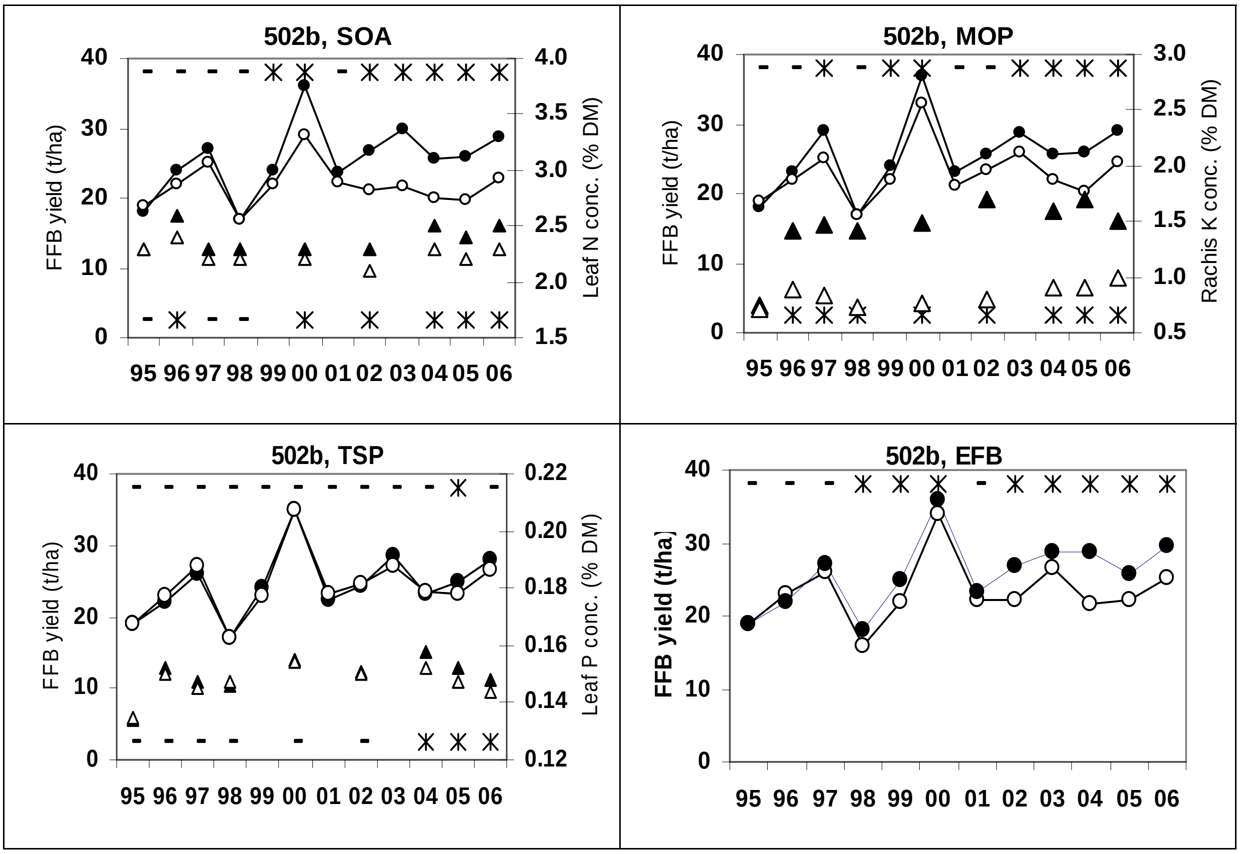
Table 5. Trial 502, effects (p values) of treatments on frond 17 nutrient concentrations in 2006**.** P values less than 0.05 are indicated in bold.

	Leaflet Nutrient Concentrations				Rachis Nutrient Concentrations		
Source	N	P	K		N	P	K
SOA	**<0.001**	0.81	0.33		0.23	**<0.001**	0.36
MOP	0.51	0.24	**<0.001**		**0.03**	0.12	**0.003**
TSP	0.37	**0.02**	0.18		0.26	**<0.001**	0.06
EFB	**<0.001**	0.35	**<0.001**		0.13	**0.05**	**0.01**
CV %	2.2	3.4	5.9		1.9	17.5	21.8

Table 6. Trial 502, main effects of treatments on frond 17 nutrient concentrations in 2006, 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	**2.26**	0.146	0.59	0.27	**0.180**	1.34
SOA1	**2.36**	0.147	0.58	0.28	**0.145**	1.36
SOA2	**2.40**	0.146	0.58	0.28	**0.104**	1.50
SOA3	**2.48**	0.147	0.57	0.27	**0.095**	1.31
LSD 0.05	*0.04*	-	-	-	*0.015*	-
MOP0	2.36	0.148	**0.51**	**0.27**	0.125	**1.04**
MOP1	2.38	0.147	**0.58**	**0.28**	0.127	**1.34**
MOP2	2.37	0.144	**0.60**	**0.27**	0.127	**1.58**
MOP3	2.39	0.145	**0.62**	**0.28**	0.145	**1.54**
LSD 0.05	-	-	*0.03*	*0.003*	-	*0.24*
TSP0	2.37	**0.144**	0.59	0.27	**0.105**	1.30
TSP1	2.38	**0.148**	0.57	0.28	**0.157**	1.46
LSD 0.05	-	*0.003*	-	-	*0.010*	-
EFB0	**2.32**	0.145	**0.54**	0.28	**0.124**	**1.25**
EFB1	**2.42**	0.146	**0.61**	0.27	**0.138**	**1.50**
LSD 0.05	*0.03*	-	*0.02*	-	*0.010*	*0.17*

Since 2000/2001 the application of N (as SOA), K (as MOP) and EFB has had significant impacts on yield, correspondingly the tissue concentrations of the specific nutrients were also higher with the input of these fertiliser sources (Figure 3). In 2000, as the leaflet N levels started to differentiate due to the application of N fertiliser 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 in 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 of the graph indicate significance of the main effect on yield	
Stars indicate significance (p<0.05)	Dashes= non-significance

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

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Fertiliser effects on oil palm vegetative growth

Summarized results for the vegetative growth parameters for 2006 are presented in Tables 7 and 8.

The main effect from fertiliser on vegetative growth was from an increase in frond size (Petiole Cross Section and frond size parameters) rather than from an increase in frond production. Hence regardless of the fertiliser regime applied, the increase in radiation interception came about from frond size not from an increase in frond number produced (the effect of SOA from 0 to 6kg/palm on frond production was on average an increase of 0.9 fronds/palm).

N fertiliser had the largest impact on vegetative growth, followed by EFB. MOP had the main influence on frond size, expressed as Frond Area. Overall TSP had little or no impact on the growth parameters assessed.

Table 7. Effect (p values) of treatments on vegetative growth parameters in 2006. P values < 0.05 are in bold.

Fertiliser Source	PCS	Radiation Interception				Dry Matter Production (t/ha)			
		GF	FP	FA	LAI	FDM	BDM	TDM	VDM
SOA	**<0.001**	0.30	**0.05**	**<0.001**	**0.02**	**<0.001**	**0.004**	**<0.001**	**<0.001**
MOP	0.15	0.63	0.21	**0.003**	0.38	**0.05**	0.08	**0.02**	**0.03**
TSP	0.36	0.13	0.45	0.47	0.12	0.66	0.25	0.31	0.87
EFB	**<0.001**	0.67	0.61	**<0.001**	**0.02**	**<0.001**	**0.001**	**<0.001**	**<0.001**
SOA.MOP	0.90	0.41	**0.05**	0.09	0.45	0.26	0.67	0.36	0.22
SOA.TSP	0.74	0.87	0.41	0.29	0.86	0.86	0.72	0.73	0.87
MOP.TSP	0.39	0.37	0.13	0.08	0.92	0.70	0.76	0.57	0.64
SOA.EFB	0.14	0.87	0.29	**0.03**	0.37	0.13	0.48	0.11	0.09
MOP.EFB	0.42	0.54	0.91	0.10	0.36	0.41	0.09	**0.04**	0.20
TSP.EFB	0.97	0.96	0.34	0.70	0.76	0.54	0.67	0.75	0.63
SOA.MOP.TSP	0.78	0.41	0.50	0.16	0.58	0.62	0.43	0.41	0.65
SOA.MOP.EFB	0.99	0.76	0.15	0.88	0.75	0.52	0.82	0.53	0.46
SOA.TSP.EFB	0.78	0.42	0.20	0.50	0.41	0.73	0.38	0.56	0.87
MOP.TSP. EFB	0.80	0.32	0.13	**0.01**	0.81	0.28	0.23	0.12	0.23
CV %	6.7	5.4	3.8	2.8	6.7	6.8	13.6	7.2	2.8

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

Table 8. Main effects of treatments on vegetative growth parameters in 2006. 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	**43.6**	33.8	**19.2**	**13.1**	**5.6**	**11.3**	**12.1**	**26.0**	**13.9**
SOA1	**48.6**	33.6	**19.8**	**13.6**	**5.8**	**13.0**	**15.2**	**31.4**	**16.1**
SOA2	**51.3**	34.3	**19.9**	**14.0**	**6.1**	**13.8**	**15.1**	**32.0**	**17.0**
SOA3	**50.6**	34.8	**20.1**	**13.8**	**6.1**	**13.7**	**15.3**	**32.1**	**16.9**
$LSD_{0.05}$	*2.6*	-	*0.6*	*0.3*	*0.3*	*0.7*	*1.6*	*1.8*	*0.8*
MOP0	47.0	34.5	19.6	**13.2**	5.8	**12.5**	13.2	**28.5**	**15.3**
MOP1	48.0	34.3	19.6	**13.7**	6.0	**12.7**	15.0	**30.7**	**15.7**
MOP2	49.7	34.1	20.1	**13.9**	6.0	**13.5**	14.5	**31.1**	**16.6**
MOP3	49.4	33.7	19.7	**13.7**	5.9	**13.1**	15.1	**31.3**	**16.3**
$LSD_{0.05}$	-	-	-	*0.3*	-	0.7	-	1.8	0.8
TSP0	48.9	33.7	19.7	13.6	5.8	13.0	14.1	30.1	16.0
TSP1	48.2	34.5	19.8	13.7	6.0	12.9	14.7	30.7	16.0
$LSD_{0.05}$	-	-	-	-	-	-	-	-	-
EFB0	**46.2**	34.0	19.7	**13.3**	**5.8**	**12.3**	**13.2**	**28.3**	**15.2**
EFB1	**50.9**	34.2	19.8	**13.9**	**6.1**	**13.6**	**15.6**	**32.4**	**16.8**
$LSD_{0.05}$	*1.8*	-	-	*0.2*	*0.2*	*0.5*	*1.6*	*1.3*	*0.6*

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 and DISCUSSION (Part 2 – Trial 511)

Yield and other components response to fertiliser treatments

Yield and its components of bunch number and bunch weight are presented for 2006 and for the average yield from 2004 to 2006, in Tables 9 and 10.

2006

N fertiliser: Strong response to N fertiliser continued into 2006 and the yield gap between no N and N fertiliser was approximately 9 t/ha. Both the number of bunches produced and the bunch weight responded positively to N fertiliser (with the largest effect from N fertiliser being on bunch weight).

K fertiliser: In 2006, the response to K was not significant with a yield increase of approximately 3 t/ha from MOP. There were no significant responses in bunch number or bunch weight from MOP.

P fertiliser: In 2006 there was a significant response to P fertiliser (as TSP) with a yield increase of 4 t/ha. Both bunch number and bunch weight responded positively to P fertiliser.

EFB: The response to EFB was highly significant, with a 7 t/ha increase in yield, primarily due to a large increase in bunch weight.

2004 to 2006

The three year, 2004 to 2006, average yield and its components were calculated to smooth out the yearly yield fluctuations resulting from different weather conditions and possible management effects.

The fertiliser responses seen in the 2004 to 2006 averaged data is essentially the same as for the 2006 data indicating that the responses seen and discussed for 2006 are real.

Table 9. Trial 511, effect (p values) of treatments on FFB yield and its components in 2006 and from 2004 to 2006 (three years of averaged data). P values less than 0.05 are presented in bold.

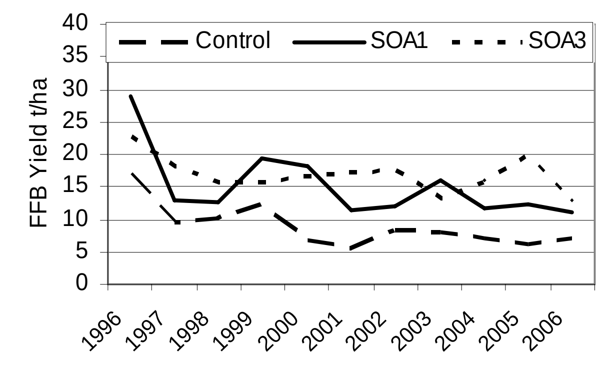
	2006			**2004 to 2006**		
Source	**Yield**	**BNO**	**SBW**	**Yield**	**BNO**	**SBW**
SOA	**<0.001**	0.06	**0.002**	**<0.001**	**0.005**	**<0.001**
MOP	0.09	0.21	0.87	0.12	0.21	0.89
TSP	**0.003**	**0.05**	**0.02**	**0.001**	**0.03**	**<0.001**
EFB	**<0.001**	0.06	**<0.001**	**<0.001**	**<0.001**	**<0.001**
SOA.MOP	0.46	0.71	0.77	0.46	0.75	0.57
SOA.TSP	0.29	0.50	0.30	0.56	0.86	**0.03**
MOP.TSP	0.52	0.82	0.56	0.57	0.57	0.61
SOA.EFB	0.43	0.43	0.09	0.14	0.29	**0.004**
MOP.EFB	0.20	0.24	0.51	0.42	0.51	0.10
TSP.EFB	0.53	0.95	0.11	0.26	0.67	**0.03**
SOA.MOP.TSP	0.80	0.85	0.88	0.81	0.95	0.34
SOA.MOP.EFB	0.37	0.61	0.68	0.44	0.78	0.23
SOA.TSP.EFB	0.55	0.61	0.73	0.94	0.99	0.81
MOP.TSP.EFB	0.22	0.38	0.83	0.53	0.65	0.68
CV %	19.4	22.9	12.2	12.2	15.8	6.4

Table 10. Trial 511, impact on yield and its component by fertiliser treatments in 2006 and from 2004 to 2006 (three years of averaged data). P values less than 0.05 are presented in bold.

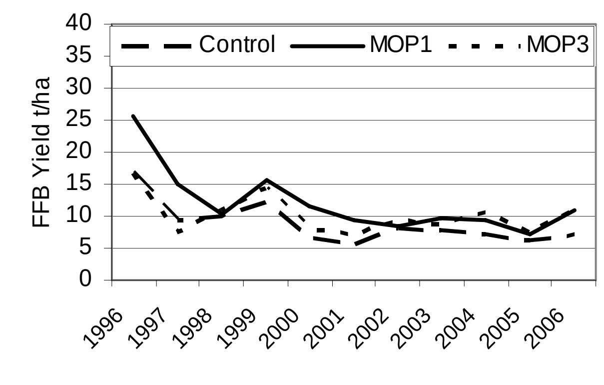
Treatments	2006			2004 to 2006		
	Yield kg/ha	BNO bunch/palm	SBW kg	Yield kg/ha	BNO bunch/palm	SBW kg
SOA0	**16.4**	6.2	**20.9**	**15.6**	**6.1**	**19.6**
SOA1	**19.3**	6.5	**23.8**	**19.0**	**6.6**	**22.5**
SOA2	**22.4**	6.7	**26.7**	**23.4**	**7.4**	**24.7**
SOA3	**25.9**	7.9	**26.3**	**25.6**	**8.1**	**25.0**
$LSD_{0.05}$	3.3	-	2.4	2.5	0.9	1.2
MOP0	18.6	6.1	24.1	19.2	6.5	22.8
MOP1	20.7	6.8	24.2	20.7	7.1	22.8
MOP2	22.6	7.3	24.9	22.0	7.4	23.1
MOP3	22.1	7.1	24.5	21.6	7.2	23.1
$LSD_{0.05}$	-	-	-	-	-	-
TSP0	**18.9**	**6.4**	**23.3**	**19.0**	**6.7**	**22.0**
TSP1	**23.1**	**7.3**	**25.5**	**22.8**	**7.4**	**23.9**
$LSD_{0.05}$	2.4	0.9	1.7	1.8	0.6	0.8
EFB0	**17.4**	6.4	**21.4**	**16.7**	**6.3**	**20.4**
EFB1	**24.7**	7.3	**27.5**	**25.1**	**7.8**	**25.5**
$LSD_{0.05}$	2.4	-	1.7	1.8	0.6	0.8

Yield trends since 1996 (commencement of trial)

There is some response to N fertiliser at this site when applied by itself (ie without other fertilisers 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 3 is between 15 and 20 t/ha, whereas for K when applied alone, all treatments yielded less than 10t/ha.



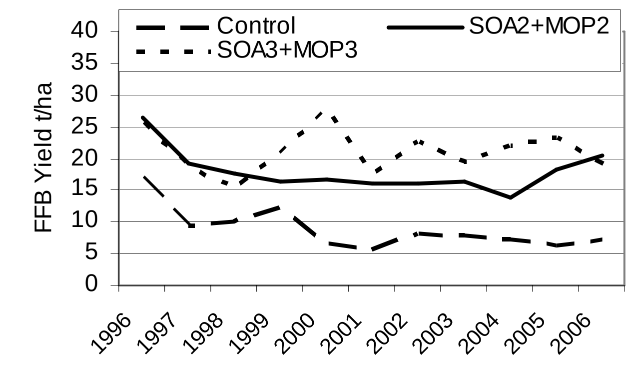
Trial 511. Response to N (as SOA)



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)

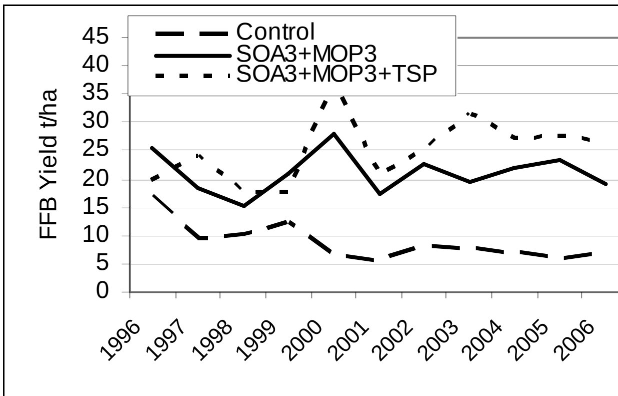
When N and K are combined (SOA + MOP) there is a significant improvement in yield. For the combined fertiliser applications yields regularly achieved around 25t/ha (for SOA and MOP both applied at level 3 see Figure 5).



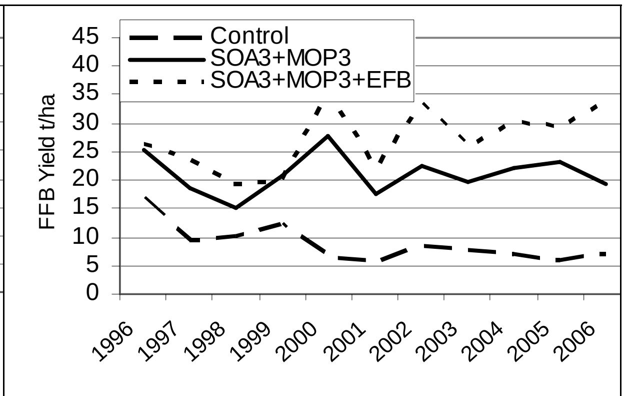
Trial 511. Response to N + K (SOA + MOP)

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 fertiliser applied in the trial.

Fertiliser effects on Frond 17 nutrient concentrations

The impact of the fertiliser 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 and K concentration in the rachis (probably through mobilization of P and K out of the rachis). Leaflet concentration of N is low for those plots not receiving SOA, but adequate for those plots receiving N fertiliser.

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

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

Tissue levels of Mg were high and are not reported in the table. Levels of Boron are relatively low at 12.1 mg/kg and Borate will be applied in 2007 as a basal fertiliser.

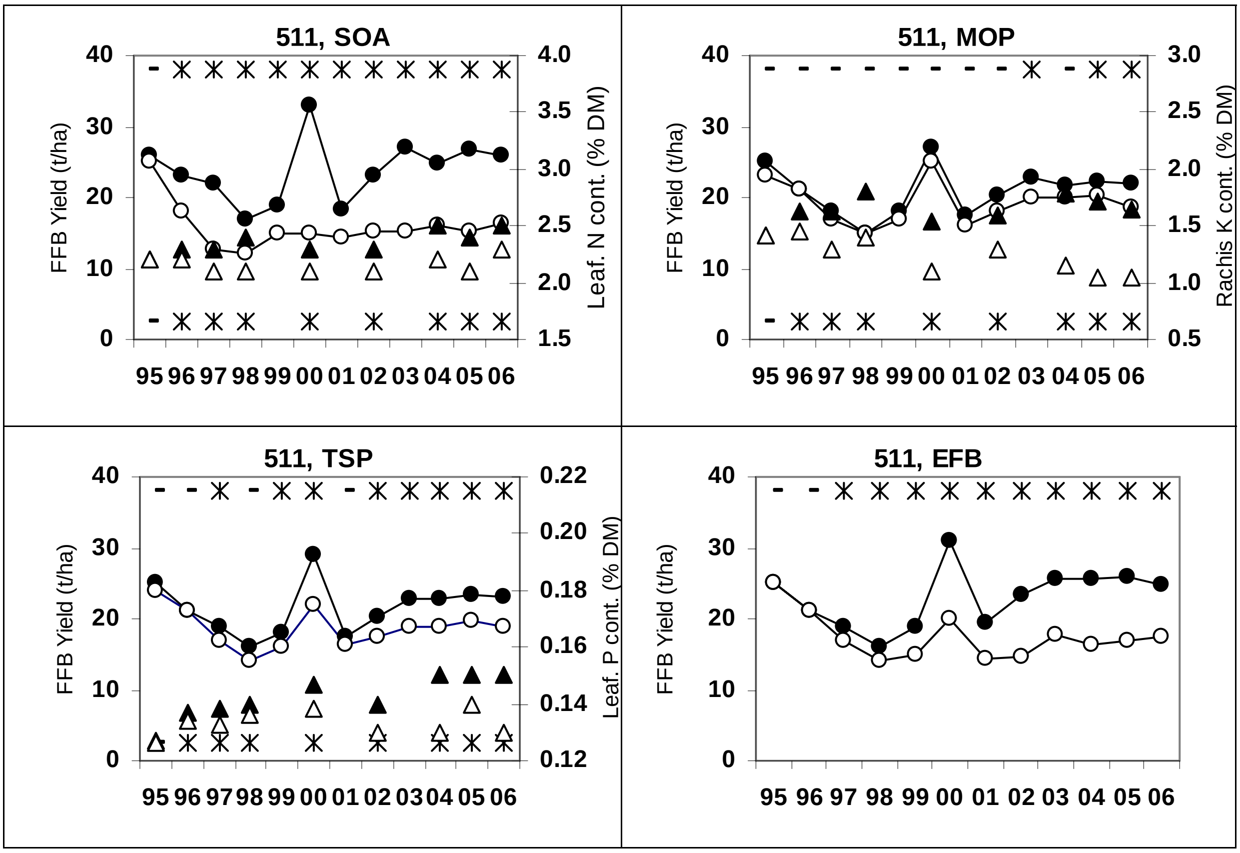
Table 11. Trial 511, effects (p values) of treatments on frond 17 nutrient concentration in 2006**.** P values less than 0.05 are indicated in bold.

Source	Leaflet Nutrient Concentration				Rachis Nutrient Concentration		
	N	**P**	**K**		**N**	**P**	**K**
SOA	**<0.001**	0.22	0.52		0.40	**<0.001**	**0.05**
MOP	0.76	0.25	**0.04**		0.50	0.14	**<0.001**
TSP	0.08	**<0.001**	0.45		0.84	**<0.001**	**0.02**
EFB	**<0.001**	**<0.001**	**0.003**		0.32	0.46	**0.004**
CV %	5.2	3.7	13.3		2.2	13.1	14.8

Table 12. Trial 511, main effects of treatments on frond 17 nutrient concentrations in 2006, in units of dry matter %. . P values less than 0.05 are indicated in bold.

Source	Leaflet Nutrient Concentration %				Rachis Nutrient Concentration %		
	N	**P**	**K**		**N**	**P**	**K**
SOA0	**2.15**	0.139	0.67		0.27	**0.127**	**1.65**
SOA1	**2.28**	0.141	0.66		0.27	**0.082**	**1.43**
SOA2	**2.38**	0.143	0.70		0.27	**0.070**	**1.46**
SOA3	**2.45**	0.140	0.69		0.27	**0.056**	**1.41**
LSD $_{0.05}$	*0.10*	-	-		-	*0.009*	*0.18*
MOP0	2.31	0.139	**0.62**		0.27	0.078	**1.05**
MOP1	2.30	0.141	**0.68**		0.27	0.088	**1.58**
MOP2	2.34	0.142	**0.71**		0.27	0.084	**1.67**
MOP3	2.33	0.142	**0.72**		0.27	0.085	**1.65**
LSD $_{0.05}$	-	-	*0.07*		-	-	*0.18*
TSP0	2.29	**0.134**	0.69		0.27	**0.043**	**1.57**
TSP1	2.35	**0.148**	0.67		0.27	**0.124**	**1.41**
LSD $_{0.05}$	-	*0.003*	-		-	*0.006*	*0.13*
EFB0	**2.24**	**0.136**	**0.63**		0.27	0.083	**1.38**
EFB1	**2.40**	**0.146**	**0.73**		0.27	0.085	**1.60**
LSD $_{0.05}$	*0.07*	*0.003*	*0.05*		-	-	*0.13*

Since year 1 of the trial in 1996, the application of N (as SOA) has had a significant impact on yield, which corresponded with higher tissue N concentration (Figure 7). The effect of MOP on yield has only been evident in the last few years even though the 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 1997 (Figure 7).



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

Legend:

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

Fertiliser effects on oil palm vegetative growth

Summarized results for vegetative growth parameters for 2006 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 fertiliser resulted in an increase in frond production of one frond per year (22 to 23 new fronds produced per year).

N fertiliser had the largest impact on vegetative growth, followed by EFB and TSP. 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 2006. P values < 0.05 are in bold.

Fertiliser Source	PCS	Radiation Interception				Dry Matter Production (t/ha)			
		GF	FP	FA	LAI	FDM	BDM	TDM	VDM
SOA	**<0.001**	0.08	**0.006**	**0.03**	**0.01**	**<0.001**	**<0.001**	**<0.001**	**<0.001**
MOP	0.84	050	0.11	0.58	0.41	0.83	0.08	0.17	0.68
TSP	**0.002**	0.27	0.55	0.22	0.12	**0.004**	**0.003**	**0.002**	**0.003**
EFB	**<0.001**	0.22	**<0.001**	0.06	**0.03**	**<0.001**	**<0.001**	**<0.001**	**<0.001**
SOA.MOP	0.45	0.38	0.35	0.76	0.76	0.56	0.39	0.68	0.62
SOA.TSP	**0.05**	0.83	**0.05**	0.48	0.48	0.05	0.31	0.20	0.07
MOP.TSP	0.33	0.70	0.13	0.97	0.96	0.21	0.58	0.31	0.21
SOA.EFB	0.08	0.66	0.15	0.35	0.28	0.09	0.37	0.23	0.11
MOP.EFB	0.20	0.27	0.96	0.87	0.65	0.28	0.12	0.22	0.29
TSP.EFB	0.51	0.96	0.76	0.10	0.09	0.51	0.56	0.51	0.50
SOA.MOP.TSP	0.78	0.78	0.56	0.76	0.60	0.72	0.88	0.86	0.76
SOA.MOP.EFB	0.38	0.76	0.39	0.95	0.89	0.37	0.34	0.38	0.39
SOA.TSP.EFB	0.25	0.91	0.51	0.61	0.49	0.26	0.46	0.68	0.35
MOP.TSP. EFB	0.97	0.34	0.36	0.48	0.62	0.96	0.33	0.59	0.96
CV %	6.5	4.5	3.6	20.1	20.8	10.2	19.0	12.6	10.3

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 2006. 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	**40.2**	32.0	**20.8**	**10.4**	**4.3**	**11.4**	**8.9**	**22.6**	**13.7**
SOA1	**45.2**	31.8	**21.0**	**11.8**	**4.8**	**12.9**	**10.4**	**25.9**	**15.5**
SOA2	**48.8**	33.3	**21.7**	**13.3**	**5.6**	**14.5**	**12.2**	**29.6**	**17.5**
SOA3	**51.6**	32.7	**22.0**	**13.8**	**5.8**	**15.3**	**14.0**	**32.5**	**18.6**
$LSD_{0.05}$	*3.3*	-	*0.6*	*2.3*	*0.9*	*1.6*	*1.8*	*2.8*	*1.4*
MOP0	46.2	32.2	21.3	11.8	4.9	13.4	10.0	25.9	16.0
MOP1	46.9	32.9	21.0	12.4	5.2	13.4	11.3	27.4	16.2
MOP2	46.4	32.6	21.8	13.1	5.4	13.8	12.2	28.8	16.6
MOP3	47.4	32.2	21.3	11.9	4.9	13.7	11.9	28.5	16.6
$LSD_{0.05}$	-	-	-	-	-	-	-	-	-
TSP0	**44.5**	32.2	21.3	11.9	4.9	**12.9**	**10.2**	**26.7**	**15.5**
TSP1	**48.9**	32.7	21.4	12.8	5.3	**14.3**	**12.5**	**29.7**	**17.2**
$LSD_{0.05}$	*2.4*	-	-	-	-	*0.8*	*1.2*	*2.0*	*1.0*
EFB0	**41.4**	32.3	**20.8**	11.6	**4.8**	**11.8**	**9.4**	**23.5**	**14.1**
EFB1	**52.0**	32.7	**22.0**	13.1	**5.4**	**15.4**	**13.3**	**31.8**	**18.6**
$LSD_{0.05}$	*2.4*	-	*0.4*	-	*0.6*	*0.8*	*1.2*	*2.0*	*1.0*

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 Trials 502 and 511

The highest yield obtained at both sites was 35 t/ha. Due to an overall inherent lower soil fertility status in trial 511 compared to 502, the fertiliser rates required to achieve these high yields were higher in trial 511. At both sites, a combination of N and K fertiliser was required to optimize yield, at trial 511 P was also required.

The N, K and EFB fertiliser 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 7mg/kg in trial 502; and only 2 to 3mg/kg in trial 511).

To some extent EFB can replace inorganic fertiliser, 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 fertiliser 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 2006 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 and Potassium Trial at 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 fertiliser. Soils in this area are of recent alluvial origin, with 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).

After 11 years, the mean FFB yield was 29.5 t/ha with an average 9.3 bunches/palm and a single bunch weight of 25.2 kg. FFB yield, frond 17 nutrient concentration and vegetative growth parameters responded well to the fertiliser treatments, especially to SOA as the N source. N drives production in this estate.

FFB yields have increased from 23.8 t/ha in 2004, 26.7 t/ha in 2005 to 29.5 t/ha in 2006, an increase of some 2.0 t/ha/year.

Although the main effect of MOP on yield was not significant (p=0.07) the highest yields with over 30t/ha were obtained from a combination of N and K fertiliser. In 2006 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). Fertiliser was first applied in 1994. Fertilisers are applied in 3 doses per year.

No basal was applied in 2006.

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

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

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

Trial data were 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 fertiliser treatments

Treatment effects on FFB yield and other components are shown in Tables 3 and 4. The overall effect of the treatments, over the course of the trial, is illustrated in Figure 1. 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 and continued into 2006 compared to the previous years. The effect of K fertiliser on yield, although significant from 2004 to 2006, is less marked compared to N fertiliser. The combination of both fertilisers resulted in the highest yields highlighting the importance of N and K nutrition on this soil type.

In 2006, 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 had less of an impact on yield ($p=0.07$) and this was brought about by a positive effect on SBW ($p=0.06$) and not by bunch number.

Table 3. Effect (p values) of treatments on FFB yield and its components for 2006 and 2004 to 2006 (3 years averaged data). P values less than 0.05 are presented in bold.

	2006			2004 to 2006		
Source	**Yield**	**BNO**	**SBW**	**Yield**	**BNO**	**SBW**
SOA	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**
MOP	0.07	0.44	0.06	**0.001**	**0.04**	**0.007**
SOA.MOP	0.92	0.84	0.44	0.85	0.89	0.45
CV %	11.9	11.3	5.2	8.5	4.2	7.3

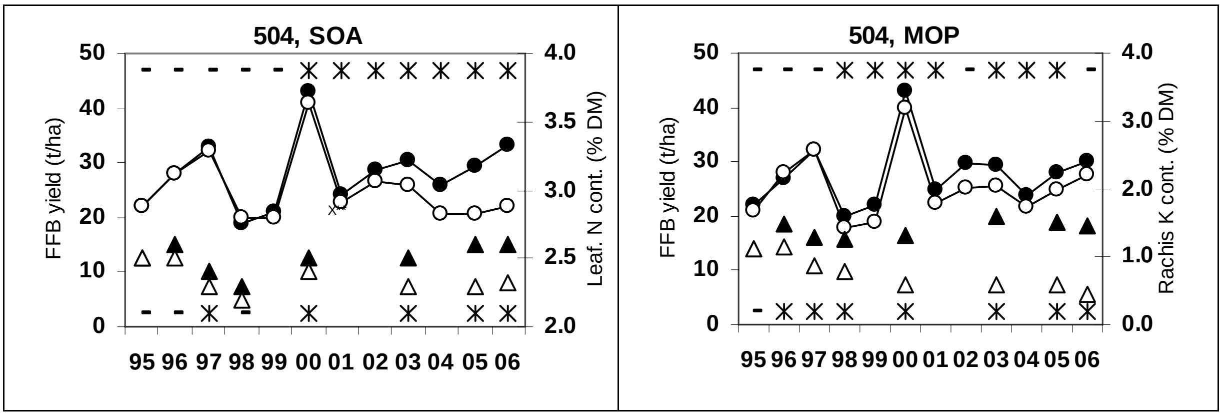
Table 4. Main effects of treatments on FFB yield (t/ha) and its components for 2006 and 2004 to 2006 (three years averaged data). P values less than 0.05 are presented in bold.

	2006			2004 to 2006		
	Yield (t/ha)	BNO (b/palm)	SBW (kg)	Yield (t/ha)	BNO (b/palm)	SBW (kg)
SOA0	**22.2**	**7.6**	**23.1**	**21.2**	**7.5**	**22.3**
SOA1	**29.5**	**9.2**	**25.6**	**26.5**	**8.6**	**24.4**
SOA2	**32.9**	**9.9**	**26.2**	**29.4**	**9.4**	**24.6**
SOA3	**33.3**	**10.2**	**26.0**	**29.6**	**9.5**	**24.5**
MOP0	27.5	8.9	24.5	**24.7**	**8.4**	**23.2**
MOP1	30.0	9.4	25.4	**26.9**	**8.8**	**24.1**
MOP2	30.6	9.4	25.7	**28.0**	**9.0**	**24.4**
MOP3	29.9	9.4	25.4	**27.2**	**8.9**	**24.2**
$LSD_{0.05}$	*1.2*	*0.3*	*0.5*	*1.6*	*0.4*	*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 2006. The treatment interaction is not significant.

SOA by MOP				
	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



Legend:

Lines = FFB yields	Triangles = tissue concentrations
Full symbols = maximum level of application	Empty symbols = zero application
Symbols at top of the graph indicate significance of the main effect on yield	
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.

Fertiliser effects on Frond 17 nutrient concentrations

N and K fertiliser had a significant impact on tissue nutrient concentration (Tables 6 and 7). SOA application resulted in reduced levels of K and Mg in the leaflets, whilst N and P levels increased. 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 on the low side with the zero N treatment and adequate at higher rates
- P and Mg levels in leaflets were adequate
- K levels were low in the leaflet for the zero K treatment and adequate at higher rates
- B levels were generally low
- N fertiliser mobilized P and K out of the rachis
- K in the rachis was very low for the zero MOP treatment

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

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

Source	**Leaflet nutrient concentration**					**Rachis nutrient concentration**		
	N	**P**	**K**	**Mg**	**B**	**N**	**P**	**K**
SOA	**<0.001**	**<0.001**	**0.017**	**<0.001**	**0.05**	**0.003**	**<0.001**	**<0.001**
MOP	0.31	0.08	**<0.001**	**<0.001**	**0.003**	0.52	**<0.001**	**<0.001**
SOA.MOP	0.12	0.27	0.1	0.88	0.65	0.54	0.19	0.34
CV %	3.0	2.2	5.4	7.2	8.3	2.5	18.0	11.8

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, except B (ppm).

Source	**Leaflet nutrient concentration**					**Rachis nutrient concentration**		
	N	**P**	**K**	**Mg**	**B**	**N**	**P**	**K**
SOA0	**2.32**	**0.155**	**0.67**	**0.36**	**13**	**0.27**	**0.214**	**1.27**
SOA1	**2.43**	**0.159**	**0.68**	**0.33**	**14**	**0.27**	**0.160**	**1.10**
SOA2	**2.57**	**0.160**	**0.67**	**0.32**	**13**	**0.28**	**0.111**	**1.00**
SOA3	**2.60**	**0.161**	**0.64**	**0.32**	**13**	**0.28**	**0.095**	**1.00**
MOP0	2.49	0.161	**0.59**	**0.36**	**14**	0.27	**0.118**	**0.45**
MOP1	2.46	0.158	**0.65**	**0.34**	**14**	0.27	**0.151**	**1.06**
MOP2	2.51	0.159	**0.71**	**0.32**	**13**	0.27	**0.149**	**1.36**
MOP3	2.48	0.159	**0.72**	**0.31**	**13**	0.27	**0.162**	**1.45**
$LSD_{0.05}$	*0.05*	*0.002*	*0.03*	*0.02*	*1*	*0.01*	*0.019*	*0.09*

Fertiliser effects on vegetative growth parameters in 2006

Tables 8 and 9 present the fertiliser effects on vegetative growth parameters. Increasing rates of SOA had a positive and significant effect on the petiole cross section (p=<0.001) and Frond dry matter production (p=<0.001). With the addition of SOA, frond dry matter production increased by more than 1.0 kg/frond (an increase of 10%).

Table 8. Effect (p values) of treatments on vegetative growth parameters in 2006. p values less than 0.05 are in bold.

Source	Height	PCS	Radiation Interception				Dry Matter Production (t/ha)			
			GF	FP	FA	LAI	FDM	BDM	TDM	VDM
SOA	0.20	**<0.001**	0.23	0.13	0.39	0.14	**<0.001**	**<0.001**	**<0.001**	**<0.001**
MOP	0.06	**0.004**	0.19	0.28	0.44	0.37	**0.003**	0.07	**0.002**	**0.002**
SOA.MOP	0.88	0.63	0.13	0.05	0.68	0.67	0.33	0.92	0.68	0.36
CV %	4.5	6.5	4.5	4.8	14.7	14.2	8.2	11.9	7.8	7.9

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

Table 9. Main effects of treatments on vegetative growth parameters in 2006. Significant effects ($p<0.05$) are shown in bold.

Source			Radiation Interception				Dry Matter Production (t/ha)			
	Height	PCS	GF	FP	FA	LAI	FDM	BDM	TDM	VDM
SOA0	8.87	**50.9**	32.6	22.3	12.7	5.3	**15.2**	**11.8**	**30.0**	**18.3**
SOA1	8.95	**56.1**	33.2	22.2	13.1	5.5	**16.9**	**15.6**	**36.2**	**20.5**
SOA2	9.11	**58.6**	33.5	22.9	13.9	5.9	**18.0**	**17.5**	**39.5**	**22.0**
SOA3	9.13	**58.6**	32.6	23.1	13.0	5.4	**18.1**	**17.7**	**39.9**	**22.1**
MOP0	9.22	**53.2**	32.5	22.4	12.8	5.3	**16.0**	14.6	**33.9**	**19.4**
MOP1	9.08	**56.6**	33.6	22.5	12.9	5.5	**17.1**	15.9	**36.6**	**20.8**
MOP2	8.91	**58.1**	33.9	23.1	13.8	5.8	**18.0**	16.2	**38.0**	**21.8**
MOP3	8.85	**56.3**	32.9	22.7	13.3	5.5	**17.1**	15.8	**37.0**	**20.9**
$LSD_{0.05}$	-	2.6	-	-	-	-	1.0	1.3	2.0	1.2

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).

