Annual Research Report

2005

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Report by the Director of Research to the Annual General Meeting October 2006

The oil palm industry in Papua New Guinea (*PNG*) fully commits itself to the internationally accepted principles of ecologically sustainable development. Considerable resources have been invested in recent years in order to make PNG's oil palm industry a unique example of achieving high development values whilst ensuring minimal degradation of environmental values.

As of September 2005, all five palm oil milling companies in PNG had achieved ISO14001 accreditation. In the world, this is the first time that the whole of a nation's major agricultural industry has achieved this environmental management standard. ISO14001 is an international standard for environmental management and a disciplined framework for lessening an organisation's footprint on the environment. Its key principles are commitment to comply with all legal requirements, a commitment to prevent pollution, and a commitment to continuous improvement. ISO14001 accreditation is independently audited and the certification authority conducts regular 9-monthly compliance audits.

During the last year, all of PNG's oil palm industry (*including PNGOPRA*) became members of the Roundtable on Sustainable Palm Oil (*RSPO*), thus committing to the Principles and Criteria of the RSPO. These Principles & Criteria ensure commitment to transparency, compliance with all applicable laws, adoption of best practices, environmental responsibility and conservation of natural resources & biodiversity, responsible consideration of employees, individuals and communities affected by growers and mills, environmentally and socially responsible development of new plantings, and commitment to continuous improvement. PNG is taking a lead in developing these Principles & Criteria into a managed auditable system. Again PNG is the only country in the world in which the whole of its oil palm industry has committed to the RSPO.

Papua New Guinea desperately needs sustainable rural development. Any development is going to have some impact on the environment, this is unavoidable. The PNG oil palm industry however has made a commitment that any development must be sustainable in terms of the use of the resources it uses and it must be sustainable in terms of the ecological & cultural integrity of the environment out of which the resources are taken. This commitment is not 'just words', this commitment has been cemented in transparent auditable action.

PNGOPRA has a significant role to play in maintaining and improving this sustainability focus. Although PNGOPRA's current research programme is directly relevant to supporting sustainability, over the next few years the framework for the research programme will be explicitly structured to address the industry's sustainability goals, and in particular focus on areas of higher risk.

The 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 Sugar Ltd and the Oil Palm Industry Corporation (*OPIC*). OPIC, by way of its Membership, represents the smallholder oil palm growers of PNG.

Members Voting Rights in 2006:

Member	FFB Production in 2005	Votes
New Britain Palm Oil Limited	643,738 tonnes	7
CTP (PNG) Ltd	439,521 tonnes	5
Hargy Oil Palms Ltd	157,777 tonnes	2
Oil Palm Industry Corporation (*smallholders*)	614,004 tonnes	7
Ramu Sugar Ltd	n/a	1
The Director of Research (*Executive Director*) also holds one vote		

The Members of the PNGOPRA have full involvement in the direction and operation of the organization. This ensures that PNGOPRA is always responsive & accountable to the needs of its Members. 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 an FFB basis*). Voting rights in 2006 are presented above.

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 service needs into the work programme of PNGOPRA. The Members voting rights within the SAC meeting are the same as for the Board of Directors meeting.

OPIC is responsible for the provision of agricultural extension for the smallholder 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. The Government of PNG regards PNGOPRA and OPIC together as the oil palm component of the National Agricultural Research System (*NARS*).

PNGOPRA as an organization is small, especially when compared to the scale of the industry it serves. The size of PNGOPRA reflects a policy decision to focus on efficiency & quality of service; traits that in many other organizations in PNG are too often compromised by the need to support large overburdening organisational structures.

PNGOPRA is financed by a research levy paid by all oil palm growers and also by external grant funding. The total operating expenditure of PNGOPRA in 2005 was K 4.2 million. During 2005, the Member's levy represented 79% of the organizations revenue and external grants 21%[1]. The Member's levy is set at a rate of K1.77 per tonne of FFB for all growers. Currently, external grant financing is provided as support for two ACIAR research projects, three AIGF projects, three European Union projects, and one PIP project. The Association's financing is planned so that the Member's levy finances the organisation's main recurrent costs, basically 'the physical organisation', whereas the external grant financing supports the operational costs of specific research projects. This arrangement ensures efficient and successful donor projects, which also have sustainable and long-term post-project benefits.

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 small, highly efficient research organisation, the Association addresses only the most significant constraints and threats to the sustainable production of palm oil. The PNGOPRA Agronomy Department carries out research into soil fertility maintenance, crop nutrition and fertiliser management practices. The Association's Entomology Department conducts research into oil palm pollination and the integrated pest management (*IPM*) of insects, weeds and other pests. The Plant Pathology Department is carrying out research into the control of the Basal Stem Rot of oil palm caused by the *Ganoderma* fungus. All research departments, in addition to conducting research, assist the industry by providing technical services support, recommendations and training. PNGOPRA does not carryout oil palm plant breeding[2].

Agronomy Programme

In 2002 PNGOPRA's agronomy research program consolidated a major change in direction that aimed at understanding the processes that determine the returns on fertilizer investments. We are beginning to increase our understanding of these processes which will, in the next few years, start to translate into agronomic management changes.

The highest returns on investment in the oil palm industry are those made on the purchase and application of fertilizer. While returns are high, the potential for losses or increased gains are also enormous.

As with all investments, the key to maximising return is to understand the nature of the investment, in this case the processes that underlie the response of oil palm to fertilizers. Considering the sums of money involved, our understanding of these processes is not yet what it should be. However, results from this change in direction are now starting to come through and our understanding of the soil and palm processes is increasing. In addition to the bottom line of profitability, the industry is increasingly committing itself to protecting the environment. One of the major potential areas of research for minimising the impact of palm oil production on the environment is the study of nutrient loss from both fertilizer inputs and (by)products of the industry. Understanding the nutrient dynamics of oil palm plantations and palm oil production, and developing appropriate management strategies is the main task of PNGOPRA's Agronomy Section.

Improving nutrient use efficiency

The first priority of the Agronomy research program was to understand the nutrient requirements of palms in different areas and to determine the response to nutrient inputs. Although that phase of research has been carried out to a large extent, it must still continue as production moves into new areas and different soils. Computer-based models have been developed which calculate how much of the applied fertilizer is taken up by the palm each year. Also, the fertilizer trials have thrown up a number of related questions. For example, what is the best way to apply nitrogen fertilizer to maximise uptake and response in the varied climates and soils of the industry? And why doesn't kieserite (*magnesium sulphate*) eliminate the symptoms of magnesium deficiency widespread in West New Britain? Underpinning all the questions about improving nutrient use efficiency is the issue of the long-term sustainability of agricultural management - how can we best maintain or improve soil fertility and avoid degradation as well as reduce negative impacts off-site?

In addition to agronomic efficiency, is the question of economic efficiency? Computer-based models have been developed that determine the economic optimum for fertilizer use based on cost of fertiliser and value of palm products. By using the annual leaf sampling results, these models will also calculate appropriate supplemental fertilizer rates.

Maintaining soil fertility

Our research therefore 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 planted areas and between different soil types, and is

[1] Government of PNG Public Investment Programme (PIP) Budget 7.1%, European Union Stabex fund 11.7%, and the Australian Government (ACIAR & AIGF) 2.2% of total revenue.

[2] 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.

also influenced by agricultural management. From earlier research it is clear that soil organic matter and soil pH are the keys to nutrient retention in most of our soils. For example, one of the negative impacts of using ammonium-based fertilizers is a decrease in soil pH, which can 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.

In 2002 two major projects commenced. They concentrate on the retention and losses of nitrogen, magnesium and potassium on volcanic ash soils (*the predominant soils supporting oil palm in PNG*).

A new project proposal has been developed to determine the impact of oil palm management on the continued ability of the soil resource to support productive oil palms. This project is on hold until suitable funding can be obtained. Through another initiative, infrastructure has been put in place to estimate losses by erosion in a number of different landscape settings in West New Britain and Milne Bay Provinces.

Minimising nitrogen losses

The 'N losses' project is being carried out in collaboration with Massey University, New Zealand and with financial support from the European Union. It is concerned with the efficacy of nitrogen fertilizer inputs. The aim is to identify the major mechanisms of nitrogen loss and to develop management practices that reduce losses as much as possible.

Fertilizer constitutes the major cost input in oil palm cropping systems in PNG for both smallholder and plantation alike. The vast bulk of this fertilizer is nitrogenous fertilizer and the viability of the industry depends upon it. By far the biggest agronomic problem facing smallholder growers is nitrogen deficiency. 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 very high due to one or a combination of leaching, surface run-off and denitrification. Losses could amount to as much as 50% of applied nitrogenous fertilizer. Success in the project could have an enormous impact on the economics of oil palm production in PNG.

Results so far indicate that the major mechanism of nitrogen loss is through leaching; erosion, surface run off, and gaseous losses contribute only minor amounts to N loss. Results have also shown that the most active roots in water uptake are under the weeded circle. This also implies that this will be the zone of most active nutrient uptake.

This project is nearing completion in terms of its funding base. However, the research will be continued with PNGOPRA financing.

Improving cation nutrition

The 'Magnesium nutrition' project is being carried out in collaboration with the Commonwealth Scientific and Industrial Research Organisation (*CSIRO*) and James Cook University, Australia and with financial support from the Australian Centre for International Agricultural Research (*ACIAR*). It originally related to the cation nutrition problems experienced on the volcanic ash soils in West New Britain and Oro Provinces that support most of PNG's oil palm crop. The project has now been expanded to include cation nutrition in other regions such as Milne Bay, New Ireland and Morobe provinces.

In West New Britain, calcium dominates the system to at least one metre depth, frequently exceeding the soil cation exchange capacity, thus 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. Trials with 'hot spots' of magnesium- and potassium-containing compounds have been set up, and the first of these has shown a reduction in Mg deficiency symptoms. The project has also studied 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; 1) determining the properties of soils that will allow us to predict where various management practices should be used, and 2) 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. Results have already confirmed that a soil from Bialla has a high selectivity for Ca over Mg. Furthermore, computer modelling has shown that when Mg is added as kieserite, a large portion remains in an uncharged state – suggesting that it will be highly vulnerable to leaching losses.

Under the expansion of this project, we now have evidence that potassium is being locked up in soils in Milne Bay Province. Although the potassium is not lost from the system, it appears that it is not available to the palms either – meaning that potassium use efficiency is low. How to release this potassium for uptake by palms will be the subject of future research.

Understanding responses to fertilizer trials in West New Britain

A third major project, which commenced in 2002, concerns the anomalous and poor responses to fertilizers in trials in West New Britain. Over the years considerable effort has gone into ensuring that experimental designs were suitable for measuring responses. However, it still appears as though fertilizers are moving from fertilized areas into control plots. This apparent movement has implications not just for experimental design, but also for management of nutrition in oil palm plantings. We have established experiments aimed at determining whether nutrients are moving in shallow groundwater, and are looking into ways of determining from where nutrients in a particular area have come.

Computer simulation models have confirmed that there could be substantial movement of water, and thus nutrients, laterally in the upper soil layers. This has the potential to diminish the magnitude of potential fertilizer responses in field trials by allowing nutrients to pass from treated plots to untreated control plots.

Trials with large plots and a systematic layout of fertilizer treatments (*to minimise plot-to-plot influence*) are now showing responses to N fertilizer input. These trials will be the basis for N-fertilizer recommendations in West New Britain in the future. In addition, large trials with boron are also beginning to show responses.

More effective use of existing information

A fourth project aims at rationalizing and making full use of the soil resource information that is available but not being properly utilized in the industry. By combining the resource maps available, and reviewing classification of soil types, we have been able to extend fertilizer management recommendations from plantation to smallholders at an individual block level. These soil maps and fertilizer recommendations have been incorporated into a GIS. This project was funded through AIGF. It is now planned to extend this work to the other oil palm areas.

Technical support

PNGOPRA Agronomists give close technical support to the efforts of the smallholder extension service through farmer field days, advisory services, training for extension officers, and regular workshops for industry field staff.

Agronomy research also addresses other issues such as nursery fertilizer practices, palm poisoning, and assisting in the development of mapping and GIS for the industry. PNGOPRA has also assumed responsibility for monitoring 'quality assurance' in relation to leaf nutrient analysis.

Recently, a monitoring programme has been initiated that will actively maintain the high quality of PNGOPRA trial results.

Entomology Programme

Insect pollination

Preliminary results from this study indicate that there is no strong evidence to show that nematode infestations identified from adults of the pollinating weevil, *Elaedobius kamerunicus*, (*Coleoptera: Curculionidae*) adversely affect the weevil's overall effectiveness as efficient pollinators of oil palm, and populations are indeed healthy. Weather patterns, particularly extended rainfall, do affect weevil activity, however this activity is quickly restored once the rain ceases. Moreover, data from some palms used in a long-term experimental site showed that fruitset was consistently high even during periods of bad weather, while field observations confirmed that weevils are present on the male spikelets even when conditions are overcast. A major factor in weevil biology is the clear correlation between the number of male flowers and numbers of weevils. Fewer male flowers available as breeding sites, equated closely to the subsequent availability of weevils.

As a part of this EU funded project, additional stocks of *E. kamerunicus* will be brought from Ghana, West Africa, to strengthen the current genetic diversity of the populations in PNG. The new material will be subjected to rigorous quarantine regulations, and PNGOPRA now has a fully certified quarantine facility (*the certification process has been completed, and the paperwork is awaited*), into which the weevils will be placed for rearing and genetic screening. The regular monitoring the sex ratios of weevil populations from selected sites is continuing, as one method for monitoring the health of wild populations under PNG conditions.

Sexava Integrated Pest Management (IPM)

All entomology experimental work is aimed at improving the pest management decisions within the framework of IPM. The egg parasitoids *Leefmansia bicolor* and *Doirania leefmansi* are regularly and widely released into oil palm growing areas to enhance the local populations of these efficient parasitoids of sexava eggs. With regular checking for the presence of sexava eggs in the ground at infestations, good reservoirs of both parasitoids continue to be found, although the recoveries are dominated by the minute *Doirania leefmansi*. During the year, approximately 450,000 *Leefmansia* and 2.25 million *Doirania* were released into many sites of both plantation and smallholder growers 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 area; however this strange insect continued to prove difficult to establish in the Central & West Nakanai areas of West New Britain. In the Koropata area on mainland PNG, *Stichotrema* infection levels of the mainland sexava pest, *S. novaeguineae* remained high. There is no evidence of *Stichotrema* having become established in New Ireland, in spite of managing to induce parasitism through manual inoculation of the sexava, *S. gracilis,* which is of importance as an oil palm pest in that Province. In addition, species of parasitic Diptera known as Tachinidae were also recorded parasitizing *S. novaeguineae* on the mainland.

Field visits were made by PNGOPRA's Entomology Section to every reported infestation, of all pests, in both plantations and smallholder blocks. During field visits, samples of sexava eggs are collected, dissected and the age of the developing embryos identified. These data are used in helping to make more precise treatment decisions, as the age of the embryos and expected emergence times are continually being refined. A new major pest, a species of stick insect (*Eurycantha calcarata*), is now ranking as almost equal in importance to that of sexava, and a detailed biological study is in progress, as little is known about the biology of this insect. Other pest taxa are routinely collected during field visits, as part of the on-going addition to the inventory of insects of oil palm in PNG, as well as for training purposes. As a part of PNGOPRA's close links with smallholders and plantation, monthly meetings of the 'sexava working action group' (*SWAG*) continue to be held at Hargy Oil Palms in Bialla, and weekly meetings are held at the OPIC offices (*Hoskins Project*). At these meetings, all aspects of oil palm pest monitoring and control are discussed with the divisional smallholder and plantation 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. This will provide a valuable record of the progress of infestations over time, and when linked with the Agronomy GIS, a valuable working tool.

Field experiments have started to investigate potential alternatives for Methamidophos. Fronds are bagged and Sexava specimens placed in them and they are monitored for mortality

Pest outbreaks

Pest monitoring and visits to all reported pest infestations, and subsequent provision of control recommendations (*PestRecs*) remained a highest of priorities during 2006. In the first 10-months of 2006 141 inspection visits were made; this is 85 less than visited in 2005. Infestation reports from the two dominant taxa (*sexava and Eurycantha*) accounted for 90% of all reports.

A pest report form was designed for distribution and use by all plantations and extension services to facilitate the reporting of pest infestations.

Technical assistance

Routine monitoring of the insect trap catches at the NBPOL seed production unit were started in March 2006 as part of a phyto-sanitation initiative at the unit.

PNGOPRA is also working with NBPOL on a small project to enhance the plant biodiversity in plantations to provide nectar sources for beneficial arthropods.

Bi-monthly monitoring and sampling of oil palm nursery pests is being undertaken. Feedback from this to nursery managers will assist them in making appropriate pest management decisions.

Finschhafen Disorder (FD).

A project proposal to investigate the potential threat to the oil palm industry from the leafhopper, *Zophiuma lobulata* was presented to ACIAR. The proposals have reached the final acceptance phase, and approval is awaited for a multi-disciplinary long-term project on this potentially devastating pest of coconut and oil palm.

Queen Alexandra's Birdwing Butterfly (QABB).

A joint project is expected to be undertaken in collaboration with Conservation International and CTP (PNG) Ltd. PNGOPRA's Entomology Section is to provide the technical expertise on aspects of the host vine ecology and bio-chemistry. An attempt to propagate the *Pararistolochia* vine from seeds has so far failed, and an important part of the project will be to develop techniques for the mass propagation of the correct vine genotype, and the establishment vine nurseries for the development of corridors linking areas of potentially suitable habitats. To avoid unnecessary damage to the wild vines, a technique utilising root cuttings from a closely related species of vine is being investigated in conjunction with the oil palm tissue culture facility at NBPOL.

Biological control of weed pests.

A project to encourage the spread of the efficient biological control agent *Heteropsylla spinulosa* into areas of where Mimosa (*Mimosa diplotricha*) has invaded roadsides in oil palm plantations and smallholder blocks in Oro Province has been completed, however the redistribution of the biological control agent will continue. The gall fly (*Ceccidochares connexa*) a parasite of Siam Weed (*Chromolaena odorata*) was successfully introduced into new localities on the PNG mainland and islands provinces. The galls have been redistributed from the original release site, and continue to be re-distributed as new sites are identified.

Training

There was continued emphasis on training and information dissemination, particularly for control teams (both plantation and smallholders), in effective treatment techniques. An OPRAtive Word (Technical Note 9) on trunk injection procedures was produced that provides guidance on best practice in treatment operations. Work experience opportunities are made available to interested young people.

Pest recognition

A project to prepare oil palm pest recognition display boxes has continued to make good progress, and the boxes will soon be ready for distribution. They will fill a great need by the industry to be able to recognise clearly the major pest taxa involved. In a similar vein, a poster of PNG oil palm pests is being finalised; 2,000 of these A1 colour posters will be printed for industry-wide distribution.

PNGOPRA's Entomology Section has also assisted the National Agriculture Quarantine & Inspection Authority (NAQIA) with the identification of stored product insects. An application for the inclusion of sexava species and stick insects was made to NAQIA to have them gazetted as Notifiable Pests. The Department of Conservation and Environment (DEC), has granted PNGOPRA Approved Institution Status for the movement of scientific specimens.

Plant Pathology Programme

The oil palm industry in PNG is fortunate that severe outbreaks of disease are not a common occurrence in all regions where oil palm is grown. This is partly due to the use of disease-free germplasm as well as the heterogeneity of the oil palm population that is planted. Basal stem rot, a disease caused by the fungus Ganoderma boninense is the only serious long-term disease threat to the industry, especially as plantations and smallholders are currently progressing to a second generation of their crop.

PNGOPRA's plant pathology research programme continues to focus on the control of basal stem rot through the use of biological agents as well as exploiting the inherent resistance in oil palm. All research costs associated with this programme have been financed by the European Union under Ganoderma Stabex Project No. 4.2.

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 smallholders and large estates.

Epidemiological studies now encompass three Provinces where environmental conditions differ. Comparisons of disease levels between regions will provide a more reliable baseline for future predictions of disease pattern and prevalence.

Spatial and temporal disease patterns obtained from research in 2005 indicate that there are differences appearing in both the levels of disease and the patterns of spread between regions. Because of the time lag between detection and removal of diseased palms, it is difficult to ascertain if the control measures at this point are having an effect on disease progress. Analysis of the disease progress curves for study areas in Milne Bay show that annual disease rates are increasing. In contrast, disease rates in West New Britain and New Ireland, although higher, remain steady. Fortunately, disease incidence is still below theoretical threshold levels in all provinces and crop yields are not yet affected.

The population of G. boninense continues to diversify despite efforts to remove inoculum (spore) sources in the field through regular roguing. Genetic tests amongst isolates in Milne Bay demonstrate that the majority of fungal isolates are dissimilar and therefore vegetative spread through the soil is severely limited. Although disease patterns at trial sites in New Ireland show aggregation, genetic homogeneity amongst G. boninense isolates has not been demonstrated.

The pathogen population is now being studied in West New Britain and this will enable some comparisons to be made on the mating type frequencies between the two populations.

Spatial spread of disease is also influenced by environmental conditions and the condition of the environment is also influenced by management practices. As indicated in previous reports, correlations between disease levels and soil and site factors have been poor. PNGOPRA is attempting to integrate these types of studies into the research programme in order to gain a better understanding of the effect of environment on the establishment and spread of basal stem rot. This will require additional resources outside of the current project financing.

Biological control

The use of naturally occurring fungi to control disease is the most appropriate means of control for smallholder farmers. 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.

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 our laboratory in PNG and have been shown to be effective in suppressing the growth of Ganoderma in vitro.

The mechanisms of this antagonism are now being investigated at the University of Kent in the United Kingdom as part of a collaborative project under the framework of the EU Ganoderma Project. It is expected that this work will be completed in early 2007 and the development of a formulation for application in the field will follow on from these investigations. Detailed ecological investigations on Trichoderma and other fungi in the oil palm micro-environment will also require investigation for effective utilization of any formulated product.

Host resistance

Several avenues of research are being pursued for the long-term control of basal stem rot. Initial studies have concentrated on the development of a whole palm nursery screening technique that will allow partial or full resistance amongst oil palm progeny to be identified. This assay is a prerequisite for laboratory-based assays that will permit larger numbers of progeny to be screened. Pathogenicity assays in the nursery have been modified and the disease has now been induced in young palms under somewhat artificial conditions. Whether or not differences amongst progeny can be quantified using this technique remains to be seen.

Laboratory based assays have also been modified several times with limited success. The main problem has been contamination by saprophytic fungi on plant roots. The technique is undergoing refinement and it is expected that a reliable test will be devised in the near future.

Both the nursery and laboratory assays are to be complemented by field trials to test the different progeny for resistance to infection under high disease pressure. The disease pressures in PNG are relatively low and hence several sites in the Solomon Islands have been selected for the trials. These trials will determine if laboratory-based assays are a reliable indication of field resistance and also determine the influence of environmental conditions on the resistance of oil palm to basal stem rot.

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 agency (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. This successful Hoskins trial is now being extended to Bialla in West New Britain. This new Mobile Card trial is a collaborative effort between OPIC, PNGOPRA and Hargy Oil Palms Ltd. The trial focuses on the following types of blocks: a) VOP blocks, b) blocks managed by "caretakers", c) labour-short blocks of elderly growers in the older LSS subdivisions where replanting has been delayed, and d) labour-short blocks among recently married couples with young children.

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 smallholders 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 smallholder.

Technical Services

The staff employed by the Association represent an invaluable knowledge resource for oil palm industry. The services provided by PNGOPRA extend beyond research alone. The Association's scientists are committed to providing technical support via special investigations, recommendations and direct technical input. For example, the Plant Pathology Section is closely involved in the implementation of Ganoderma control measures, the Entomology Section is an integral part of the pest management systems through their role in making recommendations and the production and release of biological control agents, PNGOPRA's Agronomists are involved in the process of providing annual fertiliser recommendations to plantations and smallholder growers. PNGOPRA staff spend a significant amount of their time providing technical training to plantation staff and smallholder extension officers.

For smallholder growers, research work is of limited value unless it operates hand-in-hand with an effective extension service. Although these two functions are carried out by different organisations in PNG's oil palm industry, the close and effective working relationship between PNGOPRA and OPIC is something that we feel proud of. It is not so much the formalised interface that produces this excellent working relationship but an informal interaction borne of willingness by individuals in both organisations to work with a single-team attitude.

Summary

Since its formation 25-years ago, the PNGOPRA has had a major impact upon the productivity and profitability of PNG's oil palm industry, and there is still much scope for future advancement. PNGOPRA's research programme aims at the production of optimum sustainable economic yields with the minimum pesticide and fertiliser inputs, this approach incorporates the principle that high and sustainable productivity is only possible by managing with an environmentally, culturally and economically focussed sensitivity.

Ian Orrell
Director of Research
October 2006

1. AGRONOMY RESEARCH

SUMMARY

(M.J. Webb)

The highest returns on investment in the oil palm industry are those made on the purchase and application of fertiliser. While returns are high, the potential for losses or increased gains are also enormous.

As with all investments, the key to maximising return is to understand the nature of the investment, in this case the processes that underlie the response of oil palm to fertilisers. Considering the sums of money involved, our understanding of these processes is not yet what it should be. In addition to the bottom line of profitability, the industry is increasingly committing itself to protecting the environment. One of the major potential 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 (by) products of the industry. Understanding the nutrient dynamics of oil palm plantations and palm oil production, and developing appropriate management strategies is the main task of PNGOPRA's Agronomy Section.

The first priority of the Agronomy research program was to understand the nutrient requirements of palms in different areas and to determine the response to nutrient inputs. Although that phase of research has been carried out to a large extent, it must still continue as production moves into new areas and different soils. What has now become clear is that there may be large potential gains in efficiency of fertiliser use. Also, the fertiliser trials have thrown up a number of related questions. For example, what is the best way to apply nitrogen fertiliser to maximise uptake and response in the varied climates and soils of the industry? And why doesn't kieserite (magnesium sulphate) eliminate the symptoms of magnesium deficiency widespread in West New Britain? Underpinning all the questions about improving nutrient use efficiency is the issue of the long-term sustainability of agricultural management - how can we best maintain or improve soil fertility and avoid degradation as well as reduce negative impacts off-site?

In addition to agronomic efficiency, is the question of economic efficiency. In collaboration with industry partners and statisticians, we will address the concept of maximising economic returns of fertiliser inputs through advanced statistical modelling based on factorial fertiliser trials and leaf nutrient analysis.

In 2002, the Agronomy program underwent a large change in direction in order to find solutions to these problems.

Nutrient Cycling and Soil Fertility

Three years ago several major projects commenced. The first two concentrate on the retention and losses of nitrogen and magnesium on volcanic ash soils and have both attracted donor funding.

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 fertilizer application. The project is being carried out in collaboration with Massey University, New Zealand and with financial support from the European Union, and is the project in which Murom Banabas is undertaking 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 very high due to one or a combination of leaching, surface run-off and denitrification. Losses could amount to as much as 50% of applied nitrogenous fertiliser. Success in the project could have an enormous impact on the economics of oil palm production in PNG.

The project can be divided into 4 groups of studies and they included;

a) The characterisation of the areas under the palms

The areas under the palms were grouped into 5 different management zones, frond piles, front tips, between zones, weeded circle and the harvest palm. 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 they reflected the different management decisions. The frond piles had the highest N and C content compared to the other zones while rooting distribution studies indicated, most of the roots were in the weeded circle. The implications here 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 uptake by the palms.

b) The water balance or the hydrology of oil palm growing systems

Water balance is a very important component of the oil palm system because it is the medium that transports nutrients into the palms and also losses from the system. 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. The model predicted that at Dami, of the mean annual rainfall, 39 % is evaporated, 1 % is runoff and 61 % ends up as deep drainage, while at Popondetta, 55 % is evaporated, 8 % is runoff and 37 % as 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 done under the palms showed that on average 90% of rainfall end up as through-fall however it was highly variable. Infiltrability 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 up with loss mechanisms this will determine the most likely location for loss. The process of nitrate formation in the soils is referred to as nitrification experiments done suggested most of the nitrates were formed in the 0 – 7.5 cm soil depth and mostly in the frond piles. The data from the experiments also suggested there was little difference between the other 4 zones, frond tip, between zones, weeded circle and harvest path. Half life of ammonium was determined that will be used in modelling in #d

N loss experiments showed that surface runoff and gaseous losses were agronomically small. Leaching experiments suggested (depending on where and when fertiliser was applied) a significant amount of N can be lost through this mechanism. 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 is 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.

We are in the process of developing a model that will use water balance model, rates of nitrate formation and leaching model. The model will look at different management scenarios to decide the best option or combination of options to minimise N losses under the palms.

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 and 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 the West New Britain and parts of Oro Province. The problem occurs on nearly all types of holdings (large plantations, village oil palm and land settlement schemes) placing a profitable industry at long-term risk. Under 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 the PNGOPRA Members, found a large and general imbalance between exchangeable calcium on the one hand, and exchangeable magnesium and potassium on the other, 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-containing compounds into the soil to 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; 1) determining the properties of soils that will allow us to predict where various management practices should be used, and 2) 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 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, and Agronomy staff have been trained in its use. 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 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 also showed increased yields as a result of Mg addition. However, this response has now reverted even though symptoms of Mg deficiency are still apparent in plots not receiving Mg

An additional two trials were commenced in 2005, 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.

Poor responses in fertiliser trials in WNB

Over the last decade, an area of increasing concern has been the anomalous and poor responses to fertilizers 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 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 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 fertilizer 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, surrounded by plantation. The first two 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. In two areas where fertilizer trials have not responded as expected (Trials 125 and 402), we are monitoring of shallow perched water tables. Through the 2002-2003, 2003-2004 wet seasons groundwater was occasionally detected at about 1-1.5m below the surface, within reach of the roots. The rapid response of the watertable to rainfall and the differing heights of the groundwater suggest that it may be a conduit for nutrient movement. This has prompted a change in sampling strategy to capture this short-duration but highly-dynamic changes in water level and thus water flow. The groundwater monitoring will not detect transient lateral flow in shallower layers, so lysimeters were set up at Dami to measure lateral flow. A significant amount of water was collected moving laterally at 20 cm depth. Another approach taken has been to determine if there is a gradient in fertility down slope of a well-fertilised plantation into less well fertilized smallholder areas. A possible area has been identified and samples taken for analysis. 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.

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 are the key to nutrient retention in most of our soils. For example, one of the negative impacts of using ammonium-based fertilisers is a decrease in soil pH, 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.

Nutrient budgets and nutrient use efficiency

We have commenced routine sampling of trunk tissue and FFB in fertilizer trials in order to estimate nutrient uptake and efficiency. Distribution of nutrients in the trunk were measured so that the amount of nutrient in the trunk can be estimated from a single sample. Vegetative measurement and leaf sampling were normally done every two years. The 2004 SAC meeting recommended that these measurements be done yearly from 2005. This information will only us the calculate NUE in many of the fertiliser trials and will form part of a strategy to investigate the overall management of nutrients in plantations.

Fertiliser Response Trials

West New Britain Province (NBPOL)

In West New Britain, most factorial fertilizer trials have not been responding as expected over the last decade or so. The systematic N trials commenced a few years ago and were designed to overcome problems with possible plot-to-plot movement of nutrients. Trial 137 (Kumbango) and 138b (Haella) commenced treatments in 2003 and Trial 403 (Kaurausu) has provided its third year of results. Many of these trials are, for the first time, beginning to show small responses to increasing nitrogen. If these trends continue, they should allow us to make nitrogen fertiliser recommendations in WNBP based on trials. An additional series of fertilizer trials commenced in 2003. They have plots that are much larger than in the previous and current trials and are imposed on breeding trials, so progeny effects are controlled. Trial 142 (Kumbango and Bebere) is an N trial with each plot being an entire block and an entire breeding trial replicate. Trial 148 (Mg, Kumbango) and Trial 149 (B, Kumbango) are slightly smaller but follow the same principle. Yield recording in these trials began in 2003. Although there are clear effects of progeny on yield, there is no effect of fertiliser treatment in these new trials. Yield recording commenced in Trial 139 (Spacing, Kumbango) in 2003 and has shown that the wider avenues have increased yield in the earlier years but not in 2005. Observation also suggests that the wider avenues also promote better ground cover.

Trials relating to the Mg project were at various stages of commencement in 2004. Setup of Trial 144 (Waisisi) was completed 2003, the setup for Trial 145 (Walindi) was completed in 2004, and setup for 146 (Kumbango) continued in 2004. All trials are now fully established

Again in Trial 137 (Systematic N, Kumbango), there was a small but significant response in FFB to N in its third year with the optimal rate around 5 kg AC/palm. In Trial 138b (Systematic N, Haella), there was again a yield response in the fourth year of the trial. Trial 403 (systematic N, Kaurausu) again showed a response to N in this, the fifth year of the trial. The "Large Progeny Trials" (142, 146, & 148) have recently had yield recording commenced. While there is no difference in yield due to N or Mg fertiliser treatments, there was a significant effect of progeny (in the limited subset that could be analysed) in Trials 148 and 149. In trial 149 (Boron), there was a small increase in FFB with increasing B supply. The first of the Mg trials (Trial 144; Mg & K, Waisisi) to be established showed a yield response in 2004 but not 2005, although there continued to be a response in Mg deficiency symptoms.

West New Britain Province (Hargy)

The factorial trials 204, and 209, in general continued to show similar results to previous years. Trial 204 is recovering from a Sexava outbreak; and has once again shown a significant response to N as it did in years prior to the outbreak. At this stage the recommendation for this area would be to continue with AC application only according to the normal recommended rate. In Trial, once again, only progenies had an effect on yield. Although the ranking of progenies tends to change from year to year, progeny G has been in the poorest group in the last few years. In Trial 209 SOA, MOP, and TSP all had significant effects on yield with the highest yields when all three fertilisers were supplied at adequate rates. Last year Trials 211 (Systematic N at Navo) and 212 (Systematic N at Hargy) showed the significant response in yield; this response continued and increased in 2003. This year Trial 213 (N, P on high ground) only showed a significant response to TSP, but yields overall were generally low.

Oro Province

In the fourth year (as in 2004) of Trial 324 (N sources, Sangara) there was a significant effect of N rate on yield; but not of N fertiliser type. Once again, there were not yet any effects of treatments on Trial 326 (N x EFB, Sangara). Treatments for Trial 330 (N x S Grasslands) had not been applied in this trial because of inherent variability and problems with access. The trial has been moved to a new site, and treatments will be applied in 2006 following analysis of pre-treatment data. There are no treatment effects in Trial 333 (Mg & K Sources). This is expected as it only had treatments applied in 2004.

Milne Bay Province

In Milne Bay the three factorial fertiliser trials continued. In Waigani, the trial on the good Plantation soils (502b), SOA, MOP and EFB continue to have positive effects, with EFB proving to be an effective source of N and K in that it replaced some the requirement for SOA and MOP. For the first time, TSP had an effect on yield. On the poorer Hagita (buckshot) soils (511), there are large positive effects of SOA, TSP and EFB, and this year a smaller, but continued effect of MOP on yield. Once again EFB could partially replace the SOA requirement. In Sagarai (504), the positive effects of SOA and MOP on yield are continuing with time. The application of POME in Trial 512 has had no detrimental effect on yield at Waigani.

New Ireland Province

In the factorial fertilizer trials 251 and 252, the effects of fertilisers on yield and tissue nutrient contents in these trials were similar in 2005 to previous years except that SOA had no effect on yield in 252. MOP had a major effect on yield in both trials. These trials showed a benefit of MOP in reducing Ganoderma in 2002. Subsequently, both trials will be felled and all trunks assessed for infection at the beginning of 2006. Trial 254 (B trial) has been marked out and treatments commenced in 2005.

Ramu Sugar

Trial RM 1-03 (Factorial Trial on Immature Palms) was set up in November 2003 and has shown a significant response to AN, TSP and S in general health and appearance of palms. Trial RM 2-04 has been set up but there has been no recording to date.

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.

Yield recording in Trial 139 (Kumbango) and 331 (Ambogo) commenced in 2003 and Trial 513 (Padipadi) was planted in 2003. In Trial 139 (Spacing, Kumbango), the second year of recording continued to reveal increasing yield with increasing inter-row spacing (although no longer significant in 205). In Trial 331, there was a general trend of increased yield with increased density, however, this trend can probably be attributed to the number of palms per ha at this stage. Yield recording will commence in 2006 in trial 513 to coincide with commencement of harvesting.

Predictions and Recommendations

All our research aims at improving predictions and recommendations for the industry. However, we are also carrying 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. The monitoring site at 324 has shown surprisingly constant levels of soil moisture even with substantial changes in weekly rainfall; only decreasing after a long period with low rainfall.

Studies in short-term prediction commenced in Oro and Milne Bay. This approach, is similar to black bunch counts, but provide a 3-4 month prediction based on time of flower anthesis.

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.

Quality Control

An industry-wide set of Standard Reference Material was produced in 2004 to allow comparison of analysis of plant material. Statistical analysis of this material has show quite good repeatability within batches. There is enough material to last the industry until at least 2015.

BACKGROUND INFORMATION

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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
DM	Dry matter
EFB	Empty fruit bunch
FA	Area of Frond
FFB	Fresh fruit bunch
GM	Grand mean (average over all treatments)
KIE	Kieserite (mostly magnesium sulphate, $MgSO_4$)
LAI	Leaf Area Index
l.s.d.	Least significant difference (p=0.05)
mM	Millimolar (millimoles per litre)
MOP	Muriate of potash, or potassium chloride (KCl)
n.s.	See Sig.
p	Significance (probability that treatment effect is due to chance)
SBW	Single bunch weight
s.d.	Standard deviation
s.e.	Standard error
s.e.d.	Standard error of the difference of the means
Sig.	Level of significance (n.s. not significant, * $p<0.05$, ** $p<0.01$, *** $p<0.001$)
SOA	Ammonium sulphate ($(NH_4)_2SO_4$)
SOP	Potassium sulphate (K_2SO_4)
TSP	Triple superphosphate (mostly calcium phosphate, $CaHPO_4$)

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

CLIMATE – Summary of selected locations across the industry

Monthly and annual rainfall for 2005

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	**Total**
							West New Britain Province						
Navo	725	488	656	983	203	126	334	290	366	384	317	360	**5232**
Bialla	725	448	743	1332	153	61	272	233	308	173	268	224	**4939**
Dami	613	692	379	881	144	181	131	95	204	213	293	309	**4133**
Garu	1225	875	843	862	131	85	128	201	138	235	247	302	**5272**
							Oro Province						
Mamba	822	278	581	189	386	109	148	375	325	239	551	555	**4558**
OPRA	492	132	327	251	221	158	58	79	29	125	431	179	**2482**
Embi	241	186	271	164	145	121	107	28	38	89	89	463	**1942**
Ambogo	368	188	136	158	169	129			28	146		155	**1477**
							Milne Bay Province						
Waigani	230	152	245	210	176	105		110			134	242	**1603**
							New Ireland Province						
Poliamba													
Lakurumau	57	416	286	532	267	65	357	171	500	376	299		**3841**
Maramakas	520	430	293	397	328	50		170	309	285	239		**3021**

Monthly and annual sunshine hours in 2005

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	**Total**
							West New Britain						
Navo	188	218	287	238	276	286	293	271	284	317	292	300	**3250**
Bialla	41	71	63	148	182	151	130	135	105	191	61	99	**1376**
Dami	76	67	140	145	160	175	126	146	112	186	136	135	**1604**
							Oro Province						
Mamba	34	90	115	113	98	132	112	142	128	140	105	118	**1327**
OPRA	103	132	162	178	163	150	159	157	155	196	143	210	**1907**
							Milne Bay Province						
Sagarai													
							New Ireland Province						
Poliamba													

*nd – no data collected

NUTRIENT CYCLING AND SOIL FERTILITY

Study of Nitrogen Loss Pathways in Oil Palm Growing Agro-ecosystems on Volcanic Ash-Derived Soils in Papua New Guinea.

Project No: Stabex Project 4.22

Results and discussion of work conducted from July 05 to May 06

Introduction

Activities done from July 05 to July 06 included analysis of water samples collected, field buried and in situ nitrification studies, setting up and collecting water samples from in situ nitrification and leaching experiments at Sangara and Dami, doing root distribution studies at Sangara, re-doing small surface runoff studies at Dami however with small catch cans positioned around the plots to estimate through-fall water input into the plots. The experiments were completed and samples were analysed at Massey (NZ). Weather data collation, soil moisture monitoring using Sentek Diviner 2000 probe and large surface runoff water measurements continued at both sites. Most of the period was spent on writing up the project and will continue to end of 2006. Discussed here are some of the results of work done. For method and materials and many of the earlier results, see 2002 to 2004 annual reports.

2.0 Climate of Oil palm growing areas in PNG

The whole N loss mechanism is water driven and the main water input into oil palm growing systems is from rainfall. Rainfall is a component of the climate and is discussed here for the different oil palm growing areas in PNG. A major component of the water output in an oil palm growing system is evaporation. Evaporation is driven by other climatic factors such as wind run, air temperature, sunshine hours and rainfall.

Rainfall.

The oil palm growing provinces in PNG have mean annual rainfall ranging from 1913 mm at Ramu Sugar in Morobe Province to near 4000 mm in WNB Province and Mamba in Oro Province (Figure 1). Within each province the mean annual rainfall varies for the different plantations e.g. in WNB it ranges from 3327 mm in Hoskins area to 4451 in Bialla, and in Oro Province from 2164 mm at Ambogo to 3950 mm at Mamba. Mean annual rainfall for the two experimental sites are for Dami (1980 – 2005) 3657 mm and Sangara (1976 – 2005) 2398 mm

The rainfall at Dami in WNB and at Sangara in Oro Provinces is different in both the total amounts received and in the monthly distribution. At Dami 50 – 60 % of the total annual rainfall is received in January - April which is the high rainfall period, while the rest is shared out over the remaining 8 months (Figure 2). At Sangara the high rainfall months are from October to April while the low rainfall months are from May to September (Figure 2). The other plantations in WNB and Poliamba in NI Provinces have a similar rainfall pattern to Dami, while those in Oro Province are similar to Sangara. Ramu Sugar also has a similar pattern to Sangara, but generally lower amounts. In Milne Bay Province there appears to be a slight increase in mean monthly rainfall from March to July, but in contrast to Oro and WNB Provinces, there is no clear monthly pattern and rainfall is fairly equally distributed throughout the year.

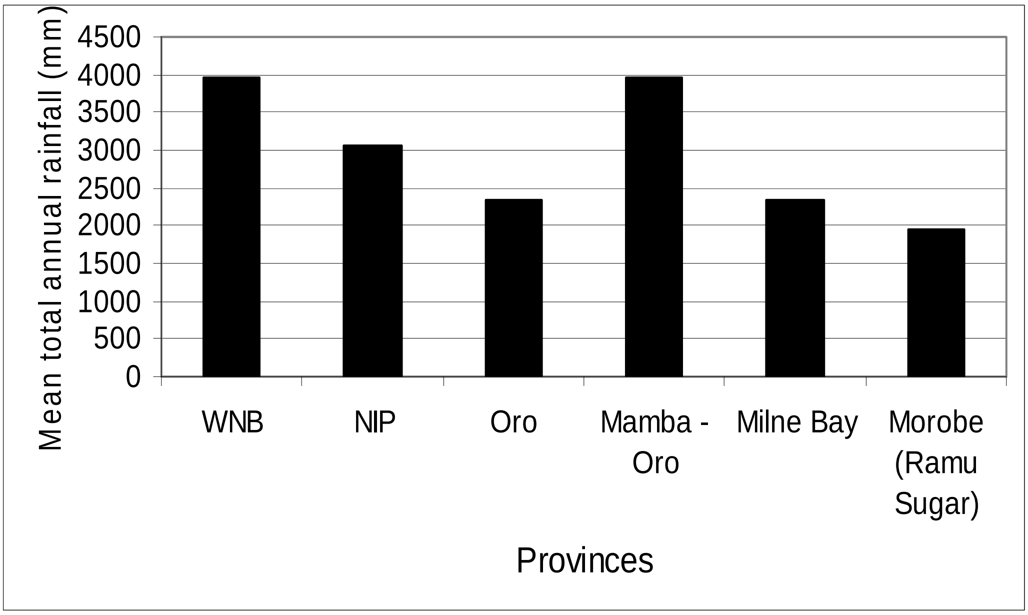


Figure 1. Mean annual rainfall (mm) in oil palm growing Provinces in PNG. WNB = West New Britain and NIP = New Ireland Province

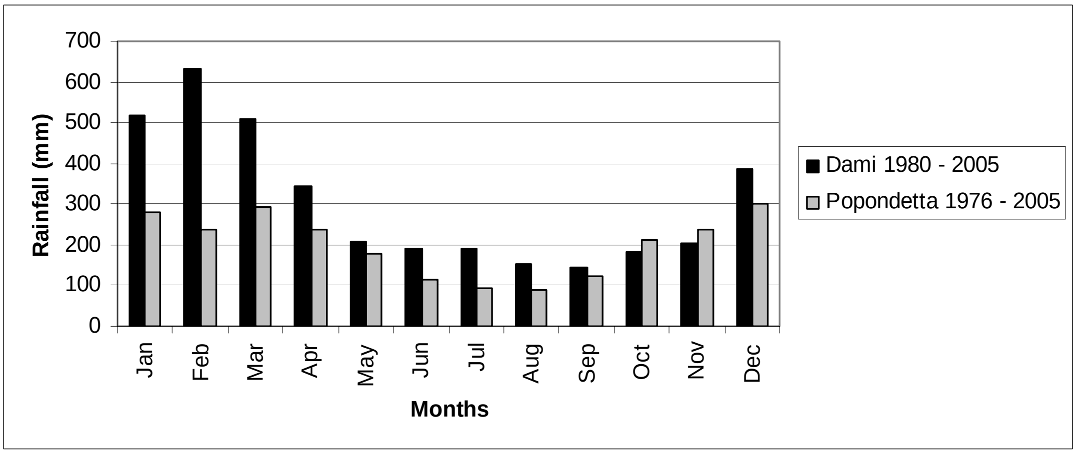
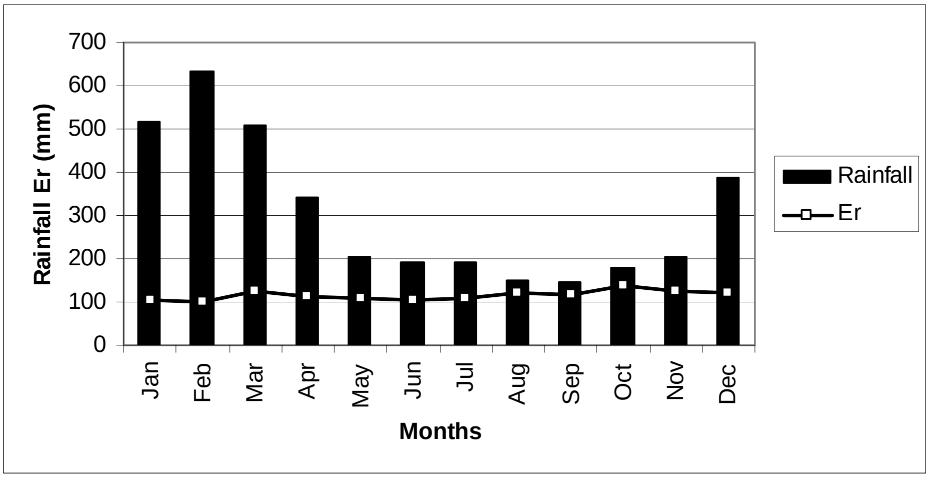
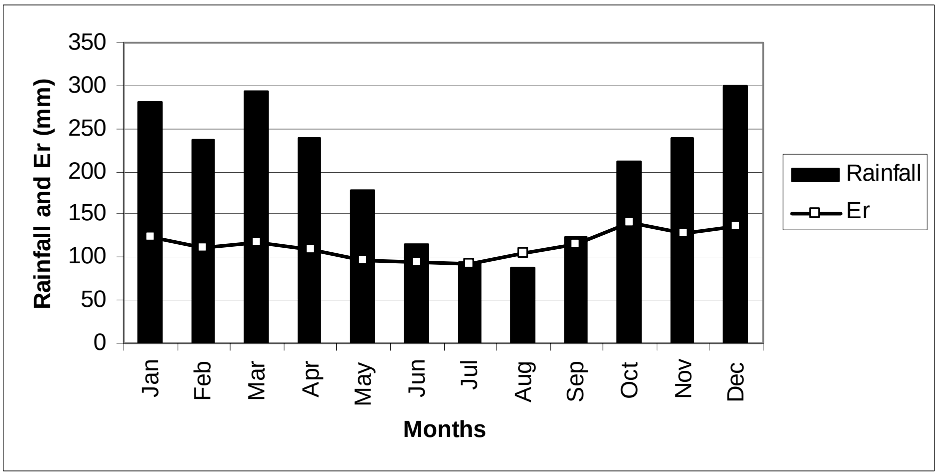


Figure 2. Mean monthly rainfall (mm) distribution for Dami and Sangara

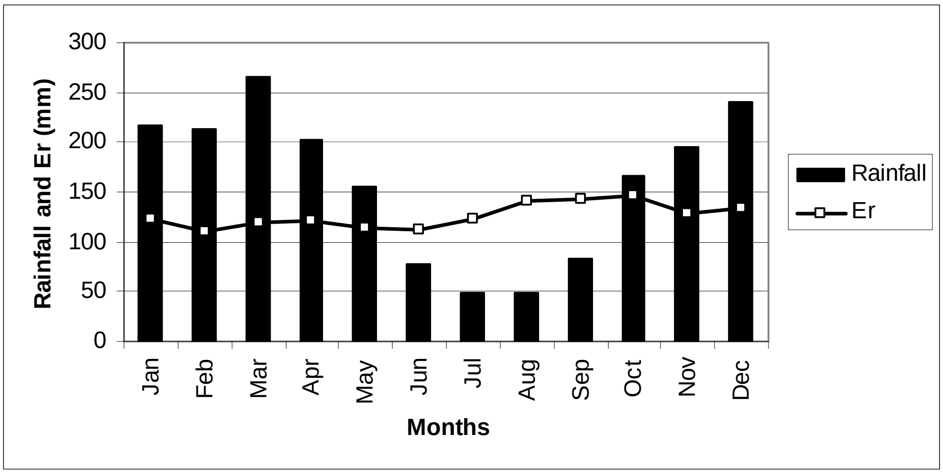
The monthly mean reference crop evaporation (E_r) for Dami was relatively constant throughout the year while at Sangara, there was a small trough in the middle of the year and at Ramu Sugar there was a slight increase after July (Fig 3 (a), (b) and (c)). Monthly E_r values for the three sites ranges from 92 mm to 147 mm, with a mean of 115 mm/month at Dami and Sangara and 126 mm/month at Ramu Sugar. This implies that in general, rainfall amounts per month have to be lower than 115 mm at Dami and Sangara and 126 mm at Ramu Sugar before the crops will extract soil held water. Depending on the soil water holding capacity of the different sites, the palms will be stressed when all readily available water within the rooting zone has been extracted. The palms at Dami are highly unlikely to be water stressed because 1) the monthly rainfall is always higher than the E_r and 2) the soils have a high water holding capacity (discussed in next section). At Sangara the palms may be stressed in July and August because of the lower soil water holding capacity (see next section). At Ramu Sugar there is a definite water deficit from June to September.



a) Dami – Rainfall 1980 – 2005 and Er 2003-2005



b) Sangara Rainfall 1976 – 2005 and Er 2003 - 2005

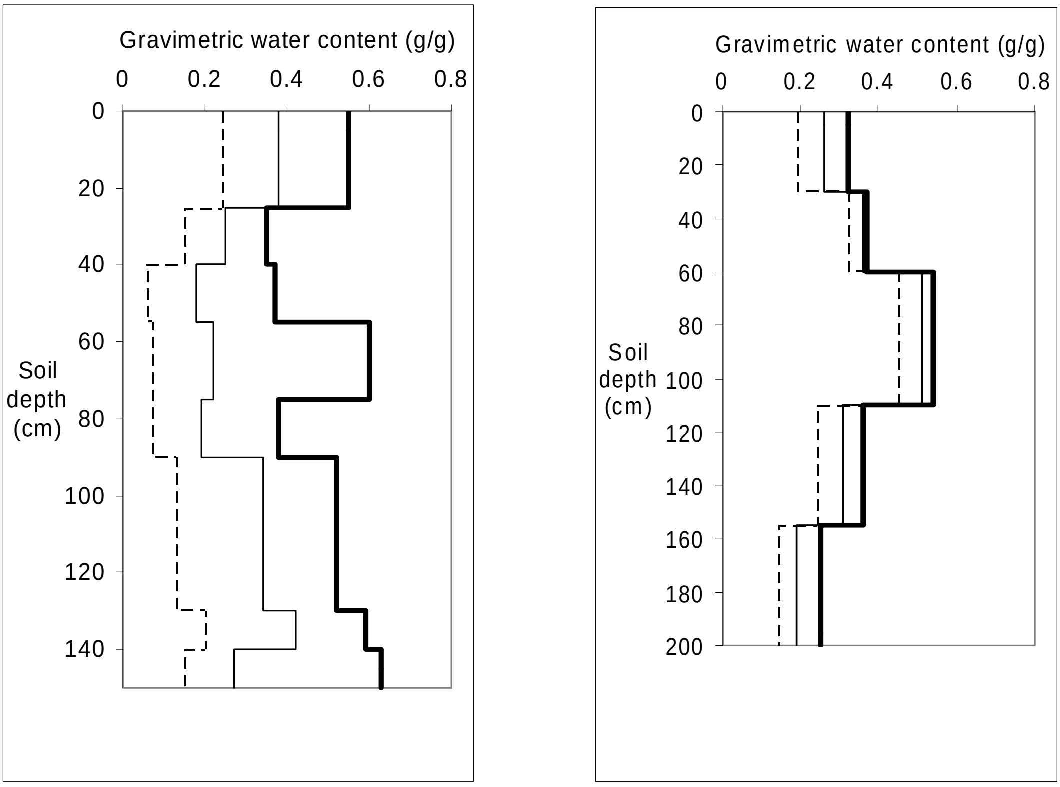


c) Ramu Sugar Rainfall 1979 – 2005 and Er 2003 - 2005

Figure 3 Mean monthly rainfall and evaporation at Dami, Sangara and Ramu Sugar

Water holding capacity

Gravimetric water content is defined as the mass of water in a soil sample per mass of solid soil. At both Dami and Sangara, the gravimetric water content at all pressure potentials fluctuated with soil depth reflecting the differences in soil textural and structural properties (Fig 4 (a) and (b)). The differences in gravimetric water content between the three different pressure potentials are larger at Dami than at Sangara. At 30 – 60 cm depth at Sangara, the difference in gravimetric water content between -10 kPa and – 100 kPa is negligible. The differences in the gravimetric water content of these soils between the two sites have very important implications in water storage capacity of these soils and inferred responses by the crop to water during low rainfall months.



a) Dami b) Sangara

Figures 4 Gravimetric soil water content at -10 kPa (▬▬▬), -100 kPa (———) and -1500 kPa (-------) pressure potentials at Dami and Sangara

Readily and total available water at Dami and Sangara

Readily (RAW) and total available water (TAW) at Dami are higher than at Sangara (Table 1). Again the RAW and TAW in the various depths reflects the different soil textural and structural properties. Mean RAW of 24 mm in the top 30 cm depth at Sangara implies that the palms will come under stress after 4-6 days of no rain compared to palms at Dami which will be stressed after 11-15 days if we assume 4mm/day as Er. However, because of the deep rooting nature of perennial tree crops, the palms may explore to greater depths for water and nutrients. Therefore at Sangara, if we take the mean available water down to 155 cm depth as 100 mm and 240 mm down to 150 cm depth at Dami, the palms will show stress symptoms after 20 days of no rain at Sangara while at Dami it will be after 43 – 45 days. Water stress is highly unlikely in Dami because mean monthly rainfall is always greater than the mean monthly Er while it is possible to experience stress at Sangara during the low rainfall months. It appears differences in stress and effects on oil palm yield at Dami and Sangara is explained by differences in soil water storage capacities of the soils.

The soils at both sites have high porosity values suggesting soils are well aerated and well drained (Table 1). However, macro-porosity values at Dami are higher than at Sangara suggesting good aeration and that drainage is rapid after heavy rain events with minimal surface runoff. At Sangara the very low macro-porosity suggests that use of machinery at Sangara could easily clog up macropores leading to water ponding resulting in increased surface runoff. Temporary water logged conditions can also occur resulting in increased denitrifications activities.

Table 1. RAW, TAW and porosity of soils at Dami and at Sangara.

Sites	**Depth (cm)**	**Bulk density (g/g)**	**RAW (mm)**	**TAW (mm)**	**Porosity**	**Macro - porosity**
Dami	0-25	0.71	31.5	55.7	0.72	0.44
	25-35	0.84	27.2	35.2	0.66	0.41
	35-43	0.84	16.0	20.0	0.66	0.41
	43-53	1.00	15.5	28.6	0.60	0.21
	53-60	1.00	12.0	22.0	0.60	0.21
	60-77	0.77	7.1	78.3	0.69	0.37
	77-90	1.06	16.3	33.2	0.58	0.19
	90-133	0.70	87.1	133.8	0.72	0.47
	133-144	0.83	10.4	30.4	0.67	0.27
	144-150	0.84	22.5	56.4	0.66	0.26
Total	0 – 150		245.6	493.6		
Sangara	0-30	1.22	23.9	47.9	0.51	0.23
	30-60	1.43	7.7	28.5	0.43	0.05
	60-110	1.14	15.2	54.0	0.54	-0.01
	110-155	1.15	24.6	64.4	0.54	0.17
	155-200	1.43	28.5	63.6	0.43	0.26
Total	0 - 200		99.9	258.4		

RAW = readily available water and TAW = total available water.

Water balance components

The surplus water was separated into deep drainage and surface runoff using the relationship between surplus water and actual measured runoff. Surface runoff and deep drainage followed closely the rainfall distribution pattern at both sites (Fig 5 (a) and (b)). During the study period (2003-2005), the estimated maximum runoff at Dami was 13 mm and deep drainage was 173 mm when there was a rainfall of 188 mm while at Sangara, maximum surface runoff was 46 mm with deep drainage of 67 mm when there was a rainfall of 133 mm. Estimated runoff at Dami was generally lower than at Sangara because the soils at Dami are highly porous with very high infiltration rates compared to Sangara.

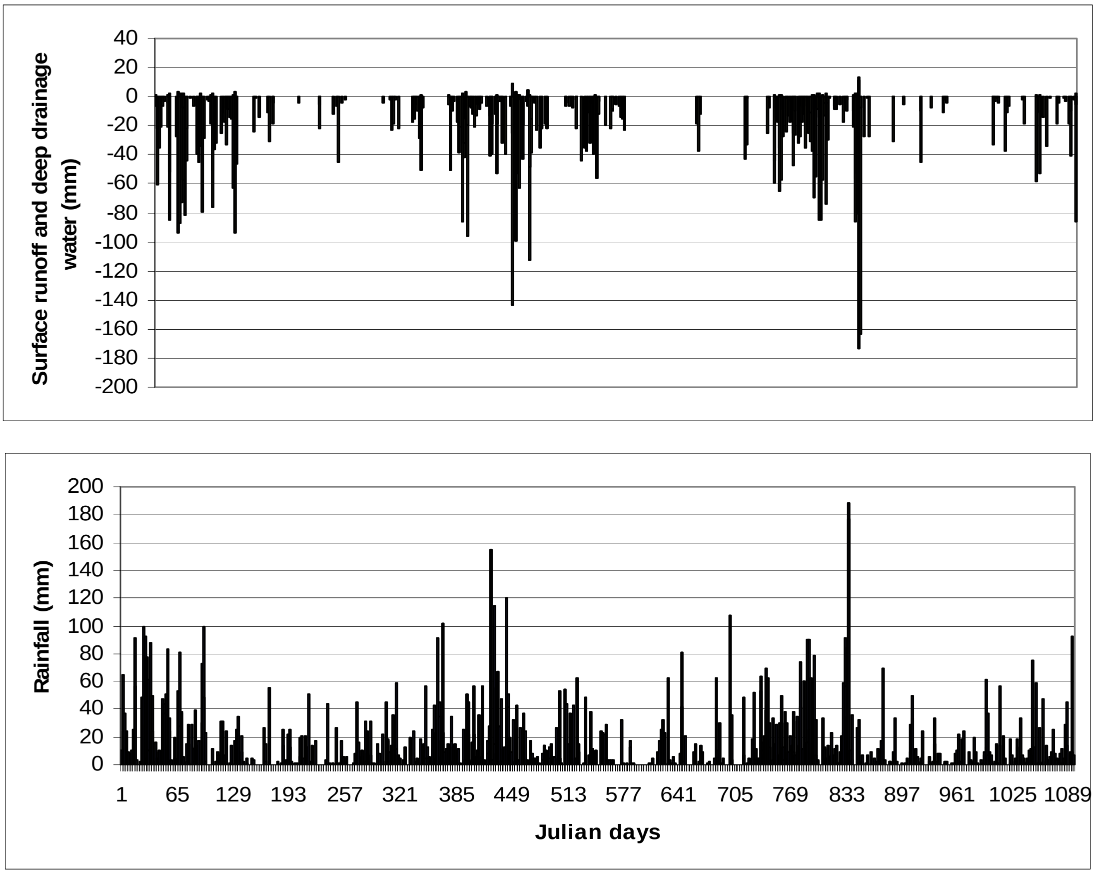


Figure 5 (a) Rainfall, runoff and drainage at Dami for 2003 – 2005

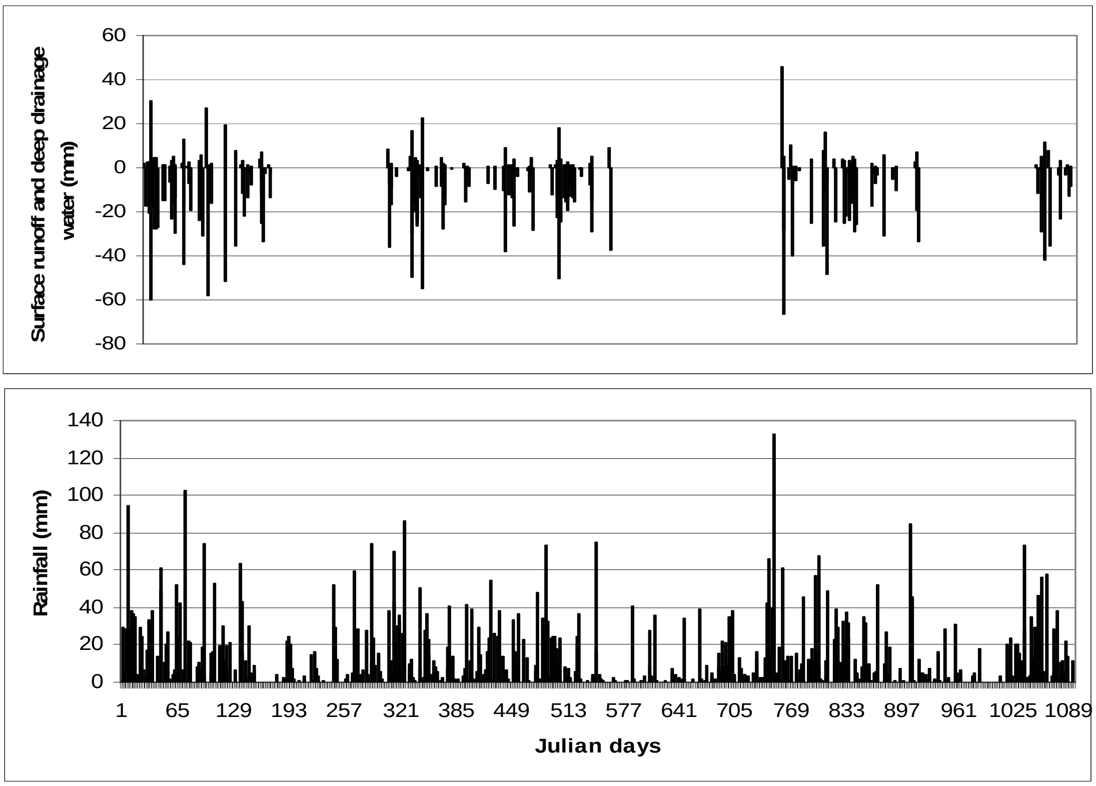


Figure 5 (b) Rainfall, runoff and drainage at Sangara for 2003 - 2005

Estimated water balance components for all the years were summarised and are presented in Table 2. The mean maximum deficit at Dami and Sangara were similar and were about 150 mm. The similar mean deficit at the two sites imply differences in crop growth and crop production between the two sites are not weather related but are either soil or management related. The highest deficit was 512 mm at Dami and 404 mm at Sangara and both were in 1997 during the El Nino year. The proportion of different water balance components relative to the mean annual rainfall for the years data collected were similar to the three years cumulative discussed in the previous section. The mean *Er* at both sites was 3.7 mm/day.

Much of the rainfall at Dami ended up as drainage (61%) than runoff (1%) while at Sangara only 37% ended up as drainage with 8% runoff (Table 2).

Table 2. Summary of soil water balance components for Dami (1993-2005) and Sangara (1983-2005).

Year	Water balance components (mm) at Sangara							Water balance components (mm) at Dami					
	Rain	E_r	Max Def	Surplus	Runoff	Drainage		Rain	E_r	Max Def	Surplus	Runoff	Drainage
2005	2482	1322	-196	1007	172	834		4133	1332	-61	2800	61	2739
2004	1767	1340	-261	599	80	519		3462	1392	-158	2072	36	2036
2003	2811	1324	-122	1487	254	1234		3941	1347	-71	2582	41	2541
2002	2326	1362	-212	969	176	792		3586	1483	-153	2178	39	2139
2001	2513	1372	-123	1132	200	932		3621	1368	-92	2348	35	2313
2000	2427	1404	-77	1006	161	846		3402	1355	-79	2178	39	2139
1999	2176	1348	-64	850	163	687		3331	1382	-73	1816	46	1770
1998	2661	1340	-187	1145	230	915		4488	1271	-224	2953	46	2907
1997	1397	1291	-404	289	46	243		2595	1545	-512	1316	18	1298
1996	2261	1412	-104	832	124	709		2770	1320	-69	1643	25	1619
1995	2280	1298	-143	988	135	853		3623	1285	-55	2299	27	2272
1994	2046	1285	-107	767	107	660		3438	1320	-293	2166	42	2124
1993	2442	1298	-227	1025	243	782		3353	1305	-165	2049	41	2009
1992	2090	1394	-217	817	144	673							
1991	2592	1298	-76	1292	243	1049							
1990	3071	1241	-75	1810	405	1405							
1989	2768	1322	-133	1470	258	1211							
1988	2651	1351	-53	1300	195	1105							
1987	2329	1360	-237	970	173	797							
1986	2360	1334	-98	1015	158	857							
1985	2808	1304	-71	1498	245	1253							
1984	2421	1315	-84	1126	187	938							
1983	3130	1341	-173	1789	346	1443							
mean	2426	1333	-150	1095	193	902		3519	1362	-154	2185	38	2147
%**		55		45	8	37			39		62	1	61
sd	390	41	84	358	80	283		502	77	129	445	11	438
cv %	16	3	-56	33	42	31		14	6	-84	20	28	20
max	3130	1412	-53	1810	405	1443		4488	1545	-55	2953	61	2907
Min	1397	1241	-404	289	46	243		2595	1271	-512	1316	18	1298

** = % of mean annual rainfall

Nitrate formation studies

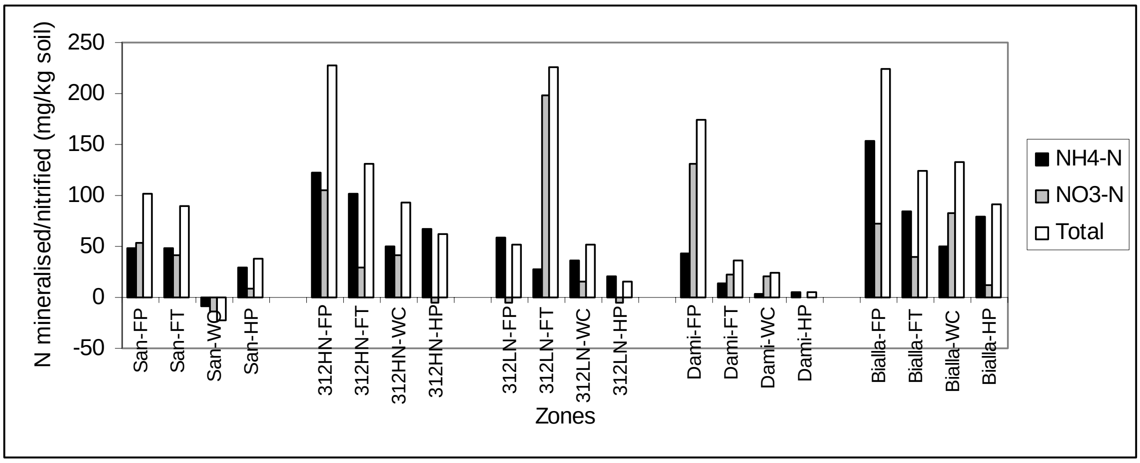
In 2002 soil samples were taken at 0-20 cm depth from FP, FT, WC and HP management zones under the palms and from four different sites. The first site was at Sangara in Oro, where all the other N Loss experiments were done at. The other site was a fertiliser trial (Trial 312) and was also in Oro Province and soil samples were taken from N fertilised and non fertilised plots. The third site was at Dami in WNB where all the other experiments were done .The fourth site was at Bialla which was also in WNB Province. The soils were air dried and stored at room temperature (26^oC) for 4-5 months before being brought to Massey University in 2003 for laboratory studies.

The net mineralisable-N (NH_4-N + NO_3-N) were statistically analysed using SAS to determine the significance of the differences between the soils from different management zones under the palms and the different field sites.

At Sangara, the net mineralised and nitrified N contents in the FP and FT were greater than in the WC and HP (Fig 1). The NH_4-N and NO_3-N amounts were about the same in the FP and FT but in the HP, the NH_4-N content was greater than NO_3-N. There was a negative N production in the WC suggesting N was probably immobilised after rewetting for laboratory incubation or because of the long storage period, there was lack of microbial activity to mineralise N.

At Trial 312 in Sangara, the net mineralised and nitrified N contents formed from the different zones in the fertilised plot were greater than those mineralised and nitrified in the nil fertilised plot except NO_3-N in the FT (Figure 1). The NH_4-N contents were about equal to or higher than NO_3-N contents in all the zones except in the FT in the nil N fertilised plots. In unfertilized plots, the oil palm canopy was not fully closed and the plots were exposed to direct sunlight encouraging growth of legume cover crops. The high N content in the FT zone may have been due to biologically fixed N and high N rich content of the legume cover crops. However on the whole, soil from the fertilised plot had greater amounts of exchangeable NH_4-N and NO_3-N than unfertilised plot.

At Dami the total net mineralised and nitrified N content in the FP was higher than the other zones (Figure 1). However, in the individual zones, the NH_4-N content was less than NO_3-N except in the HP. At Bialla, the total mineralised NH_4-N and NO_3-N in the FP was higher than the amounts formed in the other zones. In the individual zones, NO_3-N was lower than NH_4-N except in the WC. The mean total mineralised and nitrified N amounts in all the zones at Bialla were higher than from Dami, Sangara and Trial 312 plots. Bialla site was an ex-forest area and the palms were 4- 5 years old at the time of sampling and therefore time has probably not allowed for depletion of organic N in the soils.



Note: San = Sangara

Figure 6 Mineralised inorganic N at 0 – 20 cm soil depth in the various zones under the palms in Oro and WNB Provinces

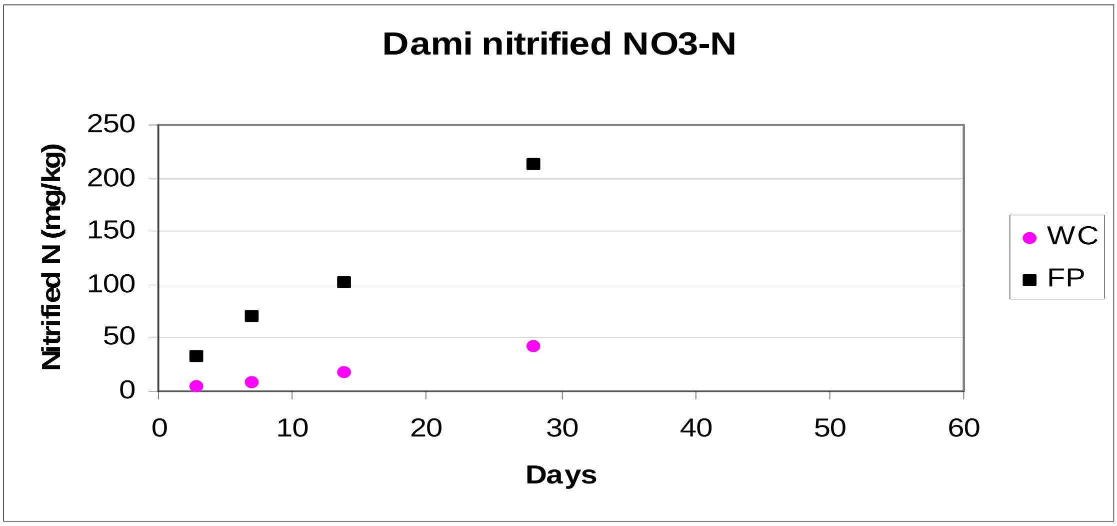
Summary

- Past land use and fertilizer history do appear to affect the amount of N mineralized
- Nitrification process is different for the different zones. FP and to a certain extent, FT appear to be different from the rest of the other zones.

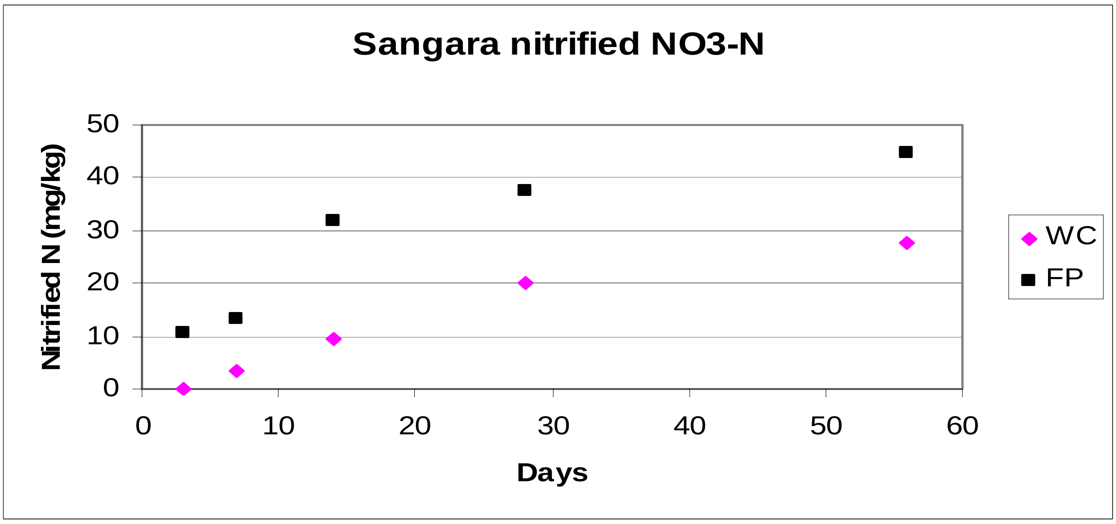
***In situ* nitrification**

At both sites, Dami and Sangara, the rate at which nitrate was formed in FP was greater than WC and more at Dami compared to Sangara (Fig 7 (a) and (b))

At Dami NH_4-N in the FP and WC were high initially but the amounts in the FP decreased sharply with time which corresponded to a sharp increase in NO_3-N.At Sangara, available NH_4-N in the FP were low (< 20 mg/kg dried soil) and decrease slowly with time to 5 mg/kg at day 56 (Table 3). In the weeded circle, NH_4-N was high but slowly declined with time. The slow drop in NH_4-N corresponded with a slow increase in NO_3-N in the FP. At both sites, the net nitrification rate was high in the FP compared to WC. For the sites, the rates in the FP and WC at Dami were higher than their corresponding zones at Sangara.



a) Dami



b) Sangara

Figure 7. Nitrate formed in the WC and FP at Dami and Sangara

Table 3 Net nitrification in the FP and WC at Dami and Sangara

Zone	Day		Dami				Sangara		
			NH_4-N	NO_3-N	Total Ni		NH_4-N	NO_3-N	Total Ni
FP	3		166	31	197		19	11	30
FP	7		109	70	179		17	13	30
FP	14		72	101	173		20	32	52
FP	28		13	212	225		16	37	53
FP	56						5	45	50
WC	3		141	3	144		78	0	78
WC	7		139	7	146		59	3	62
WC	14		151	18	169		82	9	91
WC	28		137	41	178		60	20	80
WC	56						38	28	66

Nitrogen Losses

N loss in surface runoff

Estimated N loss was determined by multiplying the mean N concentrations by the surface runoff water determined from the water balance model.

A mean total of 0.25 kg and 2.2 kg N/ha.yr were estimated to be lost through surface runoff water at Dami at Sangara respectively (Fig 1). The total amount of inorganic N lost ranged from 0.21 – 0.41 kg/ha at Dami and 0.29 – 12 kg/ha at Sangara. The high loss at Sangara compared to Dami is related to the higher surface runoff water together with higher mean N concentrations. At Dami the amount of NH_4-N lost is higher than NO_3-N but the opposite was found at Sangara. The different infiltration rates at the two sites appear to explain the differences in ratio of the two N forms and the total amount of inorganic N lost in surface runoff water per year. However the amounts lost at both sites are low compared to the amounts Kew et al (1996) reported of 15 – 22 kg lost in Malaysia. The study suggested that N loss through the process of surface runoff is unlikely to be large and of agricultural significance in the PNG volcanic soils.

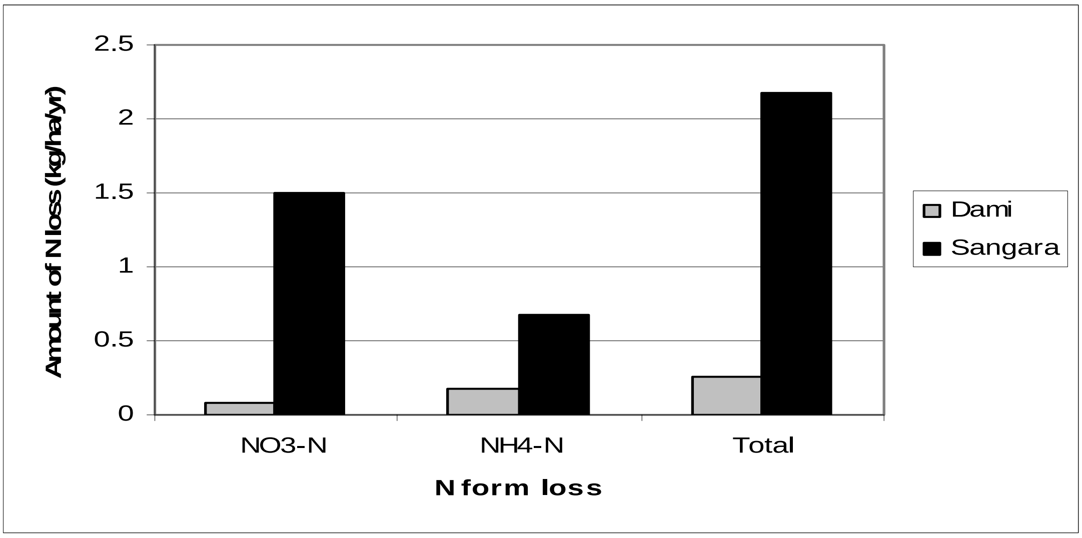


Figure 8 Mean annual inorganic N losses in surface runoff at Dami and Sangara

Fertilizer (1 kg AMC/palm) was applied just before a rain event of 57 mm rainfall and analysed results indicated 1.2 % of N and 1.5 % of Cl applied in the fertilizer was lost through surface runoff water (Table 4). More than 90% of the fertilizers remained within the plots and most likely leached through the soil. The results suggest fertilizer losses through surface runoff water in these volcanic ash derived soils are agronomically insignificant.

Table 4 Percentage recovery of inorganic N and Cl from fertilizers applied in surface runoff plots after 57 mm rainfall event at Sangara.

		NH_4-N	NO_3-N	Cl
Applied fert. AMC g/plot		1000	0	2640
Recovered g/plot		11.3	0.39	40
% N Recovered in r/off water		1.2		1.5

Nitrous oxide losses

The experiment conducted did not include inhibition of further denitrification of N_2O to N_2 and what is discussed is only for the emission of N_2O. The amount of N_2O produced from the denitrification process was highly variable with CV values of 48 to 158 % (Table 5). The high CV values reflect the large variations in soil properties and the resultant large variation in soil microbial denitrification process in the FP under the palms.

The mean N_2O emitted from the fertilised plot at both sites, Dami and Sangara, were greater that the nil fertilised plots, suggesting NO_3-N was important for denitrification in these soils (Table 5). However comparing the mean emission of N_2O at the 2 sites, the emissions were higher at Sangara than at Dami. The plots were given the same and large amount of KNO_3 (20 g KNO_3/plot) and therefore NO_3-N was not a limiting factor but the differences in soil texture could explain the differences, the soils at Dami were better drained and sandier than the soils at Sangara. In both the fertilised and nil fertilised plots at both sites, there were elevated levels of N_2O emission after rain events at Day 7, however the measured N_2O emission rates were higher in the fertilised plots than at in the nil fertilised plots. The increased N_2O production after the rain was most likely due to increased soil moisture content creating an anaerobic condition in the soils. Differences between the replicates were probably due to differences in soil properties and differences in increased soil moisture content from the different through-fall distributed by the oil palm canopy. The N_2O emissions dropped with subsequent rain events which may have been due to NO_3-N in the soil being leached to depths inaccessible by the denitrifying organisms and or low in C. Though there may have been some incorporation of NO_3-N into the organic matter, this will unlikely be the cause of reduction in NO_3-N and subsequent production of N_2O because there was sufficient NO_3-N provided from the fertiliser.

The soil temperature measured during the experiment was relatively constant at 26 ^oC at both sites. This suggested the effects on gaseous are not likely to be temperature related.

At Dami at Day 7 and in replicate 2 in the fertilised plot, the N_2O emitted was very low (12.7 g/ha.day) compared to emissions in replicate 1 (136.0 g/ha.day) for the same day. The differences in emission from these two fertilised plots at Dami could be due to variability in through-fall being higher in the plot and leached away the NO_3-N before the denitrifying organisms could to denitrify the NO_3-N, or it could be that there was less through-fall and soils were not wet enough for denitrification to occur, or it could be due to lack of denitrifying organisms to denitrify the NO_3-N in the plots.

The recovery of N in applied fertilisers in the N_2O form were very low at both sites being less than 1%, suggesting that N loss via denitrification process in the PNG volcanic soils are very low and insignificant.

The amount of N_2O emitted from the nil fertilised plots probably reflected the mean N_2O from the plantations. Calculated emissions were 7.3 kg N_2O (4.7 kg N/ha.yr) at Sangara and 1.5 kg N_2O (1 kg N/ha.yr) at Dami. The amount of N loss as N_2O at Sangara appeared to fall within the range of loss in the surface runoff at Sangara (0.29 - 12 kg N/ha.yr) but at Dami, N loss via N_2O was higher than the range of N loss in the surface runoff (0.21 – 0.41 kg N/ha.yr). The amounts lost as N_2O at both Dami and Sangara are however lower than the leaching losses determined from the suction cups and therefore losses via denitrification process is not likely to be a major route for N loss in these soils.

Methane emission

The amount of methane emitted were highly variable (CV = 19 – 148%) and was more variable at Sangara than at Dami (Table 5). The emissions were more negative at Dami than at Sangara. The more negative values at Dami suggested the soils at Dami were much better drained than the soils at Sangara. The implied better drainage at Dami related well with the N_2O production discussed earlier where it was higher at Sangara than at Dami. The fertilisers did not appear to affect the amount of methane emitted and there was no clear effect of rainfall on the production of methane production as well.

Carbon dioxide emission

The amount of carbon dioxide emitted from the soil at Dami in both the fertilised soil and the nil fertilised soils were higher than soils at Sangara (Table 5). The higher CO_2 in the soils at Dami implied the soils there were microbiologically more active than the soils at Sangara, which further meant breakdown of OM and nutrient cycling processes at Dami were faster than in the soils at Sangara. The addition of fertiliser and rainfall appeared to have no effect on the amounts of CO_2 produced.

Table 5. Nitrous oxide, methane and carbon dioxide emission at Dami and Sangara in 2005

				Dami							
	Rainfall (mm)			Nitrous oxide			Methane production			Carbon dioxide	
Day	Daily	Cum.		(g/ha.day)			(g/ha.day)			(g/ha.day)	
				Nil fert	Fert		Nil fert	Fert		Nil fert	fert
0	1.8	1.8		4	4		-12	-13		174956	177852
1											
3											
7	34	47.4		5	103		-15	-11		215312	196947
14	0	52.1		2	6		-18	-15		196996	157566
28	49	180.0		4	8		-14	-12		220349	181637
Mean				**4**	**31**		**-15**	**-12**		**201903**	**178500**
Std dev				2	48		4	2		43694	49072
CV %				48	158		25	19		22	27
				Sangara							
0	1.6	1.6		41	56		-16	-17		137593	172808
1	0	1.6		10	28		0	9		106213	117535
3	0	1.6		5	28		-13	-14		101270	109345
7	48	63.0		14	443		-15	-15		91159	135271
14	23	64.0		40	227		-14	-14		64163	80342
28	2.6	271.0		7	29		0	3		96372	126333
Mean				**20**	**135**		**-10**	**-8**		**99462**	**123606**
Std dev				24	168		9	12		22812	30727
CV %				119	124		91	148		23	25

Leaching losses estimated from suction cups

The suction cup results are presented in Tables 6 and 7 for Dami and Sangara respectively. For each of the months, mean concentrations of the inorganic N forms are presented and the loss per month is determined by multiplying the total inorganic N concentration by the volume of drainage per hectare for the month as estimated from the FAO 56 water balance model. The statistical mean, minimum, maximum, standard deviation and coefficient of variation were determined from the whole data set and not from the monthly means shown. For the two missing months, June at Dami and May at Sangara, the mean of total mean N concentrations for the six running months was used for determining the total N loss for the missing months. The mean from all the months was not used because the total mean N concentrations from the later six months during the experimental period were for a different wet season. The estimated losses per month were added together to give an estimated total annual N loss. For the months that occurred twice, only the mean of the two values was used, so the calculated total was for 12 months only. Analysis of variance was done to determine the differences between the two zones and between the different sampling dates.

The CV values of both NH_4-N and NO_3-N for the different zones at both Dami and Sangara were very high ranging from 142 % to 232 % (Table 6). There are many possible factors that may have contributed the large CV values. The large variability in through-fall and infiltration rates that affect water movement and changes in soil water content, together with no knowledge about whether the solutions sampled represent leading peak or tail sequences in the leading front. The OM levels on the soil surface and variation in evenness of fertilizer spreading also affects the concentration of N that moves down the soil depth. Other external factors would include the size and duration of rainfall events.

When the two zones are compared, total inorganic N concentrations at 150 cm depth were significantly ($p< 0.001$) higher in the solutions under the BZ than the FP zones at both sites. The BZ and the FP area just next to the palms are usually the fertilized areas under the palms however in the FP the cut fronds may be protecting N from being leached or N in the fertilizer applied may have incorporated into the organic matter. At Dami, fertilizers are spread by tractors, and suction cups positioned next to the palms in the FP may be prevented from receiving fertilizers by the presence of the oil palm trunks. The other reason could be that fertilizers spread by the tractors are not going far enough to reach the FP areas.

The ratio proportion of NH_4-N to total inorganic N concentrations shows that the of NH_4-N constitutes 27% of the total inorganic N in the FP and 5% in the BZ at Dami, but only 2-3 % from the two zones at Sangara (Tables 6 and 7). The high proportion of NH_4-N to total inorganic N at Dami implies that N is lost in both the NO_3-N and NH_4-N forms while at Sangara, N was mostly lost as NO_3-N.

At Sangara there was no fertilizer applied to the palms over the duration of the experiment (year), whereas while at Dami fertilizers were applied in May, June and September of the sampling period. The elevated inorganic N concentrations at Dami and Sangara in the months following no drainage is most likely to have come from applied fertilizer and or what inorganic N that was built up from OM mineralization/nitrification at the soil surface during the low rainfall months. Leaching at both sites occurred mostly during the wet season because this was when the soil field capacity was reached and excess water resulted in drainage water. If we assume that the soil had a uniform volumetric water content of 0.4 down to 150 cm depth, then 375 mm (150/0.4 = 3750 mm) of excess water is required to move the fertilizer to 150 cm depth. In other words, the duration over which fertilizer residues will remain within 150 cm depths depends on when the cumulative drainage water reaches 375 mm. So fertilizer applied at the beginning of the dry season or at the end of the wet season should remain longer in the 150 cm depth. At Dami, fertilizer applied in April and May could remain for 7-8 months before going beyond 150 cm depth while applied in November – February which are the wet months, cumulative drainage will reach 375 mm within less than 2-3 months and will result in inorganic N going pass the 150 cm depth. At Sangara, it takes even longer even when applied in April-May (9-10 months) but if applied during the Dec – Jan will probably take less than 3-4 months before going pass 150 cm depth.

Table 6. Inorganic N concentrations in suction cups and losses from February 2004 – February 2005

Months	Number of		Inorganic N concentrations (µg/ml)								Drainage (mm)	Loss (kgN/ha)
			FP			BZ			Total			
	Events	Samples	NO_3-N	NH_4-N		NO_3-N	NH_4-N					
Feb-04	4	58	0.95	0.23		6.89	0.23		4.14		458.7	19.0
Mar-04	3	78	1.47	0.17		2.09	0.17		1.95		589.0	11.5
Apr-04	3	52	1.19	0.15		0.60	0.15		1.04		62.2	0.6
May-04	2	30	1.58	0.07		0.36	0.07		1.04		209.6	2.2
Jun-04									2.12		180.5	3.8
Jul-04	1	14	0.33	0.20		4.08	0.20		2.41		59.9	1.4
Aug-04											0.0	
Sep-04											0.0	
Oct-04	1	16	0.24	0.57		19.27	0.70		10.39		67.6	7.0
Nov-04	2	31	0.44	0.40		17.84	0.28		9.48		0.0	
Dec-04	2	30	0.53	0.66		20.44	0.32		10.98		109.9	12.1
Jan-05	3	57	1.50	0.68		11.45	0.72		7.18		509.2	36.5
Feb-05	2	37	1.49	1.30		4.32	0.57		3.84		596.3	22.9
Total	**23**	**403**										*****96**
Mean			**1.20**	**0.44**		**7.00**	**0.34**					
Min			0.00	0.00		0.00	0.00					
Max			12.00	11.30		87.00	2.90					
Std dev			2.10	0.90		15.40	0.50					
CV %			175	218		221	142					

*** total for 12 month, for months occurring twice, mean of the means was used

Table 7 Inorganic N concentrations in suction cups and losses from February 2004 – February 2005

Months	Number of		Inorganic N concentrations (µg/ml)								Drainage (mm)	Loss (kgN/ha)
			FP			BZ			Total			
	Events	Samples	NO_3-N	NH_4-N		NO_3-N	NH_4-N					
Jan-04	2	34	4.16	0.06		5.56	0.08		4.9		27.9	1.4
Feb-04	5	91	2.46	0.09		3.42	0.10		3.0		74.3	2.3
Mar-04	6	115	0.94	0.17		1.12	0.20		1.2		99.6	1.2
Apr-04	2	31	0.11	0.26		0.05	0.05		0.2		48.4	0.1
May-04									3.0		179.4	5.4
Jun-04	2	37	3.70	0.13		6.76	0.18		5.4		89.6	4.8
Jul-04											0.0	0.0
Aug-04											0.0	0.0
Sep-04											0.0	0.0
Oct-04											0.0	0.0
Nov-04											0.0	0.0
Dec-04											0.0	0.0
Jan-05	2	35	2.89	0.02		5.07	0.05		4.0		146.7	5.9
Feb-05	1	17	3.04	0.00		5.72	0.06		4.4		36.2	1.6
Mar-05	2	32	3.76	0.02		5.22	0.02		4.5		157.8	7.1
Total	**22**	**392**										*****20**
Mean			**2.77**	**0.09**		**5.00**	**0.09**					
Min			0.0	0.0		0.0	0.0					
Max			38.0	2.3		38.9	1.0					
Std dev			3.9	0.3		7.2	0.2					
CV %			142	233		145	155					

*** total for 12 month, for months occurring twice, mean of the means was used

Modelling

Work on modelling of N loss in the oil palm system is still in progress. The model is made up of 3 sub-models, water balance model, nitrification model and leaching model.

a) Water balance model.

The driving force behind moving nitrogen through soils is the movement of water. The amount of water required to move nutrients to a certain depth or out from the rooting depth is determined from the water balance model. The water balance model takes into account the amount of rain water actually reaching the soil surface after interception by the canopy, the amount evaporated into the atmosphere and the amount ending up as surface runoff water. The model also considers the effect of evaporation on leaching of N. This was determined by finding out at what depth half the mass of the nutrient was at. Transpiration involving root uptake above the depth where the nutrient are at will reduce subsequent leaching because infiltrating water will stay on the top and will not move the nutrients down. At the same time, water uptake from below the nutrients in the soil will not affect the leaching of nutrients.

b) Nitrification modelling

Fertilisers applied as ammonium or even urea has to go through biological processes of transformation before they can be leached out of the rooting depth. The factors considered here include dissolution factor, a certain amount of rainfall is required to dissolve the fertilizer and then the time required for half the amount of fertilizer applied to convert to NO_3-N. Another important factor considered here is the difference in rates of nitrification under the different zones under the palms. These affect the amount of NO_3-N availability for leaching at any one time.

c) Leaching model

The leaching model considers all factors mentioned in the above 2 models however considers the differences in distribution of N with depth. The model also considers the difference in movement of NH_4-N and NO_3-N, NH_4-N being a cation moves slowly with depth relative to anions such as Cl and NO_3-N.

Putting the above models together will answer ‘what if’ questions such as if fertilizer is applied at a certain time of the year what are the chances that half will be lost by leaching, if applied in certain areas under the palms, what the losses be like, if the N fertilizers are applied as NO_3-N rather than in NH_4-N form, what will the differences in losses be like.

From preliminary data put together, mean residence times of fertilizers were estimated for the 2 sites and are shown in Figure 9. Fertiliser applied at Sangara between January and July appears to stay longer within the rooting depth than at Dami. The best time of applying fertilizers at Dami is between May and August when the fertilizers will stay longer than 100 days and applications in November & December through to March can result in losses by leaching. At Sangara, the best time for fertilizer application will be between March and August where fertilizers will reside in the soils for longer than 100 days however it is even better to apply between April and July when the residence time will be between 140 day and 200 days.

