Annual Research Report

2003

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

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Report by the Director of Research

to the

PNGOPRA Annual General Meeting - August 2004

Palm oil is now clearly established as Papua New Guinea's largest agricultural export and is the country's largest contributor to sustainable rural development. Despite the evident success of oil palm in PNG, the industry is facing considerable and increasing threats to its viability from lack of Government support, lack of development & maintenance of essential support infrastructure, lack of social support structures and lack of investor confidence in PNG; especially for long-term rural development investments. These problems are exemplified in the fact that there have been no new 'green-field' projects in the country since 1988. However given the difficulties, the existing oil palm industry in PNG has managed to continue developing and improving, and consistently achieves higher oil yields than its major competitors in Asia. It is the combination of excellent growing conditions, high-quality management and world-class research and development support that allows the PNG oil palm industry to keep ahead of its competitors.

Oil palm research in PNG is carried out by two 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 was formed in 1980, 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, Pacific Rim Plantations Ltd, Hargy Oil Palms Ltd, Ramu Sugar 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 a 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 their financial input to the organization. This is calculated on the previous year's FFB production, as the PNGOPRA Member's Levy is charged on an FFB basis. Voting rights in 2004 are presented below.

A sub-committee of the Board of Directors, the Scientific Advisory Committee (SAC), meets once a year and recommends the research programme for the coming year. Thus the Members can directly incorporate their research or technical service needs into the work programme of PNGOPRA. The Members voting rights within the SAC meeting are the same as for the Board of Directors meeting.

OPIC is responsible for the provision of agricultural extension for the smallholder growers. The link between PNGOPRA and smallholder extension is particularly strong with both organizations having seats on each other's planning and management meetings. Probably more important than this is a presence of a healthy and spontaneous informal communication between the officers in both organizations at both a national and local level.

Members Voting Rights in 2004:

Member	FFB Production in 2003	Votes
New Britain Palm Oil Limited	563,527 tonnes	6
Pacific Rim Plantation Ltd	450,424 tonnes	5
Hargy Oil Palms Ltd	120,406 tonnes	2
Oil Palm Industry Corporation (smallholders)	545,333 tonnes	6
Ramu Sugar Ltd	n/a	1
The Director of Research (Executive Director) also holds one vote		

PNGOPRA, as an organization, is small when compared to the scale of the industry it serves. The size of PNGOPRA reflects a policy decision, which allows a focusing 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 2003, the Member's levy represents 67.8% of the organizations revenue and external grants 32.2%[1]. The Member's levy in 2003 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 carefully structured to meet the needs of the industry as a whole. The Association's Scientific Advisory Committee, on which all Members are represented, meets annually 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, based at Dami Research Station, conducts research into oil palm pollination and the IPM-based control of insect and other pests. 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 large 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 the Association's Agronomy Section.

[1] Government of PNG Public Investment Programme (PIP) Budget 6.1%, European Union Stabex fund 17.7%, and the Australian Centre for International Agricultural Research (ACIAR) 8.4%.

Improving nutrient use efficiency

The first priority of the Agronomy research program was to understand the nutrient requirements of palms in different areas and to determine the response to nutrient inputs. Although that phase of research has been carried out to a large extent, it must still continue as production moves into new areas and different soils. 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 new project is currently being scoped that 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 practices. 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.

In the previous year two major projects commenced. They concentrate on the retention and losses of nitrogen, magnesium and potassium on volcanic ash soils. This year, a new project is being developed to determine the impact of oil palm management on the continued ability of the soil resource to support productive oil palms. Work has already commenced 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.

Most of this year (June 03 – June 04) was spent setting up experiments at Popondetta in Oro and at Dami in WNB Provinces. The experiments included small (1.2m x 1.2 m) surface water runoff plots, large surface runoff plots, installing suction cups, installing soil moisture monitoring access tubes and setting up open-air lysimeters. Data and water and soil samples were collected from the experiments over the wet season and they will be analysed later this year at Massey (NZ). Results from analysed samples and collected data will be put together to model N loss from the oil palm growing agro ecosystems.

A preliminary look at large surface water runoff data from Dami indicated that during a rain event of 120 mm/day, mean surface water runoff was 8 %. However, for all normal range of rain events (5 - 60 mm), surface water runoff was less than 4% with a mean of 0.74%. At Dami, 96 – 99 % of rainwater infiltrates the soils. This has significant consequences on the loss of nutrients through leaching. Water samples collected from suction cups and underground lysimeters will be analysed for nutrient contents and with calculated volume of water drained through the soil, the amount of N loss beyond the oil palm rooting zone will be estimated. A preliminary look at surface water runoff data from the small plots suggested runoff water from the harvest path was greater than the other zones under the palms. This has important implications on the source of water and sediment yield from the plantations. Water turbidity is also measured using a turbidity meter and this will indicate the amount of suspended sediments loss from the plots.

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 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.

Understanding responses to fertiliser trials in West New Britain

A third major project that commenced last year 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.

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.

Providing technical support

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

Entomology Programme

Insect pollination

During the year, new funding through EU Stabex was sought and a two-year project approved in July. The Pollination 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.

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. A further, previously undescribed, stage in the life cycle of the internal nematode was discovered. The finding suggests 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 shell 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 and begin producing more young. Third instar infective nematode larvae have been found to be passed out with, and 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

Further sampling of weevils from New Ireland confirmed that there are no internal nematodes on the island. Monthly samples and other collections and dissections of weevils from various sites in West New Britain Province and Oro Province have shown clearly that comparatively high (20% and above) internal nematode infection rates are only found regularly in areas of higher rainfall (e.g. Kapiura and Bialla in WNBP and Mamba in OP). 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 infection 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 other factors.

Nematode-free (both external and internal) stocks of weevils derived from New Ireland and Haella Plantation WNBP were established in the laboratory by developing new techniques for eliminating the nematodes and for breeding the weevils. These stocks were used for the introduction of nematode-free weevils into test plots at Ramu Sugar where previous surveys had shown that weevils were not present. Four test plots of young oil palm were selected and between 6,000 and 12,000 weevils were released at each site. By 2004 the weevils were well established and had spread to the other test plots as well as some older ornamental palms that were in the area.

A new quarantine facility at Dami was designed to NAQIA specifications and was built and finished during the year. The facility has already been used for the production of nematode-fee weevil stocks and allowed quarantine methods to be tested. The facility will be used for quarantining African weevil material as part of the new pollination project.

Future work will concentrate on the objectives of the new pollination project; particularly understanding the relationship between the pollinating weevil and the male and female inflorescences, and the biology and ecology of the nematodes

Sexava Integrated Pest Management (IPM)

The egg parasitoid, *Leefmansia bicolor* continued to be reared in the laboratory in sexava eggs and then released into oil palm growing areas. With the advent of regular checking for the presence of sexava eggs in the ground at outbreaks, good reservoirs of *Doirania leefmansi* were found and breeding stocks re-established. During regular fortnightly sampling of eggs from the ground in an outbreak results showed that parasitism levels of *Doirania* reached 56% in *Segestes decoratus* and, with a life cycle of about 45 days, must have gone through about six generations during the study period. Even sexava eggs close to hatching were found to be parasitized.

The results and other observations showed that *Doirania* are able to find the eggs of sexava in the ground up to depths of 2cm and, because of their high reproduction rate (250 wasps per egg) they are very efficient parasitoids. During the year, approximately 205,000 *Leefmansia* and 1,400,000 *Doirania* were bred and released into a total of 27 sites where there were low levels of sexava.

Between July 2002 and November 2003 no *Stichotrema dallatorreanum* were found during sampling and dissection of sexava from some of the release sites used during the EU Stabex project between 2002 and 2003. In November 2003 a routine check on an outbreak at Kabaiya (Bialla) showed that high numbers of *Stichotrema* were present in *Segestidia defoliaria*. Subsequent studies showed that the parasitoids had effectively suppressed the outbreak of sexava in a 300Ha area. Surveys showed that *Stichotrema* were well established in Navo Plantation and in some smallholder blocks around. 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* on WNB and *Segestidia gracilis* on New Ireland) has the potential of long-term suppression of this pest.

Regular sampling of sexava eggs from the ground in an outbreak over nine months and a large experiment in the laboratory over six months, have helped to understand the process of embryonic development over time including the monitoring of eggs arresting their development (diapause). The studies show that *S. decoratus* appear to have two periods of diapause:

1. An initial diapause that is highly variable and pre-determined. Such a diapause may last from 16-days to over 9-months and ensures that eggs laid, even in large numbers at the same time, can hatch over prolonged periods of time.
2. A late diapause where embryos can develop up to 'close to hatching' and then hold up hatching if conditions are not suitable.

The similar results from the weighing and dissecting of *S. defoliaria* and *S. novaeguineae* eggs suggest that they may also have two diapauses.

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 go through their initial diapause and then go into 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. Depending on the numbers of eggs in the late diapause, the subsequent outbreak may be noticed during that generation or may take another generation or more to reach damaging numbers. This is likely to be what happened at the end of 2002 and during 2003 where the affect of the mass hatching in late 2002 was felt throughout 2003.

Because of the potentially long initial diapause a proportion of eggs may still be viable when the affect of a second trunk injection (done at the normal 12-weeks after the first) has worn off. This could lead to further outbreaks over time and would help to explain why there are so called "hot spots" where outbreaks keep reoccurring.

These findings have caused a rethink on IPM control decisions. When there 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 hit as many nymphs as possible, but taking into account any damage occurring and avoiding further egg laying; i.e. the population should not have mature adults present before the treatment. Parasitoids should suppress any remnant populations.

Future work will concentrate on further redistribution of *Stichotrema* and attempting to successfully parasitize *S. defoliaria* and *S. gracilis* before distribution into areas where these species occur. In addition studies will examine further the nature of the two sexava egg diapauses in order to help with predictions of outbreaks and to improve control decisions.

Finschhafen disorder

Long term monitoring and individual studies of Finschhafen disorder on oil palm, caused by *Zophiuma lobulata*, have indicated that the symptoms appear about 6 months after attack. However the long-term data is showing that only low numbers of *Zophiuma* have been present over two years yet the symptoms continue to appear. A long-term project is required on this disorder.

Queen Alexandra's Birdwing Butterfly(QABB)

Work continued on the propagation and replanting of the host plant of QABB (*Pararistolochia dielsiana*). From April, 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). Logistical help was also provided to encourage the formation of Wildlife Management Areas within the Popondetta plains.

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 of *Chromolaena odorata* was successfully introduced into Oro Province. The galls have been redistributed from the original release site.

Pest outbreaks

The Entomology Section has continued with routine advisory and pest monitoring work. A total of 70 visits to areas with reported pest damage were made of which 58 where due to Sexava.

Plant Pathology Programme

Stem rots caused by the fungus *Ganoderma boninense* are a major long-term threat to oil palm growers in PNG.

In 2003, an extension to the EU Stabex supported Ganoderma Project was approved. This extension ensures funding for *Ganoderma* research until 2006. The project extension encompasses three broad areas of research concerning the control of the *Ganoderma* diseases, 1) Epidemiology, 2) biological control and 3) resistance screening.

Epidemiology

Understanding the processes of disease development and its spread are a major objective of our research into the *Ganoderma* disease of oil palm. Studies into the population dynamics of the fungus and its secondary spread within mature palm stands are continuing. Research results continue to implicate basidiospores as the main mode of dispersal of *Ganoderma* and the primary mechanism of disease development. However, disease patterns gathered from mapping of affected palms within oil palm stands indicate that clustering is increasingly evident. Despite this, secondary disease spread by root-to-root contact is not evident from genetic analysis of *Ganoderma* isolates on individual palms. These results emphasize the complexity of this disease.

The current lack of understanding of disease etiology is a hindrance to the accurate determination of the length of the disease cycle, and also to the development of suitable pathogenicity assays.

Aside from the biology of the pathogen, there are other factors that contribute to disease development. Some of these predisposing factors include host genotype, previous crop history, soil characteristics, nutrient levels and soil moisture conditions. Our studies aim to incorporate these factors into the disease analyses in order to determine correlations between these factors and disease prevalence. Thus far, single factor correlations have not been clear and it is apparent that multiple factors are influencing the development and proliferation of disease in certain areas. Future research in this area will involve a holistic approach in the design of field experiments that will allow some of these issues to be resolved.

Biological control

The reluctance within the PNG oil palm industry to utilize fungicides as a preventative measure for *Ganoderma* infection is based on environmental concerns and doubts about the efficacy of fungicide treatments. For this reason, our research has targeted naturally occurring 'biocides' within the oil palm cropping system for the control of *Ganoderma*. Indigenous and naturally occurring agents as selected so as to cause minimal disturbance to the already altered agro-ecosystem and to avoid introducing new species into PNG. Two micro-organisms (both fungi), which have been targeted are *Thielaviopsis (Ceratocystis) paradoxa* and *Trichoderma* spp.. Both of these fungi are ubiquitous in the PNG oil palm agro-ecosystem and have been selected for further testing.

Several pilot trials using *Thielaviopsis* to break down oil palm trunk tissue have shown that under ideal conditions of high moisture, colonization of woody tissue by *Thielaviopsis* is excellent. Coverage and penetration of palm wood tissue is also satisfactory under less than ideal conditions however, basal tissue is not adequately degraded; this has practical implications.

Trichoderma spp. are non-pathogenic fungi which have strong antagonistic and sometimes parasitic reactions to other fungi. A number of species are used commercially as biocides against pathogenic fungi, mainly basidiomycetes to which class *Ganoderma* belongs. *Trichoderma* species are used in South East Asia with limited success against *Ganoderma*. Sixty-three isolates of *Trichoderma* have been collected from PNG. *In* *vitro* tests against *Ganoderma boninense* isolates indicate that the antagonism is strong. The challenge is to bring this effectiveness to the field given the complex microenvironment in which the fungus coexists naturally. To this end, basic ecological studies are to be undertaken before any large-scale field application is conducted.

Resistance screening

It was recognized at the beginning of this project that host resistance was the key to long-term, effective, and sustainable control of *Ganoderma* stem rots. As a consequence, the principle objective of the *Ganoderma* research programme is to develop a rapid screening technique to differentiate resistant or susceptible oil palm progeny. Early tests were unsuccessful and alternative approaches have been highlighted in the extended phase of this project.

A large number of palms have been tested with a several inoculum types. So far, symptoms have not been able to be induced in Dami seed lines regardless of the incubation period. More drastic measures have now been taken and the methodology used by SE Asian workers has been adopted in an attempt to reproduce basal stem rot in nursery palms. One hundred and fifty palms are currently under study using a larger inoculum size. Palm age may also have a bearing on the success of this technique.

Recent work on rachis inoculations is proving more fruitful but it appears that like 'whole' palm methods, inoculum size is a critical factor for infection. In addition, reproducibility of the test must be achieved before we can begin to test different progeny lines. We are pursuing this line of investigation.

Awareness

Training and extension has continued to be an integral part of the Association's plant pathology activities. Close collaboration is maintained with plantation field-managers and smallholder extension officers to ensure adequate sanitation standards for disease control. Technical advisory reports will be a focus in the coming year.

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, 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 & 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
July 2004

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, a new project is currently being scoped that 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

Two 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. We are now commencing to measure the generation of mineral N in the soil profile (mineralisation) and the concentration of N in runoff and leachate water. Soil, water and litter samples from the experiments have been collected and will be analysed later this year at Massey University. Putting these results together will allow the first estimate of N losses by leaching and runoff.

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 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. 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.

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 year 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 treatments. 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. 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. This is the subject of a new proposal currently being developed with ACIAR, 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 was measured so that the amount of nutrient in the trunk can be estimated from a single sample. This information, together with that from a new project on maintaining the soil resource, 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. 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 will be commenced in 2004. Those trials were closed at the end of 2002. 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. 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. Trial 136 (monthly tissue sampling) was closed mid 2003, although fertiliser application continued. Yield recording commenced in Trial 139 (Spacing, Kumbango) in 2003.

Trials relating to the Mg project were at various stages of commencement in 2003. Setup of Trial 144 (Waisisi) was completed, and the designs for Trials 145 (Walindi) and 146 (Kumbango) finalised. These trials will be established during 2004.

Trial 136 (monthly tissue sampling), showed little variation in nutrient levels over the last six months of sampling, except for B, rachis K and possibly N. Looking at the trial over the 6 years, there is a clear trend of decreasing concentrations of N, P, Ca, Mg and Cl at Haella; and of N at all sites. In Trial 137 (Systematic N, Kumbango), there was a small but significant response in FFB to N in its first year with the optimal rate around 5 kg AC/palm. In Trial 138b (Systematic N, Haella), there was no yield response in the second; however, there was a response in tissue N concentration. Trial 403 (systematic N, Kaurausu) showed its first response to N in this, the third 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 Trial 148. The first of the Mg trials (Trial 144; Mg & K, Waisisi) to be established has not yet shown a yield response but has shown a significant response in Mg deficiency symptoms with Mg fertiliser. This is the first time in WNB Mg symptoms have responded to Mg fertiliser.

West New Britain Province (Hargy)

The factorial trials 204, 205 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. 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 2 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) again showed no significant response in yield, although 211 showed significant, but small, responses in single bunch weight. In the first year of Trial 213 (N, P on high ground) yield showed a significant response to AC, although yields overall were generally low.

Oro Province

In the third 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). Increasing MOP significantly increased yield, SBW, frond length, leaflet width, rachis K, and rachis ash in Trial 329 (Factorial, Mamba); Kieserite increased leaf Mg but had no effect on yield. Treatments for Trial 330 (N x S Grasslands) had not been applied in this trial because of inherent variability. Trial 333 (Mg & K Sources) has been marked out with treatments to be 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. SOA increased N concentration in frond-17 rachis and in trunk; MOP similarly increased K concentration in frond-17 rachis and in trunk. The application of POME in Trial 512 has had no effect on yield at Waigani over the last 5-years.

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 2003 to previous years. MOP had a major effect on yield in both trials. SOA has had no effect in Trial 251 but continued to have an effect in Trial 252. 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 2004. Trial 254 (B trial) has been marked out and will be implemented in 2004 with a slight change in treatments.

Ramu Sugar

Trial RM 1-03 (Factorial Trial on Immature Palms) was set up in November 2003. 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.

Spacing/thinning trials have not yet produced yield data. 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 first year of recording revealed increasing yield with increasing inter-row spacing. A range of cover crops was planted in all three trials in 2002/2003, and preliminary results from 331 are presented. The effect of spacing was significant on yield and number of bunches. However, the weak trend for increased yield with increasing density 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.

The number of spear leaves, generally accepted as an indication of moisture stress, has shown a poor relationship (through regression analysis) with soil moisture status at either the time of counting spear leaves or over the two-week period beforehand. However, closer inspection of the data reveals a ‘boundary effect’ that indicates at high soil moisture the number of spear leaves are low, but at low soil moisture the number of spear leaves is unpredictable.

BACKGROUND INFORMATION

STAFF

Senior Agronomist

Dr. Mike Webb (commenced March 2004)

Dr. Paul Nelson (Departed December 2003)

Agronomists

Mr. Murom Banabas (conducting PhD)

Mr. James Kraip, Islands Region Agronomist (commenced June 2003)

Mr. Thomas Betitis, Islands Region Agronomist (departed May 2003)

Assistant Agronomists

Ms. Rachael Pipai, Dami (commenced February 2003)

Mr. Winston Eremu, Bialla (moved from Poliamba in March 2003)

Mr. Steven Nake, Higaturu (commenced March 2003)

Ms. Jojo Papah, GIS, Higaturu

Field Supervisors

Mr. Paul Simin, Dami

Mr. Jeren Okka, Kapiura (commenced March 2003)

Mr. Graham Bonga, Higaturu

Mr. Wawada Kanama, Milne Bay

Mr. Kelly Naulis, Poliamba (moved from Kapiura in April 2003)

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 2003

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	**Total**
							West New Britain Province						
Navo	650	1325	467	386	391	155	189	35	84	300	202	147	**4331**
Bialla	480	964	712	212	216	194	63	46	51	174	184	143	**3438**
Dami	672	845	617	304	81	292	181	4	64	215	161	149	**3586**
Garu	537	1272	744	360	95	137	221	0	37	121	262	225	**4011**
							Oro Province						
Mamba	604	608	454	215	351	13	194	134	393	356	683	442	**4447**
OPRA	443	298	305	281	236	20	101	44	229	192	451	216	**2815**
Embi	973	236	225	180	141	19	45	48	90	307	679	286	**3229**
Ambogo	390	365	370	214	172	20	110	22	243	179	126	198	**2409**
							Milne Bay Province						
Waigani	99	110	144	249	121	184	217	93	38	77	47	157	**1533**
							New Ireland Province						
Poliamba	860	539	449	345	368	399	220	384	251	233	287	467	**4802**

Monthly and annual sunshine hours in 2003

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	**Total**
							West New Britain						
Navo	123	84	80	126	88	164	254	292	316	263	123	-	**1923***
Bialla	189	112	233	247	251	211	316	264	328	235	223	264	**2873**
Dami	129	70	99	190	186	127	183	229	224	186	164	178	**1964**
							Oro Province						
Mamba	144	120	109	146	156	nd	64	158	154	nd	175	158	**1392***
OPRA	126	146	115	163	180	44	101	183	175	156	183	191	**1763**
							Milne Bay Province						
Sagarai													
							New Ireland						
Poliamba	95	155	154	137	174	197	171	185	147	170	153	125	**1863**

- Data missing for June and October.
- nd – no data collected

NUTRIENT CYCLING AND SOIL FERTILITY

NITROGEN LOSSES FROM OIL PALM ON VOLCANIC ASH SOILS

(M. Banabas)

(*Results and discussion of work carried out from July 03 to July 04*)

Introduction

From July 03 to July 04, work was concentrated mostly on the setting up of experiments and collecting water and soil samples. The samples were going to be analysed later at Massey University. Therefore little is reported in terms of results and discussion.

Nitrogen dynamics in soils is related to soil water balance. The experiments set up during this phase were to look at various aspects of soil water balance and taking water samples to determine soluble N concentrations leaving the oil palm growing system through surface water runoff and leaching processes. Results from analysed samples will be used to model N loss from the oil palm growing agro ecosystems with assistance from supervisors at Massey University during the next phase. The experiments were set up at Popondetta in Oro and at Dami in WNB Provinces.

a) Through fall variability measurements

Through fall was measured at PNGOPRA Popondetta site at where other N Loss experiments were monitored. To measure through fall, 200 litre steel drums (57 cm diameter) were cut in half and painted inside to stop rusting. The half drums (5 of them) were placed from the palm base up to centre of 2 palms. The edge of the first drum was 40 cm from the palm base and the other 4 were 30 cm apart up to midway from the adjacent palm. Another half drum was placed in the centre of 3 palms. Another 2 cut drums were placed in the open next to rain gauge. The weather recording station is ~50 m from the experimental site. To collect stem flow, frond bases around a palm at 1.5 m height from the ground level were removed. A glued square gutter (100 cm x 100 cm) was placed around the stem to collect stem flow. The gutter was positioned at 20 – 30 degrees angle to allow water to flow to the lowest end that had an opening that led to a 200 L plastic drum. Clear plastic was pinned against the stem and stem flow water was collected into the gutter before flowing into the 200 L drum. The top of the 200 L drum was covered with a clear plastic to stop through fall getting into the drum. The setup was replicated 3 times on 3 neighbouring palms.

During rain events, the drums collecting stem flow were emptied as each one became full. The number of full drums emptied was recorded. The drums were calibrated with buckets and the buckets were also calibrated with a measuring cylinder. Smaller amounts were measured with graduated measuring cylinder. The volume of through fall collected in the half drums during the preceding 24 hours was measured between 07:00 and 08:00 am.

There were two periods of measurements; 9th – 29th January 2003 and 10th August – 30th September 2003. Measurements done in the 2nd period were a repeat of what was done in January 2003, however, the number of drums was increased with distance from the palm base (Table 1). The experiment was repeated to check for variability within each distance from the palm base.

Table 1. Arrangement of the number of drums during the 2 periods

Zones	Number of drums		Proportion (%) of zone covered after reset
	9^{th} – 29^{th} Jan 2003	10^{th} Aug – 30^{th} Sept 2003	
Stem	1	1	
1	1	1	4.2
2	1	2	4.8
3	1	3	4.9
4	1	4	4.9
5	1	5	4.6
Bet. 3 palms	1	1	

In addition to above, during August and September 2003, 5 half drums were placed along the frond piles. Three of the half drums were placed in the frond piles just in front of the palms while the other 2 were placed between 3 palms but on the frond pile.

Painted metal cans 7 cm diameter and 15 cm in length were also used to determine variability in through fall under the palms. The cans were tied to split bamboo stakes with rubber bands at height just above the frond plies (40 – 50cm from ground level). In order to prevent loss through splashes, clear plastic was cut into rounded shapes of 20 -25cm diameter with a hole in the middle. The plastics were then folded into funnel shapes and held with paper clips to the inside of the cans. The cans were placed 2.0 m apart; 21 were placed along the frond piles and 12 were placed between palms in the frond tip zone.

Volume of through fall collected was measured the next morning after rain.

b) Small surface water runoff plots at Popondetta and Dami

There is considerable heterogeneity in the soil surface conditions in different zones under the palms. These zones include frond piles, frond tips, between zones, weeded circle and harvest path. These management zones have different soil properties. The zones also receive different amounts of rain because of redistribution by the canopy; there is also a large variation in rainfall amounts within each zone. The zones have different amounts and types of cover and the amount of sediment and N loss from these zones in PNG is unknown. Though the surface water runoff can be estimated from the infiltration rates and through fall distribution, the actual amounts are required to be quantified and determine the amount of nutrients leaching from the different zones under the palms. This experiment was aimed to determine the amount of nutrient and water loss from the different zones under the palms.

The experiment was first set up at Popondetta in Oro and then later at Dami in WNB Provinces.

The surface water runoff plots were set up in the different zones under the palms. The plots were 120 cm x 120 cm in area and the sidewalls were 25 - 30 cm high. The sidewalls were high enough to stop rain and through fall to splash either in or out of the plots. The plots were established in the frond piles, frond tips, weeded circle and harvest path and were replicated 3 times. At Popondetta, 5 of the plots sides were constructed with galvanized steel while the other 10 were cemented. At Dami, all the plots were cemented. With galvanized metal strips, 120 cm length and 25 cm width were cut. The selected locations under the palms were marked and pegged and then a triangular slot of 10 cm deep was cut through the soil. The sheets were then placed into the slots and cemented to hold down. At the corners, the sheets were cemented so that they can be held together. At the lowest end of the plots, an opening was left. From the opening, a pvc 20 mm diameter was cemented that led out to a collection hole. At the outside walls, soil was placed and tampered to stop water going through from underneath the walls. Cemented plots also had 10 cm deep cement into the slots in the ground to stop water from outside coming through into the plots. The cement walls were 20 cm high and 15 cm thick. The hole that was prepared for putting in the collection containers was 50 – 80 cm deep and 70 – 100 cm in length and width. At Popondetta, half cut drums (100 L) were painted to stop rusting and were placed in the holes in the harvest path and in one of the weeded circles plots. Four litre plastic containers were placed in the other plots. At Dami 20 L plastic containers were used but had a small rubber hose connected to half 100 L drums for plots in the harvest path and weeded circle plots. The other plots had either 20 L containers or 4 L containers. Funnels were placed in the opening of the 20 L containers. The different size containers were used for the different plots after monitoring in the first 2 main rain events and seeing which plots were having the most runoff. The collection point and the containers were covered with plastic shelters built over to stop rain water. The vegetation and frond inside were left undisturbed during the plot preparation. However plants that grew from outside in were cut and left to dry inside the plots. The ground covers on the plots were described and scored as crop cover %. The slope was also measured using dumpy level. Heights from 4 corners of the plots and collection point opening and in the centre of the plot were determined. Slope was then calculated. The distance between the points was also measured using tape measure. Volume of surface water runoff was measured and water samples were collected the next morning after a rainfall event.

Problems faced.

The collection containers were stolen at the site in Popondetta while at Dami funnels were stolen and plastic shelters were vandalised. The plastic at Dami was cut with sharp objects and this particular experiment is put on hold at the moment.

c) Large surface water runoff plots at Dami

Aim. To determine water yield from a 4 palm plot for water balance components.

To determine soluble N and particulate N loss from large 4 palm surface runoff plots.

Rationale

N is lost from the environment through leaching, surface runoff, volatilization and denitrification. Because of the different characteristics of soils under the palms and the unequal and variable rainfall distributions under the palms, small conventional runoff plots can only estimate runoff at a small scale. To get estimates at the next scale up, plots have to cover all the zones under the palms. Water yield from the plots assist in determining water balance of an oil palm, i.e. what is not runoff is water that is held in the palm vegetation, cover crops, or leached through the soil. The volume of water that drains through the soil will be determined from the FAO 56 evapotranspiration model. Concentrations of nutrients from other measurements along with estimate nutrient loss from oil palm rooting zones will be modelled to determine the quantity of nutrients leaving the oil palm rooting system.

Method and Materials

The trials were established at Popondetta and then later at Dami. At Popondetta, the plots were 30 – 50 m from the weather station while at Dami the plots were about 500 m from the weather recording station. A rain gauge was installed next to the plots at Dami. At each site the plots were replicated 3 times. Each plot had 4 palms and a rhomboid shape of 18 m dimension on all 4 sides. A bund of 30 cm high was made with soil around the plots and a spade blade deep trench was dug around each of the plots to remove excess water from coming in from the surrounding area. The bunds were then covered with black polythene plastic to stop rainwater from spoiling the bunds. At the lowest end of the plots, an outlet was cemented to stop water from cutting through the plots. The lowest ends of the plots were determined with a dumpy level. An 80 mm diameter pvc pipe was connected from the lowest end to collection point. The collection points were dug at elevations lower than the plots. The slopes of the individual plots were measured using a dumpy level and the ground cover was assessed for each of the plots.

Two 200 L plastic drums were placed at the collection points for catching surface runoff water. A shelter made from bamboo posts and sago fronds roof was built over each of the collection points to stop rain water and through fall from being collected in the drums. The plastic drums were calibrated and during rain events when the drums were filled with surface runoff water, they were tipped over and the number of drums tipped recorded. Buckets were also calibrated so when the drums were not full to the top, water was poured into buckets, emptied and the number of buckets counted.

To collect water and sediment samples, a calibrated plastic container of 3 L was used to scoop water from every full drum. If the drums were half full, only half the scoop was collected for sample. The contents of the drums were first stirred with a wooden paddle and then a scoop of water was collected into a bucket. The scoop was attached to a bamboo stick and the stick was lowered with the scoop into drum of water. The water sample was collected from the centre of the drum. The collected water was then taken back to the office stirred and left to stand over night. The buckets of samples were left to stand overnight so that sediment and suspended sediments can settle at the bottom to allow for separation. On the following day, water sample was collected from the buckets and the remaining water was decanted slowly so that settled sediments were not poured out. Three drops of 1M HCl acid was added to all water samples and stored in a freezer. The settled sediments at the bottom of the buckets were washed into plastic bowls and air dried in the oven. The sediments were weighed after air-drying and stored away for analysis. The sediments will be analysed for total N.

At Popondetta, the collection plastic drums in plot 3 were stolen while the plastics that cover the bunds in plots 2 and 3 were also removed. The stolen drums were replaced with new ones while the stolen plastics were replaced with cut nursery poly bags.

d) Lysimeters in open air with natural rainfall at Popondetta and Dami.

Purpose

To determine the amount of N leached from soils from different management zones under the palms.

Rationale

In the high rainfall areas, amount of N leached are probably significant. Analysed mineral N results from suction cup water samples will be used with data from water balance studies to estimate the amount of N that is leached beyond the oil palm rooting zone. Depending on the properties of soils, different amounts of inorganic mineral N are probably leached from the different management zones under the palms. Results obtained from the lysimeters will be used to model the movement of N from the different zones under the palms. This experiment was set up to determine the amount of inorganic N being leached from the different management zones under the palms.

Method and materials

The lysimeter studies were carried out at Popondetta and Dami. The initial set up was tried out at Popondetta before setting up the experiment at Dami.

The lysimeter cylinders were rolled from 2mm thick steel. The internal diameter was 20 cm and 70 cm long for cylinders at Popondetta and 50 cm for cylinders at Dami. From the top end (10cm), two 15 cm metal rods were welded on opposite sided for handling purposes. Fifteen cylinders were used for each of the sites; 3 for each of the zones under the palms. The reason for shorter length at Dami than at Popondetta was because of the contrasting soil textural differences (sandy pumice) at Dami.

At Popondetta and Dami the soil cores were collected from the frond piles, frond tips, between zones, weeded circle and harvest path. The lysimeter cylinders were pressed into the soil by an excavator at Popondetta while at Dami a front end timber loader was used. The cylinders were placed in the different zones with wooden planks placed on the top ends. The machines then using their spade blade pressed on the wooden planks driving the cylinders into the soil. The operators were told when to stop and adjust the blades as the cylinders were pushed into the ground. The cylinders were then carefully dug out from the ground with soil intact. Some soil was allowed to stick out from the bottom end while the cylinders were removed from the soil. The cylinders were then turned upside down and some soil at the bottom was chipped out to 1.5 cm depth into the cylinder. The soil was chipped off using small kitchen knives to avoid smearing effects that will clog the soil pores. Coarse sand/gravel mixture (washed with diluted HCl acid) collected from Arehe Creek at Popondetta was weighed and placed inside the space left from removed soil to filter the water moving out from the cylinder before into the collection containers. The bottom end was then covered with a 20 cm diameter plastic lids that had a nylon and fly wire glued inside. The nylon and fly wire were placed inside to stop the sand and gravel falling out when the cylinders stand up right. The plastic lids were later replaced with welded galvanized sheets because the glue used was not able to hold the attachments properly. The lids had a hole in the middle with a 20 mm pvc pipe attached to it that led to a collection container. The cylinder was then allowed to stand on the wooden bench.

At the top end of the cylinders, welded galvanized cylinders extensions (20 cm length between zones, weeded circle and harvest path and 50 cm for frond pile and frond tip zones cylinders) were attached onto the cylinders. The attachments were there to stop water splashing out from the lysimeters. Decaying fronds and litter were placed in the frond pile and frond tip extensions.

The lids that closed the bottom ends, sand/gravel mixture, top extensions decaying fronds and litter were all weighed before adding them onto the lysimeters cylinders.

Soil samples were taken from pedological depths 20 cm away from where soil cores were taken to determine soil moisture contents and bulk density. Soil samples were taken on the basis of differences in field textural and structural properties. At Popondetta there were 2 main contrasting soil layers in the top 70 cm depth while at Dami 3 main contrasting layers in the top 50cm depth. At Popondetta, soil samples were taken at 0 -30 cm depth (friable sandy clay loam) and 30 – 70 cm depth (friable to firm clay loam). In the weeded circle and harvest path, the top layer was sandy clay loam but was firm to hard because of compaction. At Dami, soil samples were taken from 0 – 10 cm (very friable moderately developed sandy loam), 10 – 20 cm (weakly developed sandy loam) and 20 – 50 cm (loose – very friable structure less loamy sand – sand) depths. The soil samples were collected with aluminium cylinder cores 50 mm internal diameter. Initial weights were measured and the samples were oven dried at 105 ^{o}C.

e) Lysimeters in open air with added water at Popondetta and Dami

Aim; this experiment is set up to determine the amount of N being leached from soils from the different zones under the palms after fertilizer application.

Rationale

There is large variation in the amount of through fall both within and between the different zones under the palms. There is also a large difference in the infiltration rates because of natural soil heterogeneity and differences in management practices. The amount of N being leached from the different zones probably will be different however that cannot be quantified until we actually measure leached N from the different zones under the palms. There are a number of factors that will influence N leaching such as different fertilizer rates, different rainfall intensities, different fertilizer types, surface water runoff/run on from weeded circles and harvest paths (zones with low infiltration rates) onto the frond piles and between zones (zones with high infiltration rates) and time between when fertilizers are applied into the field when it rains, influence of organic matter, infiltration rates and uptake by roots. It is not possible to study all of these factors in one experiment. Thus the first experiment will be set up to look at leaching losses of N from the different zones both before and after fertiliser N is added. In this first experiment, we will use a relatively simple system in which common N fertilizer is used with an average amount of rainfall.

Having determined from which zones most N is leached, we can then concentrate on next experiments on these zones of interest. It is most likely that most N will be leached out from the frond piles because of the very high infiltration rates but this zone will be confirmed in the first experiment. This experiment will be followed by ones designed to study some of the other factors mentioned above (eg fertilizer type).

All lysimeters with intact soil cores used in this experiment were the same ones used in the first experiment.

At both sites, the lysimeter cylinders were covered with plastic to stop rainwater from getting into the lysimeters cylinders and to allow any water inside the cylinders to drain out. Then 2 days later, the lysimeters were weighed to get the initial soil weight. To wet up the soil, water was added in batches of 750 ml after every hour for 4 hours in 2 days, ie 6000 ml over 2 days. Water used was rainwater collected from tanks. Water was poured through an empty can that had punctured holes at the bottom. Drainage water after the first lot of water added were not sampled because it was meant for wetting up the soil. However volume was measured to determine the frequency of sampling later in the experiment. On the 7th and 8th day, the second batch of water was added. This time sampling and volume of drainage was measured after 1 hour of addition during the first 2 days. There after volume and sampling was done on daily basis for those that drained. Before the 3rd batch of water was added on the 14th and 15th day, a mixture of 10g AMN and 6 g AMC was added. After fertilizer addition, water was added and the volume measurement and sampling were repeated. Before every new batch of water was added, the lysimeters were weighed. At Popondetta for the cylinders that ponded, ponded water was siphoned, measured and a subsample was taken. Ponding in the cylinders were monitored throughout the experiment. At the end of the day after adding water, the cylinders were covered with plastic to stop rainwater being collected in the lysimeters.

f) Suction cups at Popondetta

Aim: To determine the concentration of inorganic N forms leaving the oil palms rooting zone and in the fertilized areas under the palms.

Rationale

The amount of N leaving the oil palm rooting zone is a direct loss to the oil palm growing agro ecosystem and is of significant environment concern. Due to the large variation in the redistributed rainfall, different infiltration rates between the different zones under the oil palms and difference in areas that receive fertilizers, different amounts of inorganic N are probably leached from the different areas under the palms. However of concern are the areas that receive fertilizers; frond piles and between zones. Proportion of total leached N from these zones is originally from inorganic fertilizers but this has not been quantified. Some of the N leached from the other zones is also originally from the fertilizers that have been redistributed through biological processes such as the break down of oil palm roots and fronds.

Background to suction cups/description

The soil moisture suction cups were bought from Soil moisture Equipment Corp. The kit consists of an extraction kit 50 ml syringe, a vacuum hand pump suction cup a glass rod with cup at one end. The suction cups consist of tube with a porous ceramic cup screwed tied at one end.

Suction is created using the hand pump, water is sucked into the ceramic cup and after 5 – 6 hours water samples are collected using a syringe.

To install the suction cups, the soil was augured to 1.5 m depth in the frond piles and between zones. The augured soils were placed into a bucket. Clay slurry was poured into the hole to about 1/3rd depth of the hole. Clay slurry was used to provide a good conductivity between the suction cup and the surrounding soils. At Popondetta, clayey subsurface soil was used to make slurry while at Dami, clayey soils from Kumbango and Walindi were used to make slurry. The soils at Dami were not suitable to make good slurry because of their sandy texture. After adding in the slurry, the suction cup was inserted into the hole with the ceramic cup embedded in the slurry in the hole. The rest of the hole was then back filled with soil from the augured hole and tamped.

The suction cups were installed in the frond piles and between zones with 10 replicates each. These 2 zones were chosen because fertilizers are mostly applied here. The between zone is the zone between the weeded circle and frond tips zones. Each of the replicates was installed 3 – 4 palms distance from each other within the area where other experiments were setup. For the between zones, the cups were installed at 250 cm from the palm stem. Water samples were collected a day later after rain. No duplicate samples were collected because of small volume of water in the cups. Sampling commenced in January 2004 for Popondetta and February 2004 for Dami.

g) Diviner 2000 Sentek soil moisture monitoring at Popondetta and Dami

Aim: To monitor changes in soil moisture content at various depths and at different zones under the palms during the wet and dry season.

Rationale

The soil moisture conditions under the palms are probably very different because of differences in through fall and stem flow water input, different infiltration rates in the different management zones under the palms, differences in placement of pruned fronds and differences in the oil palm rooting activities. All have effect on the changes in soil moisture content under the palms both vertically and horizontally. Changes occurring in various zones under the palms and at different depths with different root distribution will show differences in rooting activities under the palms.

Method of set up.

Diviner 2000 is a soil moisture monitoring system that comprises data display unit and a portable probe. The probe measure soil moisture at 10 cm intervals to a depth of 160 cm. Reading are taken through the walls of the PVC access tubes.

The access tubs end had a sharp end glued with PVC glue. The top screwed tied to stop water at soil surface going into the tubes.

The access tubes were installed in the frond piles, frond tips, between zones, weeded circle and harvest path. The locations selected were 3-4 palms from each other. Coring was done in frond piles, frond tips, between zones, weeded circle, harvest path and between 3 palms on the frond piles. Each of the locations under the palm was replicated 3 times.

The soil was augured to 2.0 m depth with 5cm diameter augur. The soil was augured while standing on 3 wooden standing stools that were placed around the augured area to avoid soil compaction. At Popondetta, the soils from the top 30 cm depth were placed into a bucket while clayey soil materials from the soil subsurface were placed into a separate bucket to make slurry. At Dami, clayey soil materials were collected from Kumbango and Walindi for making the slurry because sandy/pumice texture properties of the soils. After preparing the holes, the slurry was then poured into the augured hole to about half way and then the access tube was pushed slowly into the augured hole. The slurry filled up the hole when the access tubes were pushed in and this closed the gap between the soil and access tubes. Excess slurry that came out of the hole as a result of inserting the tubes was chipped off after 2 – 3 days. The measurements commenced 3 – 4 days later. Measurement was started 2 – 3 days later because the moisture in the slurry and the surrounding had to equilibrate.

Readings were generally taken everyday between 10 am and 11 am. Readings were taken lowering and raising the sensor into the access tube and readings were recorded for every 10 cm depth to 160 cm.

Calibration

Measurements were converted to volumetric soil moisture content using default calibration in the diviner. To convert to gravimetric water content, the machine has to be calibrated using field conditions soil moisture and bulk density. Three different soil conditions are required for calibration; very dry, moist and wet conditions. Calibration will also be required for the different management zones under the palms because of differences in their soil properties especially the top 30 – 40 cm depth.

To create very dry conditions, trenches of 2 m depth were dug around an area of 1.5m x 1.5 m creating an “island” of soil. Access tubes were then installed in these islands of soil. It was assumed frond tip zones will be similar to between zones. The islands were covered with plastic during the wet days to stop rain wetting the soil and the plastic was removed during clear days for the sun to dry up the soil. However, this procedure did not result in the required level of soil drying. Cover crops were planted on the ‘islands’ so that the plants will dry up the soil through the process of evapotranspiraton. The soil columns will still be covered with plastic when it rains so that the soil does not wet up.

Results and Discussion

a) General

Most of this year (June 03 – June 04) was spent setting up experiments and collecting data and soil and water samples from the experiments at Popondetta and Dami. The data and samples will be analysed at Massey University later this year. Some of the results from last year report are also presented here along with results from through fall variability measurements and surface water runoff from Dami.

b) Through fall variability measurements

Results of through fall between and within different zones from the oil palm base are presented in Table 2. There were 5 zones and they covered different radial areas from the base of the palms up to the center of 2 adjacent palms. Volume of water measured in the drums for individual rain events were adjusted to rain fall heights by dividing the volume by the area of the containers.

Through fall under different zones increased with distance from the stem. Amount of through fall in the different zones also increased with the size of rain events but did not affect the increasing trend with distance from palm base. The highest through fall was collected in zones 4 and 5. Zones 4 and 5 cover some frond piles, between palms and harvest path. Zone 5 is also an overlap zone between neighbouring adjacent palms.

There was also a large variation in through fall within the different zones (Table 3). The large variations, however, did not affect the increase in mean through fall in the different zones with distance from the palm stem.

There were also large variations in through fall along the frond piles and between palms zones measured in 5 half drums and small cans (Tables 4 and 5). These 2 zones are areas that fertilizers are applied to.

Determining the water contributed to each zone is confounded by the large variations in through fall received at the ground level and by stem flow water running over the weeded circle into the outer zones but not spreading evenly across the different zones. The large variations significantly affect the leaching and surface runoff loss of N.

Summary:

- Amount of through fall increase with distance from palm stem
- There is a large variation in through fall within different zones from the palm stem but this did not affect the increase in amount of through fall with distance from the base of the palm
- There is a large variation in through fall along the frond piles and frond tip zones.

Table 2. Amount of rainfall collected as stem flow and through fall in the different zones from palm base in August – September 2004 at Popondetta

Date	Rain-fall	Palm		Stem flow	Amount of through fall (mm) collected in the different zones													
	(mm)			(mm)	Zone 1	Zone 2		Zone 3			Zone 4				Zone 5			
						1	2	1	2	3	1	2	3	4	1	2	3	4	5
10/08	16.6	1		899.6	4.5	3.1	4.1	4.7	9.4	13.7	6.4	11.4	27.1	8.8	11.8	7.3	17.6	5.9	11.0
		2		714.9	2.7	15.5	5.3	15.7	11.0	7.8	9.2	15.9	12.7	6.2	4.5	19.0	2.4	20.6	30.0
		3		597.4	5.9	11.0	8.8	17.1	19.0	11.6	21.0	13.5	8.4	9.2	18.4	15.9	11.6	14.7	18.0
		Mean		737.3	4.4	9.9	6.1	12.5	13.1	11.0	12.2	13.6	16.1	8.1	11.6	14.0	10.5	13.7	19.7
13/08	6.8	1		383.7	1.4	2.0	5.5	2.7	5.3	5.7	4.9	5.9	8.4	7.3	10.6	4.1	12.5	1.6	6.2
		2		279.5	1.4	4.7	2.7	8.4	6.9	3.1	5.9	8.6	10.2	3.3	1.8	8.0	2.5	17.1	14.5
		3		211.2	3.1	9.8	5.1	12.2	8.4	5.1	12.9	6.3	9.8	6.2	11.2	14.7	4.9	4.7	6.5
		Mean		291.5	2.0	5.5	4.4	7.8	6.9	4.6	7.9	6.9	9.5	5.6	7.8	9.0	6.7	7.8	9.1
14/08	3	1		49.1	1.4	1.6	2.4	2.2	2.4	2.2	2.4	2.2	5.7	3.5	3.7	2.4	5.9	0.8	3.3
		2		31.4	0.0	1.8	0.3	4.7	2.4	0.8	2.2	4.1	2.4	4.7	0.8	2.9	0.5	9.0	4.1
		3		29.4	0.5	3.7	1.6	4.9	7.1	2.7	5.1	2.4	2.2	2.5	4.9	5.1	1.8	4.1	4.3
		Mean		36.6	0.6	2.4	1.4	3.9	3.9	1.9	3.2	2.9	3.4	3.6	3.1	3.5	2.7	4.6	3.9
01/09	52.2	1		3910.2	5.9	10.0	16.5	18.3	22.5	30.2	24.3	41.1	55.5	41.1	67.4	51.3	84.8	9.4	49.2
		2		2067.1	11.8	46.4	11.0	51.1	32.5	32.0	25.5	55.0	13.1	48.7	17.1	58.7	15.5	93.8	95.6
		3		2114.0	9.0	62.3	32.2	67.4	81.3	31.8	90.9	45.4	80.3	62.7	71.1	96.8	41.1	50.9	47.0
		Mean		2697.1	8.9	39.5	19.9	45.6	45.5	31.3	46.9	47.2	49.6	50.8	51.8	68.9	47.1	51.4	63.9
4/09	29.6	1		1768.2	5.1	5.3	8.2	8.6	18.4	27.8	11.6	12.9	52.9	19.8	17.6	10.6	35.3	8.6	22.2
		2		2092.2	8.6	28.2	6.7	22.2	9.4	20.8	16.9	29.4	31.2	23.1	7.1	33.3	7.8	41.1	54.2
		3		1024.7	11.0	23.5	15.9	26.5	30.2	26.9	30.1	13.1	47.0	29.0	24.1	59.5	18.6	27.2	20.0
		Mean		1628.4	8.2	19.0	10.3	19.1	19.3	25.2	19.5	18.5	43.7	24.0	16.3	34.5	20.6	25.7	32.1

Table 3: Mean through fall (mm) collected in the different zones from palm base in August – September 2004 at Popondetta

Date	Rainfall	Palm		Stem flow		Mean through fall (mm)in different zones				
	(mm)			(mm)		1	2	3	4	5
10-08-03	16.6	1		899.6		4.5	3.6	9.3	13.4	10.7
		2		714.9		2.7	10.4	11.5	11.0	15.3
		3		597.4		5.9	9.9	15.9	13.0	15.7
		Mean		737.3		4.4	8.0	12.2	12.5	13.9
13-08-03	6.8	1		383.7		1.4	3.7	4.6	6.6	7.0
		2		279.5		1.4	3.7	6.1	7.0	8.8
		3		211.2		3.1	7.4	8.6	8.8	8.4
		Mean		291.5		2.0	5.0	6.4	7.5	8.1
14-08-03	3	1		49.1		1.4	2.0	2.2	3.4	3.2
		2		31.4		0.0	1.0	2.6	3.3	3.5
		3		29.4		0.5	2.6	4.9	3.0	4.0
		Mean		36.6		0.6	1.9	3.2	3.3	3.6
01-09-03	52.2	1		3910.2		5.9	13.2	23.7	40.5	52.4
		2		2067.1		11.8	28.7	38.5	35.6	56.1
		3		2114.0		9.0	47.2	60.1	69.8	61.4
		Mean		2697.1		8.9	29.7	40.8	48.6	56.6
04-09-03	29.6	1		1768.2		5.1	6.8	18.3	24.3	18.9
		2		2092.2		8.6	17.4	17.4	25.1	28.7
		3		1024.7		11.0	19.7	27.8	29.8	29.9
		Mean		1628.4		8.2	14.6	21.2	26.4	25.8
05-09-03	12.6	1		320.6		2.4	4.3	7.4	9.7	9.0
		2		385.2		2.0	4.7	9.7	12.9	11.6
		3		318.8		1.6	9.6	9.5	11.9	19.5
		Mean		341.6		2.0	6.2	8.9	11.5	13.4
17-09-03	4.4	1		101.5		0.8	2.9	5.8	5.9	5.2
		2		114.4		2.7	1.8	3.4	6.3	7.8
		3		175.9		2.2	4.4	6.1	7.3	4.8
		Mean		130.6		1.9	3.0	5.1	6.5	5.9
23-09-03	4.8	1		121.8		1.2	2.4	5.6	5.0	3.8
		2		101.5		1.8	2.0	2.6	4.7	5.3
		3		103.5		2.0	3.3	4.4	5.4	4.7
		Mean		108.9		1.6	2.5	4.2	5.0	4.6

Table 4: Through fall (mm) measured in half 200L drums along the frond piles in September 2003

Date	Rainfall (mm)	Through fall (mm) 1	2	3	4	5	Statistics Mean	Min	Max	Median	Std dev
01-09-03	52.2	27.5	24.9	29.4	52.7	52.9	37.5	24.9	52.9	29.4	12.6
04-09-03	29.6	17.6	13.3	11.8	29.4	20.0	18.4	11.8	29.4	17.6	6.96
04-09-03	12.6	5.1	12.0	7.5	13.9	16.5	11.1	5.1	16.5	12.6	4.70
17-09-03	4.4	5.9	3.1	4.9	3.7	5.9	4.7	3.1	5.9	4.9	1.24
23-09-03	4.8	3.1	1.4	3.1	2.0	2.5	2.4	1.4	3.1	2.5	0.767
24-09-03	3.2	1.8	1.4	1.6	1.2	0.8	1.3	0.8	1.8	1.4	0.38
25-09-03	59.6	29.7	28.2	52.9	16.5	50.1	35.5	16.5	52.9	29.7	15.5
27-09-03	6.2	3.7	2.5	2.4	1.1	4.7	2.9	1.1	4.7	2.5	1.38
28-09-03	19.8	16.7	8.2	11.4	12.6	12.3	12.2	8.2	16.7	12.3	3.02
29-09-03	3.4	2.7	1.4	1.4	1.6	1.4	1.7	1.4	2.7	1.4	0.598
30-09-03	28.8	17.6	24.5	15.3	9.4	15.7	16.5	9.4	24.5	15.7	5.43

Table 5: Measurements of through fall (mm) under the frond piles and frond tip zones in cans.

