Annual Research Report

2000

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Report by the Director of Research to the Annual General Meeting May 2001

We are all too used to Papua New Guinea being way down on any international list of achievements and at the top of the list when it comes to problems. Fortunately and proudly we can say that Papua New Guinea is at the top of the international list when it comes to the performance of its oil palm industry. With higher cost structures than other countries the oil palm industry in PNG must be more productive and more efficient than elsewhere in order to survive and must constantly strive to improve. Research and development plays a vital role in ensuring this sustainability and competitiveness. Technical developments by our milling companies and our research and development functions carried out by the PNG Oil Palm Research Association Inc. (PNGOPRA) and Dami Oil Palm Research Station (NBPOL) are now leading the World in many areas of technical innovation.

Formation

The country's oil palm companies and the Papua New Guinea Government formed PNGOPRA in 1979 to function as the research arm of the oil palm industry in PNG. PNGOPRA carries out research into oil palm agronomy, crop nutrition, entomology, and plant pathology. PNGOPRA does not conduct plant-breeding work, this is carried out very effectively on a commercial basis by New Britain Palm Oil Ltd at their Dami Research Station. PNGOPRA does however have a close working relationship with the plant breeding operation.

Locations

PNGOPRA carries out research from four main centres, Dami and Bialla in West New Britain Province, Higaturu in Oro Province, and Alotau in Milne Bay Province. PNGOPRA also runs sub-stations at Kapiura in West New Britain, and Poliamba in New Ireland. PNGOPRA therefore has active research operations in all oil palm growing regions.

Membership

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 and the Oil Palm Industry Corporation (OPIC). OPIC through its Membership represents the smallholder oil palm growers of PNG. The Members of the PNGOPRA have a close involvement in the direction and running of the organization thus ensuring the PNGOPRA is always responsive to the needs of the Members. The Members each have one representative on the PNGOPRA Board of Directors. Each representative holds voting rights within the meeting that reflect their Members input to the organization. This is calculated based on the previous year's FFB production, as the PNGOPRA Member's Levy is charged on an FFB basis. Voting rights in 2001 are presented below.

A sub-committee of the Board of Directors, the Scientific Advisory Committee, 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 Scientific Advisory Committee 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 2001.

Member	FFB Production in 2000	Votes
New Britain Palm Oil Limited	555,681 tonnes	6
Pacific Rim Plantation Ltd	448,766 tonnes	5
Hargy Oil Palms Ltd	82,375 tonnes	1
Oil Palm Industry Corporation (smallholders)	531,264 tonnes	6
The Director of Research also holds one vote		

Financing

PNGOPRA as an organization is small in size, especially when compared to the scale and importance of the industry it serves. This size restriction is deliberate and allows a focusing on quality that in other organizations in PNG is too often compromised by the need to support quantity. In terms of personnel the Association is about the same size as when it was formed in 1980 and the cost of operations today for Members, in US$ terms, is no greater than it was ten years ago. Despite this, the output is much greater in terms of both quality and quantity.

PNGOPRA is funded by a research levy paid by all oil palm growers and by external funding from the PNG Government and foreign aid donors. Today the Members levy represents about 62% of the organizations revenue and external funding 38%. The Member's levy, in general, finances core recurrent costs and the external funding covers research project specific costs. The Members levy in 2001 is set at a rate of K1.305 per tonne of FFB for Member companies and K0.90 per tonnes FFB for smallholders. The smallholder levy increased on 1st January from K0.56 per tonne, a rate that had been in place for several years. Currently the external funding consists of 27.2% from the Government's Public Investment Project (PIP), 46.3% European Union Stabex (3 projects), 23.8% research component of the World Bank financed Oro Smallholder Expansion Project, and 2.6% ACIAR.

Administration

PNGOPRA is self administered and managed by a small team comprising the Director of Research, an Accounts Superintendent, an Administrative Officer, two Accounts Clerks, and a Secretary, all based at Dami Research Station. It is a deliberate strategy to limit the size of the support operation and foster an emphasis on the research functions of the organization. Although this does place a sizeable strain on the administration and accounting staff, the system does work well.

Entomology

During 2000 the Entomology Section at PNGOPRA continued to make progress in the research, development and implementation of integrated pest management (IPM) systems for key economic pests of oil palm in PNG, with significant breakthroughs in the biological control of the most important of these pests, Sexava. In addition to this, work was started on a detailed study into insect pollination of oil palm, and the potential to make improvements to the current system.

Work on Sexava biological control and IPM began in 1996 as part of European Union project. This involved collaboration with scientists from Oxford University and CABI Biosciences. The first phase of this project was completed in 1999. The IPM system developed had the following components: (1) a knowledge of the biology and ecology of the pest, (2) economic thresholds, (3) monitoring system for the pest, (4) precise targeting of chemical control agents, (5) biological control and (6) cultural and physical control. A second phase of the project, again funded by the EU, was started towards the end of the 1999 and will continue for two years. The main objective of the second phase of the project was to attempt to transfer the *strepsipteran* parasite from Oro to West New Britain Province.

The parasite has now been introduced into the oil palm growing areas of West New Britain in an attempt to get it established in field populations of *S. defoliaria* and *S. decoratus*. This began in February 2000, and a total of 4554 infected insects have now been released into 6 trial areas within

West New Britain. A further 4 release areas will be established in West New Britain during 2001. In addition to this, a further 2 release sites will be established in the oil palm growing areas of New Ireland Province, within the project area of Poliamba Limited. These two sites will involve the infection and release of the Sexava species, *Segestidea gracilis*, which is the main Sexava pest of oil palm and coconuts in New Ireland Province.

Unequivocal evidence has been gathered from the release sites that *S. dallatorreanum* can complete its life cycle in the field populations of *S. defoliaria* and *S. decoratus* in West New Britain. There is also evidence to suggest that the parasite is spreading from the original release sites to infect *S. defoliaria* and *S. decoratus* in surrounding areas. This, and the information so far gained from the Sexava IPM project, indicates that it will be possible to successfully introduce the parasite into the oil palm growing areas of West New Britain, and that this will have a significant impact on the pest status of the two species of Sexava in these areas. It is also hoped that it will be possible to successfully introduce the parasite into the oil palm growing areas of New Ireland Province, and that this will also have a significant impact on the pest status of the species of Sexava in this area.

During the later part of the 1999 work began on a project to improve insect pollination of oil palm in PNG. The European Union has agreed to fund this work, and it involves collaboration with scientists from CABI Biosciences in the UK and the University of Cape Coast in Ghana. The objectives of this project are; (1) to screen the existing *E. kamerunicus* populations within PNG for evidence of infection by the nematodes or other parasites and pathogens, (2) to determine the degree of genetic separation between weevil populations in PNG and natural populations in West Africa and (3) to assess the potential to improve the genetic base of the existing population of *E. kamerunicus* within PNG. This could be done by the introduction of fresh batches of the same weevil species, or possibly by the introduction of one or a number of new species of pollinating insects from West Africa or South America.

Work on the project during 2000 has involved the screening of samples of weevils from PNG and Ghana for evidence of infection by nematodes. Results from this work suggest that parasitic nematodes are present within the weevil populations at all oil palm project areas within PNG.

Infection levels seem to be as high as 30-40% in some areas. The nematode parasites will certainly be reducing the fitness and fecundity of the weevils and therefore having a significant impact on pollination. Recently, it has been found that the same type of nematode is not found within weevil populations in West Africa, and as such it may be unique to PNG or to South East Asia.

Work on the pollination project during 2000 has also involved using Amplified Fragment Length Polymorphism (AFLP) genetic fingerprinting technique to determine the degree of genetic separation between weevil populations sampled in PNG and West Africa. Adequate amounts of high quality DNA have been extracted from the samples from each of the sites. During the next 6-9 months the AFLP technique will be carried out using these DNA samples.

Work on the IPM of Giant African Snail is being undertaken as part of a PhD programme by one of the Association's PNG scientists.

Training of plantation staff, extension officers and smallholder growers continued throughout 2000. PNGOPRA conducted a total of 19 training days in West New Britain and Oro Provinces.

The PNGOPRA Entomology Laboratory at Dami Research Station was upgraded early in 2000 and provides the Association with a state of the art facility in which to conduct its entomology work. The new laboratory and office is being used as the center for both the Sexava and pollination projects. A considerable amount of new equipment has been purchased through the two projects, including new microscopes, as well as a-state-of-the- art imaging system including a high-resolution digital camera.

Plant Pathology

The idea to establish a Plant Pathology Section within PNGOPRA was formulated in 1994 following identification of basal stem rot in several of the plantations within PNG. A request from the industry to look at the basal stem rot prompted an application to the European Union for funding under the Stabex funding arrangement. Work commenced in mid 1995 with the setting up of the plant pathology laboratory at Milne Bay Estates. The laboratory is capable of both routine mycological work and highly sophisticated molecular research.

Since the early 1960s it was generally accepted that basal stem rot was initiated by root-to-root contact; however, after thirty years control based on this assumption is still inconsistent. Research in the early 1990s suggested the involvement of basidiospores in the epidemiology of the disease; a suggestion that required a substantial change in the oil palm industry's attitude to the disease and subsequent control strategies. Because of these implications, the initial objective of the Plant Pathology Section was to study the basal stem rot with special reference to the involvement of basidiospores in the epidemiology of the disease. Following our initial research, all of which confirmed this hypothesis, control strategies were implemented within the large commercial plantations. Research into control of basal stem rot in the low input oil palm production systems of the smallholder grower has now commenced. Research into biological control of basal stem rot by identifying non-pathogenic organisms that will colonize the natural sites of *Ganoderma boninense*, the causal agent of basal stem rot, is also in progress.

Considerable progress has been made in nearly all areas of the project. The control strategy based on the removal of palms with brackets has been implemented. The involvement of spores has been demonstrated beyond doubt by following the movement of mating alleles through the population, and the connection between early basal infection and the secondary spread through the plantations seen as upper stem infections has been established.

The international standing of the project was well demonstrated in April this year when a meeting organised by OPRA was attended by all seed producing companies in North Sumatra.

Although the primary aim of the Plant Pathology Section is the research into basal stem rot, the unit is fully equipped and trained to handle any problems that might arise within the industry. There are a growing number of requests for assistance with regard to nursery diseases. In the area of plant pathology, a solid foundation has been laid on which the next few years will continue to build."

Agronomy

The most serious factor limiting oil palm production in PNG is the ubiquitous presence of nutrient deficiencies. Understanding these problems and developing appropriate management strategies is the main task of the PNGOPRA's Agronomy Section. If acceptable crop yields are to be produced, the single highest cost involved in growing oil palm is going to be fertiliser input. A major part of PNGOPRA's research focus is on the study of the soil chemistry and plant nutrition of oil palm growing on the wide range of PNG soil types, particularly the pedologically young volcanic soils. The major goal of the agronomy research is to develop the most economically optimal fertiliser practices dependent upon soil type, physical environment and economic conditions.

A large programme of formal fertiliser trails exists throughout the country. These trials are used to develop an understanding of the nutrient requirements of the oil palm and the responses to nutrient inputs. They also provide data that allows the extrapolation of findings to other areas, the tracking of fertility characteristics with time, and ultimately economic response models. Field trials work on a large plant like oil palm is difficult and much effort has gone into improving the experimental methodologies used. In the last year a series of new trial designs have been established that should greatly improve the value of the data derived from the trials.

During the last year considerable attention has been focussed on developing specific research projects directed towards more fundamental soil and crop nutritional studies. These projects are designed to address the current knowledge gaps that hinder our development of improved nutrient management recommendations and technologies.

The first of these projects concerns the efficacy of nitrogen fertiliser inputs. 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, a loss that is intolerable to smallholder growers. PNGOPRA in collaboration with Massey University, New Zealand and with financial support from the European Union is about to initiate a study to identify the major mechanisms of nitrogen loss and to develop management practices that reduce losses as much as possible. Success in the project could have an enormous impact on the economics of oil palm production in PNG.

The second project relates to the cation nutrition problems experienced on the lowland volcanic 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 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.

Research work in progress, funded by the PNGOPRA Members, has found a large and general imbalance between exchangeable calcium on the one hand, and exchangeable magnesium and potassium on the other. 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 (magnesium sulphate) have been largely ineffective. 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 uptake these elements.

PNGOPRA in collaboration with CSIRO in Townsville are developing a project proposal with the encouragement of the Australian Centre for International Agricultural Research (ACIAR) to address this cation problem. 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) assessing the magnitude of the problem in volcanic ash soils across the Bismarck Archipelago, and (2) identifying the processes that have caused it.

PNGOPRA Agronomists gives 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.