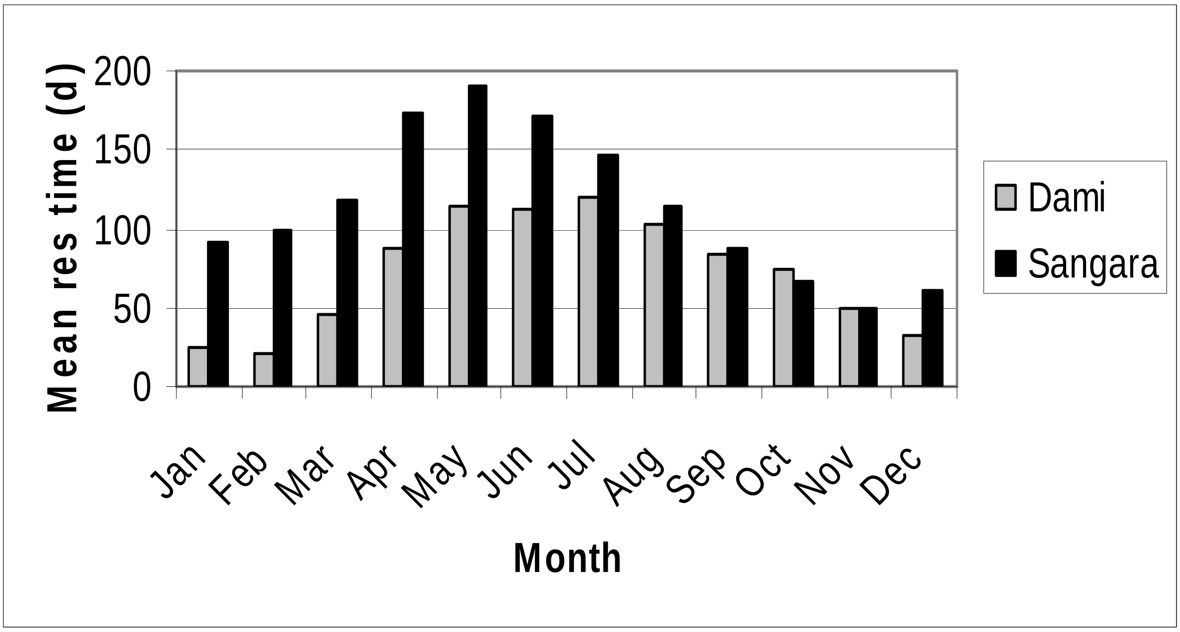


Figure 9 Ten years mean residence time of fertilizers in the 50 cm rooting depth at Dami and Sangara

OVERCOMING MAGNESIUM DEFICIENCY ON VOLCANIC ASH SOILS

The proposal for this project was given in the 'Agronomy Research Proposals for 2003'. The project commenced in October 2002. A copy of the 2003 ACIAR annual report, which includes details of experimental designs and results, has already been distributed by PNGOPRA. A copy of the 2004 Annual Report has also been distributed. Some of these activities were also included in the PNGOPRA 2002 and 2003 Annual Reports. A progress summary is included below.

PROGRESS SUMMARY

The third year of the project has seen further trials started in both countries. It has also seen the continuation of studies into palm physiology, amendment properties and modelling of water and solutes through the soil profiles. Specifically we have:

- Started implementation of two further field trials; one at Hargy plantation (Hargy Oil Palms) examining source of Mg the other at Maiwara plantation (Milne Bay Estates) examining methods of potassium application
- continued to characterise some of the chemical properties of several potential Mg fertilisers through laboratory and glasshouse trials
- modelled equilibrium behaviour of some of these sources using PHREEQC
- set up glasshouse trials to determine to ability of a small portion of the root system to take up the palm's Mg requirements
- measured the distribution of Mg through the canopy of unpruned palms
- collected samples of soil and leaf material throughout main oil palm growing areas in order to identify regions most likely to be susceptible to Mg deficiency

The results of field trials in PNG are also included in the Fertiliser Response Trials section (Trials, 144, 145, 146, 333, 216, 515). The full report of this project is available in the ACIAR Annual Progress Report (July 2005 – June 2006).

FUTURE WORK

The project was expanded following a review in 2004. New trials have been planned and established to different extents. These trials will be fully implemented in 2006. Work on modelling Mg and K movement through a greater range of soil in PNG will continue.

POOR RESPONSES IN FERTILIZER TRIALS IN WEST NEW BRITAIN (Activity 143)

BACKGROUND

Over the last decade or more, control plots in WNB fertiliser trials have been yielding as much as fertilised plots. We suspect that this is due to nutrients moving into the control plots from surrounding areas, despite guard rows and trenching between plots. 'Systematic' trials have been introduced to overcome the problem, and they are expected to be successful if the problem is due to movement between adjacent plots. However, if nutrient movement is occurring on a larger scale, from the surrounding plantation, systematic trials may not provide the answer. In order to test whether nutrients are moving at larger scales, we established the following activities in 2003: 'Omission trials (Trial 141)', 'Monitoring of shallow perched water tables', 'Tissue sampling transects' and a preliminary study to measure movement of water and nutrients through the soil profile using 'lysimeters' at Dami. In addition to these trials, several fertiliser trials with very large plots have been set up (142, 148 and 149). They are described in the 'Response to Fertilisers' section.

TRIAL 141. LARGE FERTILISER OMISSION TRIAL, HAELLA

Purpose

To improve fertiliser recommendations in West New Britain by determining yield under control conditions, and to determine how far nutrients move from fertilised into unfertilised areas.

This trial is one of the 'omission trials'. In a related trial (Trial 142), we plan to use the existing CCPT trials in a similar way, but to include a moderate and high level of N application as well. Trial 141 was marked out in 2003 and yield recording commenced in August of the same year.

Site, Palms

Top of slope site: Haella Plantation, Field 1323-10, Roads 3-4, Avenues 1-2
Bottom of slope site: Haella Plantation, Field 1322-10, Roads 6-7, Avenues 13-14
It is intended to duplicate this trial at a similar pair of sites at Kapiura.

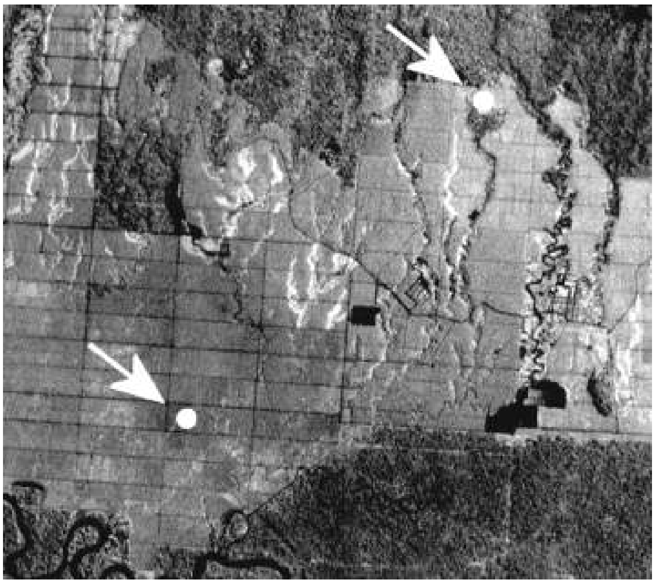


Figure 1. White circles show the position of the two omission trial sites in Haella Plantation.

Design

The trial consists of a circle, about 24 palms in diameter, to which no fertiliser is applied. Fertiliser has been applied normally to the area outside the circle. Measurements have been carried out on palms in 12 transects (1-3 palms wide) radiating from the central palm out into the fertilised area.

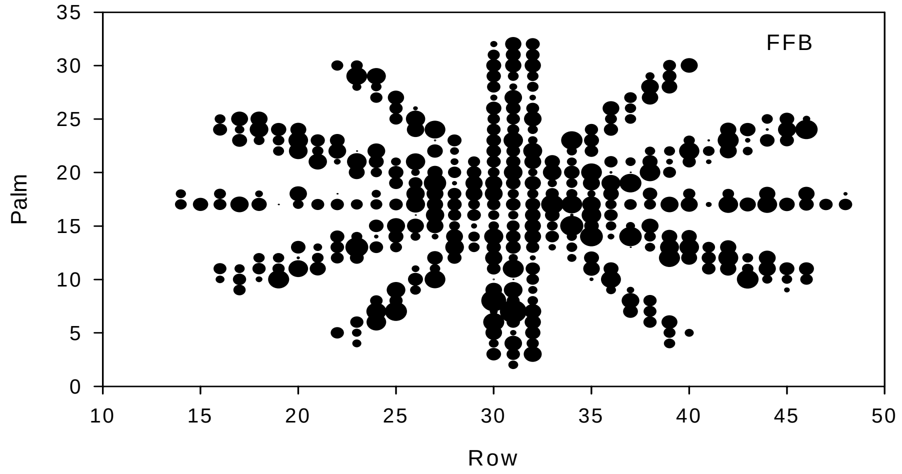
Statistical design is regression of yield or other parameters on distance from the central palm. At each distance, the mean of the palms has been be used in the regression. The number of palms at each distance is shown in Table 1. Directional effects can be tested by combining groups of the 12 transects. The slope of the line is expected to change with time.

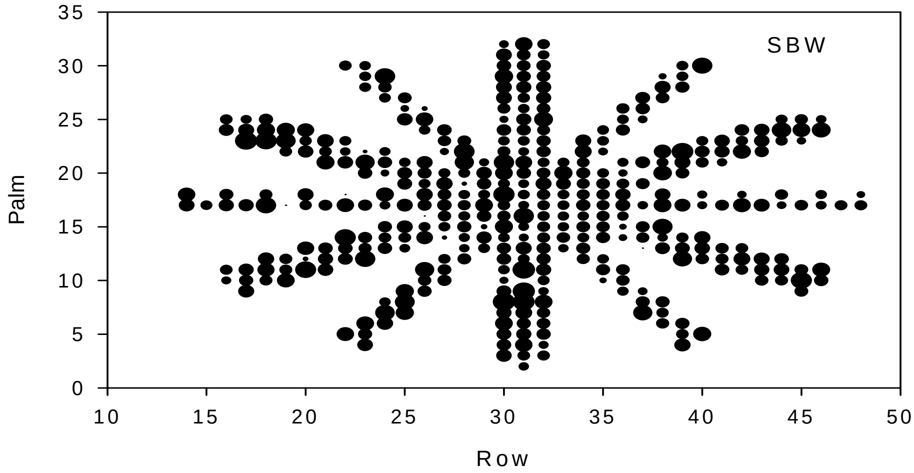
Table 1. Number of palms (N) at each distance from the central palm. Distance units are the equilateral distance between palms. Distance 15 only applies to down slope site (Div II).

Dist.	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
N	1	6	6	12	15	12	15	12	15	12	15	12	18	15	12	15

Results

Position in the slope does not appear to have had an effect yet on FFB yield, SBW and number of bunches in either trial (Figures 2 and 3).





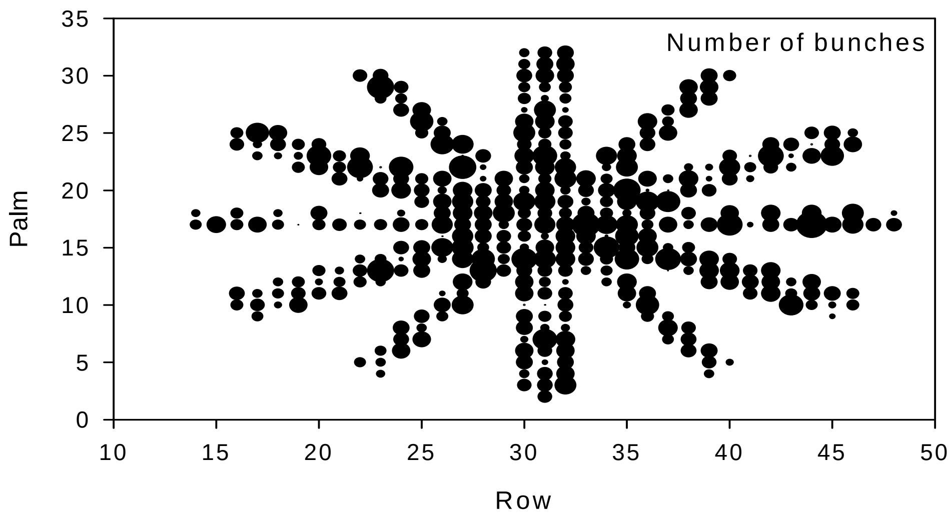


Figure 2: Effect of position of palms on yield and its components. Each dot represents a palm. The size of the dot represents the magnitude of the value. The landscape slopes downwards from north to south. Div II; down slope position.

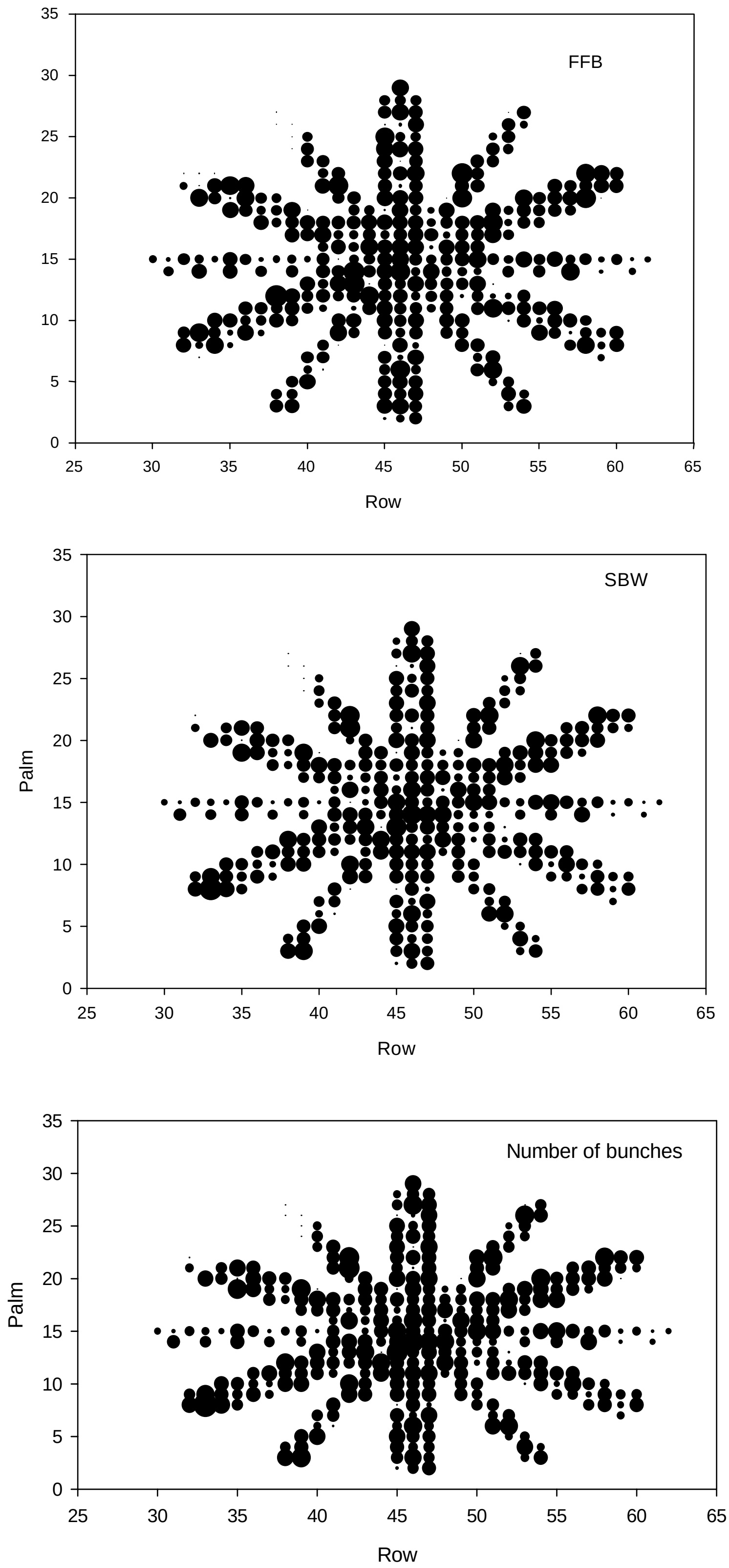


Figure 3: Effect of position of palms on yield and its components. Each dot represents a palm. The size of the dot represents the magnitude of the value. The landscape slopes downwards from north to south. Div III upslope position.

FERTILISER RESPONSE TRIAL IN WEST NEW BRITAIN PROVINCE
(New Britain Palm Oil Ltd)

(James Kraip & Mike Webb)

TRIAL 137 SYSTEMATIC N FERTILISER TRIAL, KUMBANGO

INTRODUCTION

The purpose of the trial is to provide a response curve to N fertiliser that will be used to determine optimum N input in the area.

Factorial fertiliser trials with randomised spatial allocation of treatments have been generally showing poor responses to fertilisers in NBPOL trials. Yields and tissue nutrient concentrations in control plots have been generally higher than would be expected. It is suspected that fertiliser may be moving from plot to plot. Systematic designs are seen as a way of avoiding this problem, by ensuring that high and low rates of application are not adjacent. This trial was approved in the 1999 SAC meeting. There was a change of N source from ammonium chloride (AC) to ammonium nitrate (AN) in 2004.

The soil of the trial site is freely draining pumiceous sand and gravel intermixed with finer volcanic ash. Other background information of the trial is given in Table 1.

Table 1: Trial 137 background information.

Trial number	137	Company	NBPOL
Date planted	Oct 1999	Planting Density (palms/ha)	128
Spacing	8.84 x 8.84	Pattern	Triangular
LSU or MU	Kumbango Div 2	Soil type	Eutrandepts (Inceptisols)
Recording started	Jan 2003	Palm age (years after planting)	6
Topography	Flat	Planting material	Dami commercial D x P crosses (*Elaeis guineensis* Jacq.)
Progeny	Not known	Previous land use	Oil palm
Drainage	Well drained	Area under trial soil type	Not known

MATERIALS AND METHODS

The trial has 9 treatments, which are 9 rates (0, 0.74, 1.48, 2.22, 2.96, 3.70, 4.44, 5.18 and 5.92 kg/palm/yr) of AN, and 8 replicates. Each plot is 4 rows of 15 palms. N rates (N 0 – N 5.92) vary systematically along the trial. The direction of increasing application rates is different in the different replicates, to counter the effect of any unknown fertility gradient. Plots were marked out in 2000, and treatments imposed in March 2003.

The main factor for which estimation of a response is required is nitrogen. The design allows possible K treatments to be added later if necessary. Phosphorus and magnesium are unlikely to show yield increases but may need to be applied to maintain nutrient levels. In 2006, a full complement of basal fertilisers (non-treatment) will be added. For this trial (137) TSP 0.2; KIE 1.5; MOP 0.5 and CaB 0.15 kg/palm/year will be added across the whole trial. Four replicates (1, 3, 5, & 7) receive AN in 2 doses per year while the other 4 replicates (2, 4, 6 & 8) receive 10 doses per year.

RESULTS AND DISCUSSION

Nitrogen fertiliser continued to have a statistically significant effect on fresh fruit bunch (FFB) yield in this trial (Table 2, Figure 1). Although statistically significant, the response is very small and of little yield benefit. The positive effect of N on the FFB yield in 2005 was mainly through increased number of bunches per ha (BNO/ha). These results were similar to the 2003 and 2004 results.

Despite the significant effect of N on the FFB yield, there was no response of leaflet N concentration to N fertiliser (Table 3, Figure 2), and N concentrations in tissue were in the adequate range for all treatments (Table 4). This is probably because the treatments were only imposed in March 2003. However, leaflet K, Ca and Cl were affected by N treatment (Tables 3 & 4). From an elemental point of view, AN as a N source does not supply K, Ca and Cl.

Because treatment effects take 5-6 years to show, FFB yield did not correlated well with leaflet N concentration and there was substantial variation in yield and leaflet N concentration (Table 4, Figure 3).

Table 2: Regression parameters for the effect of fertiliser application rate (kg/palm/year) on FFB yield and its components in 2005 (Trial 137). P values <0.05 are indicated in bold.

	Intercept	Slope	Slope p	r^2
FFB yield (t/ha)	27.9	0.248	**0.046**	0.055
BNO/ha	1989	19	**0.044**	0.057
SBW (kg)	14.1	-0.01	0.806	0.001

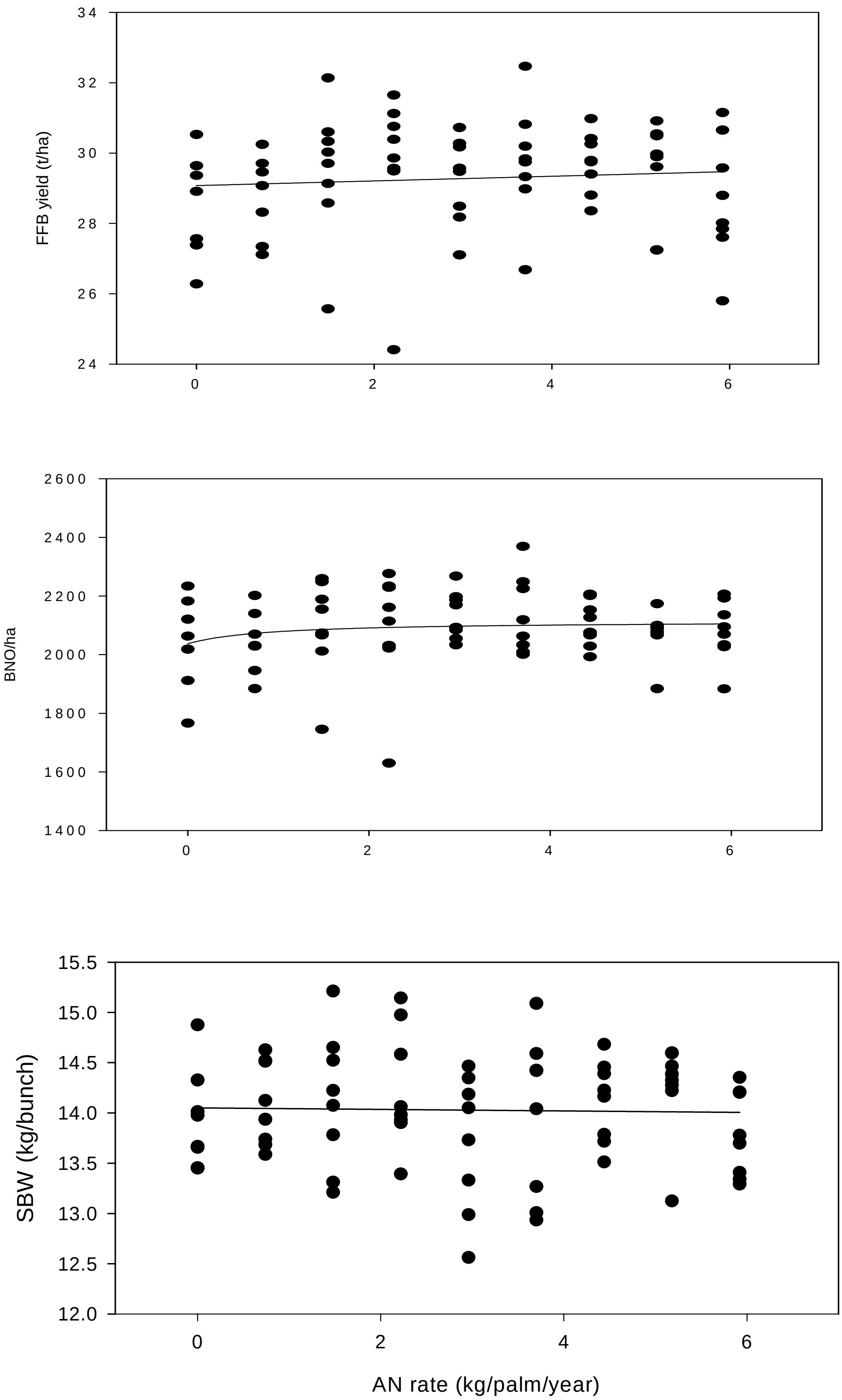


Figure 1. Effect of fertiliser rate (annual) on FFB yield, BNO/ha and SBW in 2005 (Trial 137).

Table 3. Regression parameters for the effect of fertiliser application rate (kg/palm/year) on tissue nutrient concentrations (% DM, except for B, in mg/kg DM) in 2005 (Trial 137). *p* values <0.05 are indicated in bold.

	Grand Mean	Intercept	Slope	Slope p	r^2
Leaflet					
Ash	15.8	15.5	0.1	**0.010**	0.090
N	2.66	2.66	0.0001	0.985	0.001
P	0.151	0.151	0.00003	0.881	0.001
K	0.812	0.837	-0.006	**0.004**	0.111
Mg	0.162	0.162	-0.0001	0.907	0.0002
Ca	0.94	0.902	0.010	**<0.001**	0.188
B	13.0	13.2	-0.1	0.367	0.012
Cl	0.498	0.442	0.014	**<0.001**	0.246
S	0.211	0.211	-0.0001	0.848	0.001
Rachis					
Ash	4.4	4.3	0.04	**0.040**	0.059
K	1.47	1.42	0.01	0.066	0.047

Table 4: Main effects of N application rate on leaflet nutrient, significant effects are shown in bold.

N rate (kg/palm)	Leaflet nutrient in % DM			
	N	K	Ca	Cl
0.00	2.68	**0.86**	**0.89**	**0.41**
0.74	2.67	**0.81**	**0.92**	**0.45**
1.48	2.66	**0.80**	**0.94**	**0.48**
2.22	2.65	**0.85**	**0.92**	**0.51**
2.96	2.65	**0.81**	**0.95**	**0.52**
3.7	2.64	**0.80**	**0.93**	**0.52**
4.44	2.65	**0.79**	**0.96**	**0.54**
5.18	2.67	**0.79**	**0.99**	**0.54**
5.92	2.69	**0.81**	**0.98**	**0.52**

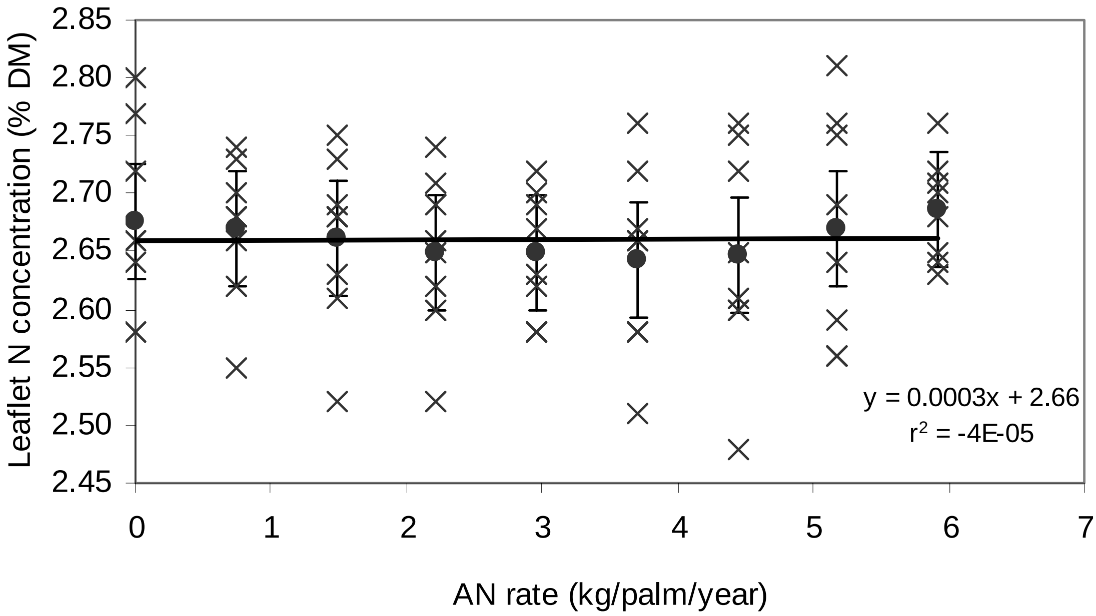


Figure 2. Effect of fertilizer rate on leaflet N concentration in 2005 (Trial 137). Crosses show values for each 60-palm plot (4 rows of 15), circles show means for treatment, and bars show s.d.

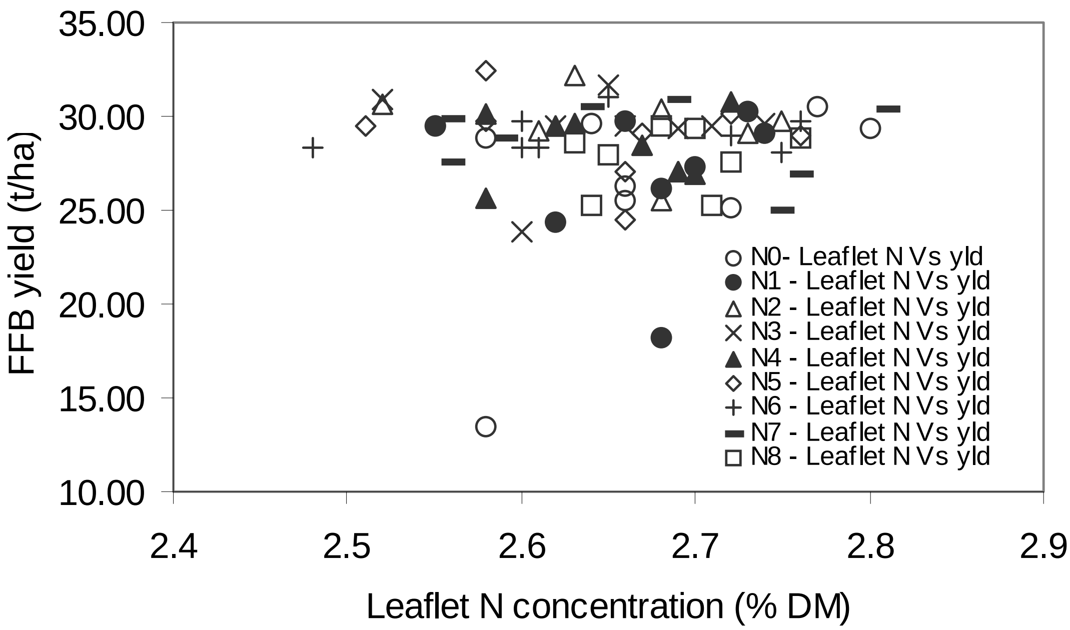


Figure 3. Relationship between FFB yield and leaflet N concentration, at varying rates of N application in 2005 (Trial 137)

TRIAL 138B SYSTEMATIC N FERTILISER TRIAL, HAELLA

INTRODUCTION

The purpose of the trial is to provide a response curve to N fertiliser that will be used to determine optimum N input in the area.

Factorial fertiliser trials with randomised spatial allocation of treatments have been generally showing poor responses to fertilisers in NBPOL trials. Yields and tissue nutrient concentrations in control plots have been generally higher than would be expected. It is suspected that fertiliser may be moving from plot to plot. Systematic designs are seen as a way of avoiding this problem, by ensuring that high and low rates of application are not adjacent. This trial was approved in the 1999 SAC meeting. There was a change of N source from ammonium chloride (AC) to ammonium nitrate (AN) in 2004.

Soil of the trial site is freely draining fine textured alluvial soils over coarse pumiceous sand and ash beds.

Table 1: Trial 138B background information.

Trial number	138B	Company	NBPOL
Date planted	1995	Planting Density (palm/ha)	128
Spacing	8.8 x 8.8	Pattern	Triangular
LSU or MU	Haella Plantation, Division 2, Field I-95, Avenue 11, Road 7-8	Soil type	Eutrandepts (Inceptisols)
Recording started	July 2002	Palm age (years after planting)	10
Topography	Flat with very minor depressions	Planting material	Dami commercial DxP crosses
Progeny*	Not known	Previous land use	Forest
Drainage	Freely draining	Area under trial soil type	Not known
Officer in charge	R. Pipai	Treatments started	July 2002

MATERIALS AND METHODS

The trial has 9 treatments, which are 9 rates of AN (0, 0.74, 1.48, 2.22, 2.96, 3.70, 4.44, 5.18 and 5.92 kg/palm/yr), and 8 replicates. Each plot is 4 rows of 15 palms. N rates (N0 – N5.92) vary systematically along the trial. Plots were marked in February 2001 and treatments and yield recording commenced in July 2002. Fertiliser is applied in 2 doses per year. In 2006, a full complement of basal fertilisers (non-treatment) will be added. For this trial (138B) TSP 0.5; KIE 1.5; MOP 0.5;CaB 0.15 kg/palm/year will be added across the whole trial.

RESULTS AND DISCUSSION

There was a significant response of fresh fruit bunch (FFB) yield to N fertiliser; mainly due to its significant effect on number of bunches per ha (BNO/ha) (Table 2, Figure 1). These results were similar to the 2004 results. However, in 2002 and 2003, N fertiliser had no significant effect on the FFB yield.

Leaflet N concentrations were affected by N fertilizer for the first time in this trial (*$p = 0.003$; $r^2 = 0.119$*). However, generally the N values were above the critical value of 2.30 %DM for mature palms

(Table 4, Figure 2). N fertilizer also had a significant effect on leaflet P, Cl, and S, and rachis N and P (Tables 3 & 4).

There was substantial variation in yield and leaflet N concentration, and FFB yield did not correlate well with leaflet N concentration (Figure 3). This is possibly because fertilizer treatments were only imposed in July 2002 and treatment effects take 5-6 years to show up.

Thus, although there is both a small response of FFB to N supply, and N concentration in leaf tissue to N supply, the yield response is not yet large enough to set a diagnostic level.

Table 2: Regression parameters for the effect of fertiliser application rate (kg/palm/year) on FFB yield and its components in 2005 (Trial 138B). p values <0.05 are indicated in bold.

	Intercept	Slope	*p*	r^2
FFB Yield (t/ha)	29.9	0.3	**0.029**	0.066
BNO/ha	1544	17	**0.006**	0.104
Single bunch wt. (kg)	19.5	-0.04	0.632	0.003

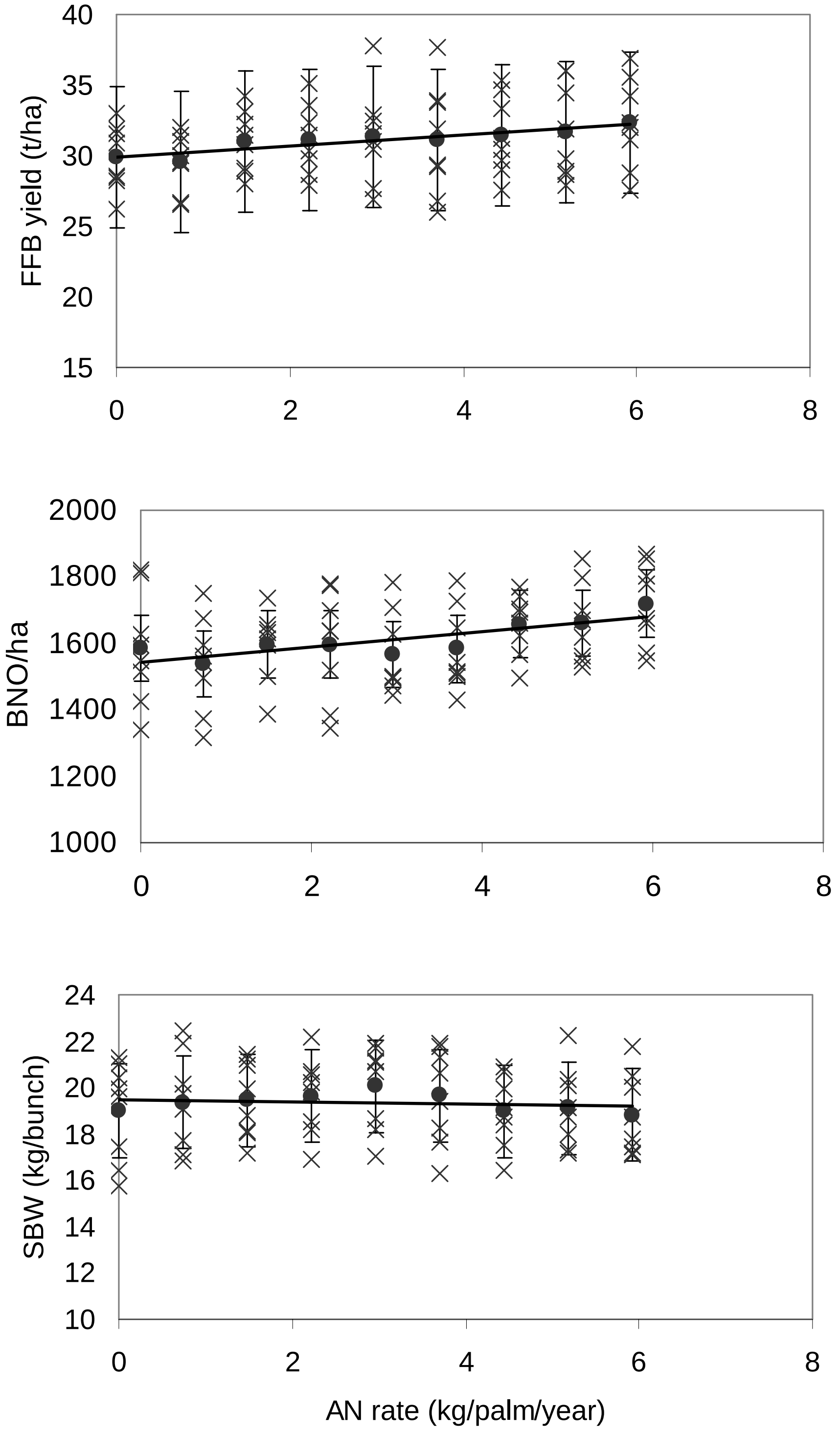


Figure 1: Effect of fertiliser rate (annual) on FFB yield, BNO/ha and SBW in 2005 (Trial 138B). For BNO/ha and SBW, crosses show values for each 60-palm plot (4 rows of 15), circles show means for treatment, and bars show s.d .

Table 3. Regression parameters for the effect of fertiliser application rate (kg/palm/year) on tissue nutrient concentrations (% DM, except for B, in mg/kg DM) in 2005 (Trial 138B). *p* values <0.05 are indicated in bold.

	Grand Mean	Intercept	Slope	*p*	r^2
Leaflet					
Ash	13.9	14.0	-0.02	0.631	0.003
N	2.48	2.42	0.02	**< 0.001**	0.206
P	0.145	0.143	0.001	**0.006**	0.104
K	0.718	0.735	0.004	0.058	0.050
Mg	0.194	0.199	-0.001	0.162	0.028
Ca	0.774	0.770	0.001	0.802	0.001
B	14.1	14.6	-0.1	0.061	0.050
Cl	0.488	0.417	0.018	**< 0.001**	0.579
S	0.206	0.202	0.001	**0.006**	0.102
Rachis					
Ash	4.46	4.39	0.02	0.437	0.009
N	0.292	0.277	0.004	**< 0.001**	0.226
P	0.078	0.085	-0.002	**0.002**	0.132
K	1.24	1.21	0.01	0.259	0.018

Table 4: Main effects of N application rate on leaf nutrient concentration (% DM), significant effects are shown in bold.

An rate (kg/palm)	Leaflet					Rachis		
	N	P	K	Cl	S	N	P	K
0.00	**2.38**	**0.142**	0.748	**0.420**	**0.200**	**0.273**	**0.089**	1.27
0.74	**2.42**	**0.144**	0.715	**0.421**	**0.201**	**0.281**	**0.084**	1.22
1.48	**2.45**	**0.143**	0.698	**0.476**	**0.203**	**0.284**	**0.075**	1.15
2.22	**2.52**	**0.145**	0.720	**0.485**	**0.210**	**0.295**	**0.077**	1.22
2.96	**2.53**	**0.146**	0.740	**0.485**	**0.210**	**0.289**	**0.082**	1.26
3.70	**2.53**	**0.148**	0.728	**0.504**	**0.211**	**0.303**	**0.078**	1.20
4.44	**2.51**	**0.146**	0.688	**0.526**	**0.209**	**0.298**	**0.075**	1.24
5.18	**2.51**	**0.100**	0.700	**0.500**	**0.200**	**0.300**	**0.072**	1.24
5.92	**2.47**	**0.145**	0.720	**0.525**	**0.204**	**0.305**	**0.073**	1.32

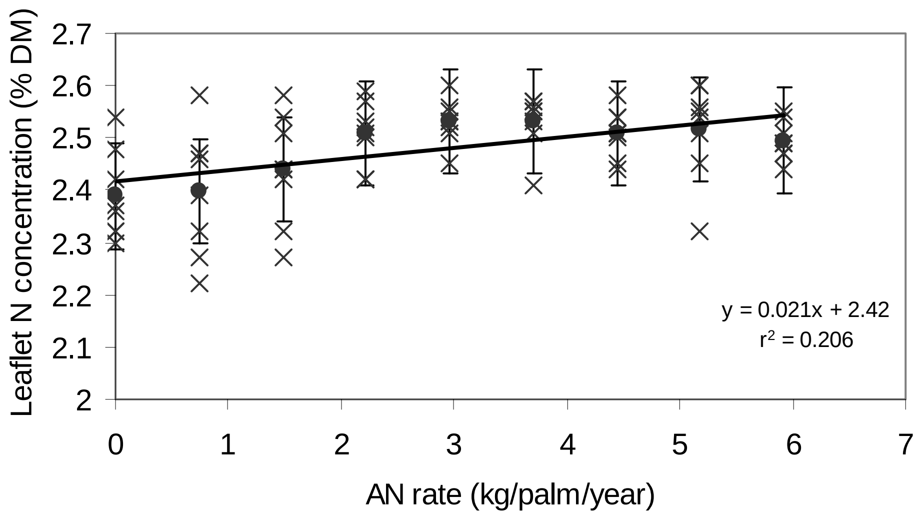


Figure 2. Effect of fertilizer rate on leaflet N concentration in 2005 (Trial 138B). Crosses show values for each 60-palm plot (4 rows of 15), circles show means for treatment, and bars show s.d.

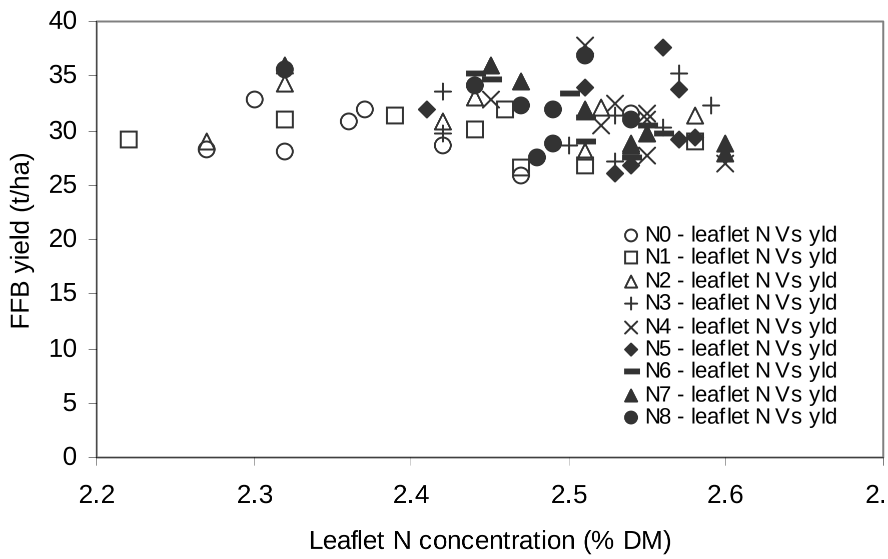


Figure 3. Relationship between FFB yield and leaflet N concentration, at varying rates of N application in 2005 (Trial 137)

TRIAL 142. N RESPONSE USING LARGE PLOTS IN OPRS PROGENY TRIALS, KUMBANGO AND BEBERE

BACKGROUND

Over the last decade or more, control plots in WNB fertiliser trials have been yielding as much as fertilised plots. We suspect that this is due to nutrients moving into the control plots from surrounding areas, despite guard rows and trenching between plots. Systematic trials have been introduced to overcome the problem, and they are expected to be successful if the problem is due to movement between adjacent plots. However, if nutrient movement is occurring on a larger scale, from the surrounding plantation, systematic trials may not provide the answer. In order to test whether nutrients are moving at larger scales, PNGOPRA is carrying out the following activities in 2003: 'Omission trials', 'Monitoring of shallow perched water tables' and 'Tissue sampling transects'. The initial idea of the omission trials was to stop applying fertiliser to a large area in the plantations in an attempt to obtain a true control. That is the purpose and design of Trial 141. In this trial (142), we use the existing CCPT trials in a similar way, but to include a moderate and high level of N application as well. We expect a substantial interaction between progeny and response of vegetative growth parameters to N. The trial is a joint one between PNGOPRA and OPRS.

PURPOSE

To establish a response curve to N fertiliser, using a large number of known progeny, and large plots to overcome suspected problems with nutrient movement in trials with conventional size plots. The purpose of the response curve is to improve N fertiliser recommendations in WNB.

SITE, PALMS

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

DxP 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

DxP 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

DESIGN

The trial tests 3 levels of N fertiliser (ammonium nitrate) at the three sites, as shown in Table 1. Other fertilisers are applied as a blanket across the trial, at recommended rates From 2006 onwards, the application of basals will be set at TSP, 0.2; KIE, 1.5; MOP, 1.5; Borate (Ca, Ca/Na, or borax) 0.15 kg/palm. Treatments commenced in 2003. Fertiliser application is split into 2 doses, the first in May, and the second in October. The estates will not apply any fertiliser in these blocks during the course of the trial.

The whole trial is being analysed as a one-way ANOVA of N level with 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 occurs in all three progeny trials. Possible movement of N into zero plots from surrounding areas may be analysed spatially if the same progeny is repeated within that plot.

Table 1. Locations of fertiliser treatments (annual rates of ammonium nitrate) in Trial 142. Each breeding trial replicate becomes 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

RESULTS

In the third year (2005), as in the first and second, there was no effect of treatments on FFB or its components (Table 2). This is not unexpected as it can sometimes take up to 5 years before responses to fertiliser treatments are observed.

Table 2. Effect of N level on FFB and its components.

N Level (kg AN/palm)	FFB (t/ha)	Number of Bunches (bunches/ha)	Bunch Weight (kg/bunch)
0	27.3	1328	20.5
3	26.6	1308	20.3
6	25.6	1344	20.1
	Significance level		
p	0.311	0.944	0.700

N level and cross had little effect on N concentration in F17 leaflets (Table 3); except that there was a trend of increasing tissue N from 0 N supply to any other level. There was however an effect of the replicate (CCPT trial site). Trial 266 seems to have a higher fertility than 256 and 260. Mostly the N concentrations were near the adequate range; again this could explain the current lack of response to N levels. As suggested, it may take up to 5 years before leaf N levels and thus yield respond to treatments.

Table 3. Effect of N level and cross on F17 leaflet N concentration (%DM).

Cross	N Level (kg AN/palm)		CCPT Trial 256	260	266	Mean
714.814x742.316	0		2.34	2.32	2.50	2.39
	3		2.38	2.46	2.59	2.48
	6		2.37	2.38	2.55	2.43
635.607x742.207	0				2.53	
	3				2.58	
	6				2.67	

Similarly, N level had little or no effect on the concentration of other nutrients (Table 4).

Table 4: Effect of N level on concentration of nutrients in leaflet and rachis of F17 (714.814x742.316). Concentrations are in %DM except B which is in mg/kg DM.

N Level	Leaflet Nutrient Level							Rachis Nutrient Level		
(kg AN/palm)	K	P	Mg	Ca	S	Cl	B	N	P	K
0	0.79	0.145	0.16	0.75	0.18	0.49	12.0	0.27	0.049	1.38
3	0.78	0.148	0.17	0.80	0.19	0.50	11.6	0.29	0.053	1.39
6	0.79	0.142	0.15	0.73	0.18	0.43	10.8	0.28	0.044	1.39

TRIAL 144 – MAGNESIUM AND POTASSIUM RESPONSE, WAISISI

BACKGROUND

Symptoms of Mg deficiency are common in West New Britain. However, given the low CEC of the soils, their high Ca contents and their low Mg and K contents, it is surprising that the palms would be Mg-deficient but not K-deficient. Cation nutrition is affected by interactions between the cations, so this trial is aimed at determining the effect of Mg and K, alone and in combination, on symptoms and yield. The experimental site chosen, Waisisi 'Mini-Estate', has a young planting and is likely to show severe Mg and possibly K deficiency as palms grow. Symptoms tend to be expressed most strongly around the age of 4-5 years. This trial is part of the ACIAR-funded Mg project.

PURPOSE

To determine if there is a response to Mg or K or both, on a site that does not have a history of fertiliser application and is in an area where Mg deficiency symptoms are common.

SITE AND DURATION

The site is a young planting (2001) at Waisisi Mini-estate. Trial will continue for about 10 years.

Location: Waisisi Mini-Estate (customary land development); northern end of Block A1, which is the northern-most corner block of the estate. Smallholder blocks in the area show Mg deficiency symptoms.

Soil: Very young, well-drained pumice soils. A very dark friable sandy loam to loamy topsoil overlies several layers of pumice gravel loamy sand and sandy loam volcanic ash. See DALLUS report numbers: 544a (Siki), 544g (Waisisi) and Table 2.

Topography: Flat to rolling.

Land use prior to this crop: Secondary forest

Palms: Dami DxP commercial, planted in 2001 at 120 palms per ha.

DESIGN

A factorial of 2 Mg treatments (nil and plus Mg) by 2 K treatments (nil and plus K) with 4 replicates. Where applied, both nutrients to be added as frequent surface application, slow release form in holes, and foliar spray. Surface and foliar applications will consist of kieserite ($MgSO_4.H_2O$) or K_2SO_4. Slow release applications will consist of large applications of QMAG product M30 (partially calcined magnesite, containing $MgCO_3$ and MgO) or K_2SO_4 in inverted coconut shells to prevent leaching loss (Table 1). Ammonium chloride was added as a basal fertiliser. From 2006 onwards, Ammonium nitrate (1.5 kg/palm), TSP (0.2 kg/palm) and Borate (0.15 kg/palm) will be added as basals.

To minimise chances of nutrient movement between plots, each plot of 16 palms will be surrounded by 2 guard rows, the inner one treated as per the plot, and the outer one untreated. No Mg or K fertiliser will be applied to the blocks surrounding the trial. Measurements will focus on uptake of Mg and K by the canopy, and expression of symptoms. As palms start to produce, yield will be measured.

The trial was marked out and fertiliser treatments (except for foliar application) commenced in mid 2003. Foliar fertiliser application began in September 2004.

Table 1. Fertiliser types and rates

Nutrient	Application method	Nutrient appl. rate (kg/ha)	Fertiliser	Nutrient cont. of fert. (%)	Fert appl. rate (kg/palm/yr)	Number of appl.
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
Mg	Foliar	6/yr	kieserite	0.1% solution	0.05	6/yr
K	Foliar	6/yr	K_2SO_4	0.1% solution	0.05	6/yr

* QMAG M30
$^+$ K_2SO_4 in inverted half coconuts

RESULTS

In the first year of yield recording the Mg treatment had a significant effect on FFB yield but no other yield components. K treatment had no significant effect on yield or its components and there were no interactions (See 2004 Annual report). Similarly, in 2005 Mg also had a significant effect on FFB but no other components and K had no significant and any yield components (Tables 2).

However, similar to last year, the significant effect of increasing Mg was unexpected as it resulted in a decrease in FFB yield (Table 3). This decrease appeared to only be an initial effect as the time-course analysis of yield shows that during 2004, the FFB yield of Mg1 had become greater than Mg0 and the difference was increasing with time (Fig. 1). But, this effect was soon lost and the yield of Mg0 again began to increase above Mg1.

At this stage, K had no effect on yield or its components.

Mg treatment increased Mg concentration in fronds sample by the end of 2005 (Fig 2), indicating that Mg was being taken up by the palms and thus suggesting that at least one of the forms in which it is supplied is available. In response to adding Mg the increase of Mg in the rachis (Table 4) was more than 50% compared to that in the leaflet (30%), suggesting that the rachis might be a more sensitive tissue for diagnostic purposes.

Mg application also affected other nutrients in leaflet and rachis. However, mostly these changes were of no consequence as the nutrient levels were in the adequate range (Table 4). The exceptions were K and B. K was adequate in the leaflet but very low in the rachis. Addition of Mg further exacerbated the low levels, especially in the rachis.

K application also increased K levels in the leaflet and rachis. However, even with the addition of K, rachis K levels were below the level of 1.0 mg/kg generally considered adequate.

K application also affected the levels of some other nutrients, especially Mg which was suppressed by about 10-20%.

Table 2. Main effects (p values) of Mg and K on FFB yield and its components in 2005.

Source	2005		
	Yield (t/ha/yr)	NoB (/ha)	SBW (kg)
Mg	**0.049**	0.119	0.347
K	0.787	0.961	0.315
Mg.K	0.506	0.891	0.258
CV%	9.4	11.6	5.7

Table 3. Mg and K effects on FFB yield and it components in 2005.

Source	2005		
	Yield (t/ha/yr)	NoB (/ha)	SBW (kg)
Mg0	**17.3**	2860	5.4
Mg1	**15.6**	2614	5.2
K0	16.4	2735	5.6
K1	16.6	2742	5.2
sed	*0.78*	*144*	*0.1*

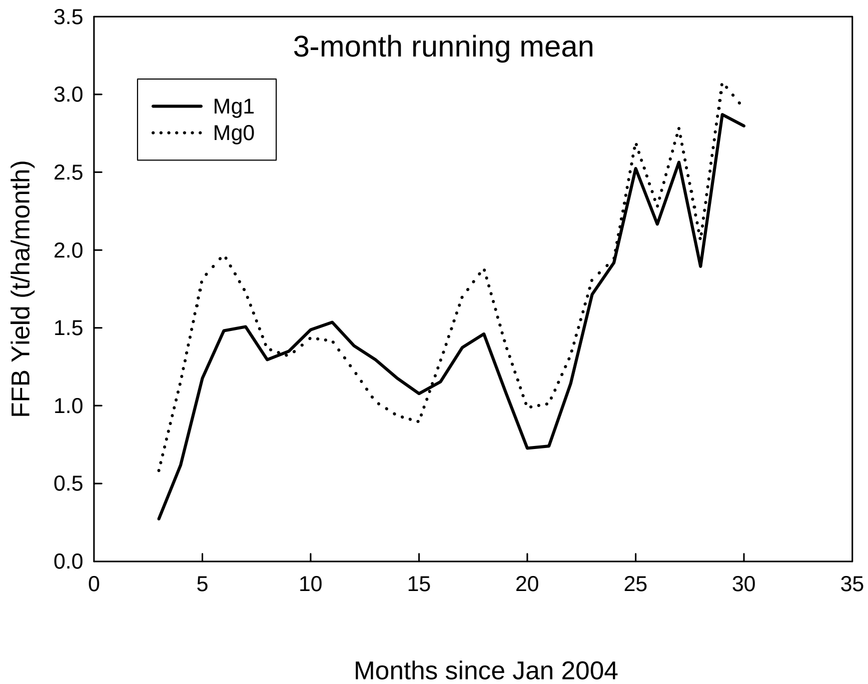


Figure 1. Three-monthly running average for FFB production since measurements started in 2004..

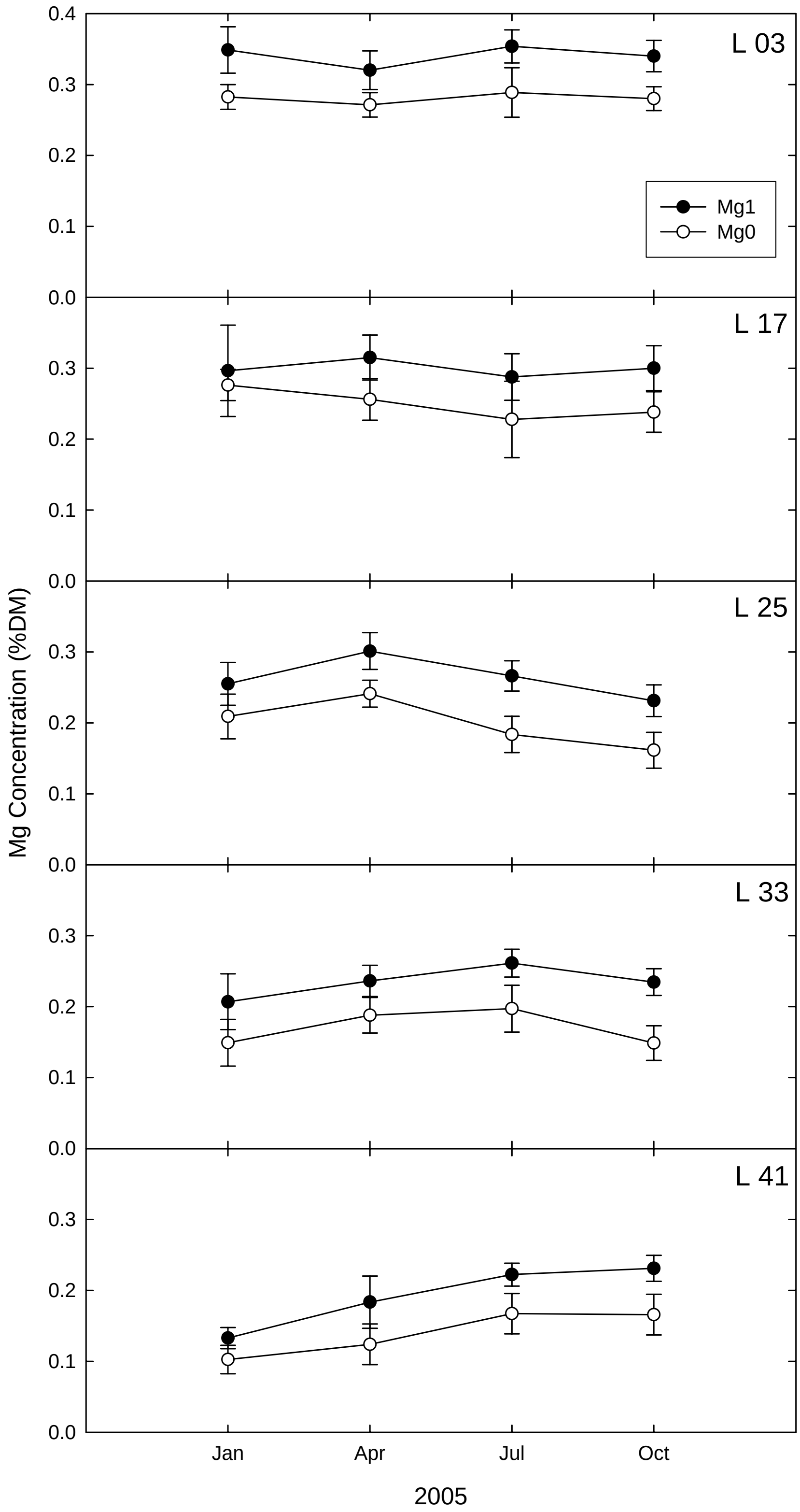


Figure 2. Changes in leaflet Mg levels in fronds of different age during 2005

Table 4. Frond nutrient concentrations (September 2005). Significance levels (*p*) for the main effect of Mg and K are shown at the bottom of the tables.

Leaflet

Mg Level	K Level	N	P	K	Ca	Mg	S	B	Fe	Mn	Cu	Zn
		% DM						mg/kg				
0	0	2.64	0.160	0.80	1.16	0.24	0.19	10.3	48	163	7.9	19.9
	1	2.71	0.160	0.84	1.23	0.21	0.19	10.1	51	189	7.7	20.1
1	0	2.65	0.157	0.75	1.09	0.31	0.19	10.1	49	174	7.8	19.6
	1	2.59	0.157	0.80	1.10	0.28	0.18	8.9	53	191	7.4	25.3
p Mg		*0.309*	*0.154*	*0.022*	*0.001*	*0.001*	*0.285*	*0.064*	*0.592*	*0.550*	*0.528*	*0.368*
	p K	*0.957*	*0.955*	*0.036*	*0.100*	*0.037*	*0.772*	*0.043*	*0.186*	*0.066*	*0.450*	*0.294*

Rachis

Mg Level	K Level	N	P	K	Ca	Mg	S	B	Fe	Mn	Cu	Zn
		% DM						mg/kg				
0	0	0.27	0.054	0.72	0.42	0.058	0.025	4.08	20.2	21.4	1.11	7.9
	1	0.26	0.065	0.89	0.41	0.049	0.026	4.07	21.3	22.1	1.07	7.3
1	0	0.27	0.050	0.54	0.40	0.091	0.026	3.99	21.0	21.4	1.09	5.7
	1	0.26	0.054	0.66	0.40	0.074	0.026	4.22	23.4	22.7	1.18	5.7
p Mg		*0.983*	*0.071*	*0.020*	*0.616*	*0.001*	*0.445*	*0.863*	*0.671*	*0.868*	*0.411*	*0.235*
	p K	*0.662*	*0.063*	*0.084*	*1.000*	*0.026*	*0.445*	*0.504*	*0.602*	*0.617*	*0.639*	*0.839*

Palms have also been assessed for symptoms of Mg and K deficiency. Similar to last year, application of Mg significant reduced the number of fronds with Mg deficiency symptoms (Table 5). As confirmation of symptom identification, K supply did not affect Mg deficiency symptoms.

Table 5. Mg deficiency symptom score; expressed as the number of fronds per palm showing symptoms typical of Mg deficiency.

Treatment		Fronds with Mg Deficiency Symptoms		
Mg	K	Jan-05	Jun-06	Aug-06
0	0	9.6	3.2	11.7
0	1	8.1	3.4	12.5
1	0	5.6	0.8	6.2
1	1	5.6	1.3	8.1
ANOVA p value	Mg effect	0.002	<0.001	<0.001
	K effect	0.384	0.334	0.228

By contrast to last year, increasing K supply did significantly reduced the number of fronds with K deficiency symptoms for some harvests. However the number of fronds with K deficiency symptoms is still quite high, supporting the suggestion above that the whole trial may be suffering from K deficiency.

Table 6. K deficiency symptom score; expressed as the number of fronds per palm showing symptoms typical of K deficiency.

Treatment		Fronds with K Deficiency Symptoms		
Mg	K	Jan-05	Jun-06	Aug-06
0	0	21.6	26.0	25.5
0	1	19.3	23.9	23.2
1	0	21.4	26.8	22.2
1	1	16.5	24.5	23.2
ANOVA p value	Mg effect	0.222	0.271	0.118
	K effect	0.021	0.003	0.491

CONCLUSION

Although the results from last year suggested that the Mg treatment was beginning to show a response, this year that response did not continue. There are a number of reasons why this might be the case:

a. In the Mg0 treatment, the concentration of Mg in the leaflet of frond 17 is still above the concentration generally regarded as adequate. Thus, the palms are not yet Mg deficient. From the three-monthly analysis, this tissue Mg is slowly dropping so that these palms should be experiencing Mg deficiency soon.

b. Application of Mg has substantially suppressed rachis K concentrations, well below the adequate concentration. This could be inducing a K deficiency that is limiting FFB productivity. This may indeed explain the suppression of FFB at Mg1.

Because of the low K concentration in tissue, consideration should be given to increasing the K application rate in the K1 treatment. It is suggested that the application of surface K (K_2SO_4) be doubled to 2 kg/palm/year.

The concentration of B in leaflet tissue is also low. However, this will be addressed when the new basal recommendation is implemented.

TRIAL 145 – MAGNESIUM SOURCE TRIAL

BACKGROUND

Magnesium deficiency of oil palm is common on the young volcanic ash soils of West New Britain (WNB). Kieserite is currently used to correct the deficiency. Kieserite is highly soluble and has the potential to be rapidly lost by leaching due to high rainfall and saturation of the soil cation exchange capacity with Ca. By using magnesium fertilisers with lower solubility than kieserite, it is envisaged that roots will have more chance of accessing the magnesium before it is lost by leaching. This trial is part of the ACIAR-funded Mg project.

PURPOSE

To compare the effects on oil palm growth and yield of a range of magnesium fertilisers.

SITE AND DURATION

A site has been chosen (Walindi Plantation) in mature palms in WNB in an area showing deficiency symptoms, The trial is expected to continue for 10 years, with ACIAR support for the first 4.

DESIGN

Three rates (0, standard, 2 times standard) by four sources (kieserite, and the QMAG products Magnesite FO1, EMAG M30 and EMAG 45) factorial with 4 reps. The current industry standard for kieserite in WNB is around 2 kg kieserite per palm per year. The other fertilisers will be applied on an equivalent magnesium basis (Table 1). All fertilisers will be surface-applied. Ammonium nitrate will be added as a basal fertiliser and other nutrients will be added as a basal application as required.

The 12 treatments will be set out as a randomised complete block design of 4 reps. Each plot will consist of 36 (6*6) palms with the inner 16 (4*4) being the recorded palms. Trenches will be dug around each plot to prevent root poaching.

Fortnightly measurements of yield will be carried out. Nutrient analysis of frond 17 and standard vegetative measurements will be carried out at time zero and regularly thereafter. The fate of magnesium in the soil and palms may be examined after several years of treatment.

Yield recording began in May 2004 and treatments weer imposed in August 2004.

Table 1. Fertiliser types and rates.

Product	Main component	Mg content (%)	Mg appl. rate (kg/plm.yr)	Product appl. rate (kg/palm.yr)	Number of appl. /yr	Amount per applic. (g/palm)
Kieserite	$MgSO_4$	17	0.34	2.00	2	1000
Kieserite	$MgSO_4$	17	0.68	4.00	2	2000
Magnesite FO-1	$MgCO_3$	26	0.34	1.31	2	654
Magnesite FO-1	$MgCO_3$	26	0.68	2.62	2	1308
EMAG M30	$MgCO_3$/ MgO	46	0.34	0.74	2	370
EMAG M30	$MgCO_3$/ MgO	46	0.68	1.48	2	739
EMAG45	MgO	56	0.34	0.61	2	304
EMAG45	MgO	56	0.68	1.21	2	607

RESULTS

Yield recording began in May 2004 just before treatments were fully imposed. As expected, there was no significant effects on yield in the first year of the trial. However, in 2005 there was a significant effect of source on yield with KIE having a lower yield than any of the carbonates/oxides (Tables 2 & 3). This effect however, is confusing as the other "sources" at the zero rates had greater yields than "KIE" at zero rate.

The significant effects on BNo and SBW in 2004 were lost in 2005. Which probably means they were only transient and of little consequence.

Table 1. Significance (p level) of main effects and interaction on FFB yield and components.

	2004			2005		
Source	Yield	BNO	SBW	Yield	BNO	SBW
Type	0.376	**0.026**	**0.049**	**0.007**	0.127	0.157
Rate	0.700	0.643	0.560	0.922	0.960	0.473
Type. Rate	0.528	0.455	0.677	0.809	0.770	0.419
CV %				*6.8*	*8.2*	*5.3*

Table 2. Average yield and components for 2005 for main effects.

	Component		
Treatments	FFB (t/ha)	BNO (bunches/ha)	SBW (kg)
KIE	29.3	1827	16.5
FO1	32.5	1967	16.9
EMAG M 30	31.4	1838	17.4
EMAG 45	31.0	1874	17.1
sed	*0.864*	*63.2*	*0.367*
lsd $_{0.05}$	*1.8*		
Rate 1	31.0	1883	16.8
Rate 2	31.2	1868	17.2
Rate 3	30.9	1879	16.9
sed	*0.748*	*54.7*	*0.646*
lsd $_{0.05}$			
Grand Mean	31.1	1876	17.0

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

	Rate 1		Rate 2	Rate 3
KIE	29.9		29.7	28.3
FO1	32.3		32.9	32.4
EMAG M 30	30.6		31.2	32.4
EMAG 45	31.3		31.1	30.7
Grand mean	33.1	*sed*		*1.50*

Neither of the treatments, source or rate, had an effect (P > 0.05) on nutrient concentrations in leaf or rachis. As treatments had only been imposed 5 months before sampling, this is to be expected. Average leaflet nutrient concentrations for all treatments are presented in Table 4.

Table 4. Average nutrient concentration for samples taken 5 months after treatment imposed (November, 2004).

Nutrient	Leaf	Rachis
	------- % DM-------	
N	2.45	0.299
P	0.151	0.106
K	1.01	1.57
Ca	0.78	0.278
Mg	0.16	0.034
S	0.18	0.031
	----- mg/kg DM----	
B	16.1	5.16
Fe	62.5	21.4
Mn	94	15.0
Cu	7.0	1.17
Zn	19.3	6.58

TRIAL 146 – MAGNESIUM PLACEMENT AND SOURCES

BACKGROUND

Mg deficiency symptoms persist in West New Britain, despite applications of kieserite. It is suspected that the cation exchange capacity of the soil is swamped with Ca, preventing Mg from being retained. It was proposed that adding Mg fertiliser in concentrated zones, or with barriers to leaching, or as less soluble sources might solve the problem of competition with Ca and loss by leaching. This trial is part of the ACIAR-funded Mg project.

PURPOSE

To determine if the placement and type of Mg fertilisers influences growth and yield of palms in an area that appears to be Mg-deficient.

SITE AND DESIGN

Site is Kumbango plantation, to be run for 10 years, with ACIAR support for the first 4.

Mg sources will be kieserite, MgO (QMAG EMAG 45) and $MgCO_3$ (QMAG Magnesite FO-1).

Application methods will be twice per year on the surface, or buried in the soil in concentrated zones in a quantity sufficient for 8 years: in trenches without any cover, in trenches covered with plastic, or in inverted coconut shells.

There will be two control treatments, one with zero Mg, and the other a positive control with multiple sources of Mg: regular surface applications of kieserite, MgO and $MgCO_3$ (QMAG M30) in a trench (sufficient for 8 years), and trunk injection with $MgSO_4$ solution.

Design is a factorial of source (3) and application method (4) plus controls (2) = 14 treatments times 4 reps = 56 plots. Trial layout will be 'randomised complete block'. Nitrogen will be applied as a basal fertiliser applied at standard rate. From 2006 onwards, ammonium nitrate (2 kg/palm) TSP (0.5 kg/palm), MOP (0.5 kg/palm), and calcium borate (0.15 kg/palm) will be added as basal fertilisers.

Vegetative growth, yield and nutrient uptake will be measured. The trial has been marked out and treatments application commenced in 2004 and continued into 2005.

Table 1. Fertiliser types and rates

Fertiliser	Placement	Mg appl. Rate (kg/palm)	Mg cont. of fert. (%)	Fert. Appl. rate (kg/palm)	Number of appl.	Amount per applic. (g/palm)
Kieserite	Surface	0.34	17	2	2/yr	1,000
Kieserite	Trench	2.72	17	16	1	16,000
Kieserite	Trench/P*	2.72	17	16	1	16,000
Kieserite	Coconuts	2.72	17	16	1	16,000
$MgCO_3$	Surface	0.34	26	1.3	2/yr	654
$MgCO_3$	Trench	2.72	26	10.5	1	10,462
$MgCO_3$	Trench/P*	2.72	26	10.5	1	10,462
$MgCO_3$	Coconuts	2.72	26	10.5	1	10,462
MgO	Surface	0.34	56	0.6	2/yr	304
MgO	Trench	2.72	56	4.9	1	4,857
MgO	Trench/P*	2.72	56	4.9	1	4,857
MgO	Coconuts	2.72	56	4.9	1	4,857
Positive control (all fertilisers below applied together in same plot)						
Kieserite	Surface	0.34	17	2.0	2/yr	1000
M30**	Trench	3.40	46	7.4	1	7394
Kieserite	Injection	0.24	(1Molar)	(10L/palm)	Continuous	

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

RESULTS AND DISCUSSION

In the first full year of recording following application of treatments, there was mostly, as could be expected, no significant responses to either source or placement (Table 2). The only exception was a significant effect of Placement on single bunch weight (SBW). This is more likely to a statistical anomaly than a real effect at this early stage.

Table 2. Significance (p values) of main effects of source and placement on FFB yield and its components. The two controls (nil Mg, combined sources of Mg) were not included in the statistical analysis.

Source	2005		
	FFB yield	BNO/ha	SBW (kg)
Source	0.569	0.179	0.241
Placement	0.942	0.861	**0.030**
Source x Placement	0.477	0.653	0.522

Although there was mostly no significant effect, the results are presented below to allow comparison with the two controls. Although there was a tendency for the positive control (combined sources) to have greater yield and components than the negative (Nil) control, in some cases (Tables 3. 4 and 5) these values were within the ranges of the treatment results, suggesting that they currently are of no real consequence. Again this is expected as this is only the first year of the recording since treatments were applied.

Table 3. Effect of Mg source and placement on FFB yield (t/ha/yr) in 2005.

Source	Placement					
	Nil	Surface	Trench	Trench/ Plastic	Coconuts	Combined
Nil	30.2					
Kieserite		30.4	31.4	29.6	29.7	
MgCO3		27.7	30.4	29.4	30.5	
MgO		32.1	29.4	30.1	30.3	
Combination						32.5

Table 4. Effect of Mg source and placement on Number of Bunches (ha/yr) in 2005.

Source	Placement					
	Nil	Surface	Trench	Trench/ Plastic	Coconuts	Combined
Nil	2218					
Kieserite		2086	2114	2104	2092	
MgCO3		1974	2036	2134	2152	
MgO		2290	2114	2214	2141	
Combination						2230

Table 5. Effect of Mg source and placement on SBW (kg) in 2005.

Source	Placement					
	Nil	Surface	Trench	Trench/ Plastic	Coconuts	Combined
Nil	14.0					
Kieserite		15.0	15.6	14.3	14.4	
MgCO3		14.2	15.2	14.1	14.7	
MgO		14.5	14.5	14.1	14.6	
Combination						14.9

TRIAL 148. Mg RESPONSE USING LARGE PLOTS IN OPRS PROGENY TRIALS, KUMBANGO

BACKGROUND

The characteristic symptoms of magnesium deficiency are marked and widespread in WNB. However, fertiliser trials over the last few decades have shown little or no response to kieserite (magnesium sulphate). Recent research has shown that the soils have very low cation exchange capacity and are saturated with calcium, which competes with magnesium for cation exchange sites. Therefore, we suspect that in this high rainfall environment, magnesium from soluble fertilisers like kieserite is being leached out of the soil profile before the roots can take it up. The PNGOPRA/CSIRO/ACIAR Mg project is addressing this issue. Another possible explanation for the lack of response to Mg in WNB is movement of nutrients into the control plots from surrounding areas. That possibility has led to a change in direction for N trials in WNB. One of the approaches being used for N is to have very large plots in progeny trials, and this trial does the same with Mg. We suspect a strong interaction between progeny and Mg fertiliser effects, especially on oil extraction rate. The trial is a joint one between PNGOPRA and OPRS.

PURPOSE

The trial has two purposes:

1. To establish a yield response curve to magnesium fertiliser, using a large number of known progeny, and large plots to overcome suspected problems with nutrient movement in trials with conventional size plots. The purpose of the response curve is to improve magnesium fertiliser recommendations in WNB.

2. To measure the effect of magnesium nutrition on yield, tissue magnesium contents and oil extraction rates of several contrasting progeny.

SITE, PALMS

Breeding Trials 282, 283 and 284, Kumbango Division II.

Planted in 2001 at 128 palms/ha

Each breeding trial has 84 plots/progeny of 12 palms each

DESIGN

The trial tests 3 levels of Mg fertiliser (Table 1). Kieserite is being applied under PNGOPRA/OPRS supervision in 2 doses (June and October). Treatments commenced in 2003. Nitrogen fertiliser is being applied by the plantation at recommended rates (blanket application across the trial). Borate was being applied (under PNGOPRA/OPRS supervision) as a blanket across the trial, at 80 g/palm. From 2006 onwards, the application of basals will be set at TSP, 0.2; AN 2.0, 1.5; MOP, 1.5; Borate (Ca, Ca/Na, or borax) 0.15 kg/palm. This trial is adjacent to a similar trial on boron (Trial 149). Treatments vary in a systematic rather than random way across the trial, plots with high rates are not adjacent to control plots.

Table 1. 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.

Breeding Trial 282 (PNGOPRA Rep 1)			Breeding Trial 283 (PNGOPRA Rep 2)			Breeding Trial 284 (PNGOPRA Rep 3)		
Rep 1	Rep 2	Rep 3	Rep 1	Rep 2	Rep 3	Rep 1	Rep 2	Rep 3
0	2	4	4	2	0	0	2	4

The whole trial is being analysed as a one-way ANOVA of kieserite level with 3 replicates (each progeny trial being a replicate). Two-way ANOVA of kieserite (3 levels) x progeny (3 progeny) with 3 replicates will be carried out for those progeny that occur in all three trials (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 has high OER and is being used in much of Dami's commercial seed.

RESULTS

This is the second full year of data collection. There was no effect of Mg on yield or its components when analysed by one-way ANOVA (Table 2).

As there were three progenies which were common to each breeding trial, it was possible to look at the progeny effects as well on a subset of the data. Unlike last year, there was no effect of progeny on FFB yield. However, progeny had a substantial effect on Number of Bunches and Single Bunch Weight (Table 3 & 4) although the pattern of response was different in the two years. The same three progenies are also in trial 149 and show a similar relative response.

Table 2: Effect of N level on FFB and its components.

Mg Level (kg/palm)	FFB (t/ha)	Number of Bunches (bunches/ha)	Bunch Weight (kg/bunch)
0	19.5	3121	6.3
2	19.5	3165	6.2
4	19.2	3079	6.2
	Significance level		
p	0.701	0.279	0.915

Table 3: Effects (p value) of progeny and Mg treatment on FFB, Number of Bunches and Bunch Weight. p values less than 0.1 are shown in bold.

Source of variation	FFB	Number of Bunches	Bunch Weight
Progeny	0.295	**<0.001**	**<0.001**
Mg	0.439	0.521	0.971
Progeny.Mg	0.872	0.804	0.252

Table 4: Progeny effect on FFB and its components.

Female Parent	Male Parent	FFB (t/ha/year)	Number of Bunches (/ha/year)	Bunch Weight (kg/bunch)
635.607	742.207	20.9	3392	6.2
714.712	742.316	21.7	2865	7.7
5035.216	742.316	21.9	3250	7.0

There were a number of significant effects of Mg level on leaf nutrients (Table 5). For example, increase Mg supply, decreased leaflet and rachis P, and leaflet Ca; and increased leaflet Mg (Table 6). However, mostly, nutrient levels remained within the adequate range; thus these effects are of no biological consequence at this early stage in the trial.

Progeny, on the other hand, affected the leaf level of most nutrients. In particular, there was a substantial difference in leaflet Mg. This difference is large enough to be of importance in Mg nutrition (Table 7).

Table 5: P values for leaf nutrient concentrations.

Source	Ash	N	P	K	Ca	Mg	S	Cl	B
					leaf				
Progeny	**0.003**	**0.094**	**0.003**	**0.015**	0.853	**0.002**	**0.022**	0.598	0.185
Mg	0.213	0.976	**0.044**	0.737	**0.003**	**0.093**	0.178	0.907	0.593
Progeny.Mg	0.108	0.432	**0.066**	0.737	0.159	0.676	0.178	0.467	0.510
			rachis						
Progeny	0.518	0.886	0.138	0.981					
Mg	0.196	0.916	**0.008**	0.315					
Progeny.Mg	0.744	0.244	**0.087**	0.937					

Table 6: Effect of Mg level and progeny on leaf nutrients.

Source	Ash	N	P	K	Ca	Mg	S	Cl	B
					leaf				
KIE (kg/palm)									
0	13.5	2.84	**0.159**	0.86	**1.08**	**0.18**	0.22	0.50	16.10
2	13.8	2.82	**0.157**	0.84	**1.05**	**0.19**	0.22	0.49	15.90
4	13.4	2.84	**0.156**	0.85	**1.01**	**0.21**	0.22	0.49	15.50
Progeny									
5035.216x742.316	**13.9**	**2.86**	**0.159**	**0.88**	1.04	**0.17**	**0.22**	0.50	15.50
635.607x742.207	**13.2**	**2.80**	**0.155**	**0.82**	1.04	**0.22**	**0.22**	0.49	16.20
Grand Mean	13.6	2.83	0.157	0.85	1.04	0.19	0.22	0.49	15.80
		rachis							
KIE (kg/palm)									
0	5.3	0.30	**0.069**	1.48					
2	5.2	0.30	**0.063**	1.48					
4	4.9	0.30	**0.060**	1.40					
Progeny									
5035.216x742.316	5.1	0.30	0.065	1.45					
635.607x742.207	5.2	0.30	0.062	1.45					
Grand Mean	5.2	0.30	0.064	1.45					

Table 7: Effect of both Mg level and progeny on leaflet Mg concentration.

	Mg Level (kg/palm)		
	0	2	4
Progeny			
5035.216x742.316	0.16	0.16	0.19
635.607x742.207	0.20	0.22	0.23

TRIAL 149. B RESPONSE USING LARGE PLOTS IN OPRS PROGENY TRIALS, KUMBANGO

BACKGROUND

Boron deficiency is suspected of being involved in problems of fruit set and maturation in WNB and elsewhere. We suspect a strong interaction between progeny and B fertiliser effects, and therefore plan to carry out a trial testing the interaction between the two. The trial is a joint one between PNGOPRA and OPRS. It complements factorial trials with boron and other nutrients that PNGOPRA has recently started in Haella and Poliamba.

PURPOSE

To determine the effect of progeny, B nutrition and their interaction on yield and its components.

SITE, PALMS

Breeding Trials 285, 286, 287 and 288, Kumbango Division II. Each trial has 75 plots/progeny of 9 palms each.

Planted in 2001 at 128 palms/ha.

DESIGN

The trial will test 3 levels of B fertiliser (Table 1). Ca borate will be applied by PNGOPRA in June. Treatments commenced in 2003. Nitrogen fertiliser is being applied by the plantation at recommended rates (blanket application across the trial). Kieserite is being applied by PNGOPRA as a blanket across the trial, at an annual rate of 1 kg/palm, applied as one dose in June and a second in October. Blue paint was applied to palms around the perimeter of the whole area (OPRS trials 285-288), to remind plantation workers not to enter the blocks with kieserite or borate. Every 5th palm around the perimeter of the whole area was labelled 'No kieserite or borate'. Fertiliser applications by PNGOPRA are being carried out in collaboration with Dami OPRS.

Table 1. Locations of fertiliser treatments (annual rates of Ca borate in g/palm) in Trial 149. The 'replicates' referred to below are replicates of the breeding trials and are plots of the fertiliser trial

OPRS Trial:		285			286			287			288	
Replicate:	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 occur in all three trials (635.607 x 742.207, 714.712 x 742.316, and 5035.216 x 742.316). Progeny 714 has a low OER and 635 has high OER and is being used in much of Dami 's commercial seed.

RESULTS

Even though treatments only commenced as recently as July 2003, they are already beginning to have an effect.

Across the whole trial, B significantly ($p<0.1$) increased FFB yield and SBW (Table 2) but had no effect on the number of bunches. This is in contrast to the 2004 results.

Table 2: Effect of B level on FFB and its components.

B Level (g/palm)	FFB (t/ha)	Number of Bunches (bunches/ha)	Bunch Weight (kg/bunch)
0	16.5	2930	5.7
80	17.4	2988	5.8
160	17.6	3020	5.8
	Significance level		
p	***0.077***	*0.296*	***0.096***
sed	*0.424*	*52.9*	*0.064*

As there were three progenies which were common to each breeding trial, it was possible to also look at the progeny effects on a subset of the data. There was a substantial effect of progeny on FFB yield and its components (Tables 3-6); and the relative responses were similar to those in 2004. In both years, 635.607 x 742.207 gave the greatest number of bunches (Table 5), and 5035.216 x 742.316 the greatest yield of FFB (Table 4). In contrast to 2004, this year 714.712 x 742.316 had the greatest SBW (Table 6).

The same three progenies are also in trial 148 and show a similar relative response.

Compared to the whole trial, there was also an even stronger effect of B on FFB and SBW within these three progenies, with increased B increasing both FFB and SBW (Tables 4 & 5).

Progeny 714.712 x 742.316, which has low OER, had the greatest response to B, with 3.0 t/ha increase in FFB and a 1.3 kg increase in SBW with an increase in B supply. It will be interesting to measure the effect of B on OER of this progeny.

Table 3: Effects (p value) of progeny and B treatment on FFB, Number of Bunches and Bunch Weight. p values less than 0.1 are shown in bold.

Source of variation	FFB	Number of Bunches	Bunch Weight
Progeny	**0.096**	**<0.001**	**<0.001**
B	**0.030**	0.235	**0.008**
Progeny.B	0.828	0.172	**0.060**

Table 4: Progeny and B effect on FFB (t/ha).

		Progeny				
		F:635.607 M:742.207	F:714.712 M:742.316	F:5035.216 M:742.316	**Mean**	*sed*
	0	17.1	16.8	19.6	**17.8**	
Boron	80	19.2	20.3	20.6	**20.0**	*0.86*
(g/palm)	160	19.5	19.5	21.0	**20.0**	
	Mean	**18.6**	**18.9**	**20.4**	**19.3**	
	sed		*0.86*			*1.49*

Table 5: Progeny and B effect on Number of Bunches (/ha).

		Progeny				
		F:635.607 M:742.207	F:714.712 M:742.316	F:5035.216 M:742.316	**Mean**	*sed*
	0	3413	2721	3250	**3128**	
Boron	80	3593	3122	3266	**3327**	*114*
(g/palm)	160	3728	2629	3374	**3244**	
	Mean	**3578**	**2824**	**3297**	**3233**	
	sed		*114*			*197*

Table 6: Progeny and B effect on Single Bunch Weight (kg).

		Progeny				
		F:635.607 M:742.207	F:714.712 M:742.316	F:5035.216 M:742.316	**Mean**	*sed*
	0	5.1	6.2	6.0	**5.7**	
Boron	80	5.4	6.5	6.3	**6.1**	*0.17*
(g/palm)	160	5.2	7.5	6.3	**6.4**	
	Mean	**5.2**	**6.8**	**6.2**	**6.1**	
	sed		*0.17*			*0.30*

TRIAL 403 SYSTEMATIC N FERTILISER TRIAL, KAURAUSU

INTRODUCTION

The purpose of the trial is to provide a response curve to N fertiliser that will be used to determine optimum N input in the area.

Factorial fertiliser trials with randomised spatial allocation of treatments have been generally showing poor responses to fertilisers in West New Britain. Yields and tissue nutrient concentrations in control plots have been generally higher than would be expected. It is suspected that fertiliser may be moving from plot to plot. Systematic designs are seen as a way of avoiding this problem, by ensuring that high and low rates of application are not adjacent. This trial was approved in the 1999 SAC meeting. There was a change of N source from ammonium chloride (AC) to ammonium nitrate (AN) in 2004.

The soil of the trial site is freely draining, formed on redeposited pumiceous volcanic ash and sand. Other background information of the trial is given in Table 1.

Table 1: Information on trial 403.

Trial number	403	Company	NBPOL
Date planted	1987	Planting Density (palm/ha)	120
Spacing	9.1 x 9.1	Pattern	Triangular
LSU or MU	Kaurausu Plantation, Division 1, Block I-3 and I-4, Field Mn	Soil type	Eutrandepts (Inceptisols)
Recording started	Jan 2001	Palm age (years after planting)	17
Topography	Flat	Planting material	Dami commercial DxP crosses
Progeny	Not known	Previous land use	Forest
Drainage	Freely draining	Area under trial soil type	Not known
Officer in charge	R. Pipai	Treatments started	Sept 2000

MATERIALS AND METHODS

The trial has 9 treatments, which are 9 rates of AN (0, 0.74, 1.48, 2.22, 2.96, 3.70, 4.44, 5.18 and 5.92 kg/palm/yr), and 8 replicates. Each plot is 4 rows of 15 palms. N rates (N 0 – N 5.92) vary systematically along the trial. The trial was laid out in 2000 and treatments commenced in September 2000. From 2000 to 2002, fertiliser was applied in two doses per year. From 2003, fertiliser application frequency is 2 doses/year in replicates 1, 3, 5, & 7 and 10 doses/year in replicates 2, 4, 6 & 8. In 2006, a full complement of basal fertilisers (non-treatment) will be added. For this trial (403) TSP 0.5; KIE 1.5; MOP 0.5; CaB 0.15 kg/palm/year will be added across the whole trial.

The trial is being analysed as a regression with 9 points (N levels). The 4 rows comprise one plot, but when analysing the data, it will be useful to examine the data on a row-by-row basis, to see if the effects of higher N levels encroach onto plots with lower N levels. Therefore, all recording is being done on the basis of rows (or in fact individual palms), rather than plots.

RESULTS AND DISCUSSION

Similar to last year, N fertilizer treatments had a significant effect on FFB yield when fitted to a quadratic function (Table 2, Figure 1) but not on other yield components. Since treatments commenced in 2001, N fertilizer has now had a significant effect on FFB yield in 2003, 2004 and 2005.

At this stage, the results suggest an application rate of 3-4 kg AN will provide maximum yield.

Table 2. Regression parameters for the effect of fertiliser application rate (kg/palm/year) on FFB yield and its components in 2005 (Trial 403).

	Intercept	AN	AN^2	*p*	r^2
FFB yield (t/ha)	23.2	1.39	-0.221	0.0.02	0.163
BNO/ha	900	4		0.275	0.017
SBW (kg)	27.1	-0.04		0.572	0.005

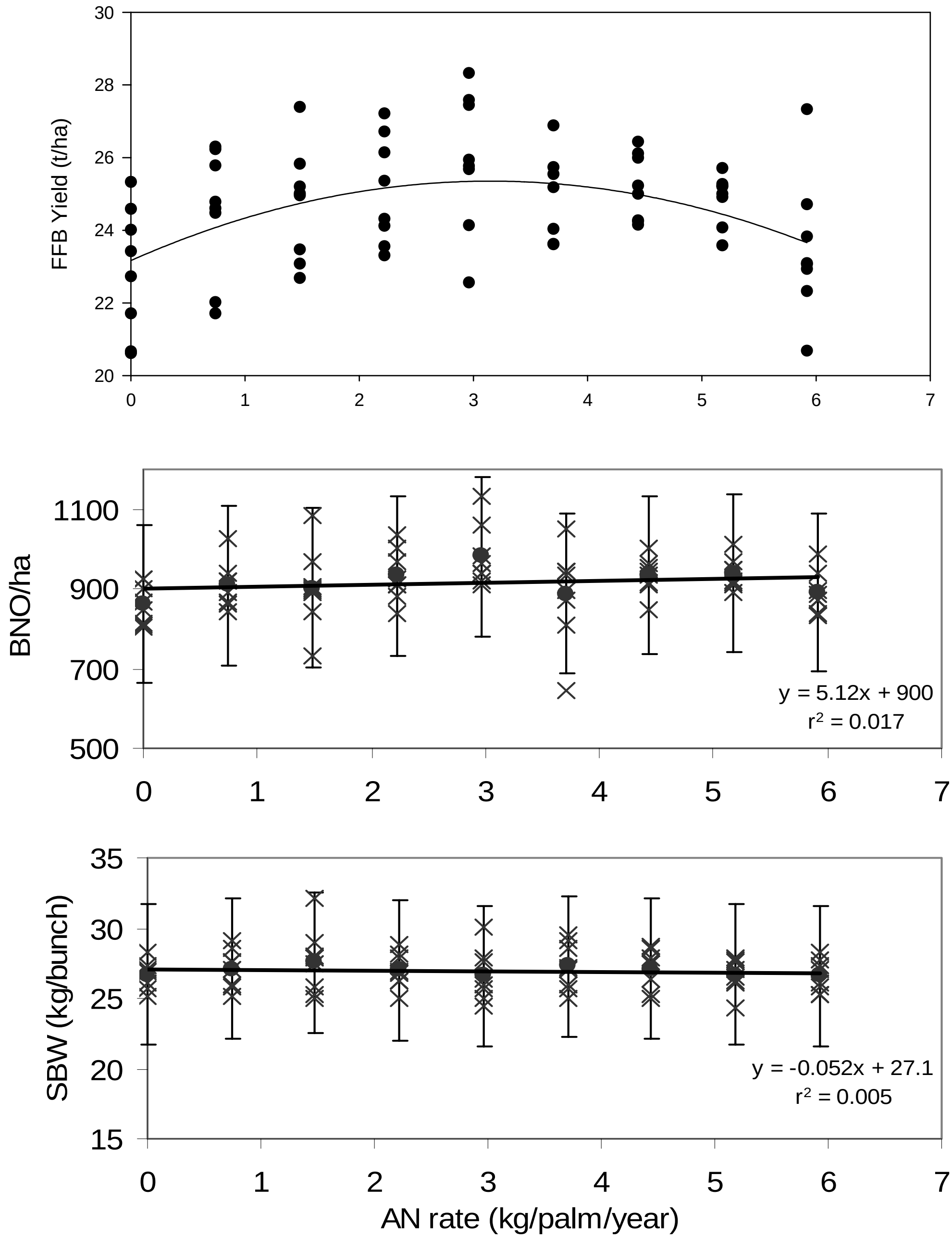


Figure 1. Effect of fertiliser rate (annual) on FFB yield, BNO/ha and SBW in 2005 (Trial 403). Crosses show values for each 60-palm plot (4 rows of 15), circles show means for treatment, and bars show s.d for BNO/ha and SBW.

FERTILISER RESPONSE TRIAL IN WEST NEW BRITAIN PROVINCE

(Hargy Oil Palms Ltd)

(James Kraip & Mike Webb)

TRIAL 204: FACTORIAL FERTILISER TRIAL AT NAVO PLANTATION

SUMMARY

Addition of 3 and 6 kg/palm of Ammonium chloride (N) significantly increased fresh fruit bunch (FFB) yield in 2005 and during the combined 2003-2005 period by 7-9 t/ha per year. On the other hand, 2 and 4 kg/palm of Triple superphosphate (P) and 3 kg/palm of potassium chloride (K) depressed FFB yield by about 0.1 – 0.8 t/ha in 2005 and during the combined 2003-2005 period. The effect of 3 kg/palm of kieserite (Mg) on FFB yield was only 0.8 t/ha in 2005.

However, the net effect of nitrogen (N) on FFB yield depends on P, K and Mg additions. A maximum FFB yield of 34.8 t/ha was achieved at a combined application of 6 kg AC, 2 kg TSP, 0 kg MOP and 3 kg KIE per palm. The recommendation for this area is to continue to include N fertilisers in routine application. Application of P, K and Mg should be considered based on annual leaf analysis results.

INTRODUCTION

The purpose of the trial is to provide fertiliser response information that will be useful in developing strategies for fertiliser application on oil palm (*Elaeis guineensis* Jacq.).

The soil of the trial site was formed on air-fall volcanic scoria. The soil is very young, course textured and freely draining. Other background information of the trial is given in Table 1.

Table 1: Trial 204 background information.

Trial number	204	Company	Hargy Oil Palms Ltd
Date planted	1986	Planting Density (palms/ha)	115
Spacing	9.3 x 9.3	Pattern	Triangular
LSU	Navo, field 9, block GH, Avenues 23 - 25	Soil type	Eutrandepts (Inceptisols)
Recording started	Jan 1989	Palm age (years after planting)	19
Topography	Flat	Planting material	Dami D x P
Progeny		Previous land use	Natural forest
Drainage	Freely draining	Area under trial soil type	
Officer in charge	W. Eremu	Treatments started	Jan 1989

MATRIALS AND METHODS

The N P K Mg trial was set up as a 3 x 3x 2 x 2 factorial design with 36 palms per plot, resulting in 36 treatments (Table 2). The 36 treatments were replicated twice and grouped into 2 blocks (not corresponding with replicates). The design allows for a further two-level factor to be imposed if desired in the future.

Treatments commenced in January 1989. The AC application was made in two doses per year, while the other fertilisers were applied once per year.

Recordings and measurements were taken on the central 16 palms in each plot. 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. 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 variable of interest using the GenStat statistical program.

Table 2. Fertiliser rates in Trial 204.

	Amounts (kg/palm/year)		
	Level 1	Level 2	Level 3
Ammonium Chloride (AC)	0	3	6
Triple Superphosphate (TSP)	0	2	4
Potassium Chloride (MOP)	0	3	-
Kieserite (KIE)	0	3	-

RESULTS AND DISCUSSION

Mean trend over time – FFB yield and yield components

Single bunch weight tended to increase over the course of the trial, while number of bunches (BNO) per ha decreased to a low of about 800 in 1999 (Figure 1). The decrease in BNO/ha in 1999 was probably caused by lack of moisture due to the prolonged dry season in most areas of PNG in 1997-1998. The BNO/ha tended to recover in 2000 but due to Sexava defoliating all the oil palm leaves in 2001, it dropped to minimum of about 400. After the oil palms recovered from Sexava damage, BNO/ha tended to increase from 2002 to 2005.

The net effect was that FFB yield decreased by about 8 t/ha to 23 t/ha in 1999 due to moisture stress but seemed to recover in 2000. However, defoliation of the oil palms leaves by the Sexava caused the FFB yield to drop to minimum of about 8 t/ha in 2001 but recovered progressively after 2001.