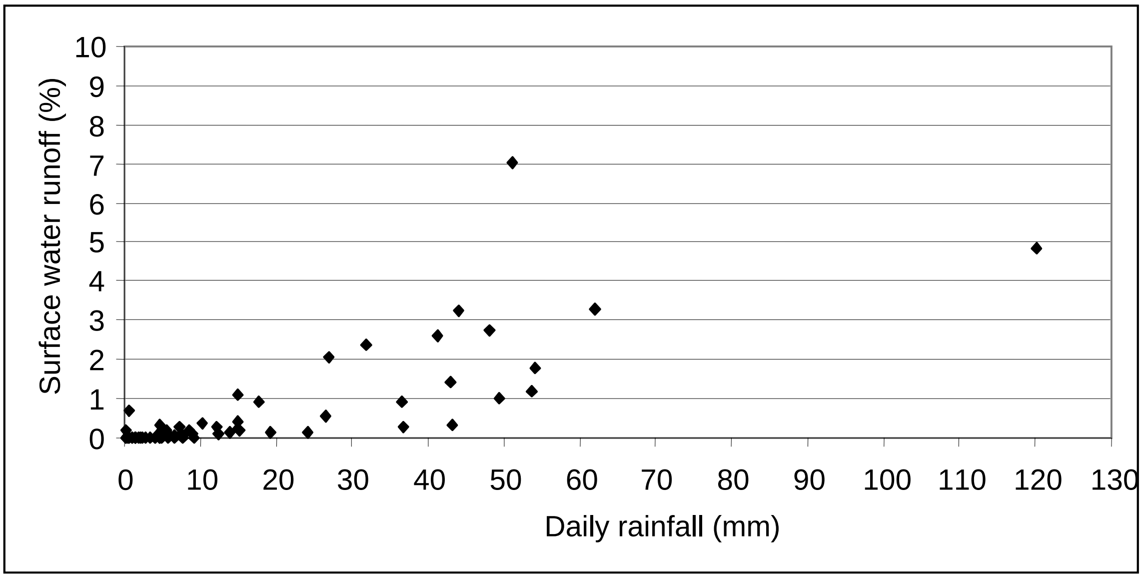
Date	R/fall (mm)	Through fall measured along the frond piles (n = 21)						Through fall measured in the frond tip area (n=12)					
		Mean	Min	Max	Median	std dev	No. of cans O/F	Mean	Min	Max	Median	std dev	No. of cans O/F
10-08-03	16.6	19.2	0.0	65.0	15.6	20.0	1	9.6	0.0	62.4	0.0	19.9	0
13-08-03	7.0	2.5	0.0	22.1	0.0	6.4	1	1.4	0.0	16.9	0.0	4.9	0
14-08-03	3.2	1.4	0.0	7.8	0.0	2.4	0	4.5	0.0	26.0	0.0	8.1	0
01-09-03	52.2	41.9	5.5	143.0	24.2	48.5	0	32.5	0.0	136.0	12.5	39.4	0
04-09-03	29.6	25.0	0.0	80.9	7.3	28.2	0	18.6	0.0	54.6	13.0	17.9	1
05-09-03	12.6	9.9	0.0	48.1	3.1	14.1	0	14.7	0.0	94.9	3.3	27.1	0
16-09-03	4.4	3.0	0.0	17.4	0.0	5.5	0	4.2	0.0	19.5	0.0	6.7	0
23-09-03	4.8	2.7	0.0	13.0	0.0	4.3	0	1.8	0.0	6.5	0.0	2.8	0
24-09-03	3.2	2.2	0.0	10.7	0.0	3.5	0	1.1	0.0	5.5	0.0	2.0	0
25-09-03	59.6	41.0	8.3	100.1	31.2	31.8	0	46.2	8.1	98.8	30.5	35.0	0
27-09-03	6.2	6.1	0.0	28.6	2.6	8.2	0	5.3	0.0	15.6	2.7	6.4	0
28-09-03	19.8	23.6	0.0	101.4	11.3	27.0	1	26.1	0.0	91.0	12.0	30.6	0
29-09-03	3.4	2.9	0.0	18.7	0.0	5.0	0	2.5	0.0	9.6	0.0	3.7	0
30-09-03	28.8	23.4	3.1	98.8	12.5	25.6	0	31.5	3.1	74.1	29.1	25.3	2
12-10-03	4.4	3.7	0.0	18.5	1.3	4.9	0	4.7	1.3	17.4	1.3	5.4	0
15-10-03	74.0	41.5	8.3	91.0	33.8	30.3	4	73.8	9.1	104.0	84.5	34.7	2

O/F = over flow

c) Large surface runoff plots at Dami

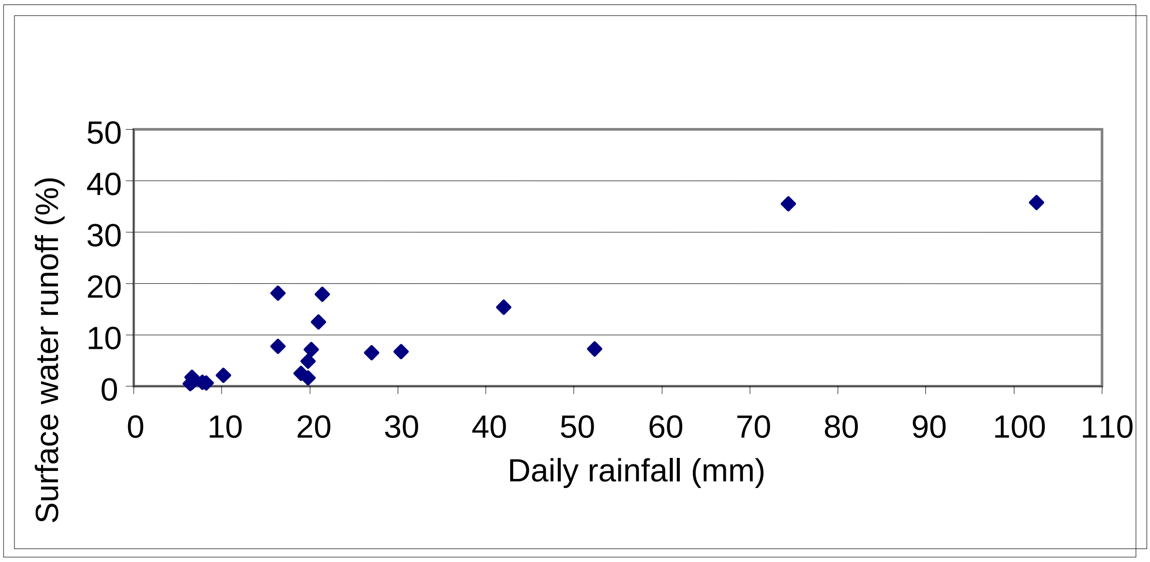
Results from the Popondetta large surface water runoff plots were reported last year, however, is reported again with results from Dami.

Less than 10% of daily rainfall was surface water runoff at Dami (Figure 1). Even at a rain event of 120 mm, surface water runoff was only 5% of the rainfall. The 7% surface water runoff was recorded the day after the day with 120 mm of rainfall. The soil was already wet and therefore there was a large surface water runoff. Compared to Popondetta, surface water runoff ranged from 0 to 35% (Figure 2). The relationship between surface water runoff and size of rain events was better at Popondetta than at Dami. More water infiltrates the soils at Dami than at Popondetta. The differences in surface water between the 2 sites relate well to the differences in the infiltration rates between the 2 sites; Dami having generally greater infiltration rates than at Popondetta in the frond piles (Figure 3). The results also imply differences in the N loss pathways between the 2 sites.



$y=0.0464x - 0.128 \quad r^2 = 0.62$

Figure 1. Surface water runoff from 4 palm plots at Dami 17th March to 30th June 2004



y=0.3684x - 0.3851 $r^2 = 0.74$

Figure 2. Surface water runoff from 4 palm plots at Popondetta in January 2003

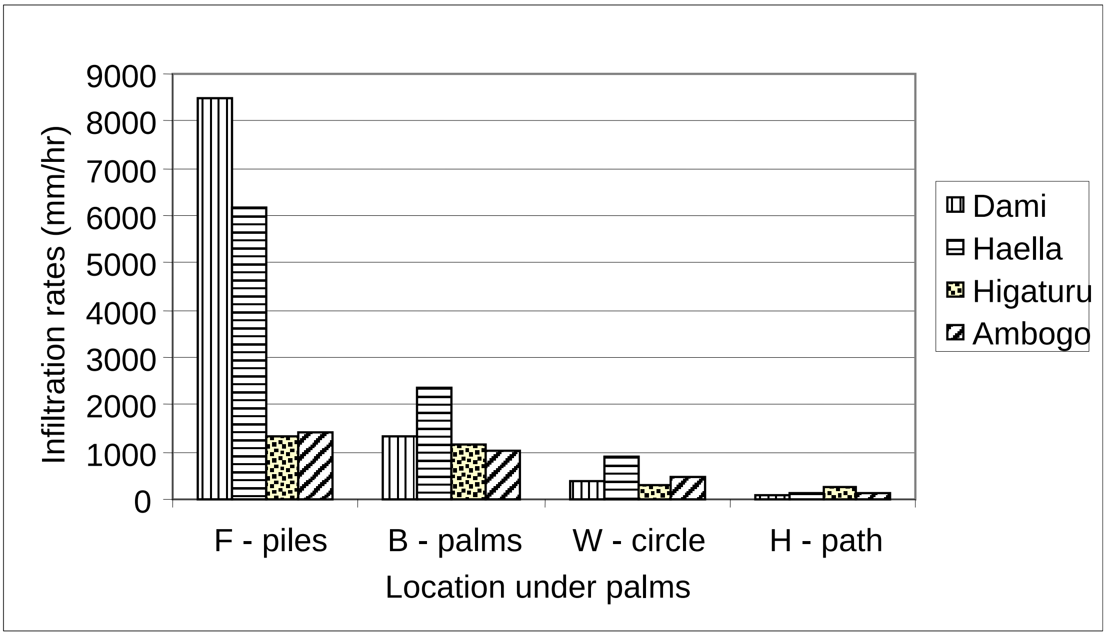


Figure 3. Mean infiltration rates (mm/hr) for different locations at different sites

d) Summary and problems encountered

There is a large variation in redistributed rainfall under the palms. Surface runoff water at Dami is less than at Popondetta and this relates well to the large infiltration rates in the Dami soils.

The main problems faced during this year were stealing and vandalism of experimental set up equipment. Many of the replaceable equipment/materials were replaced and security was organized that stopped the problems. At Dami the small surface runoff plots were stopped because of vandalism. Work will resume later during the year.

e) Work for the next 12 month

It is planned that during the next 12 months 1) soil, litter and water samples will be analysed 2) all climatic data from Dami and Popondetta will be put together to estimate evapotranspiration and drainage water 3) commence setting up second phase lysimeter studies 4) complete N mineralization experiments 5) start modeling N loss and 6) commence N denitrification/volatilizations studies.

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. Some of these activities were also included in the PNGOPRA 2002 Annual Report. A progress summary is included below.

PROGRESS SUMMARY

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

- planned four field trials in PNG; completing the establishment of two, with the other three well under way. These field trials are examining the effectiveness of alternatives to the standard Mg fertiliser (soluble kieserite) in overcoming Mg deficiency.
- established nutrient omission pot trials in both PNG and Australia (two trials in each country) to determine nutrient limitation independently of field trials in PNG
- characterised some of the chemical properties of several potential Mg fertilisers
- measured the response of Mg concentration in fronds of various ages and 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

In addition, through this project we have also taken the opportunity to:

- investigate the nutritional status of locally produced vegetable crops, and
- start a preliminary investigation into the nutritional consequences of Finschhafen disorder – a disorder primarily of coconuts but which has recently been found to affect oil palm. The potential for wide-spread infestation of oil palm is currently unknown.

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.

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.

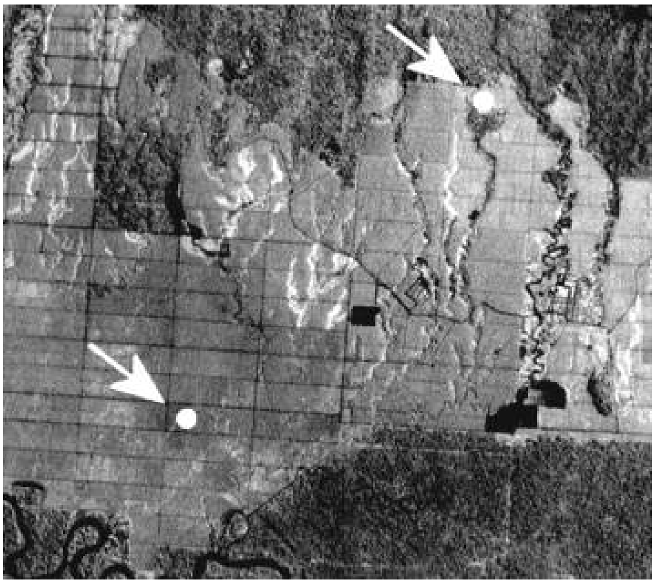


Figure 4. White circles show the position of the two omission trial sites in Haella Plantation.

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 6. Directional effects can be tested by combining groups of the 12 transects. The slope of the line is expected to change with time.

Table 6. 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

The trial was marked out and commenced in 2003. Yield recording only commenced in August 2003. During the August – December period only a limited amount of data was collected. Regression analysis of bunches/palm and individual bunch weight (all transects combined) on equilateral distance from the central palm indicate non-significant differences between the distances (Table 7 & 8). A full year of data may be useful to determine any statistical differences.

Table 7: Regression parameters in 2003 (Trial 141 Div II - Downslope)

	Intercept	Slope	Slope p	r^2
Bunches/palm	3.0	0.01	0.728	0.009
Bunch wt. (kg)	19.15	0.117	0.492	0.034

Table 8: Regression parameters in 2003 (Trial 141 Div III - Upslope)

	Intercept	Slope	Slope p	r^2
Bunches/palm	6.0	-0.03	0.629	0.019
Bunch wt. (kg)	15.51	0.049	0.762	0.007

MONITORING OF SHALLOW PERCHED WATERTABLES (Activity 143a)

Purpose

To determine the depth of shallow perched groundwater tables in two fertiliser trials in WNB that had not shown responses, to determine whether lateral water movement through the soil might be responsible for moving nutrients between experimental plots.

Site & Design

Piezometers were installed in August 2002 in every second plot in Trials 125 (Kumbango) and 402 (Bilomi). Piezometers consisted of 50 mm diameter PVC pipe, slotted every 25 mm to allow water entry. The piezometers were inserted to a depth of about 1.5 m, with about 0.3 m protruding from the soil surface. During times of rainfall, the depth of water in the piezometers was measured.

Results

In Trial 402, ground levels have not yet been determined, so the only data we have at this stage is depth of water below the top of the tube (Table 9). Water levels were deeper than 1.5 m most of the time and only in 2 piezometers were depths <1 m occasionally recorded. Only two events occurred in the second have of the year that resulted in water in the piezometers

In Trial 125, ground levels have been taken, so groundwater levels could be determined and flow directions inferred. Figure 5 shows the ground level at each piezometer, In Trial 125, groundwater was more than 1.5 m deep over most of the site most of the time. The piezometers that held water most often (8, 22, 23, 24 and 28) were mostly on the eastern and southern sides of the site, close to the Dagi River, which is adjacent to the site. Most of the data for 2003 was reported in the 2002 Annual Report. Further analysis of this data from the piezometers nearest the Dagi Rivers shows that groundwater level is influenced to some extent by the contour of the soil surface (Figure 6). However, it is also clear that there is a tendency for the ground water levels to the horizontal; possibly indicating lateral flow. When there was sufficient water to raise the groundwater level enough for it to be measured in each of the piezometers, the water level was close to the surface at piezometer 8 which is in a low lying area. However these events were uncommon and water quickly receded below the depth of the piezometers.

The dynamic nature of the groundwater levels is also shown in Figure 7. The change in water level was much more pronounced in the low lying piezometer 8 compare to piezometer 6 which was nearby but on higher ground. That the peaks in groundwater level also persisted longer in piezometer 8 than piezometer 6 suggest that the water level in piezometer 8 in influenced by water moving towards the river from higher ground. .

The data from both figures suggests that there is substantial lateral movement of water in this landscape. This water movement would also have the potential to move nutrients through the landscape and possibly to the river. It also suggests that a daily time-step might not be adequate to capture the true nature of the groundwater dynamics. Piezometers set up in Trial 137 have had water in them more frequently in 2004 than have 125 and 402, and thus will be a valuable source of information on groundwater dynamics once the soils surface levels have been determined.

Figure 5. Diagram showing approximate positions of Trial 125 plots and of piezometers (bold). The height of the ground surface above an arbitrary datum (m) is shown at each piezometer. Shading shows ground height in increments of 0.5m.

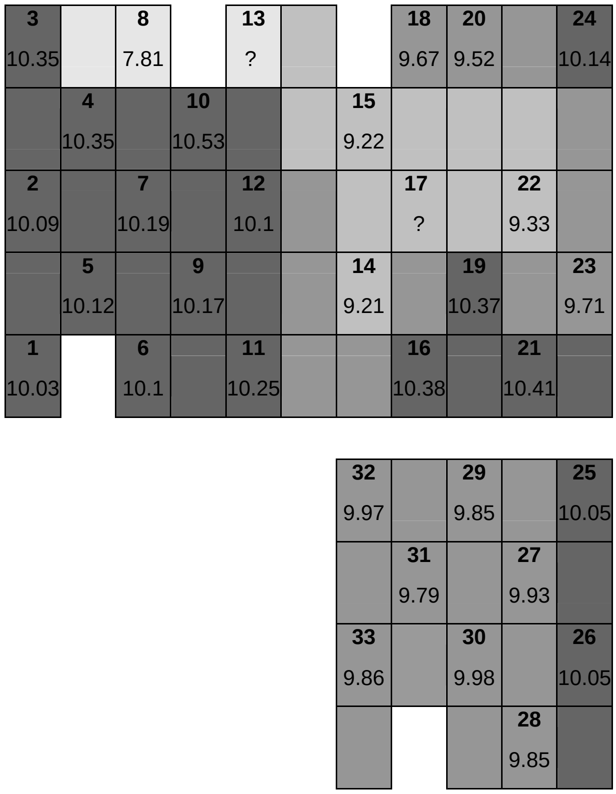


Table 9. Depth of groundwater below top of piezometer (cm) in Trial 402.

Date.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**34**	35	36	37	38	39	40
26/1/03																																								
27/1/03																																								
31/1/03	165	167	164		172	145	153		153	173	166	163	110	173	167		172	168	167			160	170	169					174			173	164	168	164			164	170	
16/2/03	168	167											159																											
23/2/03	150	158													162																									
25/2/03	150	158													162																									
27/2/03	166	165	162		169	127	142		149	169	162	151	59	168	164		159	158	160			149	163	165					165			163	152	160	160					
14/3/03	167	165	162		169	127	142		149	169	161	151	60	168	165		159	162	162			151	165	167					167			167	158	162	165					
8/3/03	166	165	162		169	127	142		149	169	161	151	59	168	164		159	160	160			149	165	165					165			165	156	160	163					
10/3/03	150	158													162																									
11/3/03	145	155	150	125	132	143	150	167	167	169	165	155	107	140			167	169	167	170	170	167	166	167				168	169			172	160	166	169					167
17/3/03	123	123	149	130	124	126	150			130	152			132		133	142	146	152	160	132	128		130	139		118	126	132		126	147	162	135	142		130	160		125
26/3/03	160	162																																						
27/3/03	155	164																																						
28/3/03	155	153																																						
31/3/03	135	145	164																																					
3/4/03	134	145	164			160			153			167					160			150															170					
4/4/03	131	143	154			132											153			132																				
5/4/03	115	128	146			159			148	133	155	150					133		62			168											159	150	146					
7/4/03	89	105	120																	138																				
5/8/03am	165																					167																		
5/8/03pm	168																					170																		
18/12/03	170																																							

Figure 6: Groundwater level in 5 piezometers at three times during 2003. These piezometers are close to the Dagi River. Piezometers are labelled “P”.

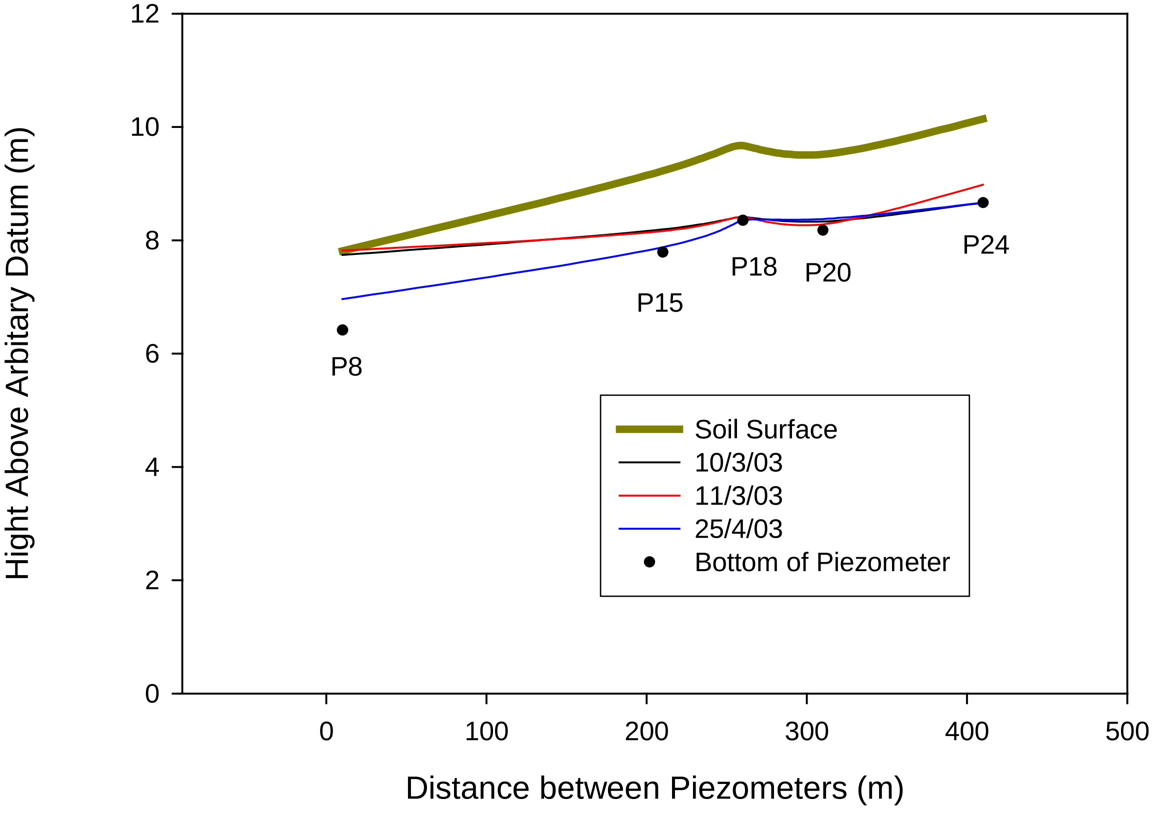
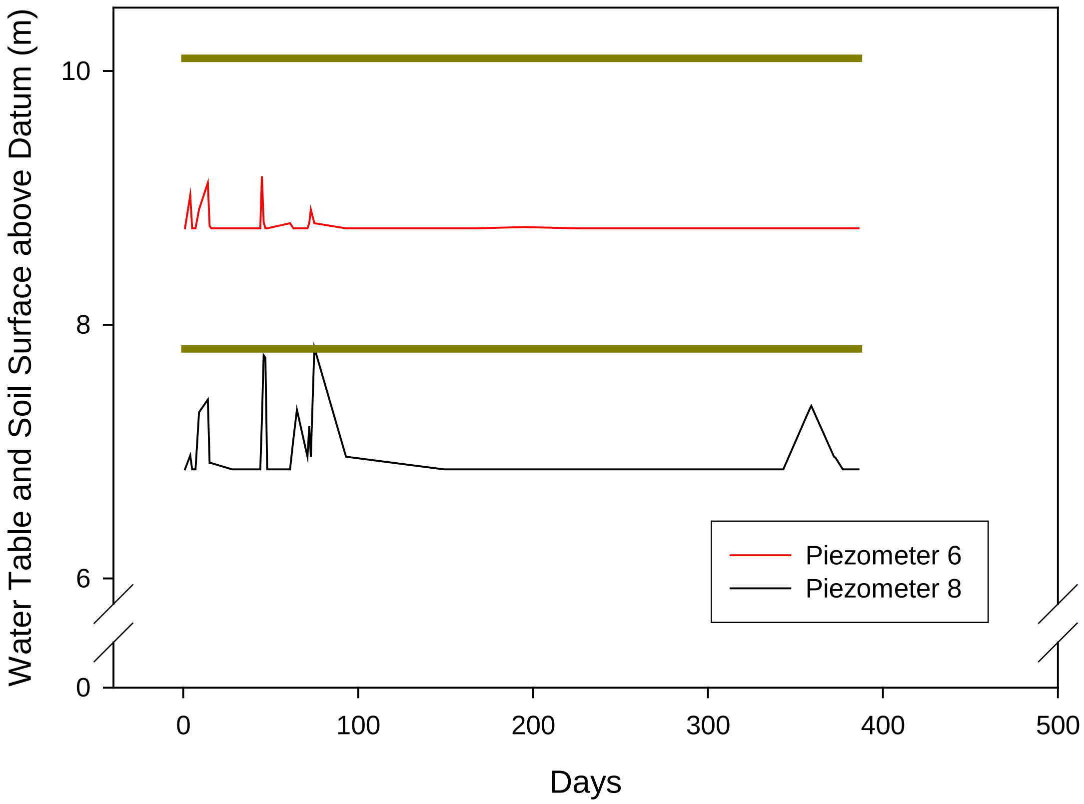


Figure 7: Changes in groundwater level during 2003 at two piezometers which are close by (approx 150 m) but differ in soils surface elevation. The soil surface is represented by a thick line. The 'flat-lining' of each curve represent the bottom of the piezometer. All vertical measurements are relative to a common arbitrary datum.



WATER AND NUTRIENT MOVEMENT THROUGH THE SOIL PROFILE (Activity 143c)

Background

We suspect that nutrients applied in fertilizers are moving below the root zone and possibly transported laterally through the soil. Losses via these pathways potentially cost the industry large sums. In the 'N losses' and 'Mg nutrition' projects we are starting to quantify these losses. Associated with those major studies, and also to address the question of whether or not nutrients are moving laterally through the soil profile, several lysimeters were set up at Dami and monitored through the 2002/03 wet season. Saturated hydraulic conductivity was also measured at several sites at several depths so that water fluxes could be estimated. Further analysis of the lysimeters were conducted for the 2003/2004 wet season.

Purpose

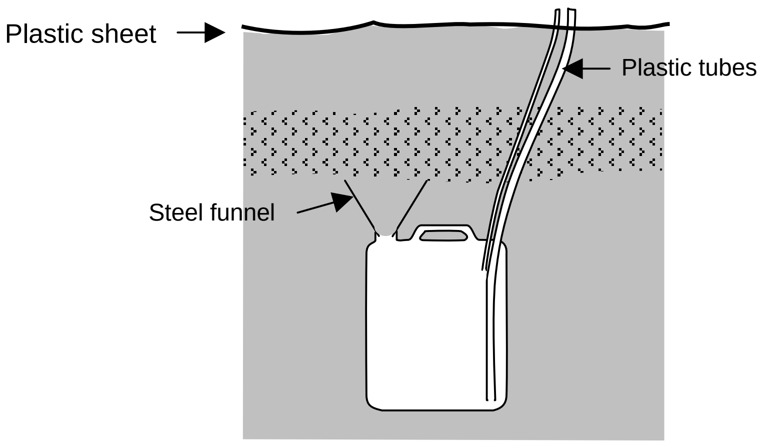
To determine how much water and nutrient move downwards through and beyond the rootzone, and sideways through soil layers.

Design

Lysimeters

Three lysimeters (Figure 8) were set up in the northernmost block at Dami. (See 2002 Annual Research Report). A further 10 stations (three lysimeters each station) were set up in Dami, 2003/2004. However, there is little data from these at present.

Figure 8. Cross-section showing lysimeter design.



Analysis of water collected in the original lysimeters is shown in Figure 9. The upper lysimeter (L3) is just above the pumice layer (0.2 m); L2 is at the bottom of the pumice layer (1.0 m), and L1 is at a depth of 1.8 m. There was no water collected in L2 during the 2003/2004 wet season. Most of the water was collected in the upper lysimeter with water collecting in the lower lysimeter on only a few occasions. As all of these lysimeters had a plastic covering just below the soil surface, any water that entered them must have moved laterally. Clearly a substantial amount of water must have moved laterally in the upper layer, whilst little moved in the to lower lysimeter. No water was collected in the lysimeter under the pumice layer. This would imply that substantial lateral water movement is occurring the upper (heavier soil) layer only. This could be a result of the pumice layer restricting water movement causing saturation of the layer above and thus causing hydraulic flow. At times when the water potential of the upper layer exceeds (less negative than) that of the pumice layer, water would then move into the pumice layer; the amount being controlled by the hydraulic conductivity of the upper layer. Because lower (heavy soil) layer would also have a lower (more negative) water potential, water would be quickly drawn into that layer. If there is sufficient rain, it would be possible that the lower layer becomes saturated, resulting in lateral flow, even though the pumice layer does not.

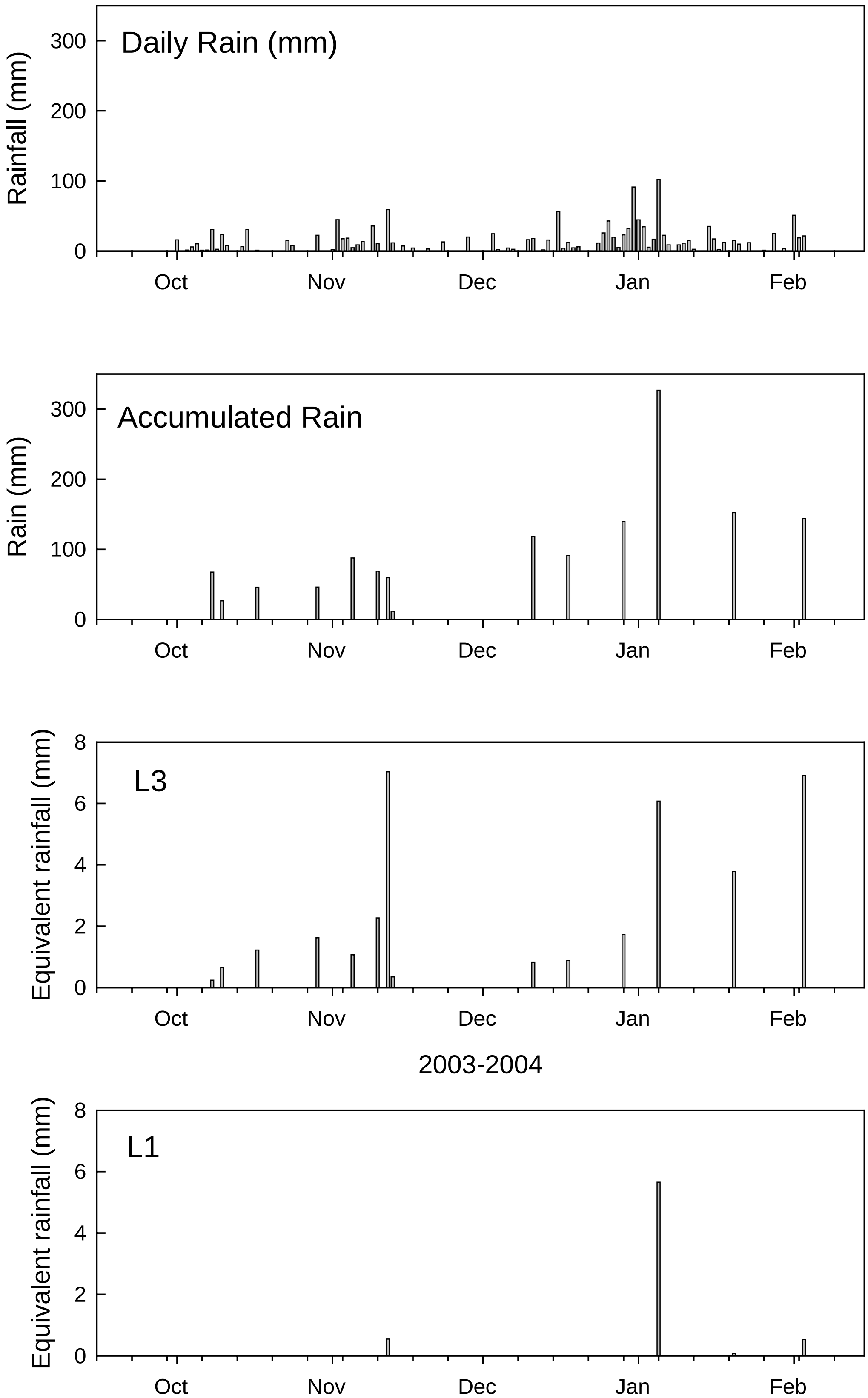


Figure 9: Daily rainfall, accumulated rainfall (between emptying lysimeters), and water collected (in rainfall equivalents) in the upper (L3) and lower (L1) lysimeters.

A Conceptual Framework for Understanding Nutrient Capital and Nutrient Dynamics in the Oil Palm Industry

Fertiliser use is one of the major investments in the oil palm industry. An understanding of the distribution and flow of nutrients, (whether from fertilisers or from endogenous sources) in the industry is essential for their efficient and economic use.

Last year's annual report detailed the importance of maintaining the soil resource and the efficient use of fertilisers. In this report, we put these concepts into a single conceptual framework, which will also identify gaps in the knowledge of nutrient management.

Background

Palm requirements

All higher plants, including palms have a number of essential requirements in order to grow and reproduce. These are:

- Radiant energy in the form of adequate and appropriate wavelengths of light
- Ambient energy in the form of an adequate temperature
- Water,
- Carbon dioxide (CO_2), oxygen (O_2), and water (H_2O); and
- Nutrients

Generally, we have little control over the supply of the first four of these, especially in the oil palm industry, with the possible exception of water in a nursery operation.

The fifth, nutrients, can to a large extent, be influenced by management of oil palm plantations and subsequent extraction and processing of oil. The simplest of which is the provision of exogenous fertilisers.

Higher plants have a requirement for 17 essential elements in order to complete their life cycles (C, H, O, N, P, K, Ca, Mg, S, Fe, Zn, Mn, Cu, B, Mo, Cl, Ni)[1]. Every one of these must be present in the plant tissue for normal function and growth; although the amount required varies by several orders of magnitude and can be dependent on the specific requirements of different plant organs. Nevertheless, if any one of these is not being supplied in adequate amounts to meet the plant's requirement, no matter how small that requirement might be, the plant will not grow and reproduce normally.

The first three of these essential elements are supplied by air (CO_2, O_2) and water (H_2O) and are sometimes not included in the list of essential nutrients as they must be supplied in these combined forms. So the list of requirements for plant growth is often listed in more practical terms as: Light, Water, Air (CO_2, O_2), and mineral nutrients. The fourth element in the list, N, holds special status. Although it can be converted from gaseous N_2 into plant available forms (eg NH_4) by legumes through a process of nitrogen fixation, this process is carried out by symbiotic bacteria; N_2 *per se*, is not taken up by higher plants, but rather the products of microbial N_2 fixation. Thus the remaining 14 essential elements (including N) are often referred to as mineral nutrients. It is these mineral nutrients that are discussed further in this framework.

Nutrient Capital

Nutrient capital is the 'bank account' of nutrients. Imports into this capital are the 'deposits'; and exports are the 'withdrawals'. The 'closing balance' of nutrients, at any scale, is the 'opening balance' plus the 'deposits' minus the 'withdrawals' over any particular time period. Just like a bank account, a diminishing balance is generally not sustainable in the long term.

[1] Na, and Si, are also considered essential for some plants.

The Whole of the Industry - PNG

At the whole of the industry scale (≈ 100,000 ha), the 'bank account' can be described in relatively simple terms (Figure 10). The nutrient capital, at any one point in time, is the sum of all nutrients in the industry. The most obvious of these will include nutrients in the soil, the vegetation (palms, ground cover, and epiphytes; but also gardens lawns and non-palm forests, grasslands, and bush), soil water, soil organic matter, and soil organisms. The less obvious is what is present in wastes and effluent.

The most obvious imports into this system will come from fertilisers, N_2 fixation, and alluvial and volcanic deposition. However, rainfall, dry deposition and sea-spray will also contribute to nutrient import. Mineral weathering is included but its inclusion depends on whether we are considering total nutrients (in which case it is not an import) or plant-available nutrients (in which case it is an import)

A clear source of nutrient export is the commercial products such as the palm oil (CPO, PKO, or refined oil products), but also includes the palm kernel and PKE meal from some plantations. Other exports of nutrients are those losses through smoke and ash (although these may be redeposited), volatilisation, drainage below the root depth, and soluble & particulate nutrients to streams.

At this scale the exports only represent those where the nutrients are taken completely out of the area of land on which oil palm production and processing takes place. So, for example, transport and redeposition of fertiliser from one part of the plantation to another is not an export as it is still contained within the industry. Similarly, POME, contained within ponds, is not an export unless it enters into streams or rivers and is then lost from the industry property.

Thus at this scale, there may be little in the way of nutrient losses through products and by products; as it is unlikely that the oil will contain substantial amounts of mineral nutrients (although it will represent a large export of C and H). In addition, EFB, although a potentially large contributor to nutrient export, is usually completely recycled within the industry and therefore is not regarded as an export. The large unknowns are how much nutrient is lost through deep drainage and overland flow into streams and rivers. Judging by the transport of soil particles during rainfall events, this source is probably a small contributor to nutrient loss in well-established plantation blocks; but has the potential to be a substantial source in poorly managed new plantings. Outside the plantation blocks (eg roads), especially in areas with highly erodible soils, erosion is a major source of nutrient loss. One only has to compare the level of the road base to the surrounding plantation to get an estimate of the amount of soil (and thus nutrient) that has been lost by erosion.

Although much of the nutrient capital may be retained within the industry, it is its distribution (and redistribution) that will have a major influence on current and future potential productivity.

The Single Palm

At the single palm scale (≈ 80 m^2), many of the items and processes discussed above still exist, but are allocated to different categories (Figure 10). For example, the nutrient capital is represented by fewer items, *viz*. the vegetation, the soil, and soil components (water, organisms, and organic matter). That is, the by-products of processing the fruit now fall into nutrient imports (or potential nutrient imports), and products of fruit processing are now encapsulated in one item, FFB.

With regard to other imports, the natural imports and fertiliser remain largely the same. However, the distance for transport processes is greatly reduced; 'alluvial' now referring to metres rather than 10's of kilometres. Similarly for exports, the same natural processes occur that occur at the industry scale, it is just that the horizontal scale is much reduced.

Whole Industry	***Single Palm***	
Fertiliser	Fertiliser	
N_2 fixation	N_2 fixation	
Dry deposition (incl. sea spray)	Dry deposition (incl. sea spray)	
Rainfall	Rainfall	
Alluvial	Alluvial	
Volcanic	Volcanic	**Nutrient Imports**
[Mineral weathering]	[Mineral weathering]	
	Wastes (eg EFB, PKE, mesocarp fibre)	
	Effluent	

⇓ ⇓

Palms, ground cover, epiphytes	Palms, ground cover, epiphytes	
Soil	Soil	
Soil water	Soil water	
Soil organisms, insects	Soil organisms, insects	
Soil organic matter	Soil organic matter	
Large fauna (incl. Human)		**Nutrient Capital**
Wastes (eg EFB, PKE, mesocarp fibre)		
Effluent		

⇓ ⇓

Oil products	FFB	
PKE meal, palm kernels		
Particulate (smoke, ash)		
Volatilisation	Volatilisation	**Nutrient Exports**
Deep drainage	Deep drainage	
Soluble & particulate nutrients to streams & rivers	Soluble & particulate nutrients to streams & rivers	

Figure 10: Nutrient Capital, Imports and Exports for the PNG Oil Palm Industry, and a single palm.

The Block or LSU/MU

The block scale can largely be considered the same as the single palm scale. If the single palm is considered a 'pixel', then the block can simply be regarded as a large array of identical (or at least average) pixels[2]. Clearly, the horizontal scale of nutrient transport may be an order or two of magnitude greater; but on average, should follow the same principles. It is only if there is considerable variation within a block (eg different soil type, rainfall, drainage patterns, progeny) that this argument would fail[3].

Within the single palm

Although the 'single palm' can be scaled up to the block, it cannot be scaled down. Within each single palm there is an enormous level of heterogeneity. It can easily be conceived to divide the single palm scale into a number of soil zones; *viz*. the harvest path, the weeded circle, the frond pile, the frond tip pile (where 'boxing' is practiced), the zone between the weeded circle and the frond zones, plus the zone under the palm trunk. Each of these zones will have different soil physical, chemical, biological, and hydrologic properties. Overlaid on this is the influence of the canopy on (i) the redistribution of rainfall, and (ii) light penetration to ground level (hence growth of ground cover).

Each of these zones will have different nutrient capital, nutrient import, and nutrient export regimes; largely driven by management (frond and fertiliser placement, in-field harvesting equipment) and hydrology.

Comparison of scales

What is evident from the above discussion is that the nutrient capital, imports, and exports are different, both categorically and numerically, at these various scales. These differences highlight a need to understand nutrient dynamics at the various scales, even if nutrients are managed, for practical purposes, at an LSU/MU level.

Management scales

Decisions about nutrient application (fertiliser, waste products) are often made at the block scale; although there is an increasing effort to make these decisions at an LSU/MU scale or at least a scale that has a higher degree of homogeneity in, for example, soil type, aspect, climate, progeny, and tissue analysis results. Although the technologies exist (GPS, GIS), management at the precision of the single palm is not yet practical. Hence nutrient management is usually carried out at a scale of 10's – 100's of ha.

However, even though nutrient management decisions are made at this higher scale, nutrient application at the palm scale is not homogenous[4]. Nutrients tend to be placed in specific zones; for example, fertilisers made be spread only on the frond pile, EFB only placed in the between palm zone. That is, while fertiliser recommendations may be made at the block scale, they are applied at the zone scale. Adding further to this complication is the heterogeneity of other important elements such as water distribution, light distribution, and organic matter distribution. All of which will influence soil physical, chemical, biological, and hydrologic properties at a very small scale.

The mill scale (plantation vs. smallholder)

There is no doubt that there is a net movement of nutrients from smallholder blocks to plantation blocks. Nutrients are exported in FFB. These nutrients are rarely returned to smallholder blocks in the form of EFB or POME as smallholders are generally reluctant to pay for transport costs; instead they are returned to plantation blocks, usually in the vicinity of the mill.

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[2] This, of course, does not mean that simply measuring attributes of one single palm can be extrapolated to the whole block. The normal procedures of statistical design for sampling still apply.
[3] This concept emphasises the importance of allocating LSU's or MU's on the basis of homogeneity of palms/soil/environment etc rather than surveyors' boundaries. Indeed, it is feasible that a single LSU/MU may cover non-contiguous areas.
[4] This argument would most likely still apply even if nutrient decisions were made at the single palm scale.

Although some nutrients are returned in the form of fertilisers, this is usually only N (and the associated anion). However, increasing production by smallholders by increasing N fertiliser will also result in an increase in export of other nutrients such as K, P, and S in the FFB. As supplemental fertilisation with K, P, and S is uncommon, this only will lead to a more rapid decline in these nutrients and a long-term decline in soil fertility and thus productivity. From a nutrient capital perspective, careful and responsible advice needs to be exercised in the quest to increase smallholder productivity.

Managing Nutrient Supply

To be able to grow and reproduce (produce fruit) palms need access to nutrients. Some of these nutrients can be accumulated by palms and redistributed later; others cannot and therefore must be provided in constant supply. One of the determining factors in this requirement is the particular nutrient's mobility within the plant. Nutrients can generally be placed in one of three categories depending on their mobility (Table 10). Mobility in this sense refers to 'phloem' mobility; which is the mobility after the nutrient has been initially taken up and deposited in a tissue or organ.

Table 10: Nutrient mobility with plants.

Mobile	Variably mobile	Immobile
Nitrogen (N)	Sulphur (S)	Calcium (Ca)
Phosphorus (P)	Copper (Cu)	Manganese (Mn)
Potassium (K)	Molybdenum (Mo)	Boron (B)
Magnesium (Mg)	Zinc (Zn)	Iron (Fe)

How a nutrient is classified has important implications for its management. Nutrients that are mobile can often be supplied less frequently and in larger amounts as long as the plant has the ability to take up and store those nutrients. These stored nutrients can then be remobilised by the palm at a later time to be utilised where and when needed; for example, the growing point (cabbage) or new developing leaves, developing fruit.

By contrast, the immobile nutrients, once deposited in a particular location, cannot be remobilised from that location. A good example is Ca. Once it is deposited in the leaf (usually associated with cell walls), it cannot be moved out again. Indeed, it remains there until the leaf senesces, falls from the palms and decomposes.

The third category, variably mobile, has particular interest for the oil palm industry because of the way palm fronds are managed. A variably mobile nutrient tends to be immobilised in green leaves, only moving out (with the nitrogen) when the leaves senesce, either naturally or through nitrogen deficiency. Thus, in the oil palm industry, where nitrogen supply is adequate and the green fronds (below the harvested fruit) are removed before they senesce, variably mobile nutrients can be regarded as immobile.

Thus, in order to maintain growth and productivity, the variably mobile and immobile nutrients must be constantly available for uptake by palm roots. This is even more important in oil palm than some other crops. Annuals and seasonal plants will often have periods of very high demand for nutrients (eg fruit set) as well as periods of lower demand. Nutrient management can therefore be designed around the peak demand periods. Oil palm, on the other hand is in continually production (although it the magnitude of the productivity may have some seasonality) and therefore has a year-round demand for nutrients and thus for an external nutrient supply in relation to the variably mobile and immobile nutrients.

Another aspect of nutrient supply that is often overlooked is the location of the nutrient requirement. Whilst it is usually recognised that different organs (leaves, flowers, fruit etc) may have different nutrient requirements, the so-called, ‘external’ requirement, is often not appreciated. Both Ca and B play an important role external to the root surface. For a root to function properly and take up nutrients and water, it must be bathed in a solution (soil solution) that contains adequate amounts of Ca and B. This ‘external’ requirement cannot be satisfied by Ca and B already within the plant tissue. So once again, a continuous supply of these nutrients to the solution surrounding the roots is essential for healthy palms. This is a reason why B deficiency is often more severe in dry weather.

Managing to Maintain a High Nutrient Capital

In order to maintain productivity it is necessary to maintain a high level of nutrient capital. A high nutrient capital can of course be maintained by high nutrient imports even in the face of high exports. However, this is clearly not desirable. What is needed is to maintain a high nutrient capital with the minimum of nutrient imports by reducing the nutrient exports.

There are two main ways in which this can be achieved: (i) by matching nutrient supply to nutrient demand, and (ii) by ensuring that the soil retains nutrients in an available form and against losses below or away from the root zone.

This can be achieved through an understanding of (i) the concepts of nutrient use efficiency (NUE), and (ii) the physical, chemical, biological, and hydrologic characteristics of the soil resource, which in turn, determine the soils’ nutrient holding and retention capacity, and thus its fertility. Although both of these concepts have been dealt with to varying degrees in the previous annual report, and NUE is described in detail in Fairhurst & Härdter[5], they will be referred to again here in the context of maintaining nutrient capital. It is important to note that both of these related and interdependent concepts are vital to maintaining a high nutrient capital.

Nutrient Use Efficiency

There are a number of definitions of NUE[6], which vary depending on the purpose required. One of the more useful definitions for the oil palm industry is the Agronomic Efficiency (AE). This is the increase in yield for each additional unit of fertiliser applied to the soil[7]. The AE, can be divided into two components, *viz*, the physiological efficiency (PE) and the recovery efficiency (RE). PE is the increase in yield for each additional unit of fertiliser that is taken up by the palm. PE is influenced by progeny, crop management (eg spacing), and environmental conditions (rainfall, light etc). It is generally a goal to increase PE; as it makes sense to get as much yield out of each unit of nutrient within the palm. The RE is the proportion of fertiliser applied that is taken up by the palm. Again it is generally a goal to increase RE; as it makes sense to get as much uptake as possible from of each unit of fertiliser applied . From both of these ‘goals’ it can be assumed that it is also a goal to increase AE.

However, caution needs to exercised in the quest for high AE. As NUE is a ratio, information on the magnitude of yield and fertiliser increment are lost. It is commonly acknowledged that the highest increases in yield are obtained by satisfying the requirements of the most deficient nutrient. Thus the most deficient palms can have the highest AE (see [7]). Similarly, smallholder blocks, on which little or no fertiliser is applied, can still achieve yields of ≈ 10 t FFB/ha. This again would constitute a high AE. Clearly, this is not what is intended by the quest for high AE. On the other hand, a low AE might be measured because some nutrient, other than the one being measured, is limiting yield potential. Thus, while striving for a high AE is a worthy goal, it must be considered in the context of absolute yield figures.

[5] Fairhurst & Härdter (2003). Oil Palm. Management for Large and Sustainable Yields.

[6] NUE, in this text, is used as a generic term to cover the various types of NUE, such Agronomic Efficiency, Physiological Efficiency, Recover Efficiency, etc.

[7] This, by its nature, follows the “law of diminishing returns, which simply means that, as we approach maximum yield, each addition unit of fertiliser produces less additional yield.

NUE can also be considered in the longer term. Within the crop cycle scale, theoretically, apart from nutrients exported in CPO & PKO, and nutrients sequestered into trunk growth increment, the same atom of a nutrient (eg K), can be re-used many times if it is returned in the form of EFB, POME, or other waste materials. Beyond the crop-cycle scale, even the nutrients sequestered in the trunk can be re-used. It is an important realisation that, although nutrients are "used", they are not "used up". Thus, in theory, the ultimate quest to achieving the best NUE would be to only have to replace the nutrients exported in the commercial oil.

An understanding of NUE, especially AE, will give us information on the amount (or proportion) of nutrients that are NOT being utilised for yield production. Its partner, the maintenance of soil fertility, will give us information on the fate (retention or loss) of these nutrients NOT being utilised (immediately) for yield production.

Maintenance of Soil Fertility

This important issue, and reasons for its importance, have been detailed in the 2002 Annual Research Report. In the context of nutrient capital and nutrient dynamics, the role of soil fertility is paramount.

A soil with high fertility will, by its nature, also have a high nutrient capital. Soil fertility and soil nutrient capital are inextricably linked. Declining soil fertility will result in declining nutrient capital (and associated nutrient export); declining nutrient capital will result in declining soil fertility. This also affects the soil's ability to recycle and retain nutrients, leading to a further (and accelerated) decline in both – a 'vicious circle' – ending up with a soil depleted in nutrients, organic matter, and biological activity. This usually also leads to a soil with poor physical and hydrologic properties.

Unfortunately, this is a one-way process. Soil degradation often results in irreversible changes. Rejuvenation of a degraded soil is a difficult and expensive task that requires substantial inputs; inputs that are orders of magnitude greater than the accumulated cost of preventing that degradation. This is truly a case of "a stitch in time saves nine"; but probably more like 9,000!

In order to maintain a high nutrient capital, it is necessary to understand the process of nutrient dynamics. Some of these are already well known and can be accounted for, such as export of EFB. Others, namely, the soil processes, are less well known.

A new proposal is being developed with ACIAR, JCU & CSIRO that will address the impact of the industry and its management on soil organic matter, soil acidification, cation exchange capacity, water infiltration and soil erosion – the driving forces that control soil nutrient capital and soil fertility. A draft of this proposal will be presented in the 2005 Research Proposals.

While this approach will provide in formation at a block or LSU/MU scale, we also need to understand these processes at the zone scale. As previously mentioned, nutrient management decisions are made on a block or LSU/MU scale, but nutrient application is done at the soil zone scale. This then leads to questions of how to manage these zones in such a way that they retain their nutrient capital. Thus decisions on placement of, for example, fronds, EFB, POME, and fertilisers, as well as the orientation of harvest paths, and terracing, require and understanding of how these decisions affect soil organic matter, soil acidification, cation exchange capacity, water infiltration, and soil erosion. A simple example is the question of placement of nitrogen fertilisers. Often it is advocated that they should be placed on the frond pile as the fronds will protect the fertiliser from being washed away with surface flow of water and this is also a zone of high root activity. However, it is also a zone of high water infiltration. Thus any highly soluble fertiliser, such as the N sources, may well be rapidly washed through the soil beyond the root zone. It is these sorts of questions that can also be answered through an understanding of the processes control soil organic matter accumulation and turnover, soil acidification rates, cation exchange capacity changes, water infiltration rates, and soil erosion rates.

Some of our current projects are already addressing some of these questions: *viz*. the nitrogen loss project, the Mg (K) project, lack of fertiliser response, and fertiliser placement projects; and infrastructure is already in place to measure long term erosion and deposition at about 40 sites in

WNB and Milne Bay. Again, the proposal being developed with ACIAR will contribute further to the understanding of the processes.

Summary

- Maintaining a high nutrient capital is the key to maintaining a soil fertility success.
- Maintaining a fertile soil is the key to agronomic success.
- Maintaining agronomic success whilst minimising nutrient export is the key to economic success

So the judicious use of fertilisers and waste products based on an understanding of soil organic matter, soil acidification, cation exchange capacity, water infiltration, and soil erosion, is literally “money in the bank”.

FERTILISER RESPONSE TRIALS IN WEST NEW BRITAIN (NBPOL)

(J. Kraip, M.J. 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 11) are arranged in a randomised complete block design with 4 replicates.

Table 11. 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 ammonium chloride and kieserite is applied to all plots receiving fertiliser. The fertiliser is applied on the weeded circle, the frond pile or the EFB (Table 12). The four treatments are arranged in a randomised complete block design with 8 replications.

Table 12. 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	-

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

This trial will now be used to measure the effects the different zones (weeded circle, frond pile, EFB) on the retention of cations.

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.

Sampling Strategy – Soils:

Soils will be sampled at a number of times following application of fertiliser. The sampling will be about 9 months after fertiliser application.

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.

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

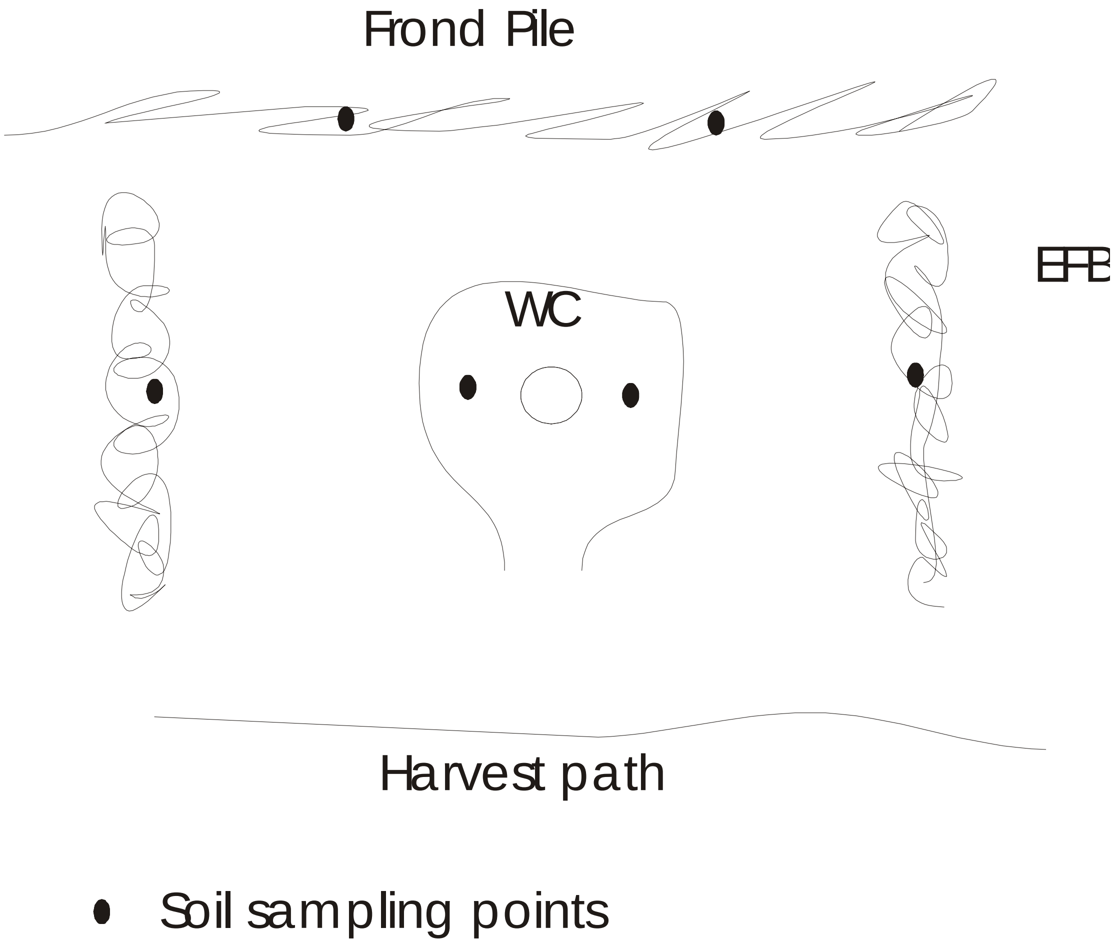
Thus there are 7 zones to be sampled per replicate (with 3 of these zones being sampled from the one plot).

Depths equal 4 (0-5, 5-10, 10-20, 20-40)

Timing 9-months after fertiliser application.

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.


Frond Pile
EFB
WC
Harvest path
Soil sampling points

TRIAL 136. MONTHLY FROND SAMPLING TRIAL

PURPOSE

To determine variations in tissue nutrient levels over the year to help interpret routine tissue sampling results.

BACKGROUND

The PNGOPRA Scientific Advisory Committee meeting in 1997 requested that monthly leaf sampling be conducted on NBPOL plantations. Similar trials have been carried out in Oro in 1985-1987 (Trial 708, 1988 Annual Report), Milne Bay in 1990 (Trial 508, 1990 Annual Report) and Bebere in 1984 (Trial 101b, 1984 Annual Report).

DESIGN

Plantation sites selected for sampling are listed in Table 13. The trial commenced in early 1998 and continued for a period of about five years.

Table 13. Plantation and Sampling sites for Trial 136.

