Annual Research Report

2004

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

CONTENTS

Agronomy Research – continued… **Page**

Report by the Director of Research
to the
Association's Annual General Meeting
September 2005

This month saw Papua New Guinea celebrate the 30th anniversary of its independence. This was a time to celebrate nationhood, pride in past achievements and look forward to the future. Everyone involved in the PNG oil palm industry was a part of these celebrations.

The PNG oil palm industry is uniquely Papua New Guinean and has developed during the 30-years of PNG's independence into a successful & sustainable rural development engine that integrates very well with the country's people, culture and precious environment. When the country looks back over the last 30-years, at the top of its list of achievements must be the oil palm industry. This is an industry that has developed an international reputation for its quality, efficiency, its social & cultural sensitivity, and its environmental management policies. PNG's oil palm industry, in performance if not size, is quite simply a world-leader. This success is not simply some intrinsic function of the oil palm crop but is the result of shear hard-work, disciplined management, excellent growing conditions and world-class research & development; this is the hallmark of PNG's oil palm industry.

Supporting the oil palm industry are two research organisations, the 'PNG Oil Palm Research Association Inc.' (PNGOPRA) and New Britain Palm Oil Ltd's 'Dami Oil Palm Research Station' (Dami OPRS). The PNGOPRA, which began operations in 1981, carries out agricultural research & development for all of PNG's oil palm growers, both large-scale plantations and smallholder growers alike. PNGOPRA's principle areas of research are a) **soils & plant nutrition**, b) **entomology** and c) **plant pathology**. PNGOPRA also conducts **smallholder related socio-economic studies** through external collaboration. Plant breeding and seed production is carried out commercially by Dami OPRS. NBPOL's Dami Research Station (Dami OPRS) has a worldwide reputation as producing some of the best oil palm seed material in the world. PNGOPRA works closely with the plant breeders at Dami OPRS and as such has no need to duplicate this function.

The Association

PNGOPRA is an incorporated 'not-for-profit' research Association. Its current Membership comprises New Britain Palm Oil Limited (incorporating Guadalcanal Plains Palm Oil Limited (GPPOL)), Pacific Rim Plantations 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.

The Members of the PNGOPRA have full involvement in the direction and running of the organization, thus ensuring that PNGOPRA is always responsive to the needs of its Members. The Members 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 2005 are presented in table 1.

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

Table 1. Members Voting Rights in 2005:

Member	FFB Production in 2004	Votes
New Britain Palm Oil Limited	618,228 tonnes	7
Pacific Rim Plantation Ltd	421,262 tonnes	5
Hargy Oil Palms Ltd	143,676 tonnes	2
Oil Palm Industry Corporation (smallholders)	584,041 tonnes	6
Ramu Sugar Ltd	n/a	1
The Director of Research (*Executive Director*) also holds one vote		

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.

PNGOPRA, as an organization, is small 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. During 2004, the Member's levy represented 69.2% of the organizations revenue and external grants 30.8%[1]. The Member's levy in 2004 is set at a rate of K1.77 per tonne of FFB for all growers. Currently, external grant financing is provided to support two ACIAR research 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.

Research

The research programme of the PNGOPRA is structured to meet the needs of the 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 is addressing only the most prominent constraints and threats to the production of palm oil. The PNGOPRA Agronomy Section carries out research into soil fertility, crop nutrition and fertiliser management practices. The Association's Entomology Section conducts research into oil palm pollination and the integrated pest management (IPM) of insect and other pests (including weeds). The Plant Pathology Section, based in Milne Bay, is carrying out research into the control of the Basal Stem Rot of oil palm caused by the *Ganoderma* fungus. All Sections, in addition to conducting research, assist the industry by providing technical support, recommendations and training.

Agronomy Programme

In 2002 the Agronomy research program consolidated a major change in direction that aimed at understanding the processes that determine the returns on fertiliser investments. We expect that improved management recommendations based on the new work will start emerging within the coming years.

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.

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

[1] Government of PNG Public Investment Programme (PIP) Budget 8.9%, European Union Stabex fund 20.4%, and the Australian Centre for International Agricultural Research (ACIAR) 1.5%.

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, a project which began in 2004 will address the concept of maximising economic returns of fertiliser inputs through advanced statistical modelling based on factorial fertiliser trials and leaf nutrient analysis.

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 plantations and between different soil types, and is also influenced by management. From earlier research it is 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.

In 2002 two major projects commenced. They concentrate on the retention and losses of nitrogen, magnesium and potassium on volcanic ash soils. Last year, a new project was 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 fertiliser inputs. The aim is to identify the major mechanisms of nitrogen loss and to develop management practices that reduce losses as much as possible. Fertiliser constitutes the major cost input in oil palm cropping systems in PNG for both smallholder and plantation alike. The vast bulk of this fertiliser is nitrogenous fertiliser and the viability of the industry depends upon it. 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 fertiliser. Success in the project could have an enormous impact on the economics of oil palm production in PNG.

Data from the various water balance experiments have incorporated into the FAO 56 model to develop a water balance model for the oil palm agro ecosystem. This has been combined with results from various N-leaching, runoff, and gaseous loss measurements to predict the fate of applied N-fertiliser.

Results suggest only small amounts of the applied N are lost in runoff or by denitrification. The major loss pathway is via leaching. This is independent of site, although the (small) losses via runoff were greater at the Popondetta site, which had lower infiltration rates, than the Dami site.

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 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 and Oro 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. Early results have already confirmed that a soil from Bialla has a high selectivity for Ca over Mg. Potential sources of Mg, such as sparingly soluble Mg carbonates and oxides are being assessed for their Mg-availability to palm roots. In field trials, young palms that have not had any Mg added in the past are showing responses to Mg fertiliser through a reduction in the severity of Mg deficiency symptoms. These trials are now showing increased FFB production as a result of application of Mg fertilisers. This is the first time that a direct response by palms to the addition of Mg fertiliser has been shown in West New Britain soils.

Glasshouse trials, at CSIRO in Australia, using solution culture techniques are showing that Mg is efficiently retranslocated from old fronds (when they senesce) to younger fronds. These results may have implications for the practice of frond pruning, in which fronds are pruned before there is an opportunity for Mg retranslocation.

Understanding responses to fertiliser trials in West New Britain

A third major project that commenced in 2002r 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 fertilisers are moving from fertilised areas into control plots. This apparent movement has implications not just for experimental design, but also for management of nutrition in plantations. 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 fertiliser responses in field trials by allowing nutrients to pass from treated plots to untreated control plots.

Trials with large plots and systematic layout of fertiliser treatments (to minimise plot-to-plot influence) are just beginning to show responses to N fertiliser. These trials will be the basis for N-fertiliser recommendations in WNBP in the future.

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 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. This project has recently received new funding through AIGF. This will facilitate extension of plantation-based trial results to smallholders in WNBP (initially) and thus increase smallholder incomes through site-specific fertiliser recommendations.

Providing technical support

PNGOPRA Agronomists give close technical support to the efforts of the extension service 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 fertiliser 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 bee initiated that will actively maintain the high quality of OPRA trial results.

Entomology Programme

Insect pollination

The EU financed Stabex project is entering its final phase, however further information has been collected confirming that the internal nematodes are immature when the majority of the female weevils emerge from the spikelets and are mature and producing larvae when most of the male weevils are emerging. Male weevil mortality appears to take place prior to emergence if there is a high level of parasitization. The findings suggest that the nematodes may have a shorter life than the host weevils. It appears that when an adult nematode is dying, or dies, the eggs inside its body hatch into larvae (which is the norm) but, instead of passing out into the haemocoel (blood cavity) of the weevil, they grow and moult inside the adult nematode until they burst out. Some of these then pass out of the weevil in the normal way while others stay in the weevil and grow to adult females and begin producing additional young. Third instar (J3) infective nematode larvae have been found in the faeces of the weevils. Since insects normally defecate while they are feeding, the infective nematode larvae will normally be deposited on the male spikelets where they will be able to seek out new hosts. Moisture is thought to play an important part in parasite transmission.

Further sampling of weevils from New Ireland confirmed that there are low numbers of the internal nematodes on the island.

Data collected on fruitset in two high rainfall areas, to examine for possible poor weevil performance due to internal nematode infections, indicates that high levels of infestation do not appear to affect pollination. It is suggested from this and other data that weevils were in sufficient numbers at both sites throughout the year to produce good fruitset. In addition there were large variations in fruitset for individual bunches, even though there were indications that ample numbers of weevils were available for pollination. Poor pollination may not usually be due to the lack of weevils but to factors such as the lack of sufficient spikelets for the weevils to breed in. Data show clearly the relationship between the weevils and numbers of male spikelets.

The facility will be used for quarantining African weevil material as part of the pollination project.

Future work will concentrate on monitoring weevil/nematode populations at selected sites; particularly understanding the relationship between the pollinating weevil and the male and female inflorescences, and analysis of the large amounts of data gathered. The collection of nematode free material from West Africa will also be addressed.

Sexava Integrated Pest Management (IPM)

The egg parasitoids *Leefmansia bicolor,* and *Doirania leefmansi* continued to be reared in the laboratory in sexava eggs for release into oil palm growing areas. With regular checking for the presence of sexava eggs in the ground at outbreaks, good reservoirs of *both parasitoids* were found and breeding stocks re-established. . Even sexava eggs close to hatching were found to be parasitized. Research results and field observations showed that these parasitoids are able to find the eggs of sexava in the ground up to depths of 2 cm. During the year, approximately 16,500 *Leefmansia* and 198,500 *Doirania* released into a total of 9 sites where there were low levels of sexava.

Surveys showed that *Stichotrema* were well established in the Bialla area and in some smallholder blocks.. This was a very significant event as this is the first time that *Stichotrema* have been successfully introduced onto an island from mainland PNG and into another species of sexava. Successful redistribution of the parasitoid to other oil palm growing areas and into other species of sexava (*Segestes decoratus* and *Segestidea defoliaria* on WNB and *S. gracilis* on New Ireland) has the potential of long-term suppression of this pest. However regular monitoring of sexava field collected eggs is essential. Enhancement of the plant biodiversity in plantations to provide additional nectar sources is also being addressed with OPRS.

In a field situation, eggs in the ground subjected to intermittent rain might be expected to go through their initial diapause, hatching at different times, but not go into late diapause. In severe dry seasons, eggs will hold up in a late diapause, the numbers ready to hatch building up over time as individual eggs reach a late embryonic stage. The longer the dry period, the greater the numbers of eggs there are waiting to hatch. When suitable rain comes the eggs will hatch en masse and cause subsequent outbreaks.

Because of the potentially long initial diapause, a proportion of eggs may still be viable when the effect of a second trunk injection (done at 16-weeks after the first) has worn off. When there are very few or no eggs in the ground and no laying adults at first observation, only one trunk injection round is recommended. If there are eggs in the ground then a second treatment is required, but this should be held back as long as possible to kill as many nymphs as possible, while taking into account any damage occurring and preventing further egg laying; i.e. the population should not have mature adults present before the treatment. Parasitoids should suppress any remnant populations, particularly if sexava populations are not at outbreak levels.

Future work will concentrate on continual redistribution of *Stichotrema* and continued attempts will be made to parasitize *S. decoratus* and *S. gracilis* before distribution into areas where these species occur.

Finschhafen disorder

Long term monitoring and individual studies of Finschhafen disorder on oil palm, caused by the leafhopper, *Zophiuma lobulata*, have indicated that the symptoms appear about 6-7 months after attack. However the data are show that only low numbers of *Zophiuma* have been present over the last two years yet the symptoms continue to appear. A project document has been prepared for funding.

Queen Alexandra's Birdwing Butterfly (QABB)

Work continued on the propagation and replanting of the larval food plant of QABB. It was decided to germinate seeds from the pods of vines that had been used by QABB, since local knowledge suggested that the butterflies only went for one type of the vine (with narrower leaves?). Plans for a new project are being considered, as there are still important issues that need addressing.

Weed control

The redistribution of Psyllid bugs (*Heteropsylla spinulosa*) into areas of mimosa in oil palm plantations and smallholder blocks in Oro Province continued throughout the year. In addition a galling fly parasite of Siam Weed, *Chromolaena odorata* was successfully introduced into new localities on the mainland and islands within PNG. The galls have been redistributed from the original release site.

Pest outbreaks

There will continue to be a strong emphasis on training of treatment teams in effective treatment and advice provided as requested to the industry on all aspects of pest management in oil palm. The Entomology Section has continued with pest monitoring work. A total of 163 visits to areas with reported pest damage were made of which the vast majority were due to sexava.

Pest recognition

Visual toolkits are being prepared under a new funding, which will be beneficial to growers throughout the industry.

Plant Pathology Programme

A major long-term threat to the sustainability of oil palm industry in PNG is the disease known as Basal Stem Rot caused by the fungus *Ganoderma boninense.*

The Plant Pathology programme therefore continues to focus on the understanding the epidemiology of the pathogen, it's control using biological (natural) agents and utilizing host resistance as a means of long-term control. All the research costs associated with this programme were funded by the European Union under Ganoderma Stabex Project N0.4.2.

Epidemiology

Research in this area aims to provide critical management strategies for this disease to oil palm growers - both large estates and smallholders. A broadening of study areas to other Provinces has revealed that disease prevalence is spreading and is influenced by environmental conditions; to what extent is as yet unknown. Remarkably, temporal disease progress curves (a measure of disease progress with time) indicate that despite differences in disease rates, disease progress follows a similar trend in all Provinces where the disease is present. This year, analysis of disease epidemiology in Milne Bay and New Ireland indicated that annual disease rates were below 1% and this trend was likely to continue into 2005. Therefore, disease at the present levels is still manageable and the present control strategy is cost effective. The effects of disease on yields per hectare is not significant.

Evidence for the spread of the disease by basidiospores continues to be reinforced despite disease maps showing increasing aggregation of affected palms. Unfortunately, pathogen populations have not been studied in great detail (due to the large amount of work involved) in the other Provinces and this makes comparisons with the main study area, Milne Bay, difficult.

The influence of environmental and management conditions on disease levels also has to be considered if control is to be successful. Attempts so far to correlate criteria such as soil type and previous crop history have not determined any clear associations apart from the obvious influence of coconuts on disease incidence in coastal areas. These types of factors need to be integrated into the research programme in order to ascertain the factors that predispose palms to disease. Additional resources will be required to investigate these variables.

Biological control

As mentioned in earlier reports, the use of fungicides is the last option with regard to control of basal stem rot. Biological control using naturally occurring fungi that are antagonistic to *Ganoderma* is the preferred route of investigation.

The approach to this research is two-pronged. One area of investigation is the rapid breakdown of woody substrate such as oil palm trunks that will prevent the establishment of *G. boninense* within the plantation environment. Studies using *Ceratocystis* have progressed well with good results, however there is a reluctance to use this fungus on a large scale. The ability of *Ceratocystis* to antagonize and kill *Ganoderma* will be investigated in 2005. Depending on these results, the decision to introduce this fungus on a larger scale within the plantation shall be made.

The other area of investigation is to utilize a known bioactive fungus called *Trichoderma* to prevent infection of *Ganoderma* in young palms and at the same time possibly enhance the growth of the palm to maintain resistance. In vitro (laboratory) tests have been promising with most isolates of *Trichoderma* probably parasitizing and eventually killing the *Ganoderma*. Further laboratory tests will be carried out in 2005 to confirm the reproducibility of the initial tests. In addition, investigations into the variability amongst the isolates in their ability to antagonize and destroy *Ganoderma* will be carried out. Detailed ecological investigations on *Trichoderma* in the oil palm micro-environment will require additional resources.

Host resistance

From the outset, the primary aim of the *Ganoderma* research programme was to develop an effective screening technique that would allow different oil palm germplasm to be screened for resistance (or susceptibility) to basal stem rot. Numerous tests have been carried out under this programme with limited success. Numerous changes have been made to the inoculum techniques and some progress has been made with regard to inducing infection in rachis tissue. However, reproducibility of the technique remains a challenge. Whole palm inoculations this year has had some success, with infection being induced in 2% of palms in one experiment. The results are inconclusive as the percentage infection is so low. Other alternatives are being pursued.

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 works hand-in-hand with an effective extension service. Although these two functions are carried out by different organisations in the 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 interface borne of willingness by individuals in both organisations to work with a single-team attitude.

Since its formation 24-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 to prevent environmental degradation. This approach is equally applicable to both smallholder growers and plantation companies.

Ian Orrell
Director of Research
September 2005

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 water balance is critical in determining the amount of runoff and leaching and most of the work so far has concentrated on quantifying the water balance. We have determined that the distribution of rainfall under the canopy is very non-uniform, with stem flow varying from 1-7% of rainfall and much of the remainder falling at the intersection of two palm canopies. Infiltration capacity of the soil is also not uniform, being highest under the frond pile and lowest in the harvest path and weeded circle. Surface infiltration rates are generally very high. Surface runoff must therefore be generated in the harvest paths and weeded circles or when hydraulic conductivity of deeper layers is exceeded and the soil profile fills with water. We have measured runoff in several large plots on the Higaturu soil type. It varies from about 1% of rainfall in small events (of around 5 mm) to 36% in large events (around 100 mm). We have also measured runoff in large surface runoff plots at Dami in WNB and less than 10% of rainfall ends up as runoff. Knowledge of the surface infiltration characteristics of soils will allow us to predict runoff at other sites with similar slope. Mineralisation studies are showing that mineralisation differs both between sites (Popondetta and Dami) and between zones within each site. For example, at Popondetta, mineralisation was greatest in soil from surfaces horizons under frond piles and frond tips. By contrast, at Dami, (net) nitrification under the frond piles was much lower than under other zones; suggesting that nitrate may have been immobilised in the organic matter. Work has also commenced on gaseous losses of nitrogen from various zones. These trials are currently been analysed at Massey University.

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 is 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 are now also showing increased yields as a result of Mg addition. This is the first time that definitive responses to Mg application have been shown in WNBP.

This project underwent a mid-term review by ACIAR in Dec 2004 as part of normal project monitoring. Because of the early successes of this project, we were able to convince the review team to recommend an expansion of the project (and funding) to cover K nutrition in MBP. This has subsequently been approved and a new trial is being designed.

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 recently 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 first 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 these 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 downslope 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 2003 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. In 2002 it was decided to close trials 125, 126 and 129. Those trials were closed at the end of 2002. In Trial 129 (fertilizer placement), treatments have continued as effects on the soil may still take some years to develop. In trial 129 soil sampling was done in 2004. The results show that organic matter (fronds, EFB) and other fertilisers, especially those containing cations (AC, KIE), can have a substantial influence on the ability of the soil to retain cations. The systematic N trials commenced recently and were designed to overcome problems with possible plot-to-plot movement of nutrients. Of the systematic trials, 138a (Haella) was closed at the end of 2002 as it is a 2-row trial and will provide no extra information than the adjacent 4-row trial 138b. Trial 137 (Kumbango) and 138b (Haella) commenced treatments in 2003 and Trial 403 (Kaurausu) has provided its third year of results. Some 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 finally 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. Trial 136 (monthly tissue sampling) was closed mid 2003, although fertiliser application continued. Yield recording commenced in Trial 139 (Spacing, Kumbango) in 2003 and has shown that the wider avenues have increased yield. Observation also suggests that the wider avenues also promote better ground cover.

Trails 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.

Again in Trial 137 (Systematic N, Kumbango), there was a small but significant response in FFB to N in its second year with the optimal rate around 5 kg AC/palm. In Trial 138b (Systematic N, Haella), there was the first yield response in the third year of the trial. Trial 403 (systematic N, Kaurausu) again showed a response to N in this, the fourth 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 fertiliser treatments, there was a significant effect of progeny (in the limited subset that could be analysed) in Trials 148 and 149. The first of the Mg trials (Trial 144; Mg & K, Waisisi) to be established has now shown a yield response – this is the first such response to Mg in WNBP. This response in yield was preceded by a response of symptoms as reported in last years Annual Report.

West New Britain Province (Hargy)

The factorial trials 204, and 209, in general continued to show similar results to previous years. In 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 205 EFB produced a small but significant effect on yield last year but not this year. However, once again, progenies had the biggest 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. Trials 211 (Systematic N at Navo) and 212 (Systematic N at Hargy) for the first time showed small but significant response in yield. Trial 213 (N, P on high ground) again showed a significant response to AC, although yields overall were generally low.

Oro Province

In the fourth year of Trial 324 (N sources, Sangara) there was a significant effect of N rate on yield; but not of N fertiliser type. 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. It was prosed at the 2004 SAC meeting that this trial be moved to another site. Trial 333 (Mg & K Sources) 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. TSP continues to have no effect. On the poorer Hagita (buckshot) soils (511), there are large positive effects of SOA, TSP and EFB, and this year a smaller, but significant 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 2004 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 end of 2005. Trial 254 (B trial) has been marked out and treatments commenced in 2004.

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. In Trial 331, there was a general trend of increased yield with in creased density, however, this trend can probably be attributed to the number of palms per ha at this stage.

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. 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. A similar trend has been found in the one plantation that has been studies. 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

Smallholder Tissue Analysis

Comparison of tissue analysis results from 2001 and 2004 shows a substantial difference in the variability of results from year to year and the relationship between subsequent analysis from the same block. The extent of these differences also depends on the nutrient analysed.

Quality Control

An industry-wide set of Standard Reference Material was produces to allow comparison of analysis of plant material. This will allow, within batch, between batch and between years comparisons. There is enough material to last the industry until at least 2015.

BACKGROUND INFORMATION

STAFF

Senior Agronomist

Dr. Mike Webb (commenced March 2004)

Agronomists

Mr. Murom Banabas (conducting PhD)

Mr. James Kraip, Islands Region Agronomist

Assistant Agronomists

Ms. Rachael Pipai, Dami

Mr. Winston Eremu, Bialla

Mr. Steven Nake, Higaturu

Ms. Jojo Papah, GIS, Higaturu (departed July 2004)

Field Supervisors

Mr. Paul Simin, Dami

Mr. Jeren Okka, Kapiura

Mr. Graham Bonga, Higaturu

Mr. Wawada Kanama, Milne Bay

Mr. Kelly Naulis, Poliamba

Ms Norma Konimor, Dami

Ms Pauline Hore, Higaturu

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 2004

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	**Total**
						West New Britain Province							
Navo	693	589	708	277	371	369	180	287	415	423	74	103	**4489**
Bialla	604	505	400	256	232	185	332	246	401	464	224	199	**4047**
Dami	408	579	707	168	319	276	150	36	195	206	120	297	**3462**
Garu	730	523	618	184	419	164	28	14	139	103	313	165	**3400**
						Oro Province							
Mamba	362	482	272	302	267	267	136	195	323	444	360	260	**3671**
OPRA	116	256	215	169	289	192	10	90	54	85	157	137	**1769**
Embi	193	299	351	158	324	127	40	nd	nd	nd	nd	83	**1575**
Ambogo	188	107	170	160	345	145	8	63	4	138	112	nd	**1440**
Milne Bay Province													
Waigani	nd	117	215	216	188	241	88	55	66	146	157	128	**1615**
						New Ireland Province							
Poliamba	334	455	406	434	326	256	146	83	162	239	187	120	**3148**

Monthly and annual sunshine hours in 2004

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	**Total**
West New Britain													
Navo	71	213	275	324	289	278	301	308	310	246	230	228	**3073**
Bialla	61	106	107	145	73	154	167	131	130	127	157	122	**1479**
Dami	135	106	110	161	136	86	130	181	125	185	164	179	**1698**
						Oro Province							
Mamba	153	43	98	131	No		cards	111	137	181	156	109	**1119**
OPRA	217	122	104	193	66	No	cards	134	196	245	200	182	**1656**
						Milne Bay Province							
Sagarai													
						New Ireland							
Poliamba	173	137	148	182	197	121	208	190	175	192	nd	nd	**1723**

*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 done from July 04 to July 05

Introduction

This report covers activities done from July 04 to July 05 including analysis of water samples collected from various experiments at Popondetta and Dami in laboratory at Massey, running soil water retention tests at Massey, setting up laboratory (Massey) and field mineralization experiments (PNG), setting up field leaching front experiment and setting up of pilot field denitrification studies. The field experiments were set up at Popondetta in Oro and at Dami in WNB Provinces. 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. All experiments done during this period are discussed.

Method and Materials

1 Incubation and mineralization experiments

The mineralization and nitrification rates of organic matter and inorganic fertilizers under the field conditions in oil palm plantations in PNG is unknown even though the process is very important in determining the availability of mineral N both for crop uptake and loss to the environment through various pathways. The generation of mineral N from soils from the various zones under the palms is important in terms of contribution to the total plant uptake and loss to the environment however the differences between the different zones under the palms are unknown.

Two experiments were carried out to address these unknowns and were done with the following aims

Aims

1. To determine the amount of N converted from AMC fertilizer to nitrate over time under field conditions.
2. To determine the amount of N released over time from organic matter under field conditions.

Method and materials

Soil samples were taken at 3 depths; 0-7.5, 7.5-15 and 15 – 30 cm depths from frond piles, frond tips and between zones while only at 0 – 7.5 cm depth in the weeded circle and harvest path. Soil samples were taken at only 1 depth in the weeded circle and harvest path because less nitrification was seen from the laboratory incubation experiment. At Dami because of the large organic layer in the frond piles, the top 5 cm layer was also taken and labelled as litter layer. For each of the zones, the soil samples were taken from 5 sampling points and from 5 palms at a distance of 3 - 4 palms from each other. However at Dami, soil samples were taken a palm distance from each other because the other areas were fertilized at the time of sampling except the sampling site. At each sampling point, a 30 cm deep hole was dug with a spade and samples were taken from the 3 required depths. All samples for each respective zone and depth were compounded. The compounded soils were then sieved through a 2mm sieve and thoroughly mixed. All 5 zones are considered because soil moisture monitoring data indirectly suggests the palms take up water (and nutrients) irrespective of distance from the palms and areas (frond piles) traditionally thought of having high rooting activities.

The soil samples were then divided into 2 groups. The first group was to be incubated without added N fertilizer while the second had fertilizer added. For the nil fertilized soils, a 100g of sieved soil was packed (loosely) into a cut pvc pipe of 5 cm diameter and 7 cm length. For the litter samples at Dami, 50 g of soil was packed into the pipes because the volume of the litter was large. The open end of the pipes were closed with nylon cloth and fly wire and held together with rubber band. Nylon cloth and fly wire were used to allow moisture and temperature inside the tubes to equilibrate with that of the soil outside. Each sample from each of the zones and depths was replicated five times.

For the fertilized soils, a 100 g of soil was mixed thoroughly with 0.5 g of AMC fertilizer and packed as was done for the nil fertilized samples. For the litter layer samples from Dami, 0.25 g AMC was added because the sample weight was only 50 g.

The samples were then buried into a space in the soil 50cm deep and 1.5 m x 2 m area. The tubes were buried side ways to avoid the packed samples coming out of the pipes if the rubber bands break or loosened up during the period of incubation. The samples were buried at the bottom of the pit and then covered with a plastic. A 10 cm thick layer of soil was then place over the plastic. A sheet of plastic was then placed over incubation site to prevent rain water getting into the pit and wetting up the incubated soils.

Extractions for inorganic N forms were done with 2M KCl solutions (5 g soil to 50 mls KCl) and were done on Days 0, 1, 3, 7, 14 and 28. Soil moisture content was determined for each of the samples on the respective extraction days.

Soil temperature was measured at each of the incubation during the incubation period. For the Dami soils, soil pH and total dissolved solids were also measured at the end of the experiment.

From the original soil samples a sub sample from each of the zone and depth were frozen to determine Total N, C, CEC and any other chemical characteristics that may be required subsequently.

2. Leaching front experiment

Because of the large variability in through fall and redistribution of stem flow, soil heterogeneity in terms of micro topography, infiltration rates and ground cover, differences in soil hydraulic conductivity due to differences in soil texture with depth, initial soil moisture conditions under oil palm, it is assumed that water movement with nutrients through the soil is not uniform. This is probably a valid assumption, however, no measurements have been made to verify this assumption for oil palm especially in areas where fertilizers are spread onto. The differences in movement of nutrients through the soils and their redistribution with depth have significant implications for their availability for crop uptake.

Aims

1. To determine the depth variation in nutrient movement in the soil that fertilizer is applied to (frond piles and between zones) under oil palm.
2. To determine the differences in depth variation in nutrient movement between frond piles and between zones (the two fertilised zones).

Method and materials

This experiment was conducted at both Popondetta and Dami. The experiment was done at Popondetta first and then at Dami because of earlier rainfall peak at Popondetta which is normally around December than at Dami, which is around February/March. The experiment was carried out at the sites where all other N loss experiments were and are currently running.

The experiment was done in the frond piles and between zones areas because these are the two areas to which fertilizers are mostly applied. The two areas were marked out and pegged. For the frond pile, the length was 10 m and the width was 1.5 m. The between zones also had a similar width of 1.5 m but had two lengths of 5 m each on either side of a palm. Each of the zone was surrounded by a bund of earth covered with plastic to stop run on and runoff from and to the rest of the plantation. Along the length and width on all sides of the zones, empty cans attached to bamboo stakes were placed at every 0.5 m to measure through fall. Plastic folded into funnel shapes were inserted into the cans to stop through fall splashing out from the can. After every rain event, through fall collected in the cans were measured. At Dami, the marked out zones were surrounded with bamboo stakes to stop plantation field workers from applying fertilizers onto the zones.

In the frond piles, large undecomposed fronds were moved carefully to one side of the marked out zones leaving only the partly and fully decomposed litter layer behind. Fertiliser was then spread evenly over the area. The undecomposed materials were then returned to their original locations after the fertilizer was applied. At Popondetta in the between zones there are no pruned fronds, therefore fertilizer was spread directly onto the area. However, at Dami there were frond tips in the between zones therefore they moved to the sides and after fertilizing and returned after spreading fertilizer. Any growing undergrowth was left as it was.

Ammonium chloride was applied onto the 2 zones at a rate of 500 g per 1.5 m2 (5.0 kg AMC per 10m2). The rate was high on a per palm per year basis and was also high enough to swamp the background levels. The fertilizer was weighed into small plastic bags at 500 g each for each of the 1.5 m^2 area. Fertiliser was then evenly spread over each of the 1.5 m^2.

The date of sampling was determined from total rainfall less ETo over the same period. It was decided to sample when there was excess of 300 mm over ETo. After the excess rainfall amount was reached, the plots were covered with plastics to stop further rainfall falling onto the plots. At Dami soil samples were taken using an augur at 20 cm depth intervals and 20 cm apart. At Popondetta, a 3m deep trench next to the sampling site was dug with an excavator. Soil samples were then collected using bulk density cups at 10 cm depth intervals and 15 cm apart but were later compounded for 20 cm depths. At both stations all samples from the sampling points across the plot were compounded to 20 cm depths and were thoroughly mixed.

The soils were then extracted with 0.5M K_2SO_4 at 17 g soil to 50mls. The samples were shaken end over end in a clothes drying machine for 1 hour. The sample bottles were then allowed to stand for 30 minutes to settle the suspended solids before carefully decanted into small plastic bottles. After decanting the samples, the bottles were stored in a freezer. They were later sent to Massey and were analysed for Cl, NH_4-N and NO_3-N.

Soil moisture content was determined for each of the samples.

3. Pilot denitrification experiment

Nitrogen is lost from an agro ecosystem through leaching, in solution and particulate forms in surface runoff water, with harvested products and gaseous forms through denitrification. Nitrogen loss in gaseous form is very important not only because of its economic significance but also because of its contribution to the depletion of ozone layer. Very little has been done to quantify N gaseous loss from oil palm plantations. Because of the differences in soil chemical, physical and biological properties under the palms which are a result of management decisions, it can be assumed that there are also differences in denitrification process and resultant N loss in gaseous forms from the different management zones under the palms. This assumption will need verification.

Denitrification process depends on a number of factors including the soil oxygen levels, the quality of soil carbon, soil pH and presence of denitrifying organisms and soil nitrate levels. Though most oil palm growing soils are relatively well drained, there are periods of continuous rain events which last for 3 – 4 days resulting in many parts of plantations being temporarily water logged. Also there are patches of depressed areas in the weeded circles and harvest paths which can remain water logged for several days. The frond piles are also always moist and during rainy seasons, they can have water content above field capacity resulting in temporary semi water logged conditions. These different scenarios have the potential of triggering the denitrification process.

A pilot study was planned with the following aims before deciding on a comprehensive experiment.

Aim. 1) To estimate amount of N gaseous loss from the areas fertilizers are applied to.

2) To determine the amount of N gaseous loss as nitrous oxide from fertilized and non fertilized soils under palms.

Method and materials

PVC pipes 15 cm internal diameter and 30 cm length with welded galvanized sheets as lids were used as gas collection chambers. One end of the pvc pipes were sharpened from outside in so that this end when pressed into the soil, it would not cause any compaction at the edges. The pvc pipes were placed on soil under in the frond pile. The cut fronds were moved to the side leaving only decomposed materials on the soil surface. Before the pipes were pressed into the soil, a groove (4-5 cm deep) the size of the pipe edge was made with a sharp knife in the soil. The sharp end of the pipe was then placed into the groove and then using blocks of wood, the pipes were pressed into the soil to 5 cm depth. The outside edges were then pressed with soil to hold the pipes firmly in the soil.

The other end of the pipes was to be covered with welded galvanized sheet as the lid. A hole, size of an antibiotic bottle cap was made in the centre of the lid and a penicillin rubber cap was glued to the lid over the hole. The rubber cap was self sealed and a syringe needle was used to penetrate the rubber to collect gas samples from the bottles.

To close the lids, vaseline was rubbed between the lid and the pipes contact surfaces before closing the lids. Then a grey packing tape was placed around the contact points. This was done to ensure no gas produced inside was lost into the atmosphere during the experiment.

The chambers were left to stand without the lids overnight to equilibrate the surrounding soil conditions with the soil inside the chambers before any gas samples can be collected. There were 4 chambers used; 2 of the chambers had 20 g KNO3 fertiliser added to the soil surface and the other two had no fertilizer added.

At Popondetta, two 25 mls gas samples from the open air were collected at the start of the experiment. The chambers were then closed at 7 am and 25 ml gas samples were collected with a syringe at 2 pm. To collect gas samples from the chambers, the gas inside the chambers were mixed by pulling in about 40 mls of gas from the chambers and pumping it back into the chamber 3 times before pulling out 25 ml sample for analysis. After sampling at 2 pm the lids were removed. Gas samples were collected at Days 0, 1, 3, 7, 14 and 28. Soil temperature was measured during the sampling periods.

At Dami, gas samples were collected from the chambers straight after the lids were placed and 1 hour later at Days 0, 7, 14 and 28. The samples were collected in vacuumed glass bottles and were sent to Massey University. At Massey the samples were analysed by New Zealand Landcare for nitrous oxide, carbon dioxide and methane.

4. Nitrogen fertiliser loss in surface water runoff plots at Popondetta.

Aim. 1) To determine water yield from a 4 palm plot for water balance component.

2) To determine the proportion of applied N fertilizer lost through surface runoff water.

Water yield from the large surface runoff plots assist in determining water balance of an oil palm agroecosystem, ie what is not runoff is water that is held in the palm vegetation, cover crops, or percolates through the soil. The volume of water that drains through the soil will be determined from the FAO 56 evapotranspiration model. Concentrations of soluble N in surface runoff water have been determined however proportion of added fertilizer lost in surface runoff water have yet to be determined. This experiment was an extension to water balance experiment established earlier and was done at Popondetta.

Method and materials

For details of trial setup see 2003 annual report.

Three additional plots were established at Popondetta, totalling 6 plots. The 6 plots were divided into 3 pairs. The 3 pairs of plots were chosen on the basis of about equal amounts of water yield. From each of the pairs of plots, one plot had fertilizer applied to the frond piles and between zone areas while the other had no fertilizer added. Fertiliser applied was ammonium chloride and applied at the rate of 1 kg per palm. A second dose was given 2 months later.

Water yield was measured and water samples were collected for rain events just before and subsequent to rain events after fertiliser was applied. For a couple of rain events, water samples were also collected for every 200 litre drum that was full. This was done to see the amount of nutrient loss during a single rain event. Two lots of water samples were collected from the runoff plots, the 1st lot had HCL acid added to stop microbial growth while the 2nd lot did not have anything added to. The acid added samples were to be analysed for NH4-N and NO3-N while the second lot of samples were to be analysed for Cl. Collected water samples were sent to Massey University for analysis.

Results and discussion

a) General

Most of this year (June 04 – June 05) was spent analysing water, plant and soil samples in Massey, setting up experiments and collecting data and soil and water samples from the experiments at Popondetta and Dami. Some of the results from last 2 years report are also presented here along with results from some of the experiments done in the last 12 months.

b) Infiltration rates

Infiltration rates in WNB were higher in the frond piles than in the other zones under the palms (Figure 1). In Oro Province, the infiltration rates in the frond piles and between palms were comparable but were higher than in the weeded circle and harvest path. The rates were low in the weeded circle and harvest path due to soil compaction in the soil surface.

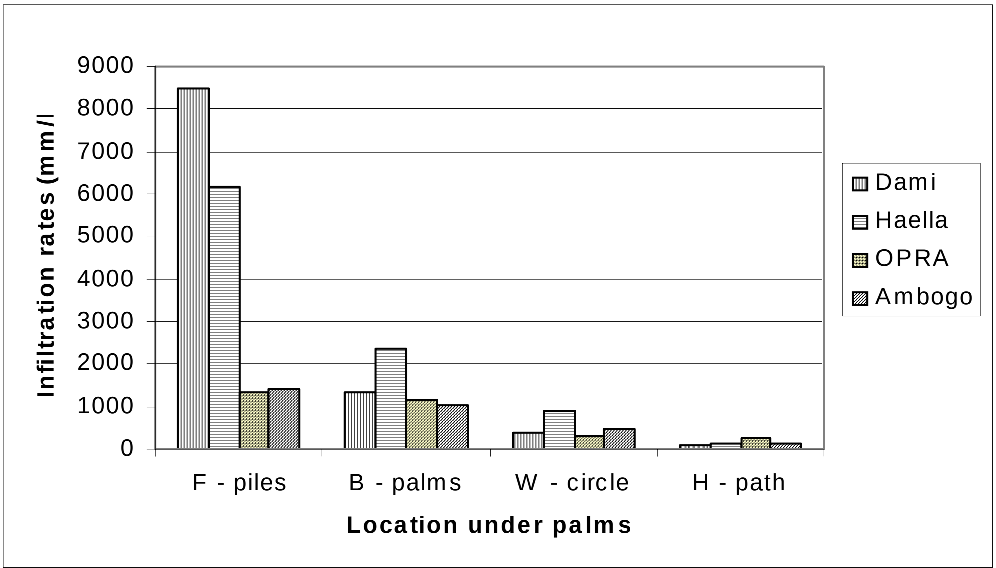


Figure 1. Mean infiltration rates (mm/hr) for different locations at different sites

c) Through fall and stem flow

The percentage of rain appearing as trunk flow showed considerable variation, both between replicates and from day to day. On individual days one of the three replicate palms measured produced up to twice as much stem flow as the one with the least trunk flow. To show the day-to-day variation, the percentages of the daily rainfall falling over the 81 m^2 area occupied by each palm that appeared as trunk flow are plotted as a function of daily rainfall in Figure 2. Each data point is the average of the three replicate measurements on that day. Trunk flow was typically less than 7% of rainfall for days with less than 5 mm of rain, but between 10 and 20% on wetter days.

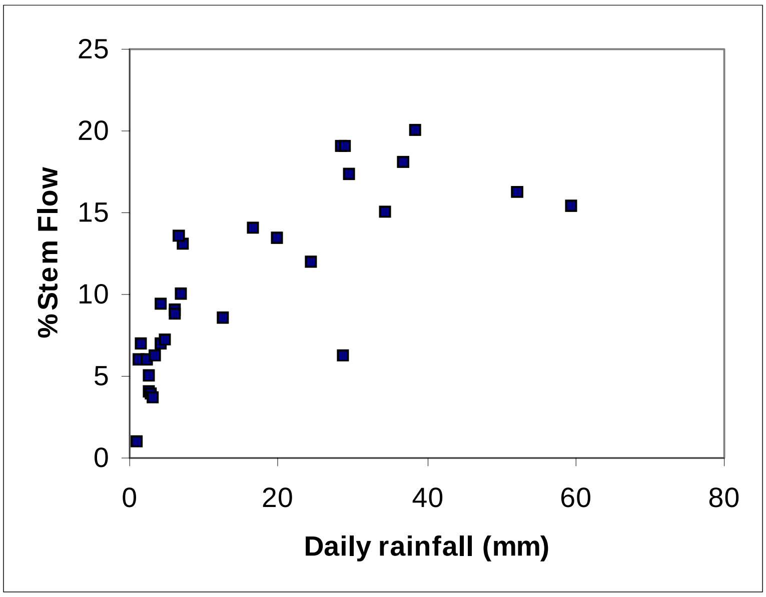


Figure 2. The average daily trunk flow for three oil palms, expressed as a percentage of daily rainfall, plotted against the daily rainfall.

The percentage of rainfall collected as through fall in the five annular zones around the trunks was found to vary markedly, from 27% in zone 1 adjacent to the trunk, to around 100% in zones 4 and 5 furthest from the trunk, as shown in Figure 3a. This three-fold difference has implications for management that will be discussed later. However it must be remembered that the trunk flow water probably mostly infiltrates in zone 1, which covers only 7.5% of the area. Thus zone 1 may be the zone subject to the most rather than the least leaching.

The 21 small cans placed at 2 m spacing in a row along the frond pile provide data on through fall variability on a smaller scale. There seems to be some spatial correlation in the data, with adjacent cans tending to give similar values (Figure 3b). For example, cans 10 to 13 have low values? As the palms were spaced 9 m apart, periodic variation in the values every four or five cans might be expected. There may be a suggestion of this in the data, but it does not stand out clearly

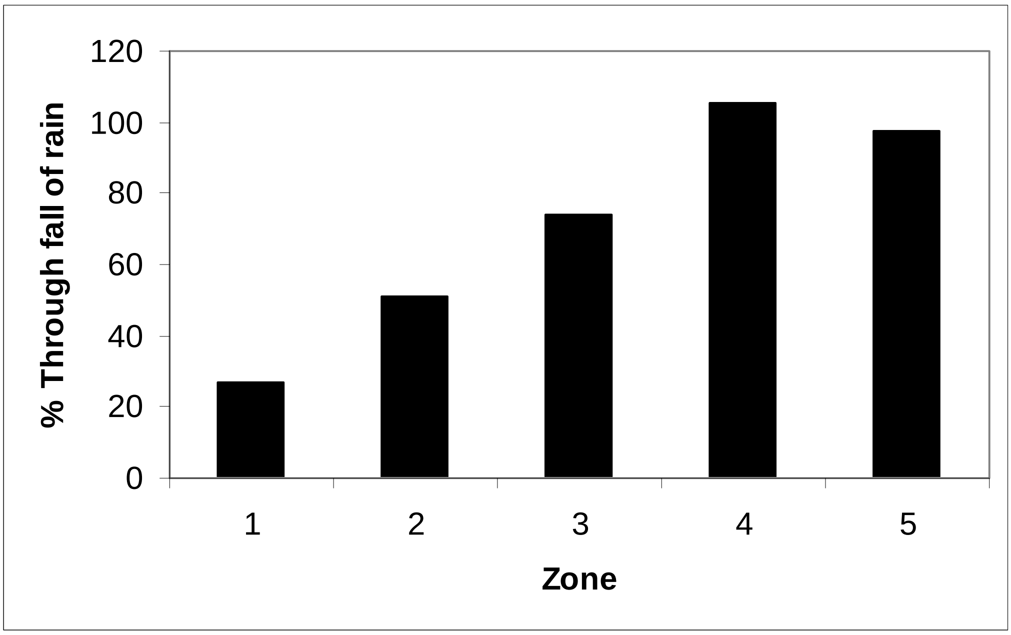


Figure 3a. The measured through fall in the drums as a percentage of rainfall for the five annular zones around the trunk. Zone 1 is closest to the trunk

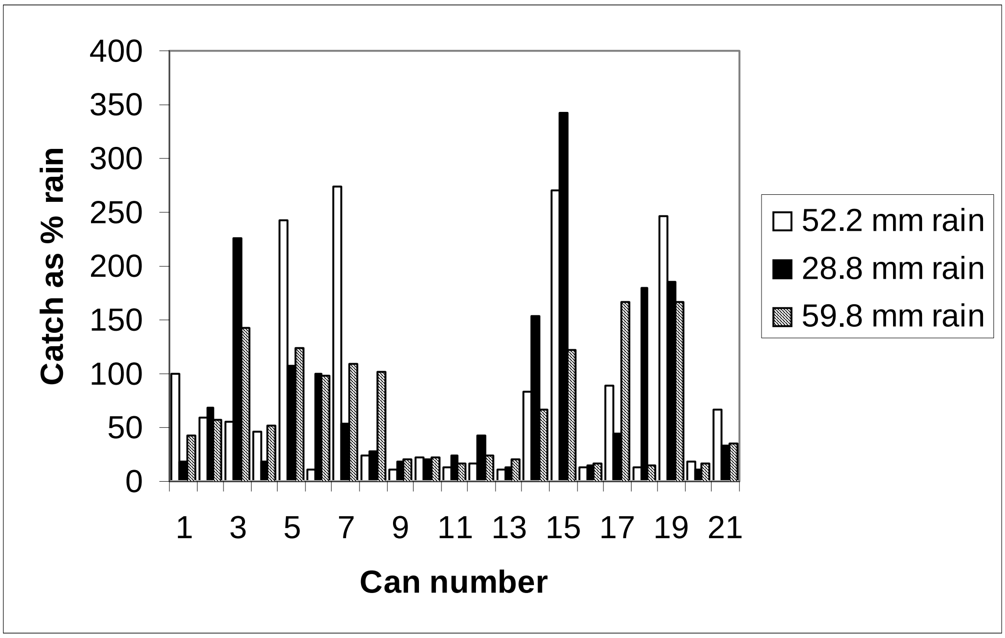


Figure 3b. The through fall catch on three wet days in 21 small cans spaced 2 m apart along a frond pile.

d) Large surface runoff plots

Runoff coefficients were high in Popondetta compared to Dami. The highest coefficient in Popondetta was 44 % while at Dami it was only 8 % (figures 4 and 5).

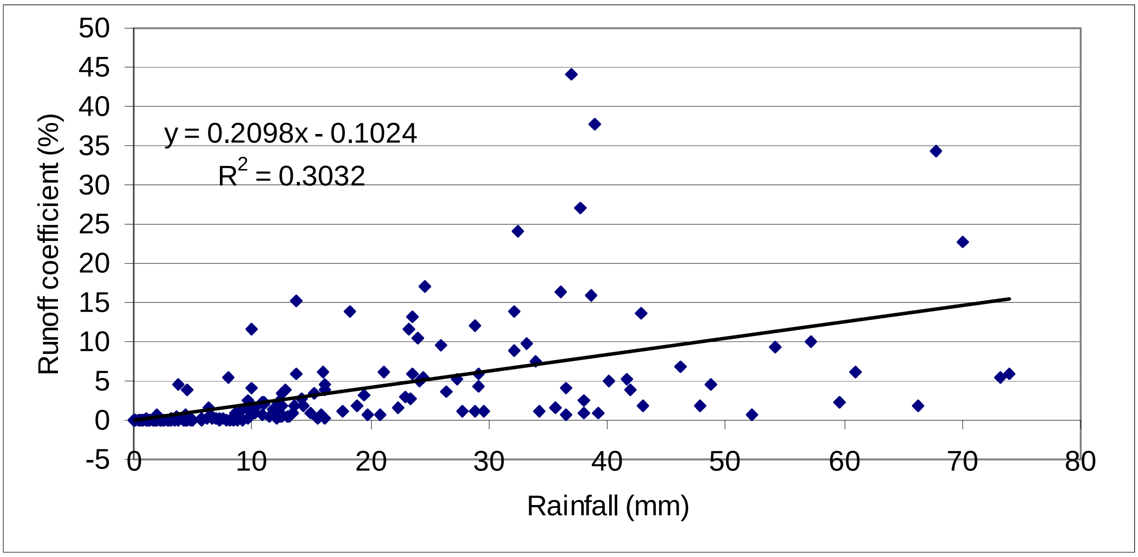


Figure 4. Mean runoff coefficients for large 4 palm surface water runoff at Popondetta

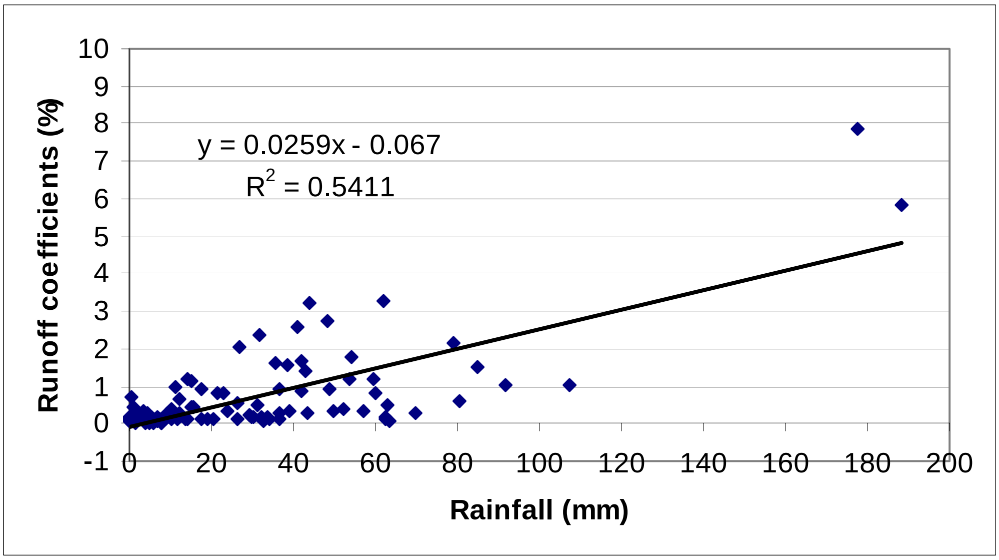


Figure 5. Mean runoff coefficients for large 4 palm surface water runoff at Dami

At both sites, significant runoff occurred when mean theta (soil volumetric water content to 160 cm depth) for all the zones under the palms exceeded 600 mm (Figures 6 and 8). The relationship was much clearer between theta and runoff coefficients especially from the weeded circle (Figures 7 and 9). It appears the main trigger to surface runoff is probably stem flow and soil wetness under the weeded circle.

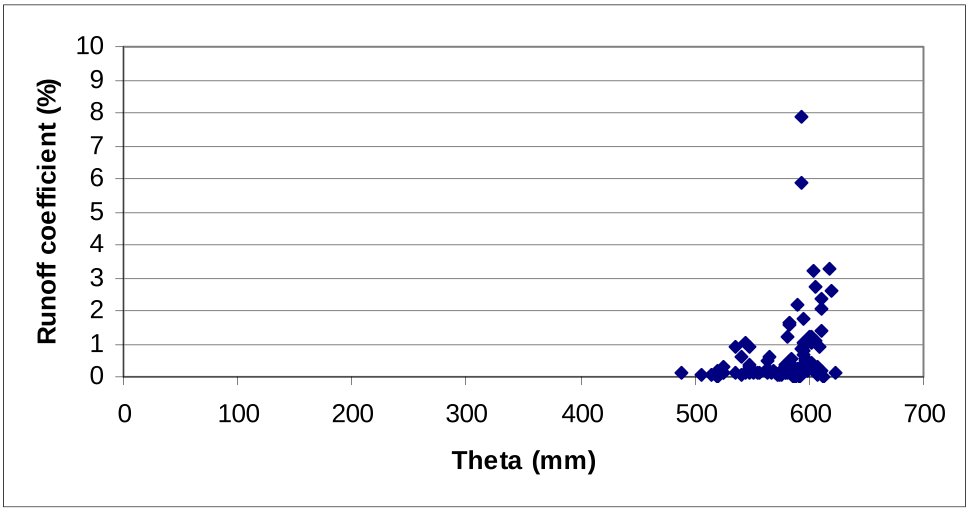


Figure 6. Relationship between mean runoff coefficient and mean theta from all the zones at Dami

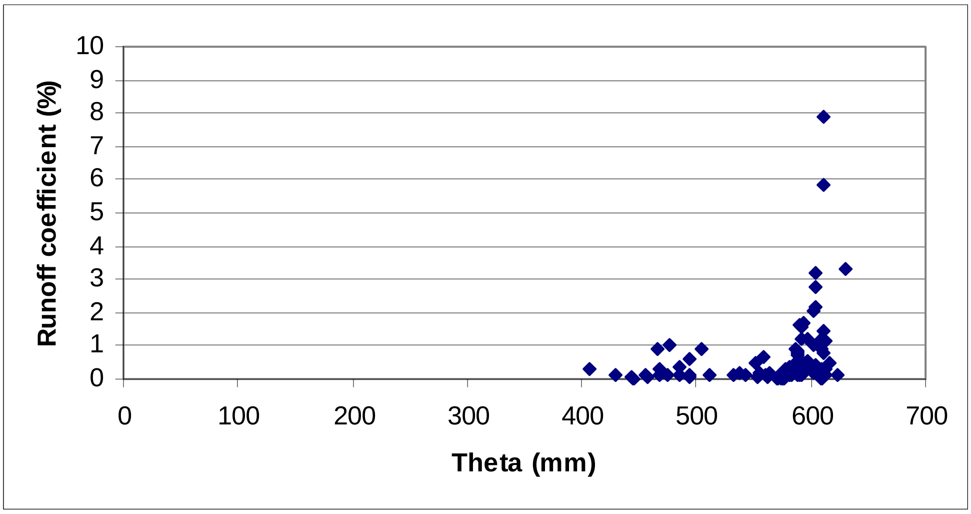


Figure 7. Relationship between mean runoff coefficient and theta from the weeded circle at Dami

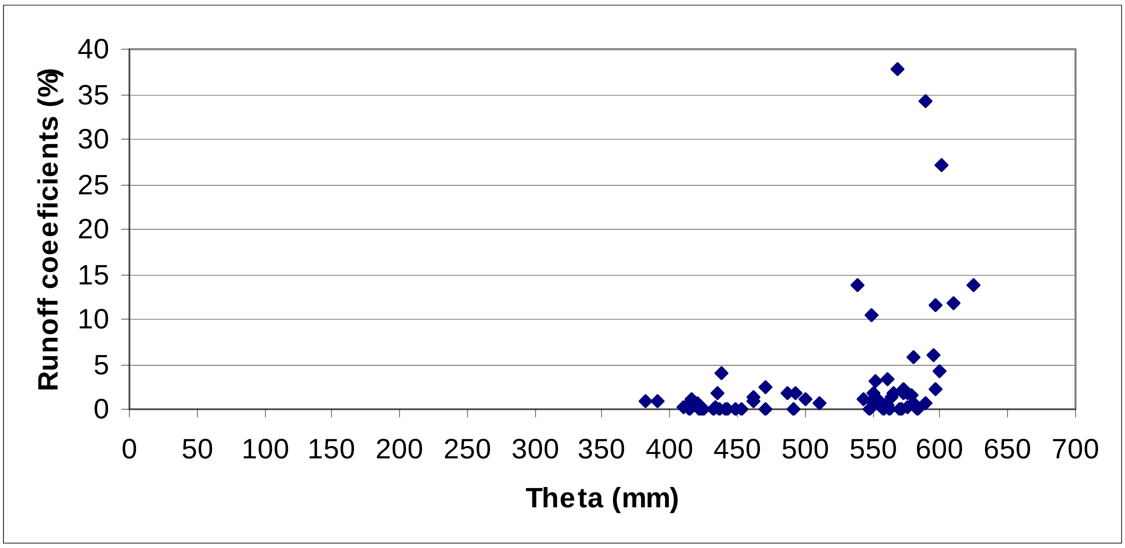


Figure 8. Relationship between mean runoff coefficient and mean theta from all the zones at Popondetta

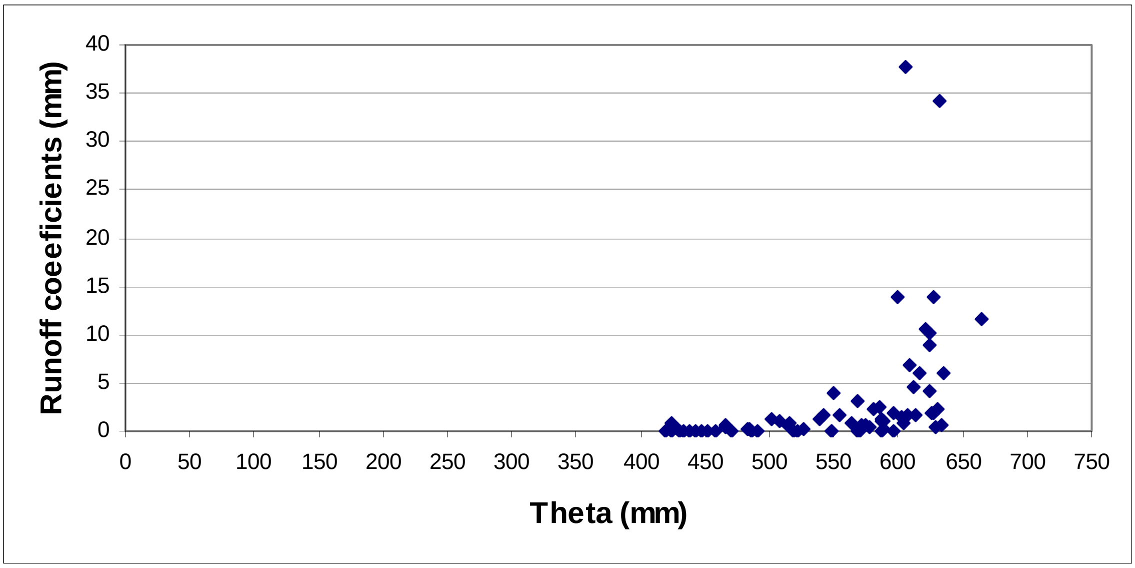


Figure 9. Relationship between mean runoff coefficient and theta from the weeded circle at Popondetta

Soil moisture monitoring (Sentek Diviner 2000)

At Popondetta a period of 39 days with no rain was chosen and water uptake during this period was looked at. The difference of water content at the beginning and end of the period was taken to be water taken up by the oil palm crop. It is shown that irrespective of distance from the palm and the different zones, water was taken up from everywhere under the palms both at Dami and at Popondetta (Figures 10 and 14). Water uptake after 7 days of drying showed that water uptake from the weeded circle area was higher than from the other zones (figure 11 and 15).