During 2001 the Agronomy Section is undergoing significant strengthening with the recruitment of a new Senior Agronomist and Agronomist. Following the lead of the Entomology Section and the Plant Pathology Section, I am confident that the improved staff strength and the newly formulated agronomy research programme will soon make its mark on the international stage as practitioners of leading oil palm research.

Smallholder Studies

One of the most significant problems for the oil palm industry and its function in rural development is poor productivity in the larger part of the smallholder sector. The reason for the poor productivity appears to be a related combination of social, economic and agronomic factors. In order to develop effective mechanisms to improve the situation, an understanding of the nature of these limiting factors is essential. With the support of the ACIAR and the collaboration of the Australian National University in Canberra, PNGOPRA has started a study into the socio-economic constraints to smallholder oil palm production and the interplay these have with agronomic constraints. This project started in mid 2000 and the first phase will be completed towards mid 2001.

Interim results of the study to date illustrate how important such studies and their output are in terms of the potential benefits their implementation can have on smallholder growers and the oil palm industry in general. Following discussions between ACIAR, ANU and PNGOPRA it has been agreed that a 2-year project extension should be applied for and that such studies should be a longer-term component of PNGOPRA's research programme.

Technical Services

The personnel within PNGOPRA represent an invaluable knowledge resource for its Members. The services provided by PNGOPRA go beyond research alone. PNGOPRA staff from all sections are committed to providing technical support via special investigations, recommendations and direct technical input. For example; Plant Pathology are closely involved in the implementation of *Ganoderma* control measures, Entomology is an integral part of the pest management systems in place through their role in making recommendation and the production and release of biological control agents, PNGOPRA's Agronomists conduct the large scale annual leaf sampling operations for Members and formulate the annual fertiliser recommendations for most Members. PNGOPRA staff also spend a significant amount of their time in providing technical training to plantation staff and extension officers.

Since its formation, PNGOPRA has had an enormous impact upon the productivity and profitability of PNG's oil palm industry, and there is still much more scope for further advances. The current research programme aims at producing the maximum sustainable economic yields with the minimum pesticide and fertiliser inputs, this approach incorporates the principle that high sustainable yields are only possible by managing to prevent environmental degradation. The Members of PNGOPRA have a scientific service that they can be proud of and one that reflects the commitment and professionalism of the industry it serves.

Ian Orrell
Director of Research
April 2001

1. AGRONOMY RESEARCH

(Dr. P. Nelson, M. Banabas & T. Betitis)

INTRODUCTION

STAFF

Senior Agronomist

During 2001 a new position of Senior Agronomist was created. The Senior Agronomist has responsibility for all of PNGOPRA's agronomy programmes. Two Agronomists under the Senior Agronomist are responsible for the Islands and mainland regions respectively. Dr. Paul Nelson was appointed to the position of Senior Agronomist in late July 2001.

Agronomists

Islands region (New Ireland and West New Britain Provinces): Mr. Barnabas Toreu left in February 2001 and Mr. Thomas Betitis joined in May 2001

Mainland Region (Oro and Milne Bay Provinces): Mr. Murom Banabas

Assistant Agronomists

Mr. Peter Tarramurray, Bialla
Ms. Jojo Papah, Smallholders & mapping, Popondetta
Mr. Winston Eremu, Milne Bay

Field Supervisors

Mr. Wawada Kanama, Poliamba
Mr. Kelly Naulis, Kapiura
Mr. Graham Bonga, Dami
Mr. Paul Simin, Popondetta
Ms. Pauline Hore, Smallholders, Popondetta
Ms. Norma Konimor, Smallholders, Dami

During the period July 2000 to July 2001, in addition being responsible for all mainland trials, Murom Banabas was acting OIC for Popondetta.

New staff

Mr. Thomas Betitis joined us from the Land Utilisation Section of the Department of Agriculture and Livestock. He had worked with the section for 9 years, and led it for the last six months. His expertise is in soil survey, land evaluation and GIS. He has a Masters in Soil Science from Lincoln University in New Zealand, where he looked at soil variability and production of *Pinus radiata*. In PNG he was involved in the Oro expansion project, mapping of agricultural systems in PNG, and was heavily involved development of PNG Resource Information System.

Dr. Paul Nelson joined us from CSIRO in Townsville, Australia. He has 14 years of experience in soil management research in various agricultural systems in Australia and Europe. Results of that work have been published in 3 book chapters, 15 scientific papers and 5 technical manuals.

TRIALS AND RESEARCH PROJECTS

In the Islands region, trial yields were generally much higher in 2000 than in 1999. Work was undertaken as scheduled in most of the existing trials. Trial 402 was closed in 2000; Trial 204, which was due to be closed in 2000, was extended to 2001 due to Sexava damage. Some new trials were scheduled to start in 2001. Of these, only 403 commenced treatments and data collection, while 132 still has to have its design finalised. Of the other proposals for 2001, Trials 211, 212 are still to get off the ground and the need for 213 and 214 will be reviewed. One of the issues affecting agronomy work in the Islands region over the last 3 years has been the frequent change of agronomy staff.

In the Mainland Region, all work was carried out as scheduled. New trials off the ground were 324 and 329. Trial 311 was closed at the end of 2000. Full leaf sampling was carried out on all Mainland trials in 2000.

LOGISTICS

In the Islands region, the L200 was tendered for sale in 2000 and is to be sold in 2001. The two Canter trucks and Landcruiser are old and due for replacement. In Bialla, a new drying oven was installed in 2000 and a container for fertiliser storage was obtained in 2001.

A new Landcruiser bought for Milne Bay in Feb 2000 was a relief for agronomy work. The old Milne Bay Canter was shipped to Popondetta for parts. The current Canter is no longer roadworthy and we are considering replacing it with a Landcruiser.

At Dami and Popondetta, the email system was set up and data management system updated.

SMALLHOLDERS

Officers participated in field days at Popondetta, Bialla and Hoskins.
All Local Planning Committee (LPC) meetings were attended at Popondetta and Hoskins and Bialla and every second one was attended at Milne Bay. M. Banabas carried out presentations about the functions of OPRA to smallholders growers associations at Milne Bay and Popondetta.

TRAINING

J. Papah and T. Betitis attended a six week GIS training course at the Australian National University.

Mainland: M. Banabas provided fertiliser training for Milne Bay Estate Managers, Divisional Managers and Supervisors concerning the functions of different fertilisers, application techniques, and management of different soil types. Annual leaf sampling training was given at all estates.

REPORTS and MEETINGS

Draft final reports for Trials 305 and 306 have been written by M. Banabas and circulated for comment. The complete set of data has been assembled to enable a final report to be written for Trial 311.

- Murom Banabas attended the Planters conference in Malaysia in May 2000.
- Mrs. Jojo Papah gave a presentation on the Oro Mapping Project at the National Planning Workshop in Port Moresby in October 2000.

ABBREVIATIONS

AMC	Ammonium chloride (NH_4Cl)
AMS	Sulphate of ammonia or ammonium sulphate ($(NH_4)_2SO_4$)
BA	Bunch ash (burned EFB)
BNO	Number of bunches
CV	Coefficient of variation
DM	Dry matter
EFB	Empty fruit bunch
FFB	Fresh fruit bunch
GM	Grand mean (average over all treatments)
KIE	Kieserite (mostly magnesium sulphate, $MgSO_4$)
l.s.d.	Least significant difference (p=0.05)
MOP	Muriate of potash or potassium chloride (KCl)
n.s.	See Sig.
SBW	Single bunch weight
s.e.	Standard error
Sig.	Level of significance (n.s. not significant, * p<0.05, ** p<0.01, *** p<0.001)
TSP	Triple superphosphate (mostly calcium phosphate, $CaPO_4$)

FERTILISER COMPOSITION

Fertiliser and abbreviation	Approximate Elemental Content						
	N	P	K	S	Mg	Cl	B
	------------------(% by weight)----------------						
Ammonium sulphate (AMS)	21			24			
Ammonium chloride (AMC)	25					66	
Ammonium nitrate (AMN)	35						
Urea	46						
Diammonium phosphate (DAP)	18	20					
Potassium sulphate (POS)			14	17			
Triple superphosphate (TSP)		20		2			
Kieserite (KIE)				23	10		
Potassium chloride (MOP)			50			47	
Sodium chloride						61	
Borax							11
Ulexite							10

CLIMATE

As climate, especially rainfall and sunshine, have a marked effect on trial yields and can have important interactions with treatments, we provide a monthly summary of rainfall (Table 1.1) and sunshine (Table 1.2) for relevant recording stations in 2000.

Table 1.1. Monthly and annual rainfall for 2000

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Total
							New Ireland Province						
Poliamba	252	26	178	156	386	151	134	312	78	318	134	214	2337
							West New Britain Province						
Kapiura	392	503	471	356	397	372	171	279	149	279	330	380	2810
Garu	834	229	446	280	481	121	157	318	102	247	290	444	3949
Dami	529	157	442	293	565	138	156	249	217	207	179	270	3402
Kumbango	176	113	270	135	261	84	95	221	59	134	117	283	1949
							Oro Province						
Mamba	545	371	660	326	613	310	368	291	366	408			4258*
Ambogo	180	114	383	277	220	125	241	104		113		381	2135*
OPRA	242	108	317	174	215	236	188	115	171	214	181	241	2400
Embi	406	88	471	190	357	123	135		182	195		384	2531*
							Milne Bay Province						
Waigani	212	106	604	206	520	676	25	70			139	114	1749*

*These annual totals are underestimates because rainfall data is not available for all months
Blank spaces indicate months with no record

Table 1.2. Monthly and annual sunshine hours in 2000

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Total
							West New Britain						
Dami	122.0	223.8	139.2	173.7	139.1	158.1	139.2	150.9	200.9	159.8	170.4	102.3	1880
							Oro Province						
Mamba			92.1	163.5	157.3	103.8	146.4	151.4	143.6	159.2	161.3	72.9	1352*
OPRA	120.8	192.9	155.0	192.6	186.7	148.2	163.9	178.7	209.4	199.0	180.8	88.0	2016

*These annual totals are underestimates because rainfall data is not available for all months
Blank spaces indicate months with no record

AGRONOMY TRIALS IN NEW IRELAND PROVINCE

(Dr. P. Nelson, T. Betitis)

Trials 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.

DESCRIPTION

Sites Trial 251: Fields 2B, 2C, 2D and 3A, Maramakas Plantation.
Trial 252: 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.

Palms Dami commercial DxP crosses.
Planted in March 1989 (251) and September 1989 (252) at 128 palms/ha.
Treatments started in April 1991.

DESIGN

There are 36 treatments at both sites, comprising all factorial combinations of N and K at three levels and P and Mg each at two levels (Table 1.3).

Table 1.3 Rates of fertiliser used in Trials 251 and 252.

	Level (kg /palm/year)		
	0	1	2
Ammonium sulphate	0.0	2.5	5.0
Muriate of potash	0.0	2.5	5.0
Triple superphosphate	0.0	2.0	---
Kieserite	0.0	2.0	---

Note: Treatments are factorial combinations of levels of these fertilisers

Annual fertiliser application rates are split into three applications.

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. The 1995 and 1996 data was analysed with a site factor included in the single analysis for these two trials. However, as the two trials are performing quite differently the data for the two trial sites were analysed separately since 1997.

There are 36 plots at each site, each plot consisting of 36 palms (6x6), of which the central 16 are recorded. High order interactions provide the error term in the statistical analysis. Soil depth was measured for each plot and used as a covariate in the analysis of variance.

RESULTS (TRIAL 251)

The soil depth covariate was not significant for any parameters, but results reported below include it in the analysis. The only significant treatment effect on yield and its components in 2000 and 1998-2000 was the main effect of potassium. Yield was more than doubled between 0 and 2.5 kg/palm/yr, but the higher rate (5 kg/palm/yr) gave no further improvement in yield (Tables 1.4 and 1.5). Effects of interactions between MOP, AMS and TSP on FFB yield were not significant (Tables 1.6 and 1.7).

The tissue concentrations of most elements were significantly affected by MOP. MOP application had the effect of increasing leaflet concentrations of N, P and K, and decreasing leaflet concentrations of Mg, Ca and B (Table 1.8). The only other fertiliser to significantly influence tissue concentrations was kieserite, which raised leaflet Mg concentration (Table 1.8). Leaf N content was not significantly affected by AMS (Table 1.8) or the interaction between AMS and MOP (Table 1.9).