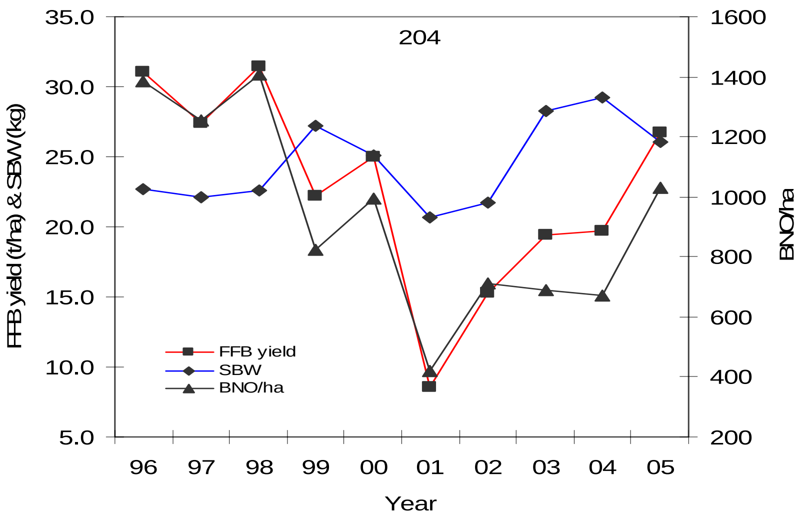


Figure 1: Mean FFB yield, BNO/ha and SBW from 1996 to 2005.

Main effects on FFB yield, yield components and tissue nutrient concentrations

Over the course of the trial, AC generally had a significant effect on the FFB yield (Figure 2), while TSP, MOP and KIE had no significant effect on the FFB yield. The leaf nutrient concentrations were affected by the fertiliser treatments in some years in this trial.

Addition of either 3 or 6 kg/palm of AC produced 8-9 more t/ha of FFB yield in 2005 compared to 0 kg/palm of AC, and these effects were statistically significant (Table 3). The significant increases in FFB yield were due to significant increases in BNO/ha and SBW. Similarly, 3 and 6 kg/palm of AC increased average FFB yield (7-9 more t/ha) significantly during the combined 2003-2005 period compared to 0 kg/palm of AC. Leaflet N concentrations in 2005 were increased significantly by adding AC but the concentrations were lower than the critical 2.30% DM (Tables 4 & 5).

Addition of TSP decreased FFB yield by 0.1-0.7 t/ha in 2005, mainly caused by depressive effect of 2 and 4 kg/palm of TSP on the SBW (Table 3) however, this effect was not significant. Also during the combined 2003-2005 period, 2 and 4 kg/palm of TSP had a depressive effect on SBW but this did not affect the FFB yield. The average FFB yield, for the combined 2003-2005 period, increased by 0.2-0.5 t/ha with 2 and 4 kg/palm of TSP compared to 0 kg/palm of TSP, but again these effects were not significant. Leaflet P concentrations were below the critical value of 0.140% DM in 2005 (Tables 4 & 5).

Compared to 0 kg/palm, 3 kg/palm of MOP decreased FFB yield by 0.3 t/ha in 2005 and this effect was due to the depressive effect of MOP on BNO/ha and SBW (Table 3). The effects of MOP during the combined 2003-2005 period were similar to the effects in 2005. As with TSP, these small effects were not significant. The lack of a positive effect on FFB yield could possibly be explained by the relatively high rachis K concentrations in 2005 (Tables 4 & 5).

The effect of 3 kg/palm of KIE on FFB yield was an increase of 0.8 t/ha in 2005 (but not significant) and no increase in FFB yield during the combined 2003–3005 period, compared to the 0 kg/palm of KIE (Table 3). Leaflet Mg concentrations were above the critical of 0.20% in 2005, and this could be a possible explanation for a lack of FFB yield response to Mg treatment (Tables 4 & 5).

Table 3: Main effects of fertiliser treatments on FFB yield in trial 204

	2003-2005			2005		
	FFB yield (t/ha)	BNO (per ha)	SBW (kg)	FFB yield (t/ha)	BNO (per ha)	SBW (kg)
AC 0	**18.7**	**786**	**23.9**	**20.9**	**929**	**22.6**
AC 3	**26.1**	**901**	**29.2**	**29.3**	**1059**	**28.2**
AC 6	**27.8**	**954**	**29.3**	**29.9**	**1109**	**27.4**
p	***<0.001***	***<0.001***	***<0.001***	***<0.001***	***0.001***	***<0.001***
TSP 0	23.9	857	27.9	27.0	1016	26.6
TSP 2	24.1	880	27.3	26.9	1047	25.9
TSP 4	24.6	903	27.1	26.3	1034	25.6
p	*0.76*	*0.256*	*0.321*	*0.285*	*0.792*	*0.281*
s.e.d.	*0.9*	*27*	*0.5*	*1.3*	*47*	*0.6*
$Lsd_{0.05}$	*1.9*	*55*	*1.1*	*2.7*	*93*	*1.3*
MOP 0	24.6	892	27.6	27.3	1050	26.3
MOP 3	23.8	868	27.3	26.1	1015	25.9
p	*0.275*	*0.285*	*0.403*	*0.447*	*0.352*	*0.446*
KIE 0	24.2	888	27.2	26.3	1026	25.8
KIE 3	24.2	872	27.8	27.1	1038	26.4
p	*0.966*	*0.485*	*0.181*	*0.103*	*0.751*	*0.237*
s.e.d.	*0.8*	*22*	*0.4*	*1.1*	*37*	*0.5*
$Lsd_{0.05}$						
GM	*24.2*	*880*	*27.4*	*26.7*	*1032*	*26.1*
CV %	*13*	*11*	*7*	*17*	*15*	*8*

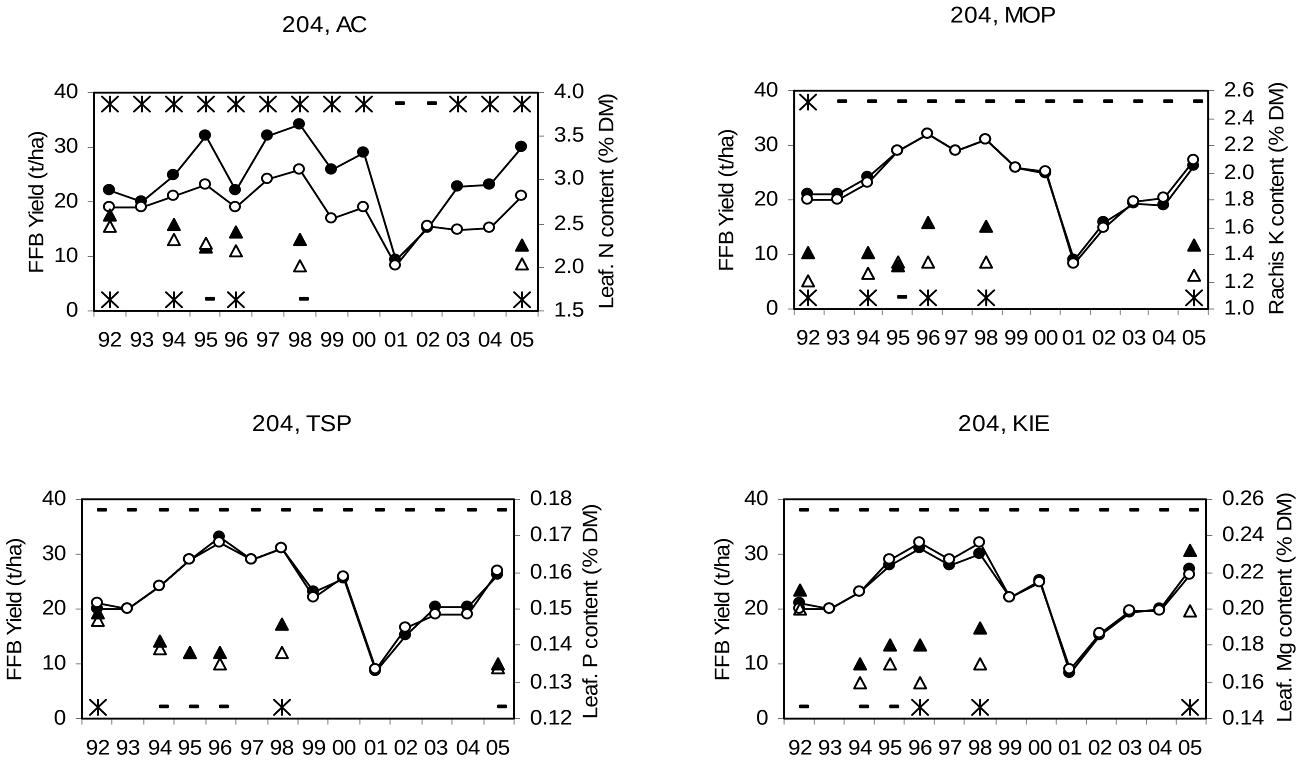


Figure 2. Main effects of AC, MOP, TSP and KIE over the course of Trial 204. Lines with circles are FFB yields and triangles are tissue nutrient concentrations. Full symbols represent the maximum level of application, and empty symbols zero application. Symbols along the top of the graph indicate significance 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.

Table 4. Effects (p values) of treatments on frond 17 (F17) nutrient concentrations in 2005 (Trial 204). p values <0.05 are indicated in bold.

	Leaflet						Rachis			
Source	N	P	K	Mg	Cl	S	Ash	N	P	K
AC	**<0.001**	**<0.001**	**0.008**	**<0.001**	**<0.001**	**0.002**	**<0.001**	**<0.001**	**<0.001**	**<0.001**
TSP	**0.005**	0.125	0.272	0.494	0.183	0.441	**0.040**	0.861	**<0.001**	0.054
MOP	0.319	0.524	0.367	0.115	**<0.001**	0.178	**<0.001**	0.536	0.275	**<0.001**
KIE	0.629	0.831	0.221	**<0.001**	0.058	0.293	0.119	**<0.001**	0.869	0.076
AC.TSP	0.128	0.058	0.470	0.566	0.794	0.532	**0.039**	0.532	**<0.001**	0.343
AC.MOP	0.384	0.513	**0.043**	0.250	**0.001**	0.812	**0.003**	0.592	0.383	**0.002**
TSP.MOP	0.744	0.503	0.095	0.960	0.912	0.441	0.909	0.258	0.794	0.756
AC.KIE	0.416	0.897	**0.016**	0.795	0.638	0.174	0.124	**<0.001**	0.762	**0.034**
TSP.KIE	0.485	0.897	0.781	0.135	0.095	0.310	0.569	0.747	0.527	0.865
MOP.KIE	0.911	0.654	0.167	0.386	0.803	0.880	0.414	0.372	0.709	0.492
AC.TSP.MOP	0.891	0.849	0.829	0.435	0.727	0.267	0.068	0.053	0.946	0.983
AC.TSP.KIE	0.282	0.600	0.575	0.657	0.929	0.338	0.643	0.981	0.582	0.140
AC.MOP.KIE	0.978	0.741	0.660	0.942	0.229	0.493	0.355	0.587	1.000	0.852
TSP.MOP.KIE	0.964	0.889	0.469	0.913	0.489	0.911	0.457	0.444	0.138	0.250
AC.TSP.MOP.KIE	**0.027**	0.233	0.843	0.774	0.375	0.164	0.429	0.267	0.454	0.513
CV%	*4*	*4*	*5*	*12*	*10*	*5*	*9*	*13*	*29*	*8*

Table 5. Main effects of treatments on F17 nutrient concentrations in 2005, in units of % dry matter (Trial 204). Effects with p<0.05 are shown in bold.

	Leaflet						Rachis			
Source	N	P	K	Mg	Cl	S	Ash	N	P	K
AC 0	**2.03**	**0.132**	**0.64**	**0.262**	**0.405**	**0.162**	**5.09**	**0.234**	**0.149**	**1.51**
AC 3	**2.19**	**0.136**	**0.62**	**0.204**	**0.500**	**0.167**	**4.77**	**0.153**	**0.072**	**1.32**
AC 6	**2.26**	**0.138**	**0.64**	**0.182**	0.491	0.170	**4.41**	**0.310**	**0.055**	**1.26**
TSP 0	**2.20**	0.134	0.64	0.212	0.453	0.168	**4.86**	0.167	**0.051**	1.41
TSP 2	**2.15**	0.137	0.63	0.220	0.479	0.165	**4.85**	0.163	**0.102**	1.35
TSP 4	**2.13**	0.135	0.63	0.215	0.464	0.165	**4.56**	0.168	**0.121**	1.33
sed	*0.03*	*0.0014*	*0.008*	*0.007*	*0.014*	*0.002*	*0.13*	*0.010*	*0.008*	*0.06*
MOP 0	2.17	0.135	0.63	0.221	**0.441**	0.168	**4.48**	0.168	0.088	**1.25**
MOP 3	2.15	0.135	0.63	0.211	**0.489**	0.165	**5.03**	0.163	0.095	**1.47**
KIE 0	2.15	0.135	0.63	**0.199**	0.476	0.165	4.67	**0.185**	0.091	1.34
KIE 3	2.16	0.135	0.64	**0.232**	0.454	0.167	4.84	**0.146**	0.092	1.39
sed	*0.02*	*0.0012*	*0.007*	*0.006*	*0.011*	*0.002*	*0.11*	*0.008*	*0.006*	*0.05*
GM	*2.16*	*0.135*	*0.63*	*0.216*	*0.465*	*0.166*	*4.76*	*0.266*	*0.092*	*1.36*

Interaction between fertiliser treatments

The effect of the interaction between AC, TSP, MOP and KIE on the FFB yield was significant for the period 2003 to 2005 and for 2005 alone (Table 6). The maximum FFB yields of 30.1 and 34.8 t/ha during the combined 2003-2005 period and in 2005 respectively, were produced by a combined addition of 6 kg of AC, 2 kg of TSP, 0 kg of MOP and 3 kg KIE per palm per year.

Table 6: Effect of interaction between AC, TSP, MOP and KIE on FFB yield (t/ha) during the combined 2003-2005 period and in 2005.

	2003 - 2005			2005		
	AC 0	AC 3	AC 6	AC 0	AC 3	AC 6
TSP 0, MOP 0, KIE 0	19.0	26.0	28.2	19.0	30.3	30.6
TSP 2, MOP 0, KIE 0	16.4	27.3	26.9	17.1	32.3	28.1
TSP 4, MOP 0, KIE 0	22.8	27.8	26.0	28.9	26.6	26.6
TSP 0, MOP 3, KIE 0	23.0	26.2	25.7	26.4	27.8	29.6
TSP 2, MOP 3, KIE 0	15.9	25.7	28.0	16.4	29.9	32.7
TSP 4, MOP 3, KIE 0	13.8	27.8	28.8	14.3	30.8	25.7
TSP 0, MOP 0, KIE 3	21.4	24.0	28.6	26.9	28.5	30.2
TSP 2, MOP 0, KIE 3	21.0	26.4	30.1	22.3	30.2	34.8
TSP 4, MOP 0, KIE 3	18.1	23.7	29.5	20.4	26.2	32.2
TSP 0, MOP 3, KIE 3	14.5	26.5	23.7	15.1	30.8	28.1
TSP 2, MOP 3, KIE 3	15.0	27.5	29.3	16.9	30.3	32.0
TSP 4, MOP 3, KIE 3	24.1	24.2	28.2	27.2	28.0	28.2
p		*0.003*			*<0.001*	
sed		*2.7*			*3.7*	
lsd		*5.5*			*7.4*	
GM		*24.2*			*26.7*	

CONCLUSION AND RECOMENDATION

AC had a significant effect on the FFB yield in this trial while TSP, MOP and KIE had no significant effect on FFB yield. However, the net effect of N on FFB yield depends on P, K and Mg application. The maximum yield was achieved at 6 kg AC, 2 kg TSP 0 kg MOP and 3 kg KIE per palm year. However, in 2004 the maximum yield was achieved at 6 kg SOA, 4 kg TSP, 3 kg MOP and 3 kg KIE per palm year.

The leaf nutrient concentrations were affected by fertiliser treatments at various stages of the trial.

The recommendation for this area is to continue to include N fertilisers in routine application. Application of P, K and Mg should be considered based on annual leaf analysis results.

TRIAL 205: EFB/FERTILISER TRIAL AT HARGY PLANTATION

SUMMARY

Triple superphosphate (TSP), kieserite (KIE) and empty fruit bunch (EFB) significantly increased fresh fruit bunch (FFB) yield in some years but the results were not consistent over the course of the trial. Results for the last 2 years indicate that there was no significant effect of TSP and KIE on FFB yield, however EFB increased FFB yield by only small increments.

Leaf P, Mg and K concentrations were significantly increased by TSP, KIE and EFB respectively.

Of the physiological growth parameters measured, only petiole cross-section (PCS), dry frond weight (FW), frond dry matter (FDM), total dry matter (TDM) and vegetative dry matter (VDM) were significantly increased by EFB treatment. Kieserite had no significant effect on all the physiological growth parameters, while TSP had a significant but negative effect only on Bunch Index (BI).

Progeny had a significant effect on FFB yield and all the physiological growth parameters.

As the effects of TSP, KIE and EFB on the FFB yield vary over the course of the trial, it is recommended that this trial be continued.

INTRODUCTION

The purpose of the trial is to investigate the response of oil palm (*Elaeis guineensis* Jacq.) to applications 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.

For the first 36 months, the palms received a standard immature palm fertiliser input. The fertiliser treatments were first applied in June 1997. A blanket application of 3 kg/palm/year of ammonium chloride (AC) is applied across the trial.

The soil of the trial site is freely draining andosol, formed on intermediate to basic volcanic ash. Other background information of the trial is given in Table 1.

Table 1: Trial 205 background information

Trial number	205	Company	Hargy Oil Palms Ltd
Date planted	Aug 1993	Planting Density (palms/ha)	135
Spacing	8.6 x 8.6	Pattern	Triangular
LSU or MU	Hargy Area 9, blocks 7 & 8	Soil type	Eutrandepts (Inceptsols)
Recording started	Aug 1996	Palm age (years after planting)	12
Topography	Gentle mid-slope, sloping towards NE	Planting material	Dami D x P
Progeny*		Previous land use	Oil palm
Drainage	Freely draining	Area under trial soil type	
Officer in charge	W. Eremu	Treatment started	June 1997

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

MATERIALS AND METHODS

There are eight treatments comprising all factorial combinations of EFB, TSP and KIE each at two levels (Table 2). The treatments are replicated six times, with each replicate comprising one block. 36 palm plots (6x6 palms) are used, the central 16 palms are recorded and the outer 20 palms are regarded as guard row palms. The recorded palms comprise 16 different identified Dami DxP progenies, which have been arranged in a random spatial configuration in each plot. The 16 progenies are shown in Table 3. The trial is analysed as a split-plot design.

Recordings and measurements were taken on the central 16 palms in each plot. 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. 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 2: Fertiliser and EFB treatments used 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, and Leaf Analysis

Mean trend over time

Fresh fruit bunch yield increased to a peak of about 45 t/ha in 2000 and then decreased progressively to about 25 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 (BNO) per ha. However, generally BNO/ha decreased progressively until 2002 when it began to stabilise. On the other hand, SBW increased progressively over the course of the trial.

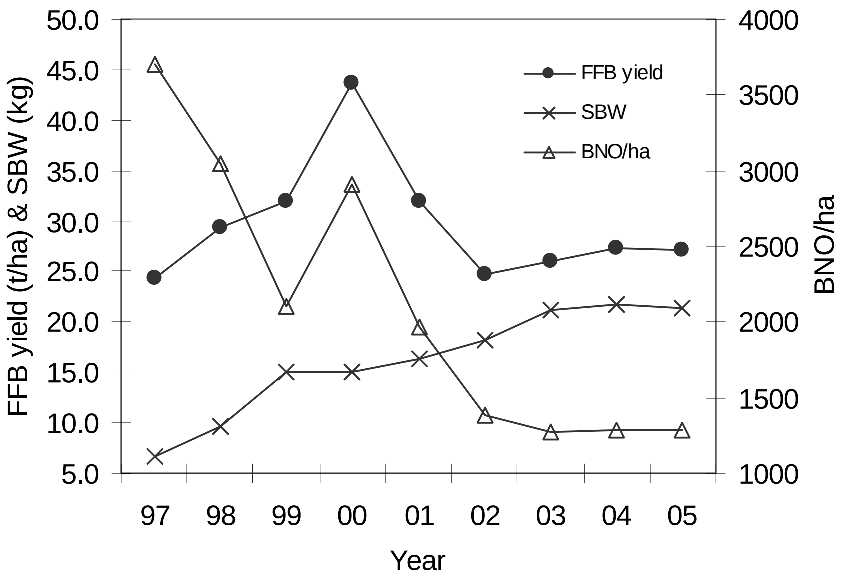


Figure1: Mean FFB yield, BNO/ha and SBW from 1997 to 2005.

Main effects on FFB yield, yield components and leaf nutrient concentrations

Over the course of trial, addition of 3 kg/palm of TSP increased FFB yield significantly in the first three years but not in the later years, and it began to have a suppressive effect since 2004 (Figure 2). Kieserite application increased FFB yield significantly in 1999 and 2002, but tended to have a suppressive effect in 2005. EFB application on the other hand resulted in small incremental increases in FFB yield over the course of the trial. Despite significant effect of TSP and EFB treatments on leaflet P and rachis K concentrations, their levels continue to decrease, irrespective of treatment over the course of the trial (Figure 2). Application of 3 kg/palm of KIE on the other hand increased leaflet Mg concentration significantly only over time.

TSP, KIE and EFB had no significant effect on FFB yield during the combined period 2003-2005 and in 2005 (Tables 4 and 5). Addition of 3 kg/palm of TSP resulted in a decrease of FFB yield by about 1-2 t/ha during the combined 2003-2005 period and in 2005, compared to the FFB yield for 0 kg/palm of TSP however this was not significant. The BNO/ha and SBW for the same period were also decreased by addition of 3 kg/palm of TSP compared to 0 kg/palm of TSP.

Similar to the effects of TSP, KIE had a suppressive effect on FFB yield, BNO/ha and SBW during the combined 2003-2005 period and in 2005. On the other hand, addition of 230 kg/palm of EFB increased FFB yield by about 1.5 t/ha during the combined 2003-2005 period and in 2005, although the 2005 effects were not statistically significant.

Despite having no significant effect on the FFB yield in 2005, TSP, KIE and EFB significantly increased leaflet P and Mg, and rachis K concentrations (Table 6 and 7).

Progeny had a significant effect on the FFB yield during the combined 2003-2005 period, but not in 2005 (Tables 4 and 5). The significant effect of progeny on the FFB yield during the combined period was due to its significant effect on the SBW.

Year to year variation in the FFB yield existed between the high yielding progenies but the poorest yielding progenies (**E** and **G**) were the same in the last five years.

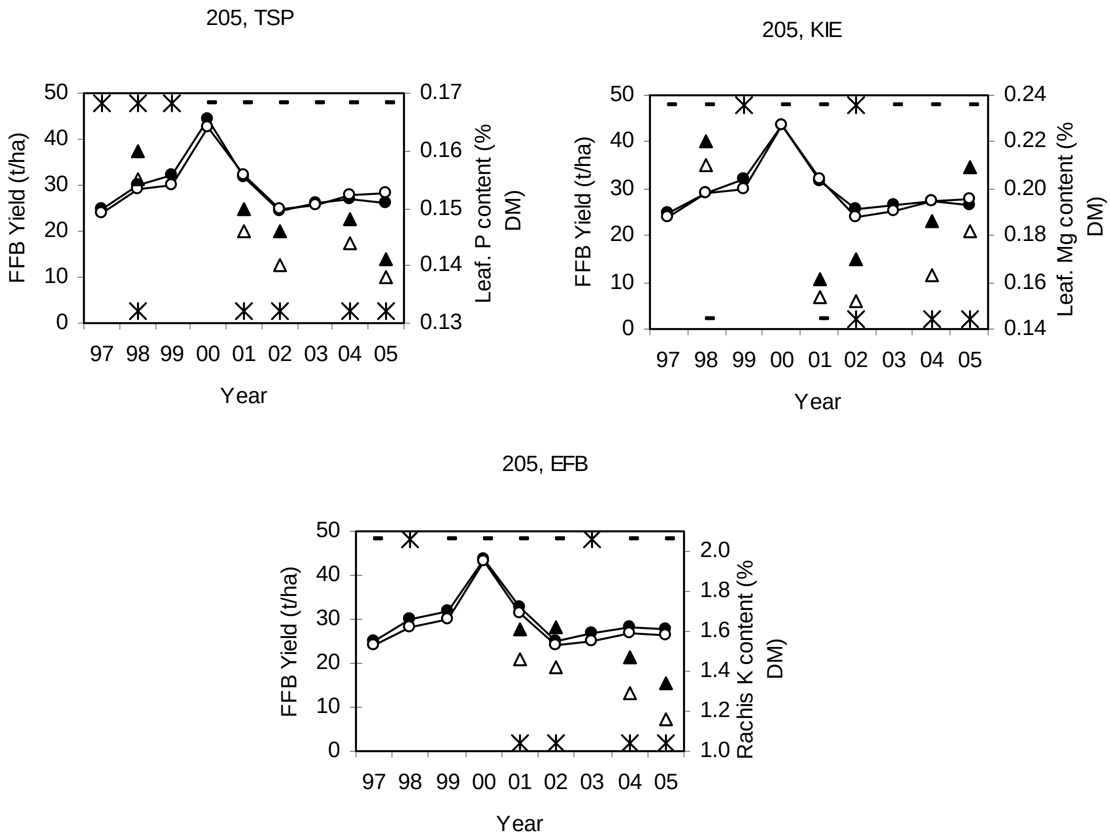


Figure 2. Main effects of TSP, KIE and EFB over the course of Trial 205. Lines are FFB yields and triangles are tissue concentrations. Full symbols represent the maximum level of application, and empty symbols the lowest level. Symbols along the top of the graph indicate significance of the main effect on yield, and along the bottom indicate significance of the main effect on tissue concentration. Stars indicate significance ($p<0.05$) and dashes non-significance.

Table 4: Effects (p values) of treatments on FFB yield and its components in 2002-2004 and 2004 (Trial 205). p values <0.05 are indicated in bold.

	2003-2005			2005		
Source	FFB yield	BNO/ha	SBW (kg)	FFB yield	BNO/ha	SBW (kg)
Rep.Plot stratum						
TSP	0.238	0.108	0.418	0.058	**0.023**	0.540
KIE	0.859	0.991	0.608	0.221	0.255	0.865
EFB	**0.049**	0.447	**0.019**	0.124	0.326	**0.043**
TSP.KIE	0.565	0.980	0.304	0.729	0.902	0.802
TSP.EFB	0.918	0.686	0.383	0.459	0.322	0.861
KIE.EFB	0.429	0.131	0.134	0.751	0.360	0.265
TSP.KIE.EFB	0.609	0.166	0.056	0.628	0.112	**0.024**
CV%	*9*	*9*	*4*	*12*	*11*	*5*
Rep.Plot.Progeny stratum						
Prog	**<0.001**	0.107	**<0.001**	0.066	0.679	**<0.001**
TSP.Prog	0.737	0.552	0.514	0.073	0.276	0.350
KIE.Prog	0.863	0.867	0.756	0.852	0.876	0.719
EFB.Prog	0.799	0.544	0.398	0.714	0.735	0.640
TSP.KIE.Prog	0.456	0.574	0.603	0.304	0.659	0.230
TSP.EFB.Prog	0.956	0.431	0.223	0.793	0.577	0.204
KIE.EFB.Prog	0.936	0.871	0.156	0.915	0.337	0.448
TSP.KIE.EFB.Prog	**0.023**	**0.025**	0.087	**0.044**	0.054	0.063
CV %	*26*	*27*	*16*	*37*	*36*	*19*

Table 5: Main effects of treatments on FFB yield (t/ha) and its components (Trial 205). Effects with p<0.05 are shown in bold.

	2003-2005			2005		
	FFB yield (t/ha)	BNO/ha	SBW (kg)	FFB yield (t/ha)	BNO/ha	SBW (kg)
TSP 0	27.0	1287	21.3	28.1	**1331**	21.3
TSP 3	26.1	1234	21.5	26.2	**1232**	21.5
KIE 0	26.6	1260	21.5	27.7	1305	21.4
KIE 3	26.5	1260	21.3	26.6	1258	21.4
EFB 0	**25.8**	1248	**21.1**	26.4	1265	**21.1**
EFB 230	**27.3**	1272	**21.7**	27.9	1302	**21.7**
Fert. s.e.d.	*0.7*	*32*	*0.3*	*0.9*	*41*	*0.3*
A	**27.3**	1264	**21.7**	27.7	1282	**21.7**
B	**27.9**	1166	**24.2**	28.4	1176	**24.4**
C	**26.7**	1252	**21.5**	26.1	1242	**21.2**
D	**26.8**	1281	**21.1**	26.0	1257	**20.7**
E	**23.0**	1192	**19.8**	23.3	1183	**20.0**
F	**27.1**	1247	**22.3**	28.2	1311	**21.9**
G	**22.5**	1169	**19.6**	24.1	1236	**19.5**
H	**27.2**	1325	**20.9**	29.3	1388	**21.3**
I	**28.6**	1388	**21.0**	27.5	1358	**20.7**
J	**28.2**	1269	**22.5**	29.4	1322	**22.5**
K	**26.9**	1245	**22.0**	28.0	1337	**21.3**
L	**25.4**	1195	**21.8**	26.5	1254	**21.5**
M	**28.6**	1294	**22.5**	29.9	1345	**22.6**
N	**26.0**	1263	**20.7**	27.1	1267	**21.7**
O	**26.7**	1295	**20.9**	26.8	1268	**21.2**
P	**26.0**	1318	**19.9**	25.9	1276	**20.2**
Prog. s.e.d.	*1.4*	*69*	*0.7*	*2.0*	*94*	*0.8*
GM	*26.5*	*1260*	*21.4*	*27.1*	*1281*	*21.4*

Table 6: Effects (p values) of treatments on frond 17 (F17) nutrient concentrations 2005 (Trial 205). p values <0.05 are indicated in bold.

	Leaflet						Rachis			
Source	Ash	N	P	K	Mg	S	Ash	N	P	K
TSP	0.787	**0.018**	**0.003**	**<0.001**	0.212	**0.019**	0.517	0.091	**<0.001**	0.152
KIE	0.765	0.064	0.170	0.731	**<0.001**	0.870	0.257	0.423	0.349	0.160
EFB	0.102	**<0.001**	**<0.001**	**<0.001**	**0.030**	**<0.001**	**0.038**	**0.004**	0.257	**<0.001**
TSP.KIE	0.268	0.423	0.275	0.099	0.678	0.624	0.331	0.730	0.184	0.416
TSP.EFB	0.967	**0.025**	0.120	0.736	0.562	0.870	0.563	0.566	0.946	0.064
KIE.EFB	0.377	0.612	0.738	0.434	0.803	0.416	0.478	**0.004**	0.591	0.571
TSP.KIE.EFB	0.052	0.354	0.599	0.757	0.163	**0.039**	0.754	**0.034**	0.349	0.709
CV%	*3*	*3*	*2*	*4*	*9*	*5*	*9*	*4*	*10*	*8*

Table 7: Main effects of treatments on F17 nutrient concentrations in 2005, in units of % dry matter, except for B (mg/kg) (Trial 205). Effects with $p<0.05$ are shown in bold.

	Leaflet nutrient concentration						Rachis concentration			
Source	Ash	N	P	K	Mg	S	Ash	N	P	K
TSP 0	13.9	**2.35**	**0.138**	**0.69**	0.193	**0.175**	4.08	0.278	**0.065**	1.27
TSP 3	13.9	**2.30**	**0.141**	**0.65**	0.199	**0.169**	4.14	0.284	**0.104**	1.23
KIE 0	13.9	2.33	0.140	0.67	**0.182**	0.172	4.17	0.283	0.085	1.27
KIE 3	13.9	2.32	0.139	0.67	**0.209**	0.172	4.05	0.280	0.083	1.33
EFB 0	14.0	**2.26**	**0.137**	**0.65**	**0.201**	**0.164**	**4.00**	**0.275**	0.083	**1.16**
EFB 230	13.8	**2.39**	**0.142**	**0.69**	**0.190**	**0.180**	**4.22**	**0.287**	0.086	**1.34**
sed	*0.1*	*0.02*	*0.001*	*0.01*	*0.005*	*0.003*	*0.11*	*0.02*	*0.03*	*0.03*
GM	*13.9*	*2.33*	*0.140*	*0.67*	*0.196*	*0.172*	*4.11*	*0.281*	*0.084*	*1.25*

Interaction between fertiliser treatments

The effect of the interaction between TSP, KIE and EFB on the FFB yield was not significant for the combined 2003-2005 period and in 2005 (Tables 4 and 8).

Table 8: Effect of TSP, KIE and EFB on FFB yield (2003-2005 and 2005).

	2003-2005				2005			
	KIE 0		KIE 3		KIE 0		KIE 3	
	EFB 0	EFB 230	EFB 0	EFB 230	EFB 0	EFB 230	EFB 0	EFB 230
TSP 0	26.1	27.6	26.5	27.7	27.5	29.5	26.5	28.8
TSP 3	25.2	27.6	25.6	26.2	26.2	27.7	25.5	25.5
p	*0.609*				*0.628*			
GM	*26.5*				*27.1*			
sed	*3.9*				*5.8*			

Effects of fertiliser treatments on physiological growth parameters

The EFB treatment significantly increased PCS, FW, FDM, TDM and VDM in 2005 (Tables 9 and 10). However, the corresponding effect of EFB treatment on FFB yield was only small and statistically not significant. Kieserite had no significant effect on any of the physiological growth parameters, while TSP had a significant but negative effect only on Bunch Index (BI). Uncorrected leaf area (ULA), frond area (FA), leaf area index (LAI) and bunch dry matter (BDM) were not affected by any of the fertiliser treatment.

Table 9: Effects (p values) of fertiliser treatments on physiological growth parameters in 2005 (Trial 205). p values <0.05 are indicated in bold.

Source	Radiation Interception					Dry matter production (t/ha)				Conversion
Rep.Plot stratum	PCS (cm^2)	ULA (m2)	FW (kg)	FA (m^2)	LAI	FDM	BDM	TDM	VDM	BI
TSP	0.240	0.266	0.240	0.266	0.931	0.946	0.055	0.115	0.644	**0.009**
KIE	0.413	0.362	0.413	0.362	0.752	0.921	0.191	0.307	0.856	0.213
EFB	**0.002**	0.497	**0.002**	0.497	0.018	**<0.001**	0.111	**0.003**	**<0.001**	0.396
TSP.KIE	0.529	0.783	0.529	0.783	0.530	0.252	0.790	0.845	0.327	0.511
TSP.EFB	0.139	0.936	0.139	0.936	0.762	0.144	0.756	0.782	0.208	0.230
KIE.EFB	0.655	0.447	0.655	0.447	0.833	0.651	0.754	0.927	0.731	0.240
TSP.KIE.EFB	0.060	**0.013**	0.060	**0.013**	**0.013**	0.053	0.527	0.846	0.103	0.057
CV%	*4*	*4*	*4*	*4*	*6*	*5*	*12*	*7*	*5*	*6*
Rep.Plot.Progeny stratum										
Prog	**<0.001**	**0.001**	**<0.001**	**0.001**	**<0.001**	**<0.001**	**0.094**	**0.002**	**<0.001**	**0.012**
TSP.Prog	0.871	0.240	0.871	0.240	0.413	0.993	0.088	0.098	0.928	0.302
KIE.Prog	0.428	0.720	0.428	0.720	0.530	0.376	0.815	0.728	0.391	0.618
EFB.Prog	0.432	0.126	0.432	0.126	0.183	0.490	0.652	0.549	0.451	0.354
TSP.KIE.Prog	0.453	0.101	0.453	0.101	0.671	0.326	0.358	0.171	0.201	0.577
TSP.EFB.Prog	0.504	0.228	0.504	0.228	0.337	0.155	0.735	0.574	0.163	0.815
KIE.EFB.Prog	**0.033**	0.435	**0.033**	0.435	0.256	**0.019**	0.906	0.819	**0.038**	0.533
TSP.KIE.EFB.Prog	0.055	0.899	0.055	0.899	0.944	0.062	**0.027**	**0.005**	**0.019**	0.128
CV %	*14*	*19*	*13*	*19*	*22*	*15*	*36*	*20*	*14*	*22*

Table 10: Main effects of fertiliser treatments on physiological growth parameters in 2005 (Trial 205). Effects with values <0.05 are indicated in bold.

Treatment	Radiation Interception					Dry matter production (t/ha)				Conversion
Rep.Plot stratum	PCS (cm2)	ULA (m2)	FW (kg)	FA (m2)	LAI	FDM	BDM	TDM	VDM	BI
TSP 0	51.1	9.6	5.4	5.5	2.5	14.3	15.0	32.5	17.6	**0.45**
TSP 3	50.4	9.5	5.4	5.4	2.5	14.3	14.0	31.4	17.4	**0.43**
KIE 0	50.5	9.5	5.4	5.4	2.5	14.3	14.8	32.3	17.5	0.44
KIE 3	51.0	9.6	5.4	5.5	2.5	14.3	14.1	31.6	17.5	0.43
EFB 0	**49.7**	9.5	**5.3**	5.4	2.4	**13.7**	14.1	**30.9**	**16.8**	0.44
EFB 230	**51.8**	9.6	**5.5**	5.5	2.5	**14.9**	14.9	**33.1**	**18.2**	0.44
Fert. s.e.d.	*0.6*	*0.1*	*0.06*	*0.06*	*0.04*	*2*	*0.5*	0.7	0.3	0.1
Rep.Plot.Progeny stratum										
A	**52.8**	**10.8**	**5.6**	**6.1**	**2.9**	**15.0**	**14.7**	**33.0**	**18.3**	**0.43**
B	**54.2**	**9.6**	**5.7**	**5.5**	**2.6**	**15.4**	**15.1**	**33.8**	**18.8**	**0.43**
C	**48.8**	**9.4**	**5.2**	**5.4**	**2.5**	**13.8**	**13.9**	**30.8**	**16.9**	**0.43**
D	**36.5**	**9.3**	**5.0**	**5.3**	**2.5**	**13.5**	**13.9**	**30.4**	**16.6**	**0.45**
E	**48.2**	**9.6**	**5.1**	**5.5**	**2.6**	**13.9**	**12.4**	**29.3**	**16.8**	**0.41**
F	**45.9**	**9.2**	**4.9**	**5.2**	**2.4**	**13.2**	**14.8**	**31.2**	**16.3**	**0.46**
G	**56.0**	**9.1**	**5.9**	**5.2**	**2.4**	**15.4**	**13.1**	**31.7**	**18.6**	**0.40**
H	**54.2**	**9.6**	**5.7**	**5.5**	**2.4**	**14.9**	**15.8**	**33.8**	**18.3**	**0.46**
I	**50.7**	**10.0**	**5.4**	**5.7**	**2.5**	**14.3**	**14.8**	**32.4**	**17.6**	**0.45**
J	**49.5**	**9.2**	**5.3**	**5.2**	**2.4**	**14.2**	**15.6**	**33.1**	**17.5**	**0.46**
K	**45.6**	**9.1**	**4.9**	**5.2**	**2.3**	**12.8**	**14.9**	**30.7**	**15.8**	**0.47**
L	**49.9**	**9.7**	**5.3**	**5.6**	**2.6**	**14.3**	**14.2**	**31.7**	**17.5**	**0.43**
M	**53.8**	**9.9**	**5.7**	**5.6**	**2.6**	**15.2**	**16.0**	**34.6**	**18.6**	**0.45**
N	**54.0**	**9.6**	**5.7**	**5.5**	**2.5**	**14.9**	**14.5**	**32.7**	**18.1**	**0.42**
O	**50.4**	**9.0**	**5.3**	**5.2**	**2.3**	**13.8**	**14.3**	**31.3**	**17.0**	**0.44**
P	**51.6**	**9.6**	**5.5**	**5.5**	**2.5**	**14.4**	**13.8**	**31.3**	**17.5**	**0.42**
Prog. s.e.d.	*1.4*	*0.4*	*0.15*	*0.22*	*0.11*	*4*	*1.1*	*1.3*	*0.5*	*0.2*
GM	*50.8*	*9.5*	*5.4*	*5.4*	*2.5*	*14.3*	*14.5*	*32*	*17.5*	*0.44*

CONCLUSIONS AND RECOMENDATION

Generally TSP, KIE and EFB treatments had no significant effect on FFB yield over the course of the trial. During the combined 2003-2005 period and in 2005, 3 kg/palm of either TSP or KIE suppressed FFB yield by about 1-2 t/ha (but not significant). Only EFB increased FFB yield by about 1.5 t/ha during the combined 2003-2005 period and in 2005. Prior to 2004, fertiliser treatments had a positive effect on FFB yield but this trend started to change since 2004.

Progeny had a significant effect on FFB yield in this trial. Year to year variations exist between progenies but the poorest yielding were E and G, for the last 5 years. Progeny also had a significant effect on all the physiological growth parameters.

EFB treatment significantly increased PCS, FW, FDM, TDM and VDM, while kieserite had no significant effect on all the physiological growth parameters. TSP had a significant effect only on BI.

Generally, the leaf P, Mg and K concentrations were significantly increased by TSP, KIE and EFB additions in this trial.

Based on the inconsistency in the main effects of TSP, KIE and EFB on the FFB yield, it is recommended that this trial be continued.

TRIAL 209 FACTORIAL FERTILISER TRIAL AT HARGY PLANTATION

SUMMARY

Sulphate of ammonia (SOA), triple superphosphate (TSP) and potassium chloride (MOP) had a significant effect on FFB yield of oil palm (*Elaeis guineensis* Jacq.) in this trial but not kieserite (KIE).

In 2005 and during the combined 2003–2005 period, increases of 4-5 t/ha of FFB yield were produced by SOA, TSP and MOP additions. However, a combined application of 8 kg/palm SOA, 2 kg/palm TSP, 4 kg/palm MOP and 0 kg/palm KIE produced a maximum FFB yield of 42.7 t/ha in 2005. Increasing SOA to 8 kg/palm in the presence of other nutrients increased FFB yield by about 5-10 t/ha in 2005 while the main effects were only 4-5 t/ha.

Nitrogen (N), phosphorus (P) and potassium (K) fertilisers should be included in routine additions.

INTRODUCTION

The purpose of the trial is to provide fertiliser response information that will be useful in developing strategies for fertiliser recommendations. The trial was proposed to replace the discontinued trial 201.

The site was surveyed, and palms labelled in November 1996. For the first 36 months, the palms received a standard immature palm fertiliser input. The fertiliser treatments were first applied in June 1998.

The soil of the trial site was formed on intermediate to basic volcanic ash. Other background information of the trial is given in Table 1.

Table 1: Background information on trial 209

Trial number	209	Company	Hargy Oil Palms Ltd
Date planted	Oct/Nov 1994	Planting Density (palm/ha)	135
Spacing	8.6 x 8.6	Pattern	Triangular
LSU	Hargy Area 1, blocks 4, 6 & 8	Soil type	Eutrandepts (Inceptisols)
Recording started	Jan 1998	Palm age (years after planting)	11
Topography	Gently sloping	Planting material	Dami D x P*
Progeny*		Previous land use	Oil Palm
Drainage	Freely draining	Area under trial soil type	
Officer in charge	W. Eremu	Treatments started	June 1998

** Identified Dami commercial DxP crosses (the same 16 progeny in each plot)*

MATERIALS AND METHODS

The N P K Mg trial was set up as a 3 x 3x 3 x 3 factorial design with 36 palms per plot, resulting in 81 treatments (Table 2). The 81 treatments are not replicated, and they are arranged in 9 blocks of 9 plots.

Recordings and measurements were taken on the central 16 palms in each plot. 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. Leaf sampling was carried out according to standard procedures and analysed for nutrient concentrations using standard analytical procedures.

Basal applications of other nutrients were carried out according to plantation recommended rates. Palms that were not in plots but were in the same block were termed perimeter palms, and were fertilised according to plantation practice.

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

Table 2: Fertiliser levels and rates used in Trial 209.

	Amount (kg/palm/year)		
Fertiliser	Level 1	Level 2	Level 3
SOA	2	4	8
TSP	0	4	8
MOP	0	2	4
KIE	0	4	8

RESULTS AND DISCUSSION

FFB Yield and its Components, and Leaf Analysis

Mean trend over time – FFB yield

Generally the number of bunches (BNO) per ha decreased while SBW increased progressively over the course of the trial (Figure 1). The net effect was that FFB yield increased progressively in the first three years (immature phase) and then stabilised over the mature phase.

The mean annual FFB yield in any year was closely related to annual rainfall two years previously (Figure 2). This relationship could only be expected to hold for a given range of rainfall and yield, but similar relationships appear to hold for mature oil palm in other trials in PNG.

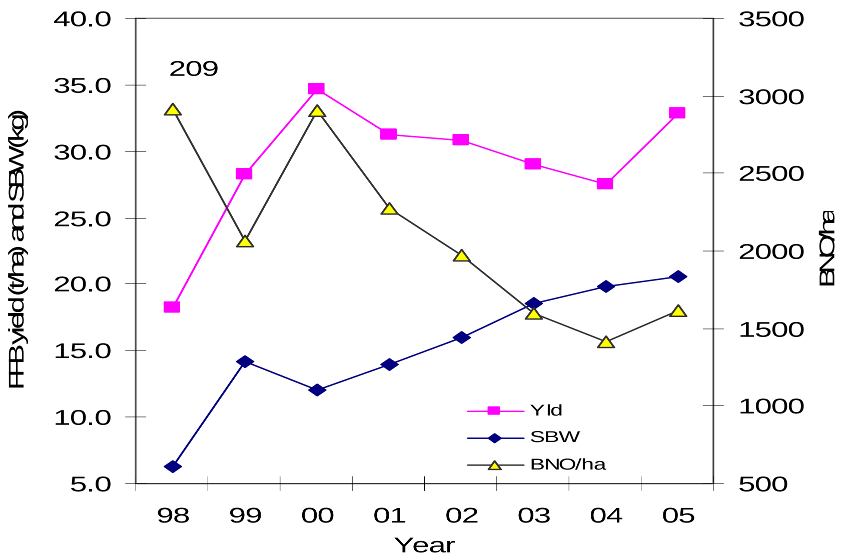


Figure 1: Mean FFB yield, BNO/ha and SBW from 1998 to 2005.

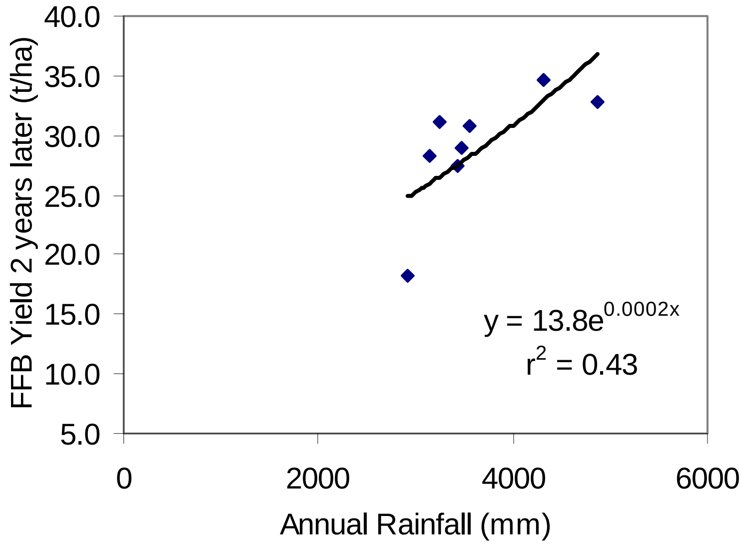


Figure 2: Relationship between mean FFB yield and rainfall (2 years previously) over the course of the trial.

Main effects on FFB yield, yield components and leaf nutrient concentrations

Increases in FFB yield due to additions of SOA, TSP and MOP were only 1-4 t/ha during the first five years of the trial and some of these were statistically significant (Figure 3). Only after the sixth year (2003) of the trial, the increases in FFB yield were substantial (5+ t/ha) and these were also statistically significant. On the other hand, KIE treatment had very little effect on FFB yield over the course of the trial.

The leaf nutrient concentrations were affected by the fertiliser treatments during the course of the trial (Figure 3). Mg concentration in the leaflet was significantly increased by KIE application, but the values were below the critical of 0.20 % DM regardless of treatment. This may suggest that not all Mg supplied is taken up by the palms. One possible reason for this is that, cation exchange capacity of the soil where this trial is located, and other volcanic ash soils of West New Britain are dominated by calcium (Gilman, 2001). Mg supplied in highly soluble fertilisers like KIE may not stay long enough in the soil/root zone to be accessed by the palms in this high rainfall environment. This could be an explanation for no response with Mg treatment on FFB yield in this and other similar trials in West New Britain.

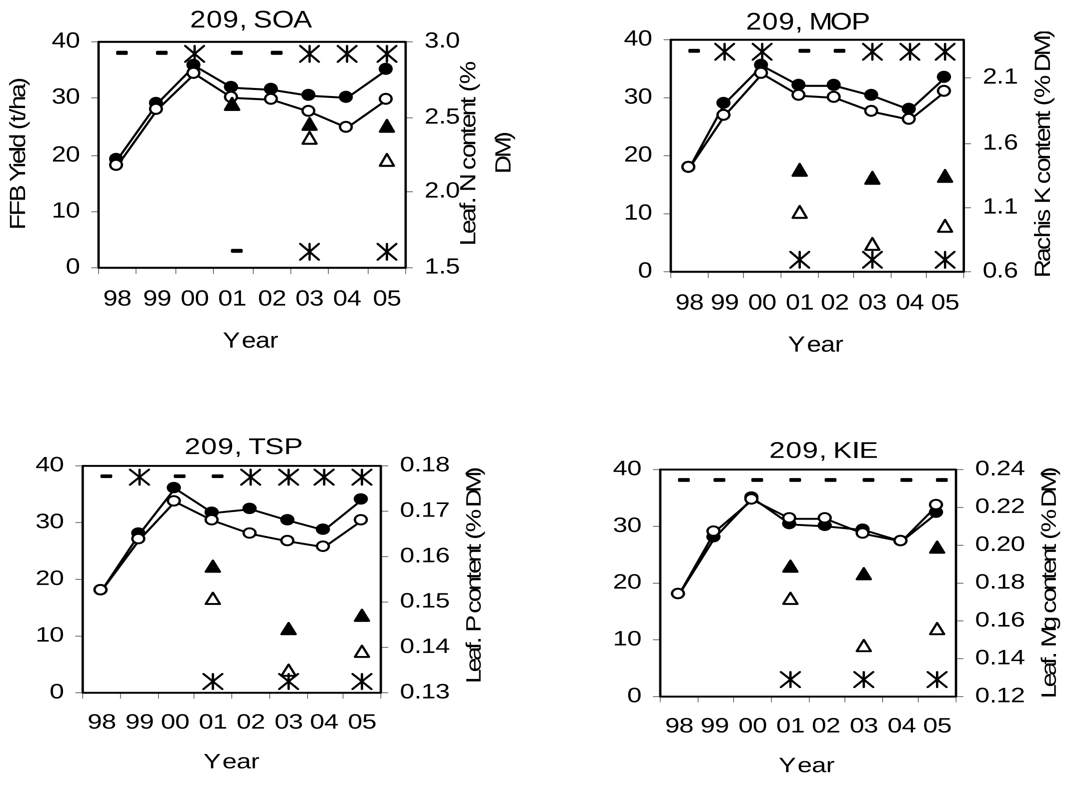


Figure 3. Main effects of SOA, MOP, TSP and KIE over the course of Trial 209. Lines are FFB yields and triangles are tissue concentrations. Full symbols represent the maximum level of application, and empty symbols the lowest level. Symbols along the top of the graph indicate significance of the main effect on yield, and along the bottom indicate significance of the main effect on tissue concentration. Stars indicate significance ($p<0.05$) and dashes non-significance.

In 2005 and during the combined 2003-2005 period, SOA, TSP and MOP continued to have a significant effect on the FFB yield while KIE had no significant effect on the FFB yield (Tables 3 and 4). The significant effect of SOA on increasing the FFB yield was due to its significant effect on increasing the BNO/ha and increasing the SBW. On the other hand, the significant effect of TSP on increasing the FFB yield was mainly due to its significant effect on increasing the BNO/ha while, the positive effect of MOP on increasing the FFB yield was mainly due to its effect on increasing the SBW.

The highest FFB yields were obtained at the highest rate of SOA, and at 4 or 8 kg/palm TSP and at 2 or 4 kg/palm MOP in 2005.

Table 3. Effects (p values) of fertilizer treatments on FFB yield and its components in 2003-2005 and 2005 (Trial 209); p values <0.05 are indicated in bold.

Source	2003-2005 FFB yield (t/ha)	2003-2005 BNO	2003-2005 SBW (kg)	2005 FFB yield (t/ha)	2005 BNO	2005 SBW (kg)
SOA	**<0.001**	**0.005**	**0.002**	**<0.001**	**0.017**	**0.020**
TSP	**<0.001**	**0.001**	0.331	**0.003**	**0.016**	0.348
MOP	**0.013**	0.922	**<0.001**	**0.027**	0.535	**0.046**
KIE	0.939	0.892	0.874	0.380	0.358	0.955
SOA.TSP	0.782	0.890	0.578	0.503	0.899	0.480
SOA.MOP	0.728	0.843	0.778	0.918	0.967	0.942
TSP.MOP	0.580	0.623	0.945	0.147	0.218	0.689
SOA.KIE	0.160	**0.050**	0.427	0.720	0.383	0.714
TSP.KIE	0.563	0.417	0.738	0.670	0.649	0.923
MOP.KIE	0.717	0.944	0.486	0.310	0.738	0.259
SOA.TSP.MOP	0.497	0.149	0.280	0.416	0.693	0.287
SOA.TSP.KIE	0.996	0.916	0.817	0.470	0.644	0.766
SOA.MOP.KIE	0.514	0.326	0.264	0.554	0.621	0.931
TSP.MOP.KIE	0.422	0.562	0.409	0.701	0.782	0.795
CV %	*9*	*9*	*6*	*11*	*12*	*8*

Table 4: Main effects of fertiliser treatments on FFB yield and its components in 2003-2005 and 2005 (209). Effects with *p* <0.05 are shown in bold.

	2003-2005 FFB yield (t/ha)	2003-2005 BNO/ha	2003-2005 SBW (kg)	2005 FFB yield (t/ha)	2005 BNO	2005 SBW (kg)
SOA 2	**27.0**	**1449**	**18.9**	**29.8**	**1524**	**19.9**
SOA 4	**29.9**	**1551**	**19.5**	**33.5**	**1644**	**20.6**
SOA 8	**31.7**	**1593**	**20.3**	**35.1**	**1686**	**21.2**
TSP 0	**27.3**	**1432**	19.3	**30.4**	**1521**	20.2
TSP 4	**30.3**	**1568**	19.7	**33.9**	**1675**	20.7
TSP 8	**30.9**	**1593**	19.7	**33.9**	**1658**	20.8
MOP 0	**28.2**	1525	**18.8**	**31.1**	1588	**19.9**
MOP 2	**30.0**	1529	**20.0**	**33.6**	1647	**20.7**
MOP 4	**30.4**	1539	**20.1**	**33.6**	1619	**21.0**
KIE 0	29.6	1539	19.7	33.6	1662	10.6
KIE 4	29.5	1532	19.5	32.5	1601	20.5
KIE 8	28.4	1521	19.6	32.2	1591	20.6
s.e.d.	*0.7*	*38*	*0.3*	*1.0*	52	0.4
$Lsd_{0.05}$	*1.5*	*81*	*0.6*	*2.1*	*109*	0.9
GM	*29.5*	*1531*	*19.6*	*32.8*	*1618*	*20.6*

In 2005, N treatment had a significant effect on leaflet N, P, Mg and S concentrations (Table 6). N treatment also had a significant effect on rachis ash, N, P and K concentrations. Leaflet N, P and S concentrations were increased by increasing N rates, while leaflet Mg concentration was decreased by increasing rates of N (Table 7). Similarly, rachis ash, N and K concentrations were increased by increasing N rates, while rachis P concentration were decreased by increasing rates of N. The significant increase in leaf N and S concentrations was due to the increasing rates of N and S in SOA. On the other hand, increased leaflet P concentration due to N treatment is not possible from an elemental point of view. However, the parallel decease in rachis P suggests that the increasing N supply mobilises P from the rachis to the leaflet.

TSP treatment increased leaflet and rachis P concentrations significantly, while leaflet K, and rachis ash and K concentrations were significantly decreased by TSP treatment (Tables 6 & 7).

MOP treatment significantly increased only rachis K concentration and not leaflet concentration (Tables 6 & 7). The Cl component of MOP increased leaflet concentration significantly. Leaflet Mg concentration was significantly decreased, and rachis ash and P concentrations were increased by MOP treatment.

Kieserite treatment significantly increased leaflet Mg concentration, but this did not equate to any FFB yield increase in 2005 (Tables 6 & 7). The values were lower than the critical of 0.20 % DM.

Table 6. Effects (p values) of treatments on frond 17 (F17) nutrient concentrations 2005 (Trial 205). p values <0.05 are indicated in bold.

	Leaflet							Rachis			
Source	Ash	N	P	K	Mg	S	Cl	Ash	N	P	K
SOA	0.901	**<0.001**	**<0.001**	0.539	**0.006**	**<0.001**	0.499	**0.024**	**0.033**	**<0.001**	**0.002**
TSP	0.095	0.290	**<0.001**	**0.002**	0.776	0.627	0.919	**0.004**	0.465	**<0.001**	**<0.001**
MOP	**<0.001**	0.640	0.874	0.103	**0.002**	0.450	**<0.001**	**<0.001**	0.223	**0.004**	**<0.001**
KIE	**0.019**	0.860	0.689	0.077	**<0.001**	0.853	0.606	0.515	0.067	0.494	0.665
SOA.TSP	0.245	0.449	0.278	0.244	0.098	0.106	0.841	0.284	0.251	0.257	0.066
SOA.MOP	0.395	0.709	0.920	0.327	0.573	0.456	0.313	0.302	0.570	0.327	0.271
TSP.MOP	0.879	0.800	0.619	0.120	0.484	0.792	0.384	0.662	0.232	0.082	0.536
SOA.KIE	0.664	0.458	0.618	**0.038**	0.542	0.291	0.198	0.626	0.105	0.758	0.368
TSP.KIE	0.208	0.841	0.929	0.436	0.211	0.566	0.603	0.156	0.318	0.151	0.102
MOP.KIE	0.381	0.637	0.736	0.432	0.579	0.382	0.848	0.903	0.194	0.134	0.972
SOA.TSP.MOP	0.394	0.789	0.999	0.520	0.082	0.080	0.223	0.587	0.305	0.595	0.704
SOA.TSP.KIE	0.222	0.846	0.833	0.119	0.058	0.136	0.876	0.459	0.141	0.902	0.405
SOA.MOP.KIE	0.700	0.525	0.215	0.170	0.437	0.220	0.173	0.514	0.162	0.168	0.610
TSP.MOP.KIE	0.095	0.503	0.138	0.424	**0.007**	0.075	0.156	0.543	0.417	0.781	0.403
CV%	*4*	*4*	*4*	*4*	*7*	*5*	*9*	*9*	*6*	*22*	*11*

Table 7. Main effects of treatments on F17 nutrient concentrations in 2005, in units of % dry matter, except for B (mg/kg) (Trial 205). Effects with $p<0.05$ are shown in bold.

	Leaflet							Rachis			
Source	Ash	N	P	K	Mg	S	Cl	Ash	N	P	K
SOA 2	14.5	**2.22**	**0.140**	0.67	**0.186**	**0.174**	0.369	**4.30**	**0.273**	**0.095**	**1.23**
SOA 4	14.6	**2.34**	**0.144**	0.67	**0.183**	**0.188**	0.374	**4.12**	**0.277**	**0.077**	**1.13**
SOA 8	14.6	**2.44**	**0.148**	0.67	**0.173**	**0.196**	0.380	**4.97**	**0.285**	**0.071**	**1.13**
TSP 0	14.7	2.31	**0.139**	**0.69**	0.179	0.185	0.372	**4.36**	0.275	**0.057**	**1.27**
TSP 4	14.5	2.32	**0.146**	**0.67**	0.181	0.1685	0.376	**4.08**	0.279	**0.086**	**1.13**
TSP 8	14.4	2.36	**0.147**	**0.65**	0.182	0.187	0.374	**3.95**	0.281	**0.100**	**1.09**
MOP 0	15.5	2.32	0.144	0.68	**0.189**	0.184	**0.161**	**3.56**	0.275	**0.070**	**0.95**
MOP 2	14.1	2.35	0.144	0.67	**0.179**	0.188	**0.459**	**4.21**	0.277	**0.086**	**1.19**
MOP 4	14.0	2.33	0.144	0.66	**0.174**	0.186	**0.502**	**4.62**	0.283	**0.087**	**1.35**
KIE 0	**14.8**	2.33	0.144	0.67	**0.156**	0.186	0.379	4.20	0.280	0.079	1.17
KIE 4	**14.5**	2.32	0.145	0.66	**0.187**	0.185	0.370	4.08	0.272	0.084	1.15
KIE 8	**14.4**	2.34	0.143	0.68	**0.199**	0.187	0.372	4.11	0.283	0.081	1.18
s.e.d.	*0.2*	*0.03*	*0.001*	*0.01*	*0.004*	*0.003*	*0.01*	*0.11*	*0.004*	*0.005*	*0.03*
$Lsd_{0.05}$	*0.3*	*0.05*	*0.003*	*0.02*	*0.008*	*0.006*	*0.02*	*0.22*	*0.009*	*0.010*	*0.07*
GM	*14.5*	*2.33*	*0.144*	*0.67*	*0.181*	*0.186*	*0.374*	*4.13*	*0.278*	*0.081*	*1.16*

Interaction between fertiliser treatments

Main effects of SOA, TSP, and MOP were 4-5 t/ha and these were statistically significant. Even though the interaction between nutrients on FFB yield were generally not significant, FFB yield responses to different combinations of fertiliser treatments were substantial, with a maximum of 42.7 t/ha produced by 8 kg/palm SOA, 4 kg/palm TSP, 2 kg/palm MOP and 0 kg/palm KIE (Table 8 and Figure 4).

Table 8. Effect of SOA.TSP.MOP.KIE interaction on the FFB yield (t/ha) in 2005 (Trial 209).

			SOA		
TSP	MOP	KIE	2	4	8
0	0	0	27.8	30.9	32.9
		4	27.4	29.9	28.4
		8	23.8	22.3	31.9
	2	0	26.8	35.2	33.3
		4	29.6	23.5	35.9
		8	32.9	24.9	27.6
	4	0	31.2	30.6	36.5
		4	28.5	37.3	34.4
		8	26.7	36.3	34.3
4	0	0	34.6	37.5	34.6
		4	27.3	33.6	39.7
		8	25.0	32.5	37.6
	2	0	32.5	35.8	42.7
		4	32.0	35.1	35.6
		8	28.3	36.8	34.4
	4	0	29.6	33.5	34.6
		4	31.5	33.1	33.8
		8	31.0	33.0	40.3
8	0	0	29.3	29.1	27.5
		4	32.2	36.6	29.6
		8	27.4	36.3	32.8
	2	0	32.8	39.9	39.8
		4	33.2	34.7	39.2
		8	27.4	37.9	40.1
	4	0	33.4	37.7	35.6
		4	29.5	32.3	33.2
		8	31.6	37.0	40.2

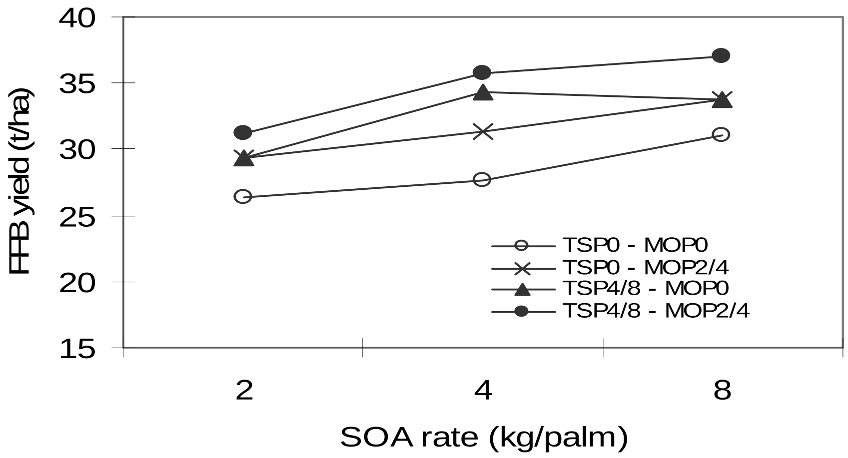


Figure 4: Effect of SOA.TSP.MOP.KIE (average of 3 rates) on FFB yield in 2005 (Trial 209)

Effects of fertiliser treatments on physiological growth parameters

SOA and TSP had a significant effect on leaf petiole cross section (PCS), uncorrected leaf area (ULA), frond weight (FW), frond area (FA), leaf area index (LAI), frond dry matter (FDM), bunch dry matter (BDM), total dry matter (TDM) and vegetative dry matter (VDM) (Table 9). These effects correspond well to the effects SOA and TSP treatments on the FFB yields. Generally, increasing either SOA from 2 or TSP from 0 to any other rate increased all the physiological growth parameters, except bunch index (BI).

MOP had a significant effect only on PCS, FW, BDM, TDM and VDM, while KIE had no significant effect on any of the physiological growth parameters (Table 9). The effects of KIE on the physiological growth parameters were similar to its effect on the FFB yield.

Table 9. Effect of SOA.TSP.MOP.KIE (average of 3 rates) on physiological growth parameters in 2005 (Trial 209)

	Radiation Interception					Dry matter production (t/ha)				Conversion
Treatment	PCS (cm2)	ULA (m2)	FW (kg)	FA (m2)	LAI	FDM	BDM	TDM	VDM	BI
SOA 2	**44.8**	**11.8**	**4.8**	**6.8**	**3.2**	**17.5**	**15.8**	**37.0**	**21.2**	0.426
SOA 4	**46.6**	**11.9**	**5.0**	**6.8**	**3.2**	**19.0**	**17.7**	**40.8**	**23.1**	0.434
SOA 8	**48.5**	**12.2**	**5.2**	**7.0**	**3.3**	**20.2**	**18.6**	**43.1**	**24.5**	0.431
p	***<0.001***	***0.015***	***<0.001***	***0.015***	***0.016***	***<0.001***	***<0.001***	***<0.001***	***<0.001***	*0.641*
s.e.d.	*0.8*	*0.1*	*0.1*	*0.1*	*0.06*	*0.5*	*0.5*	*0.8*	*0.5*	*0.008*
$Lsd_{0.05}$	*1.7*	*0.3*	*0.2*	*0.2*	*0.13*	*1.0*	*1.1*	*1.7*	*1.1*	
TSP 0	**44.9**	**11.8**	**4.8**	**6.7**	**3.1**	**17.8**	**16.1**	**37.7**	**21.6**	0.427
TSP 4	**47.5**	**12.0**	**5.1**	**6.9**	**3.2**	**19.4**	**18.0**	**41.6**	**23.6**	0.432
TSP 8	**47.4**	**12.2**	**5.1**	**6.9**	**3.3**	**19.5**	**18.0**	**41.6**	**23.6**	0.431
p	***0.007***	***0.030***	***0.007***	***0.030***	***0.029***	***0.002***	***0.003***	***<0.001***	***0.001***	*0.768*
s.e.d.	*0.8*	*0.1*	*0.1*	*0.1*	*0.06*	*0.5*	*0.5*	*0.8*	*0.5*	*0.008*
$Lsd_{0.05}$	*1.7*	*0.3*	*0.2*	*0.2*	*0.13*	*1.0*	*1.1*	*1.7*	*1.1*	
MOP 0	**45.1**	11.9	**4.8**	6.8	3.2	18.4	**16.5**	**38.8**	22.3	0.424
MOP 2	**47.2**	11.9	**5.0**	6.8	3.2	18.9	**17.8**	**40.8**	23.0	0.436
MOP 4	**47.6**	12.2	**5.1**	6.9	3.3	19.4	**17.8**	**41.3**	23.5	0.431
p	***0.014***	*0.074*	***0.014***	*0.074*	*0.089*	*0.142*	***0.026***	***0.016***	*0.094*	*0.311*
s.e.d.	*0.8*	*0.1*	*0.1*	*0.1*	*0.06*	*0.5*	*0.5*	*0.8*	*0.5*	*0.008*
$Lsd_{0.05}$	*1.7*		*0.2*				*1.1*	*1.7*	*1.1*	
KIE 0	47.3	12.1	5.0	6.9	3.2	19.2	17.8	41.1	23.3	0.433
KIE 4	46.3	11.9	4.9	6.8	3.2	18.8	17.2	40.0	22.9	0.430
KIE 8	46.3	11.9	4.9	6.8	3.2	18.7	17.1	39.8	22.7	0.428
p	*0.343*	*0.354*	*0.343*	*0.354*	*0.926*	*0.489*	*0.374*	*0.234*	*0.420*	*0.859*
s.e.d.	*0.8*	*0.1*	*0.1*	*0.1*	*0.06*	*0.5*	*0.5*	*0.8*	*0.5*	*0.008*
$Lsd_{0.05}$										
GM	*46.6*	*12.0*	*5.0*	*6.8*	*3.2*	*18.9*	*17.4*	*40.3*	*22.9*	*0.430*

CONCLUSIONS AND RECOMENDATION

SOA, TSP and MOP continued to increased FFB yield significantly while KIE had no significant effect on yield in this trial.

In 2005 and during the combined 2003-2005 period, FFB yields were increased by about 4-5 t/ha by additions of SOA, TSP and MOP, and these effects were statistically significant. KIE had no significant effect on the FFB yield over the course of the trial even though leaflet Mg concentrations were increased by increasing Mg supply and we generally below the critical level of 0.20 %.

Compared to the main effects, examination of the “Interaction Tables” revealed increases of 5-10 t/ha of FFB yield at various combinations of fertiliser treatments; with 8 kg/palm SOA, 4 kg/palm TSP, 2 kg/palm MOP and 0 kg/palm producing the maximum FFB yield (42.7 t/ha) in 2005.

Fertiliser treatments had a significant effect on the leaf nutrient concentrations in this trial.

The recommendation for this area is to continue to include N, P and K fertilisers in routine additions. Final recommendations will depend on the annual leaf analysis results.

TRIAL 211 SYSTEMATIC N FERTILISER TRIAL AT NAVO

INTRODUCTION

The purpose of the trial is to provide N response information that will be useful for determining optimum N input in the area.

Factorial fertiliser trials with randomised spatial allocation of treatments are generally showing poor responses to fertilisers in West New Britain. Yields and tissue nutrient concentrations in control plots are generally higher than would be expected. It is suspected that fertiliser may be moving from plot to plot. Systematic designs are seen as a way of avoiding this problem, by ensuring that high and low rates of application are not adjacent. This trial was approved in the 1999 SAC meeting as a replacement for Trial 204. There was a change of N source from ammonium chloride (AC) to ammonium nitrate (AN) in 2004.

The soil of the trial site is aerated peat soils over redeposited scoria ash fall over coarse sandy subsoils with loose structure. Other background information of the trial is shown in Table 1.

Table 1: Trial 211 background information.

Trial number	211	Company	Hargy Oil Palms Ltd
Date planted	March 1998	Planting Density (palm/ha)	115
Spacing	9.3 x 9.3	Pattern	Triangular
LSU	Navo Plantation, Field 11, Road 6 and 7, Avenue 11, 12 and 13	Soil type	Eutrandepts (Inceptisols)
Recording started	Feb 2002	Palm age (years after planting)	7
Topography	Flat and swampy	Planting material	Dami commercial DxP crosses
Drainage	Poor	Previous land use	Mostly sago and forest
Other site factors	Area extensively drained	Area under trial soil type	Not known
Officer in charge	W. Eremu	Treatments started	November 2001

MATERIALS AND METHODS

The trial has 9 treatments, which are 9 rates of AN (0, 0.74, 1.48, 2.22, 2.96, 3.70, 4.44, 5.18 and 5.92 kg/palm/yr), and 8 replicates. Each plot is 4 rows of 15 palms. N rates vary systematically along the trial. Standard immature fertiliser regime was used initially. Plots were marked in 2001, fertiliser treatments commenced in November 2001, and yield recording commenced in February 2002. Fertiliser is applied in 2 doses per year.

In 2006, a full complement of basal fertilisers (non-treatment) will be added. For this trial (211) TSP 0.2; KIE 1.5; MOP 0.5; CaB 0.15 kg/palm/year will be added across the whole trial.

RESULTS AND DISCUSSION

Fresh fruit bunch (FFB) yield has responded to N fertilizer in 2005 (*p=0.002; r=0.123)*, mainly due to a significant effect of N on number of bunches per ha (BNO/ha) (Table 2). Although significant the response is very small and of little biological or economic consequence (Figure 1). It is expected that the response will increase with time. These results are similar to the 2004 results, where FFB yield responded to N fertilizer, mainly due to increased single bunch weight (SBW). Before 2004 (2002 and 2003) there was no significant effect of N fertilizer on FFB yield or its components.

Similar to its effect on FFB yield, N fertilizer had a positive effect on leaflet N concentrations in 2005 (Table 3, Figure 2), but all the N values were above the critical value irrespective of AN treatment (Table 4); Until the leaflet N levels fall below the critical concentration, it is unlikely that there will be strong yield responses. Leaflet K, Mg, Ca and Cl were also affected by the AN treatment in 2005 (Tables 3 & 4).

Table 2. Regression parameters for the effect of fertiliser application rate (kg/palm/year) on FFB yield and its components in 2005 (Trial 211).

	Intercept	Slope	Slope p	r^2
FFB (t/ha)	27.6	0.32	**0.002**	0.123
BNO/ha	1660	10	**0.022**	0.073
SBW (kg)	16.5	0.1	0.196	0.024

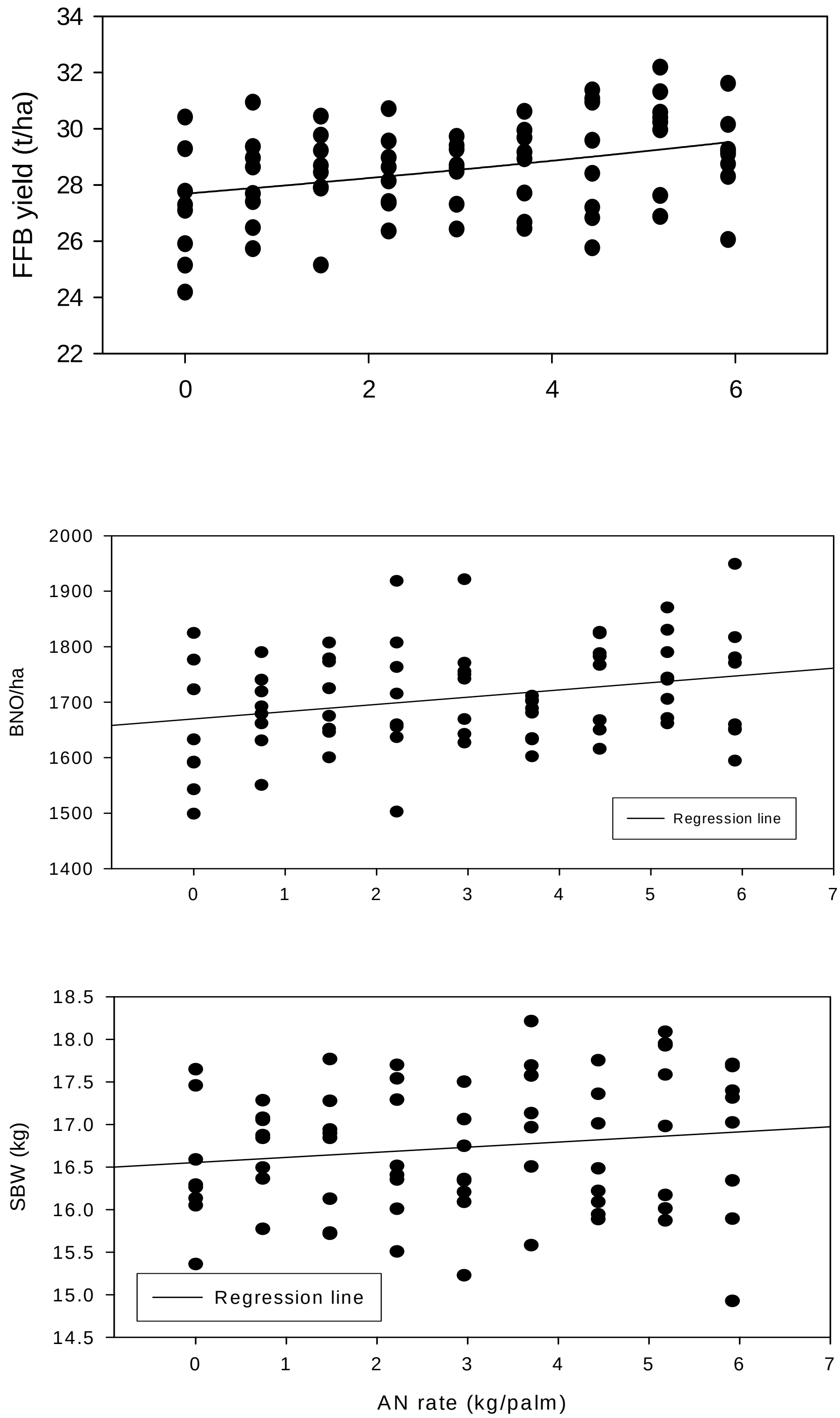


Figure 1. Effect of fertiliser rate (annual) on FFB yield, BNO/ha and SBW in 2005 (Trial 211).

Table 3. Regression parameters for the effect of fertiliser application rate (kg/palm/year) on tissue nutrient concentrations (% DM, except for B, in mg/kg DM) in 2005 (Trial 211). *p* values <0.05 are indicated in bold.

	Grand Mean	Intercept	Slope	Slope p	r^2
Leaflet					
Ash	12.5	12.9	-0.08	**<0.001**	0.174
N	2.66	2.62	0.007	**0.017**	0.079
P	0.150	0.149	0.0002	0.175	0.026
K	0.829	0.802	0.005	**0.016**	0.080
Mg	0.201	0.218	-0.003	**<0.001**	0.204
Ca	0.871	0.90	-0.01	**0.001**	0.143
B	15.4	16.0	-0.13	0.196	0.024
Cl	0.54	0.418	0.005	**0.011**	0.088
S	0.208	0.206	0.0004	0.227	0.021
Rachis					
Ash	5.5	5.6	-0.03	0.174	0.027
N	0.282	0.277	0.001	0.229	0.020
P	0.049	0.047	0.001	0.126	0.033
K	1.53	1.54	0.002	0.747	0.002

Table 4: Main effects of N application rate on leaf nutrient concentrations in % DM, significant effects are shown in bold.

	Leaflet									Rachis		
AN rate	Ash	N	P	K	Mg	Ca	B	Cl	S	RN	RP	RK
0.00	**12.9**	**2.60**	0.149	**0.818**	**0.218**	**0.906**	15.9	**0.424**	0.204	0.268	0.047	1.53
0.74	**12.8**	**2.63**	0.149	**0.810**	**0.214**	**0.878**	15.8	**0.416**	0.205	0.274	0.046	1.50
1.48	**12.6**	**2.65**	0.150	**0.830**	**0.206**	**0.880**	15.6	**0.431**	0.206	0.284	0.048	1.53
2.22	**12.6**	**2.67**	0.150	**0.815**	**0.200**	**0.875**	15.6	**0.436**	0.211	0.288	0.048	1.56
2.96	**12.4**	**2.68**	0.150	**0.813**	**0.198**	**0.879**	15.3	**0.446**	0.211	0.285	0.05	1.58
3.70	**12.4**	**2.66**	0.149	**0.838**	**0.201**	**0.854**	15.2	**0.451**	0.210	0.279	0.052	1.58
4.44	**12.4**	**2.69**	0.152	**0.820**	**0.195**	**0.869**	15.7	**0.461**	0.208	0.285	0.051	1.55
5.18	**12.4**	**2.68**	0.150	**0.858**	**0.190**	**0.855**	14.6	**0.454**	0.209	0.289	0.053	1.52
5.92	**12.2**	**2.65**	0.150	**0.863**	**0.190**	**0.845**	14.9	**0.444**	0.206	0.285	0.049	1.47

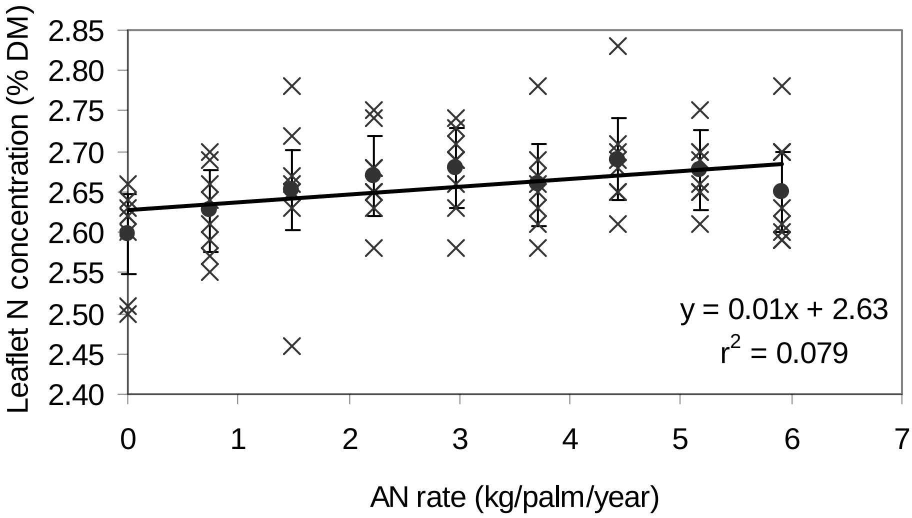


Figure 2. Effect of fertilizer rate on leaflet N content in 2005 (Trial 211). Crosses show values for each 60-palm plot (4 rows of 15), circles show means for treatment, and bars show s.d.

CONCLUSION

The AN treatment had a significant effect on FFB yield in 2005 but this response is of little biological or economic consequence at this early stage in the trial. There was a substantial variation in FFB yields and leaflet N concentrations between different AN treatments.

The trial has not yet had enough time to develop for the results to be used to make N fertiliser recommendations.

TRIAL 212 SYSTEMATIC N FERTILISER TRIAL AT HARGY

INTRODUCTION

The purpose of the trial is to provide N response information that will be useful for determining optimum N input in the area.

Factorial fertiliser trials with randomised spatial allocation of treatments are generally showing poor responses to fertilisers in West New Britain. Yields and tissue nutrient concentrations in control plots are generally higher than would be expected. It is suspected that fertiliser may be moving from plot to plot. Systematic designs are seen as a way of avoiding this problem, by ensuring that high and low rates of application are not adjacent. This trial was approved in the 1999 SAC meeting as a replacement for Trial 209. There was a change of N source from ammonium chloride (AC) to ammonium nitrate (AN) in 2004.

The soils of the trial site are freely draining, formed on volcanic ash. Other background information of the trial is given in Table 1.

Table 1. Trial 212 background information.

Trial number	212	Company	Hargy Oil Palms Ltd
Date planted	Feb 1996	Planting Density (palm/ha)	140
Spacing	8.4 x 8.4	Pattern	Triangular
LSU or MU	Hargy Estate, Area 8, Blocks 10 and 11	Soil type	Eutrandepts (Inceptisols)
Recording started	2002	Palm age (years after planting)	9
Topography	Gentle to moderate slope	Planting material	Dami commercial DxP crosses
Progeny*		Previous land use	Oil Palm
Drainage	Freely draining	Area under trial soil type	
Officer in charge	W. Eremu	Treatments started	2002

MATERIALS AND METHODS

The trial has 9 treatments, which are 9 rates of AN (0, 0.74, 1.48, 2.22, 2.96, 3.70, 4.44, 5.18 and 5.92 kg/palm/yr), and 8 replicates. Each plot is 2 rows of 15 palms. N rates vary systematically along the trial. The site was chosen in 2001 and treatments commenced in 2002. From 2003, fertiliser application frequency is 2 doses/year in replicates 1, 3, 5, & 7 and 10 doses/year in replicates 2, 4, 6 & 8.

In 2006, a full complement of basal fertilisers (non-treatment) will be added. For this trial (212) TSP 0.2; KIE 3.0; MOP 2.0; CaB 0.15 kg/palm/year will be added across the whole trial.

RESULTS AND DISCUSSION

N fertilizer continued to have a significant effect on fresh fruit bunch (FFB) yield two years after the treatment commenced in 2002. The positive response of N on the FFB yield in 2005 was due to a significant effect of N on single bunch weight (SBW) and number of bunches (BNO) per ha (Table 2, Figure 1). The response of tissue N concentration to N fertiliser was also significant in 2005 (Table 3,

Figure 2), but generally the values were above the critical N concentration of 2.3% DM for mature oil palm.

Table 2. Regression parameters for the effect of fertiliser application rate (kg/palm/year) on FFB yield and its components in 2005 (Trial 212).

	Intercept	Slope	Slope p	r^2
Yield (t/ha)	23.4	0.7	**<0.001**	0.346
BNO/ha	1353	30.6	**<0.001**	0.156
SBW (kg)	17.9	0.31	**<0.001**	0.179

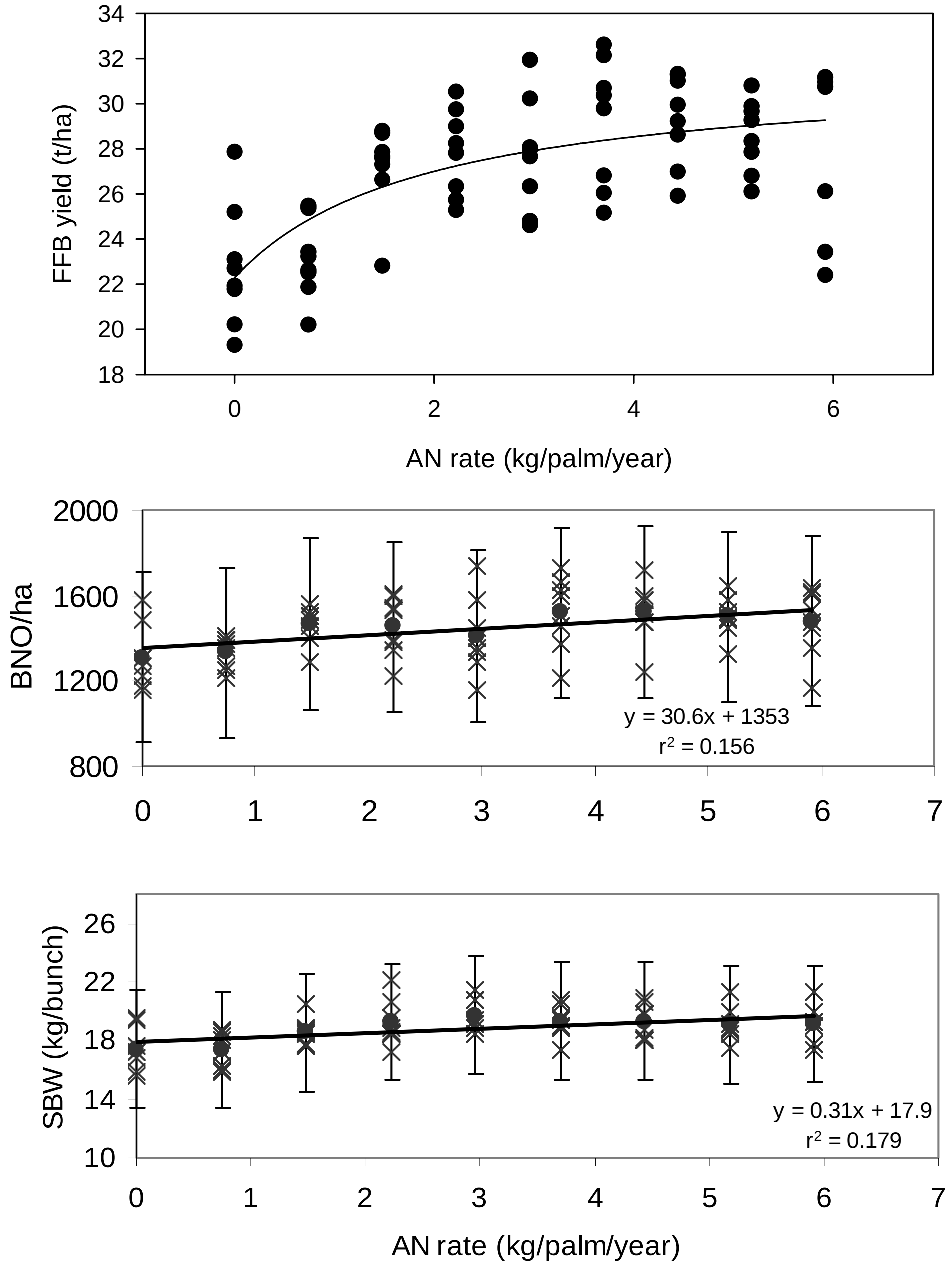


Figure 1. Effect of fertiliser rate (annual) on FFB yield, BNO/ha and SBW in 2005 (Trial 212). Crosses show values for each 30-palm plot (2 rows of 15), circles show means for treatment, and bars show for the BNO/ha and SBW.

Table 3. Regression parameters for the effect of fertiliser application rate (kg/palm/year) on tissue nutrient concentrations (% DM, except for B, in mg/kg DM) in 2005 (Trial 212). Slope *p* values <0.05 are indicated in bold.

	GM	Intercept	Slope	Slope p	r^2
Leaflet					
Ash	13.8	13.7	0.01	0.669	0.003
N	2.45	2.32	0.03	**<0.001**	0.511
P	0.143	0.138	0.001	**<0.001**	0.229
K	0.708	0.701	0.001	0.640	0.003
Mg	0.178	0.195	-0.003	**<0.001**	0.272
Ca	0.969	0.977	-0.002	0.467	0.007
B	12.0	12.4	-0.1	**0.090**	0.041
Cl	0.522	0.462	0.012	**<0.001**	0.349
S	0.195	0.183	0.002	**<0.001**	0.394
Rachis					
Ash	4.56	4.32	0.05	**0.019**	0.076
N	0.265	0.250	0.003	**<0.001**	0.155
P	0.034	0.030	0.001	**<0.001**	0.188
K	1.23	1.23	0.01	0.119	0.034

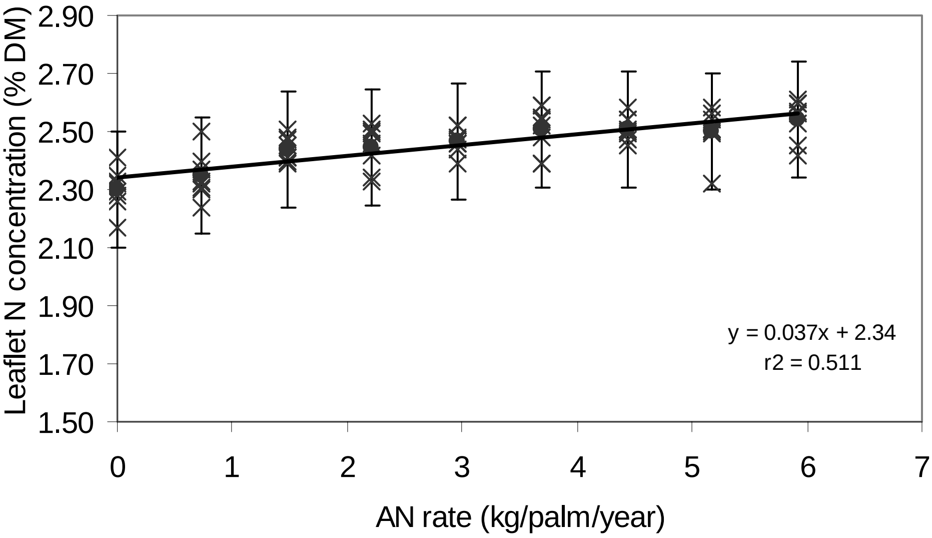


Figure 2. Effect of fertilizer rate on leaflet N concentration in 2005 (Trial 212). Crosses show values for each 30-palm plot (2 rows of 15), circles show means for treatment, and bars show s.d.

TRIAL 213 N AND P FERTILISER TRIAL FOR THE HIGH GROUND AT HARGY PLANTATION

SUMMARY

The purpose of the trial was to provide fertiliser response information necessary for determining fertiliser recommendations for the palms on the high ground of Hargy Plantation.

The nitrogen (N) by phosphorus (P) trial was set up as a 3x3x4 factorial design (3 N rates; 3 P rates; 4 replicates) with 36 palms per plot. Recordings and measurements were taken on the central 16 palms in each plot.

Both N and P had positive effects on fresh fruit bunch (FFB) yield in the first three years of the trial and these results will be verified with subsequent years of data collection. The results suggest a combine application of 2.2 kg AN per palm and 3 kg TSP per palm will result in near maximal FFB yield but it is expected that the requirements for N and P will change as these young palm mature.

Leaflet N and P concentrations were increased significantly to levels above the critical by added AN and TSP. However, rachis K level which relate well to FFB yield was below the critical of 1.00 %DM, and thus basal application of K fertiliser is recommended in this trial.

INTRODUCTION

The purpose of the trial is to provide fertiliser response information necessary for determining fertiliser recommendations for the palms on the high ground of Hargy Plantation.

This trial was proposed at the 2000 SAC meeting. It had been observed that oil palm on the high ground at the back of Hargy plantation was exhibiting poor growth. It was suspected from visual observation that the poor growth may be due to deficiencies of nitrogen (N) and phosphorus (P).

Set up of the trial was completed at the end of 2002. Fertiliser treatments commenced at the beginning of 2003. Background information of the trial is given in Table 1. Pre-treatment yield data and leaf nutrient concentrations are presented in Tables 2 and 3.

Table 1: Trial 213 background information.

Trial number	213	Company	Hargy Oil Palms Ltd
Date planted	Feb/Mar 1997	Planting Density (palms/ha)	129
Spacing	9.67 x 8.5 x 9.67	Pattern	Triangular
LSU or MU	Area 8, blocks 9 & 10	Soil type	Hargy
Recording started	Jan 2003	Palm age (years after planting)	8
Topography	Moderately sloping	Planting material	Dami D x P (*Elaeis guineensis* Jacq.)
Progeny	Not known	Previous land use	Forest
Drainage	Well drained	Area under trial soil type	Not known
Officer in charge	W. Eremu		

Table 2: Pre-treatment yield and its components (Trial 213)

	2002		
	FFB yield (t/ha/year)	Number of bunches/ha/yr	Single bunch weight (kg)
Treatment			
AN 0 - TSP 0	16.3	1587	10.6
AN 0 - TSP 3	19.1	1777	10.8
AN 0 - TSP 6	14.0	1379	10.5
AN 2.2 - TSP 0	15.0	1524	9.9
AN 2.2 - TSP 3	16.7	1663	10.1
AN 2.2 - TSP 6	17.5	1699	10.6
AN 4.4 - TSP 0	16.3	1556	10.5
AN 4.4 - TSP 3	17.9	1669	10.8
AN 4.4 - TSP 6	16.9	1568	10.6

Table 3: Initial nutrient concentration [% Dry Matter (DM); except B, mg/kg] in leaf and rachis (pre-treatment data).

	Leaf								Rachis	
Treatment	Ash	N	P	K	Mg	Ca	Cl	B	Ash	K
AN 0 - TSP 0	11.5	2.7	0.158	0.85	0.225	1.12	0.44	12.1	3.6	1.0
AN 0 - TSP 3	11.5	2.7	0.154	0.83	0.223	1.14	0.49	11.0	3.9	1.1
AN 0 - TSP 6	10.9	2.7	0.150	0.85	0.253	1.09	0.41	11.4	3.8	1.0
AN 2.2 - TSP 0	10.9	2.7	0.153	0.82	0.238	1.13	0.47	11.2	3.4	0.8
AN 2.2 - TSP 3	11.5	2.7	0.155	0.85	0.230	1.07	0.43	11.3	3.5	0.9
AN 2.2 - TSP 6	11.3	2.6	0.149	0.84	0.225	1.12	0.49	10.8	3.1	0.8
AN 4.4 - TSP 0	11.4	2.7	0.154	0.86	0.225	1.14	0.39	11.6	3.5	0.9
AN 4.4 - TSP 3	11.2	2.7	0.154	0.86	0.230	1.09	0.49	11.2	3.8	0.9
AN 4.4 - TSP 6	11.1	2.7	0.153	0.88	0.228	1.13	0.49	10.9	3.5	0.8

MATERIALS AND METHODS

The N by P trial was set up as a 3x3x4 factorial design (3 N rates; 3 P rates; 4 replicates) with 36 palms per plot (Table 4). Recordings and measurements were taken on the central 16 palms in each plot. 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. Leaf sampling was carried out according to standard procedures and analysed for nutrient concentrations using standard analytical procedures.