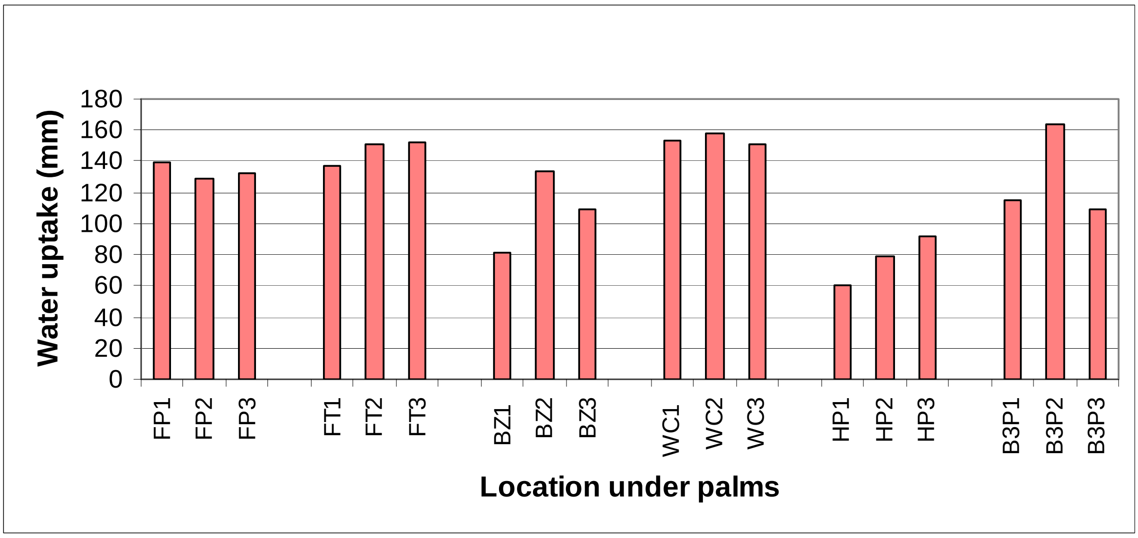


Figure 10. Water uptake from all the zones under the palms at Popondetta over 39 days period

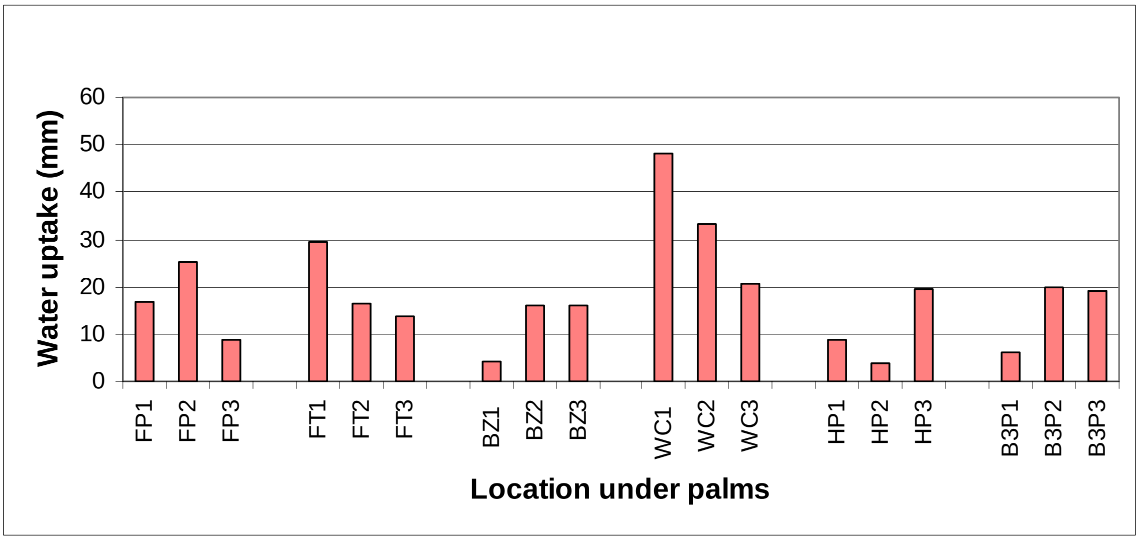


Figure 11. Water uptake from all the zones under the palms at Popondetta over the first 7 days.

At Popondetta, after 40 mm of rainfall, zones were compared to see which zones had the highest change in soil moisture content (figure 12). The weeded circle had the highest change in soil moisture content. The change in moisture occurred to more than 160 cm depth (Figure 13). Much of the stem flow appears to infiltrate in the weeded circle.

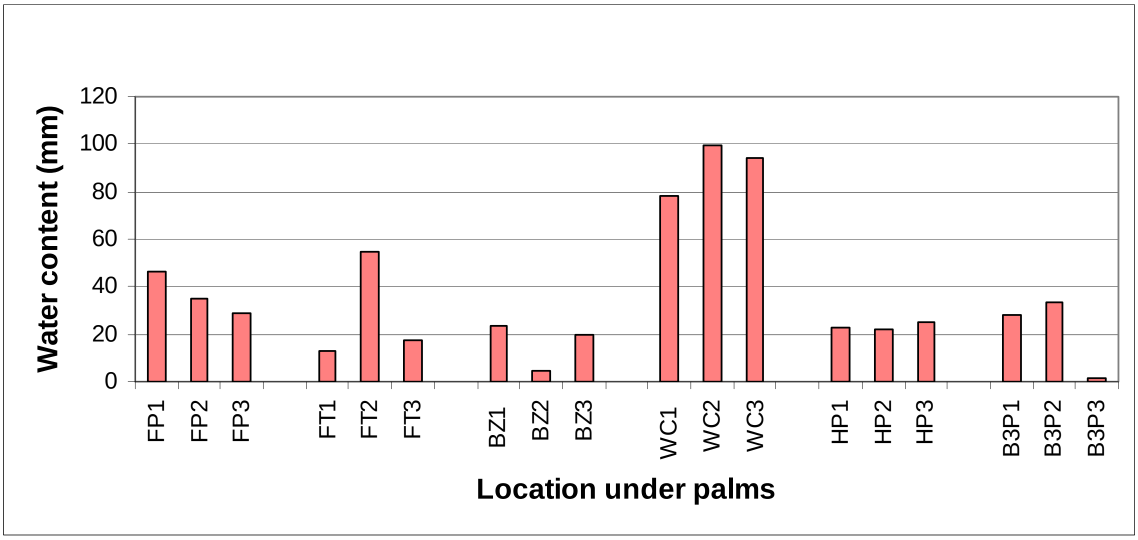


Figure 12. Change is soil water content in the different zones after 40 mm rainfall at Popondetta

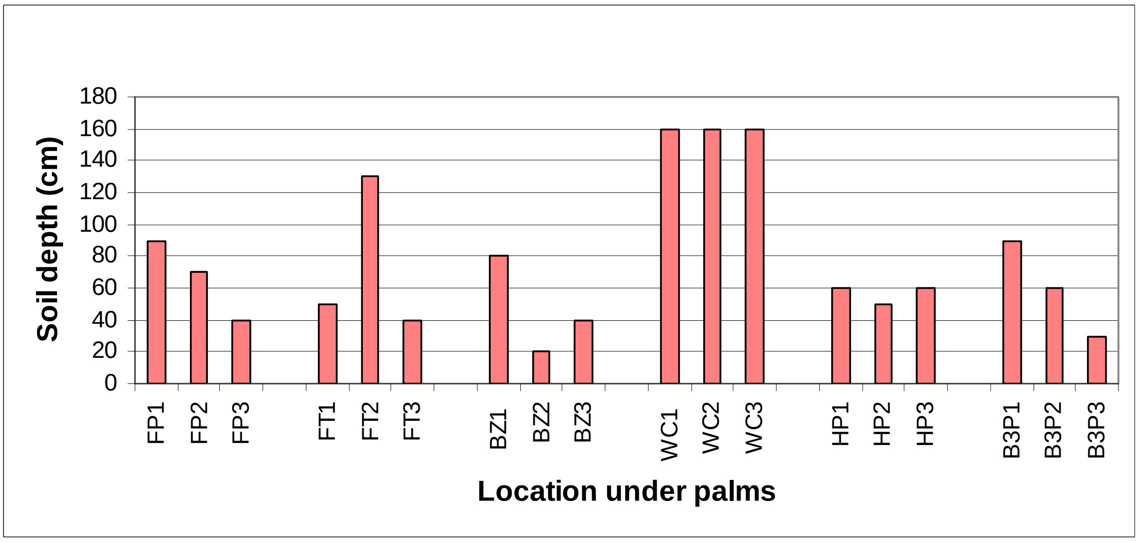


Figure 13. Soil depth to which water content changed after 40 mm rainfall at Popondetta.

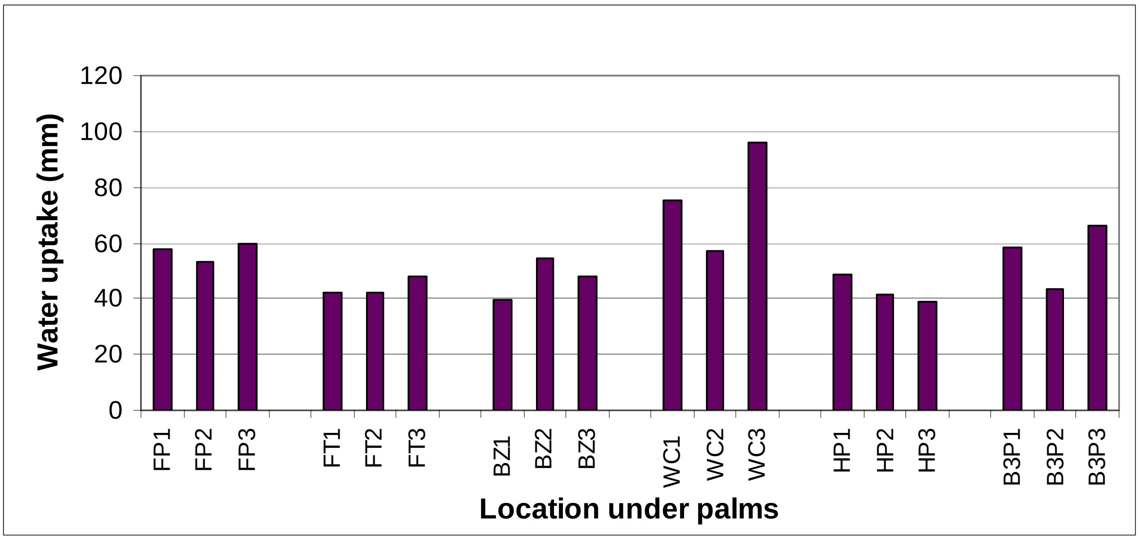


Figure 14. Water uptake from all the zones under the palms at Dami 20 days period

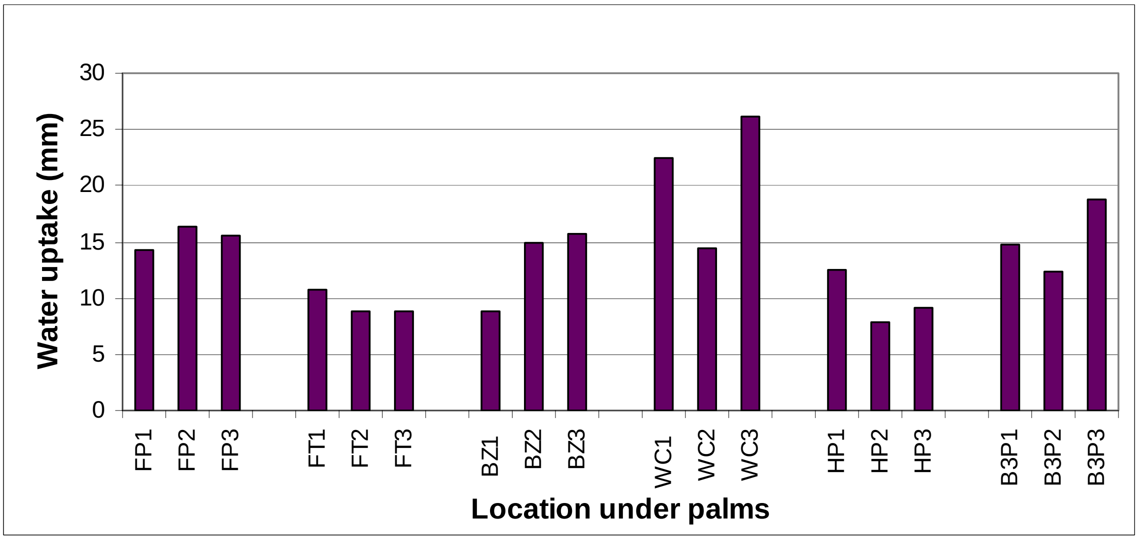
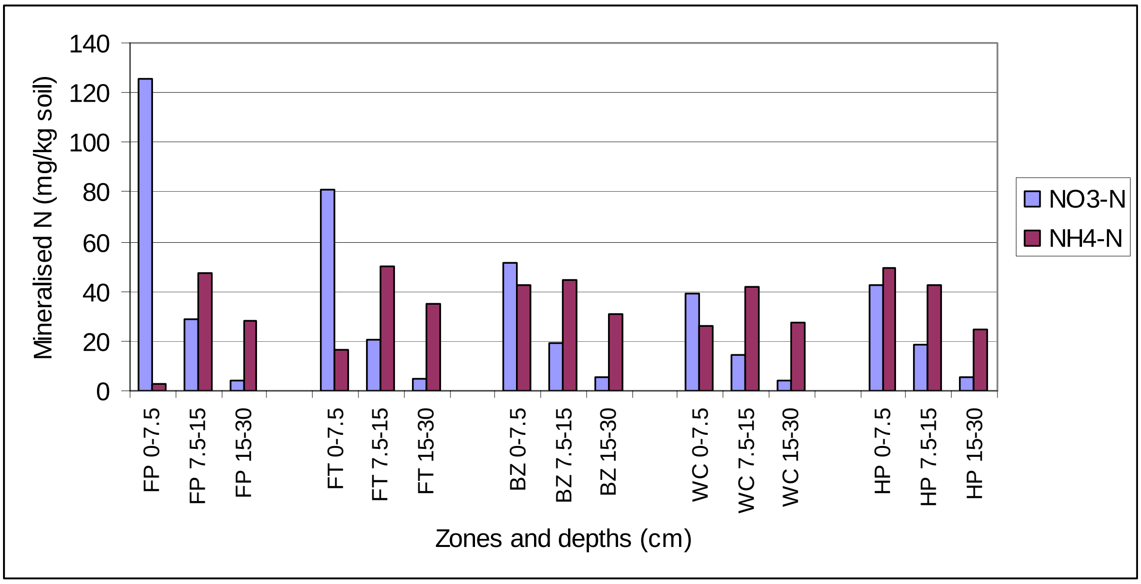
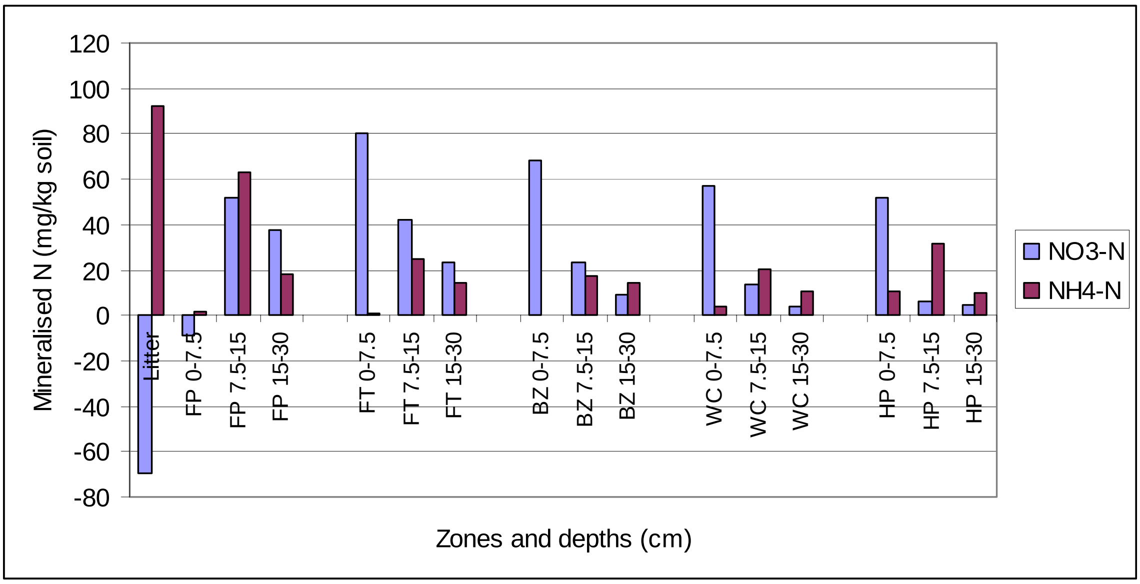


Figure 15. Water uptake from all the zones under the palms at Popondetta over the first 7 days.

f) Nitrogen mineralization

Full results from field incubation and mineralization were not available at the time of reporting therefore only laboratory incubation/mineralization results are presented. At Popondetta, nitrates production was highest in the frond piles and frond tips 0-7.5 cm depth. In the other zones and lower depth, there appeared to be some inhibition effect of nitrate production. At Dami there was a large production of nitrates in the 0-7.5 cm depth except in the frond piles. In the frond piles, nitrate produced in the litter layer and 0-7.5 cm depth was immobilized most likely into the organic matter.





g) N loss processes and amounts

Some calculations were done to estimate the amount of mineral N that is lost through surface runoff water and through the leaching process. There was a mean of 4 kg N los through surface runoff water in Popondetta compared to 0.23 kg at Dami (Table 1). Most N lost in Popondetta was in the NO_3-N form while at Dami it appeared to be in the NH4-N form.

Most of the N lost at both sites appears to be through the leaching process and in the between zones (Table 2). The common N form lost was NO_3-N.

Table 1. Estimated N loss in surface runoff water in Popondetta and Dami.

		Popondetta			Dami		
		NO3-N	NH4-N	Total	NO3-N	NH4-N	Total
N Conc.	Mean	0.79	0.36	1.15	0.17	0.48	0.64
(mg/l)	Min	0.07	0.02	0.08	0.00	0.04	0.04
	Max	5.20	1.66	6.85	0.41	1.03	1.44
Annual rainfall (mm)		3500	3500	3500	3500	3500	3500
Mean daily (140 days rain)		25	25	25	25	25	25
Surface runoff (mm)		2	2	2	0.26	0.26	0.26
Runoff (L/ha)		3444805	3444805	3444805	365260	365260	365260
N loss	Mean	2.73	1.23	3.96	0.06	0.17	0.23
(kg/ha)	Min	0.23	0.06	0.29	0.00	0.02	0.02
	Max	17.90	5.71	23.61	0.15	0.38	0.52

Table 2. Estimated N loss through leaching process in Popondetta and Dami

		Popondetta			Dami		
		NO3-N	NH4-N	Total	NO3-N	NH4-N	Total
Frond pile (µg/ml)	Mean	2.34	0.14	2.48	1.22	0.17	1.39
	Min	0.00	0.00	0.00	0.00	0.00	0.00
	Max	38.90	2.25	41.15	9.30	1.80	11.10
	Std dev	4.10	0.29		1.77	0.28	
Between Zones (µg/ml)							
	Mean	4.67	0.15	4.82	2.68	0.23	2.91
	Min	0.00	0.00	0.00	0.00	0.00	0.00
	Max	38.90	0.93	39.83	42.30	4.73	47.03
	Std dev	7.87	0.20		5.96	0.58	
		Popondetta			Dami		
Drainage	(mm)	2500	2500	2500	2500	2500	2500
	in m3/ha	25000	25000	25000	25000	25000	25000
	in l/ha	25000000	25000000	25000000	25000000	25000000	25000000
		Leached N (kg/ha)					
Frond pile		NO3-N	NH4-N	Total	NO3-N	NH4-N	Total
Mean		58.4	3.6	62.0	30.5	4.2	34.7
Min		0	0	0	0	0	0
Max		972.5	56.25	1028.75	232.5	45	277.5
Between Zones.							
Mean		116.9	3.7	120.6	66.9	5.8	72.7
Min		0	0	0	0	0	0
Max		972.5	23.3	995.8	1057.5	118.3	1175.7

h) Planned work for June 2005 – June 2006

Complete root distribution studies

Complete leaching front experiment

Complete nitrogen uptake experiment

Complete denitrification studies

Complete write up of a) through fall and stem flow experiments

b) small and large surface runoff water experiments

c) Root distribution paper (with Paul Nelson)

d) N incubation and mineralisation

OVERCOMING MAGNESIUM DEFICIENCY ON VOLCANIC ASH SOILS

(M.J. Webb, P. Nelson, S. Berthelsen)

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 second 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:

- Fully implemented three of the four field trials in PNG, with the last one almost completed. These field trials are examining the effectiveness of alternatives to the standard Mg fertiliser (soluble kieserite) in overcoming Mg deficiency.
- continued to characterise some of the chemical properties of several potential Mg fertilisers through laboratory and glasshouse trials.
- measured the response of Mg concentration and photosynthetic parameters in fronds suffering various degrees of Mg deficiency symptoms
- run simulation models of water and solute movement through soil profiles to assess the potential of alternative Mg fertiliser strategies.
- 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, and 333).

FUTURE WORK

This project was reviewed externally as part of a scheduled mid-term review in Dec 2004. The project team accompanied the review team and presented results and progress from various aspects of the project. They also presented ideas for an expansion of the project into areas that showed K deficiency. This expansion (in two parts) was accepted by ACIAR with a new budget and proposal which will continue in parallel with the original project. Details of the expansion projects are available in the Research Proposals 2006.

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.

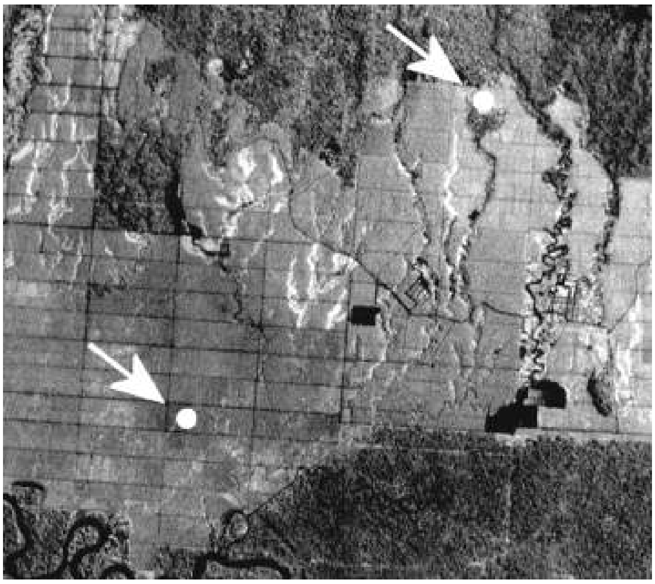


Figure 1. White circles show the position of the two omission trial sites in Haella Plantation.

DESIGN

The trial consists of a circle, about 24 palms in diameter, to which no fertiliser is applied. Fertiliser will be applied normally to the area outside the circle. Measurements will be 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 will 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 downslope 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 or Number of Bunches in either trial (Figures 2 and 3).

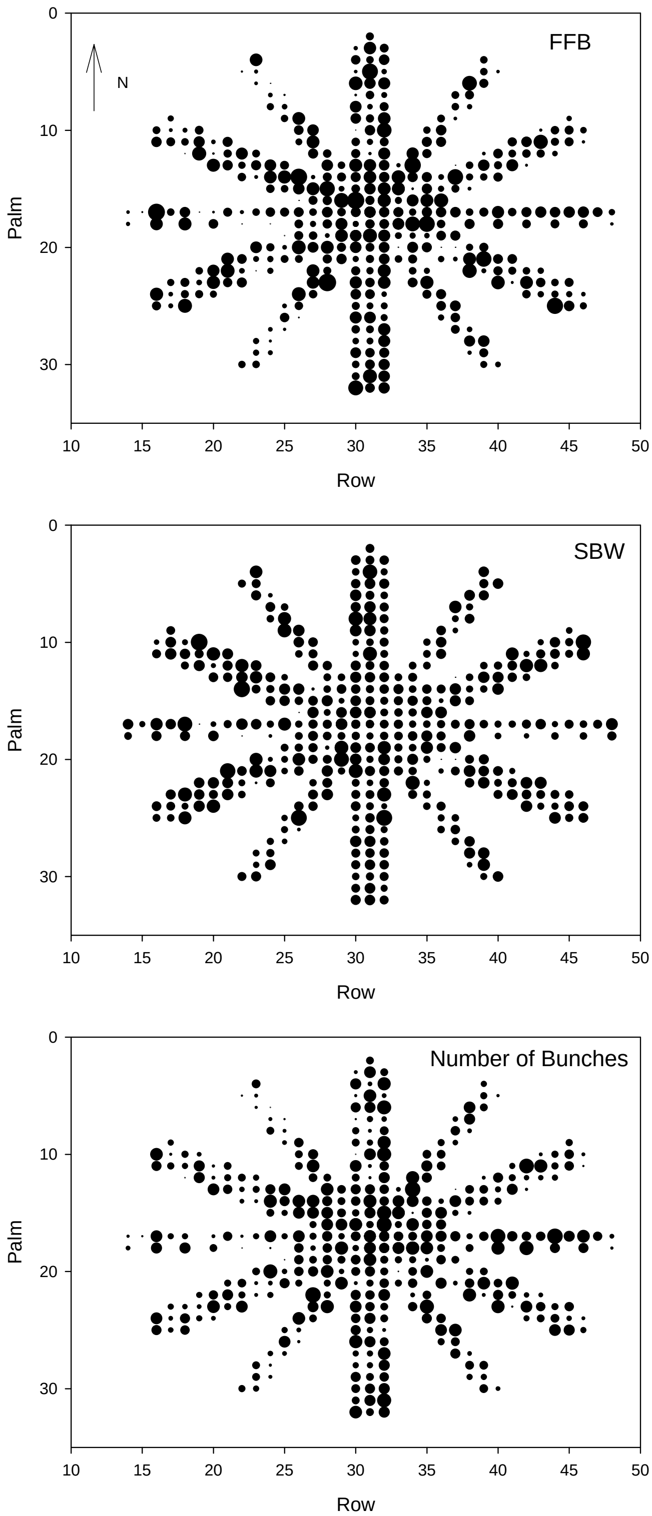


Figure 2. Effect of position of palms on yield and it components. Each dot represents a palm. The size of the dot represents the magnitude of the value. The landscape slopes downwards from north to south. Div II; downslope position

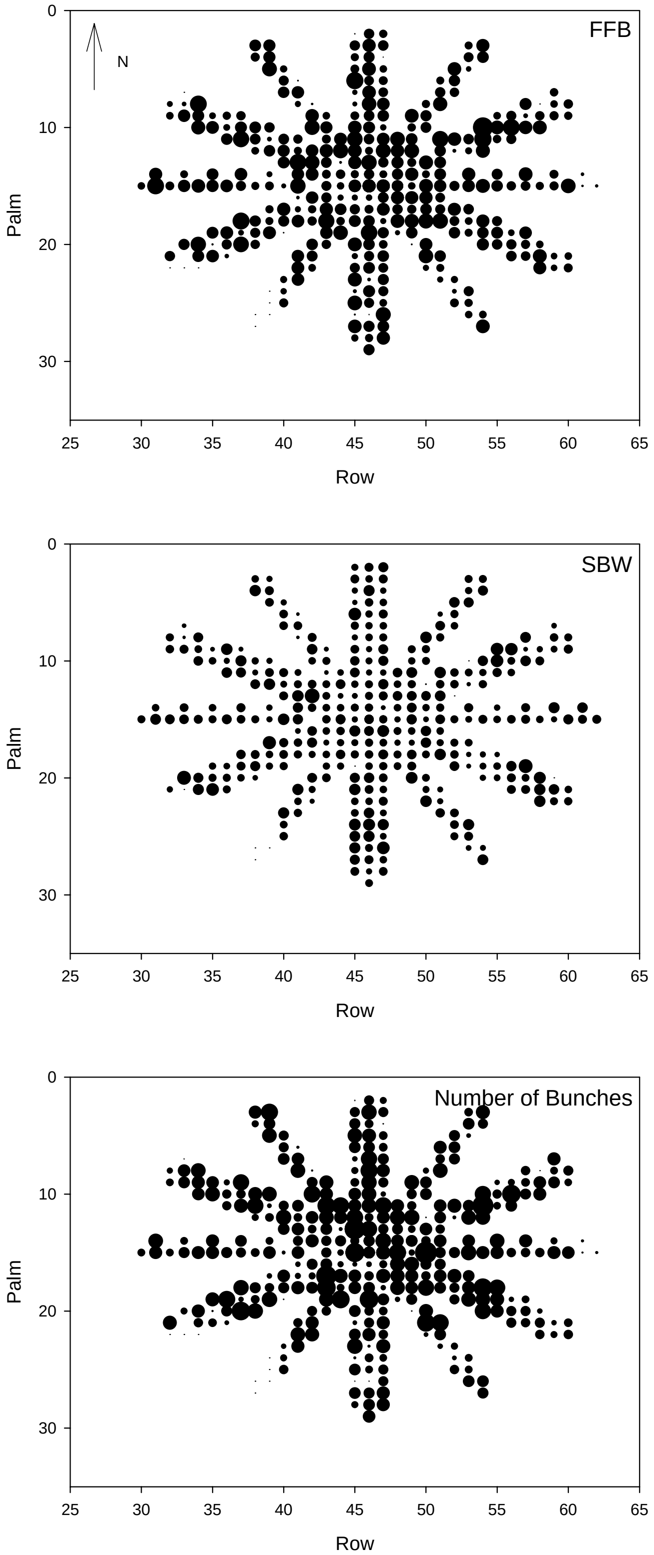


Figure 3. Effect of position of palms on yield and it components. Each dot represents a palm. The size of the dot represents the magnitude of the value. The landscape slopes downwards from north to south. Div III; upslope position.

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

(James Kraip & Mike Webb)

TRIAL 129 CROP RESIDUE AND FERTILISER PLACEMENT TRIAL, KUMBANGO

PURPOSE

To determine the effect of placing fertiliser on the weeded circle, frond pile or EFB.

SITE and PALMS

Site: Kumbango Plantation, Division 1
Soil: Young coarse textured freely draining soils formed on alluvially redeposited andesitic pumiceous sands and gravel with intermixed volcanic ash.
Palms: Dami commercial DxP crosses.
Planted in October 1994 at 135 palms/ha.

DESIGN

The trial was designed by biometricians from IACR - Rothamsted and the Pacific Regional Agricultural Program as a replacement for Trial 122 in 1998 replantings. There are in fact two separate trials side by side but the results will be reported together.

In Trial 129a there are two EFB treatments (nil & 50 t/ha.yr). The EFB is applied on either side of the harvest path as per normal plantation practice. A standard fertiliser treatment of ammonium chloride (AC) and kieserite (KIE) is applied to all plots receiving fertiliser. The fertiliser is applied on either the weeded circle or on the frond pile. The six treatments (Table 1) are arranged in a randomized complete block design with 4 replicates.

Table 1. Treatments in Trial 129a

Treatment Number	Crop Residue	Fertiliser Applied (kg/palm.yr)	Fertiliser Placement
1	EFB	3 kg AC & 3 kg KIE	Weeded Circle
2	EFB	3 kg AC & 3 kg KIE	Frond Pile
3	EFB	Nil	-
4	Nil	3 kg AC & 3 kg KIE	Weeded Circle
5	Nil	3 kg AC & 3 kg KIE	Frond Pile
6	Nil	Nil	-

In Trial 129b all plots receive EFB at a rate of 50 t/ha.yr. A standard fertiliser treatment of AC and KIE is applied to all plots receiving fertiliser. The fertiliser is applied on the weeded circle, the frond pile or the EFB (Table 2). The four treatments are arranged in a randomized complete block design with 8 replications.

Table 2. Treatments in Trial 129b.

Treatment Number	Crop Residue	Fertiliser Applied (kg/palm/yr)	Fertiliser Placement
1	EFB	3 kg AC & 3 kg KIE	Weeded Circle
2	EFB	3 kg AC & 3 kg KIE	Frond Pile
3	EFB	3 kg AC & 3 kg KIE	EFB
4	EFB	Nil	-

RESULTS

This is one of the trials that at the 2002 SAC meeting were discussed for closure due to lack of response to fertiliser application. Yield recording stopped at the end of 2002. However, treatments, leaf sampling and vegetative measurements continue, as expected effects on nutrient retention and supply by the soil may take some years to develop.

Fertiliser/EFB treatment had a significant effect on leaflet K, Mg and Ca concentrations (Table 4) although leaflet N and P concentrations were in the adequate range even with no fertilizer applied. It appears that the major effect on leaflet K was a significant increase with the addition of EFB. By contrast, there was a significant decrease in Ca and Mg with the application of EFB. One explanation may be the competitive effect of K from EFB on Mg and Ca uptake by palms.

Table 3. Analysis structure for results in this report (Trial 129)

Treatment no.	EFB	AC & KIE	Placement	No. of reps	Code
1	0	0	0	4	0 0
2	0	1	Weeded circle	4	0 Weed
3	0	1	Frond pile	4	0 Frond
4	1	0	0	12	1 0
5	1	1	Weeded circle	12	1 Weed
6	1	1	Frond pile	12	1 Frond
7	1	1	EFB	8	1 EFB

Table 4. Effects of treatments on frond 17 nutrient concentrations in 2004, in units of % dry matter, except for B (mg/kg) (Trial 129). Effects with $p<0.05$ are shown in bold.

Treat. Code	Leaflet Ash	N	P	K	Mg	Ca	B	Cl	S	Rachis Ash	K
0 0	13.7	2.50	0.154	0.740	0.180	0.830	11.8	0.538	0.173	5.1	1.61
0 Weed	14.4	2.46	0.153	0.710	0.173	0.823	12.3	0.593	0.173	5.4	1.76
0 Frond	13.9	2.43	0.153	0.730	0.183	0.830	12.2	0.600	0.170	4.8	1.57
1 0	13.9	2.47	0.151	0.758	0.163	0.801	12.0	0.585	0.174	5.8	1.71
1 Weed	14.1	2.49	0.151	0.783	0.167	0.774	11.9	0.608	0.178	5.8	1.74
1 Frond	13.9	2.47	0.150	0.775	0.168	0.767	11.6	0.606	0.174	5.7	1.73
1 EFB	14.0	2.47	0.149	0.781	0.168	0.752	12.0	0.624	0.176	5.8	1.69
GM	*14.0*	*2.47*	*0.151*	*0.765*	*0.169*	*0.785*	*11.9*	*0.599*	*0.175*	*5.7*	*1.71*
p	*0.339*	*0.682*	*0.241*	***0.001***	***0.027***	***0.006***	*0.765*	*0.089*	*0.596*	*0.093*	*0.272*
s.e.d.	*0.3*	*0.04*	*0.002*	*0.021*	*0.007*	*0.028*	*0.6*	*0.030*	*0.005*	*0.4*	*0.09*
$lsd_{0.05}$				*0.041*	*0.014*	*0.055*					
CV %	*3*	*2*	*2*	*4*	*6*	*5*	*7*	*7*	*4*	*11*	*8*

NEW USE: SAMPLING 129 - HOTSPOTS OF ORGANIC MATTER

PURPOSE

Zones of high soil organic matter content could be expected to develop near the soil surface under frond piles or areas where empty fruit bunches (EFB) are applied. The new organic CEC probably has a lower Ca:Mg ratio than the existing CEC of the West New Britain soils, as the ratio of Ca:Mg is less in returned plant material than that in the soil (exchangeable Ca:Mg). Therefore, adding kieserite to these zones of high organic matter may reduce the loss of Mg by leaching compared to broadcast application. In an existing trial (Trial 129) at Kumbango in West New Britain, ammonium chloride and kieserite are being applied to the weeded circle, the frond pile, or onto EFB applications. The trial commenced in 1999, and to date only measurements of yield have been carried out. It is proposed that in this project, the amounts of Mg, other cations and CEC in the soil (under weeded circle, frond pile and EFB) be measured to determine if the cation and Mg-holding capacity of the soil is being improved by addition of organic matter. Also, the nutrient (Mg) use efficiency of the palms should be determined by measuring biomass and concentrations of Mg in plant tissues. (Extract from proposal).

SAMPLING STRATEGY – SOILS

Soils will be sampled at a number of times following application of fertiliser. The first sampling will be about 9 months after fertiliser application with the second and third samplings being, 1(?) and 3(?) months respectively.

Because of the experimental design, it will not be necessary to sample every plot in order to get appropriate soil samples that represent the different methods of fertiliser and OM application. Mostly, experiment 129b will be used with 129a providing one of the controls.

The soil profile was examined at a couple of plots and found to contain a couple of identifiable layers; one at 0-5 cm, 5-10 cm, 10-20 cm which will form the basis of the sampling strategy. A deeper sample 20-40 cm will also be collected. Initially only the upper two samples will be analysed.

Sampling protocol: (see diagram below)

Use an auger to sample soil to appropriate depth

Base sampling points around palms 1, 4, 13 and 16 if possible.

Weeded Circle: take two samples per palm, and combine the 8 samples to form a composite for that plot. Samples should be taken half way between palm and edge of the weeded circle; and on opposite sides of the palm. For example, for palm 1, one sample should be taken in the weeded circle on the palm 2 side, and the other sample on the opposite side.

Frond Pile: take two samples per palm, and combine the 8 samples to form a composite for that plot. Samples should be taken from the frond pile nearest the palms listed above. The two samples from each palm should be about and about 4 m apart.

EFB: take two samples per palm, and combine the 8 samples to form a composite for that plot. Samples should be taken from middle of the EFB pile on opposite sides of the palm.

EFB zone but without EFB (sample code D): Sample as for EFB, but estimating were the EFB zone would be.

Table 5. Allocation of plots and zones to sampling strategy.

Sampling Code	**Sampling Zone**	**Fertiliser/ Zone**	**Trial***	**Trmt***	**Plots**	**Database Trmt** Number**	**Other Plots available *****
A	WC	nil	129b	4	27,32,33,37	4	1,11,18,21, 42,45,51,55
B	FP	nil	129b	4	27,32,33,37	4	1,11,18,21, 42,45,51,55
C	EFBz+EFB	nil	129b	4	27,32,33,37	4	1,11,18,21, 42,45,51,55
D	EFBz-EFB	nil	129a	6	4,10,13,19	1	
E	WC	Yes/WC	129b	1	25,30,34,39	5	3,12,14,23, 44,48,49,56
F	FP	Yes/FP	129b	2	26,31,36,38	6	5,7,16,22, 41,47,50,53
G	EFBz+EFB	Yes/EFBz	129b	3	28,29,35,40	7	43,46,52,54

WC = Weeded Circle

FP = Frond Pile

EFBz+EFB = EFB zone with added EFB

EFBz-EFB = EFB zone as above but without EFB being added

* Trial 129b has 8 replicates. Only the first 4 were selected. Treatment refers to the particular trial (i.e. 129a or 129b) – see 2002 annual report

** Database treatment number refers to trial 129a & 129b combined (i.e. a unique number) which is entered as just 129 in database

Thus there are 7 zones to be sampled per replicate (with 3 of these zones being sampled from the one plot).

Depths equals 4 (0-5, 5-10, 10-20, 20-40 cm)

Timing: 9 months after fertiliser application

Replicates equals 4.

Total number of samples = 7(zones) x 4(depths) x 4(reps) = 122.

But only 7(zones) x 2(depths) x 4(reps) = 56 will be analysed initially.

RESULTS

Soils have been analysed from the 7 zones for the first two depths (0-5, 5-10 cm).

Both organic matter (from fronds and EFB) and fertiliser had an effect on most soil properties.

Organic matter increased pH whereas fertiliser (AC, KIE) decrease pH; most likely due the ammonium in the AC (Table 6). Organic matter also increased the CEC as would be expected (Table 7) whereas addition of AC and KIE deceased it. It is possible that the nitrogen encouraged more rapid breakdown of organic matter. The exchangeable Ca in the soil seemed only to be affected by fertiliser. This may have been a result of competition from the other cations (NH_4, Mg) in the fertiliser added and subsequent leaching of Ca. The results for exchangeable K were similar to those for Ca except that organic matter also affected exchangeable K (Table 8). Without fertiliser, exchangeable Mg responded in a similar way to that of K. But with fertiliser, the EFB was more effective in capturing the added Mg than was the frond pile. Available P and P retention were affected more by organic matter than by fertiliser. Thus the available P was greater and P retention less in the zones with added organic matter. Similar results were found even when EFB was not adde to the zone that usually receives EFB, probably reflecting less disturbance than in the weeded circle.

CONCLUSIONS

In terms of Mg nutrition, it appears that it is more effective if placed on the EFB pile rather than on the weeded circle or the frond pile. This interpretation is complicated by the simultaneous placement of AC, which may result in competition with Mg for exchange sites.

Table 6. Effect of zone, organic matter and fertiliser (AC, KIE) on soil pH.

Parameter	pH (water)	
Depth	0-5 cm	
Zone	Fertiliser	
	No	Yes
Weeded Circle	5.5	5.0
Frond Pile	6.0	4.8
EFB zone + EFB	6.0	5.3
EFB zone - EFB	5.8	

Parameter	pH ($CaCl_2$)	
Depth	0-5 cm	
Zone	Fertiliser	
	No	Yes
Weeded Circle	4.8	4.5
Frond Pile	5.5	4.3
EFB zone + EFB	5.6	4.9
EFB zone - EFB	5.3	

Parameter	pH (water)	
Depth	5-10 cm	
Zone	Fertiliser	
	No	Yes
Weeded Circle	5.7	5.1
Frond Pile	6.0	5.0
EFB zone + EFB	6.4	5.5
EFB zone - EFB	5.9	

Parameter	pH ($CaCl_2$)	
Depth	5-10 cm	
Zone	Fertiliser	
	No	Yes
Weeded Circle	5.1	4.6
Frond Pile	5.4	4.5
EFB zone + EFB	5.8	5.1
EFB zone - EFB	5.3	

Table 7. Effect of zone, organic matter and fertiliser (AC, KIE) on soil CEC and Exch Ca.

Parameter	CEC	
Depth	0-5 cm	
Zone	Fertiliser	
	No	Yes
Weeded Circle	6.5	2.9
Frond Pile	28.4	10.1
EFB zone + EFB	26.5	22.8
EFB zone - EFB	10.1	

Parameter	Exch Ca	
Depth	0-5 cm	
Zone	Fertiliser	
	No	Yes
Weeded Circle	6.2	2.2
Frond Pile	22.9	8.0
EFB zone + EFB	20.9	19.0
EFB zone - EFB	10.5	

Parameter	CEC	
Depth	5-10 cm	
Zone	Fertiliser	
	No	Yes
Weeded Circle	5.7	2.1
Frond Pile	16.5	6.0
EFB zone + EFB	18.5	13.6
EFB zone - EFB	7.6	

Parameter	Exch Ca	
Depth	5-10 cm	
Zone	Fertiliser	
	No	Yes
Weeded Circle	5.2	1.8
Frond Pile	13.7	4.4
EFB zone + EFB	16.0	9.9
EFB zone - EFB	8.3	

Table 8. Effect of zone, organic matter and fertiliser (AC, KIE) on soil Exch K and Mg.

Parameter: Exch K; Depth: 0-5 cm

Zone	Fertiliser No	Fertiliser Yes
Weeded Circle	0.4	0.3
Frond Pile	1.3	0.8
EFB zone + EFB	0.7	0.8
EFB zone - EFB	0.6	

Parameter: Exch Mg; Depth: 0-5 cm

Zone	Fertiliser No	Fertiliser Yes
Weeded Circle	0.7	0.4
Frond Pile	4.1	3.5
EFB zone + EFB	4.5	9.8
EFB zone - EFB	1.4	

Parameter: Exch K; Depth: 5-10 cm

Zone	Fertiliser No	Fertiliser Yes
Weeded Circle	0.4	0.2
Frond Pile	1.3	0.5
EFB zone + EFB	1.5	0.7
EFB zone - EFB	0.6	

Parameter: Exch Mg; Depth: 5-10 cm

Zone	Fertiliser No	Fertiliser Yes
Weeded Circle	0.6	0.4
Frond Pile	2.3	1.7
EFB zone + EFB	4.2	6.0
EFB zone - EFB	1.1	

Table 9. Effect of zone, organic matter and fertiliser (AC, KIE) on soil Bicarbonate P and P Retention.

Parameter: Bicarb P; Depth: 0-5 cm

Zone	Fertiliser No	Fertiliser Yes
Weeded Circle	94	82
Frond Pile	131	192
EFB zone + EFB	125	177
EFB zone - EFB	167	

Parameter: P Retn; Depth: 0-5 cm

Zone	Fertiliser No	Fertiliser Yes
Weeded Circle	59	61
Frond Pile	40	49
EFB zone + EFB	35	31
EFB zone - EFB	52	

Parameter: Bicarb P; Depth: 5-10 cm

Zone	Fertiliser No	Fertiliser Yes
Weeded Circle	35	47
Frond Pile	108	165
EFB zone + EFB	84	147
EFB zone - EFB	119	

Parameter: P Retn; Depth: 5-10 cm

Zone	Fertiliser No	Fertiliser Yes
Weeded Circle	57	59
Frond Pile	48	56
EFB zone + EFB	48	48
EFB zone - EFB	50	

TRIAL 137 SYSTEMATIC N FERTILISER TRIAL, KUMBANGO

PURPOSE

To provide a response curve to N fertiliser that will be used to determine optimum N input in the area.

BACKGROUND

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.

SITE and PALMS

Kumbango Division 1
Soil: Freely draining pumiceous sand and gravel intermixed with finer volcanic ash
Topography: Flat
Land use prior to this crop: Oil palm
Palms: Dami commercial DxP crosses
Planted in October 1999 at 128 palms/ha

DESIGN

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 16 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.

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. Four replicates receive their AN in 2 doses per year while the other 4 replicates receive 10 doses per year.

RESULTS

Nitrogen fertiliser continued to have a significant effect on fresh fruit bunch (FFB) yield in this trial (Table 1, Figure 1). Although significant, the response is very small and of little significance. The positive effect of N on the FFB yield in 2004 was mainly through increased number of bunches (BNO) per ha. But again the response was small. These results were similar to the 2003 results. Despite the significant effect of N on the FFB yield, there was no response of leaflet N concentration to N fertiliser (Table 2, Figure 2). However, the N concentrations in tissue were in the adequate range for all treatments. This is probably because the treatments have not been imposed for very long.

Table 1: Regression parameters for the effect of fertiliser application rate (kg/palm/year) on FFB yield and its components in 2004 (Trial 137). P values <0.05 are indicated in bold.

	Intercept	Slope	Slope p	R^2
FFB yield (t/ha)	24.4	0.355	**0.027**	0.36
BNO/ha	2188	43	**0.004**	0.11
SBW (kg)	11.1	-0.04	0.251	0.012

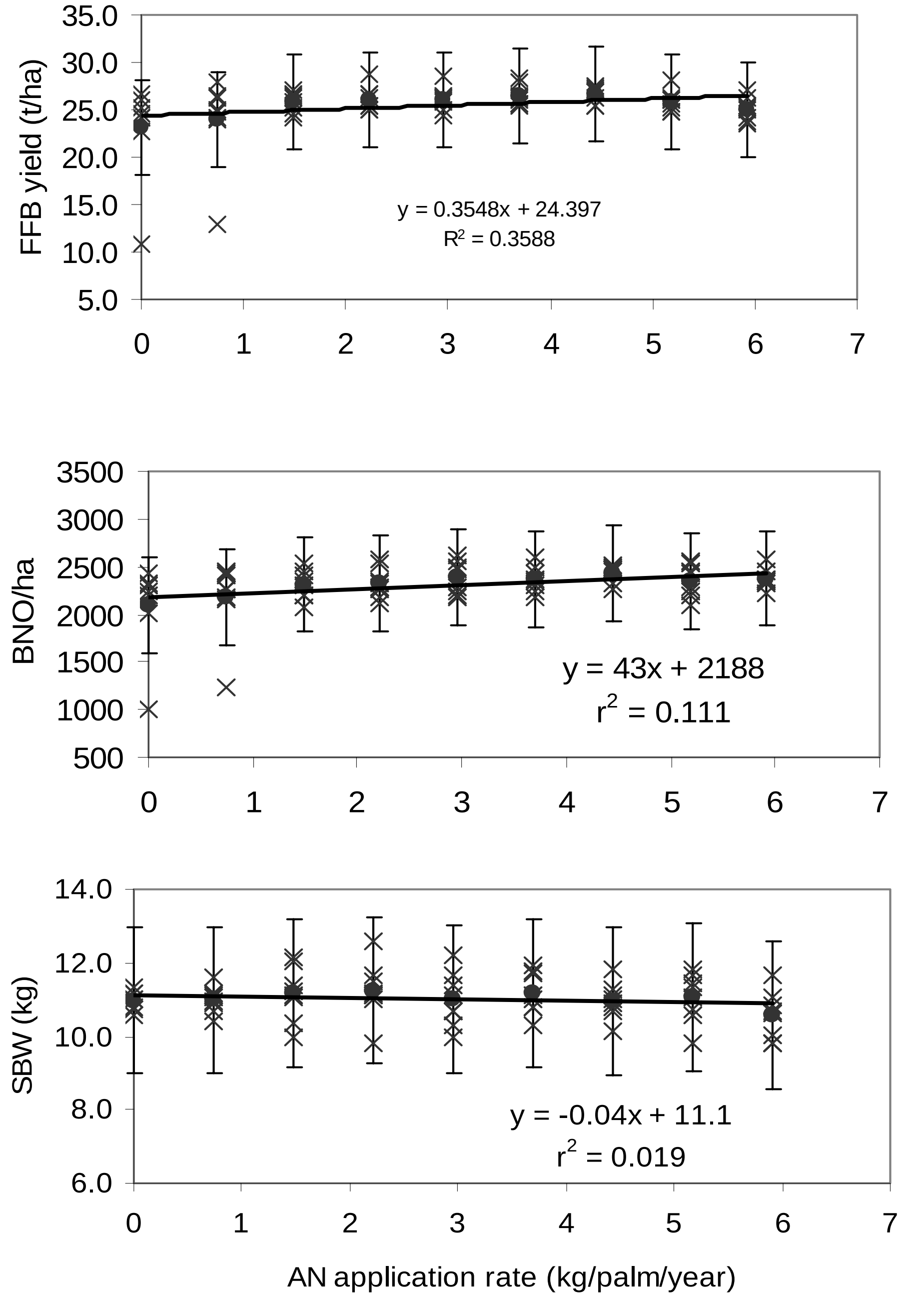


Figure 1. *Effect of fertiliser rate (annual) on FFB yield, BNO/ha and SBW in 2004 (Trial 137). Crosses show values for each 64-palm plot (4 rows of 16), circles show means for treatment, and bars show sd.*

Table 2. 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 2004 (Trial 137). *p* values <0.05 are indicated in bold.

	Grand Mean	Intercept	Slope	Slope p	r^2
Leaflet					
Ash	15.3	14.7	0.114	**<0.001**	0.281
N	2.7	2.7	-0.01	0.176	0.026
P	0.151	0.152	0.0001	0.785	0.002
K	0.77	0.81	-0.0065	0.002	0.130
Mg	0.16	0.17	-0.0019	**0.001**	0.140
Ca	1.05	0.97	-0.0130	**<0.001**	0.212
B	13.5	13.5	-0.0265	0.512	0.006
Cl	0.54	0.46	0.0150	**<0.001**	0.361
S	0.194	0.195	-0.0007	0.080	0.043
Rachis					
Ash	5.5	5.8	0.0617	**0.020**	0.016
K	1.76	1.69	0.0017	0.791	0.005

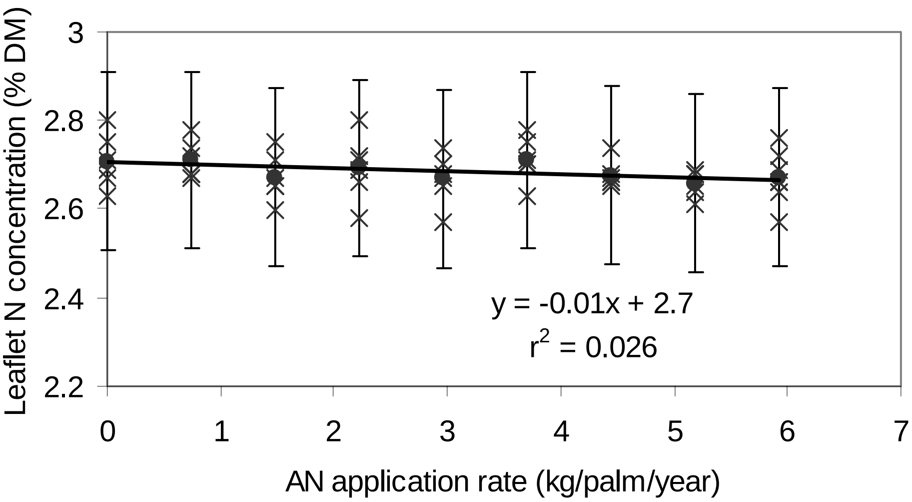


Figure 2. *Effect of fertilizer rate on leaflet N concentration in 2004 (Trial 137). Crosses show values for each 64-palm plot (4 rows of 16), circles show means for treatment, and bars show s.d for the BNO/ha and SBW*

TRIAL 138B SYSTEMATIC N FERTILISER TRIAL, HAELLA

PURPOSE

To provide a response curve to N fertiliser that will be used to determine optimum N input in the area.

BACKGROUND

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.

SITE and PALMS

Haella Plantation, Division 2, Field I-95, Avenue 11, Road 7-8
Soil: Freely draining fine textured alluvial soils over coarse pumiceous sand and ash beds
Topography: Flat with very minor depressions
Land use prior to this crop: Forest
Palms: Dami commercial DxP crosses
Planted in 1995 at 128 palms/ha

DESIGN

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 32 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.

RESULTS

There was a significant response of fresh fruit bunch (FFB) yield to N fertiliser for the first time in this trial (Table 1, Figure 1). In the previous two years, N fertiliser had no significant effect on the FFB yield and N concentration of the leaflets. The positive effect of N on the FFB yield in 2004 was mainly due to its significant effect on number of bunches (BNO) per ha.

Table 1: Regression parameters for the effect of fertiliser application rate (kg/palm/year) on FFB yield and its components in 2004 (Trial 138B). p values <0.05 are indicated in bold.

	Intercept	Slope	Slope p	r^2
FFB Yield (t/ha)	27.0	0.5	**<0.001**	0.208
BNO/ha	1424	25	**0.007**	0.098
Single bunch wt. (kg)	19.2	-0.01	0.919	0.0004

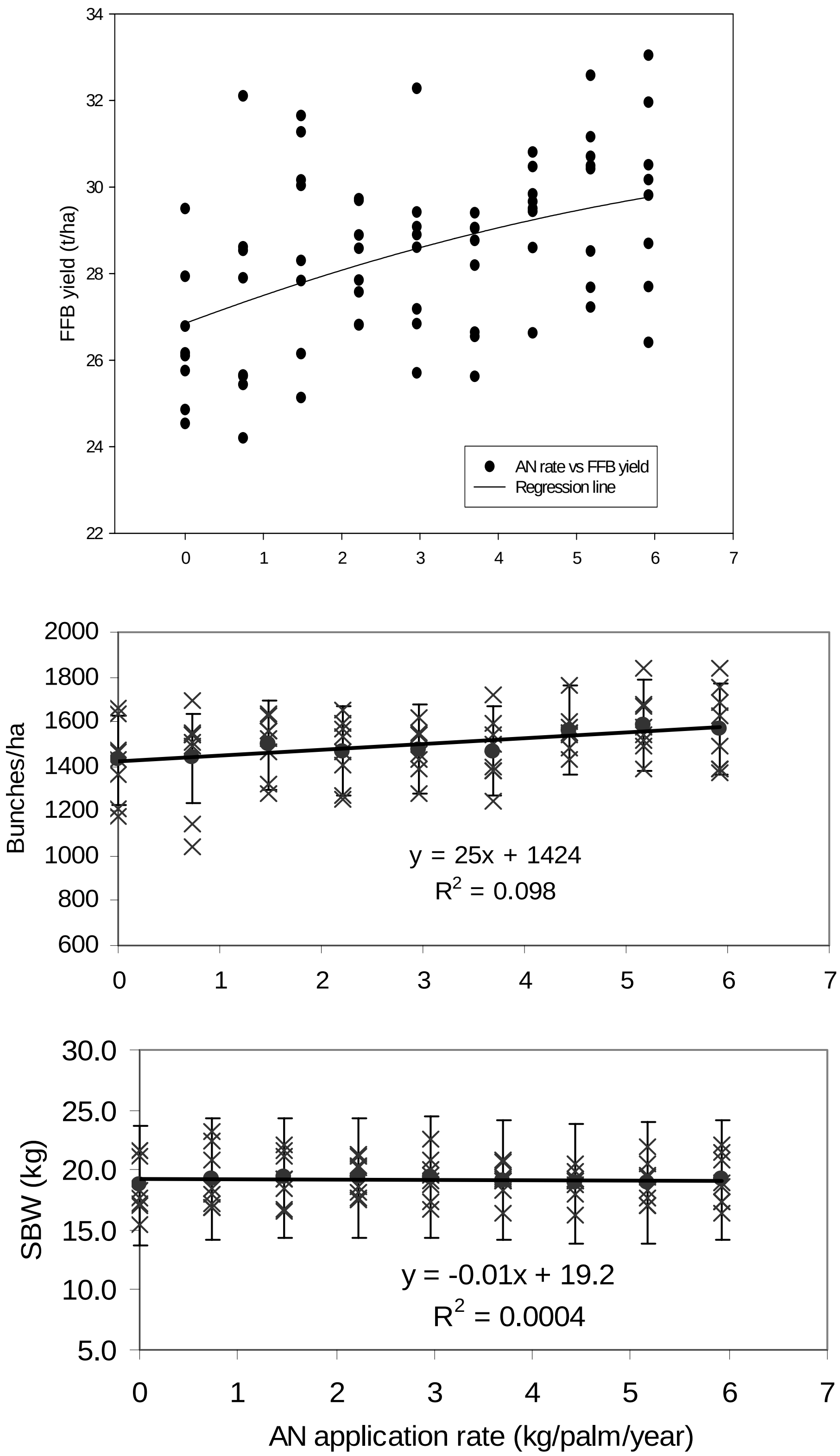


Figure 1. Effect of fertiliser rate (annual) on FFB yield, BNO/ha and SBW in 2004 (Trial 138B). Crosses show values for each 128-palm plot (4 rows of 32), circles show means for treatment, and bars show sd for the BNO/ha and SBW. Equation for FFB yield: $y=26.7 + 4.2*(1- e^{(-0.2\,x)})$; $p<0.0001$; $R^2 = 0.21$.

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, OPRA 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 will be the purpose and design of Trial 141. In this 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. We expect a substantial interaction between progeny and response of vegetative growth parameters to N. The trial is a joint one between OPRA 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 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 will test 3 levels of N fertiliser (ammonium nitrate) at the three sites, as shown in Table 1. Other fertilisers will be applied as a blanket across the trial, at recommended rates. 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 second year (2004), as in the first, there was no effect of treatments on FFB or its components (Table 2).

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

N Level (kg/palm)	FFB (t/ha)	Number of Bunches (bunches/ha)	Bunch Weight (kg/bunch)
0	26.5	1386	19.9
3	26.7	1413	19.7
6	26.7	1387	20.0
	Significance level		
p	0.854	0.547	0.471

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 PALMS

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. Ammonium chloride will be added as a basal fertiliser. See Table 1 for treatment rates.

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 has been marked out and fertiliser treatments (except for foliar application) commenced in mid 2003.

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 (Table 2). K treatment had no significant effect on yield or its components and there were no interactions.

The significant effect of increasing Mg was unexpected as it resulted in a decrease in in FFB yield. However, this decrease appears 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).

Table 2. Main effects (p values) of Mg and K on FFB yield and its components in 2004.

Source	2004		
	Yield (t/ha/yr)	NoB (/ha)	SBW (kg)
Mg	**0.091**	0.119	0.347
K	0.698	0.961	0.315
Mg.K	0.700	0.891	0.258
CV%	13.2	11.6	5.7

Table 3. Mg and K effects on FFB yield and it components in 2004.