Nutrient Use Efficiency

Nutrient Use Efficiency (NUE) investigates the efficiency at which nutrients applied as fertiliser 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 fertiliser (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)

For trial 504 we did not have (i) nutrient analysis for bunches produced in different treatments; and (ii) trunk incremental growth. To calculate NUE we had to assume that nutrient concentrations in bunches between treatments was the same; and that trunk growth between treatments and nutrients stored in the trunk were the same for different treatments. In 2007 we will be measuring these parameters for selected trials and treatments to get a more accurate estimate of NUE in different regions, soils and trials.

NUE can be expressed as Recovery Efficiency (RE) which is the efficiency of uptake of an applied nutrient either applied by itself or in combination with other nutrients.

NUE of trial 504 in 2006 (also see table 10):

- Control treatment (no fertiliser) had a yield of 20.8 t/ha which together with the new fronds produced contained 255 kg N/ha and 214 kg K/ha (this is supplied by the soil without the addition of fertiliser, in other words this is the native or indigenous nutrient supply);
- When K was applied in the absence of N, the amount of K in the bunches and new fronds went up to 300 kg K/ha (compared to 214 kg K/ha in the native state). The fertiliser rate applied was 324 kg of K/ha, the Recovery Efficiency is 23% (only one quarter of the applied K has been taken up by the palm);
- When N was applied in the absence of K, the amount of N in the bunches and new fronds went up to 330 kg N/ha (compared to 225 kg N/ha in the native state). The fertiliser rate applied was 107 kg of N/ha, the Recovery Efficiency is 70% (nearly three quarters of the applied N has been taken up by the palm);
- When both N and K were applied at the same rate as above the uptake of N increased to 393 kg N/ha (compared to 255 kg N/ha in the native state) and for K the uptake increased to 398 kg K/ha (compared to 214 kg K/ha in the native state). Which equates to a Recovery Efficiency for N of 130% and for K 44%.

The uptake of applied fertiliser N is much more efficient compared to the uptake of fertiliser K (RE of 70 vs 23%). When both fertilisers were applied the efficiency of uptake increased dramatically to a RE of 130% and 44% for N and K respectively. The RE of 130% for N means that there is more N in the fronds and bunches than had been applied for this treatment – this indicates that N is possibly mobilized out of the trunk because of the better growing conditions enjoyed in this treatment.

Table 10. Nutrient Use Efficiency for selected fertiliser treatments calculated as RE (Recovery Efficiency).

Fertiliser applied		**FFB**	**FFB**		**Tissue**		**RE (% of applied fertiliser)**	
N kg/ha	**K kg/ha**	**t/ha**	**kg N/ha**	**kg K/ha**	**kg N/ha**	**kg K/ha**	**N**	**K**
0	0	20.8	97	112	158	102	-	-
0	324	23.7	111	128	175	202	-	23
107	0	30.9	144	166	185	71	70	-
107	324	35.0	163	188	230	210	130	44

CONCLUSION

N fertiliser, applied as SOA, was the main driver of production in this trial. N treatments resulted in higher concentrations of N in the 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 fertiliser, applied as MOP, is becoming more important over time as K levels are dropping in the zero MOP plots. Palms in these plots have low rachis and leaflet K levels.

Highest yield 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 relatively low for applied K. NUE increased dramatically for both nutrients when applied in combination – probably due to improved growing conditions (closer to optimum nutrient supply).

Other Nutrient Work At MBE

Trial 512: Monitoring of Mill Waste Product Treated Areas

SUMMARY

POME (Palm Oil Mill Effluent) and decanter cake have had positive effects on FFB yield and tissue nutrient concentration. In 2006, yield from the blocks receiving no POME remained at 17 t/ha while the POME treated blocks maintained FFB production at between 22 to 25 t/ha. Leaflet levels of N and P were higher in the POME treated blocks, whilst rachis K was substantially higher in the POME treated blocks.

The three blocks used in this trial are due for replanting in 2007 and this was the last year of experimentation. Before the blocks are felled a full soil sampling will be undertaken to assess whether soil conditions have changed markedly over the last 11 years of POME and decanter cake application.

INTRODUCTION

Trial 512 was established to determine the effect of POME and decanter cake on oil palm growth and soil properties. The trial commenced in 1995. Three blocks were selected in this study; two of these are receiving POME and decanter cake while an area in the third block receives no POME or decanter cake (this area is treated as the control). Plantations have been applying POME and decanter cake to some of their field blocks, however, there is little knowledge or understanding on the effects (either positive or negative) of this on palm growth, yield, tissue nutrients and soil properties (chemical and physical) in PNG. It is anticipated that the results generated from this study will give some basic understanding of the impact of using POME and decanter cake on production and soil condition.

METHODS

Trial Background Information

Table 1. Trial 512 background information.

Trial number	**512**	Company	CTP Milne Bay Estates
Estate	Hagita/Waigani	Block No.	See trial description
Planting Density	128 palms/ha	Soil Type	Clays (alluvium); OMP8=D
Pattern	Triangular	Drainage	Moderate
Date planted	1986	Topography	Flat
Age after planting	21 years	Altitude	20 m asl
Recording Started	1995 and 1997	Previous Landuse	Ex-Forest/coconut plantation
Planting material	Dami D x P	Area under trial soil type (ha)	3057
Progeny	unknown	Agronomist in charge	Steven Nake

Experimental Design and Treatments

Three areas, similar in soil type and topography, but with different histories of POME application (Table 2) were selected and monitored for POME effects since 1995. A 4 ha area in block 6306 is treated as the control as this area has not received POME or decanter cake at any time.

Table 2. Location and treatment of the monitored areas.

Estate	Block	Code	Treatment	Area (ha)
Waigani	6602	POME W	Received POME since 1995	58
Hagita	6304	POME H	Received POME since 1998, but not prior	50
Hagita	6306	No POME	No POME application	4

Trial Maintenance and Upkeep

Similar to other PNG OPRA trials, Waigani and Hagita estates take charge of the general upkeep of the block, which includes the POME and decanter cake application and harvesting. The trial is fertilized on a palm basis with fertilisers and rates recommended by MBE (Table 3). The amount of POME and decanter cake applied is also listed in Table 3.

Table 3. Fertilisers applied in 2006 by MBE.

Estate	Block	Abbreviation	Urea (kg/palm)	MOP (kg/palm)	TSP (kg/palm)	POME t/ha	Decanter cake t/ha
Waigani	6602	POME W	2.1	3	0.5	9.0	13.9
Hagita	6304	POME H	2	3	2	23.3	7.8
Hagita	6306	No POME	2	3	-	-	-

Data Collection

Yields are obtained by physical weighing of bunches and recording bunch number in the 4 ha control plot in Block 6306. The approximate yields, using fruit truck delivery weights, from blocks 6602 and 6304 are obtained from plantation records.

Leaf tissue samples are also taken from 10 selected palms in each block to investigate the effects of the treatments on leaflet and rachis nutrient concentration.

Pre-Treatment Data

POME is known to have a high biological oxygen demand (BOD), and low pH. Samples taken in 1994 also show high contents of K and moderate contents of N, Ca and Mg (Table 4).

Table 4. Concentration (mg/L) of nutrients in samples taken from POME ponds in 1994.

Pond	N	P	K	Ca	Mg	Mn	B	Cu	Zn
1	921	195	2028	502	438	4.8	1.8	1.42	2.08
2	308	127	1521	353	311	4.7	0.87	0.36	0.98
3	171	70	1014	231	211	6.0	1.2	0.09	1.16
4	232	79	831	861	490	13.1	1.5	4.33	3.42
Mean	**408**	**118**	**1349**	**487**	**363**	**7.2**	**1.3**	**1.55**	**1.91**

RESULTS and DISCUSSION

The effects of the POME on FFB yield over the course of the trial are shown in Table 5 and Figure 1. The block at Waigani (POME W, 6602) has maintained its yield over time at around 25t/ha. The block receiving POME and decanter cake at Hagita (POME H, 6304) has declined a little in yield over the last 4 years and is currently yielding 22 t/ha. The control plot, receiving no POME at Hagita (No POME, 6306) has decreased in yield over the last 5 years and is currently yielding 17t/ha.

Tissue nutrient concentration are highest in POME W (block 6602) are adequate in POME H (block 6304) and are low, especially for K, in the No POME control block (6306) (Figure 2).

Table 5. Effects of POME on FFB yields (1996 – 2005).

Treatment	Block No.	FFB Yields (t/ha)										
		1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
POME W	6602	24.8	25.9	22.2	23.4	26.2	23.2	26.0	27.0	26.2	24.2	25.8
POME H	6304			19.9	23.7	27.2	22.7	25.3	24.7	22.7	21.2	22.6
No POME	6306	31.2	30.2	31.3	24.8	25.4	23.6	20.9	21.6	16.6	16.2	17.0

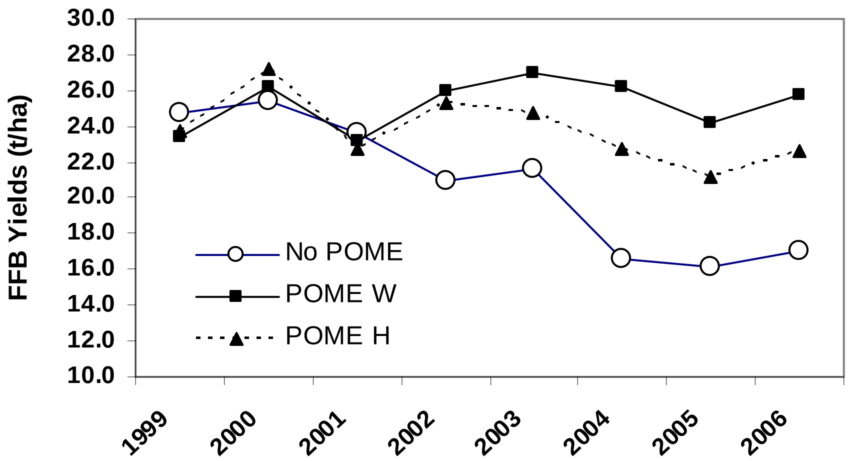
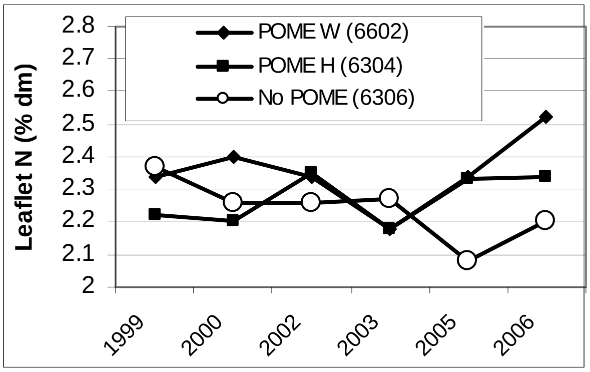
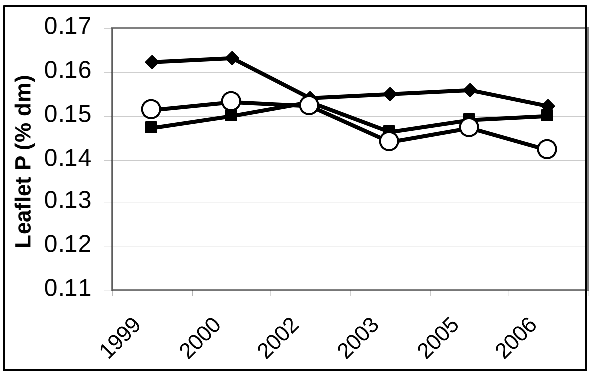


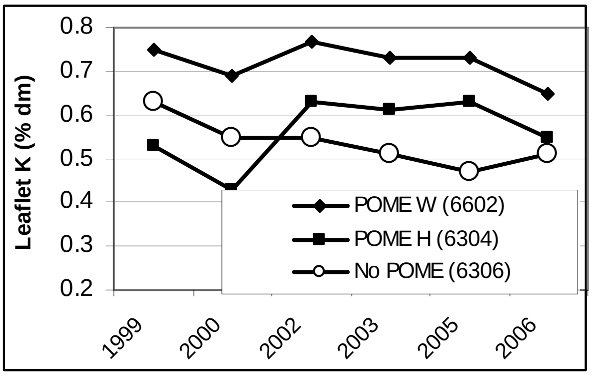
Figure 1: Effect of POME on FFB yield.



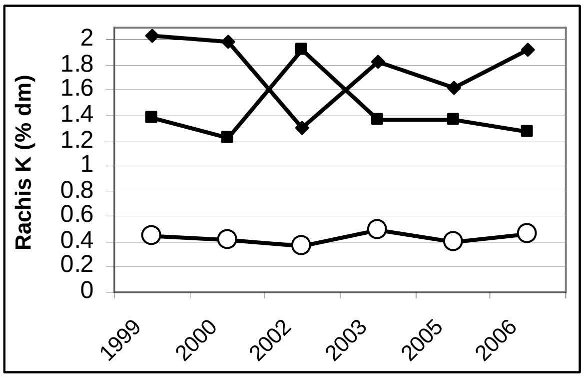
Leaflet N for + POME and No POME



Leaflet P for + POME and No POME



Leaflet K for + POME and No POME



Rachis K for + POME and No POME

Figure 2. Trial 512: Tissue nutrient concentration over time

CONCLUSION

POME and decanter cake had positive and beneficial effects on both the FFB yield and tissue nutrient concentration. With POME and decanter cake, yield was maintained at around 22 to 25 t/ha while in the absence of POME, the yield dropped to 17 t/ha, a difference of 5 to 8 t/ha.

The three blocks used in this experiment are due for replanting in 2007 and 2006 was the last year of experimentation. A full sampling procedure for soil condition will be undertaken before the sites are felled and replanted.

Higaturu Oil Palm, Oro Province: Summary and Synopsis

(James Kraip and Harm van Rees)

Fertiliser response trials with Higaturu comprised three main areas of interest:

1. Factorial 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.

   Outcome:

   (i) N.P.K.Mg trial – only K increased yield as rachis K level of 0.55 for the control indicates that K is limiting yield production in this area.

   (ii) SOA.EFB – no effect as yet because the soil has high levels of N and Mg.

   (iii) Urea.Sulphur – no positive yield response as it is only the first year after treatments.

   (iv) Mg.K source – no positive yield response since the treatment commenced in 2004 but tissue Mg and K were affected by treatments.

   (v) Urea.TSP – established in late 2006 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 (33t/ha) and yield increased with increasing rate of N up to 1.68 kg N per palm (28 to 33 t/ha, control only 7 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: At age 5 of the palms (immature phase), density of 192 or more produced higher yield, mainly due to increase bunch number per palm. The yield response is expected to drop as palms mature, thus the purpose of thinning after year 5 from field planting.

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 2006 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	10	N type (NS) N rate 28 to 33 Control 7	N B/palm 12.6 (NS) N rate SBW 18-20	N type LN 2.40 (NS) N rate LN 2.30 to 2.49 RN 0.31 to 0.33 LP 0.148; RP 0.14 LK 0.74; RK 1.5 LMg 0.19, LB 12	N rate PCS 37 to 40 FP 28 to 26 LAI 6.0 (NS)	Highest yield: 1.68 kg N/palm) B low
326 Sangara SOA, EFB (factorial) Soil: Volcanic	7	SOA 35 (NS) EFB 35 (NS)	SOA B/palm 17 (NS) SOA SBW 15 (NS) EFB (NS)	EFB LK 0.76 to 0.81 RK 1.22 to 1.56 LN 2.70; RN 0.31 LP 0.158; RP 0.08 LMg 0.21, LB 12ppm	PCS 36 (NS) FP 25 (NS) LAI 7.0 (NS)	High levels of soil N, thus no response B low
330 Heropa (ex Grassl) Urea, Elemental S Soil: Sandy	6	Urea 15 (NS) S (NS)	B/palm 10.7 (NS) SBW 10 (NS)	Urea LN 2.60 (NS) RN 0.32 (NS) Sulphur LS 0.21 (NS) LP 0.159; RP 0.09 LK 0.64; RK 1.0 LMg 0.29; LB 13ppm	PCS 22 (NS) FP 26 (NS) LAI 4.8 (NS)	Young palms with low bunch no.? High OM, high LN Low B
329 Mamba SOA, TSP, MOP, KIE (factorial) Soil: Volcanic	9	SOA 23 (NS) TSP 24 (NS) MOP 21 to 25 KIE 23 (NS)	B/palm 7.4 (NS) MOP SBW 23-25	SOA LN 2.89 (NS) RN 0.30 (NS) TSP LP 0.172 to 0.176 RP 0.07 to 0.08 MOP LK 0.79 to 0.93 RK 0.55 to 1.40 KIE LMg 0.19 to 0.31 LB 12	PCS 49 (NS) FP 27 (NS) LAI 7.5 (NS)	Tissue: K required N high B low LAI high
333 Mamba Group 1Mg sources, Group 2 K sources, Group 3 Mg & K Factorial Soil: Volcanic	13	Mg source 26 (NS) K source 26 (NS) MgxK 26 (NS)	B/palm 7 (NS) SBW 28 (NS)	K source LK 0.70 (NS) RK 0.83 to 1.34 Mg source LMg 0.25 (NS) RMg 0.63 to 0.70 LN 2.58; RN 0.30 LP 0.155; RP 0.04 LB 13ppm	PCS 55 (NS) FP 31 (NS) LAI 6.2 (NS)	Low rachis P (needs P fertilizer) Low bunch no.? 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	15ppm	0.32	0.08	1.2

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

Note: PNG OPRA and Higaturu Oil Palm to determine what is happening in:

(i) trial 330 with very low bunch number for young palms and very high variability in yield results between treatments;

(ii) trials at Mamba with low bunch number.

Trial 324: Nitrogen Source Trial on Volcanic soils, Sangara Estate

SUMMARY

The trial was established to test relative effect of different nitrogen fertilisers on volcanic ash soils. The design of the trial was a Randomised Complete Block Design (RCBD). Five different sources of N were tested at 3 different levels; each treatment was replicated 4 times.

N-type treatment had no significant effect on FFB yield in 2006 and for the combined 2004-2006 period. The corresponding effect on bunch dry matter production (BDM) and bunch index (BI) in 2006 was similar. Only leaflet N was significantly affected by N-type treatment.

N-rate treatment had a significant effect on yield, tissue N and most physiological growth parameters. For most variables, the between N-rate difference was significant for 0.42 kg N per palm and either 0.84 or 1.68 kg N per palm but not for 0.84 and 1.68 kg N per palm.

Compared to the grand mean yield of 30.8 t/ha for palms that received N fertiliser, mean yield for the palms that did not receive N fertiliser was only 6.6 t/ha in 2006. This indicates the importance of N for oil palm production on volcanic ash soil.

The results of this trial indicate that there are no differences in uptake and performance of the five most commonly used sources of N fertilisers, for oil palm grown on volcanic soils at Higaturu. For plantation management N fertiliser can be purchased on price and ease of application without loss of productivity.

INTRODUCTION

Nitrogen is the most limiting nutrient in oil palm growth and production. Oil palm requires substantial amounts of N to incorporate into organic compounds including proteins, nucleic acids and growth regulators.

It was established that N is the major limiting element in soils derived from Mt Lamington volcanic ash material. However, it is not known which fertiliser is a better source for this environment both in relation to high yields and the long-term sustainability of the soils. Results from completed trials such as 309 and 310, which were both located on an outwash plain, showed that SOA is a better source of N compared to AMC or urea, in these ex grassland sandy loam soils.

Whether this is the case on other soil is not known. Hence, the purpose of this trial is to test relative effectiveness of different nitrogen fertilisers on Higaturu Soils (Volcanic Plains). The trial commenced in January 2001, about 5 years after field planting. Other background information on the trial is presented in Table 1.

Pre-treatment soil data for the trial field indicate high levels of N, organic matter and Ca (Table 2). Exchangeable K and Mg, and CEC are moderate, while pH is generally neutral.

Table 1. Trial 324 background information.

Trial number	**324**	Company	Higaturu Oil Palms
Estate	Sangara	Block No.	Blocks 2102 & 2103
Planting Density	135 palms/ha	Soil Type	Higaturu Soils
Pattern	Triangular	Drainage	Good
Date planted	1996	Topography	Flat
Age after planting	10	Altitude	130 m asl
Recording Started	2001	Previous Land-use	Cocoa Plantation
Planting material	Dami D x P	Area under trial soil type (ha)	3000
Progeny	Not known	Agronomist in charge	James Kraip

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

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

METHODS

Experimental Design and Treatments

This trial was a Randomised Complete Block Design (RCBD) wth a treatment structure of 5 N sources x 3 rates x 4 replicates, resulting in 60 plots. For each replicate, 12 treatments were randomly allocated to 12 plots within a block. 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. Because the control plots were not randomised in the trial design they were not used in the statistical analysis. In total there were 64 plots in this trial. Each plot consisted of 36 palms, the central 16 were recorded and the outer 20 were guard palms. To minimise poaching of nutrients by roots of palms between plots, trenches were dug around the edges of the plots in 2001/02.

The N sources were ammonium sulphate (SOA), ammonium chloride (AMC), ammonium nitrate (AMN), urea and diammonium phosphate (DAP). The rates applied provide equivalent amounts of N for the different N sources (Table 3). Fertiliser treatments were applied in 3 doses per year. Blanket application of MOP at 2 kg per palm per year (2 doses per year) was applied to all palms in the trial field since the trial commenced. In 2006, all palms within the trial field received an annual blanket application of kieserite, TSP and Calcium borate (B) as well, at 1.0, 0.5 and 0.2 kg per palm respectively.

This trial was the same design as Trial 325 in Ambogo and Trial 125 in Kumbango. See 2001 Proposals for background.

Table 3. Nitrogen source treatments and rates

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

Data Collection

Recordings and measurements were taken on the central 16 palms in each plot. The number of bunches and bunch weights were recorded fortnightly 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. During 2007 it is planned to harvest this trial on 10 day harvesting intervals in line with company practice. Leaf sampling was carried out once annually according to standard procedures and analysed for nutrient concentrations using standard analytical procedures.

Statistical Analysis

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

RESULTS and DISCUSSION

Effects of treatments on FFB yield and its components.

The difference in FFB yield between different N-fertiliser types was not statistically significant in 2006 and the combined 2004-2006 period (Tables 4 & 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 2006 and the combined 2004-2006 period, the significant effect on yield was mainly due to increased single bunch weight (SBW). The yield difference between annual N-rate of 0.84 and 1.68 kg per palm was not significant at $l.s.d._{0.05}$ but the differences between either 0.42 and 0.84, and 0.42 and 1.68 kg per palm were significant at $l.s.d._{0.05}$.

In 2006 the difference in yield between +N and –N was about 24 t/ha. The average yield for +N was 30.8 t/ha and the average yield for –N was 6.6 t/ha. This indicates the importance of N in oil palm FFB production. The yields in the control plots (zero N applied) continued to drop in 2006, due to drop in the number of bunches and SBW.

Table 4. Effects (p values) of treatments on FFB yield and its components in 2004–2006 and in 2006. p values <0.05 are shown in bold.

	2004 - 2006			2006		
Source	**Yield**	**BNO**	**SBW**	**Yield**	**BNO**	**SBW**
Type	0.418	**0.037**	0.826	0.718	0.544	0.201
Rate	**<0.001**	0.287	**0.008**	**<0.001**	0.097	**<0.001**
Type. Rate	0.179	**0.027**	0.791	0.276	0.309	0.824
CV %	*6.0*	6.6	*6.1*	*9.4*	9.6	*5.7*

Table 5. Main effects of treatments on FFB yield (t/ha) from 2004 to 2006 and 2006. p values <0.05 are shown in bold.

	2004 - 2006			2006		
	FFB yield (t/ha)	BNO/ha	SBW (kg)	FFB yield (t/ha)	BNO	SBW (kg)
Control				6.6	500	12.6
SOA	33.4	**1894**	17.7	31.7	1647	19.6
AMC	33.4	**1922**	17.6	30.4	1633	19.1
Urea	33.4	**1993**	17.6	30.1	1625	19.0
AMN	34.5	**2040**	17.2	31.1	1714	18.5
DAP	34.5	**2022**	17.6	30.0	1701	19.0
l.s.d.$_{0.05}$		*324*				
Rate 1	**32.4**	1940	**17.0**	**28.2**	1604	**18.0**
Rate 2	**34.3**	1977	**17.7**	**31.3**	1674	**19.4**
Rate 3	**35.5**	2006	**18.1**	**33.0**	1715	**19.8**
l.s.d.$_{0.05}$	*2.9*		*1.5*	*1.9*		*1.6*
Grand Mean	34.0	1974	17.6	30.8	1664	19.1

Effects of treatments on leaf (F17) nutrient concentrations

The between N-types difference in leaflet N was significant but not for rachis N in 2006 (Tables 6 and 7). However, only the difference between AMC and other N-types was significant at l.s.d.$_{0.05}$. AMC significantly increased leaflet Cl, mainly due to the Cl content in the AMC fertiliser.

The between N-rates difference in leaflet N, P, K, Ca, Cl and S was significant and most nutrient concentrations increased with increasing N-rates except Ca (Tables 6 and 7). Similarly, rachis N and K concentrations were significantly increased with increasing N-rates while, the rachis P was decreased by increasing N-rates (Tables 6 and 8). This indicates a loss of P from the rachis and gain of P in the leaflet, which was probably triggered by improving N nutrition of the palms.

The leaflet N concentration for the control plots was below the value considered critical (2.3%DM) for oil palm, compared to leaflet N concentrations for palms that received fertiliser. On the other hand, rachis N concentrations were similar for both control and fertilised palms (Table 8).

Table 6. Effects (p values) of treatments on frond 17 nutrient concentrations in 2006. p values less than 0.05 are in bold.

Source	**Leaflet Nutrient Concentrations**								
	Ash	**N**	**P**	**K**	**Ca**	**Mg**	**Cl**	**S**	**B**
Type	**0.037**	**0.003**	0.057	0.098	0.142	0.695	**<0.001**	**0.003**	0.100
Rate	0.213	**<0.001**	**<0.001**	**0.024**	**<0.001**	0.091	**0.025**	**<0.001**	0.282
Type. Rate	0.164	0.738	0.190	0.056	0.297	0.640	**<0.001**	0.794	0.401
CV %	3.6	3.0	2.3	4.8	5.0	7.2	6.3	3.2	7.4
	Rachis Nutrient Concentrations								
	Ash	N	P	K	Mg				
Type	0.102	0.244	0.100	0.071	**<0.001**				
Rate	**0.011**	**0.005**	**<0.001**	**<0.001**	0.958				
Type. Rate	0.520	0.587	0.053	0.070	0.342				
CV %	5.9	5.6	19.1	6.4	10.8				

Table 7. Main effects of treatments on frond 17 nutrient concentrations in 2006, 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**	**S**	**B ppm**
Control	*15.8*	*2.05*	*0.145*	*0.64*	*0.21*	*0.95*	*0.42*	*0.183*	*13.3*
SOA	**15.4**	**2.41**	0.147	0.75	0.185	0.80	**0.46**	**0.197**	11.6
AMC	**15.4**	**2.34**	0.147	0.72	0.187	0.83	**0.55**	**0.188**	11.0
Urea	**14.8**	**2.41**	0.148	0.75	0.180	0.83	**0.45**	**0.195**	11.8
AMN	**14.9**	**2.43**	0.149	0.74	0.187	0.83	**0.45**	**0.196**	11.8
DAP	**15.3**	**2.46**	0.151	0.74	0.187	0.80	**0.46**	**0.198**	11.7
$l.s.d._{0.05}$	*0.3*	*0.06*					*0.03*	*0.005*	
Rate 1	15.1	**2.30**	**0.145**	**0.73**	0.183	**0.84**	**0.46**	**0.186**	11.4
Rate 2	15.1	**2.44**	**0.150**	**0.74**	0.191	**0.83**	**0.48**	**0.197**	11.8
Rate 3	15.3	**2.49**	**0.150**	**0.76**	0.182	**0.78**	**0.48**	**0.202**	11.6
$l.s.d._{0.05}$		*0.05*	*0.002*	*0.02*		*0.03*	*0.02*	*0.004*	
GM	15.2	2.41	0.148	0.74	0.185	0.82	0.47	0.195	11.6

Table 8. Main effects of treatments on frond 17 nutrient concentrations in 2006, 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.

	Rachis Nutrient Concentrations				
Treatment	**Ash**	**N**	**P**	**K**	**Mg**
Control	*5.4*	*0.30*	*0.289*	*1.67*	*0.068*
SOA	5.8	0.32	0.120	1.59	**0.055**
AMC	5.5	0.31	0.136	1.66	**0.068**
Urea	5.8	0.31	0.131	1.54	**0.055**
AMN	5.4	0.31	0.124	1.56	**0.053**
DAP	5.6	0.32	0.146	1.60	**0.059**
$l.s.d._{0.05}$					*0.005*
Rate 1	**5.5**	**0.31**	**0.152**	**1.55**	0.058
Rate 2	**5.4**	**0.31**	**0.123**	**1.54**	0.058
Rate 3	**5.7**	**0.33**	**0.120**	**1.67**	0.058
$l.s.d._{0.05}$	*0.02*	*0.01*	*0.016*	*0.07*	
Mean	5.5	0.32	0.131	1.59	0.058

Effects of fertiliser treatments on Vegetative parameters

N-type treatment had a significant effect on PCS and FP but other physiological parameters were not affected by N-type treatment (Tables 9 & 10). DAP increased PSC significantly compared to Urea and AMN while the difference between DAP and either SOA or AMC was not significant ($l.s.d._{0.05}$).

N-rate treatment had a significant effect on most physiological parameters except FDM and VDM (Table 9 &10). The difference between 0.42 and either 0.84 or 1.68 kg of N per palm was significant but that between 0.84 or 1.68 kg of N per palm was not ($l.s.d._{0.05}$.).

Generally, physiological parameters decreased substantially for the control plots compared to the palms that received N fertiliser. These results correspond well with yield and tissue results. BI is over 2 times lower the average of the palms that received fertiliser.

Table 9. Effect (p values) of treatments on vegetative growth parameters in 2006. 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	**0.013**	**0.044**	0.313	0.108	0.483	0.728	0.570	0.469	0.664
Rate	**0.004**	**<0.001**	**<0.001**	**<0.001**	0.443	**<0.001**	**<0.001**	0.279	**<0.001**
Type.Rate	0.989	0.521	0.157	0.143	0.972	0.254	0.395	0.947	0.399
CV %	6.5	3.3	3.1	5.3	6.7	9.2	6.0	6.2	5.3

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 10. Main effects of treatments on vegetative growth parameters in 2006. Significant effects ($p<0.05$) are shown in bold.

Source	Radiation Interception				Dry Matter Production (t/ha)				
	PCS	FP	FA	LAI	FDM	BDM	TDM	VDM	BI
Control	29.8	30.7	9.5	4.4	13.4	3.3	18.6	15.3	0.17
SOA	**38.4**	**27.1**	11.8	6.0	15.1	16.8	35.4	18.6	0.47
AMC	**39.3**	**26.7**	11.8	5.9	15.2	16.0	34.7	18.6	0.46
Urea	**37.1**	**27.5**	11.6	5.7	14.8	16.1	34.3	18.2	0.47
AMN	**37.4**	**27.4**	11.7	5.7	14.8	16.5	34.8	18.3	0.47
DAP	**40.4**	**26.5**	11.9	6.0	15.5	16.5	35.5	19.0	0.46
$LSD_{0.05}$	*2.1*	*0.7*							
Rate 1	**37.2**	**28.0**	**11.5**	**5.6**	15.1	**14.9**	**33.3**	18.4	**0.45**
Rate 2	**38.4**	**26.7**	**11.9**	**6.0**	14.9	**16.8**	**35.1**	18.4	**0.48**
Rate 3	**39.9**	**26.4**	**11.9**	**6.0**	15.3	**17.4**	**36.3**	18.9	**0.48**
$LSD_{0.05}$	1.6	0.6	0.2	0.2		1.0	1.3		0.02
GM	38.5	27.0	11.8	5.8	15.1	16.4	34.9	18.6	0.47

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 2006 and for the combined 2004-2006 period. These results were similar compared to the past 5 years since the trial started in 2001. Similarly, BDM and BI, which correspond well to yield, were not affected by N-type treatment in 2006. However, N-type had a significant effect on leaflet N concentration in 2006.

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, TDM and BI.

Yield, leaflet N and values for physiological growth parameters for the palms that did not receive N fertiliser were comparatively lower than the palms that received N fertiliser. This indicates that without fertiliser N, oil palm production can not be sustained or increased.

Trial 326: Nitrogen x EFB Trial on Volcanic Soils, Sangara Estate

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 design of the trial 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 palm to help formulate fertiliser recommendations on volcanic plain soils of Higaturu, Popondetta.

SOA and EFB treatments had no significant effect on yield and its components in 2006. 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 fertiliser recommendations on volcanic plain soils. Nitrogen is by far the main nutrient limiting fresh fruit bunch (FFB) production in oil palm and thus large amounts are required to increase yields of FFB. However, N requirement can be reduced when applied in combination with EFB as shown by results from closed PNG OPRA field trials 311 and 312. In trial 312, no FFB yield plateau was reached when increasing SOA from 0 to 6kg of SOA per palm but FFB yield did plateau off at a combined application of 4kg of SOA and 250 kg of EFB per palm per year.

In trials 311 and 312, only 1 rate of EFB (250 kg/palm/year) was tested. This trial was designed to test 3 rates to determine which rate would produce optimum FFB yield, when applied in combination with varying rates of SOA. EFB contains 0.6, 2.0 and 0.05 % (dry matter) of N, K and P respectively.

Background information of trial 326 is presented in Table 1. Pre-treatment soil data indicate that pH is slightly acidic in the topsoil and becomes less acidic at soil depth (Table 2). CEC falls between the low and moderate category, with adequate levels of exchangeable Mg. Exchangeable K is moderate in the top 0-10 cm layer, the next three layers have low levels of exchangeable K. Organic matter contents and total N are quite reasonable.

Table 1. Trial 326 background information.

Trial number	**326**	Company	Higaturu Oil Palms
Estate	Sangara	Block No.	Kasi Block
Planting Density	135 palms/ha	Soil Type	Volcanic
Pattern	Triangular	Drainage	Good
Date planted	1999	Topography	Flat
Age after planting	7	Altitude	150 m asl
Recording Started	2002	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	James Kraip

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

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

METHODS

The SOA.EFB trial was set up as a 4 x 3 factorial arrangement, resulting in 12 treatments (Table 3). The design of the trial is Randomised Complete Block Design (RCBD). The 12 treatments were replicated 5 times, resulting in 60 plots. Each plot consists of 36 palms, with the inner 16 being the recorded and the outer 20 being the guard palms. This trial is the same design as Trial 327 in Ambogo and Trial 125 in Kumbango. See 2001 Proposals for background.

SOA treatments are applied in 3 doses per year. EFB treatments are applied once every year.

The plots are surrounded by a trench to prevent nutrient poaching between plots. Palms that are not in plots but are in the same block are termed perimeter palms, and they receive 2 kg per palm of urea.

Every palm within the trial field receives basal applications of 1 kg Kieserite, 0.5 kg of TSP and 0.2 kg of Calcium Borate every year. Only those palms not receiving EFB treatments receive MOP at 2 kg per palm as basal.

Recordings and measurements are taken on the central 16 palms in each plot. The number of bunches and bunch weights are recorded fortnightly 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. During 2007 it is planned to harvest this trial on 10 day harvesting intervals in line with company practice. Leaf sampling is carried out according to standard procedures and analysed for nutrient concentrations using standard analytical procedures.

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

Table 3. Fertiliser treatments and levels for Trial 326.

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

RESULTS and DISCUSSION

Effects of treatment on FFB yield and its components

SOA and EFB treatments had no significant effect on yield and its components in 2006 (Tables 4 and 5). Average yield and its components for the 2004 to 2006 period were also not affected by treatments. These results are similar to the past 4 years since the trial commenced in 2002.

Table 4. Effects (p values) of treatments on FFB yield and its components in 2004 – 2006 and 2006.

	2004 - 2006			**2006**		
Source	**Yield**	**BNO**	**SBW**	**Yield**	**BNO**	**SBW**
SOA	0.404	0.628	0.891	0.058	0.100	0.340
EFB	0.328	0.890	0.412	0.058	0.333	0.159
SOA.EFB	0.877	0.940	0.498	0.946	0.312	0.283
CV %	6.9	6.4	5.6	8.5	9.3	6.4

Table 5. Main effects of treatments on FFB yield (t/ha) from 2004 to 2006 and 2006.

	2004 - 2006			**2006**		
	FFB yield (t/ha)	**BNO/ha**	**SBW (kg)**	**FFB yield (t/ha)**	**BNO**	**SBW (kg)**
SOA 0	34.7	2371	14.8	35.9	2183	16.8
SOA 2.5	35.6	2418	14.9	37.5	2255	17.0
SOA 5.0	34.3	2369	14.7	35.7	2210	16.5
SOA 7.5	34.4	2347	14.9	34.3	2072	17.2
EFB 0	34.1	2366	14.6	34.6	2148	16.5
EFB 130	34.9	2374	14.9	35.8	2156	17.1
EFB 390	35.2	2389	14.9	37.0	2236	17.0
Grand Mean	34.7	2376	14.8	35.8	2180	16.9

Effects of interaction between treatments on FFB yield

There was no significant interaction effect of SOA.EFB but a highest yield of 38.7 t/ha was achieved with a combined application of 2.5 kg per palm of SOA and 390 kg per palm of EFB (Table 6).

Table 6. Effect of SOA and EFB (two-way interactions) on FFB yield (t/ha/yr) in 2006. The interaction was not significant (p=0.946).

	EFB 0	**EFB 130**	**EFB 390**
SOA 0	34.6	36.7	36.3
SOA 2.5	36.5	37.2	38.7
SOA 5.0	33.9	36.0	37.3
SOA 7.5	33.6	33.5	35.9
	Grand mean: 35.8	*s.e.d = 1.9*	

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

SOA treatment had no significant effect on leaflet and rachis nutrient concentrations in 2006 (Tables 7 and 8). All nutrients were above their respective critical concentrations for leaflet.

EFB treatment had a significant effect on the concentration of leaflet and rachis ash, leaflet and rachis K, leaflet Cl, and rachis P but not other nutrients (Table 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 2006 (Trial 326). p values <0.05 are indicated in bold.

	Leaflet								Rachis			
Source	**Ash**	**N**	**P**	**K**	**Mg**	**Cl**	**S**	**B**	**Ash**	**N**	**P**	**K**
SOA	0.52	0.28	0.50	0.29	0.50	0.20	0.61	0.92	0.60	0.92	0.75	0.40
FFB	**0.01**	0.29	0.06	**0.01**	0.98	**<0.001**	0.37	0.30	**<0.001**	0.40	**<0.001**	**<0.001**
SOA.EFB	0.34	0.43	0.53	0.47	0.32	0.05	0.74	0.49	0.10	**0.03**	0.32	0.46
CV%	*4.2*	*2.5*	*3.4*	*5.6*	*7.6*	*9.7*	*3.2*	*8.1*	*11.6*	*5.5*	*12.6*	*9.4*

Table 8: Main effects of treatments on F17 nutrient concentrations in 2006, in units of % dry matter, except for B (mg/kg) (Trial 326). Effects with p<0.05are shown in bold.