Table 1.4. Main effects of treatments on FFB yield and yield components in 2000. P values for significant results ($p<0.05$) are shown in bold. (Trial 251)

	Treatment and level			p	s.e.d.	CV%
	AMS0	**AMS1**	**AMS2**			
Yield (t/ha)	21.9	25.8	26.5	0.246	4.9	20.1
Bunches/ha	1169	1292	1337	0.288	183	14.5
kg/bunch	18.9	19.0	19.2	0.984	1.7	8.9
	MOP0	**MOP1**	**MOP2**			
Yield (t/ha)	12.7	30.9	30.6	**0.006**	4.9	20.1
Bunches/ha	869	1453	1476	**0.009**	183	14.5
kg/bunch	14.1	21.6	21.5	**0.003**	1.7	8.9
	TSP0	**TSP1**		0.487		
Yield (t/ha)	24.6	24.9		0.606	4.9	20.1
Bunches/ha	1256	1276		0.741	183	14.5
kg/bunch	19.3	19.9			1.7	8.9
	KIE0	**KIE1**				
Yield (t/ha)	25.2	24.3		0.840	4.9	20.1
Bunches/ha	1278	1254		0.539	183	14.5
kg/bunch	19.4	18.8		0.632	1.7	8.9

Table 1.5. Main effects of treatments on FFB yield and yield components in 1998-2000. P values for significant results ($p<0.05$) are shown in bold. (Trial 251)

	Treatment and level			p	s.e.d.	CV%
	AMS0	**AMS1**	**AMS2**			
Yield (t/ha)	19.4	20.5	21.1	0.749	3.2	15.8
Bunches/ha	1139	1157	1192	0.955	175	15.0
kg/bunch	16.8	17.3	17.3	0.776	1.28	7.5
	MOP0	**MOP1**	**MOP2**			
Yield (t/ha)	11.3	24.5	25.2	**0.004**	3.2	15.8
Bunches/ha	861	1282	1346	**0.021**	175	15.0
kg/bunch	12.7	19.4	19.2	**0.002**	1.28	7.5
	TSP0	**TSP1**				
Yield (t/ha)	20.5	20.2		0.723	3.2	15.8
Bunches/ha	1159	1167		0.534	175	15.0
kg/bunch	17.4	16.8		0.425	1.28	7.5
	KIE0	**KIE1**				
Yield (t/ha)	20.9	19.8		0.638	3.2	15.8
Bunches/ha	1174	1152		0.349	175	15.0
kg/bunch	17.5	16.7		0.430	1.28	7.5

Table 1.6 Effects of two-way interactions between MOP, AMS and TSP on FFB yield (t/ha) in 2000. (Trial 251)

AMS.MOP, p= 0.359, l.s.d.= 13.9

	MOP0	**MOP1**	**MOP2**
AMS0	14.9	23.5	27.3
AMS1	9.7	36.0	31.5
AMS2	13.6	33.2	32.8

TSP.MOP, p= 0.490, l.s.d.= 9.8

	MOP0	**MOP1**	**MOP2**
TSP0	13.5	31.3	28.8
TSP1	11.9	30.5	32.3

Table 1.7 Effects of two-way interactions between MOP and AMS on FFB yields (t/ha) in 1998-2000 (Trial 251).

AMS. MOP, p= 0.640, l.s.d = 9.0

	MOP 0	**MOP 1**	**MOP 2**
AMS 0	13.3	19.7	25.2
AMS 1	8.1	28.3	25.1
AMS 2	12.3	25.6	25.3

Table 1.8 Main effects of treatments on tissue nutrient concentrations (based on dry matter) in 2000 (Trial 251). Concentrations are in leaflets of frond 17, except for those designated "R", which are in the rachis of frond 17. Significant p values (<0.05) are shown in bold. No treatment interactions were significant.

	Treatment and level			p	s.e.d.	CV%
	AMS0	**AMS1**	**AMS2**			
Ash (%)	6.8	7.1	6.8	0.859	1.2	18.1
N (%)	2.5	2.5	2.5	0.837	0.1	5.3
P (%)	0.0153	0.015	0.0150	0.664	0.006	4.0
K (%)	0.63	0.61	0.64	0.702	0.10	16.1
Mg (%)	0.34	0.35	0.35	0.683	0.03	7.7
Ca (%)	1.15	1.10	1.09	0.405	0.12	9.4
B (mg/kg)	14.1	14.9	14.5	0.377	1.59	10.9
Cl (%)	0.62	0.62	0.65	0.561	0.07	11.6
R. ash (%)	3.96	4.05	3.68	0.373	0.56	14.3
R. K (%)	0.94	1.04	0.78	0.229	0.32	35.1
	MOP0	**MOP1**	**MOP2**			
Ash (%)	7.9	6.6	6.1	0.084	1.2	18.1
N (%)	2.3	2.7	2.5	**0.010**	0.1	5.3
P (%)	0.142	0.156	0.157	**0.011**	0.006	4.0
K (%)	0.36	0.73	0.78	**0.004**	0.10	16.1
Mg (%)	0.52	0.26	0.25	**<0.001**	0.03	7.7
Ca (%)	1.24	1.05	1.06	**0.041**	0.12	9.4
B (mg/kg)	18.2	13.0	12.3	**0.009**	1.59	10.9
Cl (%)	0.66	0.59	0.65	0.228	0.07	11.6
R. ash (%)	3.24	4.09	4.37	**0.030**	0.56	14.3
R.K (%)	0.30	1.15	1.31	**0.008**	0.32	35.1
	TSP0	**TSP1**				
Ash (%)	7.0	6.8		0.759	1.2	18.1
N (%)	2.5	2.5		0.456	0.1	5.3
P (%)	0.149	0.154		0.081	0.006	4.0
K (%)	0.63	0.63		1.000	0.10	16.1
Mg (%)	0.35	0.34		0.920	0.03	7.7
Ca (%)	1.09	1.14		0.358	0.12	9.4
B (mg/kg)	14.3	14.7		0.928	1.59	10.9
Cl (%)	0.62	0.64		0.597	0.07	11.6
R. ash (%)	4.04	3.76		0.234	0.56	14.3
R.K (%)	1.02	0.82		0.149	0.32	35.1
	KIE0	**KIE1**				
Ash (%)	6.9	6.9		0.836	1.2	18.1
N (%)	2.5	2.5		0.433	0.1	5.3
P (%)	0.151	0.152		0.720	0.006	4.0
K (%)	0.65	0.60		0.180	0.10	16.1
Mg (%)	0.32	0.37		**0.008**	0.03	7.7
Ca (%)	1.12	1.11		0.580	0.12	9.4
B (mg/kg)	14.0	15.1		0.797	1.59	10.9
Cl (%)	0.63	0.63		0.917	0.07	11.6
R. ash (%)	3.77	4.03		0.318	0.56	14.3
R. K (%)	0.87	0.96		0.817	0.32	35.1

Table 1.9 Effects of two-way interactions between MOP and AMS on leaf nitrogen content in 2000 (Trial 251).

AMS. MOP, p = 0.701, l.s.d = 13.87			
	MOP 0	**MOP 1**	**MOP 2**
AMS 0	2.3	2.7	2.5
AMS 1	2.3	2.6	2.6
AMS 2	2.2	2.6	2.5

RESULTS (TRIAL 252)

The soil depth covariate was significant for some parameters, and it has been included in the analysis. For FFB yield, the main effects of AMS, TSP and MOP were all significant in 1998-2000, as were most of the three-way interactions between them and kieserite. The effects on yield were largely due to single bunch weights, but the number of bunches was also affected. Yields were very low (6.4 t/ha/yr) where no AMS, MOP or TSP was added. Main effects of fertilisers on yield are shown in Table 1.10. Effects of interactions between MOP, AMS and TSP on yield are shown in Table 1.11. MOP application increased yield at all levels of AMS and TSP. A positive effect of TSP occurred only where no MOP was added.

In 2000 there were significant main effects of fertilisers on yield and its components (Table 1.11), but none of the treatment interactions were significant. The only significant effect on yield was the main effect of MOP application (Table 1.12).

Table 1.10 Main effects of treatments on FFB yield and yield components in 2000. P values for significant results ($p<0.05$) are shown in bold (Trial 252).

	Treatment and level			p	s.e.d.	CV%
	AMS0	**AMS1**	**AMS2**			
Yield (t/ha)	25.0	31.0	29.3	0.071	3.9	13.9
Bunches/ha	1338	1559	1456	0.073	147.3	10.1
kg/bunch	18.3	20.1	19.5	**0.031**	0.87	4.5
	TSP0	**TSP1**				
Yield (t/ha)	27.2	29.7		0.153	3.9	13.9
Bunches/ha	1391	1510		0.099	147.3	10.1
kg/bunch	18.9	19.8		**0.050**	0.87	4.5
	MOP0	**MOP1**	**MOP2**			
Yield (t/ha)	20.8	31.9	32.7	**0.008**	3.9	13.9
Bunches/ha	1270	1541	1541	**0.025**	147.3	10.1
kg/bunch	15.5	20.9	21.5	**<0.001**	0.87	4.5
	KIE0	**KIE1**				
Yield (t/ha)	28.6	28.2		0.829	3.9	13.9
Bunches/ha	1471	1430		0.529	147.3	10.1
kg/bunch	19.1	19.5		0.178	0.87	4.5

Table 1.11. Effects of two-way interactions between AMS, MOP and TSP on FFB yields (t/ha) in 1998-2000 (Trial 252).

AMS. MOP, **p = 0.003,** l.s.d = 1.70			
	MOP 0	MOP 1	MOP 2
AMS 0	13.3	24.4	24.6
AMS 1	20.5	26.5	28.2
AMS 2	13.7	25.8	28.6
TSP.MOP, **p= 0.004**, l.s.d = 1.29			
	MOP 0	MOP 1	MOP 2
TSP 0	12.7	25.9	27.2
TSP 1	18.9	25.2	27.0

Table 1.12 Main effects of treatments on FFB yield and yield components in 1998-2000. P values for significant results (p<0.05) are shown in bold (Trial 252).

	Treatment and level			p	s.e.d.	CV%
	AMS0	**AMS1**	**AMS2**			
Yield (t/ha)	20.7	25.0	22.7	**0.003**	0.91	4.0
Bunches/ha	1277	1466	1334	**0.011**	62.0	4.6
kg/bunch	15.8	17.2	16.4	**0.005**	0.38	2.3
	TSP0	**TSP1**				
Yield (t/ha)	21.9	23.7		**0.009**	0.91	4.0
Bunches/ha	1319	1399		**0.031**	62.0	4.6
kg/bunch	16.1	16.9		**0.009**	0.38	2.3
	MOP0	**MOP1**	**MOP2**			
Yield (t/ha)	15.8	25.5	27.1	**<0.001**	0.91	4.0
Bunches/ha	1118	1447	1512	**<0.001**	62.0	4.6
kg/bunch	13.6	18.0	17.9	**<0.001**	0.38	2.3
	KIE0	**KIE1**				
Yield (t/ha)	23.2	22.4		0.096	0.91	4.0
Bunches/ha	1387	1331		0.086	62.0	4.6
kg/bunch	16.4	16.5		0.409	0.38	2.3

Table 1.13 Main effects of treatments on tissue nutrient concentrations (based on dry matter) in 2000 (Trial 252). Concentrations are in leaflets of frond 17, except for those designated "R", which are in the rachis of frond 17. P values for significant results (p<0.05) are shown in bold.