Plantation	Year of planting	Location
Haella	1995	Between road 5 and 6 and Avenue 12 and 13
Kumbango	1993 (replant)	Behind Kumbango office, D/C 13-14
Malilimi	1985	Field 85B – Road 1 and 2 and Avenue 5 and 6.
Bilomi	1987	Field 86K- Road 2 and 3, and Avenue 9 and 10
Kautu	1986	Road 7 and 8, Avenue 14 – 15

Leaf and rachis tissue were taken from frond-17 from approximately 40 palms from each field at the same time each month. Sampling intensity was every 10^{th} palm in every 10^{th} row with different palms sampled on each date. Samples were taken to the station where they were dried according to standard procedure. Analyses were carried out for the major nutrients – N, P, K and the secondary nutrients – Ca, Mg and Cl. Boron was the only minor nutrient included in these analyses. Rachis samples were analysed for K only.

Fertiliser applications at each sampling site were carried out under the management of each plantation. This varies with each site and each year.

RESULTS

The mean annual tissue nutrient concentrations for the five sites are shown in Table 14. K and Mg concentration generally appeared to be low and Ca concentration high. Of the 5 locations, Haella, the most recently planted site, consistently has the highest leaflet N, P and K concentrations. Kumbango has the highest rachis K and the lowest leaflet Mg and B concentrations. Malilimi has the lowest leaflet N and P. Kautu has the highest Mg concentration and the lowest Ca and Cl. Over the 5-year period, there has been a consistent downward trend for P at most sites. Other nutrients have not shown consistent trends over the period except at specific sites. For example, N, Ca, Mg, and Cl concentrations also all appear to be decreasing with time at Haella; however, this may be a result of the younger age of the palms rather than an effect on the site.

The 2003 monthly rainfall, fertilizer application and tissue nutrient concentrations for the five sites are shown in Tables 15-19 and figure 11. All sites recorded the highest rainfall in March except Haella (January) and lowest in June. At Kautu, leaflet N, P, K, and B concentration tended to peak during the drier months while ash and Ca took the opposite trend. At Bilomi, leaflet N and P concentrations were lowest while K and Cl were highest during the driest month (June). Ca content was fairly constant throughout the year while B and ash concentrations were lowest during the wettest month (March) at Bilomi. Leaflet N content peaked during the wettest month while ash content was lowest during the driest month at Malilimi. For the same site, P, Mg and Ca concentrations peaked during the driest month and Cl concentration was fairly constant during the year. At Kumbango, leaflet P concentration was lowest during the wettest month and K progressively declined over the year. The B and ash concentrations were lowest and Cl at its peak in the month (May) that recorded the lowest rainfall at Kumbango. Leaflet N and K concentrations were fairly constant over the year while P, Mg and Ca concentrations peaked in June when rainfall was lowest at Haella.

Table 14. Mean annual nutrient concentrations in Frond-17 for the five sites in 1998 – 2003. Nutrient concentrations are for leaflets except where rachis is specified. For each year, the highest value of each parameter for the 5 locations is highlighted in bold.

Site	Nutrient	1998	1999	2000	2001	2002	2003
Haella	Ash			14.2	14.4	14.9	13.9
Kumbango	(% DM)			15.8	**16.1**	**16.9**	15.7
Malilimi				15.3	15.0	15.4	15.9
Bilomi				**15.9**	15.7	15.5	**16.1**
Kautu				14.3	13.7	13.6	14.7
Haella	Nitrogen	**2.62**	**2.42**	**2.61**	**2.56**	**2.58**	**2.48**
Kumbango	(% DM)	2.38	2.38	2.42	2.37	2.38	2.32
Malilimi		2.26	2.38	2.33	2.24	2.19	2.28
Bilomi		2.37	2.34	2.34	2.36	2.26	2.30
Kautu		2.46	2.38	2.42	2.42	2.38	2.38
Haella	Phosphorus	**0.160**	**0.158**	**0.158**	**0.153**	**0.153**	**0.148**
Kumbango	(% DM)	0.146	0.143	0.146	0.142	0.141	0.137
Malilimi		0.141	0.138	0.137	0.136	0.131	0.127
Bilomi		0.148	0.138	0.140	0.139	0.134	0.133
Kautu		0.157	0.153	0.150	0.150	0.148	0.144
Haella	Potassium	**0.81**	**0.81**	**0.80**	**0.75**	**0.77**	**0.79**
Kumbango	(% DM)	0.69	0.76	0.68	0.69	0.72	0.73
Malilimi		0.67	0.73	0.69	0.73	0.69	0.67
Bilomi		0.66	0.79	0.69	0.70	0.70	0.68
Kautu		0.72	0.74	0.72	0.73	0.73	0.69
Haella	Calcium	0.92	0.88	0.85	0.87	0.85	0.77
Kumbango	(% DM)	**0.97**	**0.89**	**0.92**	**0.98**	**0.90**	0.81
Malilimi		0.91	0.85	0.83	0.88	0.88	**0.92**
Bilomi		0.93	0.82	0.86	**0.98**	0.89	**0.92**
Kautu		0.79	0.70	0.68	0.75	0.73	0.73
Haella	Magnesium	**0.26**	**0.23**	**0.21**	0.21	0.20	0.19
Kumbango	(% DM)	0.17	0.14	0.14	0.14	0.14	0.16
Malilimi		0.16	0.15	0.15	0.16	0.15	0.17
Bilomi		0.18	0.17	0.15	0.16	0.14	0.15
Kautu		0.24	**0.23**	0.19	**0.23**	**0.22**	**0.23**

Haella	Chlorine	**0.69**	**0.71**	**0.63**	**0.59**	0.51	0.50
Kumbango	(% DM)	0.59	0.62	0.59	0.56	**0.52**	0.52
Malilimi		0.46	0.48	0.44	0.45	0.49	0.52
Bilomi		0.57	0.61	0.50	0.54	0.50	**0.53**
Kautu		0.49	0.50	0.44	0.44	0.43	0.45
Haella	Boron		**13.4**	14.0	14.9	15.0	14.7
Kumbango	(mg/kg DM)		11.4	11.9	13.2	12.9	13.6
Malilimi			12.4	15.0	17.4	15.1	15.3
Bilomi			11.9	14.6	**17.8**	14.6	15.1
Kautu			12.9	**15.5**	16.9	**15.2**	**17.0**
Haella	Rachis K	1.34	1.43	1.50	1.42	1.41	1.26
Kumbango	(% DM)	**1.50**	1.47	**1.57**	**1.59**	**1.62**	**1.48**
Malilimi		1.05	1.15	1.07	1.24	1.22	1.39
Bilomi		1.48	**1.49**	1.39	1.51	1.51	1.40
Kautu		1.22	1.04	1.09	1.05	1.25	1.15

Table 15. Rainfall, fertiliser applications and tissue nutrient concentrations at Kautu in 2003.

Month	Rainfall (mm)	Fertiliser (kg/palm)	Nutrient concentration (% DM, except B, in mg/kg)								
			Ash	N	P	K	Mg	Ca	B	Cl	Rachis K
Jan	422		15.66	2.37	0.146	0.69	0.22	0.74	17.5	0.39	1.26
Feb	314		15.33	2.33	0.142	0.75	0.21	0.65	15.2	0.50	1.38
Mar	686		17.79	2.24	0.130	0.61	0.18	0.84	17.3	0.46	0.95
Apr	334		14.37	2.44	0.144	0.69	0.22	0.74	17.6	0.38	1.07
May	334		13.01	2.44	0.149	0.73	0.24	0.73	16.1	0.42	1.38
Jun	72		13.33	2.37	0.147	0.69	0.27	0.68	17.8	0.50	1.01
Jul	286		13.29	2.44	0.149	0.67	0.27	0.72	17.2	0.48	0.97
Aug	293										
Sept	180										
Oct	162										
Nov		(4)*									
	141	(4)+									
Dec	255										
Total:	**3480**	**Mean:**	**14.7**	**2.38**	**0.144**	**0.69**	**0.23**	**0.73**	**17.0**	**0.45**	**1.15**

* = MOP 6/11/03; + = AMN 12/11/03

Table 16. Rainfall, fertiliser applications and tissue nutrient concentrations at Bilomi in 2003.

Month	Rainfall (mm)	Fertiliser (kg/palm)	Nutrient concentration (% DM, except B, in mg/kg)								
			Ash	N	P	K	Mg	Ca	B	Cl	Rachis K
Jan	386		17.68	2.27	0.129	0.73	0.12	0.92	15.8	0.49	1.38
Feb	311		17.80	2.20	0.134	0.73	0.13	0.92	16.4	0.48	1.42
Mar	700		13.95	2.56	0.140	0.69	0.17	0.92	13.0	0.51	1.50
Apr	301		17.07	2.34	0.132	0.61	0.14	0.97	17.5	0.47	1.50
May	307	(2.0)*	15.97	2.23	0.134	0.65	0.19	0.94	14.6	0.58	1.34
Jun	56		14.68	2.20	0.126	0.75	0.18	0.90	14.7	0.61	1.38
Jul	411		15.65	2.27	0.134	0.63	0.14	0.90	13.8	0.54	1.30
Aug	273										
Sept	203										
Oct	274	(2.0)*									
Nov	223										
Dec	368	(100g)+									
Total:	**3813**	**Mean:**	**16.1**	**2.30**	**0.133**	**0.68**	**0.15**	**0.92**	**15.1**	**0.53**	**1.40**

* = AMN 16/5/03 & 3/10/03; + = Boron 4/12/03

Table 17. Rainfall, fertiliser applications and tissue nutrient concentrations at Malilimi in 2003.

Month	Rainfall (mm)	Fertiliser (kg/palm)	Nutrient concentration (% DM, except B, in mg/kg) Ash	N	P	K	Mg	Ca	B	Cl	Rachis K
Jan	525		16.51	2.06	0.127	0.77	0.14	0.89	13.6	0.51	1.26
Feb	393		16.06	2.40	0.126	0.65	0.15	0.92	16.8	0.54	1.50
Mar	726		16.52	2.43	0.127	0.69	0.17	0.89	15.6	0.53	1.34
Apr	326		15.56	2.39	0.124	0.61	0.16	0.88	14.5	0.51	1.34
May	306		15.68	2.06	0.126	0.69	0.19	0.91	14.7	0.52	1.42
Jun	52	(4)*	14.91	2.36	0.132	0.63	0.20	1.03	16.3	0.52	1.46
Jul	222										
Aug	252										
Sep	239										
Oct	188										
Nov	349										
Dec	427										
Total:	**4005**	**Mean:**	**15.9**	**2.28**	**0.127**	**0.67**	**0.17**	**0.92**	**15.3**	**0.52**	**1.39**

** AMN 19/6/03 & 24/6/03 @ 2kg/application*

Table 18. Rainfall, fertiliser applications and tissue nutrient concentrations at Kumbango in 2003.

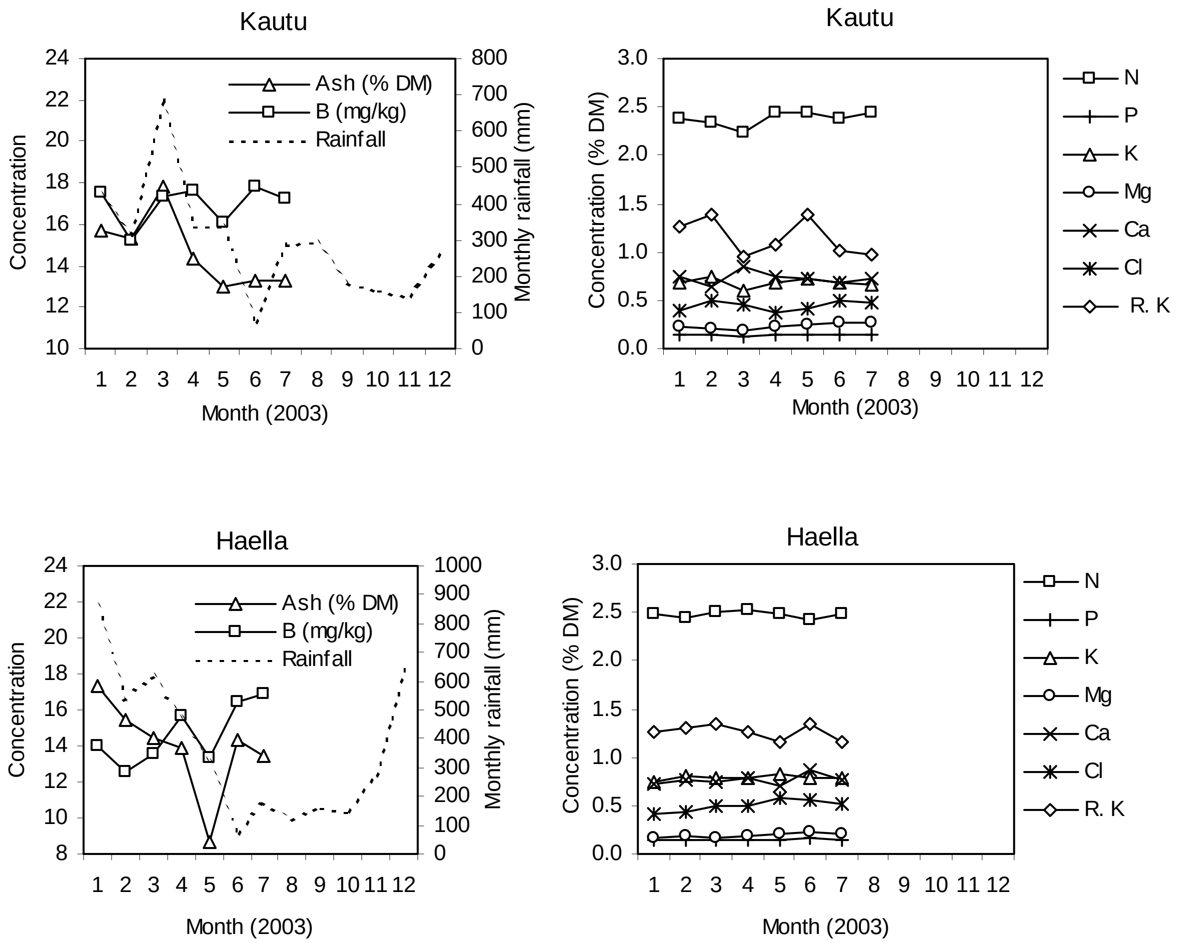
Month	Rainfall (mm)	Fertiliser (kg/palm)	Nutrient concentration (% DM, except B, in mg/kg) Ash	N	P	K	Mg	Ca	B	Cl	Rachis K
Jan	643		16.07	2.27	0.135	0.81	0.16	0.74	13.1	0.49	1.54
Feb	390		17.14	2.21	0.135	0.73	0.14	0.78	13.0	0.53	1.30
Mar	728		15.54	2.33	0.133	0.71	0.16	0.81	14.8	0.49	1.46
Apr	308		15.68	2.44	0.142	0.71	0.18	0.88	14.9	0.52	1.58
May	291		13.98	2.34	0.139	0.69	0.17	0.85	12.3	0.56	1.54
Jun	46	AMN* (3.0)									
Jul	231										
Aug	135										
Sep	112										
Oct	189	AMN* (3.0)									
Nov	348										
Dec	438										
Total:	**3859**	**Mean:**	**15.7**	**2.32**	**0.137**	**0.73**	**0.16**	**0.81**	**13.6**	**0.52**	**1.48**

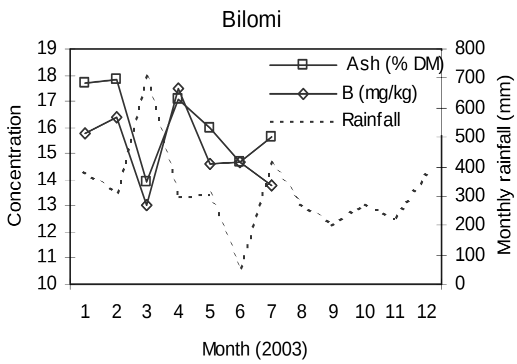
*AMN 17/6/03, AMN 7/10/03

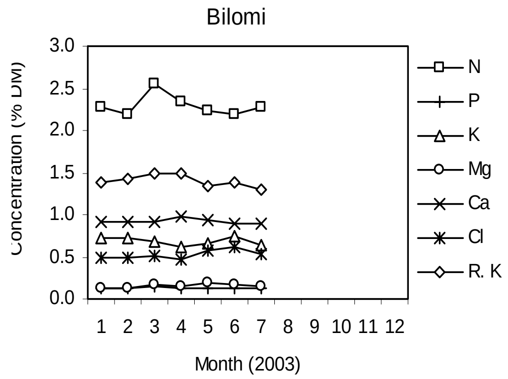
Table 19. Rainfall, fertiliser applications and tissue nutrient concentrations at Haella in 2003.

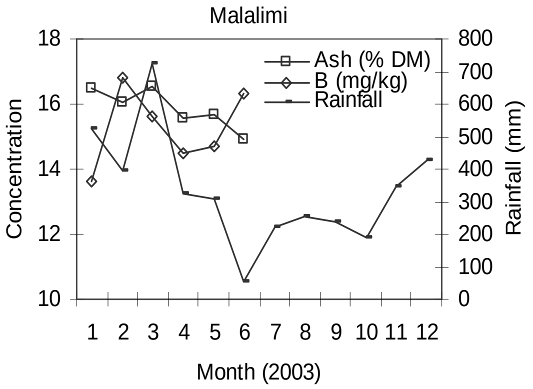
Month	Rainfall (mm)	Fertiliser (kg/palm)	Nutrient concentration (% DM, except B, in mg/kg)								
			Ash	N	P	K	Mg	Ca	B	Cl	Rachis K
Jan	864		17.33	2.48	0.150	0.75	0.16	0.73	14.0	0.42	1.26
Feb	538		15.46	2.44	0.144	0.81	0.19	0.77	12.6	0.43	1.30
Mar	618		14.40	2.51	0.147	0.79	0.17	0.74	13.6	0.50	1.34
Apr	473		13.88	2.53	0.142	0.79	0.19	0.78	15.7	0.50	1.26
May	316		8.67	2.48	0.151	0.83	0.20	0.71	13.3	0.57	1.16
Jun	68		14.37	2.42	0.156	0.79	0.22	0.86	16.5	0.56	1.34
Jul	178		13.47	2.48	0.146	0.79	0.20	0.77	16.9	0.52	1.16
Aug	118										
Sep	162										
Oct	147										
Nov	271										
Dec	642										
Total:	**4395**	**Mean:**	**13.9**	**2.48**	**0.148**	**0.79**	**0.19**	**0.77**	**14.7**	**0.50**	**1.26**

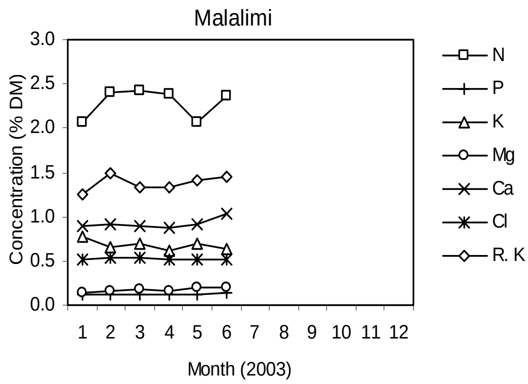
Figure 11. Graphs of monthly rainfall, leaflet nutrient concentrations and rachis K concentration during 2003 (Trial 136).

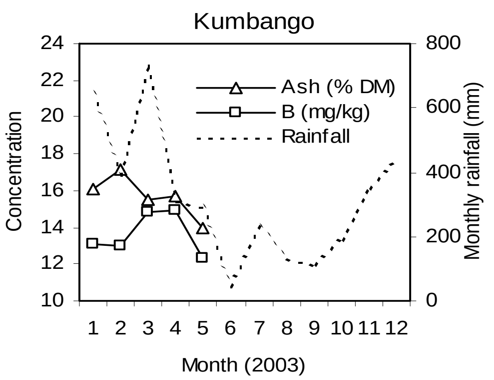


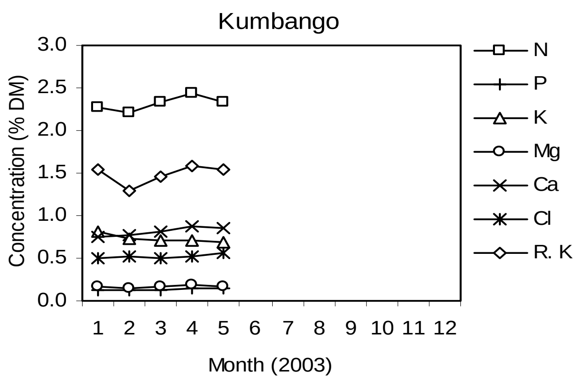

Bilomi
Ash (% DM)
B (mg/kg)
Rainfall
Concentration
Monthly rainfall (mm)
Month (2003)


Bilomi
N
P
K
Mg
Ca
Cl
R. K
Concentration (% DM)
Month (2003)


Malalimi
Ash (% DM)
B (mg/kg)
Rainfall
Concentration
Rainfall (mm)
Month (2003)


Malalimi
N
P
K
Mg
Ca
Cl
R. K
Concentration (% DM)
Month (2003)


Kumbango
Ash (% DM)
B (mg/kg)
Rainfall
Concentration
Monthly rainfall (mm)
Month (2003)


Kumbango
N
P
K
Mg
Ca
Cl
R. K
Concentration (% DM)
Month (2003)

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 are generally showing poor responses to fertilisers in NBPOL trials. 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.

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 will have 9 treatments, which are 9 rates of ammonium chloride (0, 1, 2, 3, 4, 5, 6, 7 and 8 kg AMC/palm.yr), and 8 replicates. Each plot is 4 rows of 16 palms. N rates (N 0 – N 8) vary systematically along the trial. The direction of increasing application rates is different in the different replicates, to counter the effect of any unknown fertility gradient. Plots were marked out in 2000, and treatments commenced in March 2003.

The main factor for which estimation of a response is required is nitrogen. The design allows possible K treatments to be added later if necessary. Phosphorus and magnesium are unlikely to demonstrate yield increases but may need to be applied to maintain nutrient levels. Four replicates will receive their AMC in 2 doses per year while the other 4 replicates will receive 10 doses per year.

RESULTS

There was a response of yield to N fertiliser in this first year of the trial (Table 20., Figure 12). The positive effect of N on yield was mainly through increase bunch numbers, even though this was not an expected result in the first year of the trial. Any positive effect of N fertiliser on yield through increase bunch numbers would come after year two of the trail as it takes about two years from fruit set to harvesting. The optimum rate of AMC application appears to be 5 kg/palm/year (Figure 12). Of the 288 16-palm rows that were harvested 23 times in the first year of the trial (total of 6624 row-harvests), 3 or about 0.05 % were missed. The number of missed harvests was fairly small, so they were ignored when analysing the results.

Table 20: Regression parameters for the effect of fertiliser application rate (kg/palm/year) on FFB yield and its components in 2003 (Trial 137).

	Intercept	Slope	Slope p	r^2
Yield (t/ha)	22.81	0.243	0.007	0.100
Bunches/ha	2913.0	40.5	0.006	0.101
Bunch wt. (kg)	7.89	-0.0286	0.206	0.023

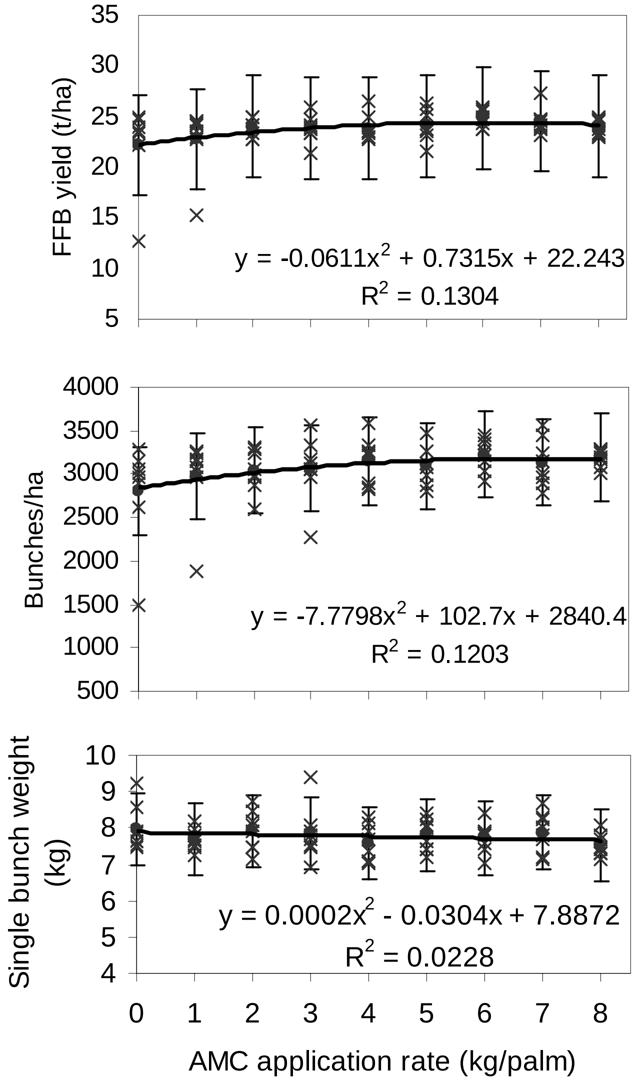


Figure 12 Effect of fertiliser rate (annual) on FFB yield, bunch numbers and single bunch weights in 2003 (Trial 137). Crosses show values for each 64-palm plot (4 rows of 16), circles show means for treatment, and bars show sd. Quadratic equations are shown as they fitted slightly better than the linear model described in Table 20.

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 are generally showing poor responses to fertilisers in NBPOL trials. 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.

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 ammonium chloride (0, 1, 2, 3, 4, 5, 6, 7 and 8 kg AMC/palm/yr), and 8 replicates. Each plot is 4 rows of 32 palms. N rates (N0 – N8) 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 no response of yield or its components to N fertiliser in the second year of the trial (Table 21., Figure 13). Nitrogen fertiliser did have a positive effect on the tissue N content (Table 22, Figure 14). Of the 288 32-palm rows that were harvested 25 times (total of 7200 row-harvests), 87 or about 1.2 % were missed. The distribution of these missed harvests was fairly random, so they were ignored when analysing the results.

Table 21 Regression parameters for the effect of fertiliser application rate (kg/palm/year) on FFB yield and its components in 2003 (Trial 138B).

	Intercept	Slope	Slope p	r^2
Yield (t/ha)	22.3	-0.018	0.824	0.001
Bunches/ha	1448.8	0.05	0.995	0.000
Bunch wt. (kg)	15.6	-0.038	0.553	0.005

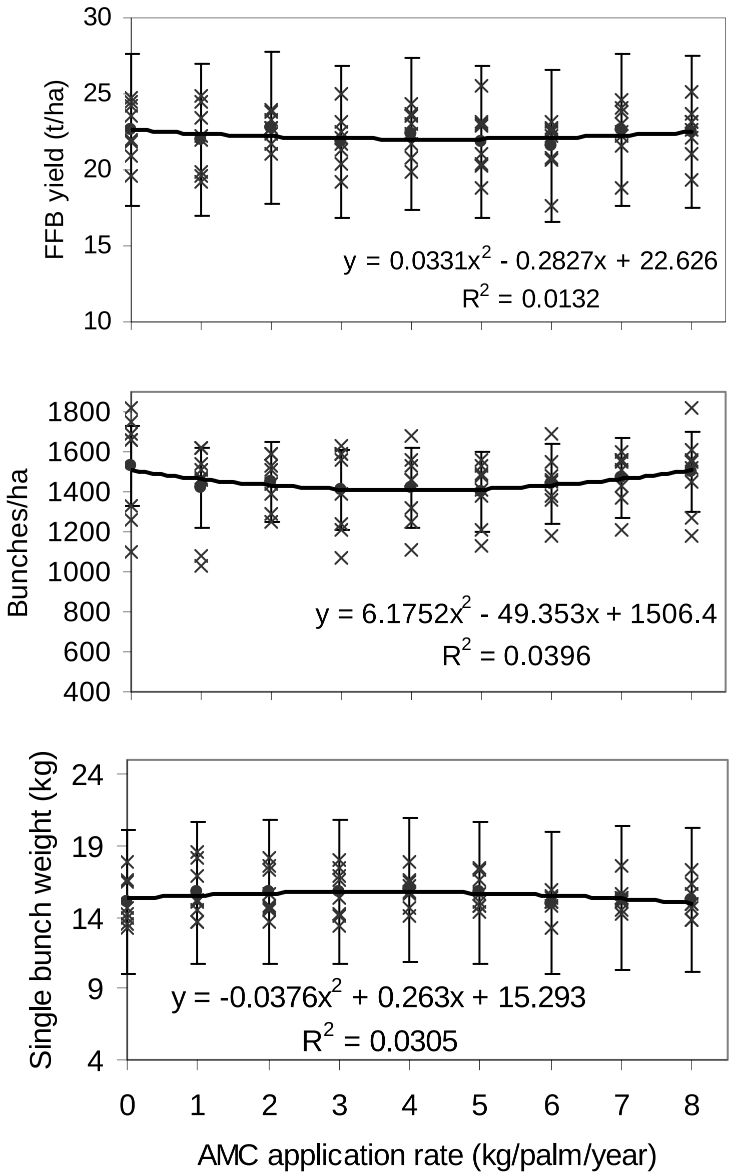


Figure 13. Effect of fertiliser rate (annual) on FFB yield, bunch numbers and single bunch weights in 2003 (Trial 138B). Crosses show values for each 128-palm plot (4 rows of 32), circles show means for treatment, and bars show sd. Quadratic equations are shown as they fitted slightly better than the linear model described in Table 21.

Table 22 Regression parameters for the effect of fertiliser application rate (kg/palm/year) on tissue nutrient contents (% DM, except for B, in mg/kg DM) in 2003 (Trial 138B). Slope *p* values <0.1 are indicated in bold.

	GM	Intercept	Slope	Slope p	r^2
Leaflet					
Ash	13.77	13.770	0.0005	0.986	0.000
N	2.49	2.456	0.0081	**0.040**	0.059
P	0.148	0.146	0.0006	**0.003**	0.120
K	0.746	0.768	-0.0055	**0.017**	0.079
Mg	0.188	0.188	0.00002	0.979	0.000
Ca	0.877	0.840	0.0092	**0.003**	0.012
B	14.55	14.393	0.0402	0.659	0.003
Cl	0.618	0.533	0.0211	**<0.001**	**0.689**
S	0.152	0.153	-0.00015	0.697	0.002
Rachis					
Ash	4.425	4.200	0.0562	**<0.001**	**0.146**
K	1.300	1.271	0.0072	0.253	0.019

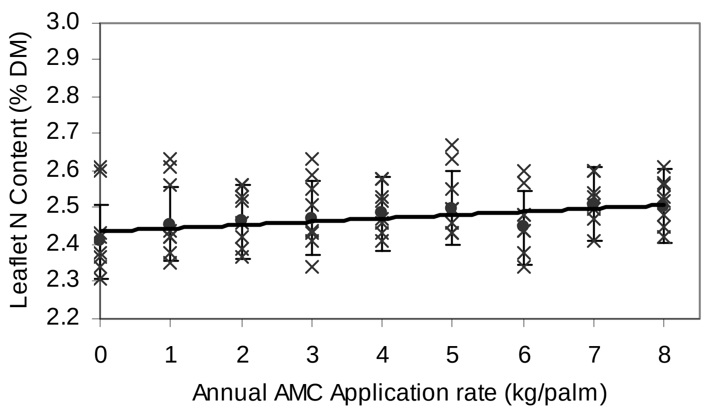


Figure 14. Effect of fertilizer rate on leaflet N content in 2003 (Trial 138B). Crosses show values for each 128-palm plot (4 rows of 32), circles show means for treatment, and bars show s.d.

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 and crop production 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 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 23. Bunch numbers and weights are being measured on every palm in every third row.

Table 23 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 9.50 (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 on yield and number of bunches/ha but not single bunch weights in this the first year of the trial (Tables 24 and 25). Of the three treatments, treatment 3 had the highest yield and bunches/ha.

Table 24 Effects (p values) of treatments on FFB yield and its components in 2003 (Trial 139). p values <0.1 are indicated in bold.

	2003		
Source	Yield	Bun./ha	kg/bun.
Treatment	**0.014**	**0.012**	0.473
CV%	*3.0*	*2.7*	*3.1*

Table 25 Main effects of treatments on FFB yield (t/ha) and its components (Trial 139). Effects with p<0.1 are shown in bold.

	2003		
	Yield	Bun./ha	kg/bun.
Treatment 1	**17.5**	**2672**	6.54
Treatment 2	**18.2**	**2688**	6.76
Treatment 3	**19.4**	**2915**	6.66
s.e.d.	*0.45*	*60.7*	*0.168*
GM	*18.4*	2758	*6.65*

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 26. 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 26 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 first year of treatments (2003) there was no effect on FFB or its components even if the previous year's FFB (before treatments) was used as a covariate (Table 27).

Table 27 Effect of N level on FFB and its components. The level of significance when the previous year's (2002) yield is used as a covariate is also given.

N Level (kg/palm)	FFB (t/ha)	Number of Bunches (bunches/ha)	Bunch Weight (kg/bunch)
0	25.4	1537	18.0
3	24.3	1487	17.8
6	23.3	1465	17.4
	Significance level		
p	0.431	0.327	0.527
p (covariate)	0.184	0.444	0.956

TRIAL 144 – MAGNESIUM AND POTASSIUM RESPONSE, WAISISI

BACKGROUND

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

PURPOSE

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

SITE AND DURATION

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

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

Soil: Very young, well-drained pumice soils. A very dark friable sandy loam to loamy topsoil overlies several layers of pumice gravel loamy sand and sandy loam volcanic ash. See DALLUS report numbers: 544a (Siki), 544g (Waisisi) and Table 30.

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 28 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 28. 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

Yield recording had not commenced in 2003 (due to commence Jan 2004). However, palms have been assessed for symptoms of Mg deficiency. Results from late 2003/early 2004 indicate that palms not receiving Mg have a greater severity of symptoms than those that are receiving Mg (Table 29).

Table 29 Mg deficiency symptom score; expressed as the number of fronds per plot showing symptoms typical of Mg deficiency.

	K_0	K_1
Mg_0	29.2	26.2
Mg_1	9.5	9.2

p values: Mg, 0.063; K, 0.856; Mg_xK, 0.878.

A more recent assessment (June 2004) has shown an even stronger response. This is the first time in WNB that it has been demonstrated that symptoms typically thought to be associated with Mg deficiency have responded to Mg application, thus providing evidence that symptoms previously assumed to have been Mg deficiency in fact are Mg deficiency.

Table 30 Description of soil pit at north-eastern edge of block A1.

Author	Betitis Date: 15/11/02
Location	Lamavoro (Waisisi) Mini estate
Landform	Alluvial flood plain, slope <1%
Previous land use	First planting oil palm from virgin forest
Dominant vegetation	Oil palm 2001 planting, cover crop (Pueraria spp) and short shrubs
Surface features	Clear felled and windrowed
Soil drainage	Well drained .
Parent material	Volcanic ash and pumice; airfall and alluvially redeposited
Soil classification	Eutrandepts (Inceptisol)?
Comments	Area prone to flooding during wet season.

Horizon	**Depth (cm)**	**Description**
A	0-16	Very dark grey (10YR 3/1); silty clay loam mixed with recent volcanic ash; weakly developed, fine crumbs; friable, slightly sticky, slightly plastic; many fine and medium roots; rapid permeability; few fine subrounded pumice fragments; smooth clear boundary;
AC	16-28	Very dark grey (2.5Y 3/1); coarse pumice mixed with fine ash; structureless; friable, slightly sticky, non plastic; common fine pores; rapid permeability; very fine roots; smooth clear boundary;
C1	28-52	Yellowish brown (2.5Y 6/4) ;Pumice; structureless; non sticky, non plastic; very rapid permeability; very few fine roots; smooth clear boundary;
bAg	52-60	Very dark grey (2.5Y 3/1; fine loamy clay ; common fine to medium distinct very dark grayish brown (2.5Y 3/2) volcanic ash mottles ; moderately developed; friable when dry; non sticky, non plastic; very few fine pores; slow permeability; common pumice fragments; very few fine roots; smooth clear boundary;
BC	60-80	Dark yellowish brown (10YR 4/6); sandy clay loam; weakly developed fine crumb structure; friable, non stick, non plastic, rapid porosity; common pumice fragments; very few fine roots; gradual diffuse boundary
C2	80-110	Olive brown (2.5Y 4/3); medium fine sand; structureless; very friable; non sticky, non plastic; very rapid permeability; pumice fragments; very few fine roots; gradual diffuse boundary;
C3	110-140	Greyish brown (2.5Y 5/2); coarse sand; structureless; very friable; non sticky, non plastic; very rapid permeability; pumice fragments; smooth clear boundary;
Bw	140-160	Light olive brown (2.5Y 5/6), sandy clay loam; weakly developed; medium sub angular blocky structure, slightly firm, slightly sticky, non plastic; very few fine pores, moderate permeability; pumice fragments; very few fine, medium and coarse roots; smooth clear boundary
C 3	160-200	Coarse pumice layer Drill by auger to 200 cm showed pumice at depth. This is most likely to be alternating again below 2.5.

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 31). 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 31 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

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) (Table 32).

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 is currently being marked out and treatments will commence in 2004.

Table 32 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, 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 33). 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 33 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			Breeding Trial 283			Breeding Trial 284		
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, 714.814 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

Only three months of data (Nov-Dec) have been collected for 2003 even though treatments were imposed at the beginning of 2003. There was no effect of Mg on yield or its components (one-way ANOVA, data not shown). The data shown are only those in which the same progeny are represented by in each replicate (two-way ANOVA). There was no significant difference in yield of FFB or number of bunches between Mg treatments although there was strong progeny effect for both yield and number of bunches (Tables 34 & Table 35).

Table 34 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	**0.017**	**<0.001**	**<0.001**
Mg	0.113	0.248	0.249
Progeny.Mg	0.883	0.590	0.859

Table 35 Progeny effect on FFB and its components. Note that the units for FFB and Number of Bunches are per palm per 3 months.

Progeny	FFB (kg/palm/3 mth)	Number of Bunches (no./palm/3 mth)	Bunch Weight (kg/bunch)
635.607	35.6	10.8	3.3
714.712	40.1	10.4	4.0
5035.216	37.5	9.3	4.1

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 & 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 (Table36). 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 36 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, 714.814 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.

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.

SITE & 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 ammonium chloride (0, 1, 2, 3, 4, 5, 6, 7 and 8 kg AMC/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 the beginning of 2003, fertiliser is being applied in 2 doses per year in 4 replicates and 10 doses per year in the other 4 replicates.

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

RESULTS

There was a response of yield to N fertiliser in this the third year of the trial (Table 37, Figure 15). The positive effect on yield was mainly due to increase bunch numbers. There was no significant effect of N fertilizer on single bunch weights. Optimum AMC application rate appears to be 4 kg/palm/year (Figure 15). Of the 288 15-palm rows that were harvested 25 times in the year (total of 7200 row-harvests), 172 or 2.4 % were missed. The distribution of these missed harvests was fairly random, so they were ignored when analysing the results.

Table 37. Regression parameters for the effect of fertiliser application rate (kg/palm/year) on FFB yield and its components in 2003 (Trial 403).

	Intercept	Slope	Slope p	r^2
Yield (t/ha)	25.03	0.215	0.033	0.063
Bunches/ha	903.5	9.340	0.025	0.070
Bunch wt. (kg)	27.78	-0.049	0.491	0.007

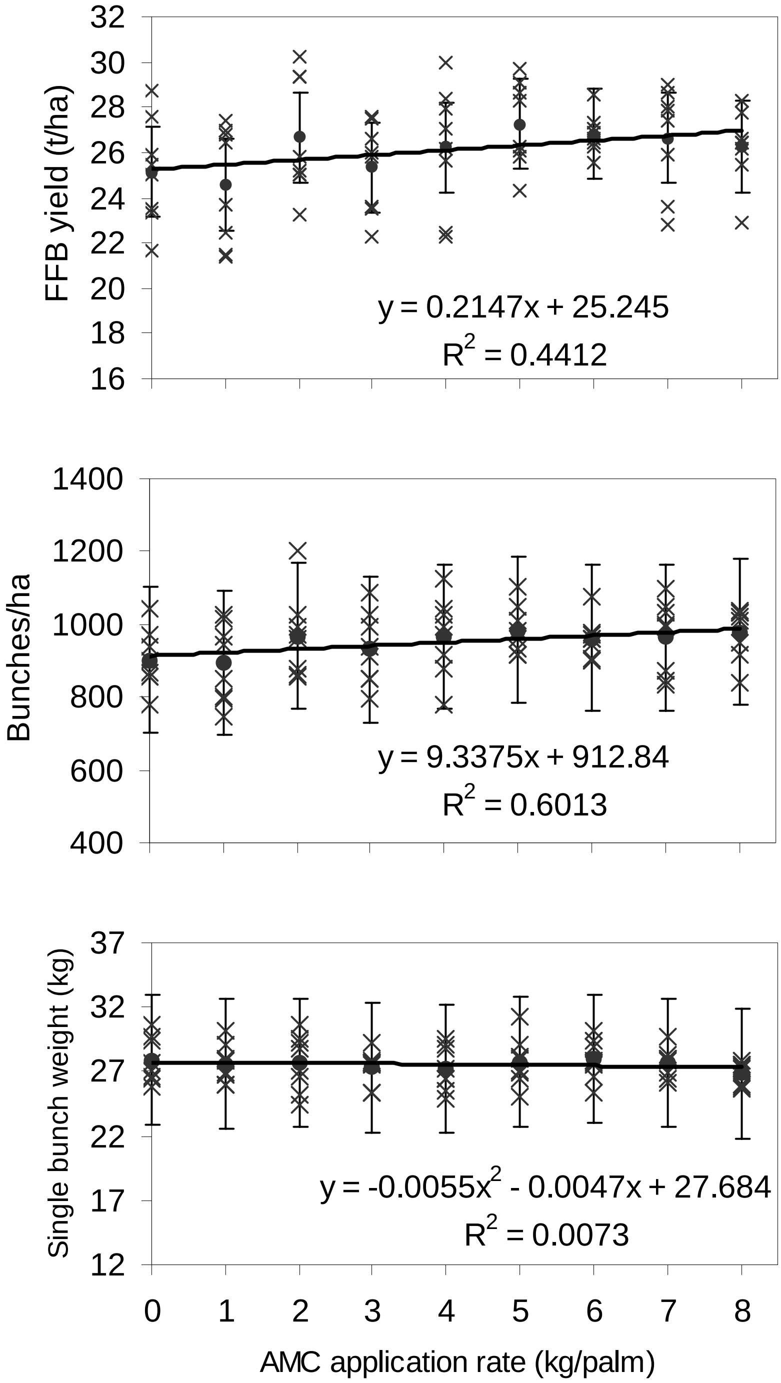


Figure 15. Effect of fertiliser rate (annual) on FFB yield, bunch numbers and single bunch weights in 2003 (Trial 403). Crosses show values for each 60-palm plot (4 rows of 15), circles show means for treatment, and bars show s.d. Quadratic equations are shown as they fitted slightly better than the linear model shown in Table 37.

FERTILISER RESPONSE TRIALS IN WEST NEW BRITAIN (Hargy)

(J. Kraip, M.J. Webb)

TRIAL 204 FACTORIAL FERTILISER TRIAL AT NAVO PLANTATION

PURPOSE

To provide fertiliser response information that will be useful in developing strategies for fertiliser use.

SITE

Site: Navo Plantation, Field 9, Block GH, Avenue 23, 24 and 25

Soil: Very young coarse textured freely draining soils formed on air-fall volcanic scoria

Topography: Flat

Palms: Dami commercial DxP crosses

Planted in 1986 at 125 palms/ha

DESIGN

Treatments commenced in May 1989. There are 36 treatments, comprising all factorial combinations of ammonium chloride (AMC) and triple superphosphate (TSP), each at three levels, and potassium chloride (MOP) and kieserite (KIE), each at two levels (Table 38). The AMC application is made in two doses per year, while the other fertilisers are applied once per year.

Table 38 Fertiliser rates in Trial 204.

	Amounts (kg/palm/yr)		
	Level 0	Level 1	Level 2
AMC	0	3	6
TSP	0	2	4
MOP	0	3	-
KIE	0	3	-

The 36 treatments are 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.

RESULTS

The main effects of SOA, MOP, TSP and kieserite over the course of Trial 204 are shown in figure 16. Yield continues to pick up again in this trial, following the crash in 2001 due to Sexava damage. Previous to the Sexava damage AMC had a large positive effect on yield. In 2001 yield was low irrespective of fertiliser treatment. In 2002, fertilisers were again beginning to have an impact on yield. The positive effect of fertilizer treatment on yield continued in 2003.

The effects of fertiliser treatments on FFB yield and its components during the 2001-2003 period and in 2003 are shown in Tables 39 and 40. There was a significant response of yield and single bunch weights to AMC during the 2001-2003 period. Yield and single bunch weights were highest at 6 kg AMC/palm/year compared to either 0 or 3 kg of AMC/palm/year during the 2001-2003 period. MOP, TSP and Kieserite did not have significant effects on yield or its components during the same period. The effect of AMC on yield and its components was again highly significant (*p<0.001)* in 2003. Yield and its components were highest at 6 kg AMC/palm/year compared to either 0 or 3 kg AMC/palm/year. MOP and TSP did not have significant effects on yield and its components in 2003, with Kieserite having a significant effect only on single bunch weights but not yield or bunch numbers. Variation in bunch numbers across the trial increased markedly in 2001-2003, probably due to patchiness of the Sexava damage, and it remained high in 2003 (see CV in Table 39).

Effects of interaction between AMC, TSP and Kieserite on FFB yield and bunch numbers in 2003 are shown in Table 41. The net effect of AMC on yield depended on TSP and KIE application. Overall, yield was highest at the highest rate of AMC with highest rates of TSP and kieserite added.

At this stage the recommendation for this area would still be to apply AMC and no other fertilizers, but another year of results should make the effects of fertilisers on recovery from Sexava damage clear.

Table 39. Effects (p values) of treatments on FFB yield and its components in 2001-2003 and 2003 for the block*units stratum (Trial 204). p values <0.1 are indicated in bold. CV% is for the interaction of block x plot.

	2001-2003			2003		
Source	Yield	Bun./ha	kg/bun.	Yield	Bun./ha	kg/bun.
AMC	**0.001**	0.733	**<.001**	**<.001**	**<.001**	**<.001**
MOP	0.180	0.121	0.444	0.944	0.865	0.444
TSP	0.136	0.180	0.955	0.189	0.389	0.886
KIE	0.382	0.230	0.239	0.672	0.285	**0.060**
AMC.MOP	0.441	0.561	0.791	0.158	0.167	0.572
AMC.TSP	**0.054**	**0.012**	0.161	0.356	**0.096**	**0.027**
MOP.TSP	0.722	0.586	0.618	0.976	0.862	0.289
AMC.KIE	0.383	0.753	0.340	0.561	0.785	0.248
MOP.KIE	0.550	0.739	0.951	0.827	0.962	0.604
TSP.KIE	0.633	0.243	0.421	0.839	0.902	**0.044**
AMC.MOP.TSP	0.550	0.720	0.174	0.132	0.411	0.409
AMC.MOP.KIE	0.424	0.205	0.328	0.753	0.479	0.484
AMC.TSP.KIE	**0.029**	**0.008**	**0.098**	0.125	**0.096**	**0.095**
MOP.TSP.KIE	**0.093**	0.104	0.984	0.602	0.412	0.725
AMC.MOP.TSP.KIE	0.580	0.793	0.310	**0.013**	**0.027**	0.286
CV %	*15.1*	*15.5*	*6.4*	*15.1*	*15.3*	*7.0*

Table 40 Main effects of treatments on FFB yield (t/ha) and its components (Trial 204). Effects with p values <0.1 are shown in bold.

	2001-2003			2003		
	Yield	Bun./ha	kg/bun.	Yield	Bun./ha	kg/bun.
AMC0	**12.6**	587	**21.8**	**15.0**	**614**	**24.5**
AMC1	**14.1**	572	**25.1**	**20.5**	**697**	**29.8**
AMC2	**15.0**	591	**25.7**	**22.9**	**760**	**30.4**
s.e.d.	*0.61*	*26.2*	*0.45*	*0.85*	*30.6*	*0.57*
MOP0	13.6	566	24.3	19.5	688	28.4
MOP1	14.2	600	24.1	19.4	692	28.1
s.e.d.	*0.50*	*21.4*	*0.36*	*0.69*	*25.0*	*0.46*
TSP0	14.4	604	24.1	19.0	685	28.1
TSP1	13.2	556	24.2	18.9	672	28.3
TSP2	14.1	590	24.3	20.4	714	28.3
s.e.d.	*0.61*	*26.2*	*0.45*	*0.85*	*30.6*	*0.57*
KIE0	14.1	596	24.0	19.6	704	**27.8**
KIE1	13.7	570	24.4	19.3	677	**28.7**
s.e.d.	*0.50*	*21.4*	*0.36*	*0.69*	*25.0*	*0.46*
GM	*13.9*	*583*	*24.2*	*19.4*	*690*	*28.3*

Table 41. Effect of interaction between AMC, TSP and KIE on FFB yield ($lsd_{0.05}$ = 4.22) and bunch number ($lsd_{0.05}$ =152.0) in 2003 (Trial 204).

Yield (t/ha)						
	TSP0		TSP1		TSP2	
	KIE0	KIE1	KIE0	KIE1	KIE0	KIE1
AMC0	16.7	14.3	13.7	14.8	14.8	15.4
AMC1	17.8	19.8	22.5	19.2	23.0	20.6
AMC2	23.9	21.7	20.5	23.0	23.5	**25.9**
Bunches/ha						
	TSP0		TSP1		TSP2	
	KIE0	KIE1	KIE0	KIE1	KIE0	KIE1
AMC0	628	621	616	603	607	609
AMC1	593	663	801	624	769	730
AMC2	868	739	663	724	790	778

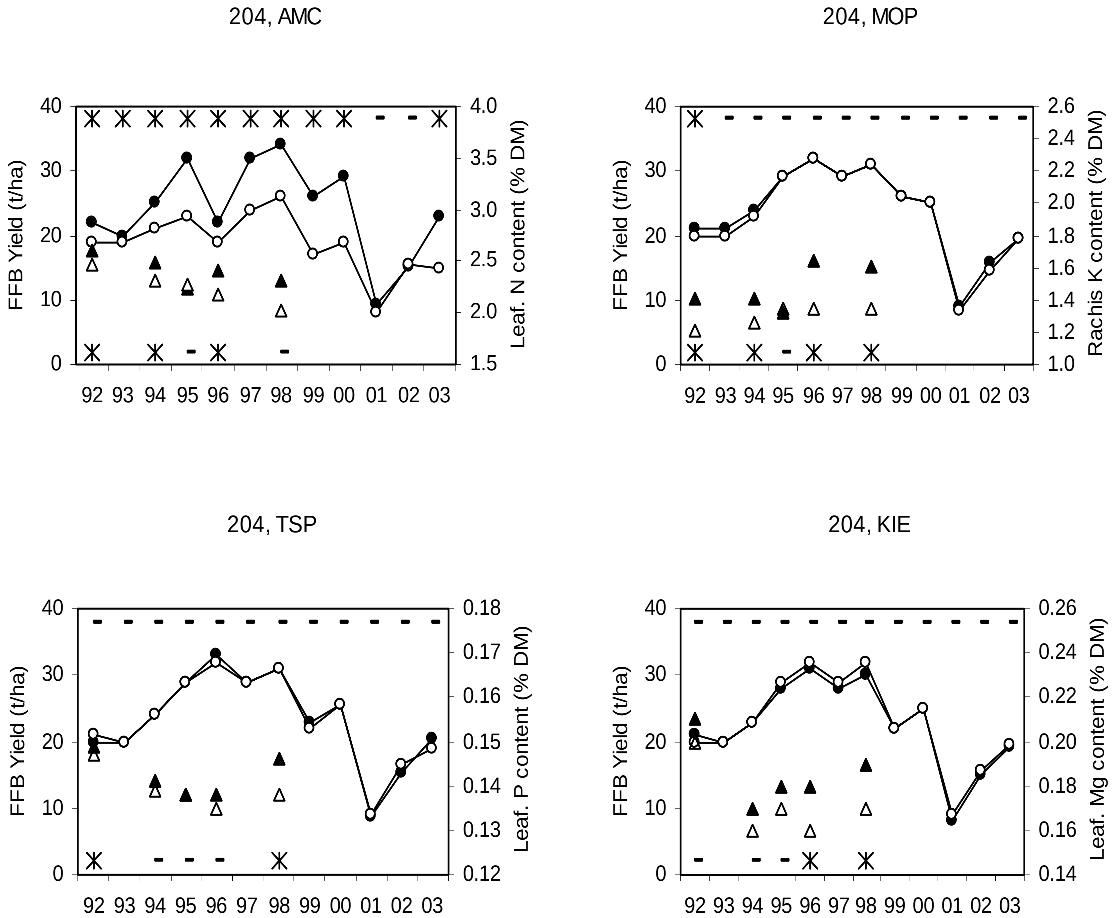


Figure 16. Main effects of AMC, MOP, TSP and Kieserite over the course of Trial 204. Lines with circles are FFB yields and triangles are tissue nutrient concentrations. Full symbols represent the maximum level of application, and empty symbols zero application. Symbols along the top of the graph indicate 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.

TRIAL 205 EFB X FERTILISER TRIAL AT HARGY PLANTATION

PURPOSE

To investigate the response of oil palm to application of empty fruit bunches (EFB), and to investigate whether the uptake of phosphorus and magnesium from triple superphosphate and kieserite can be improved by applying the fertiliser in conjunction with EFB.

SITE and PALMS

Site: Blocks 7 and 8, Area 9, Hargy Plantation, Bialla, WNBP.

Soil: Freely draining Andosol formed on intermediate to basic volcanic ash.

Topography: Gentle mid-slope, sloping towards NE

Land use prior to this crop: Replant. Previous crop was clear felled and windrowed

Palms: 16 Dami identified DxP crosses.

Planted in July and August 1993 at 135 palms/ha

DESIGN

There are eight treatments comprising all factorial combinations of EFB, triple superphosphate (TSP) and kieserite (KIE) each at two levels (Table 42). The treatments are replicated six times, with each replicate comprising one block. A blanket application of 3 kg/palm/year of ammonium chloride is applied across the trial. 36-palm plots (6 x 6 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 that have been arranged in a random spatial configuration in each plot. The 16 progenies are shown in Table 43. The trial is analysed as a split-plot design.

Table 42. 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 43. 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

Effects of EFB, TSP and kieserite on yield over the course of trial 205 are shown in Figure 17. There was a progressive decline in yield from 2000 to 2002. In 2003 yield started to pick up again. The effects of EFB and fertilizer treatments varied from year to year. Effect of TSP on yield was significant during the first three years of the trial. From 2000 to 2003 TSP had no significant effect on yield. The effect of Kieserite on yield was significant only in 1999 and 2002. Similarly the effect of EFB on yield was significant only in 1998 and 2003.

The effects of progeny and EFB, TSP and kieserite treatments on FFB yield and its components during the 2001-2003 period and in 2003 are shown in Tables 44 and 45. Progenies had the largest effect on yield in 2001 – 2003 and again in 2003 while EFB and fertilisers only had small effects. EFB was the only amendment that significantly increased yield in 2003. The progenies that yielded best in and 2003 were different to those that yielded best in 2001 or 2002, but one of the poorest performer (**G**) was the same in the three years.