	Leaflet %dm (except B ppm)								Rachis %dm			
Source	**Ash**	**N**	**P**	**K**	**Mg**	**Cl**	**S**	**B**	**Ash**	**N**	**P**	**K**
SOA 0	14.1	2.68	0.157	0.77	0.21	0.43	0.21	12.1	4.5	0.30	0.079	1.3
SOA 2.5	14.3	2.69	0.157	0.79	0.21	0.41	0.21	12.2	4.4	0.31	0.078	1.3
SOA 5.0	14.1	2.71	0.159	0.79	0.21	0.44	0.21	12.0	4.4	0.31	0.076	1.4
SOA 7.5	14.3	2.73	0.158	0.80	0.20	0.43	0.21	12.2	4.5	0.31	0.077	1.4
$l.s.d_{0.05}$												
EFB 0	14.5	2.68	0.155	**0.76**	0.21	**0.38**	0.21	12.1	**4.0**	0.31	**0.069**	**1.2**
EFB 130	14.3	2.72	0.159	**0.79**	0.21	**0.43**	0.21	12.4	**4.6**	0.31	**0.075**	**1.4**
EFB 390	13.8	2.71	0.159	**0.81**	0.21	**0.47**	0.21	11.9	**4.7**	0.31	**0.087**	**1.5**
$l.s.d_{0.05}$	*0.4*			*0.03*		*0.05*			*0.3*		*0.006*	*0.1*
GM	*14.2*	*2.70*	*0.158*	*0.79*	*0.21*	*0.43*	*0.21*	*12.1*	*4.4*	*0.31*	*0.077*	*1.4*

Effects of fertiliser treatments on Vegetative parameters

SOA had a significant effect only on bunch index (BI) but not other measured and calculated vegetative parameters (Tables 9 and 10). Dry matter production was significantly increased by EFB treatment except bunch dry matter (BDM).

Table 9. Effect (p values) of treatments on vegetative growth parameters in 2006. 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	
SOA	0.785	0.879	0.458	0.251	0.714	0.058	0.416	0.888	**0.046**
EFB	0.061	0.136	0.824	0.237	**0.015**	0.058	**0.003**	**0.007**	0.810
SOA.EFB	0.233	0.758	0.470	0.287	0.400	0.946	0.913	0.453	0.494
CV %	8.4	3.1	5.1	5.5	8.4	8.5	6.3	7.5	4.8

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 2006. Significant effects ($p<0.05$) are shown in bold.

Source	Radiation Interception				Dry Matter Production (t/ha)				BI
	PCS	FP	FA	LAI	FDM	BDM	TDM	VDM	
SOA 0	36.0	25.2	13.1	6.9	13.2	19.0	35.8	16.8	**0.53**
SOA 2.5	35.5	25.3	13.1	6.9	13.1	19.9	36.6	16.7	**0.54**
SOA 5.0	36.4	25.4	13.1	7.0	13.4	18.9	35.9	17.0	**0.53**
SOA 7.5	36.5	25.4	13.4	7.1	13.5	18.2	35.2	17.0	**0.52**
$LSD_{0.05}$									0.02
EFB 0	35.1	25.2	13.1	6.9	**12.9**	18.4	**34.7**	**16.3**	0.53
EFB 130	35.8	25.2	12.2	7.0	**13.1**	19.0	**35.7**	**16.7**	0.53
EFB 390	37.4	25.6	13.2	7.1	**13.9**	19.6	**37.2**	**17.6**	0.53
$LSD_{0.05}$	-	-	-	-	0.7	-	1.4	0.8	0.02

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. However, in 2006 highest yield of 38.7 t/ha was achieved at a combined application of 2.5 kg per palm of SOA and 390 kg per palm of EFB.

Leaf nutrient concentrations were not affected by SOA treatment and all the nutrients were above their respective critical concentrations. On the other hand, EFB treatment only increased leaflet K and CL, and rachis P and K concentrations.

Frond and vegetative dry matter production was significantly increased by EFB treatment and this resulted in a significant increase in total dry matter production in 2006. SOA treatment had a significant effect on only bunch index in 2006 but not other measured or calculated growth parameter.

Trial 329: Nitrogen, Potassium, Phosphorus and Magnesium Trial on Mamba Soils

SUMMARY

The N.P.K.Mg trial was established on Mamba soils in Oro Province to provide a guide to fertiliser recommendations to estates and oil palm smallholder growers in this area. The trial block was planted in 1997 and the trial commenced in September 2002. The fertiliser treatments included SOA (2 rates); and MOP, Kieserite and TSP, all tested at 3 rates.

Only MOP treatment had a significant effect on yield. Increasing MOP from 0 to either 2 or 4 kg per palm increased FFB yield by 1.5 to 3.0 t/ha. When combined with 4 kg of SOA, FFB yield increased by another 3 t/ha, specifically at 4 kg MOP per palm per year. Leaf K levels were increased significantly by higher rates of MOP treatment but for MOP 0, K level dropped below the critical of 1.0% (rachis K). This indicates that K is limiting FFB production in this area. The effect of MOP on bunch dry matter (BDM), total dry matter (TDM) and bunch index (BI) corresponded well to its effects on yield and leaf K. Higher rates of MOP treatment significantly increased BDM, TDM and BI in 2006.

One reason for other fertiliser treatments having no significantly effect on variables measured is that soil N, P, Mg levels are high in the trial area, thus any response to N, P and Mg treatments are unlikely in the short to intermediate term.

INTRODUCTION

The trial was established with the intention to provide information for fertiliser recommendations for estates and smallholders in the Kokoda Valley, and Ilimo/Papaki and Mamba areas. Some back ground information about this trial is presented in Table 1.

Table 1: Trial 329 back ground information.

Trial number	**329**	Company	Higaturu Oil Palms
Estate	Mamba	Block No.	Komo Div. Blocks 6298G1
Planting Density	135 palms/ha	Soil Type	Mamba Soils
Pattern	Triangular	Drainage	Poor
Date planted	1997	Topography	Flat
Age after planting	9	Altitude	Not known
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	James Kraip

Soils of Ilimo/Kokoda and Mamba areas are different from soils of the Popondetta plains. The soils at Mamba are generally acidic (pH in water), are intermediate in cation exchange capacity (CEC) and have high P retention (Table 2). The soils are susceptible to frequent water-logging. Total N, OM%, total P, exchangeable K and exchangeable Mg are high in the top 10 cm of the soil and decrease progressively down the soil profile down to 60 cm.

Table 2: Soil chemical characteristics for bulked samples taken from each of the three experimental blocks in 2001.

Depth (cm)	pH	Olsen P	P Ret.	Exch. K	Exch. Ca	Exch. Mg	CEC	Org. Matter	Total N	Avail. N	Sulfate S	B
		mg/kg	(%)	(cmolc/kg)				(%)	(%)	(kg/ha)	(mg/kg)	
0-10	5.6	22	98	0.37	7.5	1.62	25.5	15.6	0.84	137	16	0.4
10-20	5.3	8	100	0.16	0.6	0.22	16.2	9.4	0.51	51	98	0.2
20-30	5.3	5	100	0.13	<0.5	0.11	11.6	6.3	0.36	23	184	0.1
30-60	5.4	7	92	0.14	<0.5	0.11	8.1	3.0	0.19	<10	176	0.1
0-10	5.6	17	99	0.43	6.3	1.41	24.2	14.4	0.81	130	23	0.4
10-20	5.3	6	100	0.16	0.9	0.24	14.9	8.9	0.52	55	133	0.2
20-30	5.4	5	100	0.17	0.6	0.19	12.9	7.5	0.38	38	202	0.1
30-60	5.5	7	95	0.18	<0.5	0.11	8.4	3.5	0.20	<10	201	<0.1
0-10	5.8	14	96	0.37	9.3	1.94	25.1	13.9	0.81	128	16	0.3
10-20	5.6	5	100	0.22	1.3	0.33	14.5	9.1	0.52	58	75	0.2
20-30	5.6	5	100	0.18	0.7	0.19	11.0	6.8	0.40	23	155	0.1
30-60	5.6	7	97	0.17	<0.5	0.14	8.5	4.0	0.23	<10	182	0.1

METHODS

The N P K Mg trial was set up as a 2 x 3x 3 x 3 factorial arrangement, resulting in 54 treatments with 36 palms per plot (Table 3). The 54 treatments were not replicated, and were arranged in 3 blocks of 18 plots. Fertilisers used were ammonium sulphate (SOA), triple superphosphate (TSP), potassium chloride (MOP) and kieserite (KIE) (Table 3). The fertiliser treatments were applied in 3 doses per year. The plots were surrounded by a trench to prevent plot-to-plot nutrient poaching. Palms that were not in plots but were in the same block were termed perimeter palms, and were fertilised according to plantation practice.

The trial area received a basal application of borate at 50 g/palm/year.

Recordings and measurements were taken on the central 16 palms in each plot. The number of bunches and bunch weights were recorded fortnightly 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. During 2007 it is planned to harvest this trial on 10 day harvesting intervals in line with company practice. Leaf sampling was carried out according to standard procedures and analysed for nutrient concentrations using standard analytical procedures.

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

Table 3: Fertiliser levels and rates used in Trial 329

	Amount (kg/palm/year)		
Fertiliser	**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

Over the course of the trial, increasing SOA rates from 2 to 4 kg per palm resulted in a small increase in FFB yield, statistically these effects were not significant (Figure 1). One possible explanation for the lack of N response is that leaflet N concentrations were in the adequate range, indicating that N nutrition is not limiting yield. The reason for the high inherent N nutrient status is that soil organic matter and total N are high. High levels of soil organic matter and total N result in high levels of mineralisation and available N, thus responses to N fertiliser are unlikely until soil N reserves are depleted over time.

Similar to the effects of SOA treatment, TSP and KIE treatments had no significant effect on FFB yield during the course of the trial. Increasing KIE from 0 to 4 kg per palm increased leaflet Mg concentration but this did not equate to a yield increase; leaflet Mg concentration for KIE 0 has dropped below the critical valve of 0.20. TSP treatment had no significant effect on leaflet P concentration and all P values were above the critical level of 0.150 %DM.

On the other hand, increasing MOP from 0 to 4 kg per palm resulted in a substantial yield increase (by 1 to 3 t/ha) and in most years these effects were statistically significant. Rachis K levels dropped substantially from 1.51 %DM in 2003 to 0.89 %DM in 2005 for MOP 4 treatment, and this corresponded well to the lower yield in 2005 compared to that of 2003. However, non-nutritional factors like rainfall and sunshine do cause yield fluctuation over time. The 4 kg MOP per palm may not meet K requirements for the palms over time as rachis K, which is a good indicator of K nutrition, is declining over time. This will be validated with more data.

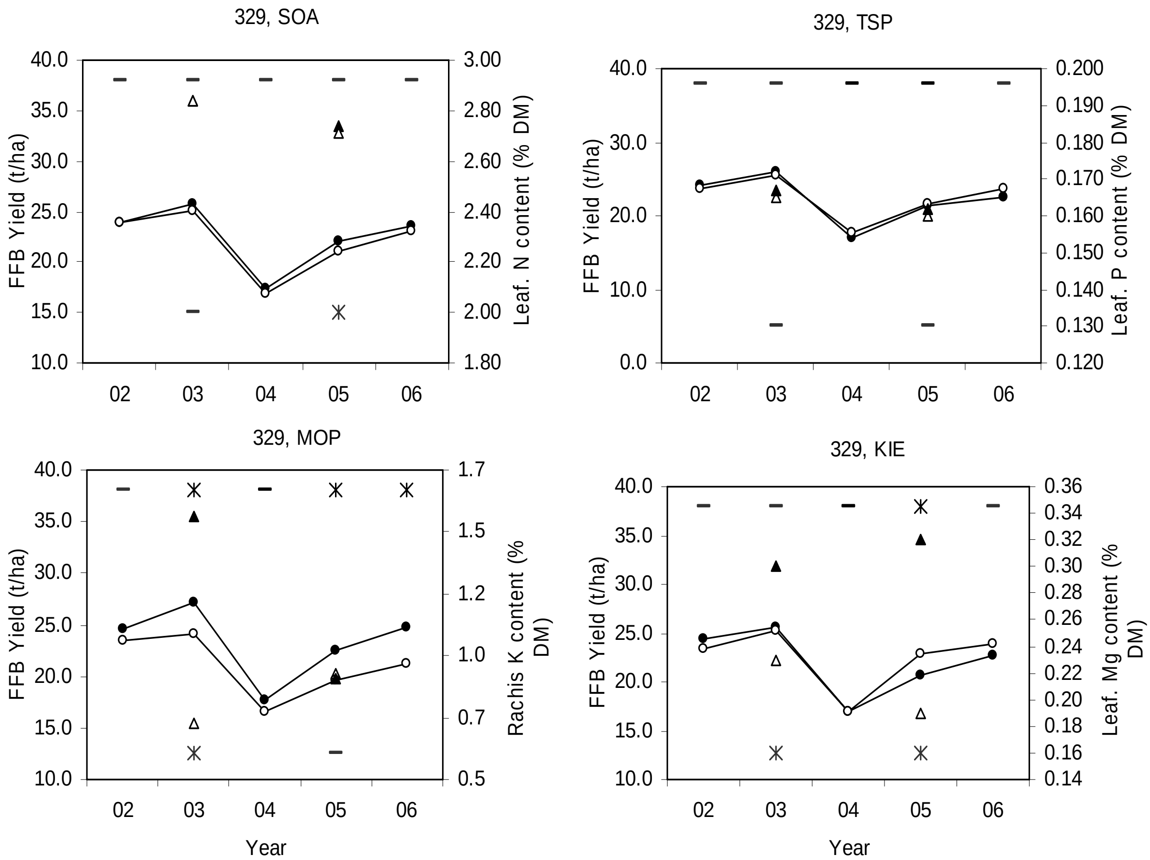


Figure 1. Main effects of TSP, KIE and EFB over the course of Trial 329. Lines are FFB yields and triangles are tissue nutrient concentrations. Full symbols represent the maximum level of application, and empty symbols the lowest level. Symbols along the top of the graph indicate significance of the

main effect on yield, and along the bottom indicate significance of the main effect on tissue nutrient concentration. Stars indicate significance ($p<0.05$) and dashes non-significance.

Effects of treatment on FFB yield and yield components in 2006 and 2005-2006 period

Increasing MOP from 0 to 2 or 4 kg per palm increased FFB yield by 2.5 to 3.6 t/ha in 2006 and these effects were statistically significant (Tables 4 and 5). Rachis K levels in 2005 were below the critical of 1.0% DM, which indicates that K is limiting FFB yield production in this area and any addition of MOP fertiliser should have a positive effect. The increase in yield was due to an increase in the number of bunches per ha and SBW. The MOP treatment had similar results during the combined 2005-2006 period.

SOA and TSP treatments had no significant effect on FFB yield in 2006 and during the combined 2005-2006 period (Tables 4 &5).

Increasing KIE from 0 to any other rate decreased yield in 2006 and during the combined 2005-2006 period. The decrease in yield was significant during the combined 2005-2006 period. Further analyses of the data indicate that only the yield difference between KIE 0 and KIE 4 was significantly different at $LSD_{0.05}$.

Table 4: Effects (p values) of treatments on FFB yield and its components in the combined harvest for 2005 – 2006 and for 2006 alone. p values less than 0.05 are in bold.

	2005- 2006			**2006**		
Source	**Yield**	**BNO**	**SBW**	**Yield**	**BNO**	**SBW**
SOA	0.105	**0.047**	0.536	0.579	0.931	0.696
TSP	0.223	0.340	0.989	0.371	0.359	0.703
MOP	**<0.001**	**0.033**	**0.002**	**0.012**	0.191	**0.007**
KIE	**0.035**	0.082	0.581	0.503	0.396	0.818
SOA.TSP	0.202	0.138	0.110	0.256	0.273	**0.016**
SOA.MOP	**0.005**	**0.036**	**0.048**	**0.012**	**0.025**	**0.015**
TSP.MOP	0.215	**0.045**	0.320	0.538	0.139	0.280
SOA.KIE	0.231	0.497	0.293	0.101	0.200	0.579
TSP.KIE	0.670	0.653	0.371	0.498	0.577	0.889
MOP.KIE	0.856	0.029	0.150	0.542	0.493	0.134
SOA.TSP.MOP	0.084	0.253	0.549	0.299	0.212	0.480
SOA.TSP.KIE	0.184	0.121	0.927	0.426	0.509	0.797
SOA.MOP.KIE	0.257	0.129	0.165	0.436	0.349	0.206
TSP.MOP.KIE	0.102	0.064	**0.027**	0.093	0.310	**0.029**
CV %	6.9	6.6	4.7	11.8	11.5	4.9

Table 5: Main effects of treatments on FFB yield (t/ha) for the combined harvest for 2005 – 2006 and 2006 alone (Yield, Bunch No and SBW in bold are significant at P<0.05).

	2005-2006			2006		
	FFB yield (t/ha)	BNO/ha	SBW (kg)	FFB yield (t/ha)	BNO	SBW (kg)
SOA 2	22.0	**978**	23.4	23.0	990	24.1
SOA 4	22.8	**1019**	23.2	23.5	993	24.2
$Lsd_{0.05}$		*41*				
TSP 0	22.5	1008	23.3	23.6	1006	24.1
TSP 2	22.8	1009	23.3	23.7	1011	24.0
TSP 4	21.9	979	23.3	22.5	958	24.3
MOP 0	**20.5**	**957**	**22.2**	**21.2**	949	**23.2**
MOP 2	**23.1**	**1018**	**23.6**	**23.7**	1000	**24.5**
MOP 4	**23.6**	**1021**	**24.1**	**24.8**	1015	**24.8**
$Lsd_{0.05}$	*1.2*	*50*	*0.8*	*2.1*		0.91
KIE 0	**23.3**	1029	23.5	23.8	1017	24.0
KIE 2	**22.2**	996	23.2	23.2	995	24.2
KIE 4	**21.7**	972	23.2	22.7	962	24.3
GM	*22.4*	*999*	*23.3*	*23.3*	*991*	*24.2*

Effects of interactions between treatments on FFB yield

Combined application of SOA and MOP increased yield in 2006 and this effect was statistically significant (Table 4 and Figure 2). A maximum yield of 26.9 t/ha was produced at a combined application of 4 kg SOA and 4 kg MOP. At 2 kg SOA, increasing MOP from 0 to a higher rate did not increase yield.

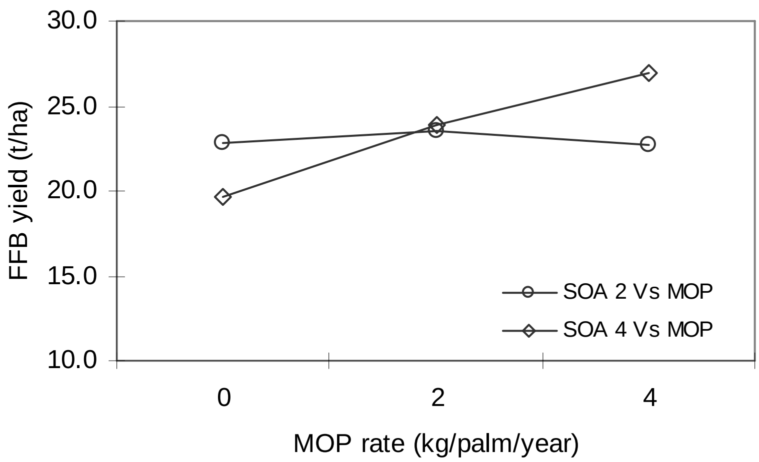


Figure 2: Effect of SOA.MOP interaction on FFB yield in 2006 (Trial 329)

Effects of treatments on leaf (F17) nutrient concentrations

SOA treatment had no significant effect on leaflet and rachis nutrient concentrations in 2006, except leaflet Mg (Tables 7 and 8). However, all nutrients were above their respective critical concentrations for leaflet.

TSP treatment had a significantly effect on both leaflet and rachis P 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 and Cl concentrations and rachis K concentration (Tables 6 & 7). The K difference between various rates of MOP treatment was significant at $l.s.d_{0.05}$. The difference in leaflet Cl was only significant at $l.s.d_{0.05}$ for the MOP 0 and MOP 4 treatments. Rachis K of 0.55% for MOP 0 treatment is well below the critical value of 1.0%. This indicates that K nutrition is limiting FFB yield production and the yield data (Tables 4 & 5) supports the leaf data.

Higher rates of Kieserite treatment increased leaflet Mg concentrations significant (Tables 6 & 7). The leaflet Mg for Kieserite 0 fell below the value considered critical for oil palm but its effect on yield has not shown up yet.

Table 6: Effects (p values) of treatments on frond 17 (F17) nutrient concentrations 2006 (Trial 329). p values <0.05 are indicated in bold.

	Leaflet							Rachis		
Source	**N**	**P**	**K**	**Mg**	**Cl**	**S**	**B**	**N**	**P**	**K**
SOA	0.11	0.43	0.16	**0.04**	0.53	0.64	0.71	0.79	0.95	0.90
TSP	0.35	**0.04**	0.17	0.36	0.08	0.68	0.41	0.80	**0.002**	0.62
MOP	0.13	0.42	**<0.001**	**0.03**	**<0.001**	0.23	0.05	0.54	**<0.001**	**<0.001**
KIE	0.73	0.75	0.15	**<0.001**	0.26	0.12	0.33	0.85	0.94	0.18
SOA.TSP	0.26	0.18	0.28	0.25	0.32	0.14	0.80	0.61	0.16	0.72
SOA.MOP	0.35	0.20	0.45	0.09	0.06	0.14	0.55	0.75	0.95	0.42
TSP.MOP	0.93	0.44	0.10	0.15	0.88	0.80	0.73	0.94	0.17	0.29
SOA.KIE	0.56	0.95	0.93	0.83	0.57	0.68	0.49	0.49	**0.02**	0.33
TSP.KIE	0.80	0.74	0.54	0.54	0.20	0.30	0.13	0.75	0.29	0.84
MOP.KIE	0.95	0.24	0.32	0.18	0.22	0.74	0.94	0.41	0.88	0.40
SOA.TSP.MOP	0.11	0.56	0.52	0.97	0.46	0.11	0.81	0.95	0.39	0.74
SOA.TSP.KIE	0.81	0.23	0.73	0.63	0.65	0.99	0.59	0.99	0.47	0.48
SOA.MOP.KIE	0.43	0.12	0.22	0.31	0.63	0.21	0.92	0.93	0.33	0.28
TSP.MOP.KIE	0.71	0.86	0.36	0.38	0.26	0.18	0.75	0.86	0.27	0.85
CV%	*2.2*	*2.3*	*6.4*	*10.8*	*15.3*	*2.4*	*9.2*	*8.3*	*11.7*	*9.4*

Table 7: Main effects of treatments on F17 nutrient concentrations in 2006, in units of % dry matter, except for B (mg/kg) (Trial 329). Effects with p<0.05are shown in bold.

	Leaflet (% dm, except for B ppm)								**Rachis (% dm)**			
Source	Ash	N	P	K	Mg	Cl	S	B	Ash	N	P	K
SOA 2	8.6	2.89	0.174	0.85	**0.26**	0.48	0.23	12	3.45	0.30	0.077	0.98
SOA 4	8.6	2.86	0.173	0.88	**0.24**	0.46	0.23	12	3.49	0.30	0.077	0.99
$Lsd_{0.05}$					*0.02*							
TSP 0	8.7	2.86	**0.172**	0.84	0.26	0.43	0.23	12	3.43	0.30	**0.068**	0.94
TSP 2	8.7	2.89	**0.174**	0.88	0.25	0.49	0.23	12	3.49	0.30	**0.078**	1.00
TSP 4	8.4	2.89	**0.176**	0.87	0.26	0.48	0.23	12	3.49	0.30	**0.084**	1.01
$l.s.d_{0.05}$			*0.003*								*0.007*	
MOP 0	**9.2**	2.85	0.173	**0.79**	**0.27**	**0.27**	0.23	13	**2.55**	0.29	**0.064**	**0.55**
MOP 2	**8.4**	2.88	0.175	**0.88**	**0.25**	**0.55**	0.23	12	**3.51**	0.30	**0.080**	**1.00**
MOP 4	**8.2**	2.90	0.174	**0.93**	**0.24**	**0.61**	0.23	11	**4.35**	0.30	**0.086**	**1.40**
$l.s.d_{0.05}$	*0.7*			*0.04*	*0.02*	*0.06*			*0.34*		*0.007*	*0.08*
KIE 0	**9.2**	2.87	0.173	0.88	**0.19**	0.50	0.23	12	3.67	0.30	0.077	1.07
KIE 2	**8.4**	2.88	0.174	0.88	**0.27**	0.46	0.23	12	3.36	0.30	0.077	0.92
KIE 4	**8.3**	2.88	0.174	0.84	**0.31**	0.46	0.23	12	3.38	0.30	0.077	0.95
$l.s.d_{0.05}$	*0.7*				*0.02*							
GM	*8.6*	*2.88*	*0.174*	*0.87*	*0.25*	*0.47*	*0.237*	*12*	*3.47*	*0.30*	*0.077*	*0.98*

Effects of fertiliser treatments on Vegetative parameters

The effects of fertiliser treatments on physiological parameters in 2006 were similar to the treatment effects on yield, only MOP had a significant effect on BDM, TDM and BI (Tables 8 and 9). Increasing MOP from 0 to 4 kg per palm increased BDM, TDM and BI significantly at *$l.s.d_{0.05}$* .

Table 8. Effect (p values) of treatments on vegetative growth parameters in 2006. 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	0.491	0.055	0.698	0.404	0.131	0.452	0.655	0.161	0.199
TSP	0.230	0.454	0.090	0.167	0.524	0.232	0.838	0.654	0.164
MOP	0.149	0.111	0.506	0.717	0.675	**0.006**	**0.019**	0.423	**0.023**
KIE	0.305	0.155	0.494	0.315	0.383	0.565	0.332	0.354	0.878
SOA.TSP	0.160	0.128	0.487	0.766	0.091	0.115	0.538	0.132	**0.040**
SOA.MOP	0.167	0.135	0.180	0.719	0.545	**0.006**	0.095	0.819	**0.007**
TSP.MOP	0.678	0.483	0.101	0.425	0.521	0.582	0.994	0.632	0.378
SOA.KIE	0.544	**0.020**	0.199	0.204	0.195	0.084	0.804	0.303	**0.029**
TSP.KIE	0.167	0.698	0.058	0.161	0.277	0.513	0.359	0.277	0.608
MOP.KIE	0.194	0.411	0.102	0.621	0.199	0.483	0.322	0.205	0.568
SOA.TSP.MOP	0.739	0.249	0.543	0.252	0.661	0.127	0.153	0.537	0.457
SOA.TSP.KIE	0.058	0.481	0.341	0.079	0.110	0.171	0.441	0.146	0.076
SOA.MOP.KIE	0.190	0.133	0.374	0.346	0.118	0.351	0.195	0.120	0.312
TSP.MOP.KIE	0.514	**0.010**	0.053	0.191	0.080	**0.029**	0.061	0.084	0.051
CV%	*5.8*	*3.6*	*4.8*	*7.1*	*6.1*	*10.7*	*6.2*	*5.9*	*7.7*

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 9. Main effects of treatments on vegetative growth parameters in 2006. Significant effects ($p<0.05$) are shown in bold.

Source	Radiation Interception				Dry Matter Production (t/ha)				
	PCS	FP	FA	LAI	FDM	BDM	TDM	VDM	BI
SOA 2	48.9	27.0	13.1	7.3	18.9	12.0	34.4	22.4	0.35
SOA 4	48.4	26.5	13.2	7.4	18.4	12.3	34.1	21.8	0.36
TSP 0	47.8	26.9	12.8	7.1	18.5	12.4	34.3	21.9	0.36
TSP 2	48.6	26.7	13.3	7.4	18.6	12.4	34.4	22.0	0.36
TSP 4	49.6	26.6	13.3	7.4	18.9	11.7	34.0	22.3	0.34
MOP 0	47.5	27.1	13.0	7.3	18.5	**11.1**	**32.9**	21.7	**0.34**
MOP 2	49.3	26.5	13.2	7.4	18.7	**12.3**	**34.5**	22.2	**0.36**
MOP 4	49.3	26.6	13.2	7.3	18.8	**13.1**	**35.4**	22.3	**0.37**
l.s.d$_{0.05}$						*1.0*	*1.6*		*0.02*
KIE 0	48.6	27.1	13.3	7.2	18.9	12.4	34.7	22.2	0.36
KIE 2	49.5	26.5	13.1	7.4	18.8	12.1	34.4	22.2	0.35
KIE 4	47.9	26.7	13.0	7.4	18.3	11.9	33.6	21.7	0.35
GM	*48.6*	*26.7*	*13.1*	*7.3*	*18.7*	*12.2*	*34.3*	*22.1*	*0.35*

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

CONCLUSION

Of all the fertiliser treatments only MOP had a positive effect on FFB yield in 2006. Increasing MOP from 0 kg per palm per year to any other rate increased yield by 1 to 3 t/ha. Leaf K levels and dry matter production, specifically BDM, TDM and BI were also increased by higher rates of MOP. Rachis K level, which is a good indicator of palm K nutrition dropped below the critical value of 1.0 %DM in 2006, thus response to fertiliser MOP is most likely over time.

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.

Although the main effect of SOA was only 0.5 to 0.8 t/ha in 2006, it increased yield when applied in combination with MOP. The maximum yield of 26.9 t/ha was produced at 4 kg SOA and 4 kg MOP in 2006. This combination produced 3t/ha more FFB yield compared to the main effects of the MOP treatment alone.

Trial 330: Grassland Sulphur Trial on Outwash Plains, Heropa Mini Estate

SUMMARY

The Nitrogen (N) x Sulphur (S) trial was established on the grasslands of Popondetta for the purpose of developing a fertiliser strategy for oil palm grown on the sandy soils of the grasslands.

In the first year treatment, there was no significant effect of fertilisers on yield, tissue nutrients and the physiological growth parameters.

INTRODUCTION

With increased oil palm plantings in the Popondetta grassland areas, both by smallholders and the mini-estate schemes, this trial was initiated purposely to provide information for fertiliser recommendations. In the grassland areas, N and S are expected to be the major limiting nutrients. The soils in the grassland areas are sandy with very low organic matter content. These areas also experience periods of water deficit during low rainfall months. Due to the porous nature of the sandy soils, leaching of nutrients can be a problem during periods of heavy rainfall. Soil results indicate low levels of K and P levels in the top 30 cm of the soil layer (Table 2). However, N and organic matter levels are high within the top 30 cm of the soil, possibly as products of mineralization of decaying plant debris within the oil palm establishment. With frequent burning during the dry season, soil C (OM) is not expected to accumulate in the surrounding grassland areas.

The objective of the trial is to provide information for fertiliser recommendations (especially for N and S) to the Estate, mini estates and the smallholder growers in the grassland areas of Popondetta.

Background information of the trial is presented in Table 1.

Table 1. Trial 330 background information.

Trial number	**330**	Company	Higaturu Oil Palms
Estate	Sangara	Block No.	Blocks 1 & 2
Planting Density	135 palms/ha	Soil Type	Sandy Soils
Pattern	Triangular	Drainage	Moderate
Date planted	2000	Topography	Flat
Age after planting	6	Altitude	130 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	James Kraip

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

Depth	**pH in**	**Exch K**	**Exch Ca**	**Exch Mg**	**CEC**	**OM**	**Total N**	**Olsen P**
cm	**water**	**cmol/kg**				**%**	**%**	**mg/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) is now using. Table 3 shows different rates of each fertiliser tested. Fertiliser treatments commenced in 2006 and treatments were applied in two applications per year. There was no nil N treatment because it was felt landowners might not want very low crop yields in the mini estates. The trial received an annual blanket application of MOP (2.0 kg/palm/yr), Borate (0.2 kg/palm/yr), FO1 magnesite (0.66 kg/palm/yr) and TSP (0.5 kg/palm/yr).

Table 3. Fertiliser treatments and levels in Trial 330.

	Amount (kg/palm/year)			
Fertiliser	**Level 1**	**Level 2**	**Level 3**	**Level 4**
Elemental Sulphur	0	0.15	0.30	-
Urea	0.5	1.5	2.5	3.5

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 per ha per year. Single bunch weight (SBW) was calculated from these data. During 2007 it is planned to harvest this trial on 10 day harvesting intervals in line with company practice. Leaf sampling was carried out once annually according to standard procedures and analysed for nutrient concentrations using standard analytical procedures.

Statistical Analysis

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

RESULTS and DISCUSSION

Effects of treatment on FFB yield and its components

Fertiliser treatments had no significant effect on FFB yield and yield components in the first year of the treatments application (Tables 4 & 5). The CV% for yield and BNO were very high and this indicates huge variability between plots in terms of bunch number and subsequently yield. One possible explanation for this is because of the substantial moisture difference observed within the trial block, mainly due to the difference in the soil's physical properties.

Table 4. Effects (p values) of treatments on FFB yield and its components in 2006.

	2006		
Source	**Yield**	**BNO**	**SBW**
Urea	0.389	0.452	0.407
Elemental Sulphur	0.398	0.293	0.695
Urea. Sulphur	0.776	0.610	0.972
CV %	55.0	43.4	15.1

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

Fertiliser (kg/palm)	2006 FFB yield (t/ha)	BNO	SBW (kg)
Urea 0.5	15.2	1458	10.1
Urea 1.5	13.5	1338	10.0
Urea 2.5	15.5	1451	10.2
Urea 3.5	9.9	1066	9.1
Elemental Sulphur 0	13.2	1288	10.0
Elemental Sulphur 0.15	11.6	1162	9.6
Elemental Sulphur 0.30	15.8	1535	10.0
Grand Mean	13.5	1328	9.9

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

Fertiliser treatments had no significant effect on leaf nutrients and all the nutrients were in the adequate range except leaflet K (Tables 6 & 7).

Table 6: Effects (p values) of treatments on frond 17 (F17) nutrient concentrations 2006 (Trial 330). p values <0.05 are indicated in bold.

	Leaflets							Rachis		
Source	**N**	**P**	**K**	**Mg**	**Cl**	**S**	**B**	**N**	**P**	**K**
Urea	0.132	0.832	0.962	0.392	0.857	0.762	0.859	0.434	0.928	0.415
S	0.390	0.938	0.217	0.936	0.899	0.330	0.944	0.916	0.855	0.635
Urea.S	0.556	0.368	0.495	0.669	0.710	0.226	0.386	0.692	0.488	0.698
CV%	*2.3*	*3.3*	*7.3*	*12.5*	*9.4*	*3.2*	*12.3*	*5.4*	*33.0*	*24.6*

Table 7: Main effects of treatments on F17 nutrient concentrations in 2006, in units of % dry matter, except for B (mg/kg) (Trial 330). Effects with p<0.05 are shown in bold.

	Leaflet (% dm) (except for B ppm)							Rachis (% dm)		
Source	**N**	**P**	**K**	**Mg**	**Cl**	**S**	**B**	**N**	**P**	**K**
Urea 0.5	2.58	0.158	0.64	0.28	0.52	0.21	13.0	0.30	0.096	0.89
Urea 1.5	2.60	0.160	0.64	0.29	0.51	0.21	13.5	0.31	0.097	1.04
Urea 2.5	2.65	0.158	0.65	0.28	0.53	0.21	13.6	0.31	0.088	1.08
Urea 3.5	2.61	0.159	0.63	0.31	0.52	0.21	13.6	0.32	0.094	1.03
S 0.00	2.59	0.159	0.62	0.29	0.53	0.21	13.6	0.31	0.098	0.98
S 0.15	2.61	0.159	0.66	0.29	0.52	0.21	13.4	0.31	0.093	1.07
S 0.30	2.63	0.159	0.65	0.29	0.52	0.21	13.3	0.31	0.091	0.99
GM	*2.61*	*0.159*	*0.64*	*0.29*	*0.52*	*0.21*	*13.4*	*0.31*	*0.094*	*1.01*

Effects of fertiliser treatments on Vegetative parameters

There was no significant effect of fertiliser treatment on vegetative growth parameters (Tables 8 and 9).

Table 8. Effect (p values) of treatments on vegetative growth parameters in 2006. 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	0.187	0.057	0.568	0.856	0.168	0.407	0.281	0.154	0.610
S	0.861	0.101	0.919	0.698	0.538	0.390	0.563	0.738	0.177
Urea.S	0.980	0.563	0.989	0.839	0.982	0.724	0.871	0.996	0.562
CV %	13.1	3.7	11.2	9.8	13.2	56.2	30.0	14.9	22.3

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 9. Main effects of treatments on vegetative growth parameters in 2006. Significant effects ($p<0.05$) are shown in bold.

Source	Radiation Interception				Dry Matter Production (t/ha)				BI
	PCS	**FP**	**FA**	**LAI**	**FDM**	**BDM**	**TDM**	**VDM**	
SOA 0.5	22.5	26.4	8.1.	4.7	8.9	8.0	18.9	10.8	0.41
SOA 1.5	21.1	26.2	8.1	4.8	8.4	6.9	17.0	10.1	0.39
SOA 2.5	22.4	25.3	8.1	4.8	8.5	8.2	18.5	10.3	0.42
SOA 3.5	19.9	25.6	7.6	4.7	7.7	5.3	14.5	9.2	0.37
$LSD_{0.05}$									
S 0	21.8	26.4	8.0	4.8	8.7	6.7	17.2	10.4	0.38
S 0.15	21.5	25.7	8.1	4.9	8.3	6.2	16.1	9.9	0.37
S 0.30	21.1	25.6	7.6	4.7	8.2	8.4	18.4	10.0	0.43
$LSD_{0.05}$	-	-	-	-					
GM	*21.5*	*25.9*	*8.0*	*4.8*	*8.2*	*7.1*	*17.2*	*10.1*	*0.39*

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

CONCLUSION

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

Trial 333: Slow Release Options for Magnesium and Potassium 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 fertilisers, 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 fertiliser 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 fertiliser treatments in 2006. Leaflet Mg concentrations were above the crtitical 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.

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 fertiliser 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 fertilisers 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 fertilisers 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 fertilisers, 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	13	Altitude	800 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	James Kraip

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 144 at Waisisi, WNB), a boiler ash treatment, (supplies Mg and K in approximately the correct ratio) and a control with zero Mg and K. Fertiliser rates for the various treatments are given in Table 2.

Group 1, Mg sources
The following 4 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) Kieserite, 2) Magnesite (QMAG Magnesite 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 and this treatment will be exhumed after 2.5 years to ascertain how much is left. 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 would include 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 Fertiliser -see below) plot for each replicate 'tripled up' as the control for each group.

Basal fertiliser
Nitrogen (Urea) was applied across the trial as urea 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.

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

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

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. Fertiliser types and rates

Trt No	Fertiliser	Nutrient	Nutrient appl. rate (kg/palm)	Nutrient cont. of fert. (%)	Fert. appl. rate (kg/palm)	Number of appl.	Amount per applic. (g/palm)
	Group 1 (Mg sources)						
1	Kieserite	Mg	0.425	17	2.5	2/yr	1,250
2	Magnesite (FO1)	Mg	0.425	26	1.6	2/yr	817
3	Dolomite[1]	Mg	0.425	10	4.3	2/yr	2,125
4	MgO (EMAG 45)	Mg	0.425	56	0.8	2/yr	379
	Basal (all plots)						
	MOP	K	1.25	50	2.5	2/yr	1,250
	MOP trenches & plastic	K	3.75	50	7.5	1	7,500
	Group 2 (K sources)						
5	MOP surface	K	1.25	50	2.5	2/yr	1,250
6	MOP trenches & plastic	K	3.75	50	7.5	1	7,500
7	EFB[2]	K	2.50	0.83	300	1/yr	44 tonnes
	Basal (all plots)						
	Kieserite	Mg	0.14	17	0.8	2/yr	417
	Magnesite	Mg	0.14	26	0.5	2/yr	272
	MgO	Mg	0.14	56	0.3	2/yr	126
	Group 3 (Mg and K factorial)						
8	MOP	K	1.25	50	2.5	2/yr	1,250
	MOP trenches & plastic	K	3.75	50	7.5	1	7,500
9	Kieserite	Mg	0.14	17	0.8	2/yr	417
	Magnesite	Mg	0.14	26	0.5	2	272
	MgO	Mg	0.14	56	0.3	2	126
10	Tr 8 + tr 9						
11	Boiler Ash[3]	Mg & K	0.425 & 1.39	1.5 & 4.9	28.3	2	14,167
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) so 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 K/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 per ha per year. Single bunch weight (SBW) was calculated from these data. During 2007 it is planned to harvest this trial on 10 day harvesting intervals in line with company practice. 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 of the main effects of fertiliser 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 and the single bunch weights in 2006 and for the combined 2005-2006 period (Table 3). The fertiliser treatments only commenced in April 2004, thus it still early for any significant effect to occur.

One-Way ANOVA for either Mg or K sources only had no significant effect on yield. Even, yield from palms adequately supplied with Mg and K was not affected by treatments. Since the results of One-Way ANOVA (p values and main effects) showed no significant effects of treatments, the results are not presented.

Table 3. Effects (p values) of treatments on FFB yield and its components in 2005 – 2006 and 2006.