Source	2004		
	Yield (t/ha/yr)	NoB (/ha)	SBW (kg)
Mg0	**15.4**	2862	5.4
Mg1	**13.6**	2614	5.2
K0	14.7	2735	5.6
K1	14.3	2742	5.2
sed	*0.69*	*144*	*0.10*

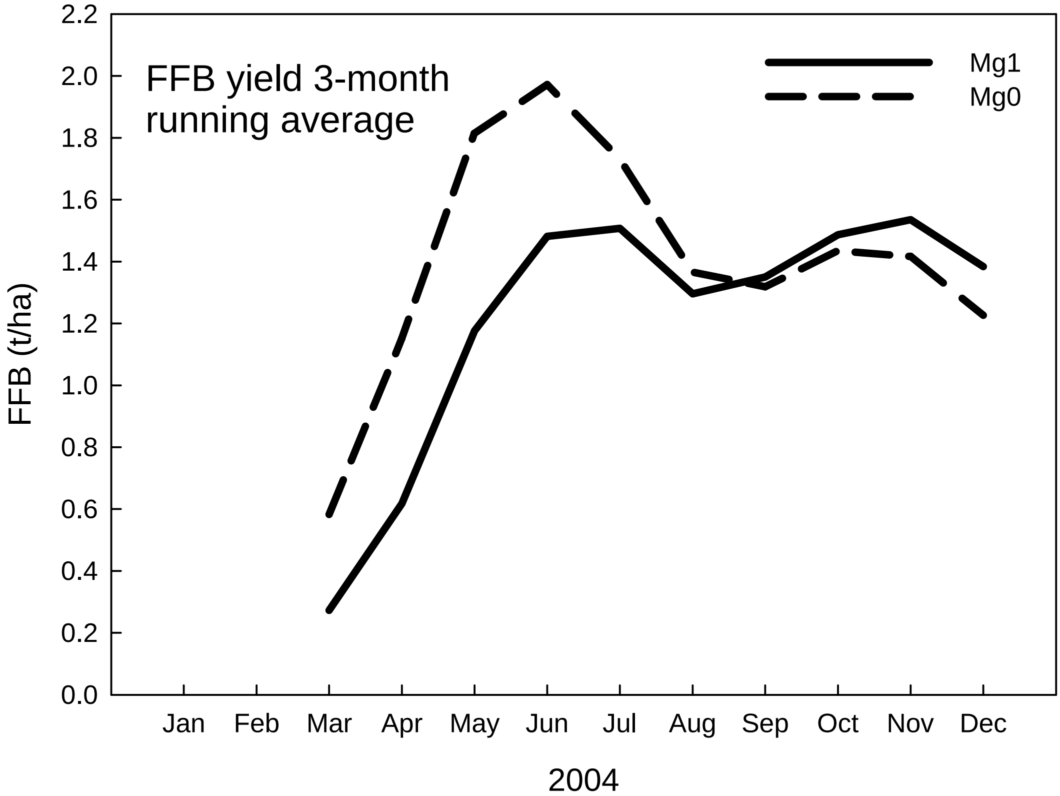


Figure 1. Three month running mean for FFB yield for 2004 since yield recording began in January 2004.

Palms have been assessed for symptoms of Mg and K deficiency. Results from 2004 indicate that palms not receiving Mg have a greater number of fronds with symptoms than those which are receiving Mg (Table 4).

Table 4. 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-04	Jun-04	Oct-04
0	0	1.8	5.6	10.8
0	1	1.6	6.4	10.2
1	0	0.6	3.5	6.4
1	1	0.6	2.9	5.5
ANOVA p value	Mg effect	0.063	< 0.001	< 0.001
	K effect	0.856	0.870	0.388

Scoring for symptoms of K deficiency only began in October. Although symptoms of K deficiency seem quite prevalent, addition of K seems to have had no effect on symptoms (Table 5).

Table 5. 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-04	Jun-04	Oct-04
0	0			23.5
0	1			20.1
1	0			22.0
1	1			20.8
ANOVA p value	Mg effect			0.882
	K effect			0.159

Tissue nutrient concentrations were determined just before treatments were applied and at 3-month intervals. The results for the pre-treatment and first post treatment samples are shown in Tables 6 & 7. Leaf age has the largest effect of nutrient concentration for most nutrients. Both Mg and K had some effects on tissue nutrients concentrations. But at this early stage all of these effects small and probably of little biological consequence.

Table 6. Pre-treatment leaf nutrient concentrations.

Frond	N	P	K	Ca	Mg	S	Fe	B	Zn	Cu	Mn
	(% DM)						*(mg/kg DM)*				
3		0.170	1.24	1.03	0.28	0.20	63.3	12.3	22.9	8.3	89
17		0.139	0.82	1.39	0.25	0.17	54.3	10.5	14.5	6.3	146
25		0.141	0.65	1.79	0.18	0.17	50.7	10.1	11.1	5.5	170

Table 7. Effect of treatments and leaf age on foliar nutrient concentrations 7 months after treatments applied.

Frond	Mg Lev	K level	N	P	K	Ca	Mg	S	Fe	B	Zn	Cu	Mn
				(% DM)							(mg/kg DM)		
3	0	0		0.196	1.34	0.89	0.27	0.22	61.9	12.7	25.6	8.8	108
	0	1		0.193	1.40	0.84	0.26	0.22	63.0	12.5	26.5	8.6	99
	1	0		0.191	1.31	0.83	0.27	0.22	61.5	12.6	24.7	8.8	109
	1	1		0.188	1.37	0.75	0.25	0.21	59.1	11.9	23.4	8.6	104
17	0	0		0.152	0.71	1.37	0.29	0.17	57.6	11.8	16.7	6.5	123
	0	1		0.152	0.74	1.34	0.28	0.18	51.5	12.1	15.2	6.6	110
	1	0		0.150	0.68	1.39	0.29	0.18	51.2	11.9	15.1	6.6	128
	1	1		0.146	0.70	1.31	0.27	0.17	51.3	11.0	15.1	6.4	133
25	0	0		0.145	0.59	1.47	0.22	0.17	47.7	10.5	11.8	5.7	146
	0	1		0.146	0.64	1.45	0.20	0.17	47.1	10.4	11.6	5.5	135
	1	0		0.145	0.57	1.58	0.20	0.17	47.9	9.9	11.9	5.6	171
	1	1		0.141	0.59	1.45	0.20	0.17	48.5	9.4	11.4	5.4	175

CONCLUSION

Last year's results indicated that palms were just beginning to respond to Mg. This year's the results confirm that with respect to leaf symptoms. Furthermore, FFB yield is now showing an increased yield in response to increased Mg following an initial negative effect. This trial is the first one to show a definitive response to Mg fertiliser.

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.

Treatments have been imposed and yield recording will begin in 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, in this early stage of the trial, there was no effect of Mg source ($p = 0.376$) or Mg rate ($p = 0.700$) on FFB yield. The mean yield (May-Dec) was 13.6 t/ha (S.D. = 2.1). This early yield data can be used as a covariate if required.

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 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. Layout will be randomised complete block. Nitrogen will be applied as a basal fertiliser applied at standard rate.

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 2. 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

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 OPRA/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 OPRA 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 and PALMS

Breeding Trials 282, 283 and 284, Kumbango Division II.
Planted 2001 at 128 palms/ha
Each breeding trial has 84 plots/progeny of 12 palms each

DESIGN

The trial will test 3 levels of Mg fertiliser (Table 1). Kieserite is being applied under OPRA/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 is being applied (under OPRA/OPRS supervision) as a blanket across the trial, at 80 g/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 (OPRA Rep 1)			Breeding Trial 283 (OPRA Rep 2)			Breeding Trial 284 (OPRA 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 OER and 635 has high OER and is being used in much Dami seed.

RESULTS

This is the first 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 progeny which were common to each breeding trial, it was possible to look at the progeny effects as well on a subset of the data. There was a substantial effect of progeny on FFB yield and it components (Table 3 & 4). The same three progeny 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	16.8	3700	4.4
2	16.1	3702	4.3
4	16.4	3710	4.4
	Significance level		
p	0.864	0.988	0.694

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

Source of variation	FFB	Number of Bunches	Bunch Weight
Progeny	**<0.001**	**<0.001**	**<0.001**
Mg	0.492	0.528	0.386
Progeny.Mg	0.780	0.899	0.205

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	18.3	4030	4.5
714.712	742.316	13.9	2874	4.9
5035.216	742.316	17.3	3411	5.0

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 OPRA and OPRS. It complements factorial trials with boron and other nutrients that OPRA 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 and PALMS

Breeding Trials 285, 286, 287 and 288, Kumbango Division II. Each trial has 75 plots/progeny of 9 palms each
Planted 2001 at 128 palms/ha

DESIGN

The trial will test 3 levels of B fertiliser (Table 1). Ca borate will be applied by OPRA 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 OPRA 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 OPRA is being carried out with joint supervision by OPRS supervisor.

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 Dami seed.

RESULTS

Although treatments were applied in July 2003, yield recording only began in November 2003; so 2004 is the first year of results.

Across the whole trial, there was no effect of B on FFB yield or SBW (Table 2). There was a small effect on number of bunches but the pattern in not clear.

As there were three progeny which were common to each breeding trial, it was possible to look at the progeny effects as well on a subset of the data. There was a substantial effect of progeny on FFB yield and it components (Table 3 & 4). There was also an effect of B on SBW within these three progenies, with increased B increasing SBW (Table 5).

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

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

B Level (g/palm)	FFB (t/ha)	Number of Bunches (bunches/ha)	Bunch Weight (kg/bunch)
0	13.8	3303	4.1
80	13.4	3194	4.0
160	13.5	3235	4.0
	Significance level		
p	0.148	**0.061**	0.300

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

Source of variation	FFB	Number of Bunches	Bunch Weight
Progeny	**<0.001**	**<0.001**	**<0.001**
B	0.137	0.734	**0.024**
Progeny.B	0.783	0.817	0.758

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	16.5	3995	4.2
714.712	742.316	12.9	2802	4.6
5035.216	742.316	18.5	3486	5.3

Table 5: B effect on FFB and its components (subset of common progeny.

B Level (g/palm/year)	FFB (t/ha/year)	Number of Bunches (/ha/year)	Bunch Weight (kg/bunch)
0	15.4	3409	4.5
80	15.8	3393	4.7
160	16.7	3481	4.8

TRIAL 403 SYSTEMATIC N TRIAL, KAURAUSU

PURPOSE

To provide a response curve to N fertiliser that will be used to determine optimum N input in the area.

BACKGROUND

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. There was a change of N source from ammonium chloride (AC) to ammonium nitrate (AN) in 2004.

SITE and PALMS

Kaurausu Plantation, Division 1, Block I-3 and I-4, Field Mn
Soil: Freely draining soils formed on redeposited andesitic pumiceous volcanic ash and sand
Topography: Flat
Land use prior to this crop: Forest
Palms: Dami commercial DxP crosses
Planted in 1987 at 120 palms/ha

DESIGN

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 8) 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. 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 once the responses become large enough. Therefore, all recording is being done on the basis of rows (or in fact individual palms), rather than plots.

RESULTS

There was a significant response of fresh fruit bunch (FFB) yield to N fertiliser in this the fourth year of the trial (Table 1, Figure 1). The positive effect on the FFB yield was mainly due to increase number of bunches (BNO) per ha. These results are similar to the 2003 results but prior to that there was no response of the FFB yield to N fertilizer. Despite the significant effect of N on the FFB yield, there was no response of leaflet N concentration to N fertiliser (Table 2, Figure 2).

Table 1. Regression parameters for the effect of fertiliser application rate (kg/palm/year) on FFB yield and its components in 2004 (Trial 403).

	Intercept	Slope	Slope p	R^2
FFB yield (t/ha)	28.4	0.3	**0.005**	0.105
BNO/ha	1050	14	**0.005**	0.109
SBW (kg)	27.1	-0.03	0.686	0.002

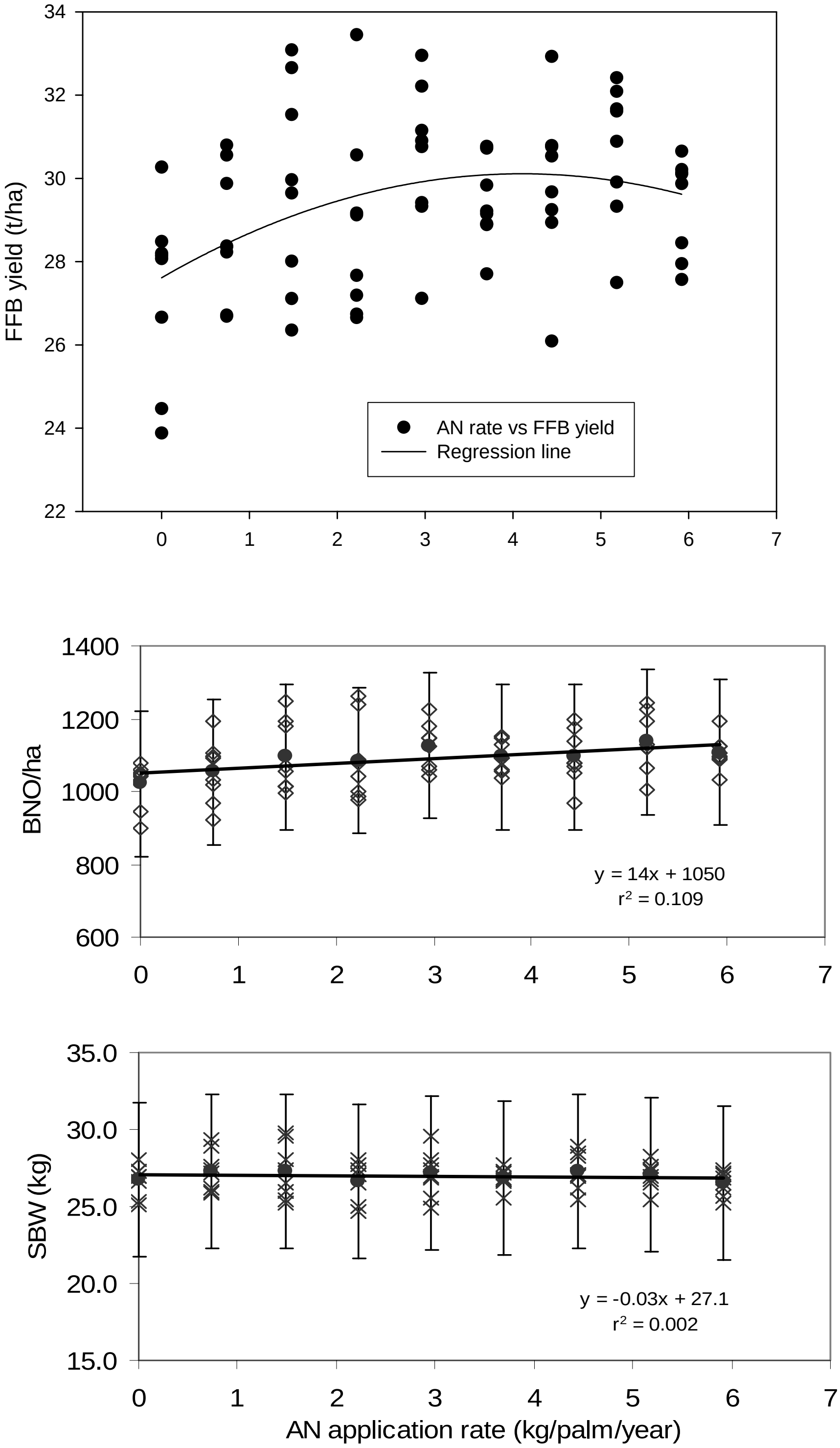


Figure 1. *Effect of fertiliser rate (annual) on FFB yield, BNO/ha and SBW in 2004 (Trial 403). Crosses show values for each 60-palm plot (4 rows of 15), circles show means for treatment, and bars show s.d for the BNO/ha and SBW.*

Table 2. 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 2004 (Trial 403). *p* values <0.05 are indicated in bold.

	GM	Intercept	Slope	Slope p	R^2
Leaflet					
Ash	13.78	13.58	0.05	0.164	0.028
N	2.57	2.57	0.001	0.889	0.0003
P	0.148	0.147	0.0002	0.616	0.004
K	0.735	0.721	-0.004	0.114	0.035
Mg	0.179	0.193	-0.004	**<0.001**	0.154
Ca	0.823	0.851	-0.007	**0.008**	0.096
B	14.27	14.54	-0.07	0.156	0.029
Cl	0.518	0.495	0.006	**0.002**	0.128
S	0.204	0.207	-0.001	0.315	0.014
Rachis					
Ash	5.31	5.37	-0.02	0.509	0.007
K	1.64	1.65	-0.002	0.806	0.001

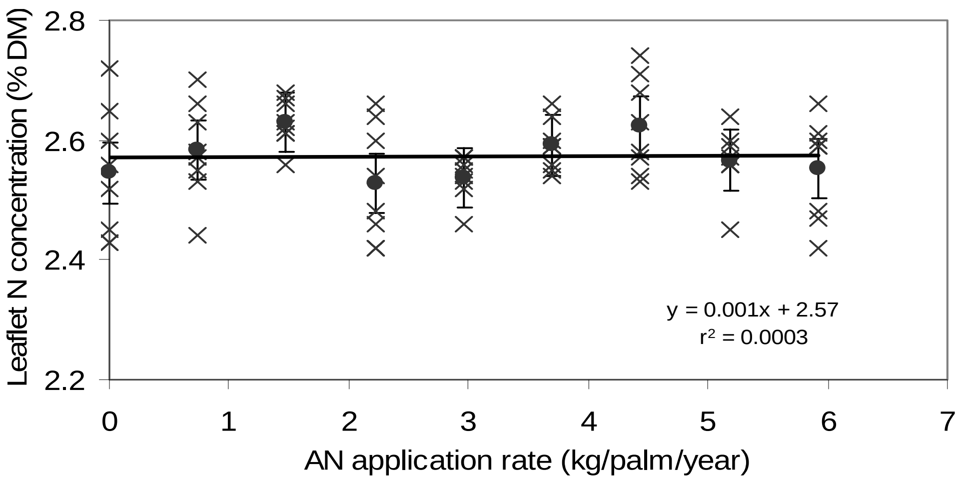


Figure 2. *Effect of fertiliser rate on leaflet N concentration in 2004 (Trial 403). Crosses show values for each 60-palm plot (4 rows of 15), circles show means for treatment, and bars show s.d.*

FERTILISER RESPONSE TRIAL IN WEST NEW BRITAIN PROVINCE (Hargy Oil Palms Ltd)

(James Kraip & Mike Webb)

TRIAL 204 FACTORIAL FERTILISER TRIAL AT NAVO PLANTATION

EXECUTIVE SUMMARY

Ammonium chloride (AC) had a significant effect on fresh fruit bunch (FFB) yield of oil palm (*Elaeis guineensis* Jacq.) in this trial. Triple superphosphate (TSP), potassium chloride (MOP) and kieserite (KIE) had no significant effect on the FFB yield. However, the net effect of nitrogen (N) on FFB yield depends on TSP, MOP and KIE application. Inclusion of N fertiliser in routine additions is recommended for this area.

INTRODUCTION

The purpose of the trial is to provide fertiliser response information that will be useful in developing strategies for fertiliser application.

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: Information on trial 204.

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 or MU	Navo, field 9, block GH, Avenues 23 - 25	Soil type	Navo
Recording started	Jan 1989	Palm age (years after planting)	3
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

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 Jan 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
AC	0	3	6
TSP	0	2	4
MOP	0	3	-
KIE	0	3	-

RESULTS AND DISCUSSION

FFB yield and its components and tissue analysis

Mean trend over time

The FFB yield decreased by about 8 t/ha to 23 t/ha in 1999 (Figure 1). This may have been caused by the generally lack of moisture due to the prolonged dry season in most areas of PNG in 1997-1998. The FFB yield dropped to a very low of about 8 t/ha in 2001 and the Sexava defoliating all the oil palm leaves caused this huge drop. However, the FFB yield seems to be recovering from the Sexava damage as the FFB yield increased progressively after 2001.

The number of bunches (BNO) per ha followed the same trend as the FFB yield over the course of the trial. On the other hand, the SBW increased progressively over the course of the trial.

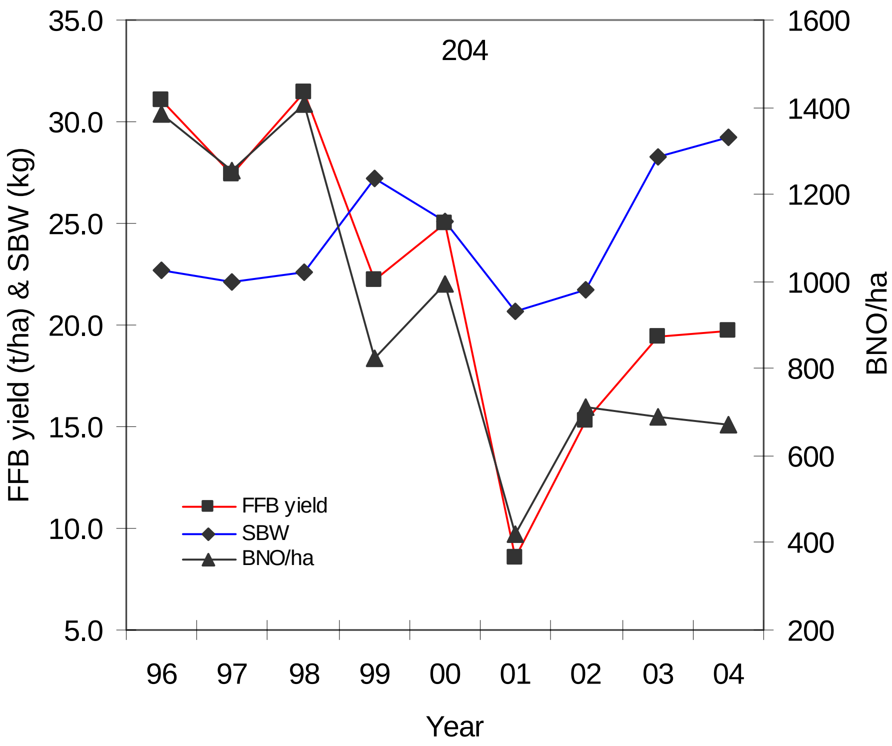


Figure 1: Mean FFB yield,BNO/ha and SBW from 1996 to 2004.

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). On the other hand, 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.

In 2004, AC continued to have a significant effect on the FFB yield while TSP, MOP and KIE had no significant effect on the FFB yield (Table 3). The significant effect of AC was due to the increase in the BNO and SBW. The effect of TSP on the BNO was significant but this did not equate to any significant increase in the FFB yield because SBW fell with increasing P.

During the combined period 2002-2004, AC had a significant effect on the FFB yield while TSP, MOP and KIE had no significant effect (Table 3). The significant effect of AC on the FFB yield was due to its significant effect on the BNO/ha and the SBW.

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

	2002-2004 FFB Yield (t/ha)	BNO (per ha)	SBW (kg)	2004 FFB Yield (t/ha)	BNO (per ha)	SBW (kg)
AC 0	**16.9**	731	**23.4**	**15.1**	**603**	**25.3**
AC 3	**21.1**	767	**28.0**	**20.8**	**683**	**30.7**
AC 6	**22.6**	800	**28.6**	**23.1**	**735**	**31.6**
p	***<0.001***	***0.019***	***<0.001***	***<0.001***	***<0.001***	***<0.001***
TSP 0	20.4	770	26.9	18.8	**629**	29.8
TSP 2	19.6	741	26.7	19.7	**673**	29.1
TSP 4	20.7	786	26.5	20.5	**717**	28.7
p	*0.268*	*0.162*	*0.771*	*0.346*	***0.019***	*0.329*
s.e.d.	*0.7*	*23*	*0.6*	*1.1*	*30*	*0.8*
$Lsd_{0.05}$					*60*	
MOP 0	20.2	757	26.8	20.3	689	29.5
MOP 3	20.3	774	26.4	19.0	658	28.9
p	*0.773*	*0.372*	*0.304*	*0.167*	*0.206*	*0.352*
KIE 0	20.4	777	26.4	19.5	674	28.9
KIE 3	20.1	754	26.9	19.9	672	29.5
p	*0.664*	*0.234*	*0.293*	*0.684*	*0.947*	*0.357*
s.e.d.	*0.6*	*19*	*0.5*	*0.9*	*24*	*0.6*
$Lsd_{0.05}$						
GM	*20.2*	*766*	*26.7*	*19.7*	*673*	*29.2*
CV %	*12*	*11*	*7*	*20*	*15*	*9*

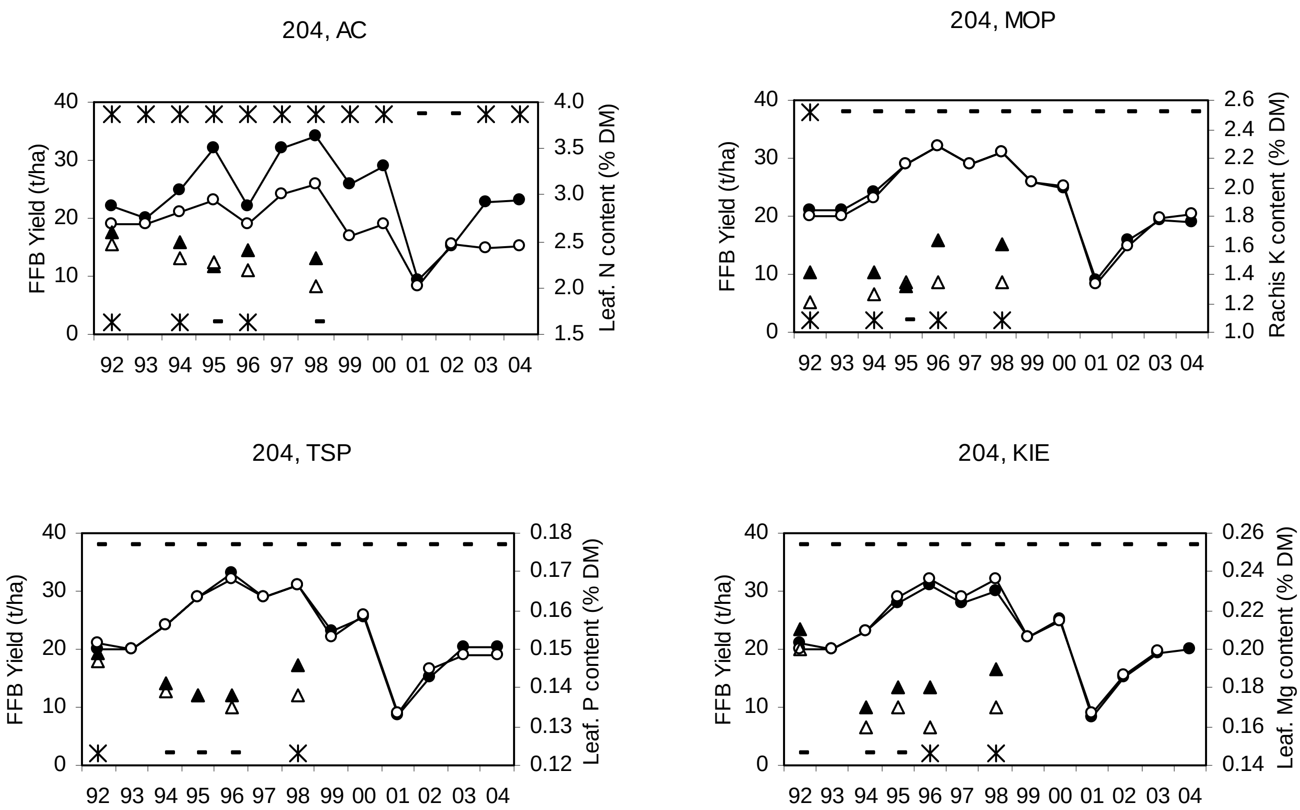


Figure 2. Main effects of AC, MOP, TSP and KIE over the course of Trial 204. Lines with circles are FFB yields and triangles are tissue nutrient concentrations. Full symbols represent the maximum level of application, and empty symbols zero application. Symbols along the top of the graph indicate significance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

Interaction between fertiliser treatments

The effect of the interaction between AC, TSP, MOP and KIE on the FFB yield was not significant for the combined period 2000-2004 and 2004 (Table 4). However, examining the various combinations revealed that the highest levels of AMC, TSP, MOP and KIE produced the highest FFB yields.

Table 4: Effect of interaction between AC, TSP, MOP and KIE on FFB yield (t/ha) during the combined period 2002-2004 and 2004.

	2002 - 2004			2004		
	AC 0	AC 3	AC 6	AC 0	AC 3	AC 6
TSP 0, MOP 0, KIE 0	17.2	20.1	24.4	16.8	22.1	21.3
TSP 2, MOP 0, KIE 0	15.8	22.3	19.5	13.4	19.8	25.2
TSP 4, MOP 0, KIE 0	18.7	24.4	21.1	15.7	22.8	22.5
TSP 0, MOP 3, KIE 0	19.4	22.2	22.5	18	21.4	17.2
TSP 2, MOP 3, KIE 0	16.6	21.3	20.9	12	17.8	24.3
TSP 4, MOP 3, KIE 0	13.6	21.7	24.9	12.4	22.1	25.9
TSP 0, MOP 0, KIE 3	18.9	19.2	23.1	15.8	20.8	23.7
TSP 2, MOP 0, KIE 3	18.0	20.1	22.1	19.1	22.2	25.8
TSP 4, MOP 0, KIE 3	15.9	18.7	23.3	14.7	18.9	25.1
TSP 0, MOP 3, KIE 3	14.6	21.8	21.4	11.4	19.2	18
TSP 2, MOP 3, KIE 3	13.9	21.7	23.1	11.6	23.4	22
TSP 4, MOP 3, KIE 3	20.7	20.2	25.3	20.5	19.4	25.7
	sed = 2.4	*GM = 20.2*	*p = 0.063*	*sed = 3.9*	*GM = 19.7*	*p = 0.468*

CONCLUSIONS and RECOMENDATIONS

AC had a significant effect on the FFB yield in this trial while TSP, MOP and KIE had no significant effect on the FFB yield. However, the net effect of N on FFB yield depends on P, K and Mg application. The highest 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.

EXECUTIVE 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. However, leaf P, Mg and K concentrations were significantly increased by TSP, KIE and EFB respectively.

As the effects of TSP, KIE and EFB on the FFB yield vary over the course of the trial, it is recommended that this trail 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 and magnesium 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 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: Information on trial 205.

Trial number	205	Company	Hargy Oil Palms Ltd
Date planted	Aug 1993	Planting Density (palm ha^{-1})	135
Spacing	8.6 x 8.6	Pattern	Triangular
LSU or MU	Hargy Area 9, blocks 7 & 8	Soil type	Hargy
Recording started	Aug 1996	Palm age (years after planting)	3
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.*

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 as per ha. 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 tissue 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 over the course of the trial. On the other hand, SBW increased progressively over the course of the trial.

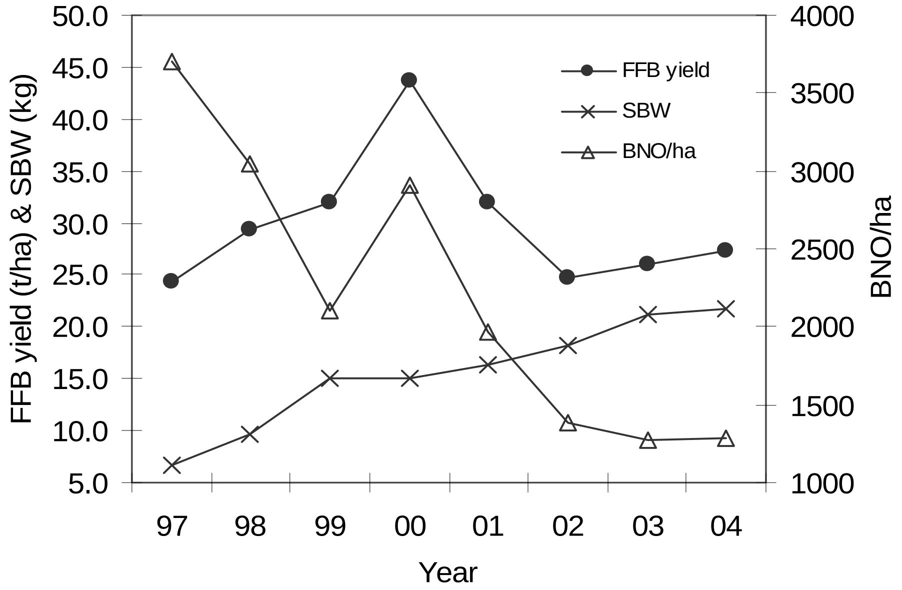


Figure 1: Mean FFB yield, BNO/ha and SBW from 1997 to 2004.

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

Effects of TSP, KIE and EFB on the FFB yield and leaf nutrient concentration over the course of trial are shown in Figure 2. TSP application increased the FFB yield significantly in the first three years but not in the later years of the trial. Similarly, KIE application increased the FFB yield significantly in 1999 and 2002, and EFB application increased the FFB yield significantly in 1998 and 2003.

Generally application of TSP, KIE and EFB had a significant effect on the leaf nutrient concentrations in this trail. However, leaflet Mg concentration started to increase significantly only over time.

During the combined period 2002-2004 and in 2004, the application of TSP, KIE and EFB had no significant effect on the FFB yield, the BNO/ha and the SBW, except EFB, which increased the SBW significantly during the combined period 2002-2004 (Table 4 and 5). Despite having no significant effect on the FFB yield in 2004, 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 period 2002-2004 but not in 2004 (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 BNO/ha and 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 four years.

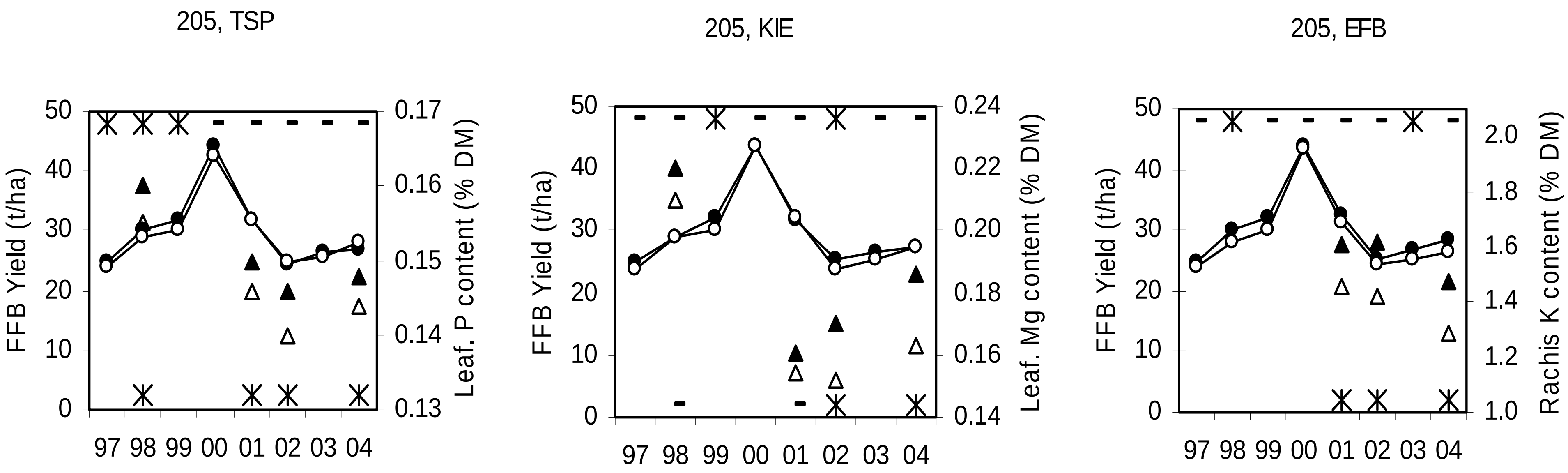


Figure 2. Main effects of TSP, KIE and EFB over the course of Trial 205. Lines are FFB yields and triangles are tissue concentrations. Full symbols represent the maximum level of application, and empty symbols the lowest level. Symbols along the top of the graph indicate significance of the main effect 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.

Source	2002-2004 FFB yield	BNO/ha	SBW (kg)	2004 FFB yield	BNO/ha	SBW (kg)
Rep.Plot stratum						
TSP	0.509	0.235	0.220	0.250	0.210	0.886
KIE	0.346	0.583	0.781	0.843	0.702	0.727
EFB	0.085	0.848	**0.019**	0.066	0.441	0.060
TSP.KIE	0.307	0.968	0.156	0.328	0.597	0.231
TSP.EFB	0.837	0.711	0.239	0.095	0.040	0.424
KIE.EFB	0.200	0.089	0.303	0.947	0.508	0.325
TSP.KIE.EFB	0.404	0.157	0.092	0.795	0.739	0.213
CV%	*8*	*9*	*5*	*11*	*11*	*5.1*
Rep.Plot.Progeny stratum						
Prog	**<0.001**	**0.016**	**0.006**	0.199	0.190	**<0.001**
TSP.Prog	0.950	0.914	0.417	0.888	0.899	0.343
KIE.Prog	0.380	0.897	0.397	0.790	0.587	0.881
EFB.Prog	0.587	0.425	0.986	0.625	0.191	0.546
TSP.KIE.Prog	0.985	0.961	0.225	0.840	0.441	0.720
TSP.EFB.Prog	0.822	0.543	0.887	0.662	0.556	0.299
KIE.EFB.Prog	0.750	0.754	0.098	0.898	0.983	0.578
TSP.KIE.EFB.Prog	0.170	0.435	0.287	0.361	0.084	0.136
CV %	*27*	*31*	*17*	*38*	*38*	*20.6*

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.

	2002-2004			2004		
	FFB yield (t/ha)	BNO/ha	SBW (kg)	FFB yield (t/ha)	BNO/ha	SBW (kg)
TSP 0	26.0	1317	20.1	27.9	1306	21.8
TSP 3	25.6	1275	20.5	26.9	1253	21.9
KIE 0	25.5	1286	20.3	27.3	1271	21.9
KIE 3	26.1	1306	20.4	27.5	1287	21.8
EFB 0	25.2	1292	**20.0**	26.6	1263	21.5
EFB 230	26.3	1299	**20.7**	28.3	1296	22.2
Fert. s.e.d.	*0.6*	*35*	*0.3*	*0.9*	*42*	*0.4*
A	**25.6**	**1289**	**20.3**	28.8	1288	**22.6**
B	**27.9**	**1328**	**21.5**	28.9	1199	**24.5**
C	**27.3**	**1376**	**20.3**	28.6	1294	**22.3**
D	**25.4**	**1279**	**20.3**	28.5	1367	**21.4**
E	**23.0**	**1234**	**19.1**	24.6	1275	**19.9**
F	**25.6**	**1255**	**20.8**	27.1	1223	**22.8**
G	**21.8**	**1149**	**19.1**	25.3	1266	**20.0**
H	**25.8**	**1343**	**19.8**	25.6	1235	**21.4**
I	**25.5**	**1255**	**20.8**	31.3	1478	**21.7**
J	**26.3**	**1259**	**21.2**	27.6	1229	**22.6**
K	**24.3**	**1169**	**21.3**	28.7	1252	**22.9**
L	**25.2**	**1258**	**20.6**	25.5	1178	**22.3**
M	**27.5**	**1347**	**20.8**	26.5	1195	**22.5**
N	**27.0**	**1394**	**19.7**	26.6	1295	**20.9**
O	**26.4**	**1353**	**20.0**	27.0	1294	**21.4**
P	**27.5**	**1446**	**19.2**	28.0	1401	**20.3**
Prog. s.e.d.	*1.4*	*81*	*0.7*	*2.1*	*98*	*1.0*
GM	*25.8*	*1296*	*20.3*	*27.4*	*1279*	*21.8*

Table 6. Effects (p values) of treatments on frond 17 (F17) nutrient concentrations 2004 (Trial 205). p values <0.05 are indicated in bold.

	Leaflet									Rachis	
Source	Ash	N	P	K	Mg	Ca	B	Cl	S	Ash	K
TSP	0.810	0.488	**0.002**	0.053	**0.012**	**<0.001**	**0.043**	0.675	0.725	0.143	**<0.001**
KIE	0.083	0.157	0.542	0.517	**<0.001**	**<0.001**	0.196	0.366	**0.018**	0.247	0.408
EFB	0.705	**<0.001**	0.001	0.109	0.072	**0.024**	0.175	0.834	**0.003**	**0.025**	**<0.001**
TSP.KIE	0.179	0.548	0.490	0.220	0.120	0.718	0.102	0.577	0.725	0.072	0.116
TSP.EFB	0.538	0.460	0.839	0.468	1.000	0.402	0.218	0.577	0.725	**0.041**	**0.009**
KIE.EFB	0.769	0.518	0.352	0.422	0.792	0.370	0.833	0.944	0.725	0.736	0.577
TSP.KIE.EFB	0.472	0.711	0.542	0.319	0.599	0.099	0.961	0.100	0.725	0.759	0.116
CV%	*3*	*3*	*2*	*20*	*6*	*5*	*7*	*8*	*5*	*8*	*8*

Table 7. Main effects of treatments on F17 nutrient concentrations in 2004, in units of % dry matter, except for B (mg/kg) (Trial 205). Effects with p<0.05are shown in bold.

	Leaflet									Rachis	
Source	Ash	N	P	K	Mg	Ca	B	Cl	S	Ash	K
TSP 0	13.5	2.40	**0.144**	0.78	**0.170**	**0.98**	**12.9**	0.515	0.168	4.59	**1.45**
TSP 3	13.5	2.39	**0.148**	0.69	**0.179**	**1.04**	**13.4**	0.510	0.169	4.43	**1.31**
KIE 0	13.6	2.41	0.146	0.75	**0.163**	**1.04**	13.3	0.507	**0.172**	4.57	1.40
KIE 3	13.4	2.39	0.146	0.72	**0.186**	**0.99**	13.0	0.518	**0.166**	4.45	1.37
EFB 0	13.5	**2.36**	0.144	0.70	0.178	1.03	13.0	0.511	**0.165**	**4.38**	**1.29**
EFB 230	13.5	**2.44**	0.148	0.77	0.172	1.00	13.3	0.513	**0.173**	**4.63**	**1.47**
sed	*0.1*	*0.02*	*0.001*	*0.04*	*0.003*	*0.01*	*0.3*	*0.012*	*0.002*	*0.11*	*0.03*
GM	*13.5*	*2.40*	*0.146*	*0.74*	*0.175*	*1.01*	*13.2*	*0.512*	*0.169*	*4.51*	*1.38*

Interaction between fertiliser treatments

The effect of the interaction between TSP, KIE and EFB on the FFB yield was not significant for the combined period 2000-2004 and in 2004 (Tables 4 and 8). However, examining the interactions indicated that the net effect of TSP on the FFB yield depended on the EFB application (Table 8). Highest yields were obtained at the highest rates of TSP and EFB while KIE had a depression effect on the FFB yield at its highest rate during the combined period and in 2004.

Table 8: Effect of TSP, KIE and EFB on FFB yield (2002-2004 and 2004).

	2002-2004				2004			
	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	24.6	26.1	26.1	**27.0**	27.2	27.6	**28.5**	28.4
TSP 3	24.4	**26.7**	25.7	25.4	25.7	**28.8**	24.9	28.2
P=0.404, GM=25.8, sed=4.1, $lsd_{0.05}$*=8.0*					*P=0.795, GM=7.4, sed=6.1,* $lsd_{0.05}$*=11.9*			

CONCLUSIONS and RECOMENDATIONS

With the addition of TSP, KIE and EFB, the FFB yield increased significantly for the main effects in some years but these results were not consistent over the course of the trial. During the combined period 2002-2004 and in 2004, the fertiliser and EFB treatments had no significant effect on the FFB yield.

The effect of the interaction between TSP, KIE and EFB on the FFB yield was not significant but examining the interactions revealed that the highest yield was obtained at the highest rates of TSP and EFB with no KIE added in 2004.

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 trail be continued.

TRIAL 209 FACTORIAL FERTILISER TRIAL AT HARGY PLANTATION

EXECUTIVE SUMMARY

Sulphate of ammonia (SOA), triple superphosphate (TSP) and potassium chloride (MOP) had a significant effect on FFB yield in this trial but not kieserite (KIE). 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: 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 or MU	Hargy Area 1, blocks 4, 6 & 8	Soil type	Hargy
Recording started	Jan 1998	Palm age (years after planting)	4
Topography	Gently sloping	Planting material	Dami D x P (*Elaeis guineensis* Jacq.)*
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)*

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 tissue analysis

Mean trend over time
Generally number of bunches (BNO) per ha decreased while the SBW increased progressively over the course of the trial (Figure 1). As expected of 4-year old palms, the FFB yield was low (in 1998) but increased sharply to maximum in 2000 and has declined slightly thereafter.

The mean annual FFB yield in any one year was closely related to annual rainfall two years previously for this young oil palm (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.

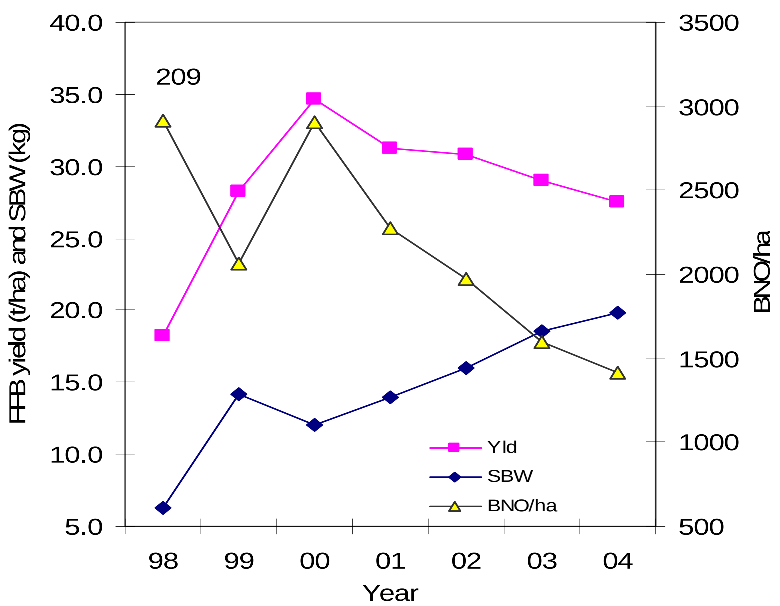


Figure 1: Mean FFB yield, BNO/ha and SBW from 1998 to 2004.

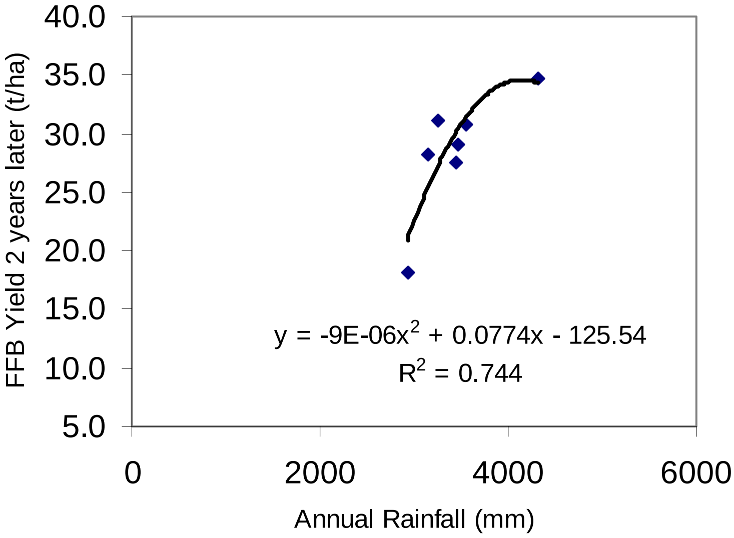


Figure 2 Relationship between mean FFB yield and rainfall (2 years previously) over the course of the trial.

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

Generally SOA, TSP and MOP had a significant effect on the FFB yield over the course of the trial (Figure 3). On the other hand, KIE had no significant effect on the FFB yield over the course of the trial. The leaf nutrient concentrations were affected by the fertiliser treatments during the course of the trial. Mg concentration in the leaflet was significantly increased by KIE application in 2001 and 2003, but the values were in or close to the adequate range even with no KIE addition. This could be the reason for KIE having no significant effect on the FFB yield in this trial.

In 2004 and during the combined period 2002-2004, 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 rates of SOA, TSP and at 2 kg MOP per palm per year respectively for each of the main effects.

Table 3. Effects (p values) of fertilizer treatments on FFB yield and its components in 2002-2004 and 2004 (Trial 209); p values <0.05 are indicated in bold.

	2002-2004			2004		
Source	FFB yield (t/ha)	BNO	SBW (kg)	FFB yield (t/ha)	BNO	SBW (kg)
SOA	**<0.001**	**0.045**	**0.004**	**<0.001**	**0.003**	**<0.001**
TSP	**<0.001**	**<0.001**	0.646	**0.005**	**0.021**	0.259
MOP	**0.026**	0.361	**<0.001**	**0.034**	0.763	**<0.001**
KIE	0.797	0.621	0.861	0.625	0.652	0.976
SOA.TSP	0.912	0.767	0.494	0.796	0.635	0.148
SOA.MOP	0.942	0.913	0.567	0.199	0.172	0.671
TSP.MOP	0.779	0.764	0.919	0.833	0.981	0.718
SOA.KIE	**0.040**	**0.011**	0.140	0.139	**0.047**	0.414
TSP.KIE	0.154	0.052	0.593	0.397	0.649	0.358
MOP.KIE	0.361	0.515	0.783	0.852	0.882	0.310
SOA.TSP.MOP	**0.018**	**0.010**	0.554	0.423	0.085	0.348
SOA.TSP.KIE	0.714	0.658	0.668	0.741	0.672	0.566
SOA.MOP.KIE	0.112	0.075	0.185	0.964	0.767	**0.046**
TSP.MOP.KIE	0.486	0.562	0.543	0.662	0.488	0.290
CV %	*9*	*10*	*6*	*11*	*10*	*6*

Table 4: Main effects of fertiliser treatments on FFB yield and its components in 2002-2004 and 2004 (209). Effects with *p* <0.05 are shown in bold.

	2002-2004			2004		
	FFB yield (t/ha)	BNO/ha	SBW (kg)	FFB yield (t/ha)	BNO	SBW (kg)
SOA 2	**27.1**	**1580**	**17.5**	**24.8**	**1328**	**19.1**
SOA 4	**29.0**	**1672**	**17.6**	**27.8**	**1428**	**19.8**
SOA 8	**30.5**	**1693**	**18.5**	**30.1**	**1491**	**20.6**
TSP 0	**26.4**	**1520**	17.7	**25.7**	**1345**	19.6
TSP 4	**29.8**	**1695**	17.9	**28.2**	**1448**	19.9
TSP 8	**30.4**	**1730**	18.0	**28.6**	**1455**	20.1
MOP 0	**27.8**	1664	**17.1**	**26.2**	1411	**19.0**
MOP 2	**28.8**	1611	**18.3**	**28.5**	1432	**20.4**
MOP 4	**29.9**	1670	**18.3**	**27.8**	1404	**20.2**
KIE 0	29.0	1658	17.9	27.2	1400	19.8
KIE 4	29.0	1663	17.8	28.0	1436	19.9
KIE 8	28.6	1624	18.0	27.4	1411	19.9
s.e.d.	*0.7*	*44*	*0.3*	*0.8*	39	0.3
$Lsd_{0.05}$	*1.5*	*92*	*0.6*	*1.7*	*83*	0.6
GM	*28.9*	*1648*	*17.9*	*27.5*	*1416*	*19.8*

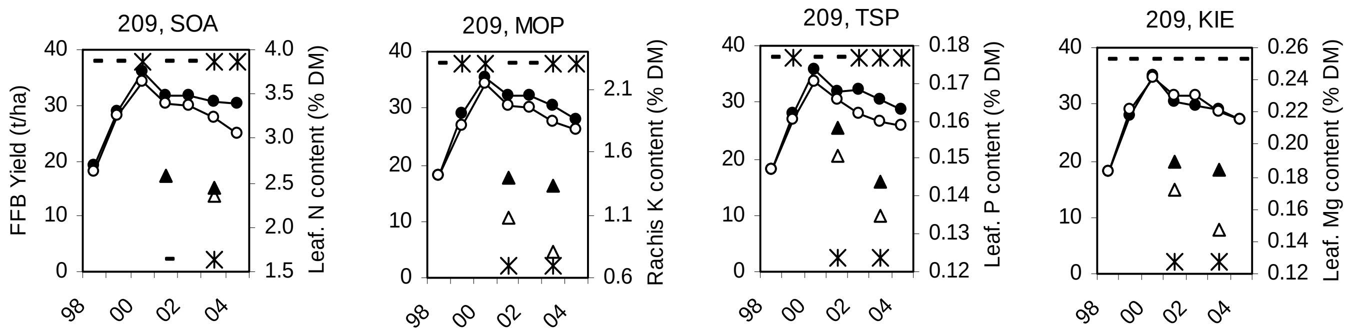


Figure 3. Main effects of SOA, MOP, TSP and KIE over the course of Trial 209. Lines are FFB yields and triangles are tissue concentrations. Full symbols represent the maximum level of application, and empty symbols the lowest level. Symbols along the top of the graph indicate significance of the main 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.

Interaction between fertiliser treatments

The effect of the interactions between SOA and KIE, and between SOA, TSP and MOP were significant for the combined period 2002-2004 (Table 3). For the SOA.KIE interaction, the highest FFB yield was obtained at highest rates of SOA and KIE (Table 5).

For the SOA.TSP.MOP interaction, the highest FFB yield of 34.3 t/ha was obtained at a combined application of 8, 4 and 4 kg per palm per year SOA, TSP and MOP respectively (Table 6) which is the same as in 2003.

Table 5. Effect of SOA.KIE interaction on the FFB yield (t/ha) in 2002-2004 (Trial 209). *P*= 0.040, $lsd_{0.05}$ = 2.5.

	KIE 0	KIE 4	KIE 8
SOA1	27.6	28.7	24.9
SOA2	28.7	28.5	29.7
SOA3	30.6	29.8	**31.2**

Table 6. Effect of SOA.TSP.MOP interaction on the FFB yield (t/ha) in 2002-2004 (Trial 209). p= 0.018, grand mean = 28.9, sed= 2.1, , $lsd_{0.05}$ = 4.4.

		MOP 0	MOP 2	MOP 4
SOA 2	TSP 0	24.3	23.2	26.6
	TSP 4	26.0	28.0	29.0
	TSP 8	28.7	29.9	27.7
SOA 4	TSP 0	24.6	24.6	28.9
	TSP 4	29.2	32.7	28.9
	TSP 8	28.9	29.5	33.4
SOA 8	TSP 0	29.2	29.7	26.3
	TSP 4	30.8	29.0	**34.3**
	TSP 8	28.9	32.5	34.0

CONCLUSIONS and RECOMENDATIONS

SOA, TSP and MOP had a significant effect on the FFB yield during the combined period 2002-2004, in 2004 and over the course of the trial. KIE had no significant effect on the FFB yield over the course of the trial as the leaflet Mg concentrations were in the adequate range even with no KIE addition; however, these appear to be falling and may affect yield in future years.

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

PURPOSE

To provide N response information that will be useful for determining optimum N input in the area.

BACKGROUND

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.

SITE and PALMS

Navo Plantation, Field 11, Road 6 and 7, Avenue 11, 12 and 13
Soil: Aerated peat soils over redeposited scoria ash fall over coarse sandy subsoils with loose structures
Topography: Flat and swampy
Land use prior to this crop: Mostly sago and forest
Other site factors: Area extensively drained
Palms: Dami commercial DxP crosses
Planted in March 1988 at 115 palms/ha

DESIGN

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.

RESULTS

Fresh fruit bunch (FFB) yield has responded to N fertilizer in this the third year of the trial (Table 1, Figure 1). In the previous two years, there was no response of the FFB yield to N fertiliser. The positive response of N on the FFB yield was mainly due to an almost significant effect of N on single bunch weight (SBW).

Table 1. Regression parameters for the effect of fertiliser application rate (kg/palm/year) on FFB yield and its components in 2004 (Trial 211).

	Intercept	Slope	Slope p	R^2
FFB Yield (t/ha)	30.2	0.31	**0.038**	0.42
BNO/ha	2164	12.7	0.115	0.29
SBW (kg)	14.0	0.06	0.092	0.46

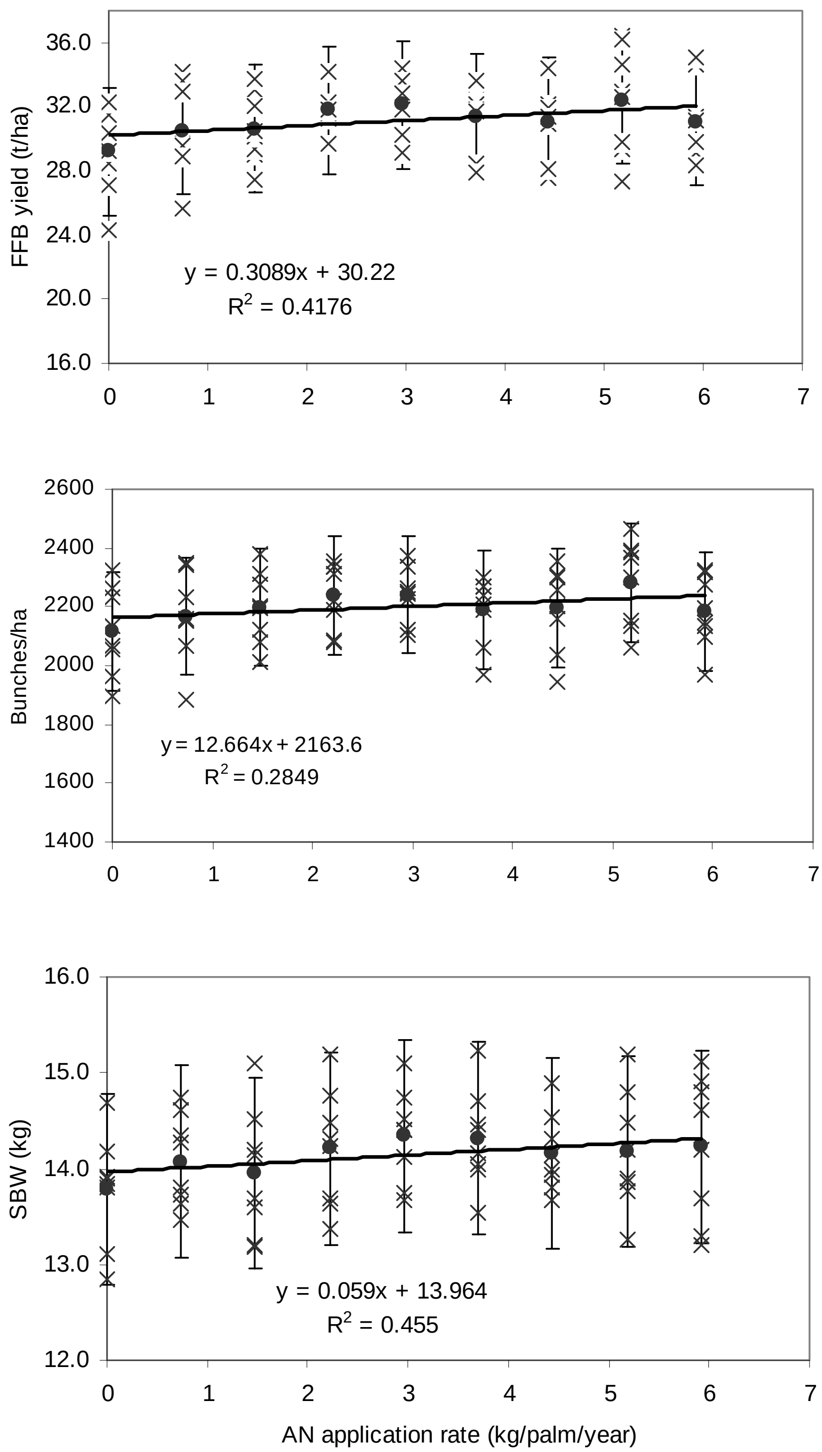


Figure 1. Effect of fertiliser rate (annual) on FFB yield, BNO/ha and SBW in 2004 (Trial 211). Crosses show values for each 60-palm plot (4 rows of 15), circles show means for treatment, and bars show sd for the BNO/ha and SBW.