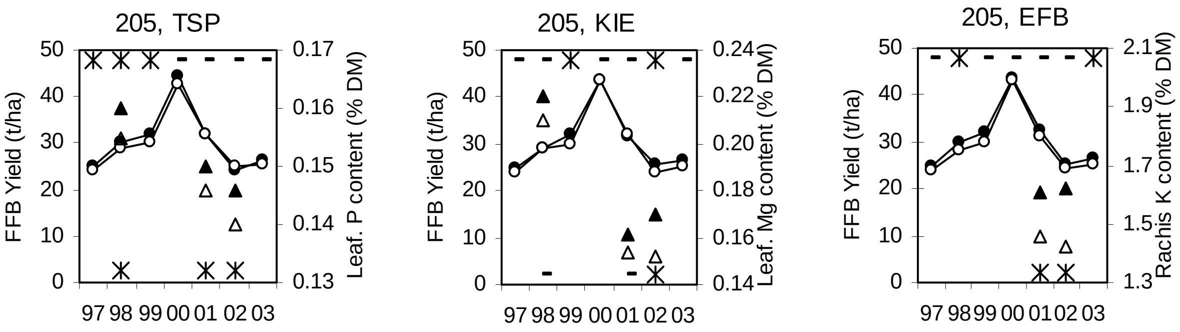


Figure 17. Main effects of TSP, kieserite and EFB over the course of Trial 205. Lines with circles are FFB yields and triangles are tissue concentrations. Full symbols represent the maximum level of application, and empty symbols zero application. Symbols along the top of the graph indicate significance of the main effect on yield, and along the bottom indicate significance of the main effect on tissue concentration. Stars indicate significance (p<0.1) and dashes non-significance.

Table 44 Effects (p values) of treatments on FFB yield and its components in 2001-2003 and 2003 (Trial 205). p values <0.1 are indicated in bold.

	2001-2003			2003		
Source	Yield	Bun./ha	kg/bun.	Yield	Bun./ha	kg/bun.
Rep.Plot stratum						
TSP	0.977	0.388	0.150	0.350	0.706	0.155
KIE	0.268	0.379	0.541	0.245	0.209	0.864
EFB	**0.063**	0.585	**0.046**	**0.074**	0.535	**0.010**
TSP.KIE	0.516	0.836	0.270	0.668	0.365	0.455
TSP.EFB	0.135	0.292	0.364	0.647	0.922	0.241
KIE.EFB	0.102	**0.041**	0.654	0.707	0.366	0.212
TSP.KIE.EFB	0.747	0.240	**0.065**	0.426	0.266	0.227
CV%	*7.6*	*7.8*	*4.1*	*11.7*	*12.1*	*5.1*
Rep.Plot.Progeny stratum						
Prog	**<0.001**	**0.011**	**<0.001**	**0.017**	0.316	**<0.001**
TSP.Prog	0.199	0.285	0.342	0.739	0.778	0.762
KIE.Prog	0.302	0.511	0.122	0.472	0.866	0.788
EFB.Prog	0.940	0.799	0.437	0.456	0.400	0.392
TSP.KIE.Prog	**0.077**	**0.058**	0.855	0.789	0.923	0.838
TSP.EFB.Prog	0.657	**0.041**	0.696	0.969	0.695	0.790
KIE.EFB.Prog	0.777	0.789	0.114	**0.077**	0.228	0.355
TSP.KIE.EFB.Prog	0.105	0.330	0.262	0.115	0.395	0.858
CV %	*24.9*	*26.2*	*14.1*	*40.6*	*42.3*	*20.6*

Table 45 Main effects of treatments on FFB yield (t/ha) and its components (Trial 205). Effects with $p<0.1$ are shown in bold.

	2001-2003			2003		
	Yield	Bun./ha	kg/bun.	Yield	Bun./ha	kg/bun.
TSP0	27.5	1551	**18.0**	25.5	1247	20.9
TSP1	27.5	1521	**18.3**	26.3	1263	21.4
KIE0	27.2	1521	18.1	25.4	1227	21.2
KIE1	27.8	1551	18.2	26.4	1283	21.1
EFB0	**26.9**	1526	**17.9**	**25.1**	1241	**20.7**
EFB1	**28.1**	1545	**18.4**	**26.7**	1269	**21.6**
Fert. s.e.d.	*0.61*	*34.4*	*0.22*	*0.87*	*43.9*	*0.31*
A	**28.4**	**1512**	**18.8**	**25.8**	1221	**21.4**
B	**28.3**	**1452**	**19.7**	**27.4**	1170	**23.7**
C	**27.1**	**1529**	**18.1**	**25.9**	1249	**21.3**
D	**26.4**	**1467**	**18.2**	**25.8**	1218	**21.7**
E	**25.5**	**1538**	**17.1**	**23.7**	1254	**19.5**
F	**26.1**	**1434**	**18.4**	**25.9**	1201	**22.1**
G	**23.9**	**1440**	**16.7**	**20.4**	1103	**19.1**
H	**29.0**	**1658**	**17.7**	**27.3**	1387	**20.4**
I	**29.3**	**1620**	**18.4**	**27.8**	1358	**20.8**
J	**29.1**	**1520**	**19.5**	**27.4**	1252	**22.1**
K	**25.8**	**1446**	**18.0**	**24.6**	1166	**22.6**
L	**27.4**	**1521**	**18.4**	**25.1**	1198	**21.4**
M	**29.5**	**1567**	**19.1**	**30.0**	1370	**22.7**
N	**27.0**	**1531**	**17.8**	**25.4**	1283	**19.9**
O	**28.0**	**1623**	**17.3**	**26.7**	1347	**20.4**
P	**29.1**	**1716**	**17.1**	**24.7**	1308	**19.1**
Prog. s.e.d.	*1.40*	*82.1*	*0.54*	*2.15*	*108.3*	*0.89*
GM	*27.5*	1536	*18.14*	*25.9*	*1255*	*21.1*

TRIAL 209 FACTORIAL FERTILISER TRIAL AT HARGY PLANTATION

PURPOSE

To provide fertiliser response information that will be useful in developing strategies for fertiliser recommendations.

BACKGROUND

Proposed to replace the discontinued trial 201.

SITE and PALMS

Hargy Plantation, Area 1, Blocks 4, 6 and 8

Soil: Freely draining Andosol formed on intermediate to basic volcanic ash

Topography: Gently sloping

Land use prior to this crop: Replant

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

Planted in October and November 1994 at 135 palms/ha

DESIGN

There are 81 treatments comprising all factorial combinations of ammonium sulphate (SOA), triple superphosphate (TSP), potassium chloride (MOP) and kieserite (KIE), each at three levels (Table 46). There are a total of 81 plots, comprising one replicate, and they are arranged in 9 blocks of 9 plots. The site was surveyed, and palm labelling was carried out in November 1996. For the first 36 months, the palms received a standard immature palm fertiliser input. Pre-treatment yield recording commenced in January 1997 and the treatments were first applied in June 1998.

Table 46 Rates of fertiliser used in Trial 209.

	Amounts (kg/palm/yr)			
	Level 0	Level 1	Level 2	Level 3
SOA	-	2	4	8
TSP	0	4	8	
MOP	0	2	4	
KIE	0	4	8	

RESULTS

Effects of treatments on yield and tissue nutrient concentrations over the course of trial 209 are shown in Figure 18. The effects of the fertilisers on yield appear to be increasing with time up to 2002 but starting to decrease in 2003. Yields in 2001 and 2002 were similar but dropped slightly in 2003. There were significant effects of SOA, MOP, TSP and KIE on tissue nutrient concentrations in 2003. Over time nutrient concentrations seem to be declining.

Over the 2001-2003 period, SOA, TSP and MOP all significantly ($p<0.08$) increased yield (Tables 47 and 48). In 2000-2002 the effects of SOA, TSP and MOP on yield were also significant. Both SOA and MOP treatments increased yield through increase bunch weights while TSP increased yield through increase bunch numbers. In 2003 the effect of TSP on yield was highly significant ($p<0.001$) compared to SOA and MOP that also had significant effects on yield. There were significant interactions between SOA.TSP.MOP and SOA.MOP.KIE (Tables 49 and 50). With the SOA.TSP.MOP interaction, highest yield was obtained at 8kg SOA, 4kg TSP and 4kg MOP per palm per year (Table 49). With the SOA.MOP.KIE interaction, highest yield was obtained at 8 kg SOA, 4kg MOP and 4kg KIE (Table 50).

The fertilisers significantly increased tissue N, P, K and Mg contents (Table 51 and 52), but the values were in the adequate range even with no fertilizer addition. Ash content in leaflets is quite high compared to other sites. However, this is consistent with 2001 results.

CONCLUSION

Effects of fertilisers were small, but yield was highest at the highest rates of SOA, TSP and MOP, irrespective of kieserite application.

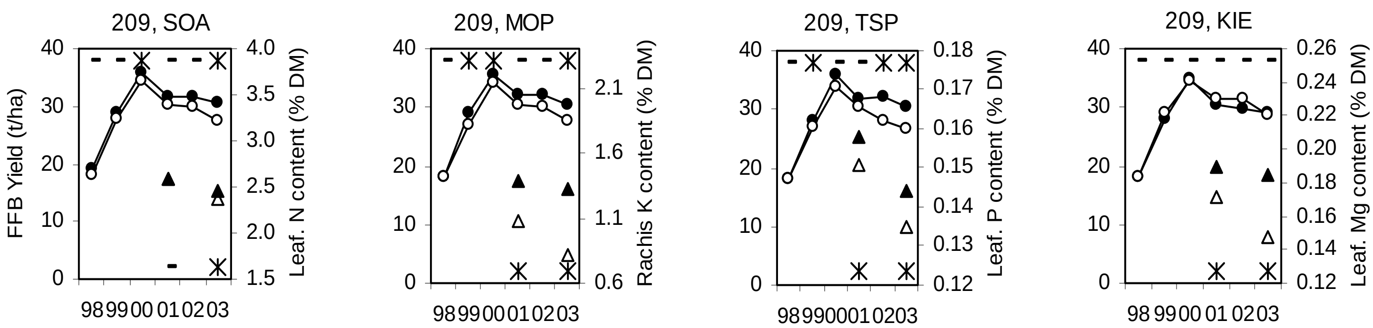


Figure 18. Main effects of SOA, MOP, TSP and KIE over the course of Trial 209. Lines are FFB yields and triangles are tissue concentrations. Full symbols represent the maximum level of application, and empty symbols the lowest level. Symbols along the top of the graph indicate significance of the main 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.

Table 47. Effects (p values) of treatments on FFB yield and its components in 2001-2003 and 2003 (Trial 209). p values <0.1 are indicated in bold.

	2001-2003			2003		
Source	Yield	Bun./ha	kg/bun.	Yield	Bun./ha	kg/bun.
SOA	**0.008**	0.117	**0.014**	**0.006**	0.225	**0.019**
TSP	**<0.001**	**0.002**	0.357	**<0.001**	**0.001**	0.716
MOP	**0.007**	0.326	**<0.001**	**0.009**	0.395	**<0.003**
KIE	0.361	0.276	0.406	0.851	0.929	0.916
SOA.TSP	0.902	0.924	0.550	0.813	0.726	0.787
SOA.MOP	0.865	0.627	0.435	0.451	0.601	0.538
TSP.MOP	0.764	0.711	0.877	0.662	0.768	0.849
SOA.KIE	**0.052**	**0.017**	0.110	0.158	**0.097**	0.372
TSP.KIE	**0.091**	**0.095**	0.704	**0.020**	**0.013**	0.813
MOP.KIE	**0.016**	0.128	0.926	0.410	0.505	0.978
SOA.TSP.MOP	**0.002**	**0.006**	0.393	**0.067**	**0.046**	0.910
SOA.TSP.KIE	0.311	0.583	0.625	0.840	0.816	0.941
SOA.MOP.KIE	**0.012**	**0.030**	0.235	**0.039**	**0.055**	0.421
TSP.MOP.KIE	0.333	0.401	0.580	0.587	0.821	0.668
CV %	*7.4*	*8.9*	*5.0*	*9.9*	*10.7*	*7.0*

Table 48 Main effects of treatments on FFB yield and its components (Trial 209). Effects with p<0.1 are shown in bold.

	2001-2003			2003		
	Yield (t/ha)	Bun./ha	kg/bun.	Yield (t/ha)	Bun./ha	kg/bun.
SOA1	**28.9**	1878	**15.7**	**27.6**	1554	**18.2**
SOA2	**30.4**	1979	**15.6**	**28.9**	1602	**18.4**
SOA3	**31.1**	1951	**16.2**	**30.5**	1638	**19.3**
TSP0	**28.1**	**1819**	15.6	**26.7**	**1477**	18.6
TSP1	**31.0**	**1978**	16.0	**29.8**	**1629**	18.8
TSP2	**31.4**	**2011**	15.9	**30.5**	**1688**	18.5
MOP0	**29.2**	1952	**15.2**	**27.6**	1601	**17.8**
MOP1	**29.8**	1894	**16.0**	**29.0**	1564	**19.0**
MOP2	**31.4**	1962	**16.3**	**30.4**	1629	**19.1**
KIE0	30.5	1956	15.8	28.8	1588	18.6
KIE1	30.3	1961	15.7	29.0	1606	18.6
KIE2	29.6	1891	16.0	29.2	1599	18.7
s.e.d.	*0.61*	*46.9*	*0.22*	*0.78*	*46.5*	*0.36*
GM	*30.1*	*1936*	*15.8*	*29.0*	*1598*	*18.6*

Table 49 Effect of SOA.TSP.MOP interaction on FFB yield (t/ha) in 2003 (Trial 209). P= 0.067, $lsd_{0.05}$ = 4.95. Yields >35 t/ha are highlighted.

		MOP0	MOP1	MOP2
SOA1	TSP0	23.6	25.8	26.6
	TSP1	27.8	25.9	30.2
	TSP2	28.7	30.9	28.9
SOA2	TSP0	22.7	28.1	28.1
	TSP1	29.6	32.8	28.9
	TSP2	28.5	28.5	33.0
SOA3	TSP0	29.0	27.8	29.0
	TSP1	30.0	27.7	**35.2**
	TSP2	28.9	33.0	34.2

Table 50 Effect of SOA.MOP.KIE interaction on FFB yield (t/ha) in 2003 (Trial 209). P= 0.039, $lsd_{0.05}$ = 4.95.

		KIE0	KIE1	KIE2
SOA1	MOP0	25.0	30.4	24.7
	MOP1	24.9	30.4	27.4
	MOP2	32.5	26.4	26.8
SOA2	MOP0	25.1	27.0	28.7
	MOP1	29.7	28.1	31.6
	MOP2	30.9	28.9	30.0
SOA3	MOP0	29.8	27.0	30.2
	MOP1	30.7	27.2	30.6
	MOP2	30.5	34.9	33.0

Table 51 Effects (p values) of treatments on frond-17 nutrient concentrations in 2003 (Trial 209). p values less than 0.1 are indicated in bold.

	Leaflet									Rachis	
Source	Ash	N	P	K	Mg	Ca	B	Cl	S	Ash	K
SOA	0.272	**0.002**	**0.005**	0.394	**0.001**	**0.002**	0.738	0.314	0.297	0.353	0.489
TSP	**0.006**	**0.029**	**<0.001**	**0.009**	0.553	0.102	0.831	0.623	0.217	**0.004**	**<0.001**
MOP	**<0.001**	0.556	0.905	**0.002**	**0.006**	**0.006**	**<0.001**	**<0.001**	0.556	**<0.001**	**<0.001**
KIE	**<0.001**	0.238	0.735	0.324	**<0.001**	**<0.001**	**0.017**	**0.070**	0.336	0.735	0.252
SOA.TSP	0.153	0.981	0.870	0.995	0.177	0.584	0.337	0.680	0.165	**0.045**	**0.062**
SOA.MOP	**0.078**	0.281	0.172	0.328	0.138	**0.010**	**0.069**	0.669	0.775	0.541	0.695
TSP.MOP	0.382	0.302	0.200	**0.068**	**0.047**	0.883	**0.080**	0.835	0.391	0.366	**0.019**
SOA.KIE	0.275	0.880	0.644	0.585	0.113	**0.040**	**0.008**	0.445	0.915	0.792	0.866
TSP.KIE	0.391	0.816	0.831	0.505	0.103	0.722	0.374	0.158	0.942	0.237	**0.025**
MOP.KIE	0.493	0.541	0.279	0.263	**0.045**	0.415	0.620	0.944	0.317	0.404	0.496
SOA.TSP.MOP	**<0.001**	0.522	**0.015**	**0.071**	**0.045**	0.113	**0.007**	0.677	**0.017**	0.343	0.274
SOA.TSP.KIE	**0.012**	0.540	0.483	0.206	**0.082**	0.600	**0.020**	0.516	0.191	0.366	0.678
SOA.MOP.KIE	**0.001**	0.519	**0.023**	0.428	**0.024**	0.103	**0.007**	0.450	**0.005**	**0.010**	**0.005**
TSP.MOP.KIE	**0.002**	0.997	0.407	0.503	0.576	0.143	**0.014**	**0.042**	0.134	**0.090**	**0.046**
CV %	*2.6*	*3.3*	*2.5*	*4.2*	*6.6*	*4.9*	*7.0*	*9.5*	*5.8*	*8.7*	*10.4*

Table 52 Main effects of treatments on frond-17 nutrient concentrations in 2003, in units of % dry matter, except for B (ppm) (Trial 209). Significant effects (p<0.1) are shown in bold.

	Leaflet									Rachis	
	Ash	N	P	K	Mg	Ca	B	Cl	S	Ash	K
SOA1	14.7	**2.36**	**0.139**	0.69	**0.174**	**1.00**	13.4	0.37	0.153	3.82	1.11
SOA2	14.8	**2.42**	**0.142**	0.70	**0.169**	**0.97**	13.4	0.38	0.156	3.69	1.08
SOA3	14.8	**2.45**	**0.142**	0.70	**0.160**	**0.94**	13.6	0.37	0.152	3.73	1.11
TSP0	**14.7**	**2.37**	**0.135**	**0.71**	0.169	0.95	13.4	0.37	0.156	**3.94**	**1.21**
TSP1	**14.9**	**2.42**	**0.142**	**0.68**	0.166	0.98	13.5	0.37	0.152	**3.70**	**1.07**
TSP2	**14.6**	**2.44**	**0.144**	**0.69**	0.168	0.98	13.5	0.38	0.154	**3.60**	**1.02**
MOP0	**15.7**	2.40	0.141	**0.71**	**0.174**	**0.94**	**14.8**	**0.19**	0.154	**3.17**	**0.81**
MOP1	**14.3**	2.42	0.141	**0.68**	**0.167**	**0.98**	**13.1**	**0.45**	0.155	**3.84**	**1.16**
MOP2	**14.3**	2.41	0.140	**0.69**	**0.162**	**0.99**	**12.5**	**0.49**	0.152	**4.23**	**1.33**
KIE0	**15.1**	2.39	0.141	0.69	**0.147**	**1.03**	**13.8**	**0.39**	0.154	3.77	1.10
KIE1	**14.6**	2.41	0.141	0.70	**0.172**	**0.95**	**13.5**	**0.37**	0.156	3.77	1.07
KIE2	**14.5**	2.43	0.140	0.70	**0.185**	**0.93**	**13.0**	**0.37**	0.152	3.71	1.13
s.e.d.	*0.10*	*0.022*	*0.001*	*0.008*	*0.003*	*0.027*	*0.26*	*0.01*	*0.002*	*0.089*	*0.03*
GM	*14.7*	*2.41*	*0.141*	*0.69*	*0.168*	*0.97*	*13.5*	*0.374*	*0.154*	*3.75*	*1.10*

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.

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 ammonium chloride (0, 1, 2, 3, 4, 5, 6, 7 and 8 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

There was no response of yield or bunch numbers to N fertiliser in this the second year of the trial. However, N fertiliser had a significant effect on single bunch weights (Table 53, Figure 19). Of the 288 15-palm rows that were harvested 24 times in the year (total of 6912 row-harvests), 461 or about 6.7 % were missed. The distribution of these missed harvests was fairly random so they were ignored when analysing the results.

Table 53. Regression parameters for the effect of fertiliser application rate (kg/palm/year) on FFB yield and its components in 2003 (Trial 211).

	Intercept	Slope	Slope p	r^2
Yield (t/ha)	27.2	0.192	0.214	0.022
Bunches/ha	2244	4.000	0.727	0.002
Bunch wt. (kg)	12.1	0.066	0.010	0.090

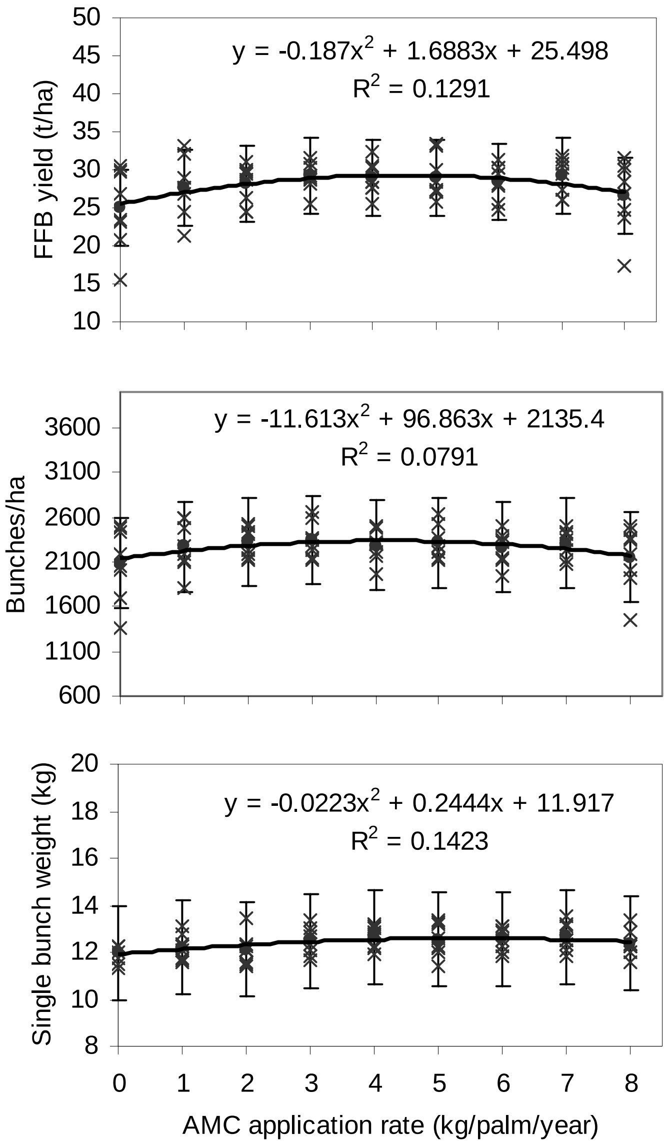


Figure 19 Effect of fertiliser rate (annual) on FFB yield, bunch numbers and single bunch weights in 2003 (Trial 211). Crosses show values for each 60-palm plot (4 rows of 15), circles show means for treatment, and bars show sd. Quadratic equations are shown as they fitted slightly better than the linear model shown in Table 53.

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.

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 ammonium chloride (0, 1, 2, 3, 4, 5, 6, 7 and 8 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 no response of yield or its components to N fertiliser in this the second year of the trial (Table 54, Figure 20). Of the 144 15-palm rows that were harvested 25 times in the year (total of 3600 row-harvests), 280 or 7.8 % were missed. The distribution of these missed harvests was fairly random, so they were ignored when analysing the results.

Table 54 Regression parameters for the effect of fertiliser application rate (kg/palm/year) on FFB yield and its components in 2003 (Trial 212).

	Intercept	Slope	Slope p	r^2
Yield (t/ha)	26.1	-0.048	0.770	0.001
Bunches/ha	1703	-11.4	0.280	0.017
Bunch wt. (kg)	15.4	0.078	0.144	0.030

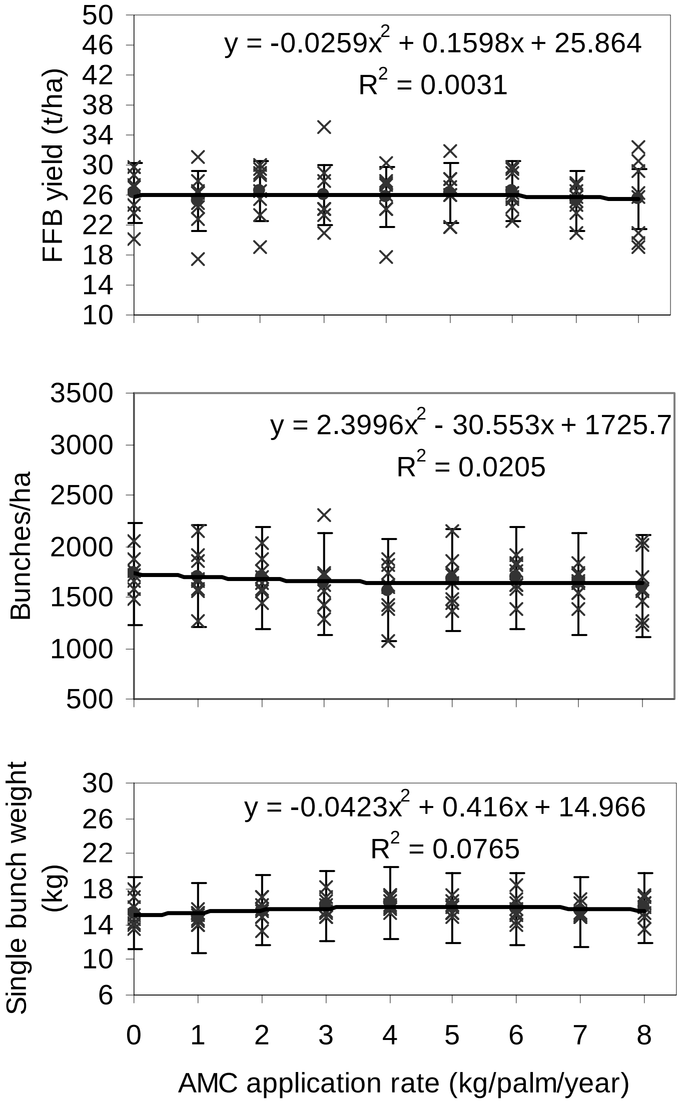


Figure 20 Effect of fertiliser rate (annual) on FFB yield, bunch numbers and single bunch weights in 2003 (Trial 212). Crosses show values for each 30-palm plot (2 rows of 15), circles show means for treatment, and bars show sd. Quadratic equations are shown as they fitted slightly better than the linear model shown in Table 54.

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

PURPOSE

To provide fertiliser response information necessary for determining fertiliser recommendations for the palms on the high ground of Hargy Plantation.

BACKGROUND

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 had been exhibiting poor growth. It was suspected from visual observation that the poor growth may be due to deficiencies of nitrogen and phosphorus.

SITE and PALMS

Hargy Estate, Area 11, Blocks 9 and 10

Soil: Freely draining Andosol formed on volcanic ash

Topography: Moderately sloping

Land use prior to this crop: Forest

Palms: Dami commercial DxP crosses

Planted in February/March 1997 at 129 palms/ha

DESIGN

Factorial design with 3 levels of ammonium chloride (AMC, 0, 3 and 6 kg/palm/year), 3 levels of triple superphosphate (TSP, 0, 3 and 6 kg/palm/year) and 4 replicates, resulting in a total of 36 plots. Plots consist of 36 palms (6x6), of which the central 16 (4x4) are recorded. Boron may be applied, depending on visual symptoms.

RESULTS

In the first year of treatments, AMC significantly increased yield and individual bunch weight but not bunch number (Tables 55 & 56). The highest yield was obtained at 6kg of AMC application. TSP has no significant effect on yield or its components. TSP significantly increased tissue P concentration and AMC had no significant effect on tissue N concentration (Table 57 and 58). The tissue nutrient concentrations were in the adequate range even with no fertilizer addition.

Table 55 Effects (p values) of treatments on FFB yield and its components in 2003 (Trial 213). p values <0.1 are indicated in bold.

	2003		
Source	Yield	Bun./ha	kg/bun.
AMC	**0.046**	0.126	**0.067**
TSP	0.273	0.388	0.371
AMC.TSP	0.317	0.409	0.774
CV %	*17.1*	*16.2*	*7.1*

Table 56 Main effects of treatments on FFB yield and its components (Trial 213). Effects with p<0.1 are shown in bold.

	2003		
	Yield (t/ha)	Bun./ha	kg/bun.
AMC 0kg	**15.6**	1345	**11.69**
AMC 3kg	**17.9**	1532	**11.97**
AMC 6kg	**18.6**	1513	**12.53**
TSP 0kg	16.2	1386	11.79
TSP 3kg	18.1	1511	12.27
TSP 6kg	17.8	1494	12.14
s.e.d.	*1.21*	*96.9*	*0.35*
GM	*17.4*	*1463*	*12.07*

Table 57 Effects (p values) of treatments on frond-17 nutrient concentrations in 2003 (Trial 213). p values less than 0.1 are indicated in bold.

	Leaflet									Rachis	
Source	Ash	N	P	K	Mg	Ca	B	Cl	S	Ash	K
AMC	**0.045**	0.752	**0.073**	0.248	0.742	**0.073**	0.753	**0.002**	0.141	**0.005**	0.276
TSP	**0.046**	0.258	**<0.001**	0.284	0.336	0.322	0.394	0.269	0.318	0.247	**0.007**
AMC.TSP	0.902	0.947	**0.096**	0.854	0.243	0.471	0.316	0.637	0.184	0.613	0.501
CV %	*3.6*	*3.7*	*3.3*	*8.4*	*9.5*	*5.6*	*7.5*	*15.4*	*7.2*	*13.7*	*20.9*

Table 58 Main effects of treatments on frond-17 nutrient concentrations in 2003, in units of % dry matter, except for B (ppm) (Trial 213). Significant effects ($p<0.1$) are shown in bold.

	Leaflet									Rachis	
	Ash	N	P	K	Mg	Ca	B	Cl	S	Ash	K
AMC 0kg	**11.7**	2.59	**0.15**	0.82	0.23	**1.02**	11.3	**0.54**	0.16	**2.8**	0.65
AMC 3kg	**11.9**	2.58	**0.15**	0.77	0.23	**1.07**	11.6	**0.67**	0.17	**3.2**	0.68
AMC 6kg	**12.2**	2.61	**0.15**	0.80	0.23	**1.06**	11.3	**0.69**	0.17	**3.4**	0.74
TSP 0kg	**12.1**	2.56	**0.14**	0.82	0.23	1.03	11.6	0.61	0.17	3.2	**0.74**
TSP 3kg	**12.0**	2.60	**0.15**	0.78	0.23	1.05	11.2	0.67	0.17	3.3	**0.76**
TSP 6kg	**11.7**	2.62	**0.16**	0.78	0.24	1.07	11.4	0.62	0.17	3.0	**0.57**
s.e.d.	*0.18*	*0.04*	*0.002*	*0.03*	*0.01*	*0.02*	*0.35*	*0.04*	*0.01*	*0.18*	*0.06*
GM	*11.9*	*2.59*	*0.15*	*0.80*	*0.23*	*1.05*	*11.4*	*0.63*	*0.17*	*3.14*	*0.69*

FERTILISER RESPONSE TRIALS IN ORO PROVINCE

(S. Nake & M.J. Webb)

TRIAL 324 NITROGEN SOURCE TRIAL ON HIGATURU SOILS, SANGARA ESTATE

PURPOSE

To test relative effectiveness of different nitrogen fertilisers on Higaturu Soils (Volcanic plains).

SITE and PALMS

Site: Sangara Estate Blocks 2 and 3

Soil: Higaturu family, Deep sandy clay loam with good drainage, derived from volcanic ash.

Palms: Dami commercial DxP crosses replanted in 1996 at 135 palms per hectare.

DESIGN

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 59). 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. 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. The trial started in January 2001. This trial is the same design as Trial 325 in Ambogo and Trial 125 in Kumbango. See 2001 Proposals for background.

Table 59 Nitrogen source treatments and levels

	Amount (kg/palm.year)		
Nitrogen Source	Level 1	Level 2	Level 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

* Because of problems with availability of AMN, it is proposed to replace this with Calcium Ammonium Nitrate which is 20% calcium carbonate and 80% ammonium nitrate resulting a 27% N. This will mean increasing application rates to 1.5, 3.0 and 6.0 kg/palm.

RESULT

Unlike 2002 and 2001 (refer to 2001 annual report), FFB yield and single bunch weight (SBW) in 2003 was significantly affected by the fertilizer rates (Table 60). This is evident in Table 61 where both the FFB yield and single bunch weight increased steadily with the rates.

The type of N-fertilisers tested had no significant effect (P>0.1) on the FFB yield, number of bunches harvested per hectare and the single bunch weight. Similarly, interactions were still not significant 3 years after commencing the fertilizer treatments.

Regardless of the fertilizer type and the rates used, the yield and its components (BNO, SBW) were much higher in 2003 than in 2002. The trend was different for the palms in the control plots where no N-fertilizer was applied (Table 61), where the FFB yield as well as the other two components were much lower than that of 2002, indicating a significant drop. The yield dropped by 7.6 tonnes (25.3 %) in 2003. This is mostly due to nitrogen stress imposed on the palms in the control plots.

The interactions are tabulated in table 62 and 63. Though not significant, interaction between fertilizer type and rate showed increasing AMC, SOA and AMN fertilizers increased FFB yields (Table 62). Similarly, SOA and DAP increased the single bunch weight as their rates were increased (Table 63).

CONCLUSION

FFB yield and SBW responded positively to the fertilizer rates applied. Both components were increased with increasing rates of fertilizer. Fertiliser type still had no significant effects on the yield and its components three years after application of the treatments. The treatment combinations were also not significant, but some of the interactions were starting to show some positive response.

Table 60 Effects (p values) of treatments on FFB yield and its components in 2003. P values <0.1 are shown in bold.

	2002			2003		
Source	Yield	BNO	SBW	Yield	BNO	SBW
Type	0.134	**0.059**	0.190	0.489	0.566	0.733
Rate	0.851	0.196	0.146	**0.079**	0.767	**0.088**
Type. Rate	0.416	0.107	0.128	0.864	0.484	0.575
CV %	*7.7*	5.5	*6.6*	*6.7*	7.5	*5.6*

Table 61 Main effects of treatments on FFB yield and its components in 2003. No effects were significant at P<0.1 (See Table 60). Values for plots receiving zero N (in brackets) were not included in the analysis of variance.

	2002			2003		
	Yield (t/ha)	BNO (/ha)	SBW (kg)	Yield (t/ha)	BNO (/ha)	SBW (kg)
Zero N	(30)	(2611)	(12.0)	(23.4)	(2546)	(9.2)
AMC	33.1	**2798*bc***	12.0	40.0	2748	14.6
AMN	34.6	**2844*b***	12.4	40.9	2857	14.5
DAP	35.8	**2914*a***	12.6	41.7	2892	14.7
SOA	33.7	**2769*cd***	12.3	41.1	2828	14.6
Urea	34.1	**2734*d***	12.7	41.8	2840	15.0
sed	*1.07*	*63.3*	*0.33*	*1.12*	*87.3*	*0.34*
Level 1	34.0	2856	12.1	**40.1*c***	2828	**14.4*c***
Level 2	34.5	2813	12.5	**41.0*b***	2811	**14.7*b***
Level 3	34.2	2766	12.5	**42.1*a***	2860	**15.0*a***
sed	*0.83*	*49.0*	*0.26*	*0.87*	*67.6*	*0.26*
Grand Mean	*34.3*	*2812*	*12.4*	*41.1*	*2833*	*14.7*

Means followed by different letters are significantly different by Duncan's Multiple Range Test (DMRT) at p<0.1. Means followed by the same letters are not statistically different.

Table 62 Effect of interaction between fertiliser type and rate on FFB yield (t/ha) in 2003. The interaction was not significant. $Lsd_{0.05}$ = 3.73

	AMC	SOA	Urea	AMN	DAP	Means
Rate 1	**38.4**	**39.6**	41.7	**39.1**	41.9	40.1
Rate 2	**40.3**	**41.9**	40.6	**41.4**	40.7	41.0
Rate 3	**41.2**	**41.7**	43.1	**42.2**	42.5	42.1
Means	40.0	41.7	41.8	40.9	41.7	

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

Table 63 Effect of interaction between fertiliser type and rate on single bunch weight (kg) in 2003. The interaction was not significant. $Lsd_{0.05}$ = 1.17

	AMC	SOA	Urea	AMN	DAP	Means
Rate 1	14.4	**14.3**	15.1	14.1	**14.0**	14.4
Rate 2	14.9	**14.5**	14.9	14.8	**14.5**	14.7
Rate 3	14.6	**15.1**	14.9	14.7	**15.3**	14.9
Means	14.6	14.6	15.0	14.5	14.6	

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

TRIAL 326 NITROGEN x EFB TRIAL ON HIGATURU SOILS, SANGARA ESTATE

PURPOSE

To provide information on the minimum EFB requirements of palms to help formulate fertiliser recommendations on volcanic plain soils

SITE and PALMS

Site: Sangara Estate

Soil: Higaturu family, Deep sandy clay loam with good drainage, derived from volcanic ash.

Palms: Dami commercial DxP crosses replanted in 1998/1999 at 135 palms per hectare.

DESIGN

A randomised complete block design with 4 levels of ammonium sulphate (SOA) and 3 levels of EFB in all factorial combinations (Table 64) in 5 replicate blocks, resulting in 60 plots. Each plot will have 36 palms; the inner 16 being recorded and the outer 20 acting as guard rows. The plots will also be surrounded by a trench to prevent plot-to-plot poaching. SOA will be applied in 3 doses per year. EFB treatments will be applied once per year. MOP will be applied as a blanket across the trial at the commercial rate of 2 kg/palm in order to maintain adequate K levels in the rachis. The trial has the same design as Trial 327 in Ambogo. See 2001 Proposals for background. Treatments and yield recording commenced in 2002.

Table 64 Fertiliser treatments and levels in Trial 326.

	Amount (kg/palm.year)			
	Level 0	Level 1	Level 2	Level 3
SOA	0	2.5	5.0	7.5
EFB	0	130	390	-

RESULTS

There are no significant responses in terms of FFB yield, BNO and the SBW after two years of treatment applications (Table 65). The interaction was also not significant (P>0.1). However, although not significant at this stage, there is a trend towards increasing FFB and number of bunches with increasing SOA (Table 67). SOA treatment increased the FFB yields and bunch number per hectare in 2003 (Table 66), although no significant differences were obtained. The effects of the treatments on the vegetative parameters measured in 2003 are shown in Table 68 and 69. Both treatments as well as their interactions showed no significant effects on all the parameters measured.

CONCLUSION

Similar to 2002, the treatments as well as their interactions had no significant effects on the yield and its components (number of bunches/ha and the single bunch weight). There were also no positive responses shown by the vegetative parameters.

Table 65 Effects (p values) of treatments on FFB yield and its components in 2002 & 2003.

Source	2002			2003		
	Yield	Bunches/ha	SBW	Yield	Bunches/ha	SBW
SOA	0.713	0.670	0.906	0.695	0.725	0.668
EFB	0.616	0.209	0.950	0.950	0.992	0.731
SOA.EFB	0.509	0.642	0.401	0.860	0.972	0.284
CV %	*11.8*	*9.0*	*8.2*	*10.0*	*7.2*	*8.2*

Table 66 Main effects of treatments on FFB yield and its components in 2003.

	2002			2003		
	Yield (t/ha)	Bunches/ha	SBW (kg)	Yield (t/ha)	Bunches/ha	SBW (kg)
SOA0	17.9	2249	8.0	30.1	2672	11.3
SOA1	18.0	2294	8.0	30.1	2683	11.3
SOA2	18.3	2314	7.9	30.4	2732	11.3
SOA3	18.8	2340	8.1	31.3	2736	11.6
sed	*0.8*	*75*	*0.23*	*1.1*	*71*	*0.3*
EFB0	18.5	2343	8.0	30.4	2710	11.3
EFB1	15.3	2322	8.0	30.3	2703	11.3
EFB2	17.9	2233	8.0	30.6	2704	11.5
sed	*0.7*	*65*	*0.21*	*1.0*	*62*	*0.3*
Grand Mean	*18.2*	*2299*	*8.0*	*30.5*	*2706*	*11.4*

Table 67 Effect of the interactions between SOA and EFB on FFB yield (t/ha) in 2003. The interaction was not significant.

	SOA 0	SOA 1	SOA 2	SOA 3	Means
EFB 0	30.1	29.9	30.5	31.1	30.4
EFB 1	28.9	29.9	30.2	32.3	30.3
EFB 2	31.3	30.5	30.4	30.4	30.7
Mean	*30.1*	*30.1*	*30.4*	*31.3*	

Table 68 Effects (p values) of fertiliser treatment on palm vegetative growth parameters in 2003

Source	Leaf length	No. of Leaflets	Leaflet Length	Leaflet Width	LAI	FA	Rachis WxT
SOA	0.745	0.264	0.393	0.251	0.377	0.536	0.306
EFB	0.969	0.330	0.813	0.807	0.854	0.750	0.946
SOA x EFB	0.215	0.182	0.863	0.306	0.415	0.622	0.511
CV %	*3.5*	*3.1*	*2.9*	*10.2*	*11.4*	*12.2*	*24.8*

Table 69 Fertiliser treatment effects (main effects) on palm vegetative growth parameters in 2003

Treatments	Leaf length (cm)	No. of Leaflets	Leaflet Length (cm)	Leaflet Width (cm)	LAI	FA (m^2)	Rachis WxT (cm^2)
SOA-0	469	153	91.4	4.5	6.2	11.5	20.4
SOA-1	464	151	91.3	4.6	6.3	11.6	19.9
SOA-2	469	152	91.8	4.6	6.5	11.6	21.4
SOA-3	471	150	92.9	4.9	6.7	12.2	20.8
	ns	*ns*	*ns*	*n.s*	*ns*	*ns*	*n.s*
EFB-0	467	153	92.0	4.6	6.5	11.8	20.7
EFB-1	469	152	91.5	4.7	6.5	11.7	20.7
EFB-2	468	151	92.1	4.6	6.4	11.5	20.5
	n.s	*n.s*	*n.s*	*n.s*	*n.s*	*n.s*	*n.s*
GM	468	152	91.9	4.6	6.4	11.7	20.6

ns = not significant at p=0.1

** = significant at p<0.05*

**** = significant at p<0.001*

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 G1

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 70). 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 70 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 treatment (fertilizer) effects on yield and its other two components (number of bunches per hectare & single bunch weight) in 2003 are shown in Tables 71, 72, 73 and 74. The effect of MOP on FFB yield as well as single bunch weights were significant at $p<0.1$ (Table 71). The FFB yields were significantly increased by MOP applications. The highest level of MOP produced the highest yield of 26.9 t/ha. Similarly, the single bunch weight was significantly increased with increasing levels of MOP (Table 72). The two-way interaction showed SOA with MOP having significant effects ($p=0.028$) on the single bunch weights. FFB yield and single bunch weight was also significantly affected by three-way interactions between TSP, MOP and KIE (Table 71). The interactions showing significant effects are shown in Tables 73 and 74. Though significant, the interactions were not strong enough to show any marked relationship at this stage.

The treatments effects on the vegetative parameters are given in Tables 75 and 76. The vegetative measurements included in this year's data analysis were the leaf length, total number of leaflets produced, the length and width of those leaflets, measurement of the rachis thickness and width, the leaf area index and the frond area. The main effects showed only MOP having significant effects on some of the vegetative parameters (leaf length, leaflet length and leaflet width). The two-way and three-way interactions also showed some of those treatment combinations having significant effects some of those vegetative parameters (Table 75). The main effects are shown in Table 76. MOP significantly increased the leaf length and the leaflet width.

Table 77 and 78 shows the treatments effects on the leaflet and rachis nutrient concentrations. Significant differences were obtained in the levels of ash, Mg, Ca, and B in the leaflets as well as rachis ash and K when MOP was applied. Increasing the rates of MOP resulted in significant increases made in the leaflet levels of Ca and rachis levels of ash and K. Kieserite significantly increased leaflet levels of Mg while lowering the Ca levels (Table 78).

Table 71 Effects (p values) of treatments on FFB yield and its components in 2003 (Trial 329). P values less than 0.1 are in bold.

Source	Yield	Bun./ha	kg/bun.
SOA	0.350	0.354	0.480
MOP	**0.013**	0.381	**0.010**
TSP	0.401	0.306	0.482
KIE	0.845	0.780	0.415
SOA.TSP	0.492	0.668	**0.028**
SOA.MOP	0.458	0.696	0.646
TSP.MOP	0.347	0.728	0.453
SOA.KIE	0.988	0.924	0.817
TSP.KIE	0.438	0.602	0.577
MOP.KIE	0.678	0.748	0.653
SOA.TSP.MOP	0.400	0.491	0.281
SOA.TSP.KIE	0.683	0.430	0.234
SOA.MOP.KIE	0.768	0.942	0.159
TSP.MOP.KIE	**0.065**	0.607	**0.008**
CV %	9.1	11.5	5.3

Table 72 Main effects of treatments on FFB yield and its components in 2003 (Trial 329).

	Yield (t/ha)	Bun./ha	kg/bun.
SOA1	24.9	1963	13.0
SOA2	25.5	2024	12.8
s.e.d.	*0.63*	*62.1*	*0.19*
MOP0	**23.9**	1954	**12.4**
MOP1	**24.8**	1968	**13.0**
MOP2	**26.9**	2058	**13.4**
s.e.d	*0.77*	*76.1*	*0.23*
TSP0	25.3	2006	12.9
TSP1	24.6	1924	13.1
TSP2	25.7	2049	12.8
s.e.d	*0.77*	*76.1*	*0.23*
KIE0	25.0	1964	13.1
KIE1	25.4	1998	13.0
KIE2	25.3	2017	12.8
s.e.d	*0.77*	*76.1*	*0.23*

CONCLUSION

Unlike last year (2002) where no yield responses were obtained from the fertilizer treatments, MOP in 2003 started showing significant effects on the yield and the single bunch weight. SOA, TSP and Kieserite continue to have no significant effect on the yield and its components. MOP also had substantial effects on some of the vegetative parameters. Similarly leaflet and rachis levels of certain nutrients were significantly affected by MOP applications. There were also some responses to certain leaflet nutrient levels by TSP and Kieserite applications.

Table 73 Effect of the interactions between SOA and TSP on single bunch weight (SBW) in 2003 (Trial 329). The interaction was significant, $Lsd_{0.05}$ =0.74

	SOA 1	SOA 2	Means
TSP 0	12.5	13.2	12.9
TSP 1	13.4	12.8	13.1
TSP 2	13.1	12.5	12.8
Means	13.0	12.8	

Table 74 Effect of the interactions between MOP, TSP and Kieserite on FFB yield (t/ha) in 2003 (Trial 329). The interaction was significant, $Lsd_{0.05}$ =1.58

MOP	TSP	Kieserite		
		0	1	2
0	0	21.4	23.3	27.8
	1	24.4	19.6	23.5
	2	25.3	27.2	22.9
1	0	26.9	26.5	23.8
	1	21.9	26.5	23.8
	2	25.1	24.1	25.0
2	0	28.3	24.8	24.8
	1	24.8	27.9	29.4
	2	26.8	28.9	26.4

Table 75 Effects (p values) of fertiliser treatment on palm vegetative growth parameters in 2003. P values less than 0.1 are in bold.

Source	Leaf length	Leaflet Number	Leaflet Length	Leaflet Width	LAI	FA	Rachis WxT
SOA	0.971	0.834	0.951	0.117	0.395	0.789	0.824
MOP	**0.038**	0.147	**0.064**	**0.008**	0.446	0.554	0.343
TSP	0.474	0.599	0.446	0.679	0.653	0.647	0.664
KIE	0.865	0.472	0.942	0.695	0.931	0.891	0.447
SOA.TSP	**0.041**	0.621	0.121	**0.052**	0.205	0.115	0.625
SOA.MOP	0.321	0.618	0.860	0.315	0.134	0.417	0.442
TSP.MOP	0.180	0.222	0.111	**<0.001**	**0.018**	**0.022**	0.237
SOA.KIE	0.794	0.773	0.596	**0.010**	0.549	0.347	0.827
TSP.KIE	0.595	0.568	0.396	**0.023**	0.186	0.347	0.734
MOP.KIE	0.120	**0.065**	0.140	0.171	0.894	0.709	0.100
SOA.TSP.MOP	0.423	0.439	0.235	0.618	0.509	0.746	0.145
SOA.TSP.KIE	0.944	0.997	0.377	0.201	0.432	0.876	0.289
SOA.MOP.KIE	0.656	0.147	0.659	**0.030**	0.365	0.714	0.266
TSP.MOP.KIE	**<0.001**	**0.004**	0.211	0.142	0.326	0.262	0.179
CV %	*15.2*	*13.9*	*16.1*	*17.2*	*7.3*	*7.0*	*19.4*

Table 76 Main effects of fertiliser treatments on palm vegetative growth parameters in 2003. Significant effects at $P<0.1$ are in bold.

Source	Leaf length (cm)	Leaflet Number	Leaflet Length (cm)	Leaflet Width (cm)	LAI	FA (m^2)	Rachis WxT (cm^2)
SOA-1	569	168	96.9	5.0	9.9	18.5	30.0
SOA-2	569	168	97.0	5.1	10.1	18.6	29.0
sed	*5.9*	*1.59*	*1.07*	*0.06*	*0.19*	*0.36*	*0.28*
MOP-0	**558**	169	**97.9**	**4.9**	9.9	18.6	29.6
MOP-1	**572**	166	**95.2**	**5.0**	9.9	18.4	29.8
MOP-2	**576**	170	**97.8**	**5.1**	10.2	18.9	30.3
sed	*7.2*	*1.95*	*1.31*	*0.07*	*0.24*	*0.44*	*0.34*
TSP-0	564	167	96.9	5.1	10.1	18.8	29.8
TSP-1	573	169	97.8	5.0	10.0	18.6	30.2
TSP-2	569	169	96.2	5.0	9.9	18.4	29.8
sed	*7.2*	*1.95*	*1.31*	*0.07*	*0.24*	*0.44*	*0.34*
KIE-0	571	170	97.2	5.0	10.0	18.7	30.2
KIE-1	569	167	96.9	5.0	10.0	18.5	29.9
KIE-2	567	168	96.8	5.0	10.0	18.5	29.6
sed	***7.2***	*1.95*	*1.31*	*0.07*	*0.24*	*0.44*	*0.34*

Table 77 Effects (p values) of treatments on frond-17 nutrient concentrations in 2003**.** P values less than 0.1 are indicated in bold.

Treatments	*Leaflet Nutrient Concentrations*								**Rachis Nutrient Conc.**	
	Ash	**N**	**P**	**K**	**Mg**	**Ca**	**B**	**S**	**Ash**	**K**
SOA	0.439	0.981	0.884	0.491	0.137	0.889	0.972	0.271	0.899	0.273
MOP	**0.018**	0.432	0.829	0.982	**0.011**	**0.028**	**0.078**	0.277	**<0.001**	**<0.001**
TSP	0.266	0.876	0.338	0.545	0.384	0.366	**0.042**	0.751	0.103	0.118
KIE	0.214	0.726	0.787	0.330	**<0.001**	**0.026**	0.469	0.389	0.226	0.186
SOA.TSP	0.952	0.698	0.565	**0.096**	0.368	0.955	**0.031**	0.799	0.581	0.667
SOA.MOP	0.258	0.693	0.515	0.440	0.801	0.7031	0.320	0.570	0.187	0.152
TSP.MOP	0.445	0.855	0.959	0.233	0.480	0.714	0.376	0.732	0.412	0.244
SOA.KIE	0.781	0.698	0.208	0.440	0.945	0.759	0.282	0.124	0.837	0.289
TSP.KIE	0.455	0.338	0.654	0.851	0.594	0.468	**0.065**	0.708	0.389	0.100
MOP.KIE	0.138	0.804	0.627	0.563	0.752	0.338	**0.074**	0.602	0.555	0.503
SOA.TSP.MOP	0.832	0.317	0.451	0.542	0.176	0.746	0.602	0.776	0.852	0.738
SOA.TSP.KIE	0.902	0.987	0.824	0.867	0.429	0.453	0.306	0.866	0.293	0.365
SOA.MOP.KIE	0.614	0.377	0.926	0.761	0.976	0.730	0.221	0.866	0.600	0.471
MOP.TSP.KIE	0.625	0.896	0.780	0.144	0.689	0.225	**0.021**	0.726	0.156	0.211
CV (%)	7.0	1.9	2.7	6.3	7.7	6.5	13.0	9.2	8.7	8.8

Table 78 Main effects of treatments on frond-17 nutrient concentrations in 2003. Significant effects (p<0.1) are shown in bold. All values are expressed as percentage dry matter (% DM) except B (mg/kg).

Treatments	*Leaflet Nutrient Concentrations (%)*								**Rachis Nutrient Conc.**	
	Ash	**N**	**P**	**K**	**Mg**	**Ca**	**B**	**S**	**Ash**	**K**
SOA-1	8.46	2.84	0.166	0.84	0.27	1.00	11.6	0.16	3.73	1.21
SOA-2	8.59	2.84	0.166	0.85	0.26	1.00	11.6	0.17	3.72	1.17
sed	*0.16*	*0.02*	*0.001*	*0.01*	*0.003*	*0.01*	*0.41*	*0.004*	*0.09*	*0.03*
MOP-0	**8.92**	2.84	0.165	0.84	**0.28**	**0.97**	**11.6**	0.17	**2.65**	**0.72**
MOP-1	**8.18**	2.82	0.167	0.84	**0.26**	**1.03**	**12.3**	0.17	**4.07**	**1.34**
MOP-2	**8.47**	2.85	0.166	0.84	**0.26**	**1.04**	**11.0**	0.16	**4.47**	**1.51**
sed	*0.20*	*0.02*	*0.002*	*0.01*	*0.01*	*0.02*	*0.50*	*0.01*	*0.11*	*0.04*
TSP-0	8.44	2.83	0.165	0.83	0.27	1.02	**11.5**	0.16	3.63	1.16
TSP-1	8.72	2.83	0.166	0.85	0.27	0.99	**12.5**	0.16	3.68	1.17
TSP-2	8.40	2.84	0.167	0.84	0.26	1.02	**10.9**	0.16	3.88	1.24
sed	*0.20*	*0.02*	*0.002*	*0.01*	*0.01*	*0.02*	*0.50*	*0.01*	*0.11*	*0.04*
KIE-0	8.74	2.83	0.166	0.85	**0.23**	**1.06**	11.3	0.16	3.76	1.19
KIE-1	8.39	2.84	0.166	0.85	**0.28**	**0.99**	12.0	0.17	3.81	1.22
KIE-2	8.43	2.84	0.167	0.82	**0.30**	**0.99**	11.6	0.16	3.61	1.15
sed	*0.20*	*0.02*	*0.002*	*0.01*	*0.01*	*0.02*	*0.50*	*0.01*	*0.11*	*0.04*

TRIAL 330 GRASSLAND SULPHUR TRIAL ON OUTWASH PLAINS, PARAHE MINI ESTATE

PURPOSE

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

SITE, 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

A 'factorial' design with 4 rates of ammonium nitrate (0.7, 2.0, 3.3 and 4.6 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 (Table 79). Each of the 36 plots has 16 recorded palms plus 2 guard rows, resulting in a total of 64 palms/plot. Double 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 and 2002 in order to get the palms and cover crops established.

Table 79 Fertiliser treatments and levels in Trial 330.

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

PROGRESS

The fertilizer treatments for this trial still has not been applied in 2003 because of high degree of variability between the plots especially their growth. Instead, we've continued to do blanket application SOA and MOP in 2003. Two rounds of W x T measurements were taken in 2003, the first one in March and the second round in August. The August measurements indicated much lesser variability between the plots, thus formal treatments will commence in 2004. Yield recording for the trial commenced in 2003 but continuing disputes between the landowners and the company have prevented most harvests being recorded properly. Water logging is a major problem in this block.