	2005 - 2006			2006		
Source	**Yield**	**BNO**	**SBW**	**Yield**	**BNO**	**SBW**
Treatment	0.881	0.745	0.434	0.567	0.767	0.657
CV %	14.6	15.2	6.1	12.4	13.9	6.8

Table 4. Main effects of treatments on FFB yield (t/ha) from 2004 to 2006 and 2006.

		2005 - 2006			2006		
		FFB yield (t/ha)	**BNO/ha**	**SBW (kg)**	**FFB yield (t/ha)**	**BNO**	**SBW (kg)**
1	Control	22.5	829	27.8	25.7	952	27.8
	Group 1						
2	Dolomite	23.8	874	28.3	27.2	1002	28.2
3	$MgCO_3$	23.8	894	27.6	25.7	961	27.7
4	$MgSO_4$	25.1	924	28.3	28.1	1059	27.7
5	MgO	26.4	892	27.5	25.5	918	27.7
	Group 2						
6	MOP Trench/Plastic	23.4	851	27.9	26.6	957	28.2
7	EFB	22.8	837	27.9	26.7	955	28.3
8	MOP surface	20.6	753	28.0	24.3	878	28.2
	Group 3						
9	MOP Surface + Trench	22.9	881	25.9	24.5	952	26.3
10	$MgSO_4$+$MgCO_3$+MgO	23.2	952	25.7	23.9	996	25.7
11	Treatment 9+10	24.2	916	27.4	27.0	1009	27.7
12	Boiler ash	22.1	814	28.1	23.1	869	27.7
	Grand mean	23.2	868	27.5	25.7	959	27.6

Effects of fertiliser treatments on leaf (F17) nutrient concentrations

The Mg and K fertiliser treatments had a significant effect on leaflet Mg and K concentrations in 2006 (Table 5). Similarly, rachis Mg and K concentrations were affected by fertiliser treatments.

Regardless of the treatment effects, leaflet Mg levels were above the critical value of 0.20% DM and leaflet K values were below the critical of 0.75% except for MgO+adequate K and all sources Mg +

all sources K treatments (Table 6). All rachis K levels were above the value considered critical for oil palm (1.0%DM), except that for the control plot which was below the critical value. In terms of differences between K source fertilisers, only 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 2006 (Trial 333). p values <0.05 are indicated in bold.

	Leaflet								Rachis			
Source	**Ash**	**N**	**P**	**K**	**Mg**	**Cl**	**S**	**B**	**N**	**P**	**K**	**Mg**
Trt	0.36	0.59	0.278	**0.03**	**0.01**	0.18	0.26	0.55	0.62	**<0.001**	**0.007**	**0.002**
CV%	*7.1*	*4.1*	*3.1*	*7.8*	*12.0*	*5.3*	*4.7*	*10.3*	*5.1*	*10.2*	*16.0*	*15.4*

Table 6: Main effects of treatments on F17 nutrient concentrations in 2006, in units of % dry matter, except for B (mg/kg) (Trial 333). Effects with p<0.05are shown in bold.

	Leaflet %dm (except for B ppm)								Rachis % dm			
Source	**Ash**	**N**	**P**	**K**	**Mg**	**Cl**	**S**	**B**	**N**	**P**	**K**	**Mg**
Control	11.8	2.61	0.159	**0.70**	**0.29**	0.54	0.21	14	0.29	**0.043**	**0.83**	**0.63**
Group 1												
Dolomite	11.3	2.62	0.155	**0.74**	**0.23**	0.53	0.22	13	0.30	**0.041**	**1.15**	**0.68**
$MgCO_3$	11.4	2.57	0.157	**0.70**	**0.22**	0.54	0.21	13	0.30	**0.041**	**1.15**	**0.65**
$MgSO_4$	11.0	2.60	0.153	**0.73**	**0.25**	0.52	0.21	14	0.31	**0.043**	**1.15**	**0.70**
MgO	11.4	2.63	0.156	**0.76**	**0.23**	0.54	0.22	13	0.31	**0.042**	**1.28**	**0.65**
Group 2												
MOP Trench/Plastic	11.2	2.56	0.151	**0.68**	**0.24**	0.51	0.21	13	0.30	**0.040**	**1.09**	**0.80**
EFB	10.9	2.66	0.161	**0.74**	**0.24**	0.49	0.22	13	0.29	**0.053**	**1.34**	**0.65**
MOP surface	11.1	2.56	0.154	**0.67**	**0.25**	0.53	0.21	13	0.30	**0.055**	**1.14**	**0.83**
Group 3												
MOP Surface+Trench	12.1	2.53	0.154	**0.73**	**0.28**	0.55	0.21	13	0.30	**0.046**	**1.27**	**0.50**
$MgSO_4$+$MgCO_3$+MgO	12.0	2.51	0.153	**0.64**	**0.24**	0.52	0.21	14	0.29	**0.037**	**0.92**	**0.88**
Treatment 9+10	11.2	2.58	0.155	**0.77**	**0.23**	0.55	0.21	14	0.30	**0.039**	**1.32**	**0.65**
Boiler ash	12.1	2.50	0.157	**0.68**	**0.23**	0.52	0.20	15	0.30	**0.052**	**1.03**	**0.75**
l.s.d.$_{0.005}$				*0.08*	*0.04*					*0.006*	*0.08*	*0.02*
Grand mean	*11.5*	*2.58*	*0.155*	*0.71*	*0.23*	*0.53*	*0.21*	*13.5*	*0.30*	*0.041*	*1.14*	*0.70*

Effects of fertiliser treatments on Vegetative parameters

Fertiliser treatments had no significant effect on any of the physiological growth parameters n 2006 (Tables 7 and 8).

Table 7. Effect (p values) of treatments on vegetative growth parameters in 2006. 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	
Treatment	0.307	0.952	0.689	0.945	0.227	0.384	0.210	0.209	0.645
CV %	4.5	4.3	7.4	11.0	5.0	11.3	6.0	5.0	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 8. Main effects of treatments on vegetative growth parameters in 2006. Significant effects ($p<0.05$) are shown in bold.

Source	Radiation Interception				Dry Matter Production (t/ha)				BI
	PCS	FP	FA	LAI	FDM	BDM	TDM	VDM	
Control	55.6	31.5	13.2	5.9	26.5	14.0	45.0	31.0	0.31
Group 1									
Dolomite	55.7	31.6	13.1	5.9	26.7	14.9	46.2	31.3	0.32
$MgCO_3$	54.6	31.0	14.8	6.7	25.6	14.1	44.2	30.0	0.32
$MgSO_4$	51.5	31.1	13.2	6.1	24.3	12.6	41.0	28.4	0.31
MgO	55.3	30.5	13.3	6.3	25.5	14.4	44.3	29.9	0.33
Group 2									
MOP Trench/Plastic	55.4	30.9	13.1	5.9	25.9	13.0	44.2	30.2	0.30
EFB	55.1	31.6	13.5	6.2	26.3	12.9	43.6	30.7	0.30
MOP surface	51.6	31.2	13.8	6.1	24.4	12.8	41.4	28.6	0.31
Group 3									
MOP Surface+Trench	53.8	30.4	13.3	6.3	24.8	11.9	40.7	28.9	0.29
$MgSO_4$+$MgCO_3$+MgO	53.8	30.2	13.3	6.2	24.6	12.3	41.0	28.7	0.30
Treatment 9+10	56.8	31.2	13.8	6.5	26.8	13.2	44.5	31.2	0.30
Boiler ash	54.7	31.0	13.9	6.4	25.6	12.9	42.8	29.9	0.30
Grand mean	54.5	31.0	13.5	6.2	25.6	13.3	43.1	29.9	0.31

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

CONCLUSION

Fertiliser treatments had no significant effect on yield and physiological growth parameters in 2006. These results were similar to the previous years' results since the trial commenced in 2004.

The leaflet and rachis Mg and K concentrations were affected by fertiliser treatments in 2006. Rachis K which is regarded as a good indicator of K nutrition in oil palm was above the critical value for every treatment except the control plot. Leaflet Mg concentrations were above the critical value regardless of fertiliser treatments.

Poliamba Estates, New Ireland Province: Summary and Synopsis

(Harm van Rees and Kelly Naulis)

A single fertiliser response trial was undertaken with Poliamba in 2006:

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

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

Two other factorial trials, 251 and 252, were discontinued at the end of 2005. Harvest is still continuing for trial 252 but no fertiliser treatments are being applied. The combined results for both trials are being written up as a final report.

CTP Poliamba Estates: Synopsis of 2006 PNG OPRA trial results and recommendations

Trial	Palm Age	Yield t/ha	Yield Components	Tissue	Notes
254 Poliamba B, MOP (factorial) Soil: Clay over coral	17	B x MOP 26 (NS)	B/palm 9.3 (NS) SBW 22.3 (NS)	MOP LK 0.66 (NS) RK 1.50 (NS) B LB 18 to 20 LN 2.50%; LP 0.151%; RP 0.10%; LMg 0.25%	Operational issues in field (pruning, harvest) also site issues main problems with this 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 fertiliser strategies can be calculated if costs of production are provided to OPRA
5. Plantation management (harvest time, pruning, clean weeded circles, fertiliser 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 fertiliser 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 Estates.

SUMMARY

There were no differences in yield or tissue nutrient concentration from Borate and MOP fertiliser treatments in 2006. The trial is only in its first year of full monitoring and assessment.

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 fertiliser applications at Poliamba. Specifically, the trial is designed to test responses to Ca borate or Na borate at two rates, and secondarily, to test the interaction of Boron with Potassium.

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	17 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	Kelly Naulis

Experimental Design and Treatments

Boron fertiliser is 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 is applied at two rates (2.5, 7.5 kg MOP/palm/yr).

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 = $Na_2B_4O_2 . 10\ H_2O$) is 11%B

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

Basal fertilisers applied to all plots: TSP 1 kg / palm, Kieserite 1 kg / palm (split into 2 applications), and SOA 5 kg / palm (spit into 2 applications)

RESULTS and DISCUSSION

Yield and its components

There were no significant effects of Borate (type or rate) or MOP (rate) on yield (Table 2), Bunch number (Table 3) or SBW (Table 4) in 2006.

Table 2. Trial 254: Impact on FFB yield in 2006 from Borate fertiliser (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	26.4	28.4
CaB	0.08	25.7	27.1
CaB	0.16	25.5	24.6
NaB	0.073	25.6	29.4
NaB	0.146	26.6	27.0
	Significant Difference:	**NS**	
	CV%:	**10.3**	

Table 3. Trial 254: Impact on Number of Bunches (per ha) in 2006 from Borate fertiliser (2 types, 2 rates) and MOP (2 rates)

Borate source	Rate (B kg/p)	No. of Bunches/palm	
		MOP 2.5 kg/p	MOP 7.5 kg/p
No Borate (control)	0	1216	1293
CaB	0.08	1178	1216
CaB	0.16	1139	1152
NaB	0.073	1203	1331
NaB	0.146	1178	1254
	Significant Difference:	**NS**	
	CV%:	**10.2**	

Table 4. Trial 254: Impact on Single Bunch Weight (kg/bunch) in 2006 from Borate fertiliser (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	22.2
CaB	0.08	22.5	22.5
CaB	0.16	22.8	21.9
NaB	0.073	21.8	22.0
NaB	0.146	22.9	22.0
	Significant Difference:	**NS**	
	CV%:	**4.1**	

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 on either leaflet or rachis K. The application of Borate (either as Ca or Na borate) was significant but the trend was not consistent (Table 5). The control treatments (no borate fertiliser) did have low leaflet boron concentration but not significantly lower than several of the borate treatments. The results are inconclusive in this the first year of the trial.

Table 5. Trial 254: Tissue leaflet and rachis nutrient concentration in 2006 resulting from Borate fertiliser (2 types, 2 rates) and MOP (2 rates) application.

Borate source	Boron kg/p	Muriate of Potash kg/p					
		2.5	7.5	2.5	7.5	2.5	7.5
		Leaflet K (%)		Rachis K (%)		Boron (mg/kg)	
No Borate (control)	0	0.66	0.68	1.59	1.76	15.0	16.6
CaB	0.08	0.71	0.68	1.70	1.76	18.8	21.6
CaB	0.16	0.65	0.65	1.51	1.58	17.6	16.1
NaB	0.073	0.67	0.67	1.70	1.49	17.2	19.6
NaB	0.146	0.71	0.68	1.45	1.73	20.4	20.4
Significant Difference:		**NS**		**NS**		**P=0.01**	
$LSD_{0.05}$						**2.0**	
CV%:		**10.3**		**12.4**		**16.3**	

The levels of leaflet N (mean 2.5%), leaflet P (mean 0.151%), leaflet Mg (mean 0.25%) and rachis P (mean 0.10%) were all adequate and were not affected by the fertiliser treatments.

CONCLUSION

Muriate of Potash (MOP) and Borate fertiliser had no impact on yield or on tissue nutrient concentration. The trial treatments were first applied in 2005 and this year was the first full year of monitoring and assessment. It could be too early yet to tell whether the treatments will impact on yield and its components.

Ramu Oil Palm, Markham Valley

(Lastus Kuniata, Ramu Sugar)

Trial # Rm 1-03 : Factorial Fertiliser Trial on Immature Palms at Gusap

This trial was planted in November 2003 in block NG203 (Gusap). A NxKxPxS factorial design with 2 replicates was used (see details of treatments – Table 1). Sixteen identified progenies were used in each plot. All the treatments were randomised – the progenies within the plots and the fertilizers 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 basal starting July 2005 was discontinued and all the plots will from now on receive designated treatments as detailed in the trial plan. The current applications are for year 4 which is basically same as for year 3.

Table 1: Details of elements and rates used in trial # RM1-03 (grams element per palm).

		Planting hole	Year 1	Year 2	Year 3	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

There were no vegetative assessments done in 2006 and 2007, however fresh fruit bunches (FFB) yield recordings have started as from June 2007. The preliminary data (for June) on number of bunches showed significant ($p<0.05$) responses to application of potassium while the interactions were highly significant potassium and sulphur (Table 2). In the total bunch weights, nitrogen and potassium had significant responses to fertilizer application (Table 2). The nitrogen x potassium x sulphur interactions were highly significant (Figure 1). Although bunch weights increased with application of nitrogen and potassium, the highest rate of nitrogen was less effective but this is too early to make any conclusions. The interactions observed with sulphur and the other nutrients applied were highly significant (Figure 1b & 1c). The application of phosphorus and potassium also increased the average bunch weight (Figure 1d). The progeny effect was not significant.

Table 2: Preliminary observations on FFB numbers and total bunches weight for June 07 (start of harvest).

Interactions observed	Level of significance	P
Bunch number		
- Potassium	*	<0.05
- Potassium x Sulphur	***	<0.001
- Nitrogen x Phosphorus x Potassium	*	<0.05
- Nitrogen x Potassium x Sulphur	***	<0.001
- Nitrogen x Phosphorus x Sulphur	**	<0.01
- Nitrogen x Potassium x Phosphorus x Sulphur	***	<0.001
Total bunch weight		
- Nitrogen	*	<0.05
- Potassium	**	<0.01
- Potassium x Sulphur	***	<0.001
- Nitrogen x Potassium x Sulphur	***	<0.001
- Nitrogen x Potassium x Phosphorus x Sulphur	***	<0.001

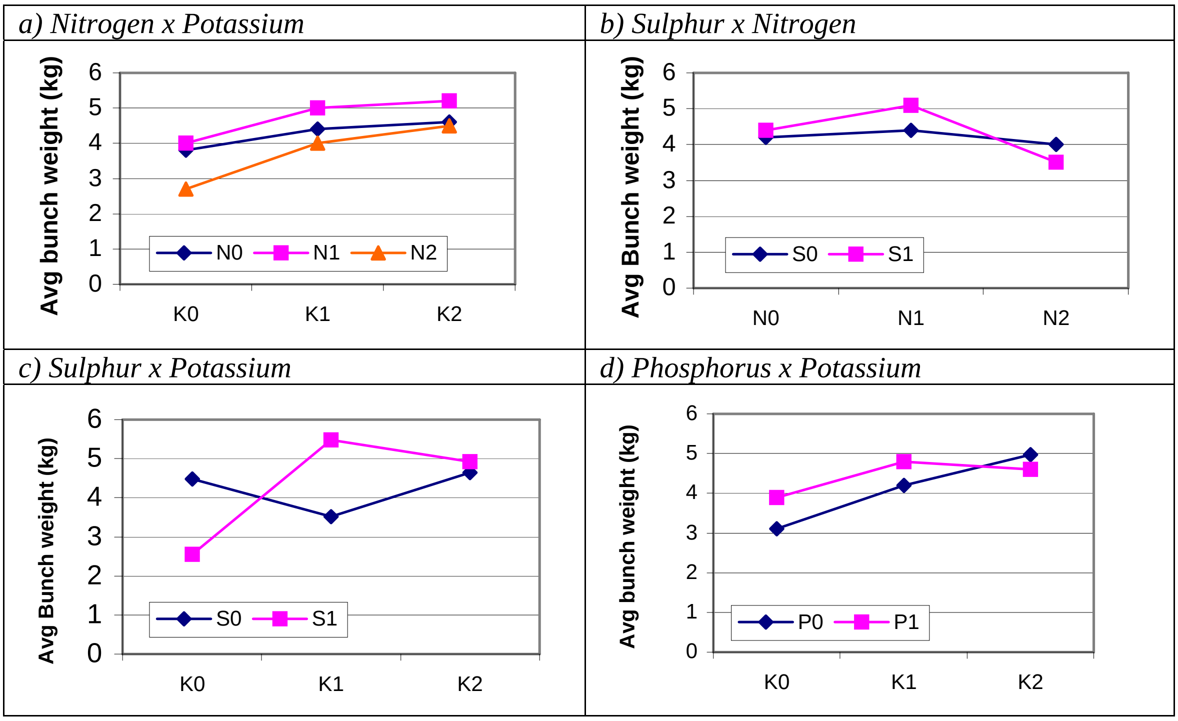


Figure 1: Summary of preliminary observations made for nutrient interactions observed for average bunch weight (GN203 Jun07 data).

Trial # Rm 2-03: Factorial Fertiliser Trial on Immature Palms at Gusap

The trial was planted in December 2003 in block GN106 (Gusap). The layout and progenies used were similar to trial RM1-03. Commercial rates of fertilizer were applied during the immature stage of the palms. These have now been stopped and the treatments will be imposed at mature stage starting in October 2007. Fresh fruit bunch yield recordings have started as of July 2007.

Trial # Rm 3-04 : Factorial Fertiliser Trial on Immature Palms at Gusap

This trial was planted in December 2004 in block GN409 (Gusap). The trial layout and treatments were similar to trial # RM1-03 except that the soil type was deep loam and progenies were different. Fertilizer treatments used in 2007 were for year 3 as detailed in Table 1. FFB yield recordings have started as from July 2007.

Spacing Trials

Trial 331: Spacing and Thinning Trial, Ambogo Estate, Higaturu Oil Palm

SUMMARY

The trial was designed to test the effects of spacing configuration, thinning and planting density on fresh fruit bunch (FFB) yield and other variables of interest. From field planting, there were six densities treatments (128, 135, 143, 192, 203 and 215 palms/ha) but at 5 years of age (May 2006), the densities 192, 203 and 215 were thinned to 128, 135 and 143, respectively, which now become the replicate of the three originally lower densities but with different spacing configurations.

Prior to thinning, a significantly high number of bunches (BNO) were produced at densities 192, 203 and 215 compared to the three lower densities. In 2006, the increase in the BNO resulted in significantly higher FFB yields. At lower densities, single bunch weight (SBW) was significantly higher.

INTRODUCTION

The purpose of the trial was to determine the effects of spacing configuration, thinning and density on palms, cover crops and soils, with a view to facilitating mechanical in-field collection. Mechanical removal of FFB from the field after harvest is now a common practice in some plantations. This 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 3	Soil Type	Alluvial volcanic ash
Pattern	Triangular	Drainage	Good
Date planted	2001	Topography	Flat
Age after planting	5	Altitude	130 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	Not known	Agronomist in charge	James Kraip

METHODS

Design and treatments

Initially there were 6 treatments of different planting densities with equilateral triangular spacing (Table 2). In treatments 4, 5 and 6 every third row was removed 5 years after planting (May 2006) and treatments 1, 2 and 3 remained as planted. The final densities of treatments 4, 5 and 6 were the same as treatments 1, 2 and 3 but they have closely spaced pairs of rows with wide avenues between the pairs. There were 3 replicates of the 6 spacing treatments, giving a total of 18 plots. Each plot had 4 rows of recorded palms and these plots were surrounded by guard palms.

In 2002, about a year after the palms were planted, 7 cover crops were sown in small plots throughout replicate 2 of the spacing trial in order to assess their performance under the different light and traffic conditions of the different spacing treatments. The cover crops were Pueraria, Calapogonium, Mucuna, Vigna, Desmodium, Centrosema and Stylo. The cover crop trial was discontinued as there was poor germination and establishment.

Table 2. Treatment allocations in Trial 331. 'Thinning' involves the removal of every third row 5 years after planting in treatments 4, 5 and 6.

Treatment No	Initial density (palms/ha)	Triangular spacing (m)	Initial number of rows/plot	Density after thinning (palms/ha)	Inter-row width after thinning (m)
1	128	9.50	7	128	8.2
2	135	9.25	7	135	8.0
3	143	9.00	7	143	7.8
4	192	7.75	8	128	13.4 & 6.7
5	203	7.55	9	135	13.1 & 6.5
6	215	7.33	9	143	12.7 & 6.4

Data Collection

Recordings and measurements were taken on the 4 row of palms in each plot. The number of bunches and bunch weights were recorded fortnightly on an individual palm basis (individual palms not numbered) and totalled for each plot, then totalled for each harvest and expressed per ha per year. Single bunch weight was calculated from these data. During 2007 it is planned to number every recorded palm in each plot and record data against each numbered palm in the computer database system.

Leaf sampling was carried out once annually according to standard procedures and analysed for nutrient concentrations using standard analytical procedures. Every 5th palm in every recorded row of palms was leaf sampled and vegetative measurements were also taken from same palms.

Statistical Analysis

Analysis of variance (One-way ANOVA) of the main effects of density treatments was carried out for each of the variables of interest using the GenStat statistical program.

RESULTS and DISCUSSION

Effects of density treatment on yield and yield components

Density treatments had a significant effect on yield and it components in 2006 (Table 3). The higher densities (192, 203 and 215) produced significantly ($P<0.001$) higher yields compared to the lower densities (128, 153 and 143) in the 5th year after field planting (Table 4). The increase in yield at higher densities was mainly due to increased number of bunches. Single bunch weight on the other hand was significantly higher for lower density plantings (128, 153 and 143). There is a benefit in yield with densities of 192 or more for younger palms, especially due to higher number of bunch produced during the immature phase (6 years old or less). However, when the palms pass the immature phase, bunch numbers usually decline while SBW continues to increase.

Table 3. Effects (p values) of treatments on FFB yield and its components in 2006.

	2006		
Source	**Yield**	**BNO**	**SBW**
Density treatment	**<0.001**	**<0.001**	**0.001**
CV %	5.6	7.4	2.7

Table 4. Main effects of treatments on FFB yield (t/ha) in 2006 (treatments which are significantly different at P<0.05 are presented in bold).

		2006	
Density Treatment	**FFB yield (t/ha)**	**BNO**	**SBW (kg)**
128	**29.6**	**2651**	**11.2**
135	**29.0**	**2680**	**10.8**
143	**29.9**	**2825**	**10.7**
192	**40.2**	**4079**	**10.2**
203	**37.8**	**3973**	**9.8**
215	**41.4**	**4171**	**10.1**
$LSD_{0.05}$	*3.6*	*455*	*0.5*
Grand Mean	34.7	3396	10.5

Leaf tissue nutrient concentrations

All leaf tissue nutrient levels were above their respective critical values for oil palm (Table 6). There were significant differences in leaflet P and Mg levels between densities and this occurred only by chance (Table 5).

Table 5: P values of frond 17 nutrient concentrations 2006. (Trial 331). p values <0.05 are indicated in bold.

	Leaflet							**Rachis**		
Source	**N**	**P**	**K**	**Mg**	**Cl**	**S**	**B**	**N**	**P**	**K**
Density	0.066	**0.018**	0.072	**0.037**	0.068	0.052	0.622	0.223	0.656	0.071
CV%	*1.9*	*0.9*	*4.1*	*3.6*	*4.1*	*2.4*	*26.9*	*4.1*	*8.1*	*4.0*

Table 6: Main effects of treatments on F17 nutrient concentrations in 2006, in units of % dry matter, except for B (mg/kg) (Trial 330). Effects with $p<0.05$are shown in bold.

	Leaflet (% dm, except Boron ppm)							Rachis (% dm)		
Density	N	P	K	Mg	Cl	S	B	N	P	K
128	2.61	**0.158**	0.75	**0.27**	0.51	0.21	20.3	0.30	0.129	1.81
135	2.63	**0.160**	0.75	**0.28**	0.52	0.21	22.8	0.30	0.127	1.87
143	2.68	**0.161**	0.73	**0.26**	0.49	0.21	29.7	0.32	0.121	1.84
192	2.57	**0.157**	0.74	**0.27**	0.52	0.20	25.0	0.32	0.135	1.87
203	2.54	**0.156**	0.70	**0.29**	0.48	0.20	22.9	0.31	0.124	1.68
215	2.64	**0.158**	0.68	**0.28**	0.52	0.21	25.8	0.31	0.125	1.81
$LSD_{0.05}$		*0.003*		*0.02*						
GM	*2.61*	*0.158*	*0.73*	*0.273*	*0.507*	*0.205*	*24.4*	*0.308*	*0.127*	*1.81*

CONCLUSIONS

The density treatment had a significant effect on yield in 2006 with the higher yields achieved at the higher planting densities of 192, 203 and 215 palms/ha (compared to the lower density of 128, 135 and 143 palms/ha). The number of bunches were significantly higher for the three higher densities while single bunch weight was higher for the three lower densities. In 2005, density treatments had no significant effect on yield but treatment had a significant effect on number of bunches and single bunch weight.

Leaf tissue nutrient levels were generally at an adequate level.

Trial 513: Spacing and Thinning Trial at Padipadi, CTP Milne Bay Estates

SUMMARY

The trial was designed to test the effects of spacing configuration, thinning and planting density on fresh fruit bunch (FFB) yield and other variables of interest. From field planting, there were six densities treatments (128, 135, 143, 192, 203 and 215 palms/ha) but at 5 years of age (in 2008), the densities 192, 203 and 215 will be thinned to 128, 135 and 143, respectively, which will become the replicate of the three originally lower densities but with different spacing configurations.

The palms are 3 years old and fresh fruit bunch (FFB) yield recording only commenced in April 2006. However, density effect on yield was significant and this was mainly due to increase in bunch numbers at higher densities. More data are required to validate these results.

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 is now a common practice in some plantations. This is intended to reduce harvesting costs. Little is known however about the impacts that machine traffic have 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. 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	3	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	Mix	Agronomist in charge	Steven Nake

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. 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 wide 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.

Within one of the replicates, plots with different cover crops were established. Fertiliser application will follow an immature fertiliser program during the immature phase (0 to 6 years).

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.

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 2 guard rows

Data Collection

Recordings and measurements are taken on the 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 are not numbered) 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. During 2007 it is planned to number every recorded palm in each plot and record data against each numbered palm in the computer database system.

Leaf sampling will be carried out once annually according to standard procedures and analysed for nutrient concentrations using standard analytical procedures. Every 5th palm in every recorded row of palms will be leaf sampled and vegetative measurements will also be taken from same palms.

Statistical Analysis

Analysis of variance (One-way ANOVA) of the main effects of density treatments will be carried out for each of the variables of interest using the GenStat statistical program.

RESULTS and DISCUSSION

Density treatments had a significant effect on yield and number of bunches per ha but single bunch weight was not affected by density treatment in the first 7 months of yield recording (Table 3). These results will be validated with more data over time.

Table 3. Impact of planting density on Yield (t/ha), BNO/palm and SBW for part of the year in 2006.

Density Treatment	Yield (t/ha)	BNO/ha	SBW (kg)
128	**1.63**	**239**	**6.6**
135	**1.56**	**241**	**6.4**
143	**2.14**	**294**	**7.2**
192	**2.84**	**381**	**7.4**
203	**3.18**	**402**	**7.7**
215	**3.17**	**428**	**7.4**
Grand Mean	2.42	331	7.1
P value ($LSD_{0.05}$)	***<0.001 (0.69)***	***<0.001 (48)***	***0.089***
CV%	*15.6*	*7.9*	*7.8*

CONCLUSION

Density treatment had a significant effect on yield and number of bunches in the first 7 months of yield recording. The significant yield increase at higher densities was mainly due to increase in bunch numbers.

Trial 139: Palm Spacing Trial, Kumbango Plantation, NBPOL

SUMMARY

At a planting density of 128 palms/ha with varying avenue widths of 8.2, 9.5 and 10.6 m there is no difference in yield and palm performance. 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). The investigation will include looking at the effects of planting patterns on oil palm growth, tissue nutrient levels, crop production and ground cover as well as the effect of mechanical in-field collection on soil properties.

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	7	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 fertilisers applied in 2006: AN 1.5kg/palm; Kieserite 2kg/palm (replicate 2 only); Borate 150g/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. Bunch numbers and weights are being measured on 34 palms in every third row of each replicate. In each plot, rows 2, 5, 8, 11, 14, 17, 20, 23, 26, 29, 32 and 35 are recorded.

Leaf sampling, frond marking and vegetative measurements are being done in every 5th palm per recorded row per plot.

Table 2. Spacing treatments in Trial 139.

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

RESULTS and DISCUSSION

Spacing treatment effect on yield

Yield increased from 17.0 t/ha in 2003 to 26.7 t/ha in 2006 (age of palms from 4 to 7 years). However, thus far there is no effect of changing the row and avenue spacing configuration on yield (Figure 1).

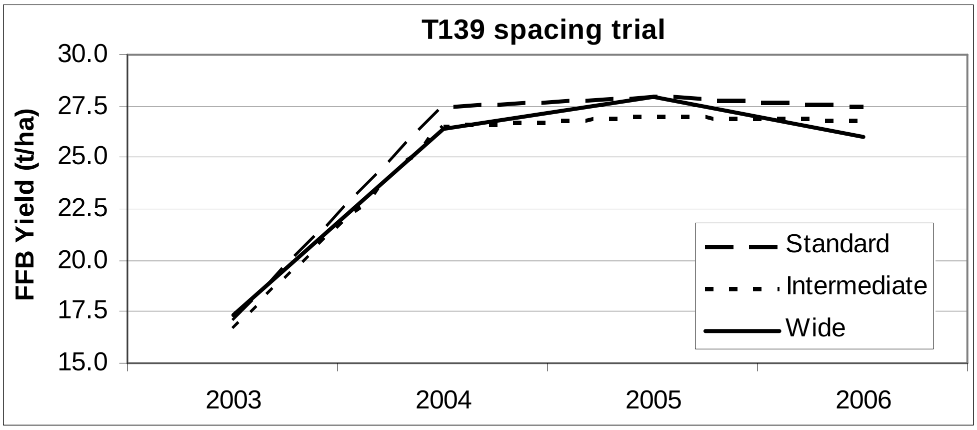


Figure 1. The impact of Avenue Width on yield (keeping planting density the same) for Trial 139.

Spacing treatment effect on tissue nutrient levels

There were some significant differences between avenue width treatments in the nutrient status of the palms (Table 3). However, the differences are only small and do not make much biological sense.

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	2.57	0.144	0.71	0.30	0.08	1.47
Intermediate	2.51	0.139	0.73	0.31	0.07	1.45
Wide	2.57	0.141	0.73	0.29	0.07	1.52
Significant diff:	P=0.04	P=0.03	NS	NS	NS	NS
$LSD_{0.05}$	0.05	0.002	-	-	-	-
CV%	0.9	0.9	4.7	5.1	7.4	12.4

CONCLUSION

At this stage in the trial, as palms are reaching maturity, there are no differences in yield between planting palms at a standard avenue width of 8.2m compared to wider avenues of 9.5 and 10.6m (whilst keeping density the same).

It also appears that the wider avenues have much better ground cover compared to narrower avenues. This coming year we will be quantifying ground cover (% cover and dry matter production) between treatments.

2. ENTOMOLOGY RESEARCH

(C. F. Dewhurst)

SUMMARY

General IPM Related Issues

Monitoring of all pests, improving reporting and control techniques as well as efficiency of oil palm insecticide treatment continues be a priority for operational research with direct smallholder and plantation relevance.

Ad hoc and formalised training sessions and field days continued during the year, resulting in improved awareness among smallholder growers and plantation managers.

As a direct result of increasing the pressures on all pests, it was felt that this resulted in a subsequent reduction in pests and in the number of reported infestations from both plantations and smallholders during the year.

As mentioned in the Annual Report of 2005, some pest reports are still not being channelled through PNGOPRA, especially from Plantations, and it is therefore possible that reports of some taxa are being greatly under-represented.

The proposed Notifiable Pest Status which has been with NAQIA since March was still not resolved and the gazettal process has not yet been completed.

Information

Meetings of the Sexava Working Action Group (SWAG) and the weekly Sexava Action Group (SAG), part of the OPIC Divisional Managers meeting at Nahavio continued to keep participants fully informed of the current situation, and for Action Points to be put forward and followed up upon.

An issue of the OPRAtive Word Technical Note No. 9, "*Control of Insect Pests in Oil Palm; Trunk injection procedures*", was produced during August.

Infestation Reports

During 2006, there were 141 reports received, of damage to oil palm by insect pests in WNB, when all were visited.

This was a reduction of reports on the previous year (2005) when 211 reports received and 210 visited. In WNB, 59 reports were received from plantations, and 82 reports were received through OPIC Divisional Managers (n=141).

Infestations were reported from New Ireland (in smallholder's blocks and Plantations) by the native sexava (*Segestidea gracilis*) and stick insect (*Eurycantha calcarata*). Infestations were confirmed, and during the course of two visits new infestations were found, surveyed, and recommendations for control were made.

Three pest reports were received from mainland PNG from plantations and a single report from OPIC (none involved sexava (*S.novaeguineae*), but were Coleoptera: Dynastinae).

Invasive Weeds

There were 27 reports received of areas with the main taxa of invasive weeds from mainland oil palm growing areas, *Mimosa diplotricha*, *Chromolaena odorata*, *Sida rhombifolia*, (see below).

Pest Infestation Reports 2006

Pest infestation reports from West New Britain continued to fall from the numbers reported during 2005, which is encouraging.

During the year, PNGOPRA Entomology section, with strong support from our colleagues in OPIC (Hoskins and Bialla), and plantations continued to put pressure on pest populations through better reporting, swift survey, subsequent monitoring and tighter treatment operations, coupled with training given to the control teams.

Results show that there were two (small) peaks of infestation reports from West New Britain during the year, rising through March and April with a small peak in November (Figs. 1-3).

The pest report database currently in use (in Excel) will require updating during 2007 to enable more efficient interrogation and interpretation of the database. A full integration of all localities and pest taxa will be more readily accessible.

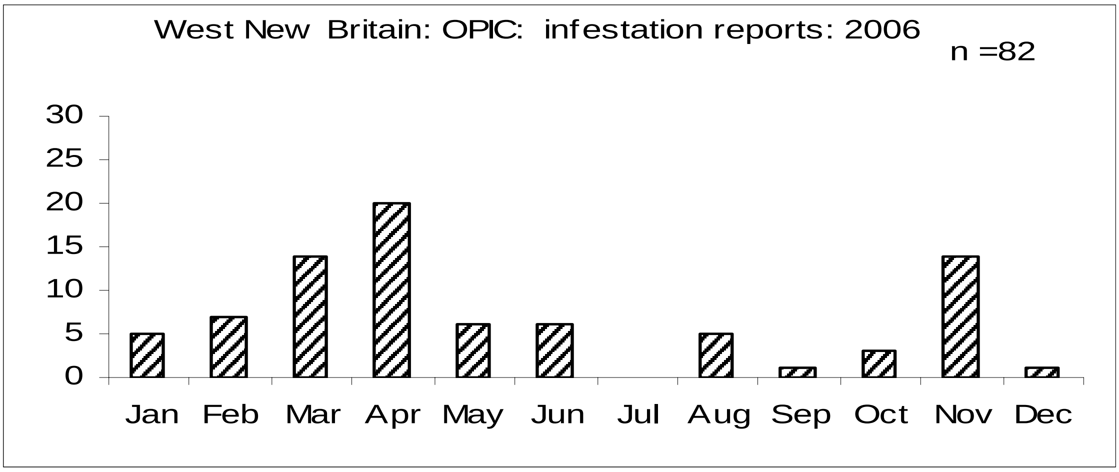


Figure 1. 2006: Pest reports from OPIC, West New Britain

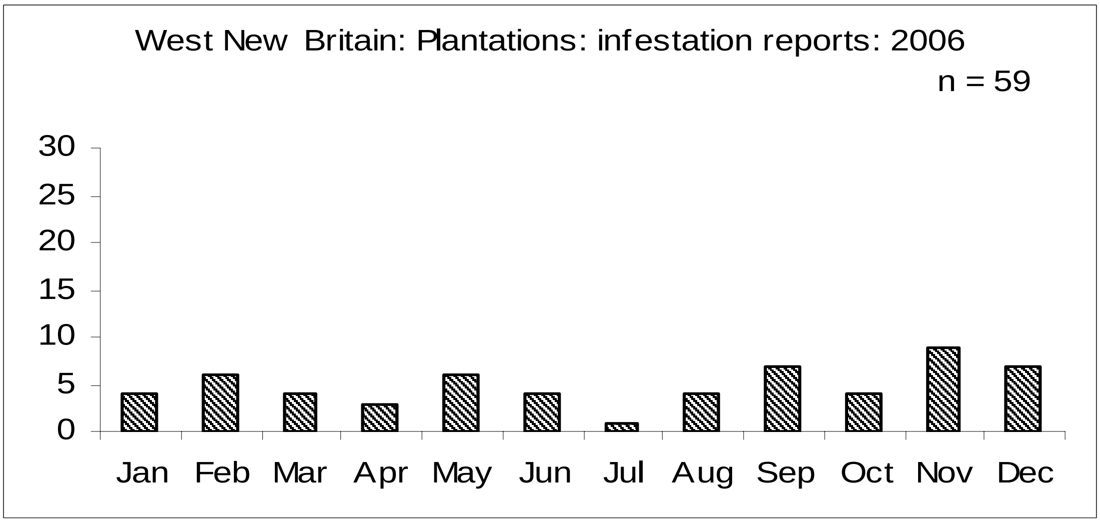


Figure 2. 2006: Pest reports from Plantations, West New Britain

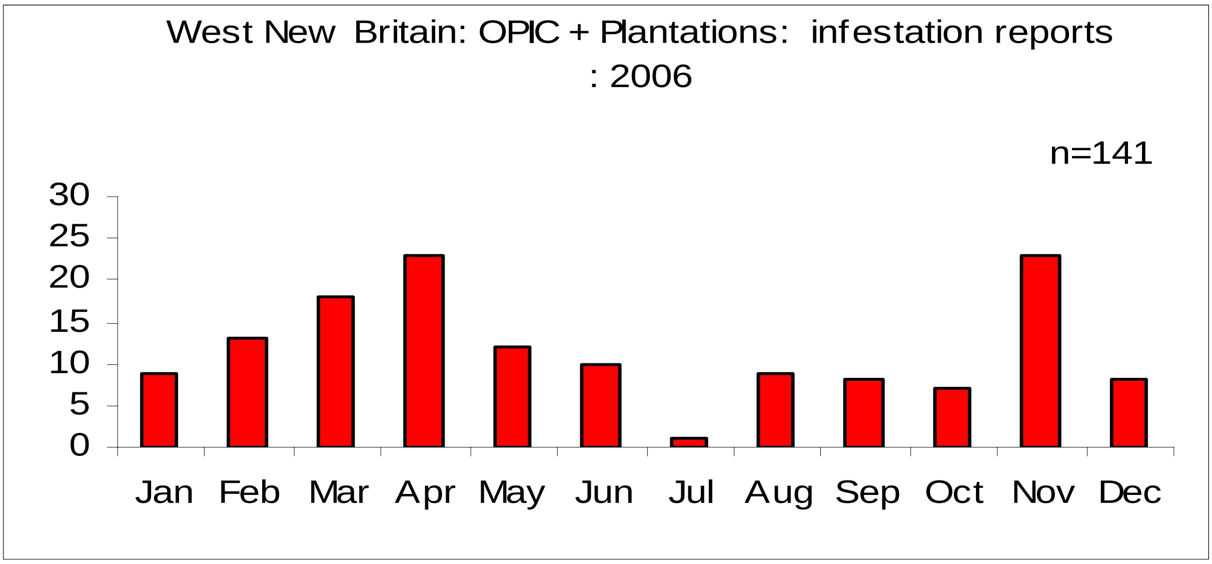


Figure 3. 2006: Pest reports OPIC and Plantations, West New Britain

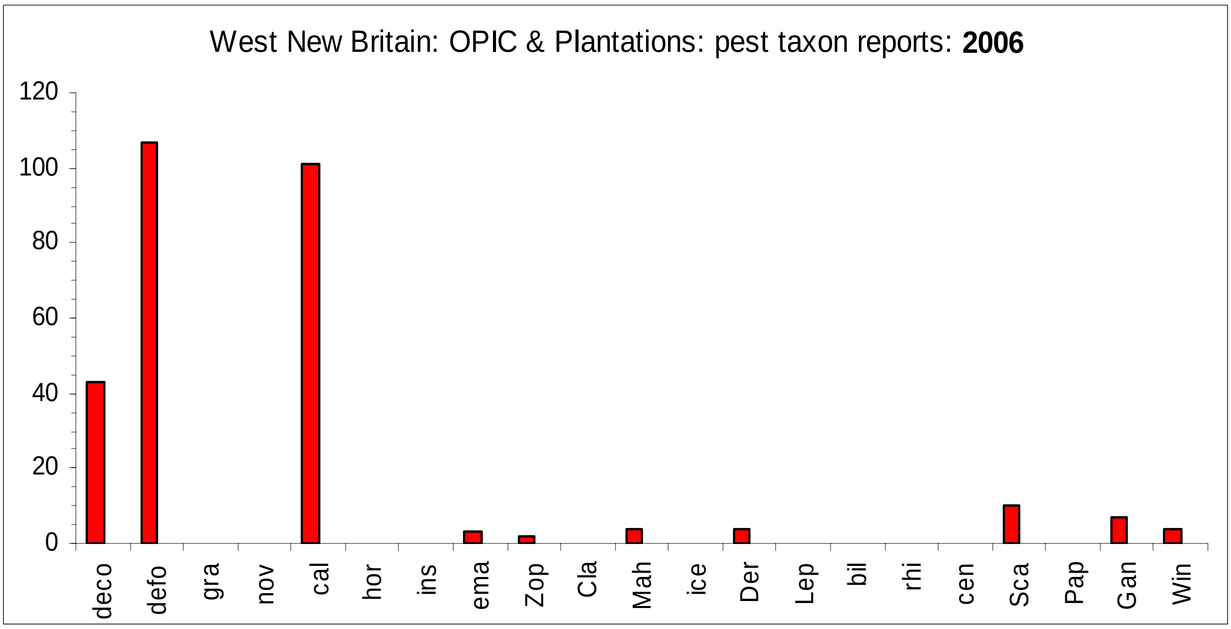


Figure 4. 2006: Pest taxa recorded for West New Britain.