	Treatment and level			p	s.e.d.	CV%
	AMS0	**AMS1**	**AMS2**			
Ash (%)	6.2	6.2	6.3	0.869	0.51	8.2
N (%)	2.3	2.5	2.5	0.096	0.13	5.5
P (%)	0.146	0.152	0.150	0.157	0.006	4.4
K (%)	0.59	0.65	0.64	**0.008**	0.017	2.7
Mg (%)	0.32	0.28	0.29	0.206	0.040	13.6
Ca (%)	1.12	1.03	1.05	0.161	0.083	7.8
B (mg/kg)	13.5	12.7	13.3	0.176	0.79	6.0
Cl (%)	0.60	0.61	0.64	0.444	0.043	6.9
R. ash (%)	4.20	4.02	3.90	0.350	0.479	11.8
R. K (%)	0.99	0.98	0.91	0.656	0.228	23.8
	TSP0	**TSP1**				
Ash (%)	6.2	6.2		0.867	0.51	8.2
N (%)	2.4	2.5		0.459	0.13	5.5
P (%)	0.147	0.152		0.091	0.006	4.4
K (%)	0.61	0.64		**0.007**	0.017	2.7
Mg (%)	0.31	0.28		0.121	0.040	13.6
Ca (%)	1.06	1.07		0.678	0.083	7.8
B (mg/kg)	13.4	13.0		0.211	0.79	6.0
Cl (%)	0.63	0.60		0.152	0.043	6.9
R. ash (%)	4.05	4.03		0.956	0.479	11.8
R.K (%)	0.96	0.96		0.923	0.228	23.8
	MOP0	**MOP1**	**MOP2**			
Ash (%)	7.0	5.8	5.9	**0.015**	0.51	8.2
N (%)	2.3	2.5	2.5	**0.033**	0.13	5.5
P (%)	0.145	0.151	0.151	0.118	0.006	4.4
K (%)	0.38	0.72	0.77	**<0.001**	0.017	2.7
Mg (%)	0.43	0.23	0.23	**0.002**	0.040	13.6
Ca (%)	1.11	1.06	1.03	0.321	0.083	7.8
B (mg/kg)	15.4	12.6	11.5	**0.003**	0.79	6.0
Cl (%)	0.59	0.61	0.65	0.241	0.043	6.9
R. ash (%)	2.96	4.26	4.90	**0.005**	0.479	11.8
R.K (%)	0.21	1.15	1.51	**0.002**	0.228	23.8
	KIE0	**KIE1**				
Ash (%)	6.3	6.1		0.328	0.51	8.2
N (%)	2.4	2.4		0.517	0.13	5.5
P (%)	0.150	0.148		0.427	0.006	4.4
K (%)	0.63	0.62		**0.037**	0.017	2.7
Mg (%)	0.27	0.32		**0.049**	0.040	13.6
Ca (%)	1.10	1.003		0.089	0.083	7.8
B (mg/kg)	13.4	12.9		0.156	0.79	6.0
Cl (%)	0.61	0.62		0.422	0.043	6.9
R. ash (%)	4.01	4.08		0.677	0.479	11.8
R. K (%)	0.98	0.93		0.611	0.228	23.8

Table 1.14 Leaflet K concentrations (% DM); effects of significant two-way interactions in 2000 (Trial 252).

AMS.MOP, **p<0.05**, l.s.d. 0.04			
	MOP0	**MOP1**	**MOP2**
AMS0	0.34	0.68	0.75
AMS1	0.43	0.75	0.78
AMS2	0.39	0.74	0.79
TSP.MOP, **p<0.01**, l.s.d. 0.03			
	MOP0	**MOP1**	**MOP2**
TSP0	0.33	0.72	0.78
TSP1	0.44	0.73	0.76

Table 1.15 Effects of two-way interactions between MOP and AMS on leaf nitrogen content (% DM) in 2000 (Trial 252).

AMS. MOP, p = 0.868, l.s.d =0.25			
	MOP 0	**MOP 1**	**MOP 2**
AMS 0	2.2	2.4	2.4
AMS 1	2.3	2.6	2.5
AMS 2	2.4	2.5	2.6

For tissue nutrient concentrations in 2000, almost all of the significant effects involved potassium. MOP applications had the effect of increasing concentrations of leaflet N, leaflet K, Rachis ash and rachis K, and decreasing concentrations of leaflet ash, leaflet Mg and leaflet B (Table 1.13). In addition to those effects, leaflet K, which was generally in the deficient range, was significantly influenced by the main effect of all fertilisers, and by most interactions except those involving kieserite. At high levels of MOP, ammonium sulphate had a positive influence on leaflet K (Table 1.14). On the other hand, TSP had a positive effect on leaflet K in the absence of MOP (Table 1.14). The only significant effect not involving K in some way was the positive effect of kieserite on leaflet Mg (Table 1.13). The only tissue nutrient concentrations not significantly influenced by the treatments were leaflet P, leaflet Cl, and leaflet Ca, which was at excessive concentrations in all treatments.

CONCLUSION

Low K and high Ca are by far the most important nutrition issue on these soils. In 1998-2000, addition of muriate of potash more than doubled yields. There was no evidence of boron deficiency.

AGRONOMY TRIALS IN WEST NEW BRITAIN PROVINCE

(T. Betitis, Dr. P. Nelson)

Trial 125 Sources of Nitrogen Fertiliser Trial, Kumbango Plantation.

PURPOSE

To investigate the relative effects of different types of nitrogen fertiliser available in PNG, on oil palm. Of particular interest is the effect of the various nitrogen fertilisers on potassium and magnesium nutrition. The results of the trial will be used in formulating fertiliser recommendations.

DESCRIPTION

Site One or more of field numbers c4, c5 or c6, Division II, Kumbango Plantation, near Kimbe, WNBP.

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 April & May 1993 at 135 palms/ha.
Treatment applications commenced in June 1997.

DESIGN

The design of this trial has been changed on the advice of biometricians from the Pacific Regional Agricultural Programme and IACR - Rothamsted.

There are 15 fertiliser treatments in each replication and 4 control plots (Table 1.16). The 15 treatments will be replicated four times in a randomised complete block design. The four control plots are plots on the edge of the trial from which yield will be recorded but the data will not be used in the analysis of variance. The mean yield from the control plots will be reported in the table of means as a comparison with the fertiliser treatments. 36 palm plots (6x6 palms) are used, the central 16 palms are recorded and the outer 20 palms are guard row palms.

Table 1.16. Treatments used in Trial 125

Fertiliser	Level (kg/palm/year)		
	1	**2**	**3**
g N/palm/year	520	1040	2080
Ammonium chloride	2.0	4.0	8.0
Ammonium sulphate	2.6	5.2	10.3
Urea	1.2	2.4	4.7
Ammonium nitrate	1.5	2.9	5.8
Di-ammonium phosphate	3.0	6.0	12.0

Each rate of fertiliser at the same level contains the same amount of nitrogen. Experimental fertiliser treatments were first applied in June 1997 after pre-treatment yield data had been collected. Plot isolation trenches were completed prior to the first application of treatments. Until this time the palms had received a standard immature palm fertiliser input. Frond 17 leaflet, and rachis cross-section sampling were carried out prior to treatments being applied. This trial is the same design as Trials 324 and 325 in Oro Province.

RESULTS

Yields and yield components for 2000, which is the third full year of yield recording since fertiliser treatments commenced, are given in Table 1.17. In general, FFB yields were higher in 2000 than 1999 (mean over whole trial of 34.8 t/ha and 23.9 t/ha, respectively). The results however show that neither the type nor rate of fertiliser had a significant effect on yield, single bunch weight or bunch number in 2000 (Table 1.17) or 1998-2000 (Table 1.18).

Table 1.17. Main effects of fertiliser type and rate on yield and yield components in Trial 125 in 2000. Statistical analysis does not include controls.

Fertiliser type	Yield (t/ha)	kg/bunch	Bunches/ha
Control	35.4	15.9	2263
Ammonium chloride	36.2	17.5	2129
Ammonium sulphate	34.9	17.0	2115
Urea	35.0	16.6	2163
Ammonium nitrate	33.8	16.9	2028
Di-ammonium phosphate	34.3	16.9	2065
p	0.292	0.543	0.569
s.e.	2.6	1.2	211.2
CV (%)	7.5	7.2	10.1
Fertiliser Rate (g N/palm/year)	**Yield (t/ha)**	**kg/bunch**	**Bunches/ha**
520	34.7	17.1	2082
1040	35.8	16.8	2174
2080	33.9	17.0	2045
p	0.090	0.806	0.159
s.e.	2.7	1.2	215
CV (%)	7.8	7.2	10.2

Table 1.18. Main effects of fertiliser type and rate on yield and yield components in Trial 125 in 1998- 2000. Statistical analysis does not include controls.

Fertiliser Type	Yield (t/ha)	kg/bunch	Bunches/ha
Control	20.1	22.8	2222
Ammonium chloride	29.2	14.1	2113
Ammonium sulphate	28.8	14.0	2107
Urea	28.6	14.0	2112
Ammonium nitrate	28.1	14.0	2047
Di-ammonium phosphate	28.0	13.8	2054
p	0.517	0.895	0.837
s.e.	1.9	0.76	193
CV (%)	6.6	5.5	9.2
Fertiliser Rate (g N/palm/year)	**Yield (t/ha)**	**kg/bunch**	**Bunches/ha**
520	28.4	14.0	2053
1040	29.0	13.7	2155
2080	28.1	14.0	2052
p	0.345	0.363	0.159
s.e.	1.9	0.76	193
CV (%)	6.6	5.5	9.2

Out of all the tissue nutrient concentrations measured, only leaflet P and leaflet Cl were significantly affected by the treatments. Leaflet P was highest where diammonium phosphate was applied, and leaflet Cl was highest where ammonium chloride was applied (Table 1.19).

Table 1.19. Main effects of treatments on tissue nutrient concentrations (based on dry matter) in 2000. Concentrations are in leaflets of frond 17, except for those designated "R", which are in the rachis of frond 17. Significant effects (p<0.05) are shown in bold (Trial 125). Statistical analysis does not include controls.

	Treatment						p	s.e.d.	CV%
	Control	**AMC**	**AMS**	**Urea**	**AMN**	**DAP**			
Ash (%)	15.6	14.8	15.1	14.5	15.1	14.8	0.293	0.81	5.5
N (%)	2.58	2.5	2.5	2.5	2.3	2.6	0.410	0.33	13.2
P (%)	0.232*	0.148	0.145	0.146	0.147	0.150	**0.018**	0.004	2.4
K (%)	0.86	0.81	0.83	0.85	0.85	0.83	0.789	0.089	10.8
Mg (%)	0.15	0.146	0.143	0.149	0.149	0.153	0.821	0.021	14.4
Ca (%)	0.78	0.78	0.71	0.72	0.71	0.73	0.076	0.707	9.7
B (mg/kg)	12.8	11.9	12.9	12.6	12.4	12.9	0.291	1.209	9.6
Cl (%)	0.41	0.57	0.40	0.45	0.42	0.43	**<0.001**	0.059	12.9
R. ash (%)	5.0	5.1	4.9	4.8	4.8	5.2	0.868	1.085	22.0
R. K (%)	1.59	1.71	1.52	1.56	1.54	1.67	0.683	0.381	23.9
	Control	**Level 1**	**Level 2**	**Level 3**					
Ash (%)	15.6	14.6	15.1	14.9			0.157	0.81	5.5
N (%)	2.58	2.4	2.5	2.5			0.406	0.33	13.2
P (%)	0.232*	0.147	0.149	0.150			**0.008**	0.004	2.4
K (%)	0.86	0.85	0.83	0.81			0.396	0.089	10.8
Mg (%)	0.15	0.149	0.148	0.148			0.975	0.021	14.4
Ca (%)	0.78	0.72	0.75	0.71			0.244	0.707	9.7
B (mg/kg)	12.8	12.5	12.9	12.3			0.316	1.209	9.6
Cl (%)	0.41	0.45	0.47	0.45			0.453	0.059	12.9
R. ash (%)	5.0	4.9	4.8	5.1			0.721	1.085	22.0
R. K (%)	1.59	1.59	1.55	1.66			0.653	0.381	23.9

** 0.150 if one of the four plots is excluded*

CONCLUSION

In 1998-2000 and 2000, there were no significant effects of nitrogen fertiliser or type on yield or yield components. Where N was added as phosphate or chloride, leaflet P and Cl concentrations responded accordingly. The lack of response to fertiliser N will be examined in a project proposed for 2002.

Trial 126 Factorial Fertiliser Trial, Malilimi

PURPOSE

To provide fertiliser response information that will be useful in developing strategies for fertiliser usage. This trial was also designed to investigate further the yield responses seen in Trial 119, i.e. was the response due to potassium or chlorine?

DESCRIPTION

Site Malilimi Plantation, WNBP.

Soil Young coarse textured freely draining soils formed on alluvially redeposited andesitic pumiceous sand and volcanic ash. Palaeosols are common.

Palms Dami commercial DxP crosses.
Planted in 1985 at 135 palms/ha.
Treatments started in May 1996.

DESIGN

There are 72 treatments comprising all factorial combinations of sulphate of potash (potassium sulphate), sulphate of ammonia (ammonium sulphate), each at three levels, and triple superphosphate, kieserite (magnesium sulphate) and sodium chloride, each at two levels (Table 1.20). The 72 treatments are replicated only once and are divided among two blocks. The 3 factor interaction '2x2x2' is confounded with blocks. Third and higher order interactions provide the error term in the statistical analysis. Each of the 72 plots consists of 36 palms (6x6) of which the central 16 palms are recorded and the outer 20 palms are regarded as guard row palms.

Table 1.20 Fertiliser rates in Trial 126.

Fertiliser	Level (kg/palm/year)		
	0	1	2
Ammonium sulphate	0	3	6
Potassium sulphate	0	3	6
Triple superphosphate	0	4	---
Kieserite	0	4	---
Sodium chloride	0	4	---

Note: Treatments are factorial combinations of levels of these fertilisers.

The ammonium sulphate and potassium sulphate are split into two applications per year, while the other fertilisers are applied once per year.