Palms that were not in plots but were in the same block were termed perimeter palms, and were fertilised according to plantation practice.

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 4: Fertiliser levels and rates used in trial 213.

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

RESULTS AND DISCUSSION

Mean Trend over Time – FFB Yield

Since the beginning of the trial, number of bunches (BNO) continued to decrease while SBW increased (Figure 1). The FFB yield rose to a high in 2004 and remained steady in 2005.

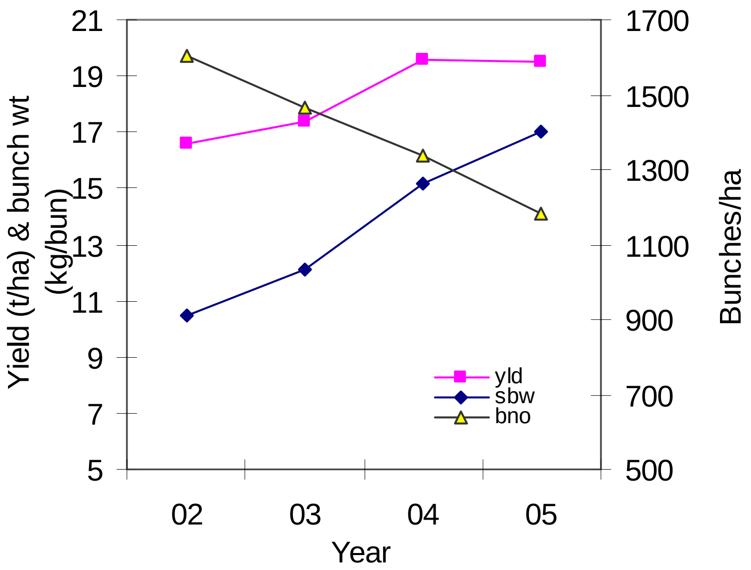


Figure 1: Mean FFB yield, BNO/ha and SBW from 2002 to 2005

Main Effects on FFB Yield and Yield Components, and Leaf nutrient Concentrations

Addition of AC and TSP resulted in FFB yield increases of about 2-4 t/ha over the course of the trial (Figure 2). For AC, the main effects were statistically significant in 2003 and 2004, while the effects of TSP were significant in 2004 and 2005.

In 2005 and during the combined 2003-2005 period, AC addition increased FFB yield by 2-3 t/ha and the effect of AC was statistically significant during the combined 2003-2005 period (Table 5). The significant effect of AC on FFB yield during the combined 2003-2005 period was mainly due to its significant effect on BNO/ha.

Addition of TSP had a similar effect on FFB yield, with increases of 2-3 t/ha in 2005 and during the combined 2003-2005 period. The effect of TSP on FFB yield was statistically significant in 2005 and during the combined 2003-2005 period, mainly due to its significant effect on SBW.

Leaf N and P concentrations for plots receiving no AC and TSP were 2.49 %DM and 0.149 %DM respectively, and these were below the critical N and P concentrations (Table 7). However, adding AC and TSP significantly increased N and P concentrations in 2005 (Tables 6 and 7). Similarly S concentration for plots receiving no TSP was lower than the critical but increased significantly by added TSP. Rachis K level, which relates well with FFB yield was lower than the critical of 1.00 %DM in 2005. Routine addition of K fertilisers should be carried out in this trial and the surrounding plantation.

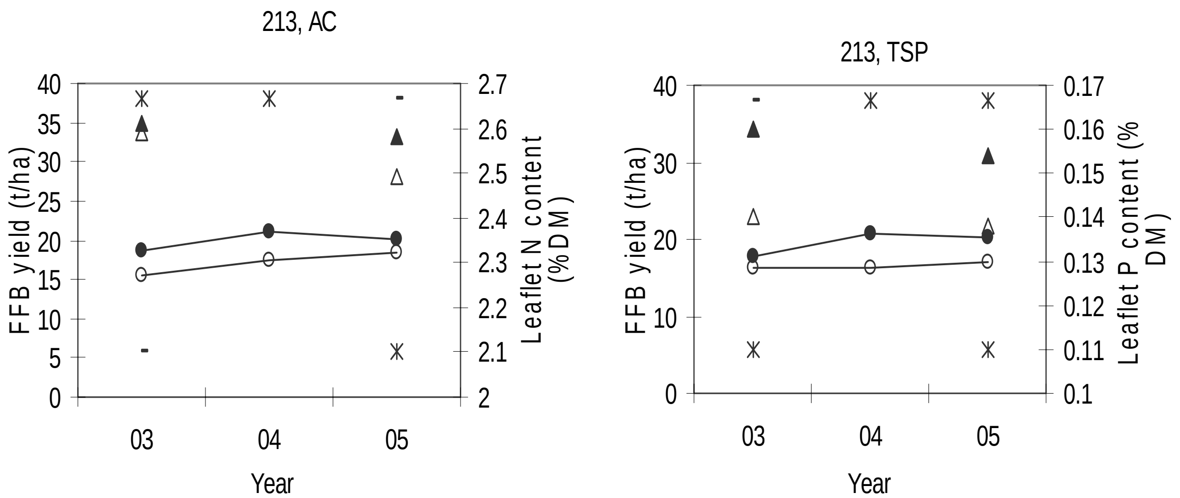


Table 5: Main effects of fertiliser treatments on yield in trial 213

	2003-2005			2005		
	FFB yield (t/ha)	BNO/ha	SBW (kg)	FFB yield (t/ha)	BNO/ha	SBW (kg)
AN 0	**16.6**	**1182**	14.1	18.4	1123	16.7
AN 2.2	**19.0**	**1359**	14.4	20.0	1232	17.0
AN 4.4	**19.6**	**1346**	14.7	21.2	1189	17.4
p	***0.007***	***0.007***	*0.454*	*0.169*	*0.244*	*0.563*
TSP 0	**16.3**	**1211**	**13.7**	**17.1**	1110	**14.3**
TSP 3	**19.9**	**1365**	**14.9**	**21.3**	1249	**15.7**
TSP 6	**19.0**	**1311**	**14.6**	**20.2**	1185	**15.6**
p	***0.002***	***0.035***	***0.042***	***<0.001***	*0.112*	***0.008***
s.e.d.	*0.9*	*56*	*0.5*	*1.0*	64	0.7
$Lsd_{0.05}$	*1.9*	*116*	*1.0*	*2.1*	*131*	1.3
GM	*18.4*	*1296*	*14.4*	*19.5*	*1181*	*17.0*
CV %	*12*	*11*	*8*	*13*	*13*	*9*

Table 6: Main effects (p values) of fertiliser treatments on yield in trial 213

	Leaflet						Rachis	
Source	Ash	N	P	K	S	Cl	Ash	K
AC	0.415	**0.002**	0.134	0.309	**0.024**	**<0.001**	**0.003**	0.512
TSP	**0.020**	**<0.001**	**<0.001**	**0.005**	**0.007**	0.101	0.053	**0.001**
AC.TSP	0.189	0.416	0.746	0.909	0.093	0.346	0.855	0.168
CV%	*3*	*2*	*2*	*5*	*3*	*12*	*11*	*22*

Table 7: Main effects of fertiliser treatments on yield in trial 213

	Leaflet						Rachis	
Source	Ash	N	P	K	S	Cl	Ash	K
AC 0	13.1	**2.49**	0.145	0.658	**0.198**	**0.403**	**2.9**	0.53
AC 2.2	12.9	**2.57**	0.147	0.643	**0.203**	**0.517**	**2.9**	0.55
AC 4.4	12.8	**2.58**	0.148	0.640	**0.205**	**0.603**	**3.4**	0.58
TSP 0	**13.2**	**2.48**	**0.138**	**0.672**	**0.198**	0.479	3.2	**0.66**
TSP 3	**12.9**	**2.57**	**0.149**	**0.643**	**0.204**	0.535	3.0	**0.54**
TSP 6	**12.7**	**2.59**	**0.154**	**0.627**	**0.205**	0.508	2.9	**0.46**
s.e.d.	*0.2*	*0.02*	*0.001*	*0.01*	*0.002*	*0.025*	*0.1*	*0.05*
$Lsd_{0.05}$	*0.4*	*0.05*	*0.003*	*0.03*	*0.005*	*0.051*	*0.3*	*0.10*
GM	*12.9*	*2.54*	*0.147*	*0.647*	*0.202*	*0.508*	*3.0*	*0.55*

Interaction between AN and TSP

Examination of the "interaction tables" indicate that near maximum FFB yield of about 23 t/ha was achieved at 3 kg/palm TSP and 2.2 kg/palm AC for this young oil palm. Further data will verify these results.

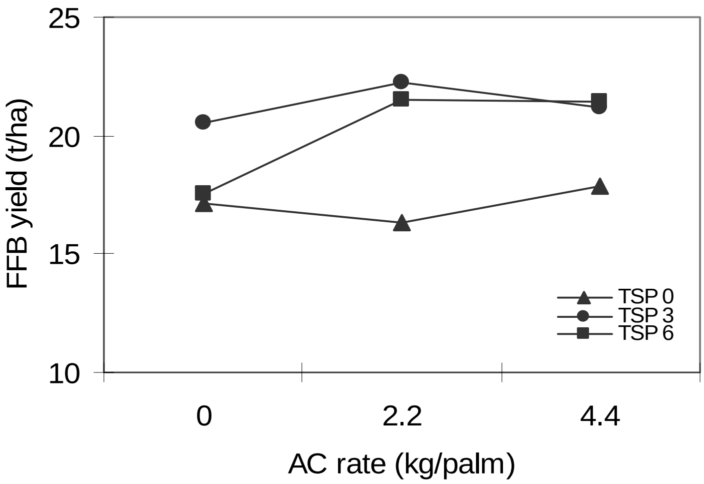


Figure 2: Effect of AN and TSP on average FFB yield (2003-2005).

CONCLUSION

Both N and P had positive effects on yield in the first three years of the trial and these results will be verified with subsequent years of data collection. The results suggest rates of 2.2 kg AC per palm and 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 AC and TSP were below their respective critical values. However, plots that received AC and TSP increased N and P levels significantly. Rachis K levels were below the critical of 1.00 %DM, thus addition of K fertilisers is recommended in this trial.

FERTILISER RESPONSE TRIAL IN ORO PROVINCE
(Higaturu Oil Palms)

(Steven Nake & Mike Webb)

Trial 324. NITROGEN SOURCE TRIAL ON HIGATURU SOILS, SANGARA ESTATE

SUMMARY

Trial 324 was established in Popondetta (Higaturu Oil Palms) to test relative effectiveness of different nitrogen fertilizers on Higaturu Soils (Volcanic Plains). The trial commenced in 2001. Five different sources of N (ammonium sulphate, ammonium chloride, urea, ammonium nitrate and di-ammonium phosphate) are being tested at 3 different (non-zero) rates in a factorial trial design (15 treatments). The treatments are replicated 4 times totalling 60 plots. Four additional control plots (Zero N) which are not fully randomised are set at the edge of the trial, so 64 plots in total.

Regardless of the fertilizer types and rates used, addition of nitrogen (N) was observed to increase FFB yield, tissue nutrient concentrations and the vegetative growth parameters (radiation interception and dry matter production) when compared to the control plots (no N added). The yield and other components show a difference between the control and the N-fertilized plots, this difference also increased over time. In 2005, the mean FFB yield was around 38 t/ha/year compared to 22 t/ha/year in the control plots representing a yield difference of about 42 %.

Within the fertilized treatments, significant yield increases as a result of increasing fertiliser rates first appeared in 2003 and this trend continued in 2004 and 2005. Similar response was also apparent on the single bunch weight in 2005. Although rates of fertiliser have had a significant effect on yield, the type (source) of fertilizer has not. This lack of response by the fertilizer type was also witnessed on the N levels in the leaflets. The number of bunches however responded to the fertilizer type in 2005.

The preliminary results from this trial stress the importance of N-fertilisers in volcanic ash soils.

INTRODUCTION

Nitrogen is the most limiting nutrient in oil palm growth and FFB yield in PNG. Oil palm requires substantial amounts of N to incorporate into organic compounds including proteins, nucleic acids, chlorophyll and growth regulators which are important for growth and production of fresh fruit bunches.

It has been established that N is the major limiting element in soils derived from Mt Lamington volcanic ash materials. However, it is not known which fertilizer is a better source for this environment both in relation to high yields and the long-term sustainability of the soils. Results from completed trials like 309 and 310 which were both on outwash plains have shown that SOA is a better source of N than AMC and urea in the ex grassland sandy loam soils. Whether this is the case on other soil is not known. Thus it was proposed and approved during the 1999 SAC meeting in Popondetta to establish a trial to test different N sources. Hence, the purpose of this trial is to test relative effectiveness of different nitrogen fertilizers on Higaturu Soils (Volcanic Plains). The trial commenced in January 2001.

METHODOLOGY

Trial Background Information

Table 1. Trial 324 background information.

Trial number	324	*Company*	Higaturu Oil Palms
Estate	Sangara	Block No.	2102 & 2103
Date planted*	1996	Planting Density*	135 palms/ha
Spacing	???	Pattern	Triangular
LSU or MU*	Higaturu	Soil Type	Higaturu Soils
Recording Started	2001	Age after planting*	8
Topography	Flat	Planting material	Dami D x P
Progeny	???	Altitude	130 m.a.s.l
Drainage*	Good	Previous Landuse*	Cocoa plantation
Officer in charge	S.Nake	Area under trial soil type (ha)*	3,000

**Data should be synchronous with OMP.*

The trial is part of an ongoing research and development program to investigate yield and growth response to different fertiliser types on different soil types in Oro Province.

Experimental Design and Treatments

Five N sources are tested at 3 different rates. The N sources are ammonium sulphate (SOA), ammonium chloride (AMC), ammonium nitrate (AMN), urea and diammonium phosphate (DAP). The rates provide equivalent amounts of N for the different N sources (Table 2). Fertiliser is applied in 3 doses/year. Each treatment is replicated 4 times. There are also 4 zero fertiliser plots at the edge of the trial, giving a total of 64 plots. Data collected from the zero fertiliser plots is not used in the analysis of variance (ANOVA). A basal application of MOP at 2 kg/palm/year (2 doses/year) is applied to all plots. Each of the plots consists of 36 palms, the central 16 being recorded. This trial is the same design as Trial 325 in Ambogo and Trial 125 in Kumbango. See 2001 Proposals for background.

Table 2. 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
Diammonium phosphate	2.3	4.6	9.2
	(g N/palm/year)		
All sources	420	840	1680

Field Establishment

Matured oil palm seedlings were planted in this block in 1996. However, the trial commenced in January 2001 (5 year after field planting) after marking out the plots and palms. Treatment application started in April 2001.

Soil samples were collected to determine the initial soil nutrient status of the two blocks before treatment application (refer to soil data, Table 3).

Trial Maintenance and Upkeep

Like all PNGOPRA established trials, any upkeep work in the trial block is solely taken care of by the estate on which the trial is located, in this case Sangara Estate of HOP and this includes activities such as ring weeding, herbicide spraying, wheelbarrow path clearance, cover crop maintenance and other routine plantation practices. Any fertilizer application close to the trial has to be closely supervised by plantation supervisors so that fertilizers are not accidentally applied in the trial block. To avoid such incidents, fertilization (standard rates used by estate) of the boundary and perimeter palms is done by PNGOPRA. **As of 2006 onwards, this trial will receive basal application of kieserite and boron on both experimental and non experimental palms.**

Trenches were dug around the plots in 2001/02 to minimize treatment poaching by neighbouring plots. These trenches are maintained biannually.

Trials are maintained regularly so that treatments effects on yield and other measured parameters are not compromised by poaching.

Data Collection

Yield recording (weighing of bunches) is done on a fortnightly basis (14 days). Recorders walk through the plots along the harvest paths and record the number of bunches harvested and weight of those bunches. Loose fruits are also collected and weighed with their respective bunches. Bunches from the guard row palms are not weighed. The data is recorded onto the yield record sheets in the field and later on entered onto the computer database using Microsoft Access and are later on converted into yield expressed in tonnes per hectare, total number of bunches harvested per hectare and the single bunch weight.

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

Tissue sampling (leaf & rachis) is done either every year or every two years depending on the fertilizer responses. Before sampling the leaflets, frond 17 is firstly identified following the standard protocol, and then harvested. Two pairs of leaflets (one from upper rank and one from lower rank) are taken from both sides of the middle portion of leaf. All samples from each plot are kept separately in plastic bags. Part of the rachis where the leaflets are taken from are also chopped off and included with the leaflets. These are later processed, packed in brown paper bags, oven dried at 70 –75 °C for 24 hours and dispatched to AAR for analysis. Rachises are dried longer than the leaves (36 hours).

Pre-Treatment Data

Table 3 presents the analysis data for the soil collected before the fertiliser treatments commenced. The soil pH is almost neutral throughout the soil profile an increased in soil depths in reps 2, 3, 4 and control plots except rep 1. CEC in general was moderate, with high levels of exchangeable Ca and moderate levels of exchangeable K and Mg. Total N contents and organic matter contents was also very high. In general, the soil in this trial is a chemically fertile soil.

Table 3. Initial soil analysis results from soil samples taken in 2000

	Depth	pH in water	Exch K	Exch Ca	Exch Mg	Exch Na	CEC	Al	Res. K	Res. Mg	Base Sat.	Org. Matter	Total N	Avail N	Olsen P	Tot. P	Sulphate S	Org S	Boron	P Reten
	(cm)		(cmolc/kg)								(%)	(%)	(%)	(kg/ha)	(g/kg)	(g/kg)	(mg/kg)			
Rep1	0-10	6.6	0.43	10.7	1.45	<.0.05	14.5	<0.1	0.26	20.5	87	4.3	0.26	173	20	458	3	4	0.4	42
	10-20	6.4	0.24	6.5	0.77	<0.05	10.1	<0.1	0.26	20.5	74	1.8	0.11	54	5	584	3	<2	0.2	49
	20-30	6.6	0.29	8.1	1.13	0.06	12.3	<0.1	0.20	26.4	78	1.2	0.07	28	7	710	4	<2	<0.1	71
	30-60	6.7	0.40	9.3	1.92	0.11	15.6	<0.1	0.18	29.9	75	1.0	0.05	<10	15	715	9	2	<0.1	83
Rep2	0-10	6.1	0.35	7.9	1.44	<0.05	13.1	<0.1	0.20	17.4	74	3.7	0.24	160	16	706	3	4	0.4	33
	10-20	6.4	0.30	8.1	0.94	<0.05	12.6	<0.1	0.20	23.2	74	1.9	0.11	44	8	606	4	2	0.2	58
	20-30	6.6	0.23	8.0	1.05	0.08	11.7	<0.1	0.20	28.8	80	1.0	0.07	20	5	436	4	<2	<0.1	65
	30-60	6.8	0.29	9.8	1.69	0.15	14.8	<0.1	0.28	34.8	81	0.8	0.05	<10	11	710	6	<2	<0.1	84
Rep3	0-10	6.4	0.38	10.6	1.57	<0.05	16.2	<0.1	0.23	17.6	77	4.9	0.30	180	23	822	3	3	0.7	31
	10-20	6.6	0.33	7.3	0.81	<0.05	10.7	<0.1	0.20	20.3	79	1.8	0.12	57	7	492	4	<2	0.3	46
	20-30	6.8	0.33	9.4	1.17	0.05	13.5	<0.1	0.20	30.7	81	1.1	0.07	17	9	474	6	<2	0.1	64
	30-60	6.8	0.36	11.1	1.84	0.12	17.4	<0.1	0.23	35.6	77	0.9	0.05	<10	18	812	11	<2	<0.1	89
Rep4	0-10	6.2	0.41	8.8	1.55	<0.05	14.2	<0.1	0.18	19.6	76	4.8	0.30	202	19	766	6	3	0.4	32
	10-20	6.3	0.34	6.2	0.78	<0.05	9.8	<0.1	0.20	25.1	76	1.5	0.11	56	4	392	6	<2	0.2	46
	20-30	6.7	0.28	8.8	1.18	0.09	12.9	<0.1	0.20	33.1	81	0.9	0.06	<10	4	422	8	<2	<0.1	69
	30-60	6.7	0.29	9.7	2.08	0.17	15.1	<0.1	0.20	38.0	81	0.8	0.05	<10	9	580	15	2	<0.1	82
Zero	0-10	6.1	0.42	7.4	1.57	<0.05	13.1	<0.1	0.20	21.2	72	4.1	0.25	144	20	782	3	3	0.4	31
	10-20	6.1	0.41	6.6	0.72	<0.05	12.1	<0.1	0.18	22.5	64	2.0	0.17	56	8	538	5	3	0.3	41
	20-30	6.4	0.37	7.4	0.87	0.07	11.7	<0.1	0.23	27.3	75	1.1	0.10	20	8	550	10	<2	0.1	62
	30-60	6.7	0.31	9.3	1.82	0.15	14.4	<0.1	0.23	36.3	80	0.9	0.08	<10	18	992	12	2	<0.1	83

RESULTS & DISCUSSION

Yield and other components response to fertilizer treatments

The treatment effects on FFB yield and other components are presented in Tables 4, 5, 6, 7 and 8.

There was no significant yield response to different N-fertiliser types in the years 2001 to 2005. Despite this, urea came out to be the most superior N-source producing the highest FFB yield (39.5 t/ha) in 2005. The FFB yields however responded positively (p = 0.010) to the fertilizer rates from 2003 to 2005 by increasing steadily. The highest rate yielded the highest FFB yield of 39.1 t/ha in 2005. Despite this, the overall mean yield effect for the 5 years (2001-2005) showed yield responses to the fertilizer type (p=0.097).

The number of bunches responded significantly (p= 0.019) to the fertilizer type in 2005 (Table 4 and 6). Urea continued to maintained the highest number of bunches produced per hectare followed by AMN and DAP. Fertilizer rates did not have any significant effects (p=0.665) on the number of bunches, however a positive trend was seen though not significant.

The N-fertiliser types continued to have no effect on the single bunch weight in 2005, instead, the N-fertiliser rates showed significant positive effects (p=0.012) on the single bunch weight. The highest rate of N fertilizers produced the highest single bunch weights.

The interactions (type x rate) were only significant on the number of bunches and not the FFB yield or the SBW. Table 8 depicts the effect of the interactions on the FFB yield. Interactions showed increases in FFB yield as the rates of SOA and AMC were increased (Table 8). 2005 results showed yield being maximized when applying rate 3 of Urea.

The yields in the control plots (zero N applied) continued to drop in 2005. This drop in yield is attributed to a decline in the number of bunches in the same year (Figure 1). However, the drop in both parameters (yield and BNO) was not as large as the drop in 2004. The SBW continued to increase steadily in 2005. After 9 years, the average bunch weight was around 19 kg per bunch.

The plots which received N had consistently greater yield, number of bunches, and single bunch weights (Figure 1). These differences increased with time, presumably as residual N in the soil was used. Mean yield for plots with N in 2005 was 38.0 t FFB/ha/yr which is quite high. The number of bunches and SBW in the treated plots (with N) also increased substantially in 2005. The trend showed in Figure 1 by all the 3 parameters in the control and treated plots clearly illustrates the importance of N fertilizers.

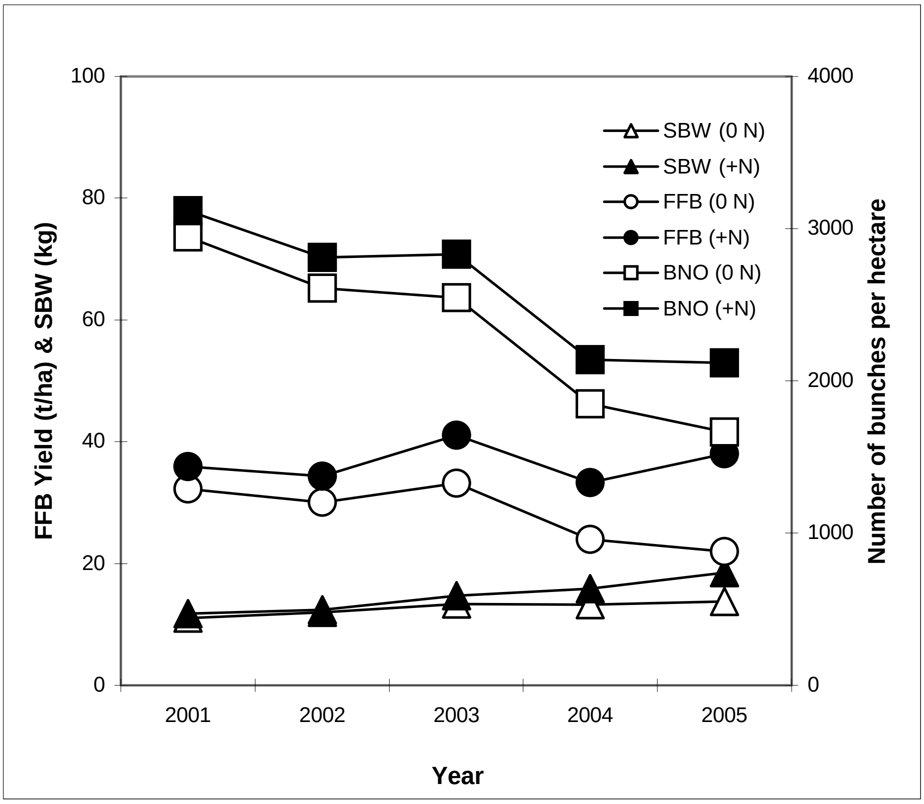


Fig. 1: Effect of N fertilizer on annual yield of FFB, number of bunches and SBW.

Table 4. Effects (p values) of treatments on FFB yield and its components in 2001 – 2005 and 2005. P values <0.1 are shown in bold.

	2001 - 2005			2005		
Source	Yield	BNO	SBW	Yield	BNO	SBW
Type	**0.097**	0.102	0.783	0.222	**0.019**	0.603
Rate	**0.098**	0.815	0.100	**0.010**	0.665	**0.012**
Type. Rate	0.549	**0.010**	0.564	0.125	**0.006**	0.570
CV %	*4.5*	4.5	*6.0*	*6.7*	6.2	*6.3*

Table 5. Main effects of fertilizer treatments on FFB yield (t/ha) from 2001 – 2005.

Treatments	**2001** (5 years)	**2002** (6 years)	**2003** (7 years)	**2004** (8 years)	**2005** (9 years)	**2001 - 2005**
Control	*32.3*	*30.0*	*33.2*	*23.9*	*22.0*	*28.3*
SOA	35.6	33.7	41.1	32.4	36.9	**35.2**
AMC	34.4	33.1	40.0	32.7	37.8	**34.8**
Urea	35.9	34.1	41.8	33.1	39.5	**36.1**
AMN	37.2	34.6	40.9	34.0	37.8	**36.1**
DAP	35.6	35.8	41.7	34.5	37.9	**36.3**
sed	*1.2*	*1.1*	*1.1*	*0.49*	*1.04*	*0.65*
Rate 1	36.5	34.0	**40.1**	**32.2**	**36.6**	**35.1**
Rate 2	35.3	34.5	**41.0**	**33.4**	**38.4**	**35.7**
Rate 3	35.5	34.2	**42.1**	**34.3**	**39.1**	**36.3**
sed	*0.94*	*0.83*	*0.87*	***0.38***	***0.80***	***0.50***
Grand mean	35.9	34.3	41.1	33.3	38.0	35.7

Table 6. Main effects of fertilizer treatments on number of bunches per /ha from 2001 – 2005

Treatments	**2001** (5 years)	**2002** (6 years)	**2003** (7 years)	**2004** (8 years)	**2005** (9 years)	**2001 - 2005**
Control	*2947*	*2611*	*2546*	*1848*	*1662*	*2323*
SOA	3157	**2769**	2828	2054	**2017**	2524
AMC	3075	**2798**	2748	2095	**2077**	2518
Urea	3012	**2734**	2840	2131	**2192**	2541
AMN	3274	**2844**	2857	2213	**2149**	2626
DAP	3070	**2914**	2892	2203	**2147**	2600
sed	*125*	*63*	*87*	*82*	*54*	*48*
Rate 1	3182	2856	2828	2108	2099	2572
Rate 2	3133	2813	2811	2152	2115	2564
Rate 3	3038	2766	2860	2157	2136	2549
sed	*97*	*49*	*68*	*63*	*42*	*37*
Grand mean	3118	2812	2833	2139	2117	2562

Table 7. Main effects of fertilizer treatments on single bunch weight (kg) from 2001 – 2005

Treatments	**2001** (5 years)	**2002** (6 years)	**2003** (7 years)	**2004** (8 years)	**2005** (9 years)	**2001- 2005**
Control	*11.0*	*12.0*	*13.3*	*13.2*	*13.8*	*12.7*
SOA	11.5	12.3	14.6	15.9	18.6	14.5
AMC	11.5	12.0	14.6	15.9	18.8	14.5
Urea	12.3	12.7	15.0	15.8	18.6	14.8
AMN	11.7	12.4	14.5	15.7	18.1	14.4
DAP	12.0	12.6	14.7	16.1	18.3	14.7
sed	*0.42*	*0.33*	*0.34*	*0.49*	*0.48*	*0.35*
Rate 1	11.7	12.1	**14.4**	15.6	**17.8**	14.3
Rate 2	11.6	12.5	**14.7**	15.8	**18.7**	14.6
Rate 3	12.0	12.5	**15.0**	16.2	**18.9**	14.9
sed	*0.32*	*0.26*	*0.26*	*0.38*	*0.37*	*0.27*
Grand mean	11.8	12.4	14.7	15.9	18.5	14.6

Table 8. Effect of interaction between fertiliser type and rate on FFB yield (t/ha) in 2005. The interaction was not significant (p=0.125)

	SOA	AMC	Urea	AMN	DAP	Means
Rate 1	35.2	36.3	39.2	34.0	38.3	36.6
Rate 2	36.9	37.7	38.6	40.0	38.7	38.4
Rate 3	38.9	39.4	40.6	39.6	36.8	39.1
Means	37.0	37.8	39.5	37.9	37.9	

Interactions showing positive response (but statistically not significant) are highlighted

Tissue (Leaf and Rachis)

The treatments effects on the oil palm leaflet and rachis nutrient levels for 2005 are shown in Tables 9, 10 and 11. Most of the foliar nutrients are within the optimum range except K and Mg level that are deficient. Mg levels are also slightly low. Fertiliser type had no significant effects (p>0.05) on the major nutrients (N, P, K & Mg) except Ca and Cl in the leaflets. The leaflet N level was comfortably within the optimum range (2.40 – 2.80), this is probably one of the reasons why the leaflet N showed no significant response (p=0.458) and may have attributed again to the no yield response from the fertilizer types. Despite that, leaflet N (with Ca and S) responded significantly to the fertilizer rates (Table 9), explaining the significant and positive response to the yield by the fertilizer rates.

Rachis ash and P responded significantly to the fertilizer types (Table 10b), while fertilizer rates had significant effects on the rachis N, P and K. The fertilizer rates increased rachis levels of N and K while reducing the P levels.

The interactions were only significant on the leaflet K (Table 9). SOA, urea and AMN continued to have a very positive effect on the leaflet N, though not significant (Table 11). These three N sources increased N level in the leaves when applied. AMC, AMN and DAP also increased rachis K levels (Table 11).

Table 9. Effects (p values) of treatments on frond 17 nutrient concentrations in 2005. p values less than 0.1 are in bold.

Source	Leaflet Nutrient Concentrations								
	Ash	N	P	K	Ca	Mg	Cl	S	B
Type	0.249	0.458	0.200	0.173	**0.058**	0.682	**<0.001**	0.815	0.709
Rate	0.306	**<0.001**	0.372	0.125	**0.001**	0.743	0.276	**<0.001**	0.529
Type. Rate	0.175	0.181	0.214	**0.015**	0.794	0.848	0.112	0.167	0.349
CV %	4.6	2.4	2.4	4.7	6.3	10.3	6.8	3.1	9.1
	Rachis Nutrient Concentrations								
	Ash	N	P	K					
Type	**0.070**	0.112	**<0.001**	0.120					
Rate	0.391	**0.020**	**<0.001**	**0.072**					
Type. Rate	0.249	0.777	0.611	0.260					
CV %	5.3	6.3	11.1	5.4					

Table 10 a. Main effects of treatments on frond 17 nutrient concentrations in 2005, in units of % dry matter. p values less than 0.1 are shown in bold. Values for plots receiving zero N (control) were not included in the analysis of variance.

Treatment	Leaflet Nutrient Concentrations								
	Ash	N	P	K	Mg	Ca	Cl	S	B
Control	*16.2*	*2.11*	*0.148*	*0.65*	*0.20*	*0.93*	*0.50*	*0.180*	*14.3*
SOA	15.6	2.44	0.148	0.67	0.20	**0.82**	**0.50**	0.200	12.5
AMC	15.8	2.41	0.150	0.65	0.20	**0.86**	**0.61**	0.198	11.9
Urea	15.2	2.43	0.151	0.67	0.20	**0.86**	**0.49**	0.198	12.2
AMN	15.3	2.45	0.151	0.67	0.20	**0.86**	**0.51**	0.198	12.3
DAP	15.7	2.46	0.151	0.68	0.20	**0.81**	**0.51**	0.200	12.5
sed	*0.29*	*0.02*	*0.001*	*0.01*	*0.01*	*0.02*	*0.02*	*0.003*	*0.46*
Rate 1	15.6	**2.36**	0.149	0.66	0.20	**0.87**	0.52	**0.192**	12.1
Rate 2	15.3	**2.48**	0.151	0.66	0.20	**0.86**	0.54	**0.203**	12.5
Rate 3	15.7	**2.48**	0.150	0.68	0.20	**0.81**	0.52	**0.202**	12.2
sed	*0.23*	*0.02*	*0.001*	*0.01*	*0.01*	*0.02*	*0.01*	*0.002*	*0.35*

Table 10 b. Main effects of treatments on frond 17 nutrient concentrations in 2005, in units of % dry matter. p values less than 0.1 are shown in bold. Values for plots receiving zero N (control) were not included in the analysis of variance.

Treatment	Rachis Nutrient Concentrations								
	Ash	N	P	K	Mg	Ca	Cl	S	B
Control	*4.7*	*0.26*	*0.204*	*1.30*					
SOA	**5.1**	0.30	**0.118**	1.42					
AMC	**5.4**	0.31	**0.129**	1.47					
Urea	**5.2**	0.30	**0.133**	1.39					
AMN	**5.2**	0.30	**0.126**	1.41					
DAP	**5.4**	0.32	**0.155**	1.45					
sed	0.11	0.01	0.006	0.02					
Rate 1	5.2	**0.29**	**0.147**	**1.40**					
Rate 2	5.3	**0.30**	**0.128**	**1.43**					
Rate 3	5.3	**0.31**	**0.122**	**1.45**					
sed	0.09	0.01	0.004	0.03					

Table 11. Effects of interaction between N source and rate on leaflet N and rachis K content

Leaflet N (% DM), interaction not significant (p= 0.181)					
	SOA	AMC	Urea	AMN	DAP
Rate 1	2.38	2.37	2.33	2.32	2.39
Rate 2	2.48	2.46	2.47	2.48	2.49
Rate 3	2.47	2.41	2.49	2.54	2.48
Rachis K (% DM), interaction not significant (p= 0.260)					
	SOA	AMC	Urea	AMN	DAP
Rate 1	1.40	1.42	1.39	1.35	1.43
Rate 2	1.47	1.48	1.41	1.39	1.42
Rate 3	1.38	1.51	1.39	1.50	1.50

Table 12. Effects (p values) of treatments on vegetative parameters in 2005. p values less than 0.1 are shown in bold.

Source				**Radiation Interception**						**Dry Matter Production (t/ha/yr)**				
	Frond length	LL No.	PCS	FP	FPR	GF	FA	LAI	FW	FDM	BDM	TDM	VDM	BI
Fert type	0.572	0.741	**0.021**	**0.018**	**0.074**	0.143	0.759	**0.097**	**0.021**	**0.005**	0.222	0.482	**0.022**	**<.001**
Rate	0.903	0.139	**0.087**	**<.001**	**<.001**	**0.007**	0.336	**0.001**	**0.087**	**0.002**	**0.010**	**0.001**	**<.001**	0.565
Type.Rate	0.157	0.179	0.991	**0.084**	0.329	0.232	0.736	0.391	0.991	0.934	0.125	0.286	0.907	0.233
CV %	2.7	1.8	6.0	2.8	3.3	3.8	4.0	4.7	5.7	7.1	6.7	5.8	6.2	2.2

Table 13. Effects of treatments on vegetative parameters in 2005. p values less than 0.1 are shown in bold.

				Radiation Interception						**Dry Matter Production (t/ha/yr)**				
Treatment	Frond length (cm)	Leaflet No.	PCS (cm^2)	FP (per year)	FPR (per month)	GF	FA (m^2)	LAI	FW (kg)	FDM	BDM	TDM	VDM	BI
Control	*552.7*	*179*	***29.7***	***20.8***	***1.70***	*33.9*	*10.7*	***4.90***	***3.24***	***9.1***	*18.9*	*31.0*	***12.2***	***0.606***
SOA	606.1	179	**35.0**	**24.5**	**2.04**	36.5	11.31	**5.56**	**3.78**	**12.5**	30.3	47.6	**17.3**	**0.637**
AMC	610.7	177	**36.0**	**24.1**	**2.02**	37.0	11.50	**5.74**	**3.88**	**12.6**	30.9	48.5	**17.5**	**0.639**
Urea	601.3	179	**34.1**	**24.0**	**2.01**	36.3	11.51	**5.64**	**3.68**	**11.9**	32.4	49.2	**16.8**	**0.657**
AMN	610.6	178	**34.7**	**24.1**	**2.03**	36.3	11.42	**5.59**	**3.75**	**12.2**	31.0	48.0	**17.0**	**0.646**
DAP	609.5	178	**36.9**	**24.8**	**2.08**	37.5	11.52	**5.83**	**3.97**	**13.3**	31.1	49.4	**18.3**	**0.629**
sed	*6.64*	*1.29*	*0.87*	*0.27*	*0.028*	*0.58*	*0.186*	*0.11*	*0.089*	*0.36*	*0.85*	*1.14*	*0.44*	*0.006*
Rate 1	608.2	179	**34.5**	**23.7**	**1.98**	**35.9**	11.33	**5.49**	**3.72**	**11.9**	**29.9**	**46.5**	**16.6**	0.644
Rate 2	606.3	179	**35.9**	**24.6**	**2.06**	**37.4**	11.54	**5.82**	**3.87**	**12.8**	**31.5**	**49.2**	**17.8**	0.639
Rate 3	608.4	177	**35.6**	**24.7**	**2.07**	**36.8**	11.49	**5.71**	**3.84**	**12.8**	**32.0**	**49.8**	**17.8**	0.643
sed	*5.14*	*1.01*	*0.67*	*0.21*	*0.021*	*0.45*	*0.144*	*0.08*	*0.069*	*0.28*	*0.66*	*0.88*	*0.34*	*0.005*

PCS = petiole cross-section; FP = Number of fronds produced/year; FPR = Frond production rate; GF = Number of green frond; FA = Frond area; LAI = Leaf area index; FW = Dry frond weight; FDM = Frond dry matter; BDM = Bunch dry matter; TDM = Total dry matter; VDM = Vegetative dry matter; BI = Bunch index

Vegetative Growth Parameters

Summarised results for the vegetative growth parameters for 2005 are shown in Tables 12 and 13. Unlike yield and tissue nutrient, there was a marked response by vegetative parameters to both treatments (fertilizer type and rates). Both treatments (fertilizer type and rate) did not have any significant effect ($p<0.1$) on the FA, however the rates still increased the FA though statistically not significant. The LAI responded significantly ($p=0.097$ and $p=0.001$) to the fertilizer type and rates respectively. The LAI in the DAP and AMC plots were the greatest. The control plots where no N was applied had lower FA and LAI values compared to the fertilized plots.

The fertilizer effects (type and rate) observed on the PCS, FP and FPR are also seen on the FW, FDM, and VDM, by showing significant positive effects. All these vegetative parameters increased as the fertilizer rates were increased (Table 13). There were substantial differences in the vegetative growth between the control plots (no N) and the fertilized plots. The FDM in the control plots were about 3 tonnes less than the fertilised plots.

Regardless of the fertilizer type, N application in general improved the radiation interception and the dry matter production. This scenario now highlights the importance of N in oil palm management.

CONCLUSION

Irrespective of the N form or rate, when palms were fertilized with N, there was an increase in productivity and general health (evidenced from vegetative measures) of the palms. This confirms that N application is still required to achieve acceptable productivity.

However, the trial is not yet conclusive with respect to N-fertiliser types or rates of application. While the fertilizer rates have significantly increased yield in 2005, fertilizer types have not shown any significant effects. The lack of response of the yield (and other components) to the fertilizer types is probably explained by the lack of response of the leaflet N concentrations to fertiliser type. This year’s results suggest yield is maximized when applying rate 3 of urea.

Similarly, there was no significant response by N nutrient levels in the leaflet and rachis to the fertilizer types. This negative response explains the lack of response also on the yield as a result of the fertilizer types.

The vegetative parameters (radiation interception and dry matter production) responded well to the treatments.

No new recommendations will be made from this trial at this stage because no one type of N-fertiliser appears to be substantially better than any other, while rates of application have already shown effects.

Trial 326. NITROGEN X EFB TRIAL ON HIGATURU SOILS, SANGARA ESTATE, HIGATURU OIL PALMS

SUMMARY

Trial 326 was established in 2002 at Higaturu Oil Palms (Popondetta) to provide information on minimum EFB and N requirements of palm to help formulate fertilizer recommendations on volcanic plain soils. The trial is a randomized block design with 4 SOA levels and 3 EFB levels with 12 treatments combinations. These treatments are replicated 5 times resulting in 60 plots.

The yield and the bunch weights continued to increase steadily each year since the trial began, unlike the number of bunches which dropped in 2005. The treatment effects on yield and other components (number of bunches per hectare and single bunch weights) was not significant. Similarly, there were nil or very slight (weak) responses on the tissue nutrient concentration and vegetative parameters. Despite of this, EFB is starting to show some slight positive effects.

INTRODUCTION

The oil palm is one of the largest consumers of inorganic fertilizer nutrients because of its high nutrient demand and the increasing area cultivated for the crop alone. However, of all the total nutrients taken up from the soil by the crop, only a small quantity is actually is lost out of the system through its products. Most of the nutrients are still available for use in the crop residues such as the empty fruit bunches (EFB), and plantations can benefit by to utilizing these crop residues in the field. EFB contains 0.6, 2.0 and 0.05 % (dry matter) of N, K and P respectively so can help reduce application rates of these nutrients. However, contributions made by EFB to overall oil palm nutrition in terms of amounts of nutrients contributed, providing carbon for micro organisms to function in these low to moderate OM level soils and improving soil physical properties are not known and not quantified for palms cultivated on soils derived from volcanic ash deposits. The rate of breakdown and release of nutrients and their relationships with different soil types are also very important, these aspects have not been studies and quantified as well. This information is very useful in that it can be used to provide the basis for fertilizer recommendations. To date, there is no data available to provide information on the minimum EFB requirements. This information is vital to make plans for areas to be covered and for inorganic fertilizer requirements. Trial 311 and 312 which were both conducted on the Ambogo/Penderetta soils have shown a strong positive yield responses to low levels of N with EFB, however only one rate of EFB was used. This trial was proposed and approved in the 1999 SAC meeting to provide information on the minimum EFB requirements of palms to help formulate fertilizer recommendations on volcanic plain soils.

METHODOLOGY

Trial Background Information

Table 1. Trial 326 background information.

Trial number	326	Company	Higaturu Oil Palms
Date planted	1999	Planting Density	135 palms/ha
Spacing	???	Pattern	Triangular
LSU or MU	Higaturu	Soil Type	Higaturu Family
Recording Started	2002	Age after planting	5
Topography	Flat	Planting material	Dami D x P
Progeny	???	Altitude	150 m.a.s.l
Drainage	Good	Previous Landuse	Cocoa plantation
Officer in charge	S.Nake	Area under trial soil type (ha)	

Experimental Design and Treatments

A randomized block design with 4 levels of N (ammonium sulphate) and 3 levels of EFB all combined in a factorial design (see Table 2), with 5 replicates resulting in 60 plots. Fertiliser (ammonium sulphate) is applied in 3 doses/year. EFB treatments are applied once every year. Each of the plots consists of 36 palms, the central 16 being recorded. The surrounding 20 palms act as guard rows. This trial is the same design as Trial 327 in Ambogo and Trial 125 in Kumbango. See 2001 Proposals for background.

Table 2. 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	-

Field Establishment

The trial was mapped out in 2001 and commenced in 2002. The treatments also commenced in the same year. Experimental palms are painted with black paint with numbers written on ranging from 1 to 16. Directly surrounding those experimental palms are 20 guard row palms and these are painted with blue paint with initial GR. Boundary palms as well as those on gulleys or any marginal area within the block that is not suitable to allocate plots to are painted in red. Each experimental palm is identified by two numbers. The numbers represent the plots and the palm number. Soil samples were collected in April 2002 to determine the initial soil nutrient status of the block before treatment application (refer to soil data, Table 4).

Trial Maintenance and Upkeep

Like all PNGOPRA established trials, upkeep work is taken care of by the estate on which the trial is located, in this case Sangara Estate. This includes activities such as harvesting, pruning, ring weeding, herbicide spraying, wheelbarrow path clearance, cover crop maintenance and other routine plantation practices. Any fertilizer application close to the vicinity of the trial has to be closely supervised by plantation supervisors so that fertilizers are not accidentally applied in the trial block. To avoid such incidents, fertilization (standard rates used by estate) of the boundary is done by PNGOPRA. **In 2005, the trial will receive basal application kieserite (Mg) and boron. Potassium in the form of MOP will not be applied because of EFB being a treatment.**

The trial also has trenches (30-40 cm wide and 1 m deep) dug around the plots to avoid or minimize treatment poaching by neighboring plots. These trenches are maintained biannually or as required.

Trials are maintained regularly so that treatments effects on yield and other measured parameters are not compromised by poaching.

Data Collection

Yield recording (weighing of bunches) is done on a fortnightly basis (14 days). Recorders walk through the plots along the harvest paths and record the number of bunches harvested and weight of those bunches. Loose fruits are also collected and weighed with their respective bunches. Bunches from the guard row palms are not weighed. The data is recorded onto the yield record sheets in the field and later on entered onto the computer database using Microsoft Access and are later on converted into yield expressed in tonnes per hectare, total number of bunches harvested per hectare and the single bunch weight.

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

Tissue sampling (leaf & rachis) is done either every year or every two years depending on the fertilizer responses. Before sampling the leaflets, frond 17 is firstly identified following the standard protocol, and then harvested. Two pairs of leaflets (one from upper rank and one from lower rank) are taken from both sides of the middle portion of leaf. All samples from each plot are kept separately in plastic bags. Part of the rachis where the leaflets are taken from are also chopped off and included with the leaflets. These are later processed, packed in brown paper bags, oven dried at 70 –75 °C for 24 hours and dispatched to AAR for analysis. Rachis are dried longer than the leaves (36 hours).

Pre-treatment data

There was no yield data taken before the treatments were applied (pre-treatment). The first yield recording was done after first dose of fertilizer treatments applied in 2002. Pre-treatment soil analysis results are presented in Tables 3. According to the soil analysis (Table 4), pH is slightly acidic and increases with soil depth throughout all 5 replicates. CEC falls between the low and moderate category, with adequate levels of exchangeable Mg. Exchangeable K is moderate in the first depth only (0-10 cm), the next three soil depths have low levels of exchangeable K. Organic matter contents and total N are quite reasonable.

Table 3. Initial soil analysis results from soils taken in 2002.

	Depth	pH	Exch K	Exch Ca	Exch Mg	Exch Na	CEC	Res. K	Base Sat.	Org. Matter	Total N	Olsen P	Sulfate S	Org S
			(cmolc/kg)						(%)	(%)	(%)	(g/kg)	(mg/kg)	
Rep1	0-10	5.7	0.32	6.1	1.23	<0.05	13	<0.1	58	4.4	0.24	6	7	6
	10-20	5.7	0.22	4.9	0.72	<0.05	10	0.1	57	2.2	0.13	4	5	3
	20-30	5.9	0.15	5.4	0.86	0.08	10	0.1	64	1.4	0.08	4	6	2
	30-60	6.1	0.17	6.4	1.16	0.15	12	<0.1	67	0.9	0.07	5	10	<1
Rep2	0-10	5.5	0.29	5.8	1.18	<0.05	14	<0.1	52	4.7	0.26	7	4	7
	10-20	5.6	0.19	5.0	0.78	<0.05	11	<0.1	54	2.7	0.15	3	7	4
	20-30	5.9	**0.05**	**1.5**	**0.26**	<0.05	**3**	<0.1	67	1.5	0.10	<1	7	2
	30-60	6.2	0.16	6.7	1.23	0.16	12	<0.1	71	1.0	0.06	4	13	<1
Rep3	0-10	5.5	0.29	5.1	1.06	<0.05	13	<0.1	50	3.8	0.23	5	8	4
	10-20	5.7	0.18	4.5	0.69	<0.05	10	<0.1	52	2.2	0.13	2	5	3
	20-30	6.0	0.11	5.3	0.81	0.09	10	<0.1	63	1.5	0.08	3	6	2
	30-60	6.2	0.12	6.8	1.39	0.17	12	<0.1	68	0.9	0.10	4	10	1
Rep4	0-10	5.4	0.26	5.1	1.06	<0.05	14	<0.1	47	4.5	0.23	5	9	6
	10-20	5.6	0.17	4.3	0.73	<0.05	11	<0.1	48	2.2	0.15	3	7	3
	20-30	5.8	0.11	5.0	0.84	0.10	10	<0.1	59	1.4	0.10	3	7	2
	30-60	6.1	0.10	6.5	1.26	0.19	12	<0.1	66	1,0	0.07	4	11	2
Rep5	0-10	5.4	0.25	5.3	0.96	<0.05	13	<0.1	49	4.6	0.29	5	9	14
	10-20	5.5	0.14	4.5	0.64	<0.05	11	<0.1	49	2.6	0.15	2	7	4
	20-30	5.8	0.09	5.4	0.81	0.10	11	<0.1	60	1.5	0.09	2	6	1
	30-60	6.1	0.10	6.1	1.12	0.15	11	<0.1	66	0.9	0.06	3	9	1
Means	1-10	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	0.10	4.5	0.72	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

** Values in bold are laboratory errors*

RESULTS & DISCUSSION

Yield (and other components) responses to fertilizer treatments

FFB yield and other component results from 2002 – 2005 are shown in Tables 4 - 8. Similar to the 3 past years (2002, 2003 and 2004), there was still no significant (p>0.05) yield response to both treatments (SOA & EFB) in 2005. The other two yield components (BNO and SBW) also showed no response to the treatments. Though not significant, there was a very positive response by FFB yield and SBW to EFB application.

The FFB yield and the SBW continued to increase in 2005 whereas the BNO continued to drop again in 2005. Despite the lack of response, the FFB yields were reasonable high and at the age of 6 years, an average yield of 35.4 t/ha was achieved. The overall FFB yield increased from an average of 18 t/ha/yr in 2002 (3 years after planting) to 30.5 t/ha/yr in 2003, a further increase by another 3 tonnes in 2004 and 35.4 tonnes in 2005 (Table 5). The single bunch weights also showed similar trend from 2002 to 2006. BNO however saw a substantial drop in 2004 and 2005.

The interactions were also not significant (p= 0.852) in 2005 (Table 8).

Table 4. Effects (p values) of treatments on FFB yield and its components in 2002 – 2005 and 2005.

Source	2002 - 2005			2005		
	Yield	BNO	SBW	Yield	BNO	SBW
SOA	0.707	0.742	0.903	0.644	0.830	0.999
EFB	0.939	0.545	0.684	0.972	0.939	0.742
SOA.EFB	0.364	0.943	0.421	0.852	0.920	0.477
CV %	*6.3*	*4.4*	*5.9*	*7.5*	*8.1*	*6.0*

Table 5. Main effects of treatments on FFB yield (t/ha) from 2002 to 2005

Treatments	Age and Year				
	3 2002	4 2003	5 2004	6 2005	2002 - 2005
SOA0	17.9	30.1	32.8	35.9	29.2
SOA1	18.0	30.1	34.2	35.7	29.5
SOA2	18.3	30.4	32.4	34.9	29.0
SOA3	18.8	31.3	33.9	35.0	29.7
sed	*0.79*	*1.1*	*1.1*	*0.96*	*0.68*
EFB0	18.5	30.4	32.7	35.3	29.2
EFB1	15.3	30.3	33.8	35.4	29.5
EFB2	17.9	30.6	33.5	35.5	29.4
sed	*0.68*	*1.0*	*1.0*	*0.84*	*0.59*
Grand Mean	18.2	30.5	33.3	35.4	29.4

Table 6. Main effects of treatments on number of bunches per hectare from 2002 to 2005

Treatments	Age and Year				
	3 2002	4 2003	5 2004	6 2005	2002-2005
SOA0	2249	2672	2504	2455	2470
SOA1	2294	2683	2597	2434	2502
SOA2	2314	2732	2517	2400	2492
SOA3	2340	2736	2580	2399	2513
sed	*75.2*	*71.0*	*63.6*	*71.8*	*39.8*
EFB0	2343	2710	2548	2424	2506
EFB1	2322	2703	2559	2432	2504
EFB2	2233	2704	2542	2410	2472
sed	*65.1*	*62.0*	*55.0*	*62.2*	*34.5*
Grand Mean	2299	2706	2550	2422	2494

Table 7. Main effects of treatments on single bunch weight (kg) from 2002 to 2005

Treatments	Age and Year				
	3 2002	4 2003	5 2004	6 2005	2002 - 2005
SOA0	7.9	11.3	13.3	14.9	11.9
SOA1	7.9	11.3	13.3	14.9	11.9
SOA2	7.9	11.3	13.1	14.9	11.8
SOA3	8.1	11.6	13.3	14.9	12.0
sed	*0.23*	*0.30*	*0.31*	*0.33*	*0.26*
EFB0	8.0	11.3	13.0	14.8	11.8
EFB1	8.0	11.3	13.4	14.9	11.9
EFB2	8.0	11.5	13.4	15.0	12.0
sed	*0.21*	*0.30*	*0.27*	*0.29*	*0.22*
Grand Mean	8.0	11.4	13.3	14.9	11.9

Table 8. Effect of SOA and EFB (two-way interactions) on FFB yield (t/ha/yr) in 2005. The interaction was not significant (p=0.852).

	EFB 0	EFB 1	EFB 2
SOA 0	36.7	35.4	35.9
SOA 1	35.4	35.0	36.7
SOA 2	34.6	35.2	35.0
SOA3	34.6	35.9	34.5
Grand mean: 35.4	*sed: 1.67*		

Effects of fertilizer treatments on leaflet and rachis nutrient concentrations

The treatment effects on the leaflets and rachis tissue nutrients for 2005 are shown in Tables 9 and 10. Unlike FFB yield, there were some responses to certain leaf nutrients by both treatments. Leaflet ash and rachis N were significantly (p<0.1) affected by SOA application. Leaflet N did not respond significantly to SOA. The rest of the leaflet and rachis nutrients, including N showed no responses to the SOA treatments. Leaflet K, though low, still did not respond favorable to either treatment. By contrast, EFB significantly increased leaflet N, Ca, Cl, rachis Ash and K concentration. The effect of the treatment interactions is shown in Table 11. The mean values for all the nutrients are within the adequate range, except leaflet K that is low.

Table 9. Effects (p values) of treatments on frond 17 nutrient concentrations in 2005, in units of % dry matter. p values less than 0.1 are shown in bold.

	Leaflet Nutrient Concentration									Rachis Nutrient Concent.			
Source	Ash	N	P	K	Mg	Ca	Cl	S	B	Ash	N	P	K
SOA	**0.079**	0.620	0.654	0.364	0.834	0.326	0.201	0.948	0.945	0.870	**0.063**	0.504	0.728
EFB	**0.005**	**0.079**	0.378	0.834	0.174	**0.008**	**<.001**	0.588	0.135	**0.023**	0.775	0.172	**0.008**
SOA.EFB	0.242	0.654	**0.059**	0.529	0.956	0.357	**0.004**	0.428	0.170	**0.051**	0.157	0.496	0.183
CV %	4.2	1.8	2.1	4.6	9.2	5.0	9.2	2.8	7.6	9.9	5.1	18.9	12.4

Table 10. Main effects of treatments on frond 17 nutrient concentrations in 2005, in units of % dry matter. p values less than 0.1 are shown in bold.

	Leaflet Nutrient Concentration									Rachis Nutrient Concent.			
Source	Ash	N	P	K	Mg	Ca	Cl	S	B	Ash	N	P	K
SOA0	**13.8**	2.61	0.151	0.72	0.22	0.82	0.50	0.217	12.4	4.34	**0.31**	0.092	1.37
SOA1	**14.3**	2.62	0.150	0.72	0.22	0.82	0.48	0.219	12.3	4.27	**0.30**	0.083	1.31
SOA2	**14.0**	2.63	0.151	0.72	0.22	0.80	0.49	0.218	12.4	4.39	**0.31**	0.087	1.35
SOA3	**14.2**	2.62	0.150	0.74	0.22	0.80	0.47	0.218	12.2	4.38	**0.30**	0.086	1.33
sed	*0.21*	*0.02*	*0.001*	*0.01*	*0.01*	*0.01*	*0.02*	*0.002*	*0.34*	*0.15*	*0.01*	*0.006*	*0.06*
EFB0	**14.3**	**2.61**	0.151	0.72	0.22	**0.79**	**0.45**	0.218	12.0	**4.13**	0.31	0.083	**1.24**
EFB1	**14.1**	**2.62**	0.150	0.72	0.21	**0.82**	**0.49**	0.217	12.6	**4.40**	0.31	0.085	**1.36**
EFB2	**13.7**	**2.64**	0.151	0.73	0.23	**0.83**	**0.52**	0.219	12.2	**4.51**	0.30	0.093	**1.41**
sed	*0.18*	*0.01*	*0.001*	*0.01*	*0.01*	*0.01*	*0.01*	*0.001*	*0.29*	*0.14*	*0.01*	*0.005*	*0.05*
GM	*14.1*	*2.62*	*0.150*	*0.72*	*0.22*	*0.81*	*0.49*	*0.218*	*12.3*	*4.35*	*0.30*	*0.087*	*1.34*

GM = Grand mean

Table 11. Effects of interaction between SOA and EFB on leaflet N and Rachis K.

Leaflet N (% DM), Interaction not significant (p= 0.654)				
	SOA0	SOA1	SOA2	SOA3
EFB0	2.61	2.58	2.62	2.61
EFB1	2.62	2.63	2.62	2.61
EFB2	2.60	2.64	2.65	2.65
Rachis K (% DM), Interaction not significant (p=0.183)				
	SOA0	SOA1	SOA2	SOA3
EFB0	1.33	1.21	1.16	1.27
EFB1	1.35	1.23	1.46	1.41
EFB2	1.43	1.47	1.43	1.31

Effects of fertilizer treatments on Vegetative parameters in 2005

The effects of the treatments on the radiation interception and the dry matter production (vegetative parameters) are shown in Tables 12 and 13. There was a significant increase (P=0.020) on the annual frond production by EFB application. Otherwise, the response by all the other vegetative parameters to both treatments was not significant. The dry matter production (FDM, BDM, VDM, TDM), PCS and frond area was increased with EFB application, though not significant. Therefore the responses by these parameters were positive but not significant. The SOA effect was not yet clear at this time.

The interactions were also not significant.

CONCLUSION

Both treatments (and their interaction) continued to show no significant effects on the yield, numbers of bunches per hectare and the single bunch weights in 2005. However, yield and single bunch weights also continued to respond positively to EFB though the response was not significant.

EFB significantly increased N and K levels in the leaflets and rachis respectively. SOA did not have any positive effect of the N levels in the leaflets. Responses are not yet very clear at this stage.

The effect of the treatments on the vegetative parameters was also not significant, though some of the responses to EFB were very positive.

Therefore, effects of the treatments on yield, tissue and vegetative parameters not yet clear at this stage though EFB is starting to show some positive effects.

The general lack of response in yield is probably a result of high concentrations of N and K in leaflet and rachis, respectively; indicating that palms are still getting adequate N and K from indigenous soil supplies.

Table 12. Effects (p values) of treatments on vegetative parameters in 2005. p values less than 0.1 are shown in bold.

Source			Radiation Interception					Dry matter production (t/ha/yr)				
	Frond length	PCS	Frond Prod (annual)	No. of green frond	Frond Area	LAI	FW	FDM	BDM	VDM	TDM	BI
SOA	0.143	0.381	0.692	0.438	0.761	0.133	0.381	0.126	0.644	0.238	0.840	0.167
EFB	0.725	0.931	**0.020**	0.323	0.694	0.379	0.931	0.164	0.972	0.167	0.729	0.639
SOA x EFB	0.757	0.689	0.507	0.867	0.789	0.976	0.689	0.539	0.852	0.472	0.733	0.905
CV %	3.6	6.0	3.1	3.5	6.7	5.2	5.6	5.5	7.5	4.6	5.5	2.8

Table 13. Main effects of fertiliser treatments on vegetative growth parameters in 2005.

Fertiliser	Level			Radiation Interception					Dry matter production (t/ha/yr)				
		Frond length (cm)	PCS (cm^2)	Frond Prod (annual)	No. of green frond	Frond Area (m^2)	LAI	FW (kg)	FDM	BDM	VDM	TDM	BI
	0	567.1	30.4	26.8	39.6	14.6	5.26	3.31	12.0	29.5	16.6	46.1	0.640
SOA	1	569.7	29.7	26.7	39.4	14.7	5.19	3.23	11.6	29.3	16.2	45.5	0.644
	2	582.3	30.8	27.0	40.2	14.8	5.36	3.35	12.2	28.7	16.7	45.4	0.631
	3	579.4	30.6	26.9	40.0	14.9	5.41	3.33	12.1	28.7	16.6	45.3	0.633
sed		*7.54*	*0.67*	*0.31*	*0.51*	*0.36*	*0.10*	*0.07*	*0.24*	*0.79*	*0.28*	*0.91*	*0.007*
	0	576.8	30.3	**26.6**	39.8	14.7	5.27	3.29	11.8	29.0	16.4	45.3	0.639
EFB	1	571.7	30.4	**26.7**	39.5	14.7	5.27	3.30	11.9	29.0	16.4	45.4	0.638
	2	575.3	30.5	**27.3**	40.1	14.9	5.38	3.32	12.2	29.1	16.8	45.9	0.634
sed		*6.53*	*0.58*	*0.27*	*0.44*	*0.31*	*0.09*	*0.06*	*0.21*	*0.69*	*0.24*	*0.79*	*0.006*

LAI – Leaf area index, FW – dry frond weight, FDM – frond dry matter production, BDM – Bunch dry matter production, VDM – Vegetative dry matter production, TDM – Total dry matter production, BI – Bunch index

Trial 329. NITROGEN, POTASSIUM, PHOSPHORUS AND MAGNESIUM TRIAL ON MAMBA SOILS, MAMBA ESTATE

SUMMARY

Trial 329 was established on Mamba soils in Oro Province to provide a guide to fertilizer recommendations to estates and oil palm smallholder growers in this area. The trial block was planted in 1997 but the actual treatments application and data collected commenced in 2002. The palms were planted at a density of 135 palms/ha. The fertilizer treatments included SOA (2 rates); and MOP, Kieserite and TSP all tested at 3 different levels.

Unlike the results from the last 3 years (2002, 2003, 2004), the trial showed some very positive and significant responses by the treatments on FFB yield, nutrient concentrations in the leaflets and vegetative growth parameters in 2005.

The FFB yield recovered from the drastic drop in 2004 by increasing from 17.1 t/ha in 2004 to 21.5 t/ha in 2005, an increase of about 26 %. The single bunch weights continued to increase in 2005 with an average bunch weight of 22.4 kg. The number of bunches continued to increase despite the increase in FFB yield and SBW. The number of bunches dropped to just around 1000 bunches/ha in 2006.

SOA (p=0.062) and MOP (p=0.003) both significantly increased FFB yields to more than 21.5 t/ha. SOA also increased number of bunches in 2005, despite the fact that the overall mean bunch number for the trial in general has continued to drop from 2004. MOP significantly (p=0.003) increased the mean bunch weights (SBW) to 22.5 kg in 2005.

SOA significantly increased N (p=0.006) and K (p=0.038) concentrations in the leaflets. MOP also significantly increased N (p=0.017), K (p=<0.001), Mg (p=0.020) and Cl (p=<0.001) leaflet levels. Mg level in the leaflets was also raised significantly (p=<0.001) by applying kieserite. Leaflet N also responded significantly (p=0.003) and positively to TSP application. The main treatments did not have any significant effects on the nutrient concentration in the leaf rachis. All the nutrient concentration in the leaflets are in their adequate levels except K which is a little bit low.

SOA significantly increased dry matter production (BDM, TDM) in 2005. MOP significantly increased the petiole cross section (PCS), LAI, dry frond weight (FW) and the dry matter production (FDM, BDM, TDM, VDM). Kieserite and TSP had some significant effects on the vegetative growth parameters but the responses were not very obvious at this stage.

INTRODUCTION

Soils up at Ilimo/Kokoda and Mamba areas are different from soils of the Popondetta plains. The soils at Mamba are quite acidic with low CEC and high P retention and at the same time susceptible to frequent water-logging.

Trial 329 was established in 1997 at the Mamba Estate (Komo Division) to provide more information for fertilizer recommendations for estates and smallholders in the Kokoda Valley and Ilimo/Papaki and Mamba areas.

METHODOLOGY

Trial Background Information

Table 1. Trial 329 background information.

Trial number	329	Company	Higaturu Oil Palms
Estate	Mamba	Block No.	Komo div. Blk. 6298G1
Date planted*	1997	Planting Density*	135 palms/ha
Spacing	???	Pattern	Triangular
LSU or MU*	Mamba	Soil Type	Mamba Soils
Recording Started	Sep 2001	Age after planting*	9
Topography	Flat	Planting material	Dami D x P
Progeny	???	Altitude	
Drainage*	Poor	Previous Landuse*	Cocoa plantation
Officer in charge	S.Nake	Area under trial soil type (ha)*	3,000

**Data should be synchronous with OMP.*

Experimental Design and Treatments

This trial is a 2x3x3x3 factorial with a single replicate and 54 plots, which are arranged in 3 blocks of 18. Fertilisers used are ammonium sulphate (SOA), triple superphosphate (TSP), potassium chloride (MOP) and kieserite (KIE) (Table 2). The fertilizer treatments are applied in 3 doses per year. Each plot has 36 palms; 20 of the palms will provide the guard row while recording is done from the 16 core palms. The plots are also surrounded by a trench to prevent plot-to-plot poaching. The trial area receives a basal application of borate at 50 g/palm.year. Treatments and yield recording started in September 2001. See 2001 Proposals for background.

Table 2. Fertiliser treatments and levels in Trial 329.

	Amount (kg/palm.year)		
Fertiliser	Level 0	Level 1	Level 2
SOA	-	2	4
TSP	0	2	4
MOP	0	2	4
KIE	0	2	4

.

Trial Maintenance and Upkeep

Like all PNGOPRA established trials, any upkeep work in the trial block is done by the Mamba estate workers and this include activities such as ring weeding, herbicide spraying, wheelbarrow path clearance, cover crop maintenance and other routine plantation practices. Any fertilizer application close to the trial has to be closely supervised by plantation supervisors so that fertilizers are not accidentally applied in the trial block. To avoid such incidents, fertilization (standard rates used by estate) of the boundary and perimeter palms is done by PNGOPRA. Basal application of Boron (50 g) is also applied to individual palms.

Trials are maintained regularly so that treatments effects on yield and other measured parameters are not compromised by poaching.

Data Collection

Yield recording (weighing of bunches) is done on a fortnightly basis (14 days). Harvesting and yield recording is done on every Thursdays on the non-company pay week. Recorders walk through the plots along the harvest paths and record the number of bunches harvested and weight of those bunches. Loose fruits are also collected and weighed with their respective bunches. Bunches from the guard row palms are not weighed. The data is recorded onto the yield record sheets in the field and later on entered onto the computer database using Microsoft Access and are later on converted into yield expressed in tonnes per hectare, total number of bunches harvested per hectare and the single bunch weight.

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

Tissue sampling (leaf & rachis) is done either every year or every two years depending on the fertilizer responses. Before sampling the leaflets, frond 17 is firstly identified following the standard protocol, and then harvested. Two pairs of leaflets (one from upper rank and one from lower rank) are taken from both sides of the middle portion of leaf. All samples from each plot are kept separately in plastic bags. Part of the rachis where the leaflets are taken from are also chopped off and included with the leaflets. These are later processed, packed in brown paper bags, oven dried at 70 –75 °C for 24 hours and dispatched to AAR for analysis. Rachises are dried longer than the leaves (36 hours).

Pre-Treatment Data

Pre-treatment soil analysis is shown in Table 3. Exchangeable Mg levels are fairly high, possible because the site had had kieserite for about 3 years. The soil pH is high (acidic).

Table 3. Soil chemical characteristics for bulked samples taken from each of the three experimental blocks in 2001.

Depth	pH	Olsen P	Total P	P Ret.	Exch. K	Exch. Ca	Exch. Mg	Exch. Na	CEC	Base Sat.	K/Mg	Res. K	Res. Mg	Exch. Al	Org. Matter	Total N	Avail. N	Org. S	Sulfate S	B
				(%)	(cmolc/kg)					(%)		(cmolc/kg)			(%)	(%)	(kg/ha)	(mg/kg)		
Block 1																				
0-10	5.6	22	1670	98	0.37	7.5	1.62	<0.05	25.5	37	0.2	0.23	25.8	0.2	15.6	0.84	137	9	16	0.4
10-20	5.3	8	1980	100	0.16	0.6	0.22	<0.05	16.2	6	0.7	0.33	28.0	0.4	9.4	0.51	51	<2	98	0.2
20-30	5.3	5	1280	100	0.13	<0.5	0.11	<0.05	11.6	<5	1.1	0.38	32.2	0.2	6.3	0.36	23	<2	184	0.1
30-60	5.4	7	926	92	0.14	<0.5	0.11	<0.05	8.1	6	1.3	0.46	40.0	0.1	3.0	0.19	<10	<2	176	0.1
Block 2																				
0-10	5.6	17	1610	99	0.43	6.3	1.41	<0.05	24.2	34	0.3	0.23	25.5	0.2	14.4	0.81	130	8	23	0.4
10-20	5.3	6	1710	100	0.16	0.9	0.24	<0.05	14.9	9	0.7	0.31	30.0	0.3	8.9	0.52	55	<2	133	0.2
20-30	5.4	5	1440	100	0.17	0.6	0.19	<0.05	12.9	7	0.9	0.31	31.0	0.2	7.5	0.38	38	<2	202	0.1
30-60	5.5	7	1010	95	0.18	<0.5	0.11	<0.05	8.4	7	1.7	0.36	38.5	0.1	3.5	0.20	<10	<2	201	<0.1
Block 3																				
0-10	5.8	14	1820	96	0.37	9.3	1.94	<0.05	25.1	46	0.2	0.26	25.1	0.9	13.9	0.81	128	9	16	0.3
10-20	5.6	5	1740	100	0.22	1.3	0.33	<0.05	14.5	13	0.7	0.33	29.4	0.3	9.1	0.52	58	3	75	0.2
20-30	5.6	5	1570	100	0.18	0.7	0.19	<0.05	11.0	10	0.9	0.38	35.4	0.1	6.8	0.40	23	<2	155	0.1
30-60	5.6	7	1000	97	0.17	<0.5	0.14	<0.05	8.5	9	1.2	0.44	40.9	<0.1	4.0	0.23	<10	<2	182	0.1

RESULTS & DISCUSSION

Yield and other components response to fertilizer treatments

The treatment effects on the FFB yield and other components are shown in Tables 4 – 11. The FFB yield in 2005 increased by 25.7 % after experiencing a dramatic drop in 2004. The FFB mean yield of 21.5 t/ha was achieved from this trial in 2005. Similarly, the single bunch weights continued to increase in 2005 and at the age of 8, the average bunch weight was 22.4 kg which represents an increased of 6.8 kg. The number of bunches however continued to drop again in 2005 by another 100 bunches. This drop did not affect the FFB yield in the same year.

Unlike 2004, there were responses shown on the yield and its components (BNO, SBW) by the fertilizer treatments (Table 4). The effects of SOA, MOP and KIE were significant on the FFB yield except TSP, however the yield only responded positively to SOA and MOP whereas KIE application reduced FFB yield as its rates was increased. BNO only responded positively and significantly (p=0.015) to SOA, by increasing the number of bunches (Table 6). However the number of bunches produced was still very low (average of 1006 bunches). MOP had a significant (p=0.003) and positive effect on the SBW. MOP application increased SBW from 21.3 kg where no K was added to 23.4 kg with the highest K rate.

The interactions in tables 8, 9, 10 and 11 were significant.

Table 4. Effects (p values) of treatments on FFB yield and its components in 2002 – 2005 and 2005. P values less than 0.1 are bolded.

	2002 - 2005			2005		
Source	Yield	BNO	SBW	Yield	BNO	SBW
SOA	**0.050**	0.153	0.174	**0.062**	**0.015**	0.169
MOP	**0.001**	0.504	**0.014**	**0.003**	0.138	**0.003**
KIE	0.745	0.636	0.185	**0.022**	0.218	0.106
TSP	0.741	0.419	0.384	0.571	0.947	0.687
SOA.MOP	0.117	0.652	0.123	0.174	0.972	0.249
SOA.KIE	0.184	0.929	0.376	0.473	0.774	0.206
MOP.KIE	0.100	0.480	0.758	**0.061**	**0.031**	0.194
SOA.TSP	0.373	0.759	0.253	0.124	0.169	0.802
MOP.TSP	0.146	0.484	0.429	**0.072**	0.219	0.486
KIE.TSP	0.474	0.975	0.176	0.217	0.545	**0.085**
SOA.MOP.KIE	**0.055**	0.418	0.126	0.182	0.408	0.225
SOA.MOP.TSP	0.151	0.450	0.305	0.305	0.690	0.320
SOA.KIE.TSP	**0.017**	0.223	0.975	**0.040**	**0.060**	0.865
MOP.KIE.TSP	**0.006**	0.433	**0.006**	**0.020**	0.131	**0.041**
CV %	4.4	8.3	4.8	8.7	9.6	5.6

Table 5. Main effects of treatments on FFB yield (t/ha) from 2002 – 2005.

Treatments	Age and Year				
	5 2002	6 2003	7 2004	8 2005	2002-2005
SOA1	22.9	24.9	16.8	**20.9**	**21.4**
SOA2	22.9	25.5	17.4	**22.1**	**22.0**
sed	*0.84*	*0.63*	*0.65*	*0.51*	*0.26*
MOP0	22.7	**23.9**	16.5	**19.7**	**20.7**
MOP1	22.6	**24.8**	17.0	**22.4**	**21.7**
MOP2	23.3	**26.9**	17.8	**22.5**	**22.6**
sed	*1.03*	*0.77*	*0.80*	*0.63*	*0.32*
KIE0	22.4	25.0	16.9	**22.8**	21.8
KIE1	23.0	25.4	17.4	**21.2**	21.7
KIE2	23.2	25.3	17.0	**20.6**	21.5
sed	*1.03*	*0.77*	*0.80*	*0.63*	*0.32*
TSP0	22.7	25.3	17.6	21.5	21.8
TSP1	23.0	24.6	16.6	21.9	21.5
TSP2	22.9	25.7	17.0	21.3	21.7
sed	*1.03*	*0.77*	*0.80*	*0.63*	*0.32*
Grand mean	22.9	25.2	17.1	21.5	21.7

Table 6. Main effects of treatments on the number of bunches (BNO) per hectare from 2002 – 2005.

Treatments	Age and Year				
	5 2002	6 2003	7 2004	8 2005	2002-2005
SOA1	1993	1963	1100	**965**	1505
SOA2	2011	2024	1158	**1046**	1559
sed	*83.0*	*62.1*	*35.7*	*26.3*	*34.5*
MOP0	1984	1954	1126	965	1507
MOP1	2003	1968	1117	1035	1531
MOP2	2018	2058	1143	1017	1559
sed	*101.6*	*76.1*	*43.7*	*32.2*	*42.2*
KIE0	1947	2006	1085	1040	1509
KIE1	2004	1924	1161	997	1540
KIE2	2054	2049	1140	980	1548
sed	*101.6*	*76.1*	*43.7*	*32.2*	*42.2*
TSP0	1982	1964	1166	1009	1541
TSP1	1993	1998	1073	1008	1500
TSP2	2030	2017	1148	1000	1556
sed	*101.6*	*76.1*	*43.7*	*32.2*	*42.2*
Grand mean	2002	1993	1129	1006	1532

Table 7. Main effects of treatments on the single bunch weights (SBW) per hectare from 2002 – 2005.

Treatments	Age and Year				
	5 2002	6 2003	7 2004	8 2005	2002-2005
SOA1	11.8	13.0	15.8	22.7	15.8
SOA2	11.6	12.9	15.4	22.2	15.5
sed	*0.23*	*0.19*	*0.31*	*0.34*	*0.20*
MOP0	11.8	**12.4**	15.1	**21.3**	**15.1**
MOP1	11.6	**13.0**	15.8	**22.7**	**15.8**
MOP2	11.7	**13.4**	15.9	**23.4**	**16.1**
sed	*0.28*	*0.23*	*0.38*	*0.42*	*0.25*
KIE0	11.8	13.1	15.9	23.0	16.0
KIE1	11.7	13.0	15.6	22.1	15.6
KIE2	11.6	12.8	15.4	22.1	15.5
sed	*0.28*	*0.23*	*0.38*	*0.42*	*0.25*
TSP0	11.7	12.9	15.5	22.4	15.6
TSP1	11.8	13.1	15.9	22.6	15.9
TSP2	11.6	12.8	15.4	22.3	15.6
sed	*0.28*	*0.23*	*0.38*	*0.42*	*0.25*
Grand mean	11.7	12.9	15.6	22.4	15.7

Table 8. Effect of the interactions (two – way) between MOP and KIE on FFB yield (t/ha) in 2005. The interaction was significant, $Lsd_{0.05}$ =2.50

MOP	KIE		
	0	1	2
0	22.0	17.8	19.3
1	22.4	23.0	22.1
2	24.0	22.9	20.5

Table 9. Effect of the interactions (two – way) between MOP and TSP on FFB yield (t/ha) in 2005. The interaction was significant, $Lsd_{0.05}$ =2.50

MOP	TSP		
	0	1	2
0	19.3	19.3	20.4
1	22.9	22.0	22.6
2	22.1	24.5	20.7

Table 10. Effect of the interactions (three-way) between SOA, KIE and TSP on FFB yield (t/ha) in 2005. The interaction was significant, $Lsd_{0.05}$ =3.54

SOA	KIE	TSP		
		0	1	2
	0	22.8	24.0	20.2
1	1	21.3	17.4	22.1
	2	20.7	20.4	20.0
	0	22.0	24.1	23.6
2	1	23.0	23.6	20.0
	2	18.9	22.0	21.6

Table 11. Effect of the interactions (three-way) between MOP, KIE and TSP on FFB yield (t/ha) in 2005. The interaction was significant, $Lsd_{0.05}$ =4.34

MOP	KIE	TSP		
		0	1	2
	0	18.3	25.1	22.6
0	1	18.8	15.6	19.1
	2	20.9	17.3	19.6
	0	24.4	23.0	19.8
1	1	23.0	21.6	24.3
	2	21.3	21.3	23.7
	0	24.5	24.1	23.4
2	1	24.6	24.3	19.7
	2	17.3	25.0	19.2

Fertiliser Effects on the leaflets and rachis nutrient concentrations

Table 12 and 13 shows the effects of the fertilizer treatments on the leaf tissue nutrients. The mean nutrient levels suggests all the nutrients are in adequate quantities in the oil palm leaflets except K which is slightly low but not in the deficient range. There was a response by leaflet N and K nutrients to SOA. SOA significantly (p=0.006) increased the N levels in the leaflets; however the leaflet levels of N in plots receiving nil SOA were within the optimum range. This is probably because of the high levels of Total N and Available N in the top 10 cm of the soil (Table 3). The positive response on the leaflet N by SOA must have caused the significant effects on the yield by the same treatment (SOA). Potassium (K) levels also responded positively and significantly (p=0.038) to SOA applications, by increasing the K levels to 0.77 % DM concentration. Ash level also increased significantly though SOA application. P and B levels were also increased though statistically not significant.

MOP had significant effects on leaflet ash, N, K, Mg and Cl; increasing N, K and Cl, and decreasing ash Mg and B (Table 13). Mg and B levels though responded significantly to MOP, showed negative effects. KIE significantly increased leaflet Mg levels, while TSP had a positive effect leaflet N. Though TSP had a significant effect of leaflet K, it never increased the K levels.

The effect of the main treatments on all the rachis nutrients was not significant at this stage, though some of the interactions have showed significant effects (Table 12).

Interestingly, rachis K is very low yet did not respond to MOP.

Fertiliser Effects on oil palm vegetative growth

Summarised results for the vegetative growth parameters for 2005 are presented in Tables 14 and 15. SOA significantly increased BDM and TDM.

MOP significantly increased PCS, LAI, dry frond weight, FDM, BDM, TDM and VDM but reduced the number of leaflets (Table 15). The dry matter production was also improved by MOP application. Frond production per year and the number of green fronds on the palms were also increased but not significant.

KIE significantly decreased FA to values below 11.9 m^2 while TSP significantly increased LAI.

CONCLUSION

The overall response by all the parameters measured (yield and its components, tissue nutrients and vegetative growth parameters) to the fertilizer treatments was significant in 2005 compared to the last 3 years when there was no response. FFB yields were significantly increased to more than 21.5 t/ha by application of SOA and MOP. SOA also increased the number of bunches in 2005; however the overall mean bunch number for the trial in 2005 continued to drop. SBW continued to increase in 2005 with significant effects showed by MOP application.

The positive responses were also evident in the leaflet tissue nutrients. SOA significantly increased leaflet N and K, while MOP increased N, K and Cl levels in the leaflets. KIE significantly increased leaflet K while TSP significantly raised N leaflet levels.

The treatments also had positive and significant effects on some of the vegetative growth parameters.

Table 12. Effects (p values) of treatments on frond 17 nutrient concentrations in 2005**.** P values less than 0.1 are indicated in bold.

Source	Leaflet Nutrient Concentrations									Rachis Nutrient Concentrations			
	Ash	N	P	K	Mg	Ca	Cl	S	B	Ash	N	P	K
SOA	**0.006**	**0.006**	0.310	**0.038**	0.289	**0.094**	0.223	**0.090**	0.776	0.868	0.524	0.984	0.693
MOP	**<.001**	**0.017**	0.852	**<.001**	**0.020**	0.563	**<.001**	0.119	**0.072**	0.735	0.178	0.586	0.741
KIE	**<.001**	0.365	0.763	**0.006**	**<.001**	**<.001**	0.110	0.454	0.959	0.327	0.952	0.103	0.397
TSP	0.369	**0.003**	0.263	0.664	0.363	0.372	0.425	0.110	0.797	0.658	0.444	0.463	0.673
SOA.MOP	0.798	0.792	0.538	0.129	0.341	0.595	0.554	0.873	0.585	0.709	0.778	0.315	0.825
SOA.KIE	**0.063**	0.442	0.223	**0.094**	0.256	0.633	0.924	0.675	0.467	0.559	0.865	0.485	0.504
MOP.KIE	0.149	0.120	0.996	**0.018**	0.849	0.894	0.817	0.900	0.543	0.991	0.682	0.772	0.988
SOA.TSP	0.283	0.448	0.942	**0.004**	0.280	0.792	0.559	0.596	0.198	0.479	0.635	**0.057**	0.403
MOP.TSP	**0.085**	0.339	0.812	**0.025**	0.957	0.867	0.560	0.995	0.709	0.932	0.489	0.533	0.897
KIE.TSP	0.514	0.381	0.772	0.363	0.406	0.552	0.582	0.940	0.228	0.660	0.150	0.634	0.711
SOA.MOP.KIE	0.119	0.117	0.323	0.400	0.232	0.682	0.512	0.841	0.576	0.589	0.141	0.669	0.556
SOA.MOP.TSP	0.378	**0.091**	0.361	0.669	0.950	0.584	0.742	0.619	0.521	0.940	0.799	0.429	0.931
SOA.KIE.TSP	0.315	**0.018**	0.486	0.128	0.716	0.426	0.829	0.323	0.248	0.514	0.285	0.241	0.519
MOP.KIE.TSP	**0.053**	0.290	**0.005**	**0.002**	0.940	0.432	0.216	0.553	0.284	0.835	**0.025**	0.275	0.864
CV %	4.5	1.3	2.3	3.3	7.8	7.9	11.9	2.9	11.8	30.7	4.4	24.9	52.2

Table 13. Main effects of treatments on frond 17 nutrient concentrations (dry matter %, except B as mg/kg) in 2005. P values less than 0.1 are indicated in bold.

Source	Leaflet Nutrient Concentrations									Rachis Nutrient Concentrations			
	Ash	N	P	K	Mg	Ca	Cl	S	B	Ash	N	P	K
SOA0	**8.16**	**2.71**	0.161	**0.75**	0.27	**0.96**	0.46	**0.21**	11.3	3.06	0.28	0.078	0.84
SOA1	**8.38**	**2.74**	0.162	**0.77**	0.26	**0.92**	0.44	**0.22**	11.4	3.10	0.28	0.077	0.89
sed	*0.10*	*0.01*	*0.001*	*0.01*	*0.01*	*0.02*	*0.01*	*0.001*	*0.37*	*0.26*	*0.003*	*0.005*	*0.12*
MOP0	**9.09**	**2.71**	0.161	**0.72**	**0.28**	0.92	**0.23**	0.22	**11.7**	3.19	0.27	0.081	0.91
MOP1	**7.92**	**2.73**	0.162	**0.77**	**0.26**	0.95	**0.54**	0.22	**11.8**	2.94	0.28	0.074	0.80
MOP2	**7.80**	**2.75**	0.162	**0.79**	**0.26**	0.94	**0.58**	0.22	**10.7**	3.10	0.28	0.078	0.89
sed	*0.12*	*0.01*	*0.001*	*0.01*	*0.01*	*0.02*	*0.02*	*0.002*	*0.45*	*0.32*	*0.004*	*0.006*	*0.15*
KIE0	**8.72**	2.72	0.161	**0.77**	**0.19**	**1.05**	0.47	0.22	11.4	3.08	0.28	0.074	0.86
KIE1	**8.11**	2.74	0.162	**0.77**	**0.28**	**0.89**	0.43	0.22	11.5	2.83	0.28	0.073	0.76
KIE2	**7.98**	2.73	0.161	**0.74**	**0.32**	**0.88**	0.44	0.22	11.2	3.33	0.28	0.087	0.98
sed	*0.12*	*0.01*	*0.001*	*0.01*	*0.01*	*0.02*	*0.02*	*0.002*	*0.45*	*0.32*	*0.004*	*0.006*	*0.15*
TSP0	8.35	**2.71**	0.160	**0.76**	0.27	0.95	0.44	0.22	11.4	2.99	0.28	0.080	0.82
TSP1	8.29	**2.72**	0.162	**0.76**	0.26	0.92	0.44	0.22	11.5	3.00	0.28	0.073	0.83
TSP2	8.17	**2.76**	0.162	**0.76**	0.26	0.94	0.46	0.22	11.2	3.25	0.28	0.080	0.95
sed	*0.12*	*0.01*	*0.001*	*0.01*	*0.01*	*0.02*	*0.02*	*0.002*	*0.45*	*0.32*	*0.004*	*0.006*	*0.15*
Grand mean	8.27	2.73	0.161	0.76	0.26	0.94	0.45	0.22	11.4	3.08	0.28	0.078	0.87

Table 14. Main effects (p values) of fertilizer treatments on the vegetative growth parameters in 2005. P values less than 0.1 are shown in bold.

Source	Height	LLen	LlNum	PCS	**Radiation Interception**				Dry FW	**Dry matter production (t/ha/yr)**				BI
					Frond Prodn	Green Frond	FA	LAI		FDM	BDM	TDM	VDM	
SOA	0.735	0.912	0.137	0.875	0.187	0.393	0.125	0.762	0.875	0.330	**0.062**	**0.057**	0.330	0.341
MOP	0.139	0.887	**0.053**	**0.028**	0.130	0.518	0.111	**0.014**	**0.028**	**0.024**	**0.003**	**0.001**	**0.024**	0.187
KIE	0.733	0.480	0.105	0.368	0.228	0.844	**0.081**	0.347	0.368	0.634	**0.022**	**0.078**	0.634	**0.054**
TSP	0.299	0.665	0.431	0.212	0.493	0.207	0.113	**0.070**	0.212	0.303	0.571	0.310	0.303	0.743
SOA.MOP	0.482	0.537	0.289	0.915	0.192	0.350	0.390	**0.077**	0.915	0.644	0.174	0.178	0.644	0.717
SOA.KIE	0.252	0.292	0.987	0.974	0.995	0.701	0.474	0.697	0.974	0.983	0.473	0.633	0.983	0.582
MOP.KIE	0.292	0.816	0.342	0.246	0.536	0.132	0.690	0.448	0.246	0.541	**0.061**	0.343	0.541	**0.043**
SOA.TSP	0.786	0.123	0.969	0.854	0.704	0.870	0.175	0.103	0.854	0.727	0.124	0.389	0.727	0.127
MOP.TSP	0.261	0.916	0.822	0.708	0.672	0.533	0.154	0.515	0.708	0.678	**0.072**	0.188	0.678	0.148
KIE.TSP	0.299	0.733	0.524	0.330	0.812	0.309	0.374	0.347	0.330	0.656	0.217	0.773	0.656	0.135
SOA.MOP.KIE	0.430	0.951	0.302	0.513	0.970	0.912	0.147	0.396	0.513	0.729	0.182	0.223	0.729	0.682
SOA.MOP.TSP	0.742	0.494	0.296	0.547	0.877	0.540	0.970	0.815	0.547	0.717	0.305	0.333	0.717	0.534
SOA.KIE.TSP	0.271	0.488	0.633	0.588	0.697	0.471	0.888	0.542	0.588	0.480	**0.040**	**0.097**	0.480	**0.092**
MOP.KIE. TSP	**0.048**	0.196	0.455	**0.066**	0.124	**0.098**	0.201	**0.025**	**0.066**	**0.070**	**0.020**	**0.013**	**0.070**	0.211
CV %	4.0	2.7	1.6	5.2	4.4	5.6	2.9	4.0	4.9	7.5	8.7	6.2	7.5	5.5

Table 15. Main effects of fertilizer treatments on the vegetative growth parameters in 2005.

Source	Height (m)	Llen (cm)	LlNum	PCS (cm^2)	**Radiation Interception** Frond Prod/yr	Green Frond	FA (m^2)	LAI	Dry FW (kg)	**Dry matter production (t/ha/yr)** FDM	BDM	TDM	VDM	BI
SOA0	4.77	658.3	180.5	39.9	25.8	35.7	11.9	4.16	4.28	14.9	**17.2**	**32.1**	14.9	0.533
SOA1	4.75	657.8	179.2	40.0	26.2	36.2	11.8	4.17	4.29	15.2	**18.1**	**33.3**	15.2	0.542
sed	*0.05*	*4.82*	*0.78*	*0.57*	*0.31*	*0.55*	*0.09*	*0.05*	*0.06*	*0.31*	*0.42*	*0.55*	*0.31*	*0.008*
MOP0	4.68	658.3	**181.3**	**38.6**	25.6	35.6	11.7	**4.04**	**4.14**	**14.3**	**16.1**	**30.5**	**14.3**	0.527
MOP1	4.77	659.4	**179.8**	**40.6**	26.0	35.8	12.0	**4.21**	**4.35**	**15.3**	**18.4**	**33.7**	**15.3**	0.546
MOP2	4.83	656.5	**178.5**	**40.7**	26.4	36.4	11.9	**4.25**	**4.36**	**15.6**	**18.4**	**34.0**	**15.6**	0.540
sed	*0.06*	*5.90*	*0.96*	*0.69*	*0.38*	*0.67*	*0.11*	*0.06*	*0.07*	*0.37*	*0.51*	*0.67*	*0.37*	*0.009*
KIE0	4.79	660.2	181.1	40.4	25.6	35.7	**12.0**	4.15	4.33	15.0	**18.7**	**33.6**	15.0	**0.554**
KIE1	4.76	660.3	179.8	40.2	26.3	36.0	**11.9**	4.22	4.31	15.3	**17.4**	**32.7**	15.3	**0.529**
KIE2	4.74	653.7	178.7	39.4	26.2	36.1	**11.7**	4.14	4.23	14.9	**16.9**	**31.8**	14.9	**0.530**
sed	*0.06*	*5.90*	*0.96*	*0.69*	*0.38*	*0.67*	*0.11*	*0.06*	*0.07*	*0.37*	*0.51*	*0.67*	*0.37*	*0.009*
TSP0	4.71	657.0	179.2	39.2	25.9	36.1	11.7	**4.11**	4.21	14.8	17.6	32.4	14.8	0.542
TSP1	4.75	656.0	180.5	40.5	26.3	36.5	12.0	**4.25**	4.34	15.4	17.9	33.4	154	0.535
TSP2	4.82	661.2	179.9	40.2	25.8	35.2	11.9	**4.14**	4.31	15.0	17.4	32.4	15.0	0.536
sed	*0.06*	*5.90*	*0.96*	*0.69*	*0.38*	*0.67*	*0.11*	*0.06*	*0.07*	*0.37*	*0.51*	*0.67*	*0.37*	*0.009*
Grand mean	4.76	658.1	179.9	40.0	26.0	35.9	11.9	4.17	4.29	15.1	17.7	32.7	15.1	0.537

TRIAL 3302. GRASSLAND SULPHUR TRIAL ON OUTWASH PLAINS, HEROPA MINI ESTATE, POPONDETTA

SUMMARY

Trial 3302 commenced in 2005 to look at N and S situation in the grassland areas of Popondetta to provide information for fertilizer recommendations to the estate, mini estates and smallholder growers. The trial block was planted in 2000 at the planting density of 135 palms per hectare. The treatment application will commence in early 2006 but the pre-treatment data collection commenced in August 2005. The fertilizer treatments will include 3 rates of Elemental Sulphur (0, 0.15, 0.30 kg/palm) and 4 rates of Urea (0.5, 1.5, 2.5, 3.5 kg/palm).

Pre-treatment data collected from the trial showed that yield and single bunch weights are quite low for a 5-year-old oil palm block. The number of bunches were reasonably high. The average FFB yield for this trial was about 14.3 t/ha while the average weight of an individual bunch was only 8.6 kg. This low FFB production and single bunch weight may be attributed to the very sandy soil condition in this area. Leaflet concentration of K is very low (deficient) while S levels are almost deficient. N, Mg and B concentrations in the leaflets are quite high. The mean PCS of the palm was 19.4 cm^2.

The measured parameters (yield, tissue and PCS) were also tested for the replicate effects and the results showed that the FFB yield and BNO were significantly ($p=0.013$ for yield and $p=<0.001$ for BNO) different between the three replicates. Replicate 1 had the highest production while replicate 3 had the lowest. The single bunch weight did not vary between the replicates, but was consistent in all 3 replicates. The PCS was also consistent in all three blocks.

INTRODUCTION

With increased oil palm plantings in the Popondetta grassland areas both smallholders and the mini-estate schemes, this trial was initiated purposely to provide information for the fertilizer recommendations. In the grassland areas, N and S are suspected 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. However, during periods of heavy down pour, leaching of nutrients is evident in such areas which can result in substantial losses of nutrients in the rooting zone. Soil results suggest sufficient cations and P levels, however, N and carbon levels (OM) are very low. With frequent burning during dry seasons, most likely C (OM) will not accumulate and quality of OM will be very low. At soil sub surface, OM levels will mostly be derived from the plant roots. When SOA is applied as an N source, the need for both N and S is also taken care of. However, with estate now applying other N sources like AMN or urea, S deficiency may occur. The objective of the trial is to provide information for the fertilizer recommendations (especially for N and S) to the estate, mini estates and the smallholder growers in the grassland areas of Popondetta.