Reports of *S.defoliaria* dominated the pest reports received, followed closely by those of the stick insect, *E.calcarata*. *S.decoratus* remained of less importance than the other pests during both 2005 and 2006 (Figs. 4 & 5), but was nevertheless of significant importance in areas where it occurs. Other pest taxa were insignificant, however *Scapanes australis* infestations became more apparent in 2006 as replanting work was undertaken.

These results were similar to the relative importance of the different taxa in 2005 (Fig. 5),

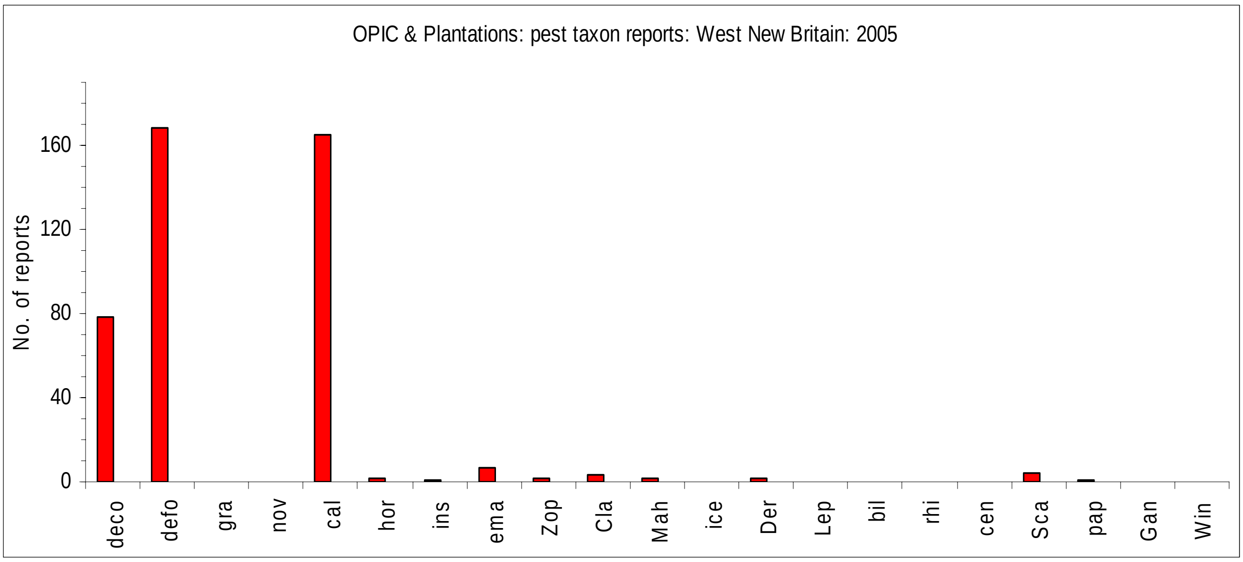


Figure 5. 2005: Relative abundance of pests reported.

SEXAVA

The relative importance of the various pest taxa represented in the infestation reports received was very marked. The tettigoniid pest, *S.decoratus* was reported much less frequently from West New Britain than either *S.defoliaria* or *E.calcarata*, while no reports of this insect were received from the mainland.

It is now possible for PNGOPRA Entomology to be able to accurately identify the damage in the field from the ground, where it is caused by the major oil palm pests. This is helpful as all sexava and stick insects are nocturnal, and often the only indicators of their presence are the damage to the oil palm leaflets.

Segestes decoratus was still represented by all female populations; however in February 2006 a single male specimen of *S.decoratus* was collected from Buluma field plantation, Dami, WNB. It is known that male and female populations of this insect occur on the western side of West New Britain, however in the last three years, this is the first specimen of a male of the species that has been caught. No other male specimens were caught during the year.

Ovaries from female specimens of *S.decoratus* were removed for investigations (in conjunction with Dr C Pilotti (PNGOPRA), and Dr J Kathirithamby (Oxford University) to try to evaluate what, if any biological agent (bacterium) might be a cause for this phenomenon, which is known from only four other members of this family worldwide.

Within CTP (PNG) plantations and smallholder areas of New Ireland, the “sexava”, *Segestidea gracilis* infestations were identified on both visits. Treatment through trunk injection was recommended.

The PNGOPRA Entomology section at Higaturu on mainland PNG continued with the sexava (*S.novaeguineae*) egg development monitoring, weighing and egg dissection to relate embryo development with egg weight. This study ceased in December, after having weighed and dissected 891 *S.novaeguineae* eggs. A strong correlation ($R^2 = 0.855$) was found between embryo size and egg weight, which will, in future be used when estimating the development of fresh, field collected eggs (Fig. 6).

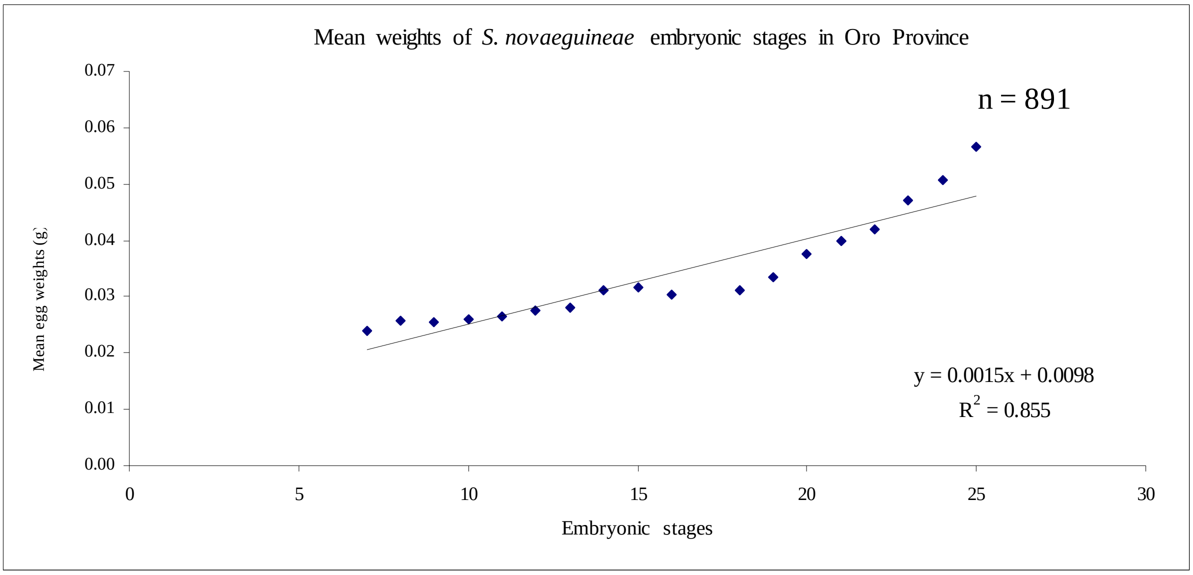


Figure 6. *S.novaeguineae*, mean egg weights (cumulative) and embryonic stages:(all dates)

Data previously collected for *S.defoliaria* from WNB, also showed a similar relationship (Fig.7), and these data will also be used in conjunction with additional data collected to relate field collected egg weights with expected hatching date.

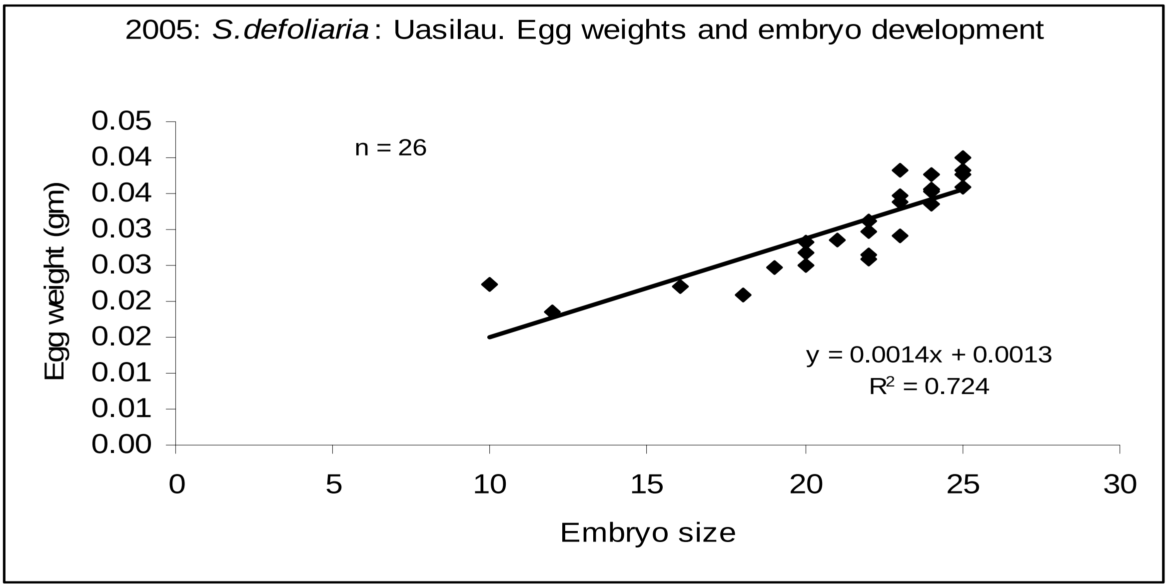


Figure 7: *S.defoliaria*, mean egg weights and embryonic stage

Figure 8 illustrates an example of field collected material of *Segestes defoliaria*, in which egg development may be monitored by weighing even a small number of eggs only, as shown in this example from 2005.

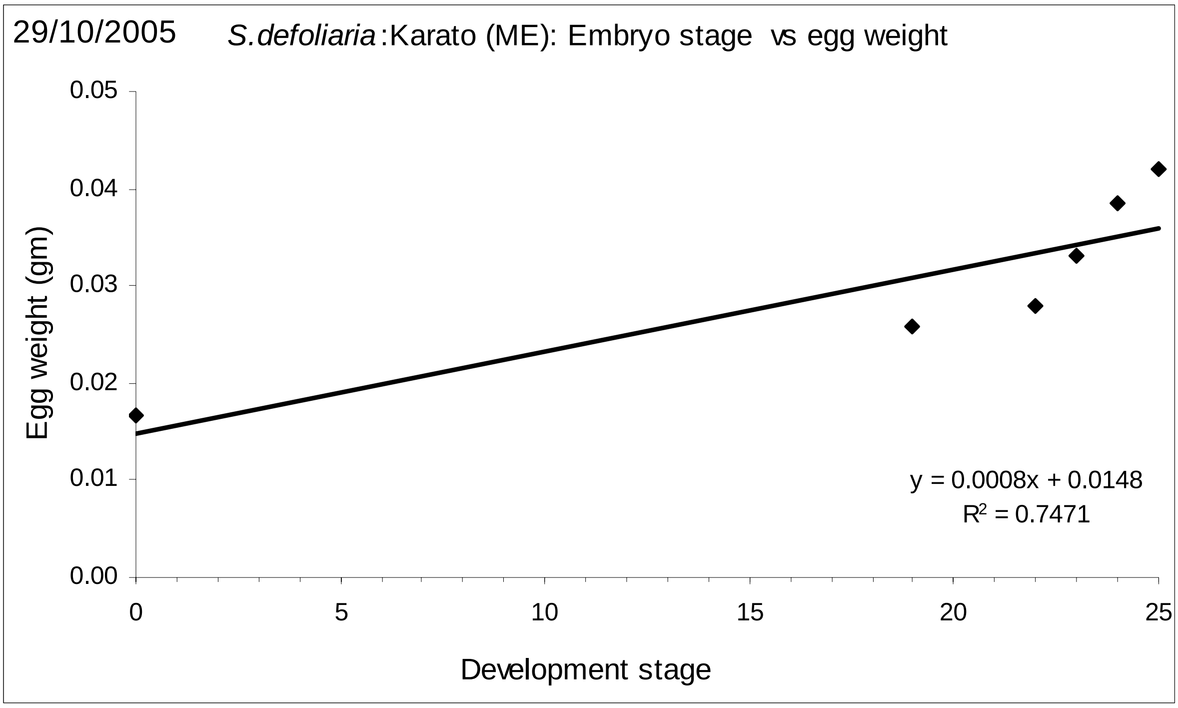


Figure 8. *S.defoliaria* egg weights and embryonic development stage from field data.

Although useful data are available, further egg development studies are required to refine these results for operational use, as this will permit more accurate interpretation of expected hatching dates and diapause activity to assist with the production of the recommendation data (PestRecs).

Sexava Biological Control

Internal parasitoids

Natural parasitism of *S.novaeguineae* on the mainland by the internal parasitoid *Stichotrema* (Mymecolacidae) was very low at about 3% as estimated from dissected eggs. Nevertheless, control by natural enemies was working, as no infestation reports of this species were received.

A sample of 396 adult *S.novaeguineae* were collected from 3 smallholder blocks at Koropata (N.Province) and almost 28% were infested (Jan-Dec). Cases of infestation with *Stichotrema* were observed throughout the year (Fig. 9), with infection levels rising from April to July then levelling off for the remainder of the year.

No infested insects were found during field surveys in March.

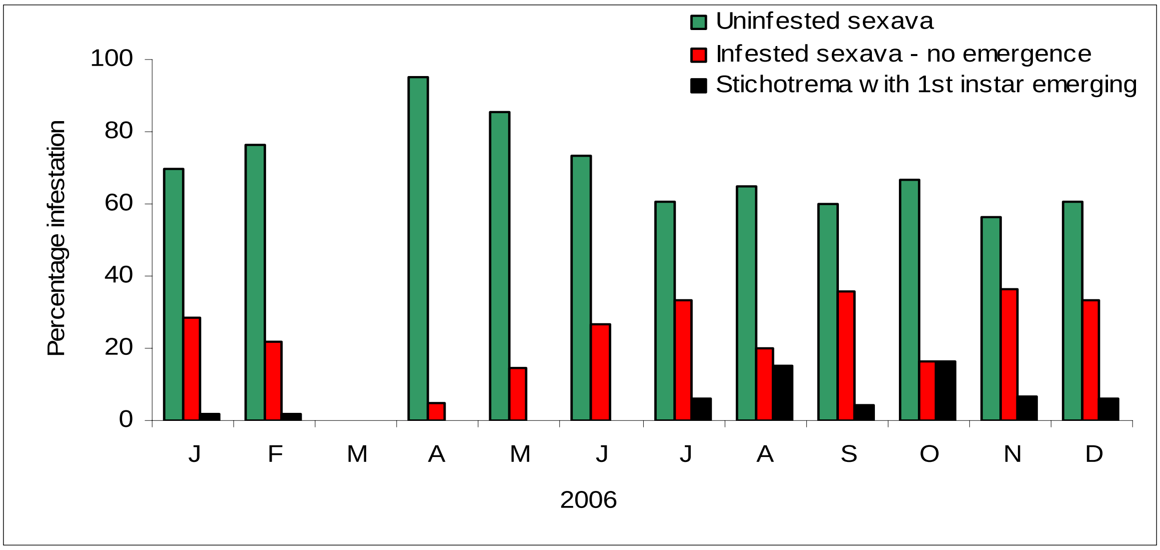


Figure 9. *Stichotrema*: Infestation rates of *S.novaeguineae* from Koropata area (N.Province, mainland PNG)

No Tachinidae (Diptera, Tachinidae) or "mermethid worms" (Nematoda) were reared from any pest taxa.

Sexava egg parasitoids

Laboratory populations of both taxa (*Doirania leefmansi*- Hymenoptera: Trichogrammatidae and *Leefmansia bicolor*- Hymenoptera: Encyrtidae), were built up during 2006, however a specific rearing facility for parasitoid production is required, as the parasitoids are reared alongside other insect material, and experimental insects are sometimes contaminated by parasitoids (see AIGF/AIGS).

All adult parasitoids are fed with minute smears of honey on emergence and prior to their release in the field; this greatly improves their longevity and chances of finding host eggs. Further feeding trials suggest that *Doirania* survived about 2 days without food and about 4 days with access to food, while *L.bicolor* survived for about 2 days without food and more than 2 weeks with food. The importance of the availability of a nectar source is clear, and will be investigated further and detailed studies on parasitoid productivity and longevity will need to be undertaken.

Egg parasitoids were released in WNB and New Ireland, but none were released on the mainland.

Although the rearing of parasitoids is a continual input for smallholder and plantations, the histograms below (Figs. 11 & 12) show that numbers produced rise sharply to a peak during June and July, then fall away rapidly, why this cycle is apparent is unclear, but is related to the availability of host egg material produced in the insectary. Laboratory populations of the parthenogenetic *Doirania*, also rapidly die out, and require replacement from field collected material. Parasitoid releases during December were not undertaken.

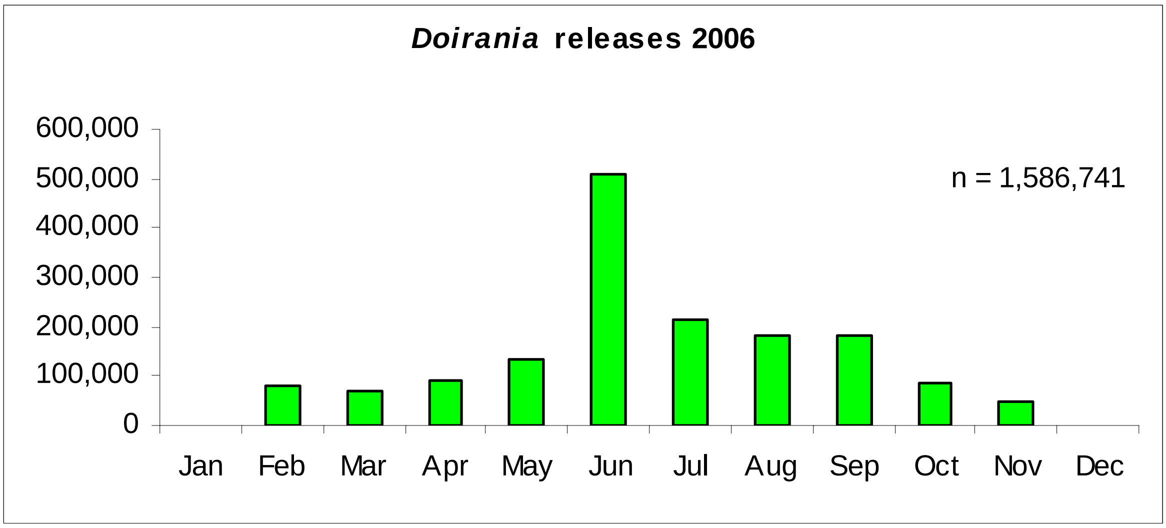


Figure 10. *Doirania leefmansi* releases, West New Britain during 2006

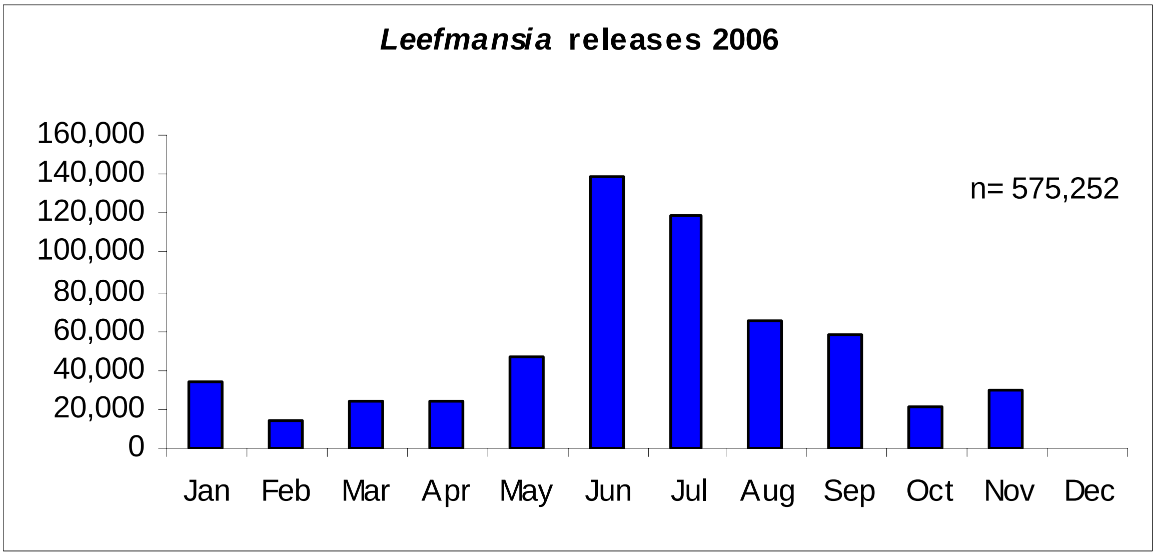


Figure 11. *Leefmansia bicolor* releases, West New Britain 2006

Doirania were released in 84 localities, and *Leefmansia* were released in 132 localities (Table 1 & Table 2). At some sites there was more than one release e.g. Dami plantation, where Entomology was attempting to assess establishment of the parasitoids. Although both parasitoid genera are routinely released into the field, only *D.leefmansi* was reported from field collections. Reasons for this are unclear, as in the laboratory it is a very efficient parasitoid of sexava eggs, and is easy to rear.

Table 1. Dates and locations of *Leefmansia* releases in WNB and NI 2006

14 January 2006	Walindi (Bob P)
26 January 2006	Dami (Buluma)
14 February 2006	Haella Div. 3
14 February 2006	Navarai
14 February 2006	Numundo Div. 2
15 February 2006	Morokea VOP
16 February 2006	Kapore LSS
19 February 2006	Dami (Buluma)
20 February 2006	Poliamba - New Ireland
22 February 2006	Malilimi Div.2
22 February 2006	Ganeboku VOP
03 March 2006	Dami (compound)
07 March 2006	Siki LSS
07 March 2006	Kavui LSS
08 March 2006	Ismin
14 March 2006	Sarakolok LSS
15 March 2006	Gavuvu VOP
15 March 2006	Rikau VOP
15 March 2006	Siki LSS
16 March 2006	Dami
18 March 2006	Hargy Area 10
21 March 2006	Dami
22 March 2006	Tamba LSS
22 March 2006	Sarakolok LSS
24 March 2006	Mai VOP
24 March 2004	Buluma VOP
28 March 2006	Hargy Area 1
01 April 2006	Sarakolok LSS
01 April 2006	Bebere Div.1 & Div. 2
04 April 2006	Kavui LSS Section 1
05 April 2006	Banaule VOP
07 April 2006	Banaule VOP
09 April 2006	Haella/Numundo
11 April 2006	Kavui LSS Section 7
11 April 2006	Kapore LSS
12 April 2006	Galai 1 LSS
19 April 2006	Vavua VOP
02 May 2006	Buluma (Police field)
04 May 2006	Kavui LSS
09 May 2006	Dami Plantation
11 May 2006	Dami Plantation
11 May 2006	Kapore LSS
18 May 2006	Numundo plantation
18 May 2006	Karato EU
19 May 2006	Banaule VOP
24 May 2006	Navo (Atata)
24 May 2006	Tiauru LSS
24 May 2006	Karausu Plantation
24 May 2006	Lavege VOP
24 May 2006	Buvussi LSS
01 June 2006	Tiaru LSS
02 June 2006	Kumbango Div 2
05 June 2006	Togulo Div 2
05 June 2006	Garu Plantation
12 June 2006	Mamota LSS
12 June 2006	Kae VOP
12 June 2006	Silanga VOP
14 June 2006	Suma (Poliamba)
14 June 2006	Lamerika (Poliamba)
14 June 2006	Kamiriba (Poliamba)
14 June 2006	Piera (Poliamba)
14 June 2006	Lakurumou (Poliamba)
14 June 2006	Medina (Poliamba)
14 June 2006	Lamusmus (Poliamba)
24 June 2006	Bilomi Div. 2
26 June 2006	Tamba LSS
26 June 2006	Sarakolok LSS
16 June 2006	Siki LSS
03 July 2006	Bebere Divisison 2
03 July 2006	Kapore LSS
05 July 2006	Uasilau LSS
06 July 2006	Tamba LSS
06 July 2006	Makasili VOP
06 July 2006	Gavaiva VOP
11 July 2006	Waisisi Purchase
11 July 2006	Galilo VOP
11 July 2006	Gule VOP
13 July 2006	Tamba LSS
13 July 2006	Mai VOP
17 July 2006	Dami Plantation
22 July 2006	Dami Plantation
25 July 2006	Sarakolok LSS
26 July 2006	Kumbango Div 2
26 July 2006	Gaungo VOP
26 July 2006	Bebere Div 1
26 July 2006	Kapore LSS
28 July 2006	Dami pln
31 July 2006	Kapore LSS
31 July 2006	Gaongo VOP
31 July 2006	Kavui LSS
04 August 2006	Haella Div 3
04 August 2006	Dami pln.
08 August 2006	Mandopa VOP
08 August 2006	Buluma VOP
08 August 2006	Mai VOP
08 August 2006	Kapore LSS
09 August 2006	Hargy Area 3, blk 1,2,3,4,5
09 August 2006	Numundo Div 1
11 August 2006	Dami pln.
18 August 2006	Mosa VOP
24 August 2006	Dami plantation
25 August 2006	Banaule VOP
29 August 2006	Kapore LSS
29 August 2006	Kavui LSS

29 August 2006	Dami Plantation	27 September 2006	Dami Plantation
30 August 2006	Kapore LSS	28 September 2006	Dami Plantation
31 August 2006	Dami Plantation	**04 October 2006**	Karato EU & ME
01 September 2006	Gule VOP	05 October 2006	Navo estate
01 September 2006	Mandopa VOP	12 October 2006	Umbai VOP
01 September 2006	Mosa VOP	14 October 2006	Dami (Buluma)
02 September 2006	Morokea (1) VOP	24 October 2006	Ganeboku VOP
07 September 2006	Tamba LSS	**01 November 2006**	Karau su Div 1
14 September 2006	Bialla (Area 3)	08 November 2006	Karato ME
20 September 2006	Dami Plantation	15 November 2006	Matilililu VOP
22 September 2006	Dami Plantation	15 November 2006	Tiauru LSS
25 September 2006	Dami Plantation	18 November 2006	Haella 132`-06 fld 17
26 September 2006	Dami Plantation	21 November 2006	Alaba Mini Estate, Bialla

Table 2. Dates and locations of *Doirania* releases in WNB and NI 2006

14 February 2006	Numundo Div. 2	14 June 2006	Poliamba Lamerika
24 February 2006	Gavuvu Mission	14 June 2006	Poliamba Kamerika
26 February 2006	Sarakolok LSS	14 June 2006	Piera Poliamba
26 February 2006	Siki LSS	14 June 2006	Poliamba Lukuruma
07 March 2006	Siki LSS	14 June 2006	Poliamba Medina
07 March 2006	Kavui LSS	15 June 2006	Poliamba Lamusmus
15 March 2006	Siki LSS	24 June 2006	Bilomi Div 2
16 March 2006	Dami	26 June 2006	Tamba LSS
21 March 2006	Dami	**03 July 2006**	Bebere Div 2
18 March 2006	Hargy Area 10	03 July 2006	Kapore LSS
22 March 2006	Tamba LSS	05 July 2006	Uasilau LSS
22 March 2006	Sarakolok LSS	06 July 2006	Tamba LSS
28 March 2006	Hargy Area 1	06 July 2006	Makasili VOP
29 March 2006	Bubu VOP	07 July 2006	Gavaiva
01 April 2006	Bebere Div.1 & Div. 2	11 July 2006	Waisisi purchase
01 April 2006	Numundo Div. 1	11 July 2006	Galilo VOP
04 April 2006	Kavui LSS Section 1	11 July 2006	Gule VOP
05 April 2006	Haella Div. 2	13 July 2006	Tamba LSS
05 April 2006	Banaule VOP	13 July 2006	Mai LSS
07 April 2006	Banaule VOP	**18 August 2006**	Dami plantation
11 April 2006	Kavui LSS Sect 7	24 August 2006	Dami plantation
11 April 2006	Kapore LSS	25 August 2006	Banaule VOP
12 April 2006	Galai 1 LSS	29 August 2006	Kapore LSS
19 April 2006	Vavua VOP	29 August 2006	Kavui VOP
04 May 2006	Kavui, 3,4,5,6	29 August 2006	Dami plantation
11 May 2006	Kapore LSS	**01 September 2006**	Gule VOP
18 May 2006	Numundo	01 September 2006	Mandopa VOP
18 May 2006	Karato EU	01 September 2006	Mosa VOP
19 May 2006	Banaule VOP	02 September 2006	Morokea (1) VOP
24 May 2006	Atata, Navo estate	14 September 2006	Bialla (Area 3)
24 May 2006	Tiaru LSS	22 September 2006	Dami plantation
24 May 2006	Kaurausu Pln	25 September 2006	Dami plantation
24 May 2006	Lavege VOP	26 September 2006	Dami plantation
24 May 2006	Buvussi LSS	27 September 2006	Dami plantation
01 June 2006	Tiauru LSS	28 September 2006	Dami plantation
02 June 2006	Kumbango Div 2	**04 October 2006**	Karato EU & ME
05 June 2006	Togulo Div 2	05 October 2006	Navo estate
05 June 2006	Garu pltn	12 October 2006	Umbai VOP
12 June 2006	Mamota LSS	14 October 2006	Dami (Buluma)
12 June 2006	Kae VOP	24 October 2006	Ganeboku VOP
12 June 2006	Silanga VOP	**01 November 2006**	Karausu Div 1
14 June 2006	Poliamba Suma	08 November 2006	Karato ME

The production of egg parasitoids relies upon the regular availability of host eggs. This may was variable as the laboratory stock usually required supplementing with *ad hoc* field collections of adult sexava.

STICK INSECTS (*Eurycantha* spp.)

The continued importance of stick insects may be seen in Figs. 4 & 5 (above), where they rank very closely in importance with *S.defoliaria* as a serious pest.

During 2006, only *E.calcarata* was reported as causing damage to oil palm. Neither *E.horrida* nor *E.insularis* was reported from oil palm during the year.

Reports of the large stick insect *Eurycantha horrida* occurring in West New Britain were not substantiated; however it was recorded from Northern Province, on mainland PNG.

Egg weights were recorded from eggs of *Eurycantha calcarata* collected in the field as an initial stage to identifying embryo development as was done with "sexava" (Fig. 12). These studies did not proceed during the year, however they will continue when sufficient material is available.

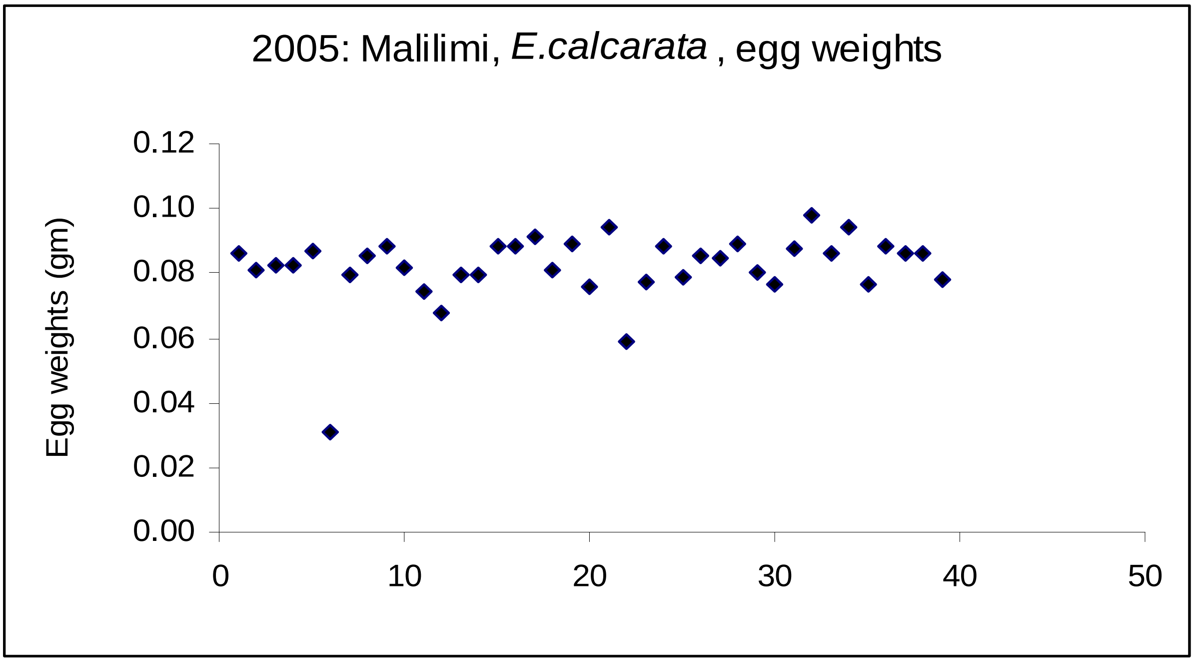


Figure 12. *Eurycantha calcarata* egg weights from field collected eggs (Malilimi)

During October, adult specimens of *E.insularis* (only found on the mainland), were collected weighed and morphometric data collected, collection of these and morphometric data will continue.

504 eggs were collected from laboratory stock material, placed into a container and returned to the field at Koropata; they were brought back to the laboratory in May and held to record parasitoid emergence, and maintained in the laboratory for parasitoid emergence. No parasitoid emergence was recorded.

In September 500 eggs were contained in a sealed fly-screen sachet and put into the field, a further 300 were placed in the field in October also at Koropata. No parasitism was recorded during the period until December, however the eggs were retained.

INSECTICIDE TRIALS

A first trial was conducted using four possible insecticide alternatives against sexava. The standard for comparison was methamidophos, and experimental insecticides were orthene, confidor, and chlorpyrifos.

The trial was set up at Kumbango (WNB), however it had to be abandoned as the field cages were either damaged or stolen, and experimental insects were also destroyed by ants, consequently the data were insufficient for analysis. Experiments to investigate alternative insecticides will be continued as insect material becomes available.

RHINOCEROS BEETLES (COLEOPTERA, SCARABAEIDAE).

There were 5 reported attacks by rhinoceros beetles in plantations in WNB, characteristically in areas of young plantings bordering forest and typically in areas that were recently cleared (e.g. Mumata, Novunabea, Alaba, Magamba and North Star). These reports were all of *Scapanes australis*.

There was a single report from Village Oil Palms (VOP) at Noau in WNB.

There were no reports from New Ireland or Mainland PNG.

Control recommendations for this pest were for hand removal ("winkling out") of the feeding adult beetles. "Winkling" requires the use of a thin piece of sharpened metal curved back at its tip is forced into the hole and the impaled beetle withdrawn; this is an efficient method for removing the beetles during their feeding phase.

On mainland PNG, reports were received from OPIC in October, of damage to oil palm seedlings that were planted in March 2006. An infestation of "white grubs" (Coleoptera, Melolonthinae) was found in young plantings from smallholder grower blocks at Sorovi division (Northern Province) Table 4. An inspection of the palms found that the larvae had severely damaged the root systems, and palms were wilting and dying.

Survey results showed that three blocks were infested, with one block heavily damaged.

Table 3: "white grub" damage.

Block #: 121740	25 out of 120 palms (21%)
Block #: 121785	6 out of 120 palms (5%)
Block #: 121678	11 out of 120 palms (9%)

A single larva collected from the site developed into an adult (Fig. 13). The identity of the insect has still to be confirmed. A report was prepared for OPIC recommending treatment to destroy any remaining larvae. There were no further reports of this insect, and there was no follow up monitoring.

Figure 13. Undescribed adult Melolonthinae beetle from oil palm seedlings. (Photo too red).

Oryctes centaurus (Coleoptera: Scarabaeidae, Dynastinae).

In July, a report was received from plantations of pest damage to young oil palms. The insect causing the damage was initially identified as *Oryctes rhinoceros*; however specimens subsequently seen at Dami showed that the insect was not this species but a first record of *O. centaurus* as an oil palm pest. This insect is a very large member of the genus, at about 7cm for males and 6cm for females (Fig. 14).

Figure 14. Adult *Oryctes centaurus* (male & female).

The larvae (Fig.15), are correspondingly very large, and were retained for rearing studies.

Figure 15. Larvae of *O. centaurus* (on the right, ventral view)

Adult beetles were boring into the spear area (base of the crown) of 3-4 year old palms at Sumbiripa, Sangara and Ambogo estates. This resulted in the older fronds collapsing. One palm died and the death was suspected to have been as a result of secondary infection by a pathogen (crown rot), (R Safitoa, pers. comm.). In the three areas surveyed, by December damage levels of 4, 8 and 2% respectively were recorded. Thirty one specimens of differing stages (adult, larvae and pupa) were collected from the decaying trunks of oil palm which remained upright after palm poisoning was completed at Ambogo estate (mainland PNG). The larvae (Fig. 15), are correspondingly very large, and were retained for rearing studies. Regular monitoring will continue.

Twenty five *O. centaurus* larvae, 3 pre-pupa, 1 pupa and two adults (1 male and 1 female) were collected from trunks of oil palm which remained upright after trunk poisoning at Ambogo estate. Decline in levels of damages was observed at Sumbiripa and Sangara estates; however there was an increase at Ambogo estate (Fig. 16).

A report on this infestation was prepared and sent to Higaturu Oil Palms.

Regular monitoring of this insect is expected to continue through 2007.