This trial was approved in the PNGOPRA Scientific Advisory Board meeting in November 1993. Site selection, a detailed site survey and site mapping was carried out in May and June 1994. Plot selection was carried out in June 1994. Pre-treatment yield recording commenced in 1995. Experimental fertiliser treatments started in July 1996. Plot isolation trenches were dug prior to commencement of treatments.

RESULTS

In 2000 the mean fresh fruit bunch (FFB) yield over the trial was 33.1 t/ha (mean of 1280 bunches/ha and 26.6 kg/bunch). The only significant treatment effect was the positive effect of ammonium sulphate on yield and single bunch weight (Table 1.21), irrespective of other fertiliser treatments. The fact that yield responded to ammonium sulphate but not magnesium or potassium sulphate indicates that the response was due to N and not S. Positive effects of triple superphosphate and sodium chloride on single bunch weights were almost significant (p=0.069 and 0.063, respectively), but were not reflected in FFB yield.

Table 1.21 Main effect of treatment (averaged across other treatments) on FFB yield and yield components in 2000 (Trial 126).

	Treatment and level			p	s.e.d.	CV%
	AMS0	**AMS1**	**AMS2**			
Yield (t/ha)	31.6	33.2	34.6	**0.025**	3.5	10.4
Bunches/ha	1272	1280	1289	0.936	158.9	12.4
kg/bunch	25.7	26.6	27.6	**0.040**	2.4	9.2
	TSP0	**TSP1**				
Yield (t/ha)	32.7	33.5		0.337	3.5	10.4
Bunches/ha	1287	1273		0.709	158.9	12.4
kg/bunch	26.0	27.2		0.069	2.4	9.2
	MOP0	**MOP1**	**MOP2**			
Yield (t/ha)	33.6	33.9	31.8	0.107	3.5	10.4
Bunches/ha	1324	1291	1226	0.118	158.9	12.4
kg/bunch	26.2	27.1	26.5	0.436	2.4	9.2
	KIE0	**KIE1**				
Yield (t/ha)	32.4	33.9		0.080	3.5	10.4
Bunches/ha	1267	1294		0.476	158.9	12.4
kg/bunch	26.2	27.0		0.200	2.4	9.2
	Salt 0	**Salt 1**				
Yield (t/ha)	33.1	33.1		0.968	3.5	10.4
Bunches/ha	1305	1255		0.200	158.9	12.4
kg/bunch	26.1	27.2		0.063	2.4	9.2

In 1998-2000, FFB yield was significantly increased by application of ammonium sulphate, magnesium sulphate and sodium chloride (Table 1.22). The interaction between triple superphosphate and magnesium sulphate was also significant; both fertilisers had a positive effect on yield only where none of the other had been applied (Table 1.23). The effects of fertilisers on FFB yield were largely related to single bunch weights rather than number of bunches/ha.

Table 1.22 Main effects of fertilisers (averaged across other treatments) on FFB yield and yield components over the 1998-2000 period (Trial 126).

	Treatment and level			p	s.e.d.	CV%
	AMS0	**AMS1**	**AMS2**			
Yield (t/ha)	28.6	29.4	30.3	**0.037**	2.04	6.9
Bunches/ha	1207	1209	1202	0.978	110	9.1
kg/bunch	24.2	24.7	25.8	**0.014**	1.7	6.8
	TSP0	**TSP1**				
Yield (t/ha)	29.1	29.8		0.170	2.04	6.9
Bunches/ha	1212	1201		0.664	110	9.1
kg/bunch	24.5	25.3		0.056	1.7	6.8
	MOP0	**MOP1**	**MOP2**			
Yield (t/ha)	29.2	29.9	29.2	0.425	2.04	6.9
Bunches/ha	1222	1221	1176	0.270	110	9.1
kg/bunch	24.5	25.0	25.2	0.312	1.7	6.8
	KIE0	**KIE1**				
Yield (t/ha)	28.9	30.0		**0.031**	2.04	6.9
Bunches/ha	1198	1214		0.545	110	9.1
kg/bunch	24.6	25.2		0.115	1.7	6.8
	Salt 0	**Salt 1**				
Yield (t/ha)	28.9	30.0		**0.042**	2.04	6.9
Bunches/ha	1202	1211		0.724	110	9.1
kg/bunch	24.5	25.3		0.056	1.7	6.8

Table 1.23 Effect of two-way interaction between TSP and kieserite on FFB yield (t/ha/year) in 1998-2000 (Trial 126).

TSP.KIE, p = **<0.001** l.s.d. = 1.2

	KIE0	**KIE1**
TSP0	27.6	30.6
TSP1	30.2	29.4

CONCLUSION

In this trial, the major response in 2000 was a positive effect of N fertiliser on FFB yield. Positive effects of N, P, Mg and Cl on yield were noted over the 1998-2000 period.

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.

DESCRIPTION

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.
Treatments applications will start 36 months after planting

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 and kieserite is applied to all plots receiving fertiliser. The fertiliser is applied on either the weeded circle or on the frond pile. The six treatments (Table 1.24) are arranged in a randomised complete block design with 4 replicates.

Table 1.24. Treatments in Trial 129a

Treatment Number	Crop Residue	Fertiliser Applied (kg/palm/yr)	Fertiliser Placement
1	EFB	3 kg AMC & 3 kg KIE	Weeded Circle
2	EFB	3 kg AMC & 3 kg KIE	Frond Pile
3	EFB	Nil	-
4	Nil	3 kg AMC & 3 kg KIE	Weeded Circle
5	Nil	3 kg AMC & 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 1.25). The four treatments are arranged in a randomised complete block design with 8 replications.

Table 1.25. Treatments in Trial 129b.

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

RESULTS

The year 2000 was the second year of yield recording for trial 129. No tissue analyses were conducted. Results of trial a and b were analysed together for the 2000 and 1999-2000 periods (Table 1.26).

Table 1.26 Analysis structure for 2000 results (Trial 129)

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

There were no significant effects of treatments in 2000 (Table 1.27) or 1999-2000 (Table 1.28). Mean annual FFB yields over the whole trial were high at 34.1 t/ha in 2000 and 30.5 t/ha in 1999-2000, primarily due to high numbers of bunches. The lack of treatment effects was also reported in the results from 1999. It is probably due to a) high levels of nutrients in the soil, indicated by the high yields in the control plots, and b) the short time that the trial has run. We would expect it to take several years for differences in organic matter contents to establish in soil under the weeded circle, frond pile and EFB application zones, and thereby influencing retention and supply of N and Mg.

Table 1.27. Effects of treatments on FFB yield and yield components in 2000 (Trial 129).

Treatment	Yield (t/ha)	Bunches/ha	kg/bunch
1	32.7	2426	13.6
2	35.0	2468	14.5
3	35.2	2584	14.0
4	34.1	2620	13.3
5	33.7	2554	13.4
6	34.7	2554	13.8
7	33.7	2592	13.4
p	0.580	0.517	0.334
s.e.d.	2.27	174	0.900
CV%	6.7	6.8	6.6

Table 1.28. Effects of treatments on FFB yield and yield components in 1999-2000 (Trial 129).

Treatment	Yield (t/ha)	Bunches/ha	kg/bunch
1	29.9	2239	13.6
2	31.6	2301	14.1
3	31.0	2400	13.2
4	30.3	2409	13.0
5	30.2	2358	13.2
6	30.7	2331	13.5
7	30.7	2397	13.3
p	0.443	0.675	0.603
s.e.d.	1.27	179	1.04
CV%	4.2	7.6	7.8

CONCLUSION

There have been no significant effects of fertiliser placement on yields in the first and second years of this trial.

Trial 135 Effect of Fertiliser on Incidence and Severity of Crown Disease, Garu and Kumbango Plantations

PURPOSE

To determine if high levels of fertiliser and boron have any effect on incidence and severity of crown disease.

DESCRIPTION

Site: Two sites, one (Trial 271) at Garu Plantation, Road 13-14, Avenue 4-5. The other (Trial 272) at Kumbango Plantation, Field C12-C13.

Soil: Young free draining, formed on alluvially redeposited pumiceous sands, gravel and volcanic ash. At Garu the site has recently been cleared from primary rainforest and sago swamp whilst on Kumbango the site has been under oil palm for 20 years.

Palms: Four selected Dami DxP progenies known to be susceptible to crown disease were chosen and are described in the 1999 report. Both sites were planted in December 1998 at 120 palms/ha.

BACKGROUND

This is a joint research project between Dami OPRS and PNGOPRA. There is evidence that crown disease is a genetic disorder but there are reports that boron and possibly high nitrogen levels during the immature phase may also be linked with expression of the disease. The trial has been planned as an agro-genetic trial.

DESIGN

There were supposed to be three progenies planted in the trial with palms planted in plots of 12 palms. There are 3 nitrogen fertiliser regimes and two levels of Boron (0, 40g/palm). The 18 treatments were supposed to be planted as three replicates of a 3x3x2 factorial at Garu and Kumbango Plantation with treatments arranged in blocks of 6. The actual field planting has consisted of 4 progenies, which makes the design unbalanced and therefore should not be regarded as a 3x3x2 factorial. Rothamstead will continue to be consulted to look into ways of further analysing the trial.

Fertiliser application commenced in January 1999. The plots receiving Boron will have 40g Borax/palm applied 3 months after planting. Details of nitrogen fertiliser schedules and recording procedure were reported in the 1999 Report.

Data were collected by Dami OPRS until the end of 2001. It was decided to continue the trial as a fertiliser x progeny trial from 2002 onwards, with recording carried out by OPRA.

RESULTS

Results from 2000 and 2001 will be reported next year.

Trial 136. Monthly Frond Sampling Trial

PURPOSE

The PNGOPRA Scientific Advisory Committee meeting in 1997 requested that monthly leaf sampling be conducted on New Britain Palm Oil Ltd plantations. This was to provide information on annual variations in leaf nutrient levels and to interpret the results of the annual plantation leaf sampling exercise. This trial commenced in early 1998 and will continue for a period of at least five years. Similar trials have been carried out in Oro in 1985-1987 (Trial 708, 1988 Annual Report) and Milne Bay in 1990 (Trial 508, 1990 Annual Report).

DESCRIPTION

Plantation sites selected for sampling are listed in the table below.

Table 1.29. 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 (replanting)	Behind Kumbango office
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

DESIGN

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

Fertiliser applications at each sampling site are 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 1.30. K and Mg contents generally appeared to be low and Ca contents high. In 2000, Haella had the highest N, P, K, Mg and Cl contents of the five sites. Kumbango had the highest Ca content and lowest K, Mg and B contents. Malilimi had the lowest N, P and Cl contents. Over the three year period, there has been a consistent downward trend for P at Malilimi and Kautu, Ca at Haella, Malilimi and Kautu, and Mg at Haella, Bilomi and Kautu. Other nutrients have not shown consistent trends over the three year period.

At all sites, leaflet contents of P, K, Mg, Ca and Cl stayed fairly constant throughout the year, showing no obvious response to rainfall or fertiliser applications (Tables 1.31-1.35 and Figure 1.1). Nitrogen content tended to decline through the year at all sites except Bilomi. Malilimi was unusual in that there was a period of high N content following the September fertiliser application. At the one site where MOP was added (Malilimi), rachis K responded. Rachis K also tended to fluctuate at the other sites, decreasing through the year at Haella and increasing then decreasing at Kumbango. B fluctuated through the year. An increase between June and October in Kautu and Bilomi appeared to occur during a series of dry months in both cases. In Malilimi, B content increased markedly in December following application of borax.