METHODOLOGY

Trial Background Information

Table 1. Trial 330b background information.

Trial number	3302	Company	Higaturu Oil Palms
Estate	Embi Heropa Mini estate	Block No.	2 & 3
Date planted*	2000	Planting Density*	135 palms/ha
Spacing		Pattern	Triangular
LSU or MU*		Soil Type	Sandy Soils
Recording Started	May 2005	Age after planting*	6
Topography	Flat	Planting material	Dami D x P
Progeny		Altitude	
Drainage*	Moderate	Previous Landuse*	Grassland
Officer in charge	S.Nake	Area under trial soil type (ha)*	

**Data should be synchronous with OMP.*

Experimental Design and Treatments

The initial plan was to test out 4 rates of ammonium nitrate (AN) and 3 rates of elemental sulphur (S). However, AN will now be replaced with urea which is the source of N that the plantation (HOP) is now using. Therefore, still 4 rates of urea (0.5, 1.5, 2.5, and 3.5 kg/palm/year) and 3 rates of elemental S (0, 0.1 and 0.3 kg/palm/year) will be applied in a factorial combination and replicated 3 times, resulting in 36 plots. Fertiliser treatments will be applied in 2 doses per year. There is no nil N treatment because it was felt landowners might not want very low crop yields in the mini estates. The trial will receive an annual blanket application of MOP (2.0 kg/palm/yr), Borate (0.2 kg/palm/yr), KIE (1.0 kg/palm/yr) and TSP (0.5 kg/palm/yr). Fertiliser treatments application will commence in early 2006.

Table 2. Fertiliser treatments and levels in Trial 3302.

	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

Trial Maintenance and Upkeep

Like all PNGOPRA established trials, any upkeep work in the trial block is done by the estate workers for the mini-estate estate and this include activities such as ring weeding, herbicide spraying, wheelbarrow path clearance, cover crop maintenance and other routine plantation practices. PNGOPRA workers will take care of fertilization of perimeter or boundary palms. Basal application of Boron, Kieserite, TSP and MOP will also be applied to all the palms.

Trials are maintained regularly so that treatments effects on yield and other measured parameters are not compromised by poaching or yield losses through poor management.

Pre-Treatment Data Collection

Yield recording (weighing of bunches) is done on a fortnightly basis (14 days). Harvesting and yield recording is done on every Fridays on the non-company pay week. Recorders walk through the plots along the harvest paths and record the number of bunches harvested and weight of those bunches. Loose fruits are also collected and weighed with their respective bunches. Bunches from the guard row palms are not weighed. The data is recorded onto the yield record sheets in the field and later on entered onto the computer using Microsoft Access Database.

In 2005, the following vegetative data were colleted; leaf and leaflet measurements, (total leaf length, leaflet width, leaflet length, total number of leaflets) and petiole cross-section. Total frond count and marking of leaf 1 was also done twice (every six months). Leaf 1 marking was used to calculate the frond production rate.

Tissue sampling (leaf & rachis) was also done in 2005 by collecting 8 leaflets from frond 17. All samples from each plot are kept separately in plastic bags. Part of the rachis where the leaflets are taken from are also chopped of and included with the leaflets. These are later processed, packed in brown paper bags, oven dried at 70 –75 °C for 24 hours and dispatched to AAR for analysis. Rachises are dried longer than the leaves (36 hours).

Because the fertilizer treatments will commence in 2006, the data (yield, tissue and vegetative) collected will not be analysed for the effects of the treatments but instead will be used as pre-treatment data to observe initial nutrient status of the soil, oil palm leaves and the growth of the palms prior to treatment application.

RESULTS - Pre-Treatment Data

Pre-treatment data collection began in 2005, while fertilizer treatments will commence in early 2006. Data collected are analysed to observe the replicate (not treatment) effects on the FFB yield and other components, petiole cross-section (PCS) and frond 17 tissue nutrient concentrations (Table 3, 4, 5 and 6).

The 2005 yield and the SBW in general are quite low (<20 t/ha and <15 kg respectively) as expected for 5-year-old palms. The BNO are reasonably high. The FFB yields and BNO significantly (p=0.013) differ between the three replicates (Table 3 and 4). The yield in replicate 1 was higher than replicate 2 and 3 and this is further reflected by the number of bunches within these replicates. Replicate 3 yielded the lowest FFB yield of 12.8 t/ha which was 1.5 t below the replicate average yield in 2005. Similarly, number of bunches in replicate 3 were significantly lower than the other replicates. The single bunch weight was the same (8.6 kg) in all the three replicates.

The petiole cross section (PCS) was calculated by multiplying the rachis width by its thickness, which shows uniform growth by the palms across all three replicates. The PCS though not statistically significant between the replicates, showed palms in replicate 3 having the lowest PCS of about 18.8 cm^2 in 2005. PCS of palms in replicate 1 and 2 were higher than the trial mean of 19.4 cm^2.

The concentration of the nutrients in frond 17 is shown in Table 5 and 6. The mean levels show all leaflet nutrients to be at their adequate levels except K which is deficient in the leaflets (<0.75%) and S which is slightly low (very close to deficient). N, P and Mg appeared to be sufficient in the leaflets. Leaflet concentration of ash, N, P, Ca and S varies considerable between the three replicates while rachis concentrations of ash, P and K also differ significantly between replicates.

Soils data not available at the time of writing this report but will be made available next year.

Table 3. Effects (p value) of replicate on FFB yield and other components in 2005

Source	FFB Yield	BNO	SBW	PCS
Replicate	**0.013**	**<0.001**	0.989	0.478
CV %	15.0	11.4	10.0	11.3

PCS = Petiole cross section

Table 4. Effects of replicate on FFB yield and other components in 2005

Source	Yield (t/ha)	BNO	SBW (kg)	PCS (cm^2)
Rep 1	**15.4**	**1813**	8.6	19.9
Rep 2	**14.8**	**1707**	8.6	19.6
Rep 3	**12.8**	**1494**	8.6	18.8
sed	*0.876*	*77.6*	*0.351*	*0.90*
Grand mean	**14.3**	**1672**	**8.6**	**19.4**

Table 5. Effects (p values) of replicate on frond 17 nutrient concentration in 2005.

Source	Leaflet nutrient conc.									Rachis nutrient conc.			
	Ash	N	P	K	Mg	Ca	Cl	S	B	Ash	N	P	K
Replicates	**0.015**	**<.001**	**<.001**	0.231	0.525	**<.001**	0.440	**0.009**	0.119	**0.003**	0.325	**<.001**	**0.041**
CV %	7.4	1.9	2.0	3.7	13.4	7.1	9.2	2.5	18.9	9.7	17.5	22.7	15.4

Table 6. Effects of replicate on frond 17 nutrient concentration in 2005. All except B (expressed in ppm) are expressed in % DM.

Source	Leaflet nutrient conc.									Rachis nutrient conc.			
	Ash	N	P	K	Mg	Ca	Cl	S	B	Ash	N	P	K
Rep 1	**11.0**	**2.65**	**0.159**	0.62	0.31	**1.01**	0.49	**0.217**	13.2	**4.4**	0.35	**0.08**	**1.18**
Rep 2	**10.1**	**2.67**	**0.160**	0.63	0.30	**0.97**	0.50	**0.218**	14.6	**4.1**	0.38	**0.09**	**1.17**
Rep 3	**10.4**	**2.75**	**0.149**	0.64	0.29	**0.89**	0.51	**0.223**	12.4	**3.8**	0.34	**0.06**	**1.01**
sed	*0.316*	*0.02*	*0.001*	*0.01*	*0.02*	*0.028*	*0.02*	*0.002*	*1.03*	*0.162*	*0.03*	*0.007*	*0.07*
Mean	10.5	2.69	0.156	0.63	0.30	0.96	9.2	0.219	13.4	4.1	0.36	0.08	1.12

CONCLUSION

The yields (average of 14.3 t/ha) and SBW (8.6 kg) appeared to be very low for a 5-year-old oil palm block. This is because upkeep work in this block was inconsistent due to land disputes between the landowners and HOP before PNGOPRA established the trial. Furthermore, pruning, slashing and circle weeding was not done as well as fertilizer application. Another possible reason for this low productivity is the physical and chemical structure and characteristics for soils in this area, which is known to be very sandy. FFB yield and BNO differs significantly between the three replicates while the single bunch weight did not vary. There were slight differences in the PCS in the three replicates but statistically not significant. K concentration in the leaflets are deficient, S is low, while N, P, Mg and B are in adequate quantities.

TRIAL NO. 333. SLOW RELEASE OPTIONS FOR MAGNESIUM AND POTASSIUM ON ACIDIC SOILS WITH LOW CEC IN ORO PROVINCE

SUMMARY

Trial 333 was established on 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 block was planted in 1993 at 143 palms per hectare. Treatments application and data collected commenced in 2004.

After one and a half years of treatment application, it is yet too early to obtain any positive clear effects. However, preliminary results for 2005 showed tissue nutrient concentration was more pronounced than the yield and its other components. The response by the yield and other components was not significant while the treatment effect of some of the leaflet and rachis (leaflet K and rachis P, K, Mg) nutrient concentration were significant. Palms in the control plots are currently doing well in terms of productivity (FFB yield, BNO and SBW) and the tissue nutrient concentrations because the treatments only commenced one and a half years ago. Though not significant, MOP in trenches produced better yields than MOP applied on surface and the same applied to the nutrient concentrations in the leaflets and the rachis. It appears that the new method of applying MOP (i.e. applied in dug trenches) improved FFB yield.

INTRODUCTION

The soils of the Ilimo-Mamba area of Oro Province are acidic and have very low CEC. Magnesium and K deficiency symptoms are common and severe. Calcium contents of the soils are 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 is 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 charge 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, but it has the added advantage of increasing soil organic matter content.

OBJECTIVE

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.

METHODOLOGY

Trial Background Information

Table 1. Basic information on Trial 333

Trial number	333	Company	Higaturu Oil Palms
Estate	Mamba	Block No.	Ebei – 6193E
Date planted*	1993	Planting Density*	143 palms/ha
Spacing	???	Pattern	Triangular
LSU or MU*	Mamba	Soil Type	Mamba Soils
Recording Started	2004	Age after planting*	13 years
Topography	Flat	Planting material	Dami D x P
Progeny		Altitude	
Drainage*	Poor	Previous Landuse*	Ex-Forest/Logging
Officer in charge	S.Nake	Area under trial soil type (ha)*	

**Data should be synchronous with OMP.*

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 will be tested in the presence of adequate K (4 treatments). In Group 2, all K sources will be tested in the presence of adequate Mg (3 treatments). In Group 3, adequate Mg and K will be tested alone and together, similar to the trial at Waisisi. There will also be a boiler ash treatment, which supplies Mg and K in approximately the correct ratio. (5 treatments). Fertiliser rates for the various treatments are given in Table 2.

Group 1, Mg sources

The following 4 Mg sources will all be added individually at an equivalent rate of Mg, and all is 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 will be added individually. 1) MOP (2x per year, on frond pile as standard). 2) MOP in trenches covered with plastic (see Trial 146 description). Apply once at a rate equivalent to 3x the surface MOP rate and exhume after 2.5 years for post mortem. If this treatment shows promise, application in inverted coconut shells may be a practical alternative. 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 have K analyses for EFB (~2% DM) but need to get the water content to calculate application rate. 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 is included in group 3.

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

The adequate Mg treatment will comprise 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 surf + MOP trenches + Kie + Magnesite + MgO) treatment in Group 3 applied together. Boiler ash will be 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 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 will 'triple up' as the control for each group.

Basal fertiliser

Nitrogen will be 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 a rate the same as surrounding blocks.

Statistical design

The 12 treatments are replicated 4 times, giving a total of 48 plots. The field layout will be a completely randomised design. 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 – more interested in finding appropriate ways to deliver Mg or K more effectively.

Table 2. Fertiliser types and rates

Tr 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 Try and get a 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/palm gives 2.5 kg K/palm, or 4.2 kg MOP.

3 In order to obtain a rate of Mg application equivalent to the kieserite treatments, need 28.3 kg/palm (@ 1.5% Mg). This results in 1.39 kg K /palm instead of the usual 1.25.

Trial Maintenance and Upkeep

Harvesting and general upkeep work (block sanitation) in the trial block is done by the Mamba estate workers. This includes activities such as ring weeding, herbicide spraying, wheelbarrow path clearance, cover crop maintenance and other routine plantation practices. Perimeter (boundary palms) is to be fertilized by PNGOPRA workers using the same fertilizer type and rates that the plantation uses. Any fertilizer application close to the trial has to be closely supervised by plantation supervisors so that fertilizers are not accidentally applied in the trial block. Urea (2 kg/palm), TSP (0.5 kg/palm) and Borate (0.2 kg/palm) will be applied as basals to all the palms in this trial in 2006.

Trials are maintained regularly so that treatments effects on yield and other measured parameters are not compromised by poaching.

Data Collection

Yield recording (weighing of bunches) is done on a fortnightly basis (14 days). Harvesting and yield recording is done on every Thursdays on the company pay week. Recorders walk through the plots along the harvest paths and record the number of bunches harvested and weight of those bunches. Loose fruits are also collected and weighed with their respective bunches. Bunches from the guard row palms are not weighed. The data is recorded onto the yield record sheets in the field and later on entered onto the computer database system.

In 2005, the following vegetative measurements were done: height measurements, trunk diameter measurements, leaf measurements (total leaf length, leaflet width, leaflet length, total number of leaflets), width and thickness (to calculate PCS). Total frond count and marking of leaf 1 was also done twice (every six months) to calculate the frond production rate.

Tissue sampling (leaf & rachis) was also done in 2005 by collecting 8 leaflets from frond 17. All samples from each plot are kept separately in plastic bags. Part of the rachis where the leaflets are taken from are also chopped off and included with the leaflets. These are later processed, packed in brown paper bags, oven dried at 70 –75 °C for 24 hours and dispatched to AAR for analysis. Rachises are dried longer than the leaves (36 hours).

RESULTS & DISCUSSION

Yield and other components response to fertilizer treatments

The effects of the fertilizer treatments on the yield and other components are shown in Tables 3 and 4. The treatments had no significant effects on the FFB, number of bunches and the single bunch weights (Table 3). It is still too early to expect any positive responses by the FFB yield to the treatments at this stage because the treatments only commenced in April 2004. We should expect to see some responses next year. The average yield for 2005 was 21.7 t/ha with the mean bunch weight of around 27 kg per bunch which is quite high. Though the yields are reasonably high, the number of bunches was quite low (less than 1000 bunches). The high yields was not influenced by the number of bunches but highly influenced by the single bunch weights. MOP applied in trenches (MOP T) produced higher yields and BNO than MOP applied on the surface (MOPS). The control plots at this stage managed to produce reasonably high yields not different to the other treatments.

Table 3. Effect (p values) of fertilizer treatments on FFB yield and its components in 2005.

Source	Yield	BNO	SBW
Treatments	0.503	0.324	0.838
CV %	18.0	17.8	7.8

Table 4. Effect of fertilizer treatments on FFB yield and its components in 2005.

Treatments	Yield (t/ha)	BNO	SBW (kg)
Kieserite (Grp 1)	23.4	838	28.4
Magnesite, FO1 (Grp 1)	22.3	840	27.2
Dolomite (Grp 1)	22.0	807	27.4
MgO, EMAG (Grp 1)	24.4	893	27.5
MOP surface (Grp 2)	17.3	651	27.7
MOP trenches (Grp 2)	21.2	785	27.3
EFB (Grp 2)	20.1	770	27.2
*MOP S+T (Grp 3)	21.5	824	25.7
Kie+Magnesite+MgO (Grp 3)	23.9	966	25.7
**Treatment 8 + 9 (Grp 3)	22.6	866	27.2
Boiler ash (Grp 3)	21.6	782	27.9
***Control (Grp 3)	20.3	745	27.7
sed	*2.77*	*102*	*1.50*
Grand mean	**21.7**	**814**	**27.2**

** MOP S+T (Grp 3) – MOP surface combined with MOP in trenches*
*** Treatment 8 + 9 (Grp 3) – MOP S+T combined with Kie+Magnesite+MgO*
**** Control (Grp 3) – No K & Mg applied*

Fertiliser Effects on the leaflets and rachis nutrient concentrations

Unlike the yield and other components, some of the leaflet and rachis nutrients concentrations responded positively and significantly to the fertilizer treatments in 2005, however the effects were more pronounced in the rachis than the leaflets (Table 5). K levels in the leaflets responded positively to the fertilizer treatments. MOP applied on the weeded circle (basal application) combined with that applied in dug trenches (MOP S + T) had the highest concentration of K in the leaflets followed by palms receiving MgO. Rachis levels of P, K and Mg were also significantly affected by the treatments. Palms receiving MgO again had the highest level of rachis K. Similar to the yields, MOP applied in trenches (MOP T) gave higher concentration of leaflet and rachis nutrients than MOP applied on the surface (MOP S).

There are some interesting interactions between Mg and K supply and Mg and K tissue concentrations. For example, as the source of Mg becomes less soluble, (i.e. KIE > Magnesite/Dolomite > MgO) the concentration of K in the rachis increases.

N concentration in both the leaflets and the rachis was not affected by the treatments.

CONCLUSION

The treatments had no effect on the yield and its components at this stage, however significant responses may be evident in the future. The response on the tissue nutrient concentration was significant especially on leaflet K and S. Rachis P, K and Mg levels also responded positively to the treatments.

Table 5. Effect (p values) of fertilizer treatments on frond 17 nutrient concentration in 2005. p values <0.01 are shown in bold.

Source	Leaflet nutrient concentration							Rachis nutrient concentration						
	N	P	K	Mg	Ca	B	S	N	P	K	Mg	Ca	B	S
Treatments	0.391	0.924	**0.099**	0.210	0.592	0.979	0.152	0.104	**0.012**	**0.016**	**0.002**	0.201	0.862	0.844
CV %	3.3	2.9	6.8	14.4	8.9	11.4	2.8	6.6	12.6	15.7	15.1	15.7	10.7	8.7

Table 6. Effect of fertilizer treatments on frond 17 nutrient concentration in 2005. Nutrient concentration expressed in % dry matter (DM), except B which is expressed in mg/kg.

Source	Leaflet nutrient concentration							Rachis nutrient concentration						
	N	P	K	Mg	Ca	B	S	N	P	K	Mg	Ca	B	S
Kieserite (Grp 1)	2.59	0.160	**0.90**	0.27	0.90	16.8	0.19	0.28	**0.035**	**1.05**	**0.054**	0.27	4.7	0.026
Magnesite, FO1 (Grp 1)	2.53	0.161	**0.87**	0.22	1.02	17.3	0.19	0.28	**0.039**	**1.08**	**0.055**	0.36	5.4	0.028
Dolomite (Grp 1)	2.62	0.161	**0.89**	0.25	0.94	16.3	0.20	0.27	**0.038**	**1.11**	**0.056**	0.32	5.0	0.027
MgO, EMAG (Grp 1)	2.53	0.160	**0.91**	0.24	0.97	16.3	0.20	0.26	**0.034**	**1.21**	**0.059**	0.31	4.9	0.028
MOP surface (Grp 2)	2.53	0.158	**0.83**	0.27	0.94	16.8	0.19	0.26	**0.038**	**0.98**	**0.071**	0.36	5.2	0.028
MOP trenches (Grp 2)	2.60	0.160	**0.86**	0.28	0.93	16.8	0.20	0.26	**0.037**	**1.09**	**0.077**	0.35	5.3	0.028
EFB (Grp 2)	2.53	0.162	**0.85**	0.25	0.95	16.8	0.19	0.27	**0.043**	**1.10**	**0.063**	0.31	5.0	0.026
*MOP S+T (Grp 3)	2.55	0.161	**0.92**	0.21	0.95	16.3	0.19	0.27	**0.040**	**1.19**	**0.077**	0.33	5.0	0.028
Kie+Magnesite+MgO (Grp 3)	2.47	0.159	**0.81**	0.25	1.01	17.3	0.19	0.24	**0.033**	**0.82**	**0.069**	0.35	4.9	0.026
**Treatment 8 + 9 (Grp 3)	2.57	0.159	**0.90**	0.23	0.97	17.0	0.19	0.26	**0.034**	**1.20**	**0.059**	0.30	4.8	0.027
Boiler ash (Grp 3)	2.49	0.157	**0.80**	0.25	1.03	16.3	0.19	0.25	**0.046**	**0.99**	**0.067**	0.39	5.0	0.027
***Control (Grp 3)	2.53	0.160	**0.85**	0.23	0.97	18.0	0.19	0.26	**0.036**	**0.81**	**0.052**	0.34	5.0	0.026
sed	*0.06*	*0.003*	*0.04*	*0.03*	*0.06*	*1.35*	*0.004*	*0.12*	*0.003*	*0.12*	*0.006*	*0.04*	*0.38*	*0.002*
Grand mean	**2.54**	**0.160**	**0.87**	**0.25**	**0.97**	**16.8**	**0.19**	**0.26**	**0.038**	**1.05**	**0.061**	**0.33**	**5.0**	**0.027**

** MOP S+T (Grp 3) – MOP surface combined with MOP in trenches*

*** Treatment 8 + 9 (Grp 3) – MOP S+T combined with Kie+Magnesite+MgO*

**** Control (Grp 3) – No K & Mg applied*

FERTILISER RESPONSE TRIALS IN MILNE BAY PROVINCE
(Milne Bay Estates)

(Steven Nake & Mike Webb)

TRIAL 502B. NITROGEN, PHOSPHORUS, POTASSIUM AND EFB TRIAL IN MILNE BAY PROVINCE

SUMMARY

Trial 502B was established on Waigani estate in Milne Bay Province to test the response to N, P, K in factorial combination, with and without EFB, with view to using EFB to replace or supplement inorganic fertilizer. The trial block was planted in 1986 at 127 palms per hectare. Treatments application and data collected commenced in 1995.

The response in general by the yield and its components, tissue nutrient concentrations and vegetative growth parameters to the fertilizer treatments in 2005 was positive and significant.

The FFB yield though lower than 25 tonnes, improved slightly from last year's drop. The number of bunches continued to fall to around 900 bunches in 2005 while the single weights continued to increase by 1.4 kg.

SOA (p=<0.001), MOP (p=<0.001), TSP (p=0.038) and EFB (p=<0.001) significantly increased FFB yields to more than 23.0 t/ha in 2005. Yield and number of bunches for the first time in 10 years eventually responded positively to TSP. SOA, MOP, TSP and EFB also increased number of bunches in 2005, despite the fact that the overall mean bunch number for the trial in general has continued to drop from 2005. Single bunch weight also responded positively and significantly to the fertilizer treatments except TSP which showed no response.

The fertilizer treatments also had significant and positive effects on the leaflet and rachis nutrient concentrations. The vegetative growth parameters, radiation interception and dry matter production of the palms were also improved by the fertilizer treatments.

METHODOLOGY

Trial Background Information

Table 1. Trial 502B background information.

Trial number	502B	Company	Milne Bay Estates
Estate	Waigani	Block No.	Field 6503/6504
Date planted*	1986	Planting Density*	127 palms/ha
Spacing		Pattern	Triangular
LSU or MU*	Alluvium	Soil Type	Plantation family, of recent alluvial origin
Recording Started	1995	Age after planting*	20 years
Topography	Flat	Planting material	Dami D x P
Progeny		Altitude	103 masl
Drainage*	Poor	Previous Landuse*	Cocoa/coconut plantings
Officer in charge	S. Nake	Area under trial soil type (ha)*	

**Data should be synchronous with OMP.*

Experimental Design and Treatments

Trial 502B is a factorial fertiliser trial with 4 levels of ammonium sulphate (SOA), 4 levels of potassium chloride (MOP), 2 levels of triple superphosphate (TSP) and 2 levels of EFB (Table 1). It has a single replicate (64 plots), and is split into four blocks. Each plot contains 16 core palms, which are surrounded by one guard row and a trench. Trenching was completed in 1995, and the first dose of fertiliser was applied in the fourth quarter of 1994. Applications of EFB started in August 1995. EFB is applied by hand as mulch between palm circles once per year. Fertiliser is applied in 3 doses per year.

Table 2. Amount of fertiliser and EFB used in Trial 502b.

	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	-	-

Trial Maintenance and Upkeep

General upkeep work and block sanitation in the trial block is done by the estate workers. This includes activities such as ring weeding, herbicide spraying, wheelbarrow path clearance, cover crop maintenance and other routine plantation practices. Any fertilizer application close to the trial has to be closely supervised by plantation supervisors so that fertilizers are not accidentally applied in the trial block. To avoid such incidents, fertilization (standard rates used by estate) of the boundary and perimeter palms is done by PNGOPRA. Kieserite and Boron will be applied as basals to all the palms in 2006.

Trials are maintained regularly so that treatments effects on yield and other measured parameters are not compromised by poaching.

Data Collection

Yield recording (weighing of bunches) is done on a fortnightly basis (14 days). Harvesting and yield recording is done on every Thursday on the non-company pay week. Recorders walk through the plots along the harvest paths and record the number of bunches harvested and the weight of those bunches. Loose fruits are also collected and weighed with their respective bunches. Bunches from the guard row palms are not weighed. The data is recorded onto the yield record sheets in the field and later on entered onto the computer data base using Microsoft Access and are later on converted into yield expressed in tonnes per hectare, total number of bunches harvested per hectare and the single bunch weight.

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

Tissue sampling (leaf & rachis) is done either every year or every two years depending on the fertilizer responses. Before sampling the leaflets, frond 17 is firstly identified following the standard protocol, and then harvested. Two pairs of leaflets (one from upper rank and one from lower rank) are taken from both sides of the middle portion of leaf. All samples from each plot are kept separately in plastic bags. Part of the rachis where the leaflets are taken from are also chopped of and included with the leaflets. These are later processed, packed in brown paper bags, oven dried at 70 –75 °C for 24 hours and dispatched to AAR for analysis. Rachises are dried longer than the leaves (36 hours).

RESULTS & DISCUSSION

Yield and other components response to fertilizer treatments

The treatment effects on the FFB yield and other components are shown in Tables 4 – 11. Furthermore, the main effects of the treatments over the course of the trial (1995 – 2005) are graphed in Figure 1. The overall FFB yield increased slightly by 1 t/ha in 2005 after experiencing a dramatic drop in 2004. The number of bunches continued to drop in 2005 to 900, however the single bunch weights continued to increased to close to 27 kg.

SOA, MOP and EFB continued to show significant effects ($p<0.05$) on the FFB yield in 2005. SOA significantly increased FFB yields from 2002 to 2005 (Table 5). The significant increase in FFB yield was due to significant increase in the number of bunches (Table 6) and single bunch weights (Table 7). Though there was an increase in the mean FFB yield in 2005, plots receiving no N (SOA0) continued to decline. MOP started showing significant effects in 1997 but was not consistent until 2003. The plots receiving no K experienced a very dramatic drop in FFB yield between 2003 and 2004 and also in 2005. MOP significantly increased yields to more than 24 t/ha in 2005. FFB yield for the first time in 10 years after treatment application responded positively and significantly ($p=0.038$) to TSP in 2005. The FFB yields in the TSP treatments plots were 1.5 tonnes better than those in the plots with no TSP. EFB started showing positive and significant effects on the yield in 1998 and this positive effect was consistent until 2005. Plots fertilized with EFB were significantly higher than those with no EFB.

Regardless of the fertiliser treatments, the maximum number of bunches was achieved in 2000 at the age of 14 and thereafter declined to less than 1000 bunches in 2004 and 2005. Despite the declining trend, SOA continued to show significant (<0.001) and positive effects on the number of bunches. Plots treated with SOA produced number of bunches well above the trial mean of 900 bunches per hectare. MOP first showed significant effects on the BNO in 1997 and then had no significant effect until 2004 and 2005 when it started showing significant effects again. TSP and EFB also significantly increased the BNO in 2005.

SOA, MOP and EFB all significantly increased single bunch weight in 2005 except TSP, which continued to have no effect.

The treatment interaction (two- and three-way) and their effects on the FFB yield are shown in Tables 8 – 11. Interaction between SOA.EFB, MOP.EFB and MOP.TSP had significant effects on the yield. Regardless of SOA, applications of EFB significantly ($p=0.057$) increased FFB yields. Highest FFB yield was obtained when combining 4 kg of SOA with 300 kg of EFB (SOA2.EFB1). A very similar trend was also seen with MOP and EFB interactions in that the FFB yield was increased significantly with EFB regardless of MOP.

Table 4. Effects (p values) of treatments on FFB yield and its components in 2001 – 2005 and 2005. P values less than 0.1 are bolded.

	2001 - 2005			2005		
Source	Yield	BNO	SBW	Yield	BNO	SBW
SOA	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**
MOP	**<0.001**	**0.052**	**<0.001**	**<0.001**	**<0.001**	**0.003**
TSP	0.657	0.316	0.255	**0.038**	**<0.001**	0.332
EFB	**<0.001**	**0.003**	**<0.001**	**<0.001**	**0.003**	**<0.001**
SOA.MOP	0.517	0.531	0.146	0.244	**0.022**	0.476
SOA.TSP	0.923	0.439	**0.091**	0.960	**0.080**	0.319
MOP.TSP	0.200	**0.072**	**0.021**	**0.053**	**0.001**	0.235
SOA.EFB	**0.001**	**0.002**	**0.029**	**0.057**	**0.003**	0.297
MOP.EFB	**<0.001**	**0.011**	**0.001**	**0.015**	**0.002**	**0.016**
TSP.EFB	0.861	0.880	0.795	0.247	0.166	0.390
SOA.MOP.TSP	0.306	**0.069**	0.213	0.285	**0.004**	0.735
SOA.MOP.EFB	0.472	0.718	0.118	0.292	**0.003**	0.495
SOA.TSP.EFB	0.224	0.455	0.466	**0.083**	**0.007**	0.468
MOP.TSP.EFB	0.464	0.771	0.196	**0.072**	**0.003**	0.299
CV %	5.1	4.4	2.9	10.3	4.7	6.2

Table 5. Main effects of treatments on FFB yield (t/ha) from 1995 – 2005. Values with significant effects are highlighted in bold.

Treatments	Age and year										
	9 1995	10 1996	11 1997	12 1998	13 1999	14 2000	15 2001	16 2002	17 2003	18 2004	19 2005
SOA0	19.5	**25.4**	**23.9**	17.5	**22.2**	**29.3**	22.8	**21.1**	**21.8**	**20.1**	**19.6**
SOA1	19.8	**26.2**	**25.9**	18.0	**23.4**	**36.7**	23.3	**24.8**	**29.1**	**22.7**	**23.5**
SOA2	19.3	**25.9**	**27.8**	18.0	**23.8**	**37.5**	24.0	**25.2**	**29.9**	**24.9**	**27.0**
SOA3	18.9	**28.0**	**26.6**	17.8	**24.4**	**35.6**	23.1	**26.9**	**30.0**	**25.7**	**26.0**
sed	*0.76*	*0.81*	*0.84*	*1.1*	*0.43*	*1.22*	*0.94*	*1.02*	*1.18*	*0.52*	*0.87*
MOP0	20.0	26.2	**24.1**	17.9	**22.2**	**33.4**	22.1	23.5	**25.9**	**22.1**	**20.4**
MOP1	19.7	25.9	**25.1**	18.0	**24.3**	**33.6**	23.9	24.9	**27.3**	**22.7**	**25.2**
MOP2	19.1	26.6	**26.3**	17.9	**23.6**	**35.1**	23.8	24.0	**29.1**	**23.1**	**24.7**
MOP3	18.6	26.7	**28.7**	17.4	**23.8**	**36.9**	23.5	25.7	**28.7**	**25.5**	**25.8**
sed	*0.76*	*0.81*	*0.84*	*1.1*	*0.43*	*1.22*	*0.94*	*1.02*	*1.18*	*0.52*	*0.87*
TSP0	19.3	26.5	26.4	18.1	23.5	34.8	24.1	24.7	27.1	23.5	**23.3**
TSP1	19.3	26.2	25.7	17.6	23.4	34.7	22.5	24.4	28.4	23.2	**24.8**
sed	*0.54*	*0.57*	*0.59*	*0.8*	*0.31*	*0.86*	*0.66*	*0.72*	*0.84*	*0.37*	*0.62*
EFB0	19.2	26.5	25.8	**16.9**	**22.4**	**33.5**	**22.6**	**22.2**	**26.6**	**21.6**	**22.2**
EFB1	19.5	26.2	26.3	**18.7**	**24.4**	**36.0**	**24.1**	**26.8**	**28.9**	**25.1**	**25.8**
sed	*0.54*	*0.57*	*0.59*	*0.8*	*0.31*	*0.86*	*0.66*	*0.72*	*0.84*	*0.37*	*0.62*
Mean	19.3	26.3	26.1	17.8	23.4	34.7	23.3	24.2	27.7	23.3	24.0

Table 6. Main effects of treatments on number of bunches (BNO) from 1995 – 2005. Values with significant effects are highlighted in bold.

Treatments	Age and year										
	9 1995	10 1996	11 1997	12 1998	13 1999	14 2000	15 2001	16 2002	17 2003	18 2004	19 2005
SOA0	981	1149	**1196**	887	**923**	**1229**	1049	**959**	**986**	**879**	**822**
SOA1	978	1116	**1227**	822	**905**	**1491**	1024	**1018**	**1163**	**886**	**873**
SOA2	960	1102	**1319**	834	**939**	**1531**	1070	**1033**	**1170**	**933**	**967**
SOA3	957	1172	**1237**	828	**972**	**1510**	1039	**1105**	**1205**	**983**	**940**
sed	*49.8*	*46.0*	*38.0*	*46.6*	*22.5*	*63.3*	*44.9*	*40.3*	*47.6*	*24.3*	*15.1*
MOP0	993	1126	**1168**	869	906	1408	1017	1011	1101	**918**	**821**
MOP1	992	1122	**1211**	829	963	1408	1069	1053	1125	**883**	**935**
MOP2	964	1138	**1249**	848	937	1440	1059	993	1154	**911**	**899**
MOP3	927	1153	**1349**	824	933	1505	1037	1057	1145	**969**	**947**
sed	*49.8*	*46.0*	*38.0*	*46.6*	*22.5*	*63.3*	*44.9*	*40.3*	*47.6*	*24.3*	*15.1*
TSP0	962	1141	1243	844	931	1429	1066	1035	1109	924	**866**
TSP1	976	1128	1246	842	939	1452	1025	1022	1153	917	**935**
sed	*35.2*	*32.5*	*26.8*	*33.0*	*15.9*	*44.7*	*31.8*	*28.5*	*33.7*	*17.2*	*10.7*
EFB0	970	1130	1256	816	919	1417	1045	973	1117	**888**	**879**
EFB1	968	1139	1233	870	950	1464	1046	1084	1148	**952**	**922**
sed	*35.2*	*32.5*	*26.8*	*33.0*	*15.9*	*44.7*	*31.8*	*28.5*	*33.7*	*17.2*	*10.7*
Mean	969	1135	1244	843	935	1440	1045	1018	1131	920	900

Table 7. Main effects of treatments on single bunch weights (SBW) from 1995 – 2005. Values with significant effects are highlighted in bold.

Treatments	Age and year										
	9 1995	10 1996	11 1997	12 1998	13 1999	14 2000	15 2001	16 2002	17 2003	18 2004	19 2005
SOA0	20.0	**22.7**	**20.4**	**20.0**	**24.5**	24.4	**21.9**	**21.8**	**22.3**	**22.9**	**23.7**
SOA1	20.6	**24.1**	**21.8**	**22.1**	**26.5**	25.1	**23.1**	**24.3**	**25.3**	**25.8**	**27.7**
SOA2	20.4	**24.3**	**21.6**	**21.6**	**25.8**	24.9	**22.8**	**24.4**	**25.9**	**27.2**	**28.2**
SOA3	20.4	**24.7**	**22.1**	**21.7**	**25.7**	24.3	**22.8**	**24.3**	**25.1**	**26.5**	**28.0**
sed	*0.45*	*0.56*	*0.48*	*0.39*	*0.52*	*0.45*	*0.45*	*0.26*	*0.43*	*0.52*	*0.59*
MOP0	20.4	24.0	21.1	20.9	**24.7**	24.2	22.0	**23.1**	**23.7**	**23.9**	**25.0**
MOP1	20.3	23.7	21.5	21.8	**25.8**	24.8	22.6	**23.5**	**24.3**	**26.1**	**27.3**
MOP2	20.3	24.1	21.5	21.3	**25.8**	24.8	22.9	**24.1**	**25.3**	**25.7**	**27.7**
MOP3	20.3	24.1	21.8	21.5	**26.3**	25.0	22.9	**24.2**	**25.3**	**26.5**	**27.6**
sed	*0.45*	*0.56*	*0.48*	*0.39*	*0.52*	*0.45*	*0.45*	*0.26*	*0.43*	*0.52*	*0.59*
TSP0	20.5	23.9	21.7	21.6	25.8	25.0	22.9	23.7	24.6	25.7	27.1
TSP1	20.2	24.0	21.2	21.1	25.4	24.3	22.4	23.7	24.7	25.4	26.7
sed	*0.32*	*0.39*	*0.34*	*0.28*	*0.37*	*0.32*	*0.32*	*0.18*	*0.30*	*0.37*	*0.42*
EFB0	20.1	24.1	**21.1**	**21.1**	**24.9**	**24.2**	**22.0**	**22.7**	**23.9**	**24.4**	**25.3**
EFB1	20.6	23.8	**21.8**	**21.7**	**26.3**	**25.2**	**23.3**	**24.8**	**25.4**	**26.7**	**28.6**
sed	*0.32*	*0.39*	*0.34*	*0.28*	*0.37*	*0.32*	*0.32*	*0.18*	*0.30*	*0.37*	*0.42*
Mean	20.3	24.0	21.5	21.4	25.6	24.7	22.6	24.0	24.6	25.5	26.9

Table 8. Effect of two-way interactions on FFB yield (t/ha) in 2005. Significant interactions are highlighted in bold.

SOA.MOP, p=0.244, lsd = 3.9

	SOA0	SOA1	SOA2	SOA3
MOP0	17.6	21.5	21.6	21.0
MOP1	20.7	24.3	29.0	26.6
MOP2	19.1	22.4	29.5	27.9
MOP3	20.9	25.8	27.9	28.4

MOP.TSP, p=0.053, lsd = 2.8

	TSP0	TSP1
MOP0	**20.7**	**20.2**
MOP1	**24.9**	**25.3**
MOP2	**24.1**	**25.3**
MOP3	**23.3**	**28.2**

SOA.TSP, p=0.960, lsd=2.8

	SOA0	SOA1	SOA2	SOA3
TSP0	19.0	22.6	26.4	25.1
TSP1	20.2	24.5	27.6	26.8

EFB.TSP, p=0.247, lsd=1.9

	TSP0	TSP1
EFB0	21.9	22.6
EFB1	24.7	26.9

SOA.EFB, p=0.057, lsd=2.8

	SOA0	SOA1	SOA2	SOA3
EFB0	**16.0**	**22.6**	**25.7**	**24.6**
EFB1	**23.1**	**24.5**	**28.3**	**27.3**

MOP.EFB, p=0.015,lsd=2.8

	EFB0	EFB1
MOP0	**16.4**	**24.4**
MOP1	**23.6**	**26.7**
MOP2	**24.0**	**25.4**
MOP3	**24.8**	**26.7**

Table 9. Effect of the three-way interaction between SOA, MOP and EFB on FFB yield (t/ha) in 2005. P=0.083, s.e.d = 1.75 and l.s.d.=3.9 CV = 10.3%.

	EFB0				***EFB1***			
	MOP0	***MOP1***	***MOP2***	***MOP3***	***MOP0***	***MOP1***	***MOP2***	***MOP3***
SOA0	12.1	17.6	17.2	17.1	23.1	23.7	20.9	24.7
SOA1	19.5	24.1	21.4	25.3	23.6	24.5	23.5	26.4
SOA2	18.5	27.4	27.6	29.2	24.7	30.6	31.3	26.7
SOA3	15.5	25.4	29.9	27.7	26.5	27.9	25.9	30.0

Table 10. Effect of the three-way interaction between SOA, TSP and EFB on FFB yield (t/ha) in 2005. P=0.083, s.e.d = 1.75 and l.s.d.=3.9 CV = 10.3%.

	TSP0		***TSP1***	
	EFB0	***EFB1***	***EFB0***	***EFB1***
SOA0	14.4	23.5	17.6	22.7
SOA1	22.2	22.9	22.9	26.1
SOA2	26.7	26.1	24.6	30.5
SOA3	24.1	26.2	25.1	28.5

Table 11. Effect of the three-way interaction between MOP, TSP and EFB on FFB yield (t/ha) in 2005. P=0.072, s.e.d = 1.75 and l.s.d.=3.9 CV = 10.3%.

	TSP0		***TSP1***	
	EFB0	***EFB1***	***EFB0***	***EFB1***
MOP0	18.7	22.7	14.1	26.2
MOP1	23.1	26.9	24.1	26.6
MOP2	23.6	24.7	24.5	26.1
MOP3	22.0	24.5	27.6	28.9

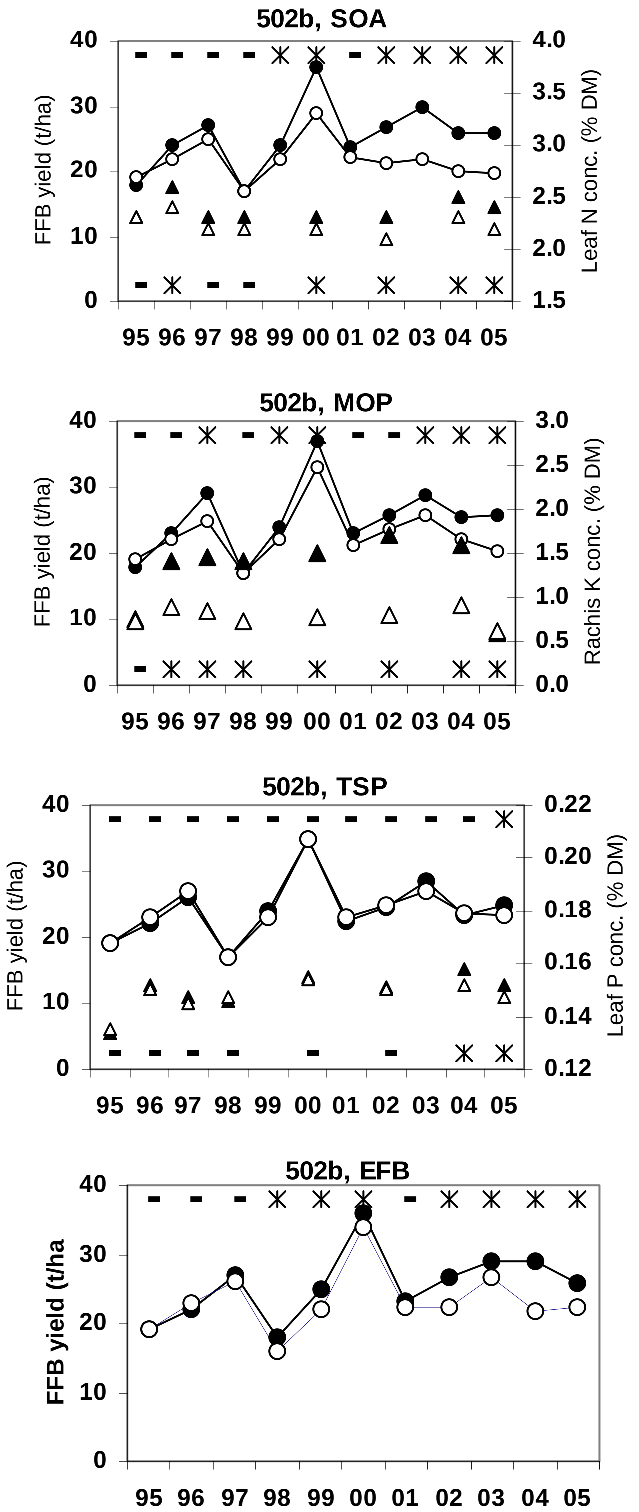


Figure 1. Main effects of SOA, MOP and TSP over the course of Trial 502b. Lines are FFB yields and triangles are tissue concentrations. Full symbols represent the maximum level of application, and empty symbols zero application. Symbols along the top of the graph indicate significance of the main effect on yield, and along the bottom indicate significance of the main effect on tissue concentration. Stars indicate significance ($p<0.05$) and dashes non-significance.

Fertiliser Effects on the leaflets and rachis nutrient concentrations

Table 12 and 13 shows the effects of the fertilizer treatments on the leaf tissue nutrients. The mean nutrient levels suggest levels of leaflet N and P are very low and close to the deficient range, while concentration of leaflet K and S are deficient. Leaflet levels of Mg, Ca and B are in adequate quantities.

SOA significantly increased leaflet concentrations of ash ($p=<0.001$), N ($p=0.007$), S ($p=0.033$) and rachis N ($p=0.007$). Despite the significant effects, the leaflet concentration of N appeared to be very low. SOA also had a significant effect on leaf K but the response was negative because the K concentrations in the leaflets were reduced by SOA application.

MOP had significant effects on leaflet K ($p= <0.001$), Mg ($p=<0.001$), Ca ($p=<0.001$), B ($p=0.054$) and rachis ash ($p=<0.001$), rachis P ($p=0.002$) and rachis K ($p=<0.001$), MOP only increased the K leaflet concentrations to more than 0.59 % and ash, P and K concentrations in the leaf rachis. Mg, Ca and B levels though responded significantly to MOP, showed negative effects.

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

Fertiliser Effects on oil palm vegetative growth

Summarised results for the vegetative growth parameters for 2005 are presented in Tables 14 and 15. SOA significantly increased radiation interception (yearly frond production, number of green fronds and Frond Area) and dry matter production (FDM, BDM, TDM, VDM) in the oil palms. Frond area was significantly ($p=0.025$) to values more than 12.98. Similarly, the annual frond production and the number of green frond present on the palm responded positively and significantly to SOA. Dry frond weight was also increased significantly ($p=<0.001$) to more than 12.4 kg. PCS and the leaf length also showed a positive response to SOA. Leaf length increased significantly to over 600 cm when SOA was applied. LAI also increased with SOA application but the response was not significant.

MOP significantly increased PCS, LAI, dry frond weight, BDM, TDM, VDM and BI (Table 15). Mean values of the PCS was increased to over 47 cm^2 while LAI was also increased to mean values more than 5.91. The dry matter production was also improved by MOP application.

The effect of TSP was only significant on BDM ($p=0.038$) and TDM ($p=0.047$). Both parameters were increased with TSP. EFB also had some very positive and significant effects on the vegetative parameters. Leaf length and PCS were significantly increased to values more than 613 cm and 47cm^2 respectively. LAI was also significantly increased ($p=0.011$) by EFB that then caused a positive response by the FA. Dry matter production in the same year was also improved significantly through EFB application.

CONCLUSION

The FFB yield and SBW continued to increase in 2005 while the number of bunches continued to decline to less than 1000. The overall response by the yield and its components to SOA, MOP and EFB was positive and consistent over the last 4 years regardless of very slight peaks and troughs in the trend. TSP started showing positively significant effects on the FFB yield and number of bunches in 2005, but still no effect on the single bunch weights. SOA, MOP and EFB significantly increased yields and the number of bunches.

The positive responses were also evident in the leaflet tissue nutrients. SOA significantly increased leaflet Ash, N and S while reduced K concentrations in the leaflet. SOA also increased the N concentration in the rachis. MOP increased leaflet K concentrations and rachis ash, P and K levels. TSP also increased leaflet N and P. Leaflet N, P, K, S and rachis ash, P and K responded positively and significantly to EFB. Concentrations for all these nutrients were increased with EFB.

The fertilizer treatments also had positive and significant effects on the vegetative growth parameters. SOA significantly increased both the radiation interception and the dry matter production. The leaf length, PCS and dry frond weight were also improved significantly by SOA. MOP also had similar positive effects on PCS, LAI, dry frond weight and the dry matter production. TSP effect on the same parameters was really obvious at this stage, however EFB response was very strong and positive. EFB increased the PCS, leaf length, radiation interception and dry matter production.

Table 12. Effects (p values) of treatments on frond 17 nutrient concentrations in 2005**.** P values less than 0.1 are indicated in bold.

Source	Leaflet Nutrient Concentrations									Rachis Nutrient Concentrations			
	Ash	N	P	K	Mg	Ca	Cl	S	B	Ash	N	P	K
SOA	**<.001**	**0.007**	0.989	**0.044**	0.739	0.619		**0.033**	0.280	0.854	**0.007**	**<.001**	0.285
MOP	**0.099**	0.787	0.737	**<.001**	**<.001**	**0.050**		0.792	**0.054**	**<.001**	0.850	**0.002**	**<.001**
TSP	0.225	**0.089**	**0.004**	0.680	0.942	0.296		0.396	0.744	0.728	0.595	**<.001**	0.308
EFB	0.136	**0.025**	**0.092**	**<.001**	**<.001**	**<.001**		**0.053**	0.178	**<.001**	0.678	**0.050**	**<.001**
SOA.MOP	0.514	0.206	0.734	0.444	0.645	0.445		0.366	0.871	0.552	0.298	0.120	0.426
SOA.TSP	0.538	0.952	0.968	0.991	0.367	0.891		0.693	0.478	0.200	0.281	**0.017**	0.205
MOP.TSP	0.546	0.204	0.860	0.962	0.720	0.795		0.653	0.931	0.293	**0.095**	0.104	0.316
SOA.EFB	0.297	0.204	0.895	0.296	0.675	0.276		0.401	0.848	0.899	0.683	0.950	0.862
MOP.EFB	**0.047**	0.771	0.892	**<.001**	**<.001**	**0.001**		0.872	**0.020**	**0.011**	0.318	**0.060**	**<.001**
TSP.EFB	0.626	0.456	0.126	0.953	0.487	0.339		0.153	0.695	0.688	0.858	**0.022**	0.327
SOA.MOP.TSP	0.141	0.375	0.423	0.261	0.567	0.140		0.661	0.633	0.519	0.563	**0.045**	0.948
SOA.MOP.EFB	**0.017**	0.344	0.944	0.491	0.950	0.620		0.677	0.516	**0.062**	**0.019**	0.231	**0.065**
SOA.TSP.EFB	0.309	0.254	0.443	0.532	0.292	**0.055**		0.241	0.212	0.214	0.504	0.901	0.393
MOP.TSP.EFB	0.567	0.142	0.892	0.476	0.978	0.746		0.174	0.769	0.347	0.944	0.164	0.926
CV %	3.9	4.0	3.4	7.0	13.8	5.7		6.3	9.4	6.4	6.4	9.9	8.4

Table 13. Main effects of treatments on frond 17 nutrient concentrations in 2005**.**, in units of dry matter %, except B (mg/kg). P values less than 0.1 are indicated in bold.

Source	Leaflet Nutrient Concentrations									Rachis Nutrient Concentrations			
	Ash	N	P	K	Mg	Ca	Cl	S	B	Ash	N	P	K
SOA0	**13.4**	**2.24**	0.149	**0.62**	0.37	0.87		**0.172**	11.4	5.0	**0.30**	**0.192**	1.40
SOA1	**13.9**	**2.67**	0.149	**0.59**	0.37	0.89		**0.171**	11.8	4.9	**0.31**	**0.148**	1.37
SOA2	**15.2**	**2.34**	0.149	**0.58**	0.36	0.90		**0.178**	12.3	5.0	**0.33**	**0.109**	1.33
SOA3	**15.1**	**2.39**	0.149	**0.58**	0.36	0.89		**0.184**	12.0	4.9	**0.34**	**0.091**	1.33
sed	*0.19*	*0.03*	*0.002*	*0.01*	*0.02*	*0.02*		*0.004*	*0.39*	*0.11*	*0.007*	*0.005*	*0.04*
MOP0	14.4	2.29	0.150	**0.51**	**0.44**	**0.92**		0.175	**12.6**	**4.3**	0.31	**0.121**	**0.85**
MOP1	14.1	2.32	0.149	**0.59**	**0.35**	**0.88**		0.176	**11.4**	**4.8**	0.32	**0.134**	**1.33**
MOP2	14.7	2.32	0.149	**0.62**	**0.35**	**0.88**		0.177	**11.7**	**5.4**	0.32	**0.138**	**1.60**
MOP3	14.4	2.32	0.149	**0.64**	**0.32**	**0.87**		0.179	**11.7**	**5.5**	0.32	**0.148**	**1.66**
sed	*0.19*	*0.03*	*0.002*	*0.01*	*0.02*	*0.02*		*0.004*	*0.39*	*0.11*	*0.007*	*0.005*	*0.04*
TSP0	14.5	**2.29**	**0.147**	0.59	0.36	0.88		0.175	11.9	5.0	0.32	**0.110**	1.37
TSP1	14.3	**2.33**	**0.152**	0.59	0.36	0.89		0.178	11.8	5.0	0.32	**0.161**	1.34
sed	*0.14*	*0.02*	*0.001*	*0.01*	*0.01*	*0.01*		*0.003*	*0.28*	*0.08*	*0.005*	*0.003*	*0.03*
EFB0	14.5	**2.28**	**0.148**	**0.54**	**0.40**	**0.92**		**0.173**	12.1	**4.7**	0.32	**0.131**	**1.15**
EFB1	14.3	**2.34**	**0.150**	**0.64**	**0.33**	**0.85**		**0.180**	11.7	**5.3**	0.32	**0.139**	**1.57**
sed	*0.14*	*0.02*	*0.001*	*0.01*	*0.01*	*0.01*		*0.003*	*0.28*	*0.08*	*0.005*	*0.003*	*0.03*
Grand mean	14.4	2.31	0.149	0.59	0.36	0.89		0.177	11.9	5.0	0.32	0.135	1.36

Table 14. Main effects (p values) of fertilizer treatments on the vegetative growth parameters in 2005. P values less than 0.1 are shown in bold.

Source	LLen	LlNum	PCS	**Radiation Interception**				Dry FW	**Dry matter production (t/ha/yr)**				BI
				Frond Prodn	Green Frond	FA	LAI		FDM	BDM	TDM	VDM	
SOA	**0.002**	**0.040**	**<.001**	**0.080**	**0.026**	**0.025**	**0.009**	**<.001**	**<.001**	**<.001**	**<.001**	**<.001**	0.129
MOP	0.178	0.320	**0.030**	0.864	0.945	**0.026**	0.257	**0.030**	0.275	**<.001**	**<.001**	**0.062**	**0.010**
TSP	0.827	0.355	0.846	0.627	0.950	0.312	0.502	0.846	0.854	**0.038**	**0.047**	0.537	0.216
EFB	**0.012**	0.338	**<.001**	0.352	0.124	**0.009**	**0.011**	**<.001**	**0.002**	**<.001**	**<.001**	**<.001**	**0.051**
SOA.MOP	0.589	0.432	0.104	0.994	0.321	0.224	0.184	0.104	0.472	0.244	0.159	0.364	0.752
SOA.TSP	0.920	0.479	0.646	0.631	0.877	0.989	0.926	0.646	0.749	0.960	0.929	0.757	0.790
MOP.TSP	0.563	0.367	0.161	0.911	0.378	0.705	0.783	0.161	0.732	**0.053**	**0.060**	0.575	0.202
SOA.EFB	**0.009**	0.715	**0.011**	0.775	0.380	0.311	0.510	**0.011**	**0.090**	**0.057**	**0.015**	**0.045**	0.294
MOP.EFB	0.250	0.736	0.504	0.696	0.402	0.357	0.274	0.504	0.451	**0.015**	**0.009**	0.182	0.102
TSP.EFB	0.527	0.625	0.325	**0.097**	0.138	0.600	0.544	0.325	0.550	0.247	0.428	0.707	0.233
SOA.MOP.TSP	0.284	0.602	0.281	0.384	0.411	0.455	0.437	0.281	0.950	0.285	0.222	0.824	0.811
SOA.MOP.EFB	**0.067**	0.787	0.744	**0.081**	0.688	0.188	0.491	0.744	0.419	0.292	0.169	0.318	0.608
SOA.TSP.EFB	0.377	0.395	0.235	0.855	0.688	0.644	0.534	0.235	0.509	**0.083**	**0.048**	0.299	0.457
MOP.TSP. EFB	0.871	0.799	0.252	0.936	0.746	0.324	0.732	0.252	0.618	**0.072**	**0.048**	0.373	0.201
CV %	2.5	1.8	5.1	5.7	5.0	5.2	8.0	4.9	8.7	10.3	6.9	7.6	5.7

Table 15. Main effects of fertilizer treatments on the vegetative growth parameters in 2005.

Source	Llen (cm)	LlNum	PCS (cm^2)	**Radiation Interception**				Dry FW (kg)	**Dry matter production (t/ha/yr)**				BI
				Frond Prod/yr	Green Frond	FA (m^2)	LAI		FDM	BDM	TDM	VDM	
SOA0	**596.5**	**195**	**42.4**	**18.1**	**34.3**	**12.46**	5.43	**4.53**	**10.8**	**16.0**	**29.9**	**13.8**	0.531
SOA1	**612.4**	**196**	**47.5**	**19.2**	**36.5**	**12.96**	6.00	**5.05**	**12.3**	**19.3**	**35.1**	**15.9**	0.548
SOA2	**622.1**	**192**	**49.9**	**19.8**	**36.2**	**13.35**	6.14	**5.29**	**13.3**	**22.1**	**39.4**	**17.2**	0.558
SOA3	**624.6**	**192**	**48.3**	**19.9**	**36.2**	**13.15**	6.05	**5.13**	**13.0**	**21.3**	**38.0**	**16.8**	0.556
sed	*5.5*	*1.26*	*0.85*	*0.40*	*0.63*	*0.24*	*0.17*	*0.09*	*0.38*	*0.72*	*0.87*	*0.43*	*0.011*
MOP0	607.7	193	**45.2**	19.5	36.0	12.44	**5.69**	**4.82**	11.9	**16.8**	**31.9**	**15.1**	**0.519**
MOP1	613.8	195	**47.0**	19.2	35.9	13.19	**6.01**	**4.99**	12.2	**20.6**	**36.5**	**15.9**	**0.564**
MOP2	621.2	194	**47.9**	19.5	35.6	13.28	**6.00**	**5.09**	12.6	**20.3**	**36.5**	**16.3**	**0.551**
MOP3	612.8	193	**48.1**	19.5	35.8	13.01	**5.93**	**5.11**	12.7	**21.1**	**37.5**	**16.4**	**0.560**
sed	*5.5*	*1.26*	*0.85*	*0.40*	*0.63*	*0.24*	*0.17*	*0.09*	*0.38*	*0.72*	*0.87*	*0.43*	*0.011*
TSP0	614.3	194	47.1	19.4	35.8	13.07	5.95	5.00	12.3	**19.1**	**34.9**	15.8	0.543
TSP1	613.5	193	46.9	19.5	35.8	12.89	5.87	5.00	12.4	**20.3**	**36.3**	16.0	0.553
sed	*3.9*	*0.89*	*0.60*	*0.28*	*0.45*	*0.17*	*0.12*	*0.06*	*0.27*	*0.61*	*0.62*	*0.30*	*0.008*
EFB0	**607.8**	194	**45.0**	19.3	35.4	**12.70**	**5.72**	**4.80**	**11.8**	**18.2**	**33.3**	**15.1**	**0.539**
EFB1	**620.0**	193	**49.0**	19.6	36.2	**13.26**	**6.10**	**5.20**	**12.9**	**21.2**	**37.9**	**16.7**	**0.557**
sed	*3.9*	*0.89*	*0.60*	*0.28*	*0.45*	*0.17*	*0.12*	*0.06*	*0.27*	*0.61*	*0.62*	*0.30*	*0.008*
Grand mean	613.9	194	47.0	19.4	35.8	12.98	5.91	5.00	12.4	19.7	35.6	15.9	0.548

TRIAL 504. NITROGEN AND POTASSIUM TRIAL IN MILNE BAY PROVINCE

SUMMARY

Trial 504 was established on Sagarai estate in Milne Bay Province to test the response to N and K and an allowance made for one additional treatment. Soils in this area come under the Tomanau family, which is of recent alluvial origin, with deep clay loam soils and reasonable drainage status. The treatments include 4 rates of SOA (0, 2.0, 4.0 & 6.0 kg/palm) and 4 rates of MOP (0, 2.5, 5.0 and 7.5 kg/palm).

After 14 years, the mean FFB yield was 26.7 t/ha with an average single bunch weight of 25.6 kg. The FFB yield and other components, frond 17 nutrient concentration and vegetative growth parameters responded well to the fertilizer treatments especially SOA as the N source.

The FFB yield was raised from 23.8 t/ha in 2004 (2004 Annual report) to 26.7 t/ha in 2005, an increase by 2.9 tonnes. The number of bunches continued to fall to 1053 bunches in 2005 while the single weights continued to increase.

SOA significantly increased FFB yields, number of bunches and single bunch weights in 2005. With SOA, the FFB yields were increased to more than 25 t/ha. Similarly, SOA also increased the number of bunches to more than 1000 bunches, despite the fact that the overall mean number of bunches for the trial continued to drop in 2005. Single bunch weight exhibited similar trend as the FFB and the BNO with an increasing trend with time.

MOP was only significant on the FFB yield and not the number of bunches and the single bunch weights. Yields from the palms with no MOP were significantly lower than the fertilized palms.

Interaction was not significant however maximum yield was achieved when combining 4 kg of SOA with 2.5 kg of MOP.

The fertilizer effects on frond 17 nutrient concentration and the vegetative growth parameters were also significant. N levels in the leaflets and the rachis were significantly increased with SOA while MOP also raised levels of K in the leaflets and rachis. Both the radiation interception and the dry matter production of the palms were improved by applying SOA and MOP, however SOA had a more pronounced effect.

METHODOLOGY

Trial Background Information

Table 1. Trial 504 background information.

Trial number	504	Company	Milne Bay Estates
Estate	Sagarai	Block No.	Field 0610, 0611 & 0612
Date planted*	1991	Planting Density*	127 palms/ha
Spacing		Pattern	Triangular
LSU or MU*	Alluvium	Soil Type	Tomanau Family
Recording Started	1995	Age after planting*	14 years
Topography	Flat	Planting material	Dami D x P
Progeny		Altitude	94 masl
Drainage*	Moderate	Previous Landuse*	Ex-Forest/Rubber plantation
Officer in charge	S.Nake	Area under trial soil type (ha)*	

**Data should be synchronous with OMP.*

Experimental Design and Treatments

There are 64 plots, each with a core of 16 palms. The numbers and weights of bunches from each individual core palm are recorded at intervals of 14 days. In each plot the core palms are surrounded by a guard row and a trench.

The 64 plots are divided into two replicates of 32 plots each. In each replicate there are 32 treatments, made up from all combinations of four levels each of N and K, and two levels of an additional treatment, which is currently vacant (Table 1). The trial commenced in 1994. Fertilisers are applied in 3 doses per year.

From 2006 the trial will also receive TSP (0.5 kg/palm) and borate (0.2 kg/palm).

Table 1. 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
Vacant Treatment	-	-	-	-

Trial Maintenance and Upkeep

The trial block is maintained by the Sagarai Estate workers. This includes activities like ring weeding, herbicide spraying, wheelbarrow path clearance, cover crop maintenance and other routine plantation practices. The trial block is also harvested by the estate workers for yield recording purposes. Fertiliser application to both experimental plots and boundary (perimeter palms) is done by PNGOPRA to avoid accidental application of fertilizers to experimental palms by the estate workers.

Trials are maintained regularly so that treatments effects on yield and other measurements are not compromised. Trenches are also dug around the plots to avoid poaching of treatments between plots.

Data Collection

Yield recording (weighing of bunches) is done on a fortnightly basis (14 days). Recorders walk through the plots along the harvest paths and record the number of bunches harvested and weight of those bunches. Loose fruits are also collected and weighed with their respective bunches. Bunches from the guard row palms are not weighed. The data is recorded onto the yield record sheets and sent to Popondetta for entering into our database system.

Vegetative measurements were carried out in 2005. Vegetative parameters included the height measurements, leaf measurements (total leaf length, leaflet width, leaflet length, total number of leaflets), petiole cross-section width and thickness (PCS WxT). Frond 1 marking and frond count was done twice to determine the annual frond production rate.

Leaf sampling was done in June 2005 to monitor the effect of the treatments on the leaf nutrient concentrations. Leaf samples (8 leaflets) are taken from frond 17 using the standard protocols, processed and then oven dried at 74 °C for 24 hours. After the samples are dried, they are ground and securely packed into paper bags before dispatched to AAR for analysis. Rachises are dried longer than the leaves (36 hours).

RESULTS & DISCUSSION

Yield and other components response to fertilizer treatments

The treatment effects on the FFB yield and other components are shown in Table 3, 4 and 5. The overall effect of the treatments over the course of the trial is also illustrated in Figure 1. The effect of the treatments, especially SOA on the yield was very consistent over the last 6 – 7 years. However, the yield differences between the maximum level and zero level of application widened in 2005 compared to the last 2 years for both SOA and MOP treatment. This highlights the importance of N and K in such soils, especially N which showed a much greater difference than K.

Ammonium sulphate (SOA) had significant effects ($p<0.001$) on the FFB yield, number of bunches (BNO) and single bunch weight (SBW) in 2005, while MOP was only significant ($p=0.055$) on the yield. SOA significantly increased FFB yield to more than 25 t/ha and this positive response was caused by significant increase in both the number of bunches and the single bunch weights. Number of bunches and single bunch weight inclined to more than 1000 bunches and 25 kg respectively as a result of SOA application. Muriate of potash (MOP) significantly increased yields. Nil application of both SOA and MOP produced yields, which are significantly lower than the fertilized palms. BNO and SBW also responded positively to MOP application though not significant.

The interaction (Table 5) was not significant, however combinations between higher levels of both SOA and MOP produced better yields. The highest FFB yield of 32.7 t/ha was produced when 4 kg SOA was applied with 7.5 kg MOP.

Fertiliser Effects on Frond 17 nutrient concentrations

The treatments were also effective on some of the major nutrients (Table 6 and 7). SOA had significant effects on leaflet concentration of ash, N, P, Mg, Ca, S and rachis concentration of ash, N, P and K. Mg and Ca levels in the leaflets were reduced with SOA application and a similar negative effect seen on rachis levels of ash, P and K. SOA also increased K concentration in the leaflets but not statistically significant at this stage.

Leaflet concentrations on K and Ca and rachis concentrations of ash, P and K were significantly increased by MOP. Response by leaflet ash, Mg and B was also significant but with a negative effect, concentrations were reduced.

Regardless of the treatments, mean levels of the nutrient concentration in the leaflets indicated that all nutrients are within the optimum level except K and S levels which falls within the deficient range. S deficiency can be corrected by applying SOA (which contains S) as seen in Table 7; applying 4 and 6 kg SOA significantly ($p=<0.001$) increased N concentration in the leaflets to levels above the deficient range. N deficiency was also seen on leaflets of palms receiving no SOA (N). The positive effect of MOP was not strong enough to push the K concentration to the optimum level, thus correcting the K deficiency in the leaflets. However, rachis levels were adequate.

Table 3. Effects (p values) of treatments on FFB yield and its components in 2001 – 2005 and 2005. P values less than 0.1 are bolded.

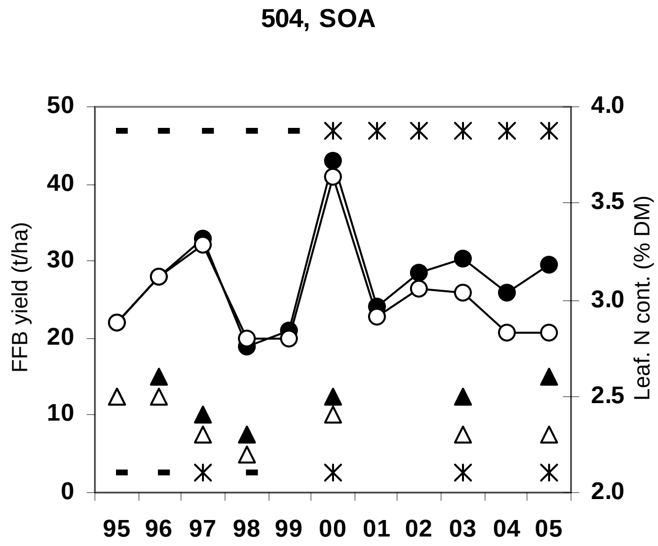
	2001 - 2005			2005		
Source	Yield	BNO	SBW	Yield	BNO	SBW
SOA	**<.001**	**<.001**	**0.003**	**<.001**	**<.001**	**<.001**
MOP	**<.001**	**<.001**	**0.011**	**0.055**	0.235	0.112
SOA.MOP	0.788	0.465	0.756	0.721	0.931	0.678
CV %	7.9	5.6	4.6	12.6	11.4	6.0

Table 4. Main effects of treatments on FFB yield (t/ha) from 2001 – 2005 and 2005. Values with significant effects are highlighted in bold.

	2001-2005			2005		
	Yield (t/ha)	BNO (/ha)	SBW (kg)	Yield (t/ha)	BNO (/ha)	SBW (kg)
SOA0	**23.3**	**1114**	**21.3**	**20.7**	**882**	**23.7**
SOA1	**26.1**	**1188**	**22.5**	**25.7**	**1020**	**25.8**
SOA2	**28.3**	**1282**	**22.6**	**30.3**	**1170**	**26.6**
SOA3	**27.6**	**1266**	**22.3**	**29.5**	**1139**	**26.4**
sed	*0.74*	*24.2*	*0.36*	*1.18*	*42.4*	***0.54***
MOP0	**24.0**	**1146**	**21.4**	**24.7**	1003	25.0
MOP1	**26.6**	**1218**	**22.3**	**26.8**	1054	25.7
MOP2	**27.6**	**1252**	**22.5**	**26.7**	1065	25.5
MOP3	**27.2**	**1235**	**22.5**	**28.0**	1090	26.3
sed	*0.74*	*24.2*	*0.36*	*1.18*	*42.4*	*0.54*
Mean	**26.3**	**1213**	**22.2**	**26.7**	**1053**	**25.6**

Table 5. Effect on SOA.MOP interaction on FFB yield (t/ha) in 2005. Treatment interaction not significant.

	SOA.MOP, p=0.721, lsd = 4.74			
	MOP0	MOP1	MOP2	MOP3
SOA0	20.5	18.9	20.5	22.9
SOA1	23.7	25.9	27.2	26.1
SOA2	27.8	30.5	30.1	32.7
SOA3	26.9	31.8	29.1	30.4



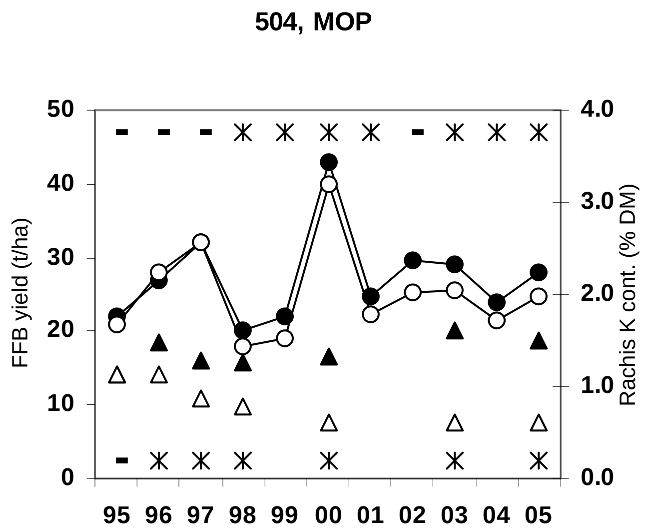


Figure 1. Main effects of SOA and MOP over the course of Trial 504. Lines are FFB yields and triangles are tissue concentrations. Full symbols represent the maximum level of application, and empty symbols zero application. Symbols along the top of the graph indicate significance of the main effect on yield, and along the bottom indicate significance of the main effect on tissue concentration. Stars indicate significance and dashes non-significance.

Table 6. Effect (p values) of treatments of frond 17 nutrient concentration. P values < 0.1 are shown in bold.

Source	Leaflet nutrient concentration								Rachis nutrient concentration			
	Ash	N	P	K	Mg	Ca	S	B	Ash	N	P	K
SOA	**0.099**	**<.001**	**<.001**	0.257	**0.001**	**<.001**	**<.001**	0.689	**0.032**	**<.001**	**<.001**	**0.012**
MOP	**0.010**	0.456	0.296	**<.001**	**<.001**	**0.006**	0.642	**<.001**	**<.001**	0.230	**<.001**	**<.001**
SOA.MOP	0.858	0.720	0.710	0.691	0.279	0.899	0.668	0.242	0.704	0.157	**0.053**	0.976
CV %	5.4	2.5	2.1	6.4	6.1	5.2	4.3	11.2	12.3	9.0	16.6	17.4

Table 7. Main effects of treatments of frond 17 nutrient concentration. P values < 0.1 are shown in bold. All units expressed in dry matter %, except B (ppm).

Source	Leaflet nutrient concentration								Rachis nutrient concentration			
	Ash	N	P	K	Mg	Ca	S	B	Ash	N	P	K
SOA0	**10.4**	**2.2**	**0.155**	0.60	**0.40**	**0.83**	**0.18**	10.1	**4.3**	**0.26**	**0.193**	**1.32**
SOA1	**10.6**	**2.4**	**0.157**	0.62	**0.37**	**0.81**	**0.19**	9.9	**4.1**	**0.27**	**0.161**	**1.19**
SOA2	**10.9**	**2.5**	**0.160**	0.62	**0.37**	**0.79**	**0.20**	10.1	**3.8**	**0.28**	**0.123**	**1.07**
SOA3	**10.9**	**2.6**	**0.161**	0.63	**0.37**	**0.77**	**0.21**	10.4	**4.0**	**0.30**	**0.110**	**1.18**
sed	*0.20*	*0.02*	*0.01*	*0.01*	*0.01*	*0.01*	*0.002*	*0.40*	*0.18*	*0.01*	*0.01*	*0.07*
MOP1	**11.1**	2.4	0.158	**0.57**	**0.41**	**0.77**	0.19	**11.6**	**2.9**	0.27	**0.124**	**0.62**
MOP2	**10.7**	2.4	0.159	**0.61**	**0.38**	**0.82**	0.19	**9.9**	**4.1**	0.28	**0.146**	**1.23**
MOP3	**10.6**	2.5	0.159	**0.64**	**0.37**	**0.81**	0.20	**9.4**	**4.6**	0.28	**0.151**	**1.44**
MOP4	**10.4**	2.4	0.157	**0.64**	**0.36**	**0.81**	0.19	**9.7**	**4.7**	0.28	**0.165**	**1.47**
sed	*0.20*	*0.02*	*0.01*	*0.01*	*0.01*	*0.01*	*0.001*	*0.40*	*0.18*	*0.01*	*0.01*	*0.07*
Mean	10.7	2.5	0.158	0.62	0.38	0.80	0.19	10.2	4.1	0.28	0.147	1.19

Fertiliser Effects on vegetative growth parameters in 2005

Table 8 and 9 presents the fertilizer effects on the vegetative growth parameters. The growth parameters also responded well to the fertilizer treatments, especially SOA. The palm height was significantly (p=0.005) increased to over 7.5 m by SOA. Height measurement was not done in 2004 so the height increment could not be calculated. SOA also had a positive and significant effect on the petiole cross section (p=<.001) and the dry frond weight (p=<.001). The dry frond weight was increased to values more than 5 kg with SOA. FDM and VDM also responded significantly (p<.001) to SOA. FDM was increased significantly to over 14 t/ha while VDM also increased to more than 17 t/ha. FDM with zero SOA was significantly lower by 2.9 t/ha than FDM from palms receiving SOA. MOP improved the radiation interception of the palms by significantly increasing the annual frond production (FP), frond area (FA) and leaf area index (LAI). With MOP the palms the annual frond production was more than 21 fronds. FA was increased up to 13.7 m^2 at the highest level of MOP.

CONCLUSION

SOA continued to play a significant role in increasing the productivity of the oil palm as seen from the better FFB yields, higher number of bunches and single bunch weights. MOP also amplified the FFB yields but not to a larger extent as SOA. Though interaction was insignificant, a more economical yield was achieved when applying 4.0 kg of SOA (SOA2) with 2.5 kg of MOP (MOP1). Frond 17 nutrient concentrations also responded significantly to the fertilizer treatments. SOA increased N concentration in the leaflets and the rachis, at the same time having a positive effect on P and S concentration in the leaflets. MOP significantly increased K levels in the leaflets and the rachis, however the overall K concentration in the leaflets was found to be very low (deficient). The treatments also improved the radiation interception and dry matter production of the oil palms.

Table 8. Effect (p values) of treatments on vegetative growth parameters in 2005. p values less than 0.1 are in bold.

Source	Height	Leaf Length	Leaflet Num	PCS	Radiation Interception				Frnd Wt	Dry Matter Production (t/ha)				BI
					GF	FP	FA	LAI		FDM	BDM	TDM	VDM	
SOA	**0.005**	0.381	**<.001**	**<.001**	0.144	**<.001**	0.324	**0.076**	**<.001**	**<.001**	0.202	0.524	**<.001**	**0.004**
MOP	0.627	0.876	0.758	0.115	0.285	**0.057**	**0.012**	**0.027**	0.115	**0.016**	**0.065**	0.215	0.338	**0.011**
SOA.MOP	0.316	0.101	0.580	0.185	0.980	0.264	**0.068**	0.556	0.185	**0.093**	0.494	0.478	0.178	0.545
CV %	2.8	1.7	1.9	4.8	4.1	2.4	3.5	5.0	4.6	5.4	21.0	12.8	5.9	10.1

PCS = Petiole cross-section; GF = number of green fronds; FP = annual frond production; FA = Frond Area; Frnd Wt = Dry frond weight

Table 9. Main effects of treatments on vegetative growth parameters in 2005. Significant effects are shown in bold.

Source	Height (m)	Leaf Length (cm)	Leaflet Num	PCS (cm^2)	Radiation Interception				Frnd Wt (kg)	Dry Matter Production (t/ha)				BI
					GF	FP	FA (m^2)	LAI		FDM	BDM	TDM	VDM	
SOA0	**7.44**	634.2	**194**	**46.7**	32.9	**20.4**	13.35	**5.58**	**4.97**	**12.9**	21.1	37.8	**16.7**	**0.553**
SOA1	**7.53**	638.6	**193**	**49.8**	33.0	**21.1**	13.66	**5.72**	**5.28**	**14.1**	19.1	36.9	**17.8**	**0.509**
SOA2	**7.71**	639.7	**189**	**51.7**	33.5	**21.6**	13.56	**5.77**	**5.48**	**15.0**	20.4	39.3	**18.9**	**0.514**
SOA3	**7.64**	640.3	**189**	**52.1**	33.9	**22.0**	13.57	**5.84**	**5.52**	**15.4**	18.2	37.3	**19.1**	**0.483**
sed	*0.08*	*3.81*	*1.28*	*0.85*	*0.48*	*0.18*	*0.17*	*0.10*	*0.09*	*0.28*	*1.5*	*1.72*	*0.38*	*0.02*
MOP0	7.62	637.7	191	49.0	33.5	**20.9**	**13.27**	**5.65**	5.20	**13.9**	20.9	38.6	17.7	**0.540**
MOP1	7.61	636.9	191	49.9	33.0	**21.3**	**13.40**	**5.61**	5.30	**14.4**	20.2	38.3	18.2	**0.517**
MOP2	7.56	639.9	192	51.1	33.8	**21.4**	**13.78**	**5.91**	5.42	**14.8**	17.2	35.6	18.3	**0.478**
MOP3	7.53	638.3	192	50.2	33.0	**21.3**	**13.69**	**5.74**	5.33	**14.4**	20.5	38.8	18.3	**0.525**
sed	*0.08*	*3.81*	*1.28*	*0.85*	*0.48*	*0.18*	*0.17*	*0.10*	*0.09*	*0.28*	*1.5*	*1.72*	*0.38*	*0.02*
Mean	7.58	638.2	191	50.1	33.3	21.2	13.53	5.73	5.31	14.3	19.5	37.8	18.1	0.515

PCS = Petiole cross-section; GF = number of green fronds; FP = annual frond production; FA = Frond Area; Frnd Wt = Dry frond weight

TRIAL 511. FERTILISER TRIAL ON INTERFLUVE TERRACE SOILS, WAIGANI, ESTATE IN MILNE BAY PROVINCE

SUMMARY

Trial 511 was established on Waigani estate in Milne Bay Province to investigate the response of oil palm to applications of ammonium sulphate (SOA), triple super-phosphate (TSP), muriate of potash (MOP) and empty fruit bunches (EFB) on interfluve terrace soils ("buckshot soils"). The treatments include 4 rates of SOA (0, 2.0, 4.0 & 6.0 kg/palm), 4 rates of MOP (0, 2.5, 5.0 and 7.5 kg/palm), 2 rates of TSP (0, 2.0 kg/palm) and 2 rates of EFB (0, 300 kg/palm).

The effect of the treatments on the FFB yield over the course of the trial was significant especially with SOA, TSP and EFB. Response to MOP for the last 11 years was not very consistent.

The mean FFB yield increased from 20.9 in 2004 to 21.5 t/ha in 2005 (2004 Annual report), a slight increase of about 2.8 %. The number of bunches continued to drop to 925 bunches in 2005 while the single weight increased by 0.7 kg.

SOA significantly increased FFB yields, number of bunches and single bunch weights in 2005. Similarly, SOA also increased the number of bunches, despite the fact that the overall mean number of bunches for the trial continued to drop in 2005. Single bunch weight exhibited a similar trend to FFB and the BNO with an increasing trend with time.

MOP was only significant on the FFB yield and not the number of bunches and the single bunch weights by increasing the yields. Yields from the palms with no MOP were significantly lower than the fertilized palms.

FFB yield and other components also responded positively to TSP and EFB.

Interactions were not significant at this stage.

It is concluded that high rates of SOA and MOP are required to produce greater yields. The results showed that greatest yields were achieved by applying 4 kg of SOA and 5 kg MOP per palm per year.

METHODOLOGY

Trial Background Information

Table 1. Trial 511 background information.

Trial number	511	**Company**	Milne Bay Estates
Estate	Waigani	**Block No.**	Field 8501 & 8502
Date planted*	1988	**Planting Density***	127 palms/ha
Spacing		**Pattern**	Triangular
LSU or MU*	Alluvium, Interfluv	**Soil Type**	Hagita Family (Interfluve terrace soils (buckshot soils).
Recording Started	1994	**Age after planting***	18 years
Topography	Flat	**Planting material**	Dami D x P
Progeny		**Altitude**	56.7 masl
Drainage*	Moderate	**Previous Landuse***	Coconut plantation
Officer in charge	S.Nake	**Area under trial soil type (ha)***	

**Data should be synchronous with OMP.*

Experimental Design and Treatments

There are 64 plots each containing 16-core palms. The numbers and weights of bunches for each individual core palm are recorded at intervals of 14 days. In each plot the core palms are surrounded by a guard row and a trench.

There is a single replicate of 64 plots, arranged in 4 blocks, comprising factorial applications of 4x2x4x2 of N, P, K and EFB treatments. The treatments are made up from all combinations of four levels each of N and K and two levels each of P and EFB (Table 1.102). EFB is applied by hand as mulch between palm circles once per year. Fertilisers are applied in 3 doses per year. The trial started in 1994.

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

Type of Fertiliser or EFB	Levels and 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		

Trial Maintenance and Upkeep

The trial block is maintained by the Waigani Estate workers. This includes activities like ring weeding, herbicide spraying, wheelbarrow path clearance, cover crop maintenance and other routine plantation practices. The trial block is also harvested by the estate workers for yield recording purposes. Fertiliser application to both experimental plots and boundary (perimeter palms) is done by PNGOPRA to avoid accidental application of fertilizers to experimental palms by the estate workers.

Trials are maintained regularly so that treatments effects on yield and other measurements are not compromised. Trenches are also dug around the plots to avoid poaching of treatments between plots.

Data Collection

Yield recording (weighing of bunches) is done on a fortnightly basis (14 days). Recorders walk through the plots along the harvest paths and record the number of bunches harvested and the weight of those bunches. Loose fruits are also collected and weighed with their respective bunches. Bunches from the guard row palms are not weighed. The data is recorded onto the yield record sheets and sent to Popondetta for entering onto our data base system.

Vegetative measurements were carried out in 2005. Vegetative parameters included leaf measurements (total leaf length, leaflet width, leaflet length, total number of leaflets), petiole cross-section width and thickness (PCS WxT). Frond 1 marking and frond count was done twice to determine the annual frond production rate.

Leaf sampling was done in May 2005 to monitor the effect of the treatments on the leaf nutrient concentrations. Leaf samples (8 leaflets) are taken from frond 17 using the standard protocols, processed and then oven dried at 74 °C for 24 hours. After the samples are dried, they are grinded and securely packed into paper bags before dispatched to AAR for analysis. Rachises are dried longer than the leaves (36 hours).

RESULTS & DISCUSSION

Yield and other components response to fertilizer treatments

The treatment effects on the FFB yield and other components are shown in Table 3, 4, 5 and 6. The overall effect of the treatments over the course of the trial is also illustrated in Figure 1. The effect of the treatments SOA, TSP and EFB was consistent over the last 4 to 10 years. For the MOP treatment, the leaf tissue levels responded well compared to the yield.

Ammonium sulphate (SOA) had significant effects ($p<0.001$) on the FFB yield in 2005. This positive response was caused by significant increase in both the number of bunches and the single bunch weights.

Muriate of potash (MOP) significantly ($p=0.035$) increased the FFB yield in 2005. BNO and SBW also responded positively to MOP application though not significant.

The two-way and three-way interactions are shown in Tables 5 and 6 respectively. Interaction between SOA and EFB was significant ($p=0.007$). SOA significantly increased the FFB yield with the presence of EFB. Yield was maximized when applying the highest rate of SOA (6 kg) with EFB.

Fertiliser Effects on Frond 17 nutrient concentrations

The fertilizer effects on the tissue nutrient concentration are shown in Tables 7 and 8. Leaflet levels of N and S were significantly raised to 2.42 and 0.20 % with SOA. K levels were also increased but statistically not significant. Similarly, the N concentration in the rachis was also increased.

K levels in both the leaflets and the rachis were significantly increased with MOP. MOP increased K levels in the leaflets to 0.64 % while at the same time raising the K concentration in the rachis to more than 1.71 %. By contrast, MOP significantly increased N, Ca and S levels in the leaflets but the response, statistically was not significant. By contrast, MOP decreased Mg levels.

TSP effects on leaflet N, P and Ca were both significant and positive in that the levels of these nutrients were increased. Similarly, rachis levels of P were also increased significantly. EFB also significantly increased leaflet levels of N, P, K and S and N and K levels in the rachis.

Regardless of the treatments, mean levels of all the nutrient in the leaflets are within the optimum level except N, K and S levels which falls within the deficient range. The significant and positive effects of SOA and MOP was not strong enough to push these nutrients (N, K and S) in the leaflets to the optimum level. However, at he top rate of SOA, leaflet N was sufficient, and at the top rates of MOP, rachis K was sufficient.

Significant interaction effects were seen on some treatment combinations are as observed in Table 7.

Table 3. Effects (p values) of treatments on FFB yield and its components in 2001-2005 and 2005. p values less than 0.1 are indicated in bold.

	2001-2005			2005		
Source	Yield	BNO	SBW	Yield	BNO	SBW
SOA	**<.001**	**0.001**	**<.001**	**<.001**	**<.001**	**<.001**
MOP	0.122	0.290	0.586	**0.035**	0.131	0.690
TSP	**<.001**	**0.014**	**<.001**	**<.001**	**0.065**	**<.001**
EFB	**<.001**	**<.001**	**<.001**	**<.001**	**<.001**	**<.001**
SOA.MOP	0.536	0.875	0.150	0.255	0.506	0.152
SOA.TSP	0.341	0.651	**0.001**	0.142	0.811	**0.001**
MOP.TSP	0.302	0.410	0.267	0.144	0.132	0.495
SOA.EFB	**0.011**	0.105	**<.001**	**0.007**	**0.025**	**<.001**
MOP.EFB	0.868	0.696	**0.035**	0.895	0.915	**0.048**
TSP.EFB	**0.027**	0.205	**0.003**	**0.047**	0.176	**0.021**
SOA.MOP.TSP	0.737	0.869	0.102	0.180	0.667	**0.080**
SOA.MOP.EFB	0.348	0.683	**0.043**	0.461	0.882	**0.041**
SOA.TSP.EFB	0.627	0.911	0.181	0.963	0.830	0.328
MOP.TSP.EFB	0.621	0.859	0.568	0.230	0.590	0.154
CV %	11.3	12.6	4.5	12.6	14.1	5.0

Table 4. Main effects of treatments on FFB yield and its components in 2001-2005 and 2005. p values less than 0.1 are indicated in bold.

	2001-2005			2005		
Source	Yield	BNO	SBW	Yield	BNO	SBW
SOA0	**15.3**	**805**	**18.6**	**15.1**	**748**	**19.3**
SOA1	**18.5**	**864**	21.4	**19.7**	**882**	**22.3**
SOA2	**22.4**	**974**	**23.1**	**24.3**	**1003**	**24.5**
SOA3	**24.2**	**1038**	**23.5**	**26.9**	**1069**	**25.6**
sed	*0.81*	*40.9*	*0.34*	*0.96*	*46.3*	*0.403*
MOP0	19.0	873	21.6	**20.2**	884	22.8
MOP1	19.8	914	21.4	**20.4**	888	22.7
MOP2	20.7	949	21.5	**23.2**	993	23.0
MOP3	21.0	945	21.9	**22.2**	936	23.2
sed	***0.81***	*40.9*	***0.34***	***0.96***	*46.3*	***0.403***
TSP0	**18.4**	**876**	**20.7**	**19.7**	**891**	**21.7**
TSP1	**21.8**	**964**	**22.6**	**23.3**	**960**	**24.1**
sed	*0.57*	*28.9*	*0.24*	*0.68*	*32.7*	*0.285*
EFB0	**16.1**	**818**	**19.4**	**17.0**	**812**	**20.4**
EFB1	**24.1**	**1022**	**23.9**	**26.0**	**1039**	**25.4**
sed	*0.57*	*28.9*	*0.24*	*0.68*	*32.7*	*0.285*
Grand Mean	20.1	920	21.6	21.5	925	22.9

Table 5. Effect on SOA.EFB interaction (two-way) on FFB yield (t/ha) in 2005. Treatment interaction significant (p=0.007).

	SOA.EFB, lsd = 3.05	
	EFB0	EFB1
SOA0	8.34	21.8
SOA1	14.5	25.0
SOA2	20.7	27.9
SOA3	24.6	29.3

Table 6. Effect on SOA.MOP.EFB interaction (three-way) on FFB yield (t/ha) in 2005. Treatment interaction not significant (p=0.461)

EFB	SOA	MOP			
		0	1	2	3
0	0	7.2	8.5	9.5	8.2
	1	15.5	10.1	16.3	16.1
	2	18.4	18.7	24.7	21.1
	3	20.4	27.7	24.6	25.6
1	0	22.3	20.9	24.4	19.4
	1	24.6	22.9	26.1	26.2
	2	24.5	27.5	30.5	29.2
	3	29.0	26.9	29.1	32.1

CONCLUSION

The fertilizer effects on the FFB yield was very consistent and significant for all the treatments. The FFB yields responded very positively to EFB by supplying additional nutrients to the oil palm to improve and maintain crop as well as vegetative growth. Higher rates of both SOA and MOP is required to increase yields and leaflet tissue levels to levels above the mean FFB yield and deficient level respectively. Therefore the results suggest that yields and tissue levels can be maximized when applying 4.0 kg SOA (SOA2), 5.0 kg MOP (MOP2) and 300 kg of EFB. Sulphur deficiency in the leaflets will be corrected when applying 4.0 kg of SOA.

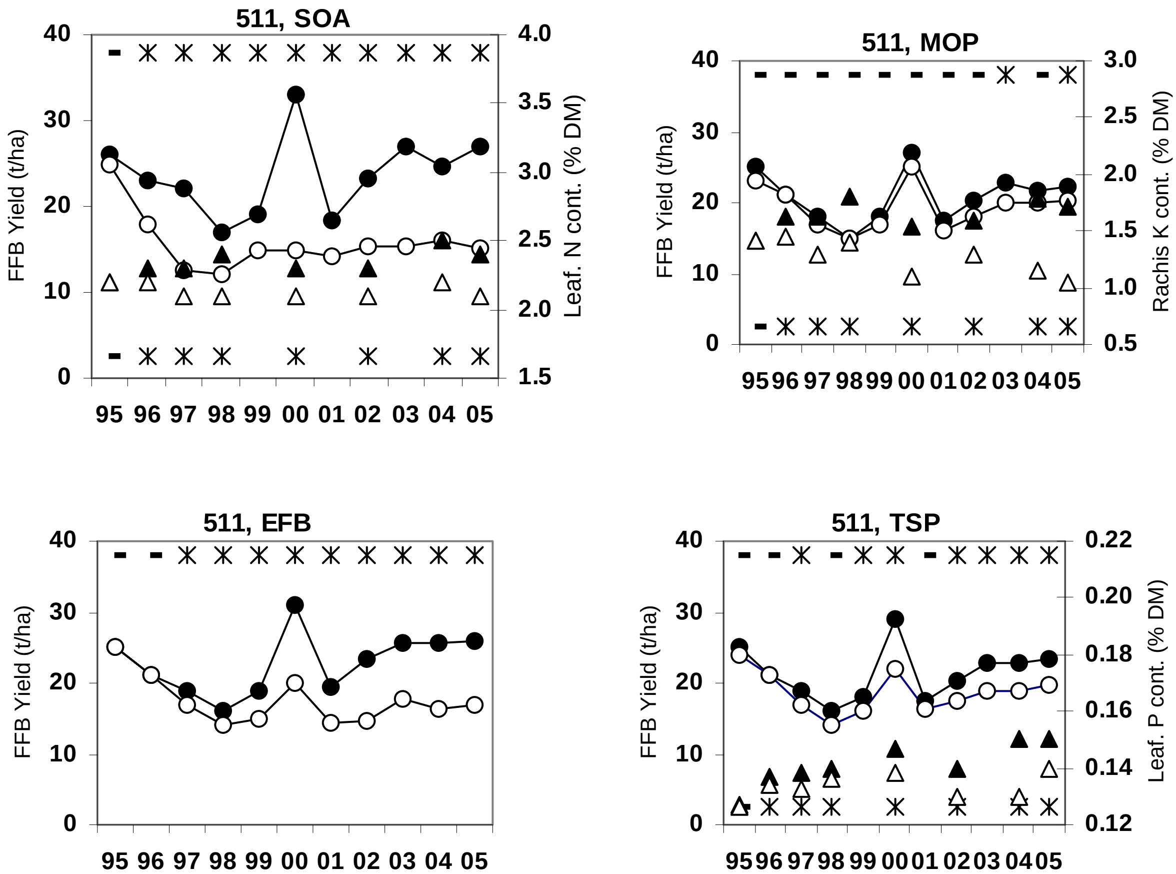


Figure 1. Main effects of SOA, MOP and TSP over the course of Trial 511. Lines are FFB yields and triangles are tissue concentrations. Full symbols represent the maximum level of application, and empty symbols zero application. Symbols along the top of the graph indicate significance of the main effect on yield, and along the bottom indicate significance of the main effect on tissue concentration. Stars indicate significance ($p<0.05$) and dashes non-significance.

Table 7. Effect (p values) of treatments of frond 17 nutrient concentration. P values < 0.1 are shown in bold.