Both of these pests were pests recorded for the first time as pests of oil palm, however *O. centaurus* is known as a pest of coconut (*Cocos nucifera*).

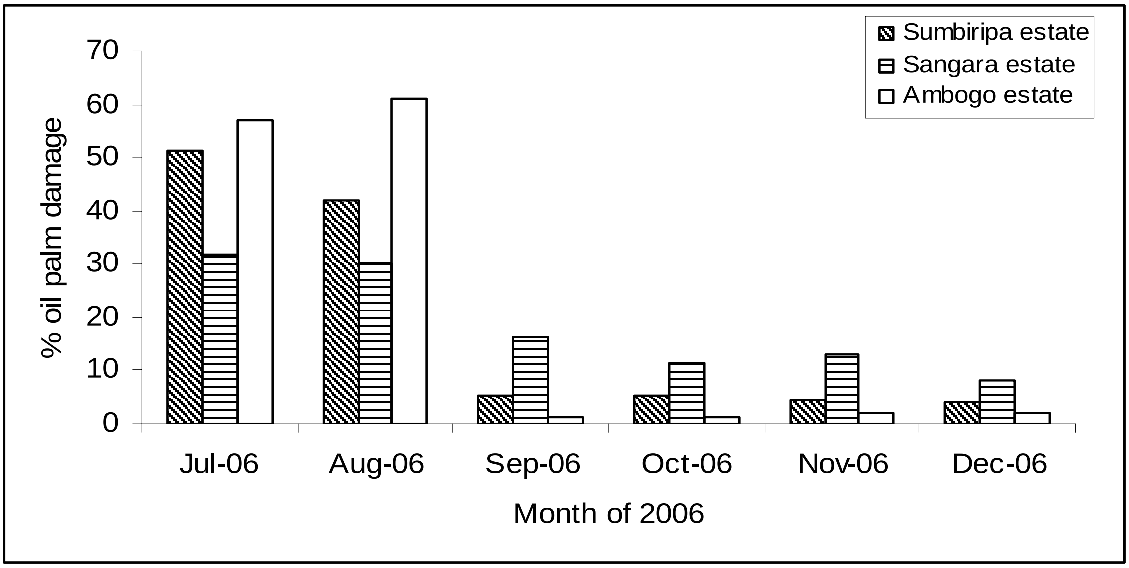


Figure 16. Percentage of oil palm damage recorded between July and December 2006.

FINSCHHAFEN DISORDER: LEAFHOPPER INTEGRATED PEST MANAGEMENT

A three-year project is expected to be finalised early in 2007, for funding through ACIAR.

Two reports of Finschhafen disorder (FD) were recorded from plantations in WNB during 2006 (Kautu in January and Lotomgam in February). Both infestations were very light with only a few palms showing the characteristic yellowing. No treatment was recommended.

On mainland PNG where regular monitoring was undertaken at Igora (Northern Province), no symptoms were observed during the year, even though adults and nymphs were sighted on the frond bases and leaflets (detailed data not available).

No reports were received from New Ireland.

A range of different parasitoid specimens reared from *Zophiuma* egg masses have still to be identified.

There were no reports of Finschhafen disorder from Land Settlement Schemes (LSS) or Village Oil Palm (VOP) growers.

OTHER PESTS

Other typical pest taxa were present in plantations and smallholder blocks, but as very minor components (Fig. 4), and could not be considered as pests.

Four reported infestations of the rough bagworm (prob. *Mahasena* sp/*Lomera* sp., although there is taxonomic confusion, between two genera), were received from plantations in WNB. No treatment was undertaken, although at Haella plantation (WNB), mass “larval/pupal bag” collection and destruction was undertaken. No treatment was required.

No reports of this pest were received by PNGOPRA from OPIC Divisional Managers in WNB or on the mainland or New Ireland.

Three reports of Oil palm webworm, *Acria* sp.nr. *emarginella* (Lepidoptera: Oecophoridae) were received from plantations on WNB but were controlled by natural enemies. There were no reports of this species from mainland PNG or New Ireland.

The Powdery chafer beetle, *Dermolepida* sp. (Coleoptera: Melolonthinae) was regularly reported, but in such low numbers as to be insignificant.

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.

Nevertheless the destruction of their main predators (almost certainly harmless snakes) on WNB continues unabated.

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

The report produced on plant taxa to be encouraged as nectar producers for the encouragement of beneficial insects was extensively edited and returned to OPRS. NBPOL implemented a planting programme.

WEEVIL POLLINATION OF OIL PALM

The final report for this project will be produced after the second visit to West Africa, and the rearing process is completed, as the project is due to end early in 2007.

On mainland PNG, three sites (Sangara, Ambogo and Heropa plantations), were selected for monitoring nematode infestation levels in the weevils. All of which were equipped with weather recording instruments. From each site, 100 weevils were sampled every month and dissected in the laboratory.

Between October and December, nematode infestation in Sangara was higher then the other sites, while Heropa was lowest at less than 5 (Figs. 17- 19).

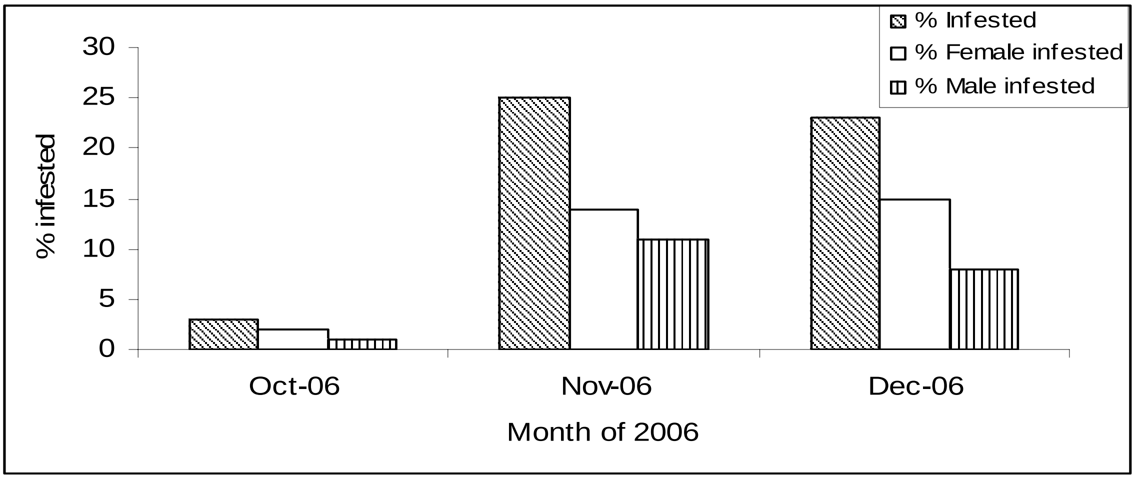


Figure 17. Nematode infestations from *E. kamerunicus* sampled from Sangara plantation, Higaturu Oil Palms, during October to December 2006.

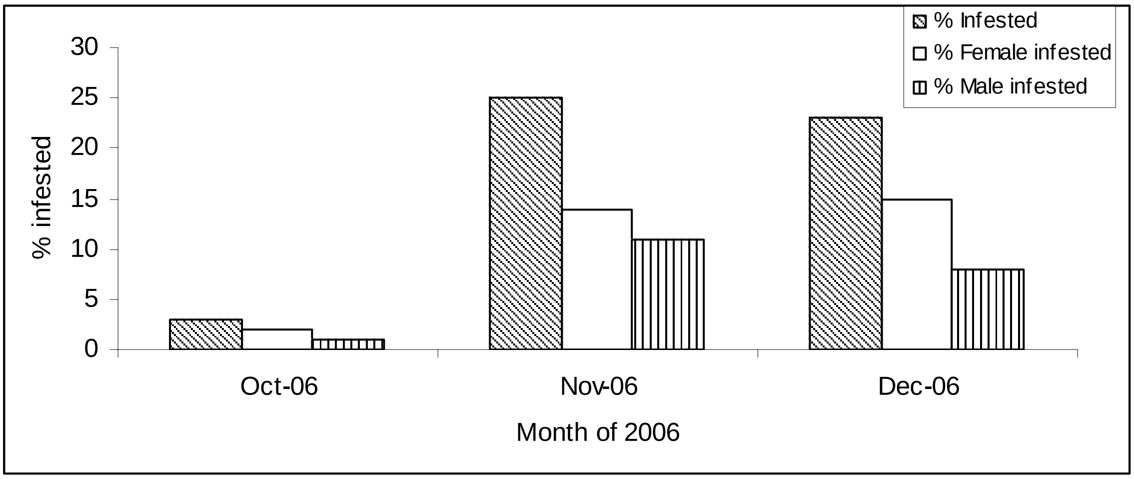


Figure 18. Nematode infestations in *E. kamerunicus* sampled from Ambogo plantations, HOP, during October to December 2006.

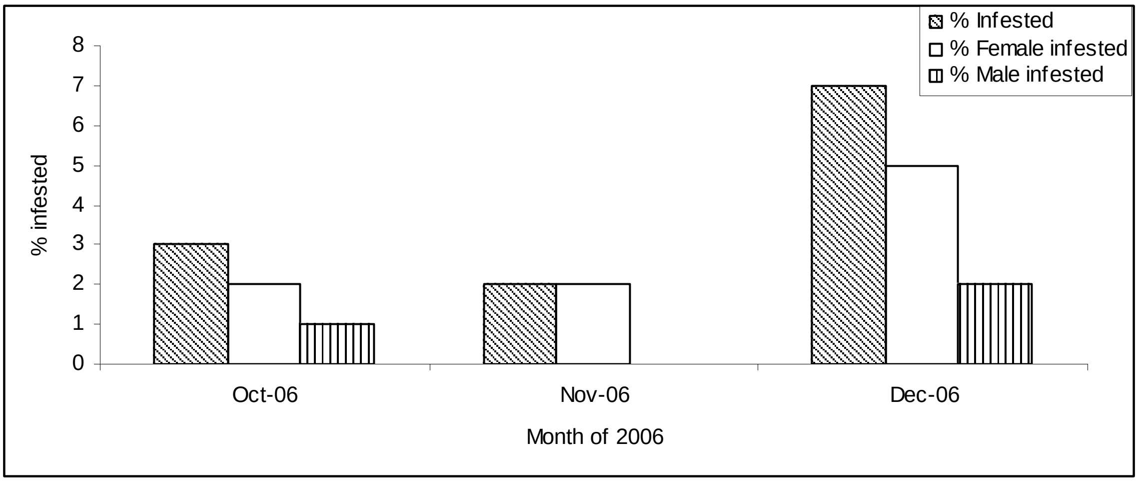


Figure 19. Nematode infestations in *E. kamerunicus* sampled from Heropa mini estate, Higaturu Oil Palms, during the period October to December 2006.

No weevil monitoring was undertaken in New Ireland.

PNGOPRA Quarantine Facility

The quarantine facility was refurbished and equipped with shelving; cupboards, deep freeze and insect trap light, and was certified and registered with NAQIA.

The facility will initially be used for the rearing and containment of the weevils to be brought in from West Africa.

IPM OF WEED PESTS.

Mimosa diplotricha

Five reports were received from the mainland plantations: (Ambogo, block 80J1 &80J2, block 80H1, 80H2 & 80H3), Sangara (block 38C), HOP Nursery, Sumbiripa (block 38A), and Sangara (along roadside 2 reports).

Psyllid bugs, *Heteropsylla spinulosa* were collected and released into patches of *Mimosa diplotricha* in plantations with the help of staff from the respective plantations on the mainland only (Table 4).

Table 4: Releases of *Heteropsylla spinulosa* into plantations in 2006.

Date released	Location	Block number	No. of Psyllid released	Date weed suppressed
Feb-06	Ambogo estate	80J1 & 80J2	25000	Aug-06
Mar-06	Ambogo estate	80J1, J2 and 80H	5000	Jul-06
Apr-06	Ambogo estate	80H1, 80H2 & 80 H3		Jul-06
May-06	Ambogo estate	80J1,80J2 and 80J3	12000	Jul-06
May-06	Sangara estate	Along road side 38C	5 000	Jul-06
May-06	Sumbiripa estate	Road side 38A	5000	Jul-06
Jun-06	Ambogo estate	80H1 and 80J2	5000	Jul-06
Jun-06	Sumbiripa estate	38A	5000	Jul-06
Jul-06	Sangara estate	38C	4500	Jul-06
Jul-06	Ambogo estate	80H2. H3, J2 & J3	2000	Jul-06
Jul-06	Sumbiripa estate		1000	Jul-06
Aug-06	Ambogo estate	80H2, 80H3, J2 and J3	1200	Ceased releasing

Broomstick, *Sida rhombifolia*

Four reports were received from the mainland, Embi (along roadside), Watus ME (along roadsides), Sumbiripa (along roadsides), and Sangara (along roadside).

Calligrapha penthrina (Coleoptera: Chrysomelidae) adults were collected from Embi and released to suppress *Sida rhombifolia* in plantations at HOP only (Table 5). A culture of this insect is maintained at the lab at Higaturu.

Table 5: Releases of *C. penthrina* into sites within HOP plantations during 2006.

Date	Sites released	No. adults released	Date controlled
Apr-06	Bakito	20	
Apr-06	Watus	200	Established
Apr-06	Sumbiripa	300	
Jul-06	Eroro village	Natural spread	Established
Aug-06	Dobuduru village	300	
Sep-06	Heropa	Natural spread	Established
Nov-06	Parahe	268	
Nov-06	Watus	210	Established
Nov-06	Heropa	80	
Nov-06	PNGOPRA rearing culture	208	Established
Dec-06	Watus	100	
Dec-06	Heropa	80	
Dec-06	PNGOPRA rearing culture	68	

Water Hyacinth, (*Eichornia crassipes*).

Neochetina bruchi (Coleoptera: Curculionidae) was cultured at Higaturu. Monthly weevil counts are shown in Table 6. No redistribution was undertaken. Fresh plants of water hyacinth (as host plant) food were collected from the Gona River.
In WNB, at Dami there is a small culture maintained in four sectioned oil drums producing weevils for local release. So far 50 weevils were released at Clean Wara.

Table 6. Numbers of *N. bruchi* per plant in the colony maintained at PNGOPRA, Higaturu in 2006.

Date	No. of weevils	No. of plants	Ratio (weevils : plant)
Jan-06	107	92	1
Feb-06	156	284	1
Mar-06	291	273	1
Apr-06	538	194	3
May-06	328	194	2
Jun-06	278	201	1
Jul-06	198	187	1
Aug-06	154	167	1
Sep-06	121	143	1
Oct-06	526	191	3
Nov-06	623	243	3
Dec-06	547	221	2

Siam Weed, *Chromolaena odorata*

Two reports of infestations were received from the mainland from Sumbiripa (block 28A), and Sangara (block 38D)

Although the project to redistribute *Chromolaena* galls was completed, galls are re-distributed whenever new locations are identified as not having the gall fly present.

"*Mile*-a-minute Weed", *Mikania micrantha*

There was no further development with the initiation of this project, but the start date was expected during 2007.

CONSERVATION OF THE QUEEN ALEXANDRA'S BIRDWING BUTTERFLY (QABB).

A project agreement with Conservation International was expected during the latter part of 2006, but was not forthcoming.

An immature seedpod was collected in January and taken to OPRS Tissue culture laboratory. Propagation of the vine from seeds failed to produce any seedlings, as there was a very heavy fungal infestation that could not be removed. Further attempts will be made during 2007.

Although seed pods will not be used in the multiplication process for the vine, it is important to set up protocols for tissue culture techniques.

The two flight cages used at Afore (N. Province) during a previous project were recovered with assistance from Higaturu Oil Palms and brought to PNGOPRA Centre at Higaturu for refurbishment and utilisation when project funding becomes available.

Table 7. Sightings of adult QABB at Voivoro.

Date visited	Adult	Pupa	Larvae	eggs	Remarks
Mar-06	2 females	2	0	0	Adults flying in dense forest pausing on host leaves
Sep-06	1 female	0	0	0	Adult hovering above host leaves in secondary forest.

OTHER PROJECTS

Oil Palm pest species recognition.

The project is now nearing completion, although the latches and screws for the boxes are still awaited. There were delays with sourcing sufficient insect material.

A further visit from the AIGF co-ordinator confirmed the progress with the project, and he was able to sign off the project in the knowledge that the distribution will be completed in accordance with the contract.

AIGF/AIGS Proposals

In November, three project proposals were sent to the AIGF Co-ordinator for funding consideration.

Topics were:

1. *Mass rearing of parasitoids as biological control agents against insect pests in smallholder oil palm*.
2. *A pocket handbook for the identification of the main insect pests of oil palm in Papua New Guinea*.
3. *Assessment of the potential threats by arboreal insect pests in smallholder oil palms*.

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 every month. No insects that might be considered a potential threat were found.

INFORMATION EXCHANGE/TRAINING

Regular meetings were held at HOPP (with plantation and OPIC), to discuss pest management issues. These meetings are scheduled monthly.

In conjunction with OPIC (Hoskins Project), Divisional Mangers, pest information meetings were held weekly throughout the year.

At both these meetings, all issues relevant for effective pest and disease management are covered. Representations from the palm poisoning and treatment teams are always present. Training opportunities are discussed.

Ad hoc training was given to OPIC staff and at every opportunity to growers during infestation visits. We operate a very "open-door" policy in Entomology Section.

P & D training was given to Group Managers and to senior plantation staff at Numundo, Haella and Mosa Groups (NBPOL) and at Poliamba (CTP).

3. PLANT PATHOLOGY RESEARCH

(C. A. Pilotti)

INTRODUCTION

Stem rots caused by Ganoderma continue to be the major threat to the oil palm industry. Research is wholly targeted towards the management of this disease.

The Ganoderma project and the sub-projects within it have been funded under the European Union Stabex over 3 phases and the final phase of the project is due to end in 2006 except for the research on the bio-control agent *Trichoderma* that will continue to May 2007.

The epidemiology of basal/upper stem rot and the population structure of *Ganoderma boninense* continues to consume the bulk of resources in terms of time and funding.

A large proportion of the research in 2006 was also spent on the development of a technique for screening of resistance of oil palm to attack by *G. boninense*.

PROJECT # 1

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.

1.1 Introduction

Studies on the progression of basal and upper 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 temporal disease data provided by plantations and surveys carried out by PNGOPRA personnel in designated study blocks in Milne Bay.

Short-term control strategies have been implemented in Milne Bay for 12 years in mature plantings but the effectiveness of the strategy is difficult to measure. In plantations where the disease is prevalent, recommended sanitation procedures may not always be practiced. This presents a challenge for researchers and growers 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 2005 survey data. Data has also been filtered to exclude inadequately sanitized stumps, steriles and standing dead palms.

1.3 Disease progress in first generation oil palm

1.3.1 Milne Bay

A summary of the number of infections in each Division (by category) is shown in Figure 1.1. In all Divisions, the number of suspect palms exceeds the number of palms observed with Ganoderma brackets. Naura Division which includes most of the oldest plantings had the highest levels of disease with over 4 palms/ha infected in 2006, more than twice that of Kwea Division (unaudited figures). These areas are due for replant soon.

Disease levels expressed as the number of diseased palms/ha in all blocks surveyed in each Division in 2006 are presented in Figures 1.2 to1. 6.

The highest incidence for Giligili Division in 2006 was recorded in Block 9102 with losses of 3-4 palms/ha (Figure 2).

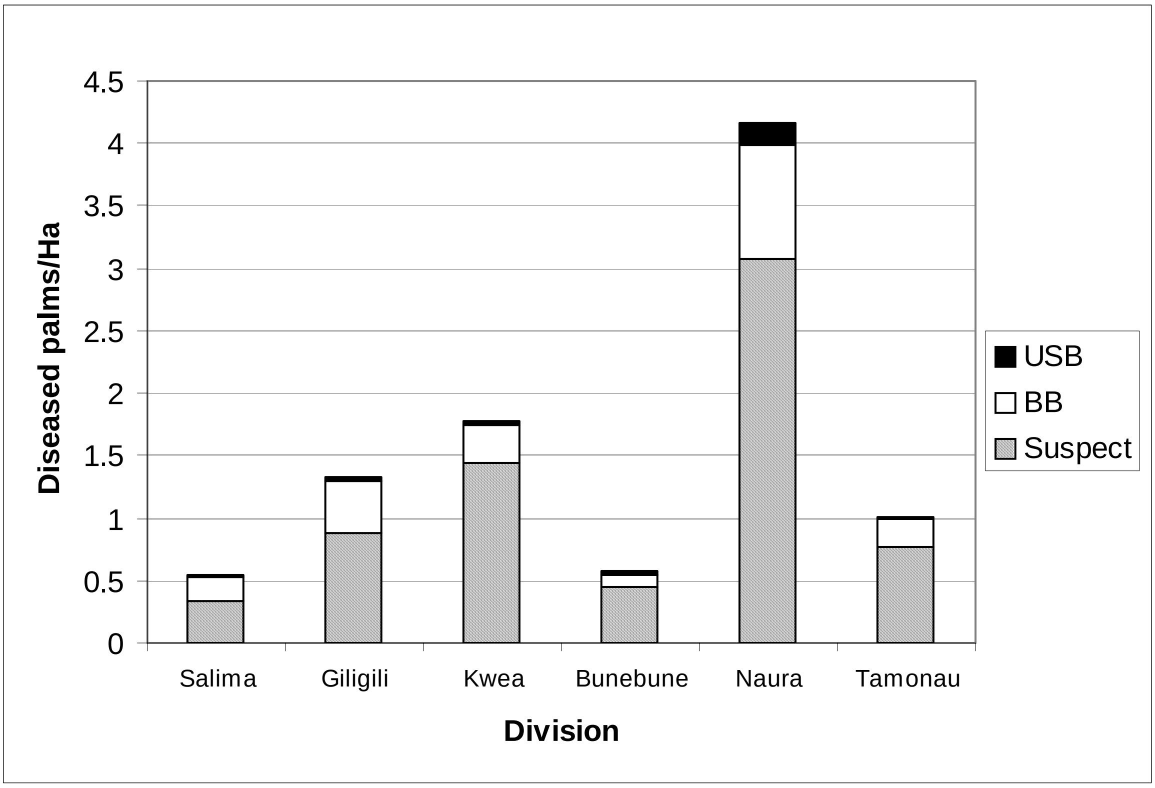


Figure 1.1. Disease incidence for all Divisions (surveyed blocks only) in Milne Bay in 2006. Disease is expressed as the number of diseased palms per hectare in each category i.e. palms with basal and upper stem rot and suspect palms.

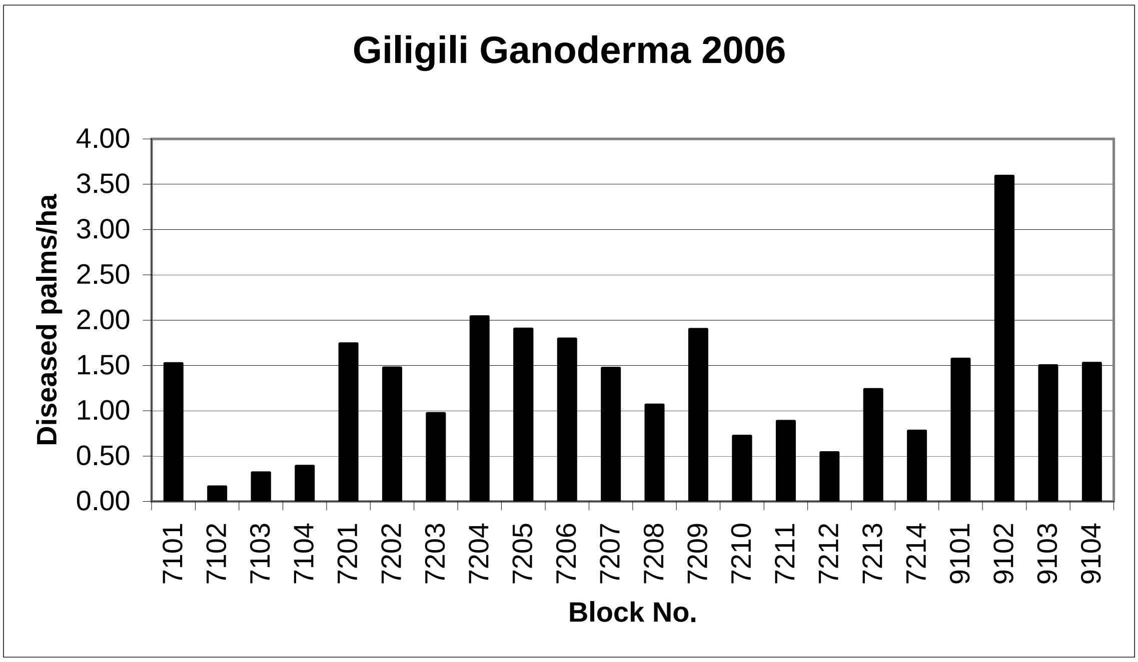


Figure 1.2. Disease incidence expressed as total number of diseased palms per hectare including palms with basal and upper stem rot and suspects, for Giligili Division, Milne Bay in 2006.

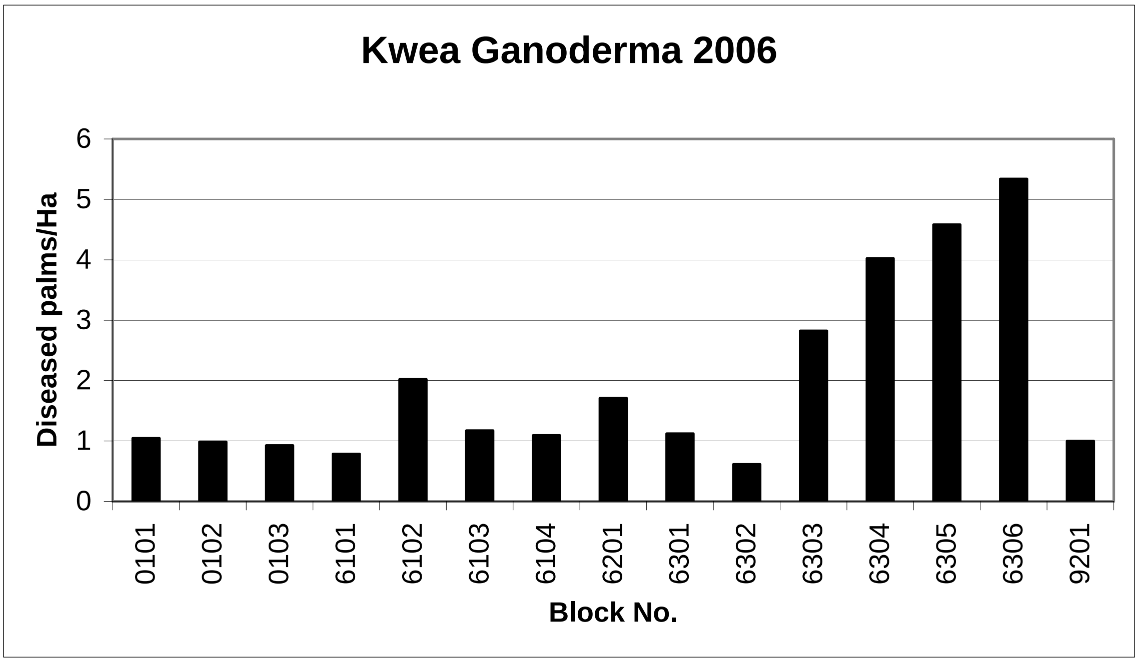


Figure 1.3. Disease incidence expressed as number of diseased palms per hectare for Kwea Division, Milne Bay in 2006. Total number of palms includes basal stem rot, upper stem rot and suspect palms.

The blocks that received mill effluent in the past (6303, 6304, 6305 and 6306) continue to have the highest disease losses in Kwea Division (Figure 1.3) with 3-5 palms/ha being infected in 2006.

Losses in individual blocks in Naura Division ranged from 1-8palms/ha in 2006. Figures for Block 7501 are notably low.

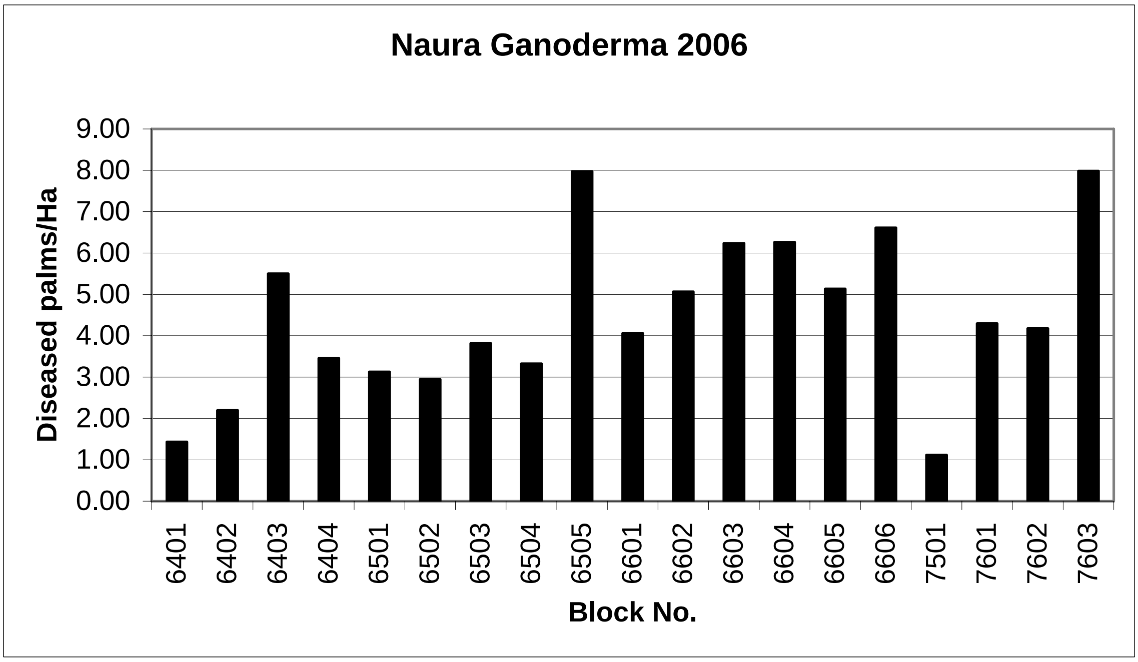


Figure 1.4. Disease incidence expressed as number of diseased palms per hectare for Naura Division, Milne Bay in 2006. The total includes palms with basal stem rot, upper stem rot and suspect palms.

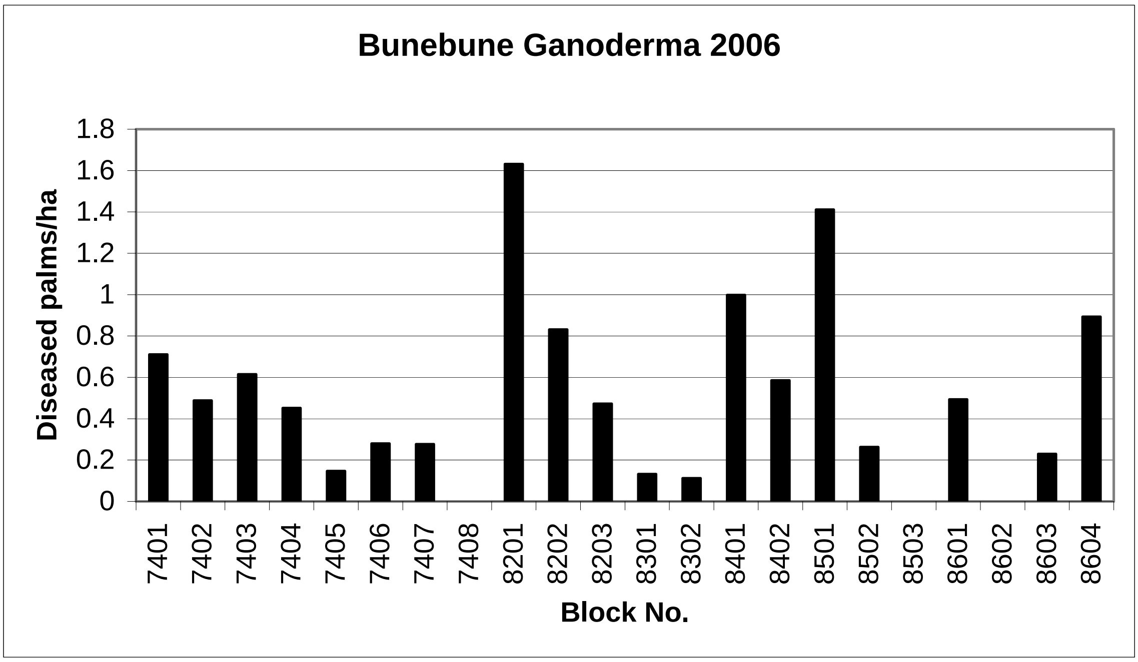


Figure 1.5. Disease incidence expressed as number of diseased palms per hectare for Bunebune Division blocks, Milne Bay in 2006. Total includes palms with basal stem rot, upper stem rot and suspect palms.

Crop losses in the younger plantings in Bunebune, Salima and Tamonau Divisions (Figures 1.5-1.7) were generally lower than the other Divisions but a single block in Tamonau (Block 2101) had losses approaching 3 palms/ha in 2006. The reason for this high incidence is unknown.

Records for Maiwara were unreliable and this Division has not been included in this report.

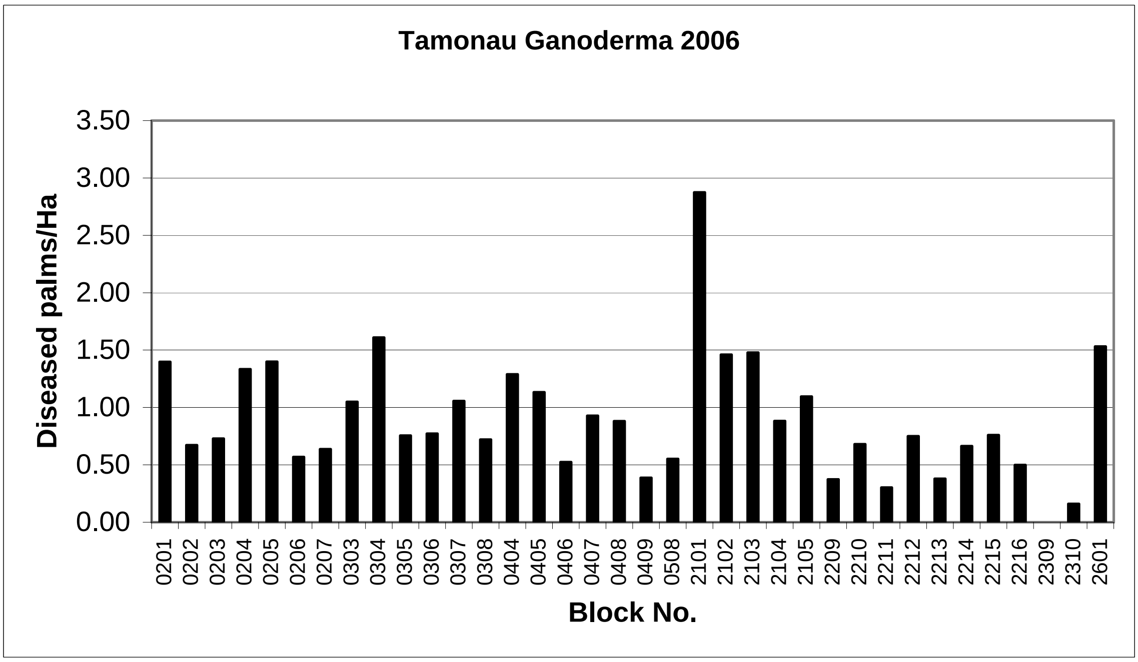


Figure1.6. Disease incidence expressed as number of diseased palms per hectare for Tamonau Division, Milne Bay in 2006. Total includes palms with basal stem rot, upper stem rot and suspect palms.

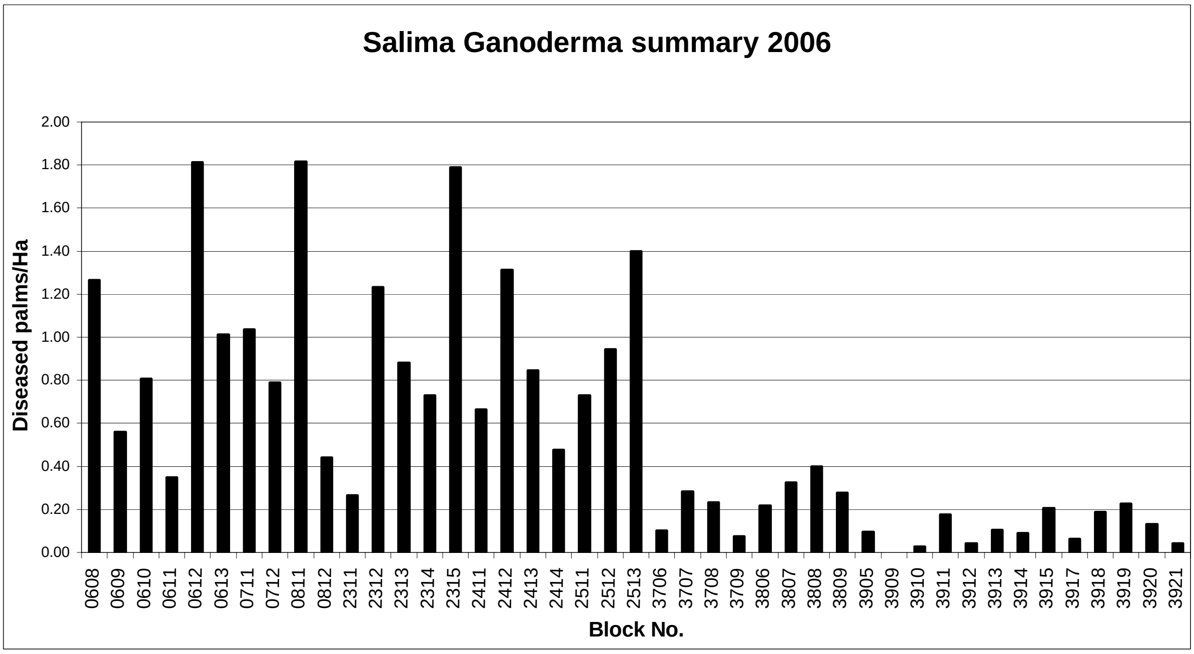


Figure 1. 7. Disease incidence expressed as number of diseased palms per hectare for Salima Division, Milne Bay in 2006. Total includes palms with basal stem rot, upper stem rot and suspect palms.

Annual disease rates expressed as a percentage of total stand are shown in Figure1.8. Disease rates were variable but generally decreased for all age groups in 2006 (from 2005) except Giligili Division where a large increase in the disease rate was observed. This is due to an incomplete survey in 2005 resulting in missing data for many of the blocks in this Division.