TRIAL 212 SYSTEMATIC N FERTILISER TRIAL AT HARGY

PURPOSE

To provide N response information that will be useful for determining optimum N input in the area.

BACKGROUND

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.

SITE and PALMS

Hargy Estate, Area 8, Blocks 10 and 11
Soil: Freely draining Andosol formed on volcanic ash
Topography: Gentle to moderate slope
Land use prior to this crop: Oil palm
Palms: Dami commercial DxP crosses
Planted in February 1996 at 140 palms/ha

DESIGN

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.

RESULTS

There was a significant response of fresh fruit bunch (FFB) yield to N fertiliser in this the third year of the trial (Table 1, Figure 1). In the previous two years, there was no response of the FFB yield to N fertiliser. The positive response of N on the FFB yield was due to significant effects of N on single bunch weight (SBW) and number of bunches (BNO) per ha. The response of tissue N concentration to N fertiliser was also significant (Table 2, Figure 2).

Table 1. Regression parameters for the effect of fertiliser application rate (kg/palm/year) on FFB yield and its components in 2004 (Trial 212).

	Intercept	Slope	Slope p	R^2
Yield (t/ha)	24.7	1.0	**<0.001**	0.309
BNO/ha	1547	28	**0.014**	0.084
SBW (kg)	16.0	0.3	**<0.001**	0.234

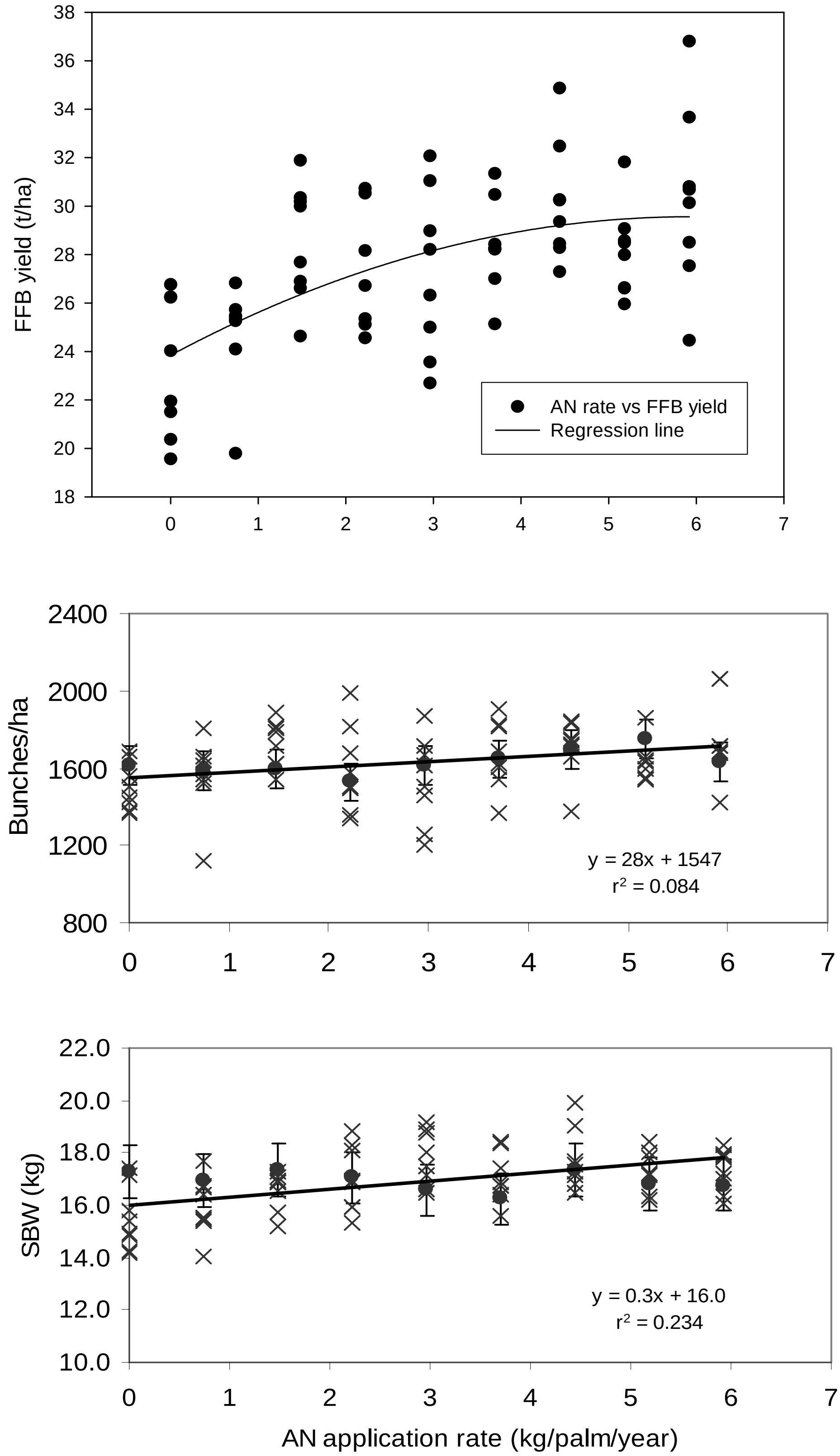


Figure 1. Effect of fertiliser rate (annual) on FFB yield, BNO/ha and SBW in 2004 (Trial 212). Crosses show values for each 30-palm plot (2 rows of 15), circles show means for treatment, and bars show sd for the BNO/h and SBW .

Table 2. 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 2004 (Trial 212). Slope *p* values <0.05 are indicated in bold.

	GM	Intercept	Slope	Slope p	r^2
Leaflet					
Ash	14.5	14.4	0.02	0.658	0.003
N	2.43	2.38	0.02	**<0.001**	0.161
P	0.140	0.138	0.001	**0.002**	0.128
K	0.689	0.691	-0.001	0.868	0.001
Mg	0.156	0.165	-0.002	**0.011**	0.089
Ca	1.07	1.08	-0.002	0.663	0.003
B	12.7	13.4	-0.1	**0.014**	0.083
Cl	0.534	0.466	0.014	**<0.001**	0.448
S	0.190	0.190	0.0001	0.771	0.001
Rachis					
Ash	4.79	4.48	0.0617	**0.007**	0.099
K	1.50	1.38	0.0249	**0.010**	0.090

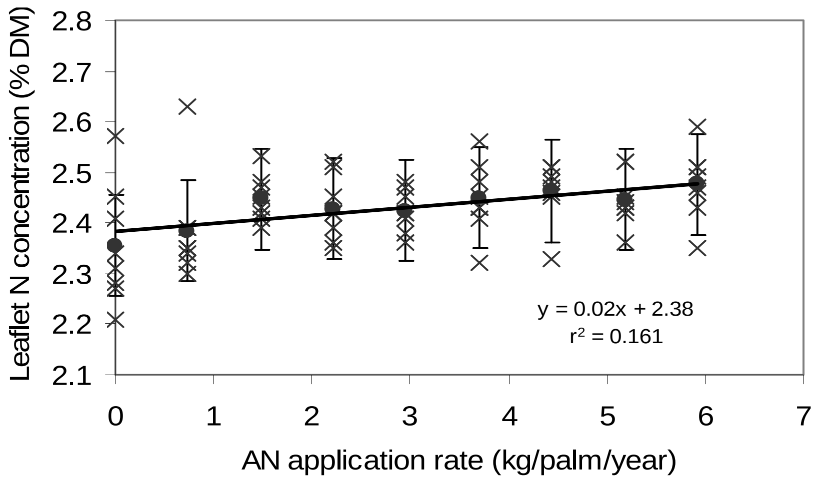


Figure 2. Effect of fertilizer rate on leaflet N concentration in 2004 (Trial 212). Crosses show values for each 30-palm plot (2 rows of 15), circles show means for treatment, and bars show s.d.

CONCLUSIONS

This is the first year that the trial has shown a significant response in yield to N supply. However, as would be expected in a trial that has had treatments applied for on three years, the response is still somewhat variable. The yield response curve shows a maximum yield at about 5 kg AN per palm per year. But the current level of variability, and the shallow response curve (although significant) means that it would be premature to suggest that 5 kg AN per palm would be of economic benefit.

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

EXECUTIVE 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 two years of the trial and these results will be verified with subsequent years of data collection. The results from this trial suggest rates 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.

INTRODUCTION

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.

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, and pre-treatment yield data and leaf nutrient concentrations are presented in Tables 2 and 3.

Table 1: Information on trial 213.

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)	5
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)

Treatment	2002 FFB yield (t/ha/year)	Number of bunches/ha/yr	Single bunch weight (kg)
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

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. 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

Yield – Mean Trend over Time

Over the 2 years since recording began, number of bunches (BNO) per ha tended to fall and SBW increased from pre-treatment figures (Figure 1). The FFB yield trend followed that of the single bunch weight. Since the palms are young, such trends are expected. The fall in the BNO/ha is expected to stabilise from 2005 onwards.

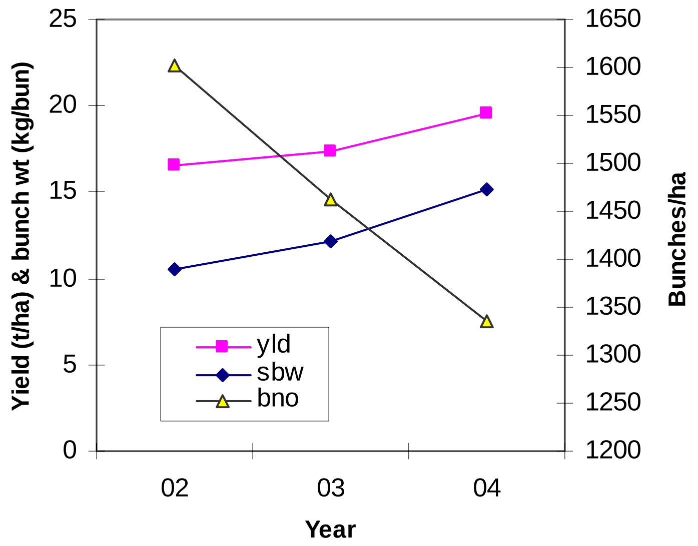


Figure 1: Mean FFB yield, BNO/ha and SBW from 2002 (pre-treatment) to 2004

Main effects

AN continued to increase the FFB yield significantly in the second year of the trial while TSP increased FFB yield significantly for the first time in 2004 (Table 5). Both AN and TSP had significant effects on the FFB yield over the combined period 2003-2004. The highest FFB yields were obtained at 4.4 kg AN and 3 kg TSP per palm/year respectively. Interestingly, increase in the FFB yield was mainly due to significant increase in the BNO/ha and not the SBW.

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

	2003-2004 FFB yield (t/ha)	BNO/ha	SBW(kg)	2004 FFB yield (t/ha)	BNO/ha	SBW (kg)
AN 0	**16.1**	**1244**	13.1	**17.4**	**1198**	14.9
AN 2.2	**18.8**	**1446**	13.5	**20.2**	**1399**	15.1
AN 4.4	**19.7**	**1447**	13.8	**21.2**	**1410**	15.5
p	***0.009***	***0.016***	*0.324*	***0.014***	***0.011***	*0.609*
TSP 0	**16.1**	1277	12.8	**16.4**	**1202**	14.3
TSP 3	**19.6**	1447	13.9	**21.6**	**1423**	15.7
TSP 6	**19.0**	1413	13.6	**20.7**	**1381**	15.6
p	***0.008***	*0.075*	*0.057*	***<0.001***	***0.012***	*0.058*
s.e.d.	*1.1*	*75*	*0.5*	*1.2*	73	0.6
$Lsd_{0.05}$	*2.3*	*154*	*0.9*	*2.5*	*149*	1.3
GM	*18.2*	*1379*	*13.5*	*19.6*	*1336*	*15.2*
CV %	*15*	*13*	*8*	*16*	*13*	*10*

Interaction between AN and TSP

The effect of the interaction between AN and TSP was not statistically significant. However, examining main effects alone can often mask the interplay between treatments. For example, the main effects of AN would suggest that increasing AN to 4.4 kg per palm (and possibly above) would increase FFB yield. However, examining the effects of the interplay between N and P revealed that near maximum FFB yield was achieved at 2.2kg AN per palm and 3kg TSP per palm (Figure 2). However, the differences between the four treatments at each of the top 2 rates of N and P (ie AN 2.2 – TSP 3; AN 2.2 – TSP 6; AN 4.4 – TSP 3; AN 4.4 – TSP 6) was small and not significant.

No attempt was made to relate yield to leaf N concentration as the samples were collected before treatments were added. However, it is interesting that they was a yield response so early in the trial when leaf N concentrations were well above the critical value of 2.5% DM at the start of the trial (see Leaf analytical data in 2003 annual report).

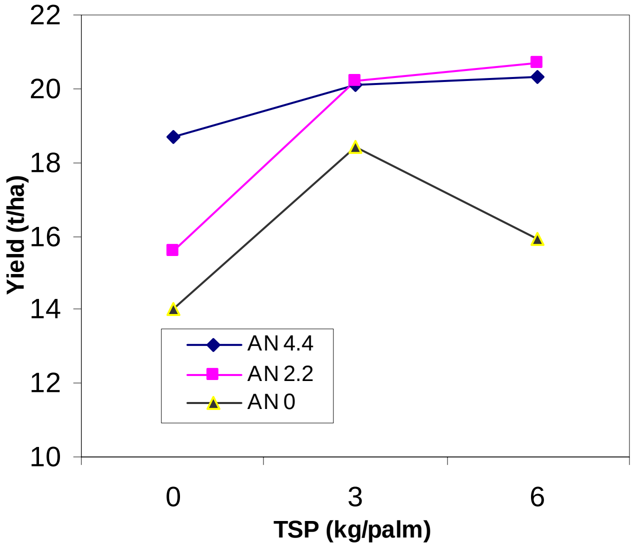


Figure 2: Effect of AN and TSP on average FFB yield (2003-2004).

CONCLUSIONS

Both N and P had positive effects on yield in the first two years of the trial and these results will be verified with subsequent years of data collection. The results suggest rates of 2.2 kg AN 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. As this is the first year that there has been a response to P fertiliser, it is not yet recommended that P be applied routinely to these plantation areas.

FERTILISER RESPONSE TRIAL IN ORO PROVINCE
(Higaturu Oil Palms)

(Steven Nake & Mike Webb)

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

EXECUTIVE 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) are set the edge of the trial, so 64 plots in total.

In comparison to the control plots, addition of nitrogen (any rate or source) has increased FFB yield with the difference between the zero N plots and N-fertilised plots increasing with time. Over this time, fertilized plots have had yields consistently greater than 30 t/ha, whereas unfertilized plots now have yields of only 24 t/ha. For 2004, in Sangara estate, the average yield was 22 t/ha.

Within the fertilized treatments, significant yield increases as a result of increasing fertiliser rates first appeared in 2003. This trend has continued and strengthened in 2004. However, similar responses are not yet apparent for other yield components such as single bunch weight (SBW) or number of bunches. Although rates of fertiliser have had a significant effect on yield, the type (source) of fertilizer has not.

Current results demonstrate that N-fertiliser requirement is at least 420 g N/palm/year (equivalent to 2 kg SOA, or 0.9 kg urea), and that an additional 2 tonnes FFB per ha is obtainable at the highest rate of N (equivalent to 8 kg SOA, or 3.6 kg urea). What is not clear at this stage is the relative effectiveness of different sources of N.

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 soils 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. Basic information on Trial 324

Trial number	324	Company	Higaturu Oil Palms
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, OPRA started the trial in January 2001, 5 year after field planting. Treatment application started in April 2001.

Before starting the trial, blocks 2 & 3 were mapped out on isometric graph paper by OPRA recorders, after which the 64 plots were plotted onto the map according to the treatment allocation (randomized block design). OPRA then followed standard procedures and demarcated plots, and numbered each palm in a plot (1 to 16). Directly surrounding those experimental palms are the guard row palms and these are painted with blue paint with initial GR written on them. Boundary palms as well as those on gullies or any marginal area within the block that is not suitable to allocate plots to are painted in red. These palms are referred to as perimeter palms. Each experimental palm is identified by two numbers. The numbers represents the plots and the palm number. Soil samples were collected to determine the initial soil nutrient status of the two blocks before treatment application (refer to soil data, Table 8).

Trial Maintenance and Upkeep

Like all OPRA established trials, any upkeep work in the trial block is solely taken care of by the estate on which the trial is located, 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 OPRA.

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

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 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 (at least 24 hours) and dispatched to AAR for analysis. Rachises are dried longer than the leaves (at least 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 and increased in soil depths in reps 2, 3, 4 and control plots except rep 1. CEC in general was moderate, with moderate to high amounts 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	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	Sulfate S	Org S	Boron	PRet
	(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 and DISCUSSION

Yield and other components response to fertilizer treatments

The main effects of the fertilizer treatments on the FFB yield and other components are summarized in Tables 5, 6 and 7.

In comparison with the control plots which did not receive any N, 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 2004 was 33.3 t FFB/ha/yr, about 19 % lower than the 2003 average yield (Table 5). This reduction in yield was mostly due to reduction in the number of bunches per hectare for that same year (Table 5). The SBW, however, continued to increase in plots supplied with N.

There was no significant yield response to different N-fertiliser types in the years 2001 to 2004. However, increasing fertilizer rates significantly increased yield in 2003 and 2004.

Number of bunches per hectare responded to the treatments in 2002 only. In 2004, there were no significant effects by either the fertilizer type or the fertiliser rate on the number of bunches per hectare. The only significant response was observed in 2002 as a result of applying different fertilizer types. The N-fertiliser types continued to have no effect on the single bunch weight in 2004. Similarly, the N-fertiliser rates had no effect on the single bunch weight in 2004 either. The only significant effect was seen in 2003 by the fertilizer rates. Although not significant, single bunch weights increased with increasing fertilizer rates in all years.

The interactions (type x rate) were still not significant in 2004 just like the preceding years. Despite that, the 2004 interactions showed increases in FFB yield as the rates of SOA, AMC and AMN were increased (Table 5). 2004 results showed yield being maximized when applying rate 3 of AMN.

The yields (with other components) in the control plots (zero N applied) continued to drop in 2004. The decline in yield in these plots (control) represents about 29 %, which is the biggest drop in the last 4 years. This substantial drop in yield is attributed to a decline in the number of bunches produced in the same year. The SBW continued to increase from 2001 to 2002, in 2004 there was a slight drop in the weight of the individual bunches. Visual symptoms from these plots also confirm nitrogen stress on the palms.

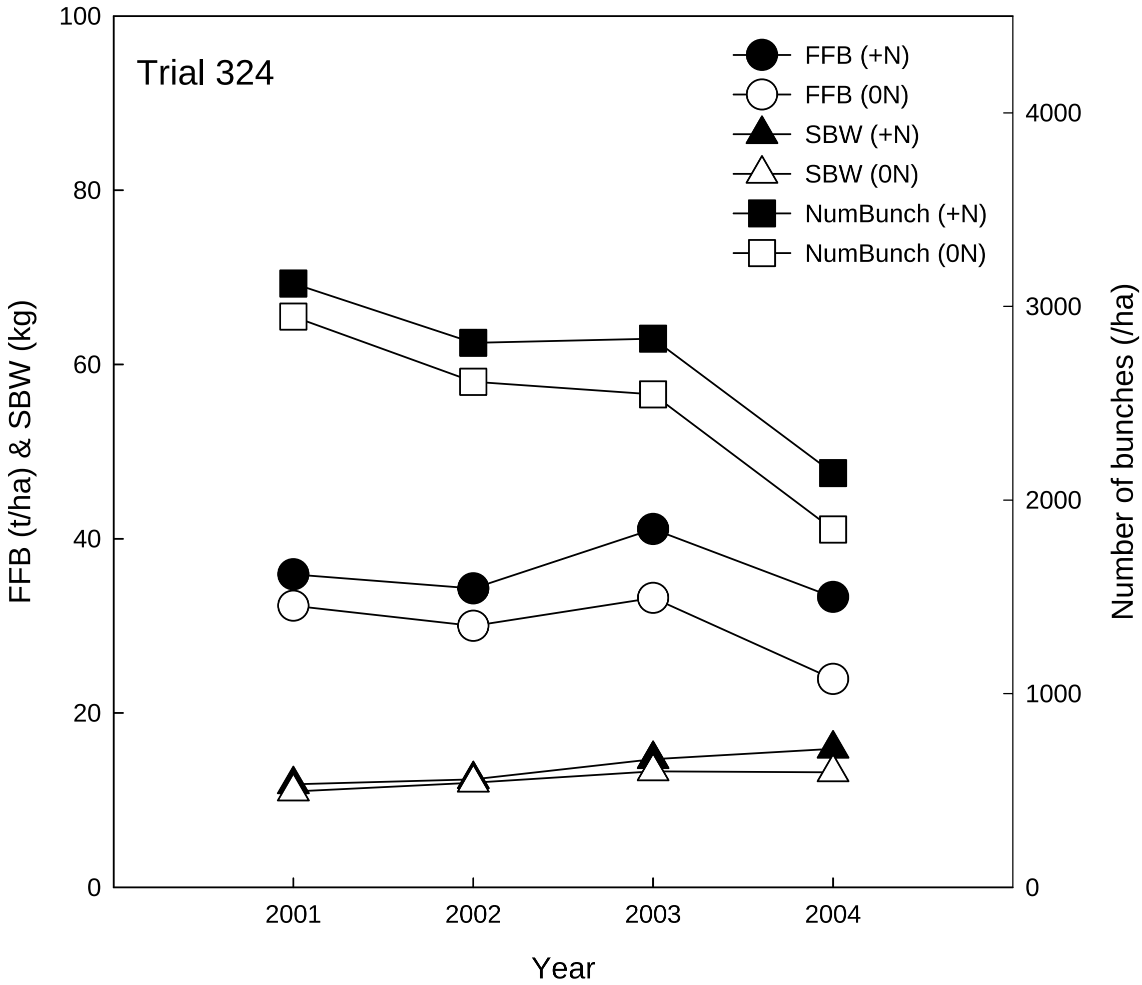


Fig. 1: Effect of N fertilizer on annual yield of FFB, number of bunches and SBW.

Table 4. Effects (p values) of treatments on FFB yield and its components in 2001 – 2004 and 2004. P values <0.1 are shown in bold.

	2001 - 2004			2004		
Source	Yield	BNO	SBW	Yield	BNO	SBW
Type	**0.056**	0.110	0.594	0.346	0.246	0.902
Rate	0.326	0.640	0.186	**0.085**	0.694	0.251
Type. Rate	0.552	**0.029**	0.544	0.832	0.272	0.794
CV %	*4.6*	4.8	*6.1*	*8.6*	9.4	*7.6*

Table 5. Main effects of fertilizer treatments on FFB yield (t/ha) from 2001 – 2004.

Treatments	**2001** (Age 5 yrs)	**2002** (Age 6 yrs)	**2003** (Age 7 yrs)	**2004** (Age 8 yrs)	**2001 - 2004**
Control (no N)	(32.3)	(30.0)	(33.2)	(23.9)	(29.8)
SOA	35.6	33.7	41.1	32.4	**34.7**
AMC	34.4	33.1	40.0	32.7	**34.1**
Urea	35.9	34.1	41.8	33.1	**35.3**
AMN	37.2	34.6	40.9	34.0	**35.7**
DAP	35.6	35.8	41.7	34.5	**35.9**
sed	1.2	1.1	1.1	0.49	0.67
Rate 1	36.5	34.0	**40.1**	**32.2**	34.7
Rate 2	35.3	34.5	**41.0**	**33.4**	34.1
Rate 3	35.5	34.2	**42.1**	**34.3**	35.3
sed	*0.94*	*0.83*	*0.87*	***0.38***	***0.52***
Grand mean	35.9	34.3	41.1	33.3	35.1

Table 6. Main effects of fertilizer treatments on number of bunches per /ha from 2001 – 2004

Treatments	**2001** (Age 5 yrs)	**2002** (Age 6 yrs)	**2003** (Age 7 yrs)	**2004** (Age 8 years)	**2001 - 2004**
Control (no N)	(2947)	(2611)	(2546)	(1848)	(2488)
SOA	3157	**2769**	2828	2054	2651
AMC	3075	**2798**	2748	2095	2628
Urea	3012	**2734**	2840	2131	2629
AMN	3274	**2844**	2857	2213	2745
DAP	3070	**2914**	2892	2203	2713
sed	*125*	*63*	*87*	*82*	*53*
Rate 1	3182	2856	2828	2108	2691
Rate 2	3133	2813	2811	2152	2676
Rate 3	3038	2766	2860	2157	2652
sed	*97*	*49*	*68*	*63*	*41*
Grand mean	3118	2812	2833	2139	2673

Table 7. Main effects of fertilizer treatments on single bunch weight (kg) from 2001 – 2004

Treatments	**2001** (Age 5 yrs)	**2002** (Age 6 yrs)	**2003** (Age 7 yrs)	**2004** (Age 8 years)	**2001 - 2004**
Control (no N)	(11.0)	(12.0)	(13.3)	(13.2)	(12.3)
SOA	11.5	12.3	14.6	15.9	13.5
AMC	11.5	12.0	14.6	15.9	13.4
Urea	12.3	12.7	15.0	15.8	13.8
AMN	11.7	12.4	14.5	15.7	13.5
DAP	12.0	12.6	14.7	16.1	13.8
sed	*0.42*	*0.33*	*0.34*	*0.49*	*0.34*
Rate 1	11.7	12.1	**14.4**	15.6	13.4
Rate 2	11.6	12.5	**14.7**	15.8	13.6
Rate 3	12.0	12.5	**15.0**	16.2	13.9
sed	*0.32*	*0.26*	*0.26*	*0.38*	*0.26*
Grand mean	11.8	12.4	14.7	15.9	13.6

Table 8. Effect of interaction between fertiliser type and rate on FFB yield (t/ha) in 2004. The interaction was not significant ($p=0.702$)

	SOA	AMC	Urea	AMN	DAP	Means
Rate 1	31.6	31.3	31.4	32.0	34.8	32.2
Rate 2	31.6	32.3	34.4	34.5	34.2	33.4
Rate 3	33.9	34.4	33.4	35.4	34.4	34.3
Means	32.4	32.7	33.1	34.0	34.5	

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

Tissue (Leaf and Rachis)

Tissue (leaflets & rachis) analysis results for 2004 are shown in Tables 9, 10 and 11. Most of the foliar nutrients are within the optimum range. There are low levels of foliar K and Mg. Fertiliser type had no significant effect ($p=0.251$) on foliar N levels, probably because the leaf levels of N were within the optimum range (2.40 – 2.80). This may have attributed to no yield response from the fertilizer types. Instead, there were significant responses on foliar K, Cl and even rachis ash (Table 8) but generally these responses were small. The fertilizer rates significantly ($p<0.001$) increased the foliar N levels. The interactions were only significant on the leaf ash levels. Though not significant, increasing rates of SOA, urea and AMN had a positive effect on the leaflet N (Table 9). These three N sources increased N level in the leaves when applied. AMC and AMN also increased rachis K levels while urea reduced the rachis K levels (Table 9).

Vegetative Growth

Vegetative growth responses to the treatments are shown in Table 10. Petiole cross-section width and thickness responded significantly to the different fertilizer types. Palms treated with DAP exhibited the highest PCS WxT but not different to palms receiving AMC and SOA, as determined by the LSD. Fertiliser rates had no significant effect on the PCS WxT, but responded positively. The frond length, leaflet number, leaflet length and width and frond production showed no responses to either fertilizer type and rate. The interactions were all not significant. After 3 years of no nitrogen fertilizer, palms is the control plots are beginning to show obvious depression in their general appearance as indicated by the growth parameters.

It is very obvious that palms receiving no nitrogen (control) exhibited very poor growth compared to those treated with N fertilizers.

Table 9. Effects (p values) of treatments on frond 17 nutrient concentrations in 2004. p values less than 0.1 are in bold.

	Leaflet								Rachis	
Source	Ash	N	P	K	Mg	Ca	Cl	S	Ash	K
Type	0.112	0.251	0.104	**0.028**	0.639	0.105	**<.001**	0.665	**0.090**	0.151
Rate	0.339	**<.001**	0.472	0.552	0.744	**0.018**	0.395	0.232	0.915	0.418
Type.Rate	**0.095**	0.185	0.958	0.362	0.421	0.393	0.155	0.980	0.730	0.529
CV %	3.6	2.2	2.5	4.2	7.9	6.0	7.8	4.6	7.0	8.3

Table 10. Main effects of treatments on frond 17 nutrient concentrations in 2004, 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.

	Leaflet								Rachis	
Source	Ash	N	P	K	Mg	Ca	Cl	S	Ash	K
Zero N	(15.1)	(2.29)	(0.143)	(0.70)	(0.18)	(0.83)	(0.39)	(0.18)	(4.9)	(1.6)
SOA	14.5	2.52	0.143	**0.74**	0.17	0.78	**0.45**	0.19	**4.8**	1.6
AMC	14.6	2.49	0.144	**0.70**	0.17	0.82	**0.54**	0.19	**5.2**	1.7
Urea	14.3	2.48	0.142	**0.72**	0.17	0.80	**0.45**	0.20	**4.9**	1.6
AMN	14.1	2.51	0.141	**0.73**	0.16	0.78	**0.45**	0.19	**5.0**	1.6
DAP	14.6	2.52	0.145	**0.72**	0.16	0.77	**0.48**	0.19	**5.0**	1.7
LSD (p=0.05)	*ns*	*ns*	*ns*	***0.02***	*ns*	*ns*	***0.03***	*ns*	***0.28***	*ns*
Rate 1	14.5	**2.43**	0.142	0.71	0.17	**0.80**	0.47	0.19	5.0	1.6
Rate 2	14.3	**2.52**	0.143	0.72	0.17	**0.79**	0.48	0.20	5.0	1.6
Rate 3	14.5	**2.55**	0.144	0.72	0.17	**0.76**	0.48	0.20	5.0	1.7
LSD (p=0.05)	*ns*	***0.04***	*ns*	*ns*	*ns*	***0.03***	*ns*	*ns*	*ns*	*ns*
CV %	3.6	2.2	2.5	4.2	7.9	6.0	7.8	4.6	7.0	8.3

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

Leaflet N (% DM), lsd $_{0.05}$ = 0.08					
	SOA	AMC	Urea	AMN	DAP
Rate 1	2.45	2.43	2.40	2.41	2.48
Rate 2	2.54	2.57	2.50	2.53	2.55
Rate 3	2.58	2.48	2.53	2.59	2.52
Rachis K (% DM), lsd $_{0.05}$ = 0.19					
	SOA	AMC	Urea	AMN	DAP
Rate 1	1.56	1.65	1.63	1.53	1.71
Rate 2	1.63	1.75	1.62	1.65	1.57
Rate 3	1.60	1.80	1.59	1.70	1.68

Table 12. Main effects of treatments on vegetative growth of frond 17.

Treatment	PCS W x T (cm^2)	Frond length (cm)	Number of Leaflets	Leaflet length (cm)	Leaflet width (cm)	Frond production rate per year
Zero N	(27.7)	(548)	(168)	(98)	(5.2)	(25.2)
Fert Type						
SOA	**34.6**	591	169	103	5.4	27.7
AMC	**35.7**	590	169	103	5.4	27.9
Urea	**33.6**	589	171	103	5.4	26.9
AMN	**34.0**	595	172	103	5.7	27.6
DAP	**36.8**	603	173	104	5.5	27.8
LSD (p=0.1)	***2.5***	*ns*	*ns*	*ns*	*ns*	***n.s***
Fert Rate						
Rate 1	34.0	594	172	103	5.4	26.9
Rate 2	34.8	594	172	103	5.6	27.9
Rate 3	36.0	594	170	103	5.5	27.9
LSD (p=0.1)	ns	ns	ns	ns	ns	ns
CV %	8.8	3.1	3.5	2.6	8.9	3.5

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 2004, 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 (4.8 kg/palm/year) of AMN. This is consistent with the previous year’s results. However that may not be a direct effect from the treatments because pre-treatment yield data also showed that the plot allocated to AMN to have produced the highest yield prior to treatments being imposed.

Thus, at this stage, no new recommendations will be made from this trial; no one type of N-fertiliser appears to be substantially better than any other, and while rates of application are beginning to show effects, those effects, while statistically significant, are possibly not yet large enough to justify the additional cost. For example, the current (July, 2005) price for CPO is USD419; which when taking production costs into account makes FFB worth USD 46/tonne. Therefore a 2-tonne/ha increase, which is about magnitude that these trials are showing from the lowest to the highest rate, would earn USD 92/ha. However, this would require an extra 2.7 kg/palm of urea (USD 390/tonne). At 130 palms, this would cost USD 137/ha, which is more than the return.

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

EXECUTIVE SUMMARY

Trial 326 was established in Popondetta (Higaturu Oil Palms) to provide information on minimum EFB and N requirements of palms to help formulate fertilizer recommendations on volcanic plain soils. The trial commenced in 2002. The trial is a randomized block design with 4 SOA levels and 3 EFB levels in 12 treatments combinations. These treatments are replicated 5 times resulting in 60 plots. The palms were planted in 1998/1999.

The yield and the bunch weights continued to increase steadily each year since the trial began, unlike the number of bunches which dropped in 2004. The treatment effects on yield and other components (number of bunches per hectare and single bunch weights) was not significant. There was no yield response to the treatments after 3 years of treatments. Similarly, there were nil or very slight (weak) responses on the tissue nutrient concentration and vegetative parameters studied.

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. 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. Basic information on Trial 326

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 complete 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. 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 gullies 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 OPRA 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 OPRA.

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

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 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 (at least 24 hours) and dispatched to AAR for analysis. Rachis are dried for longer than the leaves (at least 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	0.12	5.3	0.83	0.09	10	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 most likely laboratory errors and are not included in the mean.*

RESULTS and DISCUSSION

Yield (and other components) responses to fertilizer treatments

FFB yield and other component results for the last 3 years (2002 – 2004) are shown in Tables 4 - 7. The FFB yield and the SBW continued to increase in 2004 despite the decline in the number of bunches per hectare. Similar to the last two years, there was no significant (p>0.05) yield response to either main treatments (SOA & EFB) in 2004. The number of bunches per hectare and the SBW also showed no response to the treatments. However, yield and SBW continue to favour EFB application though not significant.

Despite the lack of response, the FFB yields were quite high (>30 t/ha/yr) at the age of 5 years. 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 and a further increase by another 3 tonnes in 2004 (Table 5). The bunch weights also showed similar trend from 2002 to 2004.

The interactions were also not significant in 2004 (Table 8).

Table 4. Effects (p values) of treatments on FFB yield and its components in 2002 – 2004 and 2004.

	2002 - 2004			2004		
Source	Yield	Bunches/ha	SBW	Yield	Bunches/ha	SBW
SOA	0.524	0.425	0.765	0.319	0.381	0.802
EFB	0.926	0.537	0.680	0.528	0.950	0.367
SOA.EFB	0.429	0.833	0.390	0.354	0.346	0.555
CV %	*7.9*	*5.0*	*6.3*	*9.1*	*6.8*	*6.3*

Table 5. Main effects of treatments on FFB yield (t/ha) from 2002 to 2004

	Age and Year			
	3	4	5	
Treatments	2002	2003	2004	2002 - 2004
SOA0	17.9	30.1	32.8	26.9
SOA1	18.0	30.1	34.2	27.4
SOA2	18.3	30.4	32.4	27.0
SOA3	18.8	31.3	33.9	28.0
sed	*0.79*	*1.1*	*1.1*	*0.79*
EFB0	18.5	30.4	32.7	27.2
EFB1	15.3	30.3	33.8	27.5
EFB2	17.9	30.6	33.5	27.3
sed	*0.68*	*1.0*	*1.0*	*0.68*
Grand Mean	18.2	30.5	33.3	27.3

Table 6. Main effects of treatments on number of bunches per hectare from 2002 to 2004

	Age and Year			
	3	4	5	
Treatments	2002	2003	2004	2002-2004
SOA0	2249	2672	2504	2475
SOA1	2294	2683	2597	2525
SOA2	2314	2732	2517	2522
SOA3	2340	2736	2580	2551
sed	*75.2*	*71.0*	*63.6*	*45.7*
EFB0	2343	2710	2548	*2534*
EFB1	2322	2703	2559	2528
EFB2	2233	2704	2542	2493
sed	*65.1*	*62.0*	*55.0*	*39.6*
Grand Mean	2299	2706	2550	2518

Table 7. Main effects of treatments on single bunch weight (kg) from 2002 to 2004

	Age and Year			
	3	4	5	
Treatments	2002	2003	2004	2002 - 2004
SOA0	7.9	11.3	13.3	10.9
SOA1	7.9	11.3	13.3	10.9
SOA2	7.9	11.3	13.1	10.7
SOA3	8.1	11.6	13.3	11.0
sed	*0.23*	*0.30*	*0.31*	*0.25*
EFB0	8.0	11.3	13.0	10.8
EFB1	8.0	11.3	13.4	10.9
EFB2	8.0	11.5	13.4	11.0
sed	*0.21*	*0.30*	*0.27*	*0.22*
Grand Mean	8.0	11.4	13.3	10.8

Table 8. Effect of SOA and EFB (two-way interactions) on FFB yield (t/ha/yr) in 2004. The interaction was not significant (p=0.354).

	EFB 0	EFB 1	EFB 2
SOA 0	33.3	31.6	33.5
SOA 1	32.9	34.2	35.3
SOA 2	31.8	32.8	32.6
SOA3	32.9	36.5	32.6
Grand mean	33.3	Standard Error	3.0

Effects of fertilizer treatments on leaflet and rachis nutrient concentrations

The leaflets and rachis tissue analysis results for 2004 are shown in Tables 9, 10 and 11. Ammonium sulphate (SOA) had significant effects on the leaflet Cl, however the nature of that effect was not clear (Table 10). The rest of the leaflet and rachis nutrients, including N showed no responses to the SOA treatments. By contrast, empty fruit bunches (EFB) significantly increased leaflet N and Ca, and rachis K concentration. The effect of the treatment interactions (SOA x EFB) was only significant on the leaflet Cl (Table 11). The mean values for all the nutrients are within the adequate range, which indicates no deficiency at this stage.

Table 10. Main effects of treatments on frond 17 nutrient concentrations in 2004, in units of % dry matter. p values less than 0.1 are shown in bold.

	Leaflet								Rachis	
Source	Ash	N	P	K	Mg	Ca	Cl	S	Ash	K
SOA0	23.7	2.67	0.153	0.74	0.21	0.87	**0.55**	0.20	4.67	1.46
SOA1	27.9	2.70	0.153	0.74	0.21	0.86	**0.48**	0.20	4.44	1.42
SOA2	28.9	2.71	0.154	0.75	0.21	0.86	**0.52**	0.20	4.53	1.46
SOA3	31.6	2.70	0.154	0.75	0.20	0.86	**0.51**	0.20	4.70	1.53
sed	*5.5*	*0.02*	*0.001*	***0.02***	*0.008*	*0.016*	***0.018***	*0.003*	***0.20***	*0.06*
EFB0	31.5	**2.67**	0.153	0.75	0.21	**0.84**	0.50	0.20	4.46	**1.37**
EFB1	27.0	**2.70**	0.153	0.75	0.21	**0.86**	0.52	0.20	4.55	**1.46**
EFB2	25.7	**2.71**	0.154	0.74	0.21	**0.90**	0.52	0.20	4.74	**1.56**
sed	*4.8*	***0.01***	*0.001*	*0.02*	*0.007*	***0.013***	*0.015*	*0.002*	*0.17*	***0.05***
Grand mean	28.1	2.69	0.153	0.75	0.21	0.86	0.51	0.20	4.58	1.47

Table11. Effects of interaction between SOA and EFB on leaflet N, leaflet Cl and Rachis K.

Leaflet N (% DM), Interaction not significant (p=0.459)

	SOA0	SOA1	SOA2	SOA3
EFB0	2.64	2.65	2.68	2.71
EFB1	2.69	2.73	2.72	2.68
EFB2	2.67	2.71	2.72	2.70

Leaflet Cl (% DM), lsd $_{0.05}$ = 0.06, Interaction was significant (p = 0.015)

	SOA0	SOA1	SOA2	SOA3
EFB0	0.56	0.42	0.52	0.49
EFB1	0.53	0.48	0.54	0.51
EFB2	0.54	0.54	0.50	0.52

Rachis K (% DM), Interaction not significant (p=0.428)

	SOA0	SOA1	SOA2	SOA3
EFB0	1.37	1.36	1.42	1.35
EFB1	1.45	1.32	1.48	1.60
EFB2	1.56	1.57	1.48	1.63

Effects of fertilizer treatments on Vegetative parameters in 2004

The vegetative parameters are shown in Table 12 and 13 and of all the parameters observed, the effects of SOA was only significant on the bunch index (BI), while the rest showed no response. Level 2 of SOA (2.5 kg/palm/yr) had the highest value (0.631) for the BI. Though not significant, SOA tend to increase frond length, PCS, frond area, frond weight and the VDM. The effects of EFB was also not significant. Despite that, number of green leaves, frond area, LAI, BDM and TDM increased with EFB application. The interactions were also not significant.

Table 12. Effects (p values) of treatments on vegetative parameters in 2004. 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	0.473	0.544	0.464	0.670	0.761	0.743	0.544	0.411	0.319	0.610	0.562	**0.029**
EFB	0.324	0.333	0.374	0.714	0.694	0.476	0.333	0.129	0.528	0.216	0.548	0.109
SOA x EFB	0.664	0.561	0.870	0.804	0.789	0.573	0.561	0.538	0.354	0.456	0.343	0.600
CV %	3.7	7.7	3.2	3.3	6.7	6.9	7.0	7.3	9.1	7.0	7.8	2.5

Table 13. Main effects of fertiliser treatments on vegetative growth parameters in 2004

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	522.4	25.4	31.3	42.5	14.6	8.77	2.85	12.1	26.9	16.4	43.3	**0.621**
SOA	1	529.6	25.6	30.8	42.5	14.7	8.86	2.87	11.9	28.0	16.4	44.4	**0.631**
	2	533.0	26.2	31.3	43.0	14.8	8.99	2.94	12.4	26.6	16.7	43.3	**0.613**
	3	530.9	26.3	31.1	42.6	14.9	8.95	2.94	12.4	27.9	16.8	44.7	**0.623**
sed		*7.1*	*0.73*	*0.36*	*0.51*	*0.36*	*0.22*	*0.08*	*0.32*	*0.91*	*0.42*	*1.24*	*0.006*
	0	533.3	25.7	31.1	42.5	14.7	8.81	2.88	12.1	26.8	16.4	43.3	0.620
EFB	1	524.1	25.5	30.9	42.6	14.7	8.84	2.86	11.9	27.7	16.3	44.0	0.628
	2	529.5	26.4	31.3	42.9	14.9	9.03	2.96	12.5	27.5	16.9	44.4	0.618
sed		*6.1*	*0.63*	*0.32*	*0.45*	*0.31*	*0.19*	*0.07*	*0.28*	*0.79*	*0.37*	*1.08*	*0.005*

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

CONCLUSION

The main treatments (SOA, EFB) and their interactions (SOA x EFB) continued to show no significant effects on the yield, numbers of bunches per hectare and the single bunch weights in 2004. However, yield and bunch weights responded positively to EFB though the response was not significant. The FFB yield (t/ha/yr) and the single bunch weights increased steadily from 2003 to 2004, whereas there was a significant drop in the number of bunches in 2004.

Unlike SOA, EFB had a significant effect on leaflet N. The N content increased as more EFB was added. Calcium (Ca) levels were also increased through EFB application. The only response from SOA was from leaflet Chlorine (Cl), but not distinct between the different SOA levels.

Similar to the yield and the leaf nutrient concentrations, the treatments had no significant effects on all the vegetative parameters, except the bunch index (BI). In spite of this, some of the parameters managed to respond positively (but not significant) to the treatments.

TRIAL 329 NITROGEN, P, K AND Mg TRIAL ON MAMBA SOILS, MAMBA ESTATE

PURPOSE

To provide information for fertiliser recommendations for estates and smallholders in the Kokoda Valley and Ilimo/Papaki areas on soils that are unlike soils of the Popondetta plains, being acidic, with low cation status and high P retention.

DESCRIPTION

Site: Mamba Estate Blocks 97 J

Soil: Dark sandy loam airfall ash overlying coarse to medium textured alluvial materials from the Mount Owen Stanley Ranges.

Palms: Dami commercial DxP crosses were planted from old cocoa plantations at 135 palms per hectare in 1997.

DESIGN

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 1). 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 will also be surrounded by a trench to prevent plot-to-plot poaching. The trial area will receive a basal application of borate at 50 g/palm/year. Treatments and yield recording started in September 2001. See 2001 Proposals for background.

Table 1. 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

RESULTS

The effects of fertilizer treatments on the FFB yield and other components are shown in Tables 2, 3, 4 and 5. The mean yield in 2004 was 17.1 t FFB/ha/yr, which was 32.5 % lower than the 2003 average crop (Table 3). This significant drop in yield was mostly due to reduction in the number of bunches (Table 3). This huge drop is also evident in other blocks surrounding this block (refer OMP8 data for 2003 and 2004). Despite this, the single bunch weights continued to increase in 2004.

Unlike 2003 where there were some responses to the fertilizer treatments, this year (2004), there was no response on the yield, number of bunches and SBW (Table 2). The yield however increased with increasing levels of SOA and MOP. MOP also increased SBW though not significant in 2004. The 2002-2004 data showed yield and SBW responses to MOP applications (Table 2 and 3).

Three way interactions between MOP, TSP and KIE showed significant effects on the yield and the SBW (Table 2, 4 and 5). The highest yield (23.3 t FFB/ha/yr) was achieved when applying 4 kg MOP with 2 kg KIE in the absence of TSP (level 2 MOP, level 0 TSP and level 1 KIE). Despite this, an optimum and reasonably high yield of 19.5 t FFB/ha/yr was also achieved when applying 4 kg MOP alone without any TSP or KIE (MOP level 2, TSP level 0, Kie level 0). Though this yield was lower than 23.3 t FFB/ha/yr, statistically they do not differ. In the absence of KIE and TSP, FFB yield tend to increase with MOP levels, this shows a positive yield response to MOP when both KIE and TSP are not applied. A similar yield response was obtained when combining the three levels of MOP with level 1 (2 kg/palm/yr) of KIE in the absence of TSP. Yields were further increased when increasing KIE levels in the absence of MOP and TSP (Table 4). In the absence of KIE, the SBW responded positively to MOP with level 2 (4 kg/palm/yr) of TSP (Table 5). SBW were also increased when increasing KIE levels in the absence of MOP and TSP (Table 5).

CONCLUSION

The trial experienced a significant drop in FFB yield by 32.5 % in 2004 that was caused mostly by the drop in the number of bunches per hectare.

The main effects in 2004 showed no significant effects on the yield, the number of bunches per hectare and the SBW. However, there was an increase in FFB yield from the SOA and the MOP treated plots. There was a response in FFB yield and the SBW from the three-way interaction between MOP, TSP and KIE. From the three-way interaction, both yield and SBW responded positively to MOP in the absence of both TSP and KIE.

Table 2. Effects (p values) of treatments on FFB yield and its components in 2002 – 2004 and 2004. P values less than 0.1 are bolded.

	2002 - 2004			2004		
Source	Yield	BNO/ha	SBW	Yield	BNO/ha	SBW
SOA	0.309	0.346	0.196	0.333	0.143	0.211
MOP	**0.026**	0.628	**0.066**	0.354	0.841	0.156
TSP	0.540	0.395	0.253	0.447	0.139	0.379
KIE	0.557	0.437	0.266	0.829	0.252	0.355
SOA.MOP	0.418	0.653	**0.074**	0.920	0.664	0.150
SOA.TSP	0.316	0.936	**0.080**	0.470	0.595	0.704
MOP.TSP	0.615	0.578	0.404	0.332	0.331	0.468
SOA.KIE	0.491	0.965	0.524	0.609	0.626	0.958
MOP.KIE	0.730	0.830	0.861	0.613	0.342	0.811
TSP.KIE	0.906	0.950	0.237	0.782	0.580	0.165
SOA.MOP.TSP	0.423	0.429	0.283	0.791	0.876	0.452
SOA.MOP.KIE	0.378	0.542	**0.079**	0.715	0.986	0.133
SOA.TSP.KIE	0.221	0.374	0.746	0.510	0.698	0.703
MOP.TSP.KIE	**0.084**	0.504	**0.001**	**0.033**	0.341	**0.002**
CV %	6.6	9.8	4.5	14	11.6	7.3

Table 3. Main effects of treatments on FFB yield and its components in 2002 – 2004 and 2004.

Treatments	**2002 - 2004** Yield (t/ha)	BNO/ha	SBW (kg)	**2004** Yield (t/ha)	BNO/ha	SBW (kg)
SOA1	21.5	1685	13.5	16.8	1100	15.8
SOA2	21.9	1731	13.3	17.4	1158	15.4
sed	*0.39*	*46*	*0.16*			
MOP0	**21.1**	1688	**13.1**	16.5	1126	15.1
MOP1	**21.5**	1696	**13.5**	17.0	1117	15.8
MOP2	**22.6**	1740	**13.7**	17.8	1143	15.9
sed	**0.48**	56	**0.20**			
TSP0	21.9	1718	13.3	17.6	1166	15.5
TSP1	21.4	1663	13.6	16.6	1073	15.9
TSP2	21.9	1742	13.3	17.0	1148	15.4
	0.48	56	0.20			
KIE0	21.4	1665	13.6	16.9	1085	15.9
KIE1	21.9	1721	13.4	17.4	1161	15.6
KIE2	21.8	1737	13.2	17.0	1140	15.4
sed	0.48	56	0.20			
Grand Mean	21.7	1708	13.4	17.1	1129	15.6

Table 4. Effect of the interactions (three – way) between MOP, TSP and KIE on FFB yield (t/ha) in 2004. The interaction was significant, $Lsd_{0.05}$ =5.5

MOP	TSP	KIE 0	KIE 1	KIE 2
0	0	15.1	15.1	17.4
	1	19.7	14.2	14.8
	2	17.2	18.7	16.5
1	0	17.6	17.5	17.2
	1	15.4	19.7	15.2
	2	15.5	15.7	19.0
2	0	19.5	23.3	16.0
	1	13.5	15.6	21.2
	2	18.2	16.5	16.1

Table 5. Effect of the interactions (three-way) between MOP, TSP and KIE on SBW (kg) in 2004. The interaction was significant, $Lsd_{0.05}$ =2.6

MOP	TSP	KIE		
		0	1	2
0	0	13.8	15.2	15.4
	1	18.0	14.0	15.1
	2	14.4	16.8	13.7
1	0	17.1	14.4	14.7
	1	17.6	16.3	14.2
	2	14.6	15.6	17.9
2	0	16.2	18.3	14.5
	1	14.6	14.7	19.0
	2	17.3	14.9	13.7

TRIAL 330 GRASSLAND SULPHUR TRIAL ON OUTWASH PLAINS, PARAHE MINI ESTATE (now relocated to new site, Heropa Mini Estate)

BACKGROUND

With increased oil palm plantings in the Popondetta grassland areas both by smallholders and the mini-estate schemes, this trial was initiated 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 from 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, S deficiency may occur. Thus this trial was proposed to look at both N and S situation in the grassland areas of Popondetta.

PURPOSE

To provide information for fertiliser recommendations to the estate, mini estates and smallholder growers in the grassland areas of Popondetta.

SITE and PALMS

Site: Parahe Mini Estate

Soil: Soils at the grassland area are formed from alluvial volcanic materials. The black top soils are loamy sand to sandy loam and over lay more sandier materials at the subsurface.

Palms: Dami commercial DxP crosses were planted at 135 palms per hectare in 2000.

DESIGN (initial/old) – refer Table 1

A 'factorial' design with 4 rates of urea (0.5, 1.5, 2.5 and 3.5 kg/palm per year) and 3 rates of elemental S (0, 0.1 and 0.30 kg/palm per year), with 3 replicates, resulting in 36 plots. Each of the 36 plots has 16 recorded palms plus guard rows, resulting in a total of 36 palms/plot. Guard rows were used to avoid the use of trenches for preventing plot-to-plot poaching.

There is no nil N treatment because it was felt landowners might not want very low crop yields in the mini estates. Also it is already known that in Popondetta soils, crop yield can be extremely low (<10 t/ha.yr) in plots not receiving nitrogen fertilisers. The trial will receive an annual blanket application of MOP at the rate recommended for HOP estates on grasslands: 0.5 kg/palm in year 1, 1 kg/palm in year 2 and 2 kg/palm in year 3 and thereafter. (2 doses of 1 kg/palm). SOA was applied in 2000, 2001, 2002 and 2003 in order to get the palms and cover crops established. First dose of treatments was applied in 2004 and the second dose was never applied after the trial was closed in the same year.

Design and treatments (updated to cater for urea) – refer Table 2

The initial plan was to test out 4 rates of ammonium nitrate (AN) and 3 rates of elemental sulphur (S). 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 trial replicated 3 times, resulting in 36 plots. 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.

Table 1. Fertiliser treatments and levels in Trial 330 (initial for old site).

	Amount (kg/palm.year)			
Fertiliser	Level 1	Level 2	Level 3	Level 4
Elemental Sulphur	0	0.15	0.30	
Ammonium nitrate	0.7	2.0	3.3	4.6

Table 2. Fertiliser treatments and levels in Trial 330 (reviewed for new site).

	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

PROGRESS

Towards the end of May 2004, The current site (Parahe mini-estate) was vacated at the end of May for two reasons: firstly the site is prone to high degree of water logging especially during prolonged wet season. This may cause surface movement of fertiliser treatments from one plot to the other. Secondly, continuous disputes between the landholders and the company has severely affected our operations in that trial. This had lead to harvesting and yield recording not been done on time or skipped. PNGOPRA then identified two possible sites at the Pingoruta and Heropa mini-estates. Leaf samples were collected from these two sites and sent to Australia for analysis for S levels. Leaf analysis suggests that this trial be located at Heropa Mini Estate because of low levels of S in this area. The trial has started in May 2005 at the new site (Heropa Mini-Estate).

TRIAL 333 – MG AND K SOURCES IN ORO

BACKGROUND

The soils of the Ilimo-Mamba area of Oro Province are acidic and have very low CEC. Magnesium and K deficiency symptoms are common. Kieserite and MOP are applied, but we expect that their effectiveness 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. Empty fruit bunch (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. This trial is part of the ACIAR-funded Mg project.

PURPOSE

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.

SITE

Ebie block, Mamba Estate, in 1993 planting.

TREATMENTS

The treatments fall into 3 groups. Fertiliser rates for the various treatments are given in Table 1. Nitrogen will be applied across the trial as urea at a standard rate.

Group 1, Mg sources in the presence of adequate K: The following 4 Mg sources will all be added individually at an equivalent rate of Mg, and all be applied in 2 doses per year: 1) kieserite, 2) magnesite (QMAG Magnesite FO1), 3) MgO (QMAG M45) and 4) dolomite.

Group 2, K sources in the presence of adequate Mg: The following 3 sources of K will be added individually. 1) MOP (2x per year, on surface). 2) MOP in trenches covered with plastic, applied once at a rate equivalent to 3x the surface MOP rate. 3) EFB at an equivalent rate of K to the surface MOP treatment (applied in 1 dose per year).

Group 3, Potential response to Mg or K: The adequate Mg treatment will comprise of kieserite + magnesite + MgO, 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 (see Group 2). An extra treatment will be boiler ash, which contains Mg and K in approximately the correct ratio.

STATISTICAL DESIGN and LAYOUT

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, or as one single experiment with 11 treatments. Plots will consist of 36 (6*6) treated palms, of which the central 16 (4*4) are recorded.

PROGRESS

The proposed site for the trial was mapped out towards the end of 2003 with the 48 plots demarcated according the treatment allocation. before application of the treatments. Fertiliser treatments were applied in August 2004.

Table 1 Fertiliser types and rates

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)						
Kieserite	Mg	0.425	17	2.5	2/yr	1,250
Magnesite	Mg	0.425	26	1.6	2/yr	817
Dolomite	Mg	0.425	10	4.3	2/yr	2,125
MgO	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)						
MOP surface	K	1.25	50	2.5	2/yr	1,250
MOP trenches & plastic	K	3.75	50	7.5	1	7,500
EFB	K				1/yr	
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)						
MOP	K	1.25	50	2.5	2/yr	1,250
MOP trenches & plastic	K	3.75	50	7.5	1	7,500
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
Boiler Ash	Mg & K	0.43 & 1.39	1.5 & 4.9	28.3	2	14,167
Control	No fertiliser applied (i.e no K & no Mg). N will be applied as urea.					

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

(Steven Nake & Mike Webb)

TRIAL 502B NITROGEN, PHOSPHORUS, POTASSIUM AND EFB TRIAL, WAIGANI ESTATE

PURPOSE

To test the response to N, P and K in factorial combination, with and without EFB, with a view to using EFB to replace or supplement chemical fertiliser.

DESCRIPTION

Site: Waigani Estate, Field 6503 and 6504.

Soil: Plantation family, which of recent alluvial origin.

Palms: Dami commercial DxP crosses. Planted 1986 at 127 palms/ha

DESIGN

Trial 502B relocation 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 which are confounded with higher order interactions. 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 1. 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	-	-

RESULTS

The effects of the fertilizer treatments on the FFB yield and nutrient concentration over the course of the trial (1995 – 2004) are illustrated in Figure 1. The effects of MOP and EFB on the FFB yield was more pronounced in 2004 than in previous years. There was no yield response to TSP application, despite the positive responses seen in the leaflet P concentrations.

Yield and yield component results for 2003 and 2004 are shown in Table 2 and 3. Despite the reduction in the overall FFB yield, there has been a marked response SOA, MOP and EFB. The decrease in FFB yield in 2004 was due to substantial decreases in the number of bunches per hectare

(BNO), though the single bunch weight continued to increase. SOA, MOP and EFB significantly ($p<0.001$) increased the FFB yield in 2004, and this was reflected in the significant increase in the bunch numbers. Single bunch weights also responded to SOA, MOP and EFB application. There were no responses to TSP application.

Two-way interaction between SOA/MOP, SOA/EFB, MOP/EFB and TSP/EFB all had significant effects on the FFB yield (Table 2 and 4), whereas in 2003 significant interactions were only registered between SOA/EFB and MOP/EFB. The two-way interactions (Table 4) indicated that EFB increased FFB yields when applied with SOA, MOP and TSP. These interactions demonstrate the classical type of responses expected; *viz*, SOA/MOP show a synergistic response, and SOA/EFB, MOP/EFB, and TSP/EFB showed that EFB could substituted for some of the N, K, and P requirements.

Three-way interaction between SOA, MOP and EFB also had significant ($p=0.034$) effects on the yield (Table 2 and 5). Similar to the two-way interactions, EFB significantly increased FFB yields with SOA and MOP. In the presence of EFB, production level at the lowest of level of SOA and MOP was reasonably high. The most optimum level of production at this stage would be 28.6 t FFB yield/ha/yr produced when applying 2 kg of SOA (SOA level 1) with 2.5 kg MOP (MOP level 1) in the presence of EFB. Again these interactions demonstrated the replacement value of EFB.