Source	Leaflet nutrient concentration								Rachis nutrient concentration			
	Ash	N	P	K	Mg	Ca	S	B	Ash	N	P	K
SOA	**0.055**	**<.001**	0.380	0.454	**0.048**	**0.060**	**<.001**	0.782	0.225	**0.004**	**<.001**	0.171
MOP	0.202	0.750	0.932	**0.002**	**0.008**	0.393	0.373	0.212	**<.001**	0.743	0.134	**<.001**
TSP	**0.018**	**0.074**	**<.001**	**0.014**	0.696	**0.004**	0.447	0.649	**0.097**	0.561	**<.001**	**0.038**
EFB	**0.002**	**<.001**	**0.003**	**<.001**	**0.002**	0.828	**<.001**	0.388	**0.002**	**0.017**	0.990	**<.001**
SOA.MOP	0.244	0.832	0.999	0.889	0.955	0.711	0.920	0.676	0.691	0.624	0.808	0.176
SOA.TSP	**0.086**	0.571	0.796	0.827	0.498	0.216	0.757	**0.070**	**0.076**	0.534	**<.001**	**0.025**
MOP.TSP	0.742	0.178	0.943	0.588	0.988	0.525	0.586	0.763	**0.049**	0.378	0.576	**0.087**
SOA.EFB	0.191	**0.014**	0.891	0.903	0.630	0.235	0.757	0.115	0.301	0.858	0.303	0.784
MOP.EFB	0.122	0.370	0.961	**<.001**	**0.034**	0.170	0.757	0.497	**0.003**	0.671	0.296	**<.001**
TSP.EFB	0.341	0.884	0.307	0.548	0.883	**0.008**	1.000	0.665	0.260	0.710	**0.014**	0.387
SOA.MOP.TSP	0.558	0.862	0.903	0.583	0.922	0.225	0.916	0.898	0.412	**0.037**	0.469	0.584
SOA.MOP.EFB	0.145	0.435	0.859	0.794	0.646	0.335	0.770	0.907	0.680	0.838	0.937	0.146
SOA.TSP.EFB	0.266	0.308	0.601	0.185	0.809	0.596	0.933	0.349	0.827	0.743	0.360	0.616
MOP.TSP.EFB	0.553	0.727	0.742	0.610	0.769	0.508	0.742	0.169	0.659	0.155	0.340	0.939
CV %	4.6	2.9	4.0	8.2	13.8	6.1	5.1	10.1	9.1	9.0	21.5	10.5

Table 8. Main effects of treatments of frond 17 nutrient concentration. P values < 0.1 are shown in bold. All units expressed in dry matter %, except B (ppm).

Source	Leaflet nutrient concentration								Rachis nutrient concentration			
	Ash	N	P	K	Mg	Ca	S	B	Ash	N	P	K
SOA0	**12.6**	**2.14**	0.143	0.62	**0.39**	0.84	**0.18**	10.9	4.74	**0.24**	**0.138**	1.58
SOA1	**13.1**	**2.21**	0.140	0.60	**0.36**	0.85	**0.18**	10.8	4.79	**0.24**	**0.089**	1.50
SOA2	**12.5**	**2.36**	0.144	0.61	**0.35**	0.82	**0.19**	10.6	4.52	**0.27**	**0.072**	1.46
SOA3	**13.0**	**2.42**	0.144	0.62	**0.34**	0.80	**0.20**	10.6	4.53	**0.28**	**0.059**	1.47
sed	*0.21*	*0.02*	*0.002*	*0.02*	*0.02*	*0.02*	*0.003*	*0.39*	*0.15*	*0.008*	*0.007*	*0.06*
MOP0	12.8	2.27	0.142	**0.55**	**0.41**	0.81	0.18	11.2	**3.78**	0.26	0.081	**1.04**
MOP1	13.1	2.28	0.143	**0.61**	**0.36**	0.84	0.19	10.8	**4.81**	0.25	0.093	**1.59**
MOP2	12.7	2.29	0.144	**0.65**	**0.34**	0.82	0.19	10.5	**4.90**	0.25	0.087	**1.67**
MOP3	12.7	2.29	0.143	**0.64**	**0.33**	0.83	0.19	10.4	**5.09**	0.26	0.098	**1.71**
sed	*0.21*	*0.02*	*0.002*	*0.02*	*0.02*	*0.02*	*0.003*	*0.39*	*0.15*	*0.008*	*0.007*	*0.06*
TSP0	13.0	**2.27**	**0.138**	**0.63**	0.36	**0.80**	0.18	10.9	**4.74**	0.25	**0.046**	**1.55**
TSP1	12.6	**2.30**	**0.147**	**0.59**	0.36	**0.85**	0.18	10.7	**4.55**	0.26	**0.133**	**1.45**
sed	*0.15*	*0.02*	*0.001*	*0.01*	*0.01*	*0.01*	*0.002*	*0.27*	*0.11*	*0.006*	*0.005*	*0.04*
EFB0	13.1	**2.18**	**0.139**	**0.58**	**0.39**	0.82	**0.18**	10.9	**4.42**	**0.24**	0.089	**1.37**
EFB1	12.5	**2.38**	**0.146**	**0.65**	**0.33**	0.83	**0.19**	10.6	**4.87**	**0.26**	0.089	**1.64**
sed	*0.15*	*0.02*	*0.001*	*0.01*	*0.01*	*0.01*	*0.002*	*0.27*	*0.11*	*0.006*	*0.005*	*0.04*
Mean	12.8	2.28	0.143	0.61	0.36	0.83	0.19	10.7	4.65	0.25	0.089	1.50

Trial 512. MONITORING OF POME TREATED BLOCKS

SUMMARY

Results from this study in 2005 have shown that POME has some positive effects on the FFB yield and the tissue concentrations in both the leaflets and the rachis. In 2005, yields from the blocks receiving no POME dropped severely to 16 tonnes/ha while the POME treated blocks maintained their FFB production between 21 -24 tonnes/ha despite the general declining trend seen in both the POME and nil POME blocks. Similarly, leaflet levels of N and P were higher in the POME treated blocks. Rachis K was substantially higher in the POME treated blocks as well. Soils data was not available this year.

INTRODUCTION

Trial 512 was established in Alotau (Milne Bay Estates) to determine the effect of palm oil mill effluent (POME) on oil palm growth and soil properties. The trial commenced in 1995. Three blocks were selected in this study; two of these are currently receiving POME while the third block receives no POME (treated as control). Plantations have been applying POME to some of their field blocks, however there is little knowledge or understanding on the effects (both positive and negative) of this on palm growth, yield, tissue nutrients and soil properties (chemical and physical) under PNG. It is anticipated that the results generated from this study to give some basic understanding on this issue.

METHODOLOGY

Trial Background Information

Table 1. Trial 512 background information.

Trial number	512	Company	Milne Bay Estates
Estate	Hagita/Waigani	Block No.	Refer to table 2.
Date planted*	1996	Planting Density*	143 palms/ha
Spacing		Pattern	Triangular
LSU or MU*		Soil Type	Hagita/Plantation Family
Recording Started	1995/1996	Age after planting*	
Topography	Flat	Planting material	Dami D x P
Progeny		Altitude	
Drainage*	Poor	Previous Landuse*	
Officer in charge	S.Nake	Area under trial soil type (ha)*	

Data should be synchronous with OMP.

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. Block 6306 is treated as the control because it has not received any POME since 1995.

Table 2. Location and treatment of the monitored areas.

Estate	Block	Code	Treatment	Area (ha)
Waigani	6602 & 6603 (86A2)	OP	Receiving POME	58
Hagita	6304 & 6305 (86A3)	NOP	Receiving POME since 1998, but not before	50
Hagita	6306 (86A4)	NP	No POME application	4

Trial Maintenance and Upkeep

Similar to other PNGOPRA trials, Waigani and Hagita estates take charge of the general upkeep of the block, which also includes manure application (including POME) and harvesting. The trial is fertilized on a palm basis with standard fertilizers and rates recommended by MBE.

Data Collection

Originally, yield recording by PNGOPRA workers was only done on Block 6306 which the block that is not receiving the POME. All palms within this block were recorded. Cumulative bunch weight was then calculated for each harvest round and this converted to FFB tonnes per hectare. The other two POME treated blocks (6602 & 6304) are not weighed by PNGOPRA workers but instead weighed by the fruit trucks and the weights then collected from the weigh bridge dockets. Since 2005, the control block (not receiving POME) is also weighed in the fruit trucks.

Leaf tissue samples are also taken from selected palms to investigate effects of the treatments on the leaflets and rachis nutrient concentration.

Pre-Treatment Data

POME is known to have 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 3).

Table 3. 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 the FFB yield over the course of the trial are shown in Table 4 and Figure 1. Regardless of the treatments and the slight peaks and troughs, there was a general decline in the FFB yield over time (Figure 1). From 1996 to 1998, FFB yields from block 6306 where POME was never applied were higher than the other two blocks (6602 & 6304) receiving POME. From 1999 onwards, FFB yields from the POME treated blocks turned out to be higher than the block receiving no POME. In 2005, the FFB yields from all three blocks continued to drop, however the yield in the nil POME block (NP) was much lower (<20 t/ha) compared to the two POME treated blocks. This highlights the positive effect that POME can have on the oil palm yields.

Figures 2 – 4 shows the effects of POME on the tissue nutrient concentration in the leaflets and the rachis. In 2005, there was a marginal difference between the N level in the leaflets (Figure 2). The N levels in the POME treated block were substantially higher than the nil POME block. N leaflet levels dropped from 2.27 % in 2004 to 2.08 % in 2005. The P levels in the leaflets in both blocks dropped in 2005, however despite the declining trend, the leaflet P in the POME treated block was much higher than the nil POME block. The rachis K continued to be at a much higher level in the POME treated block than the nil POME block. In 2005, rachis K in the POME treated block increased substantially by 0.25 % while that in the nil POME block remained at 0.44 %.

Table 4. 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
NP	6306	31.2	30.2	31.3	24.8	25.4	23.6	20.9	21.6	16.6	16.2
OP	6602	24.8	25.9	22.2	23.4	26.2	23.2	26.0	27.0	26.2	24.2
NOP	6304	XX	XX	19.9	23.7	27.2	22.7	25.3	24.7	22.7	21.2

XX = POME not applied

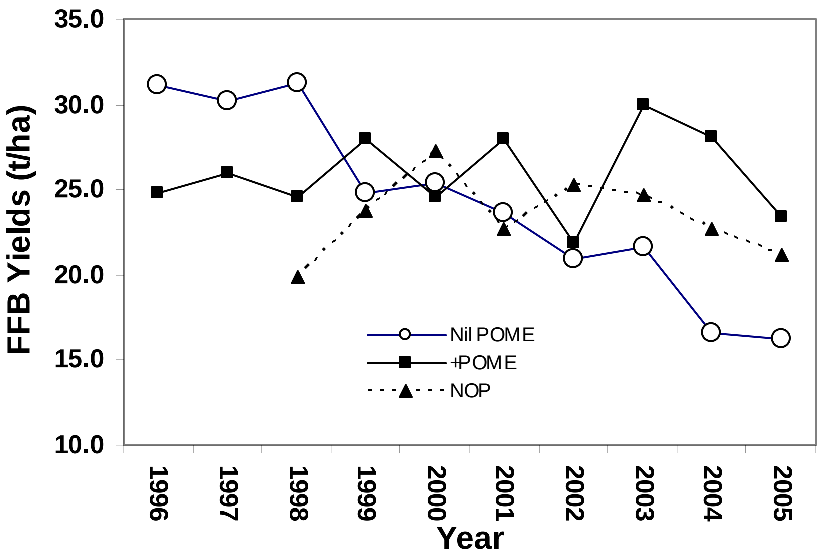


Figure 1: Effect of POME on FFB yield.

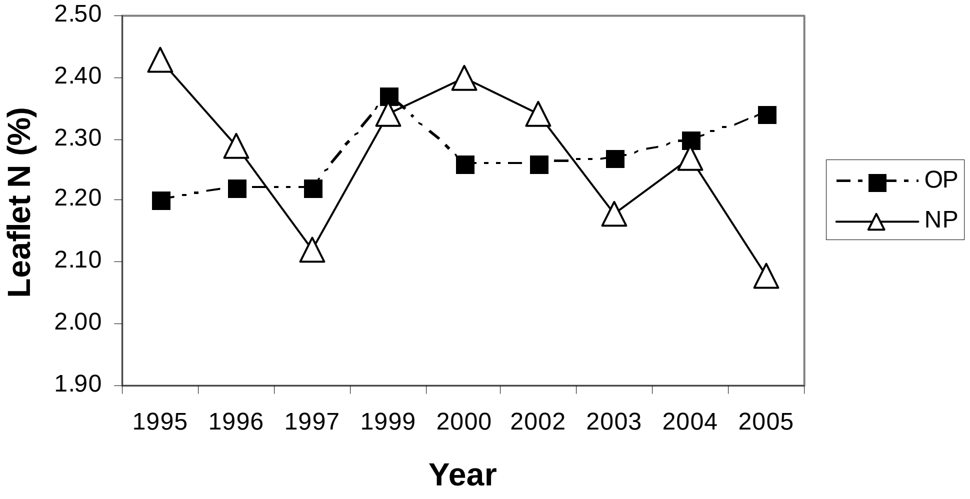


Figure 2: Effect of POME on Leaf N contents.

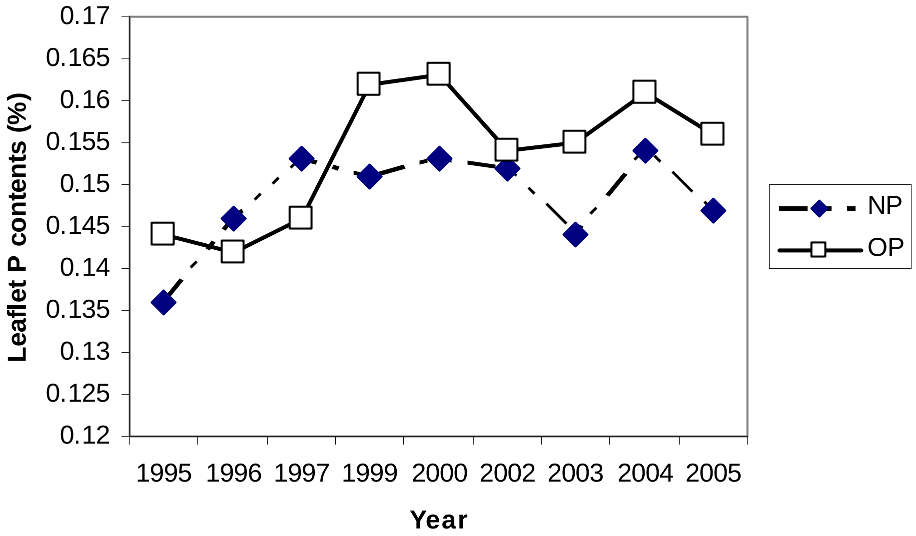


Figure 3: Effect of POME on Leaflet P contents (%)

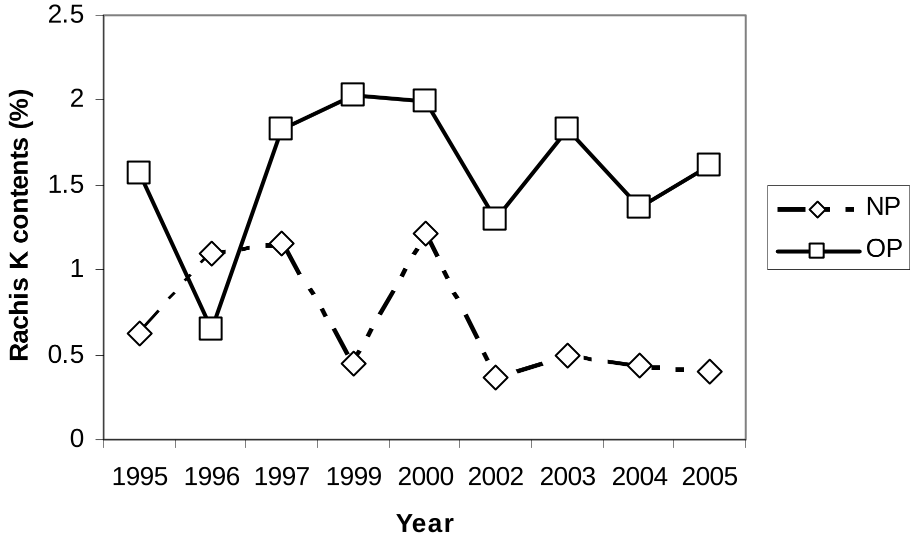


Figure 4: Effect of POME on Rachis K contents (%)

CONCLUSION

The results showed that POME had positive and beneficial effects on both the FFB yield and the tissue nutrient concentrations. With POME, yield was maintained at around 20 t FFB/ha while in the absence of POME, the yield dropped severely to 16 t FFB/ha, which is equivalent to a difference of 4 tonnes. Also with POME, leaflet levels of N and P with rachis K were increased.

FERTILISER RESPONSE TRIALS IN NEW IRELAND PROVINCE (Poliamba Estates)

(James Kraip & Mike Webb)

TRIAL 251 AND 252 FACTORIAL FERTILISER TRIALS AT MARAMAKAS AND LUBURUA PLANTATIONS

PURPOSE

To provide fertiliser response information that will be useful in developing strategies for fertiliser use.

SITE & PALMS

1. Trial 251 site: Fields 2B, 2C, 2D and 3A, Maramakas Plantation.
2. Trial 252 site: Block 4, Luburua Plantation.
3. Soils: Reddish brown clay soil overlying raised coral and showing great variability in depth. The soils are shallow on terrace margins and low ridges and moderately deep in depressions. The soil is freely draining.
4. Topography: Low rises and depressions
5. Palms: Dami commercial DxP crosses Planted in March 1989 (251) and September 1989 (252) at 128 palms/ha.

DESIGN

Treatments started in April 1991 at both sites, and both sites have the same experimental design. There are 36 treatments, comprising all factorial combinations of ammonium sulphate (SOA) and potassium chloride (MOP) each at three levels, and triple superphosphate (TSP) and kieserite (KIE) each at two levels (Table 1). Fertiliser application is split into three applications per year. Each of the 36 plots consists of 36 palms (6x6), of which the central 16 (4x4) are recorded.

Table 1: Rates of fertiliser used in trials 251 and 252.

	Amounts (kg/palm/yr)		
	Level 0	Level 1	Level 2
Ammonium sulphate (SOA)	0	2.5	5.0
Potassium chloride (MOP)	0	2.5	5.0
Triple superphosphate (TSP)	0	2.0	-
Kieserite (KIE)	0	2.0	-

These two trials were originally planned as a single 3x3x2x2 factorial trial with two replicates, but because of restricted availability of land, the two replicates were located on two separate sites and regarded as two trials. However, as the two trials are performing quite differently, the data for the two sites has been analysed separately since 1997. The 4-factor interaction provides the error term in the statistical analysis. Soil depth was measured near each palm, and the mean depth per plot is used as a covariate in the analysis of variance. Minimum, maximum, mean and standard deviation of plot soil depths are 30.7, 66.2, 46.6 and 8.7 cm, respectively for Trial 251, and 16.5, 69.7, 41.2 and 14.8 cm, respectively, for Trial 252.

RESULTS

Yield in Trial 251

MOP continued to be the only fertiliser that significantly influenced FFB yield and its components (Table2 & 3) as it had in many previous years. FFB yield was again almost doubled by the application of 2.5 kg MOP/palm, with 5 kg providing little extra benefit (Table 3). There were no significant interactions between the effects of MOP and the other fertilisers in relation to FFB yield, number of bunches, or SBW (Table 2). There was still no effect of SOA on FFB yield even after 14 years without any addition of N. It is unlikely that the soil is still providing sufficient N; perhaps the cover crop is supplying an adequate amount to maintain yields. The effect of the interaction between SOA and MOP on yield is shown in Table 4. Although there was no significant interaction, there is a suggestion that increasing SOA at the highest level of MOP may result in an increase in FFB yield of approximately 3 t/ha/year; as it has done consistently in previous years.

Similar to its effect on FFB yield, MOP significantly affected leaflet ash, N, P and K, and, rachis ash P, and K concentrations (Tables 5 and 6). The rachis K, which is a good indicator of palm K status was very low with the MOP0 treatment (0.30 %DM) compared to the MOP3 treatment (1.45 %DM) (Table 6). This confirms that K is the major limiting nutrient in this area.

SOA treatment had no significant effect on leaflet N concentrations (Table 5). The N values were close to the adequate range, even with no N fertiliser added (Table 6). This could be a possible explanation for not getting a positive FFB yield response in this trial. Increasing rates of SOA significantly decreased rachis P concentration. The decrease in rachis P is generally attributed to increasing N mobilising P out of the rachis. Leaf nutrient analysis data from a trial with a similar design, PNGOPRA Trial 209 also suggested P mobilisation from rachis to leaflet due to increasing rates of N.

TSP treatment significantly increased rachis P concentrations but not leaflet P concentrations. However, leaflet P concentrations were above the critical value of 0.140% DM, and that could be an explanation for the no FFB yield response due to TSP treatment.

Leaflet Mg concentrations were not affected by KIE treatment, and the Mg values were in the adequate range. This could be a possible explanation for a lack of FFB yield response to TSP treatment.

The effects of fertiliser treatment on physiological growth parameters generally corresponded well to the FFB yield results. MOP significantly increased petiole cross-section (PCS), uncorrected leaf area (ULA), frond weight (FW), frond area (FA), leaf area index (LAI), frond dry matter (FDM), bunch dry matter (BDM), total dry matter (TDM), vegetative dry matter (VDM) and bunch index (BI) (Table 12). SOA only increased PCS, ULA, FW, FA, LAI and VDM, while TSP and KIE had no significant effect on the physiological growth parameters.

The main effects of the treatments on yield and tissue contents over the course of the trial are shown in Figure 1. The effect of MOP has increased through time and there has been no significant effect of SOA, TSP or KIE throughout the life of the trial.

Yield in Trial 252

MOP significantly increased FFB yield and its components (Tables 7 & 8). TSP also had a significant effect in 2003, there was no effect in 2004 and 2005. SOA only increased FFB yield during the combined 2003-2005 period. There was no significant interaction (Table 7). However, as shown in Tables 9, increasing SOA at the highest level of MOP may result in an increase in FFB yield. Adding SOA at the highest rates of MOP has consistently, over a number of years, resulted in increases in FFB yield.

MOP also had a significant effect on leaflet ash, N, P, K, Mg and S, and, rachis ash and K concentrations (Tables 10 and 11). This has translated into significant FFB yield increases over the course of the trial. SOA, TSP and KIE generally had no significant effect on most of the nutrients except rachis P, which was significantly increased by TSP treatment. Data on leaflet Mg (Table 6 and 11) has shown that increasing rates of MOP significantly decreased leaflet Mg levels. This suggests an antagonistic effect, where a high supply of K suppresses Mg uptake by oil palm roots.

Physiological growth parameters generally corresponded well to the FFB yield results. MOP significantly increased PCS, ULA, FW, FA, LAI, BDM, TDM, VDM and BI (Table 13). SOA increased BDM but statistically this was not significant, while TSP and KIE had no effect on the physiological growth parameters

The main effects of the treatments on yield and tissue contents over the course of the trial are shown in Figure 1. The large effect of MOP has increased through time. SOA had started to have an effect in the last few years, but this has diminished in the most recent but tended to increase again in 2005.

Relationship between fertiliser treatments and incidence of Ganoderma (251 & 252)

The relationship between fertiliser treatment and incidence of *Ganoderma* was reported in the 2000 Annual Report using recently collected data from the 2003 Census. Another census will be done at the beginning of 2006 and this relationship will be reanalysed and updated in that report.

Plans for the trial

Yield recording had stopped at the end of 2002, but recommenced in September 2003, and continued through 2004 and 2005. When the results of nutrient analysis on soil, trunk and bunches are available, that nutrient budgets can be estimated. At the start of 2006, the entire trial will be felled for a detailed assessment of *Ganoderma* infection of trunks. These results will be analysed in relation to fertiliser treatments and trunk, leaf, and rachis nutrient concentrations.

CONCLUSION

The effects of fertilisers on yield in these trials were similar in 2005 to previous years. MOP had a significant effect on yield in both trials. SOA has had no effect in Trial 251 but has had an increasing effect in Trial 252 although this has diminished in recent years but tended to continue in 2005.

In spite of the lack of significant responses to SOA, it has, over the last few years consistently increased yield when MOP is supplied at the higher rates; suggesting that it is important for the longer term maintenance of productivity.

MOP had large effects on some leaf nutrients and physiological growth parameters in this trial.

Table 2: Effects (p values) of treatments and the soil depth covariate on FFB yield and its components in 2003-2005 and 2005 (Trial 251). p values <0.1 are indicated in bold.

	2003-2005			2005		
Source	Yield	BNo	SBW.	Yield	BNo	SBW.
SOA	0.546	0.386	0.424	0.676	0.272	0.362
MOP	**0.006**	**0.009**	**0.005**	**0.009**	**0.015**	**0.005**
TSP	0.292	0.472	0.364	0.295	0.225	0.477
KIE	0.583	0.488	0.837	0.741	0.753	0.855
SOA.MOP	0.451	0.576	0.240	0.188	0.063	0.247
SOA.TSP	0.403	0.103	0.961	0.202	0.036	0.806
MOP.TSP	0.927	0.714	0.620	0.521	0.343	0.472
SOA.KIE	0.564	0.768	0.422	0.461	0.525	0.616
MOP.KIE	0.966	0.729	0.584	0.728	0.338	0.524
TSP.KIE	0.476	0.350	0.716	0.551	0.666	0.607
SOA.MOP.TSP	0.461	0.262	0.496	0.253	0.093	0.745
SOA.MOP.KIE	0.919	0.930	0.738	0.684	0.353	0.865
SOA.TSP.KIE	0.753	0.727	0.705	0.574	0.344	0.997
MOP.TSP.KIE	0.950	0.787	0.641	0.687	0.448	0.958
Covariate	0.920	0.771	0.402	0.849	0.752	0.908
CV %	15.6	10.1	8.1	18.6	12.2	10.1

Table 3: Main effects of treatments on FFB yield (t/ha) and its components (Trial 251). Effects with p<0.1 are shown in bold.

	2003-2005			2005		
	Yield (t/ha/yr)	No Bun (/ha)	SBW. (kg)	Yield (t/ha/yr)	No Bun (/ha)	SBW. (kg)
SOA0	24.1	1198	20.3	22.3	939	23.7
SOA1	23.6	1151	20.0	22.8	960	22.4
SOA2	25.7	1235	21.2	24.3	1047	23.9
s.e.d.	*1.58*	*50*	*0.68*	*1.78*	*50*	*0.98*
MOP0	**15.8**	**956**	**16.2**	**14.3**	**769**	**17.7**
MOP1	**28.1**	**1304**	**22.2**	**26.7**	**1066**	**25.8**
MOP2	**29.5**	**1324**	**23.1**	**28.4**	**1112**	**26.5**
s.e.d.	*1.79*	*57*	*0.77*	*2.01*	*56*	*1.11*
TSP0	25.4	1213	20.9	24.1	1018	23.7
TSP1	23.5	1176	20.1	22.1	946	23.0
s.e.d.	*1.32*	*42*	*0.57*	*1.49*	*42*	*0.82*
KIE0	24.4	1184	20.8	23.7	1004	23.5
KIE1	24.5	1205	20.3	22.6	960	23.1
s.e.d.	*1.66*	*53*	*0.72*	*1.87*	*52*	*1.03*
GM	*24.5*	*1195*	*20.5*	*23.1*	*982*	*23.3*

Table 4: Effect of the interaction between SOA and MOP on FFB yield (t/ha) in 2003-2005 and 2005 (Trial 251). Yields >26 t/ha are highlighted in bold.

2003-2005, p=0.451				2005, p=0.188			
	MOP0	MOP1	MOP2		MOP0	MOP1	MOP2
SOA0	17.7	**26.2**	**28.3**	SOA0	16.1	23.0	**27.9**
SOA1	11.8	**30.1**	**29.0**	SOA1	8.6	**29.8**	**30.1**
SOA2	17.8	**27.9**	**31.2**	SOA2	18.2	**27.3**	**27.3**

Table 5: Effects (p values) of treatments and the soil depth covariate on F17 nutrient concentrations 2005 (Trial 251). p values <0.1 are indicated in bold.

	Leaflet							Rachis			
Source	Ash	N	P	K	Mg	S	Cl	Ash	N	P	K
SOA	0.293	0.477	0.516	**0.016**	0.608	0.582	0.877	0.225	0.755	**0.030**	0.388
MOP	**0.037**	**0.026**	**0.046**	**<0.001**	**0.005**	0.213	0.753	**0.006**	0.505	**0.037**	**0.004**
TSP	0.807	0.879	0.254	0.214	0.648	0.826	0.561	0.405	0.909	**0.014**	0.598
KIE	0.666	0.787	0.964	**0.012**	0.087	0.704	0.435	**0.039**	0.305	0.419	0.332
SOA.MOP	0.710	0.592	0.498	0.140	0.772	0.981	0.688	0.258	0.924	0.285	0.590
SOA.TSP	0.702	0.936	0.985	0.382	0.941	0.680	0.524	0.202	0.487	**0.044**	0.564
MOP.TSP	0.919	0.607	0.636	0.232	0.761	0.922	0.555	0.208	0.828	0.758	0.734
SOA.KIE	0.986	0.987	0.955	0.917	1.000	0.724	0.626	0.065	0.926	0.643	0.475
MOP.KIE	0.537	0.805	0.700	0.776	0.465	0.538	0.733	0.258	0.433	0.732	0.677
TSP.KIE	0.735	0.994	0.883	0.755	0.426	0.493	0.914	0.269	0.695	0.712	0.954
SOA.MOP.TSP	0.666	0.954	0.920	0.144	0.987	0.836	0.740	0.178	0.730	0.402	0.555
SOA.MOP.KIE	0.974	0.878	0.643	0.397	0.949	0.661	0.651	0.061	0.843	0.550	0.661
SOA.TSP.KIE	0.393	0.809	0.516	0.388	0.852	0.738	0.640	0.051	0.727	0.702	0.426
MOP.TSP.KIE	0.813	0.736	0.757	0.151	0.819	0.763	0.848	0.515	0.603	0.605	0.615
Covariate	0.258	0.401	0.279	0.456	0.779	0.626	0.995	**0.047**	0.923	0.416	0.807
CV %	8.4	5.9	4.2	4.0	16.0	8.8	14.3	9.6	13.2	17.3	28.6

Table 6: Main effects of treatments and the soil depth covariate on F17 nutrient concentrations 2005 (Trial 251). p values <0.1 are indicated in bold.

	Leaflet							Rachis			
Source	Ash	N	P	K	Mg	S	Cl	Ash	N	P	K
SOA0	6.5	2.42	0.151	**0.602**	0.387	0.197	0.640	4.05	0.335	**0.157**	1.01
SOA1	6.7	2.40	0.148	**0.543**	0.411	0.202	0.644	3.70	0.345	**0.120**	0.84
SOA2	6.8	2.48	0.151	**0.562**	0.387	0.205	0.658	3.96	0.331	**0.109**	0.92
s.e.d.	*0.2*	*0.06*	*0.003*	*0.010*	*0.03*	*0.007*	*0.04*	*0.16*	*0.018*	*0.009*	*0.11*
MOP0	**7.4**	**2.25**	**0.144**	**0.347**	**0.550**	0.195	0.665	**3.31**	0.352	**0.109**	**0.30**
MOP1	**6.4**	**2.55**	**0.154**	**0.665**	**0.326**	0.211	0.635	**4.05**	0.330	**0.135**	**1.02**
MOP2	**6.1**	**2.49**	**0.151**	**0.695**	**0.308**	0.198	0.643	**4.34**	0.329	**0.143**	**1.45**
s.e.d.	*0.3*	*0.07*	*0.003*	*0.011*	*0.03*	*0.008*	*0.04*	*0.18*	*0.021*	*0.10*	*0.12*
TSP0	6.6	2.43	0.148	0.575	0.400	0.201	0.637	3.90	0.336	**0.108**	0.89
TSP1	6.7	2.43	0.152	0.563	0.390	0.202	0.658	3.90	0.338	**0.149**	0.95
s.e.d.	*0.2*	*0.05*	*0.002*	*0.010*	*0.02*	*0.006*	*0.03*	*0.13*	*0.015*	*0.008*	*0.09*
KIE0	6.6	2.43	0.150	**0.590**	0.368	0.203	0.661	**3.93**	0.345	0.121	0.97
KIE1	6.7	2.43	0.151	**0.548**	0.421	0.200	0.634	**3.88**	0.329	0.136	0.88
s.e.d.	*0.3*	*0.06*	*0.003*	*0.010*	*0.03*	*0.008*	*0.04*	*0.16*	*0.019*	*0.010*	*0.12*
GM	*6.7*	*2.43*	*0.150*	*0.569*	*0.395*	*0.201*	*0.647*	*3.90*	*0.337*	*0.129*	*0.92*

Table 7: Effects (p values) of treatments and the soil depth covariate on FFB yield and its components in 2003-2005 and 2005 (Trial 252). p values <0.05 are indicated in bold.

	2003-2005			2005		
Source	Yield	BNo	SBW.	Yield	BNo	SBW.
SOA	**0.046**	0.081	0.254	0.057	0.130	0.396
MOP	**<0.001**	**0.002**	**0.003**	**0.003**	**0.012**	**0.013**
TSP	0.330	0.708	0.229	0.376	0.301	0.746
KIE	0.378	0.865	0.324	0.328	0.541	0.625
SOA.MOP	0.295	0.334	0.517	0.546	0.672	0.944
SOA.TSP	0.496	0.579	0.739	0.558	0.512	0.980
MOP.TSP	0.120	0.211	0.230	0.331	0.405	0.581
SOA.KIE	0.294	0.214	0.571	0.428	0.355	0.688
MOP.KIE	0.307	0.332	0.301	0.369	0.497	0.800
TSP.KIE	0.628	0.946	0.218	0.690	0.894	0.361
SOA.MOP.TSP	0.601	0.605	0.483	0.643	0.671	0.907
SOA.MOP.KIE	0.254	0.157	0.341	0.473	0.613	0.671
SOA.TSP.KIE	0.900	0.977	0.536	0.271	0.300	0.633
MOP.TSP.KIE	0.951	0.913	0.813	0.843	0.940	0.907
Covariate	0.101	0.212	0.230	0.339	0.397	0.638
CV %	9.7	9.2	7.4	15.6	18	14.9

Table 8: Main effects of treatments on FFB yield (t/ha) and its components (Trial 252). Effects with p<0.05 are shown in bold.

	2003-2005			2005		
	Yield (t/ha/yr)	No Bun (/ha)	SBW. (kg)	Yield (t/ha/yr)	No Bun (/ha)	SBW. (kg)
SOA0	**21.5**	1120	18.9	21.3	924	21.5
SOA1	**25.8**	1288	20.2	26.5	1118	23.4
SOA2	**25.6**	1249	20.2	28.2	1156	23.8
s.e.d.	*1.61*	*66*	*0.61*	*1.66*	*81*	*0.49*
MOP0	**14.0**	**871**	**15.7**	**13.6**	**724**	**17.1**
MOP1	**28.6**	**1378**	**21.4**	**29.4**	**1182**	**25.2**
MOP2	**30.3**	**1408**	**22.2**	**33.1**	**1293**	**26.4**
s.e.d.	*1.61*	*66*	*0.67*	*1.81*	*88*	*0.49*
TSP0	23.9	1212	19.4	24.7	1027	22.7
TSP1	24.7	1226	20.1	26.0	1107	23.1
s.e.d.	*1.31*	*54*	*0.49*	*1.33*	*64*	*0.40*
KIE0	23.9	1215	19.5	24.6	1043	22.6
KIE1	24.7	1223	20.1	26.1	1089	23.2
s.e.d.	*1.31*	*54*	*0.49*	*1.33*	*65*	*0.40*
GM	24.3	1219	19.8	25.4	1066	22.9

Table 9: Effect of the interaction between SOA and MOP on FFB yield (t/ha) in 2003-2005 and 2005 (Trial 252). Yields >26 t/ha are highlighted in bold.

	2003-2005, p=0.295				2005, p=0.546		
	MOP0	MOP1	MOP2		MOP0	MOP1	MOP2
SOA0	11.8	25.8	**26.9**	SOA0	10.2	**26.1**	**27.6**
SOA1	16.4	**30.0**	**32.0**	SOA1	15.4	**28.6**	**35.6**
SOA2	13.9	**30.9**	**32.0**	SOA2	15.2	**33.2**	**36.3**

Table 10: Effects (p values) of treatments and the soil depth covariate on F17 nutrient concentrations 2005 (Trial 252). p values <0.05 are indicated in bold.

	Leaflet							Rachis			
Source	Ash	N	P	K	Mg	S	Cl	Ash	N	P	K
SOA	0.949	0.209	0.735	0.814	0.465	0.285	0.632	0.235	0.424	0.072	0.151
MOP	**0.002**	**0.013**	**0.023**	**0.006**	**0.004**	**0.021**	0.350	**0.030**	0.061	0.099	**0.003**
TSP	0.339	0.747	0.106	0.898	0.723	0.336	0.942	0.411	0.951	**0.018**	0.941
KIE	0.221	0.565	0.850	0.877	0.113	0.728	0.934	0.348	0.855	0.474	0.923
SOA.MOP	0.522	0.659	0.761	0.929	0.966	0.660	0.641	0.663	0.667	0.296	0.493
SOA.TSP	0.369	0.380	0.635	0.889	0.535	0.461	0.553	0.934	0.976	0.987	0.739
MOP.TSP	0.361	0.858	0.911	0.610	0.866	0.638	0.555	0.845	0.862	0.383	0.859
SOA.KIE	0.073	0.268	0.156	0.576	0.294	0.189	0.415	0.880	0.942	0.904	0.995
MOP.KIE	0.214	0.379	0.478	0.929	0.915	0.052	0.500	0.458	0.717	0.304	0.698
TSP.KIE	0.163	0.877	0.513	0.681	0.385	0.413	0.659	0.854	0.809	0.793	0.986
SOA.MOP.TSP	0.381	0.377	0.709	0.948	0.425	0.188	0.710	0.1515	0.939	0.384	0.623
SOA.MOP.KIE	0.234	0.911	0.908	0.906	0.941	0.594	0.391	0.844	0.736	0.662	0.830
SOA.TSP.KIE	0.930	0.199	0.173	0.598	0.691	0.104	0.221	0.418	0.588	0.416	0.633
MOP.TSP.KIE	0.520	0.749	0.763	0.975	0.411	0.928	0.317	0.858	0.765	0.663	0.819
Covariate	0.817	0.654	0.889	0.895	0.282	0.216	0.427	0.289	0.977	0.349	0.417
CV %	4.6	3.9	3.2	17.7	17.7	3.2	9.4	14.5	14.8	17.7	26.1

Table 11: Main effects of treatments and the soil depth covariate on F17 nutrient concentrations 2005 (Trial 252). p values <0.05 are indicated in bold.

	Leaflet							Rachis			
Source	Ash	N	P	K	Mg	S	Cl	Ash	N	P	K
SOA0	6.3	2.41	0.151	0.582	0.389	0.200	0.602	4.28	0.323	0.158	1.12
SOA1	6.3	2.49	0.152	0.571	0.370	0.205	0.621	3.94	0.344	0.124	0.96
SOA2	6.4	2.48	0.152	0.562	0.356	0.204	0.615	3.78	0.352	0.125	0.85
s.e.d.	*0.12*	*0.04*	*0.002*	*0.042*	*0.028*	*0.003*	*0.024*	*0.25*	*0.018*	*0.010*	*0.11*
MOP0	**7.3**	**2.30**	**0.145**	**0.350**	**0.535**	**0.194**	0.642	**3.35**	0.389	0.127	**0.30**
MOP1	**5.9**	**2.53**	**0.155**	**0.665**	**0.292**	**0.207**	0.599	**4.06**	0.310	0.128	**1.15**
MOP2	**5.9**	**2.55**	**0.154**	**0.701**	**0.289**	**0.210**	0.598	**4.59**	0.321	0.152	**1.47**
s.e.d.	*0.13*	*0.04*	*0.002*	*0.046*	*0.030*	*0.003*	*0.026*	*0.27*	*0.021*	*0.011*	*0.12*
TSP0	6.3	2.45	0.150	0.569	0.378	0.205	0.611	3.90	0.339	**0.116**	0.97
TSP1	6.4	2.47	0.153	0.574	0.366	0.202	0.614	4.09	0.341	**0.155**	0.98
s.e.d.	*0.10*	*0.03*	*0.002*	*0.034*	*0.022*	*0.002*	*0.019*	*0.20*	*0.015*	*0.008*	*0.09*
KIE0	6.4	2.45	0.151	0.575	0.346	0.204	0.613	4.11	0.342	0.139	0.97
KIE1	6.3	2.47	0.152	0.569	0.398	0.203	0.613	3.89	0.338	0.132	0.98
s.e.d.	*0.10*	*0.03*	*0.002*	*0.034*	*0.022*	*0.002*	*0.019*	*0.20*	*0.019*	*0.008*	*0.09*
GM	*6.4*	*2.46*	*0.151*	*0.572*	*0.372*	*0.203*	*0.613*	*4.0*	*0.340*	*0.136*	*0.97*

Table 12: Effects of fertiliser treatments on physiological growth parameters in 2005 (Trial 251)

	Radiation Interception					Dry matter production (t/ha)				Conversion
Treatment	PCS (cm^2)	ULA (m^2)	FW (kg)	FA (m^2)	LAI	FDM	BDM	TDM	VDM	BI
SOA 0	**36.5**	**10.8**	**3.93**	**6.15**	**2.37**	**12.7**	11.8	27.3	**15.4**	0.429
SOA 1	**35.0**	**9.4**	**3.77**	**5.37**	**2.09**	**12.3**	121	27.1	**15.0**	0.416
SOA 2	**38.9**	**11.2**	**4.18**	**6.40**	**2.46**	**12.3**	12.9	29.0	**16.2**	0.439
p	***0.002***	***0.047***	***0.002***	***0.047***	***0.030***	***0.035***	*0.676*	*0.327*	***0.042***	*0.641*
s.e.d.	*0.3*	*0.4*	*0.03*	*0.24*	*0.07*	*0.20*	*0.9*	*1.1*	*0.3*	*0.020*
$Lsd_{0.05}$	*1.0*	*1.4*	*0.10*	*0.77*	*0.13*	*0.64*			*0.8*	
MOP 0	**30.5**	**9.3**	**3.32**	**5.28**	**2.02**	**10.5**	**7.6**	**20.1**	**12.5**	**0.363**
MOP 1	**39.8**	**11.5**	**426**	**6.53**	**2.50**	**13.8**	**14.1**	**31.0**	**16.9**	**0.456**
MOP 2	**40.2**	**10.7**	**4.30**	**6.12**	**2.40**	**14.0**	**15.1**	**32.3**	**17.2**	**0.464**
p	***<0.001***	***0.031***	***<0.001***	***0.031***	***0.017***	***<0.001***	***0.009***	***0.003***	***<0.001***	***0.036***
s.e.d.	*0.4*	*0.5*	*0.04*	*0.27*	*0.08*	*0.23*	*1.1*	*0.2*	*0.3*	***0.023***
$Lsd_{0.05}$	*1.2*	*1.5*	*0.12*	*0.87*	*0.13*	*0.72*	*3.4*	*3.9*	*0.9*	***0.073***
TSP 0	**36.2**	103	**3.90**	5.85	2.26	12.7	12.8	28.3	15.5	0.446
TSP 1	**37.4**	10.7	**4.02**	6.10	2.35	12.8	11.7	27.3	15.5	0.409
p	***0.030***	*0.278*	***0.030***	*0.278*	*0.158*	*0.487*	*0.295*	*0.370*	*0.875*	*0.137*
s.e.d.	*0.3*	*0.4*	*0.03*	*0.20*	*0.06*	*0.17*	*0.8*	*0.9*	*0.2*	*0.017*
$Lsd_{0.05}$	*0.9*		*0.9*							
KIE 0	36.4	10.8	3.90	6.14	2.38	12.8	12.6	28.2	15.6	0.432
KIE 1	37.2	10.2	4.00	5.81	2.23	12.7	12.0	27.4	15.4	0.423
p	*0.438*	*0.224*	*0.438*	*0.224*	*0.130*	*0.327*	*0.741*	*0.599*	*0.327*	*0.905*
s.e.d.	*0.3*	*0.5*	*0.03*	*0.26*	*0.08*	*0.21*	*1.0*	*1.2*	*0.3*	*0.021*
$Lsd_{0.05}$										
CV%	*2.1*	*9.8*	*2.0*	*9.8*		*3.8*	*18.6*	*9.5*	*4.0*	*11.5*
GM	*36.8*	*10.5*	*3.96*	*5.97*	*2.31*	*12.7*	*12.3*	*27.8*	*15.5*	*0.428*

Table 13: Effects of fertiliser treatments on physiological growth parameters in 2005 (Trial 252)

	Radiation Interception					Dry matter production (t/ha)				Conversion
Treatment	PCS (cm^2)	ULA (m^2)	FW (kg)	FA (m^2)	LAI	FDM	BDM	TDM	VDM	BI
SOA 0	34.0	10.8	3.67	6.18	2.48	12.3	11.5	26.4	15.0	0.402
SOA 1	38.5	11.1	4.13	6.35	2.52	14.0	14.1	31.2	17.1	0.444
SOA 2	37.4	11.0	4.02	6.25	2.49	13.3	14.8	31.2	16.4	0.453
p	*0.221*	*0.906*	*0.221*	*0.906*	*0.846*	*0.273*	*0.057*	*0.075*	*0.219*	*0.377*
s.e.d.	*2.2*	*0.66*	*0.23*	*0.38*	*0.17*	*0.9*	*0.9*	*1.7*	*1.0*	*0.034*
$Lsd_{0.05}$							*2.5*			
MOP 0	**31.2**	**8.7**	**3.39**	**4.94**	**1.95**	11.4	**7.5**	**21.0**	**13.5**	**0.335**
MOP 1	**39.3**	**11.8**	**4.21**	**6.72**	**2.64**	14.1	**15.6**	**33.0**	**17.4**	**0.472**
MO 2	**39.5**	**12.5**	**4.23**	**7.11**	**2.84**	14.2	**17.2**	**34.9**	**17.7**	**0.492**
p	***0.033***	***0.009***	***0.033***	***0.009***	***0.014***	*0.056*	***<0.001***	***0.002***	***0.027***	***0.019***
s.e.d.	*2.2*	*0.66*	*0.23*	*0.38*	*0.17*	*0.9*	*0.9*	*1.7*	*1.0*	*0.034*
$Lsd_{0.05}$	*6.2*	*1.84*	*0.63*	*1.05*	*0.47*		*2.5*	*4.7*	*2.9*	*0.095*
TSP 0	35.4	10.7	3.82	6.11	2.42	12.9	13.0	28.8	15.8	0.424
TSP 2	37.9	11.2	4.07	6.41	2.53	13.6	13.8	30.5	16.6	0.442
p	*0.244*	*0.387*	*0.244*	*0.387*	*0.463*	*0.383*	*0.330*	*0.296*	*0.360*	*0.548*
s.e.d.	*1.8*	*0.54*	*0.19*	*0.31*	*0.14*	*0.7*	*0.7*	*1.4*	*0.9*	*0.028*
$Lsd_{0.05}$										
KIE 0	36.2	10.9	3.90	6.23	2.45	13.1	13.1	29.0	16.0	0.428
KIE 4	37.1	11.0	4.00	6.29	2.50	13.4	13.8	30.2	16.4	0.438
p	*0.646*	*0.848*	*0.646*	*0.848*	*0.752*	*0.677*	*0.373*	*0.450*	*0.630*	*0.754*
s.e.d.	*1.8*	*0.54*	*0.19*	*0.31*	*0.14*	*0.7*	*0.7*	*1.4*	*0.9*	*0.028*
$Lsd_{0.05}$										
CV%	*14.8*	*14.8*	*14.1*	*14.8*	*16.8*	*16.4*	*16.1*	*14.1*	*15.7*	*19.4*
GM	*36.6*	*11.0*	*3.94*	*6.26*	*2.48*	*13.2*	*13.4*	*29.6*	*16.2*	*0.433*

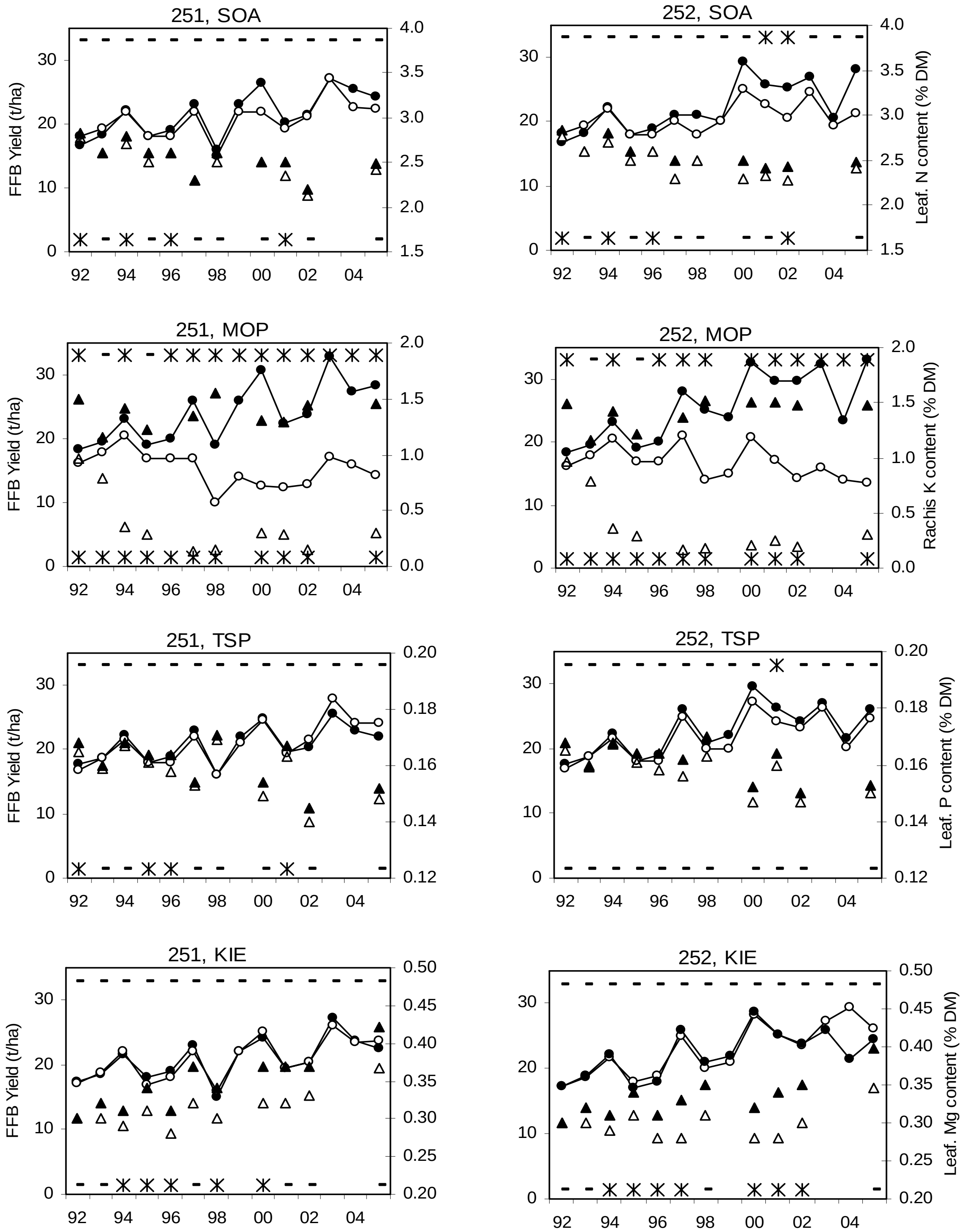


Figure 1: Main effects of SOA, MOP, TSP and KIE for Trials 251 and 252. Lines with circles, FFB yields; triangles, tissue concentrations; full symbols, maximum level of application; open symbols, zero application. Symbols along the top indicate significance of the main effect on yield, and along the bottom indicate significance of the main effect on tissue concentration. Stars indicate significance ($p<0.05$) and dashes non-significance.

TRIAL 254 BORON TRIAL AT POLIAMBA

PURPOSE

To provide information that will help make recommendations for B fertiliser use at Poliamba. Specifically, to test response to Ca borate or Na borate at several rates, and secondarily, to test the interaction of B source and rate with adequate and high applications of the major deficient nutrient, K.

SITE and PALMS

Site: Maramakas Plantation, Nalik Estates, Division 2, Blocks 1, 2 and 3

Soils: Reddish brown clay soil overlying raised coral and showing great variability in depth. The soils are shallow on terrace margins and low ridges and moderately deep in depressions. The soil is generally freely draining except in depressions where soils can remain wet below 50 cm depth.

Topography: Gently undulating, depressions or sink holes. Back swamp at the edge of block 3.

Land use prior to this crop: Coconut plantation, and virgin forest on inland blocks

Palms: Dami commercial DxP crosses, planted in 1989 at 128 palms/ha

BACKGROUND

Boron has been a matter of concern at Poliamba right from the beginning, largely based on foliar symptoms. The need for a trial was discussed at Scientific Advisory Committee meetings from 1998-2001. In addition to foliar deficiency symptoms, there has also been suppression in leaf B levels upon K addition. Levels at around 12 ppm in frond 17 are generally considered to be marginal, and as frond 17 is not particularly sensitive would speculate that the depression in younger fronds may be even greater. There is also concern about oil extraction rate, which has dropped in recent years.

DESIGN

Boron will be applied as factorial of two sources (Ca borate, Na borate) at three rates (0, 1 and 2 kg B/ha/year [= 0.08 and 0.16 kg borate / palm/yr]), and muriate of potash applied at two levels (2.5, 7.5 kg MOP/palm/year). ie. 2 B sources x 3 B rates x 2 MOP rates, with 4 replicates = 48 plots. The trial layout will be a completely randomized design, with pre-treatment measurements or other measurements used as covariates if necessary.

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

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

Basal fertilizers added to all plots

TSP: 1 kg / palm

KIE: 1 kg / palm (split into 2 applications)

SOA: 5 kg / palm (spit into 5 applications)

PROGRESS

Plot marking has been completed and soil samples taken for analysis. Soil depths are being measured. Recording commenced in 2002. Treatments commenced in 2005. Colemanite is proving difficult to purchase in commercial quantities and thus will be replaced by Ulexite (CaNa borate; 10% B).

RESULTS

Treatments only commenced in 2005 so there are no responses yet. Across the whole trial, average FFB is 24.9 t/ha; number of bunches is 1050/ha; and single bunch weight is 24.4 kg.

FERTILISER RESPONSE TRIALS AT RAMU SUGAR

(L Kuniata & M. J. Webb)

TRIAL RM 1-03 FACTORIAL FERTILISER TRIAL ON IMMATURE PALMS AT GUSAP

PURPOSE

The trial has two purposes:

1. To indicate which nutrient additions are required in by immature palms at Ramu, and for N and K, the approximate agronomic optimum rates.
2. To give an indication as to the best fertiliser regime for mature palms at Ramu

Results of the trial will not be known before commercial planting starts. However, at the end of every year, the commercial immature fertiliser recommendation will be reviewed based on growth of the trial palms in the previous year. The results of the trial will also be applicable to possible expansion into surrounding smallholder areas. The main value of the trial will be the second purpose: to give an early indication of the optimum fertiliser rates for mature palms. In existing growing areas, the fertiliser rates in year three of the immature schedules approximate the rates used in mature palms. Presence or absence of a response to a fertiliser during the immature phase will indicate likelihood of a response to that fertiliser during the mature phase.

SITE AND PALMS

Site: Gusap, field GN-1

Soils: Deep Loam

Topography: Gently sloping

Land use prior to this crop: Cattle grazing

Palms: Dami commercial DxP crosses, identified progeny, planted in November 2003 at 143 palms/ha

The deep loam soil type is dominant through the first stage planting area. A second trial, exactly the same as the one discussed here, will be established on cracking clays in the second stage planting.

BACKGROUND

Of the existing oil palm growing areas of PNG, the soils of Milne Bay are most similar to those of Gusap; alluvial soils with moderate to heavy texture, high CEC and high Mg:K ratios. Therefore the immature recommendation for Ramu was based on that for Milne Bay.

Further background detail is contained in the 2004 Research Proposals.

DESIGN

The design is a full factorial (3 rates N, 3 rates K, 2 rates P, 2 rates S) with two replicates resulting in 3x3x2x2x2=72 plots. If an element has no significant effect on growth, then plots with different rates of that element can be treated as replicates. The design allows 3 blocks of 12 plots within each replicate, with only the 4-way interaction and one 2-way interaction being confounded with blocks

(Li, 1944). Treatments were allocated according to this block structure. The plots, blocks and replicates all advance along the length of the field, so replicates and blocks will test any natural variation along the length of the field. Analysis of variance without blocks will be preferable if there is no block effect.

Each plot consists of 36 palms (6x6), with the inner 16 (4x4) recorded and the outer 20 acting as a guard row; treated but not recorded. In fertiliser trials with mature palms, trenches between each plot are usually dug to prevent root poaching. This is not necessary in the immature trial. In a subsequent mature trial (already planted with the same 16 progeny and plot structure as this trial), trenches will be considered, but the risk of creating erosion gullies will be part of the consideration.

TREATMENTS

The trial will run for three years, with possible extension depending on results. Nutrient application rates increase with time, as is normal for immature fertiliser management. The elements examined are N, K, S and P, (see background section). The treatment rates are based on the recommended rates. For each element there is a zero rate, a rate around the commercial rate, and for N and K a rate double that. The rates and doses are shown in Table q. The zero P treatment is unusual in that P was still be applied in the planting hole; as it is accepted practice in all existing growing areas. The fertilisers used are ammonium nitrate (AN) for N, elemental sulphur for S, potassium chloride (MOP) for K, and triple superphosphate (TSP) for P. Due to insolubility of elemental sulphur in 2004-05, Tiger 90 was used as source of sulphur at appropriate rates. Fertilisers are spread around the drip circle of the palms. All palms will receive an annual application of borate (borax or ulexite) of 50 g/palm.

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.

Table 1. Fertiliser rates in trial (g fertiliser/palm)

	AN0	AN1	AN2	MOP0	MOP1	MOP2	TSP0	TSP1	S0	S1
Hole	0	0	0	0	0	0	200	200	0	0
1m	0	40	80	0	80	160	0	0	0	0
3m	0	80	160	0	160	320	0	0	0	0
6m	0	80	160	0	160	320	0	300	0	50
9m	0	80	160	0	160	320	0	0	0	0
12m	0	120	240	0	240	480	0	300	0	50
Year 1 total	*(0)*	*(400)*	*(800)*	*(0)*	*(800)*	*(1,600)*	*(0)*	*(600)*	*(0)*	*(100)*
16m	0	250	500	0	450	900	0	300	0	60
20m	0	250	500	0	450	900	0	300	0	60
24m	0	350	700	0	700	1,400	0	300	0	60
Year 2 total	*(0)*	*(850)*	*(1,700)*	*(0)*	*(1,600)*	*(3,200)*	*(0)*	*(900)*	*(0)*	*(200)*
28m	0	500	1,000	0	700	1,400	0	300	0	75
32m	0	500	1,000	0	700	1,400	0	300	0	75
36m	0	700	1,400	0	1,000	2,000	0	400	0	100
Year 3 total	*(0)*	*(1,700)*	*(3,400)*	*(0)*	*(2,400)*	*(4,800)*	*(0)*	*(1,000)*	*(0)*	*(250)*

Table 2. Details of elements and rates used in trial # RM1-03 (g element/palm).

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

PREPARATION OF SITE AND PALMS

In order to control inter-progeny variation, the same 16 known progeny were used in each plot of the trial. Each progeny was randomly positioned within the plot and its position recorded. The guard rows were planted with mixed progeny and their identity/position is not recorded. The trial cover the width of a block (from one harvest road to the other. Another area was planted out exactly the same (with another set of 16 progeny), adjacent to the trial site, to allow for a mature trial. The trial site was planted in November 2003.

MEASUREMENTS

In the first two years, before the palms start yielding, growth measurements will be made. They will consist of frond production rate and Frond 17 dimensions: frond length, leaflet number and length, and rachis width and thickness. When the palms start producing flowers, the number of male and female inflorescences will be measured. When the palms start producing ripe bunches, bunch numbers and weights will be recorded. There was no vegetative assessments done in 2006 but this will be made in early 2007.

RESULTS

Subjective scoring for growth and appearance of palms showed highly significant ($p<0.001$) differences between the various elements used. Application of nitrogen and potassium had a highly significant effect on the growth of the palms (Figure 1(a)). Without nitrogen, any increase of potassium marginally improved growth. The application of both sulphur and phosphorus under different rates of nitrogen has significantly higher impact on palm growth (Figures 1(b) & (c)). Similar general trends were observed for potassium x sulphur (Figure 1(d)), potassium x phosphorus (Figure 1(e)) and sulphur x phosphorus (Figure 1(f)).

The general trends observed for frond number showed nitrogen having a highly significant ($p<0.001$) influence on frond production. Frond number increased with increasing rates of nitrogen especially with application of potassium, sulphur and phosphorus and potassium x sulphur (Figures 2(a)-(d). The interactions between potassium, phosphorus and sulphur were variable (Figure 2(e) & (f)).

These preliminary indications are showing that immature oil palms were responding significantly to applied nutrients. Significant interactions were also observed for all the treatments.

Some vegetative measurements were conducted in May 2005. Generally N had an effect on most measurements. The other nutrients only affected some measurements (Table 2).

For example, the number of fronds produced was increased slightly by N and K; and leaflet length was increased by N, K and S.

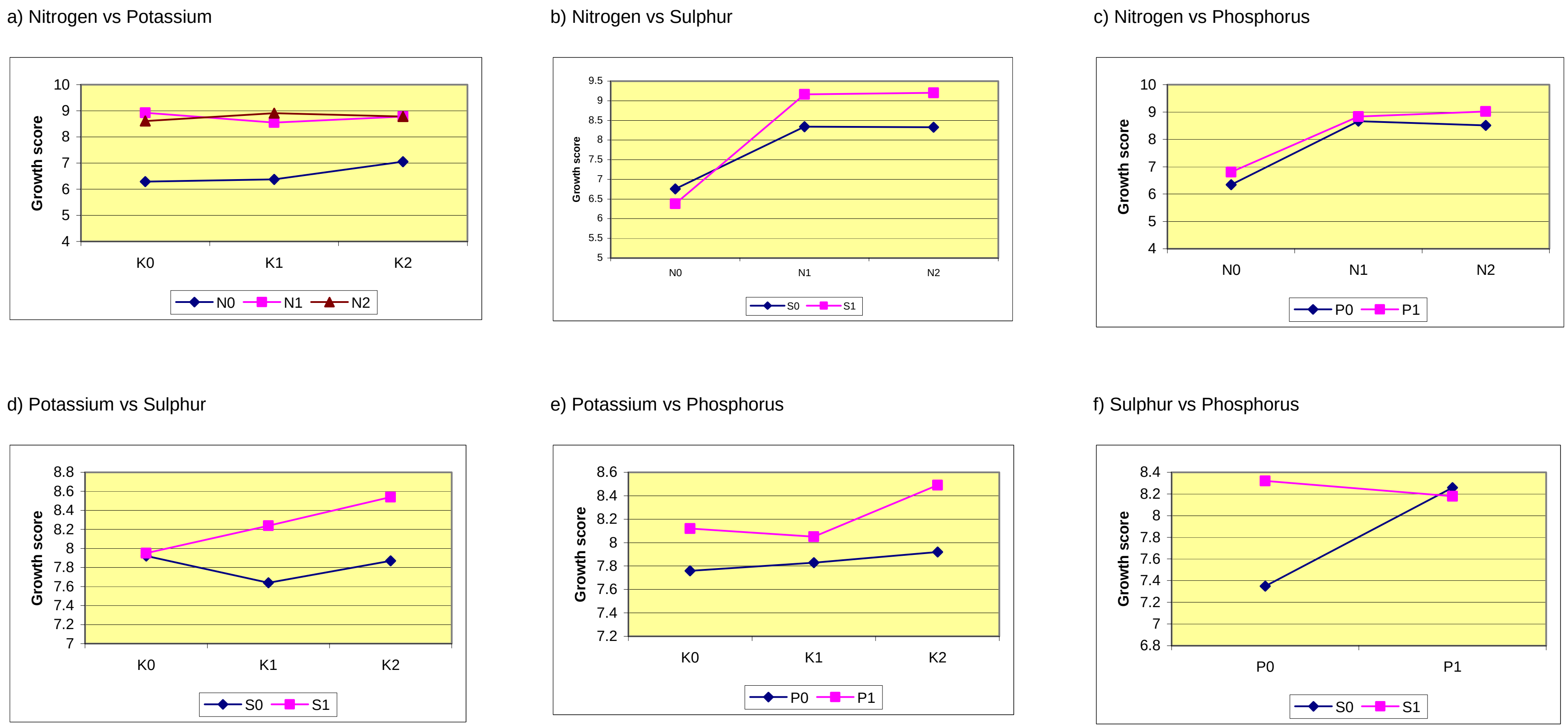
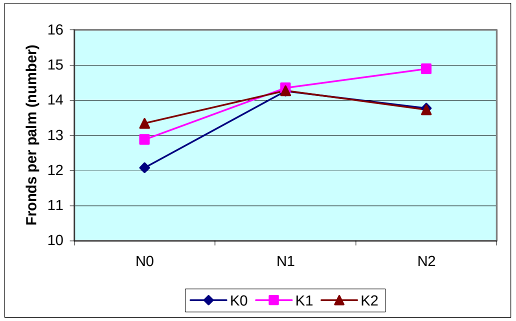
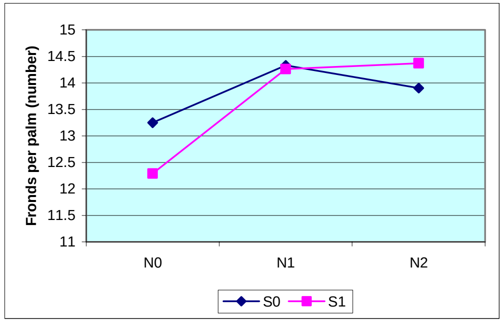


Figure 1. Summary of growth scores for immature oil palm under different nutrient levels in Trial # RM 1=03 at Ramu (Score 1=poor, 10=excellent).

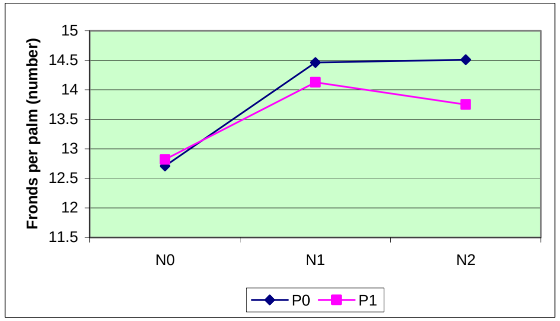
a) Nitrogen vs Potassium



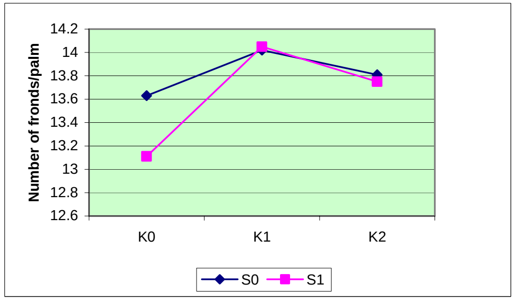
b) Nitrogen vs Sulphur



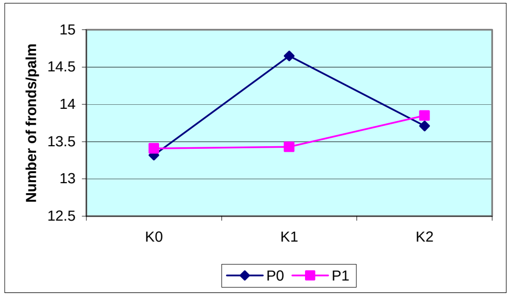
c) Nitrogen vs Phosphorus



d) Potassium vs Sulphur



e) Potassium vs Phosphorus



f) Sulphur vs Phosphorus

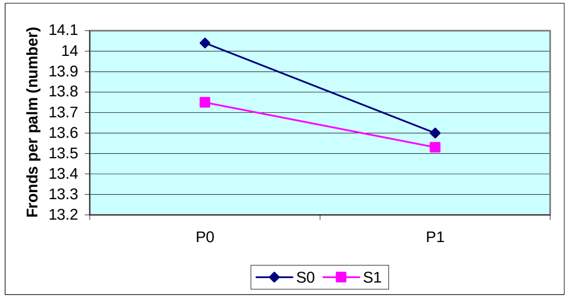


Figure 2. Summary of frond number for immature oil palm under different nutrient levels in Trial # RM 1=03 at Ramu.

Table 2. Effect of N, K, S and P on vegetative properties in May 2005. Where the treatment effect is significant, the number is in bold.

Fertilser	Level	Number of Fronds	Rachis Thickness (cm)	Frond Length (cm)	Leaflet Length (cm)	Leaflet Width (cm)
AN	0	**19.7**	**2.4**	130	**43.2**	**2.9**
	1	**20.8**	**2.6**	135	**46.0**	**3.1**
	2	**20.6**	**2.7**	137	**46.1**	**3.1**
MOP	0	**19.7**	2.6	130	**44.1**	3.1
	1	**20.8**	2.6	137	**45.4**	3.1
	2	**20.3**	2.6	135	**45.8**	3.1
Sulpur	0	20.1	2.6	131	**44.4**	**3.0**
	1	20.6	2.6	136	**45.7**	**3.1**
TSP	0	20.2	2.6	132	44.9	3.1
	1	20.5	2.6	136	45.2	3.1

CONCLUSION

To achieve good early growth of oil palm on the deep loams in Gusap, nitrogen, potassium and sulphur fertilisers are required. There is probably enough phosphorus supplied at the time of planting to last at least the first year, but its subsequent requirement is not yet clear.

TRIAL RM 2-04 FACTORIAL FERTILISER TRIAL ON IMMATURE PALMS AT GUSAP

PURPOSE

The trial has two purposes:

3. To indicate which nutrient additions are required in by immature palms at Ramu, and for N and K, the approximate agronomic optimum rates.
4. To give an indication as to the best fertiliser regime for mature palms at Ramu

Results of the trial will not be known before commercial planting starts. However, at the end of every year, the commercial immature fertiliser recommendation will be reviewed based on growth of the trial palms in the previous year. The results of the trial will also be applicable to possible expansion into surrounding smallholder areas. The main value of the trial will be the second purpose: to give an early indication of the optimum fertiliser rates for mature palms. In existing growing areas, the fertiliser rates in year three of the immature schedules approximate the rates used in mature palms. Presence or absence of a response to a fertiliser during the immature phase will indicate likelihood of a response to that fertiliser during the mature phase.

SITE AND PALMS

Site: Gusap, field

Soils: Deep Loam

Topography: Gently sloping

Land use prior to this crop: Cattle grazing

Palms: Dami commercial DxP crosses, identified progeny, planted in December 2004 at 143 palms/ha

The original plan was to plant this trial on the cracking clays. However, as the deep loam soil type is dominant through the first stage planting area, it was decided to plant a second trial on a similar soil type in the new planting area.

BACKGROUND

Of the existing oil palm growing areas of PNG, the soils of Milne Bay are most similar to those of Gusap; alluvial soils with moderate to heavy texture, high CEC and high Mg:K ratios. Therefore the immature recommendation for Ramu was based on that for Milne Bay.

Further background detail is contained in the 2004 Research Proposals.

DESIGN

The design is a full factorial (3 rates N, 3 rates K, 2 rates P, 2 rates S) with two replicates resulting in 3x3x2x2x2=72 plots. If an element has no significant effect on growth, then plots with different rates of that element can be treated as replicates. The design allows 3 blocks of 12 plots within each replicate, with only the 4-way interaction and one 2-way interaction being confounded with blocks (Li, 1944). Treatments were allocated according to this block structure. The plots, blocks and replicates all advance along the length of the field, so replicates and blocks will test any natural variation along the length of the field. Analysis of variance without blocks will be preferable if there is no block effect.

Each plot consists of 36 palms (6x6), with the inner 16 (4x4) recorded and the outer 20 acting as a guard row; treated but not recorded. In fertiliser trials with mature palms, trenches between each plot are usually dug to prevent root poaching. This is not necessary in the immature trial. In a subsequent mature trial (already planted with the same 16 progeny and plot structure as this trial), trenches will be considered, but the risk of creating erosion gullies will be part of the consideration.

TREATMENTS

The trial will run for three years, with possible extension depending on results. Nutrient application rates increase with time, as is normal for immature fertiliser management. The elements examined are N, K, S and P, (see background section). The treatment rates are based on the recommended rates. For each element there is a zero rate, a rate around the commercial rate, and for N and K a double rate. The rates and doses are shown in Table 1. The zero P treatment is unusual in that P was still be applied in the planting hole; as it is accepted practice in all existing growing areas. The fertilisers used are ammonium nitrate (AN) for N, elemental Tiger 90 for S, potassium chloride (MOP) for K, and triple superphosphate (TSP) for P. Fertilisers are spread around the drip circle of the palms. All palms will receive an annual application of borate (borax or ulexite) of 50 g/palm.

Table1. Fertiliser rates in trial (g fertiliser/palm)

	AN0	AN1	AN2	MOP 0	MOP1	MOP2	TSP0	TSP1	S0	S1
Hole	0	0	0	0	0	0	200	200	0	0
1m	0	40	80	0	80	160	0	0	0	0
3m	0	80	160	0	160	320	0	0	0	0
6m	0	80	160	0	160	320	0	300	0	55
9m	0	80	160	0	160	320	0	0	0	0
12m	0	120	240	0	240	480	0	300	0	55
Year 1 total	*(0)*	*(400)*	*(800)*	*(0)*	*(800)*	*(1,600)*	*(0)*	*(600)*	*(0)*	*(110)*
16m	0	250	500	0	450	900	0	300	0	66
20m	0	250	500	0	450	900	0	300	0	77
24m	0	350	700	0	700	1,400	0	300	0	77
Year 2 total	*(0)*	*(850)*	*(1,700)*	*(0)*	*(1,600)*	*(3,200)*	*(0)*	*(900)*	*(0)*	*(220)*
28m	0	500	1,000	0	700	1,400	0	300	0	75
32m	0	500	1,000	0	700	1,400	0	300	0	100
36m	0	700	1,400	0	1,000	2,000	0	400	0	100
Year 3 total	*(0)*	*(1,700)*	*(3,400)*	*(0)*	*(2,400)*	*(4,800)*	*(0)*	*(1,000)*	*(0)*	*(275)*

PREPARATION OF SITE AND PALMS

In order to control inter-progeny variation, the same 16 known progeny were used in each plot of the trial. Each progeny was randomly positioned within the plot and its position recorded. The guard rows were planted with mixed progeny and their identity/position is not recorded. The trial cover the width of a block (from one harvest road to the other. Another area was planted out exactly the same (with another set of 16 progeny), adjacent to the trial site, to allow for a mature trial. The trial site was planted in December 2004.

This trial was planted in December 2004. 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 have started for year 1 as detailed in Table 1. No assessments have been done yet.

MEASUREMENTS

In the first two years, before the palms start yielding, growth measurements will be made. They will consist of frond production rate and Frond 17 dimensions: frond length, leaflet number and length, and rachis width and thickness. When the palms start producing flowers, the number of male and female inflorescences will be measured. When the palms start producing ripe bunches, bunch numbers and weights will be recorded.

TRIAL RM 3-03 FACTORIAL FERTILISER TRIAL ON MATURE PALMS AT GUSAP

PURPOSE

The trial has two purposes:

5. To indicate which nutrient additions are required in by immature palms at Ramu, and for N and K, the approximate agronomic optimum rates.
6. To give an indication as to the best fertiliser regime for mature palms at Ramu

Results of the trial will not be known before commercial planting starts. However, at the end of every year, the commercial immature fertiliser recommendation will be reviewed based on growth of the trial palms in the previous year. The results of the trial will also be applicable to possible expansion into surrounding smallholder areas. The main value of the trial will be the second purpose: to give an early indication of the optimum fertiliser rates for mature palms. In existing growing areas, the fertiliser rates in year three of the immature schedules approximate the rates used in mature palms. Presence or absence of a response to a fertiliser during the immature phase will indicate likelihood of a response to that fertiliser during the mature phase.

SITE AND PALMS

Site: Gusap, field

Soils: Deep Loam

Topography: Gently sloping

Land use prior to this crop: Cattle grazing

Palms: Dami commercial DxP crosses, identified progeny, planted in November 2003 at 143 palms/ha

The original plan was to plant this trial on the cracking clays. However, as the deep loam soil type is dominant through the first stage planting area, it was decided to plant a second trial on a similar soil type in the new planting area.

BACKGROUND

Of the existing oil palm growing areas of PNG, the soils of Milne Bay are most similar to those of Gusap; alluvial soils with moderate to heavy texture, high CEC and high Mg:K ratios. Therefore the immature recommendation for Ramu was based on that for Milne Bay.

Further background detail is contained in the 2004 Research Proposals.

DESIGN

The design is a full factorial (3 rates N, 3 rates K, 2 rates P, 2 rates S) with two replicates resulting in 3x3x2x2x2=72 plots. If an element has no significant effect on growth, then plots with different rates of that element can be treated as replicates. The design allows 3 blocks of 12 plots within each replicate, with only the 4-way interaction and one 2-way interaction being confounded with blocks (Li, 1944). Treatments were allocated according to this block structure. The plots, blocks and replicates all advance along the length of the field, so replicates and blocks will test any natural variation along the length of the field. Analysis of variance without blocks will be preferable if there is no block effect.

Each plot consists of 36 palms (6x6), with the inner 16 (4x4) recorded and the outer 20 acting as a guard row; treated but not recorded. In fertiliser trials with mature palms, trenches between each plot are usually dug to prevent root poaching. This is not necessary in the immature trial. In this trial trenches will be considered, but the risk of creating erosion gullies will be part of the consideration.

TREATMENTS

The trial will run for the life of the adjacent plantation. Nutrient application rates increase with time, as is normal for immature fertiliser management. The elements examined are N, K, S and P, (see background section). The treatment rates will be based on the recommended rates for mature plantations. For each element there is a zero rate, a rate around the commercial rate, and for N and K a rate double that. The zero P treatment is unusual in that P was still be applied in the planting hole; as it is accepted practice in all existing growing areas. The fertilisers used are ammonium nitrate (AN) for N, elemental Tiger 90 for S, potassium chloride (MOP) for K, and triple superphosphate (TSP) for P. Fertilisers are spread around the drip circle of the palms. All palms will receive an annual application of borate (borax or ulexite) of 50 g/palm.

PREPARATION OF SITE AND PALMS

In order to control inter-progeny variation, the same 16 known progeny were used in each plot of the trial. Each progeny was randomly positioned within the plot and its position recorded. The guard rows were planted with mixed progeny and their identity/position not be recorded. The trial cover the width of a block (from one harvest road to the other.

MEASUREMENTS

Measurements will commence when treatments begin. The treatments will be imposed at mature stage starting in 2007.

OTHER FACTORS

SPACING AND THINNING TRIALS

TRIAL 139 PALM SPACING TRIAL AT KUMBANGO PLANTATION

(James Kraip)

INTRODUCTION

The purposes of this trial are to investigate the possibilities of 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, leaf nutrient level, 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. Little is known however about the impacts that machine traffic will have on the physical properties and long-term sustainability of these soils.

Table 1: Background information on trial 139.

Trial number	139	Company	NBPOL
Date planted	1999	Planting Density (palm/ha)	128*
Spacing	See Table 2 below	Pattern	Triangular
LSU or MU	Kumbango Plantation, Division 1, Field B	Soil type	Eutrandepts (Inceptisols)
Recording started	Jan 2003	Palm age (years after planting)	6
Topography	Flat	Planting material	Dami commercial DxP
Progeny*	Not known	Previous land use	Oil Palm
Drainage	Good	Area under trial soil type	Not known
Officer in charge	R. Pipai		

* = *spacing treatments given below*

MATERIALS AND METHODS

The field layout comprises three replicates for each of the three spacing arrangements (treatments), giving a total of nine plots, each 10.6 ha in area. The planting density remains constant at 128 palms per hectare. The three spacing regimes 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 regimes (treatments) used in Trial 139.

Treatment No	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 treatments had a significant effect on fresh fruit bunch (FFB) yield in 2003 and 2004 but not in 2005 (Figure 1). Even though not significant in a statistical sense, treatment with the widest avenue had the greatest FFB yield compared to the other two treatments (Tables 3 and 4). In 2003 and 2004, the treatment with the widest avenue also had the greatest FFB yield.

Effect of spacing treatment on BNO/ha and SBW was not significant in 2005 but again the widest avenue tended to increase BNO/ha (Tables 3 and 4).

Table 3. Effects (p values) of treatments on FFB yield and its components in 2005 (Trial 139). p values <0.05 are indicated in bold.

	2005		
Source	FFB yield (t/ha)	BNO/ha	SBW
Treatment	0.069	0.116	0.098
CV%	*2.0*	*3.0*	*2.0*

Table 4. Main effects of treatments on FFB yield and its components (Trial 139). Effects with p values <0.05 are shown in bold.

	2005		
	FFB yield (t/ha)	BNO/ha	SBW (kg)
Treatment 1	24.0	1803	13.3
Treatment 2	24.4	1749	14.0
Treatment 3	25.3	1864	13.6
s.e.d.	*0.4*	*42*	*0.2*
$Lsd_{0.05}$			
GM	*24.6*	1805	*13.6*

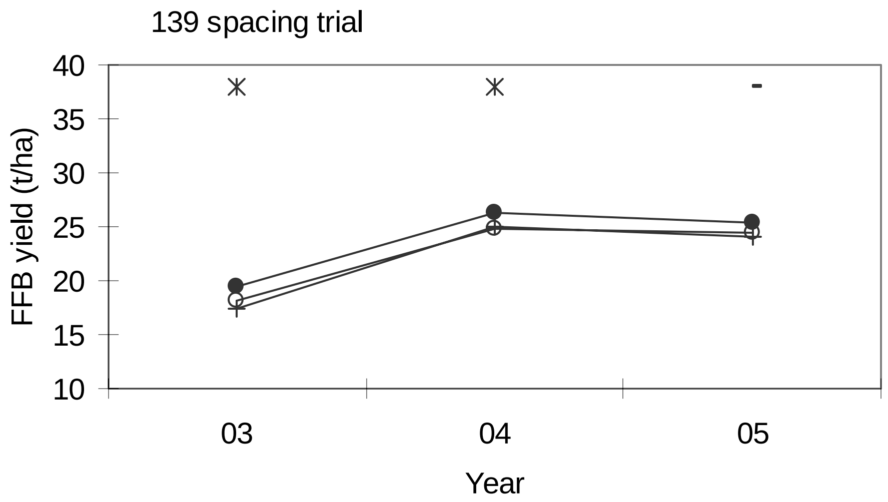


Figure 1. Main effects of spacing treatments over the course of Trial 139. Lines are FFB yields. Full symbols represent treatment 3, empty symbols represent treatment 2, and + represents treatment 1. Symbols along the top of the graph indicate significance of the main effect on yield. Stars indicate significance ($p<0.05$) and dashes non-significance.

CONCLUSION

Although the palms in this trial are only 7 years old, the spacing treatments are already having an effect on yield such that there would not be a disadvantage to wider avenues to facilitate mechanised infield collection (MIC) of FFB – indeed there is a significant advantage.

Observation also suggests that the wider avenue result in much better ground cover. This will be quantified in the future. So even if MIC is not being considered, wider avenues may be better for protection of the soil surface.

TRIAL 331. SPACING AND THINNING TRIAL, AMBOGO ESTATE

(S. Nake)

SUMMARY

Trial 331 was established at Ambogo Estate, Higaturu Oil Palms in 2001 to investigate the effects of spacing configuration on yield of palms, cover crops and soil condition. Six planting densities were used; 128, 135, 143, 192, 205 and 215 palms per hectare. The density treatments were replicated three times giving a total of 18 plots of 4 recorded rows each. The treatments effects were monitored on the FFB yield, single bunch weights, the number of bunches and the vegetative growth of the palms.

2005 results showed that yields were not affected by the density treatments but BNO and SBW responded significantly to the treatments. Though not significant, the lower planting densities produced higher yields than the higher planting densities. SBW also showed similar trend. The number of bunches were higher in the higher planting densities.

Radiation interception of the palms was also significantly affected by the density treatments but not the dry matter production.

INTRODUCTION

This trial was originally set up because mechanical removal of FFB from the field after harvest was being considered. This was intended to reduce harvesting costs. Little is known, however, about the impacts that machine traffic will have on the physical properties and long-term sustainability of these soils. Even though mechanical removal has been abandoned as a viable option, wider avenue spacings may allow more sunlight, better cover crop growth and thus less potential for soil loss by erosion. Hence the trial is being continued to investigate into this area.

METHODOLOGY

Trial Background Information

Table 1. Trial 331 background information.

Trial number	331	**Company**	Higaturu Oil Palms
Estate	Ambogo	**Block No.**	4971A2
Date planted*	2001	**Planting Density***	Mixed as per trt
Spacing	Differ	**Pattern**	Triangular
LSU or MU*	Ambogo	**Soil Type**	Ambogo Soils
Recording Started	2002	**Age after planting***	5
Topography	Flat	**Planting material**	Dami D x P
Progeny		**Altitude**	125 m.a.s.l
Drainage*	Good	**Previous Landuse***	Oil Palm Planting
Officer in charge	S. Nake	**Area under trial soil type (ha)***	

**Data should be synchronous with OMP.*

Experimental Design and Treatments

There are 6 treatments initially of different planting densities with equilateral triangular spacing (Table 1.). In treatments 4, 5 and 6 every third row will be removed 5 years after planting. September 2005, thinning exercise was implanted on the trial.. Treatments 1, 2 and 3 remained as planted. The final densities of treatments 4, 5 and 6 will then 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 from which all data are collected from.

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

Trial Maintenance and Upkeep

Like all PNGOPRA established trials, any upkeep work in the trial block is done by the Mamba estate workers and this include activities such as ring weeding, herbicide spraying, wheelbarrow path clearance, cover crop maintenance and other routine plantation practices. Unlike the factorial fertilizer trials, fertilizer application in this block is taken care of by Ambogo Estate. The trial is fertilized on a palm basis with standard fertilizers and rates recommended by HOP.

Data Collection

Harvesting and yield recording (weighing of bunches) is done on a 14 day round. The 18 plots consisted of 4 recorded rows from which data is collected. Remaining rows are treated as guards. Yield data is taken from all the palms in the 4 recorded rows while vegetative measurements and leaf sampling are done on selected palms (every 5th palm) within the 4 rows. The data is recorded onto the record sheets in the field and later on entered onto the computer data base using Microsoft Access and are later on converted into yield expressed in tonnes per hectare, total number of bunches harvested per hectare and the single bunch weight.

Vegetative parameters measured in 2005 included, leaf measurements (total leaf length, leaflet width, leaflet length, total number of leaflets), petiole cross-section width and thickness (PCS WxT). Total frond count and marking of leaf 1 is done after every six months. Leaf 1 marking is used to calculate the frond production rate.

Tissue sampling (leaf & rachis) and height measurements were not done in 2005 but scheduled for 2006.

RESULTS & DISCUSSION

Effect of density treatments on yield and other components

The effects of different density on the yield and other components in 2004 and 2005 are shown in Tables 3 and 4. Regardless of the density treatments, there was a general increase in the FFB yield, SBW and BW/palm/year in 2005 from 2004. The number of bunches (BNO) and the number of bunches per palm per year (BN/palm/yr) declined substantially in 2005 (Table 4).

FFB yield in 2005 did not respond significantly to the different densities used despite the general increase in the mean FFB yield. Higher yields were obtained in the lowest densities used, but this response was not significant. The number of bunches per hectare (BNO/ha), single bunch weight (SBW) and the bunch weight per palm per year (BW/palm/yr) all responded significantly to the density treatments. The BNO increased significantly with the planting densities. The three highest planting densities (192, 203 and 215 palms/ha) obtained significantly (p=0.006) more bunches than the three lower densities (128, 135 and 143 palms/ha). The single bunch weights (SBW) also declined significantly with increasing densities. The reduction in bunch weight at the three highest densities was probably due to the very high number of bunches. The significant decrease in SBW with increasing densities also had a similar significant effect on the BW/palm/yr.

Effect of density treatments on vegetative parameters

The effects of the treatments (density) on the palms growth, radiation interception and dry matter production were also monitored in 2005 (Tables 5 and 6). The length of the leaves (fronds) responded significantly (p=0.003) to the density treatments. The closer the palms (i.e. higher the density) the longer the leaf length. Higher leaf length was produced by palms planted at the 3 highest planting densities (192, 205, 215 palms/ha). Frond production (per year), number of green fronds on the palms, frond area (FA) and leaf area index (LAI) are parameters used to determine the palm radiation interception. All these parameters except FA responded significantly to the density treatments. Frond production was severely reduced with increasing densities while the LAI increased significantly with increasing densities. Although the number of green fronds had a significant response to density, it is not clear how to interpret this at this stage. The dry matter production did not respond positively (significantly) to the density treatments.

CONCLUSION

The yield and SBW continued to increase while the BNO dropped substantially in 2005. Total bunch weight per palm per year also increased in 2005 while the total bunch number per palm per year declined. The density effect was only significant on the BNO and the SBW while the yield response was not significant. The three highest densities produced the highest number of bunches. SBW dropped as the densities increased.

Furthermore, the density treatments had significant effects on the Radiation interception but not the dry matter production.

Table 3. Density effects (p values) on FFB yield and its components in 2004/2005. p values less than 0.1 are indicated in bold.

	2004					2005				
Treatment	Yield	BNO	SBW	BW/palm/yr	BN/palm/yr	Yield	BNO	SBW	BW/palm/yr	BN/palm/yr
Density	**<0.001**	**0.074**	**<0.001**	**0.023**	0.226	0.179	**0.006**	**0.002**	**<0.001**	0.121
CV %	*6.5*	*14*	*7.9*	*6.8*	*7.6*	*8.5*	*6.4*	*5.5*	*7.9*	*16.7*

Table 4. Density effects on FFB yield and its components in 2004 and 2005

		2004					2005				
Treat	Density (palms/ha)	Yield (t/ha)	BNO/ha	SBW (kg)	BW/palm /yr (kg)	BN/palm /yr	Yield (t/ha)	BNO/ha	SBW (kg)	BW/palm /yr (kg)	BN/palm /yr
1	128	**21.4**	**3401**	**6.3**	**167.2**	26.6	29.4	**3371**	**8.7**	**229.6**	22.3
2	135	**21.4**	**3420**	**6.3**	**158.4**	25.3	29.2	**3487**	**8.4**	**216.4**	22.7
3	143	**22.0**	**3432**	**6.4**	**154.0**	24.0	28.4	**3303**	**8.6**	**198.9**	15.6
4	192	**28.5**	**4774**	**6.0**	**148.0**	24.8	32.4	**4121**	**7.8**	**168.8**	24.6
5	203	**28.2**	**4750**	**5.9**	**138.9**	23.4	26.5	**3763**	**7.0**	**130.3**	23.5
6	215	**29.2**	**4902**	**5.9**	**136.0**	22.8	28.2	**4018**	**7.0**	**131.2**	22.4
sed		***1.4***	***219***	***0.2***	***8.7***	*1.3*	***2.00***	***191***	***0.34***	***11.6***	*3.0*
Grand Mean		***25.1***	***4111***	***6.2***	***150***	*24.4*	***29.0***	***3677***	***7.9***	***179.2***	*21.9*

Table 5. Density effects (p values) on vegetative growth parameters in 2005. P values less than 0.1 are shown in bold.

Source				Radiation Interception					Dry Matter Production (t/ha/year)			
	LLen	LlNum	PCS	Frond Prodn	Green Frond	FA	LAI	Dry FW	FDM	BDM	TDM	VDM
Density	**0.003**	0.519	0.998	**0.017**	**0.074**	0.933	**<.001**	0.998	0.108	0.179	0.179	0.179
CV %	2.0	3.3	23.9	2.5	1.5	4.9	4.0	22.1	21.6	8.5	8.5	8.5

LLen = Leaf length; LlNum = Leaflet number; PCS = petiole cross-section; FA = frond area; LAI = leaf area index; Dry FW = Dry frond weight; FDM = Frond dry matter; BDM = bunch dry matter; TDM = total dry matter; VDM = vegetative dry matter

Table 6. Density effects on vegetative growth parameters in 2005. P values less than 0.1 are shown in bold.

Density Treatment (palm/ha)			Radiation Interception						Dry Matter Production (t/ha/year)			
	LLen (cm)	LlNum	PCS (cm^2)	Frond Prodn/yr	Green Frond	FA (m^2)	LAI	Dry FW (kg)	FDM	BDM	TDM	VDM
128	**459.6**	145.5	24.9	**18.2**	**45.0**	6.54	**3.76**	2.74	6.37	24.1	59.4	35.3
135	**461.2**	143.3	23.9	**18.2**	**44.7**	6.68	**4.03**	2.65	6.44	23.9	59.1	35.1
143	**468.6**	150.4	23.0	**17.6**	**44.0**	6.83	**4.29**	2.55	6.39	23.2	57.5	34.2
192	**486.6**	144.8	24.2	**17.4**	**45.6**	6.69	**5.85**	2.68	8.97	26.6	65.5	38.9
203	**484.3**	143.6	23.1	**17.2**	**45.2**	6.66	**6.11**	2.56	8.91	21.7	53.5	31.8
215	**499.5**	146.7	23.7	**16.8**	**45.9**	6.69	**6.62**	2.63	9.54	23.1	57.0	33.9
sed	*7.84*	*3.88*	*4.65*	*0.36*	*0.56*	*0.27*	*0.17*	*0.48*	*1.37*	*1.64*	*4.05*	*2.41*
Mean	**476.6**	**145.7**	**23.8**	**17.6**	**1.5**	**6.68**	**5.11**	**2.63**	**7.77**	**23.8**	**8.5**	**34.9**

LLen = Leaf length; LlNum = Leaflet number; PCS = petiole cross-section; FA = frond area; LAI = leaf area index; Dry FW = Dry frond weight; FDM = Frond dry matter; BDM = bunch dry matter; TDM = total dry matter; VDM = vegetative dry matter

TRIAL 513. SPACING AND THINNING TRIAL, PADIPADI ESTATE

(S. Nake)

SUMMARY

Trial 513 was established at Padipadi Estate, Milne Bay Estates in July 2003 to investigate the effects of spacing configuration on yield of palms, cover crops and soil condition. Six planting densities were used; 128, 135, 143, 192, 205 and 215 palms per hectare. The density treatments were replicated three times giving a total of 18 plots of 4 recorded rows each. The treatments effects will be monitored on the FFB yield, single bunch weights, the number of bunches and the vegetative growth of the palms.

No data (vegetative and yield) was collected in 2005 as the trial was still immature. The palms are expected to come into production in 2006.

INTRODUCTION

This trial was originally set up because mechanical removal of FFB from the field after harvest was being considered. This was intended to reduce harvesting costs. Little is known, however, about the impacts that machine traffic will have on the physical properties and long-term sustainability of these soils. Even though mechanical removal has been abandoned as a viable option, wider avenue spacings may allow more sunlight, better cover crop growth and thus less potential for soil loss by erosion. Hence the trial is being continued to investigate into this area. This trial is a replica of Trial 331 at Higaturu Oil Palms.

METHODOLOGY

Trial Background Information

Table 1. Trial 513 background information.

Trial number	513	Company	Milne Bay Estate
Estate	Padipadi	Block No.	1051
Date planted*	2003	Planting Density*	Mixed as per trt
Spacing	Differ	Pattern	Triangular
LSU or MU*		Soil Type	Tomanou Soil
Recording Started	Not yet (in 2006)	Age after planting*	2
Topography	Flat	Planting material	Dami D x P
Progeny		Altitude	
Drainage*	Good	Previous Landuse*	Savanna Grassland
Officer in charge	S.Nake	Area under trial soil type (ha)*	

**Data should be synchronous with OMP.*

Experimental Design and Treatments

The design is the same as Trial 331. There are 6 treatments initially of different planting densities but of equilateral triangular spacing (Table 1). Every third row (33%) in treatments 4, 5 and 6 will be thinned at year 5 after planting while treatments 1, 2 and 3 will remain. The final densities of treatments 4, 5 and 6 will be similar to treatments 1, 2 and 3 but will have increased avenue widths. This will result in a wide avenue interline before the next pair of rows for treatments 4, 5 and 6. All treatments are replicated 3 times. The trial was marked out and planted in 2003 with the joint effort between Milne Bay Estates and the PNGOPRA. Fertiliser application will be on a per palm basis during the immature phase and is normally applied by the plantation workers. It is proposed that when the palms mature, all density/spacing treatments will receive the same amount of fertiliser on a per palm basis. Within one of the replicates, plots with different cover crops were established. However, this part of study discontinued in 2004 because the planted covers did not perform well and were all smothered by wild cover plants.