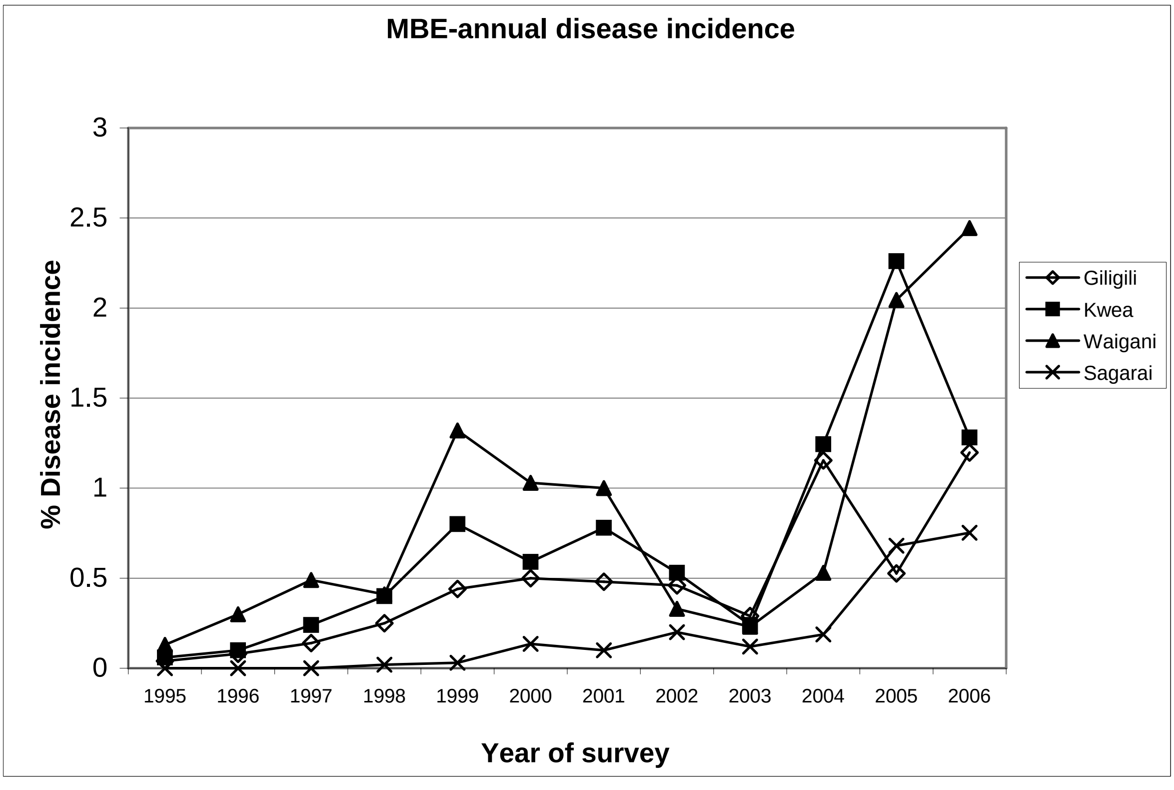


Figure 1.8. Annual disease incidence from 1995-2006 for all Divisions in Milne Bay.

Disease progress over the 12 year period from 1995-2006 for all Divisions is depicted in Figure 1.9. Disease levels in Waigani Division are now over 10% with Kwea Division approaching 9% and Sagarai (Tamonau & Salima Divisions combined) with just over 3%.

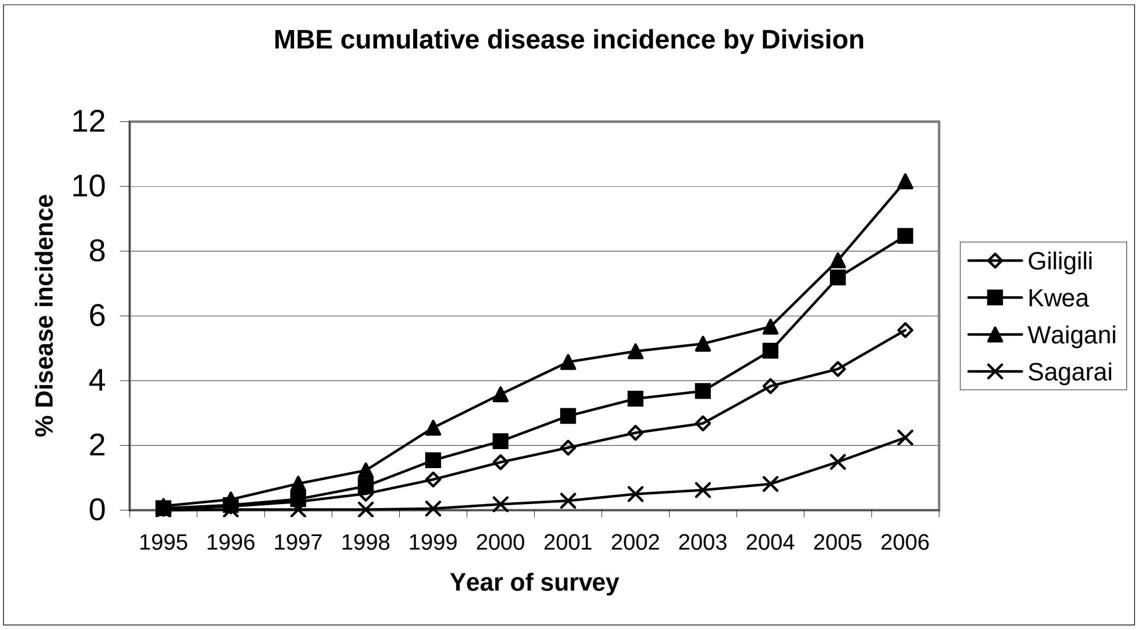


Figure 1.9. Cumulative disease incidence for all Divisions in Milne Bay from 1995-2006.

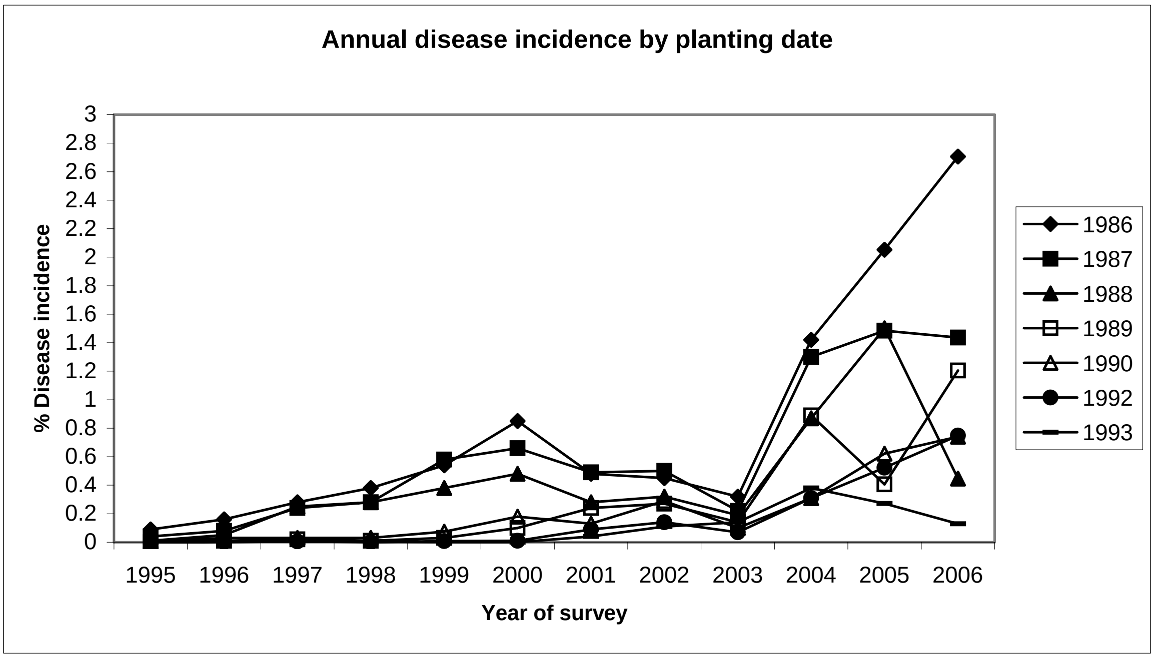


Figure 1.10. Annual disease rates from 1995-2006 for palms of different age groups (planting date) at Milne Bay.

When the data is grouped according to planting date, annual rate curves (Figure 1.10) for palms of different ages show that disease rates have generally remained steady or decreased since 2004. The only increase in rate was observed for the 1989 plantings but this is a reflection of the incomplete surveys in 2005 for palms in this age group.

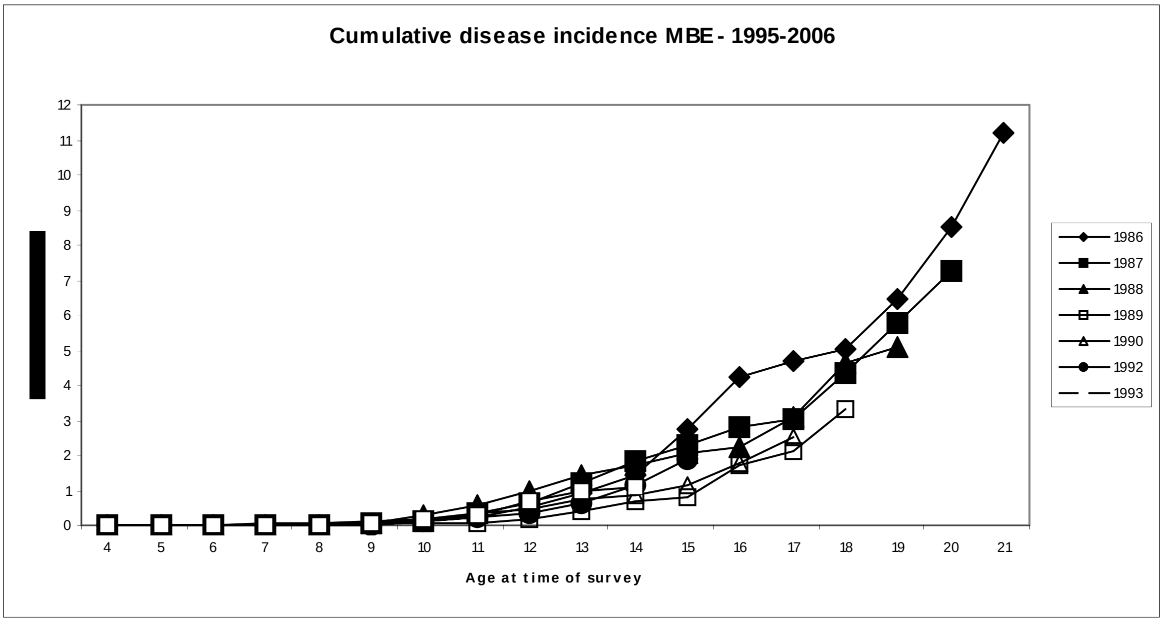


Figure 1.11. Disease progress for palms of different ages from 1995-2006 in MilneBbay.

Disease progress curves for different ages of palms in Milne Bay is shown in Figure 1.11. As expected, the highest disease incidence in is recorded in the 1986 plantings with an average of 11.2%. Disease incidence in the younger plantings at the same age continues to be lower.

Average disease levels for all Divisions in which surveys were completed in Milne Bay are shown in Figure 1.12. Basal stem rot is now at 6.6% and the levels of upper stem rot also increased to in 2006.

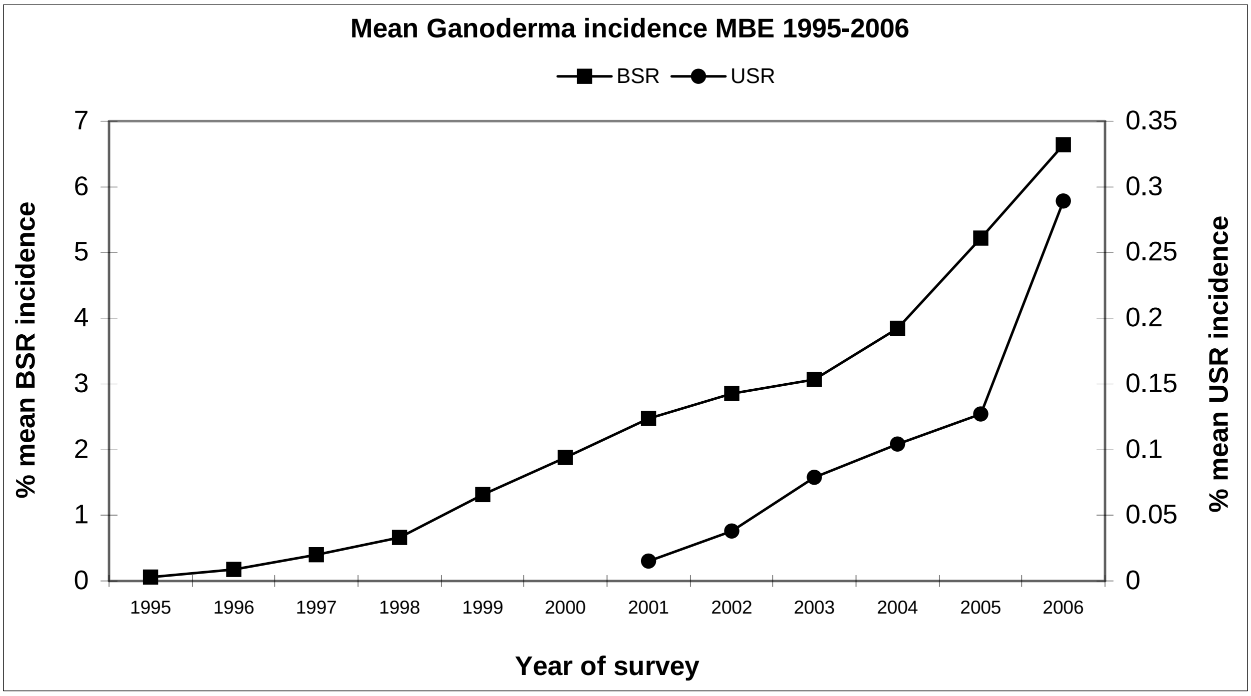


Figure 1.12. Average annual incidence of basal stem rot (BSR) including suspect palms and upper stem rot (USR) from 1995-2006 in Milne Bay.

1.3.2.Disease progress in OPRA study blocks

Disease progress curves for the six blocks used to model disease progress are shown in Figure 1.12. There is some evidence the disease epidemic may be changing for the older blocks in Waigani Division but the regressions have not been done to confirm this. The disease progress for the 2 blocks in Giligili Division appears to have continued in a linear fashion as in previous years.

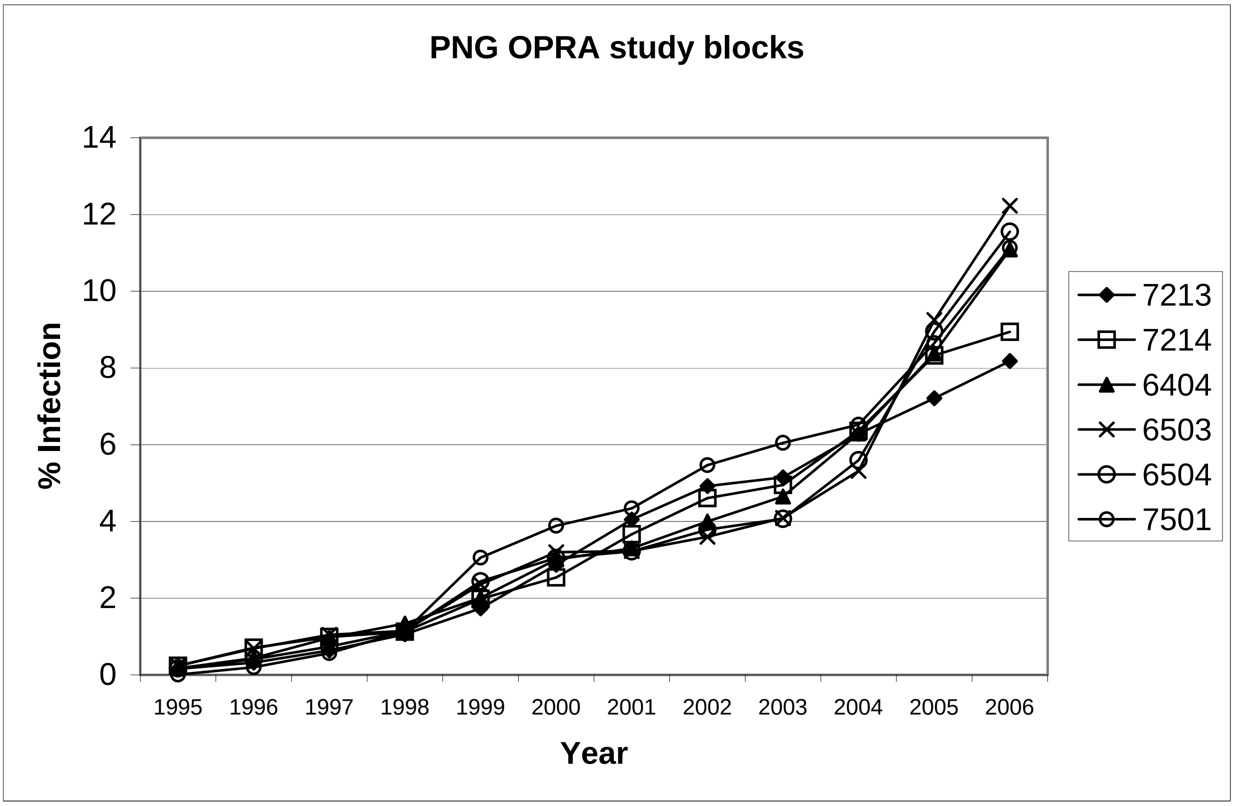


Figure 1.13. Disease progress curves for the six blocks under study by PNG OPRA.

13.3 New Ireland

Disease progress curves for different sites in New Ireland are shown in Figures 1.14 and 1.15. Disease progress continues in a linear trend with only slight changes in the disease rates that can be attributed to survey error.

Of the 1989 plantings, Medina continues to record the highest disease incidence (7.5 %) an increase of 0.9% from 2005, followed by Bolegila (6.3 %) with an increase of 1.2% from 2005. The lowest infection levels for this age group are recorded at Piera and Lugagon. There was a significant increase in the number of infections recorded at Baia (compared to previous years) which recorded an increase of 1.5% from 2005. The reasons for this are unknown.

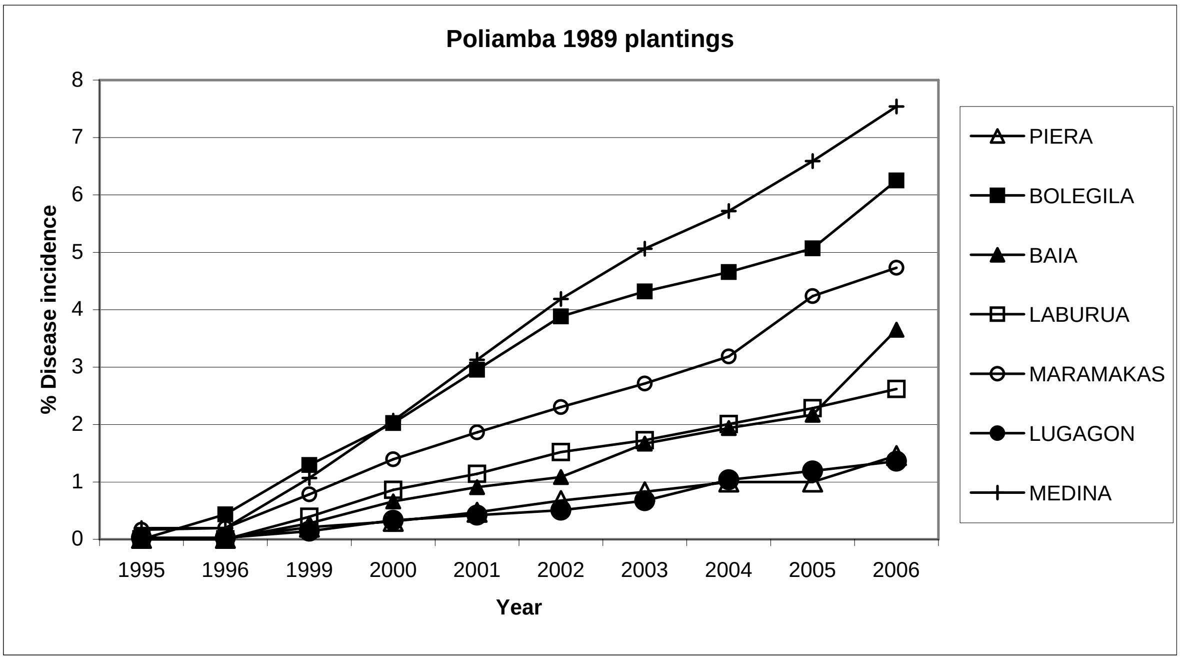


Figure 1.14. Cumulative disease incidence in 1989 plantings by plantation in New Ireland from 1995 to 2005. Data was not collected in 1997 and 1998.

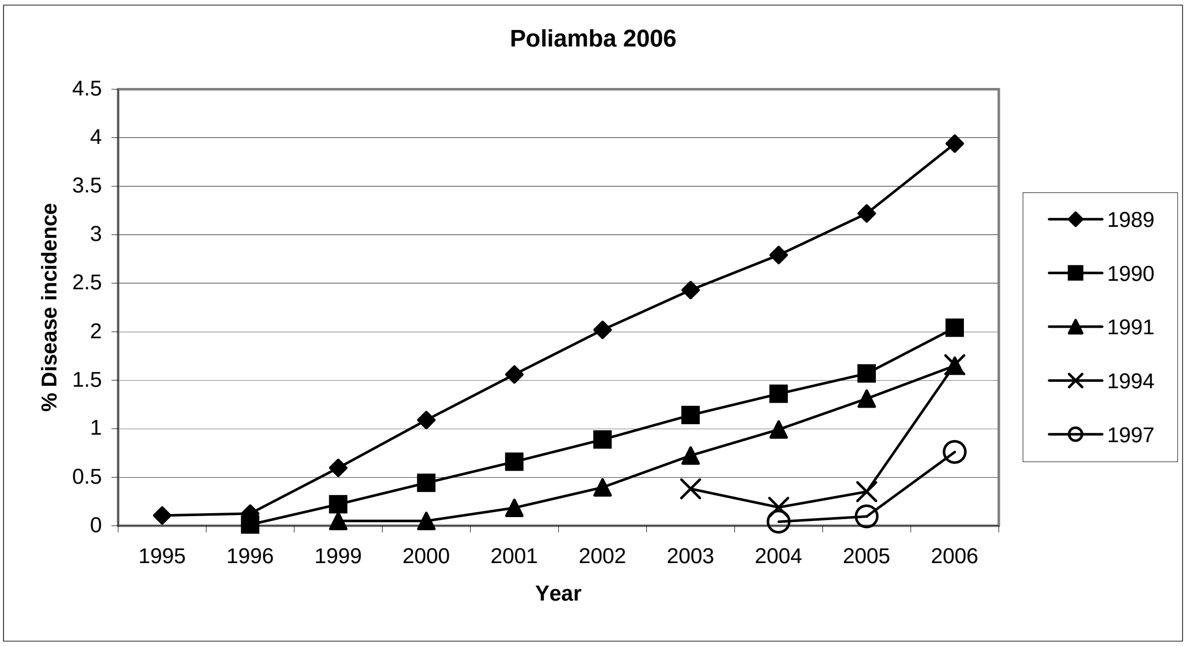


Figure 1.15. Cumulative disease incidence from 1995 to 2006 amongst palms of different ages (1989-1997 planting dates) in New Ireland. Data was not collected in 1997 and 1998.

Figure 15 shows the disease progress for palms planted in different years. The average disease incidence is still significantly lower in the 1990 plantings compared to the 1989 plantings. There was a significant increase in infection levels recorded in the 1994 and 1997 plantings in 2006. This requires investigation.

1.3.4 West New Britain

Annual disease rates for the E fields at Numundo are shown in Figure 1.16.

The rates increased from 2005 for Fields E3, E4 and E5 in 2006. Fields E1 and E2 recorded a decline in disease levels from the previous year. The increase in the rates for Fields E3, E4 and E5 are attributed to the use of survey data rather than data for removals during 2006.

Disease levels have decreased in all E fields since 2003.

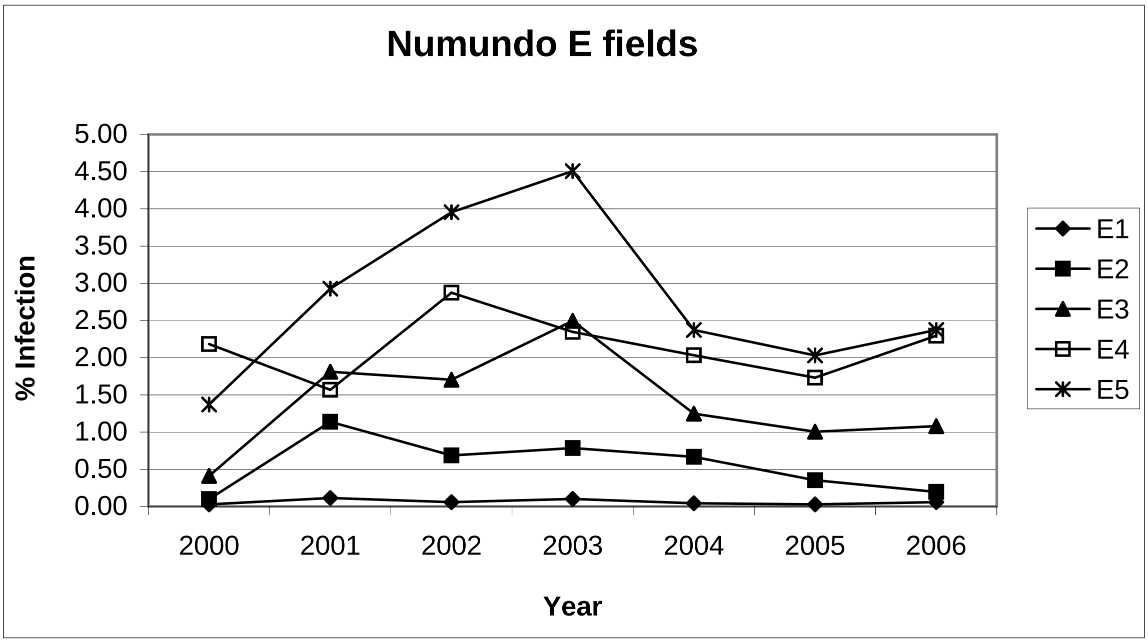


Figure 1.16. Annual disease incidence in Numundo E Fields from 2000-2006.

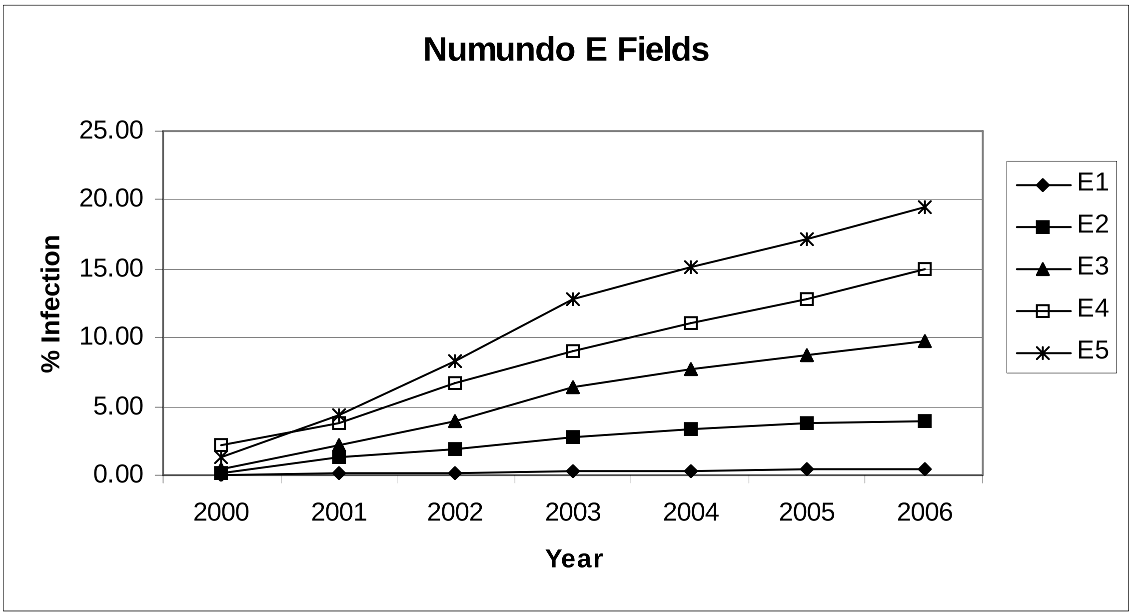


Figure 1.17. Disease progress curves for the 1994 E fields at Numundo, West New Britain Province.

Disease progress curves from 2000 to 2006 show the continuing linear trend in infection levels (Figure 1.17). The level of infection in Field E5 is now approaching 20%.

The very slow development of disease in Fields E1 and E2 compared to the other fields is intriguing and warrants further investigation.

Disease rates in the F fields remained steady or increased in 2006 except for Field F1 where a decrease was recorded (Figure 1.18). The disease rate increased significantly in Field F3 in 2006. This may be related to survey error as rates decreased dramatically in 2005 in this Field.

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 1.19) but these figures will need to be confirmed.

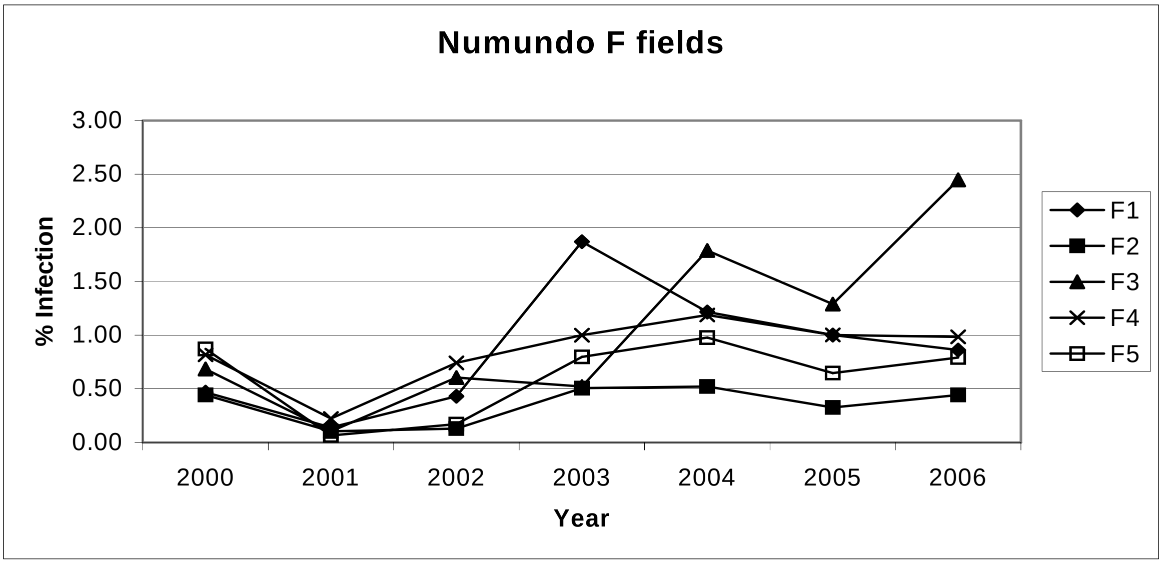


Figure 1.18. Annual disease losses for 1995 F Fields at Numundo, West New Britain Province from 2000-2006.

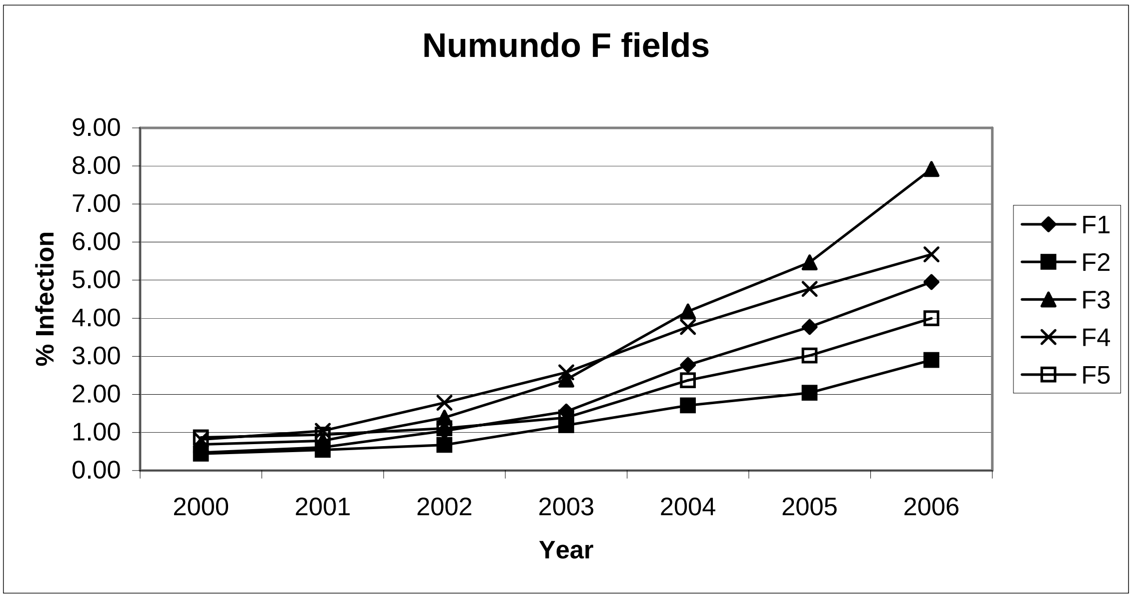


Figure 1.19. Disease progress for 1995 F fields at Numundo, West New Britain Province.

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 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 1.20 and 1.21. Only the blocks with the highest levels of disease were chosen. Unfortunately yield data was only available for MU's rather than individual Fields in West New Britain and hence the data for MU3 (Fields E4 and E5) are shown. Disease levels in both areas are not economically significant at the present time and yield levels remain unaffected in 2006.

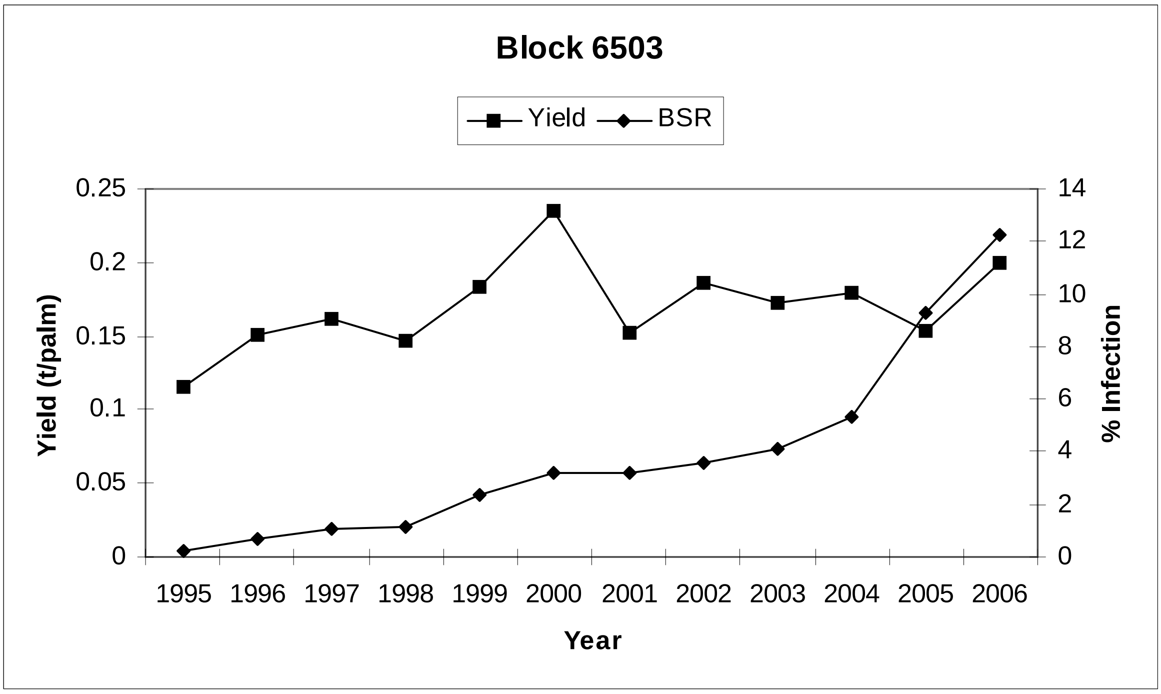


Figure 1.20. Average palm yields (plantation data) with disease progress from 1995-2006 in Block 6503, Milne Bay.Planting density is 127palms/ha.

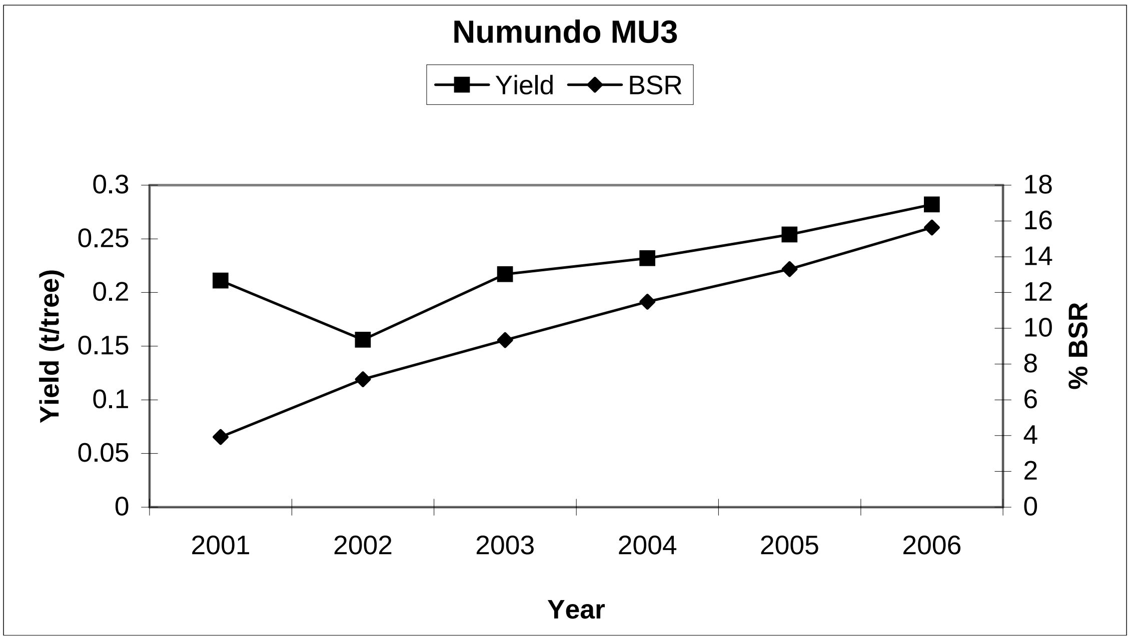


Figure 1.21. Effects of basal stem rot (BSR) on palm production in the worst affected fields (MU3) at Numundo, West New Britain from 2000-2005. Planting density is 135 palms/ha.

PROJECT # 2

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.

2.2 Results

2.2.1 The population in Milne Bay

As in previous years, bi-annual surveys of the six designated OPRA blocks were completed in 2006 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 2006 is shown in Table 2.2. This represents 6,256 individual crosses excluding reciprocal crosses of each individual isolate to determine mating types.

Table 2.1. Areas surveyed and number of Ganoderma isolates collected in the 2006 surveys at Milne Bay (OPRA blocks only).

Block #	Ha surveyed	No. isolates collected
7213	29	17
7214	16.7	5
7501	69	28
6404	63.9	37
6503	76	16
6504	36	14
9601	32	0

Crosses amongst isolates from Block 7213 continue to confirm that the isolates are of different genetic origin (data not shown). However, the number of common alleles detected appears to be increasing (data not shown). There is some indication that the population structure is changing and the variability amongst isolates may be decreasing (statistics yet to be done).

Table 2.2. Shaded portions represent the mating type crosses completed in 2006 for isolates from Block 7213, Giligili.

	Isolate number																
	1243	1245	1374	1298	1299	1359	1360	1373	1375	1376	1488	1489	1450	1492	1561	1562	1563
668																	
728																	
897																	
971																	
982																	
1162																	
1165																	
1243																	
1245																	
1374																	
1298																	
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1375																	
1376																	
1488																	
1489																	
1450																	
1492																	
1561																	
1562																	
1563																	

2.2.2 The population in New Ireland

Surveys and sampling were also carried out in the fertilizer Trials 251 and 252 at Poliamba (Table 2.3). However, genetic testing was not carried out for isolates at Poliamba in 2006 since trial 251 was undergoing felling.

Table 2.3 Number of isolates of Ganoderma collected from Trials 251 and 252(New Ireland) in 2006.

Location	**No. of isolates collected**
Trial 251	16
Trial 252	36

2.2.3 The population in West New Britain

The number of isolates collected from Fields E4 and E5 at Numundo are given in Table 2.4.

Due to the large number of isolates collected from Numundo, only the isolates obtained from neighbouring, infected palms were tested for mycelial compatibility in 2006. The results of these tests are presented in Table 2.5 and show that all isolates obtained from adjacent palms are genetically distinct.

Table 2.4 Ganoderma isolates collected from infected palms at Numundo, West New Britain Province in 2006.