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 80. Nitrogen will be applied across the trial as ammonium nitrate 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. Soil and leaf samples will be taken in early 2004 to determine the initial nutrient status of the block before application of the treatments. Fertiliser treatments will commence in 2004.

Table 80 Fertiliser types and rates

Fertiliser	Nutrient	Nutrient appl. rate (kg/palm)	Nutrient cont. of fert. (%)	Annual 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 AMN.					

FERTILISER RESPONSE TRIALS IN MILNE BAY PROVINCE

(S. Nake & M.J. 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 81). It has a single replicate (64 plots), and is split into four blocks. Each plot contains 16 core palms, which are surrounded by one guard row and a trench. Trenching was completed in 1995, and the first dose of fertiliser was applied in the fourth quarter of 1994. Applications of EFB started in August 1995. EFB is applied by hand as mulch between palm circles once per year. Fertiliser is applied in 3 doses per year.

Table 81. 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 main effects of the treatments on the FFB yield over the course of the trial are shown in figure 21. In 2003, SOA, MOP and EFB had significant effects ($p<0.1$) on both the FFB yield and the SBW (Table 82). SOA and EFB both increased yields as their rates were increased. Yields increased as MOP increased from 0 to 5 kg/palm, but then fell as the rates were further increased to 7.5 kg (Table 83). TSP has not shown any significant effect on the yield since the initiation of the trial.

Interactions between SOA and EFB, MOP and EFB were significant (Table 84). When no EFB or SAO were added, yield was very low. Adding either EFB or SOA, even at low rates substantially increased yield to almost maximum levels. This type of interaction indicates that EFB can substitute for SOA and suggests that EFB might be a useful source of nitrogen. Analysis of EFB (0.65% N in dry matter; 33% DM) indicates that it can supply an amount of N equivalent to that supplied by the lowest rate of SOA (2.0 kg/palm). However, this lower amount would probably be more effective over a longer period of time as it is likely that the nitrogen is released from the EFB at a much slower rate than from SOA.

A similar effect to that with SOA.EFB was found with the MOP.EFB interaction; again suggesting that EFB could substitute for MOP. Similar to above the EFB provided an amount of K (2.0% K in dry matter; 33% DM) equivalent to that supplied by the lowest rate of MOP.

The three-way SAO.MOP.EFB interaction emphasises this even further (Table 85). In the absence of EFB, SOA x MOP show the typical synergistic effect on yield of two limiting nutrients. However, in the presence of EFB, this effect is largely lost, indicating that EFB is supplying nutrients that are also supplied by MOP and SOA.

CONCLUSION

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

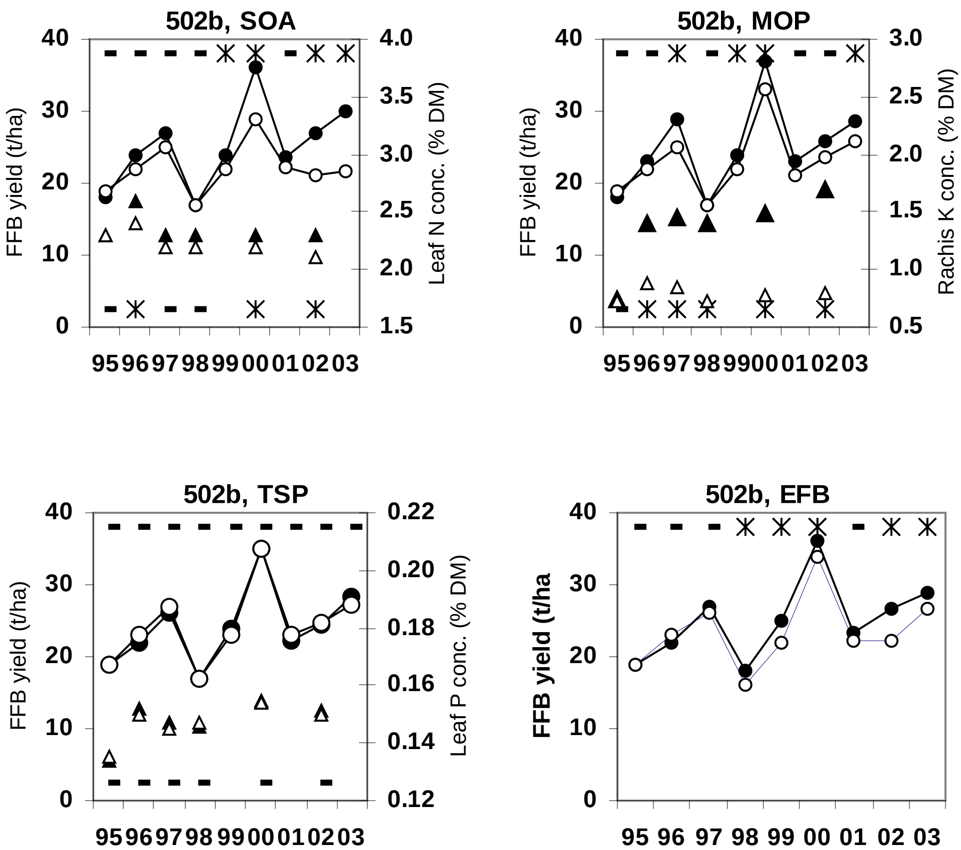


Figure 21 Main effects of SOA, MOP and TSP over the course of Trial 502b. Lines are FFB yields and triangles are tissue concentrations. Full symbols represent the maximum level of application, and empty symbols zero application. Symbols along the top of the graph indicate significance of the main effect 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 82 Effects (p values) of treatments on FFB yield and its components in 2002 and 2003. p values less than 0.1 are indicated in bold.

	2000-2003			2003		
Source	Yield	BNO	SBW	Yield	BNO	SBW
SOA	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**0.005**	**<0.001**
TSP	0.643	0.839	0.121	0.160	0.221	0.624
MOP	**0.013**	0.256	**0.001**	**0.094**	0.698	**0.011**
EFB	**<0.001**	**0.021**	**<0.001**	**0.024**	0.420	**<0.001**
SOA.TSP	0.575	0.571	**0.167**	0.595	0.380	0.261
SOA.MOP	0.802	0.670	**0.073**	0.662	0.864	0.132
TSP.MOP	0.291	0.146	**0.070**	0.928	0.705	0.181
SOA.EFB	**0.031**	**0.035**	**0.035**	**0.019**	**0.020**	0.173
TSP.EFB	0.400	0.502	0.717	0.893	0.897	0.406
MOP.EFB	**0.008**	0.203	**0.001**	**0.038**	0.148	**0.099**
SOA.TSP.MOP	0.259	0.109	**0.030**	0.486	0.417	0.340
SOA.TSP.EFB	0.414	0.629	0.443	0.606	0.878	0.607
SOA.MOP.EFB	0.791	0.683	**0.034**	0.827	0.972	**0.059**
TSP.MOP.EFB	0.805	0.841	0.469	0.736	0.638	0.266
CV %	6.0	5.8	2.4	12.1	11.9	4.9

Table 83 Main effects of treatments on FFB yield and its components (Trial 502b). Significant effects (p<0.1) are shown in bold.

	2000 - 2003			2003		
	Yield (t/ha)	BNO (/ha)	SBW (kg)	Yield (t/ha)	BNO (/ha)	SBW (kg)
SOA0	**23.7**	**1056**	**22.6**	**21.8**	**986**	**22.3**
SOA1	**28.5**	**1174**	**24.5**	**29.1**	**1163**	**25.3**
SOA2	**28.9**	**1201**	**24.5**	**29.9**	**1170**	**25.9**
SOA3	**29.1**	**1215**	**24.1**	**30.0**	**1205**	**25.1**
sed	*0.58*	*23.7*	*0.20*	*1.18*	*47.6*	*0.43*
MOP0	**26.2**	1134	**23.2**	**25.9**	1101	**23.7**
MOP1	**27.4**	1164	**23.8**	**27.3**	1125	**24.3**
MOP2	**28.0**	1162	**24.3**	**29.1**	1154	**25.3**
MOP3	**28.7**	1186	**24.4**	**28.7**	1145	**25.4**
sed	*0.58*	*23.7*	*0.20*	*1.18*	*47.6*	*0.43*
TSP0	27.7	1160	24.0	27.1	1109	24.6
TSP1	27.5	1161	23.8	28.4	1153	24.7
sed	*0.41*	*16.8*	*0.14*	*0.84*	*33.7*	*0.30*
EFB0	**26.2**	**1138**	**23.2**	**26.6**	1117	**23.9**
EFB1	**28.9**	**1185**	**24.7**	**28.9**	1145	**25.4**
sed	*0.41*	*16.8*	*0.14*	*0.84*	*33.7*	*0.30*

Table 84 Effect of two-way interactions on FFB yield (t/ha) in 2003.

	SOA.MOP, p=0.662					*MOP.TSP, p=0.928*	
	SOA0	SOA1	SOA2	SOA3		TSP0	TSP1
MOP0	21.0	27.2	29.7	25.8	MOP0	25.1	26.8
MOP1	21.9	28.6	27.8	30.7	MOP1	26.3	28.2
MOP2	21.5	30.2	32.2	30.1	MOP2	28.6	29.5
MOP3	23.0	30.5	30.1	31.1	MOP3	28.4	29.0
	SOA.TSP, p=0.595					*EFB.TSP, p=0.893*	
	SOA0	SOA1	SOA2	SOA3		TSP0	TSP1
TSP0	21.6	27.5	29.5	29.8	EFB0	26.0	27.2
TSP1	22.1	30.8	30.4	30.2	EFB1	28.2	29.6
	SOA.EFB, p=0.019, lsd=3.8					*MOP.EFB, p=0.038,lsd=3.8*	
	SOA0	SOA1	SOA2	SOA3		EFB0	EFB1
EFB0	**18.8**	**26.8**	**29.3**	**28.4**	MOP0	**22.3**	**29.5**
EFB1	**29.5**	**28.3**	**29.2**	**31.4**	MOP1	**26.2**	**28.3**
					MOP2	**28.9**	**29.2**
					MOP3	**28.4**	**28.9**

Table 85 Effect of interaction between SOA, MOP and EFB on FFB yield (t/ha) in 2003. P=0.827, s.e.d. = 3.35 and l.s.d.=7.57 CV = 12.1%. Yields > 30 t/ha are highlighted in bold.

	EFB0				EFB1			
	SOA0	SOA1	SOA2	SOA3	SOA0	SOA1	SOA2	SOA3
MOP0	15.8	23.5	25.7	24.3	26.2	**30.9**	**33.7**	27.4
MOP1	17.3	26.4	29.3	**31.8**	26.5	**30.8**	26.3	29.6
MOP2	19.8	28.0	**32.5**	**35.3**	23.2	**32.4**	**32.0**	29.2
MOP3	22.3	29.5	29.6	**34.3**	23.6	**31.5**	**30.5**	28.0

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 86). The trial commenced in 1994. Fertilisers are applied in 3 doses per year.

Table 86 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 for 2003 are depicted in Figure 22. SOA and MOP continued to have significant positive effects on FFB yield, with no significant interaction between them (Tables 87 & 88). FFB yields responded positively to SOA applications up to 4.0 kg/palm, with no change beyond that. FFB yield responded sharply to the lowest rate of MOP with little effect beyond that. The additive effect of these two fertilisers resulted yields over 30 tonnes FFB per hectare at the two highest rates of SOA and MOP (Table 89). SOA also significantly increased number of bunches produced in a hectare in 2003.

In 2003, no leaf samples were taken for nutrient analysis. Instead, samples were taken from frond-17 rachis only as well as from the trunk. The rachis samples were analysed for ash, N, K and P concentrations only while the trunk tissues were analysed for ash, N, K, P, Mg, Ca, S and B. These are all presented in Tables 90 and 91. Both SOA and MOP significantly affected the levels of all the nutrients tested in the rachis except N levels, which was not affected by MOP applications. SOA increased rachis nutrient levels of N only while reducing that of the others. MOP instead increased rachis levels of the nutrients (ash, K and P) except N.

SOA application significantly increased N levels while reducing P levels in the trunk tissues. MOP significantly increased both levels of ash and K in the trunk tissues (Table 90 & 91). MOP also raised B levels but not significantly.

CONCLUSION

Both SOA and MOP have shown to have significant effects on the FFB yield in 2003. Their interactions were however not significant. The highest FFB yield was reached at 4.0 kg/palm of SOA and 2.5 kg/palm of MOP. The fertilizer treatments also had significant effects on some of the nutrient levels in the rachis and the trunk tissues.

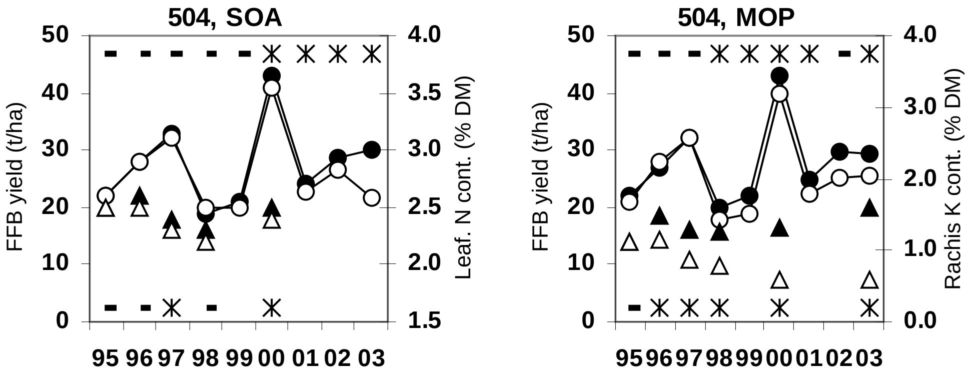


Figure 22 Main effects of SOA and MOP over the course of Trial 504. Lines are FFB yields and triangles are tissue concentrations. Full symbols represent the maximum level of application, and empty symbols zero application. Symbols along the top of the graph indicate significance of the main effect on yield, and along the bottom indicate significance of the main effect on tissue concentration. Stars indicate significance ($p<0.05$) and dashes non-significance.

Table 87 Effects (p values) of treatments on FFB yield and its components in 2000-2003 and 2003 (Trial 504). p values less than 0.1 are indicated in bold.

	2000-2003			2003		
Source	Yield	BNO	SBW	Yield	BNO	SBW
SOA	**<0.001**	**0.003**	0.255	**0.033**	**0.095**	0.177
MOP	**<0.001**	**0.013**	**0.029**	**0.036**	0.145	0.325
SOA.MOP	0.696	0.445	0.827	0.908	0.959	0.758
CV %	7.3	6.6	4.7	17.4	16.0	8.4

Table 88 Main effects of treatments on FFB yield and its components (Trial 504). Significant effects ($p<0.1$) are shown in bold.

	2000-2003			2003		
	Yield (t/ha)	BNO (/ha)	SBW (kg)	Yield (t/ha)	BNO (/ha)	SBW (kg)
SOA0	**28.9**	**1380**	21.1	**25.9**	**1278**	20.4
SOA1	**30.9**	**1442**	21.8	**28.2**	**1339**	21.4
SOA2	**32.5**	**1509**	21.7	**30.8**	**1433**	21.8
SOA3	**31.5**	**1478**	21.5	**30.3**	**1454**	21.2
sed.	*0.79*	*33.8*	*0.36*	*1.78*	*77.8*	*0.63*
MOP0	**28.5**	**1383**	**20.9**	**25.5**	1267	20.5
MOP1	**31.3**	**1466**	**21.6**	**30.2**	1432	21.6
MOP2	**32.3**	**1489**	**21.9**	**30.1**	1420	21.4
MOP3	**31.7**	**1472**	**21.8**	**29.2**	1385	21.4
sed	*0.79*	*33.8*	*0.36*	*1.78*	*77.8*	*0.63*

Table 89 Effect on SOA.MOP interaction on FFB yield (t/ha) in 2000-2003 (Trial 504). Yields >30 t/ha are highlighted in bold.

SOA.MOP, p=0.696, lsd=1.59				
	MOP0	MOP1	MOP2	MOP3
SOA0	27.4	28.1	**31.1**	**30.0**
SOA1	27.6	**31.3**	**31.9**	**33.1**
SOA2	29.7	**32.7**	**34.1**	**33.4**
SOA3	29.2	**32.8**	**32.3**	**31.6**

Table 90 Significance (p values) for effects of the fertilizer treatments on Frond-17 rachis and trunk nutrient concentrations in 2003, expressed as a proportion of dry matter, except B which is expressed in mg/kg. Significant values ($p<0.1$) are highlighted in bold.

	Ash	N	K	P	Mg	Ca	S	B
Frond-17 rachis								
SOA	**0.074**	**<0.001**	**0.054**	**<0.001**				
MOP	**<0.001**	0.122	**<0.001**	**<0.001**				
SOA.MOP	0.672	0.623	0.385	0.855				
CV %	11.9	8.0	16.3	18.6				
Trunk Tissue								
SOA	0.649	**<0.001**	0.152	**<0.001**	0.838	0.391	0.239	0.168
MOP	**<0.001**	0.973	**<0.001**	0.187	0.486	0.488	0.136	0.308
SOA.MOP	0.990	0.541	0.569	0.844	0.660	0.932	0.571	0.780
CV %	10.4	19.1	19.3	13.7	14.6	10.5	16.7	10.1

Table 91 Main effects of treatments on nutrient levels of frond-17 rachis and trunk tissues in 2003. Significant values are bolded.

	Ash	N	K	P	Mg	Ca	S	B
				Frond-17 rachis				
SOA0	**4.15**	**0.26**	**1.33**	**0.189**				
SOA1	**4.02**	**0.27**	**1.31**	**0.155**				
SOA2	**3.94**	**0.29**	**1.26**	**0.105**				
SOA3	**3.71**	**0.30**	**1.14**	**0.096**				
sed	***0.17***	***0.01***	***0.07***	***0.01***				
MOP0	**2.67**	0.27	**0.57**	**0.109**				
MOP1	**4.04**	0.29	**1.29**	**0.135**				
MOP2	**4.44**	0.29	**1.54**	**0.136**				
MOP3	**4.68**	0.28	**1.64**	**0.165**				
sed	*0.17*	*0.01*	*0.07*	*0.01*				
				Trunk Tissue				
SOA0	3.05	**0.34**	0.53	**0.095**	0.16	0.20	0.09	7.63
SOA1	3.19	**0.37**	0.61	**0.088**	0.16	0.20	0.09	7.78
SOA2	3.16	**0.49**	0.54	**0.076**	0.17	0.20	0.09	8.25
SOA3	3.16	**0.53**	0.57	**0.075**	0.17	0.21	0.10	7.93
sed	***0.12***	***0.03***	***0.04***	***0.004***	*0.01*	*0.01*	*0.01*	*0.28*
MOP0	**2.69**	0.44	**0.31**	0.080	0.16	0.20	0.10	7.67
MOP1	**3.08**	0.43	**0.54**	0.081	0.17	0.20	0.09	7.85
MOP2	**3.35**	0.44	**0.65**	0.088	0.17	0.20	0.09	7.87
MOP3	**3.44**	0.44	**0.75**	0.085	0.16	0.21	0.09	8.20
sed	*0.12*	*0.03*	*0.04*	*0.004*	*0.01*	*0.01*	*0.01*	*0.28*

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 bunch 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 92). 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 92 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 23. Unlike 2002, SOA, MOP, TSP and EFB all had significant effects on FFB yield (Tables 93 & 94). All treatments increased the FFB yields with SOA having the greatest effect.

There were significant interactions between SOA.TSP, SOA.EFB, TSP.EFB and SOA.TSP.EFB (Tables 95 & 96). The two-way interaction between TSP and SOA on yield is typical of that of two limiting nutrients, with the response to increasing SOA only able to be expressed in the presence of adequate TSP (Table 95). The two-way interactions between EFB and TSP, and between EFB and

SOA, show that EFB can, to some extent, satisfy the requirements supplied by both the TSP and SOA (Table 95).

The three-way interaction between EFB, TSP, and SOA, demonstrates the combination of synergistic effects of SOA and TSP, as well as the partial replacement effect of EFB for both SAO and TSP. This resulted in a high yield when both SOA and TSP were present at high levels irrespective of EFB supply; but also demonstrate the importance of EFB when SOA and TSP are supplied at low levels (Table 96).

CONCLUSION

Unlike last year (2002) where only SOA, TSP and EFB had significant effects on the FFB yield, this year (2003) all treatments including MOP showed substantial effects on yield. EFB substantially increases yield in the absence of SOA or TSP; indicating its partial value as a replacement for these fertilisers. That yield is further enhance in the presence of SOA and TSP confirms that EFB only partially replaces the requirement of these two fertilisers.

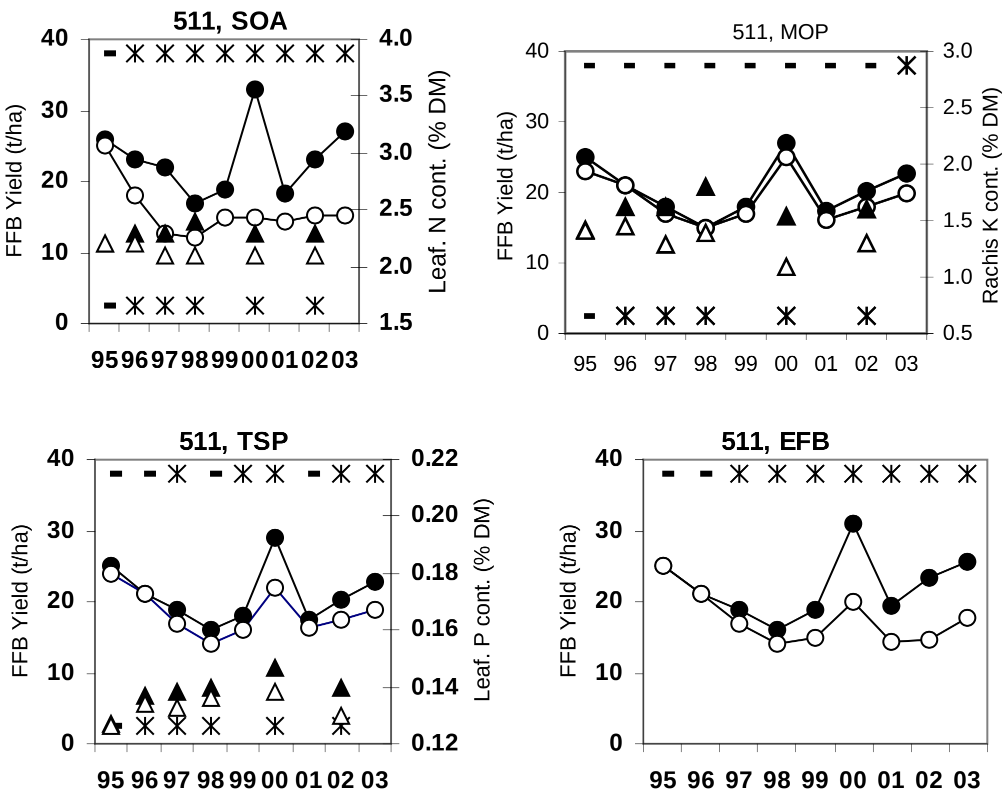


Figure 23 Main effects of SOA, MOP and TSP over the course of Trial 511. Lines are FFB yields and triangles are tissue concentrations. Full symbols represent the maximum level of application, and empty symbols zero application. Symbols along the top of the graph indicate significance of the main effect 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 93 Effects (p values) of treatments on FFB yield and its components in 2000-2003 and 2003. p values less than 0.1 are indicated in bold.

	2000 - 2003			2003		
Source	Yield	BNO	SBW	Yield	BNO	SBW
SOA	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**
MOP	0.235	0.398	0.575	**0.029**	**0.073**	0.438
TSP	**<0.001**	**0.002**	**<0.001**	**<0.001**	**<0.001**	**<0.001**
EFB	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**
SOA.MOP	0.735	0.846	0.266	0.165	0.598	0.178
SOA.TSP	0.104	0.281	**0.009**	**0.002**	**0.045**	**0.001**
MOP.TSP	0.507	0.581	0.149	0.389	0.473	**0.065**
SOA.EFB	**0.020**	0.187	**<0.001**	**0.011**	0.744	**<0.001**
MOP.EFB	0.936	0.844	0.266	0.471	0.304	**0.011**
TSP.EFB	**0.024**	0.155	**0.010**	**0.009**	0.395	**<0.001**
SOA.MOP.TSP	0.814	0.763	0.437	0.823	0.559	**0.059**
SOA.MOP.EFB	0.384	0.517	0.125	0.159	0.402	0.135
SOA.TSP.EFB	0.269	0.745	0.225	**0.050**	0.265	**0.067**
MOP.TSP.EFB	0.661	0.806	0.780	0.203	0.449	0.312
CV %	12.4	12.8	6.1	10.8	13.2	5.7

Table 94 Main effects of treatments on FFB yield and its components. Significant effects (p<0.1) are shown in bold.

	2000-2003			2003		
	Yield (t/ha)	BNO (/ha)	SBW (kg)	Yield (t/ha)	BNO (/ha)	SBW (kg)
SOA0	**15.0**	**804**	**18.5**	**15.3**	**809**	**18.7**
SOA1	**19.6**	**919**	**21.2**	**20.4**	**919**	**22.2**
SOA2	**23.3**	**1015**	**22.9**	**24.5**	**1014**	**24.2**
SOA3	**25.7**	**1125**	**22.9**	**27.0**	**1109**	**24.5**
sed	*0.91*	*43.7*	*0.46*	*0.83*	*44.8*	*0.32*
MOP0	19.8	920	21.4	**19.9**	**878**	22.8
MOP1	20.7	968	21.0	**22.1**	**983**	22.2
MOP2	21.2	980	21.3	**22.4**	**993**	22.2
MOP3	21.9	994	21.7	**22.7**	**999**	22.4
sed	*0.91*	*43.7*	*0.46*	*0.83*	*44.8*	*0.32*
TSP0	**18.7**	**898**	**20.5**	**18.9**	**878**	**21.3**
TSP1	**23.0**	**1033**	**22.2**	**24.7**	**1048**	**23.5**
sed	*0.65*	*30.9*	*0.33*	*0.59*	*31.7*	*0.23*
EFB0	**16.8**	**851**	**19.3**	**17.8**	**884**	**19.9**
EFB1	**24.9**	**1080**	**23.4**	**25.7**	**1042**	**23.5**
sed	*0.65*	*30.9*	*0.33*	*0.59*	*31.7*	*0.23*

Table 95 Effect of two-way interactions on FFB yield (t/ha) in 2003. Significant ($p<0.1$) interactions are shown in bold.

SOA.MOP, p=0.165, lsd=3.76					*MOP.TSP, p=0.389, lsd=2.66*		
	SOA0	SOA1	SOA2	SOA3		TSP0	TSP1
MOP0	14.7	18.6	23.3	22.8	MOP0	17.7	22.0
MOP1	16.3	18.8	24.5	29.0	MOP1	19.5	24.8
MOP2	15.7	20.7	24.4	28.7	MOP2	18.9	25.9
MOP3	14.3	23.3	25.6	27.4	MOP3	19.4	26.0
SOA.TSP, p=0.002, lsd=2.66					*EFB.TSP*, ***p=0.009***, *lsd=1.88*		
	SOA0	SOA1	SOA2	SOA3		TSP0	TSP1
TSP0	**14.4**	**18.6**	**20.8**	**21.7**	EFB0	**13.9**	**21.7**
TSP1	**16.1**	**22.1**	**28.1**	**32.3**	EFB1	**23.8**	**27.6**
SOA.EFB, ***p=0.011***, *lsd=2.66*					*MOP.EFB, p=0.471, lsd=2.66*		
	SOA0	SOA1	SOA2	SOA3		EFB0	EFB1
EFB0	**10.5**	**15.6**	**19.8**	**25.3**	MOP0	15.9	23.9
EFB1	**20.0**	**25.2**	**29.1**	**28.6**	MOP1	17.4	26.9
					MOP2	18.9	25.8
					MOP3	19.0	26.3

Table 96 Effect of the SOA x EFB x TSP interaction on FFB yield (t/ha) in 2003. P=0.050, s.e.d. = 1.67 and l.s.d.(0.05) = 3.76, CV (block.units)= 10.8%. Yields > 26 t/ha are highlighted in bold.

	TSP0			TSP1	
	EFB0	EFB1		EFB0	EFB1
SOA0	8.6	20.2	SOA0	12.4	19.8
SOA1	14.5	22.7	SOA1	16.7	**27.6**
SOA2	14.4	**27.2**	SOA2	25.2	**31.1**
SOA3	18.2	25.2	SOA3	**32.5**	**32.1**

TRIAL 512 MONITORING OF POME BLOCKS

PURPOSE

To determine the effect of palm oil 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 97) have been monitored since 1995.

Table 97 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 98).

Table 98 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 effect of POME treatment on FFB yield and the leaflet nutrient concentrations over the course of the trial are shown in Figure 24. In 2003, POME had no effect on FFB yield. Leaflet concentrations of N were lower in the POME block than in the control block while leaflet P was higher in the POME block. The rachis K contents were substantially higher in the POME block than the control block. Soil samples were not collected in 2003 to verify whether the POME had any effect on the soil fertility in these two blocks.

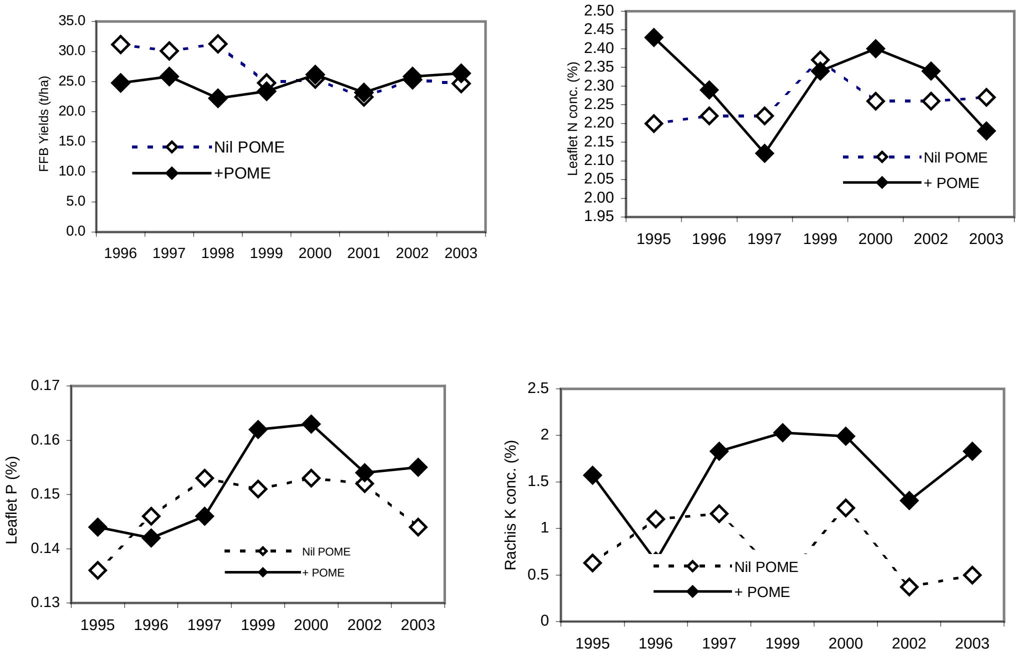


Figure 24 Effect of POME application (Blocks 6306 and 6603) on FFB yield and Frond-17 N, P and K contents.

FERTILISER RESPONSE TRIALS IN NEW IRELAND

(MJ 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 99). 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 99 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 from the first harvest (September) was ignored as the ‘round-length’ for that harvest was unknown. The data was scaled-up to 'per annum' using a factor of 3.0. This was determined by analysing the distribution of yield over the 3 months that data was collected, and comparing that to the whole of 2003 yields for palms of the same planting year in plantations in New Ireland. This information was extracted from the OMP8 database. The data from 2003 also generally show a greater 'coefficient of variation' than in previous years, which is probably a reflection of the shorter collection period.

RESULTS

Yield in Trial 251

In this trial, MOP continued to be the only fertiliser that significantly influenced FFB yield and its components (Table 100 & Table101); except that for the first time, SOA had a small effect on average bunch weight (SBW). FFB yield was again almost doubled by the application of 2.5 kg MOP/palm, with 5 kg providing little extra benefit (Table 101). There were no significant interactions between the effects of MOP and the other fertilisers in relation to FFB yield or number of bunches produced (Table 102). However, there were a number of interaction terms that were statistically significant on SBW; but the nature of the interaction and its relevance is not clear. There was still no effect of SOA on FFB yield even after 12 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 103. Soil depth did not significantly influence yield or its components (Table 100), nor did it significantly improve the model for most parameters (Efficiency factor <1, Table 101), except for SBW.

The main effects of the treatments on yield and tissue contents over the course of the trial are shown in Figure 25. 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 (Table 104 & Table 105). TSP also had a significant effect; and SOA, TSP, and KIE all showed interactions with MOP but only 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 106).

There were significant interactions between MOP, SOA, TSP and KIE in the average individual weight of bunches (Tables 107 to 110). However these effects, which were generally small, showed a greater response to MOP at the lowest level of supply of the other fertilisers.

The main effects of the treatments on yield and tissue contents over the course of the trial are shown in Figure 25. The large effect of MOP has increased through time and SOA had started to have an effect in the last few years, but not statistically significant in the most recent.

Relationship between fertiliser treatments and incidence of Ganoderma (251 & 252)

The relationship between fertiliser treatment and incidence of Ganoderma was reported in the 2002 Annual Report using recently collected data from the 2003 Census. Another census will be done at the end of 2004 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. When the results of nutrient analysis on soil, trunk and bunches are available, nutrient budgets can be estimated. At the end of 2004, 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 2003 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, statistically, this was not significant in 2003.

Because of the short harvest period (Oct-Dec), there is likely to be more variability in the 2003 data, compared to other years, than if a full year's harvest was recorded. This could have had the consequence of reducing the likelihood of significant responses and the reliability of absolute yield values.

Table 100 Effects (p values) of treatments and the soil depth covariate on FFB yield and its components in 2001-2003 and 2003 (Trial 251). p values <0.1 are indicated in bold.

	2001-2003			2003		
Source	Yield	Bun./ha	kg/bun.	Yield	Bun./ha	kg/bun.
SOA	0.709	0.587	0.489	0.774	0.496	**0.071**
MOP	**0.007**	**0.031**	**<0.001**	**0.021**	**0.076**	**0.002**
TSP	0.434	0.800	0.157	0.427	0.936	0.157
KIE	0.425	0.346	0.363	0.272	0.288	0.327
SOA.MOP	0.576	0.936	**0.095**	0.281	0.327	**0.057**
SOA.TSP	0.907	0.741	0.638	0.742	0.368	0.705
MOP.TSP	0.799	0.957	0.681	0.205	0.237	0.158
SOA.KIE	0.624	0.711	0.236	0.510	0.380	0.278
MOP.KIE	0.992	0.860	0.463	0.974	0.839	0.789
TSP.KIE	0.496	0.413	0.738	0.272	0.153	0.950
SOA.MOP.TSP	0.548	0.387	0.450	0.644	0.548	**0.096**
SOA.MOP.KIE	0.605	0.817	0.531	0.681	0.658	0.260
SOA.TSP.KIE	0.456	0.586	0.585	0.521	0.687	**0.090**
MOP.TSP.KIE	0.612	0.803	0.116	0.801	0.842	0.236
Soil depth	0.733	0.535	0.696	0.820	0.860	**0.049**
CV %	16.4	14.9	5.3	20.0	15.6	5.0

Table 101 Main effects of treatments on FFB yield (t/ha) and its components, adjusted for depth covariate (Trial 251). Also shown are the depth covariate coefficient (cm) and covariate efficiency. Effects with p<0.1 are shown in bold.

	2001-2003			2003		
	Yield (t/ha/yr)	No Bun (/ha)	SBW. (kg)	Yield (t/ha/yr)	No Bun (/ha)	SBW. (kg)
SOA0	21.9	1158	18.6	24.1	1303	**18.5**
SOA1	21.1	1085	18.6	23.1	1208	**18.8**
SOA2	22.5	1146	19.2	24.7	1231	**20.2**
s.e.d.	*1.5*	*70*	*0.41*	*2.0*	*80*	*0.39*
MOP0	**13.9**	**924**	**14.2**	**16.4**	**1063**	**15.4**
MOP1	**25.9**	**1259**	**21.0**	**26.7**	**1340**	**20.3**
MOP2	**25.6**	**1206**	**21.2**	**28.8**	**1340**	**21.8**
s.e.d.	*1.7*	*79*	*0.47*	*2.2*	*91*	*0.45*
TSP0	22.4	1137	19.2	24.9	1253	19.7
TSP1	21.2	1123	18.4	23.0	1241	18.7
s.e.d.	*1.3*	*59*	*0.35*	*1.7*	*68*	*0.33*
KIE0	21.5	1096	19.2	23.5	1217	19.5
KIE1	22.2	1162	18.5	24.5	1277	18.8
s.e.d.	*1.6*	*73*	*0.44*	*2.1*	*85*	*042*
Depth coeff.	0.10	9	-0.03	-0.09	3.00	-0.24
s.e.	*0.28*	*12.9*	*0.07*	*36.8*	*15.0*	*0.07*
Effic.	*0.79*	*0.87*	*0.80*	*0.77*	*0.76*	*3.31*

Table 102 Effect of the interaction between SOA and MOP on FFB yield (t/ha) in 2001-2003 and 2003 (Trial 251). Yields >26 t/ha are highlighted in bold.

2001-2003, p=0.576				2003, p=0.281			
	MOP0	MOP1	MOP2		MOP0	MOP1	MOP2
SOA0	15.5	25.9	24.3	SOA0	19.1	**26.6**	**26.6**
SOA1	12.1	**26.3**	24.8	SOA1	12.8	**28.9**	**27.6**
SOA2	14.1	25.5	**27.8**	SOA2	17.3	24.5	**32.2**

Table 103 Effect of the interaction between SOA and MOP on Single Bunch Weight (kg) in 2001-2003 and 2003 (Trial 251).

2001-2003, p=0.095, $lsd_{0.05}$=2.8				2003, p=0.057, $lsd_{0.05}$=2.7			
	MOP0	MOP1	MOP2		MOP0	MOP1	MOP2
SOA0	14.9	21.5	19.7	SOA0	16.5	17.4	21.6
SOA1	13.6	21.5	20.4	SOA1	12.2	23.2	20.9
SOA2	12.5	21.1	22.5	SOA2	17.4	20.4	22.9

Table 104 Effects (p values) of treatments and the soil depth covariate on FFB yield and its components in 2001-2003 and 2003 (Trial 252). p values <0.1 are indicated in bold.

	2001-2003			2003		
Source	Yield	Bun./ha	kg/bun.	Yield	Bun./ha	kg/bun.
SOA	0.127	0.160	0.269	0.396	0.544	0.165
MOP	**0.003**	**0.006**	**0.005**	**0.016**	**0.062**	**<0.001**
TSP	0.509	0.884	0.194	0.843	0.710	**0.011**
KIE	0.555	0.832	0.285	0.489	0.776	0.144
SOA.MOP	0.309	0.207	0.409	0.726	0.728	**0.028**
SOA.TSP	0.354	0.393	0.566	0.827	0.907	**0.055**
MOP.TSP	0.335	0.415	0.256	0.722	0.940	**0.016**
SOA.KIE	0.931	0.920	0.772	0.969	0.842	0.274
MOP.KIE	0.688	0.895	0.166	0.496	0.837	**0.022**
TSP.KIE	0.618	0.353	0.691	0.774	0.627	0.390
SOA.MOP.TSP	0.561	0.600	0.589	0.586	0.803	**0.025**
SOA.MOP.KIE	0.498	0.347	0.363	0.367	0.465	**0.027**
SOA.TSP.KIE	0.603	0.580	0.710	0.616	0.713	0.161
MOP.TSP.KIE	0.922	0.952	0.896	0.883	0.933	0.145
Soil depth	0.446	0.794	0.313	0.414	0.685	**0.024**
CV %	14.4	11.2	7.9	25.1	26.0	3.0

Table 105 Main effects of treatments on FFB yield (t/ha) and its components, adjusted for depth covariate (Trial 252). Also shown are the depth covariate coefficient (cm) and covariate efficiency. Effects with p<0.1 are shown in bold.

	2001-2003			2003		
	Yield	Bun./ha	kg/bun.	Yield	Bun./ha	kg/bun.
SOA0	22.3	1242	17.7	23.0	1299	17.7
SOA1	26.7	1407	19.0	27.2	1485	18.4
SOA2	25.9	1340	18.9	26.3	1397	18.4
s.e.d.	*1.6*	*62*	*0.62*	*2.7*	*152*	*0.23*
MOP0	**15.0**	**1002**	**14.9**	**15.3**	**1052**	**14.9**
MOP1	**28.7**	**1455**	**20.1**	**29.0**	**1504**	**19.4**
MOP2	**31.1**	**1533**	**20.1**	**32.3**	**1624**	**20.2**
s.e.d.	*1.7*	*68*	*0.67*	*2.9*	*166*	*0.25*
TSP0	24.5	1325	18.1	25.3	1418	**17.7**
TSP1	25.4	1336	18.9	25.7	1369	**18.7**
s.e.d.	*1.2*	*50*	*0.49*	*2.2*	*122*	*0.18*
KIE0	24.6	1337	18.2	24.7	1375	17.9
KIE1	25.4	1323	18.9	26.4	1412	18.3
s.e.d.	*1.2*	*50*	*0.49*	*2.2*	*122*	*0.19*
Depth coeff.	0.11	2	0.06	0.22	6.00	0.09
s.e.	0.13	5.4	*0.05*	*0.23*	*13.1*	*0.02*
Effic.	*0.92*	*0.77*	*1.12*	*0.97*	*0.80*	*5.25*

Table 106 Effect of the interaction between SOA and MOP on FFB yield (t/ha) in 2001-2003 and 2003 (Trial 252). Yields >30 t/ha are highlighted in bold.

2001-2003, p=0.309,				2003, p=0.726			
	MOP0	MOP1	MOP2		MOP0	MOP1	MOP2
SOA0	13.3	27.2	26.5	SOA0	13.2	27.6	28.0
SOA1	18.5	28.6	**32.8**	SOA1	18.5	29.0	**34.3**
SOA2	13.4	**30.4**	**34.0**	SOA2	14.3	**30.2**	**34.7**

Table 107 Effect of the interaction between SOA and MOP on SBW (kg) in 2001-2003 and 2003 (Trial 252).

2001-2003, p=0.409				2003, p=0.028, $lsd_{0.05}$=1.4			
	MOP0	MOP1	MOP2		MOP0	MOP1	MOP2
SOA0	13.8	19.4	20.0	SOA0	13.7	19.5	20.1
SOA1	16.2	20.5	20.3	SOA1	15.9	19.6	19.7
SOA2	14.8	29.3	21.4	SOA2	15.1	19.2	21.0

Table 108 Effect of the interaction between SOA and TSP on SBW (kg) in 2001-2003 and 2003 (Trial 252)

2001-2003, p=0.556			2003, p=0.055, $lsd_{0.05}$=1.1		
	TSP0	TSP1		TSP0	TSP1
SOA0	17.0	18.5	SOA0	17.1	18.3
SOA1	19.0	19.0	SOA1	18.5	18.2
SOA2	18.4	19.3	SOA2	17.4	19.5

Table 109 Effect of the interaction between MOP and TSP on SBW (kg) in 2001-2003 and 2003 (Trial 252).

2001-2003, p=0.256			2003, p=0.016, $lsd_{0.05}$=1.1		
	TSP0	TSP1		TSP0	TSP1
MOP0	13.8	16.1	MOP0	13.5	16.3
MOP1	20.3	19.8	MOP1	19.3	19.5
MOP2	20.3	20.8	MOP2	20.3	20.2

Table 110 Effect of the interaction between MOP and KIE on SBW (kg) in 2001-2003 and 2003 (Trial 252).

2001-2003, p=0.668			2003, p=0.022, $lsd_{0.05}$=1.2		
	KIE0	KIE1		KIE0	KIE1
MOP0	15.6	14.3	MOP0	15.5	14.2
MOP1	19.3	20.9	MOP1	18.7	20.0
MOP2	19.7	21.4	MOP2	19.6	20.9

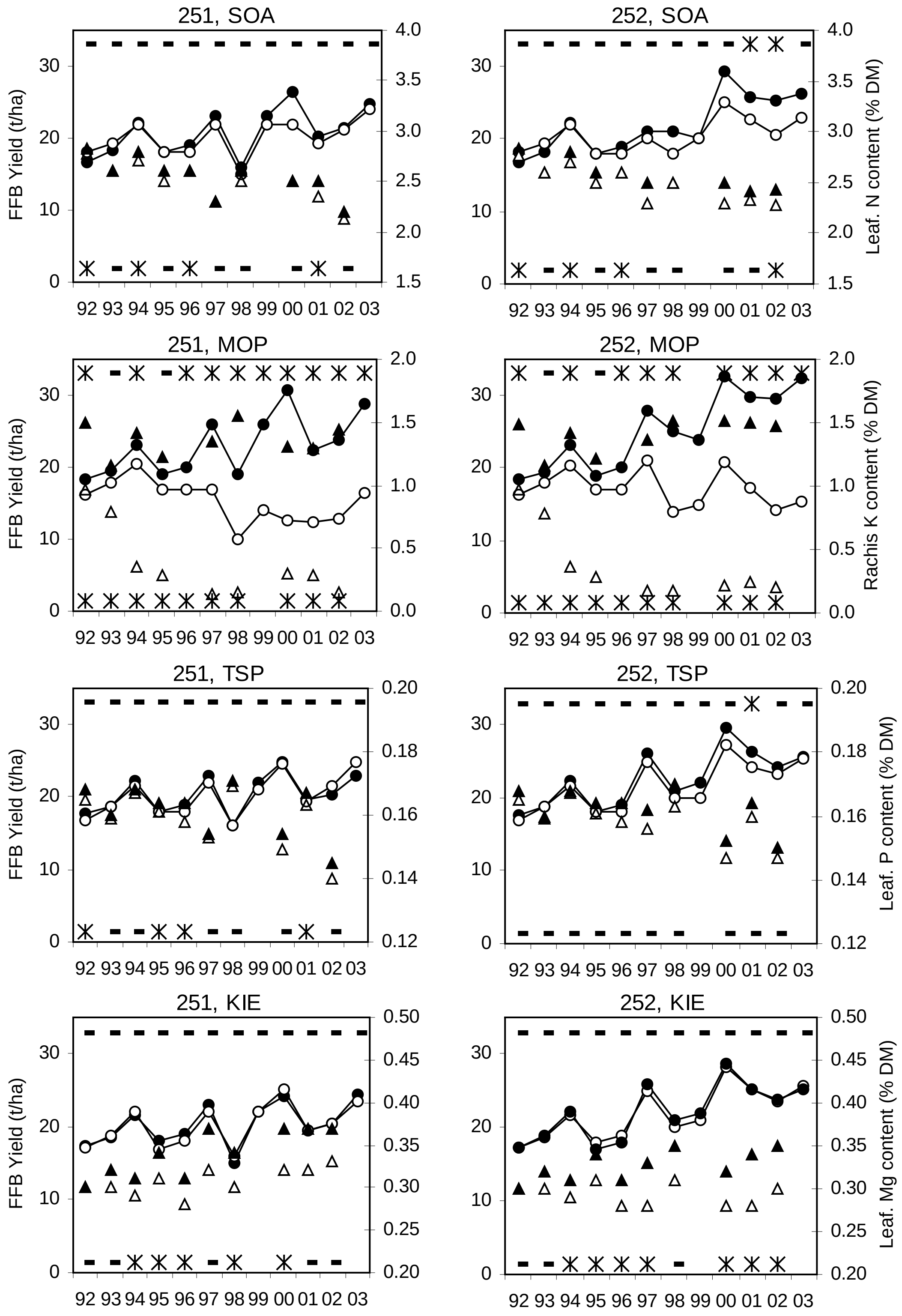


Figure 25 Main effects of SOA, MOP, TSP and KIE for Trials 251 and 252. Lines with circles, FFB yields; triangles, tissue concentrations; full symbols, maximum level of application; open symbols, zero application. Symbols along the top indicate significance of the main effect on yield, and along the bottom indicate significance of the main effect on tissue concentration. Stars indicate significance ($p<0.05$) and dashes non-significance.

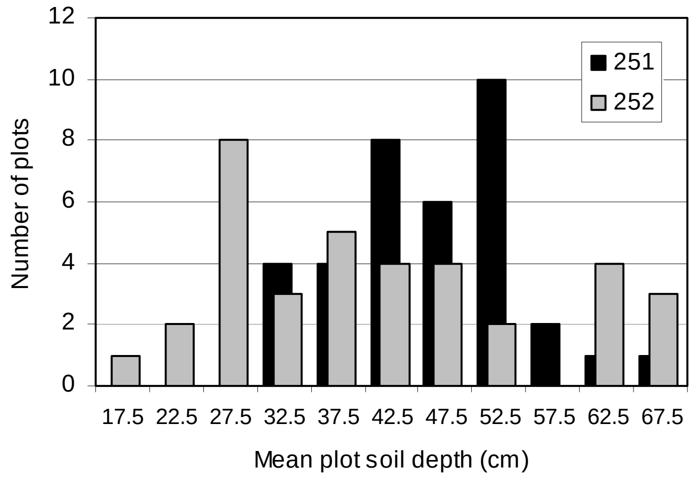


Figure 26 Distribution of mean plot soil depths in Trials 251 and 252.

	Ash	N	P	K	Ca	Mg	Cl	Si
No Covariate								
SOA	0.683	**0.056**	**0.045**	0.309	0.556	0.107	0.548	0.669
MOP	**<0.001**	**0.059**	**0.032**	**<0.001**	0.112	**0.018**	0.745	0.242
TSP	0.612	1.000	**0.019**	0.492	0.464	0.952	0.542	0.680
KIE	0.736	1.000	0.838	0.828	0.129	0.183	0.445	0.329
Depth Covariate								
SOA	0.422	**0.062**	**0.091**	0.147	0.658	**0.057**	0.605	0.408
MOP	**0.003**	0.109	**0.083**	**<0.001**	0.205	**0.011**	0.829	0.285
TSP	0.644	1.00	**0.043**	0.402	0.380	0.953	0.586	0.666
KIE	0.656	1.00	0.901	0.669	0.107	**0.063**	0.518	0.263
Cov Eff	*1.18*	*1.07*	*0.76*	*2.08*	*1.23*	*2.79*	*0.79*	*1.91*

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 2004.

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 111. 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 111 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 covers 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/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 and crop production 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 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 112. Bunch numbers and weights are being measured on every palm in every third row.

Table 112 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 9.50 (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 on yield and number of bunches/ha but not single bunch weights in this the first year of the trial (Tables 113 and 114). Of the three treatments, treatment 3 had the highest yield and bunches/ha.

Table 113 Effects (p values) of treatments on FFB yield and its components in 2003 (Trial 139). p values <0.1 are indicated in bold.

	2003		
Source	Yield	Bun./ha	kg/bun.
Treatment	**0.014**	**0.012**	0.473
CV%	*3.0*	*2.7*	*3.1*

Table 114 Main effects of treatments on FFB yield (t/ha) and its components (Trial 139). Effects with p<0.1 are shown in bold.

	2003		
	Yield	Bun./ha	kg/bun.
Treatment 1	**17.5**	**2672**	6.54
Treatment 2	**18.2**	**2688**	6.76
Treatment 3	**19.4**	**2915**	6.66
s.e.d.	*0.45*	*60.7*	*0.168*
GM	*18.4*	2758	*6.65*

TRIAL 331 SPACING AND THINNING FOR MECHANICAL IN-FIELD COLLECTION TRIAL, AMBOGO ESTATE

PURPOSE

To determine the effects of spacing configuration on palms, cover crops and soils, with a view to facilitating mechanical in-field collection.

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 115). 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.

Table 115 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 effects of different planting densities on the FFB yield and its components are shown in Tables 116 and 117. The bunch weight (t/ha/yr) and the number of bunches harvested per hectare per year were significantly affected by the different planting densities used. At this stage, there is no marked relationship between the different densities and the yield parameters (FFB & BN/ha), however current scenario is that the three highest planting densities (192, 203, 215) have shown to be producing the highest tonnes of FFB as well as the number of bunches harvested on a per hectare basis.

The vegetative growth of the palm in terms of the leaf components measured did not show a significant response to the different planting configurations (Tables 118 & 119).

Table 116 Density effects (p values) on FFB yield and its components in 2003. p values less than 0.1 are indicated in bold.

Treatment	FFB	BN	SBW	BW/palm/yr	BN/palm/yr
Density	**0.011**	**0.005**	0.276	0.631	0.593
CV %	*15.4*	*13.8*	*3.3*	*17.4*	*15.1*

Table 117 Density effects on FFB yield and its components in 2003.

Treatment Code	Density (palms/ha)	FFB (t/ha)	BN (/ha/yr)	SBW (kg)	BW/palm/yr (kg)	BN/palm/yr
1	128	**15.3**	**3021**	5.1	119	23.6
2	135	**14.4**	**2900**	4.9	107	21.5
3	143	**16.0**	**3054**	5.2	112	21.4
4	192	**23.2**	**4611**	5.0	121	24.0
5	203	**19.5**	**4001**	4.9	96	19.7
6	215	**22.7**	**4461**	5.1	106	20.8
sed		*2.3*	*415*	*0.13*	*16.0*	*2.7*

Table 118 Density effects (p values) on the vegetative growth (leaf & other components) of the oil palm in 2003.

Treatment	Number of Leaflets	Leaf Length	WxT	Leaflet length	Leaflet width
Density	0.424	0.709	0.211	0.440	0.689
CV %	*1.7*	*4.4*	*6.0*	*3.6*	*4.0*

Table 119 Density effects on the vegetative growth (leaf & other components) of the oil palm in 2003.

Density (palms/ha)	Number of Leaflets	Leaf Length (cm)	WxT (cm^2)	Leaflet length (cm)	Leaflet width (cm)
128	116	302	12.0	77	3.7
135	113	294	10.8	75	3.5
143	116	310	12.1	79	3.7
192	116	302	12.1	76	3.6
202	114	295	11.2	75	3.7
215	115	303	11.7	78	3.7
sed	*1.6*	*10.8*	*0.6*	*2.9*	*0.1*

TRIAL 513 SPACING AND THINNING FOR MECHANICAL IN-FIELD COLLECTION TRIAL, PADI PADI

PURPOSE

To investigate the possibilities of field planting requirements, and how best to make use of increased inter-row spacing to facilitate mechanical infield collection.

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 yeloowish 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: Dami D x P

DESIGN

The design is the same as Trial 331. There are 6 treatments initially of different planting densities but of equilateral triangular spacing (Table 120). 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 will be established. The trial started when the area was cleared and planted in 2002. Fertiliser application will be 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.

Table 120 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

The trial site was cleared in 2002 with the seedlings planted in July 2003. The cover crops (Table 121) were later planted in May 2003 in the second replicate. Commercial cover crop mix was sown in replicates 1 and 3. The evaluation of the cover crop performance in terms of their growth will commence in 2004. A report on this will be available in the 2004 annual report for next year's SAC.

Table 121 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. The maps digitised so far are shown in Figure 27.