In the presence of EFB, SOA1 (2.0 kg/palm) and SOA2 (4.0 kg/palm) gave the higher yield regardless of MOP applications. Additional SOA had little or no effect.

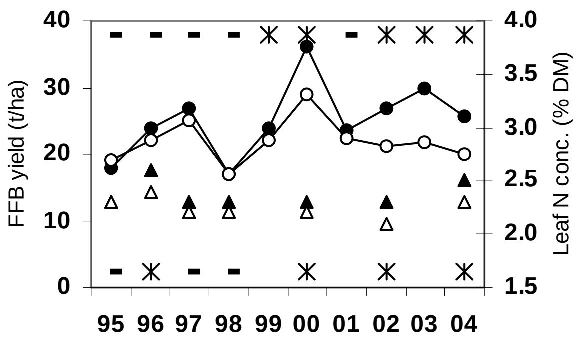
Fertilisers and EFB also influenced tissue nutrient concentrations (Table 6). In leaflets SOA increased N; MOP increase K, TSP increased P, and EFB increased, K and P (Table 7). For the first time rachis was also analysed for all the same nutrients. In general rachis levels were much more responsive to fertilisers and EFB than was the leaflet tissue. SOA almost double the rachis N, MOP increased rachis K by 50%, as did TSP with P. EFB increased both N and K

CONCLUSION

SOA, MOP and EFB continued to have significant effects on the yield in 2003 while TSP had no significant effect. Without EFB, higher levels of SOA are required to maximize FFB yield. However, when EFB is applied, lower rates of SOA and MOP are required to optimize FFB yield.

Rachis nutrient levels are far more responsive than leaf levels.

502b, SOA



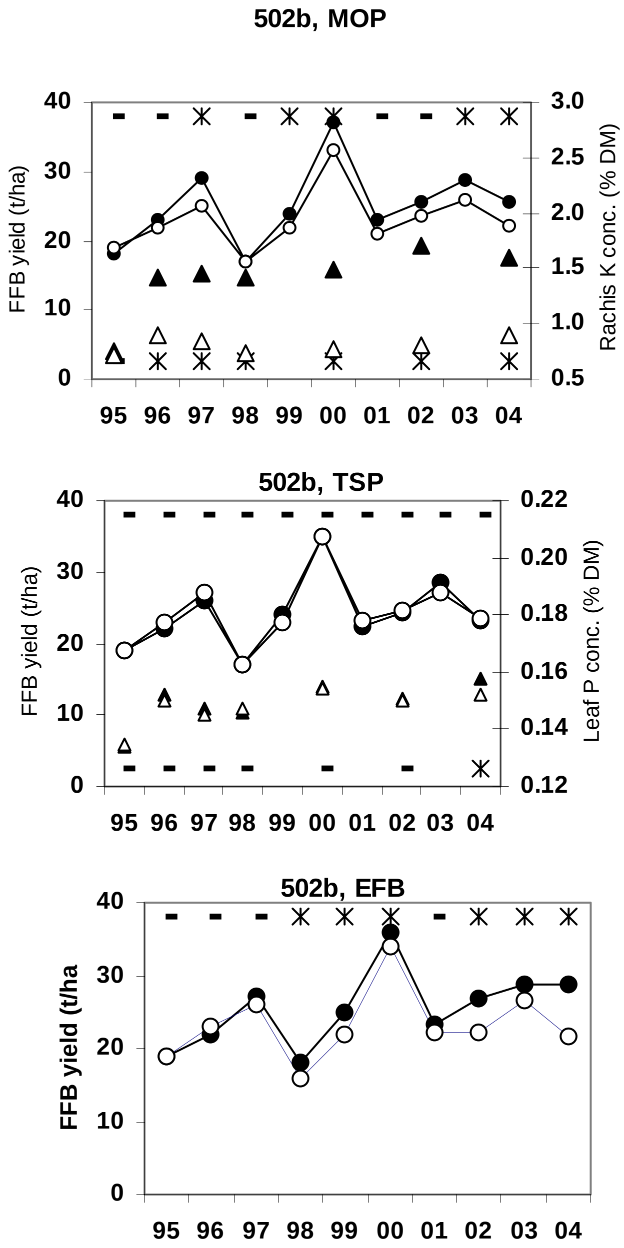


Figure 1. Main effects of SOA, MOP and TSP over the course of Trial 502b. Lines are FFB yields and triangles are tissue concentrations. Full symbols represent the maximum level of application, and empty symbols zero application. Symbols along the top of the graph indicate significance of the main effect 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.

Table 2. Effects (p values) of treatments on FFB yield and its components in 2003 and 2004. p values less than 0.1 are indicated in bold.

	2003			2004		
Source	Yield	BNO	SBW	Yield	BNO	SBW
SOA	**<0.001**	**0.005**	**<0.001**	**<0.001**	**0.007**	**<0.001**
MOP	**0.094**	0.698	**0.011**	**<0.001**	**0.038**	**0.001**
TSP	0.160	0.221	0.624	0.481	0.697	0.391
EFB	**0.024**	0.420	**<0.001**	**<0.001**	**0.005**	**<0.001**
SOA.MOP	0.662	0.864	0.132	**0.045**	0.444	0.516
SOA.TSP	0.595	0.380	0.261	0.183	**0.099**	**0.037**
MOP.TSP	0.928	0.705	0.181	0.197	0.100	**0.041**
SOA.EFB	**0.019**	**0.020**	0.173	**0.005**	**0.045**	**0.073**
MOP.EFB	**0.038**	0.148	**0.099**	**0.008**	**0.282**	**0.005**
TSP.EFB	0.893	0.897	0.406	**0.016**	**0.058**	0.448
SOA.MOP.TSP	0.486	0.417	0.340	0.760	0.918	0.427
SOA.MOP.EFB	0.827	0.972	**0.059**	**0.034**	0.205	0.424
SOA.TSP.EFB	0.606	0.878	0.607	0.758	0.880	0.374
MOP.TSP.EFB	0.736	0.638	0.266	0.581	0.980	0.177
CV %	12.1	11.9	4.9	6.3	7.5	5.0

Table 3. Main effects of treatments on FFB yield and its components. Significant effects (p<0.1) are shown in bold.

	2003			2004		
	Yield (t/ha)	BNO (/ha)	SBW (kg)	Yield (t/ha)	BNO (/ha)	SBW (kg)
SOA0	**21.8**	**986**	**22.3**	**20.1**	**879**	**22.9**
SOA1	**29.1**	**1163**	**25.3**	**22.7**	**886**	**25.8**
SOA2	**29.9**	**1170**	**25.9**	**24.9**	**933**	**27.2**
SOA3	**30.0**	**1205**	**25.1**	**25.7**	**983**	**26.5**
MOP0	**25.9**	1101	**23.7**	**22.1**	**918**	**23.9**
MOP1	**27.3**	1125	**24.3**	**22.7**	**883**	**26.1**
MOP2	**29.1**	1154	**25.3**	**23.1**	**911**	**25.7**
MOP3	**28.7**	1145	**25.4**	**25.5**	**969**	**26.5**
TSP0	27.1	1109	24.6	23.5	924	25.7
TSP1	28.4	1153	24.7	23.2	917	25.4
EFB0	**26.6**	1117	**23.9**	**21.6**	**888**	**24.4**
EFB1	**28.9**	1145	**25.4**	**25.1**	**952**	**26.7**
SE	*3.4*	*135*	*1.2*	*1.5*	*69*	*1.3*
Mean	*27.7*	*1131*	*24.6*	*23.3*	*920*	*25.5*

Table 4. Effect of two-way interactions on FFB yield (t/ha) in 2004.

SOA.MOP, p=0.045, lsd = 2.4

	SOA0	SOA1	SOA2	SOA3
MOP0	**20.7**	**20.0**	**24.0**	**23.6**
MOP1	**19.7**	**22.6**	**23.5**	**25.1**
MOP2	**19.6**	**23.9**	**24.4**	**24.7**
MOP3	**20.5**	**24.3**	**27.7**	**29.4**

MOP.TSP, p=0.197, lsd = 1.7

	TSP0	TSP1
MOP0	22.8	21.4
MOP1	22.3	23.2
MOP2	23.6	22.7
MOP3	25.3	25.6

SOA.TSP, p=0.183, lsd=1.7

	SOA0	SOA1	SOA2	SOA3
TSP0	19.6	23.3	25.3	25.7
TSP1	20.6	22.0	24.5	25.7

EFB.TSP, p=0.016, lsd=1.2

	TSP0	TSP1
EFB0	**21.2**	**22.1**
EFB1	**25.7**	**24.4**

SOA.EFB, p=0.005, lsd=1.7

	SOA0	SOA1	SOA2	SOA3
EFB0	**17.0**	**20.7**	**24.0**	**24.9**
EFB1	**23.3**	**24.7**	**25.8**	**26.5**

MOP.EFB, p=0.008,lsd=1.7

	EFB0	EFB1
MOP0	**18.9**	**25.2**
MOP1	**21.2**	**24.3**
MOP2	**22.2**	**24.1**
MOP3	**24.3**	**26.6**

Table 5. Effect of the three-way interaction between SOA, MOP and EFB on FFB yield (t/ha) in 2004. P=0.034, s.e.d = 1.5 and l.s.d.=3.3 CV = 6.3%.

	EFB0				EFB1			
	SOA0	SOA1	SOA2	SOA3	SOA0	SOA1	SOA2	SOA3
MOP0	19.2	21.7	25.2	21.7	24.5	25.3	26.6	27.2
MOP1	20.0	25.1	25.8	25.5	27.2	28.6	28.7	27.5
MOP2	21.9	26.1	26.9	26.4	23.5	26.9	28.2	25.4
MOP3	22.4	26.4	28.3	27.6	24.3	26.5	27.9	28.8

Table 6. Significance (p values) for effects of the fertilizer treatments on Frond 17 leaflet and rachis nutrient concentrations in 2004, expressed as a proportion of dry matter. p values < 0.1 are highlighted in bold.

	N	K	P	Mg	Ca	B	Cl	S
				Frond 17 leaflets				
SOA	**<0.001**	0.526	0.785	0.139	**0.090**	0.614	0.413	**0.007**
MOP	0.649	**<0.001**	0.957	**<0.001**	0.288	0.149	0.781	0.965
TSP	0.286	0.515	**0.010**	0.911	0.486	0.805	**0.045**	0.567
EFB	**<0.001**	**<0.001**	**0.072**	**<0.001**	**0.001**	0.261	**0.010**	**0.025**
CV %	3.0	5.6	4.2	9.1	5.7	13.6	6.0	4.2
				• *Frond 17 rachis*				
SOA	**<0.001**	**0.007**	**<0.001**	0.694	0.317	0.330	**0.077**	**0.007**
MOP	0.742	**<0.001**	**0.086**	**<0.001**	0.285	0.717	**<0.001**	0.965
TSP	0.261	0.858	**<0.001**	**0.046**	0.931	0.894	**0.046**	0.567
EFB	**0.002**	**<0.001**	0.136	0.154	**0.015**	0.216	0.154	**0.025**
CV %	26.3	8.9	22.4	11.2	17.7	12.3	11.2	4.2

Table 7. Main effects of treatments on frond 17 leaflet and rachis nutrient concentrations in 2004. All nutrients are in units of % dry matter except B which is expressed in mg/kg. P values less than 0.1 are shown in bold.

Treatments	N	K	P	Mg	Ca	B	Cl	S
				Frond 17 leaflets				
SOA0	**2.3**	0.63	0.154	0.38	**0.84**	10.6	0.53	**0.19**
SOA1	**2.4**	0.62	0.156	0.36	**0.82**	10.1	0.54	**0.20**
SOA2	**2.4**	0.63	0.155	0.35	**0.81**	10.7	0.53	**0.20**
SOA3	**2.5**	0.62	0.155	0.35	**0.79**	10.7	0.54	**0.21**
s.e.d	*0.03*	*0.01*	*0.002*	*0.01*	*0.02*	*0.51*	*0.01*	*0.003*
MOP0	2.4	**0.55**	0.154	**0.41**	0.84	11.3	0.54	0.20
MOP1	2.4	**0.63**	0.156	**0.35**	0.82	10.4	0.53	0.20
MOP2	2.4	**0.65**	0.155	**0.34**	0.81	10.1	0.54	0.20
MOP3	2.4	**0.66**	0.155	**0.33**	0.80	10.3	0.54	0.20
s.e.d	*0.03*	*0.01*	*0.002*	*0.01*	*0.02*	*0.51*	*0.01*	*0.003*
TSP0	2.4	0.62	**0.152**	0.36	0.81	10.6	**0.53**	0.20
TSP1	2.4	0.63	**0.158**	0.36	0.82	10.5	**0.55**	0.20
s.e.d	*0.02*	*0.008*	*0.001*	*0.008*	*0.01*	*0.36*	*0.008*	*0.002*
EFB0	2.3	**0.58**	**0.153**	**0.39**	**0.84**	10.7	**0.55**	**0.19**
EFB1	2.4	**0.67**	**0.157**	**0.33**	**0.79**	10.3	**0.53**	**0.20**
s.e.d	*0.02*	*0.008*	*0.001*	*0.008*	*0.01*	*0.36*	*0.008*	*0.002*
				Frond 17 rachis				
SOA0	**5.8**	**1.5**	**0.190**	0.16	0.37	5.8	**0.20**	**0.059**
SOA1	**5.9**	**1.3**	**0.136**	0.15	0.39	5.7	**0.93**	**0.061**
SOA2	**8.7**	**1.4**	**0.115**	0.14	0.42	6.1	**0.94**	**0.063**
SOA3	**11.4**	**1.3**	**0.091**	0.15	0.41	6.1	**0.88**	**0.066**
s.e.d	*0.74*	*0.04*	*0.01*	*0.02*	*0.03*	*0.26*	*0.03*	*0.002*
MOP0	8.1	**0.9**	**0.118**	**0.23**	0.43	5.9	**0.71**	0.063
MOP1	8.1	**1.4**	**0.127**	**0.14**	0.39	5.8	**0.94**	0.062
MOP2	7.4	**1.6**	**0.141**	**0.12**	0.38	6.0	**1.03**	0.062
MOP3	8.2	**1.6**	**0.146**	**0.12**	0.39	6.1	**1.10**	0.063
s.e.d	*0.74*	*0.04*	*0.01*	*0.02*	*0.03*	*0.26*	*0.03*	*0.002*
TSP0	7.6	1.4	**0.110**	**0.14**	0.40	6.0	**0.97**	0.063
TSP1	8.3	1.4	**0.156**	**0.16**	0.40	6.0	**0.91**	0.062
s.e.d	*0.52*	*0.03*	*0.007*	*0.01*	*0.02*	*0.18*	*0.04*	*0.001*
EFB0	**6.8**	**1.2**	0.127	0.19	**0.42**	6.1	0.92	**0.061**
EFB1	**9.1**	**1.5**	0.139	0.12	**0.37**	5.8	0.96	**0.063**
s.e.d	*0.52*	*0.03*	*0.007*	*0.01*	*0.02*	*0.18*	*0.04*	*0.001*

TRIAL 504 NITROGEN AND POTASSIUM TRIAL, SAGARAI ESTATE

PURPOSE

To test the response to N and K and an allowance made for one additional treatment in Sagarai Estate.

DESCRIPTION

Site: Sagarai Estate, Fields 0610, 0611 and 0612.

Soil: Tomanau family, which is of recent alluvial origin, with deep clay loam soils and reasonable drainage status. This is a predominant soil family on the Sagarai Estate.

Palms: Special Dami DxP crosses of 16 progenies that were randomised within each plot. The palms were planted in January 1991 at 127 palms/ha.

DESIGN

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.

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	-	-	-	-

RESULTS

The effects of the fertiliser treatments on the FFB yield and tissue nutrient contents over the last 10 years are shown in Figure 1. There was a drop in FFB yield in 2004 compared to 2002 and 2003 (Figure 1), which was possibly caused by the decreasing number of bunches within that same year (Table 3).

The fertiliser effects on the FFB yield, number of bunches per hectare (BNO) and single bunch weights (SBW) were more pronounced in 2004 compared to the previous years (Table 2). Significant responses were seen in the FFB yield, BNO and SBW as a direct effect of the treatments. The yields were increased considerably by applying SOA and MOP, however the yield increases for MOP were restricted up to as far as level 2 of the MOP rates, increasing the rates further was not of any benefit.

The combination between the treatments (SOA and MOP) did not produce any significant effects on the yield and the other components (Table 4), however, SOA increased yield substantially where MOP was not applied. Where MOP was applied, SOA increased yields up to level 2; beyond level 2 the yields were reduced. Yields increased as the MOP levels were increased as high as level 2, and dropped thereafter. The combination effects also showed that palms receiving zero rates of both SOA and MOP produced the lowest FFB yield (19.5 t/ha). FFB yield was maximized at 4 kg SOA/palm/yr (level 2) and 5 kg MOP/palm/yr (level 2), however this combination was not significant.

The 2001-2004 results also showed positive response to both SOA and MOP applications up to level 2, and dropped as levels were further increased. The interactions were also not significant (Table 3).

CONCLUSION

The fertiliser response was more pronounced in 2004 than the other past years. Both SOA and MOP showed significant effects on the FFB yield, BNO and the SBW.

Their interactions were however still not significant. The highest FFB yield was reached at 4.0 kg/palm of SOA and 5.0 kg/palm of MOP.

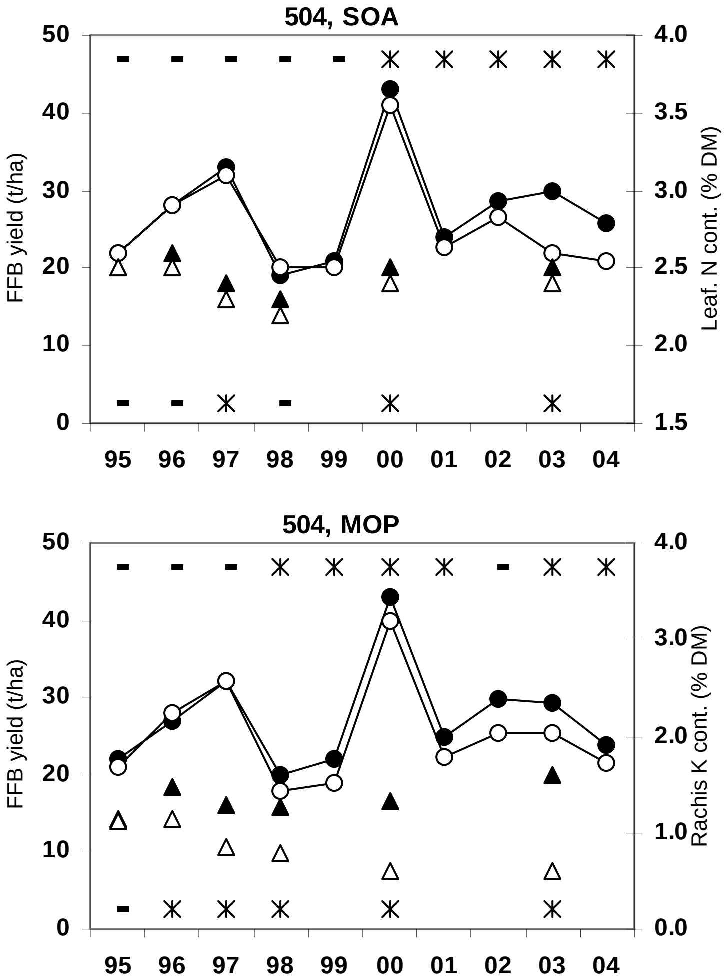


Figure 1. Main effects of SOA and MOP over the course of Trial 504. Lines are FFB yields and triangles are tissue concentrations. Full symbols represent the maximum level of application, and empty symbols zero application. Symbols along the top of the graph indicate significance of the main effect on yield, and along the bottom indicate significance of the main effect on tissue concentration. Stars indicate significance and dashes non-significance.

Table 2. Effects (p values) of treatments on FFB yield and its components in 2001-2004 and 2004 (Trial 504). p values less than 0.1 are indicated in bold.

	2001 - 2004			2004		
Source	Yield	BNO	SBW	Yield	BNO	SBW
SOA	**<0.001**	**<0.001**	**0.058**	**<0.001**	**<0.001**	**0.018**
MOP	**<0.001**	**<0.001**	**0.010**	**0.002**	**0.041**	**0.012**
SOA.MOP	0.742	0.378	0.805	0.729	0.709	0.829
CV %	7.8	5.9	5.0	5.1	9.0	7.2

Table 3. Main effects of treatments on FFB yield and its components in 2003 and 2004. Significant effects (p<0.1) are shown in bold.

	2001-2004			2004		
	Yield (t/ha)	BNO (/ha)	SBW (kg)	Yield (t/ha)	BNO (/ha)	SBW (kg)
SOA0	**23.9**	**1172**	20.7	**20.8**	**1009**	**20.7**
SOA1	**26.2**	**1229**	21.7	**23.6**	**1057**	**22.4**
SOA2	**27.8**	**1310**	21.6	**25.2**	**1153**	**22.1**
SOA3	**27.2**	**1298**	21.3	**25.9**	**1194**	**21.9**
sed	*0.7*	*26*	*0.4*	*1.1*	*35*	***0.6***
MOP0	**23.8**	**1181**	20.5	**21.6**	**1054**	**20.7**
MOP1	**26.5**	**1259**	21.5	**23.9**	**1100**	**22.4**
MOP2	**27.9**	**1299**	21.7	**26.1**	**1159**	**21.9**
MOP3	**27.0**	**1271**	21.5	**23.9**	**1100**	**22.5**
sed	*0.7*	*26*	*0.4*	*1.1*	*35*	*0.6*
Mean	*26.3*	*1253*	*21.3*	*23.8*	*1103*	*21.8*

Table 4. Effect on SOA.MOP interaction on FFB yield (t/ha) in 2004. Treatment combinations not significant.

SOA.MOP, p=0.16				
	MOP0	MOP1	MOP2	MOP3
SOA0	18.4	19.5	22.9	22.4
SOA1	20.0	25.0	25.6	23.7
SOA2	22.8	25.9	28.1	24.0
SOA3	25.2	25.1	27.8	25.4

TRIAL 511 FERTILISER TRIAL ON INTERFLUVE TERRACE SOILS, WAIGANI ESTATE.

PURPOSE

To investigate the response of oil palm to applications of ammonium sulphate, triple super-phosphate, muriate of potash and empty fruit bunches on interfluve terrace soils ("buckshot soils").

DESCRIPTIONS

Site: Waigani estate, Field 8501 and 8502

Soil: Hagita family, texture contrast soils with very slowly permeable clay to heavy clay subsoil and very gravelly loam top soil. Gravel maybe cemented into massive blocks of laterite. Soil dominantly poorly drained. Although these soils are dominantly poorly drained, somewhat imperfectly drained variants with olive grey subsoil have been included into this family. Mostly on gently sloping terraces, but also found on spur crest of hilly terrain.

Palms: Dami commercial DxP crosses. Planted in 1988 at 127 palms/ha.

DESIGN

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 1 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		

RESULTS

The treatment effects on the FFB yield and the nutrient concentrations on the leaf and the rachis over the course of the trial are shown in Figure 1. The FFB yield responded positively to SOA, TSP and EFB applications in 2004. There continued to be a lack of response on the yield with MOP. Similar response was seen in the 2001-2004 yield data (Table 2). SOA, TSP and EFB all increased FFB yields, BNO and SBW (Table 3). The yield was greatest at the highest rates of SOA, MOP, TSP and EFB (6 kg SOA/palm, 7.5 kg MOP/palm, 2 kg TSP/palm and 300 kg EFB/palm). The significant increase in yield was due to increase in the both number of bunches per hectare and the bunch weights (SBW).

There were no significant interactions (two-way and three-way) on FFB yield (Table 2). The effect of the two-way combinations of fertilisers on FFB yield is shown in Table 4, which shows that adding increasing amounts of SOA, MOP, TSP and EFB, increased FFB yield. There were, however, some significant interactions on SBW (Table 2).

The treatment effects on the nutrient concentration in the leaflets and rachis are shown in Tables 5 – 8. The fertilizer effects on the both leaf and rachis nutrient contents were more pronounced than the yield and its components. SOA increased leaf N and S, whilst MOP increased both leaf and rachis K. TSP applications also raised P levels in the leaflets. EFB had a very positive effect on most of the leaflet nutrient levels.

CONCLUSION

Yield continues to respond positively to SOA, TSP and EFB. MOP still had effect on the FFB yield and its components (BNO and SBW). There were also no yield response to the interactions. More pronounced response was observed in the leaf and rachis nutrients than the yield and its components. We expect this trend to change next crop, in which MOP might show some responses.

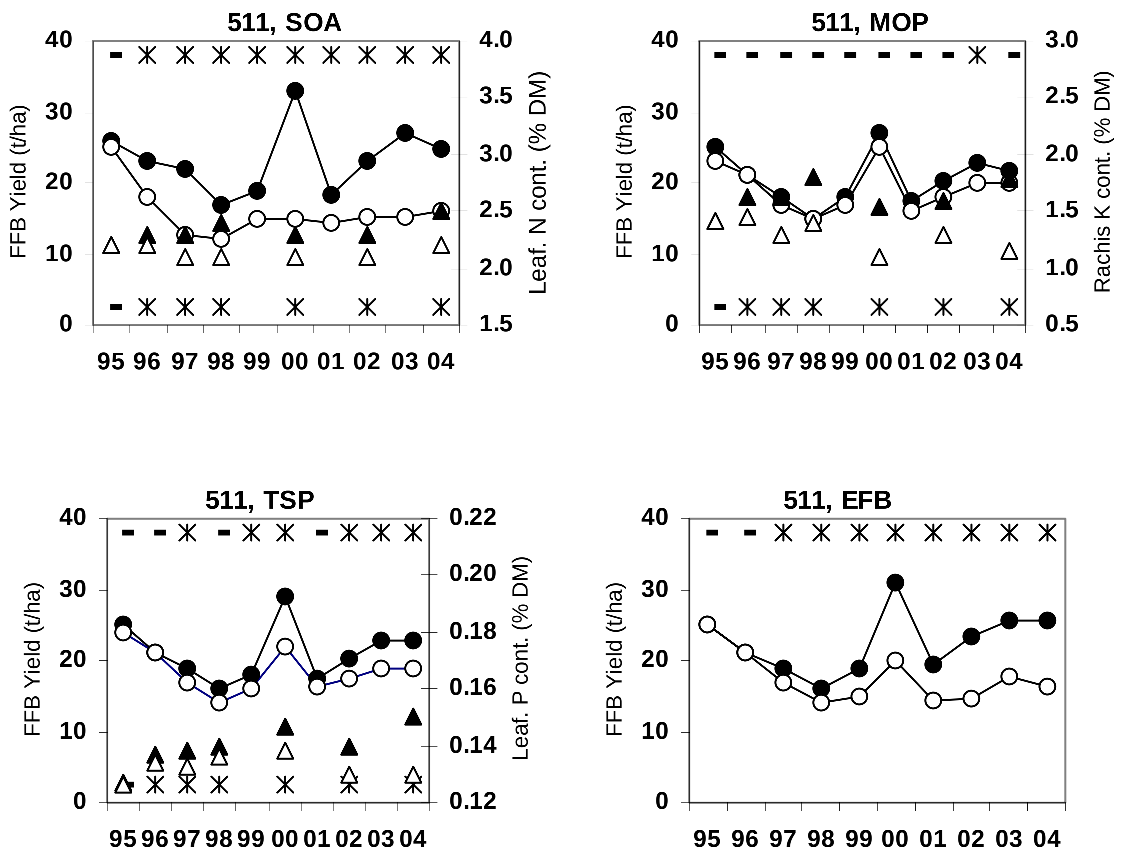


Figure 1. Main effects of SOA, MOP and TSP over the course of Trial 511. Lines are FFB yields and triangles are tissue concentrations. Full symbols represent the maximum level of application, and empty symbols zero application. Symbols along the top of the graph indicate significance of the main effect 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 2. Effects (p values) of treatments on FFB yield and its components in 2001-2004 and 2004. p values less than 0.1 are indicated in bold.

	2001-2004			2004		
Source	Yield	BNO	SBW	Yield	BNO	SBW
SOA	**<0.001**	**0.002**	**<0.001**	**<0.001**	**0.003**	**<0.001**
MOP	0.160	0.323	0.599	0.561	0.474	0.841
TSP	**<0.001**	**0.012**	**<0.001**	**<0.001**	**0.007**	**<0.001**
EFB	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**
SOA.MOP	0.632	0.878	0.152	0.642	0.796	0.541
SOA.TSP	0.462	0.544	**0.002**	0.693	0.915	**0.051**
MOP.TSP	0.282	0.537	**0.151**	0.320	0.408	0.711
SOA.EFB	**0.016**	0.168	**<0.001**	0.154	0.482	**<0.001**
MOP.EFB	0.861	0.649	**0.049**	0.446	0.865	**0.013**
TSP.EFB	**0.028**	0.237	**0.003**	0.208	0.590	**0.010**
SOA.MOP.TSP	0.834	0.817	**0.142**	0.893	0.963	0.295
SOA.MOP.EFB	0.318	0.628	0.056	0.536	0.834	0.338
SOA.TSP.EFB	0.444	0.769	**0.125**	0.312	0.442	0.755
MOP.TSP.EFB	0.622	0.800	0.790	0.664	0.546	0.983
CV %	11.6	12.8	4.8	14.9	14.5	5.9

Table 3. Main effects of treatments on FFB yield and its components in 2001-2004 and 2004. Significant effects (p<0.1) are shown in bold.

	2001-2004			2004		
	Yield (t/ha)	BNO (/ha)	SBW (kg)	Yield (t/ha)	BNO (/ha)	SBW (kg)
SOA0	**15.3**	**819**	**18.4**	**16.1**	**824**	**19.1**
SOA1	**18.3**	**860**	**21.2**	**18.8**	**845**	**21.0**
SOA2	**21.9**	**966**	**22.8**	**24.2**	**1006**	**23.9**
SOA3	**23.5**	**1030**	**22.9**	**24.7**	**1034**	**23.9**
sed	*0.8*	*42*	*0.4*	*1.1*	*48*	*0.5*
MOP0	**18.7**	871	21.3	20.2	884	22.3
MOP1	**19.6**	920	21.1	20.9	936	22.0
MOP2	**20.0**	937	21.1	20.9	929	22.1
MOP3	**20.7**	947	21.6	21.8	961	22.4
sed	*0.8*	*42*	*0.4*	*1.1*	*48*	*0.5*
TSP0	**18.0**	**873**	**20.4**	**24.2**	**869**	**21.4**
TSP1	**21.5**	**965**	**22.2**	**24.7**	**986**	**23.0**
sed	*0.6*	*29*	*0.3*	*0.8*	*34*	*0.3*
EFB0	**15.9**	**820**	**19.1**	**16.2**	**799**	**19.8**
EFB1	**23.6**	**1018**	**23.5**	**25.7**	**1056**	**24.0**
sed	*0.6*	*29*	*0.3*	*0.8*	*34*	*0.3*
GM	19.8	919	21.3	20.9	927	22.2

Table 4. Effect of two-way interactions on FFB yield (t/ha) in 2004. All two-way interactions not significant (p>0.1).

SOA.MOP, p=0.642

	SOA0	SOA1	SOA2	SOA3
MOP0	14.7	18.6	23.3	22.8
MOP1	16.3	18.8	24.5	29.0
MOP2	15.7	20.7	24.4	28.7
MOP3	14.3	23.3	25.6	27.4

MOP.TSP, p=0.320

	TSP0	TSP1
MOP0	17.7	22.0
MOP1	19.5	24.8
MOP2	18.9	25.9
MOP3	19.4	26.0

SOA.TSP, p=0.693

	SOA0	SOA1	SOA2	SOA3
TSP0	14.4	18.6	20.8	21.7
TSP1	16.1	22.1	28.1	32.3

*EFB.TSP, **p=0.208***

	TSP0	TSP1
EFB0	13.9	21.7
EFB1	23.8	27.6

*SOA.EFB**, p=0.154***

	SOA0	SOA1	SOA2	SOA3
EFB0	10.5	15.6	19.8	25.3
EFB1	20.0	25.2	29.1	28.6

MOP.EFB, p=0.446

	EFB0	EFB1
MOP0	15.9	23.9
MOP1	17.4	26.9
MOP2	18.9	25.8
MOP3	19.0	26.3

Table 5. Effects (p values) of treatments on frond 17 **leaflet** nutrient concentration in 2004. p values less than 0.1 are indicated in bold.

Source	Ash	N	P	K	Mg	Ca	Cl	S	B
SOA	0.198	**<0.001**	0.346	0.676	**0.014**	**0.023**	0.442	**0.016**	0.180
MOP	0.373	0.227	0.734	**0.066**	**0.012**	0.414	**<0.001**	0.914	0.631
TSP	**0.022**	0.136	**<0.001**	0.300	0.210	0.541	**0.002**	0.534	0.590
EFB	**0.089**	**<0.001**	**<0.001**	**0.005**	**0.001**	0.271	**0.037**	**0.015**	0.147
SOA.MOP	0.864	0.215	0.321	0.372	0.937	0.520	0.714	0.614	0.883
SOA.TSP	0.732	0.698	0.478	0.400	0.344	0.587	0.160	0.685	0.606
MOP.TSP	0.692	0.266	0.663	0.695	0.951	0.123	0.309	0.666	0.292
SOA.EFB	0.568	**0.082**	0.656	0.927	0.541	0.250	0.301	0.405	0.278
MOP.EFB	0.489	0.713	0.875	**0.004**	**0.023**	0.106	0.690	0.979	0.166
TSP.EFB	0.135	0.790	**0.079**	0.708	0.733	0.191	**0.030**	0.411	0.387
SOA.MOP.TSP	0.916	0.574	0.552	0.184	0.825	0.362	0.794	0.230	0.446
SOA.MOP.EFB	0.899	0.390	0.655	0.834	0.542	0.486	0.684	0.604	0.912
SOA.TSP.EFB	0.167	0.189	0.397	0.725	0.923	0.797	0.577	0.508	0.384
MOP.TSP.EFB	0.188	0.635	0.137	0.985	0.489	**0.027**	0.190	0.776	0.896
CV %	*8.2*	*4.8*	*4.3*	*11.2*	*12.6*	*6.4*	*6.8*	*6.0*	*11.6*

Table 6. Effects (p values) of treatments on frond 17 **rachis** nutrient concentration in 2004. p values less than 0.1 are indicated in bold.

Source	Ash	N	P	K	Mg	Ca	Cl	S	B
SOA	0.384	**<0.001**	**0.001**	0.128	0.521	**0.019**	**0.087**	**0.035**	**0.033**
MOP	**0.010**	0.206	0.249	**<0.001**	**0.002**	0.809	**<0.001**	0.781	0.221
TSP	0.816	**0.096**	**<0.001**	**0.022**	0.193	0.144	0.105	0.297	0.261
EFB	**0.082**	**<0.001**	0.935	**<0.001**	**<0.001**	0.159	0.418	**0.098**	0.875
SOA.MOP	0.887	0.826	0.771	0.421	0.818	0.501	0.230	0.657	0.270
SOA.TSP	0.846	0.303	**0.007**	0.220	0.474	**0.056**	0.770	0.875	0.160
MOP.TSP	0.873	0.188	0.817	0.903	0.790	0.675	0.634	0.936	0.323
SOA.EFB	0.979	0.268	0.180	0.476	0.947	0.148	0.686	0.328	0.278
MOP.EFB	**0.025**	0.323	0.721	**<0.001**	**0.003**	**0.045**	**0.020**	0.936	0.521
TSP.EFB	0.559	0.223	**0.034**	0.748	0.726	**0.076**	0.851	0.479	0.730
SOA.MOP.TSP	0.938	**0.050**	0.547	0.877	0.854	0.416	0.566	0.862	0.148
SOA.MOP.EFB	0.409	0.161	0.679	**0.079**	0.818	0.539	**0.040**	0.458	0.626
SOA.TSP.EFB	0.744	0.997	0.685	0.256	0.549	0.665	0.276	0.963	0.418
MOP.TSP.EFB	0.936	0.268	0.908	0.878	0.965	0.514	0.575	0.781	0.282
CV %	*17.4*	*6.7*	*38.2*	*13.6*	*26.4*	*11.4*	*15.1*	*11.2*	*7.4*

Table 7. Main effects of treatments on frond 17 **leaflet** nutrient concentrations in 2004, in units of % dry matter except for B which is expressed as mg/kg DM. Significant effects (p<0.1) are shown in bold.

Treatment	Ash	N	P	K	Mg	Ca	Cl	S	B
SOA0	**12.1**	**2.22**	0.143	0.73	**0.38**	**0.81**	0.57	**0.184**	9.7
SOA1	**12.8**	**2.30**	0.143	0.70	**0.34**	**0.83**	0.57	**0.190**	9.5
SOA2	**12.1**	**2.43**	0.144	0.72	**0.32**	**0.78**	0.57	**0.194**	9.0
SOA3	**12.7**	**2.50**	0.147	0.73	**0.32**	**0.77**	0.59	**0.200**	8.9
s.e.d	*0.36*	*0.04*	*0.002*	*0.03*	*0.02*	*0.02*	*0.01*	*0.004*	*0.38*
MOP0	**12.7**	2.35	0.145	**0.67**	**0.38**	0.79	**0.51**	0.194	9.5
MOP1	**12.6**	2.32	0.143	**0.71**	**0.33**	0.81	**0.59**	0.191	6.3
MOP2	**12.1**	2.41	0.144	**0.74**	**0.33**	0.79	**0.58**	0.191	9.3
MOP3	**12.4**	2.36	0.145	**0.76**	**0.32**	0.80	**0.61**	0.193	9.0
s.e.d	*0.36*	*0.04*	*0.002*	***0.03***	*0.02*	*0.02*	*0.01*	*0.004*	*0.38*
TSP0	**12.8**	2.33	**0.139**	0.73	0.34	0.79	**0.55**	0.193	9.4
TSP1	**12.1**	2.39	**0.149**	0.71	0.34	0.80	**0.60**	0.191	9.2
s.e.d	*0.26*	*0.02*	*0.001*	*0.02*	***0.01***	*0.01*	*0.01*	*0.003*	*0.27*
EFB0	**12.7**	**2.27**	**0.139**	**0.68**	**0.36**	0.80	**0.56**	**0.188**	9.5
EFB1	**12.2**	**2.46**	**0.149**	**0.76**	**0.31**	0.79	**0.59**	**0.197**	9.1
s.e.d	*0.26*	***0.03***	*0.001*	*0.02*	*0.01*	*0.01*	*0.01*	*0.003*	*0.27*
Grand Mean	*12.4*	*2.4*	*0.144*	*0.72*	*0.34*	*0.79*	*0.57*	*0.192*	*9.3*

Table 8. Main effects of treatments on frond 17 **rachis** nutrient concentrations in 2004, in units of % dry matter except for B which is expressed as mg/kg DM. Significant effects (p<0.1) are shown in bold.

Treatments	Ash	N	P	K	Mg	Ca	Cl	S	B
SOA0	4.9	**0.24**	**0.13**	1.67	0.12	**0.30**	**1.08**	**0.056**	**5.0**
SOA1	5.1	**0.26**	**0.07**	1.62	0.13	**0.33**	**1.21**	**0.059**	**5.1**
SOA2	4.6	**0.28**	**0.07**	1.47	0.11	**0.34**	**1.04**	**0.063**	**5.1**
SOA3	4.7	**0.31**	**0.06**	1.56	0.11	**0.34**	**1.11**	**0.064**	**5.5**
s.e.d	*0.30*	*0.006*	*0.01*	*0.08*	*0.01*	*0.013*	*0.06*	*0.02*	*0.14*
MOP0	**4.0**	0.27	0.07	**1.16**	**0.16**	0.33	**0.80**	0.061	5.3
MOP1	**5.1**	0.26	0.09	**1.65**	**0.11**	0.33	**1.19**	0.059	5.1
MOP2	**5.0**	0.27	0.08	**1.73**	**0.10**	0.32	**1.21**	0.062	5.1
MOP3	**5.2**	0.27	0.09	**1.79**	**0.10**	0.33	**1.23**	0.061	5.3
s.e.d	*0.30*	*0.006*	*0.01*	*0.08*	*0.01*	*0.013*	*0.06*	*0.02*	*0.14*
TSP0	4.8	**0.26**	**0.05**	**1.65**	0.11	0.32	1.15	0.059	5.1
TSP1	4.8	**0.27**	**0.11**	**1.51**	0.12	0.34	1.07	0.062	5.2
s.e.d	*0.21*	*0.005*	*0.01*	*0.05*	*0.01*	*0.009*	*0.04*	*0.01*	*0.09*
EFB0	**4.6**	**0.26**	0.08	**1.43**	**0.14**	0.34	1.09	**0.059**	5.2
EFB1	**5.0**	**0.28**	0.08	**1.74**	**0.09**	0.32	1.13	**0.062**	5.2
s.e.d	*0.21*	*0.005*	*0.01*	*0.05*	*0.01*	*0.009*	*0.04*	*0.01*	*0.09*
Grand Mean	*4.8*	*0.27*	*0.08*	*1.58*	*0.12*	*0.33*	*1.11*	*0.06*	*5.2*

TRIAL 512. MONITORING OF POME BLOCKS

PURPOSE

To determine the effect of palm oil mill effluent (POME) on oil palm growth and soil properties.

DESIGN

Three areas, similar in soil type and topography, but with different histories of POME application (Table 1) have been monitored since 1995.

Table 1. 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

RESULTS

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 2).

Table 2. 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

The effects of POME application on the FFB yield and other parameters are shown in Figures 1, 2, 3 and 4. The FFB yield in the Non POME block declined by 5 t/ha in 2004, following a continuous downward trend. By contrast, the POME treated showed a continuous, although slight, upward trend with time. In 2004, the POME block was yielding about 50% more than the Non-POME block

N levels in the leaflets were the same for both the POME and the control block while leaflet P was higher in the POME block. P levels in the POME block appear to be increases faster than those in the Non-POME block. The rachis K contents were substantially higher in the POME block than the control block. Soil sampling was not done in 2004 to verify whether the effects of POME on the soil fertility in these two blocks.

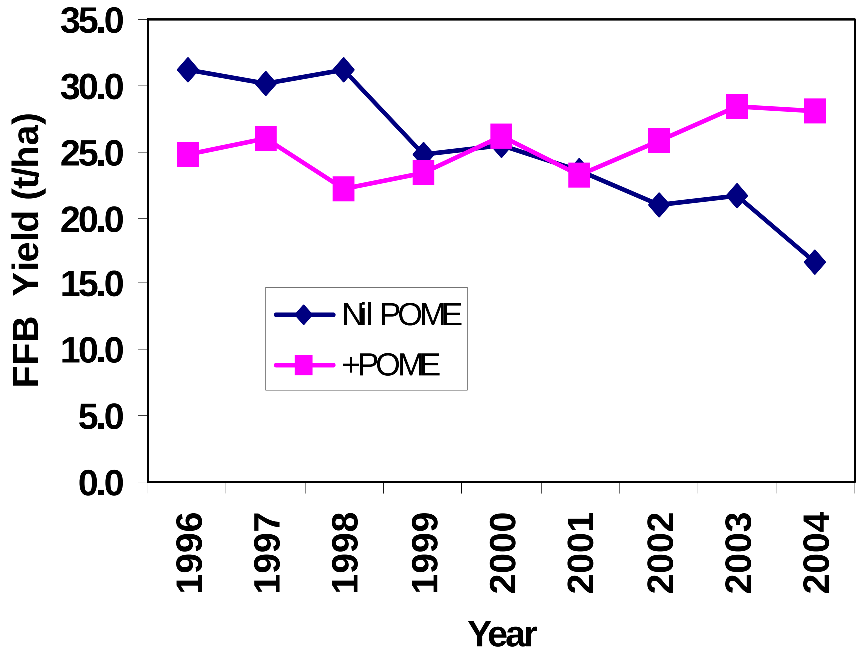


Figure 1. Effect of POME on FFB yield.

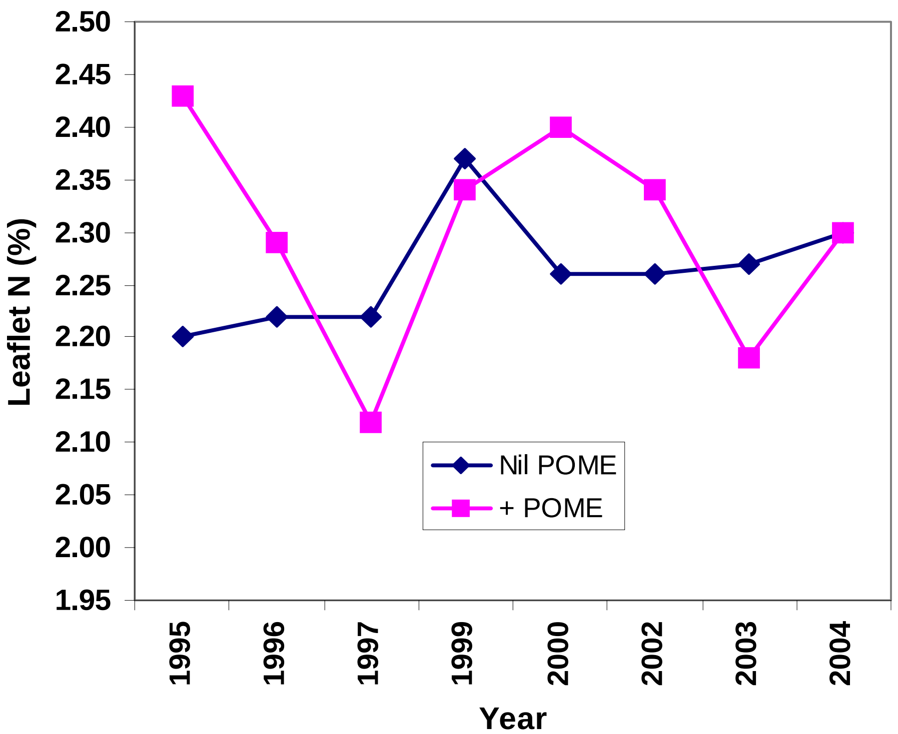


Figure 2: Effect of POME on Leaf N Contents

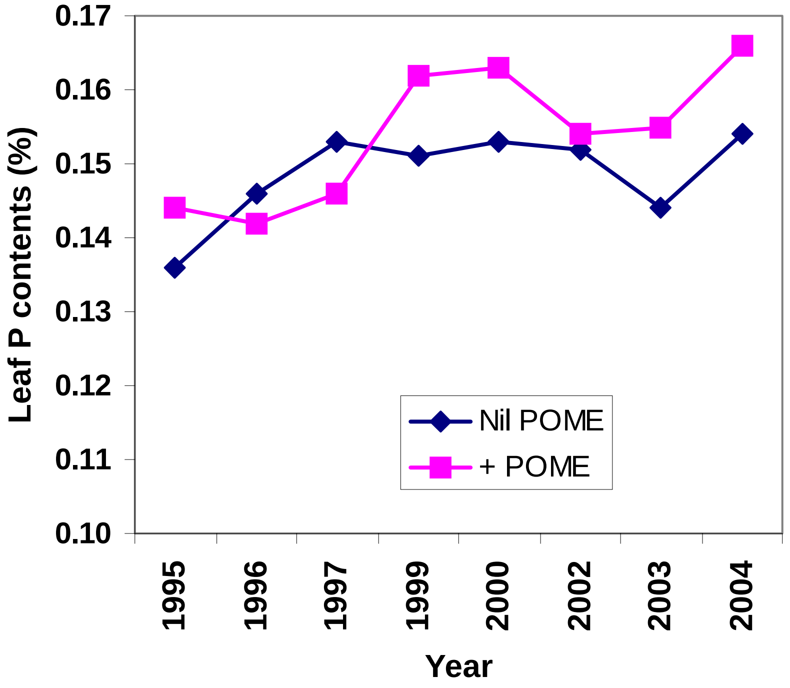


Figure 3: Effect of POME on Leaf P Contents

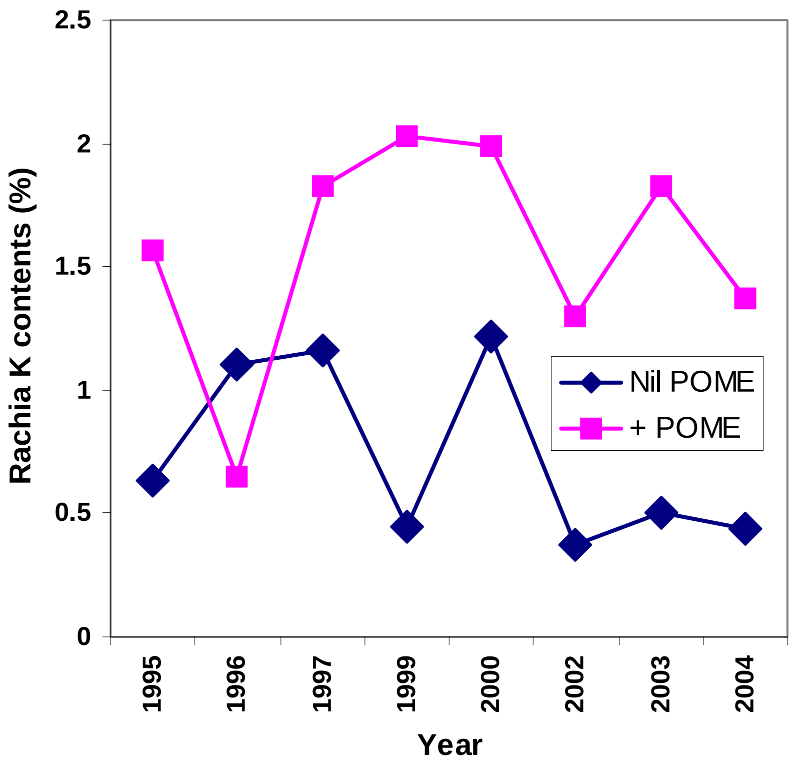


Figure 4: Effect of POME on Leaf P Contents

FERTILISER RESPONSE TRIAL IN NEW IRELAND PROVINCE (Poliamba Estates)

(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 AND PALMS

Trial 251 site: Fields 2B, 2C, 2D and 3A, Maramakas Plantation.

Trial 252 site: Block 4, Luburua Plantation.

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.

Topography: Low rises and depressions

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.

In this write-up FFB yield and its components has been calculated on a ‘per producing palm’ basis (the same as for all other trials). The collection yield data stopped for much of 2003; recommencing in September. Thus, the data used is based on only part of the year. The data was scaled-up to 'per annum' using a factor of 3.0 (see 2003 Report).

RESULTS

Yield in Trial 251

In this trial, 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 13 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 not 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.

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 had the largest effect on yield and its components (Tables 5 & 6)). TSP also had a significant effect in 2003, there was no effect in 2004. The only significant interaction this year was between SOA and MOP on SBW. Yields were highest where SOA and MOP were both applied at 5 kg/palm, or where one (either) was applied at 2.5 kg/palm and the other at 5 kg/palm (Table).

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.

Once again, although the interaction between SOA and MOP was not significant in 2004, adding SOA at the highest rates of MOP has consistently, over a number of years, resulted in increases in FFB yield.

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 end of 2005 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 end of 2005, the entire trial will be felled for a detailed assessment 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 2004 to previous years. MOP had a major 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.

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.

Table 2. Effects (p values) of treatments and the soil depth covariate on FFB yield and its components in 2002-2004 and 2004 (Trial 251). p values <0.1 are indicated in bold.

	2002-2004			2004		
Source	Yield	BNo	SBW.	Yield	BNo	SBW.
SOA	0.456	0.473	0.351	0.178	0.161	0.449
MOP	**0.001**	**0.009**	**<.001**	**0.003**	**0.005**	**0.004**
TSP	0.248	0.617	0.198	0.388	0.564	0.468
KIE	0.702	0.634	0.653	0.825	0.866	0.701
SOA.MOP	0.362	0.755	0.141	0.521	0.491	0.397
SOA.TSP	0.630	0.447	0.798	0.221	0.105	0.733
MOP.TSP	0.746	0.867	0.844	0.710	0.562	0.751
SOA.KIE	0.705	0.961	0.344	0.494	0.876	0.384
MOP.KIE	0.567	0.593	0.555	0.516	0.203	0.650
TSP.KIE	0.476	0.433	0.700	0.581	0.723	0.673
SOA.MOP.TSP	0.425	0.447	0.419	0.305	0.204	0.385
SOA.MOP.KIE	0.512	0.706	0.767	0.471	0.417	0.885
SOA.TSP.KIE	0.701	0.658	0.885	0.936	0.883	0.682
MOP.TSP.KIE	0.661	0.912	0.261	0.914	0.999	0.519
CV %	16.6	12.7	8.6	16.0	11.9	8.7

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.

	2002-2004			2004		
	Yield (t/ha/yr)	No Bun (/ha)	SBW. (kg)	Yield (t/ha/yr)	No Bun (/ha)	SBW. (kg)
SOA0	23.7	1255	18.7	22.7	1199	18.7
SOA1	22.7	1179	18.7	22.4	1159	18.9
SOA2	24.8	1269	19.5	25.7	1300	19.6
s.e.d.	*1.50*	*71*	*0.57*	*1.55*	*59*	*0.68*
MOP0	**15.1**	**977**	**15.0**	**15.9**	**970**	**16.0**
MOP1	**27.9**	**1369**	**20.7**	**27.4**	**1337**	**20.6**
MOP2	**28.2**	**1357**	**21.0**	**27.6**	**1351**	**20.6**
s.e.d.	*1.50*	*71*	*0.57*	*1.55*	*59*	*0.68*
TSP0	24.6	1250	19.3	24.2	1235	19.3
TSP1	22.9	1218	18.6	23.0	1204	18.8
s.e.d.	*1.23*	*58*	*0.47*	*1.26*	*48*	*0.55*
KIE0	23.5	1219	19.1	23.5	1224	19.0
KIE1	24.0	1249	18.8	23.7	1215	19.2
s.e.d.	*1.23*	*58*	*0.47*	*1.26*	*48*	*0.55*

Table 4. Effect of the interaction between SOA and MOP on FFB yield (t/ha) in 2002-2004 and 2004 (Trial 251). Yields >26 t/ha are highlighted in bold.

	2002-2004, p=0.362				2004, p=0.281		
	MOP0	MOP1	MOP2		MOP0	MOP1	MOP2
SOA0	17.0	**26.6**	**27.5**	SOA0	16.8	24.7	**26.6**
SOA1	12.0	**29.4**	**26.7**	SOA1	12.7	**28.0**	**26.5**
SOA2	16.2	**27.8**	**30.5**	SOA2	18.0	**29.4**	**29.6**

Table 5. Effects (p values) of treatments and the soil depth covariate on FFB yield and its components in 2002-2004 and 2004 (Trial 252). p values <0.1 are indicated in bold.

	2002-2004			2004		
Source	Yield	Bun./ha	kg/bun.	Yield	Bun./ha	kg/bun.
SOA	0.163	0.174	0.397	0.407	0.417	0.194
MOP	**0.002**	**0.003**	**0.003**	**0.012**	**0.027**	**0.001**
TSP	0.522	0.921	0.158	0.519	0.801	0.106
KIE	0.978	0.595	0.454	0.525	0.294	0.096
SOA.MOP	0.281	0.217	0.300	0.551	0.834	**0.081**
SOA.TSP	0.355	0.373	0.796	0.560	0.399	0.689
MOP.TSP	0.359	0.396	0.327	0.310	0.259	0.397
SOA.KIE	0.980	0.807	0.619	0.962	0.874	0.586
MOP.KIE	0.392	0.471	0.243	0.687	0.525	0.160
TSP.KIE	0.931	0.533	0.455	0.875	0.892	0.148
SOA.MOP.TSP	0.610	0.586	0.547	0.621	0.794	0.272
SOA.MOP.KIE	0.775	0.496	0.310	0.816	0.848	0.218
SOA.TSP.KIE	0.764	0.648	0.774	0.727	0.669	0.497
MOP.TSP.KIE	0.368	0.492	0.611	0.208	0.241	0.092
CV %	15.5	14.2	7.4	24.8	21.0	6.5

Table 6. Main effects of treatments on FFB yield (t/ha) and its components (Trial 252). Effects with p<0.1 are shown in bold.

	2002-2004			2004		
	Yield	Bun./ha	kg/bun.	Yield	Bun./ha	kg/bun.
SOA0	21.6	1193	18.0	19.5	1072	17.8
SOA1	25.4	1348	18.9	22.6	1197	18.9
SOA2	24.2	1272	18.6	20.5	1077	18.5
s.e.d.	*1.61*	*66*	*0.65*	*2.11*	*96*	*0.49*
MOP0	**14.9**	**959**	**15.4**	**14.0**	**870**	**15.4**
MOP1	**27.9**	**1421**	**20.0**	**25.1**	**1281**	**19.8**
MOP2	**28.3**	**1432**	**20.0**	**23.5**	**1194**	**19.9**
s.e.d.	*1.61*	*66*	*0.65*	*2.11*	*96*	*0.49*
TSP0	23.3	1268	18.0	20.3	1105	18.0
TSP1	24.2	1274	18.9	21.5	1126	18.8
s.e.d.	*1.31*	*54*	*0.53*	*1.72*	*78*	*0.40*
KIE0	23.7	1287	18.3	21.5	1162	18.0
KIE1	23.7	1255	18.7	20.3	1068	18.8
s.e.d.	*1.31*	*54*	*0.53*	*1.72*	*78*	*0.40*

Table 7. Effect of the interaction between SOA and MOP on FFB yield (t/ha) in 2002-2004 and 2004 (Trial 252). Yields >26 t/ha are highlighted in bold.

2002-2004, p=0.309,				2004, p=0.551			
	MOP0	MOP1	MOP2		MOP0	MOP1	MOP2
SOA0	13.1	**26.1**	25.4	SOA0	12.3	23.7	22.5
SOA1	19.2	**27.1**	**29.8**	SOA1	18.6	24.9	24.4
SOA2	12.3	**30.4**	**29.8**	SOA2	11.1	**26.7**	23.7

Table 8. Effect of the interaction between SOA and MOP on SBW (kg) in 2002-2004 and 2004 (Trial 252).