Location	Ha surveyed	No. of isolates collected
Field E4	59.05	72
Field E5	28.10	32

Table 2.5 Vegetative compatibility tests amongst isolates (dikaryons) collected from Field E5, Numundo, West New Britain Province in 2006.

Isolates from neighbouring palms		Test result
Isolate number	Isolate number	
1794	1796	incompatible
1737	1738 (1)	incompatible
1737	1738 (2)	incompatible
1804	1803	incompatible
1989	1988	incompatible
1808 (1)	1809 (1)	incompatible
1808 (2)	1809 (2)	incompatible
1918	1919	incompatible
1760	1761	incompatible
2008	2009	incompatible
1804	1805	incompatible
1912	1913	incompatible
1985	1986	incompatible
1934	1935	incompatible
1927	1928	incompatible
1944	1945	incompatible
1970	1971	incompatible
1792	1791	incompatible
1794	1796	incompatible
2013	2014	incompatible
1981	1982	incompatible
1982	1983	incompatible
2004	2005	incompatible
2009	2010	incompatible
1747	1748	incompatible

PROJECT# 3

DETERMINATION OF LATENT INFECTION LEVELS IN PLOTS WITH RELATIVELY HIGH INCIDENCES OF BASAL STEM ROT

Objective: to assess the levels of latent infection in standing 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

The first 16 plots were felled with a chainsaw and bole tissue was examined on the cross-section where the palm was cut and also longitudinally after cutting the base into quarters. The remaining 20 plots were felled manually with chisels except for one plot (Plot 2) that was felled using a front-end loader. Palms felled manually were then cut at the base using a chainsaw and examined for signs of rot. Where a rot or discolouration was seen in the bole tissue or interface between the roots, pieces were cut out with an axe and these were taken back to the office for plating onto Ganoderma Selective medium (GSM) on the same day. Some palms that had fractured at the base when pushed over were also sampled even though a rot was not visible. The plates were then sent to the Milne Bay laboratory for further processing.

Other data such as soil depth around each palm and condition of the palms at felling were recorded.

Soil pH levels were determined on soil samples also collected from around each palm before it was felled. Soil samples were not taken from around the palms that had been removed prior to this exercise.

3.2 Results

The levels of infection in each of the plots in Trial 251 at the time of felling are shown in Figures 3.1 and 3.2. Two plots, Plot 2 and Plot 19 did not have any Ganoderma infections recorded throughout the life of the trial. Disease incidence in all of the other plots ranged from 6.3 –56.3% of the total number of recorded palms.

In eight plots the number of infected guard row palms exceeded that of the recorded palms (Figure 3.2).

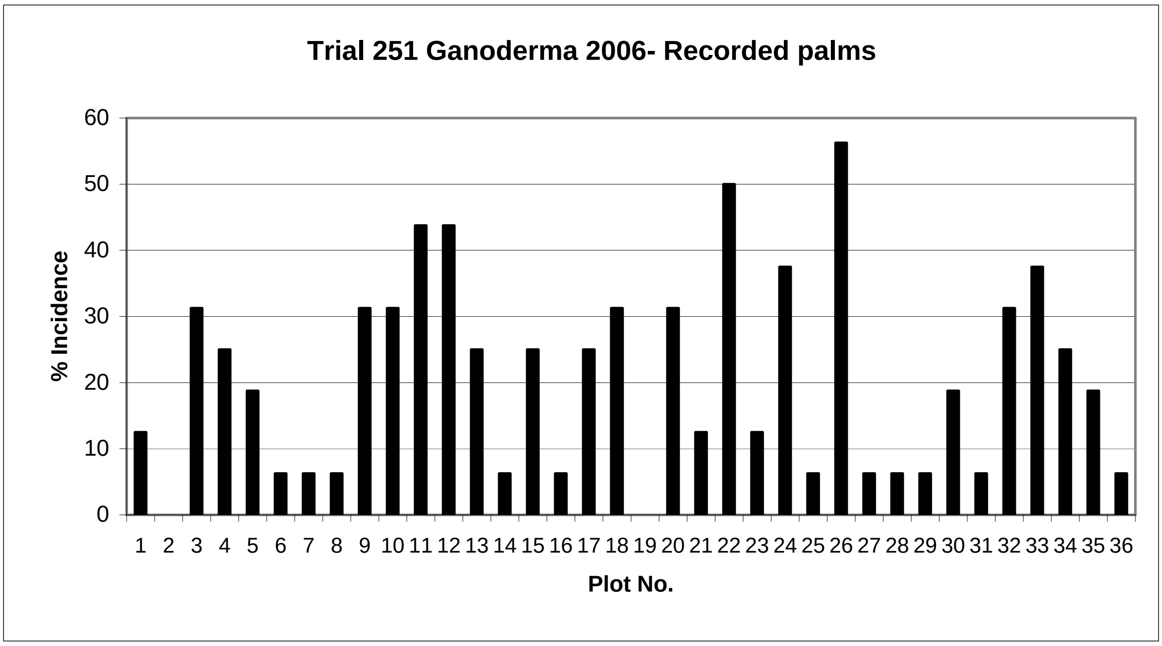

Figure 3. 1. Levels of infection expressed as a percentage of recorded palms in each of the 36 plots of Trial 251 at the time of felling in 2006.

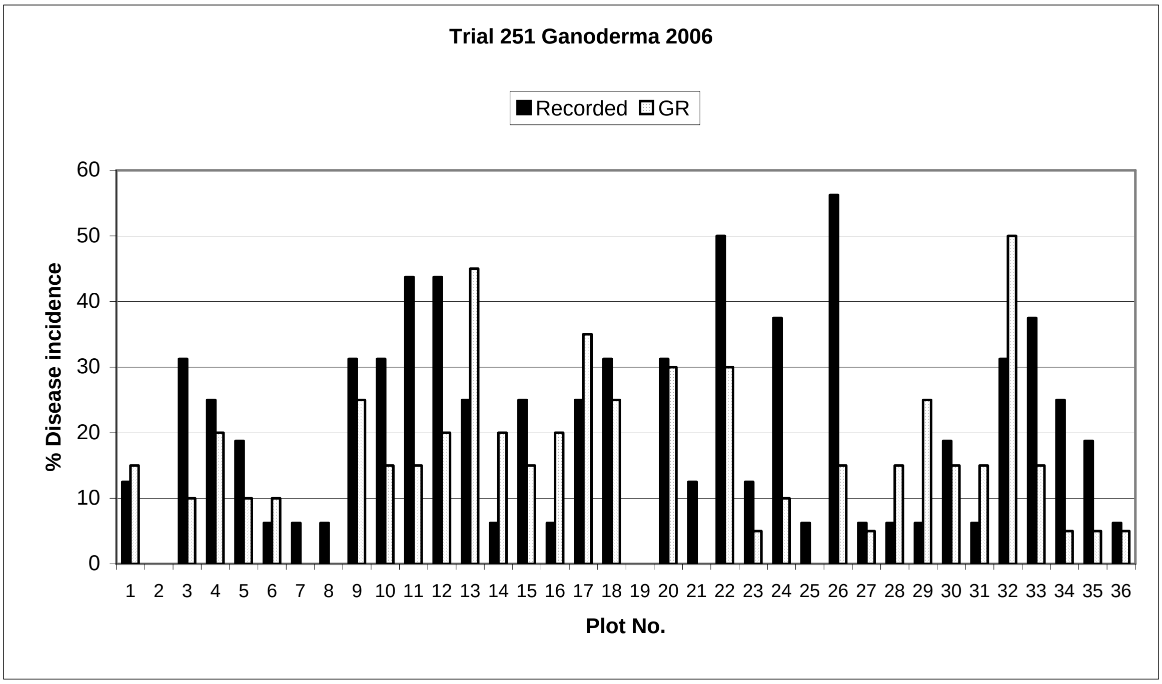

Figure 3.2. Levels of infection in recorded and guard row palms in each of the 36 plots of Trial 251 at the time of felling.

The annual disease rates for all plots combined are shown in Figure 3.3. Proportions are based on total guard row palms and total recorded palms rather than total palm sin each plot. The annual incidence for the guard row palms mirrors that of the recorded palms. There appears to be large increases in disease levels every 2-3 years for both the guard row and recorded palms. Despite this, there was no relationship between the numbers of infected guard palms and the number of infected recorded palms over the ten year period (data not shown).

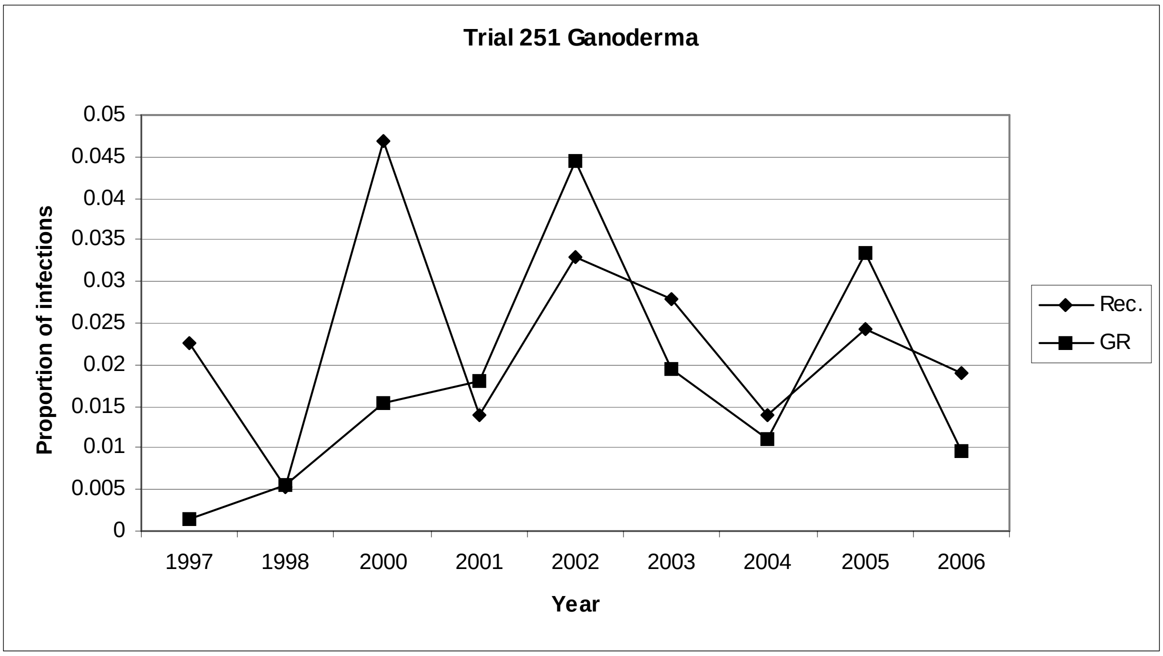

Figure 3.3.Annual disease rates for recorded and guard row palms in Trial 251, New Ireland from 1997 to 2006.

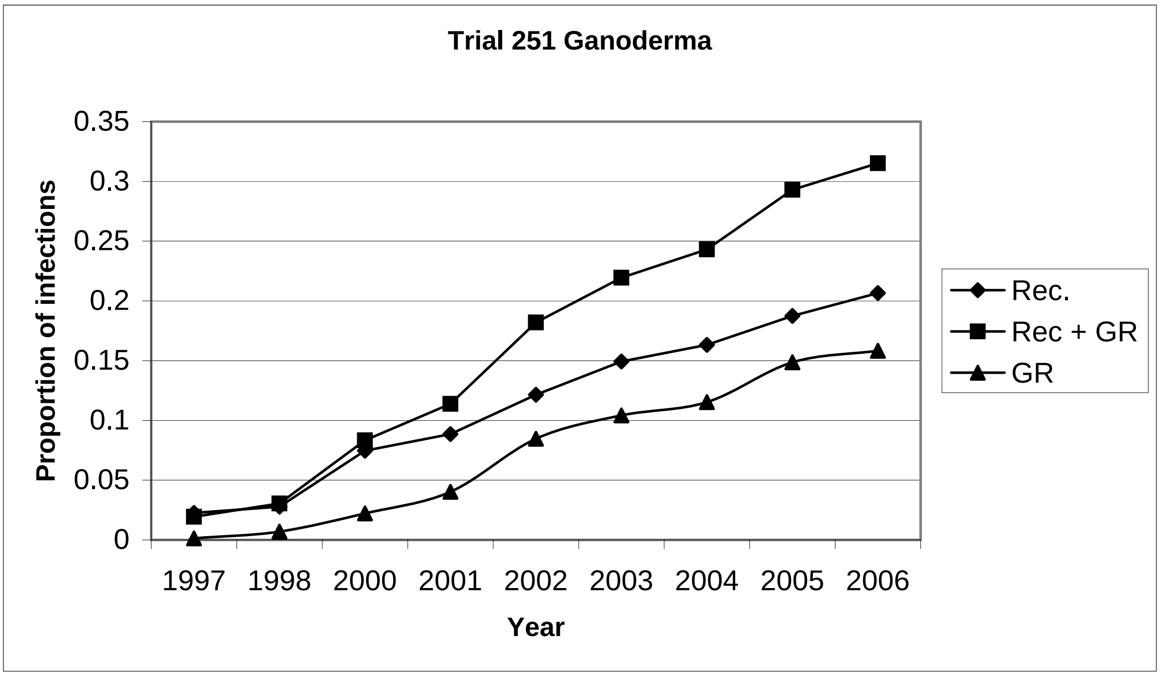

Figure 3.4. Disease progress curves for recorded, guard row and recorded plus guard row palms in Trial 251, New Ireland from 1997-2006.

A typical linear trend was observed when disease progress was plotted for the ten-year period for recorded and guard row palms (Figure 3.4). The disease incidence in recorded palms at the time of felling was 21% for all plots combined and around 32% overall with guard row palms included.

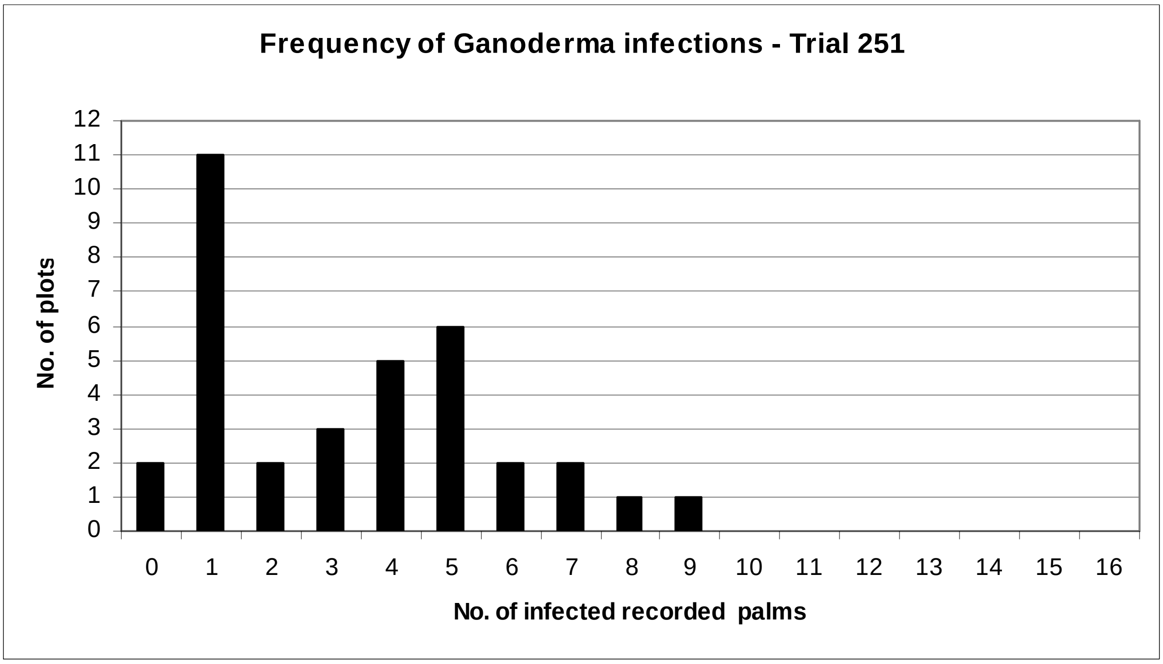

Figure 3.5. Frequency of Ganoderma infections in all plots in Trial 251 at the time of felling.

Thirty-one percent of plots had a single infected palm recorded throughout the life of the trial (Figure 3.5). The majority of plots recorded between 2-5 infected palms over the ten-year period. Only 2 plots had very high incidences of Ganoderma with 8 and 9 recorded palms being infected (50%-60%).

A summary of the results obtained from the destructive sampling of palms in Fertilizer Trial 251, New Ireland is provided in Table 3 1.

A total of 481 palms were felled in the 36 plots. Forty palms (8.3%) had latent infections in the bole tissue and these were very small lesions. Twenty-six of these were caused by fungi other than Ganoderma (as determined by reaction on GSM). From the remaining 14 palms with latent infections, Ganoderma was isolated from the bole tissue. A total of seventy-four palms (15.4%) had some infection in the base with 32 of these palms also having Ganoderma brackets present at the base. The majority of palms with symptoms (7.6%) were also due to Ganoderma infection. Only 2 palms were recorded with upper stem rot (USR) at the time of felling. Earlier deaths due to USR have not been included in Table 3.1. Fourteen plots (38.9%) did not have any visible decay in the bole tissue of the palms that were felled. The other 22 plots had varying levels of latent infection ranging from 6-33%. The majority of plots (61%) had latent infections in standing palms.

There was no correlation between the number of palms with latent infection and the disease levels in each plot (data not shown).

Table 3.1. A 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 no and 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

PROJECT #4

PROJECT TITLE: 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

Two fields at Nuundo, E4 and E5 were selected for the trials in March 2006. These fields had disease incidences of 13% and 17% respectively in 2005, the highest for the area.

Forty diseased palms were selected randomly and cut with a chainsaw to approximately breast height. Selected palms had adequate numbers of active (sporulating fruiting) bodies of *G. boninense* present.

Four-month-old seedlings were individually tagged and planted around the base of each infected stump immediately after the palms was cut as shown in Figure 4.1. Seedlings were planted at distances 0.5, 1.0 and 1.5 metres from the stump in each plot.

Four different progeny were used and these were planted randomly around each stump but always so that the same progeny were not adjacent at the same distance. A total of 24 seedlings were planted per plot. Plots were established in April 2006.

The condition of the palms was monitored each month as well as the condition of the stump and the activity of *G. boninense*. Seedlings were not pruned until 6 months after planting.

Manual weeding was also carried out on the plots as herbicide use was not permitted.

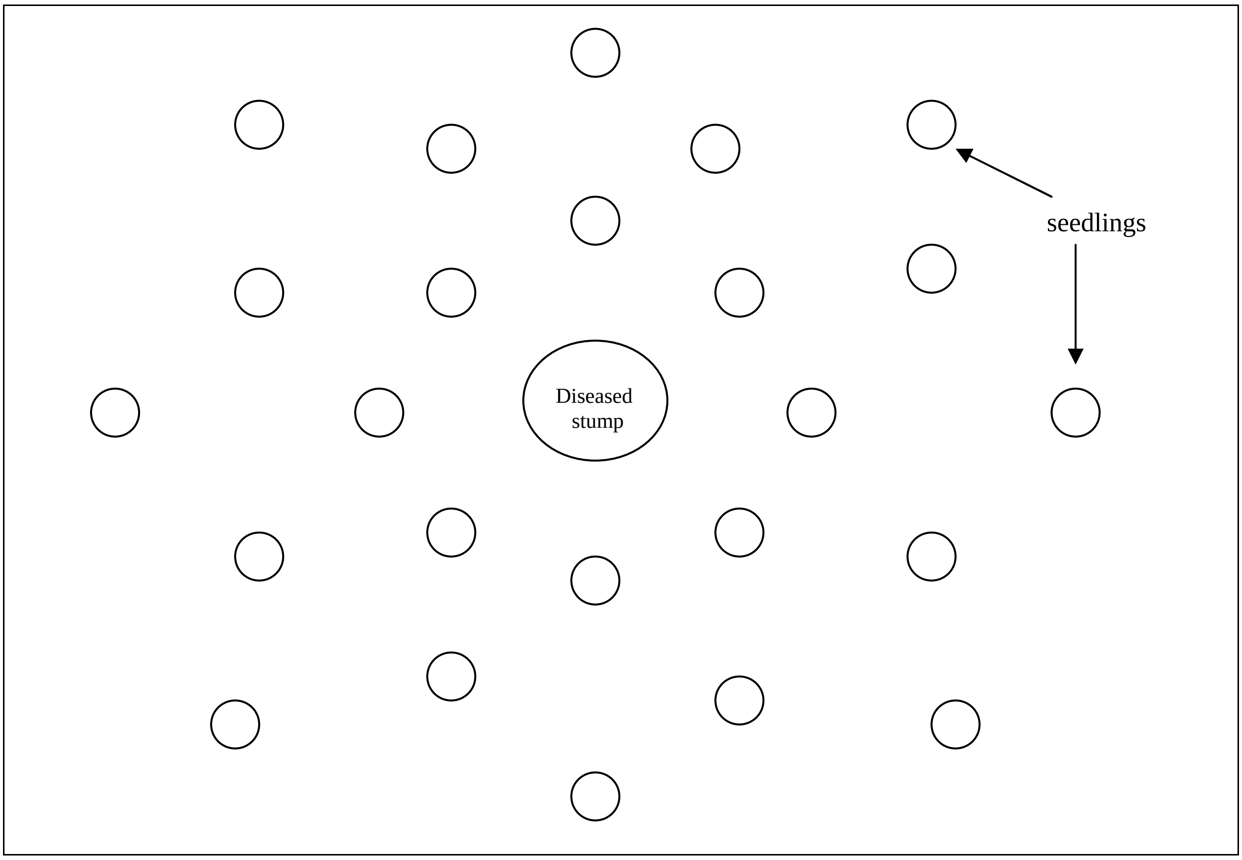

Figure 4.1. Layout of the plots in the Ganoderma trial at Numundo, West new Britanin Province (not drawn to exact scale).

4.2 Results

Table 1 shows the results of the monthly inspections over an eight-month period to December 2006.

Soon after the trials were completed, 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 8 months of recording, all palms are healthy despite having active Ganoderma fruiting bodies on the stumps and therefore a high level of inoculum within the stump itself. Monitoring is continuing.

Table 4.1. Status of seedlings in Gnaoderma trial plots at Numundo from May to December 2006. H=healthy; D=dead; M=missing.

No.	1	2	3	4	5	6	7	8	9	10	11	12
1	H	H	H	H	H	H	H	H				
2	H	H	H	H	H	H	H	H				
3	H	H	H	H	H	H	H	H				
4	H	H	H	H	H	H	H	H				
5	H	H	H	H	H	H	H	H				
6	H	H	H	H	H	H	H	H				
7	H	H	H	H	H	H	H	H				
8	H	H	H	H	H	H	H	H				
9	H	H	H	H	H	H	H	H				
10	H	H	H	H	H	H	H	H				
11	H	H	H	H	H	H	H	H				
12	H	H	H	H	1 DEAD*	M	M	M				
13	H	H	H	H	H	H	H	H				
14	H	H	H	H	H	H	H	H				
15	H	H	H	H	H	H	H	H				
16	H	H	H	H	H	H	H	H				
17	H	H	H	H	H	H	H	H				
18	H	H	H	H	H	H	H	H				
19	H	H	H	H	H	H	H	H				
20	H	H	H	H	H	H	H	H				
21	H	H	H	H	H	H	H	H				
22	H	H	H	H	H	H	H	H				
23	H	H	H	H	H	H	H	H				
24	H	H	H	H	H	H	H	H				
25	H	H	H	H	H	H	H	H				
26	H	H	H	H	H	H	H	H				
27	H	H	H	H	H	H	H	H				
28	H	H	H	H	H	H	H	H				
29	H	H	H	H	H	H	H	H				
30	H	H	H	H	H	2 DEAD*	M	M				
31	H	H	H	H	H	H	H	H				
32	H	H	H	H	H	H	H	H				
33	H	H	H	H	H	H	H	H				
34	H	H	H	H	H	H	H	H				
35	H	H	H	H	H	H	H	H				
36	H	H	H	H	H	H	H	H				
37	H	H	H	H	H	1 DEAD*	1 DEAD*	M				
38	H	H	H	H	H	H	H	H				
39	H	H	H	H	H	H	H	H				
40	H	H	H	H	H	H	H	H				

**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.*

PROJECT # 5

DEVELOPMENT OF A SCREENING TECHNIQUE FOR SUSCEPTIBILITY OF OIL PALM TO GANODERMA

Objective: 1.To develop an effective and rapid screening test for basal stem rot of oil palm. 2. To use this screening test to identify susceptible seed lines.

5.0 Introduction

The characteristics of basal stem rot make it a difficult disease to control by cultural methods or use of fungicides.

This experience has led to the conclusion that long-term control of basal stem rot can only be achieved through the identification and introgression of resistant or tolerant progeny in breeding programmes. Countries such as Malaysia and Indonesia where BSR is prevalent have been pursuing this line of research for some years with limited results.

At the start of the Ganoderma Project in PNG, this was the main theme of research. However, the difficulty of developing a more sensitive technique (to that used by MPOB) that would provide a better means of identifying phenotypic differences prevented this work from evolving.

The work described here is a further attempt to identify phenotypic differences amongst progeny using methods with high inoculum levels that are known to induce disease in immature palms.

5.1Methodology

Both laboratory and nursery assays were carried out in 2006.

Laboratory assays were carried out on young plants (single leaf stage) obtained from the field. Assays were carried out under sterile conditions using a number of different media such as water, glucose yeast medium (GYM) and GSM (Ganoderma selective medium) both with and without agar present. The growth of Ganoderma and condition of the seedlings were checked after 7 days.

Nursery assays were carried out using coconut wood or rubber wood blocks (6x6x12cm) and 8-12 month-old palms. Inoculum was grown in the laboratory for 6-8 weeks before inoculation of the seedlings.

Palms were incubated under low light conditions following the method used at Bah Lias Research Station.

Observations were made weekly initially and then monthly. Palms were scored for the severity of symptoms after 4-6 months.

5.2 Results

5.2.1 Laboratory assays

The results of the various tests were variable due to contamination of the media from the introduced plants. However, use of GSM gave good results with only a small percentage of contaminated plants (data not shown). However, the medium may not be ideal for plant growth so further refinements are necessary. The lack of a growth chamber also makes it difficult to assess the suitability of media for plant growth. This work was temporarily suspended in 2006 pending the results of nursery testing.

5.2.2 Nursery screening

In 2006 eight different sets of experiments were laid out in the nursery to determine the best inoculum type to use and to assess gross phenotypic differences as a basis for future screening tests. These tests were carried out under similar conditions to those used at Bah Lias Research Station but inoculum size was slightly larger.

Results of these initial tests in 2006 were variable but the following conclusions could be drawn:

1. Basal stem rot could be induced in young palms from 5 months to 1 year of age.
2. Rubber wood inoculum performed better (produced higher mortality) than coconut wood with seedling infection and mortality being seen earlier. This was mainly because colonization of the coconut wood took longer than rubber wood.
3. No obvious differences were observed in the effects of the different isolates of Ganoderma on single progeny (statistical tests have not been carried out as yet to confirm this observation).
4. Symptom expression and mortality was faster in the younger seedlings.
5. Shading is necessary for maintaining inoculum in good condition and rapid infection of seedlings
6. Phenotypic differences amongst progeny are not discernable (statistics have not yet been carried out to confirm this) so far

Figure 4.1. Young palms (8-12 months) inoculated with Ganoderma on rubber and coconut in the nursery.

PROJECT # 6

BIOLOGICAL CONTROL OF GANODERMA USING INDIGENOUS ISOLATES OF *TRICHODERMA* SPP.

Objective: (1). To develop methods for the rapid degradation of oil palm trunks

(2) 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 base 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 PNG OPRA 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 Systemtics

Traditional morphological characterisation of all isolates 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 1 and Table 1.1). summarises the draft analysis. Further attempts will be made to obtain the missing ech42 results and then representative sequences will be obtained for each group to allow phylogenetic 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. Ech42 provides further discrimination but analyses are on going.

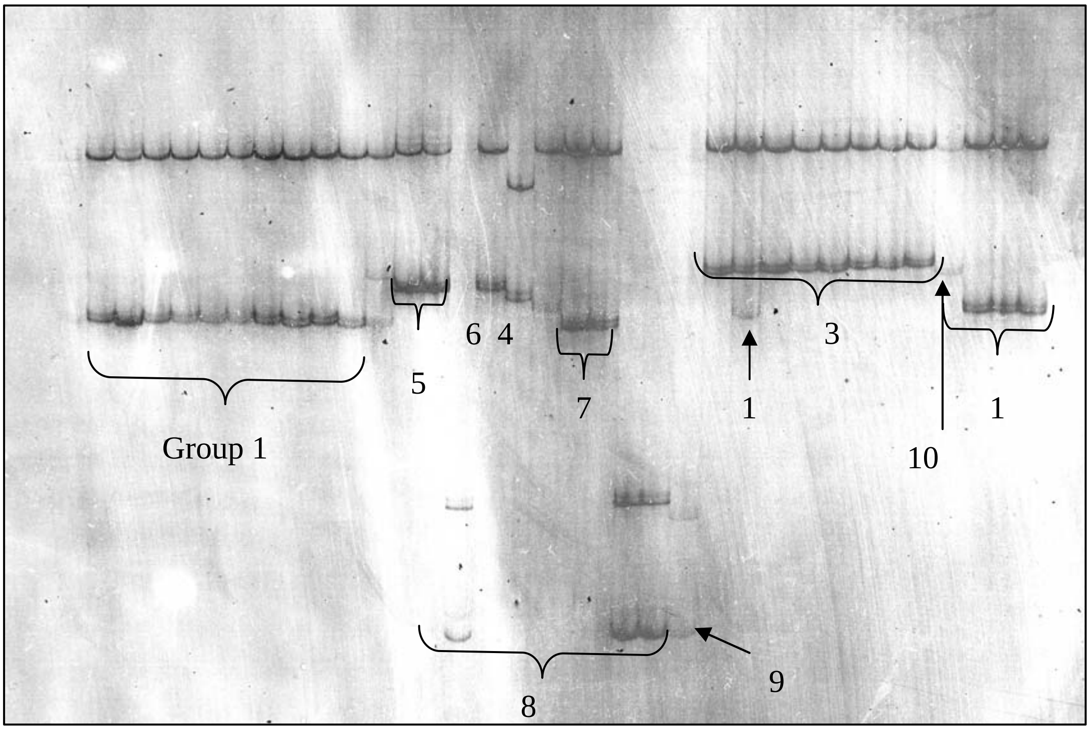

Figure 6.1. SSCP profiles of the ITS regions of several Trichoderma isolates showing polymorphisms in this region. Numbers denote the isolate groups derived from these profiles.

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

On the basis of ITS molecular grouping, the following isolates have been selected for initial determination of mechanisms of antagonism using a single isolate of *G.boninense* (1301):

R, BN, SP5A, #3, SP4B, C, BQ, 41b12, 72126p3, H1.

All isolates were tested for initial determination of mechanisms of antagonism using a single isolate of *G.boninense* (1301). Preliminary results suggest that:

- from the interaction study BQ, #3, SP5B, SP4C, BW, P, #2, 72126p3, Y, 42brl and 42r2 are all good at reducing *Ganoderma* growth on contact. Other *Ganoderma*s follow a similar trend.
- that E, BX, #2, BN, BP, R, P, A1, BV and BU are effective at reducing *Ganoderma* growth by producing volatiles.
- that C, SP4C, E, BN, 40r, WFB1, Q, Y, M and 41 B12 are effective at producing permeable substances to reduce *Ganoderma* growth.

Highlighted isolates appear in two categories, no isolate appears in all 3 lists.

Table 6.1. Comparison of SSCP patterns for the different primers. Isolates with identical SSCP profiles share the same letter.

Isolate #	Species	Mtssu primer	ITS primer	Ech42 Primer
M	*T. asperellum*	G1a	G1b	NEGATIVE
SP6B	*T. asperellum*	G1a	G1b	NEGATIVE
SP5A	*T. asperellum*	G1a	G1b	NEGATIVE
WFB1	*T. asperellum*	G1a	G1b	G1c
BQ	*T. asperellum*	G6	G1b	G1c
BX	*T. asperellum*	G1a	G1b	G1c
BP	*T. asperellum*	G1a	G1b	G1c
SP4C	*T. asperellum*	G1a	G1b	G1c
BV	*T. asperellum*	G1a	G1b	G1c
SP5B	*T. asperellum*	G1a	G1b	G1c
BW	*T. asperellum*	G1a	G1b	G2b
R	*T. asperellum*	G1a	G1b	G2b
P	*T. asperellum*	G1a	G1b	G2b
Y	*T. asperellum*	G1a	G1b	G2b
SP5B	*T. asperellum*	G1a	G1b	G2b
B1	*T. asperellum*	G1a	G1b	G3d
#2	*T. asperellum*	G1a	G1b	G3d
A1	*T. asperellum*	G1a	G1b	G4c
G	*T. virens*	G1a	G3d	G4c
BN	*T. virens*	G1a	G3d	G5g
H1	*T. virens*	G1a	G3d	G5g
E	*T. virens*	G1a	G3d	G6i
G	*T. virens*	G1a	G3d	G6i
K	*T. virens*	G1a	G3d	G6i
42brl	*T. virens*	G1a	G3d	G6i
40r	*T. virens*	G1a	G3d	G7
SP4B	*T. asperellum 2*	G1a	G4	NEGATIVE
C	*T. atroviride*	G1a	G5e	G2
Q	*T. atroviride*	G1a	G5e	NEGATIVE
BU	*T. harzianum*	G3e	G7f	G9j
7212BP3	*T. harzianum*	G3e	G7f	G9j
41r2	*Geotrichum?*	G4h	G8g	G10h
L	*unknown*	G4h	G8g	G10h
Vert-like 3	*Verticillium*	G4h	G8g	G10h
Hop 10g	*Geotrichum?*	G4	G9	G11
# 3	unknown	G5	G10	G12

7.0 Publications, Conferences and Travel

Travel

Visits were made to the following locations during 2006 by C. Pilotti: Djakarta for quarantine related work

University of Kent – for biocontrol work

Poliamba

Ramu

Higaturu

Hargy

D. Woruba visited Poliamba and Hargy.

7.1 Publications

Oil palm diseases poster

OPRAtive word # 10

7.2 Other Activities

AIGF Project –completed work on the poster on diseases of oil palm

Follow-up on disease reports

4. SMALLHOLDER STUDIES

(G. Curry & G. Koczberski)

MOBILE CARD TRIAL BIALLA

BACKGROUND

Funding from ACIAR was approved for a trial in 2006 of the Mobile Card at the Bialla oil palm land scheme. The trial at Bialla builds on the earlier successful trial of the Mobile Card payment initiative amongst Hoskins oil palm growers in 2002-2003 which was designed to mobilise labour on conflict-ridden and labour-short blocks. Instead of blockholders 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 blockholder, with the transaction handled by the extension agency. The reluctance or inability of blockholders to pay cash for labour was circumvented, and the worker was guaranteed timely payment. This greatly reduced the probability of the blockholder not complying with the labour contract. Monthly production at the trial sites at Hoskins increased from 75% of the LSS average to 113% during months when Mobile Card labour was deployed. Productivity increased on 90% of trial blocks with 30% improving by more than 50 percentage points (Curry and Koczberski, 2004).

2006 TRIAL

The Mobile Card trial is a collaborative effort between OPIC, PNGOPRA and Hargy Oil Palms Ltd. The trial focuses on the following types of blocks:

- VOP blocks.
- Blocks managed by “caretakers”.
- Labour-short blocks of elderly growers in the older LSS subdivisions where replanting has been delayed.
- Labour-short blocks among recently married couples with young children on the new LSS subdivisions of Soi and Kabaiya.

The productivity of most VOP blocks is very low. Yet, during high crop periods or when there are important social and cultural events that require cash, productivity can increase significantly. The earlier Mobile Card trial amongst Hoskins VOP/LSS growers suggests that some blockholders are not keen to use the same contract labourer for an extended period of time in case a claim to the block is built up by long-term work on the block. To circumvent this problem, the Bialla trial will also employ youth, church and sports groups as Mobile Card labour because such contract groups do not threaten the tenure rights of the blockholder.

Productivity on caretaker blocks is very low partly because of uncertain and irregular payment for labour by the leaseholder. Many elderly LSS growers without co-resident sons have “abandoned” their stands of old palms because the palms are too tall for them to harvest. Several blocks on the new subdivisions of Soi and Kabaiya have been identified by OPIC as experiencing labour constraints. Many of the leaseholders at Soi and Kabaiya are the sons/daughters of the original oil palm settlers in the older subdivisions at Hoskins and Bialla. These young families have smaller households than those on the older subdivisions. Although Soi and Kabaiya subdivisions have better housing and water supply, better farm management practices, and higher yields than the older subdivisions, production is below potential levels because of labour shortages due to small family size and/or the off-block employment of male household heads.

The extent of under-harvesting at Soi and Kabaiya (where the majority of young married families reside) and at Wilelo and Balima (the original LSS subdivisions where blocks managed by caretakers and elderly household heads are common) can be partly assessed by an OPIC "late pickup" survey conducted in November 2002. Prior to company trucks collecting smallholder fruit for the mill, OPIC counts the nets at the harvest truck pickup point to calculate the number of trucks required for fruit transport in each subdivision section. In November, 2002, when the fruit truck was delayed for 24 hours or more, OPIC conducted a "late pickup" survey and counted the nets in those sections of Soi and Wilelo (and Porkisi VOP) where the truck had been delayed. The extra time to harvest because of the late arrival of trucks resulted in an average increase in production of 36% (Table 1).

Table 1. Expected and actual numbers of nets of fruit collected in a harvest pickup round in November 2002 when harvest truck was more than 24 hours later than 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
Porkisi (VOP)	133	169	27
TOTALS	726	987	36

(Source: Koczberski and Curry 2003, 55)

With the extra time to harvest due to the late arrival of the truck at the new LSS subdivision of Soi, production increased by 26% and at the older subdivision of Wilelo it rose by 57%. The increased tonnage of fruit during delayed pickups suggests that labour shortages are a major constraint on smallholder productivity. Further evidence of under-harvesting and labour shortages on the subdivisions of Soi and Kabaiya and Wilelo and Balima was reported by Koczberski and Curry (2003) who found high rates of under-harvesting and a marked edge-effect in which harvesting rates declined from the roadside plantings through to plantings at the rear of the block. For example, less than half of the 2 ha oil palm stands at the rear of the block were fully harvested, compared with 55% of the 2 ha plantings bordering the road. Whilst a combination of factors is also likely to compound the effect of distance, insufficient labour or time to evacuate fruit from the rear of the block was a common reason cited by smallholders for under-harvesting.

By introducing a payment mechanism that guarantees payment for 1) youth groups working on VOP blocks, 2) caretakers, and 3) hired labour working on labour short blocks, labour productivity on these blocks should rise. In addition, the trial will provide greater insights into the factors constraining the emergence of a market in hired labour, and help answer the difficult question of why leaseholders find it easier to pay for labour in fruit rather than cash.

PRELIMINARY RESULTS

The smallholder Mobile Card trial has been operating at Bialla since February 2006 and concludes in December 2007. Eighty smallholder blocks participated in the trial covering a range of low-producing smallholder blocks: VOP blocks, "caretaker" blocks; labour-short LSS blocks, and blocks where the sons were reluctant to provide labour because they were not remunerated fairly by their fathers.

Preliminary results indicate that the Mobile Card has increased production and improved block maintenance. The increased production on trial blocks indicates that the Mobile Card has the capacity to enhance labour mobility within and across blocks, create incentives for young men to work on their father's block and to improve payment arrangements for caretakers and absentee leaseholders leading to higher and more stable production. There is also evidence to suggest that Mobile Card contracts operating on blocks with permanent "caretakers" leads to fewer disputes over block tenure and payment for work done. Finally, the trial has provided insights into the factors constraining the emergence of a market in hired labour and helped answer the difficult question of why leaseholders find it easier to pay for labour in fruit rather than cash.

Since the trial's inception there have been numerous enquiries about the trial and requests from smallholders to participate in the trial. It is anticipated that the Bialla project will be introducing the Mobile Card as an alternative smallholder payment mechanism in early 2008. Hargy's smallholder payment system has been modified to accommodate the payments of block holders and Mobile labour.