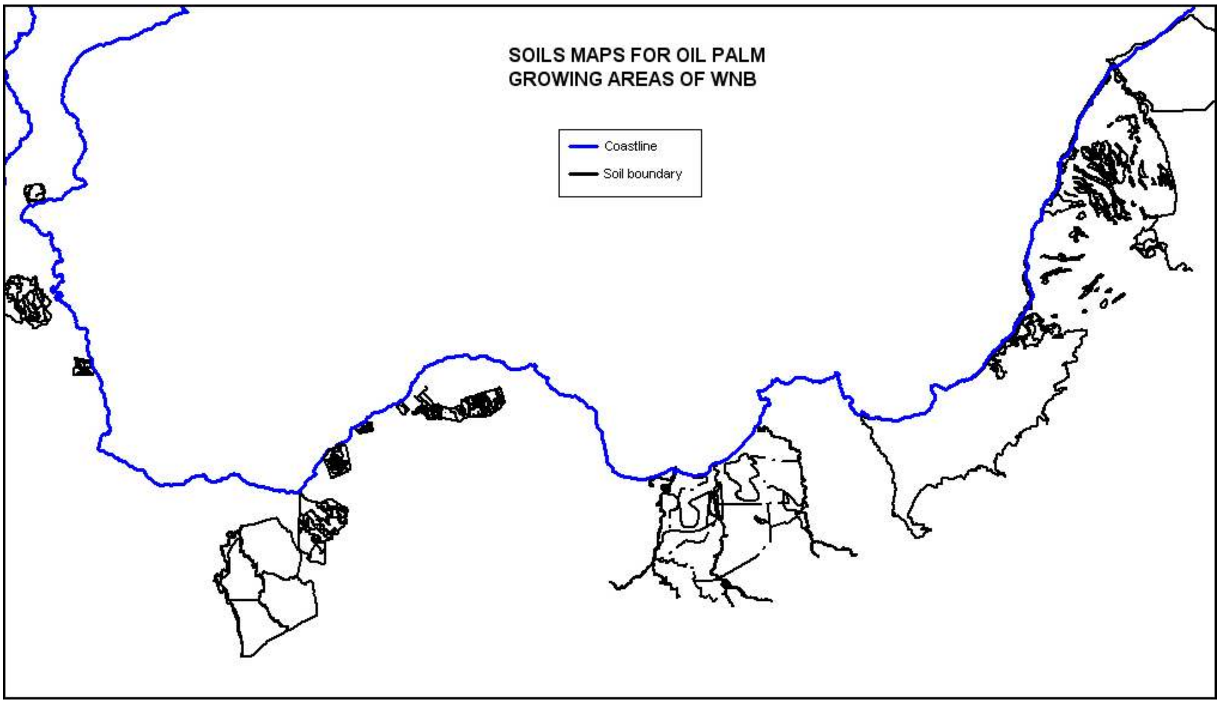


Figure 27. Soil maps that have been digitised.

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.

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

At one plantation site, where both yield and rainfall data are available over a period of time, there also appears to be a relationship between yield and rainfall two years earlier (Fig 29).

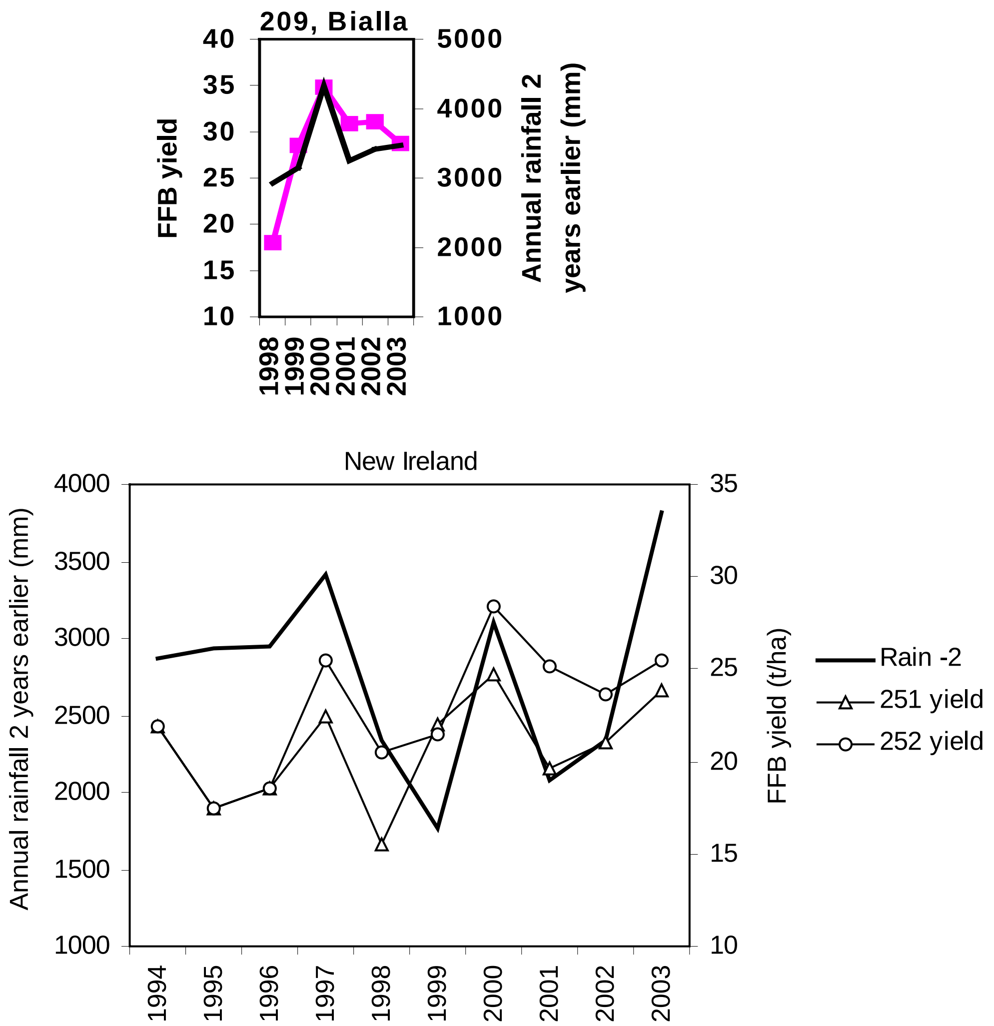


Figure 28: Updated rainfall and yield for Bialla and New Ireland

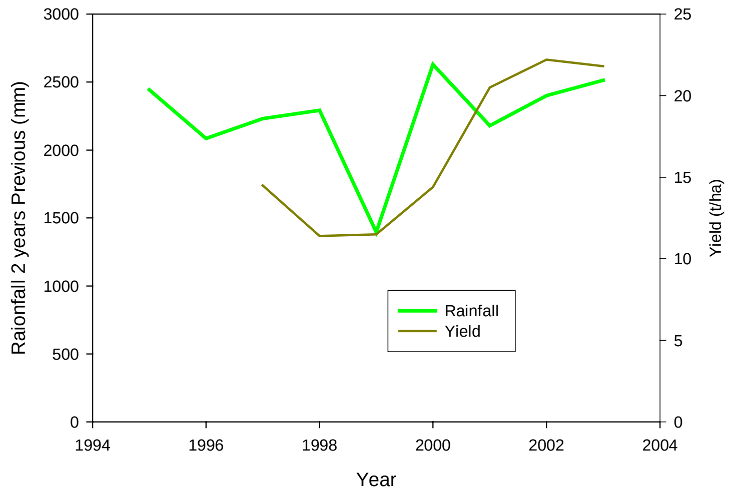


Figure 29 Relationship between FFB production per year and rainfall two years previous.

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 2 years. While longer-term trends and relationships (eg yield with prior rainfall) will require data collection over a number of years, it is possible to start analysing short-term effects.

Even though rainfall varies substantially over the year, soil moisture remains reasonably constant (Figure 30). Only during prolonged periods with low rainfall (Jun-Jul), did the soil moisture fall by any substantial amount.

There also appears to be little relationship between rainfall or soil moisture with the number of spear leaves. Number of spear leaves is generally regarded as indication moisture stress. However, it is clear that there is little correlation with soil moisture; whether current (i.e. at the time of counting spear leaves) or averaged over 1 or 2 weeks prior to counting spear leaves (Figure 31). Changing the period over which soil moisture was assessed eg previous 8 weeks, previous 4 weeks, 4 week period 8 weeks prior, or 2 week period 4 weeks prior, did not improve the relationship (data not presented).

However, if we view the data as cluster and we analyse to boundaries of that data, it provides additional information. Firstly we see that averaging data over the previous 2 weeks puts the data into a reasonably tight grouping. The dotted line on the lower graph represents a sharp boundary at the extremity of the data in that all points lie to the left and below that line. It also shows at that particular levels of soil moisture, a number of different spear leaf counts can be expected, but that the average number of spear leaves decreases to 1.0 as the soil moisture increases to about 38%. Conversely, at high spear leaf counts, the soil moisture is always at its lowest.

There are two consequences of this type of data distribution in interpreting the data in terms of oil palm yields for a plantation. If spear leaf counts are truly indicative of moisture stress being experienced by individual palms then (i) a high spear leaf count will suggest moisture stress; but the converse is not true in that a low spear leaf count may NOT indicate that soil moisture is adequate. (ii) in this particular soil, a soil moisture % of 38, would probably suggest that no palms are suffering stress.

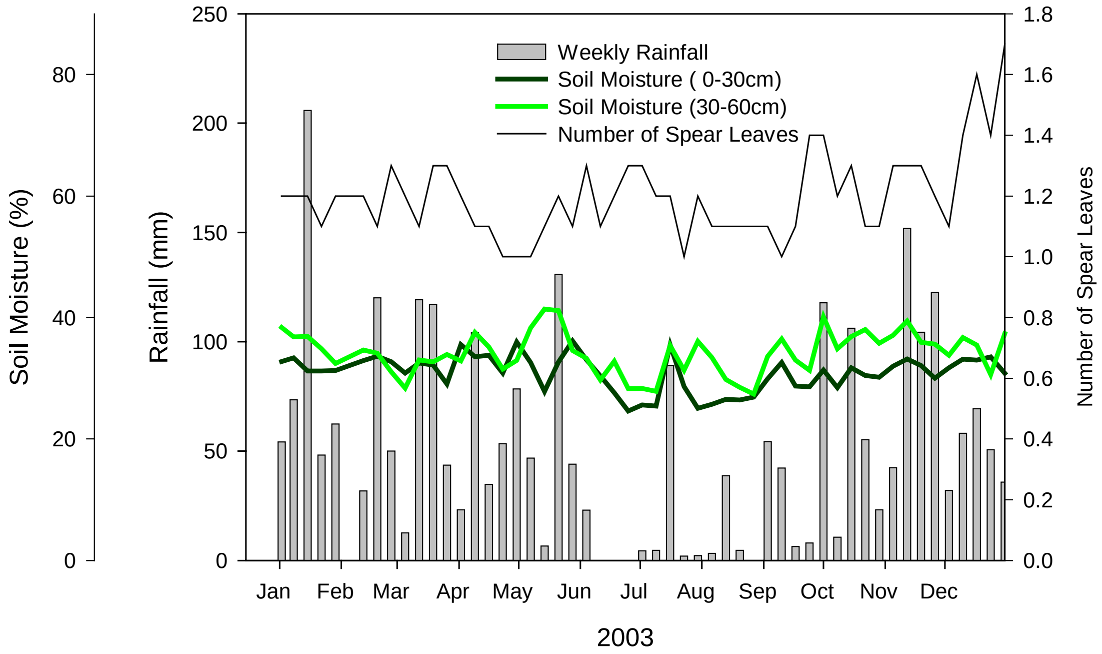


Figure 30: Weekly rainfall, soil moisture and spear leaf count for the observation plot (Trial 332) and Trial 324.

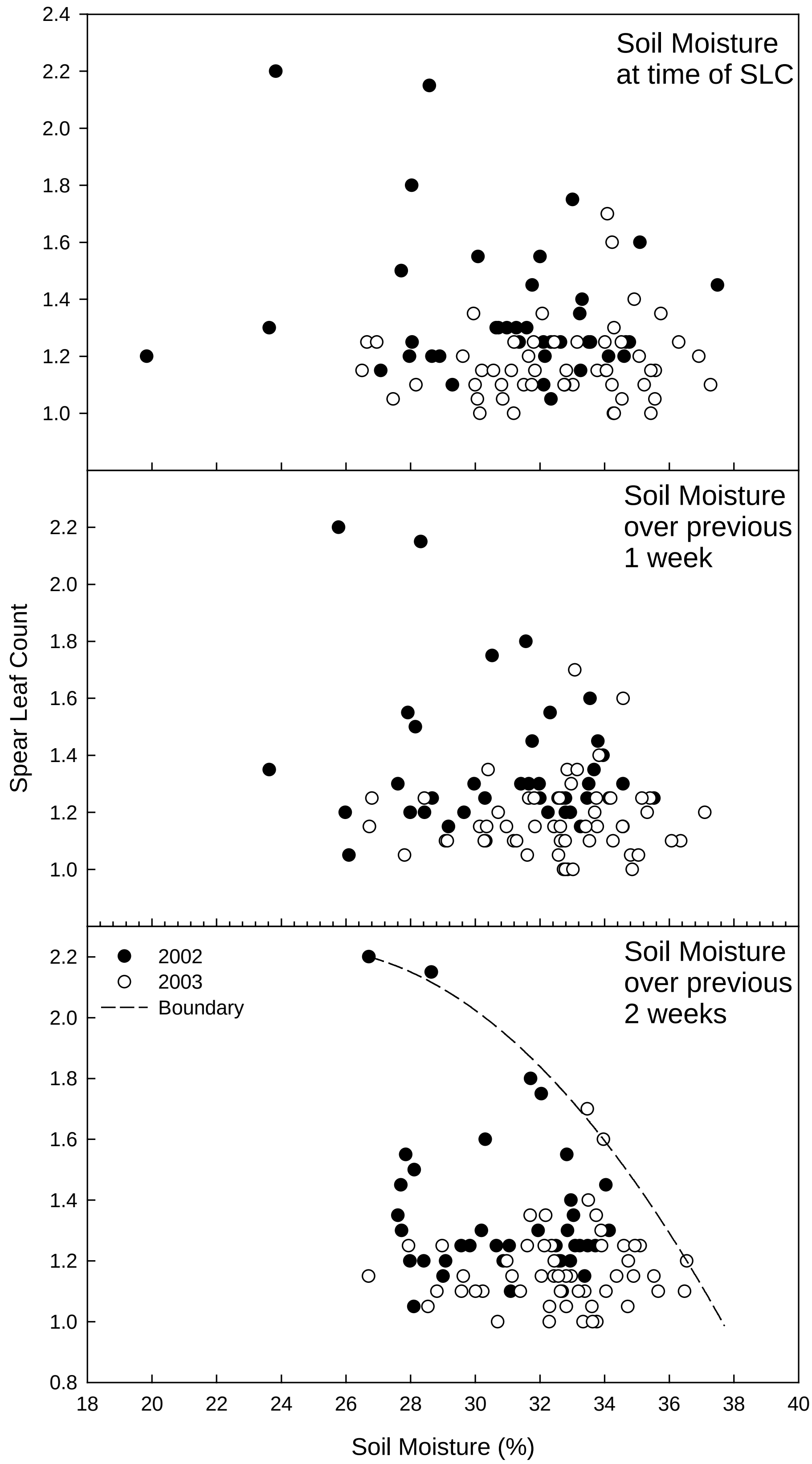


Figure 31 Response of number of spear leaves to soil moisture.

2. ENTOMOLOGY RESEARCH

(W. W. Page)

INSECT POLLINATION

Introduction

Weevils are essential for the efficient pollination of oil palm in PNG. The only other alternative, hand pollination, is no longer viable economically. The African pollinating weevil, *Elaeidobius kamerunicus* Jacq. was introduced from the Cameroon in Africa 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. The introductions of the pollinating weevil were particularly helpful to the smallholder sector because yields were significantly increased with no direct cost to the farmers.

During the last few years there have been a number of concerns expressed regarding the long-term viability of the weevil populations and their ability to efficiently pollinate the oil palms. These have included evidence from a number oil palm growing countries of declining yields due to the perceived poor pollination by *E. kamerunicus*. A EU Stabex funded project run by OPRA showed 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 the early 1980s. 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.

The current population of pollinating weevils within South East Asia is derived from only 618 individual weevils introduced from the Cameroon via quarantine in Malaysia in 1981. The weevils within PNG were a sub-sample from the initial quarantined population held in Malaysia. The oil palm industry in PNG therefore faces the same problems as in other areas of South East Asia; the narrow genetic base of the weevil population could pose a risk to viable and sustainable production.

Considerable progress was made during the first phase of the project but the results 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 do this, studies are required of the seasonal inter-relationships between the weevils, male and female inflorescences, and the internal nematodes, all of which are likely to affect the levels of pollination. It is also recognised that the small genetic base of 618 individuals that was used for the introduction of the pollinating weevils throughout the whole of South East Asia (from which PNG received a small sub-sample) is likely to have produced a high risk of in-breeding suppression, as well as greater vulnerability to infection by pathogens and parasites.

In order to address the above problems funding through EU Stabex was sought and a two year project approved 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.

Some work was undertaken during late 2002 (reported in the 2002 annual report) and further studies have taken place and are summarised below:

Life cycle of the internal nematode

Further information has been collected confirming that the 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. A previously undescribed stage in the life cycle was discovered both in laboratory-reared and field-collected weevils. Some female nematodes are found packed with infective (3^{rd} instar) larvae. In addition, near empty shells of adults with a few of 3^{rd} instar larvae trying to escape have been found. This, and previous evidence of 3^{rd} instar larvae being present in the weevils without adults, suggests that the nematodes may have a shorter life than the host weevils. It is suggested 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 shell 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 and begin producing more young. This would ensure that a weevil, once infected, is always infected even if the original nematode(s) dies. This would also help to explain why very high numbers of juvenile or adult nematodes (up to 57), which appear to be roughly the same age, are found in some individual weevils.

Third instar infective nematode larvae have been found to be passed out with, and 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 (larvae and pupae of the weevils subsequently found developing in the decaying male oil palm florets).

Levels of nematode infection

Weevils were sampled from ten oil palm areas on New Ireland during two visits by entomology staff. More than 50 weevils per site were dissected to check for internal parasitic nematodes and none were found. This confirms previous findings, from two sites on the island, that there are no internal nematodes present on the island.

Monthly and other collections and dissections of weevils from various sites in West New Britain Province and Oro Province have shown clearly that comparatively high (mean of 20% and above) internal nematode infection rates are only found regularly in areas of higher rainfall (e.g. Kapiura and Bialla in WNBP and Mamba in OP). To illustrate this data is given in Table 1 for various sites in Oro Province that have been monitored on a monthly basis.

Site	Total number collected	% males in sample	Total number dissected	Total infected	% infected	Mean annual rainfall (mm)
Komo	7687	33.5	800	167	20.9	3799*
Saga	6799	29.8	750	171	22.8	3774*
Ambogo	7502	31.6	650	68	10.5	2211
Parahe	7821	35.1	700	81	11.6	2261*
Embi	8907	36.0	650	14	2.2	2372

* Nearest weather station

Table 1. Levels of internal nematode infection for different areas in Oro Province.

Fruitset and nematode levels

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 infection do not appear to affect pollination. To illustrate this two examples are given: Kapiura (Fig. 1) and Komo (Fig 2).

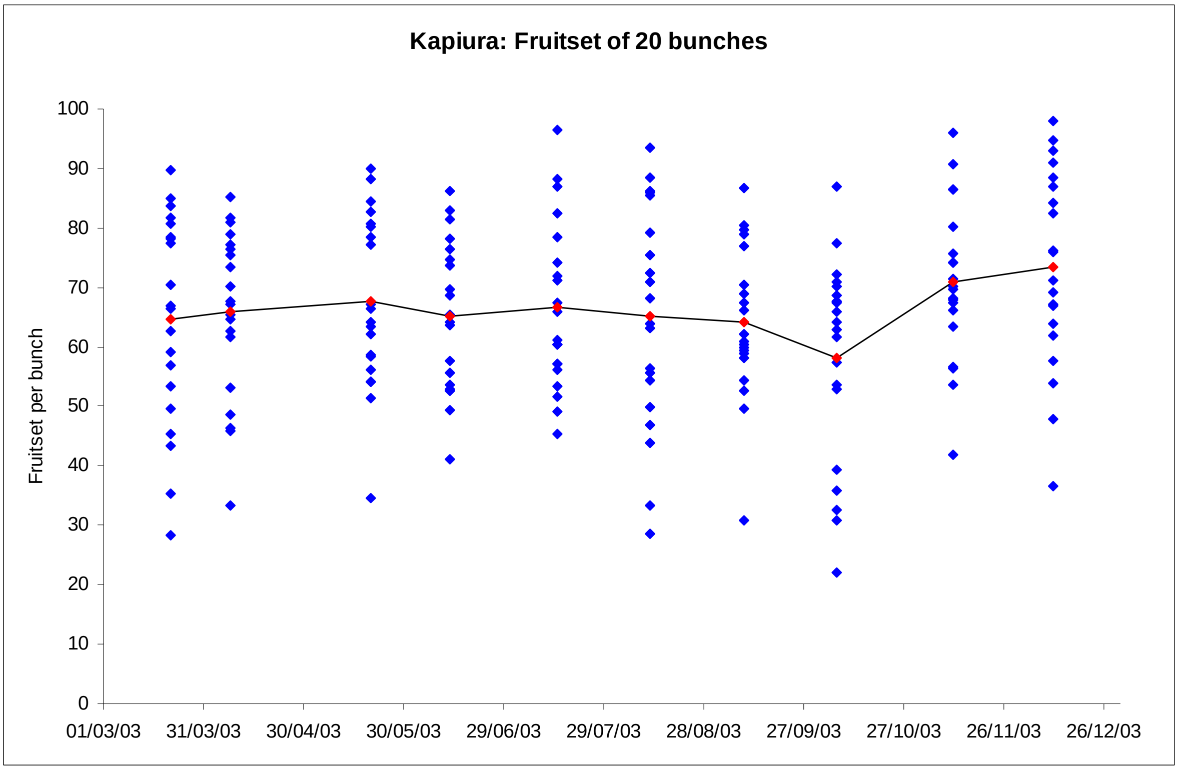


Fig. 1. Mean fruitset levels and fruitset of individual bunches at Kapiura during 2003

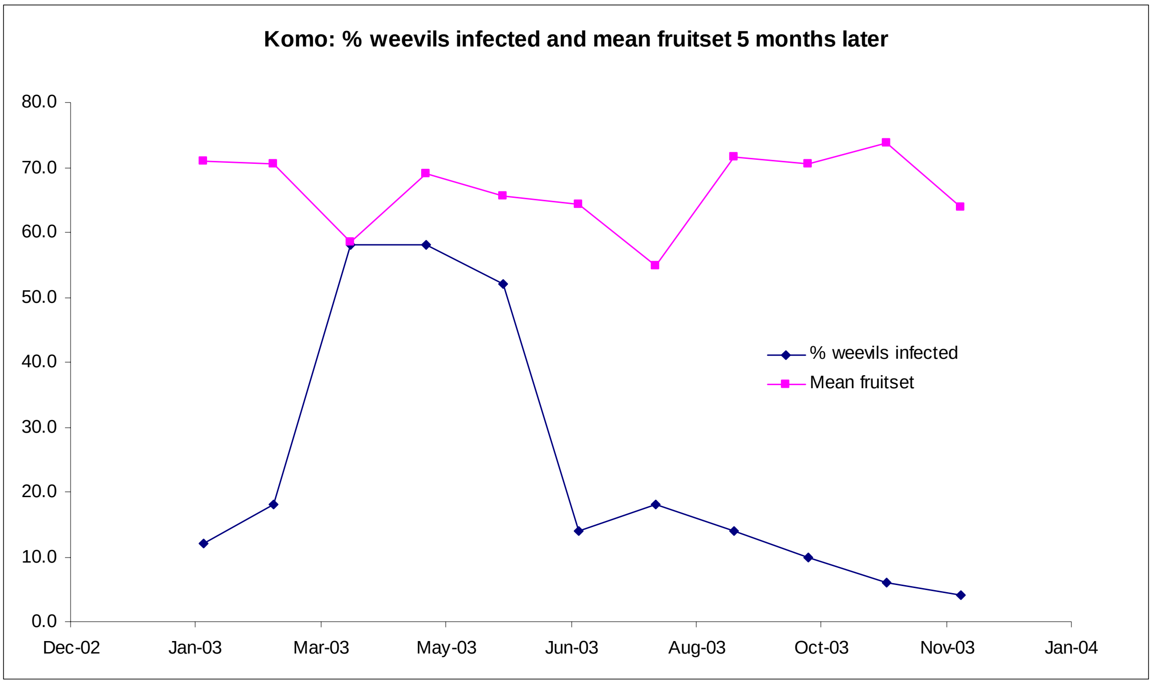


Fig.2 Mean fruitset at Komo recorded five months after high levels of nematode parasitism.

It can be seen in Fig. 1 that the data from Kapiura shows very little change in fruitset levels despite known high infections of nematodes. In all months some individual bunches had above 80% fruitset indicating that there would have been adequate weevils present each month to achieve such fruitset. A similar pattern was found for Komo (Fig.2) where, despite the field population of weevils having up to 58% parasitism, levels of fruitset recorded 5 months later (indicating pollination during the period shown in Fig 2) showed little change. It is suggested from this data that weevils were in sufficient numbers at both sites to produce good fruitset. Although a population crash due to very high nematode levels might be expected to have a short term affect on pollination, there has been no indication of this happening in the studies so far and a greater understanding of the effect of the nematodes on weevils is required. This will have to be studied under controlled laboratory conditions because of the very large variations found in the field. The fact that there are such large variations in fruitset for individual bunches, even though there are indications that ample numbers of weevils are available for pollination (see Fig.1), also requires further study as the large variations are the cause of suppressed overall fruitset levels. Poor pollination may not usually be due to the lack of weevils but to other factors. This has already been indicated 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.

Production of nematode-free stocks of weevils

Because of the need to introduce new genetic material of the pollinating weevil (*Elaeidobius kamerunicus*) from Africa it was necessary to establish techniques for the production of weevil stocks clear of both parasitic internal and harmless external nematodes. To do this, weevils were collected from known areas of internal nematode-free (New Ireland, two sites) and of very low parasitism (Haella, WNBP, one site). The weevils were set up, in groups of 50-100, onto pairs of flowering male oil palm spikelets and allowed to lay eggs over several days. All the weevils were then killed and examined by observation (external) and dissection (internal) for nematodes. If any group had been found with nematodes then the spikelets that they laid on would have been thrown away. In all cases, however no nematodes were found and nematode-free colonies from all three sites were established. The colonies were given fresh flowering spikelets to feed and breed on every Monday, Wednesday and Friday; the inflorescence that the spikelets came from had been bagged before the beginning of anthesis to avoid contamination. Every two to three weeks the colonies were sampled and checked for nematodes. One of New Ireland colonies got external nematodes in it and was therefore not used for nematode free releases at Ramu Sugar (see below). The external nematodes (*Cylindrocorpus* spp) are known to be spread worldwide by many flying insects so some getting onto non-anthesing spikelets is not surprising.

Survey and release of nematode-free weevils at Ramu Sugar

During July, the areas around Ramu Sugar were surveyed for the presence of pollinating weevils as there were known ornamental oil palms in the area and also 19 test plots of one hectare each which were young and producing inflorescences. Nine out of the 19 plots were checked for weevils on anthesing male inflorescences and none were found. In addition post-anthesis male spikelets were split open to check for signs of larvae feeding, larvae and pupae; but none were found. Similarly all the known ornamental oil palms were checked for similar signs and the very poor fruitset also indicated the lack of weevils. Since these were the only palms in the area before the test plots were put in (known plots of older palms having been removed years before), it was thought that there would not have been enough to sustain a weevil population which requires the constant supply of male inflorescences for food and breeding. Weevils were found in a two-hectare demonstration plot of oil palm at Unitech Lae (no internal nematodes found) and later in Madang (10% with nematodes). Because weevils were missing from around Ramu Sugar estates, it was decided that this was an opportunity to introduce nematode-free weevils into the test plots, which could be used subsequently to seed the new plantings beginning in October 2003 (1000 Ha and about 1000 Ha in 2004).

Nematode-free weevil stocks were produced in the Entomology quarantine facility (see below) and carried as larvae and pupae in spikelets to Ramu Sugar during November for release. The pollinating weevils were released into four of the test sites by distributing 150+ spikelets per plot giving a total of 600+ spikelets and an expected emerging population of 3000-6000 weevils per release site. By 2004 the weevils had established themselves throughout the area; including on the ornamental oil palms, which were seen to be producing large bunches with good fruitset.

Quarantine facility

In order to be able to import new weevil stocks from Africa, it was necessary for Entomology Section to have a quarantine facility to hold the stocks to ensure parasite and pathogen-free stocks before release. A facility was designed to National Agriculture Quarantine and Inspection Authority (NAQIA) standards and was built and finished during the year. The facility has already been used to produce nematode-free stocks of weevils and techniques have been developed for the handling of quarantined stocks.

SEXAVA IPM

Introduction

Sexava are the most prevalent pest 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 (see below). Work has concentrated 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.

Outbreaks

Because of the poor dry season in 2002 caused by El Nino, it was expected that there would be mass hatching of sexava eggs at the beginning of the rains at the end of the year (see 2002 Annual Report) leading to severe outbreaks in 2003. A warning to that effect was sent out in November 2002. A table of reported pest outbreaks and visits is given below (Table 2) which shows that 83% of all visits/recommendations were due to sexava. The majority of sexava outbreaks were on NBPOL plantations (particularly at Kapiura and Numundo) and Hoskins Smallholder areas (particularly Sarakolok and Siki). The low level of problems around Bialla is probably a reflection of the heavy control measures of the previous two years, which also included the large-scale release of parasites of the eggs, nymphs and adults. There were also large-scale control measures on New Ireland during 2002.

Date	Area/Plantation	Pest
	Hargy Oil Palm Ltd	
01/06/03	Hargy	Sexava
26/06/03	Hargy	Sexava
07/11/03	Navo	Sexava
	New Britain Oil Palm Ltd	
02/01/03	Dami	Sexava
13/01/03	Navarai	Sexava
31/01/03	Kautu	Sexava
02/02/03	Dami	Sexava
07/02/03	Numundo	Sexava
11/02/03	Navarai	Sexava
13/02/03	Kautu 1	Leafhopper
13/02/03	Kautu 1	Sexava
19/02/03	Togulo	Sexava
24/02/03	Dami	Sexava
26/02/03	Numundo	Rhinoceros beetle
07/03/03	Navarai	Sexava
10/03/03	Kapiura	Sexava
01/04/03	Togulo 2	Sexava
03/04/03	Kautu 2	Sexava
03/04/03	Malilimi 1&2	Sexava
03/04/03	Kautu 3	Leafhopper
09/05/03	Haella	Sexava
09/05/03	Malilimi	Sexava
19/05/03	Navarai	Sexava
29/05/03	Dami	Leafhopper
05/06/03	Bilomi 1	Sexava
10/06/03	Kautu 3	Sexava
13/06/03	Bilomi 1	Sexava
25/06/03	Numundo	Leafhopper
09/07/03	Bilomi 1	Sexava
14/07/03	Numundo	Leafhopper
07/08/03	Haella	Sexava
13/08/03	Malilimi 1&2	Sexava
15/08/03	Haella	Mole cricket
26/08/03	Haella	Mole cricket
15/08/03	Bilomi 1	Sexava
30/09/03	Bilomi and Kaurausu	Sexava
13/10/03	Kautu 3	Sexava
16/10/03	Kautu 3	Sexava
16/10/03	Kautu 3	Leafhopper
16/10/03	Kaurausu	Sexava

Date	Area	Pest
	New Britain Oil Palm Ltd (cont)	
22/10/03	Kautu 3	Sexava
24/10/03	Kaurausu	Sexava
03/11/03	Haella	Sexava
03/11/03	Navarai	Sexava
07/11/03	Kaurausu	Sexava
11/11/03	Navarai	Sexava
12/11/03	Togulo	Sexava
16/12/03	Haella	Sexava
22/12/03	Kautu 3	Sexava
	Oil Palm Industry Corporation	
15/01/03	Siki	Sexava
03/02/03	Sarakolok	Sexava
10/02/03	Kavui	Leafhopper
10/02/03	Nahavio	Leafhopper
18/02/03	Tiauru	Sexava
18/02/03	Sale	Sexava & stick
25/03/03	Galai 2	Leafhopper
16/06/03	Lavege	Sexava
15/08/03	Siki	Sexava
15/08/03	Mamota	Sexava
21/08/03	Tamabu	Sexava
22/08/03	Sarakolok	Sexava
22/09/03	Sarakolok	Sexava
24/09/03	Tamabu & Naulova	Sexava
22/10/03	Sarakolok	Sexava
27/10/03	Siki	Sexava
11/11/03	Kabaiya	Sexava
12/11/03	Siki	Sexava
03/12/03	Galai 2	Sexava
12/12/03	Sarakolok	Sexava
	Pacific Rim Plantation Ltd	
28/07/03	Poliamba	Sexava
Total reports/visits		**70**
Total sexava		**58**
% sexava		**83%**
Total leafhopper		**9**
Total mole cricket		**2**
Total rhinoceros beetle		**1**
Total stick insect		**1** (with sexava)

Table 2. Pest outbreaks during 2003, reported, visited and advised on.

Biological Control

Egg parasitoids

There are two species of wasp egg parasitoids that are used to help suppress the build up of sexava in the field and these kill the eggs that they parasitize. *Leefmansia bicolor* continued to be reared in the laboratory in sexava eggs and then released into oil palm growing areas where low-level sexava populations were present. With the advent of regular checking for the presence of eggs in the ground at outbreaks (for levels of embryonic development, hatching and parasitoids; see below) good reservoirs of *Doirania leefmansi* were found and breeding stocks re-established. During regular fortnightly sampling of eggs from the ground in an outbreak area at Numundo, results showed that parasitism levels of *Doirania* reached 56% in *Segestes decoratus* and, with a life cycle of about 45 days, must have gone through about six generations during the period of study (see Fig. 3). Even sexava eggs close to hatching were found to be parasitized. The results and observations showed that *Doirania leefmansi* are able to find the eggs of sexava in the ground up to depths of 2cm and, because of their high reproduction rate (producing 250 wasps per egg) they are very efficient parasitoids. It is known that *Doirania* are difficult to maintain in culture for more than a few generations (e.g. Froggatt, 1937) and it is suggested that the reason for this is that when a wasp lays its egg in a sexava egg the parasite produces around 250 clones of itself from that one egg. In a laboratory situation, inbreeding can therefore occur very rapidly, particularly when the parasitoids are hatching at different times from different sexava eggs. *Doirania* stocks are now replaced regularly from known wild reservoirs.

During the year, approximately 205,000 *Leefmansia bicolor* and 1,400,000 *Doirania leefmansi* were bred and released into a total of 27 sites where there were low levels of sexava.

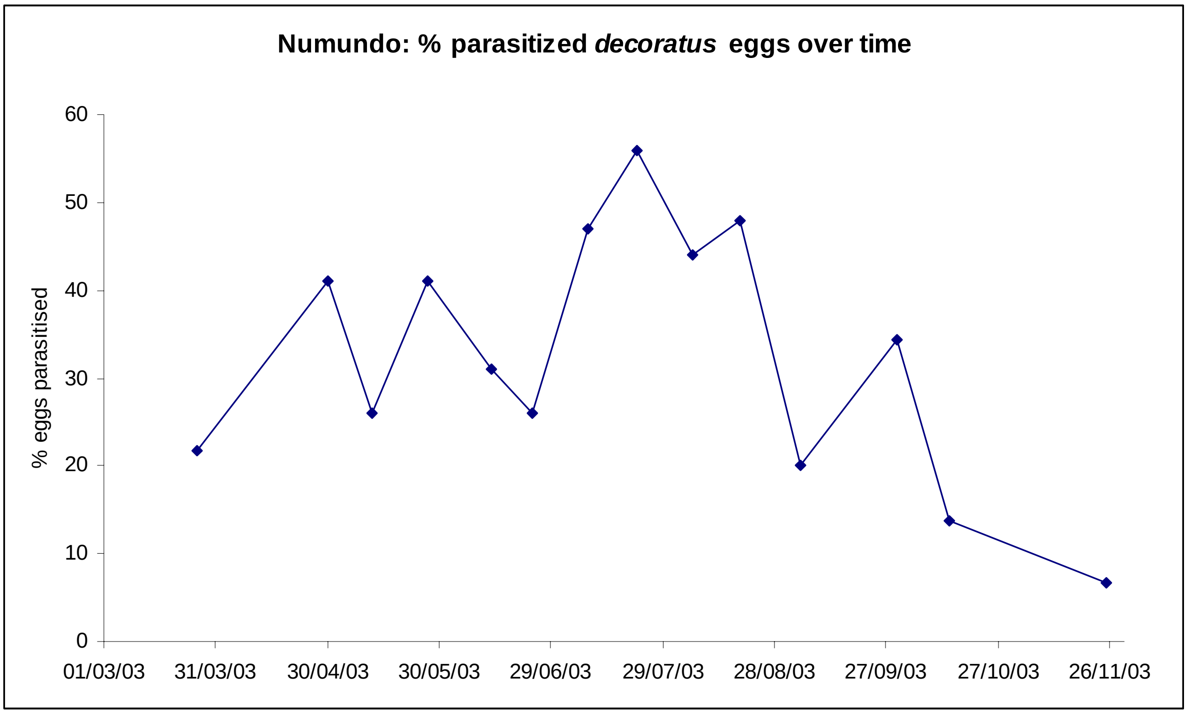


Fig 3 Levels of parasitism by *Doirania leefmansi* in the eggs of *Segestes decoratus* sampled from the field at Numundo.

<u>Strepsipteran parasites</u>

Successful introduction of Stichotrema into West New Britain

The Strepsiperan parasite *Stichotrema dallatorreanum* is found in the sexava pests *Segestidia novaeguineae* and *Segestes decoratus* on the mainland of PNG where they are known to suppress the build up of outbreaks. Work carried out by OPRA between 1995 and 2002 showed that the *Stichotrema* found around Popondetta appeared to be reproducing parthenogenetically thus excluding the complicated male life cycle (through ants). The latter was thought to be the reason that previous attempts to introduce the parasite onto the islands for coconut IPM had failed (e.g. O'Connor, 1959). Attempts were made to introduce *Stichotrema* into the three species of sexava found on New Britain and New Ireland (*Segestes decoratus*, *Segestidia defoliaria* and *Segestidia gracilis*) and all three species became infected although only in *S. defoliaria* did the parasite reach the adult stage during the trials. Large numbers of sexava (10,878 at more than 20 trial sites) were infected and released into the oil palm growing areas of New Britain and New Ireland between 2000 and 2002. Monthly monitoring up to the end of 2002 produced very few returns and between July 2002 and November 2003, despite dissecting specimens from some of the release areas to look for immature stylops, no *Stichotrema* were found.

In November 2003 a report of light damage at Kabaiya was followed up and over 30% of the *S. defoliaria* examined had adult *Stichotrema* protruding their cephalothoraxes out of the body of the hosts (seen as dark brown/black dots on the underside of the abdomen). Dissection of samples to look for immature stylops showed parasitism rates above 50%. The light damage, which would normally lead to moderate and severe damage, stayed the same over several months suggesting that the outbreak (over 300 Ha) had been suppressed. It was also noted that there was a considerable reduction in sexava numbers at the time when a large proportion of the *Stichotrema* were producing first instar larvae. This was because once the *Stichotrema* produce their first instar larvae (up to an estimated 750,000) they die and kill their host in the process. Also deaths occur before this when there is multi-parasitism and the host cannot cope with the parasite load.

The first instar larvae of *Stichotrema* are known to have male and female forms (Carvalho, 1959; Young, 1987) and examination of specimens from Bialla has shown that there were only female form first instars being produced; indicating parthenogenesis.

Subsequent surveys have shown that the distribution of *Stichotrema* in the Bialla area is quite widespread in smallholder plots and at Navo plantation. Work has begun on infecting *S. decoratus* and *S. gracilis* using the parthenogenetic stock from Bialla. In addition, redistribution of the parasitoid into other areas of Hargy Oil Palms and Bialla Smallholders has been initiated and also regular collections of parasitized sexava are being made and released into Kapiura where *S. defoliaria* is the major pest. It is hoped that *Stichotrema* will suppress sexava outbreaks on New Britain as well as they do on the mainland as this will reduce the costs of control considerably.

It is thought that *Stichotrema* was successful in building up at Bialla during 2002/2003 because there were likely to be nymphs and adults of sexava present there all the year round because of the comparatively higher rainfall in the area than elsewhere, even during the severer dry season of 2002. Because of arrested egg development in sexava (diapause, see below) the survival and build up of *Stichotrema* would not have been expected to have happened elsewhere. It is suggested that in severe dry seasons (e.g. caused by El Nino), *Stichotrema* distribution could be reduced to areas with higher rainfall where sexava hatching continues. This was seen after the severe dry season of 1997 when *Stichotrema* were only found in wetter areas around Popondetta having been more widely distributed beforehand. It is suggested therefore that after severe dry seasons *Stichotrema* may have to be redistributed from areas where they have survived.

The finding of the reservoir of parasioids at Bialla 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* on WNB and *Segestidia gracilis* on New Ireland) has the potential of long term suppression of this pest.

Male Stichotrema traps

Young (1987 and pers. comm.) had wild male *Stichotrema* being attracted to cages containing females that were parasitizing *S. decoratus*, suggesting that a sex pheromone was attracting them.

To examine whether there were any male *Stichotrema* in the population around Popondetta, pheromone traps containing virgin *Stichotrema* females were set out in selected sites to see if males could be caught. Adult *S. novaeguineae* suspected of being infected with *Stichotrema* were collected from the field and kept in cages until the cephalothorax extruded from the abdomen. They were transferred into cylindrical traps and placed at different heights within oil palm blocks. Twenty six traps were set up between May and the end of 2003, giving a total of 274 trapping days. Seven of the traps were placed within the crown, eleven were hung approximately one meter above ground and eight traps were hung in between. So far, no males have been caught in the traps, thus helping to prove that the population of *Stichotrema* in the area are parthenogenetic. The trapping will continue during 2004.

Redistribution of Stichotrema around Popondetta

The drought in 1997, caused by El Nino, appeared to wipe out the population of *Stichotrema* in some areas around Popondetta. Between 1999 and 2002 attempts to find *Stichotrema* were unsuccessful at Dobuduru, an area that had been used for collections up until 1997. During 2003, healthy sexava from Dobuduru were parasitized with *Stichotrema* using parasitized sexava adults from Koropata. These were then released into smallholder oil palm blocks at Dobuduru. Since the beginning of 2003, over 500 infected sexava have been released at Dobuduru and monitoring shows that the parasitoid has re-established.

<u>Egg diapause</u>

Introduction

It has long been thought that sexava eggs have a period of arrested development (diapause) triggered by dry periods and ended by sufficient rainfall (Froggatt and O'Connor, 1940; Young, 1985; Young, 1990). It was recognised that a study on sexava egg diapause was very important, both for a greater understanding of population dynamics and for making more reasoned control decisions with regards to biological and chemical control; in the hope of reducing overall costs of control.

Sexava belong to the family Tettigoniidae (long-horned grasshoppers), which are well known for producing eggs which go into diapause. Two stages of diapause are recognised in Tettigoniidae: (i) initial diapause, which takes place after blastoderm formation right at the beginning of embryonic development (ii) late diapause, which takes place when the embryo is fully developed (Ingrisch, 1990). Some species of Tettigoniidae have an initial egg diapause, others have a late diapause and others have both diapauses. In Europe there are species of Tettigoniidae that have egg diapauses up to 7 years! Working on what little was known of sexava egg diapause the studies below were set up on the premise that sexava had a late egg diapause, since this would produce mass hatching after a severe dry period. Two approaches were used to try and delineate the sexava diapause: (i) by regular collection of eggs from an outbreak area to monitor changes in embryonic development (ii) to set up an experiment in the laboratory using eggs of known age and giving them different treatments of soil water moisture to try and produce diapause and then break it.

Field collected eggs

Methods

An outbreak of *S. decoratus* at Numundo, where eggs had been laid in the ground prior to control by trunk injection, was used for monitoring the development of the eggs over a period of nine months. During that period, the area was treated by trunk injection three times and there was no evidence of further egg laying in the ground after the first treatment. Thus eggs sampled and examined had only been laid at the beginning of the study. A sample of sexava was collected during the first treatment period and this showed that 63% of the population were adult, 14% had already laid eggs and 43% were about to lay. This indicates that if the treatment had started any later there would have been many more eggs in the ground to cause further potential outbreaks. The estimated mean laying date of the eggs in the ground was 13/02/03. Eggs were sampled from the soil at the base of the oil palms in one area of about 2 Ha; the first sample being on 26/03/03 and then, from a month later, fortnightly until 14/10/03. A final sample was taken on 25/11/03.

An average of 548 eggs was collected in each sample (328-1017eggs). All eggs found, both empty and whole, were collected and the empty shells used to estimate the proportion of hatched eggs. 100 whole eggs were then weighed and dissected. Parasitism was recorded (see above) and, if still viable, the embryonic stage was recorded using the stages derived from Ingrisch (1984) but with the addition of a stage 0 for embryos not found (see Fig. 4). In practice, stages 4-7 were very difficult to find so would have been recorded as stage 0.

Results: embryonic development and egg weight

The weighing of the eggs throughout the 9 month collecting period allowed a picture to be built up of the relationship between the weight of individual eggs and the stage of embryonic development. This showed that up until stages 15-16, the weight of the eggs remained relatively stable and then there was a steady increase in water uptake until the last stage of development prior to hatching (stage 25, see Fig 5). The period of stable water content agrees with the work done by Young (1990), who weighed eggs over time but did not look at embryonic development of the eggs. He showed that there was a period of stable water content, for the majority of the eggs, of 16 days which would be equivalent to development observed in the field of stages up to 14.

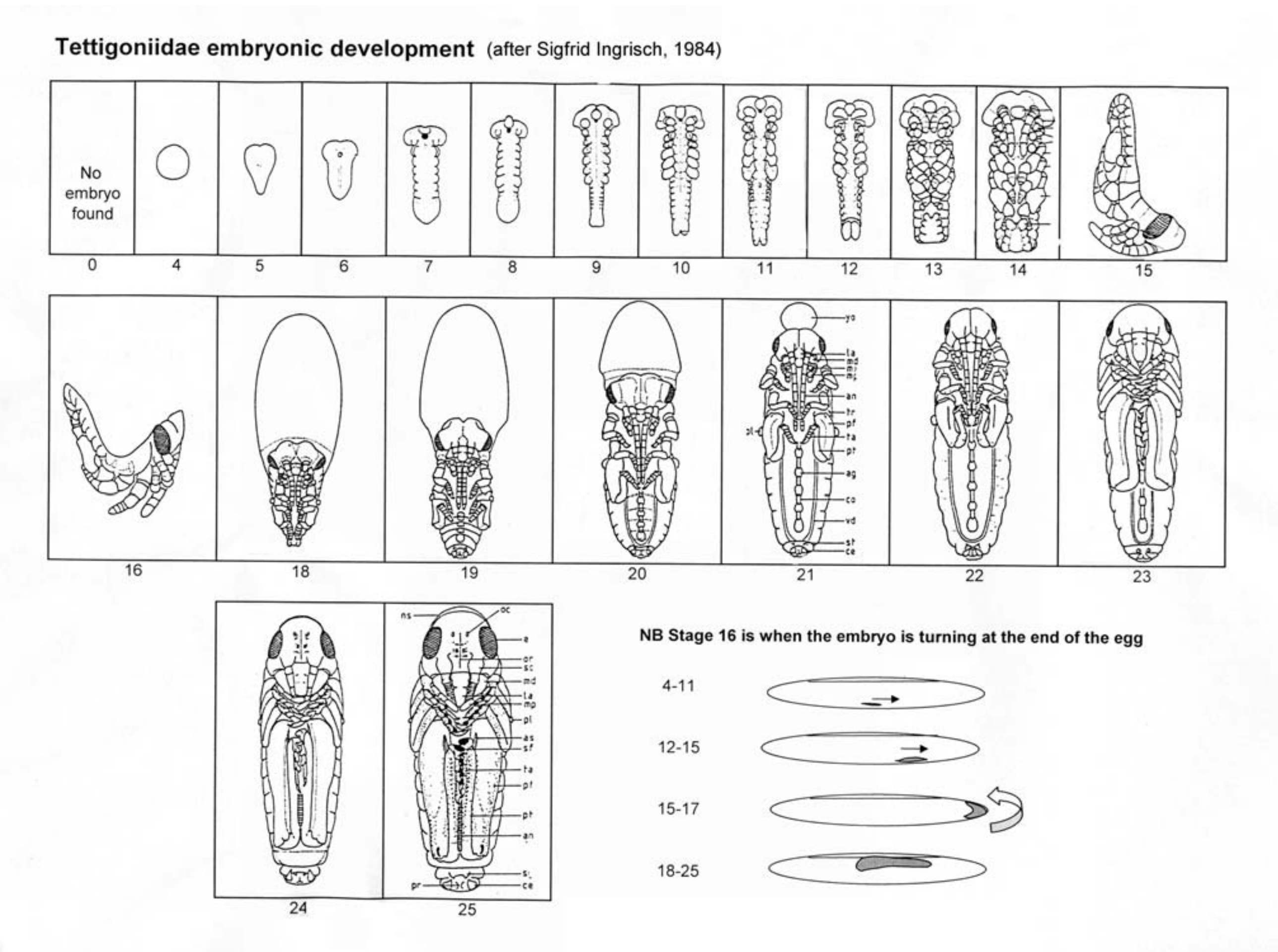


Fig. 4 Stages of Tettigoniid embryonic development used in the study of sexava eggs.

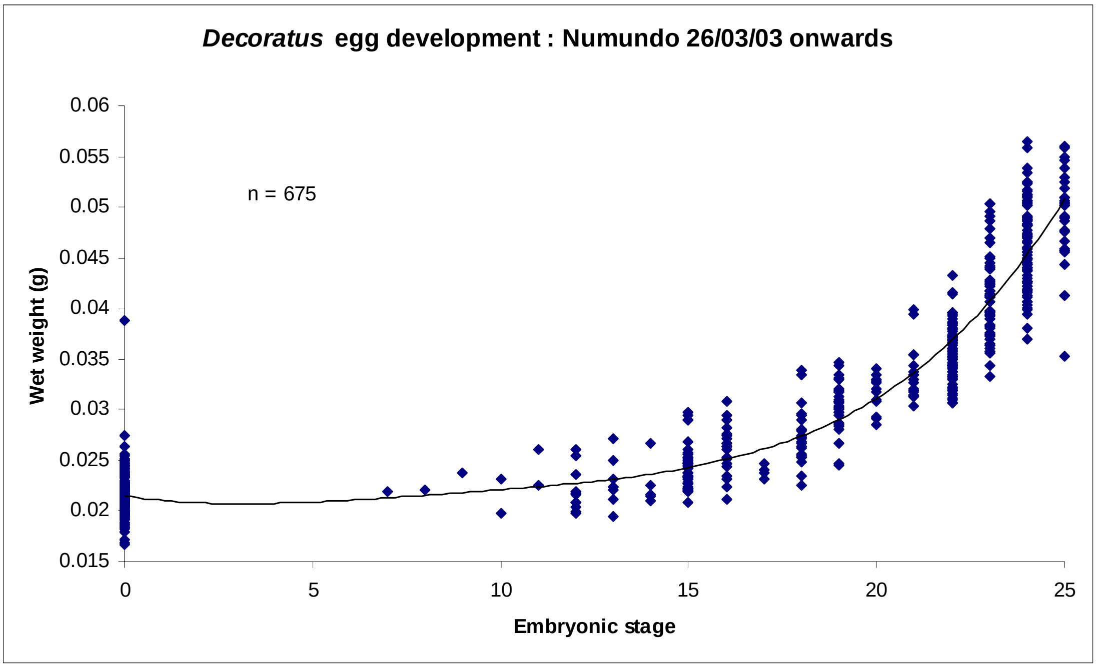


Fig 5 The weight of eggs of *S. decoratus* collected over 9 months from Numundo in relation to embryonic development

Embryonic development of other species

Because the correlation found between embryonic development and weight was so clear, and this had the potential for identifying stages of development just by weight, it was decided to collect data on other species of sexava. This would provide baseline data on embryonic development for each species. So far *Segestes decoratus*, *Segestidia defoliaria* and *Segestidia novaeguineae* eggs have been examined (Fig. 6), although more data points are required for the latter species using more accurate scales.

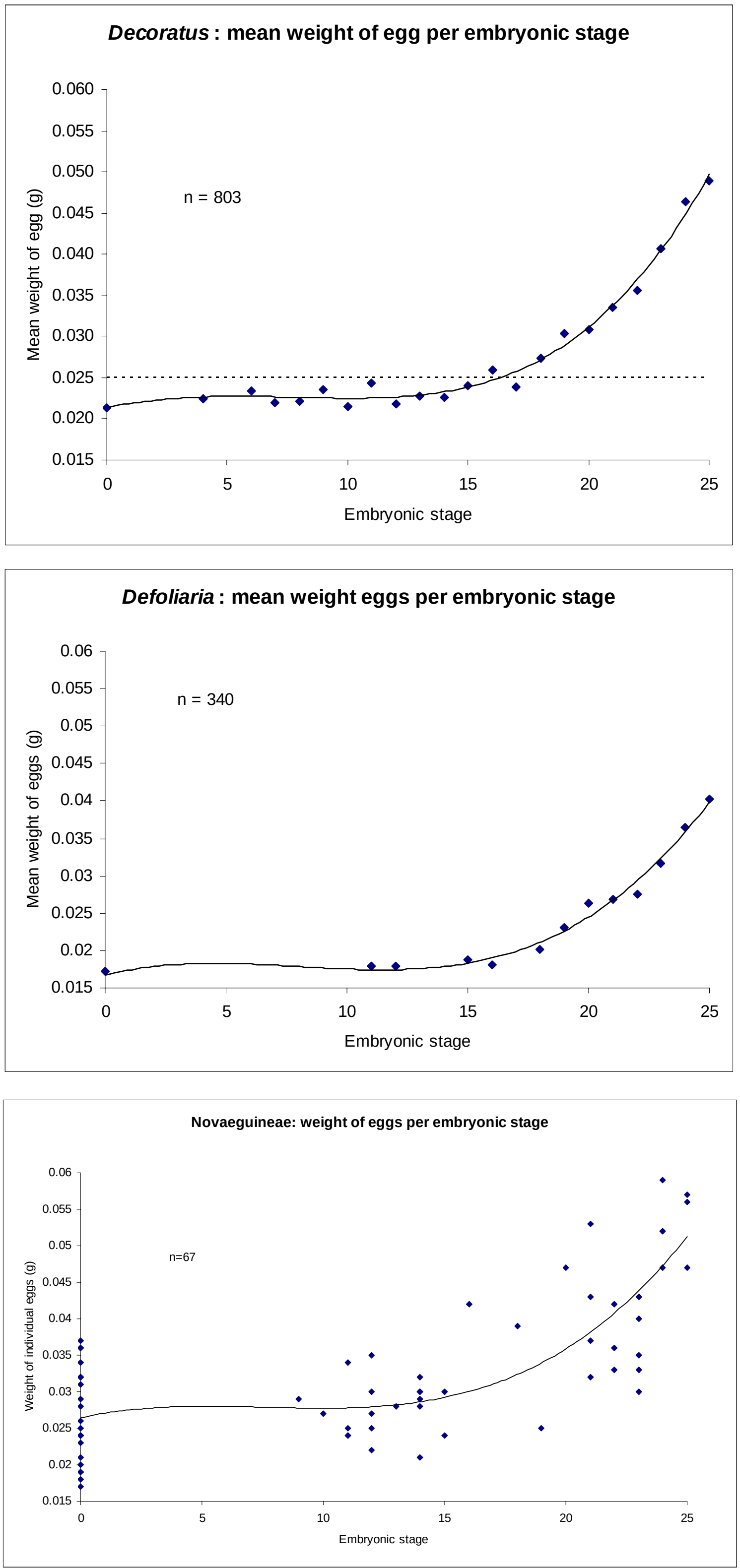


Fig. 6 The mean weight of eggs of *S. decoratus* and *S. defoliaria* and the weight of eggs of *S. novaeguineae* collected from the field in relation to embryonic development.