2002-2004, p=0.300				2004, p=0.081, $lsd_{0.05}$=2.3			
	MOP0	MOP1	MOP2		MOP0	MOP1	MOP2
SOA0	14.2	19.8	19.9	SOA0	14.4	19.3	19.8
SOA1	17.2	19.8	19.8	SOA1	17.5	19.4	19.8
SOA2	14.7	20.5	20.4	SOA2	14.3	20.9	20.2

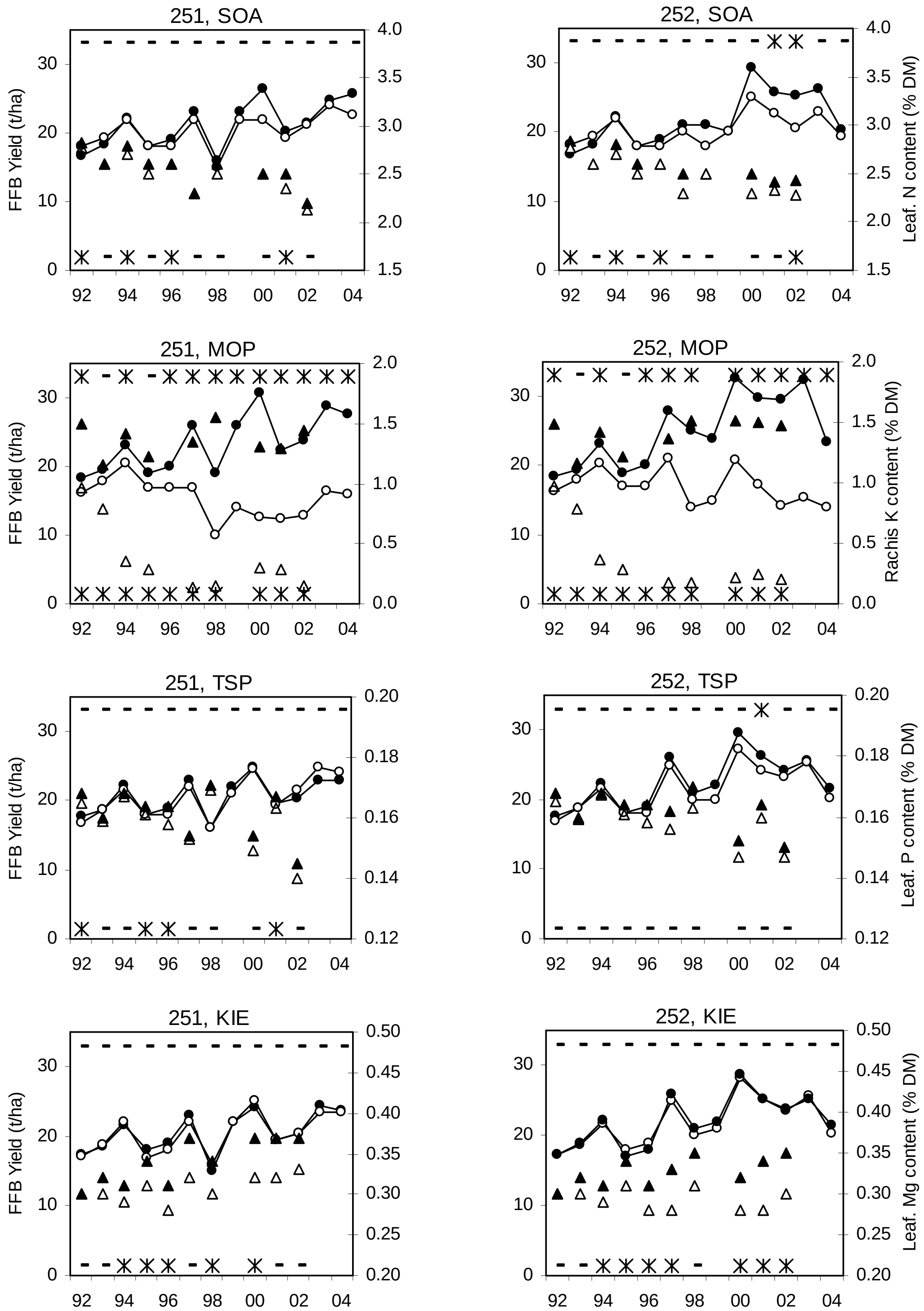


Figure 1. Main effects of SOA, MOP, TSP and KIE for Trials 251 and 252. Lines with circles, FFB yields; triangles, tissue concentrations; full symbols, maximum level of application; open symbols, zero application. Symbols along the top indicate significance of the main effect on yield, and along the 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 a 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 = $Na_2B_4O_2 . 10 H_2O$) is 11%B
Ca borate (Colemanite = $Ca_2B_6O_{11} . 5 H_2O$) 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 will commence in 2005. Colemanite is proving difficult to purchase in commercial quantities and thus will be replaced by Ulexite (CaNa borate; 10% B).

FERTILISER RESPONSE TRIAL IN MOROBE PROVINCE
(Ramu Sugar Ltd)

(Lastus Kuniata & Mike Webb)

FERTILISER RESPONSE TRIALS AT RAMU SUGAR

(MJ Webb, L Kuniata)

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 3. 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. 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.

Table 3. 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)*

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. 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.

RESULTS

Palms were assessed for general health and the number of fronds in July and December 2004.

In July, only AN had an effect on palm health score (Table 2); with increasing rates of AN increasing the health score. Scores were generally low as palms were still establishing themselves following transplanting in November the previous year.

Table 2. Main Effect of fertilisers on health score (0= Unhealthy; 10 = Healthy) of palms in July 2004.

Fertiliser	Level			*p*
	0	1	2	
AN	**3.3**	**3.8**	**3.9**	**< 0.001**
MOP	3.7	3.6	3.7	0.62
TSP	3.6	3.7		0.63
S	3.6	3.7		0.26

However, 5 months later in December 2004, the general health of the palms had increased and AN, TSP and S had effected health score (Table 3); each increasing health with increasing rates of application.

Table 3. Main Effect of fertilisers on health score (0= Unhealthy; 10 = Healthy) of palms in December 2004.

Fertiliser	Level			*p*
	0	1	2	
AN	**6.6**	**8.8**	**8.8**	**< 0.001**
MOP	7.9	7.9	8.2	0.48
TSP	**7.8**	**8.2**		**0.08**
S	**7.8**	**8.3**		**0.04**

There was also a significant interaction between AN and S ; and TSP and S. The interaction between AN and S shows that both N and S are not supplied by the soil in sufficient quantities and that there is a synergistic increase in health score i when both nutrients are added (Table 4). This is a typical response to the addition of two limiting nutrients.

Table 4. Interaction table of health score (0= Unhealthy; 10 = Healthy) of palms in December 2004 for AN and S.

		S	
		0	1
AN	0	6.8	6.4
	1	8.3	9.2
	2	8.3	9.2

By contrast, the interaction between TSP and S does not show a synergistic response (Table 5). Instead, it is clear that health score is increase when either TSP or S are added but is not increased further when both are added. This is a typical response when both fertilisers are supplying the same nutrient. In this case, as TSP supplies both P and S, it is likely that the response to TSP is to the S in TSP and not, as would generally be expected, to the P in TSP. The also implies that the TSP added in the planting hole (even in the TSP 0 treatment) is providing adequate P for the first 12 months and addition TSP is not necessary (along as S is supplied). Whether or not the TSP in the planting hole is required has not been tested in this trial.

Table 5. Interaction table of health score (0= Unhealthy; 10 = Healthy) of palms in December 2004 for AN and S.

		S	
		0	1
TSP	0	7.4	8.3
	1	8.3	8.2

The effects of fertiliser treatments on the number of fronds was less pronounced than the effect on health score with only AN producing a significant response (Tables 6 & 7).

Table 6. Main Effect of fertilisers on number of fronds on palms in July 2004.

Fertiliser	Level			*p*
	0	1	2	
AN	**12.2**	**12.8**	**13**	**0.08**
MOP	12.6	12.6	12.7	0.88
TSP	12.6	12.6		0.99
S	12.6	12.6		0.98

Table 7: Main Effect of fertilisers on number of fronds on palms in December 2004.

Fertiliser	Level			*p*
	0	1	2	
AN	**12.7**	**14.3**	**14.1**	**0.004**
MOP	13.4	14	13.8	0.41
TSP	13.9	13.6		0.39
S	13.8	13.6		0.65

CONCLUSION

To achieve good early growth of oil palm on the deep loams in Gusap, both nitrogen and sulphur fertilisers are required. There is probably enough P supplied at the time of planting to last at least the first year. Potassium is apparently being supplied by the soil in adequate amounts for the first year of growth.

TRIAL RM 2-04 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
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 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 3. 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 sulfur 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.

Table 4. 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)*

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. 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.

OTHER FACTORS

SPACING AND THINNING TRIALS

TRIAL 139 PALM SPACING TRIAL AT KUMBANGO PLANTATION

PURPOSE

Investigate the possibilities of field planting arrangements and how to make use of increased inter-row spacing to facilitate mechanised in-field collection. 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.

BACKGROUND

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.

SITE and PALMS

Kumbango Plantation, Division 1, Field B
Topography: Flat
Land use prior to this crop: Oil palm
Palms: Dami commercial DxP crosses planted in 1999 at 128 palms/ha (spacing treatments given below)

DESIGN

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 1. Bunch numbers and weights are being measured on every palm in every third row.

Table 1. 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

Plots were laid out in 2001 and yield recording commenced in 2003. Spacing treatments had a significant effect on fresh fruit bunch (FFB) yield but not number of number of bunches per ha (BNO) or single bunch weights (SBW) in 2004 (Tables 2 and 3). The treatment with the widest avenue had the greatest yield, whereas the two narrowest avenue widths showed no difference in yield. The spacing treatments had a significant effect on the FFB yield in 2003 as well (Figure 1).

Table 2. Effects (p values) of treatments on FFB yield and its components in 2004 (Trial 139). p values <0.05 are indicated in bold.

	2004		
Source	FFB yield	BNO	SBW
Treatment	**0.042**	0.234	0.514
CV%	*2.0*	*4.0*	*3.0*

Table 3. Main effects of treatments on FFB yield and its components (Trial 139). Effects with p<0.05 are shown in bold.

	2004		
	FFB yield (t ha^{-1})	BNO	SBW
Treatment 1	**25.0 a***	2358	10.6
Treatment 2	**24.8 a***	2268	10.9
Treatment 3	**26.3 b***	2416	10.9
s.e.d.	*0.4*	*72*	*0.3*
$Lsd_{0.05}$	*1.2*		
GM	*25.3*	2347	*10.8*

** same letter denotes non significant difference between treatment means and different letters denote significant difference between treatment means.*

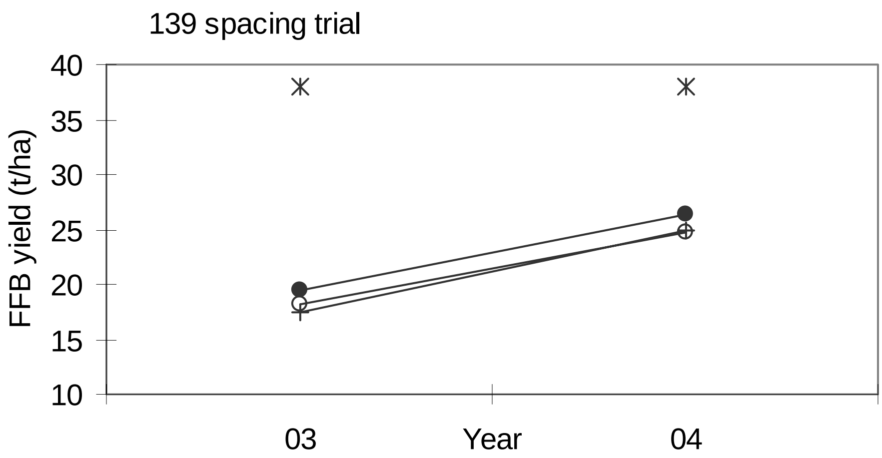


Figure 1. Main effects of spacing treatments over the course of Trial 139. Lines are FFB yields. Full symbols represent treatment 3, empty symbols represent treatment 2, and + represents treatment 1. Symbols along the top of the graph indicate significance of the main effect on yield. Stars indicate significance ($p<0.05$) and dashes non-significance.

CONCLUSION

Although the palms in this trial are only 6 years old, the spacing treatments are already having an effect on yield such that there would be no disadvantage to wider avenues to facilitate mechanised infield collection (MIC) – 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

PURPOSE

To determine the effects of spacing configuration on palms, cover crops and soils.

DESCRIPTION

Site: Ambogo Estate

Soil: Ambogo family, which is of recent alluvially reworked volcanic origin, with silty loam topsoil and sandy loam subsoil, with seasonally high water tables. Penderetta family. Thin dark sandy loam topsoil over sandy loam subsoil derived from alluvially deposited volcanic ash. Mottling due to seasonally high water tables.

Palms: Dami commercial DxP crosses replanted at various densities in April/May 2001.

DESIGN

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. Treatments 1, 2 and 3 will remain 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. The trial was planted in 2001. In 2002, 7 cover crops were sown in small plots throughout replicate 2 of the spacing trial in order to assess their performance under the different light and traffic conditions of the different spacing treatments. The cover crops were Pueraria, Calapogonium, Mucuna, Vigna, Desmodium, Centrosema and Stylo *(Cover crop results presented in the 2002 SAC meeting).*

Table 1. 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

Fertiliser application is on a per palm basis during the immature phase. It is proposed that when the palms mature, all density/spacing treatments will receive the same amount of fertiliser on a per ha basis.

RESULTS

The treatment effects are shown in Tables 2 and 3. In 2004, most of the parameters (yield, BNO, SBW, BW/palm/yr) responded significantly ($p<0.05$) to the different densities tested, except for the BN/palm/yr (Table 2). The yield and its components for the trial block exhibited a general increase in 2004 as demonstrated by the grand mean.

The yield in general increased with the planting densities. The three highest densities yielded close to 30 t FFB/ha in the second year of production, which according to normal plantation production is quite high. Palms planted at 128 palms/ha, 135 palms/ha and 143 though produced much lower yields compared with the three highest densities, and the bunch weights and the number of bunches from the individual palms were higher than that of the three highest density palms. The highest FFB yield (29.2 t/ha/yr) was obtained from the highest planting density but statistically not different from FFB yields produced by the other two highest densities (192 and 203 palms/ha). Similarly, the FFB yield from 143 palms/ha (treatment 3) did not differ from the yields from the two lowest densities (treatments 1 and 2). The single bunch weights decreased, whereas the BNO per hectare increased with increasing densities. The increase in bunches was mainly due to the increased in the number of palm stands per hectare. However, as the level of competition for sunlight and soil nutrients increases with increasing density, the SBW dropped. The number of bunches produced per palm per year and the bunch weights per palm per year also followed a similar trend.

Vegetative parameters were not measured in 2004 to confirm and compare with the above responses.

CONCLUSION

The density effects on the yield and other components was more pronounced in 2004. The FFB yield (t/ha/yr) and number of bunches per hectare (BNO) increased with the planting densities. The single bunch weight (SBW) dropped as the planting density increased. Therefore the higher the planting density, the more number of bunches are produced per hectare resulting in substantially higher yields.

Table 2. Density effects (p values) on FFB yield and its components in 2004. p values less than 0.1 are indicated in bold.

	2003					2004				
Treatment	Yield	BNO	SBW	BW/palm/yr	BN/palm/yr	Yield	BNO	SBW	BW/palm/yr	BN/palm/yr
Density	**0.011**	**0.005**	0.276	0.631	0.593	**<0.001**	**0.074**	**<0.001**	**0.023**	0.226
CV %	*15.4*	*13.8*	*3.3*	*17.4*	*15.1*	*6.5*	*14*	*7.9*	*6.8*	*7.6*

Table 3. Density effects on FFB yield and its components in 2004

	2003						2004				
Treatment Code	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	**15.3**	**3021**	5.1	119	23.6	**21.4**	**3401**	**6.3**	**167.2**	26.6
2	135	**14.4**	**2900**	4.9	107	21.5	**21.4**	**3420**	**6.3**	**158.4**	25.3
3	143	**16.0**	**3054**	5.2	112	21.4	**22.0**	**3432**	**6.4**	**154.0**	24.0
4	192	**23.2**	**4611**	5.0	121	24.0	**28.5**	**4774**	**6.0**	**148.0**	24.8
5	203	**19.5**	**4001**	4.9	96	19.7	**28.2**	**4750**	**5.9**	**138.9**	23.4
6	215	**22.7**	**4461**	5.1	106	20.8	**29.2**	**4902**	**5.9**	**136.0**	22.8
sed		*2.3*	*415*	*0.14*	*15.7*	*2.7*	***1.4***	***219***	***0.2***	***8.7***	*1.3*
Grand Mean		*18.5*	*3675*	*5.0*	*110*	*21.8*	***25.1***	***4111***	***6.2***	***150***	*24.4*

TRIAL 513 SPACING AND THINNING TRIAL, PADI PADI

PURPOSE

To investigate the effect of increased inter-row spacing.

DESCRIPTION

Site: Padi padi Estate, Block 1051
Soil: Tomanou soil family. Deep black and very dark brown clay and silty clay topsoils grading into dark yellowish brown clay B horizons overlying dark yellowish brown and very dark brown silt clay subsoils
Topography: Flat
Landuse prior to this crop: Mostly savanna
Palms: To be planted

DESIGN

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. Within one of the replicates, plots with different cover crops were established. The trial was marked out and planted in 2003 with the joint effort between Milne Bay Estates and the PNG OPRA. 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 ha basis.

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

PROGRESS REPORT

Block was cleared in 2002 and the palms planted in July 2003. The cover crops shown in Table 2 were sown in May 2003 across all spacing treatments in replicate 2 in 2003. Commercial cover crop mix was sown in replicates 1 and 3. Unfortunately, most of the cover crops did not establish well and at the same time smothered by the wild/indigenous cover crops (especially pueraria spp.) and the kunai grass (cylindrica imperata). Weeding which was the only reliable means of controlling the weeds without affecting the cover crops was time consuming and was never used. The weeds were then controlled/smothered by the rolling technique whereby a tractor with roller mounted runs from end of the row to the other. This technique was not effective either and most of the covers either died or were mixed with the wild covers of same species. As a result, it was suggested in the 2003 SAC that the cover crop study within the trial be closed, as the covers were not properly established.

OPRA now maintains the Trial for its density study. The palms are about 1 year old and have not started producing. Yield recording will commence in 2006.

Table 2. Cover crops sown in Trial 513 in 2003.

No.	Treatment	Source
1	Calopogonium (*Calopogonium mucunoides*)	MBE
2	Pueraria (*Pueraria phaseoloides*)	MBE
3	Commercial mix (later to be replaced by Mucuna or Centrosema)	MBE
4	Aztec Atro	Australia
5	Creeping Desmodium (*Desmodium spp.*)	Australia
6	Cooper Glycine	Australia
7	Verano stylo	Australia

PREDICTIONS AND RECOMMENDATIONS

SOIL RESOURCE INFORMATION (Activity 724)

In this project we aim to collate all the soil maps for oil –palm growing areas of PNG, compile them into a GIS and use them to improve our management recommendations.

We have identified 107 soil reports and 120 soil maps in oil palm growing areas. Of these we have obtained copies of all the reports and 62 of the maps, 39 as scans. We are in the process of digitising the scanned maps and incorporating them into a GIS.

In addition, the location of smallholder's 'market place' are progressively being accumulated into a GIS database, along with leaf nutrient results. These are being used to fine-tune fertiliser recommendations for smallholders based on soil type.

This work has been give a new prominence in the Agronomy programme. A grant from AIGF will facilitate the 'rationalisation' of the various soil maps for WNBP in order to better predict fertiliser responses for smallholders in areas with similar soil types to trial locations. Smallholder leaf samples were again collected in 2004 and will be used as part of this analysis. This project will begin in 2005.

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.

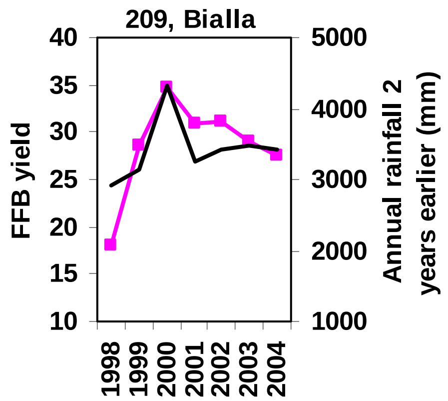
The 2002 annual report showed good correlation between yield and rainfall two years prior for PNGOPRA field trials.

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 from part of a more extensive analysis.

Figure 1 shows that new data continues to support the trend that yield follows rainfall two years prior to harvest in experimental trials



New Ireland

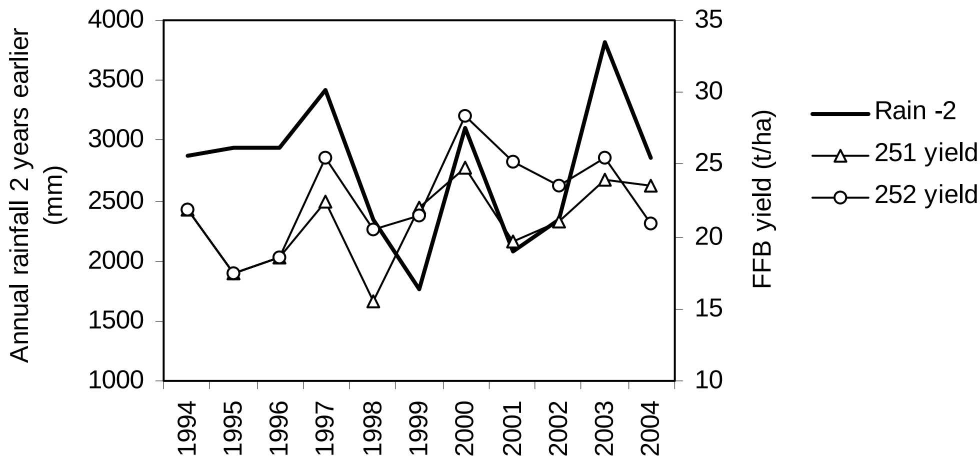


Figure 1. Updated rainfall and yield for Bialla and New Ireland.

Trials 332 and 514. 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 to 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

SITES and 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 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 have started investigating shorter-term methods of predicting yield. Only a limited amount of data is available, however it is showing that patterns of flower production and fruit harvest can be monitored in away that may allow for future predictions.

It is clear from figure 2, that with judicious observation of developing flowers (which then become bunches and are then harvested (pink lines)), it is possible to follow the 'life' of a bunch. For example, a flower which develops in late November may be harvested after 18 weeks, whereas a flower which develops mid January will not be harvested for some 20 weeks. If this pattern turns out to be predictive; then a prediction of yield some 4 months ahead may be possible.

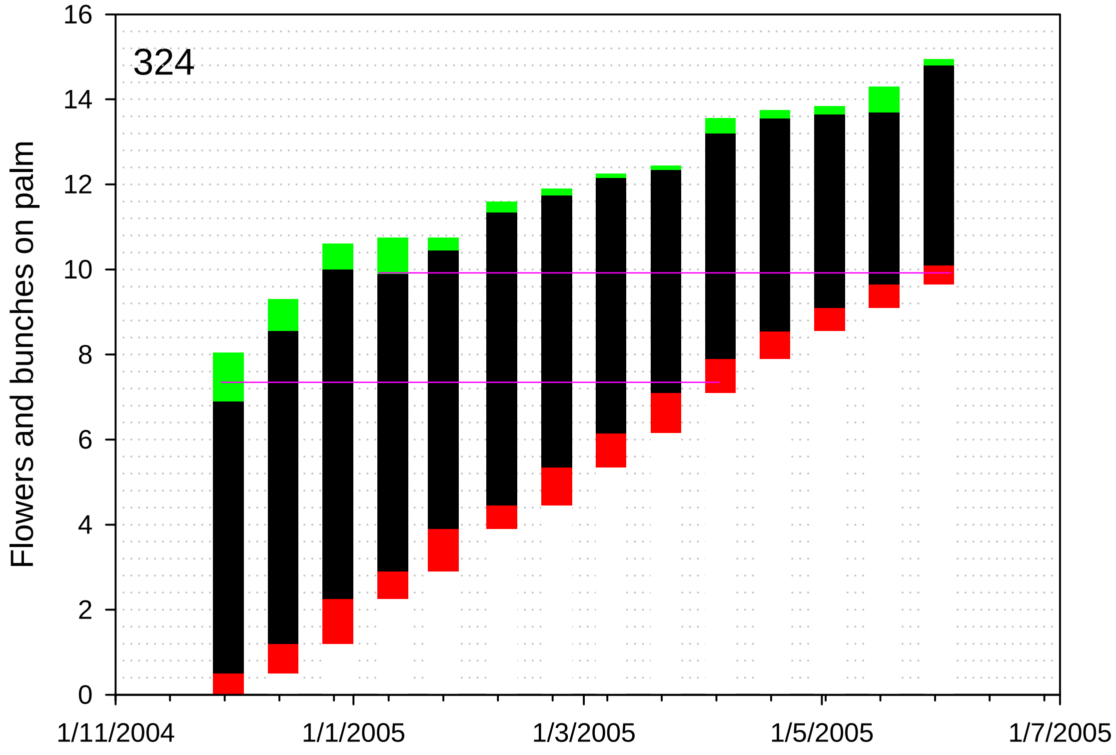


Figure 2. Development of flowers in relation to harvesting subsequent bunches.

SMALLHOLDER LEAF ANALYSIS

Smallholder leaf samples from Oro province were collected and analysed in 2004. Many of the blocks analysed in 2004 had also been analysed in 2001, thus allowing a direct comparison over time.

From 2001 to 2004, there were significant increases ($P < 0.05$, paired t-test) in tissue concentrations of leaf P and leaf S, but not of leaf N, leaf, K, leaf Mg, leaf Ca or rachis K. Indeed the there was a significant decreases in leaf K and leaf Mg from 2001 to 2004.

There was a considerable difference in the variation of tissue levels from 2001 to 2004 (Figure 1). The variation in values increased for leaf N and rachis K from 2001 to 2004, and decreased for leaf P, leaf Mg, leaf S, and leaf K over the same period.

Similarly, there was substantial variation in the relationship between tissue values in 2001 and 2004 (Figure 2). Leaf N and rachis K showed a reasonable correlation between years, but leaf P, leaf Mg, leaf S, and leaf K did not.

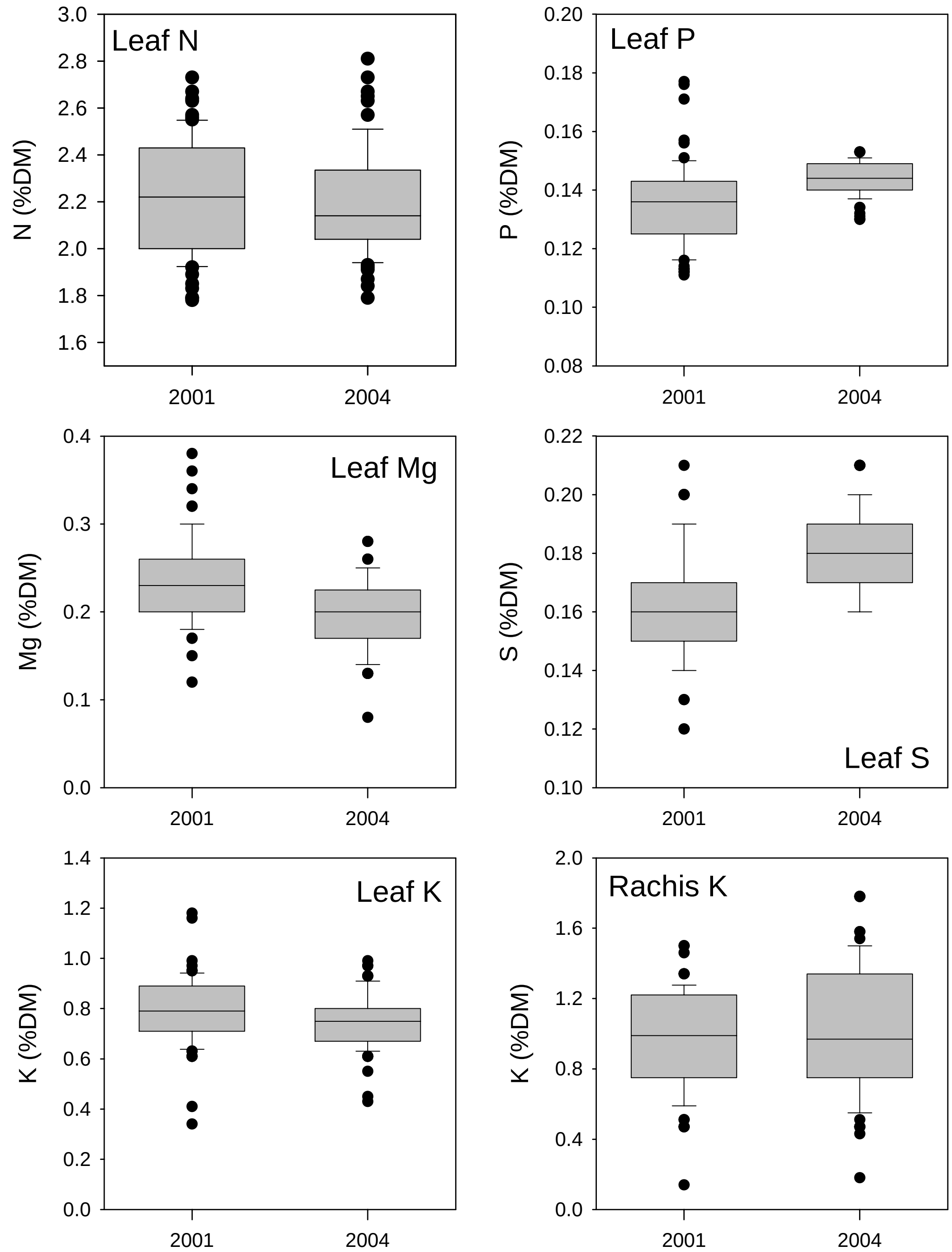


Figure 1. Distribution of tissue nutrient levels for blocks sampled and analysed o=in both 2001 and 2004. The horizontal line represents the median, the box the 25th and 75th percentiles, the whiskers, the 10th and 90th percentiles. Dots represent individual data points outside the 10th and 90th percentiles.

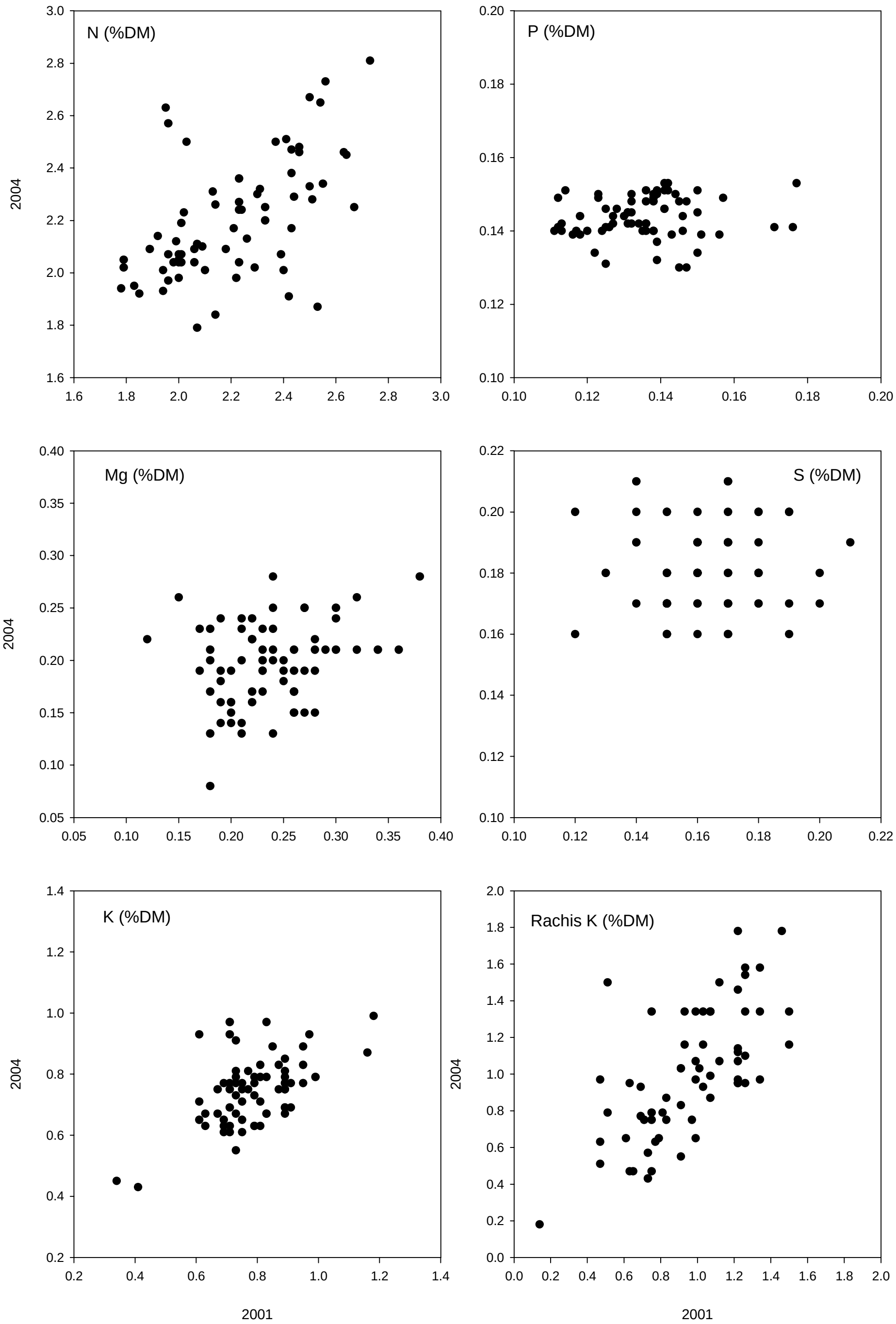


Figure 2. Relationship between analysis of the same block in two years. Each point represents the analysis of samples collected in 2001 and 2004 from the same block.

2 ENTOMOLOGY RESEARCH

(W.W. Page)

1. INSECT POLLINATION

Introduction

Weevils are essential for the efficient pollination of oil palm in PNG as hand pollination is no longer economically viable. The African pollinating weevil, *Elaeidobius kamerunicus* Jacq. was introduced into Papua New Guinea in 1981. This resulted in significant improvements to oil palm pollination, thereby improving fruitset levels and oil extraction ratios, and hence increasing yields.

Concerns have been expressed regarding the long-term viability of the weevil populations and their ability to efficiently pollinate the oil palms. To address this PNGOPRA have undertaken various studies into pollination. In the first phase of an EU Stabex-funded project it was shown that many weevils were infected by an internal parasitic nematode that may contribute to the reduction in effective pollination by reducing the weevils' reproductive capacity and ability to fly long distances between male and female inflorescences. The internal nematode was identified by Poinar *et al.* (2002) as *Elaeolenchus parthenonema*. In addition to the possible consequences of widespread nematode infection, there are also concerns that the weevil populations were derived from a very limited number of individuals that were introduced from West Africa in 1981. The narrow genetic base of the weevil population means that there is a risk of in-breeding suppression, as well as vulnerability to infection by pathogens and parasites.

Results from the first phase of the project highlighted the complexity of understanding the reasons for the reductions in pollination by the weevils in Papua New Guinea and, indeed, throughout the oil palm growing areas of South East Asia. It is very important to understand and rectify what has been causing the reduction in pollination and consequent yield loss. To address the above, further funding was sought through EU Stabex and a two year project began in July 2003. The project has the following objectives:

1. Understand the relationship between the pollinating weevil, the male and female inflorescences, the internal parasitic nematode and seasonal population fluctuations.
2. Understand the biology and ecology of the parasitic nematodes.
3. Improvements made to the genetic base of the existing pollinating weevils throughout PNG by the introduction of new material from Ghana. Production of a key to identify pollinating weevils.
4. An overall understanding of the reasons for the reduction in pollination levels in oil palm, leading to informed strategies for alleviating the problem.
5. Training throughout the project and leaflets in English and Pidgin produced.

During 2003, progress was made towards understanding the life cycle of the nematode and the levels of infestation in the field, distribution with regard to levels of rainfall and the effect on fruitset (PNGOPRA Annual Report 2003). This work continued during 2004. However, as the results from 2003 suggested that there were large variations in fruitset for individual bunches even though there were indications that ample numbers of weevils were available for pollination, it was decided to examine the relationship between the pollinating weevils and oil palm inflorescences in more detail.

Key to the Pollinating Weevils

Fig 1 *Elaeidobius kamerunicus* male

Fig 2 *Elaeidobius kamerunicus* male in profile

Fig 3 *Elaeidobius kamerunicus* male, colour variety

Fig 4 *Elaeidobius kamerunicus* dwarf male

Fig 5 *Elaeidobius kamerunicus* female

Fig 6 *Elaeidobius kamerunicus* female, colour variety

Fig. 1 Example of photos in the weevil key

As part of the EU Stabex Project, The Natural History Museum (UK) produced a key to the weevils associated with oil palms in Africa which is entitled “A key for the identification of the species of *Elaeidobius*”. This comprehensive key is illustrated with 26 colour photographs and is based on large samples from Ghana, Benin, and the Congo and smaller samples from Nigeria, Sierra Leone, Angola and Uganda. The key gives a clear guide to pollinating weevil identification and will be used when new weevil material is collected from West Africa for enhancing the diversity of the PNG weevil population. It is interesting to note that, “in spite of the wealth of secondary sexual characters present in *Elaeidobius*, the only universally reliable way to separate the sexes is by noting whether the antennae are inserted in the middle of the rostrum (females) or nearer to its apex (males)” (Thompson 2004). Thirty hard copies and an electronic copy of the key were provided.

Pollination/Fruitset Studies

Examination of previous monitoring of fruitset

In preparation for setting up a plot to monitor palms for the relationship between the pollinating weevils and oil palm inflorescences in more detail, data collected between mid-1987 and the end of 1989 by PNGOPRA (1988 and 1989 PNGOPRA Annual Reports) was re-examined to clarify which parameters to monitor in the current work. In the previous study 20 palms were monitored in three different plots for the production of male and female inflorescences, fruitset and bunch weight during 2.5 years. The data included the fruitset levels from the top, middle and bottom of the bunches as well as the overall fruitset. Two of the monitoring plots were at Buluma and Hargy (1979 planting) and the other also at Hargy, but a 1973 planting. Only the most relevant methods and data from the analyses are presented here, although other results such as further statistical analyses and production of male and female inflorescences over time are available.

For simplicity the monitored sites are referred to as Buluma, Hargy79 and Hargy73. It should be noted that all three sites were monitored over almost the same period (June 1987 – December 1989, 2.5 years) and thus the two Hargy sites will have been subject to the same weather conditions, and the Buluma site to similar seasonal conditions.

Because all three sites produced similar results for mean fruitset for each part of the bunch (top, middle and bottom) against the overall fruitset for the whole bunch, results from all 60 palms are presented in Figure 2. The percent for each part of the bunch is based on the proportion of fertilised fruits of that part of the bunch and not as a percent of the whole bunch.

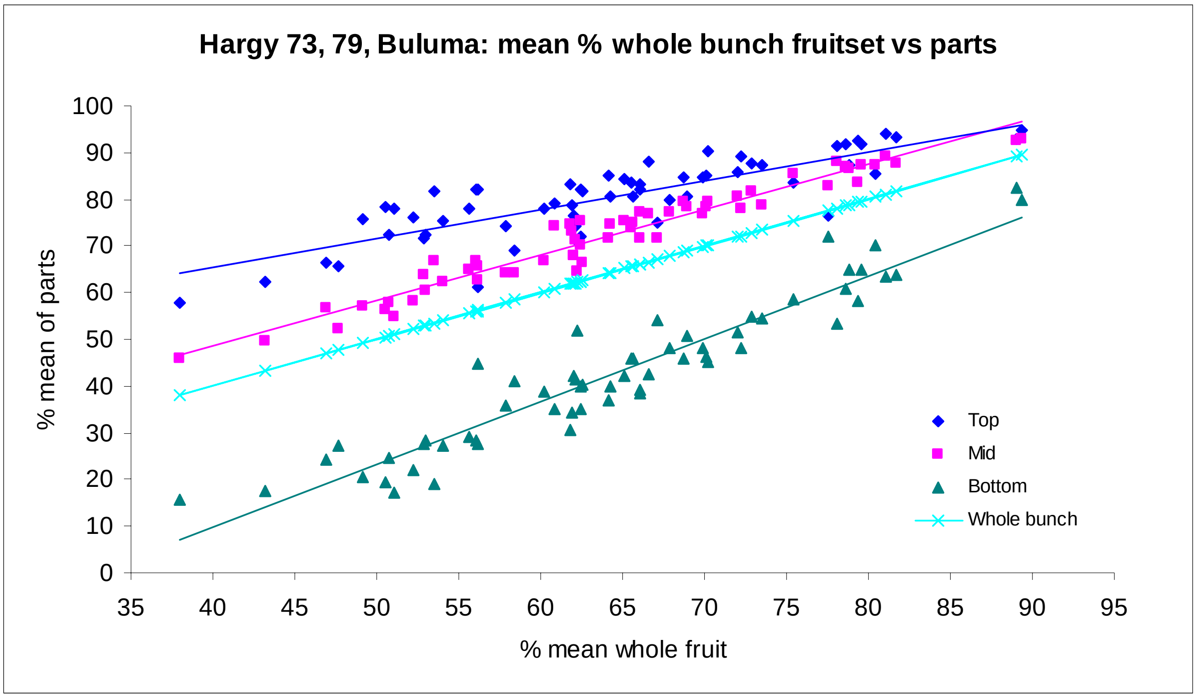


Fig 2 The contribution of mean fruitset of top, middle and bottom of bunches to the overall fruitset (Buluma, Hargy 1979 plantings and Hargy 1973 planting)

By presenting the data in this way it is possible examine the differences between the parts of the bunch and the contribution of each part to the overall fruitset. As can be seen from Figure 2, the indication is that when bunches were poorly fertilised, all parts of the bunch contributed to the reduction in fruitset rather than one particular part. There was a slight tendency for the bottom fruitset to be proportionally less for the more poorly fertilised bunches, but this was not statistically significant. Although the level of fruitset at the base of the bunches contributed most to the loss in overall fruitset the rate was proportional to the top and bottom fruitset. This dispels the idea that there are varying levels of access for the pollinating weevils (due to spathes not opening up fully) and this level contributes more to the fruitset loss than other parts of the bunch. The fact that the rate of fertilisation of the different parts of the bunch was correlated is shown by the very strong linear regressions produced. The results also suggest that individual palms may vary in their ability to become fertilised irrespective of the pollen deposited by the weevils.

By looking at the fruitset for each individual bunch for each palm it is possible to see the significant differences between the ability of palms to become fertilised. As palms at all sites showed this trend, Buluma was used as the example in Figure 3. It can be seen from this Figure that there are considerable differences between palms in their ability to become fertilised. For instance palm 7 has a mean fruitset of 40.5% compared with palm 18 with a mean fruitset of 72.0% of bunches collected over the same period, is significantly different. Even the means of palm 10 (70.1%) and palm 12 (60.3%) are significantly different (t-Test, P = 0.0038) despite the high variances around the means.

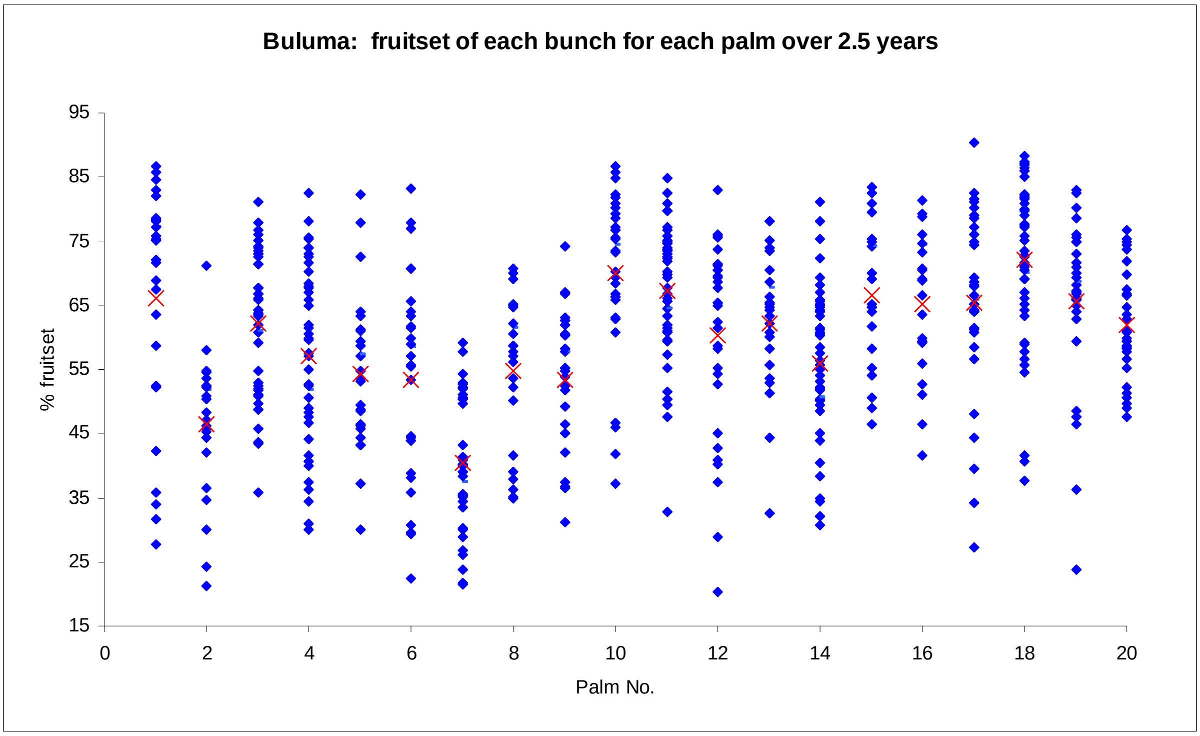


Fig. 3 Fruitset of individual bunches for each palm at Buluma for a period of 2.5 years

To examine the above results further, the data from Buluma and Hargy79 were analysed together (planted the same year) to look at the affect of different levels of fertilisation on yield. The mean fruitset of each individual palm (n=40) was sorted into order from poorest to best fruitset and then the mean bunch weights compared with this (Figure 4).

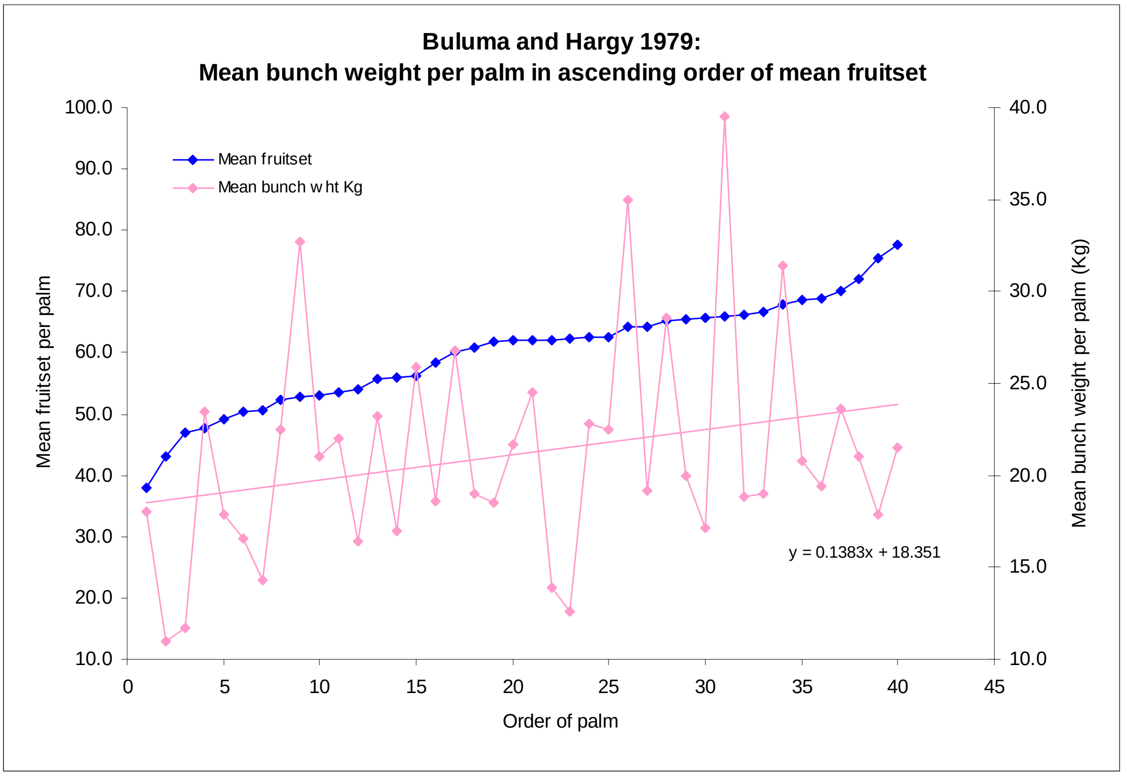


Fig. 4 Relationship between poor fruitset and mean bunch weight of 40 palms

The large variations in mean bunch weights for each palm shown in Figure 4 are primarily due to the variation in the number of fruits per bunch. Drawing a trend line through the mean bunch weights shows that there could have been up to a 22.6% mean loss in bunch weight due to poor pollination (the difference between the lowest and the highest mean fruitset).

In addition, by examining the changes in fruitset over time (Figure 5, using Buluma as an example) it can be seen that, apart from one sample, there were bunches with over 70% fruitset, suggesting that there should have been enough weevils present to produce such a level of pollination. The constraint of these data are, however, that it is difficult to assess the weather at the time of anthesis for each bunch (approx 150 days before harvesting) as harvesting was done with long intervals in between, but anthesis in female inflorescences only lasts about 3 days.

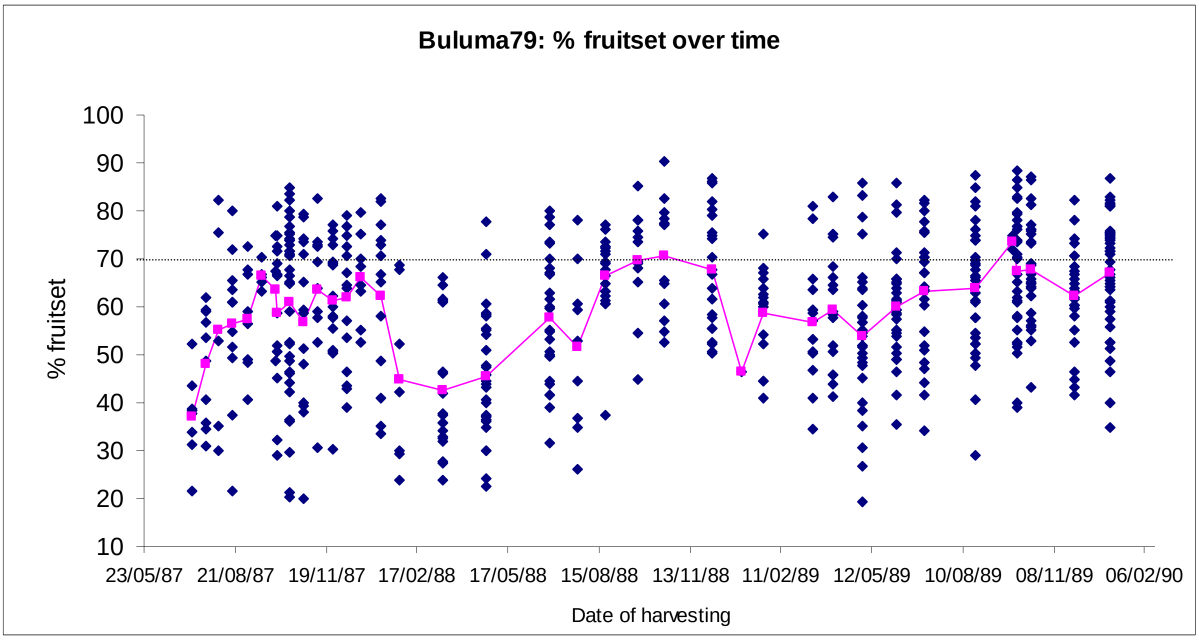


Fig. 5 Fruitset of individual bunches harvested at different times.

The above results, and others not reported here, gave the basis of requirements in a monitoring exercise set up from February 2004, described below. The general conclusion from the data indicates that palms vary (probably genetically) in their ability to become fertilised, and that weevils are probably in sufficient numbers to provide good pollination throughout most of the year.

Monitoring of fruitset at Kumbango, Mosa Group

As part of the investigation into what may be affecting pollination of female oil palm inflorescences, it was decided to study the interrelationships between the weevils and male (weevil breeding sites) and female inflorescences (pollinated by weevils) in relation to the weather at the time of anthesis, the levels of fruitset and other factors. A monitoring plot of 42 palms was set up at Kumbango, Mosa Group, in February 2004 and was monitored on a daily basis, for factors that might affect pollination/fertilisation. A map of the area of palms is shown in Figure 6, which shows the interrelationship between the palms. The numbering of palms was set up in the order that the palms were monitored.

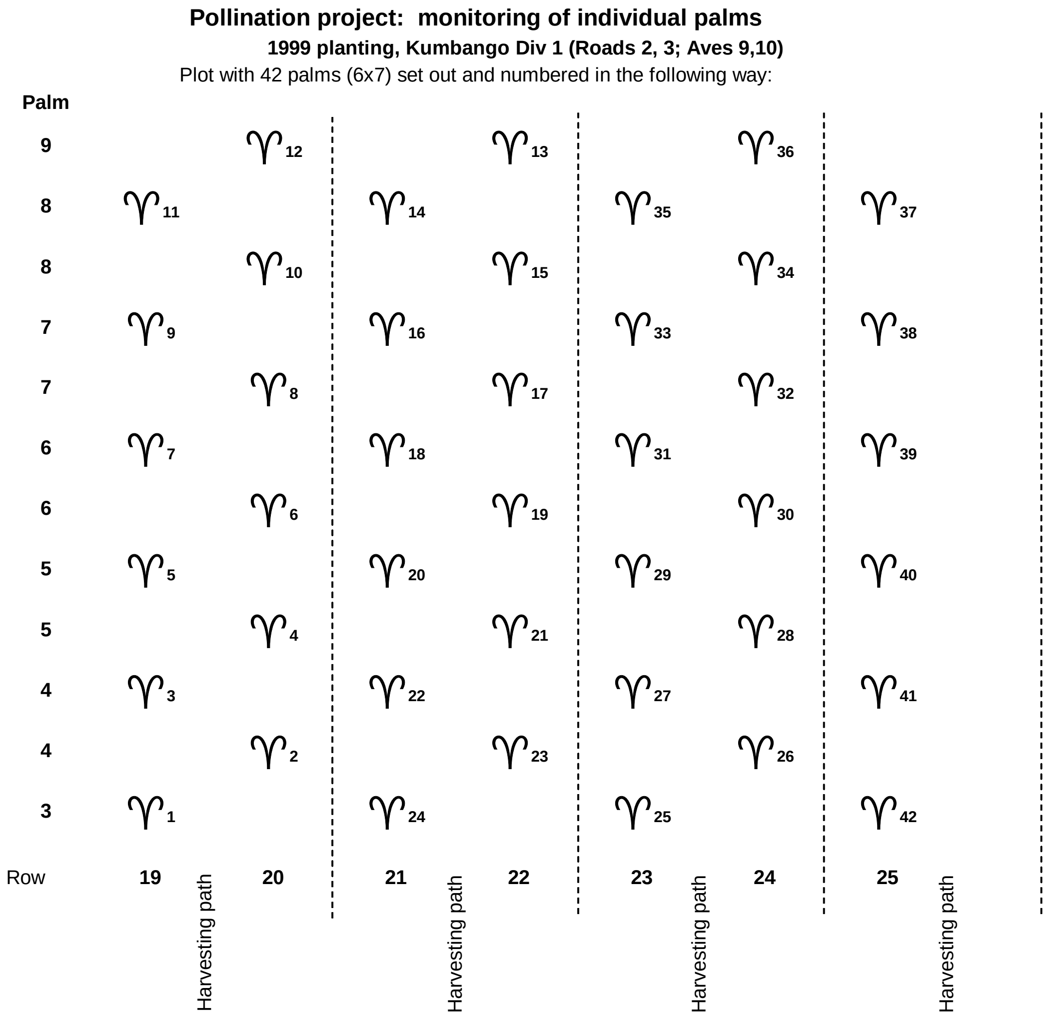


Fig. 6 Map of the monitoring site at Kumbango showing the positions of the numbered palms.

The parameters monitored and analysed for each palm included: period of time that each inflorescence was in anthesis, attraction of weevils to male and female anthesing inflorescences and subsequent weevil emergence (from male spikelets) and fruitset (of the females) obtained by separating the top, middle and bottom fruits from the bunches, counting the number of spikelets, estimating the levels of male and female inflorescences per hectare, the effects of weather on weevil activity and pollination/fertilisation, as well as fruit to bunch ratio.

As with the analysis of data from Buluma and Hargy there were significant differences between individual palms in their ability to become fertilised. This is shown in Figure 7 where the large variations between the mean fruitset for each palm are significantly different. Similarly, to look at the effect of different levels of fertilisation on yield, the mean fruitset of each individual palm (n=42) was sorted into order of poorest to best fruitset and then mean bunch weights compared with this (Figure 8). As with the Buluma example above, the large variations in mean bunch weights for each palm shown in Figure 8 are primarily due to the variation in number of fruits per bunch (see Figure 9). A trend line drawn through the mean bunch weights in Figure 8 shows that there could have been up to a 17.6% mean loss in bunch weight due to poor pollination (the difference between the lowest and the highest fruitset).

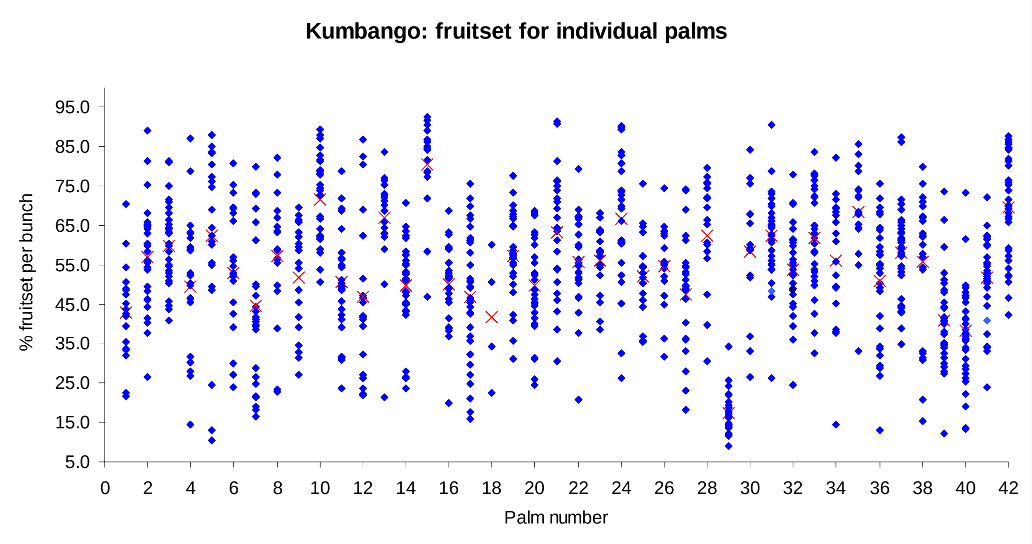


Fig 7 Fruitset of individual bunches for each palm at Kumbango between Feb to Dec 2004

Fig 8 Relationship between poor fruitset and mean bunch weight Feb to Dec 2004

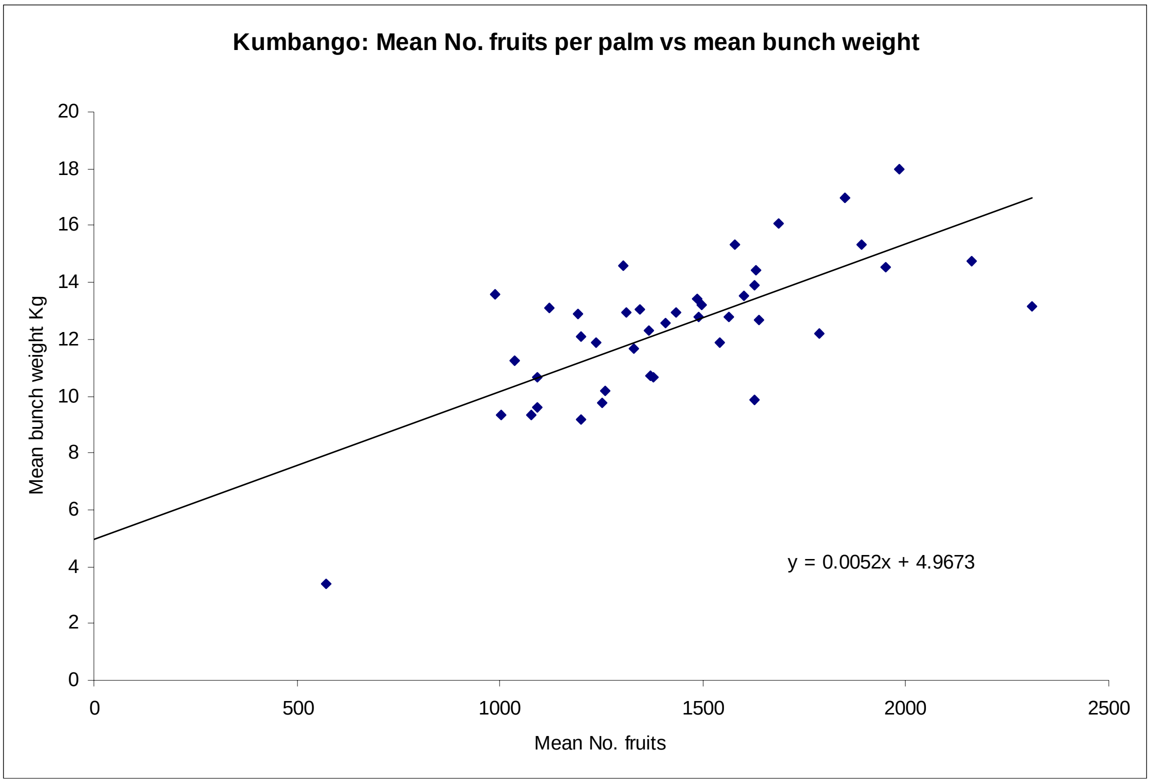


Fig. 9 Relationship between mean No. fruits and mean bunch weight per palm

By monitoring individual palms on a daily basis, where the variation around the mean fruitset is less than using a sample of palms, it becomes possible to compare fruitset with conditions at the time of anthesis/pollination/fertilisation, particularly the weather, the comparative numbers of weevils in the area, the number of male inflorescences available at the time for pollen production and the number of other anthesing female inflorescences that may be in competition for pollination. A spreadsheet was devised to record and summarise all this data, and will be used in the final analysis by the epidemiologist at Natural Resources Institute as part of the EU Stabex Project. This is planned to take place at the end of October 2005, five months after anthesis.