Table 1. Treatment allocations in Trial 513.

Treatment No	Initial Density (palms/ha)	Triangular spacing (m)	Density after thinning (palms/ha)	Avenue width (m)	Number of Rows*
1	128	9.50	No thin.	8.23	7
2	135	9.25	No thin.	8.01	7
3	143	9.00	No thin.	7.79	7
4	192	7.75	128	13.43(6.71)	8
5	203	7.55	135	13.08(6.54)	9
6	215	7.33	143	12.70(6.35)	9

( ) Avenue width before thinning
* includes 2 guard rows on either sides of the plots

Trial Maintenance and Upkeep

Similar to other PNGOPRA trials, Padipadi estate takes charge of the general upkeep of the block, which also includes fertilizer application and harvesting. The trial is fertilized on a palm basis with standard fertilizers and rates recommended by HOP.

Data Collection

As the trial matures and productive in 2006, the following data will be collected;

Yield data, through weighing of bunches

Vegetative data collection – leaf measurements (PCS, Leaf length, number of leaflets, length and wide of leaflets), height, frond count.

Harvesting and yield recording (weighing of bunches) will be done on a 14 day round. The 18 plots will consist of 4 recorded rows on which data is taken from. Remaining rows are treated as guards. Yield data is taken from all the palms in the 4 recorded rows while vegetative measurements and leaf sampling are done on selected palms (every 5th palm) within the 4 rows.

Tissue sampling (leaf & rachis) and height measurements will also be collected in 2006.

RESULTS & DISCUSSION

Because the palms are still in their immature stage and currently not producing, no data (both yield, vegetative and tissue samples) were collected from the trial in 2005, thus no data to present this year.

PREDICTIONS AND RECOMMENDATIONS

(M.J. Webb)

SOIL RESOURCE INFORMATION (Activity 724)

This work has now been facilitated through an AIGF project which began in July 2005. The project is now completed so has been included in this report even though it was still being completed in 2006. This report is included under "Smallholder Fertiliser Recommendation" below

YIELD PREDICTIONS (Activity 725)

It is well known that oil palm yields are influenced by previous rainfall, especially in the critical periods of sex differentiation about 24 months before harvest and fruit maturation and susceptibility to abortion 4-8 months before harvest. It has been widely thought that in PNG the effect would only be evident in drier areas such as Poliamba or in following particularly dry years such as 1997. The fertiliser trials give us an opportunity to determine how well rainfall correlates with yield in the various growing areas of PNG.

The 2002 annual report showed good correlation between yield and rainfall two years prior for PNGOPRA field trials.

Various rainfall periods were used, but the annual rainfall in the calendar year 2 years before the annual yield for a calendar yield generally fitted the best over all trials in all areas. The relationship must be due primarily to bunch numbers. Better predictions of yield over shorter time periods will come out of Trials 332 and 514.

At the very least the comparison is instructive in showing that the decline in yields in Oro over the period 1991-2000, which had raised some concern, appears to be related to a decline in rainfall over the 1989-1997 period.

Data is continuing to be collected for these trials as well as for the plantations and will form part of a more extensive analysis.

Trials 332, 514 and 515. YIELD FLUCTUATION MONITORING

BACKGROUND

An ability to predict FFB yield several months in advance would be of great benefit to the industry. The purpose of this proposal is to establish FFB yield forecasting models for different oil palm growing agro ecosystems in PNG. Following discussions with PacRim, M. Banabas formulated a proposal for a model to predict yields, by monitoring of a group of palms in each block or soil type. The work has been designated Trial 332 in Oro and 514 in Milne Bay. Fresh fruit bunch yield of oil palm is determined by a wide range of factors from 6 months to 2 – 3 years before a bunch is harvested. Yields also vary from one site to the other because of the heterogeneity in the different agro-ecosystems. Yield at any one particular site is largely determined by factors that are limiting during the development of fruit bunches. The complexity of oil palm flowering cycles adds to the difficulty of estimating yields 2 – 3 years ahead.

PURPOSE

- To develop FFB yield forecasting models for different oil palm growing agro ecosystems
- To collect sets of important soil, climate and oil palm physiological growth data that will be useful for FFB yield forecasting

SITE & DESIGN

Sites in plantation blocks Sangara (adjacent to Trial 324) and Mamba (adjacent to Trial 329) in Oro and Waigani in Milne Bay were selected in 2001. At each site 20 palms have been chosen and marked. The 20 palms will be monitored over a number of years and data collected will be used for yield forecasting. Palms along the centre line of blocks (perpendicular to planting rows) were chosen to minimise progeny effects. The plantations will carry out all upkeep on the palms. The following parameters are measured.

- Soil description
- Daily weather data collection from nearby stations (sunshine hours, daily rainfall and maximum and minimum temperatures)
- Weekly production of male and female flowers (flower census)
- Weekly spear leaf count
- Weekly soil moisture determination
- Fortnightly ripe bunch count and weighing
- Monthly black bunch count
- Six monthly leaf production count

RESULTS

These observation trials have now been in place for 3 years. While some shorter-term trends and relationships are developing (see 2003, 2004 Annual Report) the longer term trends will require data collection over a number of years.

In addition to these longer term effects of climate on yield, we started investigating shorter-term methods of predicting yield in 2004 (Trial 515). We have changed our approach since 2004 to improve the accuracy of recording. Only a limited amount of data is available, however it is showing that patterns of flower production and fruit harvest can be monitored in a way that may allow for improved future predictions.

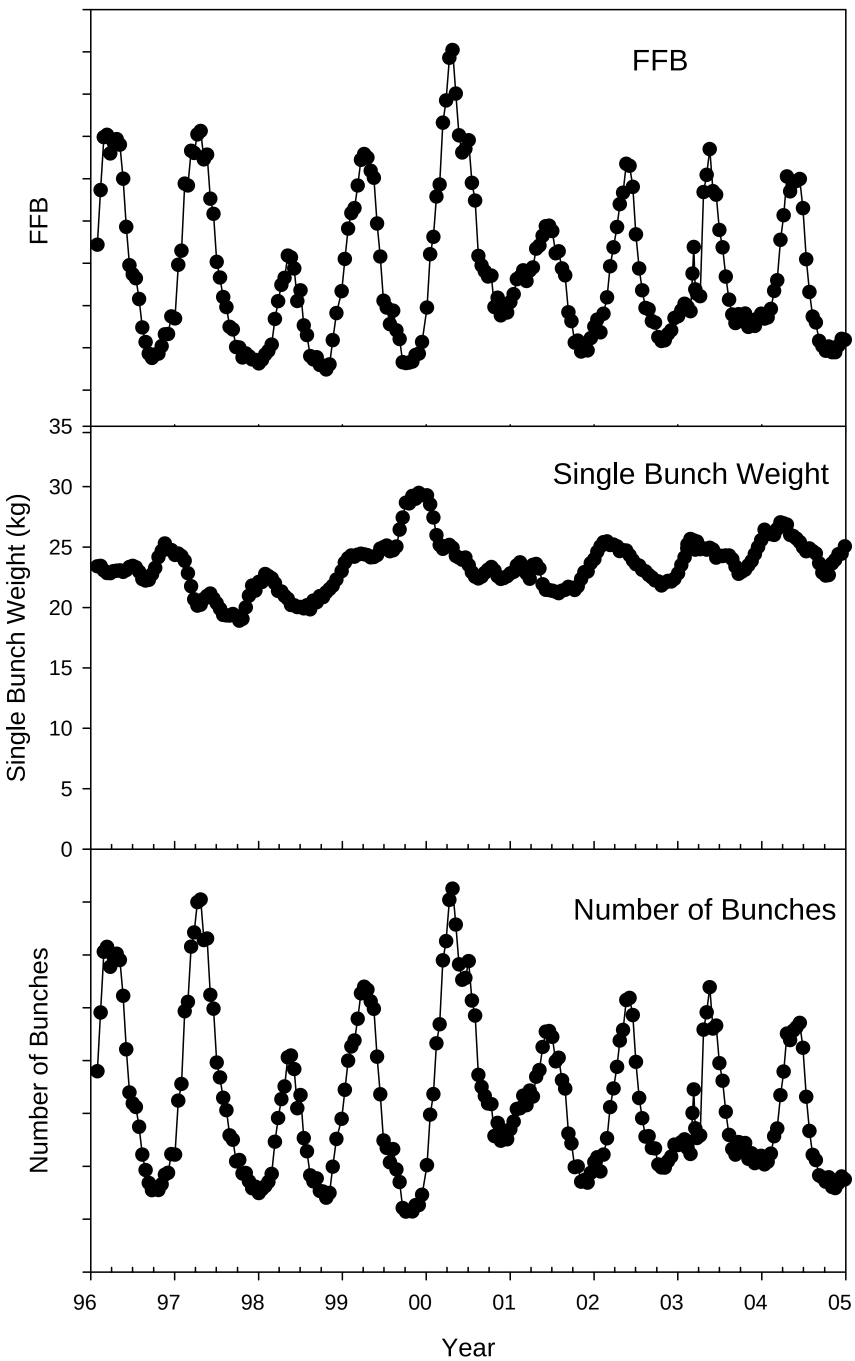


Figure 1. Variation in yield and number of bunches (3 month running mean) since the beginning of trial 502b. No figures are given on the Y-scale as it is has not been calculated per ha.

There is considerable variation in yield during a year. It is common to have 'peak' periods; but the months of this peak vary across PNG. For example, Milne Bay Estates has its peak around April/May (Figure 1). It is clear that the variation in yield can be explained by the variation in number of bunches rather than the smaller variation in single bunch weight.

By marking flowers at anthesis and following the progress of each flower to harvest, the time 'from flower to bunch' can be determined. In addition, the influence of time of year on 'from flower to bunch' can also be established. This analysis has been in place in Milne Bay Estates and Higaturu during 2005.

In MBE, there is a seasonal effect of the time it takes for a flower to mature to a bunch (Figure 2).

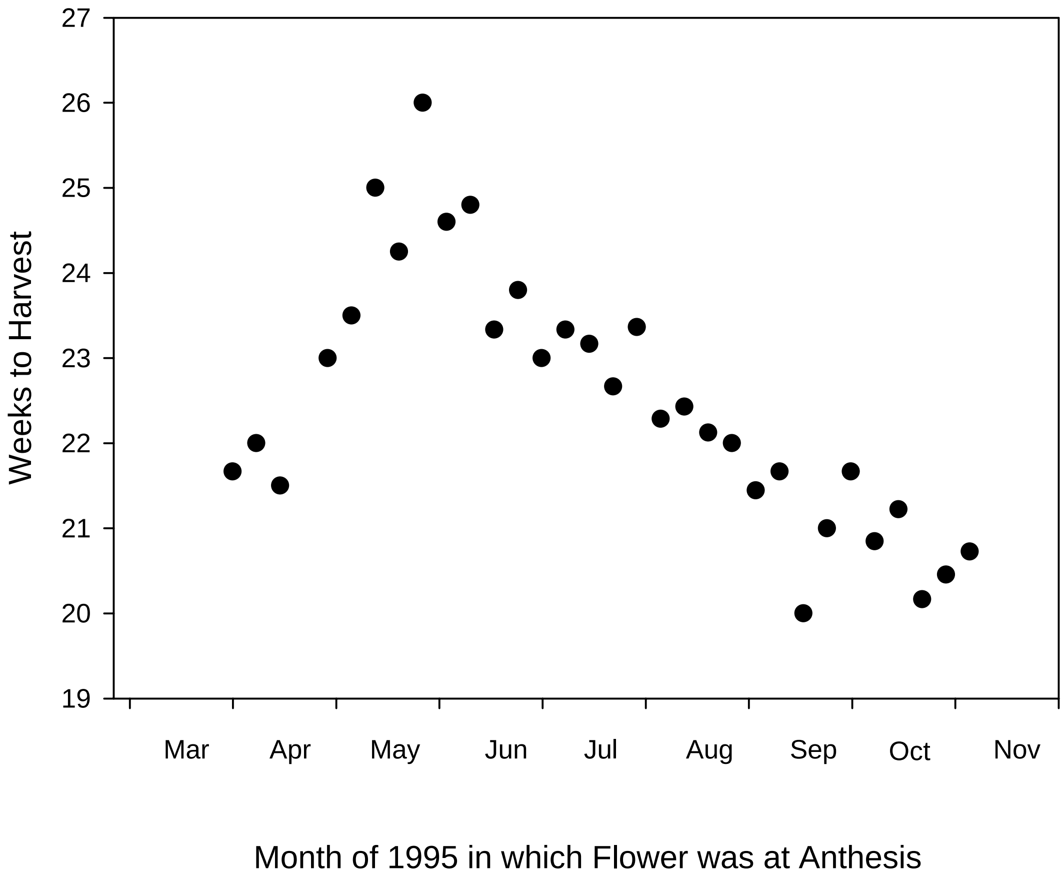


Figure 2. Time from flower to harvested bunch as a function of the month in which the flower was at anthesis.

This time from flower to bunch can explain the peak periods, although rate of flower production can also have a small influence (Figure 3). The upper half of Figure 3 represents the date that an individual flower was at anthesis; each line represents a single flower. Following a line down indicates when that particular flower becomes mature and is subsequently harvested as a bunch. Note that there is an offset in scales. The scales have been offset by the average time from flower to bunch. Thus a line that runs vertically has an average time from flower to bunch; a line that has a right displacement has a time from flower to bunch greater than the average; a line that has a left displacement has a time from flower to bunch less than the average. The magnitude of the displacement represents the magnitude of the difference from the average.

For example, the right-most line represents a flower that was at anthesis in late Dec 2005. Following this line down reveals that this flower was harvested as a ripe bunch in about the third week in May 2006. That the line displaces to the left indicates that the time from anthesis to harvest is less than the average.

In both the upper and lower parts of figure 3, the density of lines in any one month indicates the rate of flower production or bunch harvesting - as appropriate – for that month. It is clear from Figure 3 that the variation in the rate of flower production is less than the variation in rate of bunch harvesting (maturity) in that the density of lines in the upper half of the figure is less variable than in the lower half.

So although there is a greater rate of flower production from June to September, the main reason for the 'peak' in April/May is the shortening in time from flower to bunch (left displacement) in the months before April/May.

If this pattern proves to be consistent over a number of years – and the regularity of April/May peaks in MBE would suggest that this will be so – then is will be possible to predict yields with a 5-6 month lead time based on the number of flowers at anthesis – but also adjusted for the month that the flower count is done. This will be much more accurate in its prediction of yield than the current practice of black bunch counts – which 'smears' the prediction because it does not differentiate between bunches that are 'just' black and bunches that are almost 'red'.

Being able to accurately predict yield with a 5-6 month lead will have a significant economic advantage for companies as it will allow more accurate prediction for 'forward' selling of oil.

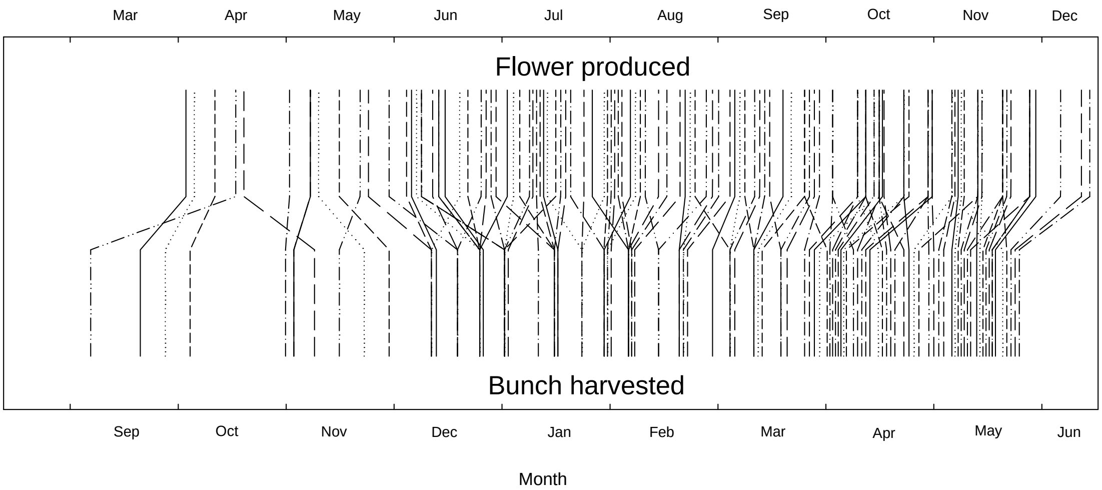


Figure 3. Relationship between the date the flower is at anthesis and the date the bunch is harvested

SMALLHOLDER FERTILISER RECOMMENDATIONS

(AIGF Project)

Fertiliser recommendations for smallholder blocks are generally the same within each region irrespective of the soil type, rainfall, or other features of those blocks. By matching soil type under smallholder blocks to soil type under plantation blocks we can use the information from the plantation to make block specific fertiliser recommendations for smallholders, thus increasing their ability to maximise profits.

METHODS

Soil and land use maps of the oil palm growing areas of WNBP were obtained from DALLUS. There were digitised, geo-referenced, and 'sewn' together so they could be incorporated into a GIS. Soil types (of which there were many) were rationalised to fewer number with common features.

Plantation maps (GIS) of MU's or LSU's were obtained from New Britain Palm Oil Ltd and Hargy Oil Palms.

Smallholder block maps (GIS) were obtained from OPIC-Hoskins project and Hargy Oil Palms.

Fertiliser recommendations for NBPOL and Hargy were obtained from PNGOPRA. These were averaged over the last three years.

Using GIS software, soil types were matched with MU or LSU blocks and their associated recommended fertiliser rates. Where a block covered more than one soil type, only the actual area under that soil type was used.

The fertiliser 'recommendation' for that soil type was weighted-averaged on the area under each recommendation.

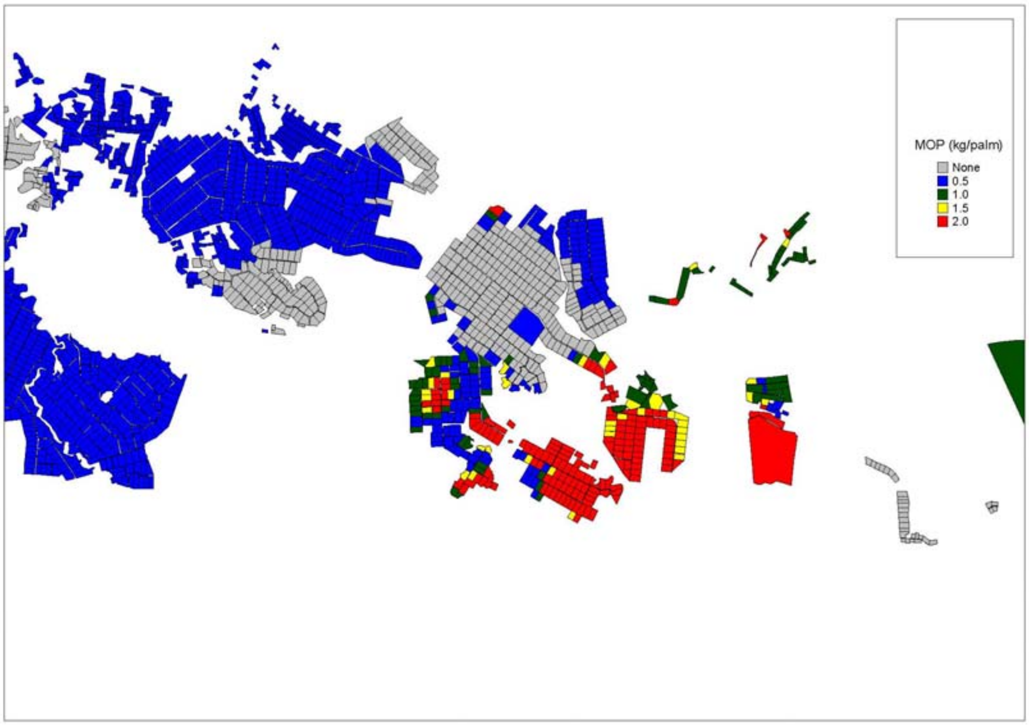
The process was then reversed to establish a fertiliser recommendation for each smallholder block. That is, the soil type under each smallholder block was determined by GIS and the associated recommendation attached to that block. Where the block covered more than one soil type, a weighted average was applied based on the relative areas of each soil type. Where, a soil type under a smallholder block was not associated with a soil type under a plantation block, the recommendation was based on that of another soil type with the same soil profile form.

This resulted in a table of smallholder blocks and fertiliser recommendations (Table 1). This has also been converted to a thematic map (Fig 1).

Table 1. Extract from block-specific fertiliser recommendation table. This example shows some smallholder blocks associated with Hargy Oil Palms.

BLOCK	AREA_ha	N Fert (kg/palm)	TSP (kg/palm)	KIE (kg/palm)	MOP (kg/palm	CaB (g/palm)
21450	6.47	3.0	0.0	1.5	0.5	100
21451	7.59	3.0	0.0	1.5	0.5	100
21452	7.07	3.0	0.0	1.5	0.5	100
21461	8.74	3.0	0.0	1.5	0.5	100
21462	8.51	3.0	0.0	1.5	0.5	100
21472	13.19	3.0	0.0	1.5	0.5	100
21474	6.57	3.0	0.0	1.5	0.5	100
21475	6.55	3.0	0.0	1.5	0.5	100
21481	7.13	1.5	0.0	1.0	0.5	50
21482	7.90	1.5	1.5	1.5	0.5	100
21483	7.13	2.0	1.5	1.5	0.5	150
21484	8.54	2.0	1.5	1.5	0.5	150
21485	8.26	3.0	0.0	1.5	0.5	100
21486	6.45	3.0	0.0	1.5	0.5	100
31235	7.19	3.0	0.0	1.5	0.5	100
31236	6.58	3.0	0.0	1.5	0.5	100
31237	6.77	3.0	0.0	1.5	0.5	100
31238	6.61	3.0	0.0	1.5	0.5	100
31239	6.54	3.0	0.0	1.5	0.5	100
31240	14.32	3.0	0.0	1.5	0.5	100

Figure 1. Example of a thematic map for MOP recommendations for parts of the Kavui and Buvussi Divisions.



This represents a ‘first pass’. With further information, such as rainfall distribution, these recommendations could be fine-tuned. They also represent the final fertiliser rate. The plan for getting to these rates would need to be done through consultation with OPIC.

Similar maps and recommendations could be produced for other regions in PNG where appropriate maps are available (eg Oro Province).

NUTRIENT USE EFFICIENCY

The 2004 PNGOPRA SAC committee recommended to the PNGOPRA Board that the necessary measurements in each PNGOPRA trial be taken so that nutrient use efficiency (NUE) can be calculated. This was approved by the Board.

As such, appropriate measurements were commenced. Because NUE needs an estimate of incremental growth of palm trunks, and thus a difference in height between years, it will not be possible to report NUE in all trials until trunk height measurements are also done in 2006. This means that NUE will not be reported on in all trials until 2007 – when PNGOPRA presents the 2006 Annual Report.

However, there are a few trials in which the appropriate data has been collected for other purposes.

As an example, trial 205b, can been analysed for NUE for N and K.

Table 1. NUE calculations for nitrogen in trial 502b

	N Supply (kg/palm)			
	0	0.42	0.84	1.26
FFB Yield (kg/palm)	136	186	224	240
FFB Yield (t/ha)	17.3	23.6	28.4	30.5
N uptake (kg/palm)				
Trunk	0.05	0.06	0.09	0.11
Frond 17	0.89	1.14	1.29	1.46
FFB*	0.40	0.55	0.65	0.67
Total	*1.34*	*1.75*	*2.03*	*2.24*
Recovery Efficiency (%)		96.9	82.1	71.3
Stepwise RE (%)			67.4	49.5
Agronomic Efficiency (kg/kg)		118.1	104.0	82.5
Stepwise AE (kg/kg)			90.0	39.4
Physiological Efficiency (kg/kg)		121.9	126.7	115.7

*FFB nutrient levels from Prabowo, Foster, and Silalahi "Recycling Oil Palm Bunch Nutrients"

Nitrogen

Recovery Efficiency (how much nutrient is taken up as a percentage of that applied)[1] of low application rates of N is high (97%), but as the rates of application increase, the recovery efficiency decreases. Thus, while adding N at 1.26 kg per palm produced maximum yield, only 71% of the N added was taken up by the palm. If we look at the Stepwise recovery efficiency (i.e. from one rate of supply to the next) of increasing N rate from 0.84 to 1.26 kg/palm/year, we see that only 50 % of the additional N added was taken up.

The fate of the N not taken up is being addressed by Murom Banabas as part of his EU sponsored PhD programme.

[1] Recovery Efficiency (RE), Agronomic Efficiency (AE), and Physiological Efficiency (PE): as defined by Goh, Härdter, and Fairhurst (2003) "Fertilizing for maximum return. In Fairhurst and Härdter (eds) "Oil Palm: Management for large and sustainable yields", PPI/PPIC/IPI.

Agronomic Efficiency (how much additional yield is produced by each kg fertiliser) also decreases with increasing rate of supply; even more so for Stepwise AE. This means that for each addition kg of fertiliser used, less additional yield is produced.

By contrast, Physiological Efficiency (how much additional yield for each additional amount of nutrient taken up), is not affected greatly by the rate of supply.

Potassium

The results for K are similar to those for N except in magnitude. The efficiency of uptake and use is less for K than N. Indeed the Stepwise RE shows that only 3% of the K from fertiliser application rates 2.5 kg to 3.75 kg/palm/yr is taken up by the palm.

This means that the other 97% is susceptible to loss.

However, results from the Mg/K ACIAR project show that the K that is being added, even if it is not taken by the palm is being stored in the soil; primarily in the surface horizons. This means that it is not being lost to the environment; but is highly susceptible to loss if appropriate processes to mitigate erosion are not put in place.

Table 2. NUE calculations for potassium in trial 502b

	K Supply (kg/palm)			
	0	1.25	2.5	3.75
FFB Yield (kg/palm)	141	202	226	249
FFB Yield (t/ha)	17.9	25.6	28.7	31.6
K uptake (kg/palm)				
Trunk	0.05	0.11	0.17	0.19
Frond 17	0.30	0.85	1.12	1.15
FFB*	0.52	0.75	0.84	0.83
Total	*0.87*	*1.71*	*2.13*	*2.17*
Recovery Efficiency (%)		66.5	50.2	34.5
Stepwise RE (%)			34.0	3.0
Agronomic Efficiency (kg/kg)		48.5	34.0	28.8
Stepwise AE (kg/kg)			19.5	18.3
Physiological Efficiency (kg/kg)		73.0	67.7	83.4

CONCULSION

As physiological efficiency is not strongly affected by the rate of supply, effort to increase Agronomic efficiency needs to be concentrated on improving recovery efficiency; that is, move effectively delivery of nutrients from fertiliser to roots.

The above calculations are likely to be an over estimate of efficiency as they do not take into account the amount of nutrient returned to the soil through pruned fronds. It is unlikely that these are completed accounted for by the nil control as the higher rates of nutrient supply results in higher concentrations of those nutrients in pruned fronds and therefore a higher amount of nutrient return to the soil.

MAXIMISING FERTILISER USE FOR OPTIMUM ECONOMIC RETURN

The agronomic optimum for fertiliser application is the amount of fertiliser that results in the maximum yield. Whereas, the economic optimum for fertiliser application is the amount of fertiliser that results in the maximum profit - where profit is the value of the palm products minus the costs to achieve those palm products.

Because there is a limit to yield in oil palm, there comes a point when additional resources such as fertiliser, do not result in a proportional additional yield increase. This is commonly known as the Law of Diminishing Returns. Thus there is also a point at which the cost of the additional resource is more than the value of addition product. At this point it is not worth investing in additional resource.

Factorial fertiliser trials are amenable to this sort of analysis, and are often the basis for determining standard fertiliser application rates. Tissue nutrient level can also be used to estimate response to fertiliser application if the appropriate "critical nutrient levels" for that nutrient is known. This information is usually used to adjust the standard fertiliser rates (supplemental fertiliser) according to the nutrient status of palms in that block.

As an example, trial 504 (NxK) was used to establish the Agronomic Optimum, and economic Optimum rates of fertiliser application. However rather than the critical nutrient level approach, a new technique called "target nutrient level" was used to adjust the standard fertiliser rate.

Trial 504 has 4 rates of N and 4 rates of K in all possible combinations (see Fertiliser Response Trials (Milne Bay Estates)) for details.

Agronomic Optimum

Yield response surfaces can be generated by finding the parameters to the following equation:

$$Yield = a + bN + cN^2 + dK + eK^2 + fNK$$

Where N and K are the rates of nitrogen and potassium respectively and NK represents the interaction.

Using multiple linear regression to obtain a, b, c, d, e and f, the resulting "yield surface" can be graphed (Figure 1). By differentiating with respect to N and K and then solving the simultaneous equations, the point of maximum agronomic yield can be obtained.

If the "yield" axis is now replaced by profit where:

Profit = value of yield – cost of fertilisers

Then the point of maximum economic yield can be obtained (Figure 2). Of course the profit will depend on both the value of the palm products and the cost of the fertiliser which will change with time.

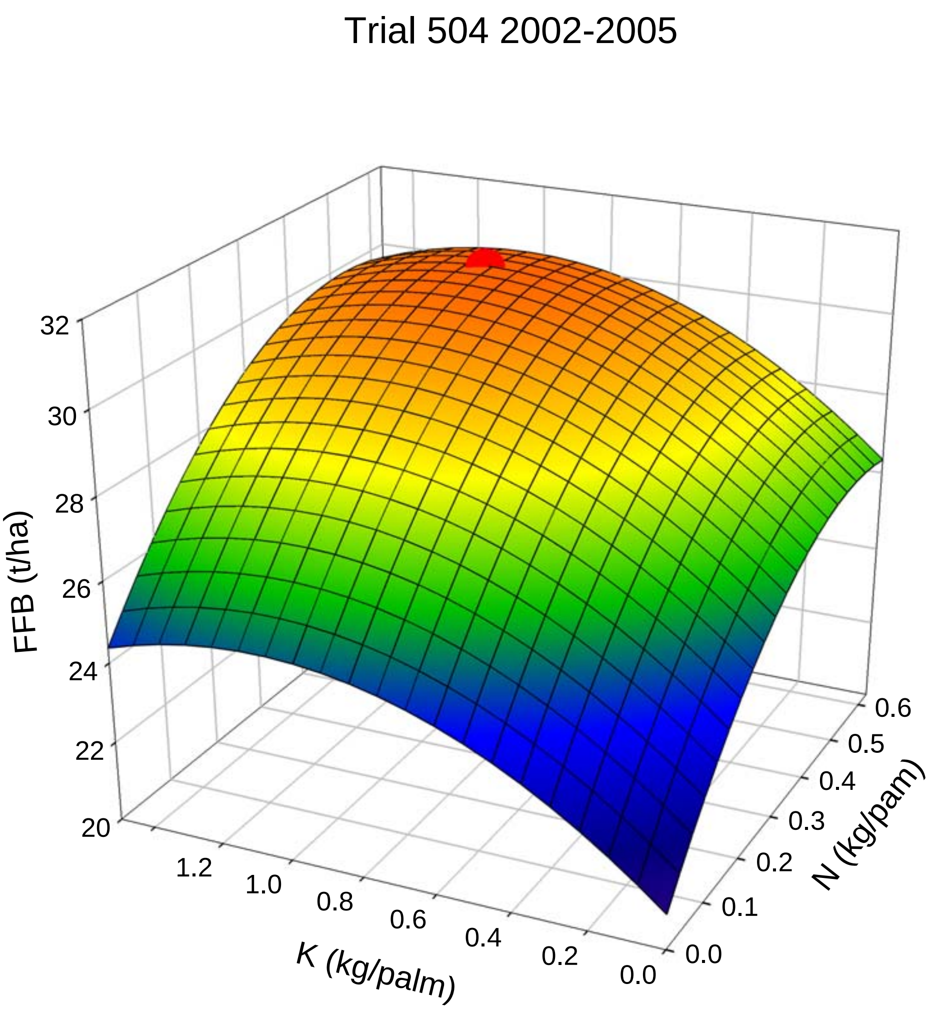


Figure 1: Yield response to N and K supply. The red dot represents maximum agronomic yield.

However, once the parameters for the yield surface have been determined (which will remain constant), the value, costs and economic optimum can be calculated in a spreadsheet (Figure 3).

This will provide the standard fertiliser rate for maximum profit at current prices.

By following a similar procedure of multiple linear regression with nutrient levels in relation to nutrient supply, it is possible to determine the nutrient level that corresponds to the economic optimum. This is called the “target nutrient level”.

Once the LSU nutrient analysis results are available the nutrient surface equations and parameters are then used to determine how much additional (supplemental) fertiliser is required to bring the palms up to the target nutrient concentration (assuming they are lower than the target) (Figure 4).

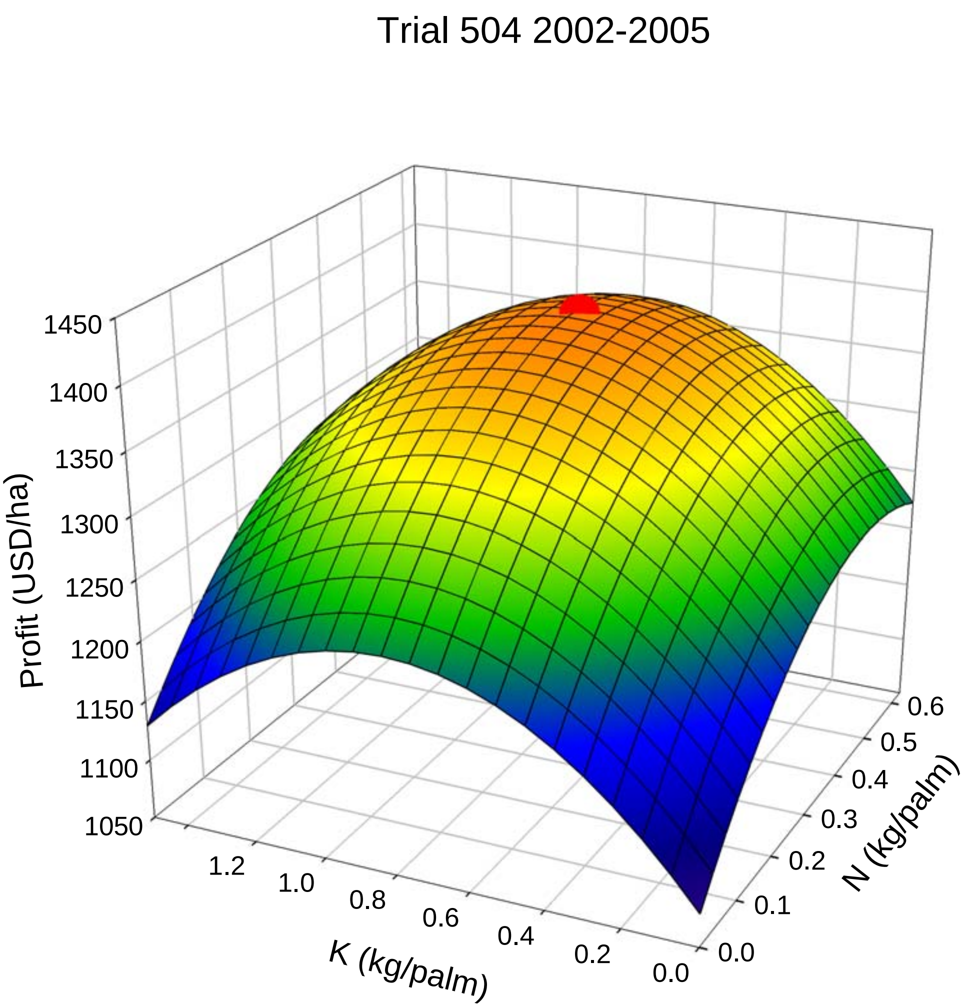


Figure 2: Profit response to N and K supply. The red dot represents maximum economic yield.

Inspection of figure 4 shows that the economic optimum target nutrient levels are 2.53 and 1.40 for leaflet N and rachis K respectively. Where the LSU analysis of either of these is below the target level (see blocks at bottom of table) the amount of fertiliser required to bring the palms to that level is calculated. For example, block 0007 has an N level greater than the target level so the fertiliser recommendation is simply the standard rate. However its K level is lower than the target, so a supplemental rate is suggested (1.06 kg KCl per palm), and this is added to the standard rate to give a recommendation (2.7 kg per palm).

Fertiliser Optimiser
Calculation of Agronomic and Economic Optima from long-term yield data and tissue analysis
Trial 504

Inputs

Oil Price (USD)	450
OER (%)	22
Palms/ha	127

Fertilisers	Source	USD/kg	% Element
N	SOA	0.25	21
K	MOP	0.35	50

Outputs

Value of PP 51.98 USD/t FFB

Agronomic Optimum

Element	(kg/palm)	Source	(kg/palm)
N	0.53	SOA	2.5
K	1.07	MOP	2.1
	(t/ha)		
Yield	30.5		

Economic Optimum

Element	(kg/palm)	Source	(kg/palm)
N	0.46	SOA	2.2
K	0.83	MOP	1.7
	(t/ha)		
Yield	30.2		

Figure 3. Front-end of a spreadsheet to calculate economic optimum fertiliser rates.

Fertiliser Optimiser
Calculation of Agronomic and Economic Optima from long-term yield data and tissue analysis
Trial 504

Inputs

Oil Price (USD)	450
OER (%)	22
Palms/ha	127

Fertilisers	Source	USD/kg	% Element
N	SOA	0.25	21
K	MOP	0.35	50

Outputs

Value of PP 51.98 USD/t FFB

Agronomic Optimum

Element	(kg/palm)	Source	(kg/palm)
N	0.53	SOA	2.5
K	1.07	MOP	2.1
	(t/ha)		
Yield	30.5		
	(%/DM)		
Target [N]	2.54		
Target [K]	1.48		

Economic Optimum

Element	(kg/palm)	Source	(kg/palm)
N	0.46	SOA	2.2
K	0.83	MOP	1.7
	(t/ha)		
Yield	30.2		
	(%/DM)		
Target [N]	2.52		
Target [K]	1.40		

LSU/Block	Leaflet	Rachis	Equivalent Supply Element		Fertiliser Requirement in Addition to Suggested Rate Agromic Optimum		Economic Optimum		Recommendations Trial Data	Trial Data
	[N]	[K]	N	K	SOA	MOP	SOA	MOP	SOA	MOP
0007	2.76	0.95	over range	0.30	0.00	1.54	0.00	1.06	2.2	2.7
0008	2.79	1.28	over range	0.65	0.00	0.84	0.00	0.36	2.2	2.0
0009	2.74	1.37	over range	0.79	0.00	0.56	0.00	0.08	2.2	1.7
0049	2.63	1.62	over range	over range	0.00	0.00	0.00	0.00	2.2	1.7
0065	2.79	1.67	over range	over range	0.00	0.00	0.00	0.00	2.2	1.7
0232	2.39	1.01	0.12	0.35	1.97	1.44	1.61	0.95	3.8	2.6
0249	2.37	1.18	0.08	0.52	2.16	1.09	1.81	0.61	4.0	2.3
0250	2.53	1.05	0.51	0.39	0.12	1.36	-0.24	0.88	2.2	2.5
0251	2.55	1.07	0.60	0.41	-0.32	1.32	-0.67	0.84	2.2	2.5

Figure 4. Front-end of a spreadsheet to calculate economic optimum fertiliser rates and recommended fertiliser rates.

ACKNOWLEDGEMENTS

This approach, as well as the mathematical techniques, were stimulated by a "session" with Dr Hugh Foster following the 2005 PNGOPRA SAC workshop.

2. ENTOMOLOGY RESEARCH[1]

(C. Dewhurst)

SEXAVA INTEGRATED PEST MANAGEMENT

As a direct result of the extreme seriousness and very widespread nature of the infestations in both the smallholder and plantation oil palms, a major effort was put into supporting the efforts to control the pests (see below); this resulted in a major inhibition of the research activity by the Entomology section. Visits were made by entomology staff to every reported infestation and written recommendations made, with advice and training given where needed. The majority of the infestations required trunk injection treatment. A much more structured and rigorous approach to the treatment decisions was discussed at the regular meetings (monthly at the Sexava Working Action Group (SWAG) held at Hargy Oil Palms, and weekly at the Sexava Action Group (SAG) held at OPIC Nahavio). As a result of the meetings, a more rigorous and aggressive treatment programme was recommended by PNGOPRA. This approach will remain a high priority until the situation is under control. It was agreed that this more pro-active approach was required if the problem was to be tackled effectively.

An issue of the OPRAtive Word Technical Note No.6 (Sexava Pests of Oil Palm) was distributed in January.

During 2005, there were 226 reports received of damage to oil palm by insect pests in West New Britain. Very few reports received from mainland PNG (none of which involved sexava); however New Ireland was also subject to infestations (including smallholders and plantations) by the native sexava (*S.gracilis*) and stick insect (*Eurycantha*).

One hundred and two (102) reports were received from plantations, while one hundred and twenty-four (124) reports were received for smallholders through the OPIC Divisional Managers. As PNGOPRA is required to visit every reported infestation, 108 individual visits were made; 59 were made to smallholders, (LSS and VOP) and 49 to plantations.

Some pest reports are however not being channelled through PNGOPRA, especially from Plantations, and it is therefore possible that reports of some taxa, especially non-insect pests (e.g. rats) are being under-reported.

Monitoring of all pests, and improving reporting and control techniques as well as treatment efficiency therefore continues to be a priority for operational research during the coming years.

Following the detailed sorting of original records during 2005, an analysis of the infestation reports revealed inconsistencies with the breakdown of reports, where some reports contained incidences of more than one clearly identified infestation. These discrepancies have now been clarified and the data which are routinely updated are more readily accessed and interrogated.

[1] **Note**: Until the end of April 2005, there was no Senior Entomologist at PNGOPRA.

Figure 1

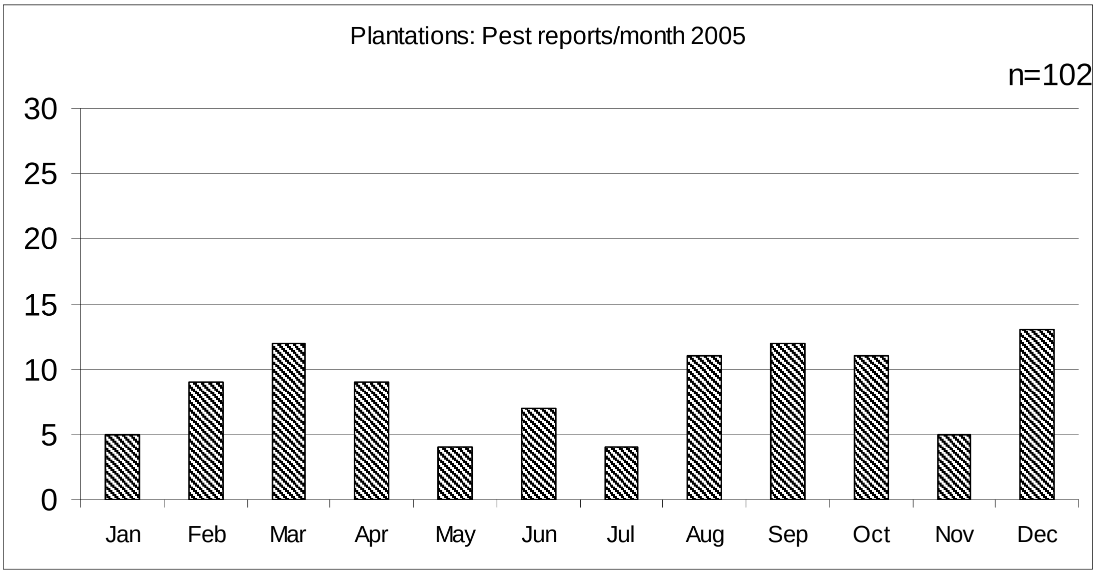


Figure 2

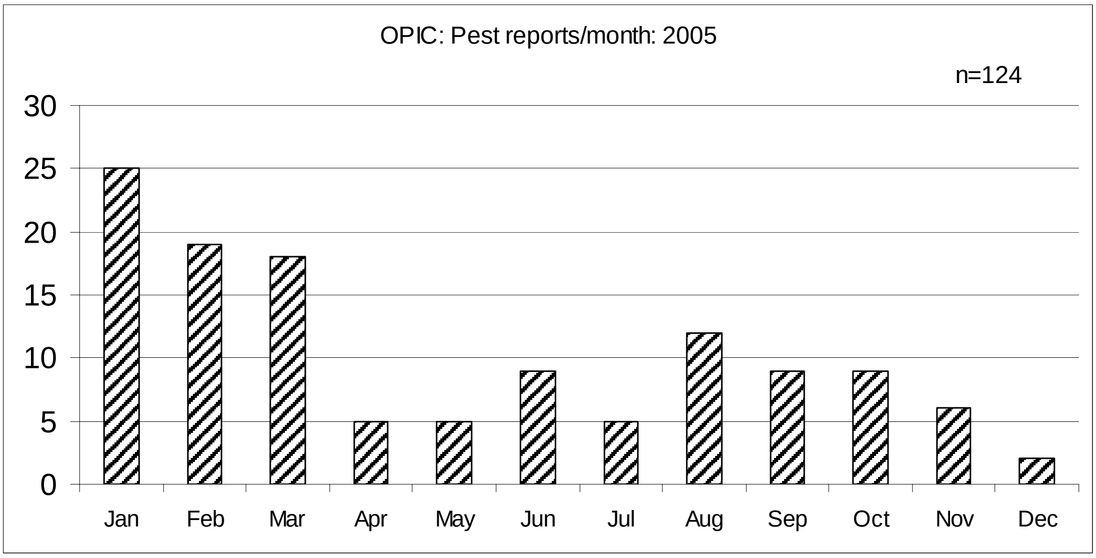


Figure 3

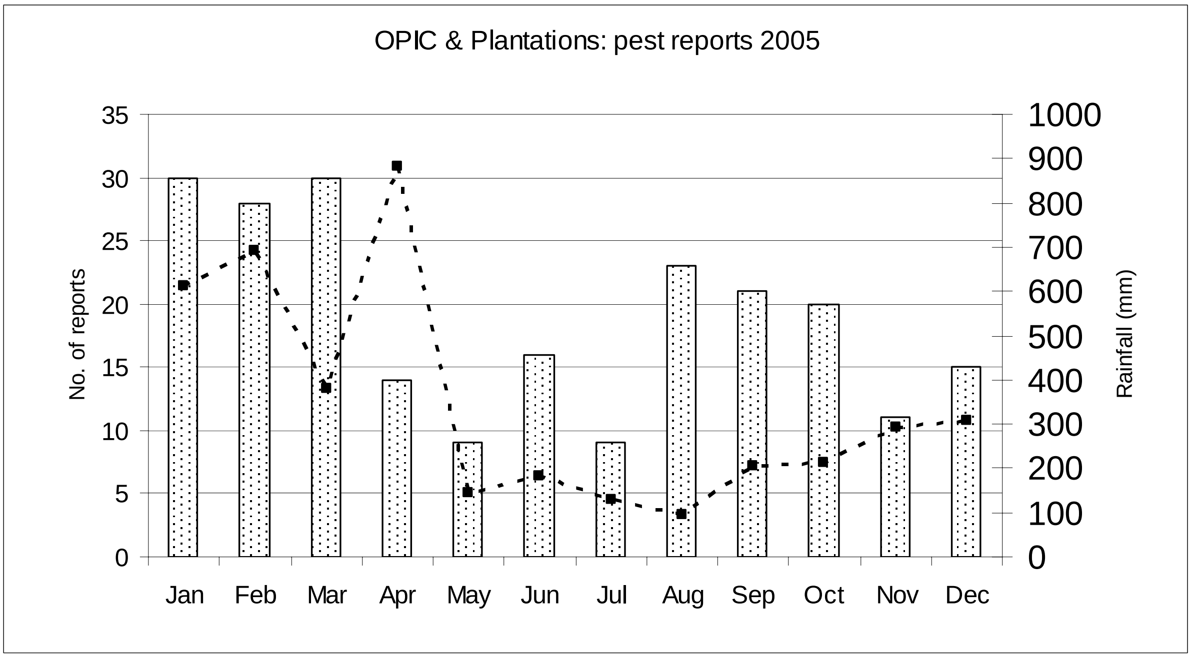


Figure 1 indicates a small build up of populations during the early part of the year followed by a similar rise later in the year in an almost bimodal pattern.

Figure 2 shows a much larger initial peak followed by a more noticeable drop in reports for the rest of the year, although numbers were still very high. A major problem identified was the often very poor state of sanitation in blocks, and the poorly coordinated responses to requests for treatment,

Figure 3 is a combination of reports from OPIC (smallholders) and plantations. It shows that when infestation data were combined from OPIC and Plantations that there was a marked seasonality of infestations reported, with higher numbers of infestations reported at the beginning of the year, during the wetter periods, and somewhat fewer infestations reported during the drier (often more windy) middle part of the year, rising again before the dry season ended. Neither the “sexava” tettigoniid grasshoppers nor the stick insects thrive under dry windy conditions, however the drop in infestation reports during that period are too rapid to be a response to rainfall, and may be explained by the effect of effective palm treatment operations during the drier periods. The subsequent rise in reports maybe due to the increasing rainfall and disruption to the treatment efforts; although this does not explain the sudden rise during August. Further analyses of these data to include rainfall for 2004 and subsequent data and rainfall for 2006 may explain these results.

Figure 4: Pest taxa recorded

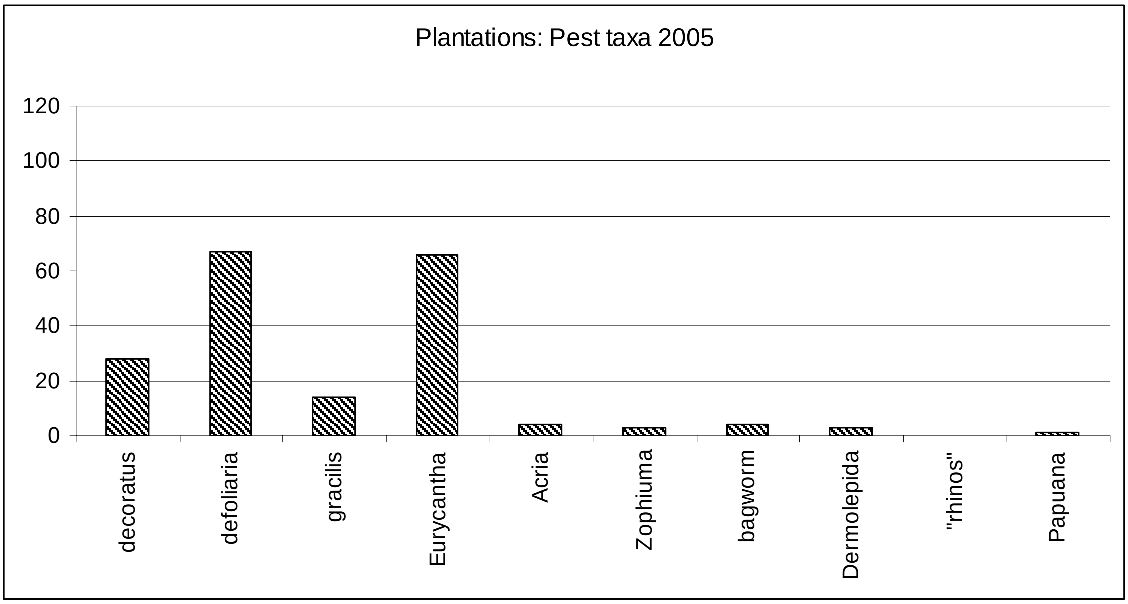


Figure 5: Pest taxa recorded

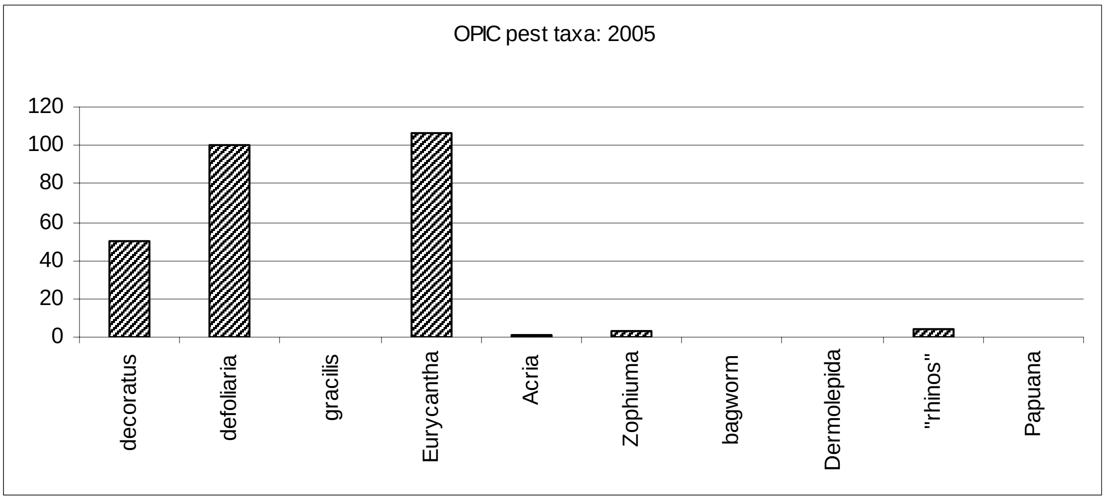
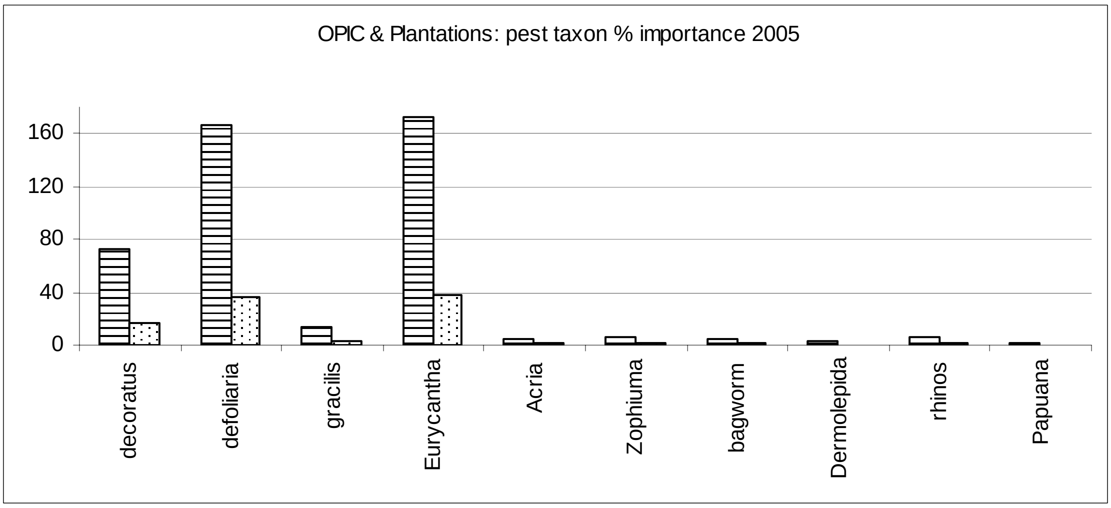


Figure 6. The presence and percentage importance of pest taxa reported.



The importance of the various pest taxa represented in the infestation reports was very marked. The tettigoniid pest, *S.decoratus* was reported much less frequently from West New Britain, and no reports of this insect were received from the mainland. The species was represented by 'all female' populations.

Segestidea defoliaria was exceeded in importance by the stick insect *Eurycantha calcarata*. The seemingly rapid rise in the importance of this stick insect cannot be explained at present, although the proximity of many infestations to the natural and riverine vegetation to the oil palm plantations is likely to be an important factor.

Plate 1.
A last instar nymph of *Eurycantha calcarata* showing the often very mottled colouring, acting as good camouflage.

On the CTP (PNG) plantations and smallholder areas of New Ireland, the "sexava", *Segestidea gracilis* infestations were widespread, and visits from PNGOPRA confirmed their presence. This insect is currently confined to New Ireland, and care must be taken to ensure that it does not move to other islands. Already *Eurycantha* has become a pest in oil palm on New Ireland.

Plate 2.
Male *Segestidea gracilis* from New Ireland. This insect is now a major pest on New Ireland

The PNGOPRA entomology section at Higaturu in Oro Province has been primarily concerned with continual monitoring of *S.novaeguineae* egg development (Figure 6), and there is now a strong correlation between egg weight and the size of developing sexava embryos. These data when used in conjunction with field collections of eggs and subsequent dissection will improve understanding of the developmental process in this insect.

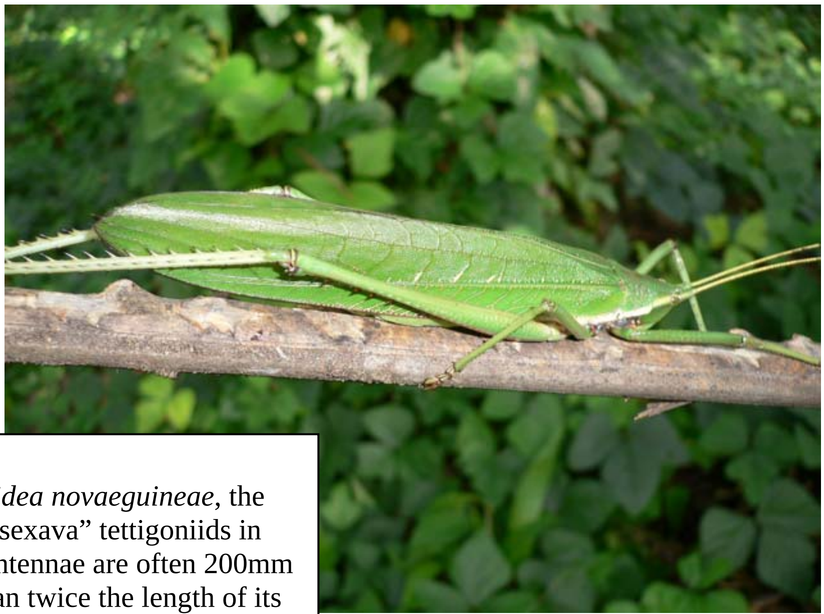
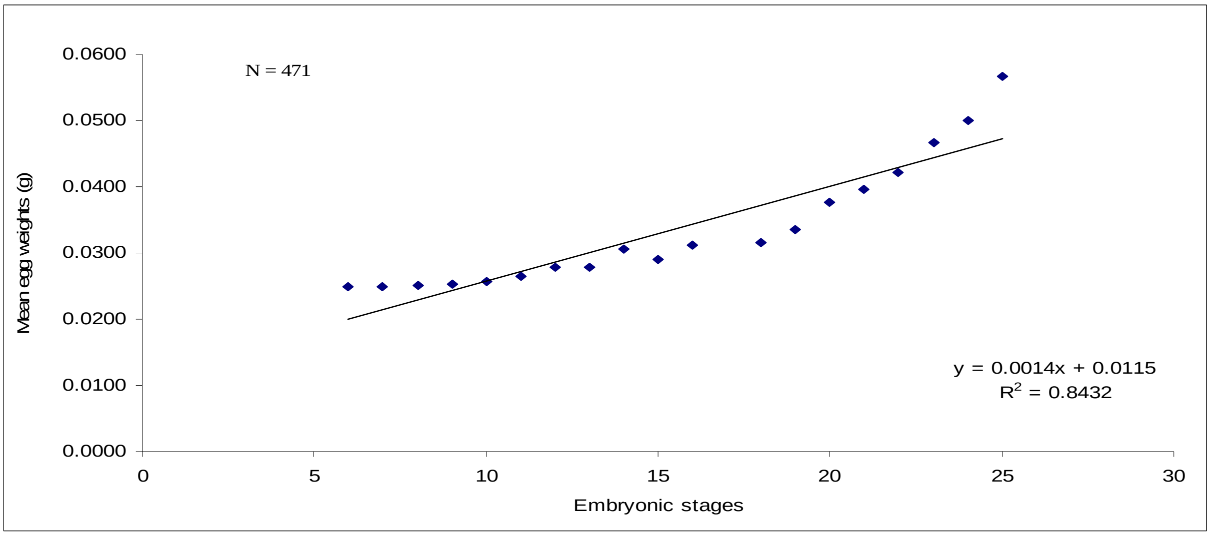


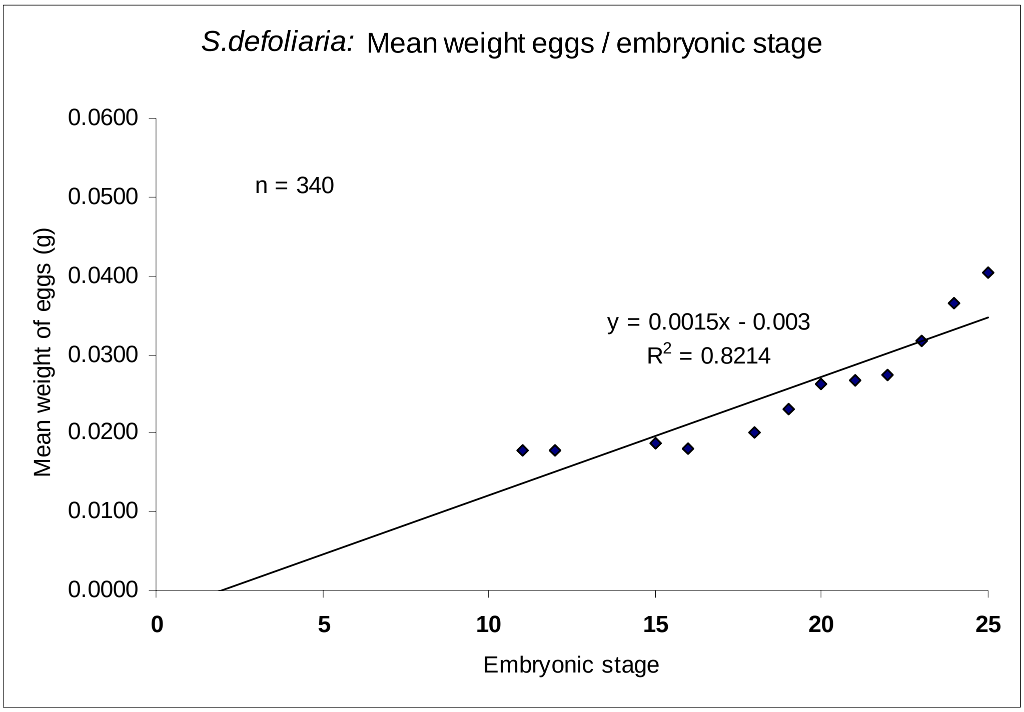
Plate 3.
A male *Segestidea novaeguineae*, the largest of the "sexava" tettigoniids in PNG, whose antennae are often 200mm long. (more than twice the length of its body).

Figure 7: *S.novaeguineae* mean egg weights (cumulative), and embryonic stages



Embryonic stages below size 7 are considered too small for accurate identification using a binocular microscope. (These data, for which there is a strong correlation between embryo size and egg weight, follow similar patterns to the studies done with *S.defoliaria* (Fig 7), however further data are required for both taxa found in West New Britain.

Figure 8: *S.defoliaria*, mean egg weights and embryonic stage



OTHER PESTS

The large stick insect, *Eurycantha* (Orthoptera: Phasmatidae) exceeded *S.defoliaria* as the most important oil palm insect pest during 2005.

This prompted the Entomology Section to begin studies on the biology of this insect. Although it attacks oil palm, it will feed on an array of plant taxa. It was reported by overseas entomologists (personal communication) that in captivity, this insect is highly polyphagous, and it has clearly become well adapted to feeding on oil palm.

All stages are highly mobile, the nymphs are well camouflaged, and like the "sexava" all stages remain concealed during the day, emerging at night to feed. Adults are very mobile, and are often seen crossing roads in PNG. This is a dispersal mechanism, as these insects are wingless.

Other pest taxa (except *Zophiuma* which is described below) were present in plantations and smallholder blocks, but as a very minor component (Figures 4 & 5) of the main pests. Four reports were received from OPIC Divisional Managers (smallholders) and 5 reports from plantations that consisted solely of other pests.

Although reports of the palm webworm, *Acria* sp. were localised, they were widespread from locations from where they were reported, typically occurring among palms 4-5 years or older (Plate 4).

The Powdery chafer beetle, *Dermolepida*, the rhinoceros beetle, *Scapanes*, the Taro beetle, *Papuana*, and bagworms were also recorded. There were six reported attacks by rhinoceros beetles in Village Oil Palms (VOP), the species was not confirmed, but more than likely to have been *Scapanes australis* ssp. *grossepunctatus*). None of these pests required any control actions. There were no reports of rats received during 2005; however it is possible that they are not being reported as a routine to PNGOPRA.

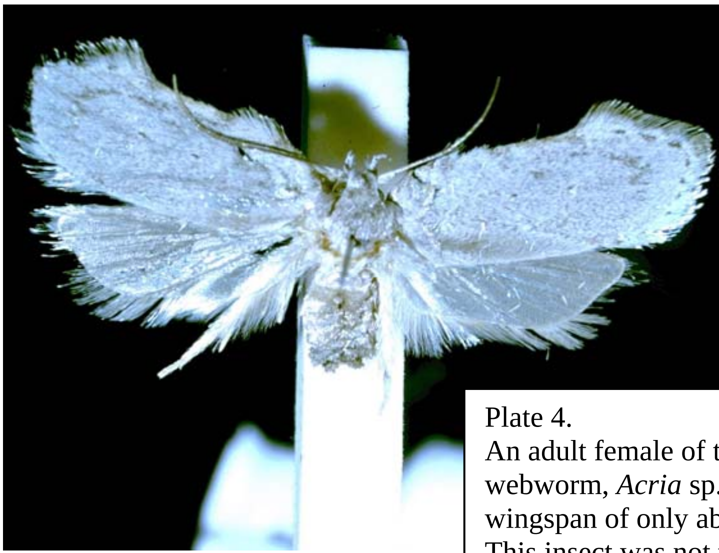


Plate 4.
An adult female of the Oil palm webworm, *Acria* sp., which has a wingspan of only about 15-20mm. This insect was not treated during 2005.

BIOLOGICAL CONTROL USING THE STREPSIPTERA PARASITOID *STICHOTREMA DALLATORREANUM* (PLATE 5).

The collection and release of sexava infested with the Strepsiptera (*Stichotrema*) parasitoids continued during 2005. Infested material was released into the plantations (plantation and smallholder), as it become available. In the central part of the island of West New Britain, no recoveries of infested material were made, although populations further east were readily available. When sexava are infested with a number of parasitoids, the host dies before the parasitoids are able to mature and release the 1st instar larvae.

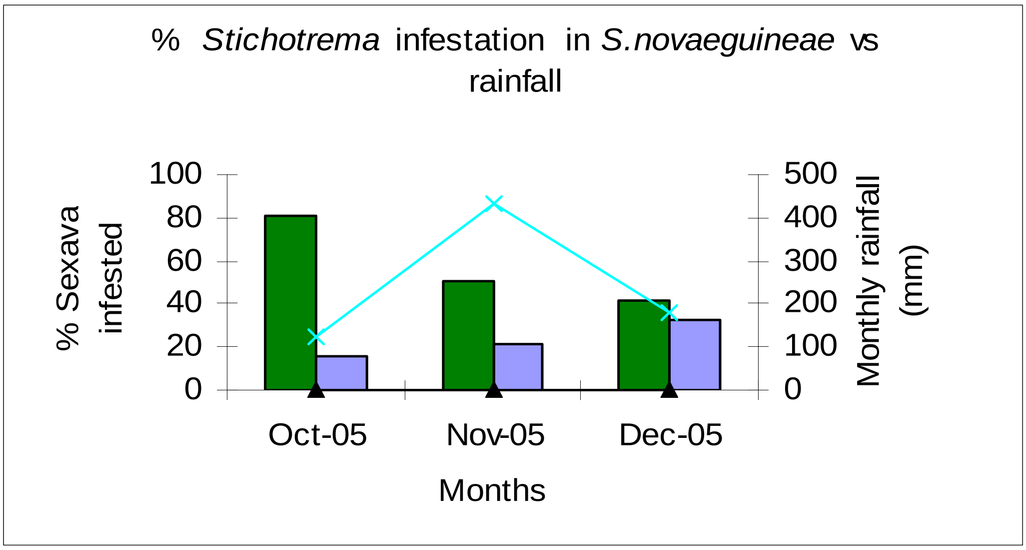
Plate 5.
Immature females of *Stichotrema dallatorreanum* removed from host abdomen. More than 80 females of differing sizes have been found in one *S.gracilis*. The parasitoid is unlikely to mature if more than two occur in any one host. The host will die, as will the parasitoids. The larger female in this photograph is not mature enough to bore out of the host abdomen. This species is parthenogenetic.

Although the first instar larvae of *Stichotrema* are known to infest the two other species of sexava occurring in oil palm (*S decoratus* and *S.gracilis*). The full life cycle in these hosts have not been completed successfully (in the laboratory), although regular infestation is readily obtained.

Stichotrema infested sexava are regularly re-distributed in suitable localities (particularly in gulley vegetation) at Hargy Oil Palms by plantation staff. A programme to increase the build up and concentration of infested sexava by building more cages will be continued during the year, and is likely to remain an on-going exercise.

The data collected from Koropata, near Higaturu on the PNG mainland (which began in October), showed that infestation levels were between 16-33%.

Figure 9: *Stichotrema* infestation of *S. novaeguineae* recorded from Koropata monitoring site.



BIOLOGICAL CONTROL OF SEXAVA USING EGG PARASITOIDS.

Laboratory populations of both taxa (*Doirania leefmansi*- Hymenoptera: Trichogrammatidae and *Leefmansia bicolor*- Hymenoptera: Encyrtidae), were built up during 2005. The use of lamp glasses for the rearing of parasitoids, and the methods for adult parasitoid extraction is very laborious, and other methods are being investigated.

Plate 6.
Joined lamp glasses with parasitised host eggs (r) & unparasitised eggs. The black plastic sheet covers the parasitised eggs, and the adults move towards the light (from r-l).

All adult parasitoids are all fed prior to their release in the field, a process which greatly improves their chances of survival.

These insects are minute, with *D.leefmansi* having a wingspan of less than 2mm. *L.bicolor* is larger, and is well marked with white antenna tips and a dark fore wing fascia, which is more pronounced in the female.

Plate 7 (*D.leefmansi*) (magnified) Plate 8 (*L.bicolor*) (magnified, female arrowed).

The nectar source flower project being undertaken by the Dami Oil Palm Research Station (OPRS) with support from PNGOPRA will greatly benefit the parasitoids, as nectar producing plant biodiversity remains poor in plantations and smallholder blocks. Advice was provided on suggested taxa for trials.

During 2005, ca. 73,932 *D.leefmansi* were released and 55,832 *L.bicolor* were released. All egg parasitoid cultures on New Ireland were lost, and work is required to re-instate colonies there.

WEEVIL POLLINATION OF OIL PALM

Plate 9. Male *Elaedobius kamerunicus* showing characteristic "humps" and hair tufts on elytra

The narrow genetic base of the weevil population (from an original importation of 1000 pupae brought into PNG from Malaysia on 10 November 1980) could have meant that there was a risk of in-breeding suppression, as well as vulnerability to infection by pathogens and parasites.

Following a concern expressed about the genetic base of the existing pollinating weevils throughout PNG, the introduction of new material from Africa was developed. Contact was made with a potential collaborator on this project in Ghana, West Africa during November; however he was expected to remain overseas until the end of March 2006.

This project will be in collaboration with an entomologist from the University of the Cape Coast to confirm the presence of *Elaedobius kamerunicus* in Ghana, to identify areas for collection of nematode-free/low infection weevils of the correct species and to set up the procedures for screening and rearing of the weevil. Endo-and ecto parasite-free weevils will be brought into PNG for mass rearing and subsequent release in selected areas of PNG.

A visit will be made to West Africa in 2006 to source weevil material and set up monitoring protocols before the surface sterilised pupae are brought back to PNG.

Fruitset monitoring at the Kumbango site in West New Britain continued during 2005, until December when the experimental data collection ceased. Data sheets were sent to the overseas consultant regularly. The long-term data collected from Mamba Estate in Oro Province (Higaturu Oil Palms) was collated and sent to the consultant for analysis, as agreed under the EU funded Pollination project. Tentative conclusions show clearly the positive relationship between the presence of the male flowering spikes and the numbers of *E.kamerunicus* weevils, as well as the fact that some palms continue to produce good FFB even following periods of rain.

Additional work on weevil trapping was suspended as the trapping methodologies failed to provide the results needed for analysis as the traps failed to catch sufficient weevils, and the losses suffered from rat damage to the trapped insects invalidated the data.

Surveys of the spatial distribution of the weevil parasitic nematodes in relation to weevil populations and biotic factors.

Monitoring of *Elaedobius* weevil populations from five sites on the mainland continued during 2005 (Fig. 9) and infestation of by nematodes during December were generally low at 12-14%, with two sites where rates were between 6-8%.

Study of the proportions of male and female weevils in relation to nematode infection.

Figure 10: *E.kamerunicus* and nematode infestation rates from mainland PNG December 2005

Locality	Overall % infestation	% Males infested	% Females infested
Komo	12.0	13.6	10.7
Saga	14.0	11.1	15.6
Ambogo	12.0	14.3	10.3
Parehe ME	8.0	11.1	6.3
Embi ME	6.0	4.8	3.5

N = 50 per site dissected

Figure 11: Male and female weevil numbers from Haella, Division 1: October 2003 – July 2005 WNBP

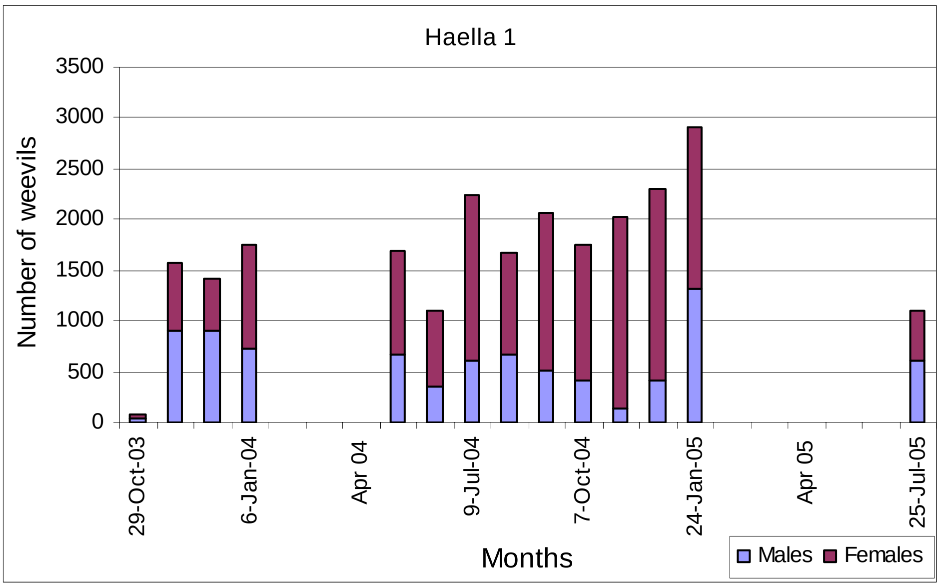
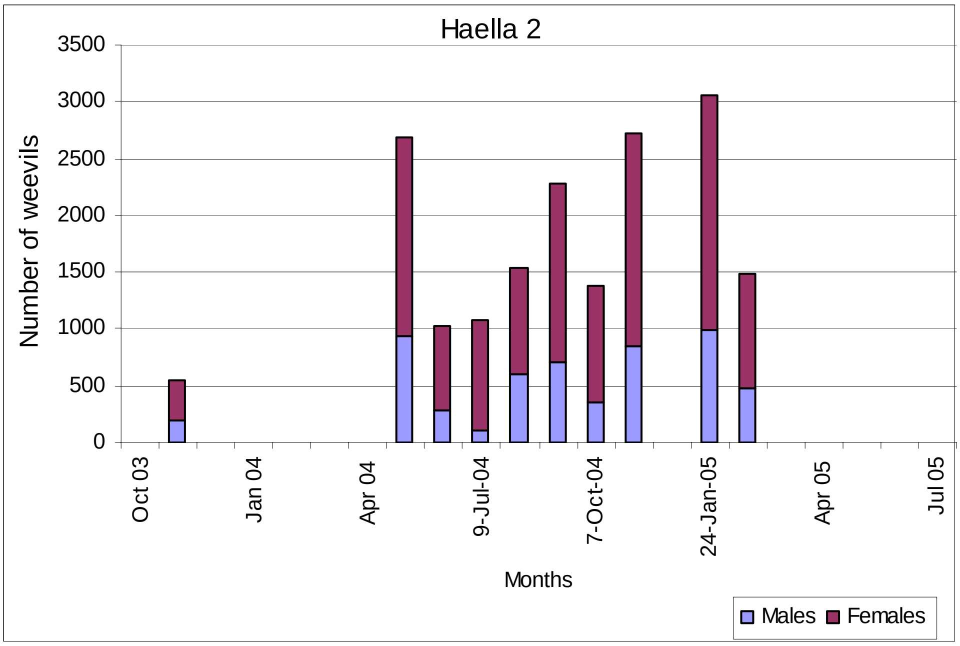


Figure 12: Weevil numbers from Haella, Division 2, October 2003 – Feb 2005, WNBP



Although these data are primarily for earlier years, the weevil sorting was undertaken in 2005.

The data from mainland PNG showed that the infestation rates were similar for males and females.

Figures 9 & 10 show data from weevil samples collected from the surface of male spikelets at Haella plantation (WNB). The preponderance of females at these sites is a clear indication of their value as breeding sites, with large numbers of females present. Weevils that are reared from spikelets on the other hand show a typical 1:2 ratio of males to females.

The Final Project report from CAB International described the life cycle of the nematode under laboratory conditions; however no further work has been done in a field situation.

Training continues on an *ad hoc* basis, and regular informal discussions are held during field visits.

CONSERVATION OF THE QUEEN ALEXANDRA'S BIRDWING BUTTERFLY (QABB).

Work continued in assisting Higaturu Oil Palms, the Department of Environment and Conservation (DEC) and the Oro Provincial Wildlife Office (PWO) in the collection and propagation of cuttings of the QABB larval food plant, the vine *Pararistolochia dielsiana* (sic!).

Monitoring surveys for QABB

Two sites where the monitoring of tagged vines was being undertaken in Northern (Oro) Province at Pahumbari (48 vines), and Parehe (50 tagged vines) were destroyed by subsistence gardening activity. At Voivoro, where there were 109 tagged vines, six were confirmed as having hosted QABB, however three pupae were apparently stolen (the supporting branches had been broken off) two others hatched, and the fate of the last one was unknown.

Plate 10
Pupa of *Ornithoptera alexandrae*
Voivoro

Only 20 of the tagged vines survived, as increased natural vegetation growth appeared to have resulted in fungal attack which killed the vines.

A visit was made to Popondetta by the Senior Entomologist to assess and further develop the work done so far, and to plan for the immediate future to continue the process of QABB re-establishment.

Contact was made with Dr Don Sands in Australia, who has had a great deal of experience working with birdwings in general, and also specifically with QABB, and a visit is planned to meet him in January 2006.

FINSCHHAFEN DISORDER: LEAFHOPPER INTEGRATED PEST MANAGEMENT

Feeding activities by the leafhopper (*Z. lobulata*) are strongly implicated in the development of Finschhafen Disorder; however the nature of the disorder is unclear. The principal concern about this disorder is that, as areas of oil palm increase in close proximity to coconuts, the leafhoppers will move on to oil palm, as has already been seen is some places such as Kapiura on West New Britain. Biotypes may develop which may thrive on oil palm and be able to reproduce in large numbers, spread throughout plantations, resulting in photosynthetic loss a subsequent reduction in oil palm seeds, and subsequently, palm oil production.

Plate 11. Adult *Zophiuma lobulata* (Homoptera: Lophopidae), the causal agent of Finschhafen Disorder

Control of the disorder is therefore dependent on the effective IPM of *Z. lobulata* populations.

The agent of Finschhafen Disorder (*Zophiuma lobulata*) was reported four times among plantations (Kautu–February, Walindi Rd.-June, Navo-June, Ambogo-August) and three occasions among smallholder blocks (Kwalakesi VOP-March), Kandori VOP–April, Ganeboku VOP-April). On no occasion was control recommended.

There were no reports of the Finschhafen Disorder from smallholder Land Settlement Schemes (LSS).

The PNGOPRA Entomology Section on the mainland (Higaturu) continued to monitor areas (Ambogo, Embi and Igora). At Igora a plot of 60 oil palms was monitored and symptoms were observed at varying times between weeks 1 and 18. At this site, the insect was found, however populations remained stable, and no treatment was recommended. Spiders were observed to be important predators of the nymphal stages in the walk-in cage. This disorder could still become a potential threat to the industry and further work is urgently required.

WEED PESTS USING INSECTS AS BIOCONTROL AGENTS.

Mimosa

The redistribution of Psyllid bugs (Hemiptera: Ciriacreminae- *Heteropsylla spinulosa*) as biological control agents, into areas where *Mimosa diplotricha* (= *M.invinsa*) was invading oil palm plantations and smallholder blocks continued during the year, and at three sites (Ambogo, Sumbiripa and the plantation nursery), plants were controlled or produced very stunted tips).

Chromolaena

The gall fly (Diptera: Tephritidae- *Cecidochares connexa*) has spread and has now become well established around Popondetta, Hongoho, Kokoda and Girigirita and Girua bridge, and will continue to be redistributed from reservoirs into new areas on mainland PNG to suppress *Chromolaena odorata*. The gall flies have also been established at Ramu Sugar Ltd. in the Markham Valley.

Further attempts to introduce the fly into West New Britain by NARI were successful in some areas, but in other places it has currently failed to become established. Small numbers of galls have now been brought into West New Britain Province by the Entomology Section through NARI, and the area of release is being monitored.

Plate 12: Siam Weed, *Chromolaena odorata* which has a number of galls developing on the stems.

Figure 13: *Chromolaena* records and release sites (2005)

12-Jan-05	West New Britain	Rikau (site 2)	Along roadsides and in oil palm blocks			12-Jan-05	Yes
13-Jan-05	West New Britain	Kabaia	In oil palm blocks, along the roadsides and in gardens			13-Jan-05	Yes
13-Jan-05	West New Britain	Kavui	Continuous along roadside			13-Jan-05	Yes
13-Jan-05	West New Britain	Lalopo	Along roadside			13-Jan-05	
13-Jan-05	West New Britain	Lavege (Bridge)	Along roadside and on hillsides			13-Jan-05	Yes
13-Jan-05	West New Britain	Malilimi	Along roadside			13-Jan-05	Yes
13-Jan-05	West New Britain	Sale/Sege (site 1)	Along roadside			13-Jan-05	No
25-Feb-05	Oro	Iora	Huge infestation near Kokoda track	?	?	25-Feb-05	
06-Mar-05	West New Britain	Ganeboku	Clumps in gardens, on hillsides and along the roadsides			06-Mar-05	
06-Mar-05	West New Britain	Namova	Clumps in gardens, on hillsides and along the roadsides			06-Mar-05	
07-Mar-05	West New Britain	Gavaiva	Under coconut plantation and along roadside			07-Mar-05	Yes
08-Mar-05	West New Britain	Galai	Along roadside				
08-Mar-05	West New Britain	Hargy, Area 3, Block 5	Patches along edge of oil palm			08-Mar-05	No
08-Mar-05	West New Britain	Koasa River	Patches along roadside			08-Mar-05	No
08-Mar-05	West New Britain	Lavege Village Oil Palm	On hillside among other vegetation			08-Mar-05	Yes
08-Mar-05	West New Britain	Sale/Sege (site 2)	Patches along roadside			08-Mar-05	Yes
08-Mar-05	West New Britain	Soi	Patches along roadside			08-Mar-05	Yes
08-Mar-05	West New Britain	Ulamona	Scattered plants in oil palm blocks				
18-May-05	Oro	Mt. Lamington	Reported by Ross Safitoa (OPRA Popondetta)				
13-Sep-05	Oro	Girigirita	Reported by Ross Safitoa (OPRA Popondetta)			Natural spread	Yes

Mikania micrantha

A collaborative project for the biological control of this invasive (“mile-a-minute”) weed has been developed by the Queensland Department of Natural Resources and Mines, and ACIAR. This will involve PNGOPRA Entomology over a three year period on the control of the “mile-a-minute” weed, (Project No: CP/2004/064). It is unlikely to begin until 2007.

OIL PALM PEST SPECIES RECOGNITION

Funding was approved by AIGF for a project entitled, “Development of major (oil palm) pest recognition tools for smallholder groups and oil palm producing companies”. (Project number AIGF 1107).

Work on this project began during Q2 of 2005. Proposed display cabinets were designed and the Riker material ordered after a great deal of searching.

DEVELOPMENT OF A FIELD MANAGERS “TOOL KIT”

This will act as an *aide memoire* for Managers when going into the field for a variety of tasks, to ensure that the right equipment is taken with the vehicle. Drafts of the tool box should be available for distribution for comment in March 2006.

3. PLANT PATHOLOGY RESEARCH

(C. A. Pilotti)

INTRODUCTION

The focus of the research within the Plant Pathology Section is the long-term control of basal stem rot in all plantations and smallholder areas of PNG and the Solomon Islands. The project has been funded by the European Union and will cease in 2006 except for the research on the bio-control agent *Trichoderma* which 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 time was also spent on the development of a technique for screening of resistance of oil palm to attack by *G. boninense*.

Research activities in 2005 were fulfilled according to the research programme with additional unplanned work being undertaken at the request of individual PNGOPRA members. A summary of the activities of the section in 2005 is provided in Figure 1.

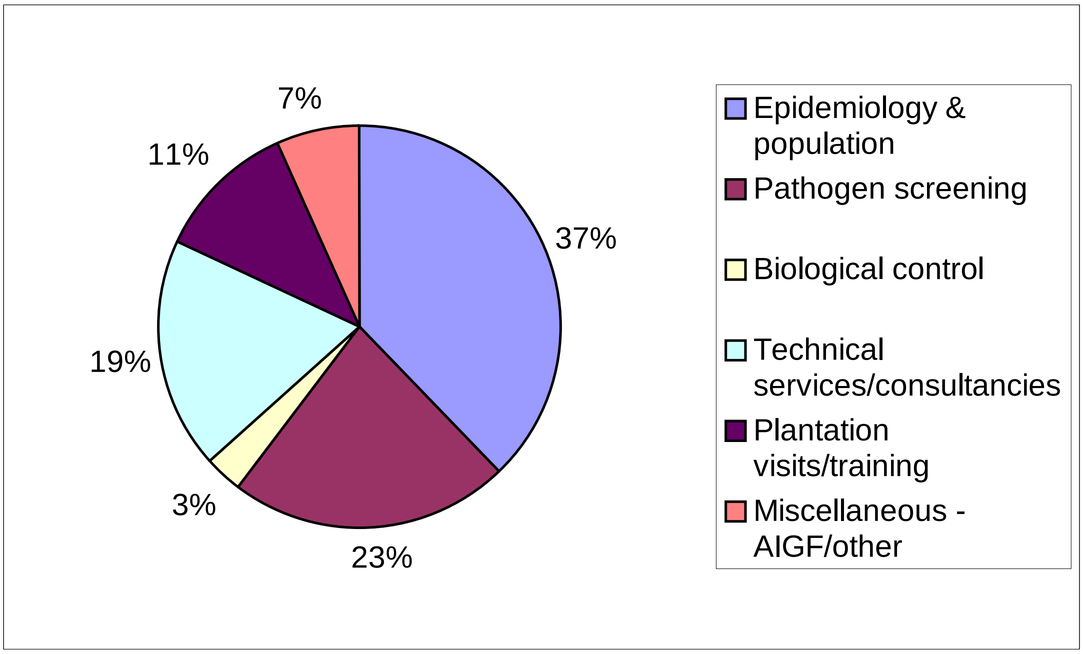


Figure 1. Proportion of different activities carried out by the Plant Pathology Section in 2005.

Quarantine issues took up the bulk of the Technical Service activities in 2005 with a small proportion of time allocated to OPRAtive technical notes and other publications. Miscellaneous activities included the drafting of a poster on diseases of oil palm in PNG which was funded under the AusAID financed Agricultural Innovations Grant Facility (AIGF). All plantations were visited at least once in 2005 by the Senior Plant Pathologist.

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 models from survey data that will allow growers to make predictions of crop loss and economic thresholds in future plantings.

Introduction

Studies on the epidemiology of basal and upper stem are essential for the long-term control of this disease. These studies enable improved management strategies in terms of cost as well as minimization of disease levels in current and future plantings. They also provide means by which predictions of crop losses may be made in future generations. Ideally such studies should also provide information on the effectiveness of short-term control strategies but within PNG this is difficult since most plantations have controls in place making comparisons difficult.

The epidemiology of basal stem rot is studied through the use of survey data compiled by plantations as well as thorough surveys carried out by PNGOPRA staff in designated study blocks in Milne Bay.

Milne Bay

Disease progress

Disease levels expressed as diseased palms/ha in all blocks with palms 6 years and older are shown in Figures 2 to 9. In Giligili Division, the majority of blocks had higher levels of palms with Ganoderma brackets present at the time of survey. Only 8 blocks had a higher number of palms without brackets (suspects). The levels of upper stem rot were generally low except for Block 7101 where the number of palms with upper stem rot exceeded that of the palms with basal stem rot.

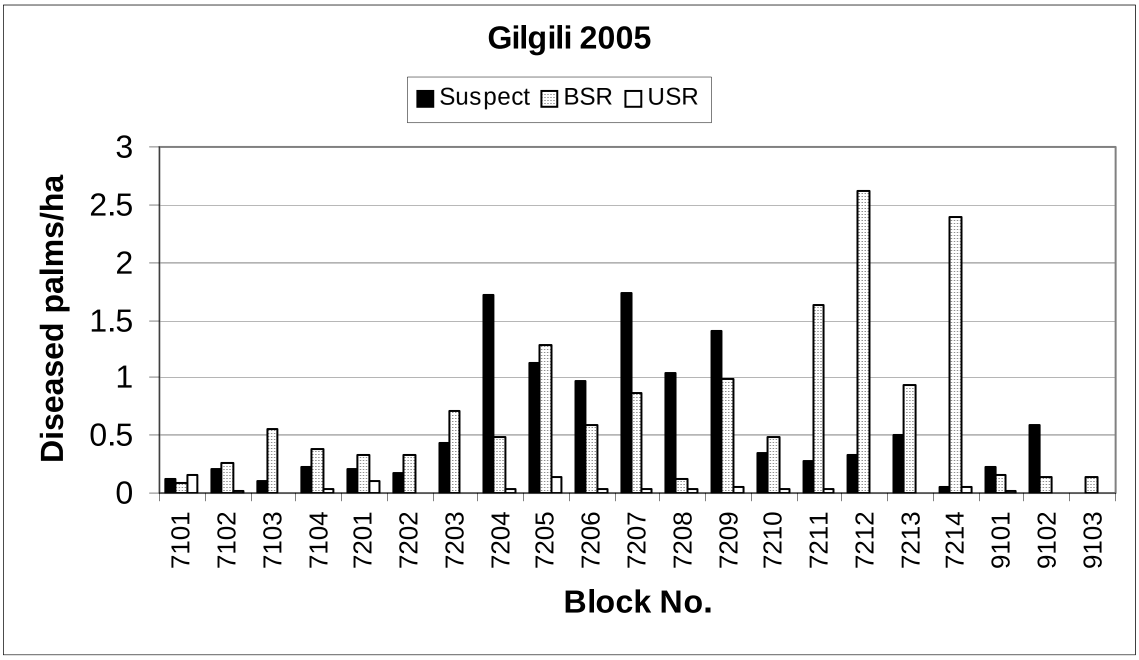


Figure 2. Disease incidence for 2005 in Giligili Division, Milne Bay by category. BSR= basal stem rot; USR = upper stem rot; Suspect= no brackets.

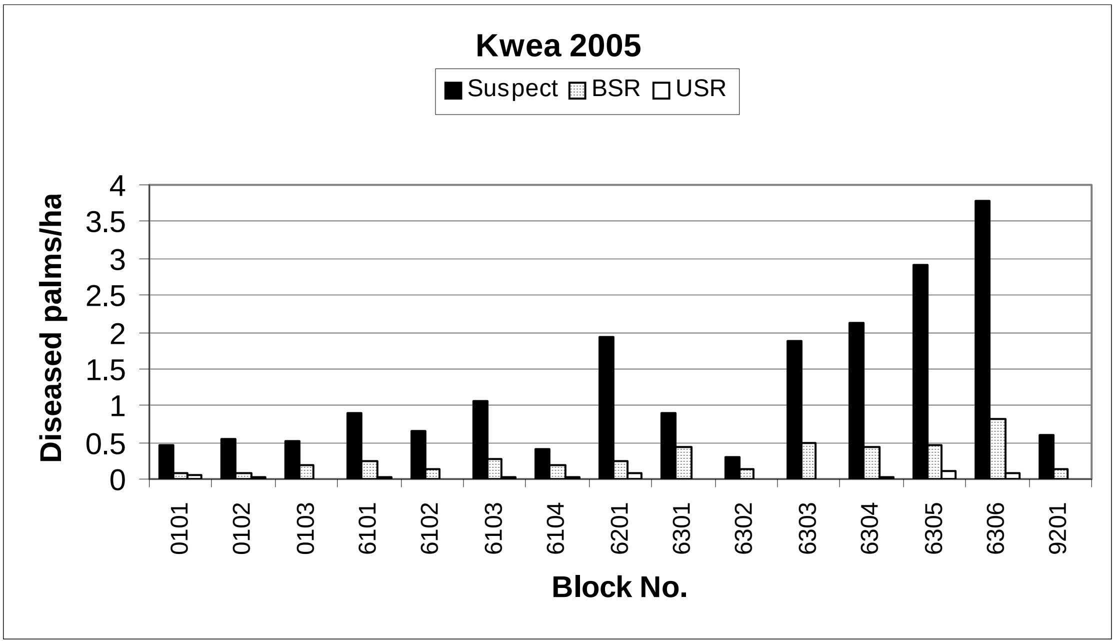


Figure 3. Disease incidence for 2005 in Kwea Division, Milne Bay by category. BSR= basal stem rot; USR = upper stem rot; Suspect= no brackets

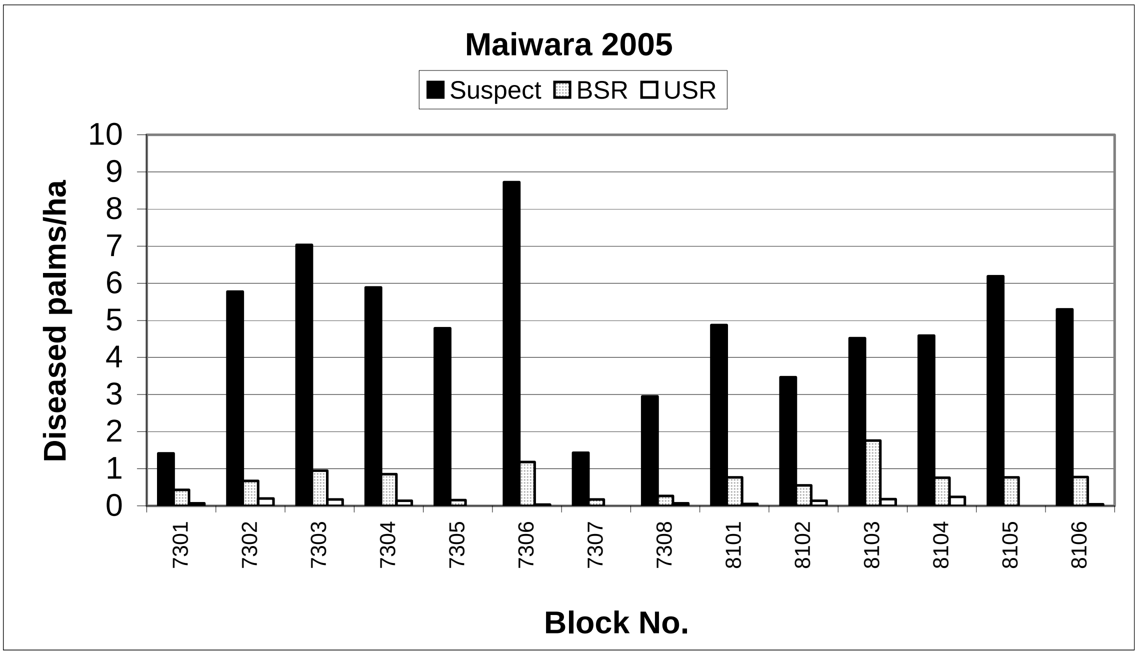


Figure 4. Number of palms affected by disease in 2005 in Maiwara Division in Milne Bay. BSR=basal stem rot; USR= upper stem rot; Suspect=no brackets present

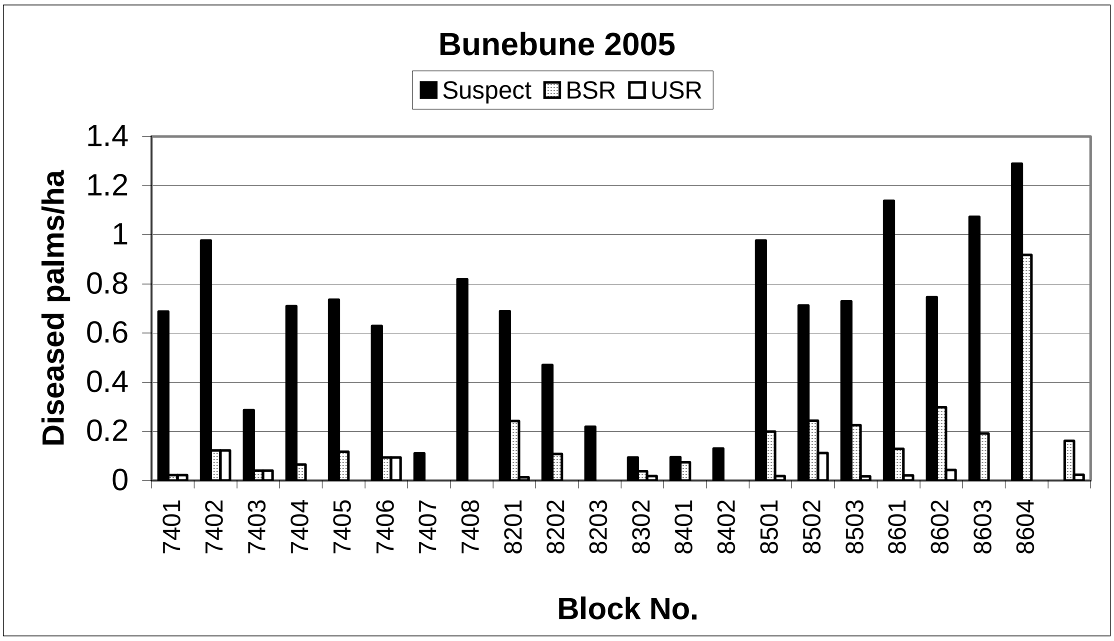


Figure 5. Number of palms affected by disease in 2005 for Bunebune Division blocks, Milne Bay by category. BSR= basal stem rot; USR= upper stem rot; Suspect= no brackets.