It can be seen from Fig. 6 that the embryonic development of the different species of sexava in relation to egg weight is very similar other than the initial start weights because of the different sizes of the species and their eggs. In all cases, the start of increase in water uptake begins at stages 15-16 when the embryos are migrating round the end of the eggs (see Fig. 4).

Results: embryonic development over time

The results from the egg samples collected over 9 months from Numundo to study embryonic development are summarised in Fig. 7.

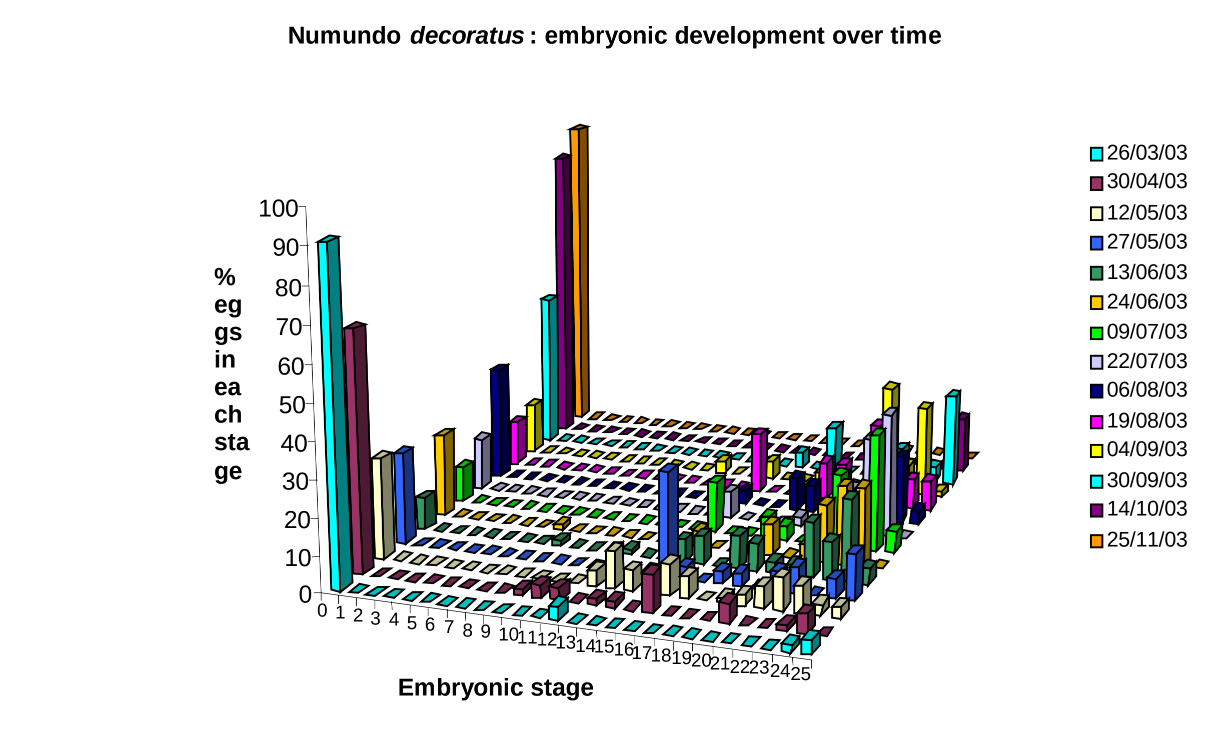


Fig. 7 The proportion of each stage of embryonic development found in samples taken over 9 months at Numundo.

It can be seen from Fig. 7, that initially, virtually all the eggs were recorded at stage 0 showing little or no development. Over time, more eggs were showing development up to and past stages 15-16, but a proportion still showed no development (diapause). In fact, by the time that the second trunk injection treatment had lost its efficacy (14/7/04 and treated 12 weeks after first treatment); around 17% of all the eggs were still viable and unhatched (taking into account hatched eggs, dead eggs and parasitized eggs). Based on the approximate numbers of eggs being dug per palm this would have equated to 300,000-500,000 potential hatching nymphs in the outbreak area being missed by the second treatment.

Towards the end of sampling less and less viable eggs were being found because most had hatched (see below). Because of this, the eggs still in diapause (stage 0) became the majority sampled, as shown between 30/9/03 and 25/11/03 in Fig 7. These eggs had been in diapause 9+ months. By the end of the study, a total of 7673 eggs had been collected and examined, and of these 1177 had been dissected.

Numbers of eggs hatching over time

The results of the proportions of hatched eggs found over the 9-month period are shown in Fig. 8. This is compared with the rainfall recorded at Numundo. It can be seen that there is a steady increase in the proportion of eggs that had hatched over time; this is despite the eggs being laid over a comparatively short period in January/February. There is an indication of a cessation of hatching between June and September when the rainfall was low but further work needs to be done on this aspect.

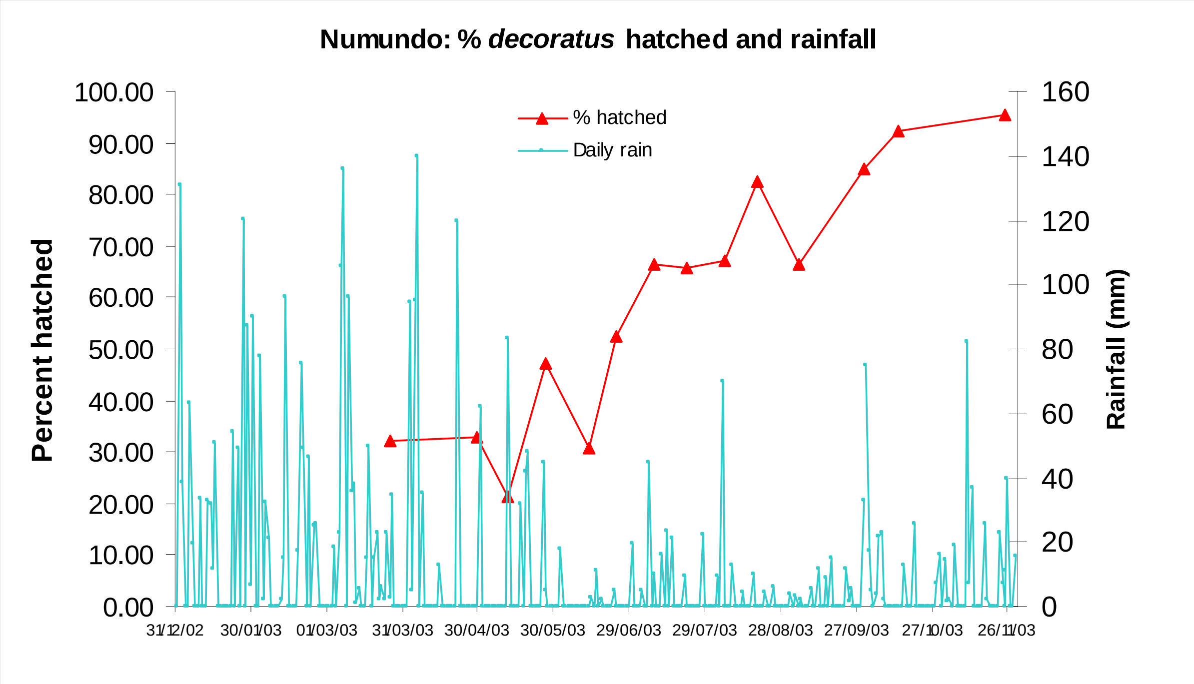


Fig. 8 The proportion of hatched eggs found in samples at Numundo over time in comparison with the rainfall

Discussion

The results of the fieldwork suggest that *S. decoratus* eggs undergo an initial diapause of variable length. This also shows that individual eggs can stay in diapause from 16 days (from Young 1990) to 9 months or more. This is typical of initial diapause in Tettigoniids (Ingrish 1990) and ensures that eggs are able to hatch throughout the year even if they are all laid around the same time. It is thought that initial diapause in grasshopper eggs can be laid down by the egg-laying female based on the levels of ecdysone in her body at the time (Chapman, 1982). Thus sexava, which lay batches of eggs, may produce batches that have different lengths of diapause. Some initial work on sexava (2004) indicates that this may be so.

Diapause experiment

The diapause experiment was designed to attempt to put sexava eggs into diapause using different treatments of soil moisture content and then to break that diapause at different times by increasing the moisture content. It was not known at the time that there would be a pre-set initial diapause imposed over this (see above). However, fortuitously, the results were able to show further aspects of the sexava egg diapause.

Methods

Female *S. decoratus* were collected from the same area at Numundo as the field collections above and allowed to lay eggs in soil. The eggs were collected every day and treatments set up in sterilised soil in plastic pots covered with fine netting using eggs laid on the same day. The treatments are shown in Table 3.

Diapause experiment: treatments

4 replicates, 6-10 eggs per replicate **Top up days: Monday, Friday**

Treatment	% moisture to maintain	Maintain until (day)	Then put water up to %	Notes
1	80	throughout		
2	70	throughout		
3	60	throughout		If these don't hatch, run through to 250 days then up to 80%
4	50	throughout		If these don't hatch, run through to 250 days then up to 80%
5	40	throughout		If these don't hatch, run through to 250 days then up to 80%
6	30	throughout		If these don't hatch, run through to 250 days then up to 80%
7	20	throughout		If these don't hatch, run through to 250 days then up to 80%
8	40	100	80	
9	40	150	80	
10	40	200	80	
11	30	100	80	
12	30	150	80	
13	30	200	80	
14	20	100	80	
15	20	150	80	
16	20	200	80	
17	80	throughout		Changed 23/6/03 to 60% with poly-bag cover
18	80	outside after 1st day		

Table 3. List of the 18 treatments set up in the diapause experiment

In order to maintain the soil moisture contents, the soil was initially dried and sterilised then water added to bring the soil up to the treatment moisture content. The pots plus soil were weighed and then the soil was watered up to the original weight every Monday and Friday. During the intervening period there was usually a moisture loss of about 10% although this could increase to up to 15% during a dry period. In this way it was hoped that the eggs in the high moisture content treatments would develop and those in the low moisture content treatments would go into diapause. After this some low moisture treatments would have their moisture contents increased at different times so that the eggs could possibly come out of diapause (Table 3). A total of 650 eggs were set up in the experiment with 4 replicates of each treatment, giving 72 pots set up.

Results

According to Young (1985) first hatching should occur from 35 days after oviposition with a mean of 56.5 days for eggs that hatched within 90 days. In the diapause experiment no hatching had occurred by 58 days after oviposition so it was decided to weigh the eggs as this would give an idea of the embryonic development of the eggs (based on the embryonic data above). The eggs were therefore carefully removed from their pots and cleaned of soil, then weighed and put back into their pots and given the same allotted treatments as before. Because hatching was still very poor at 88 and 133 days the process was repeated. The first hatching, from any treatment, occurred 85 days after laying. There was only a 2.6% egg mortality over the 133 day period. In *S. decoratus,* eggs weighing above 0.025g are likely to be developing at and beyond the 15-16 embryonic stage and therefore out of initial diapause (see *S. decoratus* egg weights in Fig. 6 where the 0.025g threshold is drawn in). So the egg weights for the three weighings at 58, 88 and 133 days were analysed according to the proportions in each treatment above 0.025g. The results are shown in Fig. 9.

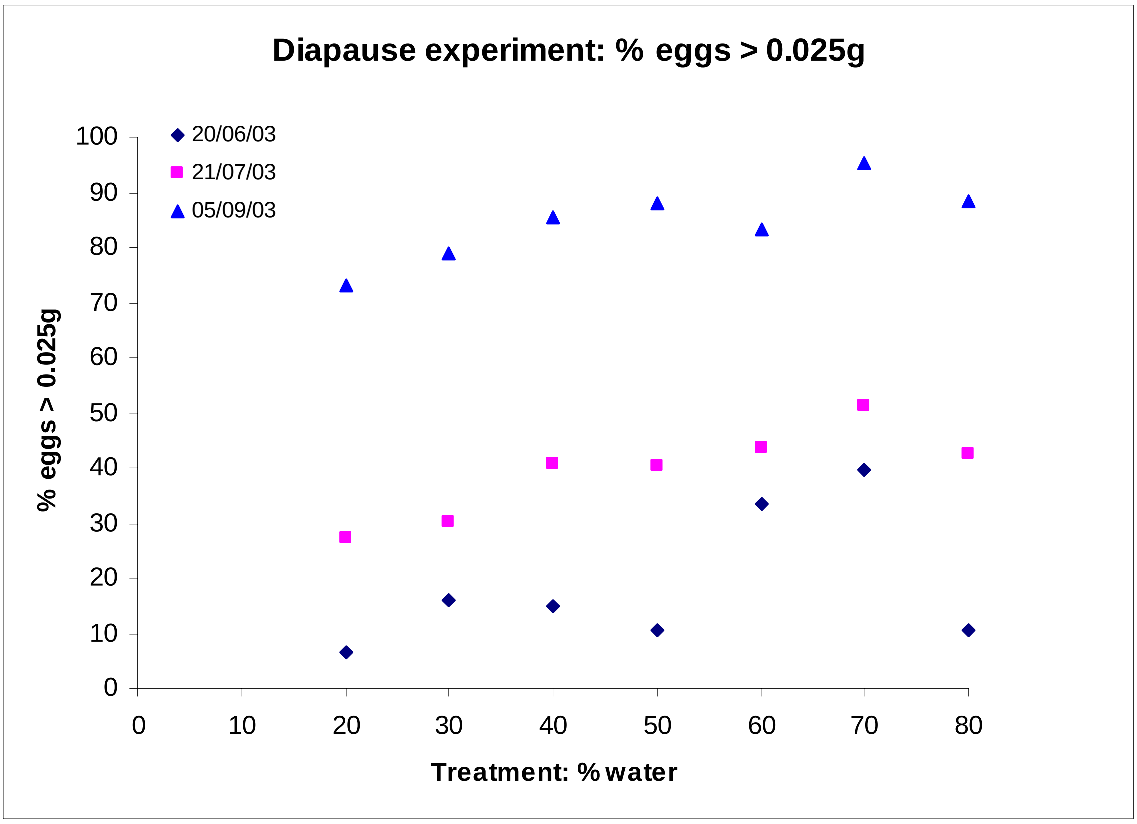


Fig. 9 The proportion of eggs in each soil moisture treatment found above 0.25g in weight (out of diapause) at 58, 88 and 133 days after being laid.

The graph in Fig. 9 shows that at 58 days the higher water moisture content treatments (60 and 70%) were ahead of the lower moisture contents in proportions above 0.025g in weight. The 80% treatment also lagged behind as the soil was over-saturated (confirming Young's observations on over-saturation, 1985). It can be seen, however, that the lower moisture content treatments tended to catch up at a later stage (88 and 133 days) suggesting that the lower treatments were slowed down in their water uptake.

Unfortunately after 133 days the wasps of the very small egg parasitoid, *Doirania leefmansi*, started to get through the fine netting covering the experimental pots so that by 178 days after laying a high proportion of the eggs were parasitized and the experiment had to be curtailed.

Compared with the field collected eggs, the egg hatching from the diapause experiment was extremely low (see Fig. 10). It was therefore decided to compare the weights of the experimental and field collected eggs at 58, 88 and 133 days after laying (using the mean egg laying date for the field collected eggs, see above). This would give an idea of the stages of development of the eggs from each. Because of the difference in numbers involved, the percent of eggs in each weight category (in steps of 0.001g) was used. The results are shown in Figs 11a, b, c.

The proportions of eggs in each category for each period are very similar for each period, despite the differences in treatment between the field and experimental eggs and the additional differences in treatments given in the diapause experiment.

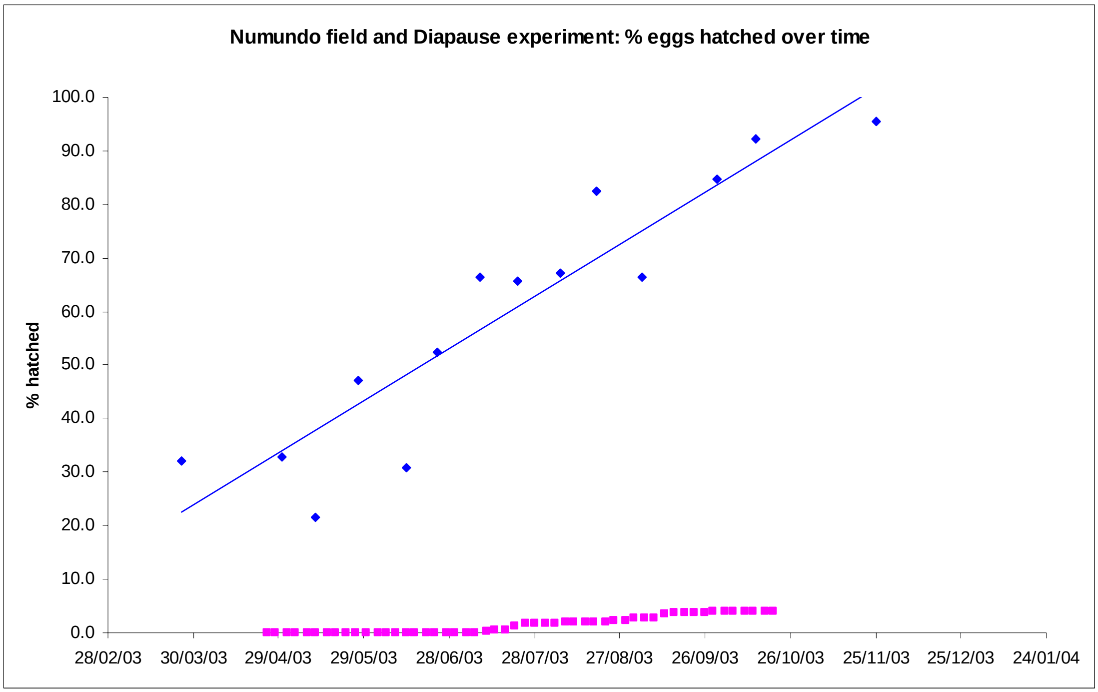


Fig. 10. The proportion of eggs hatched from the field (◆) and the diapause experiment (■) over time.

(a)
(b)
(c)

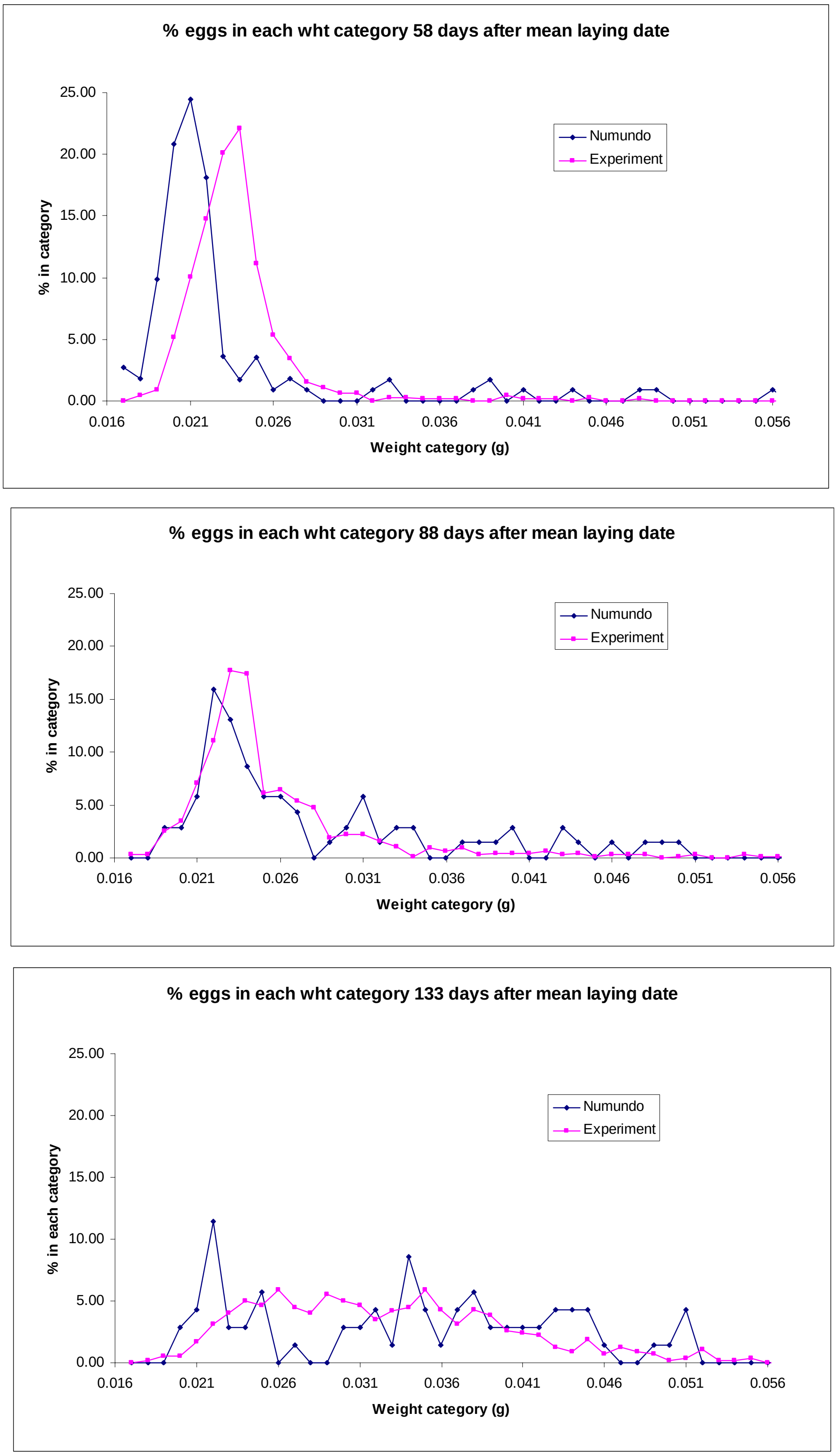


Fig 11 The proportions in each weight category (0.001g steps) of eggs from the field and diapause experiment at (a) 58 days, (b) 88 days and (c) 133 days

Discussion

The results from the diapause experiment suggest that eggs are able to take up their required water when it is available although this may be suppressed initially. The fact that the proportions of eggs in different weight categories from the field and the experiment are both very similar at 58, 88 and 133 days after the mean laying date, suggests further that the initial diapause is both variable and pre-determined. The sexava used for the diapause experiment were from the same area as the eggs in the field monitoring and the adults laying the eggs were therefore likely to have developed under the same conditions at Numundo prior to adults being brought into the laboratory for providing the eggs for the experiment. The important thing is that, although the eggs from both studies came out of the initial diapause at similar times over a period of 133 days, the field eggs went on to hatch whereas the experimental eggs hardly hatched at all. At the end of the diapause experiment there had only been 2.6% mortality and only 4% had hatched, suggesting that the vast majority were in a later diapause which was stopping the nymphs from hatching. It is suggested that the fluctuations in soil moisture content between watering days (10-15%) may have been enough to put the embryos into late diapause although the data suggests that there was development up to close to hatching before such a diapause happened. This would fit in with the known late diapause of other Tettigoniids, where it is the last stages of embryonic development that go into the diapause (Ingrish, 1990). Development in sexava embryos, post initial diapause, could continue up to a late stage even in dryer conditions as they would be able to take up sufficient water to suit their needs when sporadic rainfall occurs. The results also fit in with findings of Froggatt and O'Connor (1940) who found that 40% of eggs kept in dry soil for 110 days emerged 10 days after the soil was watered.

General conclusions and discussion on egg diapause

The studies show that *S. decoratus* appear to have two periods of diapause:

1. An initial diapause, which is highly variable and pre-determined. Such a diapause may last from 16 days to over 9 months and ensure that eggs laid, even in large numbers at the same time, can hatch over long periods. This would be ideal for grasshoppers in a tropical rainfall situation as they would be able to take advantage of continuously available food where, in general, new foliage is appearing all the time.
2. A late diapause where embryos can develop up to close to hatching and then hold up hatching if conditions are not conducive. This would be ideal for situations of drought where fresh foliage might not be available for the early instars (unopened spears in the case of oil palm).

The similar results from the weighing and dissecting of *S. defoliaria* and *S. novaeguineae* eggs suggest that they may also have two diapauses.

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 go through their initial diapause and then go into 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 number of eggs waiting to hatch. When suitable rain comes the eggs will hatch en masse and cause subsequent outbreaks. This is summarised in Fig 12. Depending on the numbers of eggs in late diapause, the subsequent outbreak may be noticed during that generation or may take another generation or more to reach damaging numbers. This is likely to be what happened at the end of 2002 and during 2003 where the affect of the mass hatching in late 2002 was felt throughout 2003. The above conclusion is however a simplified version of what may happen since during a "normal" dry season there may be periods with no rain that could put the eggs developing at that time into late diapause. A shower of rain may then stimulate their hatching. The affect could therefore be surges of egg hatching during to dry season.

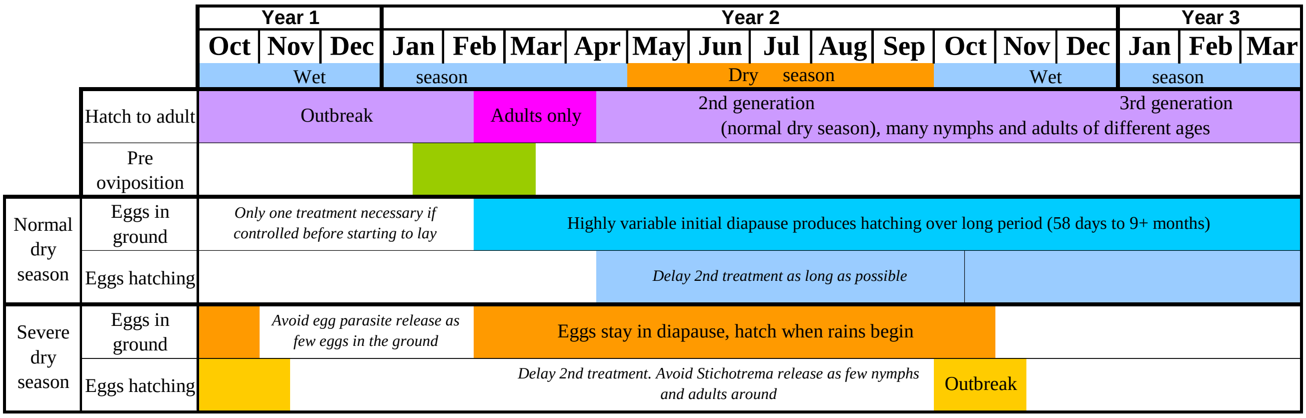


Fig. 12 A diagrammatic representation of the development of sexava populations and the control decisions after a mass hatch (top) and subsequent normal (mid) and severe (bottom) dry seasons. Shaded areas represent the stage(s) being present.

Effect on IPM strategies

The above results have important implications with regards to control decisions, both biological and chemical. As was shown during the regular sampling of the eggs from Numundo, a proportion of viable eggs could still be in the ground after the efficacy of the second trunk injection has ceased. This would mean that there is potential for another outbreak to develop and could explain why there have been so called “hot spots” where outbreaks keep re-occurring. The original timing for a second trunk injection was based on the findings from Young (1985) which suggested that if a trunk injection was done 12 weeks after the first, this would kill all the hatching nymphs since the efficacy of the insecticide (methamidophos) was a further 60 days, i.e. protection up to 5 months from the first injection. Based on the findings from these studies it is important to be aware whether eggs are in the ground in numbers at the time of the first treatment, as a second treatment could be avoided (relying on parasitoids to suppress further increases in numbers). If there are eggs in the ground and a second treatment is required, this should be held back as long as possible to hit at many nymphs as possible (see Fig 12), but taking into account any damage occurring and avoiding further egg laying; i.e. mature adults should not be present in the population before the treatment. Parasitoids should suppress any remnant populations.

With regards to parasitoid releases, the egg parasitoids would not be expected to do well after a mass sexava hatch at the end of a severe dry season as there would be few, if any, eggs in the ground. Also during a severe dry season, eggs are likely to stop hatching due to late diapause and nymphs and adults would therefore become scarce (or even die out in some areas). The build up of non-hatching eggs may be good for increases in egg parasitoids but for *Stichotrema* there would be a loss of hosts and therefore the populations could be greatly reduced or even confined to areas where there has been sufficient rainfall to sustain sexava egg hatching (see Fig 12).

It can be seen that severe dry seasons can not only cause mass hatching of sexava but can also severely restrict the populations of egg and nymphal/adult parasitoids. This is why it is important to produce stocks of these parasitoids in the laboratory and to be aware of reservoirs of them in the field for possible redistribution after such events.

FINSCHAFFEN DISORDER

Introduction

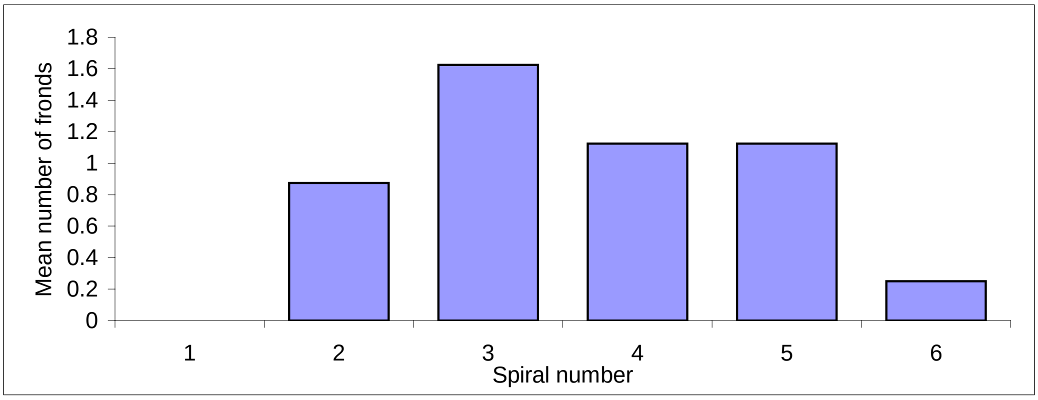
Finschhafen disorder is caused by the leafhopper, *Zophiuma lobulata*. Not a great deal is known about the leafhopper although it has been suggested that the symptoms are the result of toxic saliva produced by the leafhoppers and that (in coconut) it takes 6-7 months for the symptoms to appear (Smith, 1980) . Because of the latter, large numbers of *Z. lobulata* may not be observed on palms when symptoms are reported and surveyed.

At Higaturu, Oro Province, Finschhafen disorder was found at Embi and Ambogo estates and in smallholder blocks at Igora and Sangara divisions. At Milne Bay, approximately 30 hectares at Mariawatte oil palm plantation was severely affected by the leafhopper. In West New Britain there were symptoms found at Kautu and Numundo estates and in small holder blocks at Kavui, Nahavio and Galai

Monitoring

<u>Oro Province</u>

Work was carried out to determine frond preferences and rate of progress of the symptoms along the frond. Initial data shows that symptoms appear mostly on fronds 9 and 16 (Fig 13). Because the appearance of symptoms is likely to be delayed it would appear that *Zophiuma* would have been feeding on the opening spear to produce the symptoms observed.



spiral 1 = spear cluster, 2 = frond 1-8, 3 = fronds 9- 16, 4 = fronds 17 – 24, 5 = fronds 25 – 33, 6 = fronds 34 and below

Fig. 13 Mean number of fronds with Finschhafen symptoms per spiral

Study of outbreak at Mariawatte

The site at Mariawatte was visited in September. Palms with symptoms of the disorder covered an area of about 30 Ha, possibly more, and symptoms appeared severe in some parts. A large area of coconut palms nearby was also badly affected. A quick assessment of one low-lying wet area showed that 45% of the palms showed symptoms (20 palms).

Methods

All the palms in a quarter of a plot were examined and the proportion of fronds with symptoms estimated as a percentage of all the fronds on each palm. This method allowed a large area to be assessed.

Results

A map of the area shows the distribution of palms with symptoms and the proportions of fronds affected (Fig. 14).

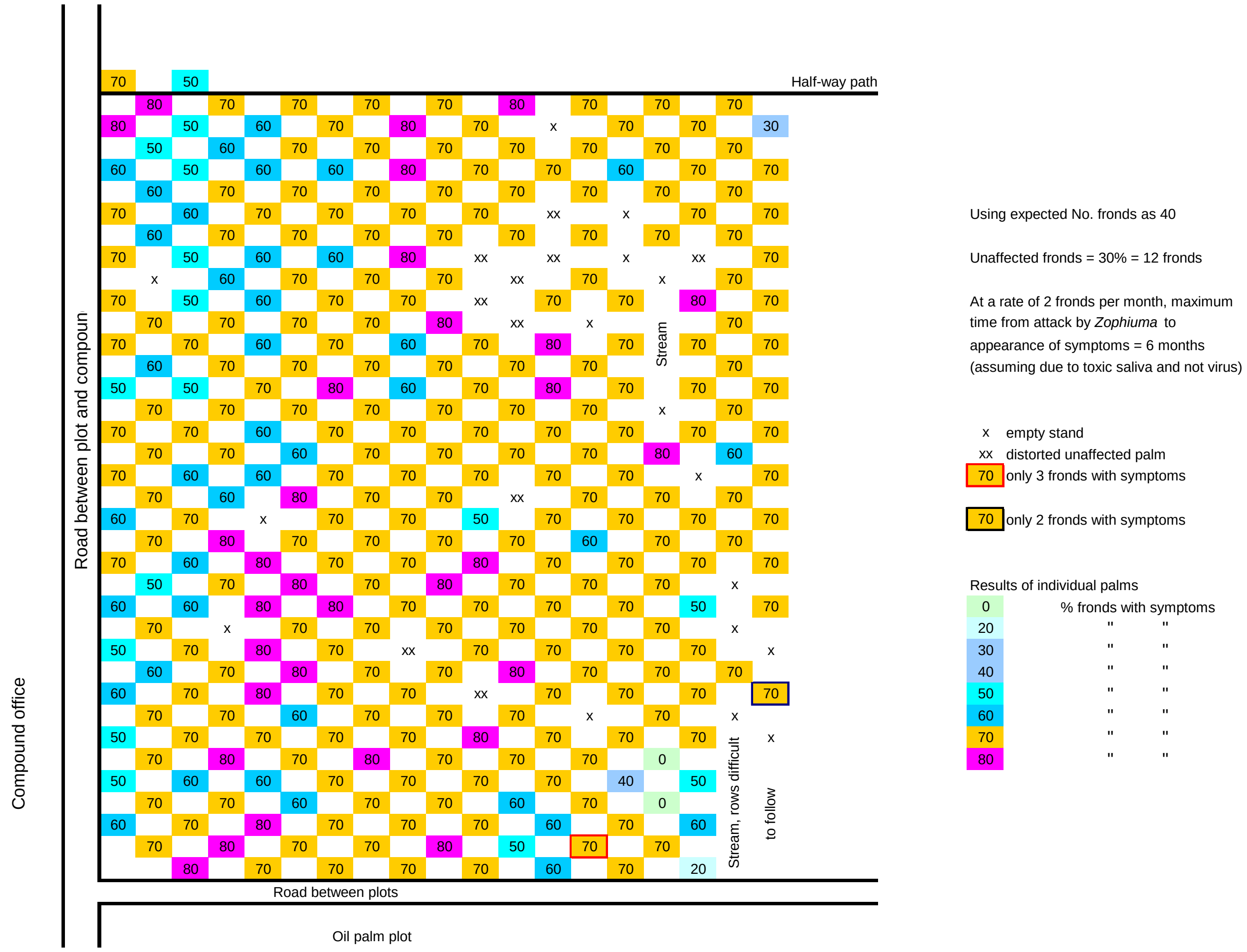


Fig.14 Map showing the % fronds with Finschhafen symptoms for a quarter of the plot (n=609 palms)

The results from this can be summarised as follows:

The map (Fig. 14) and a graph showing the numbers of palms in each row with different proportions of fronds with symptoms (Fig. 15), show that there was not the normal expected edge effect, in fact there were less palms affected on the edge than further into the plot. It wasn't until the 5th row in that the percentage of fronds with symptoms became more consistent.

1. A very high proportion of palms had 70% of their fronds with symptoms (Fig. 16) and, apart from the edge and one wet area, showed an even distribution (Figs. 14 and 15), suggesting that the time of damage by the leafhoppers was about the same for each palm. This would suggest an influx of the leafhoppers at a particular time rather than a gradual spread of the disorder from the edge of the plot or an epicentre.
2. An area with a lower incidence of the disorder (2 palms with no symptoms, 1 at 20%, 1 at 40%, and 1 at 50%; Fig. 14) was a low-lying area with standing water (rain on 23rd September but dry before so that spears had not been opening). A similar observation was made in the same plot, where there were 45% palms without symptoms in a low lying area (see above). This may suggest that the level/appearance of symptoms may have something to do with stress or water uptake and requires further investigation.
3. Using the expected number of fronds per palm as 40 and the rate of frond production as 2 per month it is possible to estimate that the maximum period for symptoms to appear after damage by the leafhoppers is six months (see Fig.14).

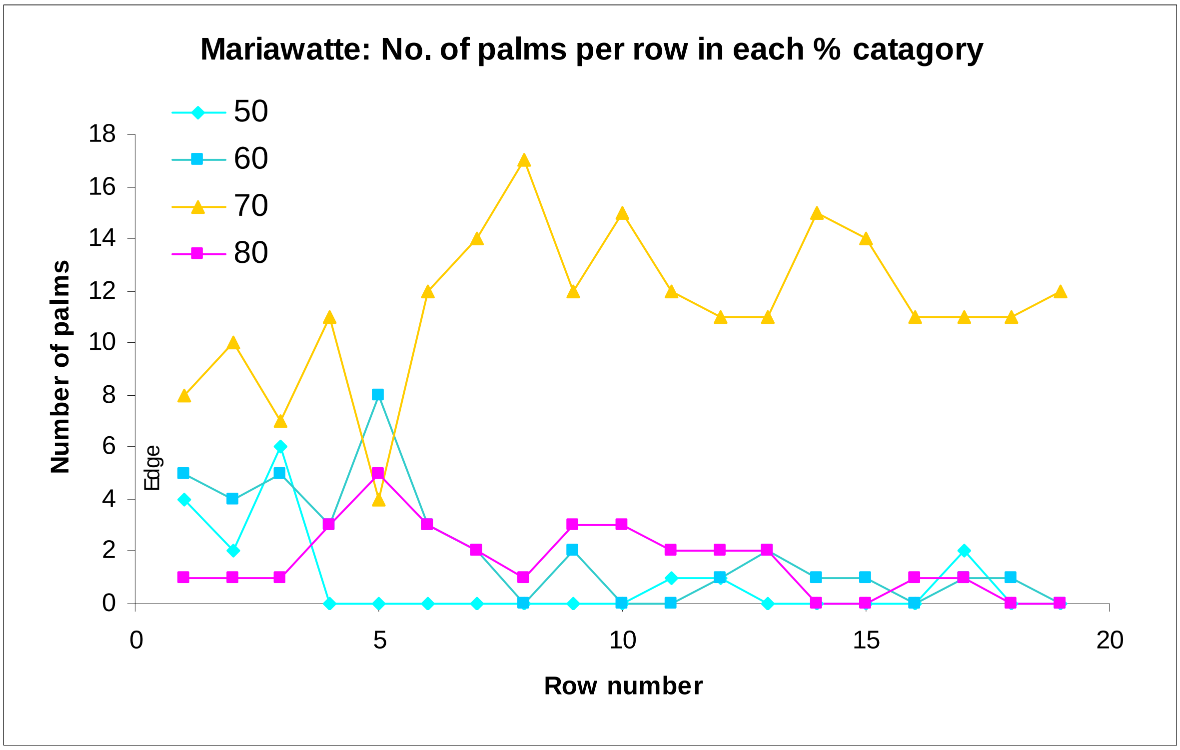


Fig. 15 No. palms per row with different % of fronds with Finschhafen symptoms

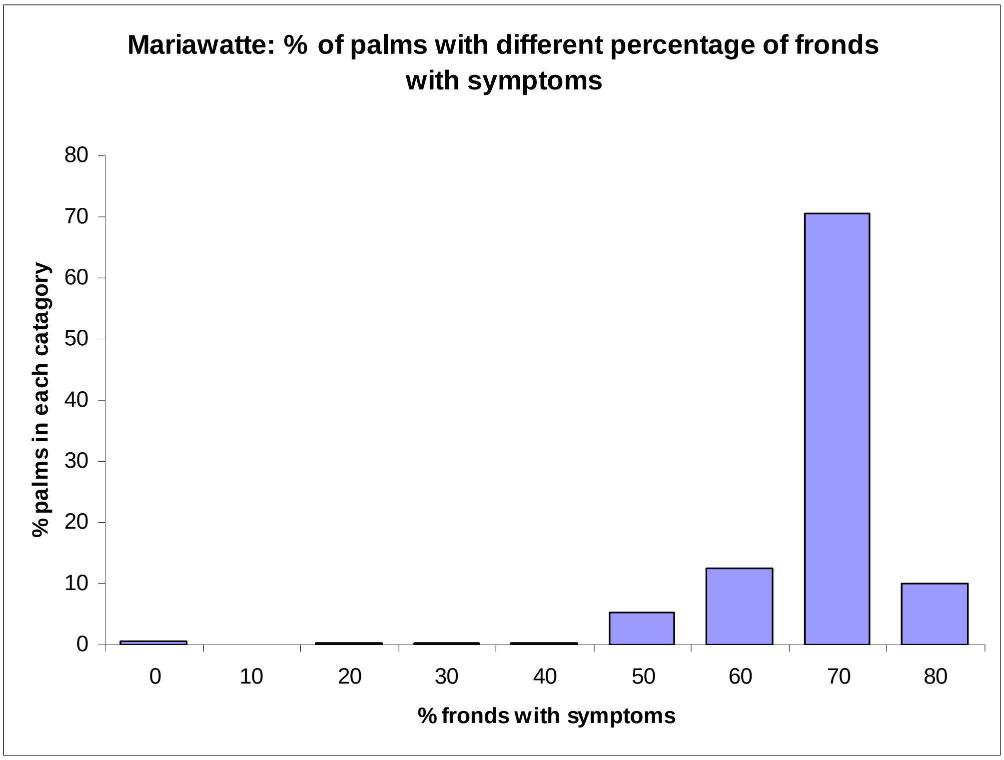


Fig.16 Proportion of palms with different % of fronds with Finschhafen symptoms

Only very low numbers of the leafhoppers were found on the oil palm plots and also very few egg batches. The latter are very distinctive being a brilliant white (due to a waxy material produced by the female to cover the eggs), about 1-2 cm in diameter and, when examined, contain up to 40 eggs. Two egg batches collected from coconut were examined. One batch had 36 eggs and the other 21. Only one egg was found to be parasitized.

Of 31 *Zophiuma* collected from the yellow leaflets at the frond tips in oil palm in the affected area, all were male, suggesting behavioural differences between males and females. Four males and one female *Zophiuma* were collected from coconut. All the leafhoppers were examined for parasitoids and none were found. A number of leafhoppers were found dead with a fungus disease.

Discussion

The results from various studies that are being made on Finschhafen disorder and *Zophiuma lobulata* have thrown up more questions than answers. A full project to study this disorder is required to understand both the nature of the disorder and its causal agent. A project proposal has already been written. The long term monitoring in Oro Province, for instance, is showing that very few *Zophiuma* have been present in the study areas for over two years, yet the symptoms are still coming through. Is the minute amount of saliva produced by these small numbers sufficient to cause so much in the way of symptoms?

QUEEN ALEXANDRA'S BIRDWING BUTTERFLY (QABB)

Introduction

The Queen Alexandra's Birdwing Butterfly (*Ornithoptera alexandrae*) is listed as an endangered species by the IUCN and is on Appendix 1 of CITES. Today it only occurs up in the Managalase plateau (Afore) and some parts of the Popondetta plains. QABB larvae only feed on *Pararistolochia dielsiana*, a coarse-leafed vine which occurs in almost all parts of Oro Province. A lot of work was done by individuals, Government organizations and NGO groups to try and protect this localised and rare species. The oil palm industry is taking an active part in protecting QABB and OPRA and Higaturu Oil Palms have continuously provided logistic support to Department of Environment and Conservation and Oro Provincial Wildlife Office for major conservation activities.

Vine propagation

Buffer zones within oil palm plantations in Oro Province have been rehabilitated with forest trees. The QABB host vines have been propagated and later planted as soon as these trees were old enough to support vines. Since April 2003 a different approach in raising host vines has been used. Speculation from local knowledge at Voivoro suggested that QABB is selective to a particular form of *Pararistolochia dielsiana* (one with narrower leaves). So instead of using vine cuttings, seeds were collected and propagated from vines that had previously hosted QABB larvae. A total 7 seed pods were collected from Voivoro and 5 pods which contained a total 380 seeds did not germinate; however, the other two seed pods with a seed count of 154 germinated and these vines are being grown for future re-planting and monitoring. Collections from QABB-used vines will continue.

Other conservation work

A lot of interest has been shown by people of the Ahora/Beuru areas and Pahumbari community to register parts of their land as Wildlife Management Areas. Some parts of Beuru were surveyed by OPRA using GPS, and DEC is compiling the area policies for the process of registering a WMA. Voivoro is yet to be registered as a WMA. The reasons for this are a lack of financing and the area survey done some years back is out off date and a new boundary survey is required.

QABB monitoring plots were established at Parahe (30 vines), Pahumbari (46 vines) and Voivoro (79 vines). These vines were numbered and tagged and are visited every five months. No QABB stages have been sighted at Parahe or Pahumbari.

OTHER PESTS

Bagworm

No bagworm outbreaks were reported during the year. Monitoring of levels of parasitism, predation and pathogens in bagworms continued in Oro Province.

Minor pests

Mole crickets (*Gryllotalpa* sp.) were found causing damage to individual young seedlings at Haella plantation. Numbers of affected seedlings were very low and control was done by tipping out the seedling from the plastic bag, finding and killing the mole cricket. In most cases the seedling had already been killed.

WEED CONTROL

Mimosa

The redistribution of Psyllid bugs (*Heteropsylla spinulosa*) into areas of mimosa in oil palm plantations and small holder blocks in Oro Province continued throughout the year in order to suppress the weed.

Chromolaena

Siam weed *Chromolaena odorata* is infesting areas in between Sangara and Ilimo along the Kokoda highway in Oro Province. The seed is dispersed by wind and therefore has a potential as a pest in oil palm growing areas, although the weed does not like the shade so is more likely to be a pest of gardens, road edges and clearings. In October 2002 NARI, with the help of OPRA released two biocontrol agents at Hohorita and Tunana. A total of 700 gall fly (*Cecidochares connexa*) and 3489 moth larvae (*Pareuchaetes pseudoinsulata*) were released but these did not become established.

A second batch of 1000 galls was air freighted to Popondetta in November 2003 and released at Hohorita. The galling flies became established and since then galls have been redistributed to other areas. A monitoring survey was done after release and it was observed that the gall fly has spread as far as Waseta. A third batch of 2000 galls was air freighted by NARI in early 2004 and these were released at Mumuni and Ilimo. Some others were released at DeMark which is located some kilometres from Hohorita. A summary of galls received from NARI and redistributed is shown in the Table 4.

Site released	***Redistributed***	***Received from NARI***
Tunana	200	
Ilimo	200	600
Hohorita		1000
DeMark		800
Mumuni		600

Table 4 The number of galls of *Chromolaena odorata* set out or redistributed in the oil palm growing areas of Oro Province.

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3. PLANT PATHOLOGY RESEARCH

(C. Pilotti)

SUMMARY

The Stabex *Ganoderma* Project 4.2 was granted a 3-year extension of funding by the European Union. The agreement was signed and funds were drawn in June 2003. The new research programme addresses, and advances, the same broad areas of study as the earlier programmes, namely a) epidemiology, b) biological control and c) long-term control (host resistance).

Epidemiological studies are essential if we are to develop effective future management of the *Ganoderma* diseases. Surveys and data collection continued in most plantations in 2003. Disease incidence varied between locations but generally in the older plantings, average cumulative levels are still under 5%. The variation in disease prevalence between sites continues to be very high and the influence of genetic and environmental factors needs to be investigated more closely. Correlations between disease incidence and soil type & soil pH in the Milne Bay area have been poor so far.

The incidence of ‘upper stem rot’ is increasing in Milne Bay with time, and this is evidence that secondary spread by basidiospores is occurring. Despite this, disease progress continues in a linear fashion and disease rates have appeared constant over the last few years; except for some sites in New Ireland and West New Britain. This may be the result of sanitation measures being carried out within plantation areas.

The population structure of *Ganoderma boninense* within the Milne Bay plantations continues to comprise of individuals that are largely unrelated. The same is also true for the population in New Ireland. Continued sampling will reveal if secondary disease spread by basidiospores is occurring.

Biological control is used in South East Asia with limited success. Our studies in this area focus on trying to prevent spores of *Ganoderma* entering oil palm trunk tissue. Trichoderma has been identified as the most potentially useful biological control agent. A large number of indigenous isolates of *Trichoderma* have been cultured in the laboratory and these will be tested against *Ganoderma in vitro* in 2004. Further testing will be carried out at the Royal Botanic Gardens, Kew, U.K.

Several field trials were carried out using *Thielaviopsis* to accelerate degradation of felled oil palm trunk tissue. In all cases, colonization of the substrate was satisfactory. However, the practicalities of field application and its wider effects need to be carefully considered before the large-scale use of this fungus.

Pathogenicity tests in 2003 were not entirely fruitful. The long time period required (6-12 months) for expression of *Ganoderma* disease symptoms is a hindrance. More rapid laboratory-based tests have been fraught with problems of sterilization resulting in contamination of rachis tissue. Leaf tissue has proven to be unsatisfactory as a medium for pathogenicity tests. Tests on tissue *in situ* are the focus at this point in time, in addition to conventional testing using large inoculum sources.

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

1.1 Disease progress

1.1.1 Milne Bay Province surveys

The downward trend in disease incidence observed in 2002 continued in 2003. Average disease levels in 2003 decreased for all estates except for Waigani (Figure 1). It is possible that the increase in Waigani could be due to an incomplete survey in 2002. The largest decrease was observed in Kwea Division (0.28%).

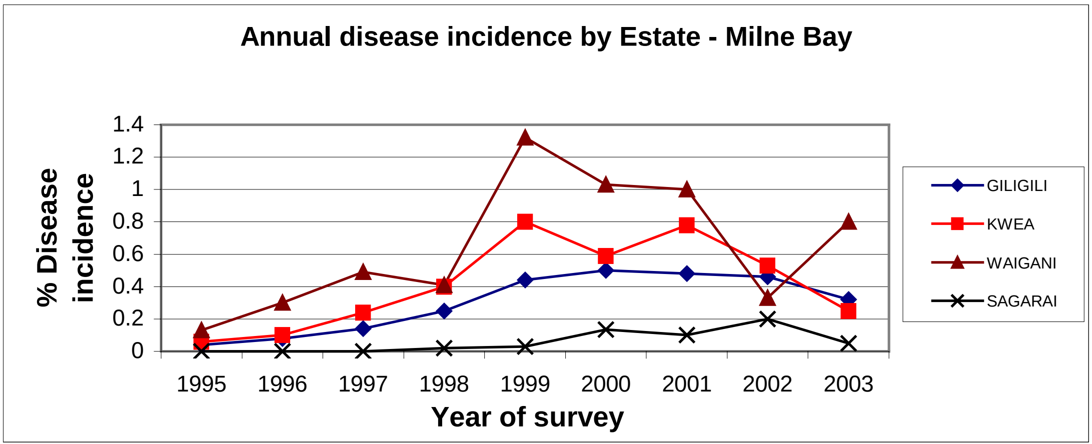

Figure 1. Annual disease incidence in Milne Bay at each survey by Estate.

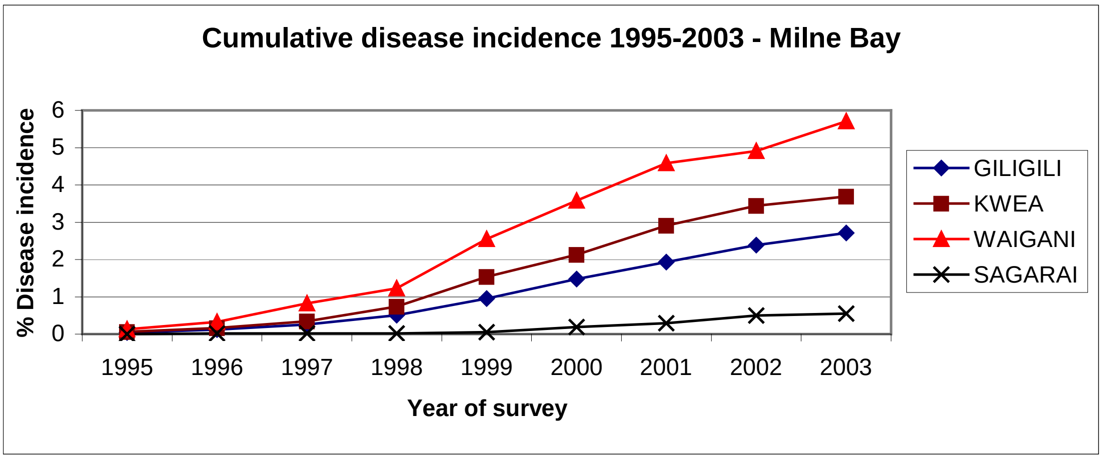

Figure 2. Cumulative disease incidence from 1995-2003 for each Estate in Milne Bay.

Cumulative disease incidence continued following a linear trend. Average disease levels are still under 5% for the whole plantation. Waigani Estate has cumulative disease levels approaching 6%. Disease incidence data by Estate is useful for management as an approximation of crop losses can be made. However, the data encompasses plantings of all ages and therefore represents an average over two or more age groups.

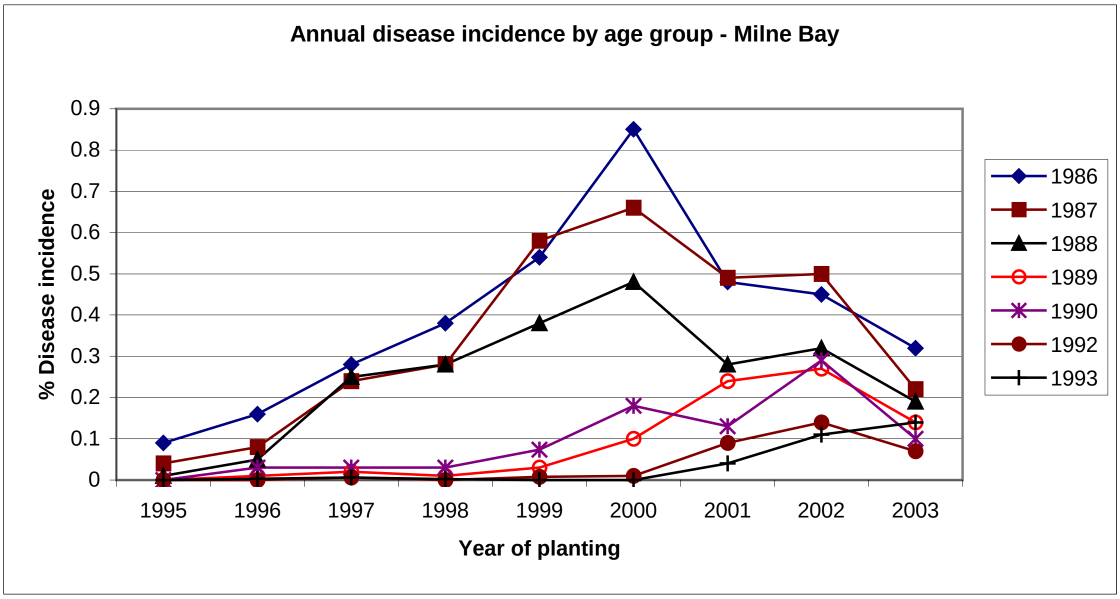

Figure 3. Annual disease incidence for palms of the same age from 1995-2003, Milne Bay.