Figure 10 shows the changes over time of fruitset at Kumbango. The graph indicates that there was a general fall in fruitset in bunches harvested between May and August 2004 inclusive, which resulted from anthesis between December and March which is the main period of rains for the area (being approximately 5 months between anthesis and harvesting). However, as with Buluma above (Figure 5), even during the rains there were bunches exhibiting good fruitset at above 70%. This is correlated to when individual palms that, on average have good fruitset, were harvested. A more detailed study of this will be made when there are sufficient records for each individual palm to enable comparisons with weather and other factors to be made.

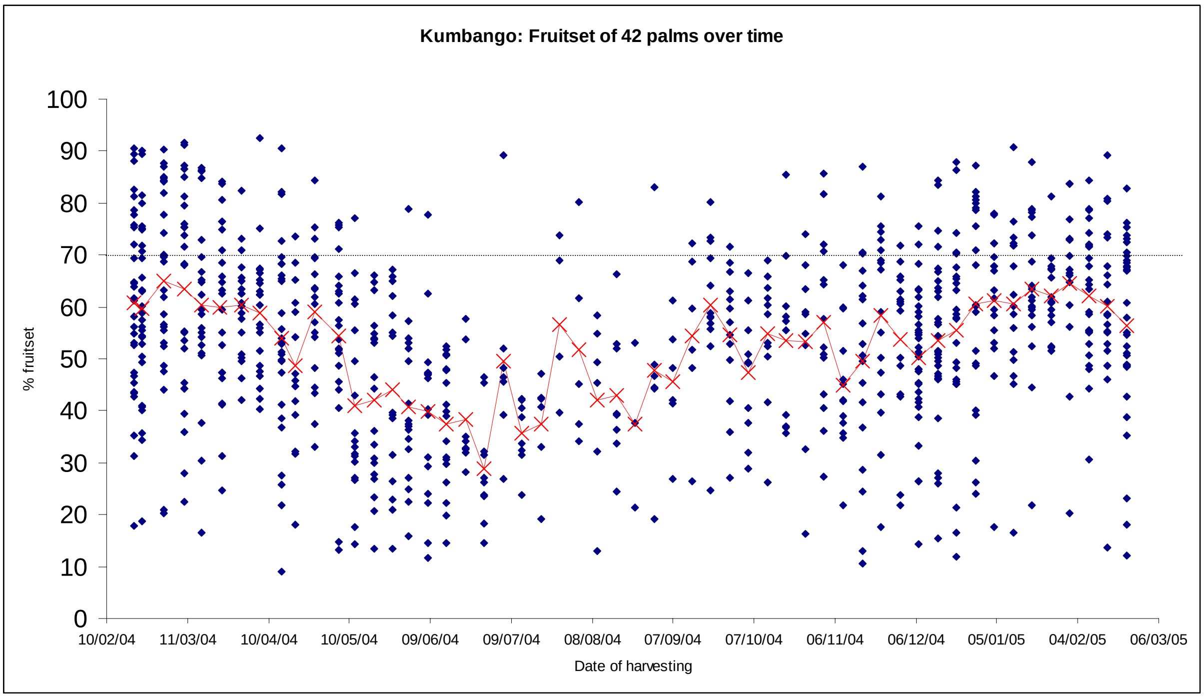


Fig. 10 Kumbango: fruitset of individual bunches harvested over time

To compare the numbers of weevils emerging from male inflorescences, the mean number emerging per 5cm is used as the baseline measurement. By examining the numbers emerging per 5cm per individual palm (Figure 11) it can be seen that there can be significant differences between palms. It is not known why there is this variation and this requires further investigation.

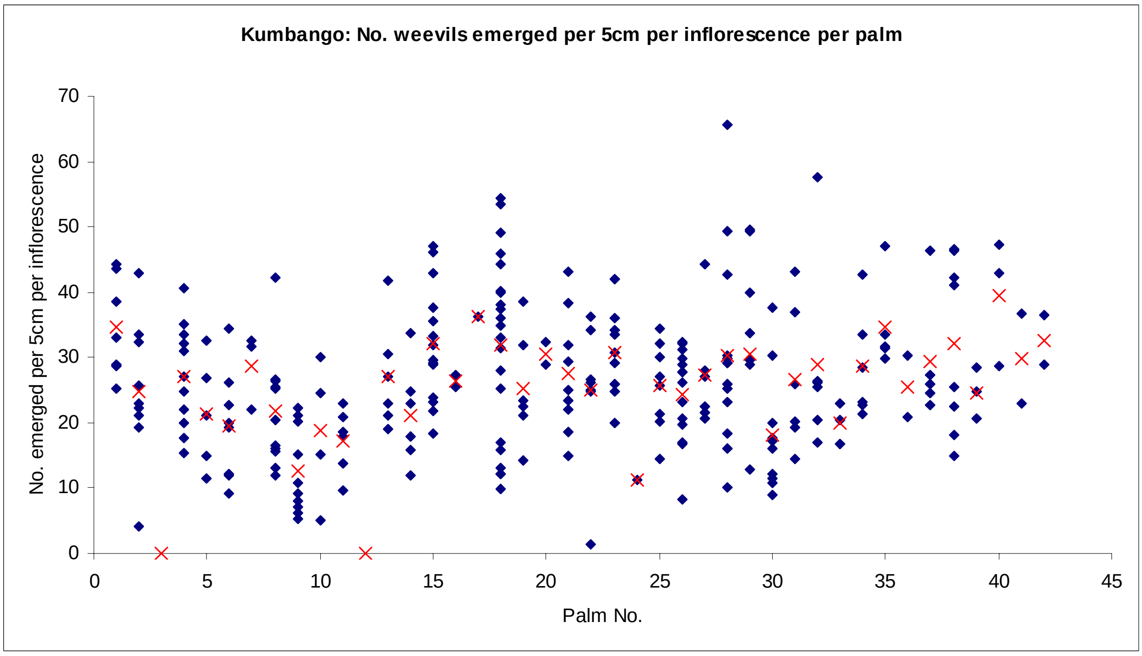


Fig. 11 Kumbango: Mean number of weevils emerging per 5cm of male spikelets per palm

Examples of some of the additional information gleaned from the study are shown in Table 1, which summarises some of the activity of palms in the field over the period of the study during 2004. The mean number of days for anthesis is based on the times that individual inflorescences started and finished flowering.

No. days of records up to 31/12/04	**319**
Total male inflorescences monitored	379
Total female inflorescences monitored	679
Total inflorescences monitored	**1058**
% male inflorescences	35.82
% female inflorescences	64.18
Mean No. of new female inflorescences per day	**1.98**
Mean No. new female inflorescences / palm / month	1.32
Mean No new male inflorescences / palm / month	0.71
Mean No. new inflorescences / palm / month	**2.04**

Mean number days for anthesing male inflorescence	3.36
Mean number days for anthesing female inflorescence	2.55
Mean No. male inflorescences in anthesis per day	3.60
Mean No. female inflorescences in anthesis per day	5.06
Mean No. inflorescences in anthesis per day	**8.66**
Mean No. female inflorescences in anthesis per day per hectare	10.98
Mean No. male inflorescences in anthesis per day per hectare	15.42
Mean No. inflorescences in anthesis per day per hectare	**26.40**
Mean % palms active per day	**20.61**
Mean No. days from female spathe splitting to anthesis	**6.83**

Table 1 Examples of information being collected from the Kumbango monitoring site.

In conclusion, the results show a genetic variation in levels of fruitset and variations in numbers of weevils emerging from spikelets from individual palms. The results here, and others not yet published, show that there appears to be compensation for the lack of fruitset by an increase in the size of fruits and/or an increase in the proportion of parthenocarpic fruits, although poor fruitset may result in up to 17.6% loss of bunch weight. It is interesting to note that, at both Buluma and in the current study at Kumbango, fruitset of 70% or more have been recorded during periods of generally poor fruitset which suggests that there were sufficient weevils available for pollination at that time. This also applies to the data from Kapiura (see below) where high levels of fruitset have been recorded for individual bunches throughout two wet seasons despite high rainfall and high nematode infestations. Therefore poor fertilisation may not be due to the lack of weevils, but to other factors. As indicated in the Annual Report of 2003, this has already been shown by Dhileepan (1994) who found that, in India, when weevil populations were comparatively low in the dry season, fruitset was high, and when the weevil populations were high in the wet season the fruitset was lower. However the current study, using daily monitoring, will be able to show why poor fertilisation takes place and should be able to make recommendations to alleviate the problem.

By the end of 2004, 712 fruit bunches had been examined for fruitset levels, 679 flowering female inflorescences and 379 male inflorescences were observed for duration of flowering and the male inflorescences were sampled for weevil emergence post-flowering. This work continues.

Long-term fruitset monitoring

Samples of weevils from anthesing male inflorescences were collected monthly throughout the year to identify nematode infestation rates and changes with time. Sites sampled on the mainland in Oro Province were at Embi and Parahe mini-estates, Ambogo estate, and Saga and Komo divisions at Mamba estate. An analysis of the Mamba data is dealt with below under "Epidemiological work on weevil pollination". Collection sites in West New Britain were at Numundo Group (Haella and Garu) and Kapiura (Kautu 1 and 2, Bilomi and Kaurausu). The data continued to show that in wetter areas (Mamba and Kapiura) there were higher nematode infestation rates (see also Annual Report 2003). Monitoring of fruitset continued on a monthly basis at Mamba in Oro Province (Komo and Saga) and at Kapiura in West New Britain Province (Kautu 1 & 2, Bilomi and Kaurausu). Analyses of data showed that high levels of nematode parasitism appeared not to reduce the capability of the weevils to enhance fruitset, although this could be masked by the very large variations in fruitset from palm to palm. At both areas there was a correlation between the proportions of male weevils present in the population and the level of parasitism.

As an example of the monthly monitoring at different sites, the results for Kapiura are shown in Figure 12, where the estimated dates of fertilisation/pollination are used instead of the date of harvesting. This gives an idea of the seasons that good (and poor) fruitset took place. Kapiura would expect the highest rainfall in the months of January to March inclusive. This once again shows that there appeared to be sufficient numbers of weevils available for pollination which resulted in bunches with 70% or more fruitset, and also showed that there was a very high variability in fruitset.

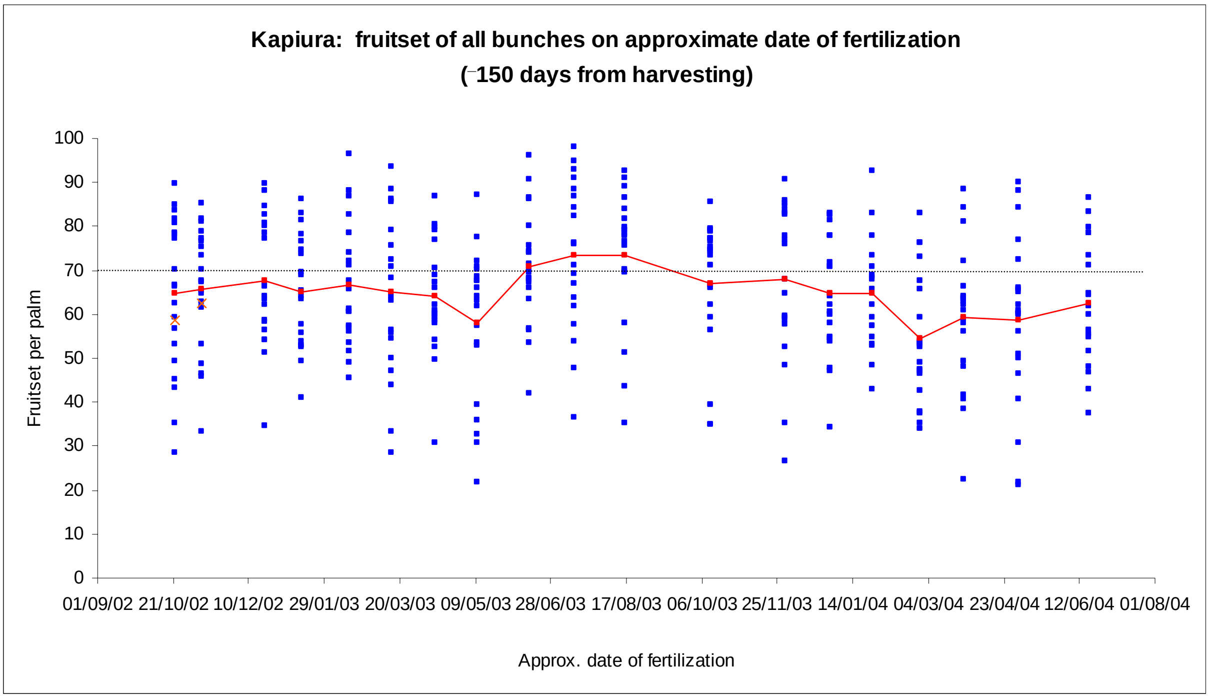


Fig. 12 Fruitset over time at Kapiura based on the approximate date of fertilisation.

<u>Incidence of internal parasitic nematodes and production of nematode-free stocks of weevils</u>

Nematode-free stocks of weevils continued to be bred in the insectary and additional nematode-free weevils were brought in from New Ireland in March to enhance the stocks. During a visit to Poliamba Estates, New Ireland Province in September, one sample from a VOP block at Laukurumau showed that 6.7% of the weevils contained internal nematodes (n =104 weevils, 67% of females in sample, were without external nematodes). This is the first record of this nematode species on New Ireland and means that the island can no longer be regarded as a site free of endoparasitic nematodes. Samples taken from 12 different sites during the last four years had previously shown no internal nematodes, indicating that the incidence of these parasites is extremely low; something also found in some areas on New Britain (e.g. Haella, Numundo Group).

<u>Life cycle of the internal nematode and the affect on weevils</u>

In November 2004, a nematode specialist, Dr David Hunt from CABI Bioscience, visited PNGOPRA to carry out laboratory experiments on the life cycle of the internal parasitic nematode of the weevils, and also the effect that they have on mortality levels and the ability of the weevils to pollinate oil palm trees. Methods were established for collecting and concentrating infective nematode larvae and also ways of infecting both individuals and large numbers of weevil larvae. New aspects of the nematode life cycle were also described.

Below are the details of his work (Hunt, 2002).

Introduction

In the previous EU Stabex project and the current extension it has been found that the parasitic nematode, *Elaeolenchus parthenonema* Poinar *et al*. (2002) of the pollinating weevils, was found to be widespread amongst the samples from oil palm growing areas of PNG, the infestation rates mostly being on the low side. Nematode infestation levels have approached 90% in some field-collected populations with a number of adult parasitic females, plus numerous eggs and developing juveniles, in each infected weevil. Male and female weevils were equally infected.

The parasitic nematode found in the weevils draws all its nutritional requirements from the host and therefore high parasitic burdens would be expected to have an effect on fecundity, perhaps even resulting in sterility due to depletion of the host's fat body. A reduction in energy reserves could also inhibit the ability of the weevils to fly and potentially impact on their ability to pollinate the oil palm flowers within a plantation.

It is still not proven whether the nematode parasite was carried to Malaysia with the original weevil introductions from West Africa (this would have to have been at a very low infestation level as the weevils were screened before release), although this seems likely from the close synchronisation of life cycles between the parasite and its host. What is clear is that the nematode is widespread in weevils collected from the Indo-Malayan region, although, from the samples examined, not all populations are infected. This in turn may be a result of physical environmental factors (such as rainfall), the chance introduction of clean weevils to isolated plantations or other, unknown factors, including the presence or absence of other organisms such as predatory mites.

Although detailed ecological studies of the population dynamics of the entomoparasite under field conditions in PNG have been carried out, the precise interaction of parasite and host remain to be elucidated. This goal can only be achieved by controlled biological studies utilising laboratory based cultures. Only then can the impact of the parasite be adequately assessed and predictions made as to future population levels and dispersal to new areas.

With the input from the nematode specialist from CABI UK, the aims of this part of the EU Stabex Project were:

1. To further study the life cycle of the parasitic nematode, in particular the timing of the infective immature female stage.
2. To establish methodology for mass extraction/production of infective stage nematodes.
3. To establish methodology for infecting weevil larvae with the parasitic nematode under controlled conditions.

Results

The results are organised according to the research aims listed above.

1. <u>To further study the life cycle of the parasitic nematode, in particular the timing of the infective immature female stage</u>

Elaeolenchus parthenonema, a parasitic nematode belonging to the superfamily Sphaerulariioidea (Order Tylenchida) was formally described by Poinar *et al*. (2002) from material collected in Malaysia. In addition to providing a rather brief description of the new species, the main aspects of the life cycle were indicated, although some details of the morphology of the parasite and its life cycle remained obscure.

Observations of the parasite by Dr Hunt have confirmed the major points described by Poinar *et al*. (2002), but have also added some important detail.

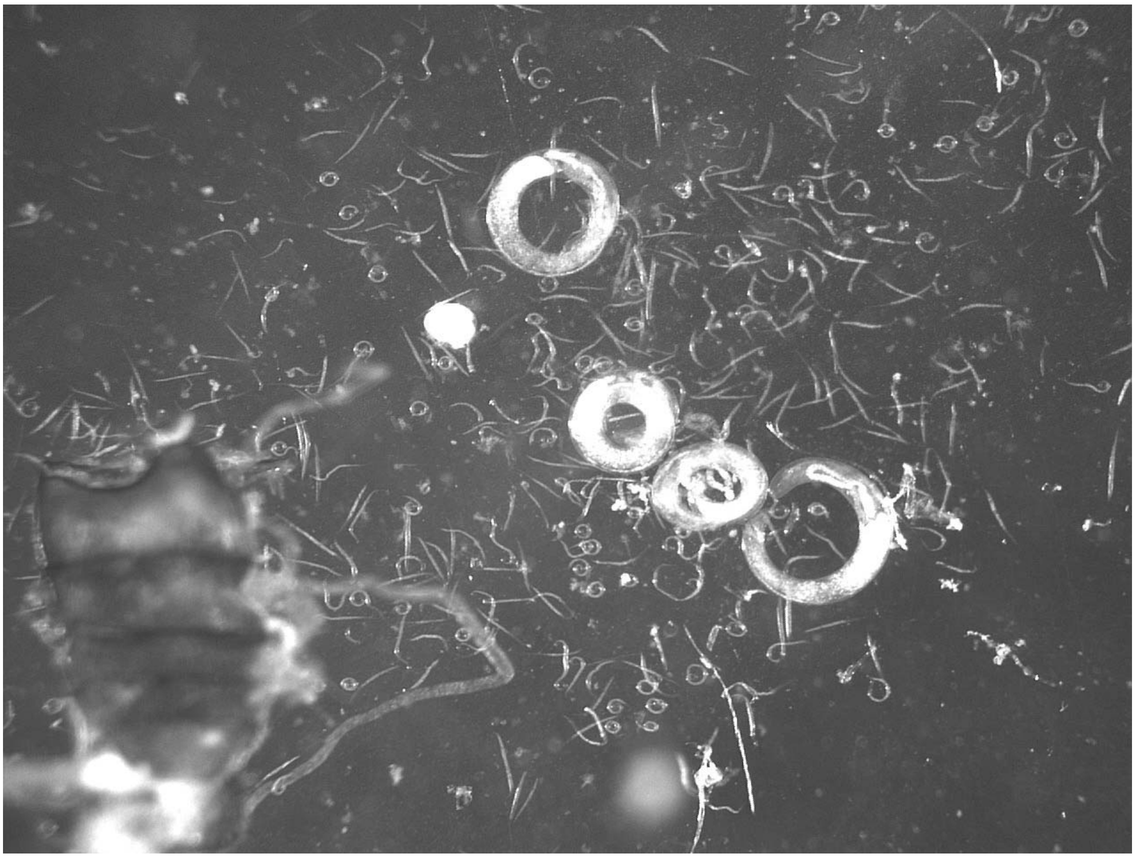


Fig. 13 Mature adult female nematodes with J3 stage from the haemocoel of an adult weevil

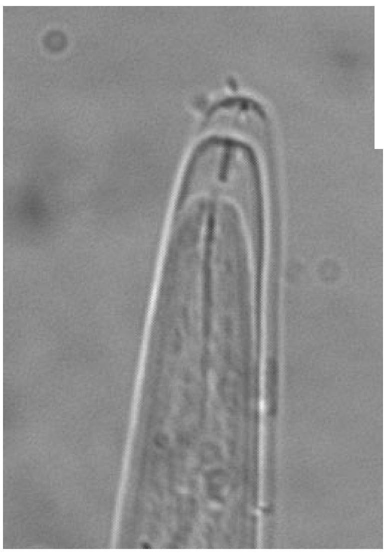


Fig. 14 Immature female enclosed in the shed J3 and J4 cuticles.

1.1 Life cycle of the nematode

The infective stage is the vermiform, sexually immature, female. No males are produced, the nematode reproducing parthenogenetically. The actual route of penetration into the larval stage of the host is still not certain, but is likely to be by passive ingestion with the food (the mandibles of the larva are large and therefore not likely to crush the small nematodes), although entry *via* the spiracles or anus can not be ruled out. Once inside the weevil larva, the vermiform female uses her stylet to bore through the gut wall into the haemocoel. A period of rapid growth then commences the female absorbing nourishment from the insect's blood and rapidly enlarging from a slender, vermiform, nematode less than 0.4 mm long to an obese, sausage-shaped female up to 1.5-1.8 mm long. By this time the infected weevils have usually developed to the adult stage. The number of females per infected weevil varies from a single worm to over 50, although in the latter case the females are much smaller because of competition for food. Different sized mature females may be found in the same host insect, thereby indicating that the vermiform infective females penetrated over a period of several days. Within the mature female, the single genital tract fills the body cavity, the highly developed ovary producing hundreds of small, almost spherical, eggs. Adult weevils may contain many J3 nematodes but no visible mature female. In this case, the female may have died, the J3 exiting and leaving behind just an empty cuticle.

Subsequent to embryonation, the first stage juvenile, or J1, moults to form the J2. The J2 uses its comparatively weakly sclerotised stylet to penetrate the thin and flexible eggshell and is therefore the stage that hatches. This occurs within the adult female, a process known as ovovivipary. The female parasite is parthenogenetic and does not require males – indeed; males appear to be entirely absent. The mature females gradually fill with hatched juveniles and these eventually emerge into the haemocoel, a process that probably occurs after the death of the female. The commonest juvenile stage in the haemocoel is the J3, a stage that is initially enclosed in the shed cuticle of the J2. The J3 grows considerably, sheds the J2 cuticle and then, using its protrusible stylet, penetrates the gut wall. It is then passed out with the faeces, hopefully on to a male inflorescence where the weevils have fed and laid their eggs. Other points of exit, such as the spiracles, may also be utilised, although there is currently no evidence to support this. It is also possible that the J3 may penetrate the genital system in order to exit the host.

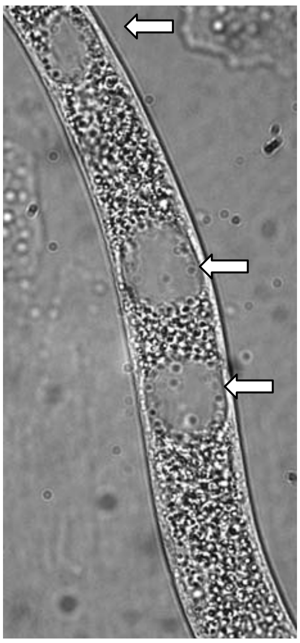


Fig. 15 Vacuoles (arrows) in gut of immature females

Once in the external environment, the J3, which is extremely active, moults rapidly through to the J4 stage and then almost immediately to the immature female, the latter often retaining both the J3 and J4 cuticles, or just the J4 cuticle, for some time. Eventually these cuticles are lost, the female pushing through the anterior region of the shed cuticles by thrusting with the protrusible spear or stylet to make a hole. The immature female is much more slender than the J3 and is also very active. In the laboratory (ambient temperature *ca* 22˚C) the immature female stage was usually reached within about 2-2.5 days after emergence of the J3 from the adult weevil, although in the field, where the ambient temperature is rather higher, this development would be substantially faster. The excretory pore and duct are very prominent and secretions from the dorsal oesophageal gland may be seen accumulating behind the stylet. These secretions may play a role in the penetration phase. The vulva of the immature female is located about 1.3 body diameters anterior to the anus, but is difficult to see at this stage (Note: the paper by Poinar *et al*. (2002) illustrates it rather more from an anterior view. They also indicate the presence of a postvulval sac in the genital tract, but this 'structure' is an artefact caused by their erroneous observations of the true vulva position). The food reserves in the intestine of the very active immature female fuel her activity, large vacuoles appearing in the intestinal lumen by days 5-7 after emergence of the J3 from the weevil as the food storage granules are utilised. Immature females were still alive in tap water after 10 days, although by this time about half of the food reserves in the intestine had, judging from the extensive vacuolation, been consumed.

The nematode stages found outside the host do not feed and rely on food reserves absorbed during the parasitic phase and then stored in the intestine. All other stages take all their nourishment directly from the insect haemocoel and may thus act as a significant drain on the food reserves of the host. The life cycle of the parasite is closely adapted to that of its host, a feature that suggests a long period of co-evolution. This in turn implies that the parasite was probably imported with the original weevils from Cameroon, the infection level being too low to be readily detected during quarantine examinations (only about 1000 weevils were originally imported into Malaysia, thereby impacting upon the practicality of screening large numbers of weevils for parasites).

2. <u>To establish methodology for mass extraction/production of infective stage nematodes</u>

2.1. Mass collection of infective nematodes

In order to conduct infection studies, it is necessary to obtain large numbers of infective female nematodes. The best source of nematode material, albeit the J3 stage, is the adult weevil. This immature stage can be collected directly from the weevil haemocoel either by lightly macerating and extracting from whole weevils, an easy, if destructive process, or by collecting the J3 as they emerged naturally from the host in the faeces. It is also possible to collect infective stage nematodes directly from the male inflorescence once it has been colonised by the weevils.

The main advantage of the weevil crush method is simplicity and the rapid collection of many nematodes. The main disadvantage is the destruction of the weevils (not necessarily a problem as they can be obtained or bred in enormous numbers). The weevil faeces method has the advantage that the weevils are not killed in the extraction process, although nematode yield is spread over several days – itself not necessarily a problem as the extracted nematodes may be stored in water for several days until sufficient inoculum has been obtained.

2.1.1. Weevil crush method

Having established from the life cycle studies that J3 removed from the weevil haemocoel would continue the life cycle *in vitro*, the weevil crush method was investigated to ascertain whether it was practical. Several hundred adult weevils were placed in the lid of a plastic 9 cm Petri-dish and lightly crushed with the base of the bottom section of the Petri-dish. Care was taken to ensure that the weevil thorax was crushed sufficiently to detach it from the abdomen, thereby allowing the J3 nematodes to emerge. The crushed weevils were then placed on an extraction filter constructed from locally available materials and extracted overnight. Recovery, although highly dependent on initial parasite density, was good. The main problem experienced was that the weevils started to decay, leading to a high bacterial count in the water and consequent low oxygen tension. Many J3 were initially immobile, but quickly revived when fresh water was added. The extract could be further cleaned by allowing the nematodes to pass through another extraction filter lined with a clean piece of facial tissue.

2.1.2. Weevil faeces method

Previous observations had shown that the faeces of adult weevil could contain large numbers of J3 parasites. Clearly, if it were possible to collect sufficient quantities of heavily nematode-infested faeces, it would be relatively easy to obtain large numbers of infective parasites for inoculation studies.

A plastic lunchbox lined with a layer of damp tissue was placed under a caged inflorescence where infected beetles were breeding. The aim was to collect beetle faeces containing J3 nematodes and then extract them from the tissue. Unfortunately, the recovery of nematodes from the laboratory culture was poor. This was due to a combination of a low infection rate in the weevil population plus an apparently low faeces collection rate (many faecal pellets being presumably trapped in the inflorescence).

This technique was then modified. Hundreds of infected adult weevils from the culture were left overnight in a plastic lunchbox. The container had a layer of damp tissue lining the base to help prevent desiccation of the faeces and any emerging nematodes. The following morning, the weevils were tapped out into another container and returned to the breeding cage to feed and continue their life cycle. The original plastic container was then lightly rinsed out with a small volume of tap water and the residue and tissue extracted. Large numbers of clean nematodes (*i.e.*, not contaminated with bacteria) were obtained by this simple method.

The productivity of this technique clearly depends on the extent to which the weevils are infected (both the % parasitism and the number of nematodes per infected weevil), but provided that a highly infected laboratory culture of the weevil is available, this simple technique should be capable of providing large numbers of viable nematodes for infection studies.

2.1.3. Male inflorescence extraction

It was possible to obtain large numbers of J3/J4/infective females by extracting nematodes from inflorescences at an early stage of colonisation by the weevils. Pieces of inflorescence were placed on an extraction filter and left overnight, nematodes migrating from the plant tissue and being collected in the water beneath. Although this could be a spectacularly good source of clean and active nematodes, it was not consistent for field collected flower spikes – a reflection of the fact that nematode parasitism varies widely from one inflorescence to another. Because of the wide variation in nematode recovery, we decided not to pursue this method further, although it may still be viable when heavily parasitized laboratory cultures are available.

2.2. Techniques for extracting and cleaning nematodes

There are two basic methods for extracting nematodes: *passive* and *active*. The former requires a variety of fine-mesh sieves to physically separate the nematodes from the substrate. Passive techniques are efficient, but require a range of expensive, imported, sieves of the appropriate mesh size to be available. Active techniques, on the other hand, rely on the motility of the nematode to move through, for example, a piece of facial tissue, into a collecting vessel containing water, the tissue serving as a filter to restrain dead nematodes and other debris from contaminating the extracted nematode suspension.

In this study it was decided to use active techniques because of simplicity and cost (the extraction filters can be readily made from cheap and locally available materials such as plastic containers, rings cut from plastic drainpipes, plastic salad drainers, plastic mosquito netting, fine mesh curtain material and facial tissue).

Two methods were developed:

a) Small extraction filters made from two plastic tubs about 12 cm in diameter, a circle of plastic mosquito netting and a layer of facial tissue (e.g. Kleenex®). To construct an extraction device, the bottom of one tub was removed so as to leave a narrow internal rim to act as a support for a circle of plastic mosquito mesh. Plastic mosquito mesh makes an ideal support for the piece of facial tissue that acts as the extraction filter – metal mesh should be avoided as many nematodes are sensitive to metal ions, become inactive and eventually die. The mosquito mesh circle is placed inside the tub with the cut-out base and a piece of facial tissue placed over the mesh. The tissue should be substantially larger than the base of the tub. The material to be extracted, such as crushed weevils, can then be placed on the tissue. The tub is then placed inside the base of another tub and water added so that the extraction filter (*i.e.*, tissue plus weevils) is moist. The set-up should be left overnight, by which time the nematodes should have migrated from the weevils, through the tissue and into the collecting container where they settle on the bottom. If extracting from crushed weevils there will be considerable bacterial contamination of the water and this, by reducing oxygen tension, will result in the nematodes becoming inactive. They may be revived by decanting surplus water and adding fresh tap water. The extract may be additionally cleaned by pouring the nematode suspension through another extraction filter set up as described above. This method is best suited for small quantities of extract, such as weevil crush, or for cleaning up an existing extract.

b) Large extraction filters made from a plastic salad drainer about 30 cm in diameter, a plastic bowl large enough for the drainer to nest within, and a piece of facial tissue (all items available locally). The salad drainer is lined with a piece of facial tissue, and the substrate from which the nematodes to be extracted is then placed on the tissue (nematode suspensions are gently poured on to the tissue, the latter then retaining the nematodes). The extraction filter is then carefully placed inside the plastic bowl and enough water added to the bowl to moisten the tissue (do not add too much water as this may result in anoxic conditions leading to immobile nematodes that then fail to migrate through the filter). This method is particularly suitable for the extraction of collections of weevil faeces or nematodes from inflorescences, the greater surface area being an advantage for the larger amounts of material involved.

Both these methods are cheap, quick and reliable and may be readily constructed from a variety of locally available materials.

<u>3. To establish methodology for infecting weevil larvae with the parasitic nematode under controlled conditions</u>

Having obtained sufficient nematode inoculum, the impact of the parasite on the host may be assessed under controlled conditions. We developed two methods, which are outlined below, although precise details of the methodology still need to be developed.

a) Individual weevil grub inoculation: The weevil grubs appeared too small for *per os* inoculation of infective nematodes (the syringe must be inserted between the mandibles with the nematodes being injected into the insect gut in a minute volume of water). The technique developed was, working with a nematode-free population, to carefully remove individual, early instar, weevil grubs from a male spikelet. Each grub could then be inserted into a suitably sized piece of clean spikelet (*i.e.*, bagged before flowering so that weevil access was prevented) by carefully removing one of the florets and placing the grub into the resulting cavity. By gently plugging the cavity with a small wad of damp tissue, the grub was prevented from exiting inappropriately and thereby encouraged to burrow through to one of the adjacent florets (this is the natural method by which the grubs develop, each grub burrowing through, and feeding on, several florets before pupating). We established that most of the grubs so treated would burrow through into one of the adjacent florets, thus opening up the possibility of following the infection process under a variety of conditions. To infect grubs *in vivo*, therefore, infective nematodes could be introduced with the weevil grub by pipetting a small volume of water containing a known number of nematodes into the same hole as the grub. Assessment of nematode inoculum can be easily done using standard dilution count methodology. Although not as reliable as successful *per os* inoculation, the juxtaposition of host and parasite thereby achieved should result in a reasonable parasitism rate, although initial experiments to assess success rate will need to be done. This technique, when implemented on an appropriate scale and with suitable control treatments, should allow the fate of individual weevil grubs to be followed, thereby enabling the impact of the parasite on the insect to be assessed under laboratory conditions.

b) Whole spikelet inoculation: Individual spikelets infested by clean populations of the weevil can be readily obtained under laboratory conditions by exposing the spikelet to weevils for one or two days to allow oviposition to occur. Many such spikelets can be obtained, thereby allowing a suitable experimental design with appropriate replication to be chosen. Infective nematodes, obtained as described above, can then be inoculated at known densities using dilution count methodology. We established that it was better to lightly spray such spikelets with tap water in order to dampen the surface. Nematode suspension could then be applied either in drops of water or as a spray, the suspension being immediately drawn between the florets and thereby bringing parasitic nematodes and host into close proximity.

Conclusions

The research has established details of the parasite life cycle and determined the time taken for the infective immature female stage to develop from the haemocoel-parasitic J3 stage.

Several methods for mass recovery of parasites were developed and extraction filters to clean the nematodes so obtained were designed and constructed from locally available materials. Large quantities of experimental material can thus be assured. Techniques were also developed whereby weevil grubs can be exposed to infective stage nematodes under controlled laboratory conditions in order to ascertain the true impact of the nematode on the weevil. Some development work remains to be done on these protocols.

To proceed with the research requires large numbers of parasitic nematodes to be readily and continuously available. Given the unpredictable incidence of the parasite in the field (even from one oil palm to the next), it is essential that the parasitic nematodes are produced under controlled conditions. As has been already demonstrated at PNGOPRA, that the weevil may be easily mass-bred in fine-mesh cages, fresh, clean, inflorescences being provided at suitable intervals for the weevils to feed upon and breed.

To enhance nematode parasitism, and hence efficiency of recovery for infection studies, it is recommended that the inflorescences be given a daily light spray with water for the first five days after the beetles begin to oviposit. The infective nematodes are very active but, like all nematodes, they require a thin film of water if they are move across the substratum. The moist (but not wet) conditions created around the male florets by light spraying should enhance nematode survival and motility, thereby facilitating a higher infection rate in the developing grubs and thus a greater recovery of infective stages for experimental purposes.

One potential problem with laboratory cultures is the build-up of predatory mites that feed upon the free-living nematode stages. The action of these mites may pose a significant constraint on parasitism levels by reducing nematode inoculum. On the other hand, they may be shown to be an important biological control agent of the infective stages of the parasite in the inflorescence.

Epidemiological work on weevil pollination

Previous data on fruitset levels (Mamba Jan 1989 – May 2004) were examined by the Natural Resources Institute (UK) epidemiologist in relation to factors such as weather, inflorescence numbers and numbers of weevils. The results are summarised below. He also provided an e-calculator to calculate sample sizes required for different aspects of the work. During discussions at NRI it was decided how best to present the pollination data being collected at Kumbango for ease of analysis. The monitoring data spreadsheet has been adapted to provide the data required on a single summary worksheet.

Summary of results from Mamba

Excepting a few months with missing values, data from Saga and Komo (Mamba, Oro Estate) were available at monthly intervals from January 1998 to May 2004. Fruitset was recorded along with a range of other variables which may affect fruitset. Throughout the analysis, because harvesting occurs some 5 months after pollination, fruitset was compared with the other variables using a five-month lag. The main objective was to explore statistical relationships affecting fruitset with a view to better understanding the processes controlling fruitset and how it might be improved.

The data for both sites showed some strong relationships with date over the period concerned. With the exception of weevil numbers, these long-term trends were similar at the two sites. Such long-term trends mean that any correlations between variables should be treated with caution. For example, if two variables both increase during the period, it is likely that they will be positively correlated; if one increases and the other decreases, it is likely that they will be negatively correlated. Such correlations may therefore have little biological meaning. With this in mind, analyses were carried out on the original fruitset data and then on fruitset data from which the long-term trend was removed.

When the long term trends were removed from the analyses, only the correlation between fruitset and number of male anthesing inflorescences were significant at both sites. At Saga, over and above a general trend for fruitset to increase with time, there was a significant effect attributable to the number of male inflorescences. The coefficient was close to 1, indicating that, within the limits of the regression, fruitset increased by one percentage point for each extra male inflorescence. There was also some indication of an effect of diminishing returns, i.e. that the value of adding extra male inflorescences declined as the number of male inflorescences increased. Below 5 inflorescences, there was clearly an effect of reduced fruitset. Above 13 inflorescences, fruitset was always high. At Komo, fruitset was positively associated with anthesing male inflorescence numbers and spikelet length, and negatively associated with rain, but these effects were masked if fruitset was not de-trended for the long-term increase which occurred over the period of the data. The relationship between fruitset and male inflorescences was similar to that found at Saga, and above 12 inflorescences, fruitset was always high.

In summary, the data shows that less than 5 male anthesing inflorescences per hectare clearly had an affect of reducing levels of fruitset and that levels above 12-13 anthesing inflorescences gave consistently higher fruitset. Between 5 and 13, the variation was quite large, but on average, the higher the number of anthesing male inflorescences, the higher the fruitset.

The current daily monitoring at Kumbango (see above) will provide more accurate details on the numbers of male inflorescences needed for good pollination as well as other correlations that cannot be picked up when recording on a monthly basis.

Future Work

Future work will continue to concentrate on the objectives of the project; particularly understanding the relationship between the weevils and the male and female inflorescences, and the biology and ecology of the nematodes and their possible affect on the weevils. These studies will lead to recommendations on improving the fruitset levels of oil palm bunches.

2. SEXAVA IPM

Introduction

Sexava (*s.l.*) are still the most important pests of oil palm in PNG although outbreaks tend to be confined to West New Britain and New Ireland, with the pest being suppressed by parasites on the mainland. Work has continued on (i) improving the biological control (ii) understanding how outbreaks can build up and why there were perceived “hot spots” for outbreaks (iii) improving knowledge so that more accurate control decisions can be made.

During this year, all visits to outbreaks also recorded a significant presence of the stick insect *Eurycantha sp.*, which although represented by a separate species on New Ireland, was also recorded as being a pest over there.

It is planned to enter all outbreak reports into a GIS system, which will provide better data to enable more in depth studies to be made on the distribution and occurrence of outbreaks; this should help in understanding the epidemiology of outbreaks of these pests.

Table 2 List of pest outbreaks reported and visited during 2004

Pest Surveys - 2004							
Date	**Location**	**"sexava"**	***Eurycantha spp.***	**Date**	**Location**	**"sexava"**	***Eurycantha spp.***
January				**August**			
13	Kaurausu Pln.	✓	✓	4	Kaurausu Pln.	✓	✓
13	Bilomi 1 Pln.	✓	✓	4	Kautu 3 Pln.	✓	✓
15	Navo Pln.	✓	✓	6	Kapore Lss	✓	✓
21	Siki Lss.	✓	✓	9	Navo Pln.	✓	✓
22	Siki Lss.	✓	✓	19	Kilungi Vop.	✓	✓
29	Hargy Pln.	✓	✓	24	Bilomi 1&2 Pln.	✓	✓
29	Kabaiya Lss.	✓	✓	24	Kautu 1 Pln.	✓	✓
February				**September**			
4	Kaurausu Pln.	✓	✓	1	Rigula Est.	✓	✓
March				3	Kapore Lss.	✓	✓
8	Kaurausu Pln.	✓	✓	6	Hargy Pln.	✓	✓
8	Kautu 3 Pln.	✓	✓	9	Kaurausu Pln.	✓	✓
19	Poliamba Pln. N.I.	✓	✓	9	Navo Vop.	✓	✓
April				14	Tamba Lss.	✓	✓
19	Bilomi 2 Pln.	✓	✓	**October**			
30	Navo Vop.	✓	✓	14	Kautu 3 Pln.	Finchhafen disorder 1ha.	
30	Uaisilau Vop.	✓	✓	29	Navo Pln.	✓	✓
May				29	Uaisilau Vop.	✓	✓
11	Kautu 3 Pln.	✓	✓	30	Kautu Pln.	✓	✓
14	Gailo Vop.	✓	✓	30	Kaurausu Pln.	✓	✓
14	Gule Vop.	✓	✓	30	Kapore Lss.	✓	✓
June				30	Mamota Lss.	✓	✓
7	Lavege Vop.	✓	✓	**November**			
7	Sarakolok Lss.	✓	✓	10	Buvussi Lss.	✓	✓
7	Uaisilau Vop.	✓	✓	19	Malilimi Pln.	✓	✓
10	Tamabie Vop.	✓	✓	25	Navo Pln.	✓	✓
21	Sarakilok Lss.	✓	✓	25	Kaiwiu Vop.	✓	✓
24	Sarakilok Lss.	✓	✓	30	Bilomi 1&2 Pln.	✓	✓
26	Sarakilok Lss.	✓	✓	30	Kautu 1 Pln.	✓	✓
July				**December**			
2	Sarakilok Lss.	✓	✓	28	Navo Pln.	✓	✓
14	Kautu 1 Pln.	✓	✓	28	Tiauru Lss.	✓	✓
14	Kautu 3 Pln.	✓	✓	30	Kaurausu Pln.	✓	✓
26	Bilomi 2 Pln.	✓	✓	31	Kautu 3 Pln.	✓	✓

Biological Control

Strepsipteran parasites

At the end of 2003 a visit to Kabaiya (Bialla) showed that significant numbers of the parasite *Stichotrema dallatorreanum* had established in the sexava populations there (*Segestidia defoliaria*) due to releases made by initially by PNGOPRA during 2002. Subsequent visits to Bialla confirmed that *Stichotrema* was present in a number of smallholder plots around Kabaiya and also in patches at Navo Plantation. Visits to Kabaiya between January and June confirmed that the *Stichotrema* had effectively suppressed the outbreak of sexava first reported during November 2003. A large reduction in sexava numbers was observed in April when high numbers of *Stichotrema* (over 50% parasitism) were producing first instar larvae and then females dying. When the parasite dies it also kills the host.

During the monitoring process egg parasitoids were also found in the area.

Redistribution of *Stichotrema* from the known sites at Navo and Kabaiya was carried out throughout the year. Infected hosts (*S. defoliaria*) were collected and redistributed into other parts of Navo and Hargy as well as in the smallholder areas around Bialla. Through the bi-monthly Sexava Action Group meetings the redistribution was co-ordinated to ensure a good spread of the parasite. Advice was provided on the methods for doing this and photos of the parasite in sexava produced for field recognition. Collections of parasitized sexava were also made every month for release at Kapiura where *S. defoliaria* are also present.

Using the parthenogenetic *Stichotrema* from Bialla, attempts to parasitize other species of sexava continued, using *S. decoratus* from West New Britain and *S. gracilis* from New Ireland. At the end of June the first adult *Stichotrema* cephalothorax was extruded from *S. decoratus*. This was the first time *Stichotrema* reached adult stage in S. *decoratus*. Unfortunately the sexava host died a week after extrusion, and therefore the *Stichotrema* also perished. This exercise will be repeated during 2005, as it will be a major breakthrough if viable populations of *Stichotrema* could become established in the sexava population on New Ireland.

Mature *S. dallatorreanum* from Bialla (ex *S. defoliaria*), Popondetta (ex *S. novaeguineae*) and Medang CCI (also ex *S. novaeguineae.*) were dissected and the 1st instar larvae checked for male and female forms. Only female forms have been found in the specimens from Bialla and Popondetta, suggesting that these *Stichotrema* populations (both originating from Popondetta) reproduce parthenogentically. The specimens from Medang produced both male and female forms of 1st instar larvae (28.3% males), suggesting that the *Stichotrema* population reproduce sexually. Work on attempting to trap the tiny winged male *Stichotrema* in pheromone traps around Popondetta continued. No males have yet been caught suggesting further that the *Stichotrema* population around Popondetta is parthenogenetic.

Egg parasitoids

Egg parasitoids (*Doirania leefmansi Waterst.* –Hymenoptera:Trichogrammatidae, and *Leefmansia bicolor Waterst.- Hymenoptera: Encyrtidae)*) continued to be reared at Dami, and released during the year in areas where low levels of sexava occurred. Releases will continue as material becomes available, however the current rearing facility is inadequate, and a proposal is to be prepared for improving the rearing facilities for all parasitoids.

Table 3 Distribution of parasitoids releases during 2004.

Location	Number of eggs parasitised in the lab		Parasitoids expected (estimated)		Releases of *Stichotrema dallatorreanum*		
	L.bicolor	*D.leefmansii*	*L.bicolor*	*D.leefmansii*	*Location*	*Date released*	*Number of infested sexava released*
NBPOL plantations					Hargy area 12	Tuesday, January 27, 2004	5
Bilomi div.1	206		4,120		Bilomi div.2	Tuesday, May 25, 2004	16
Bilomi div.2		330		82,500	Bilomi div.2	Monday, July 26, 2004	53
Ksuto div. 3	220				Kautu div. 1	Wednesday, July 14, 2004	3
Kaurausu	207		4,140		Kautu div. 2	Sunday, July 18, 2004	3
					Kautu div.3	Wednesday, July 14, 2004	3
Poliamba Pltn.					Hargy area 12	Monday, July 19, 2004	4
Lakurumau	138	193	2,760	48,250	Hargy area 11	Monday, July 19, 2004	3
Lubura	145	135	2,900	33,750	Bilomi div.2	Wednesday, August 18, 2004	2
Libba	63		1,260	20,000	Kautu div.4	Wednesday, August 18, 2004	2
Piera		80			Hargy area 7	Friday, October 29, 2004	3
Penipol		56		14,000			
TOTALS	**979**	**794**	**15,180**	**198,500**			**97**

Egg development

Work on examining egg development of *S. novaeguineae* in Oro Province continued. Monthly samples of eggs were collected and dissected to compare egg weights in relation to embryonic development. Most of the eggs sampled were of embryonic stage 10 and older. The results showed that this species follows a similar pattern as found in *Segestes decoratus* and *S. defoliaria* with water uptake beginning at about embryonic stages 15-16. An experiment to examine egg diapause in individual egg batches from known females of *S. novaeguineae* also continued. Eggs began hatching in August in the laboratory but no hatching occurred in the field using eggs from the same batches.

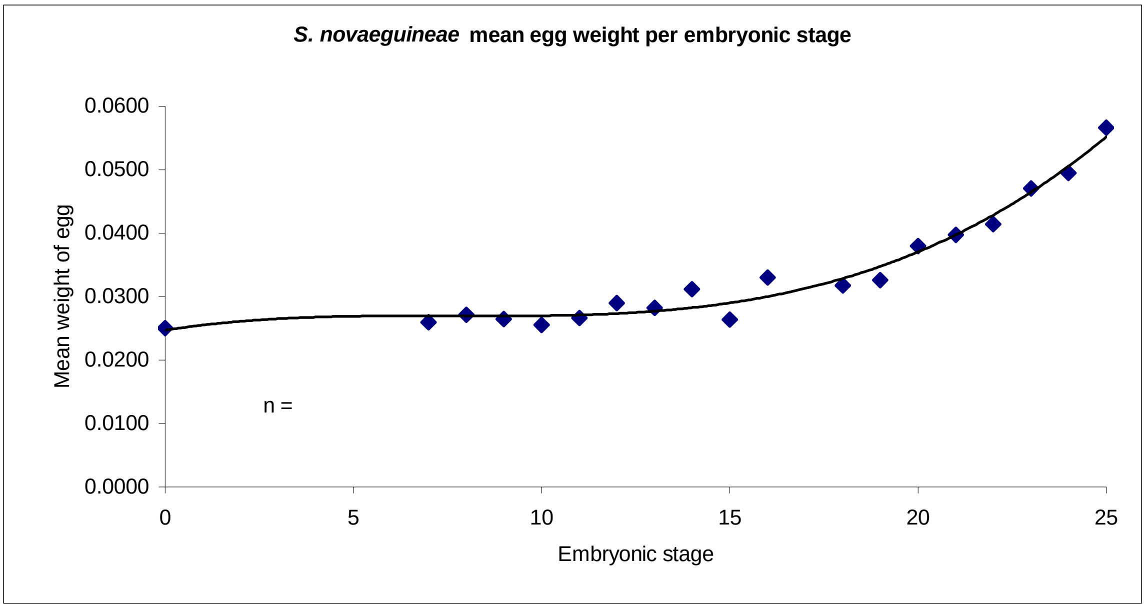


Fig. 16. Water uptake and embryonic development of *S. novaeguineae.*

Future work

Future work will concentrate on the scaling up of the parasitoids production to ensure very high numbers of releases into areas with sexava. Work will also continue on *Stichotrema* redistribution and attempting to get this parasite breeding through *Segestes decoratus* and *Segestidea gracilis*.

Insecticide trial

An insecticide trial was set up to test the efficacy of imidacloprid (Confidor 200SC), and methamidophos (Pilaron 60% W/V SL) with non-treated palms for comparison, as a possible new option for treatment against sexava.

Methods

Four, 10 year old palms (planted 1993) were injected in the normal manner with 13.5ml of imidacloprid (Confidor 200SC), four palms with 13.5 ml of methamidophos 600 (Pilaron 60% W/V SL) and four were selected as controls without treatment. At 1, 4 and 8 weeks after injection, 10 leaflets were collected from an upper frond of each palm and 10 from a lower frond and fed to 4 caged adult and late nymph *Segestes decoratus* for each palm and each level. This gave eight cages and 32 sexava tested per treatment (16 for the upper and 16 for the lower fronds). The leaflets were replaced regularly with fresh ones from the treated palms until each test was completed. Dead sexava were recorded each day and removed from the cages.

Results

Confidor injected at the rate of 13.5ml per palm was not effective for killing sexava and mortality was not significantly different from the control. The results for methamidophos, which was effective, are summarised for the first two tests at one and four weeks after the time of injection in Figures 16 and 17.

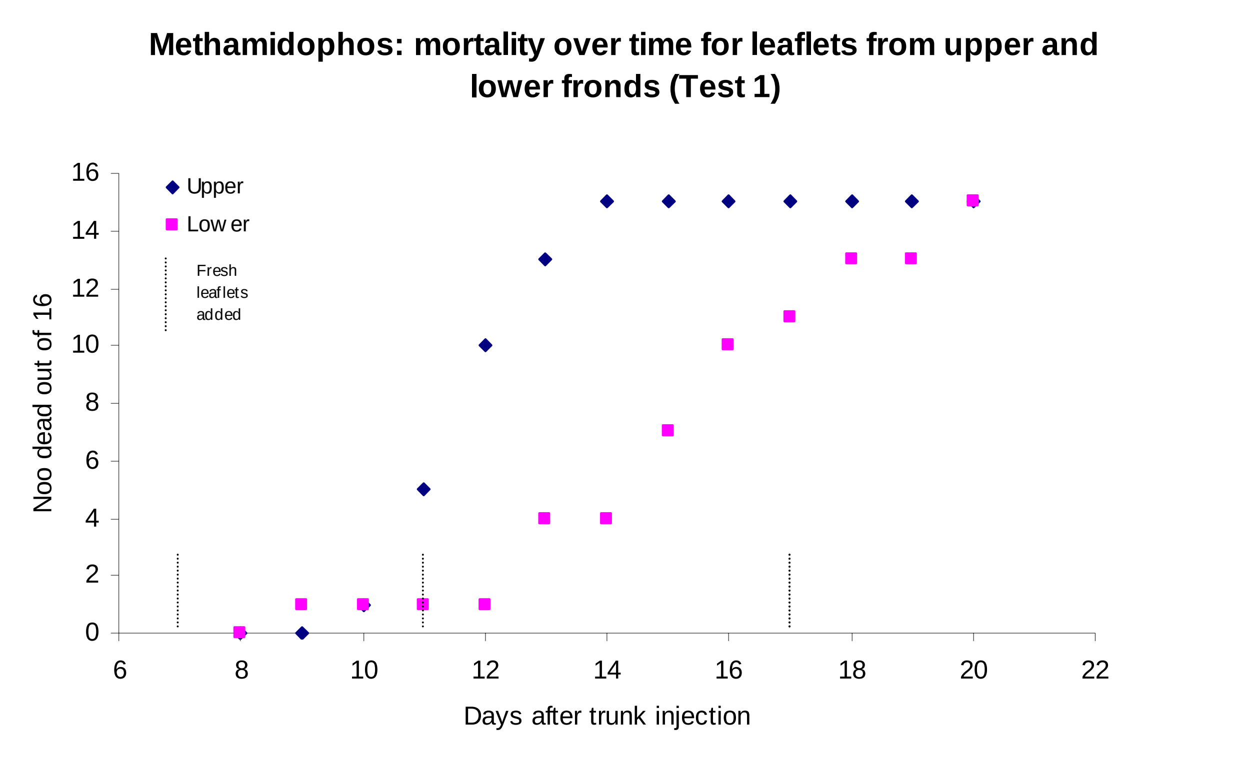


Fig. 17. Results of testing sexava against leaflets from palms treated with methamidophos one week previously.

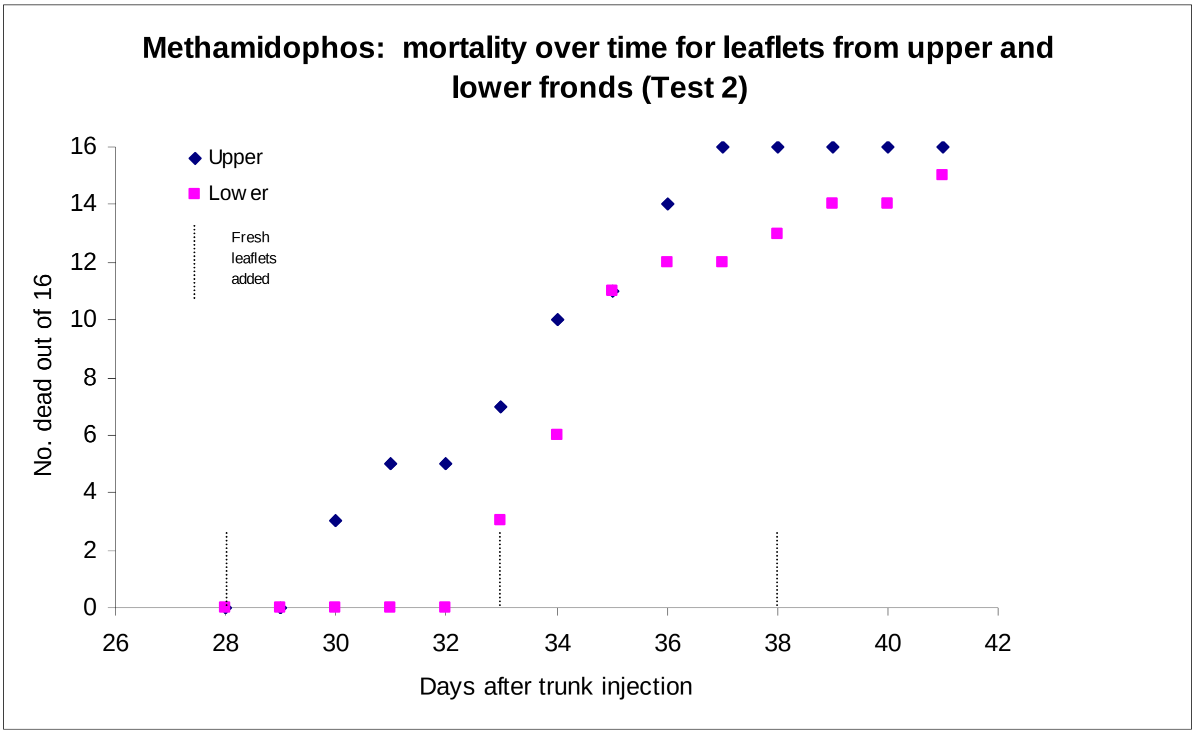


Fig. 18. Results of testing sexava against leaflets from palms treated with methamidophos four weeks previously.

It can be seen from both tests (see Figures 16 and 17) that it took a few days of leaf ingestion by sexava for methamidophos to start to take effect and this was different for the upper and lower fronds with 2+ days for the upper fronds and 5+ days for the lower fronds. This suggests that the lower fronds contained less residual insecticide than the growing upper fronds, although to a lesser extent after 8 weeks. The trial also confirmed that the suggested length of efficacy of methamidophos of 60 days is correct.