Table 1.30. Mean annual tissue nutrient concentrations for the five sites in 1998 – 2000

Site	Nutrient	1998	1999	2000
Haella	Nitrogen	2.62	2.42	2.61
Kumbango	(%)	2.38	2.38	2.42
Malilimi		2.26	2.38	2.33
Bilomi		2.37	2.34	2.34
Kautu		2.46	2.38	2.42
Haella	Phosphorus	0.160	0.158	0.158
Kumbango	(%)	0.146	0.143	0.146
Malilimi		0.141	0.138	0.137
Bilomi		0.148	0.138	0.140
Kautu		0.157	0.153	0.150
Haella	Potassium	0.81	0.81	0.80
Kumbango	(%)	0.69	0.76	0.68
Malilimi		0.67	0.73	0.69
Bilomi		0.66	0.79	0.69
Kautu		0.72	0.74	0.72
Haella	Calcium	0.92	0.88	0.85
Kumbango	(%)	0.97	0.89	0.92
Malilimi		0.91	0.85	0.83
Bilomi		0.93	0.82	0.86
Kautu		0.79	0.70	0.68
Haella	Magnesium	0.26	0.23	0.21
Kumbango	(%)	0.17	0.14	0.14
Malilimi		0.16	0.15	0.15
Bilomi		0.18	0.17	0.15
Kautu		0.24	0.23	0.19
Haella	Chlorine	0.69	0.71	0.63
Kumbango	(%)	0.59	0.62	0.59
Malilimi		0.46	0.48	0.44
Bilomi		0.57	0.61	0.50
Kautu		0.49	0.50	0.44
Haella	Boron		13.4	14.0
Kumbango	(ppm)		11.4	11.9
Malilimi			12.4	15.0
Bilomi			11.9	14.6
Kautu			12.9	15.5

Table 1.31. Rainfall, fertiliser applications and tissue nutrient concentrations at Kautu in 2000

Month	Rainfall (mm)	Fertiliser *	Element as % DM								
			Ash	N	P	K	Mg	Ca	B (mg/kg)	Cl	Rachis K
Jan	514		15.15	2.67	0.158	0.63	0.24	0.70	15.1	0.39	0.81
Feb	343		13.35	2.55	0.152	0.81	0.14	0.60	15.5	0.45	1.22
Mar	460		15.09	2.43	0.152	0.71	0.21	0.69	17.8	0.38	1.34
Apr	260		13.81	2.50	0.158	0.73	0.15	0.60	14.2	0.47	1.16
May	417		13.81	2.50	0.158	0.73	0.15	0.60	14.2	0.47	1.26
Jun	500		14.12	2.31	0.155	0.75	0.20	0.69	14.2	0.42	1.38
Jul	129	AMN	15.62	2.30	0.143	0.67	0.16	0.90	13.9	0.51	0.83
Aug	346		14.00	2.49	0.150	0.73	0.17	0.62	14.8	0.40	1.07
Sept	57		14.24	2.34	0.154	0.79	0.18	0.67	15.3	0.54	1.26
Oct	212		12.97	2.30	0.144	0.71	0.26	0.58	16.4	0.38	0.69
Nov	304		14.40	2.42	0.157	0.69	0.22	0.76	18.8	0.47	1.03
Dec	297		14.87	2.19	0.149	0.69	0.23	0.71	15.9	0.44	1.03
Total:	**3,859**	**Mean:**	**14.29**	**2.42**	**0.150**	**0.72**	**0.19**	**0.68**	**15.51**	**0.44**	**1.09**

* *Annual rate of application =2.9 kg/palm*

Table 1.32. Rainfall, fertiliser applications and tissue nutrient concentrations at Bilomi in 2000

Month	Rainfall (mm)	Fertiliser *	Element as % DM								
			Ash	N	P	K	Mg	Ca	B (mg/kg)	Cl	Rachis K
Jan	483		16.62	2.37	0.137	0.75	0.16	0.95	15.6	0.55	1.66
Feb	321		14.24	2.53	0.145	0.79	0.17	0.85	14.9	0.60	1.54
Mar	332		18.01	2.32	0.135	0.65	0.16	1.01	18.1	0.47	0.95
Apr	328		14.11	2.46	0.148	0.71	0.22	0.88	14.6	0.57	1.38
May	352	AMC	16.44	2.28	0.135	0.63	0.12	0.74	13.1	0.43	1.07
Jun	286		16.54	2.27	0.145	0.61	0.16	1.00	11.0	0.45	1.38
Jul	205		14.59	2.32	0.157	0.69	0.2	0.62	14.1	0.41	1.34
Aug	237		15.64	2.31	0.135	0.61	0.12	0.80	14.9	0.45	1.42
Sept	160	AMC	15.91	2.29	0.138	0.75	0.13	0.84	14.8	0.52	1.50
Oct	244		16.99	2.21	0.141	0.67	0.16	0.86	13.3	0.51	1.30
Nov	234		16.69	2.18	0.132	0.69	0.13	0.89	15.4	0.52	1.62
Dec	234		15.55	2.52	0.132	0.71	0.12	0.86	15.4	0.52	1.50
Total:	**3416**	**Mean:**	**15.94**	**2.34**	**0.14**	**0.69**	**0.15**	**0.86**	**14.60**	**0.50**	**1.39**

* *Annual rate of application =3kg/palm*

Table 1.33. Rainfall, fertiliser applications and tissue nutrient concentrations at Malilimi in 2000

Month	Rainfall (mm)	Fertiliser*	Element as % DM								
			Ash	N	P	K	Mg	Ca	B (mg/kg)	Cl	Rachis K
Jan	250		14.74	2.44	0.137	0.57	0.11	0.70	13.8	0.39	0.83
Feb	80		14.8	2.36	0.136	0.67	0.11	0.78	16.2	0.46	1.07
Mar	277		15.66	2.32	0.136	0.75	0.15	0.82	16.5	0.40	0.87
Apr	262		15.44	2.25	0.137	0.67	0.16	0.85	15.3	0.44	0.95
May	761	AMN	14.72	2.26	0.136	0.69	0.14	0.80	14.2	0.41	0.93
Jun	311		15.10	2.23	0.144	0.69	0.16	0.86	13.2	0.45	0.93
Jul	443		15.22	2.11	0.135	0.69	0.15	0.83	15.1	0.42	0.81
Aug	424		14.88	2.24	0.141	0.73	0.17	0.82	14.7	0.46	1.26
Sep	157	AMN	15.59	2.74	0.134	0.71	0.14	0.81	13.5	0.45	1.07
Oct	131		15.80	2.65	0.143	0.69	0.16	0.90	14.0	0.45	1.22
Nov	444	Borax	15.18	2.19	0.132	0.77	0.15	0.84	10.9	0.48	1.12
Dec	477	MOP	16.34	2.22	0.142	0.71	0.18	0.91	23.0	0.51	1.78
Total:	**4017**	**Mean:**	**15.29**	**2.33**	**0.137**	**0.69**	**0.15**	**0.83**	**15.03**	**0.44**	**1.07**

* *Annual rate of application, AMN = 4 kg/palm, Borax = 200 g/palm, MOP = 2 kg/palm*

Table 1.34. Rainfall, fertiliser applications and tissue nutrient concentrations at Kumbango in 2000

Month	Rainfall (mm)	Fertiliser*	Element as % DM								
			Ash	N	P	K	Mg	Ca	B (mg/kg)	Cl	Rachis K
Jan	176		15.05	2.50	0.142	0.47	0.10	0.80	12.4	0.52	1.30
Feb	113		15.81	2.63	0.142	0.67	0.11	0.83	12.1	0.57	1.50
Mar	270	AMC	15.98	2.43	0.139	0.69	0.12	0.87	13.0	0.56	1.54
Apr	135		15.17	2.41	0.141	0.79	0.15	0.86	12.2	0.57	1.46
May	261		14.44	2.48	0.152	0.75	0.15	0.88	10.9	0.56	1.42
Jun	84	AMC	15.43	2.33	0.151	0.71	0.15	0.98	11.8	0.69	1.66
Jul	95		15.38	2.50	0.148	0.69	0.15	0.83	12.8	0.63	1.58
Aug	221		16.36	2.44	0.154	0.71	0.15	1.01	12.2	0.64	1.74
Sep	59	Borax	16.20	2.46	0.147	0.69	0.14	0.99	12.0	0.64	1.74
Oct	134	Kieserite	15.97	2.40	0.149	0.67	0.14	1.02	12.4	0.59	1.74
Nov	117		17.14	2.17	0.148	0.73	0.14	0.98	10.5	0.58	1.95
Dec	283	Kieserite	16.89	2.35	0.143	0.69	0.13	1.00	10.9	0.54	1.30
Total:	**1,949**	**Mean:**	**15.81**	**2.42**	**0.146**	**0.68**	**0.14**	**0.92**	**11.9**	**0.59**	**1.57**

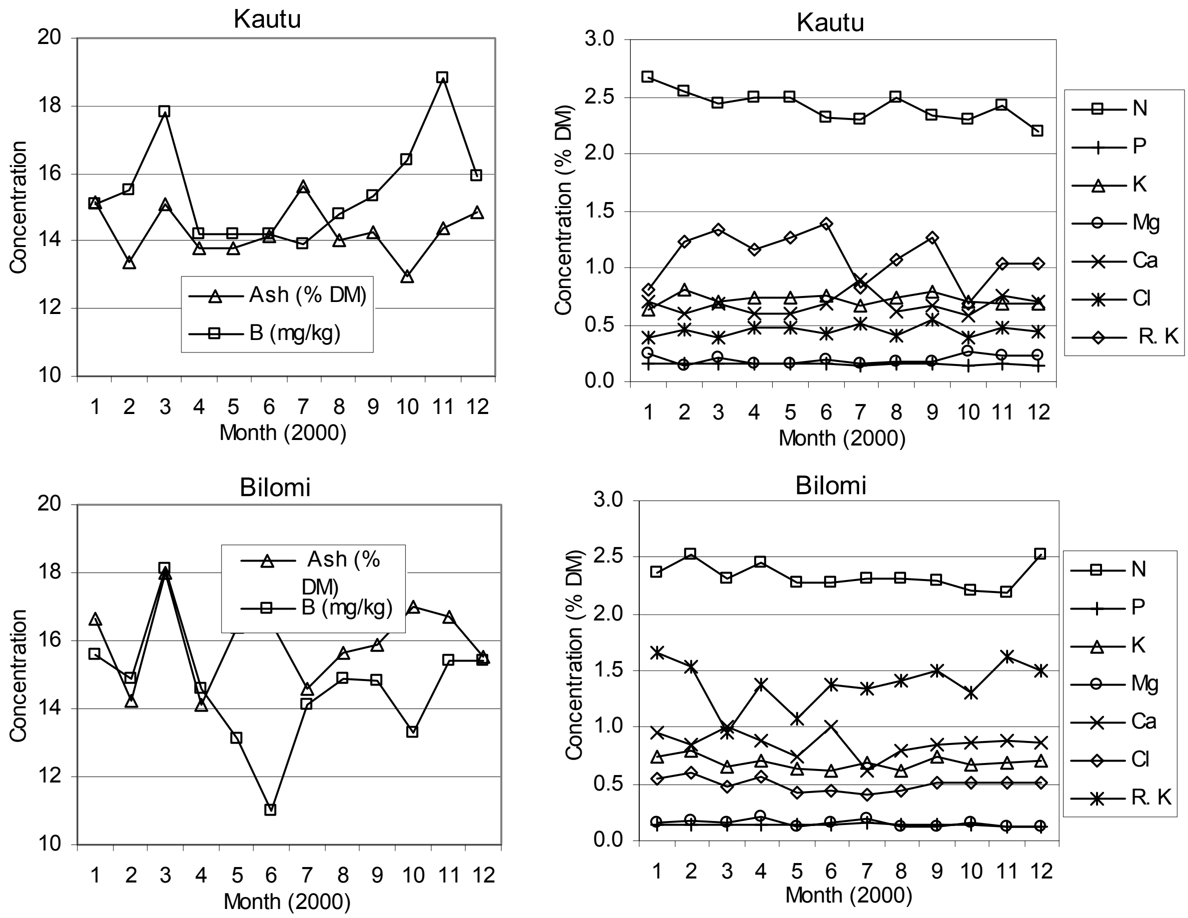
* *Annual rate of application, AMC = 4 kg/palm, Kieserite = 3 kg/palm, Borax = 200 g/palm*