Age plots provide a more realistic view of disease progress with variation in the disease incidence predominantly due to environmental and genetic factors. Annual disease incidence by planting date is shown in Figure 3. All age groups except for the 1993 plantings showed a negative trend in 2003. The decrease could be partly attributed to the incomplete survey in 2003. Several blocks within the plantation were surveyed only once and in others, the survey was not completed.

Cumulative disease progress curves by age group are shown in Figure 4. Data includes all Divisions regardless of previous crop history. The disease curve for the 1986 plantings is in contrast to that of the other age groups. From age 13 to 16, disease incidence in the 1986 plantings increased at a higher rate than in previous years (from age 9-13). Most of the 1986 plantings are ex-coconut.

This has not occurred palms in other age groups where the disease curve is roughly linear.

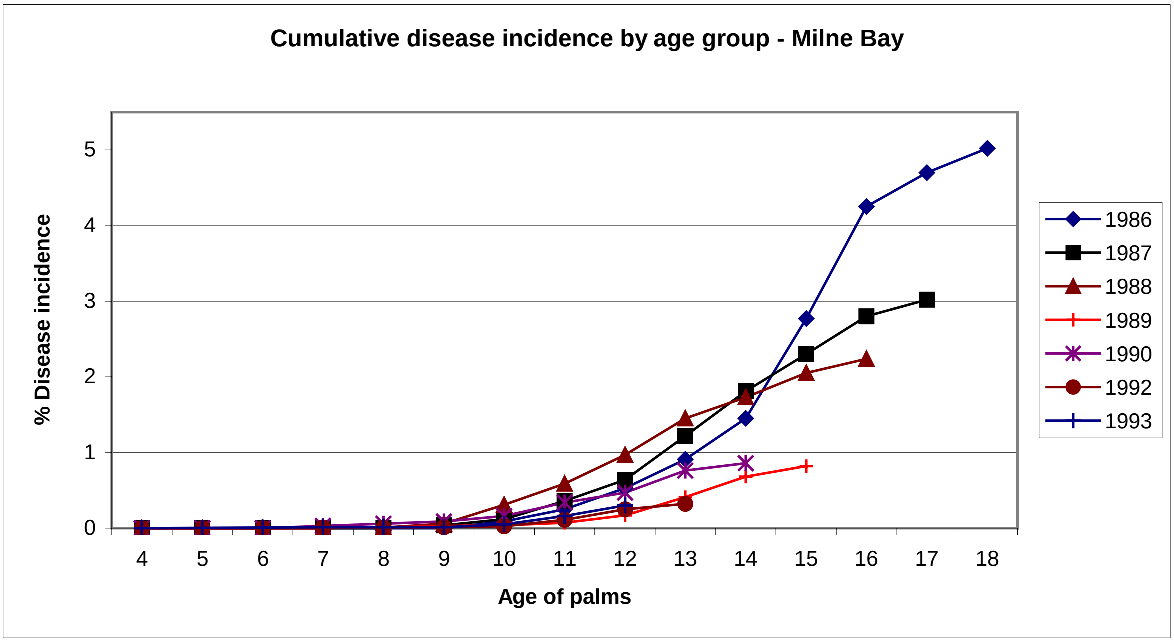

Figure 4. Cumulative disease incidence by age group from 1995-2003, Milne Bay.

Figures 5, 6, 7 & 8 show the disease incidence by block and by category in Milne Bay. There was an apparent decrease in the number of suspect palms but the figures may be erroneous due to incomplete surveys being carried out in some blocks in 2003. The number of palms with 'upper stem rot' is increasing each year with a large proportion of the blocks in each Estate containing palms with upper stem rot'. The average incidence of 'upper stem rot' in the Milne Bay Plantation is shown in Figure 9.

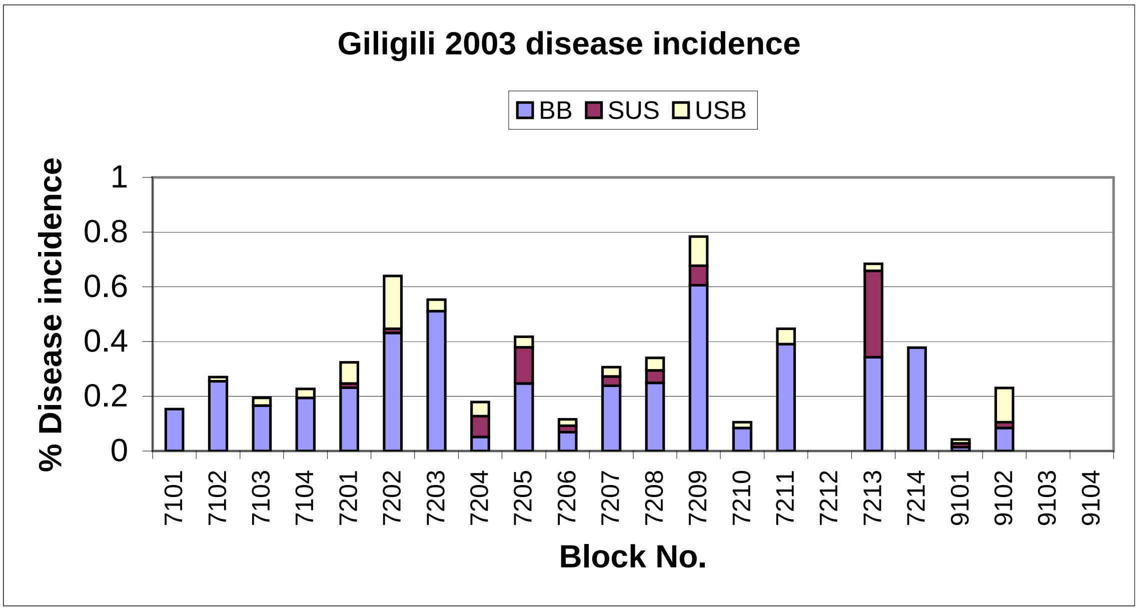

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Figure 5. Disease incidence for 2002 in Gligili Division, Milne Bay by category.

BSR= basal stem rot; USR = upper stem rot; Suspects= symptoms without brackets.

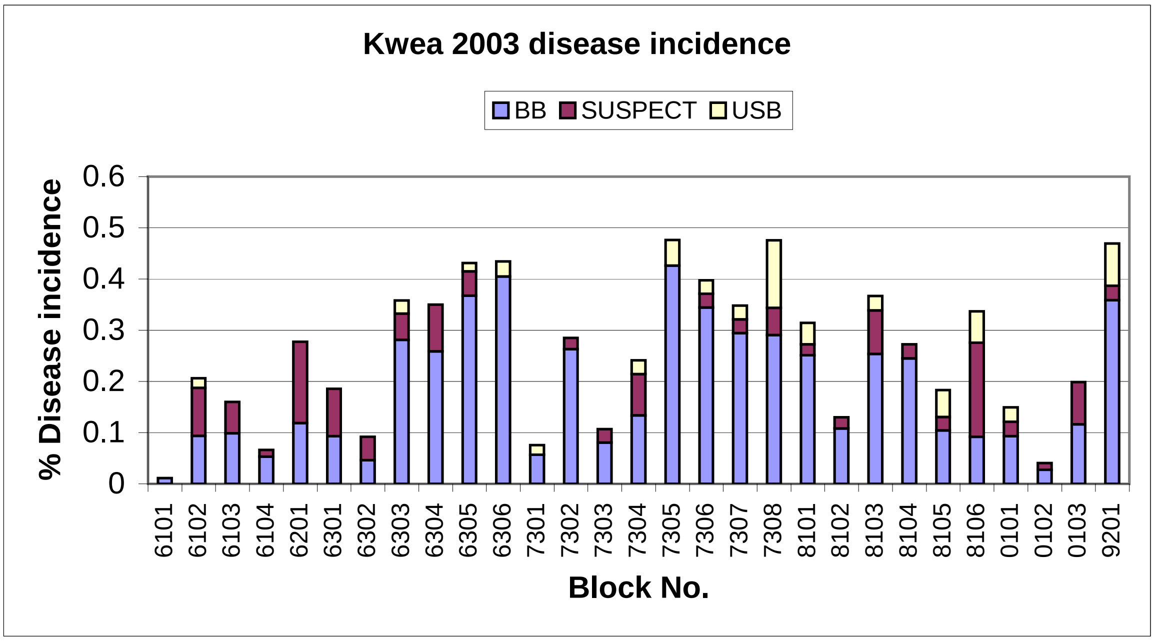

Figure 6. Disease incidence for 2002 in Kwea Division, Milne Bay by category.

BSR= basal stem rot; Usr = upper stem rot; Suspect=symptoms without brackets

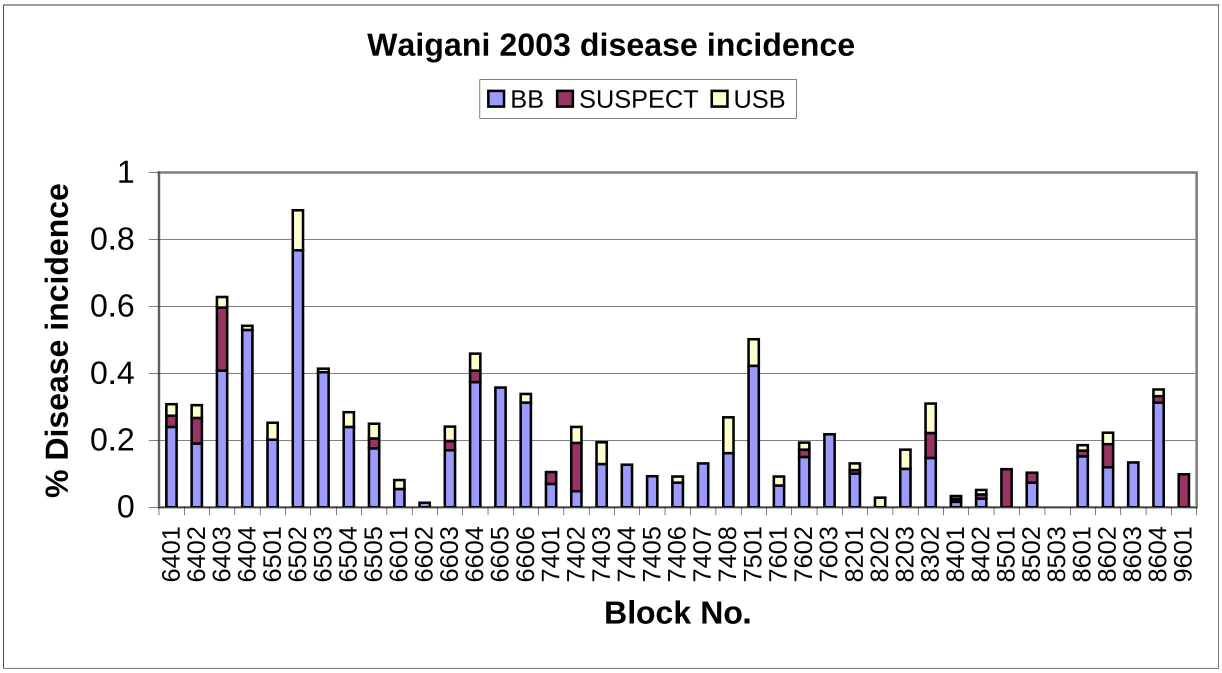

Figure 7. Disease incidence for 2002 in Waigani, Milne Bay by category.

BSR= basal stem rot; Usr= upper stem rot; Suspect= symptoms without brackets.

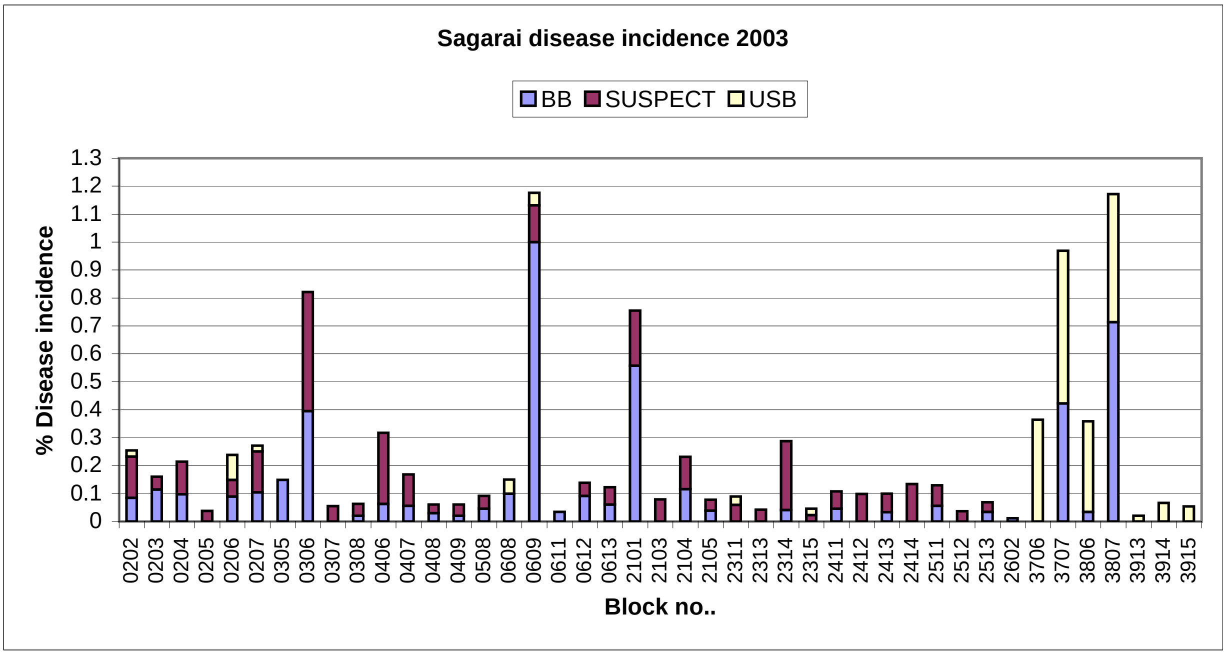

Figure 8. Disease incidence in 2003 for Sagarai, Milne Bay Estates, by category. Several blocks were not surveyed in 2003.

BSR=basal stem rot; USB=upper stem rot; Suspect = symptoms without brackets.

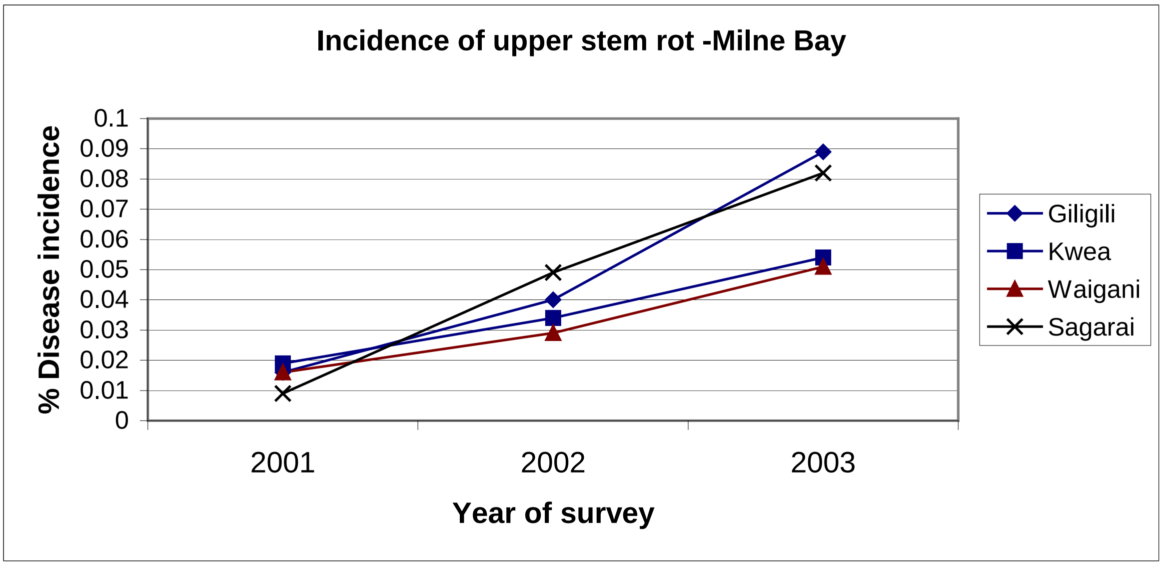

Figure 9. Cumulative incidence of upper stem rot in Milne Bay from 2001 to 2003.

Environmental effects

Figure 10 shows that that only 60% of the variation in disease incidence throughout the Milne Bay plantation can be explained by age. Clearly, other factors are influencing disease incidence. The large variation in blocks of the same age is also evident with disease levels ranging from 2palms/ha to over 9 palms/ha.

There is no correlation between soil type and disease incidence (Figures 11). Most of the 1986 and 1987 plantings are on soil types C and D and so comparisons over a range of soil types are not possible. The majority of plantings on soil types A, B, E, F and G are younger (1989-1993) and therefore disease levels are lower. No correlation was observed between soil pH and disease incidence for palms of the same age group (Figure 12).

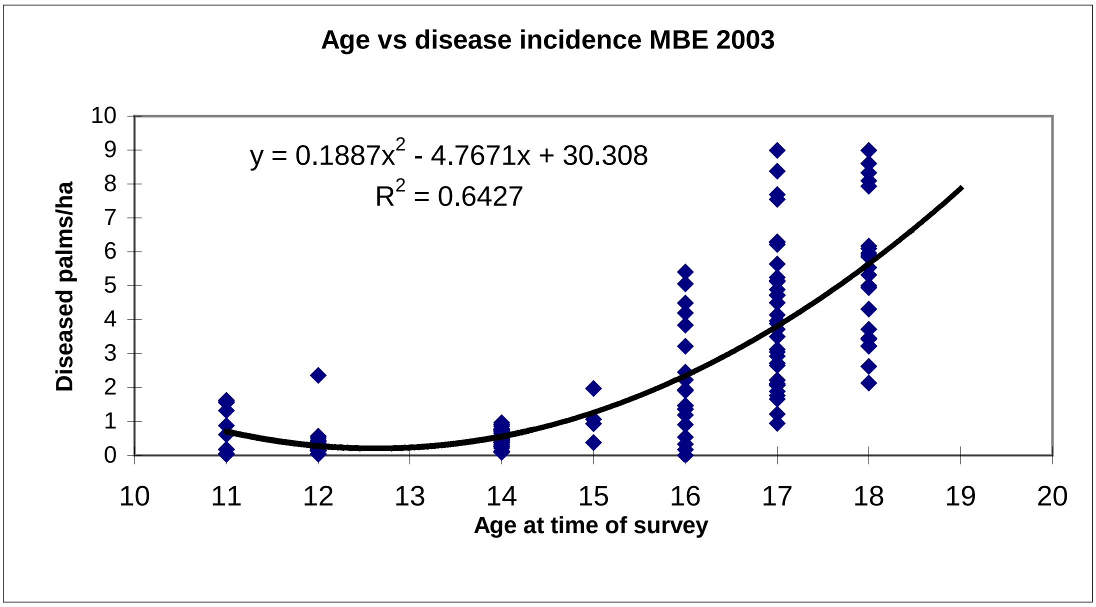

Figure 10. Losses (palms/ha) due to Ganoderma disease with increasing age in Milne Bay.

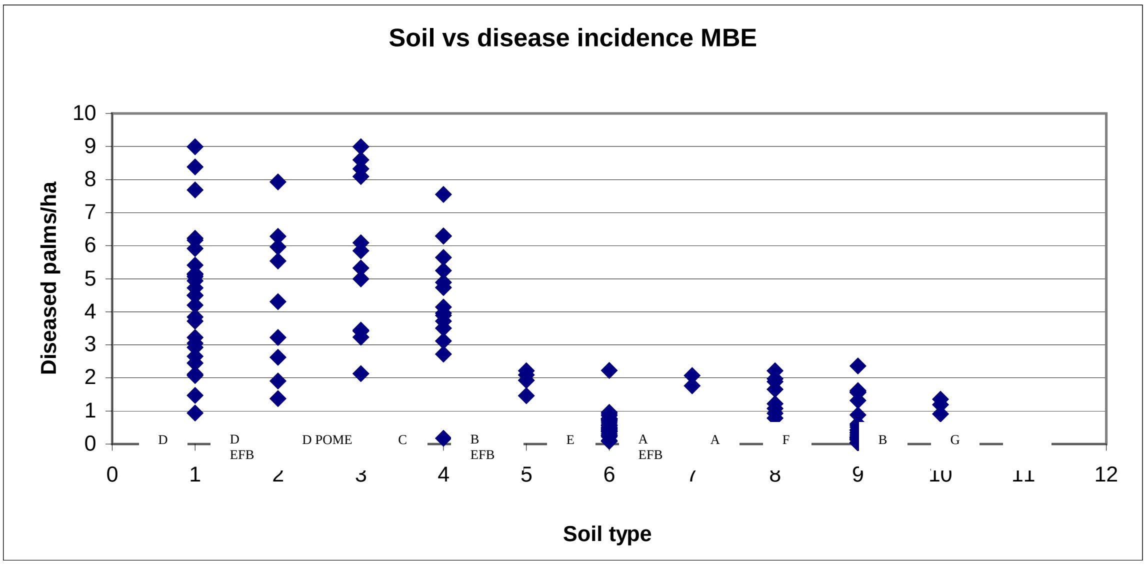

Figure 11. Correlation of soil type with disease incidence in Milne Bay. The oldest plantings (1986-1988) are on soil types C and D.

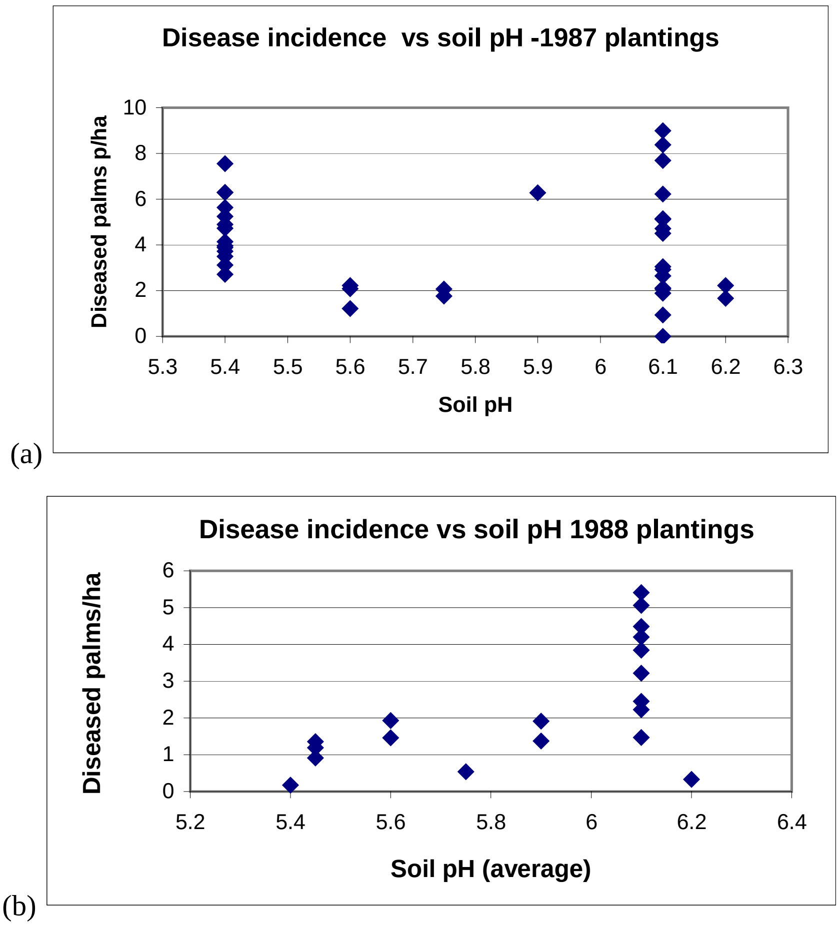

Figure 12. Correlation between soil pH and disease incidence in (a) 1987 and (b) 1988 plantings in Milne Bay.

1.1.2 New Ireland Province surveys

Survey results for Poliamba are slightly underestimated because only the sanitized palms are reported rather than the actual annual census data. The disease progress curves for all three Divisions are shown in Figures 13, 14 and 15. Each exhibits a linear trend, with Bolegila and Medina showing the highest levels of disease.

The disease-curve by age group comparison shows that the oldest plantings are averaging 3% disease incidence (Figure 16). Disease is progressing at a slower rate in the younger plantings, as seen in Milne Bay; this could be related to previous crop history. Correlation between age and disease incidence is poor (Figure 17).

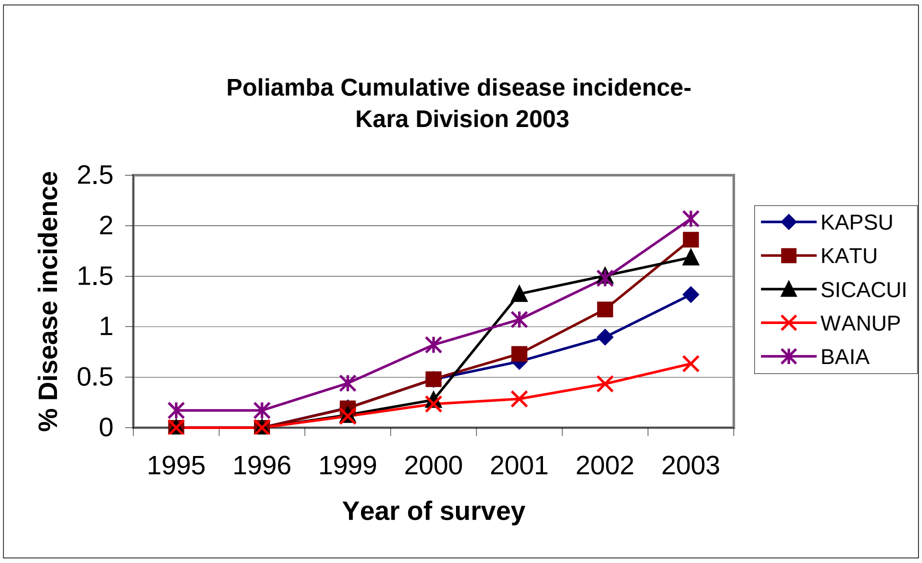

Figure 13. Cumulative disease incidence in Kara Division from 1995-2003 in New Ireland by plantation.

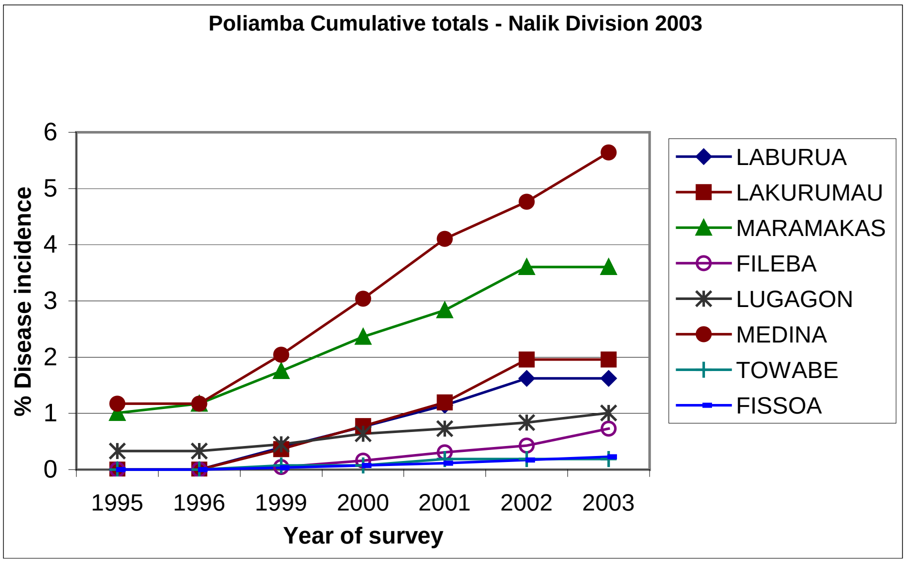

Figure 14. Cumulative disease losses in Nalik Division, New Ireland from 1995-2003.

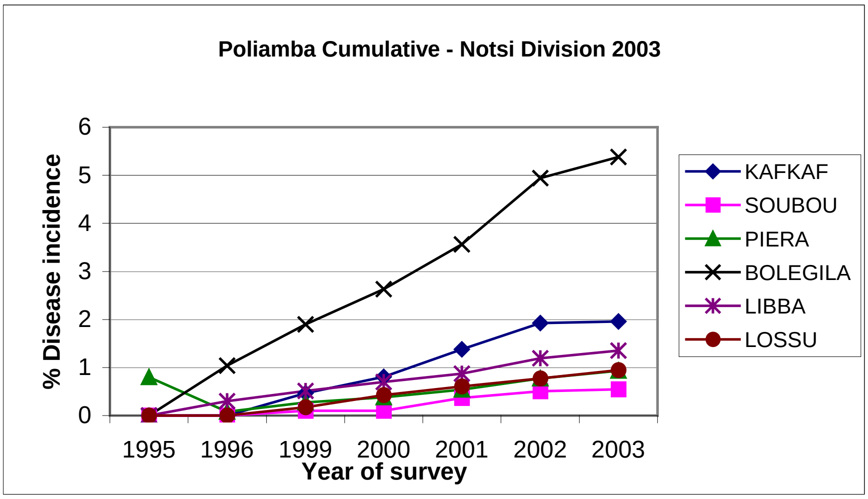

Figure 15. Cumulative disease incidence in Notsi Division, New Ireland from 1995-2003.

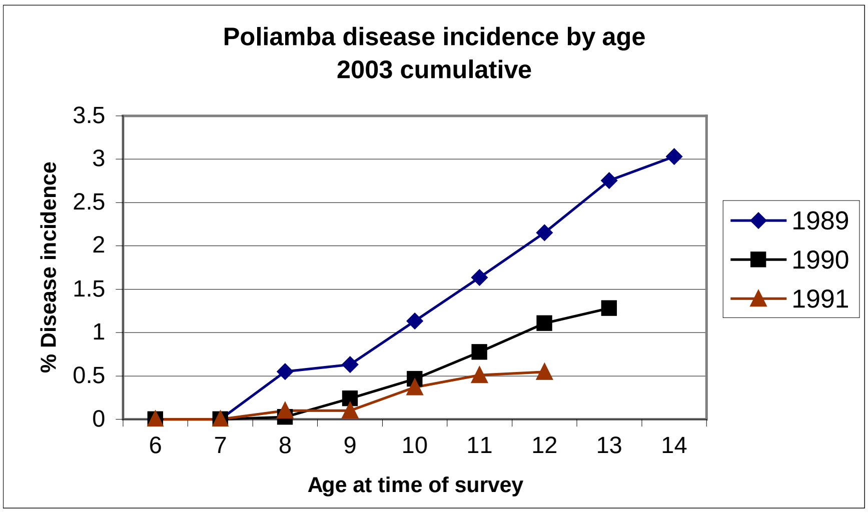

Figure 16. Cumulative disease progress by age group (planting date) at each annual survey from 1995-2003, New Ireland.

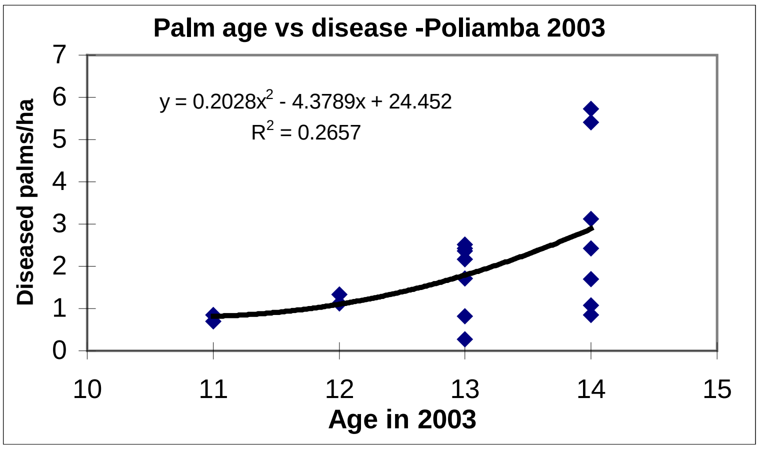

Figure 17. Correlation of *Ganoderma* disease incidence with age in 2003, New Ireland.

1.1.3 Numundo Plantation, West New Britain Province

Disease levels for 9-10 year-old palms planted in ex-coconut blocks in West New Britain have increased in most blocks (Figure 18). Disease levels are particularly high in blocks E3, E4 and E5 (Figure 19). This is difficult to explain but could be due to soil or sanitation factors related to the previous crop. Annual incidence for block E1 rose by 3% in 2003.

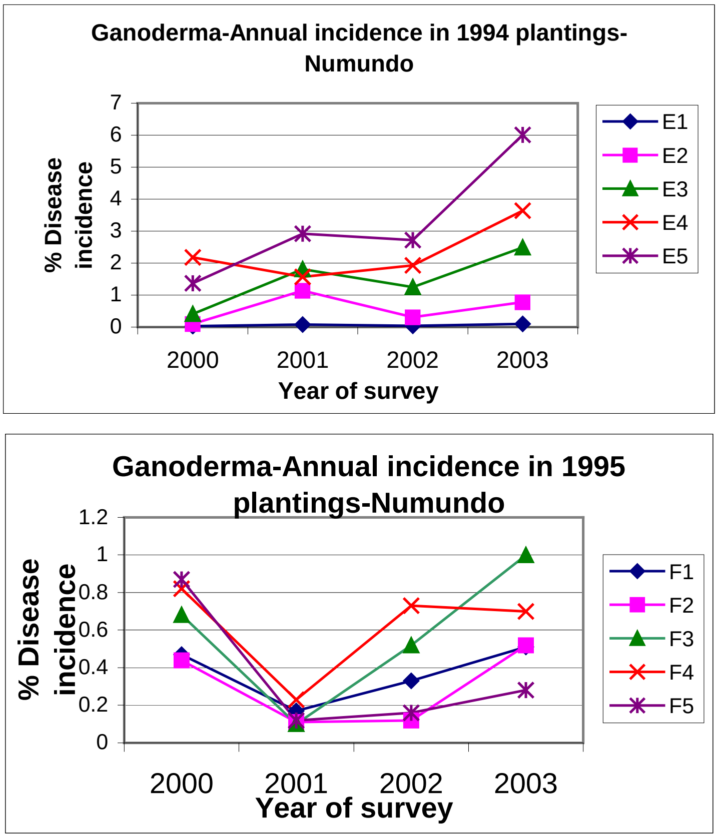

Figure 18. Annual disease incidence in blocks E1-E5 and blocks F1-F5 at Numundo from 2000 to 2003.

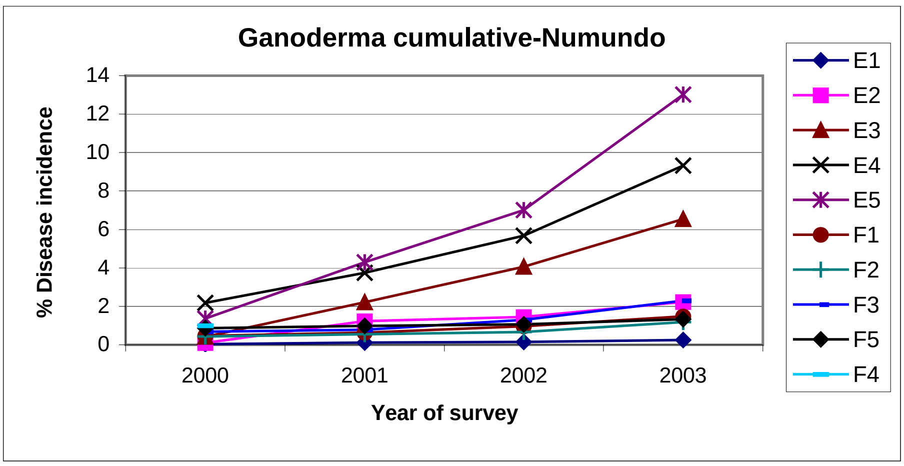

Figure 19. Cumulative disease progress at Numundo in blocks E1 – E5 and blocks F1-F5 from 2000-2003.

2. Population Studies

2.1 Milne Bay population

A further 67 samples were collected from the blocks where the *Ganoderma* population is under study. Samples were not obtained from block 6404 in 2003 due to the unavailability of survey data at the time of sampling.

Mapping in block 7213 shows that disease pattern is becoming clustered in some areas with the number of diseased neighbours increasing. In block 7213 in 2003, 14 isolates were collected from diseased palms and all crosses were completed within each plot of 20 rows. Of the 14 palms identified as infected, only 2 were adjacent or opposite neighbours that had been removed previously due to *Ganoderma* infection. The remainder were isolated infections. Table 1 shows the results of mating or vegetative compatibility tests carried out on neighbouring diseased palms. The majority of isolates for which results are available are unrelated. There are other neighbours for which data is unavailable at this time. A second link has been found between a palm with upper stem rot and one with basal stem rot. However, as with the previous result, there is no direct hereditary relationship. Crosses are continuing amongst isolates from within the other blocks under study.

ISOLATE NUMBERS	POSITION IN RELATION TO NEIGHBOUR	VEGETATIVE COMPATIBILITY	MATING TEST
820: 973	Opposite	incompatible	nd
767:816	Adjacent	compatible	incompatible
146:821	Opposite	incompatible	nd
145:767	Opposite	incompatible	nd
821:816	Opposite	incompatible	compatible
972:710	Opposite	nd	compatible
717:433	Opposite	incompatible	compatible
761:763USR	Opposite	nd	incompatible, 1 allele
882:976	Opposite	incompatible	compatible
721:725	Opposite	incompatible	incompatible, 1 allele
830:149	Adjacent	incompatible	nd
432:666	Opposite	compatible	compatible
724:829	Opposite	incompatible	incompatible, 1 allele
727:728	Opposite	nd	incompatible, 1 allele
145:600	Opposite	incompatible	nd
717:433	Opposite	incompatible	compatible
972:710	Opposite	nd	compatible
882:976	Opposite	incompatible	nd

Table 1 Genetic testing between *Ganoderma* isolates on neighbouring palms in block 7213, Milne Bay. Vegetative incompatibility indicates that isolates are genetically unique. nd= not determined, USR=upper stem rot

2.2 New Ireland population

Forty samples were collected from the fertilizer trials 251 and 252 at Poliamba, New Ireland in 2003. Disease incidence is now 10% in trial 251 at Maramakas and 9% in trial 252 at Luburua.

During 2003, all vacant points were accurately mapped and all guard row palms were numbered for ease of sampling. Results of vegetative compatibility tests amongst isolates collected within the trials were presented in the 2002 OPRA Annual Report. All isolates were spatially separated and were genetically unique. Tests on isolates collected in the latter half of 2003 are continuing.

3. Pathogenicity Trials

Objective: 1. To develop an effective and rapid pathogenicity test for basal stem rot of oil palm.
2. To use this screening test to identify susceptible seed lines.

3.1 Laboratory screening assays

In 2003, two sets of laboratory assays were carried out on rachis tissue. In both experiments, contamination rates were high and this made interpretation difficult.

3.2 Nursery screening assays

Frond-base inoculation

In January 2003, 89 palms that were inoculated in November 2001 were destructively sampled. Results were extremely variable but more encouraging than earlier samplings. Approximately 50% of the plants showed no evidence of decay in the basal plate compared to the control samples however, in the remainder, slight to significant decay was recorded although not in the region of initial inoculation. Indications are that *Ganoderma* does not move directly into the base from the frond but moves laterally, until a ‘weak’ point is found at the interface between the frond base and the stem. At this point some evidence of movement of fungal mycelium into the basal tissue was seen; usually through weakened and decayed roots below the frond base. In most cases however, the rot was not typical of *Ganoderma* and *Ganoderma* was not isolated but rather another, as yet unknown, basidiomycete. The presence of *Ganoderma* will have to be confirmed using our GanEt primer.

Another 400 3-year-old palms that were inoculated in 2002 were dissected and examined in 2003. Palms were inoculated with oil palm rods (1cm x 4cm), oil palm rachis, and rubber wood dowels containing *Ganoderma* inoculum. The inoculating material is inserted into the pruned frond base. After 18-months there were no clinical symptoms in the palms. Dissection revealed that, in many cases, the inoculum was confined to the frond base and did not progress further into the bole tissue. Inoculum was also superseded by other contaminants. An unidentified basidiomycete was present in the old frond tissue at ground level.

Rachis inoculation

A further three experiments using living and excised rachis tissue on 1-year-old palms were carried out in 2003. Inoculum consisting of agar discs of 3 different sizes with moist filter paper were placed onto the wounded rachis and allowed to incubate for 3 months. Contamination rates were high and current methods employ much shorter incubation times to minimise contamination. Generally, inoculum potential was inadequate to overcome contaminants and the plant response. These tests are continuing.

New seeds from Dami OPRS were planted in the nursery for further tests.

Wood-block inoculation

One hundred 1-year-old palms were inoculated with oil palm blocks measuring 5x6x8cm. Fifty palms were re-potted with non-sterile nursery soil and oil palm wood blocks containing *Ganoderma* inoculum were placed directly beneath the bole. Palms will be left for 6-months and destructively sampled. Seven palms collected from the field and inoculated with the wood blocks placed laterally containing *Ganoderma* were sampled after 6 months. Of these, only one palms showed slight discoloration and possibly decay of the base. The decayed area was sampled for GanEt analysis. Following this result, a further fifty 1-year-old palms were inoculated with the wood blocks placed laterally about 10cm below soil level. These will be sampled in 2004.

3.3 Miscellaneous tests

Survival of oil palm inoculum in soil

Objective: to determine if *Ganoderma* is able to survive below the soil.

Twelve oil palm wood blocks (5x6x8) containing *Ganoderma* inoculum (isolate #746) were buried in unsterilized nursery soil. Blocks were placed at 10cm and 20cm below the soil level. After 5 months, blocks were removed, washed, and split if still sound. Pieces of wood tissue were plated out onto water agar to see if *Ganoderma* inoculum was still viable. Results (Table 2) indicate that *Ganoderma boninense* does not survive after 5-months under the soil in oil palm wood tissue, even at 10cm below ground level. Similar tests will be carried out on root tissue.

Block number	Results after 5 months burial	
	Soil level	
	10cm	20cm
1	Block black, partly decayed, inoculum dead	Block completely decayed, inoculum dead
2	Block with black outer crust, solid, inoculum dead	Block with black crust, partly decayed, inside partly decayed
3	Block partly decayed, inoculum dead	Block decayed completely
4	Block partly decayed, inoculum dead	Block decayed almost completely, crumbled
5	Block partly decayed, inoculum dead	Block decayed completely, in pieces
6	Block partly decayed, inoculum dead	Block partly decayed, inoculum contaminated, dead

Table 2. Survival of *Ganoderma* inoculum (dikaryotic) in unsterlized soil after 5 months. Inoculum was introduced on oil palm wood blocks measuring 5x6x8cm that were buried at two depths.

4. Biological Control of *Ganoderma*

Objectives: 1. To develop methods for the rapid degradation of oil palm trunks

2. To utilize *Trichoderma* as a natural antagonist of *Ganoderma* to prevent *Ganoderma* infection on cut frond bases.

4.1. Rapid wood degradation and related studies

4.1.1 Thielaviopsis field trials

Several trials were carried out in the latter half of 2003 (Table 3). Oil palm logs were cut into three 1m sections and labeled base, mid and top. One face of each section was inoculated with 250ml of an aqueous suspension of the *Thielaviopsis* isolate. Two isolates were used in the trials PNG12 and PNG27. After inoculation, logs were covered with fronds and left for one week. After 1 week scores were assigned to each log depending on the surface growth of the fungus over the cross-section. Where possible, logs were also split and the longitudinal penetration was also scored. Scoring was as follows: 1- 25% coverage of the cross-section, 2- 50% coverage, 3-75% coverage, 4-100% coverage, 5- 100% coverage plus significant softening of tissue. Due to the unavailability of chainsaws some of the scores for longitudinal penetration could not be completed. However, results indicate that weather conditions are not critical since the cross-sections are covered to maintain humidity. This may have some practical limitations. Results also indicated that there was no difference between isolates or log section with regard to cross-sectional coverage. In many cases, it was found that logs were 'naturally' inoculated on the other face.

Block no.	Inoculum type/volume	Weather conditions	Section	Isolate no.	Score (cross-section)	Score (penetration)
6304	liquid	WET	base	PNG 12	5	nd
			mid	PNG12	5	nd
			top	PNG12	5	nd
6304	liquid	WET	base	PNG 27	5	nd
			mid	PNG 27	5	nd
			top	PNG 27	5	nd
6304	liquid	WET	base	PNG 27	5	nd
			mid	PNG 27	5	nd
			top	PNG 27	5	nd
6304	liquid	WET	base	PNG 27	4	nd
			mid	PNG 27	4	nd
			top	PNG 27	4	nd
7302	liquid	DRY	base	PNG12	1	nd
			mid	PNG12	3	nd
			top	PNG12	4	nd
7302	liquid	DRY	base	PNG27	4	nd
			mid	PNG27	4	nd
			top	PNG27	4	nd
6304	liquid	DRY	base	PNG12	5	100+
			mid	PNG12	5	100+
			top	PNG12	5	100
6304	liquid	DRY	base	PNG27	5	17
			mid	PNG27	5	30
			top	PNG27	5	34
6304	liquid	DRY	base	PNG 27	5	100
			mid	PNG27	5	27
			top	PNG27	5	18
6304	liquid	DRY	base	PNG 27	4	15
			mid	PNG27	4	21
			top	PNG27	4	13
7101	liquid	DRY	base	PNG 27	1	nd
			mid	PNG27	5	nd
			top	PNG27	5	nd
7201	liquid	DRY	base	PNG27	1	nd
			mid	PNG27	2	nd

			top	PNG27	3	nd
7213	liquid	WET	base	PNG12	1	7
			mid	PNG12	2	12
			top	PNG12	3	9
7213	liquid	WET	base	PNG2	3	5.9
			mid	PNG2	4	16
			top	PNG2	4	24
7213	liquid	WET	base	PNG12	2	5.5
			mid	PNG12	2	5.5
			top	PNG12	3	9.9
7213	liquid	WET	base	PNG12	1	8.2
			mid	PNG12	2	10.3
			top	PNG12	3	12
7102	liquid	DRY	base	PNG27	1	nd
			mid	PNG27	2	nd
			top	PNG27	2	nd
	liquid	DRY	base	PNG12	1	nd
			mid	PNG12	2	nd
	liquid	DRY	base	PNG27	2	nd
			mid	PNG27	2	nd
			top	nd		

Table 3. Field trials using *Thielaviopsis paradoxa* on cross-sections of oil palm trunks. Three 1m sections of the trunk namely the base, mid and top were inoculated on one face with two isolates of *Thielaviopsis* PNG12 and PNG27 under similar conditions at different sites. Score definitions are given in the text. nd= not determined.

4.1.2 Thielaviopsis ecology

Due to the possible pathogenicity of *Thielaviopsis paradoxa*, preliminary observations were carried out on the density and distribution of isolates within different fields in Milne Bay. Pieces of oil palm tissue (rachis, peduncles etc.) were collected from transects encompassing four palms. Each transect was divided into 4 plots and 3 samples of organic debris were collected from within each plot. Six transects were placed in each block giving a total of 72 samples per block. Samples were plated out onto water agar and *Thielaviopsis* and *Trichoderma* cultures identified. Results are presented graphically in Figure 20. The data shows that both *Thielaviopsis* and *Trichoderma* are present in all blocks sampled. The density of *Thielaviopsis* may be underestimated since many of the organic samples collected were aged and contained numerous other fungi.

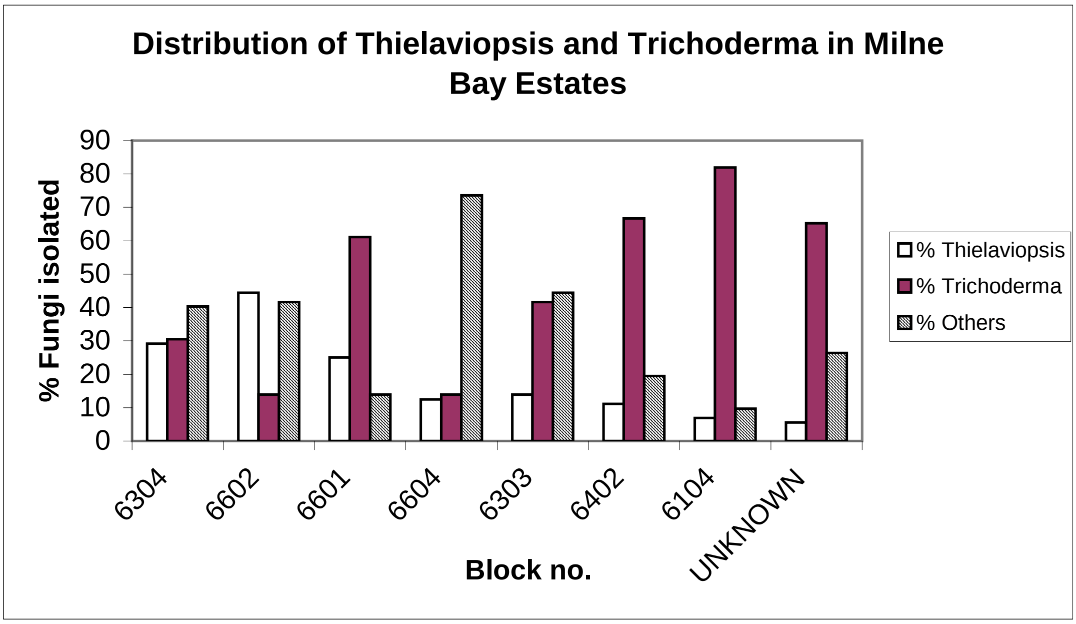

Figure 20. Distribution and density of *Thielaviopsis paradoxa* and *Trichoderma* spp.within selected oil palm blocks in Milne Bay in comparison to other unidentified fungi.

4.2. *Trichoderma* biological control agents

Further isolates were collected in 2003 and stored. Isolates are awaiting clearance from DEC to send to RBG Kew.

5. The Disease Process

Objective: To determine why some palms do not produce fruiting bodies of Ganoderma despite showing symptoms

5.1 Examination of diseased 'suspect' palms

Three diseased palms were destructively sampled. Isolations from diseased wood tissue were made onto Ganoderma selective medium (GSM). Samples were taken from areas of the bole tissue that appeared to be decayed by *Ganoderma* and from other areas distal from the main areas of rot termed the interaction zone. Results of these isolations are given in Table 4. In all cases *Ganoderma* was not isolated. This may indicate that the *Ganoderma* has already been killed by other saprophytes. Sections were sent to FRI Lae for slide preparation but microtome sections could not be made on the wood tissue. Further sampling will be carried out in 2004.

Palm & isolate number	Section sampled	Result
Palm 1-sample 1	White rotted area	Basidiomycete-unknown
Palm 2-sample 1	Yellow interaction zone	Ascomycete - unidentified
Palm 2-sample 2	Yellow interaction zone	As for sample 1
Palm 3-sample 1	Brown rotted area	Basidiomycete, unknown
Palm 3-sample 2	White rot near roots	Basidiomycete, unknown
Palm 3-sample 3	Inner root, brown rot	Basidiomycete, unknown
Palm 3- sample 4	Inner root., brown rot	Ascomycete, unknown
Palm 3- sample 5	Yellow interaction zone	Ascomycete?, unknown
Palm 3-sample 6	Yellow zone 1m from base	As for palm 2 sample-1

Table 4. Isolations from decayed wood tissue of 'suspect' palms in Milne Bay.

5. 2 Monitoring of 'suspect' palms

Three hundred and eighty suspect palms in four blocks in Kwea and 2 blocks in Giligili, Milne Bay were monitored each week over a 6-month period to determine the percentage which eventually produced brackets and the number of deaths. The results showed that only a small percentage of the palms developed brackets over the 6-month period (Table 5). The majority of palms did not develop brackets.

Palm status	No. of palms	%
Brackets developed	30	7.9
Brackets did not develop	327	86.1
Dead (without brackets)	10	2.6
Collapsed (without brackets)	11	2.9
Top broken off (dead)	2	0.5

Table 5. Status of suspect palms in Milne Bay six-months after initial observations.

6. Collaborative Research

The existing Research Agreement with Birkbeck College was transferred to Royal Botanic Gardens Kew with minor changes.

6.1 *Ganoderma* epidemiology in young palm plantings

Fifty samples were collected from the 1999 plantings at Numundo in 2003. These samples have been freeze-dried and are awaiting further analysis with the GanEt primer. Analysis has been delayed due to the change of collaborator from Birkbeck College to The Royal Botanic Gardens, Kew.

7. Publications and Visits

C. Pilotti to Medan, Indonesia in March 2003 for the Third International Workshop on Ganoderma diseases of perennial crops. This trip was funded by Biotrop.

Pilotti, C. A., Sanderson, F.R, Aitken, E.A.B., Armstrong, W. (2003). Morphological variation and host range of two Ganoderma species from Papua New Guinea. *Mycopathologia, reprints not received as yet.*

Plantation visits by C. Pilotti to Poliamba and NBPOL for training and sampling.

4. SMALLHOLDER STUDIES

(G. Curry & G. Koczberski)

Mobilising Smallholder Labour in Oil Palm Production; Results of the 'mobile card' trial, Hoskins, West New Britain, Papua New Guinea

The full report of the 'mobile card' trial[1] is a supplement to PNGOPRA Annual Report 2003. The Executive Summary of the report is reproduced below.

EXECUTIVE SUMMARY

Under-harvesting in the smallholder oil palm sector leads to substantial production losses amongst outgrowers. At Hoskins losses were estimated at around 25% of production. The main problems relate to labour supply.

A payment trial at Hoskins was designed to increase the supply of labour and so raise productivity. The trial was established jointly by OPRA and OPIC and ran for 15 months from July 2002 on LSS and VOP blocks at Hoskins.

There was a significant increase in FFB production. Monthly production for trial blocks increased from 75% of the LSS/VOP average without contract labour to 113% during months when contract labour was employed. Productivity increased on 90% of blocks with 30% improving by more than 50 percentage points.

In addition to productivity gains, those participating in the trial experienced considerable socio-economic benefits. These included:

- Utilisation of under-employed labour.
- Improved access to labour for elderly and disabled growers.
- Greater financial security for married sons and caretakers.
- More equal distribution of income within households.
- Less social conflict on blocks.

[1] Title; Mobilising Smallholder Labour in Oil Palm Production; Results of the 'mobile card' trial, Hoskins, West New Britain, Papua New Guinea, Author; Curry G., Koczberski, G., Publisher; Research Unit for the Study of Societies in Change, Curtin University of Technology, Perth, Western Australia.