3. FINSCHAFFEN DISORDER

Monitoring of oil palms for the symptoms of Finschhafen disorder, and its casual agent, *Zophiuma lobulata*, continued at three sites around Popondetta until December 2004 at Igora, Ambogo and Embi estates at Higaturu, however two sites were abandoned and monitoring only continued at Igora smallholder block, where 60 palms were monitored. No new symptoms were observed, and records of symptoms, frond preference and rate of infection along the frond showed very few fresh symptoms appearing and very low insect numbers per palm for most of the year. Fronds showing symptoms were observed and will continue to be monitored. Egg batches, which were often found at the frond bases, were easier to locate than the nymphs or adults which were observed higher in the crown cluster, or at the frond tips. Leafhoppers were examined for the presence of strepsipteran parasitoids, but none have been found. Checking for the parasitoids will continue, as strepsipteran are known to parasitize this order of insects.

Walk-in cages were been set up to accommodate oil palm seedlings in order to examine the life cycle of *Zophiuma lobulata*. All nymphs died. A further trial will be undertaken in 2005, using coconut seedlings.

A draft proposal for a three year project on the development of an integrated pest management system for the leafhoppers was written for submission to funding agencies.

4. QUEEN ALEXANDRA'S BIRDWING BUTTERFLY

Monitoring transects

Although there are numerous vines growing on the Popondetta plains, QABB is to be found at only two sites, namely Ondahari and the Managalase plateau.

Four monitoring transects, one each at Parahe (50 tagged vines), Pahumbari (48 tagged vines), Lejo (>200 tagged vines) and two sites at Voivoro (79 and 30 tagged vines) are being visited every five months to monitor the presence of stages of QABB. No QABB were found at any site except Voivoro, where six vines each hosted one larva, during the four-monthly monitoring periods. All pupae were subsequently stolen by an individual whose identity was known.

Vine propagation and raising of seedlings

Propagation and the raising of seedlings of the food vine for the Queen Alexandra's Birdwing butterfly has continued. Although the food vine has been described as *Pararistolochia dielsiana*, there is now some debate on the taxonomy of the genus. For this reason, seeds have been collected from vines that are known to have hosted larvae of QABB. The germinated seeds were grown in a small nursery next to the OPRA office at Higaturu and are then planted out in suitable habitats. Although more than 10,000 seedlings were planted out nearly all died, possibly from a fungal infestation. No anti-fungal treatment was undertaken... Cuttings from the chewed-off vines can be raised at the nursery. This option will be investigated during the coming year.

5. OTHER PESTS

Bagworm

Monitoring of bagworm continued at Higaturu (Ambogo estate) and showed that this pest was efficiently suppressed by naturally occurring biocontrol agents. In August 2004, 70% of the bagworms collected had been killed by biocontrol agents.

Minor pests

The sugar cane white grub, *Lepidiota reuleauxi*, was reported for the first time to attack immature transplanted oil palms at Ramu Sugar. Control strategies were developed with the Ramu Sugar Agronomist/Entomologist, Lastus Kuniata. It is hoped that, changes in planting practices will help to alleviate this new potential pest problem.

Attacks by bagworms, cockchafer beetle and gelatine caterpillar were reported as having caused light to moderate damage in parts Sangara Estate, HOP during the year. Control was not necessary, and the areas were monitored monthly for any increase in damage.

During a visit to Kabaiya (Bialla), black palm weevils were found to have been breeding in two oil palms that had recently been cut down by the farmer. It transpired that the farmer had made holes in the live palms to help "increase the yield" and in the process had let the weevils in to do the damage.

6. WEED CONTROL

Mimosa

No additional work was undertaken on *Mimosa* during this year.

Chromolaena.

Records of the distribution of the Siam weed, *Chromolaena odorata* during 2004, in addition to sites reported previously were confirmed as follows:

CHROMOLAENA ODORATA **INFESTATIONS IN PNG**

Date						***C. CONNEXA***	
REPORTED	**Prov.**	**Locality**	**Site description**	**Size ha.**	**Cover %**	Prior release	Establ.
3-Feb-04	Oro	Ilimo	Along the roadsides and in oil palm plantations			8-Aug-04	Yes
7-Aug-04	Oro	Peretembari	Along the roadsides and in gardens			7-Aug-04	

Fig. 19. Infestations of *C .odorata* in PNG during 2004.

The stem galling fly (*Cecidochares connexa*: Diptera:Tephritidae)) being used as a biological control agent of *Chromolaena*, has successfully spread into various areas around Popondetta as far as the Kokoda Highway, where they were introduced in October 2002, and was reported as also being established in infestations of the weed which were reported during 2004. The collection and redistribution of the galls into other areas continued.

Cecidochares connexa **RELEASE SITES (2004)**

DATE rel.	Prov.	Loc.	DESCRIPTION	ha.	Cover %	GALLS released	TOTAL released	Establ.	NOTES
4-Feb-04	Oro	Hangiri	Clumps along the roadsides	0.5	60	100	1,631	No	Re-distributed by Seno (OPRA)
1-Apr-04	Oro	Ilimo	In oil palm plantation			200	1,831	Yes	Re-distributed by Seno (OPRA)
27-Jul-04	Oro	Ombisusu	In oil palm plantation			240	2,071	Yes	Re-distributed by Seno (OPRA)
7-Aug-04	Oro	Isoge	Along the roadsides and in oil palm plantations			500	2,571	Yes	
7-Aug-04	Oro	Peretembari	Along the roadsides and in gardens			500	3,071	Yes	
8-Aug-04	Oro	Hangiri	Along roadsides and in gardens			500	3,571	No	
8-Aug-04	Oro	Ilimo	In oil palm plantation			500	4,071	Yes	
8-Aug-04	Oro	Kumusi	In oil palm plantation			300	4,371	Yes	
8-Aug-04	Oro	Mumuni	Along roadsides and in gardens			300	4,671	Yes	Nat. spread

Fig. 20. Recent distribution of *Cecidochares connexa* in PNG during 2004

This galling fly has also been observed to have spread to other areas of the Popondetta plains. Although it has established and spread to some other areas, there is not yet any evidence of a knocking-back or killing of the *Chromolaena*. The presence of the galls weakens the plant and reduces fecundity and, while only 20 galls are required to kill the weed, infestation reduces the plant density allowing the growth of other plants which are able to out compete with the *Chromolaena*. Observations on damage to some galls found that bush crickets (Tettigoniidae) are most likely to be the main cause, and inspection of the gut content of a small sample of crickets revealed fragments of plant tissue similar to that of the epidermis of the galls. This requires further investigation.

Breeding cages for bulking up the gall flies were received at Dami in November 2004, and a NARI team visited to bring in galls and help with setting up the cages.

Water hyacinth.

There is currently little evidence of effective control by the weevils in PNG. One genus of weevil (*Neochetina* sp.) was released to control the aquatic weed *Salvinia*, but it failed to survive

Other weeds.

It is anticipated that OPRA will be involved in two proposed ACIAR projects on the biological control agents of weeds. The first will be an extension of the *Chromolaena* project, which will be bringing in two new control agents for this weed. The second will be to introduce and distribute new control agents for *Mikania* and *Mimosa* in areas where they are a pest.

There is no indication that *P.pseudoinsulata* is becoming established from releases made in 2002, and there is no information currently available concerning the status of two other biocontrol agents, *C.eupatorivora* and *Lixus* sp.

7. TRAINING

Three issues of the **OPRAtive word** were written and published during the year. The technical notes were: Recommendations for applying and handling of Methamidophos (No.3), Finschhafen disorder in oil palm (No.5) and Sexava pests of oil palm (No.6). A technical note was also written on *Mimosa pigra* but was not published during this reporting period.

Papers were presented in Bangkok, Brisbane and at the Kulim Conference, Mosa:

(i) "The Papua New Guinea Oil Palm Industry's approach to integrated pest management". UNEP/WHO Sub-regional Workshop on the Reduction, Elimination and Management of Pesticides in the Context of the Stockholm Convention and Related Activities of WHO, Bangkok, Thailand, 6^{th}-12^{th} May.

(ii) "Successful cross-species release of Strepsipterans to suppress pests of oil palm in PNG" The International Congress of Entomology, Brisbane, Australia, 15^{th} – 20^{th} August.

(iii) "Integrated pest management strategies used by the oil palm industry of Papua New Guinea". Second Kulim Conference, Mosa, 28^{th}-29^{th} September.

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PLANT PATHOLOGY RESEARCH

(Dr. Carmel Pilotti)

Introduction

The Plant Pathology Section operates with major funding from the EU Stabex Ganoderma Project 4.2. This project is due to end in 2006. The project covers five areas of research namely Disease Epidemiology, Biological control, Long term control (disease screening), Short term control (smallholders) and Mechanisms of infection.

Disease epidemiology involves the monitoring, collection and analysis of survey data provided by the respective plantations as well as a study of the population dynamics of *Ganoderma*. Studies on the mechanisms of infection are also related to disease epidemiology in that early detection of Ganoderma in young plantings will be correlated with later infections in the same plantings.

The Biological control component is directed towards short-term control methods to prevent *Ganoderma* infection in young palms. Efforts are now concentrated on the development of a *Trichoderma* formulation that can be applied to newly pruned frond bases in young palms or at planting in the nursery or field to assist in the prevention of *Ganoderma* infection.

The research on disease screening aims to develop a rapid and reliable screening method to distinguish between palms susceptible and resistant to *Ganoderma* infection.

Short term control for smallholders includes developing recommendations for disease control in smallholder blocks.

The section operates with two scientists, one laboratory technician and two field staff.

1. Disease Epidemiology

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 of disease progress from accurate survey data that will allow growers to make predictions of crop and economic loss

1.1 Disease progress

1.1.1 Milne Bay plantation surveys

Disease incidence appeared to have increased significantly in each Division in 2004 (Figure 1.1). This is mainly due to the incomplete survey in 2003. The 2004 data includes diseased palms that were not recorded in 2003. The low figures for Sagarai are also due to incomplete surveys in both 2003 and 2004.

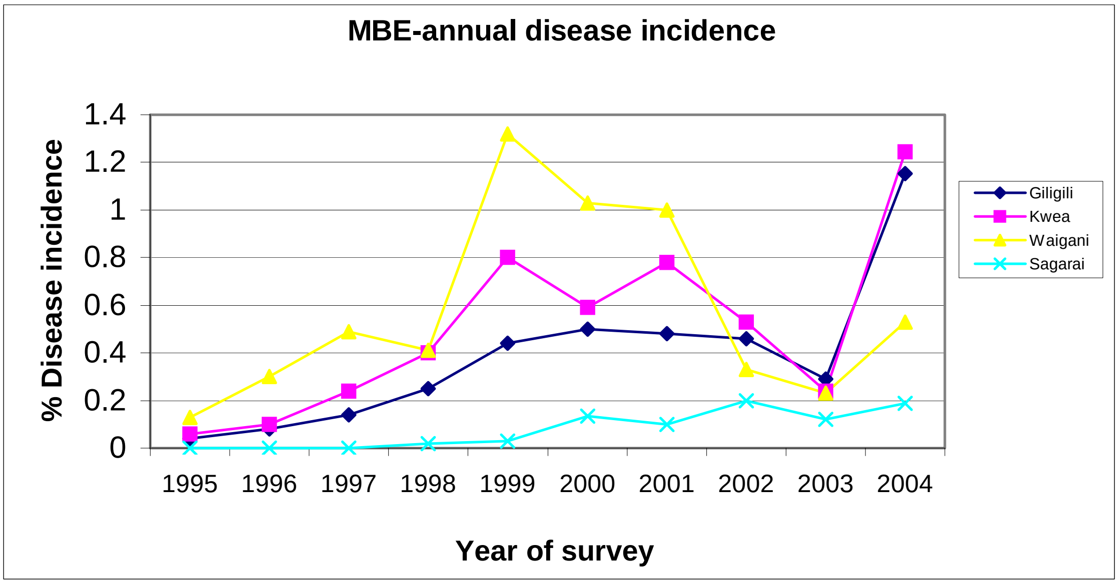

Figure 1. 1 Annual disease incidence (1995-2004) in Milne Bay by Division.

Figure 1.2 shows the annual (2004) disease incidence by category. The number of suspect palms exceeded that of palms with brackets in all Divisions. In Waigani and Kwea the number of suspect palms is three times the number of palms with basal stem rot. The increasing number of palms without brackets is unusual and this requires further investigation.

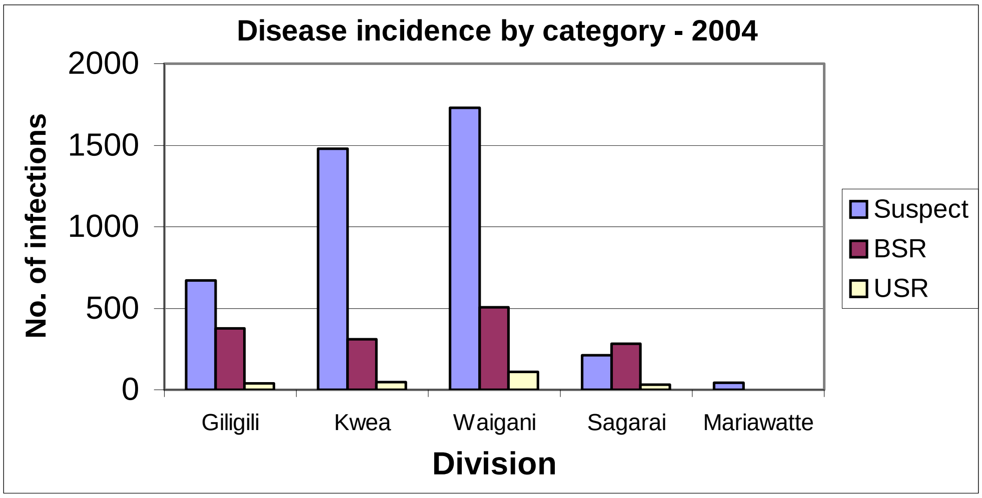

Figure 1.2 Disease incidence for 2004 in Giligili Division, Milne Bay by category. BSR= basal stem rot; USR = upper stem rot; Suspects= no brackets.

The cumulative disease curves for each Division are shown in Figure 1.3. Disease incidence in Waigani is now approaching 6%. Many of the blocks in Waigani are 1986 plantings that are due for replant possibly in 2007. Sanitation in these blocks is therefore important and should include the removal of suspect palms.

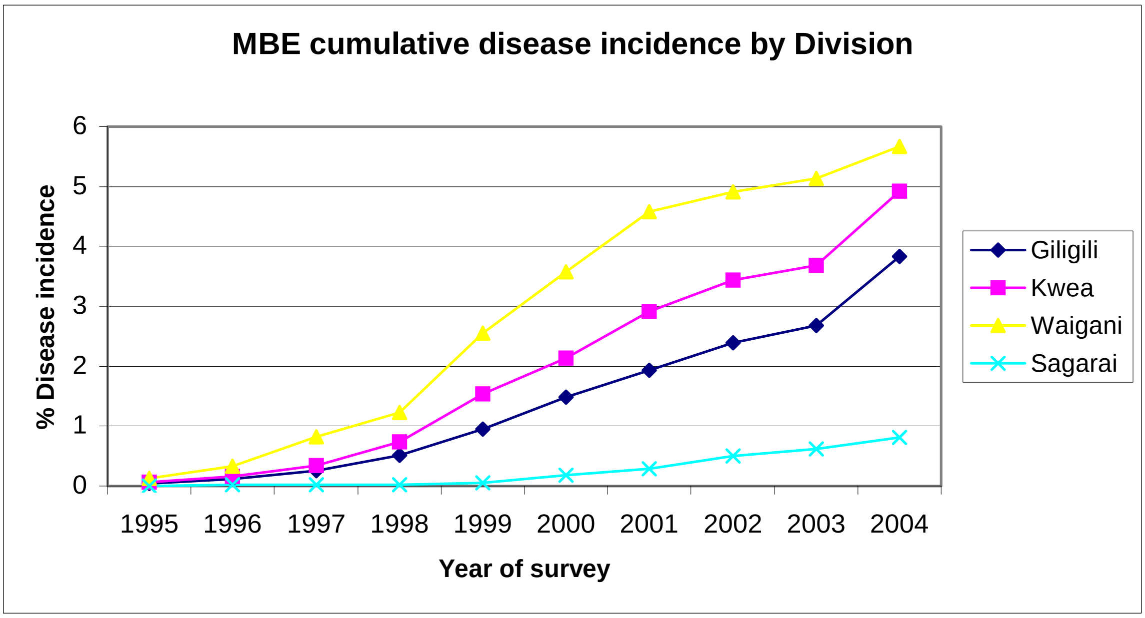

Figure 1.3. Cumulative disease incidence from 1995-2004 for each Division, Milne Bay.

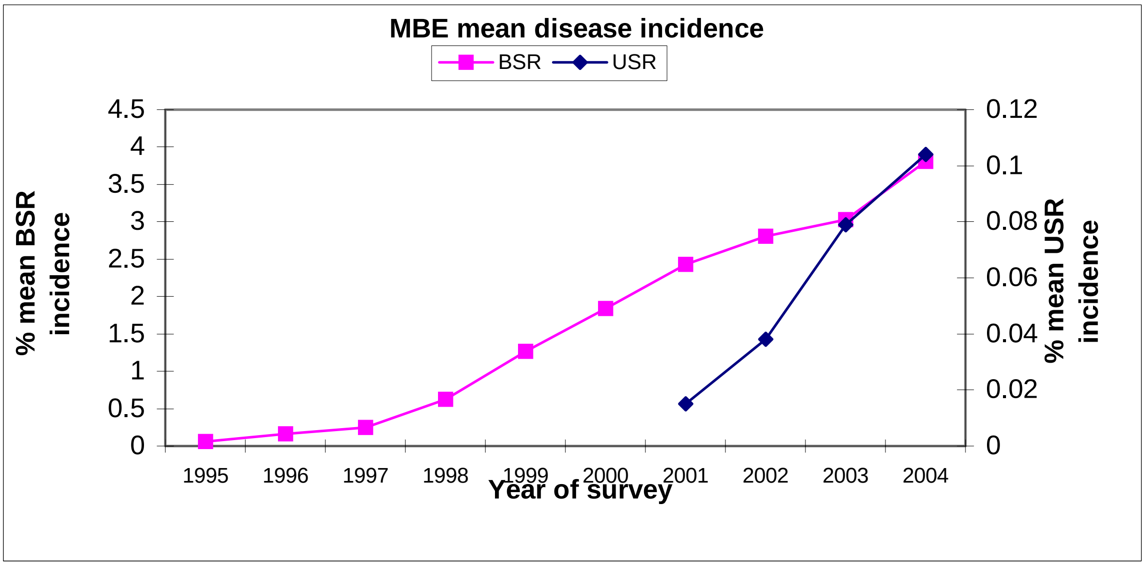

Figure 1.4. Mean incidence of basal stem rot (BSR) and upper stem rot (USR) in Milne Bay.

Figure 1.4 shows the mean disease incidence for the whole plantation in Milne Bay for basal stem rot as well as upper stem rot. Levels of upper stem rot are increasing annually and are now at 0.1%. This is the level of basal stem rot first detected in some blocks in 1995.

Cumulative disease curves by age group are shown in Figure 1.5. Data includes blocks in all Divisions regardless of previous crop history.

Although the disease rate appeared to decline for the 1986 and 1987 plantings in 2003, the rate has increased in 2004. This is mainly attributed to the inclusion of blocks that were not surveyed in 2003 into the 2004 data. The disease rates for the 1990-1993 plantings are lower than that of the older plantings at the same age. This is attributed to early roguing in the younger plantings. It is therefore essential that efficient and timely sanitation be maintained in these areas to minimise inoculum build-up.

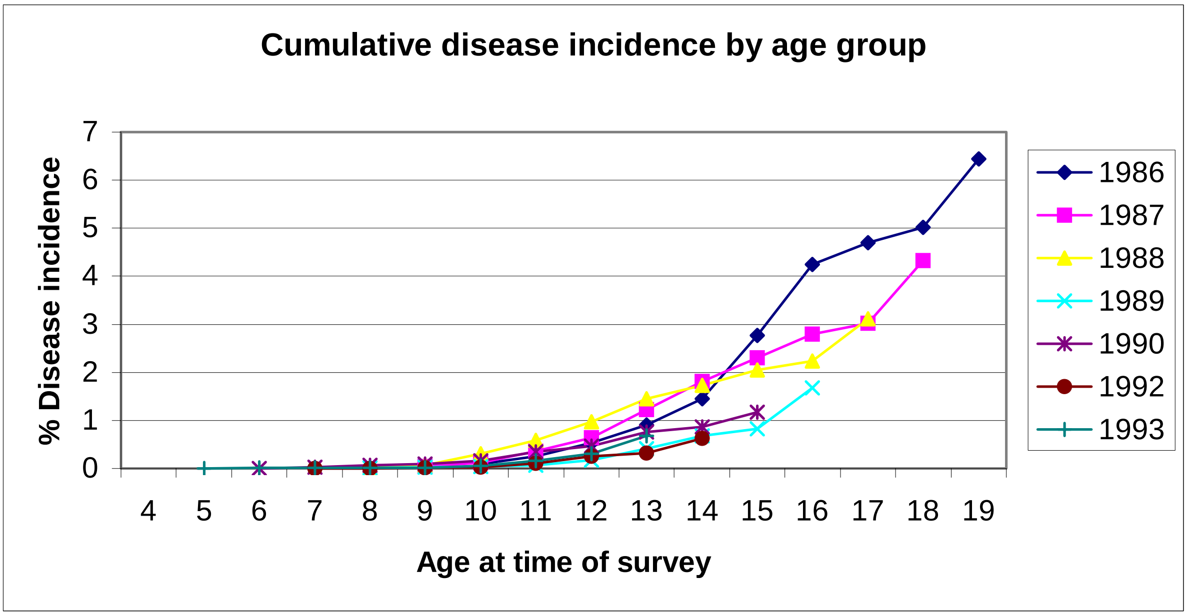

Figure 1.5. Cumulative disease incidence by age group from 1995-2004, Milne Bay.

1.1.2 Disease progress and yield loss assessment

Yield loss assessments in all six blocks under study are shown in Figures 1.6 to 1.11 The annual yield is calculated on a per tree basis taking into account all losses (removals) due to *Ganoderma* and infected palms still standing. It is assumed that all infected palms have ceased production. This is true for all but a small minority of palms that are considered insignificant in this analysis.

It is still too early to quantify, however some yield loss may be occurring in Blocks 6504 and 7501. Yield has declined in both of these blocks since 2000 although this may be due to other factors besides disease levels since the levels of disease in all blocks is very similar.

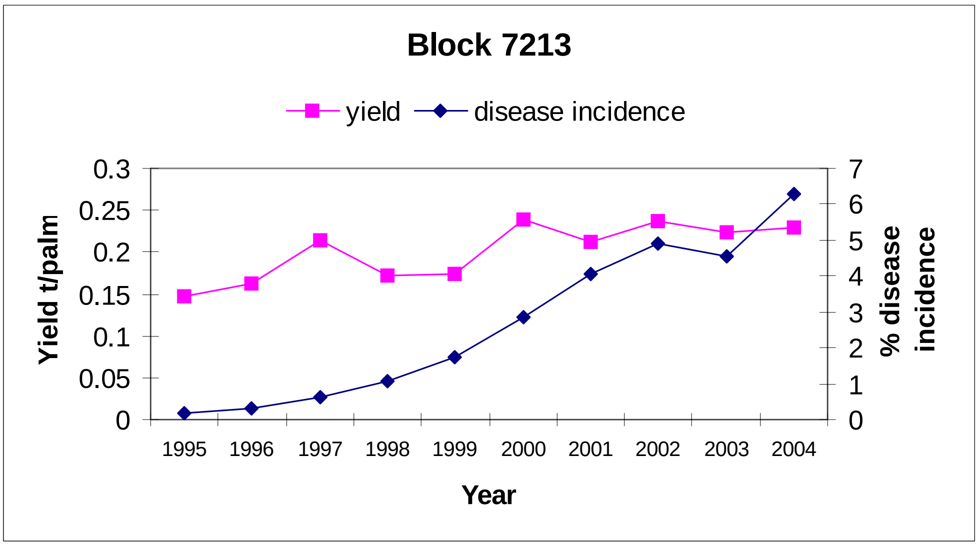

Figure 1.6. Individual palm yield and disease progress in block 7213, MBE.

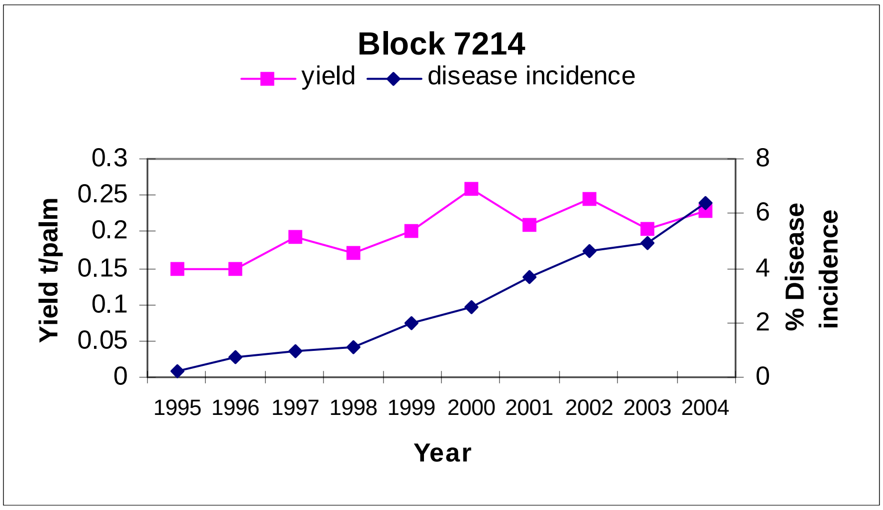

Figure 1.7. Individual palm yield and disease progress in block 7214, MBE.

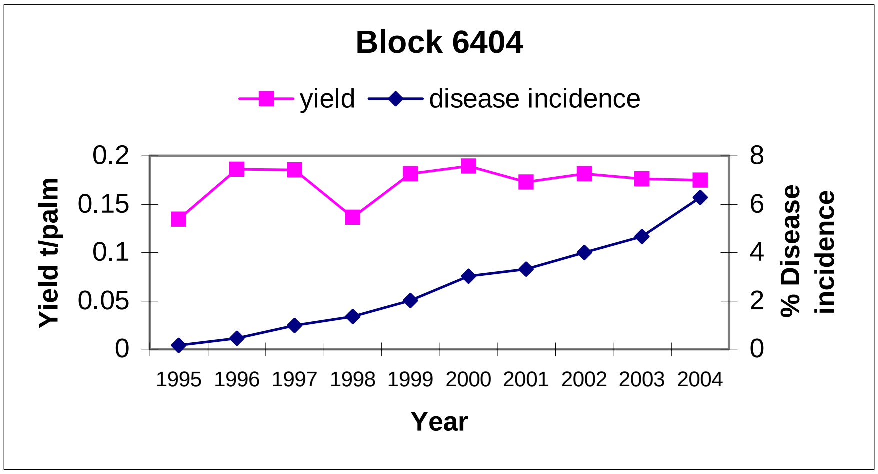

Figure 1.8. Individual palm yield and disease progress in block 6404, MBE.

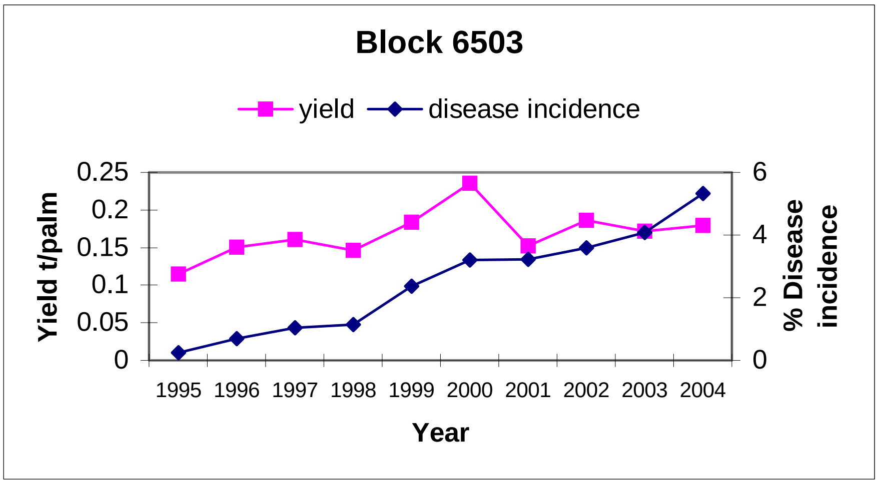

Figure 1.9. Individual palm yield and disease progress in block 6503, MBE.

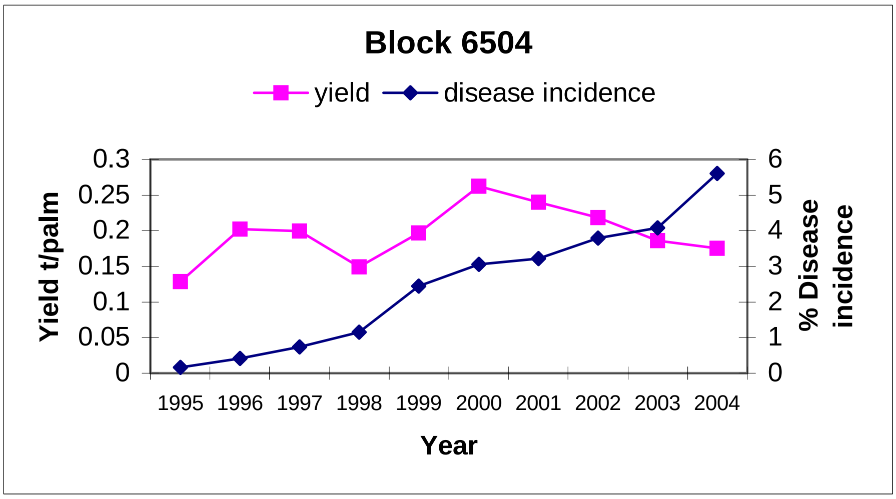

Figure 1.10. Individual palm yield and disease progress in block 6504, MBE.

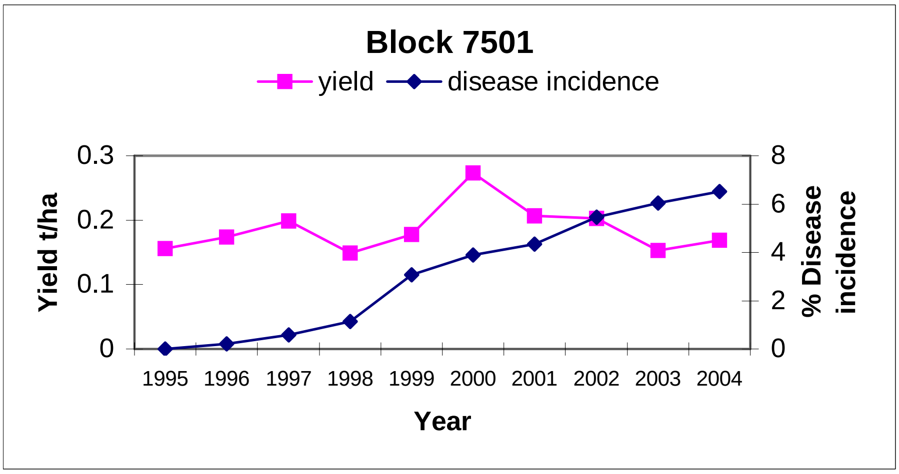

Figure 1.11. Individual palm yield and disease incidence in block 7501, MBE.

Temporal analysis of the Ganoderma survey data indicates that disease progress is linear (Table 1.1). This is unusual, even for monomolecular diseases and indicates that either the disease is still in the early stages of the epidemic or that roguing of the palms is having an effect on disease levels. The latter explanation appears more plausible.

Table 1.1. Disease progress curve approximation and disease rates (slope) in each of the six blocks under study in Milne Bay up to the end of 2003.

BLOCK	PROGRESS CURVE	SLOPE
7213	Linear	0.0078±0.0049
7214	Linear	0.0062±0.00066
6404	Linear	0.0062±0.00030
6503	Linear	0.0058±0.00053
6504	Linear	0.0058±0.00040
7501	Linear	0.0095±0.00038

1.1.3 Environmental effects

The data available on soil types in Milne Bay (i.e. pH and classification) is inadequate to establish meaningful correlations between disease incidence and soil characteristics (see PNG OPRA 2003 Annual Report).

Correlations between cropping history and disease levels have also been poor. Biological factors may be responsible for the large variation in disease levels coupled with inherent soil physical, chemical and biological characteristics so clearly, more detailed soil analyses are required.

1.1.4 Poliamba, New Ireland

Cumulative losses due to *Ganoderma* by planting date are shown in Figure 1.7. Average incidence in the 1989 plantings is 2.79%. Disease incidence in individual blocks ranges from 1 to 5.7% (Medina). These figures are a gross underestimation because they are based on removal of infected palms only rather than actual diseased palms recorded. Since the total number of diseased palms are not removed each year in each plantation, there is an underestimation in the annual disease figures submitted for analysis. Accurate survey records must be kept in order to better estimate the yield losses in New Ireland.

As seen in Milne Bay, disease progress appears to be linear for all age groups.

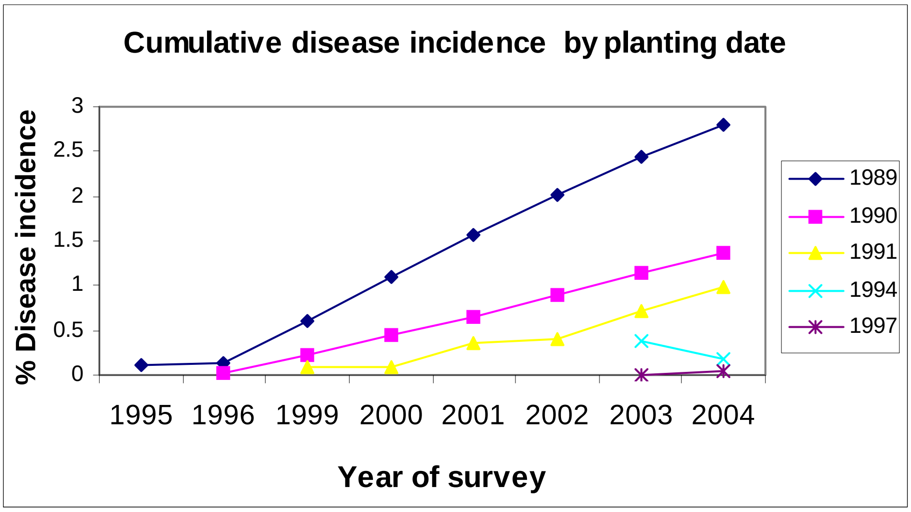

Figure 1.12. Mean cumulative disease incidence from 1995-2004 in New Ireland with age.

1.1.5 Numundo plantation

Average disease levels for 10-11 year-old palms planted in ex-coconut blocks at Numundo in West New Britain are shown in Figure 1.13. Disease levels are particularly high in blocks E3, E4 and E5 (data not shown). It is not known why this is so but could be related to soil or sanitation factors related to the previous crop. The average disease levels in the F fields are significantly lower than that of the E fields. It is interesting to note that the planting density in the E fields is higher (135 palms/ha) than that of the F fields (128palms/ha). The influence of planting density on disease levels is unknown however, it is not likely to be strong since some E blocks had very low disease incidence (data not shown).

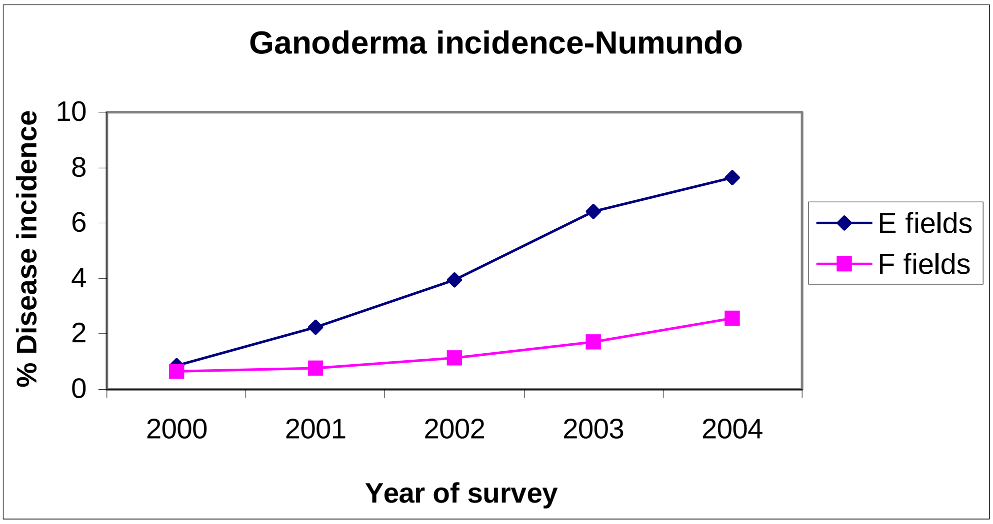

Figure 1.13. Cumulative losses due to Ganoderma at in 1994 (E fields) and 1995 (F fields) at Numundo from 2000-2004.

2. Ganoderma Population Studies

2.1 Milne Bay *G. boninense* population

In 2004, a total of 225 *Ganoderma* specimens and spore prints were collected from Blocks 7213,7214, 6503, 6504, 6404 and 7501. Due to the large number of samples to process, mating studies could be completed only for isolates in Block 7213. The number of common mating alleles is increasing within this Block, however, direct hereditary relationships between isolates have still not been found. There is some evidence that different allele ratios are appearing however; these results have to be verified with additional tests.

An update (from 2003) of vegetative and mating compatibility testing amongst isolates located on adjacent palms within Block 7213 is provided in Table 2.1. As in previous years, the majority of isolates from neighboring palms were genetically distinct indicating infection by unrelated *G. boninense* spores.

Table 2.1. Vegetative compatibility tests between neighbouring palms in block 7213 Milne Bay for 2003 and 2004. Highlighted areas are results for 2003.

Isolate numbers	Position in relation to neighbour	Vegetative test result	Mating test result
820:973	Opposite	incompatible	Nd
766:714	Adjacent	incompatible	Nd
146:821	Opposite	incompatible	Nd
145:767	Opposite	incompatible	Nd
821:816	Opposite	incompatible	Compatible
717:433	Opposite	incompatible	Compatible
761:763 USR	Opposite	nd	1 allele shared
882:976	Opposite	incompatible	Compatible
721:725	opposite	incompatible	1 allele shared
830:149	Adjacent	incompatible	Nd
432:666	Opposite	compatible	1 allele
724:829	Opposite	incompatible	1 allele
727:728	opposite	nd	1 allele
145:600	opposite	incompatible	Nd
717:433	Opposite	incompatible	Compatible
972:710	Opposite	nd	compatible
670:600	Opposite	nd	Compatible
767:816	Adjacent	compatible	Incompatible
597:669	Adjacent	nd	Nd
436:437	Opposite	incompatible	Compatible
142:992	Adjacent	incompatible	Nd
713:992	Opposite	incompatible	Nd
820:973	Opposite	incompatible	Nd
766:714	Adjacent	incompatible	Nd
1055:984	Opposite	incompatible	Nd
1030:829	Opposite	incompatible	Nd
1031:675	Opposite	incompatible	Nd
1167:437	Opposite	incompatible	Nd
1163:670	Opposite	incompatible	Nd
1219:1164	Opposite	nd	Compatible

2.2 New Ireland Ganoderma population

A further 17 *Ganoderma* samples were also collected from the fertilizer trials 251 and 252 in the New Ireland Province. Isolates from these were subjected to vegetative compatibility tests to determine if they were genetically distinct. Results in Tables 2.2 and 2.3 show that all isolates within each trial so far are of different genetic origin. There is a possibility that some of these isolates are related however as a majority of the interactions were weak to medium.

Some plots within the trials remain disease-free. This is interesting and should be investigated further.

Table 2.2 Vegetative compatibility tests amongst dikaryons (brackets) collected in 2003 and 2004 from trial 251, New Ireland. Isolates are mated with themselves as a control.

	914	915	916	917	918	919	920	921	923	925	1011	1014	1015	1022
914	vc	vi	vi	vi	vi	vi	vi	vi	vi	vi	vi	vi	vi	vi
915		vc	vi	vi	vi	vi	vi	vi	vi	vi	vi	vi	vi	vi
916			vc	vi	vi	vi	vi	vi	vi	vi	vi	vi	vi	vi
917				vc	vi	vi	vi	vi	vi	vi	vi	vi	vi	vi
918					vc	vi	vi	vi	vi	vi	vi	vi	vi	vi
919						vc	vi	vi	vi	vi	vi	vi	vi	vi
920							vc	vi	vi	vi	vi	vi	vi	vi
921								vc	vi	vi	vi	vi	vi	vi
923									vc	vi	vi	vi	vi	vi
925										vc	vi	vi	vi	vi
1011											vc	vi	vi	vi
1014												vc	vi	vi
1015													vc	vi
1022														vc

vc=vegetatively compatible; vi= vegetatively incompatible

Table 2.3 Vegetative compatibility tests amongst dikaryons collected in 2003 and 2004 from trial 252, New Ireland. Isolates are mated with themselves as a control.

	926	927	928	929	930	931	932	933	934	1023	1025	1026
926	vc	Vi	vi	vi	vi	vi	vi	vi	vi	vi	vi	vi
927		Vc	vi	vi	vi	vi	vi	vi	vi	vi	vi	vi
928			vc	vi	vi	vi	vi	vi	vi	vi	vi	vi
929				vc	vi	vi	vi	vi	vi	vi	vi	vi
930					vc	vi	vi	vi	vi	vi	vi	vi
931						vc	vi	vi	vi	vi	vi	vi
932							vc	vi	vi	vi	vi	vi
933								vc	vi	vi	vi	vi
934									vc	vi	vi	vi
1023										vc	vi	vi
1025											vc	vi
1026												vc

vc=vegetative compatible; vi=vegetatively incompatible.

3. Collaborative research

3.1 *Ganoderma* epidemiology in palm plantings

Samples were collected from Numundo 1999 plantings in 2004. These samples have not been analysed due to a change in research collaboration. They are currently being processed for analysis in Milne Bay.

4. Susceptibility/resistance screening trials

Objectives: a) To develop an effective and rapid pathogenicity-screening test for basal stem rot of oil palm.

b) To use this screening test to identify susceptible seed lines.

4.1 Nursery screening assays

4.1.1 Rachis inoculation trials

Several experiments in 2004 yielded variable results. The initial experiments were performed to determine the reproducibility of the response within the same group of palms. Figure 4.1 shows the results of two experiments on the same palms repeated two weeks apart with the same inoculum but different incubation periods. As can be seen, only four palms gave consistent results so further experiments were carried out with shorter incubation times and using different inoculum types in an attempt to form larger lesions. Although the solid oil palm and rubber wood produced larger lesion in the rachis tissue, the differences between the progeny were less obvious. There were some significant difference however, amongst the progeny and work will continue when new populations are obtained for screening.

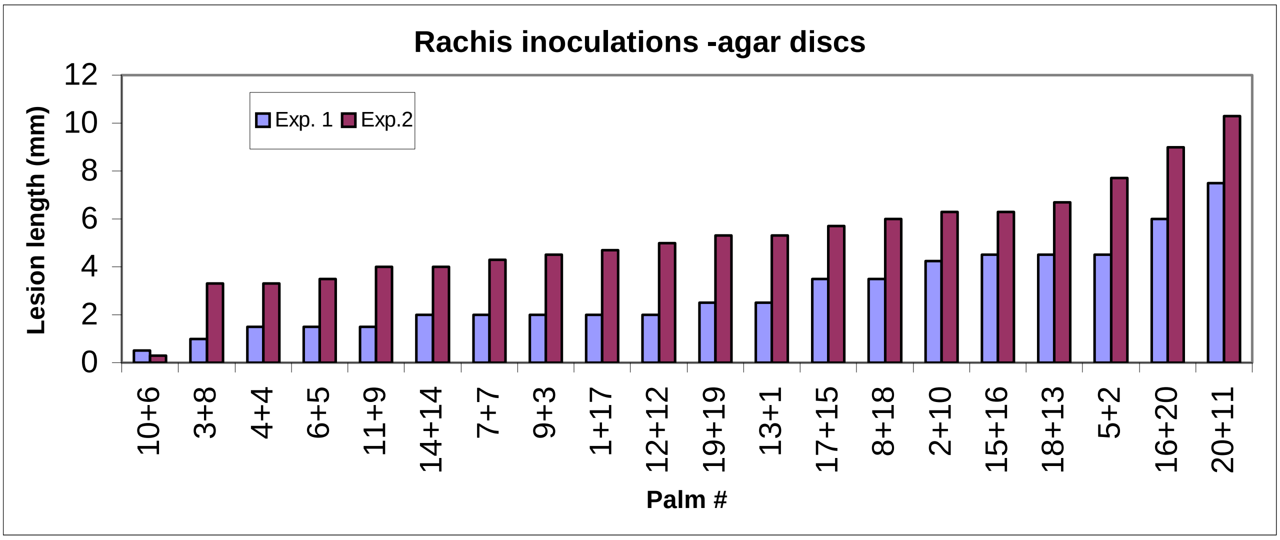

Figure 4.1. Ranking of progeny in order of resistance to Ganoderma infection by the length of the lesion formed within rachis tissue.

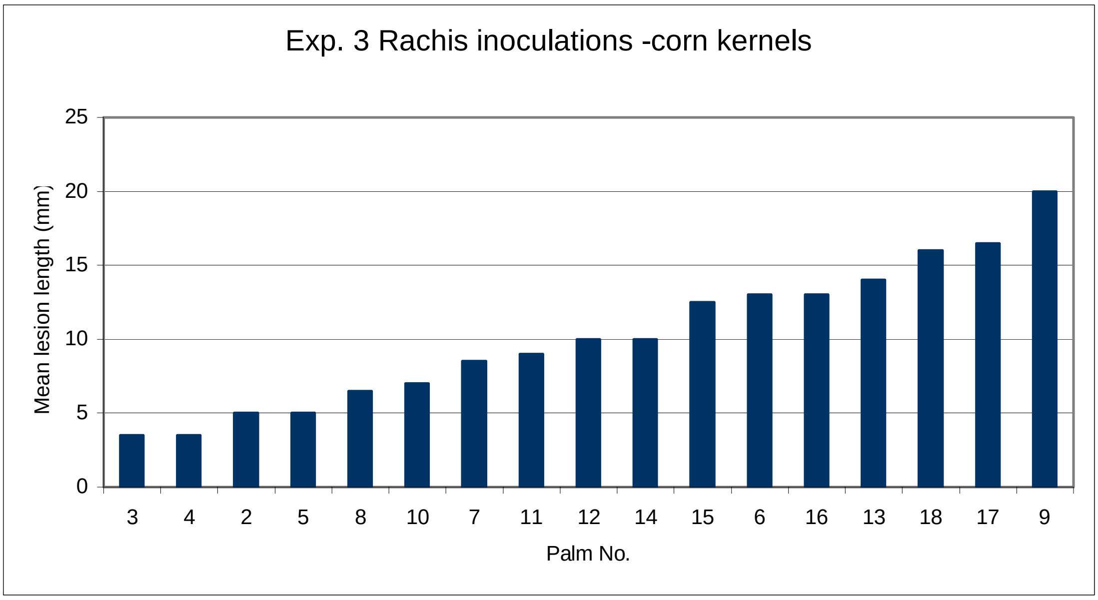

Figure 4.2. Ranking of the same palms in experiments 1 and 2 according to lesion length using corn kernel inoculum.

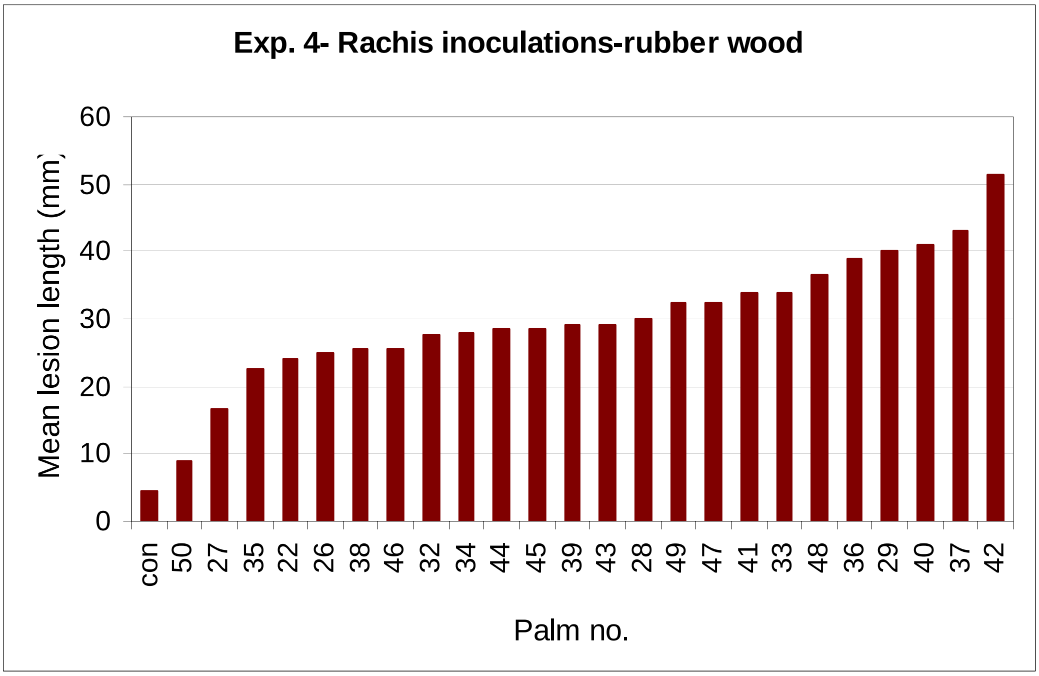

Figure 4.3. Rachis inoculations of different palm progeny using solid rubber wood as inoculum.

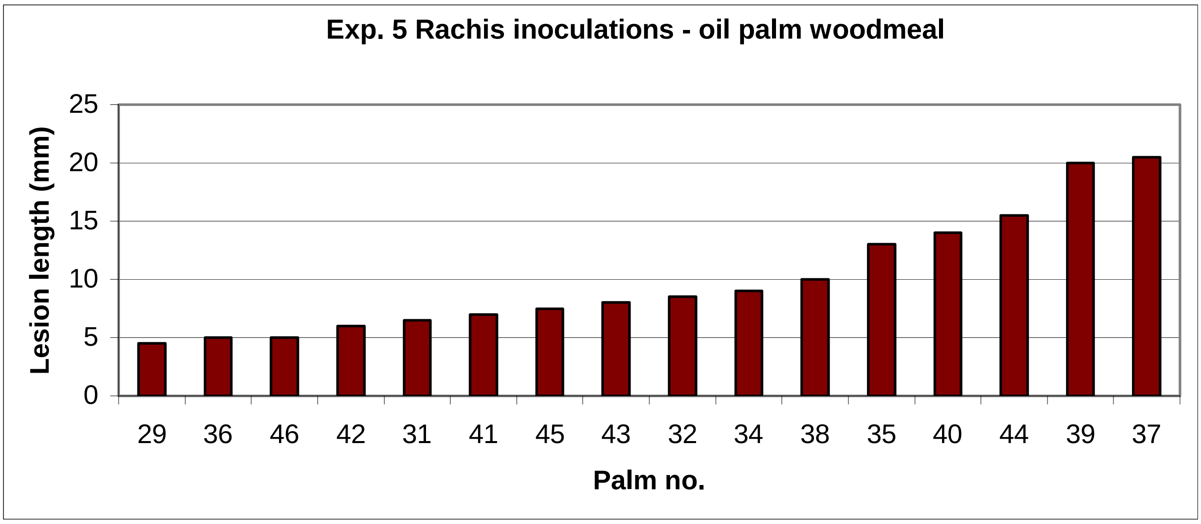

Figure 4.4. Rachis inoculations on different palm progeny using oil palm wood meal as inoculum.

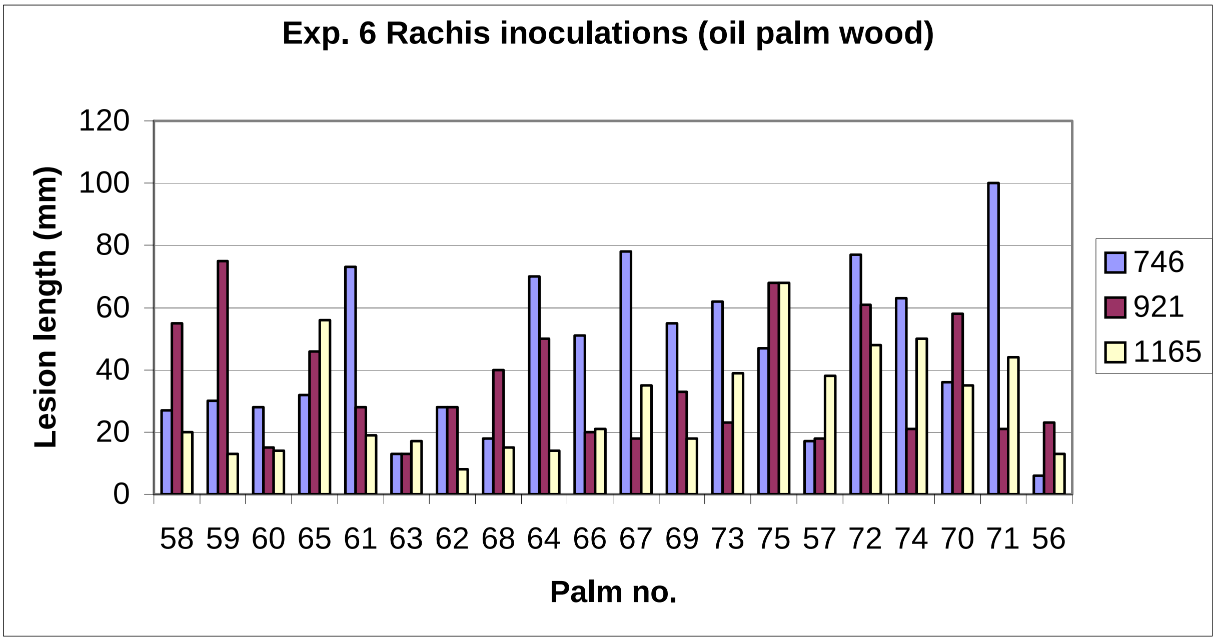

Figure 4.5. Rachis inoculations using three different *G. boninense* isolates on the same palm. Each progeny produced variable results for each isolate.

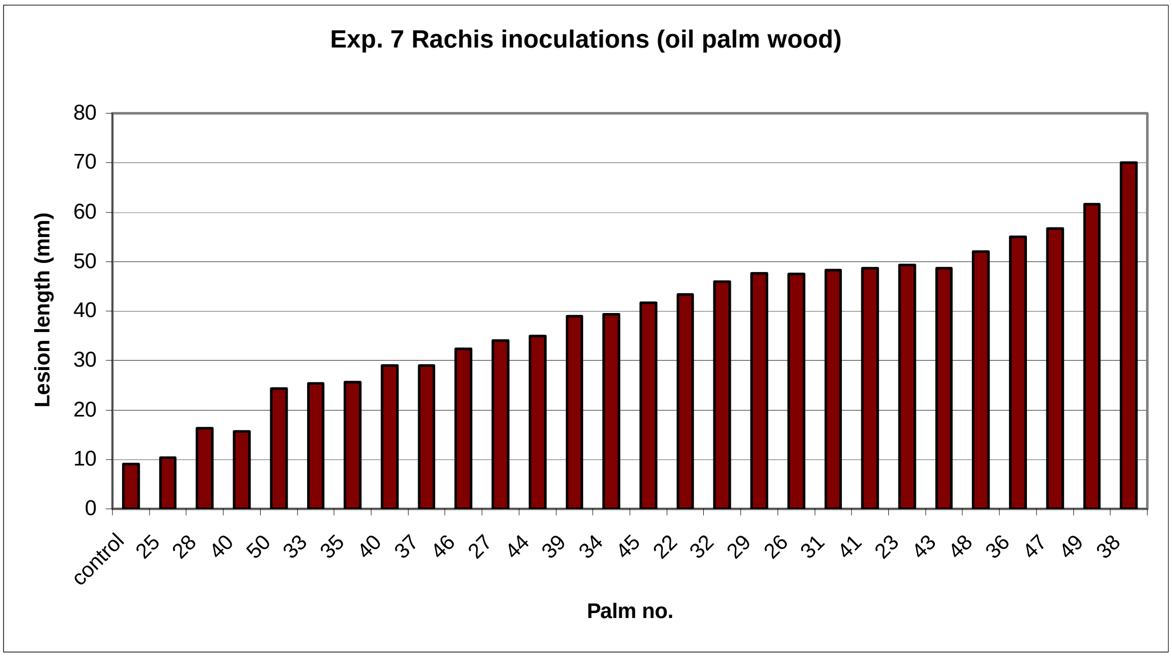

Figure 4.6. Rachis inoculations of oil palm progeny using oil palm wood blocks.

4.1.2 Whole palm inoculation trials

One hundred and fifty palms inoculated in April 2004 were dissected in October and November 2004. These palms had been inoculated with oil palm wood blocks (5 x 5 x 10cm) containing *G. boninense*. Blocks had been placed laterally approximately 3cm below the surface of the soil and others had been placed directly below the bole of the young palm approximately 10-15cm below soil level. A small percentage (6%) of the laterally placed blocks had *Ganoderma* fruiting bodies emerging from the soil surface. However, results indicated that most of the *Ganoderma* inoculum had been killed within the blocks after 6-7months. Only 2 palms developed symptoms with infection in the base. This is the first time that infection has been induced in the nursery in local palms.

4.1.3 Root inoculations

All attempts at root inoculations using the MPOB method failed to initiate infection in nursery palms. In all cases, the G. boninense inoculum did not progress into the bole of the young palms. This method was abandoned in favour of the rachis and wood block inoculations.

Table 4.2. Results of whole palm inoculation experiments to test for susceptibility to *Ganoderma* infection in PNG oil palm.

No. of palms inoculated	Inoculation method	No. infected after 6-7 months
50 (5 controls) (8 months old)	Oil palm wood block -lateral	0
50 (8 months old)	Oil palm wood block- below bole	1
50 (6 months old)	Oil palm wood block -lateral	1

5. Biological control of Ganoderma

Objectives: a) To develop methods for the rapid degradation of oil palm trunks

b) To utilize Trichoderma as a natural antagonist of Ganoderma to prevent Ganoderma infection on cut frond bases.

5.1. *Trichoderma* biological control agents

Sixty-two unidentified *Trichoderma* cultures isolated from the soil and oil palm trunks in Milne Bay were tested against a single *G. boninense* culture (duplicate) *in vitro*. The results indicate that all *Trichoderma* isolates are antagonistic towards *Ganoderma.* In addition, after two weeks of incubation, the *Ganoderma* cultures could not be revived indicating that they may have been parasitized by the *Trichoderma* hyphae. Further tests are underway.

6. Publications, conferences and visits

1. Marshall, R. , Hunt, R. and Pilotti, C.A. (2004). A low cost control method for basal stem rot of oil palm: A Poliamba initiative. *The Planter*, **80** (936): 173-176.
2. Pilotti, C. A., Sanderson, F. R., Aitken, E.A.B and Armstrong, W. (2004). Morphological variation and host range of two Ganoderma species from Papua New Guinea. *Mycopathologia*, **188**: 251-265.