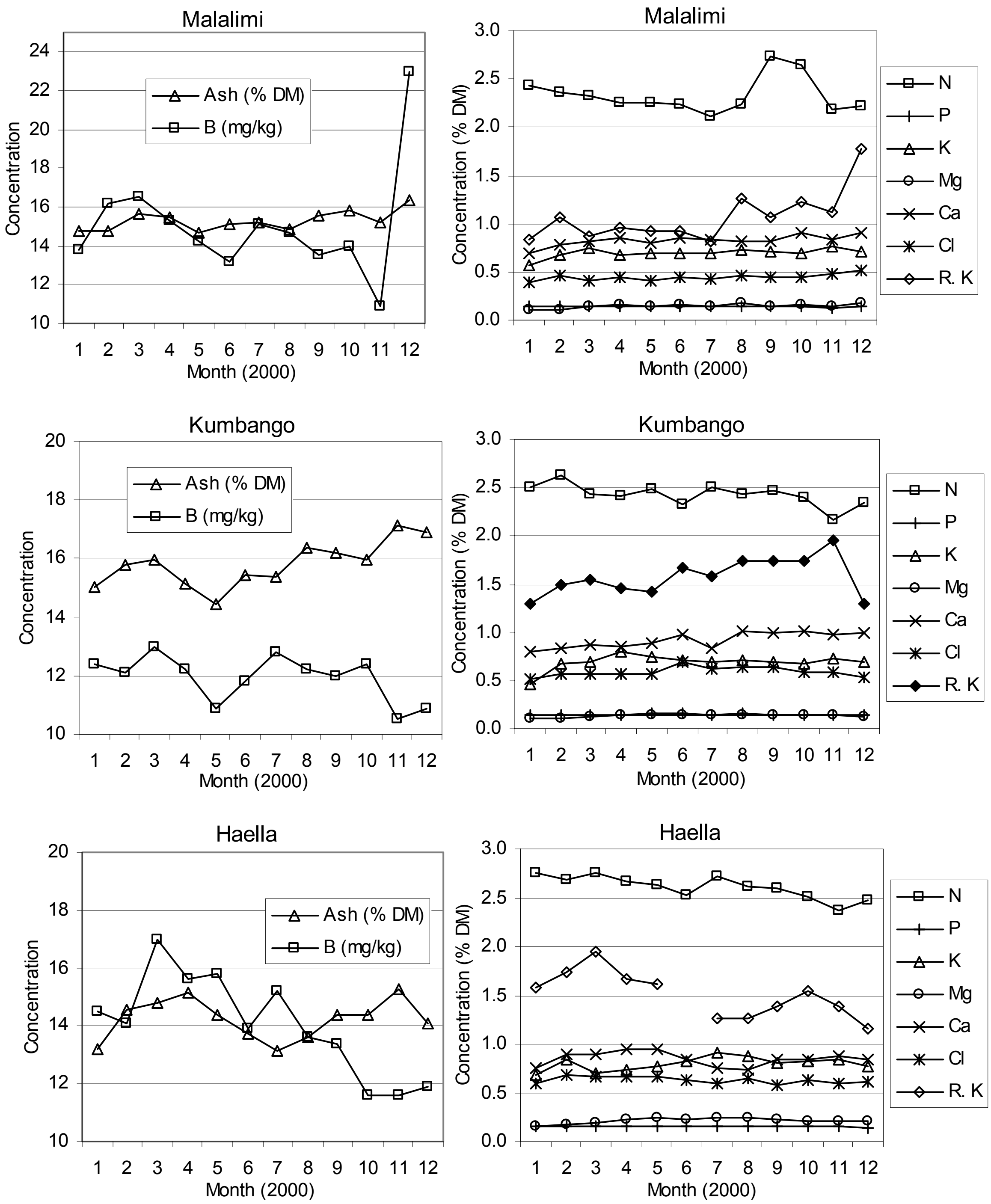
Table 1.35. Rainfall, fertiliser applications and tissue nutrient concentrations at Haella in 2000

Month	Rainfall (mm)	Fertiliser *	Element as % DM								
			Ash	N	P	K	Mg	Ca	B (mg/kg)	Cl	Rachis K
Jan	486		13.2	2.75	0.157	0.69	0.15	0.75	14.5	0.6	1.58
Feb	199		14.56	2.68	0.158	0.85	0.17	0.9	14.1	0.68	1.74
Mar	452		14.79	2.75	0.157	0.71	0.2	0.9	17	0.66	1.95
Apr	185		15.17	2.66	0.158	0.73	0.23	0.94	15.6	0.66	1.66
May	357		14.39	2.63	0.157	0.77	0.24	0.94	15.8	0.67	1.62
Jun	82	AMC	13.74	2.52	0.16	0.83	0.23	0.84	13.9	0.64	~
Jul	150		13.13	2.72	0.164	0.91	0.24	0.76	15.2	0.6	1.26
Aug	309		13.58	2.61	0.165	0.87	0.24	0.74	13.6	0.65	1.26
Sep	72		14.37	2.59	0.165	0.81	0.23	0.84	13.4	0.58	1.38
Oct	171		14.35	2.51	0.155	0.83	0.21	0.84	11.6	0.63	1.54
Nov	308	Borax	15.27	2.37	0.161	0.85	0.21	0.87	11.6	0.59	1.38
Dec	333		14.08	2.48	0.144	0.77	0.21	0.84	11.9	0.62	1.16
Total:	**3,104**	**Mean:**	**14.22**	**2.61**	**0.158**	**0.80**	**0.21**	**0.85**	**14.0**	**0.63**	**1.50**

* *Annual rate of application , AMC = 3 kg/palm , Borax = 200 g/palm. ~ missing data*

Figure 1.1. Graphs of leaflet nutrient contents and rachis K content during 2000 (Trial 136).





CONCLUSION

Most nutrient contents remained fairly constant during the year, indicating a high degree of buffering in the soil/plant system. Nitrogen content declined slightly through the year at some sites. Only B and rachis K contents appeared to fluctuate in response to rainfall or fertiliser application.

Trial 137 Systematic N Fertiliser Trial, Kumbango

PURPOSE

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

BACKGROUND

The fertiliser trials at NBPOL are currently designed with factorial treatment combinations laid out in a randomised block structure. The plots are large, consisting of an array of 6x6 palms, the central 4x4 being recorded. To date many of these trials have shown little response to increased doses of fertilisers. At other sites, Popondetta and Hargy this phenomenon has not occurred with distinct response curves being achieved. This non-response is now considered to be a product of the environment at NBPOL.

Detailed examination of the data for Trial 401, 402 and 107 have indicated two problems:

a) There is a distinct possibility that N and possible K fertilisers are spreading from plot to plot despite trenching between the plot boundaries,

b) the scale of variation within the experimental area is such that groups of plots are located within patches of particular soil fertility, thus confounding the effects of applied fertilisers, particularly nitrogen, with soil fertility.

The implications are that continuation of the trials with this structure will not result in any changes to the patterns of response achieved so far. The trials are large and expensive and consideration of an alternative design structure appears now to be necessary.

DESIGN

The main factor for which estimation of a response is required is nitrogen with potassium as a secondary factor. Phosphorus and magnesium are unlikely to demonstrate yield increases but may need to be applied to maintain nutrient levels.

In the 1999 Scientific Advisory Committee meeting the trial design was revised. It was approved to have 4 rows per treatment instead of two as previously proposed and to have 9 levels of N treatments in a replication. The 9th treatment will not however be recorded.

Each plot will consist of 36 rows of 16 palms. Each of nine levels of N (N0, N1.....N8 kg/palm) should be applied to the consecutive four rows thus providing a systematic increase in N dosage. Thus in one rep the levels of N increase across each four rows of palm from left to right. In the neighbouring plot the plot is structured the same way, except that the increase in fertiliser runs from right to left. This is planned so that any unknown fertility trend is not confounded with the direction of increase of the N application.

If required two levels of K can be applied as well. To accommodate the systematic structure of the N applications, each level of K should be applied to one of the two plots. These treated plots should be replicated as many times as possible within the limits that space and labour permit. A minimum of two replicates is required to estimate the effect of K application at each of the N levels and to estimate the effect of increased doses of N at each of the K levels.

The experiment should be continued for at least 5 years

PROGRESS

A site has been identified at Kumbango Plantation for this trial. This field was replanted in October 1999. Plots were marked out in 2000. The systematic fertiliser trial will commence following 36 months of the standard immature fertiliser schedule.

Trial 138a Systematic N Fertiliser Trial, Haella

PURPOSE

To determine the response to N fertiliser, taking into account the factors discussed in the Trial 137 report.

DESIGN

This trial was approved at the 1999 SAC meeting. The site consists of 18 rows of palms, each 32 palms long. Each of the nine treatment levels of N (N0 – N8) will be applied to consecutive pairs of rows. A site has been identified and mapped out in the 1995 planting.

PROGRESS

Pre-treatment sampling and rachis W x T measurements have been carried out in 2001.

Trial 138b Systematic N Fertiliser Trial, Haella

PURPOSE

To determine the response to N fertiliser, taking into account the factors discussed in the Trial 137 report.

DESIGN

This trial was approved at the 1999 SAC meeting. The site consists of 36 rows of palms, each 16 palms long. Each of the nine treatment levels of N (N0. – N8) will be applied to four rows of palms. A site has been identified and mapped out in the 1995 planting.

PROGRESS

Pre-treatment sampling and rachis W x T measurements have been carried out in 2001.

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.

DESIGN

The field layout will comprise three replicates for each of the three spacing arrangements, which will give a total of nine plots. The planting density remains constant at 128 palms per hectare. The tree spacing regimes are: a) standard 9.5 m triangular spacing, b) and avenue width of 9.5 m between the rows and 9 m between palms, and c) an avenue width of 10.6 m between rows and 8.6 m between palms.

PROGRESS

A site has been identified and plots laid out in 2001. Palms are receiving the immature phase fertiliser regime.

Trial 204 Factorial Fertiliser Trial at Navo Plantation.

PURPOSE

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

DESCRIPTION

Site Navo Plantation, Area 8, Blocks 10 and 11.

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

Palms Dami commercial DxP crosses.
Planted in 1986 at 115 palms/ha.
Treatments started in May 1989.

DESIGN

There are 36 treatments, comprising all factorial combinations of N and P at three levels and K and Mg each at two levels (Table 1.36)

Table 1.36 Rates of fertiliser and their approximate main element contents (Trial 204).

	Level (kg /palm/year)		
	0	1	2
Ammonium chloride	0	3	6
Triple superphosphate	0	2	4
Potassium chloride	0	3	---
Kieserite	0	3	---

Note: Treatments are factorial combinations of levels of these fertilisers.

The ammonium chloride is split into two applications per year while the other fertilisers are applied once per year.

There are 72 plots, each plot consisting of 36 palms (6x6), of which the central 16 are recorded. The 36 treatments are replicated twice and are grouped into two blocks. The trial was designed as a 3x3x2x2x2 factorial trial, but one 'x2' factor has been left "vacant" and is regarded as replication for the time being. The "vacant" treatment will be used later. The 3-factor interaction '2x2x2' is confounded with blocks. High order interactions provide the error term in the statistical analysis.

RESULTS

During the 1998-2000 period, yield and both its components were significantly improved by ammonium chloride application (Table 1.37); neither the other fertilisers, nor their interactions with ammonium chloride, had significant effects on yield. The effect of AMC was greatest between the rates of 0 and 3 kg/palm/yr, with a slight further improvement at the higher application rate (Table 1.37). The single bunch weight component of yield however was significantly influenced by interactions between the fertilisers (Table 1.38).

In 2000, the only significant effect was that of ammonium chloride, which significantly improved single bunch weight, number of bunches and FFB yield. The effect was greatest between the rates of 0 and 3 kg/palm/yr, with a slight further improvement at the higher application rate (Table 1.39).

CONCLUSION

The only consistently significant fertiliser response in this trial over the 1998-2000 period was a large positive effect of ammonium chloride (due to N) on yield and both its components.

Table 1.37 Main effect of ammonium chloride on FFB yield and yield components in 1998-2000, averaged across all other treatments (Trial 204). P values for significant results are shown in bold.

	Treatment and level			p	s.e.d.	CV%
	AMC0	**AMC1**	**AMC2**			
Yield (t/ha)	20.5	27.3	29.0	**<0.001**	2.9	11.4
Bunches/ha	966	1965	1120	**<0.001**	129	12.3
kg/bunch	21.4	26.0	26.2	**<0.001**	1.3	5.3
	TSP0	**TSP1**	**TSP2**			
Yield (t/ha)	25.9	24.8	26.1	0.267	2.9	11.4
Bunches/ha	1054	1020	1078	0.305	129	12.3
kg/bunch	25.0	24.4	24.3	0.150	1.3	5.3
	MOP0	**MOP1**				
Yield (t/ha)	25.6	25.6		0.899	2.9	11.4
Bunches/ha	1051	1050		0.987	129	12.3
kg/bunch	24.6	24.4		0.472	1.3	5.3
	KIE0	**KIE1**				
Yield (t/ha)	26.0	25.2		0.301	2.9	11.4
Bunches/ha	1068	1033		0.254	129	12.3
kg/bunch	24.4	24.6		0.470	1.3	5.3

Table 1.38. Significant effects of fertilisers (interactions with p<0.05) on single bunch weight (kg/bunch) in 1998-2000. L.s.d. is 1.9 for the AMC.TSP.KIE interaction and 1.5 for the TSP.MOP.KIE interaction. Single bunch weights of 25 kg or greater are highlighted (Trial 204).

	TSP 0		**TSP 1**		**TSP 2**	
	KIE 0	**KIE 1**	**KIE 0**	**KIE 1**	**KIE 0**	**KIE 1**
AMC 0	23.4	20.6	19.7	21.3	21.4	21.9
AMC 1	**26.9**	**27.5**	**25.6**	**26.2**	**25.7**	24.3
AMC 2	24.8	**26.5**	**26.0**	**27.4**	**26.3**	**26.0**
	MOP 0		**MOP 1**			
	KIE 0	**KIE 1**	**KIE 0**	**KIE 1**		
TSP 0	**25.4**	**25.2**	24.7	24.6		
TSP 1	23.4	**25.4**	24.1	24.6		
TSP 2	25.0	23.5	23.9	24.7		

Table 1.39 Main effect of ammonium chloride on annual FFB yield and number of bunches in 2000, averaged across all other treatments (Trial 204). Significant results are shown in bold.