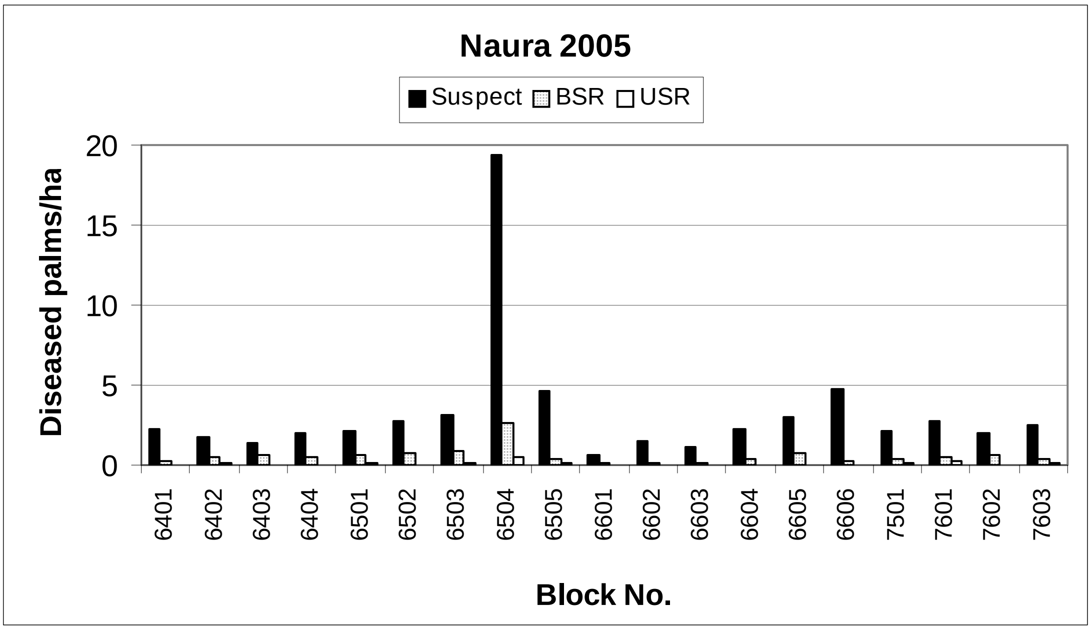


Figure 6. Number of palms affected by disease in 2005 for blocks for Naura Division, Milne Bay by category. BSR=basal stem rot; USR=upper stem rot; Suspect = no brackets.

In contrast, 100% of blocks in Kwea division with palms of similar age had higher numbers of palms without brackets present (Figure 3). Similarly, there was a higher frequency suspects compared to palms with brackets in all the other Divisions with palms of different ages(Figs 4-9). The reasons for this are unknown but could be the normal trend for this stage in the epidemic.

The highest recorded loss due to Ganoderma infection in 2005 was in Naura Block 6504 with almost 20palms/ha being identified as new infections. A large percentage of these were also suspect palms. A review of this block will be made in 2006.

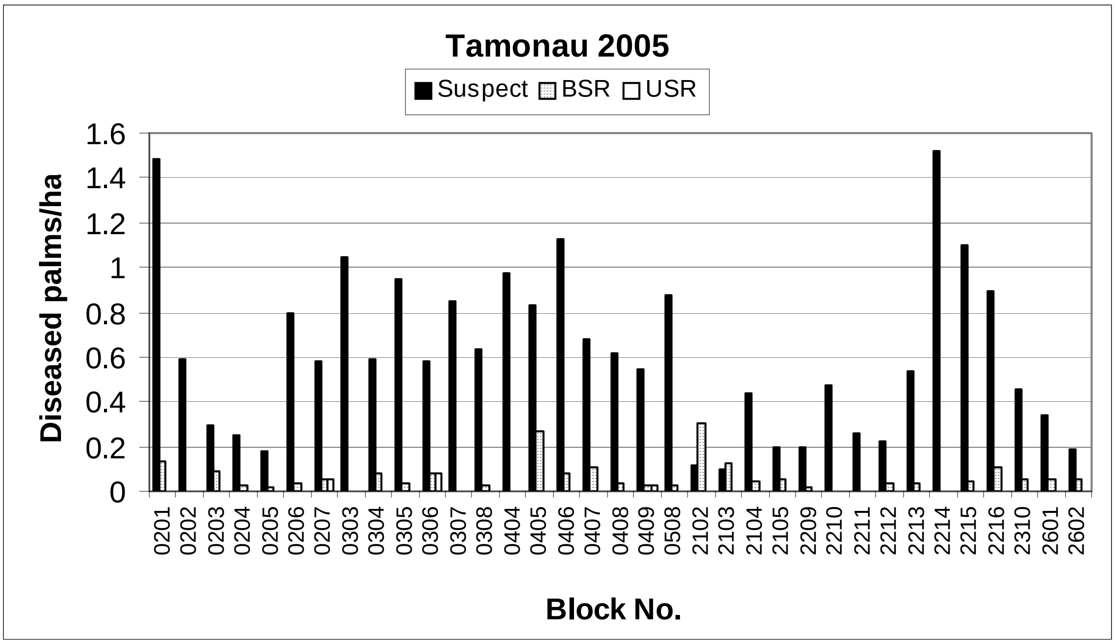


Figure 7. Number of palms affected by disease in 2005 in Tamonau Division, Milne Bay for 2005. BSR = basal bracket; USR= upper stem bracket; Suspect = no brackets

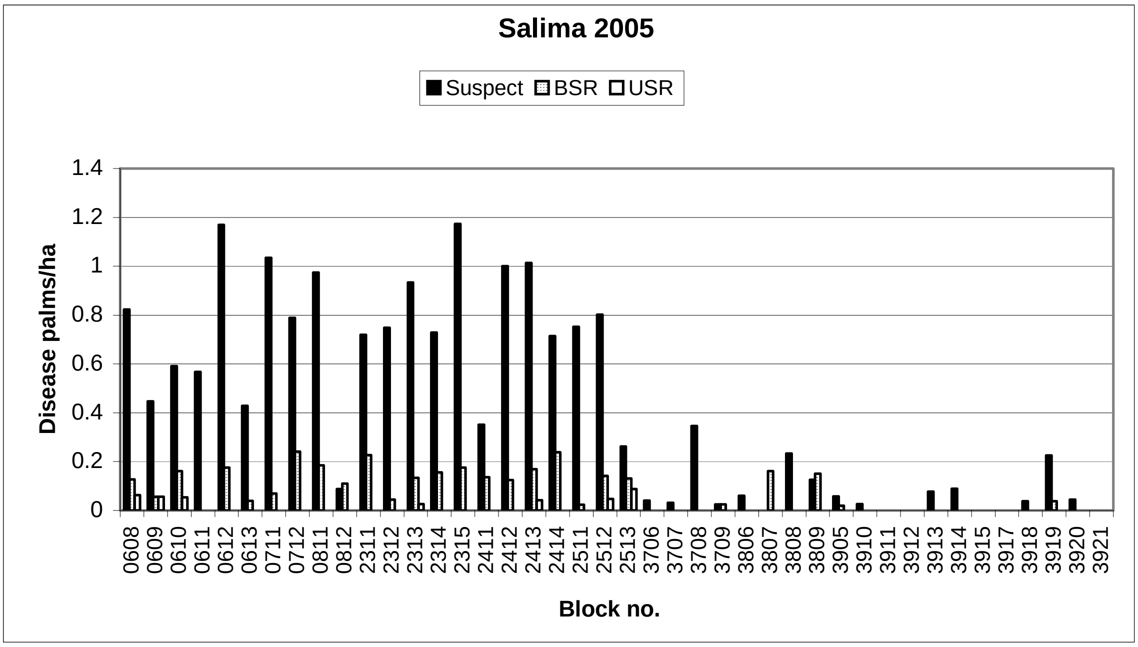


Figure 8. Number of palms affected by disease in 2005 for Salima Division in Milne Bay by category. BSR=basal bracket; USR=upper stem bracket; Suspect= no brackets

Only a single palm in Mariawatte Division had brackets present (Figure 9). All other palms were recorded as suspects. Disease incidence is still very low in this Division as the palms are still young.

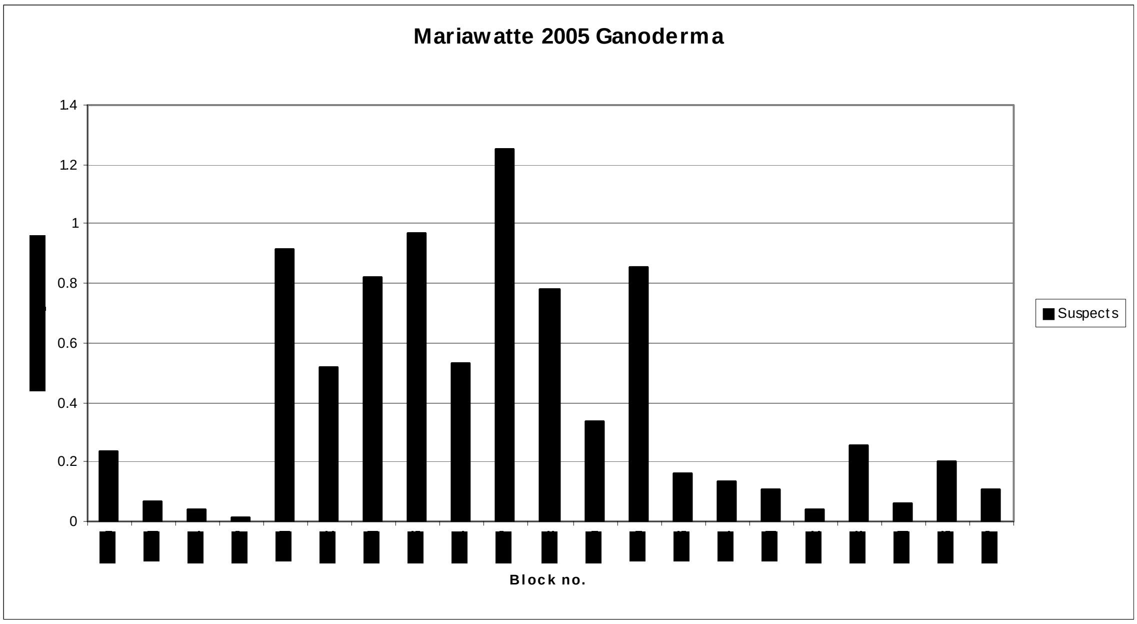


Figure 9. Number of palms affected by disease in 2005 for Mariawatte Division (1999 and 2000 plantings) by category. BSR=basal bracket; Suspect = no brackets

A summary of the number of infections in each Division is shown in Figure 10. Also included is the number of stumps of diseased palms that have been left in the ground from the 2004 survey and also from the first survey in 2005 that have subsequently developed brackets of Ganoderma. These stumps will need to be removed along with newly identified palms in the 2006 survey.

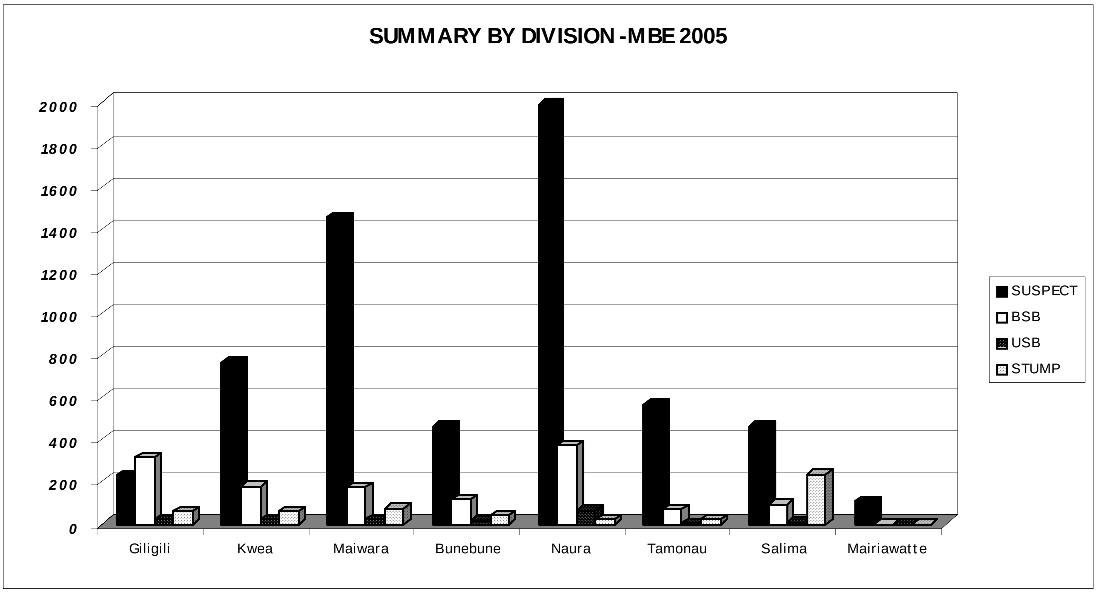


Figure 10. Annual disease rates for all categories of palms in each age group are shown in Figure 12. Disease rates were variable but generally decreased for all age groups in 2005.

Annual disease rates expressed as a percentage of total crop are shown in Figure 11. Disease rates were variable but generally decreased for all age groups in 2005 although the incidence since 2003 has increased dramatically for the older plantings.

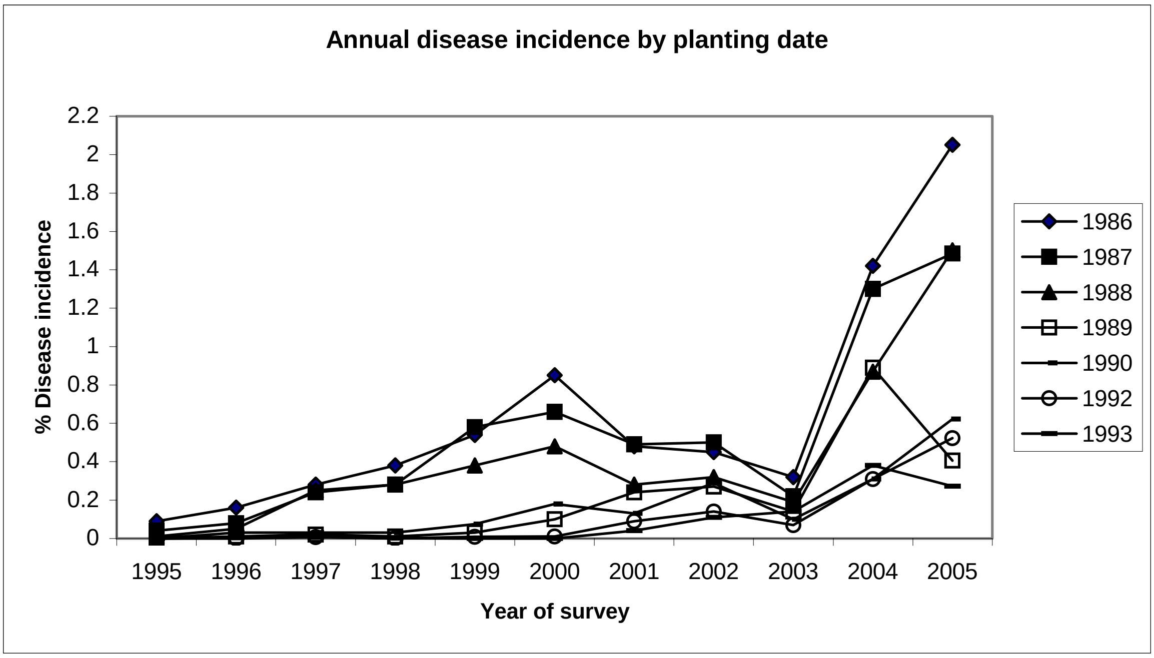


Figure 11. Annual disease incidence for different ages of palms from 1995-2005, Milne Bay.

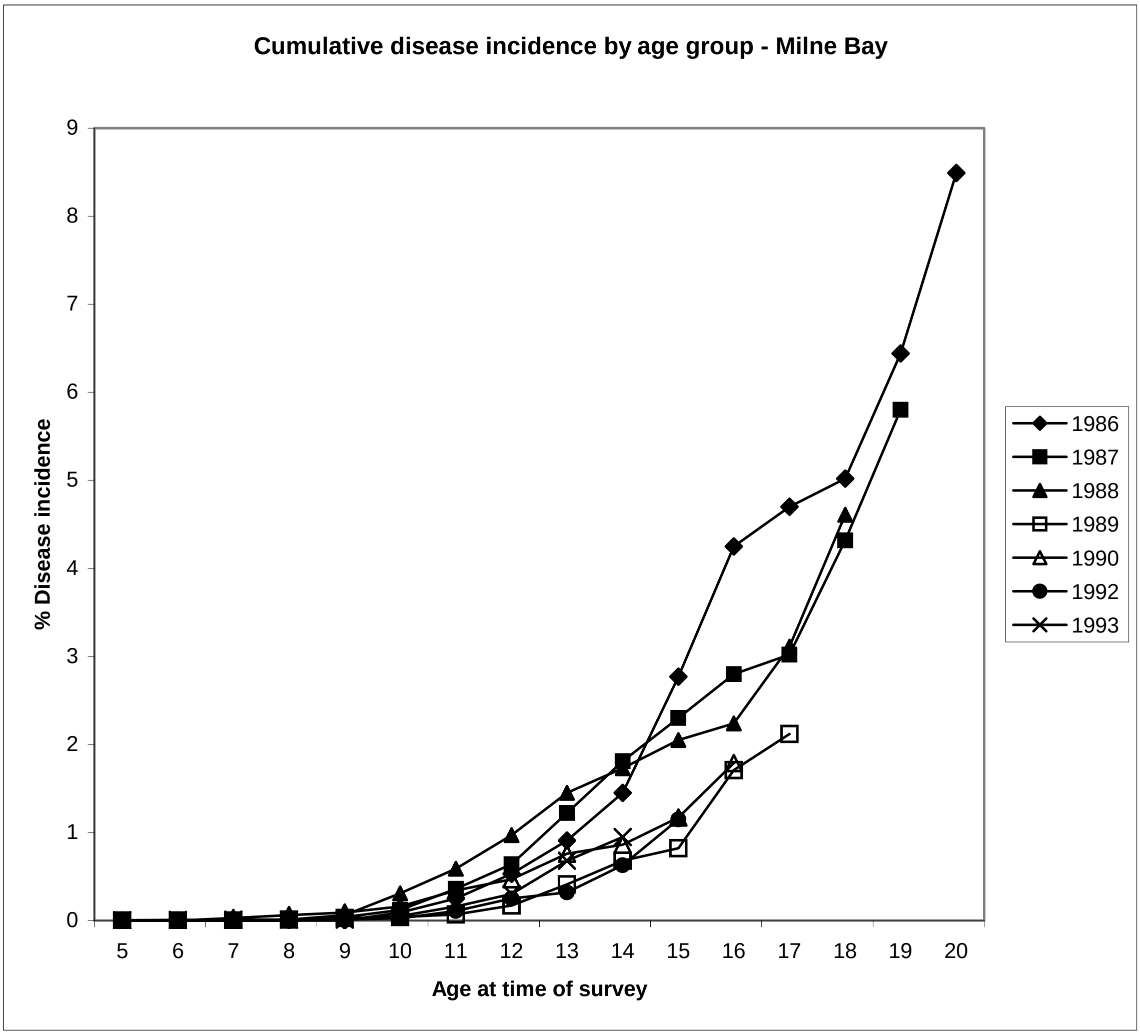


Figure 12. Cumulative disease incidence for different ages of palms from 1995-2005, Milne Bay.

Disease progress for different ages of palms in Milne Bay is shown in Figure 12. The oldest plantings (1986, 1987, 1988) continue to have the highest rates of increase with correspondingly higher average disease levels. The highest disease incidence in Milne Bay is recorded in the 1986 plantings with 8.5%. Disease incidence in the younger plantings at the same age continues to be lower. The higher disease rates in the older plantings compared to the younger plantings at the same age may be attributed either to the earlier intervention in terms of sanitation in the 1990-93 plantings or to different cropping histories. A large percentage of the younger plantings are after forest.

Average disease levels for all Divisions in Milne Bay are shown in Figure 13. Basal stem rot is now at 5.2% and the levels of upper stem rot have also increased to 0.13% in 2005.

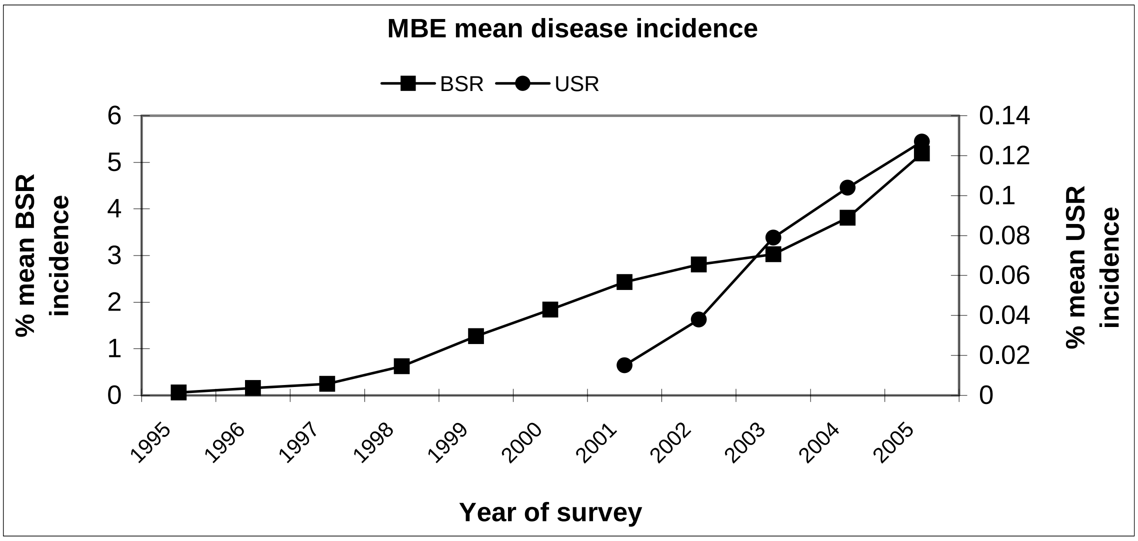


Figure 13. Average annual incidence of basal stem rot (BSR) and upper stem rot (USR) from 1995-2005 in Milne Bay.

1.1.2 *Environmental effects*

The level of disease in any plantation is strongly influenced by site or environmental factors. This is depicted in Figure 14 and 15 that show the levels of disease in palms of the same age grown at different sites. Attempts to correlate cropping history with disease levels in previous years has indicated that ex-crop factors are not entirely responsible for the variability in disease levels. This is also the case in 2005 where the differences amongst the blocks planted after coconut, forest and mixed/garden areas in the 1986 and 1987 plantings was significant (P=0.038). Surprisingly, in the 1986 plantings, the level of infection in ex-coconut blocks was lower than either ex-garden or ex-forest areas. However, the cumulative disease incidence in these blocks may indicate otherwise.

Site preparation at planting may be of more significance than type of vegetation.

In the 1987 plantings this difference between the blocks with different cropping histories was also significant (P=0.025) and ex-coconut blocks also recorded the lowest mean compared to the ex-garden/mixed and ex-forest blocks.

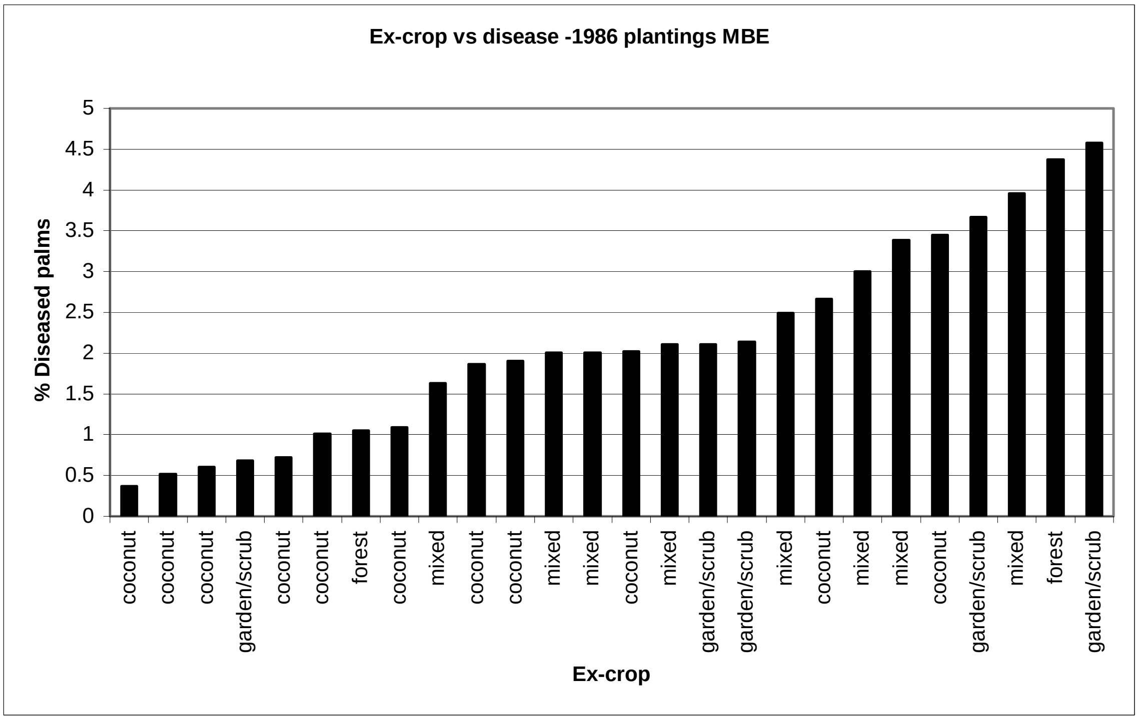


Figure 14. Percentage disease losses in 2005 amongst 1986 plantings with different crop histories.

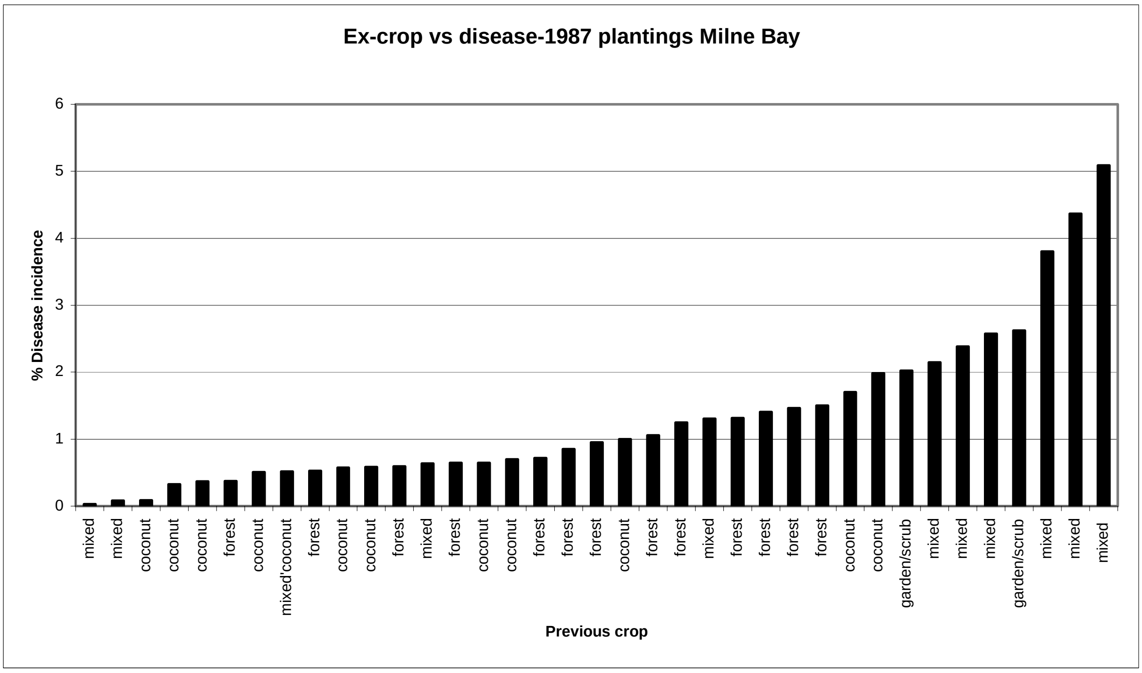


Figure 15. Percentage disease losses in 2005 amongst blocks planted in 1987 with different crop histories.

1.1.3 *Effect of disease on yield*

The disease progress curves and corresponding yield levels expressed as yield per palm are for the six study blocks in Milne Bay are shown in Figures

FFB production in 2005 in all six blocks either decreased or increased slightly from 2004 indicating that at the current levels of disease (<10%) compensation is still occurring.

Except for block 6404 a continuous downward trend has not been observed and it is expected that production will increase again in 2006.

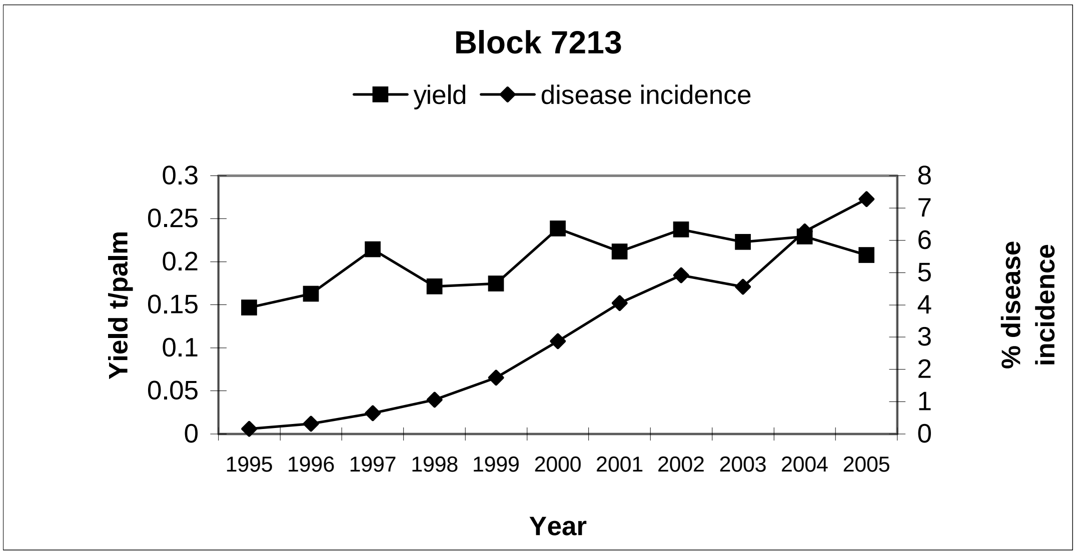


Figure 16. Average yields in tonnes/palm with disease progress from 1995-2005 in Block 7213, Milne Bay.

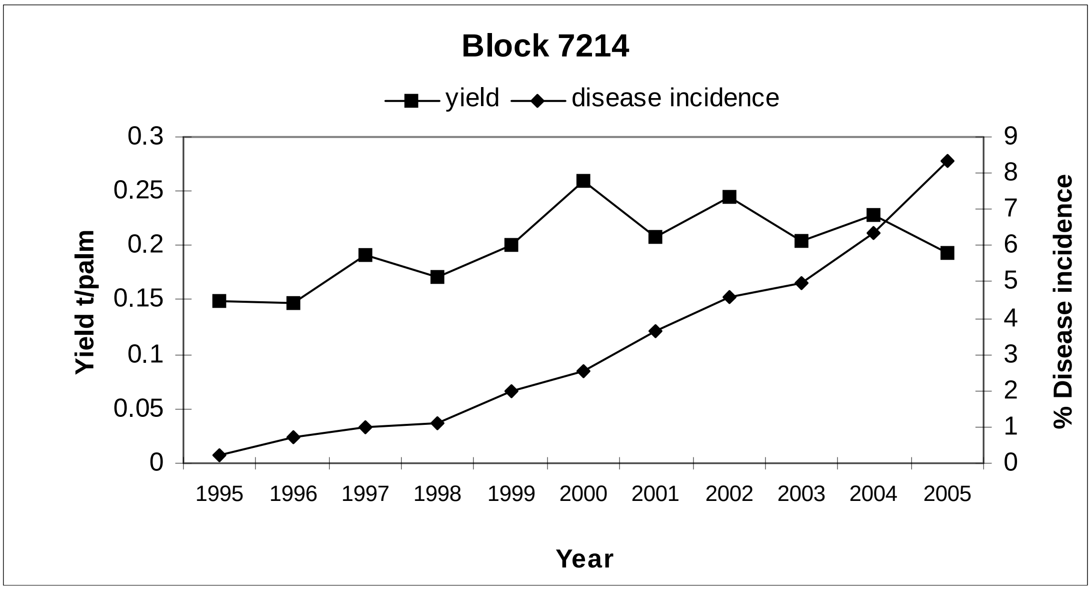


Figure 17. Individual palm yields (tonnes/palm) with disease progress from 1995-2005 in Block 7214, Milne Bay.

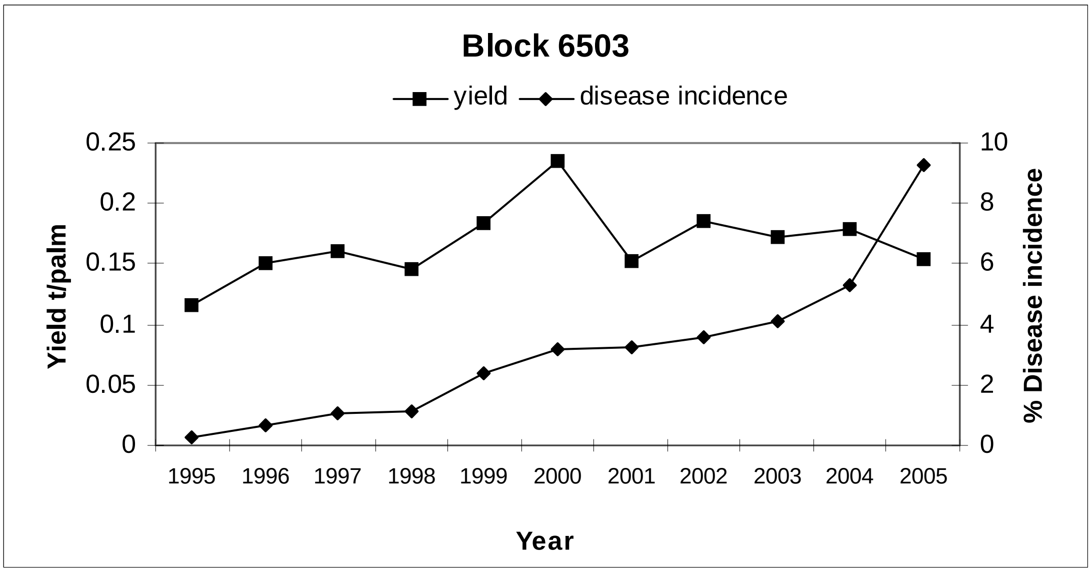


Figure 18. Yield (tonnes/palm) history and disease progress from 1995-2005 in Block 6503, Milne Bay.

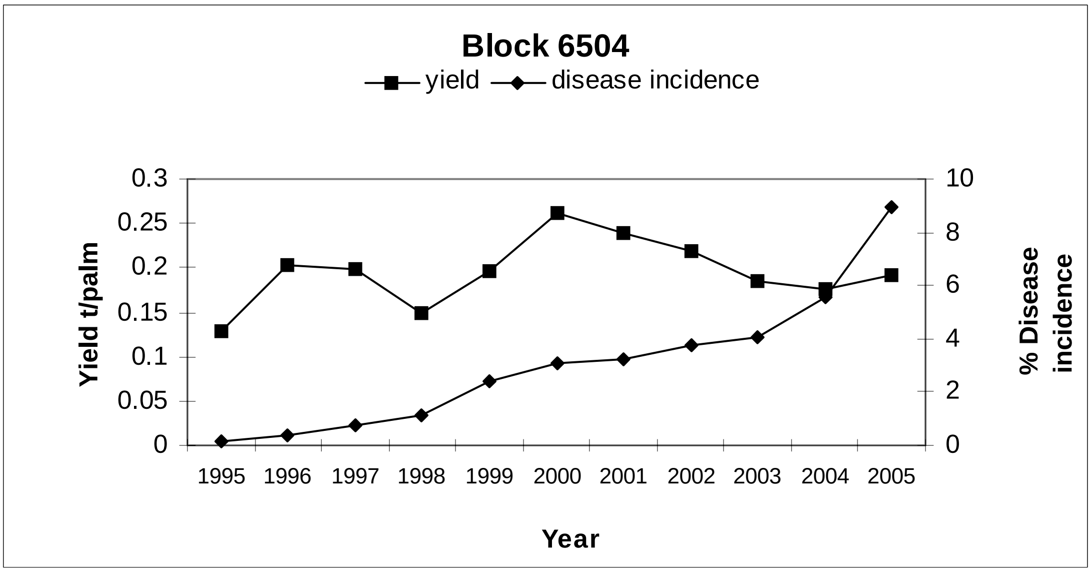


Figure 19. Average palm yields with disease progress from 1995-2005 in Block 6504, Milne Bay.

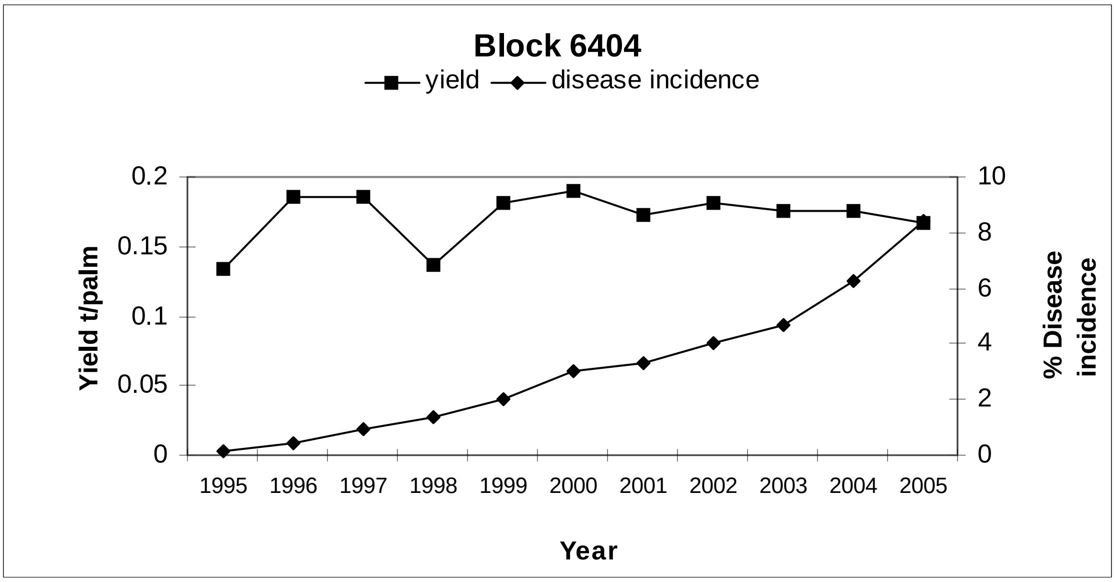


Figure 20. Average palm yields with disease progress from 1995-2005 in Block 6404, Milne Bay.

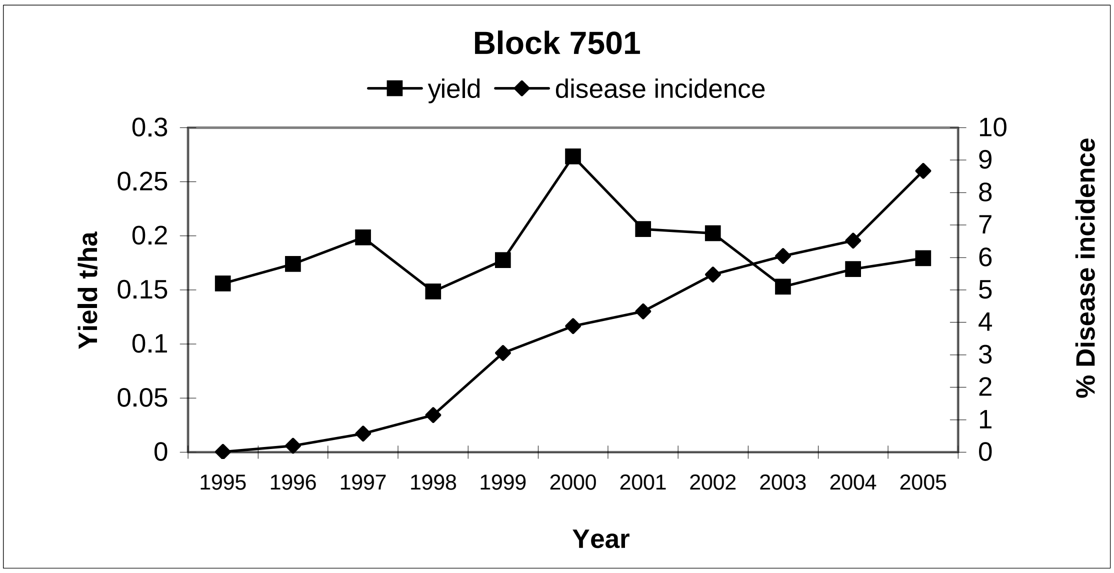


Figure 21. Average palm yields with disease progress from 1995-2005 in Block 7501, Milne Bay.

1.2 New Ireland

1.2.1 Disease progress

Disease progress curves for different sites in New Ireland are shown in Figures 22 and 23. Disease levels are slightly underestimated in all plantations as data up to 2005 was based on palm removals rather than actual recorded infections.

Of the 1989 plantings, Medina continues to record the highest disease incidence (6.6%) followed by Bolegila (5%). The lowest incidence for this age group is recorded at Piera.

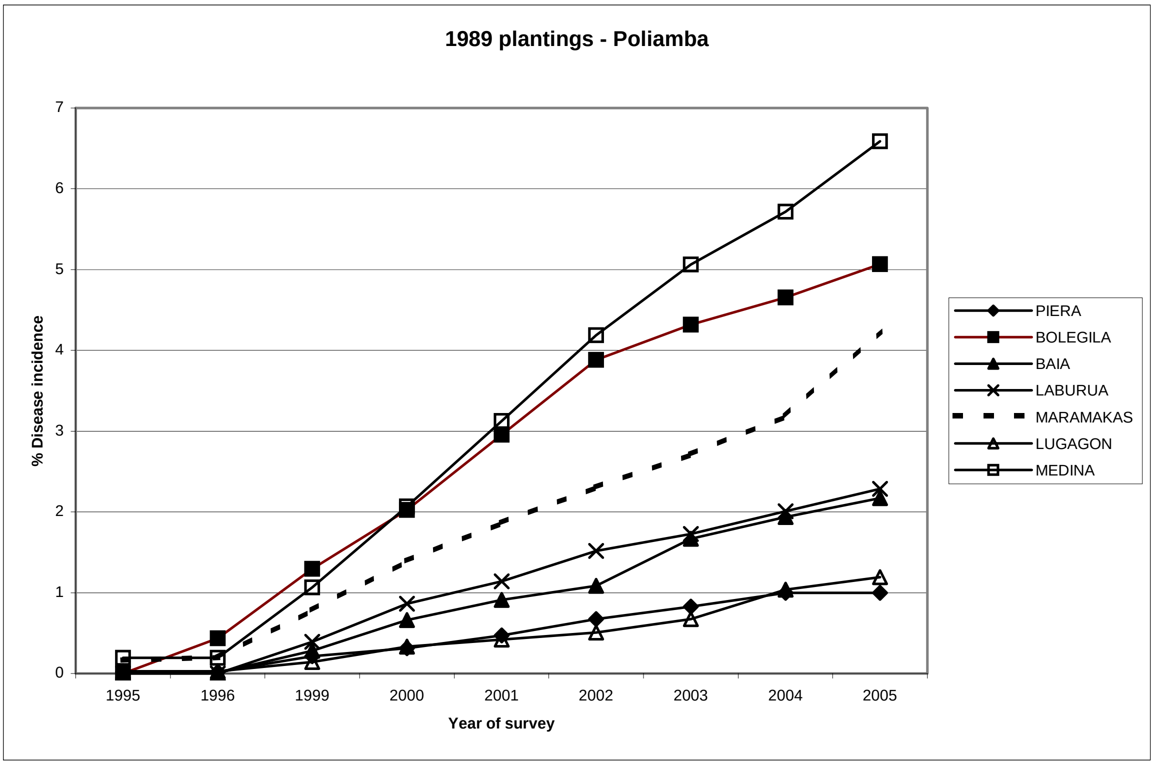


Figure 22. Cumulative disease incidence in 1990 plantings by plantation in New Ireland from 1995 to 2005. Data was not collected in 1997 and 1998.

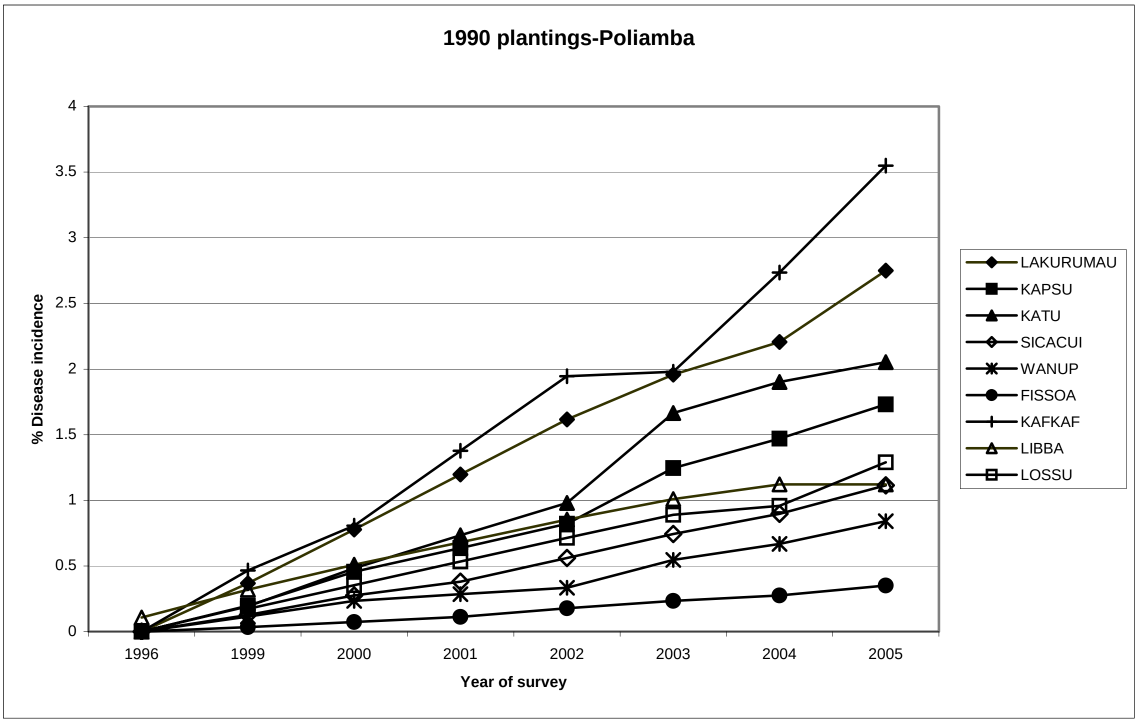


Figure 23. Cumulative disease incidence in 1990 plantings from 1996-2005 in New Ireland. Data was not collected in 1997 and 1998.

Disease incidence in the 1990 plantings is much lower than in the 1989 plantings with the highest percentage of infected palms being recorded at Kafkaf of 3.6 %. All other plantations have disease levels under 3%.

Disease progress appears to be linear (steady rates) in all plantations however the disease rates between plantations is highly variable with a range from 0.07-0.87% in the 1989 and 1990 plantings for 2005.

1.3 Numundo plantation

1.3.1 *Disease progress*

Combined (mean) disease levels for the E and F Fields at Numundo decreased slightly in 2005 compared to 2004 (Figure 24). Average incidence in the E fields was 0.98% in 2005 compared with 1.22% in 2004. Average incidence in the F fields was 0.79% in 2005 only slightly lower than for 2004 (0.86%) and this difference is not significant. The average disease incidence in the Numundo E fields appears to have decreased dramatically since 2003. The reasons for this are unknown.

Field E5 recorded the highest incidence (2.03%) in 2005 as well as all previous years however the incidence in 2005 decreased from 2004. Field E4 recorded only a slightly lower incidence of 1.73% in 2005 (Figure 25).

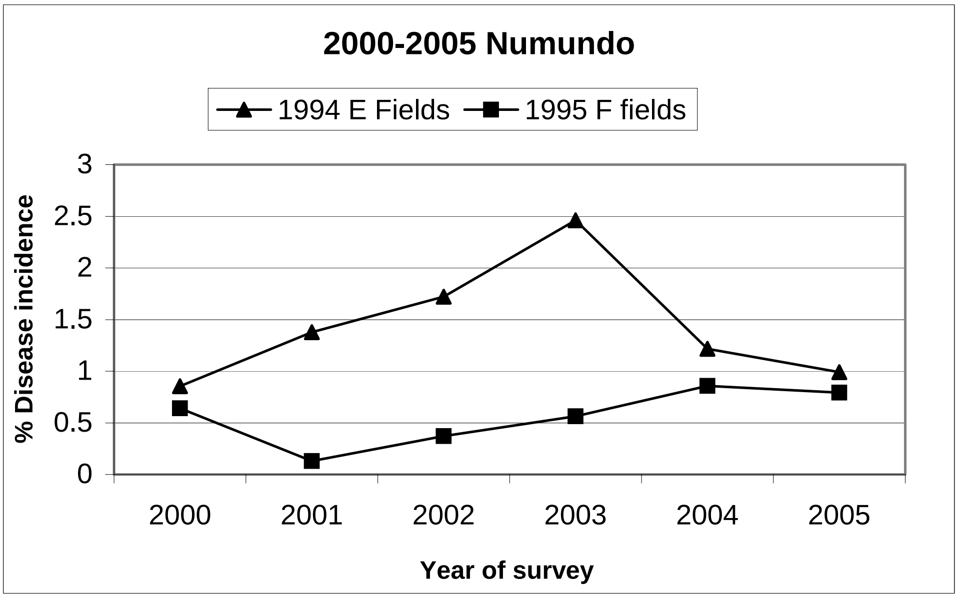


Figure 24. Annual disease incidence (2000 –2005) due to *Ganoderma* in 1994 and 1995 plantings at Numundo, West New Britain.

Disease levels in the F fields also decreased in 2005 (Figure 26). It is possible that this decrease may be due to improved recording and prompt removal of infected palms. However, the decrease is observed for all F fields and so reasons for this such as changes in prevailing weather conditions are more probable.

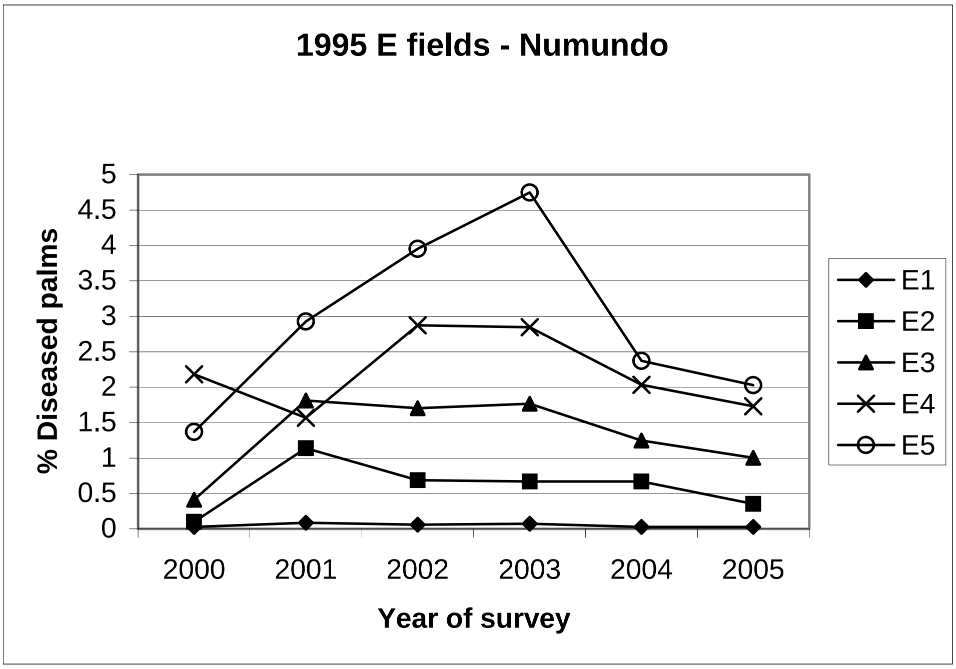


Figure 25. Annual disease incidence in Numundo E Fields from 2000-2005.

Average incidence in the E fields is now at 8.6% (Figure 27) and 3.4% in the F fields at Numundo. The large difference in disease levels between the E and F fields could be related to soil or site factors as all blocks are planted after coconut.

Disease in the half-stands at Numundo and fields at Walindi has only been monitored since 2004. Some deaths in these areas may be due to other causes such as spear rot or crown disease. Numundo half-stands at 9 years of age have similar levels of disease (1.4%) to the F fields at the same age (Figure 27).

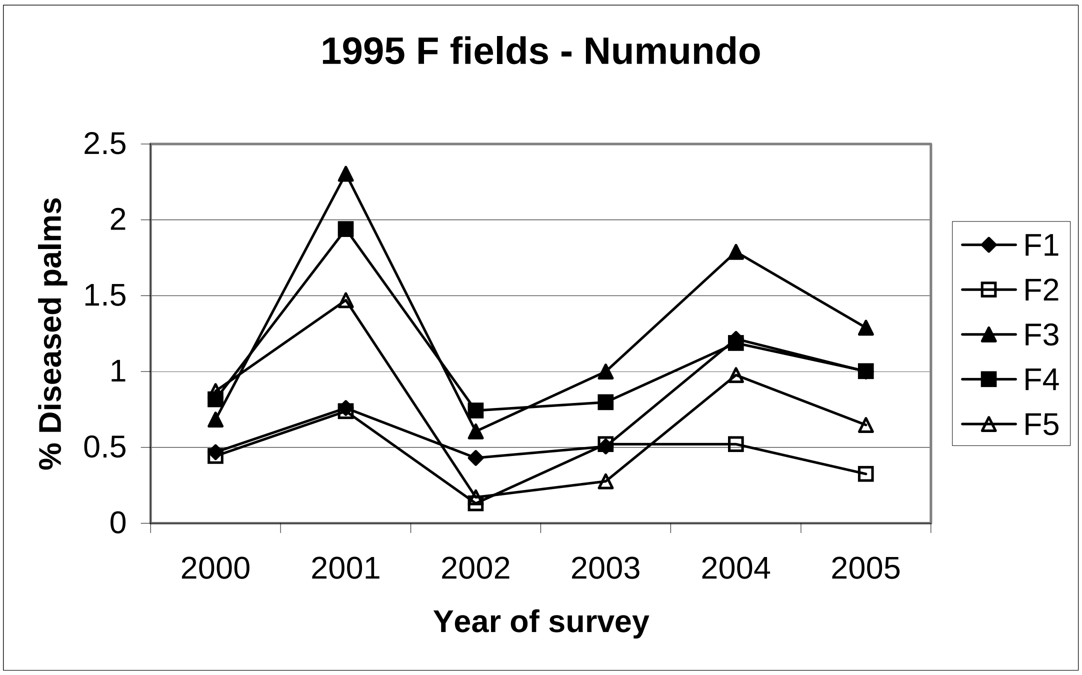


Figure 26. Annual disease losses in Numundo F Fields from 2000-2005.

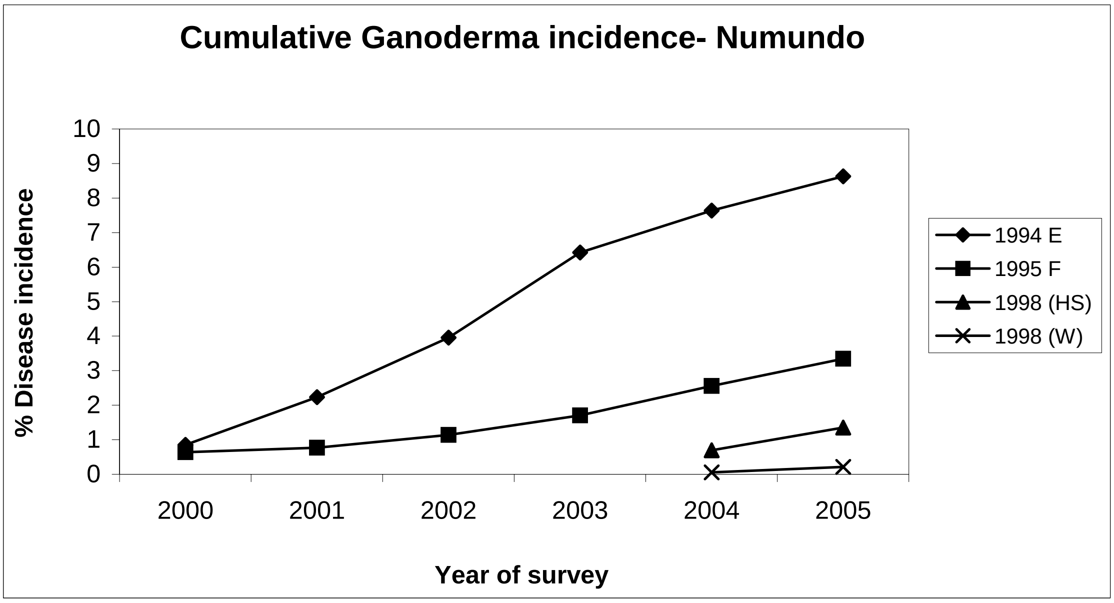


Figure 27. Average infection levels (%) in Numundo E and F fields, Numundo half-stands and Walindi from 2000-2005.

1.3.2 Effects of disease on yield

The E and F Fields at Numundo are placed into different Management Units (MU's). Disease levels in some of the MUs comprised of the E fields are above 10%. For this reason it is important to begin measuring yields from palms and to continue these observations until losses become apparent. Figures 28 to 34 show the yields obtained for MU1 to MU7 from 2000-2005 and the corresponding disease progress curve.

There is no apparent loss in yield for any of the MUs including MU3 where palm losses due to disease are approaching 14%. Clearly, adequate compensation is still occurring at this level of infection.

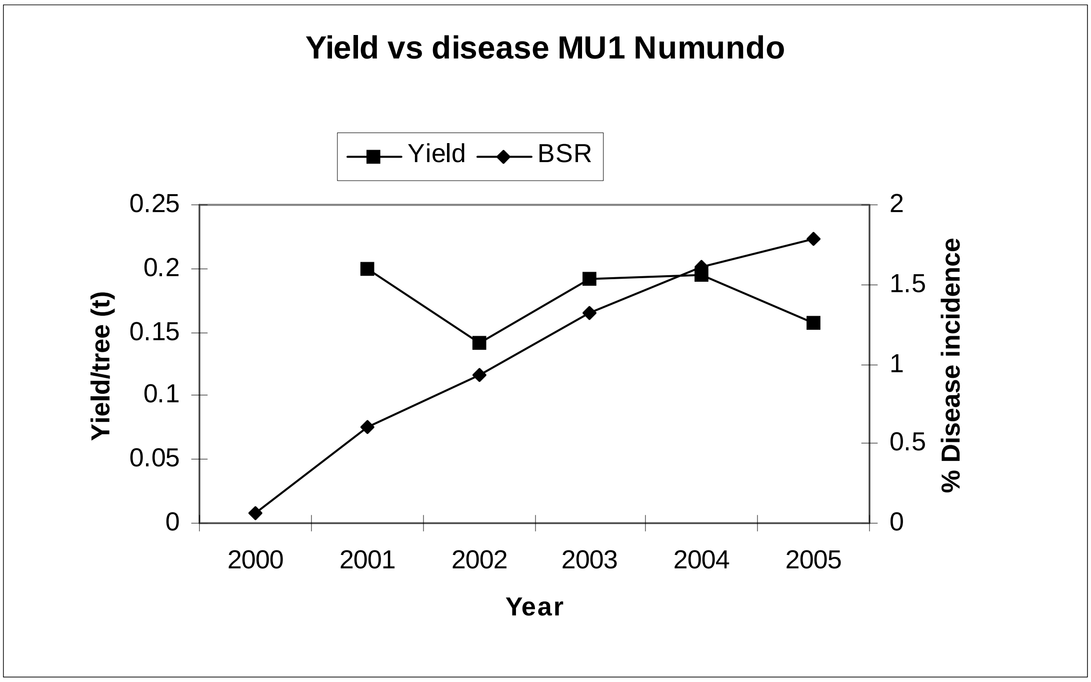


Figure 28. Effects of basal stem rot (BSR) on yield of palms in MU1 (Fields E1 and E2), Numundo, from 2000 to 2005.

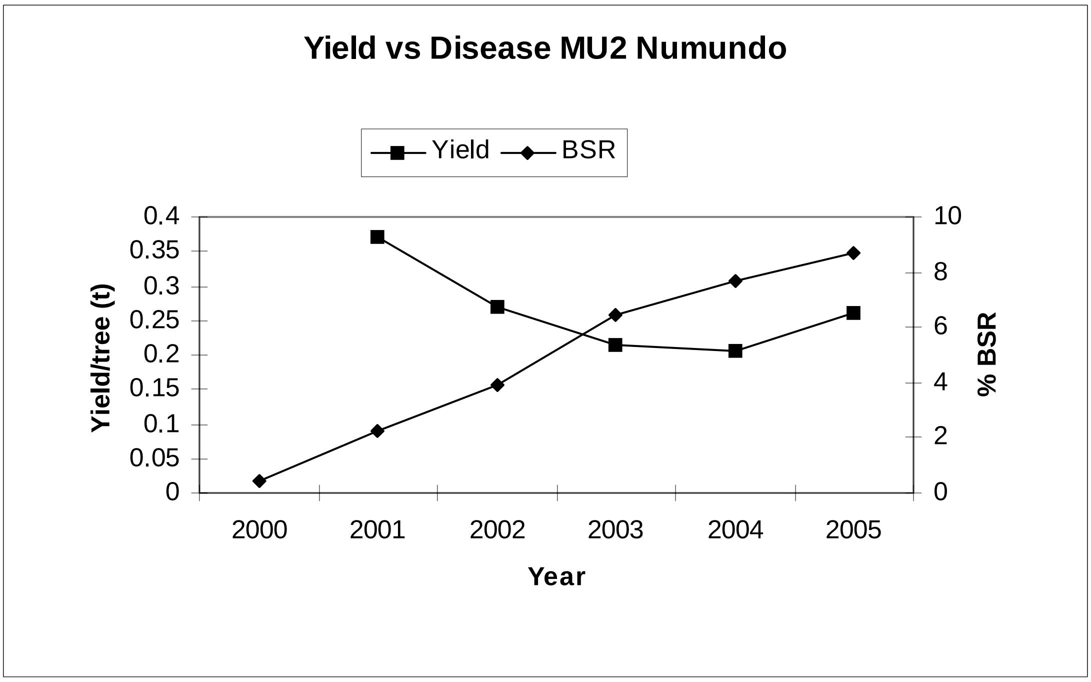


Figure 29. Effects of basal stem rot (BSR) on yield of palms in MU2, Numundo from 2000-2005.

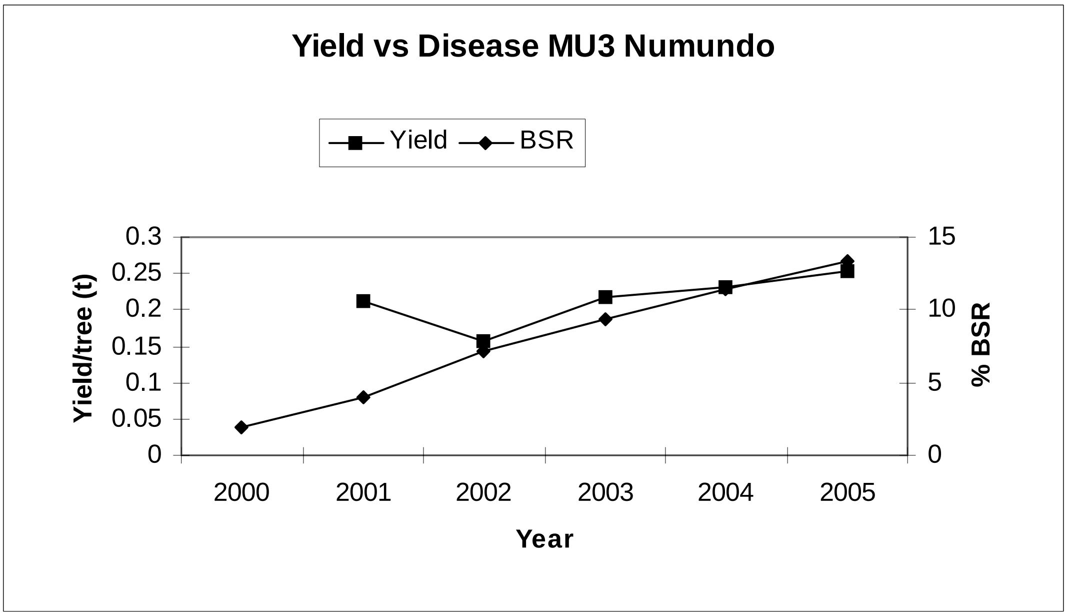


Figure 30. Effects of basal stem rot (BSR) on yield of palms in MU3, Numundo from 2000-2005.

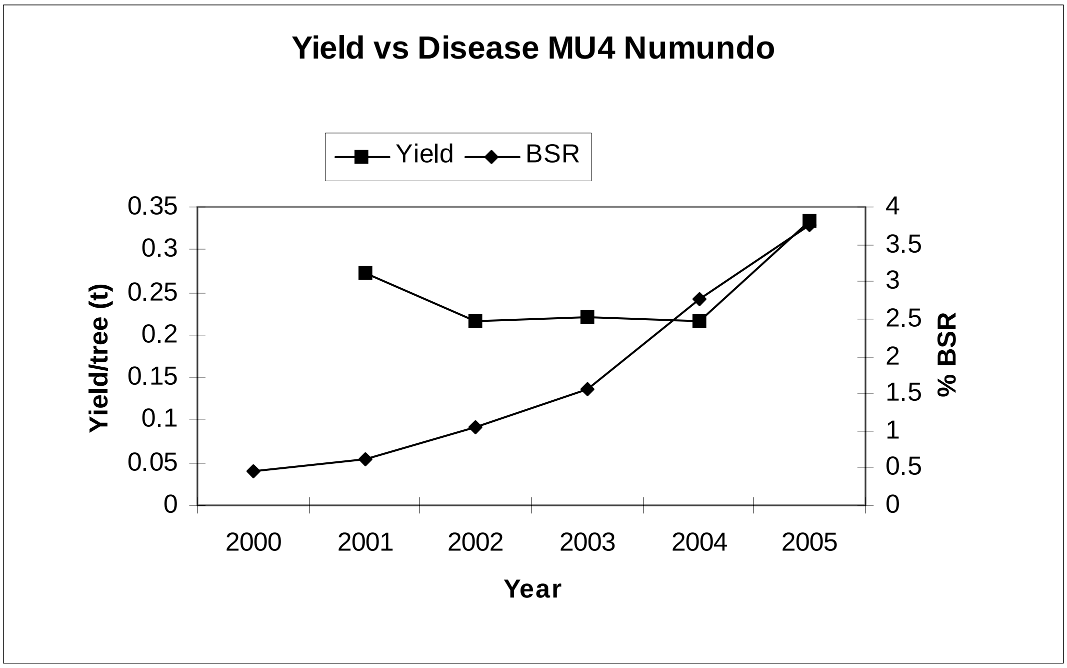


Figure 31. Effects of basal stem rot (BSR) on yield of palms in MU4, Numundo, from 2000-2005.

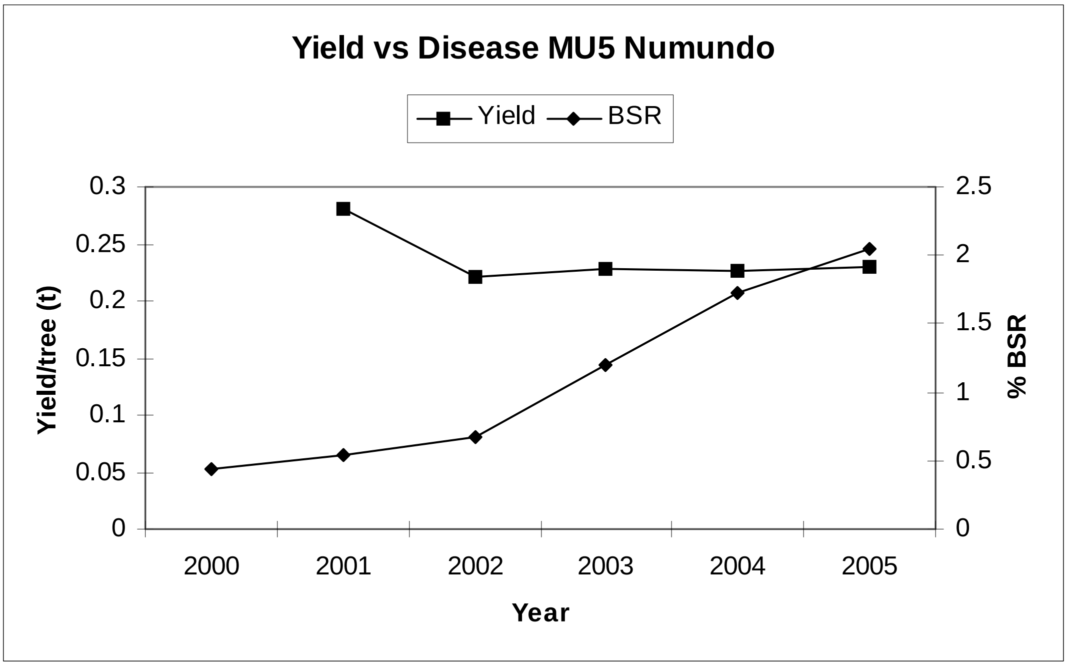


Figure 32. Effects of basal stem rot (BSR) on palms yields in MU5 at Numundo from 2000-2005.

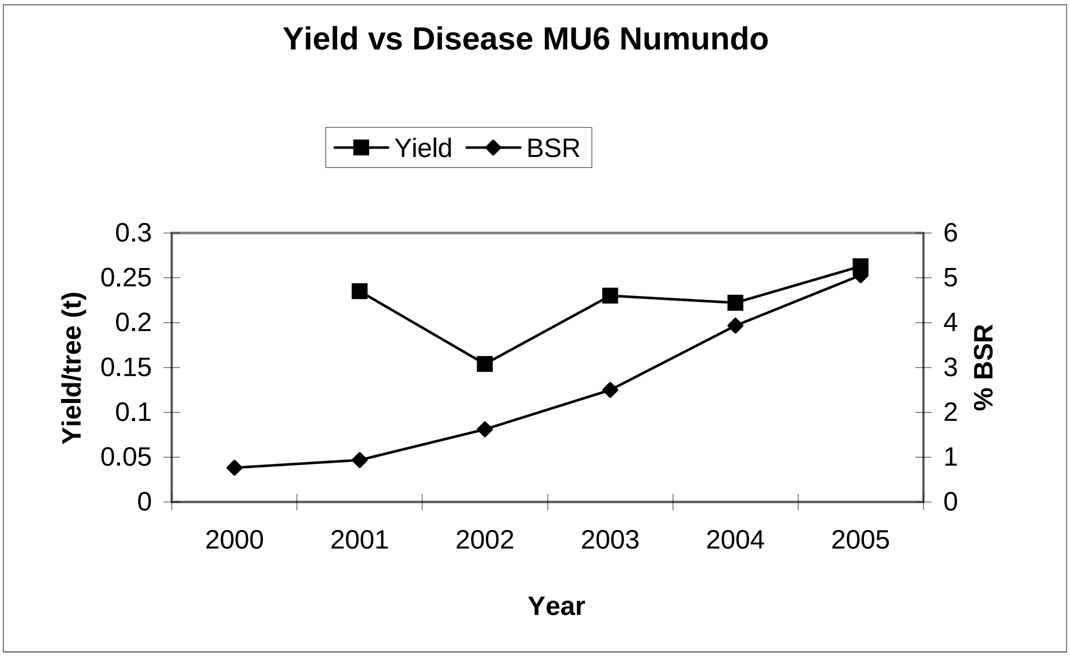


Figure 33. Effects of basal stem rot (BSR) on yield of palms in MU6 at Numundo from 2000-2005.

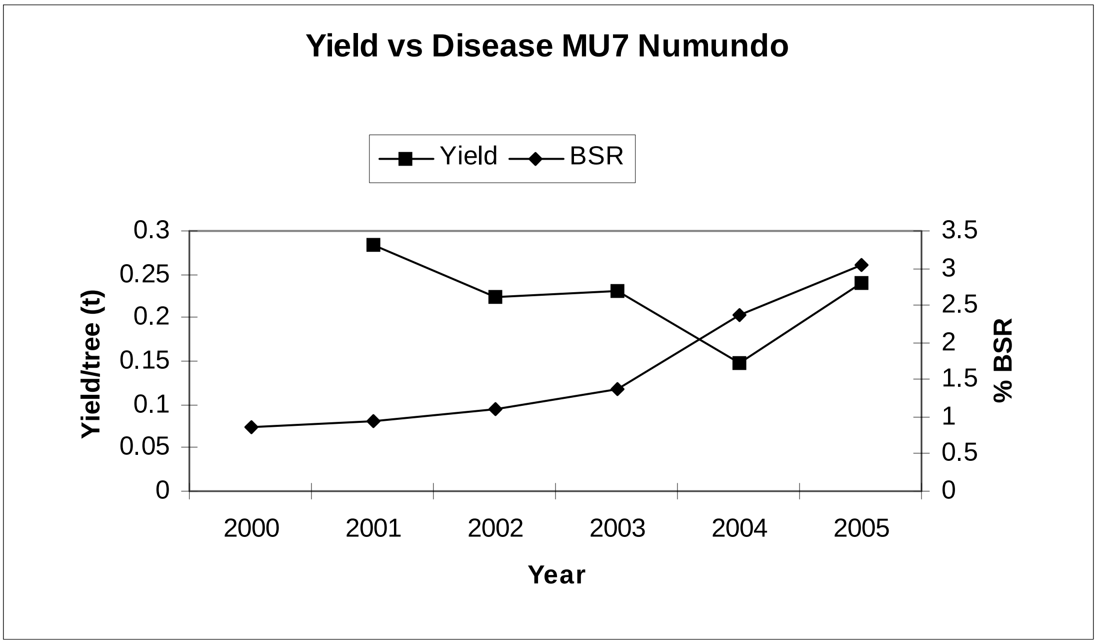


Figure 34. Effects of basal stem rot (BSR) on yield of palms in MU7, Numundo from 2000-2005.

2. *Ganoderma* population studies

2.1 *Milne Bay population*

The population of *G. boninense* continues to be monitored as part of the epidemiological study into stem rots caused by Ganoderma. This study is part of the Ganoderma project that is due to end in 2006.

In 2005, bi-annual surveys of the six designated PNGOPRA blocks were completed and samples were collected for laboratory studies. A summary of the number of isolates collected from each Block is shown in Table 1.

Crosses amongst isolates from Block 7213 continue to confirm that the isolates are of different genetic origin (data not shown).

Table 1. Areas surveyed and number of Ganoderma isolates collected in the 2005 surveys at Milne Bay (PNGOPRA blocks only).

Block #	Ha surveyed	No. isolates collected
7213	29	10
7214	16.7	13
7501	69	31
6404	63.9	44
6503	76	26
6504	36	27
9601	32	Nil

Surveys and sampling were also carried out in the fertilizer Trials 251 and 252 at Poliamba (Table 2).

Table 2. Number of isolates of Ganoderma collected from Trials 251 and 252 in 2005.

Location	**No. of isolates collected**
Trial 251	67
Trial 252	26

Fruiting bodies were collected from the trials and these have also been processed and stored.

Vegetative compatibility tests between the dikaryons from several plots in the fertilizer trials 251 and 252 (Poliamba) were completed (Tables 3 to 6). All except 3 pairs of isolates were incompatible indicating that the majority of isolates (including some from adjacent palms) were of different genetic origin. Results of some tests are not shown. Maps of the diseased palms in the plots are being updated.

Table 3. Vegetative compatibility tests amongst dikaryons collected from Trial 251, Poliamba in 2004.

	Isolate number							
251	919	1113	1114	1012	1013	1112	1116	1101
918	vi	vi	vi	vi	vi	vi	vi	vi
919	vc	vi	vi	vi	vi	vi	vi	vi
1113		vc	vi	vi	vi	vi	vi	vi
1114			vc	vi	**vc**	vi	vi	vi
1012				vc	vi	vi	vi	vi
1013					vc	vi	vi	vi
1112						vc	vi	vi
1116							vc	vi

vc=vegetative compatible; vi=vegetatively incompatible.

Table 4. Vegetative compatibility tests amongst dikaryons collected from Trial 252, Poliamba in 2004.

	Isolate number										
	1117	1119	1120	1122	1123	1124	1126	1127	1128	1025	1023
1117	vc	vi	vi	vi	vi	vi	vi	vi	vi	vi	vi
1119		vc	vi	vi	vi	vi	vi	vi	vi	vi	vi
1120			vc	vi	vi	vi	vi	vi	vi	vi	vi
1122				vc	vi	vi	vi	vi	vi	vi	vi
1123					vc	vi	vi	vi	vi	vi	vi
1124						vc	vi	vi	vi	**vc**	vi
1126							vc	**vc**	vi	vi	vi
1127								vc	vi	vi	vi
1128									vc	vi	vi
1025										vc	vi
1023											vc

Table 5. Vegetative compatibility tests amongst dikaryons collected from Trial 251, Poliamba in 2005.

	Isolate number							
	1304	1305	1447	1448	1449	1450	1451	1452
1305	vi	vc	vi	vi	vi	vi	vi	vi
1306	vi	vi	vi	**vc**	vi	vi	vi	vi
1447	vi	vi	vc	vi	vi	vi	vi	vi
1448	vi	vi	vi	vc	vi	vi	vi	vi
1011	v	vi	vi	vi	vi	vi	vi	vi
891	vi	vi	vi	vi	vi	vi	vi	vi
1307	vi	vi	vi	vi	vi	vi	vi	vi
1308	v	vi	vi	vi	vi	vi	vi	vi

Table 6. Vegetative compatibility tests amongst dikaryons collected from Trial 252, Poliamba in 2005.

	Isolate number			
	1117	1126	1127	1333
1117	vc	vi	vi	vi
1126		vc	vi	vi
1127			vc	vi
1333				vc

The incidence of Ganoderma and corresponding yields expressed as tonnes per plot from each of the 36 plots comprising Trial 251 are shown in Table 7. Plots 2, 19 and 25 have no disease recorded up to 2005. Yields were highly variable amongst the plots probably reflecting differences in the nutrient status of each plot. There was no correlation between disease levels and yield for 2005(Figure 35). Yield over several years will be assessed.

Table 7. Infection levels in each of the plots and recorded yields for the same plots for Trial 251 Poliamba in 2005.

Plot No.	% Ganoderma infection		Total yield (t) in 2005
	Including guard row palms	Recorded palms only	Recorded palms
1	8.3	19	1.04
2	Nil	0	2.96
3	16.7	25	3.33
4	22.2	31	1.26
5	19.4	19	1.68
6	13.9	6	2.35
7	2.8	6	3.07
8	2.8	6	3.42
9	25.0	31	1.78
10	22.2	31	2.53
11	16.7	44	1.91
12	22.2	25	1.02
13	30.6	6	3.35
14	13.9	25	3.30
15	22.2	6	0.17
16	11.1	12	3.69
17	22.2	12	3.45
18	22.2	0	1.54
19	Nil	31	3.53
20	25.0	12	2.55
21	5.6	0	3.13
22	27.8	31	2.69
23	8.3	12	2.82
24	16.7	38	2.99
25	Nil	0	2.93
26	30.6	56	1.24
27	5.6	6	3.58
28	11.1	12	4.23
29	22.2	6	1.28
30	13.9	31	1.72
31	5.6	6	2.63
32	33.3	38	0.88
33	22.2	38	3.7
34	13.9	25	0.29
35	8.3	19	2.63
36	5.6	6	3.46

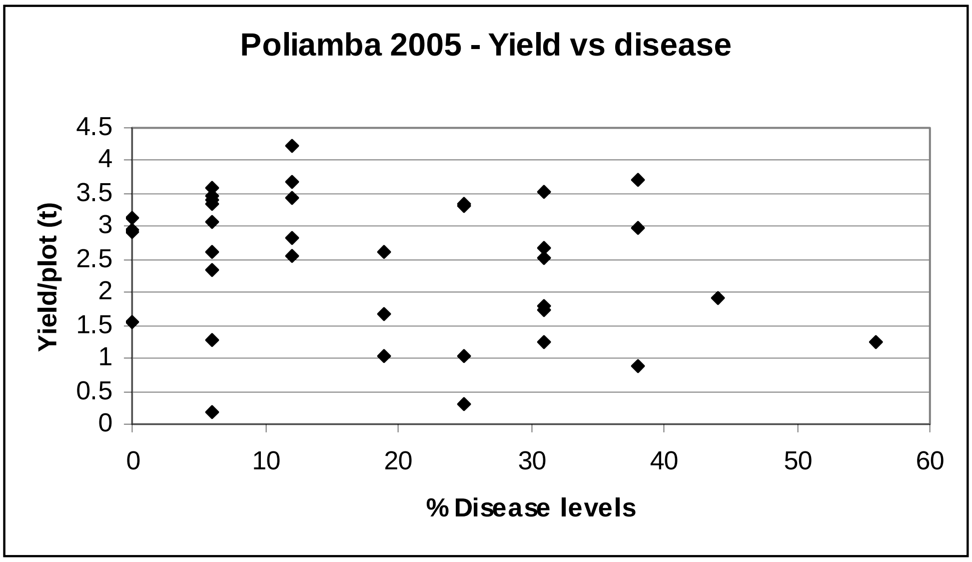


Figure 35. Scatterplot of the data in Table 7 above showing the poor correlation between Ganoderma incidence and yields for recorded palms only.

3. Pathogenicity of Ganoderma

Objective:

1.To develop an effective and rapid pathogenicity screening test for basal stem rot of oil palm.

2. To use this screening test to identify susceptible seed lines.

3.1 Laboratory screening assays

Several sets of experiments to develop methodology to test the pathogenicity of Ganoderma under laboratory conditions were completed.

Test tube cultures were maintained in a variety of media and plantlets or leaves introduced to assess decay.

Results were inconclusive due to the high contamination rates observed in the liquid and agar-based media. Work will continue in 2006.

3.2 Nursery screening assays

Specific crosses and clones were received from Dami OPRS for further nursery testing. 2200 seeds were planted in the pre-nursery and are growing well. Another 100 ramets were also planted.

A total of 250 palms that had been inoculated with Ganoderma in 2003 and 2004 were dissected for assessment of the bole tissue. All palms had been inoculated with blocks of oil palm wood (5x5x10cm). Of these, four (4) palms showed varying levels of decay in the base. Two of the infected palms were inoculated at one year of age and the decay in the base was extensive. Ganoderma was re-isolated from only one of these palms. This was the only palm that showed external symptoms typical of basal stem rot. The three others were asymptomatic indicating phenotypic and possibly genotypic differences.

Figure 36. Nursery palm showing infection by *Ganoderma boninense.*

Two of the palms inoculated at six months of age showed some discolouration of the bole tissue (after 9 months) and decay was just beginning. Ganoderma could not be re-isolated from these palms but samples have been frozen for testing using the GanEt primer.

The results indicate that Ganoderma infection is possible but the conditions for growth must be determined in order to get consistent results. Reaction times are long and twenty-five 8-month-old palms were inoculated with rachis bases containing Ganoderma.

Coconut wood was collected and prepared in November for nursery assays in 2006.

3.3 Infection process – aggressiveness of *G. boninense*

Pathogenicity assays must be accompanied by tests of aggression amongst individual isolates from Ganoderma fruiting bodies since these are derived from a sexual population.

Experiments to assess the differences amongst isolates were started.

The results of an experiment to determine the ability of dikaryotic isolates from New Ireland, West new Britain and Milne Bay are shown in Figure 37. Oil palm wood blocks were inoculated with ten isolates of *G. boninense* and these were incubated for five weeks. Decay rates were determined by differences in the weight loss of the blocks after 2 and 5 weeks.

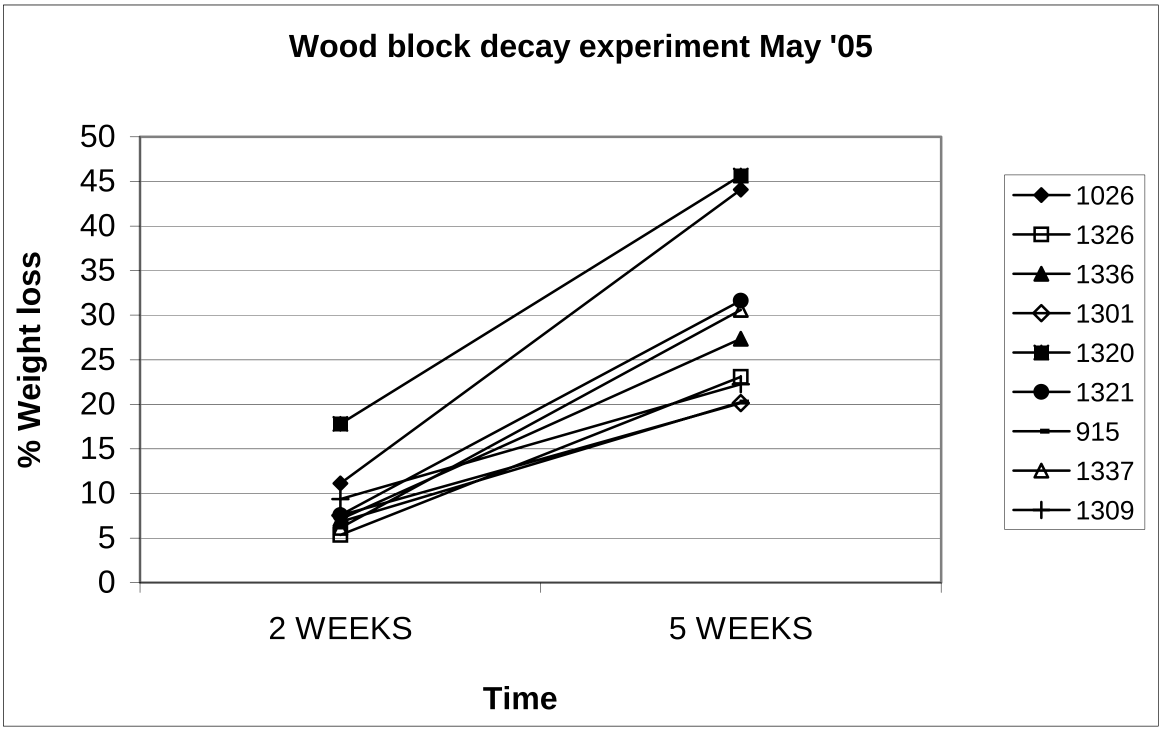


Figure 37. Differences in decay rates of oil palm wood blocks amongst different isolates of G. boninense.

Isolate 1320 and 1321, both from New Ireland showed higher decay rates than the other isolates. Work on production of metabolites is continuing.

4. Biological control of Ganoderma

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.

4.2. Trichoderma biological control agents

Naturally occurring *Trichoderma* isolates obtained from within the plantation were tested against *Ganoderma in vitro*.

Ten isolates of *Trichoderma* obtained from different sources and ten different isolates of *Ganoderma* were challenged on agar plates (results not shown). After 2 weeks, the *Ganoderma* was sub-cultured to selective medium and recorded for viability. In the majority of cases, *Ganoderma* was killed by the *Trichoderma* isolates. Only one *Trichoderma* isolate (# SP5A) showed poor antagonism towards *Ganoderma* in culture.

The previous work using *Trichoderma* was repeated to verify the earlier results. Ten isolates of *Trichoderma* obtained from different sources and ten different isolates of *Ganoderma* were challenged on agar plates but this time the *Ganoderma* was allowed to grow for 3 days before Trichoderma was introduced. After 2 weeks, the *Ganoderma* was sub-cultured to selective medium and recorded for viability. Results are shown in Table 8.

Table 8. Antagonistic reactions between Ganoderma and Trichoderma in culture. SA = strong antagonism; A= antagonism; N=no antagonism

Ganoderma isolate	***Trichoderma isolate***									
	H2	**BA**	**BL**	**P**	**2**	**BV**	**BP**	**SP5A**	**BD**	**T**
1320	*A*	*A*	*N*	*N*	*SA*	*N*	*N*	*N*	*A*	*SA*
1321	*A*	*N*	*N*	*N*	*A*	*N*	*N*	*N*	*A*	*SA*
1442	*SA*	*A*	*A*	*SA*	*A*	*SA*	*N*	*N*	*A*	*SA*
1309	*A*	*A*	*SA*	*SA*	*SA*	*SA*	*SA*	*N*	*A*	*SA*
1026	*N*	*A*	*SA*	*N*	*A*	*SA*	*N*	*N*	*A*	*SA*
1301	*A*	*A*	*N*	*SA*	*A*	*SA*	*N*	*N*	*N*	*SA*
1336	*A*	*A*	*N*	*N*	*A*	*N*	*N*	*N*	*A*	*SA*
1337	*A*	*A*	*N*	*SA*	*A*	*SA*	*N*	*N*	*A*	*SA*
1326	*A*	*A*	*N*	*SA*	*SA*	*SA*	*N*	*N*	*N*	*SA*
915	*A*	*N*	*N*	*N*	*SA*	*N*	*N*	*N*	*A*	*SA*

Table 9. Viability of Ganoderma isolates after2 weeks incubation with isolates of Trichoderma in vitro (on PDA).

		***Trichoderma* isolate**									
***Ganoderma* isolate**		**H2**	**BA**	**BL**	**P**	**2**	**BV**	**BP**	**SP5A**	**BD**	**T**
	1320	*D*	*D*	*V*	*V*	*V*	*V*	*V*	*V*	*V*	*D*
	1321	*D*	*V*	*V*	*V*	*V*	*V*	*V*	*V*	*V*	*D*
	1326	*D*	*D*	*D*	*D*	*D*	*D*	*V*	*V*	*V*	*D*
	1442	*D*	*D*	*V*	*D*	*V*	*D*	*V*	*V*	*V*	*D*
	915	*D*	*D*	*V*	*V*	*D*	*V*	*V*	*V*	*V*	*D*
	1309	*D*	*D*	*D*	*D*	*D*	*D*	*D*	*V*	*V*	*D*
	1026	*V*	*D*	*D*	*V*	*D*	*D*	*V*	*V*	*V*	*D*
	1301	*D*	*V*	*D*	*D*	*V*	*D*	*V*	*V*	*V*	*D*
	1336	*D*	*D*	*V*	*V*	*D*	*V*	*V*	*V*	*V*	*D*
	1337	*D*	*D*	*V*	*D*	*V*	*D*	*V*	*V*	*V*	*D*

V= viable after 2 weeks; D = dead after 2 weeks

5. Publications, conferences and travel

Travel

C. Pilotti- visited plantations in Colombia from January 23rd to February 14th 2005, at the invitation of Cenipalma.

- visited Mindanao Island in The Philippines from 11th-18th July 2005 at the request of NBPOL.
- visited Korindo Plantation, Papua Province, Indonesia from October 31st November 7th 2005, at the request of NBPOL
- traveled to Kavieng in October to collect Ganoderma samples
- visited GPPOL plantation in the Solomon Islands from 14th – 18th November 2005 to advise on survey and sanitation procedures and identify disease trial sites

- visited Higaturu Oil Palm in October to 2005 to inspect quarantine facilities and collect Ganoderma survey data
- visited NBPOL in November to assess Ganoderma control and identify sites for field experiments

6. Other activities

AIGF Project – travel was undertaken to Dami and New Ireland to take photographs of diseases and disorders of oil palm.

Quarantine documents were prepared for circulation and nursery inspection forms were drafted. Nursery inspections were carried out at Higaturu and Milne Bay Estates.

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 underharvesting 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 underharvesting 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 underharvesting 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 underharvesting.

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.

In February 2006 the Mobile Card trial began with the employment of two Mobile Card Officers and several meetings with smallholders to explain the Mobile Card and the income and production benefits of the new payment system. Hargy Oil Palms has incorporated the percentage split between the blockholder and the Mobile Card worker into their smallholder payment system.

As at June, 2006, 12 growers have been included in the trial from the following subdivisions:

Wilelo (1)

Sege – (2)

Tiaru – (3)

Soi – (4)

Kabaiya (2)

A preliminary assessment of these 12 blocks indicate that production and block management are steadily improving, and the new payment system introduced into the company payment system is operating successfully. Between August and December 2006 the trial will be extended to a further 28 blocks, reaching a total of 40 blocks by the end of the year. These blocks will be monitored for improvements in block production, block management and income.

Since the trial's inception there have been numerous requests from smallholders for Mobile Card workers to work on their blocks. In short there is a great deal of interest in the scheme from both blockholders requesting labour and young men willing to sell their labour.