	Treatment and level			p	s.e.d.	CV%
	AMC0	**AMC1**	**AMC2**			
Yield (t/ha)	18.9	27.1	29.1	**<0.001**	4.4	17.4
Bunches/ha	850	1028	1101	**<0.001**	164	16.5
kg/bunch	22.3	26.4	26.6	**<0.001**	1.8	7.0
	TSP0	**TSP1**	**TSP2**			
Yield (t/ha)	25.7	23.9	25.5	0.304	4.4	17.4
Bunches/ha	1017	950	1012	0.295		
kg/bunch	25.3	25.1	25.0	0.876	1.8	7.0
	MOP0	**MOP1**				
Yield (t/ha)	25.1	25.0		0.919	4.4	17.4
Bunches/ha	1001	985		0.675	164	16.5
kg/bunch	25.1	25.2		0.747	1.8	7.0
	KIE0	**KIE1**				
Yield (t/ha)	24.9	25.1		0.841	4.4	17.4
kg/bunch	25.3	24.9		0.301	1.8	7.0

Trial 205 EFB x Fertiliser Trial at Hargy Plantation

PURPOSE

To investigate the response of oil palm to applications 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.

DESCRIPTION

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

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

Palms Dami identified DxP crosses.
Planted in July and August 1993 at 135 palms/ha.
Treatments to start 36 months after planting.

DESIGN

There are eight treatments comprising all factorial combinations of EFB, triple superphosphate and kieserite each at two levels (Table 1.40). The treatments are replicated six times, with each replicate comprising one block. 36 palm plots (6x6 palms) are used, the central 16 palms are recorded and the outer 20 palms are regarded as guard row palms. The recorded palms comprise 16 different identified Dami DxP progenies that have been arranged in a random spatial configuration in each plot. The 16 progenies are shown in Table 1.41

Table 1.40. Fertiliser and EFB treatments used in Trial 205.

Treatment	EFB (kg/palm/yr)	TSP (kg/palm/yr)	Kieserite (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 1.41 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

During the1998-200 period, yields were high and while triple superphosphate and EFB both had significant positive effects, the interaction was not significant. The effects on yield were due to increases in bunch weights (Table 1.42); number of bunches was not significantly affected. In 2000 yields were particularly high and the treatment effects were similar to the 1998-2000 period, although not as pronounced (Table 1.43).

Table 1.42. Main treatment effects on FFB yield and yield component in 1998-2000 (Trial 205). P values for significant results are shown in bold.

	Treatment and level		P	s.e.d.	CV%
	TSP0	**TSP1**			
Yield (t/ha)	33.8	35.4	**0.002**	1.7	4.8
Bunches/ha	2656	2705	0.178	123	4.6
kg/bunch	12.8	13.1	**0.006**	0.39	3.0
	KIE0	**KIE1**			
Yield (t/ha)	34.3	34.8	0.342	1.7	4.8
Bunches/ha	2673	2688	0.659	123	4.6
kg/bunch	12.9	13.0	0.385	0.39	3.0
	EFB0	**EFB1**			
Yield (t/ha)	33.9	35.2	**0.012**	1.7	4.8
Bunches/ha	2665	2696	0.394	123	4.6
kg/bunch	12.8	13.2	**0.005**	0.39	3.0

Table 1.43 Main treatment effects of yield and yield component on FFB yield for 2000 (Trial 205). P values for significant results are shown in bold.

	Treatment and level		p	s.e.d.	CV%
	TSP0	**TSP1**			
Yield (t/ha)	42.6	44.4	0.081	3.4	7.9
Bunches/ha	2870	2926	0.325	196	6.8
kg/bunch	15.0	15.3	0.078	0.64	4.3
	KIE0	**KIE1**			
Yield (t/ha)	43.5	43.5	0.997	3.4	7.9
Bunches/ha	2886	2910	0.674	196	6.8
kg/bunch	15.2	15.1	0.441	0.64	4.3
	EFB	**EFB1**			
Yield (t/ha)	43.3	43.7	0.724	3.4	7.9
Bunches/ha	2920	2876	0.445	196	6.8
kg/bunch	14.9	15.3	**0.049**	0.64	4.3

CONCLUSION

During the 1998-2000 period, triple superphosphate and EFB both had significant positive effects on yield, with no significant interaction between them. Kieserite had no significant effect on yield.

Trial 209 Factorial Fertiliser Trial at Hargy Plantation.

PURPOSE

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

DESCRIPTION

Site Blocks 4 and 6, Area 1, Hargy Plantation, Bialla, WNBP.

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

Palms Dami commercial DxP crosses.
Planted in October and November 1994 at 135 palms/ha.
Treatments commenced in June 1998 36 months after planting.

DESIGN

There are 81 treatments comprising all factorial combinations of ammonium sulphate, triple superphosphate, potassium chloride and kieserite each at three levels. There are 81 plots each consisting of 36 palms (6x6) of which the central 16 palms are recorded and the outer 20 are guard row palms. The 81 treatments are replicated only once and will be divided among nine blocks each of nine plots (Table 1.43).

Table 1.43. Fertiliser used in Trial 209.

	Level (kg /palm/year)		
	0	1	2
Ammonium sulphate	2	4	8
Triple superphosphate	0	4	8
Potassium chloride	0	2	4
Kieserite	0	4	8

PROGRESS

The trial was planted in October and November 1994. The site was surveyed and mapped, and plot 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 treatments were first applied in June 1998.

RESULTS

The mean FFB yield in this trial was 34.7 t/ha in 2000 and 31.5 t/ha over the 1999-2000 period. Several treatment interactions are confounded with blocks in this design. When blocks are taken into account, there were no significant effects of treatments on yield or its components in 1999-2000 or 2000. However, the main effects of ammonium sulphate and triple superphosphate were almost significant (p=0.086 and p=0.064, respectively) in 1999-2000. When blocks are ignored, the effect of most fertilisers was significant. The effect of the two significant three-way interactions on FFB yield in 1999-2000 is shown in Table 1.44. The main effect of all fertilisers except kieserite was significant (Table 1.45). The effects were primarily due to increases in bunch weights. In 2000, the interaction between all fertilisers except kieserite was again significant (Table 1.46), primarily due to the effect of ammonium sulphate and potassium chloride on single bunch weights. Main effects of fertilisers were not significant, but AMS and TSP had p values of 0.090 and 0.073 respectively (Table 1.47).

Table 1.44. The effects of the two significant three-way interactions (AMS.TSP.MOP, p=0.008 and AMS.MOP.KIE, p=0.016) on FFB yield (t/ha/yr) in 1999-2000. Yields of 32 t/ha or greater are highlighted. Ls.d. is 1.3 for both interactions (Trial 209).

		MOP 0	**MOP 1**	**MOP 2**
AMS 0	**TSP 0**	30.0	28.9	30.3
	TSP 1	30.6	30.8	31.8
	TSP 2	**32.2**	**33.0**	31.8
AMS 1	**TSP 0**	27.9	28.9	**32.4**
	TSP 1	30.8	**33.2**	30.5
	TSP 2	29.8	31.6	**33.9**
AMS 2	**TSP 0**	31.7	**33.3**	31.3
	TSP 1	**33.8**	30.2	**34.0**
	TSP 2	29.8	**34.0**	**33.7**
		KIE 0	**KIE 1**	**KIE 2**
AMS 0	**MOP 0**	**33.0**	30.6	29.2
	MOP 1	29.7	30.1	32.8
	MOP 2	**33.1**	30.3	30.4
AMS 1	**MOP 0**	29.1	30.6	28.8
	MOP 1	**32.8**	27.0	**33.9**
	MOP 2	**32.7**	**32.2**	**32.0**
AMS 2	**MOP 0**	31.3	**32.8**	31.3
	MOP 1	31.4	**33.7**	**32.3**
	MOP 2	**32.1**	**33.1**	**33.7**

Table 1.45. Main effect of treatments on FFB yield and yield components for 1999-2000 (Trial 209). P values for significant effects are shown in bold.

	Treatment and level			p	s.e.d.	CV%
	AMS0	**AMS1**	**AMS2**			
Yield (t/ha)	31.0	31.0	32.4	**0.007**	0.44	5.1
Bunches/ha	2444	2514	2482	0.451	53.5	7.9
kg/bunch	12.9	12.4	13.3	**0.005**	0.22	6.4
	TSP0	**TSP1**	**TSP2**			
Yield (t/ha)	30.5	31.7	32.9	**0.004**	0.44	5.1
Bunches/ha	2427	2508	2505	0.262	53.5	7.9
kg/bunch	12.7	12.8	13.1	0.295	0.22	6.4
	MOP0	**MOP1**	**MOP2**			
Yield (t/ha)	30.8	31.5	32.2	**0.017**	0.44	5.1
Bunches/ha	2480	2473	2487	0.965	53.5	7.9
kg/bunch	12.5	12.9	13.1	**0.047**	0.22	6.4
	KIE0	**KIE1**	**KIE2**			
Yield (t/ha)	31.7	31.2	31.6	0.448	0.44	5.1
Bunches/ha	2488	2486	2465	0.895	53.5	7.9
kg/bunch	12.9	12.7	13.0	0.405	0.22	6.4

Table 1.46. The effects of the significant three-way interaction **(p=0.013**) on FFB yield (t/ha/yr) in 2000. Yields of 36 t/ha or greater are highlighted. L.s.d. is 2.8 (Trial 209).

		MOP 0	MOP 1	MOP 2
AMS 0	**TSP 0**	32.4	30.7	35.5
	TSP 1	32.5	32.5	35.3
	TSP 2	35.9	**38.7**	35.1
AMS 1	**TSP 0**	33.5	30.6	**36.0**
	TSP 1	**36.2**	34.3	30.7
	TSP 2	33.6	34.0	**35.6**
AMS 2	**TSP 0**	35.3	**38.6**	30.7
	TSP 1	**36.8**	32.1	**38.8**
	TSP 2	32.0	**38.1**	**40.6**

Table 1.47 Main treatment effect on yield and yield components for 2000 (Trial 209).

	Treatment and level			p	s.e.d.	CV%
	AMS0	**AMS1**	**AMS2**			
Yield (t/ha)	34.3	33.8	35.9	0.090	0.92	9.7
Bunches/ha	2888	2914	2923	0.911	82.7	10.4
kg/bunch	12.0	11.6	12.3	0.011	0.21	6.4
	TSP0	**TSP1**	**TSP2**			
Yield (t/ha)	33.7	34.4	35.9	0.073	0.92	9.7
Bunches/ha	2856	2891	2977	0.346	82.7	10.4
kg/bunch	11.8	12.0	12.1	0.326	0.21	6.4
	MOP0	**MOP1**	**MOP2**			
Yield (t/ha)	34.3	34.4	35.4	0.452	0.92	9.7
Bunches/ha	2942	2919	2891	0.687	82.7	10.4
kg/bunch	11.7	12.0	12.2	0.058	0.21	6.4
	KIE0	**KIE1**	**KIE2**			
Yield (t/ha)	34.7	34.5	34.9	0.901	0.92	9.7
Bunches/ha	2914	2919	2891	0.936	82.7	10.4
kg/bunch	12.0	11.8	12.1	0.440	0.21	6.4

CONCLUSION

In the 1999-2000 period, yields tended to be highest at the highest rates of N, P and K, irrespective of Mg application.

Trial 402 Factorial Fertiliser Trial at Bilomi Plantation.

PURPOSE

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

DESCRIPTION

Site Kapiura Estates, Bilomi Plantation, Division 2, Field 11C.

Soil Young coarse textured freely draining soils formed on alluvially redeposited andesitic pumiceous sands and volcanic ash.

Palms Dami commercial DxP crosses.
Planted in early 1987 at 120 palms/ha.
Treatments started in May 1990.

DESIGN

There are 36 treatments, comprising all factorial combinations of N and P at three levels and K and Mg each at two levels (Table 1.48).

Table 1.48. Fertiliser rates used in Trial 402 and their main element contents.

	Level (kg /palm/year)		
	0	1	2
Ammonium chloride	0	3	6
Triple superphosphate	0	2	4
Muriate of potash	0	3	---
Kieserite	0	3	---
		(t/ha/yr)	
EFB	0	50	---

Note: Treatments are factorial combinations of levels of these fertilisers.

The ammonium chloride is split into two applications per year, while the other fertilisers are applied only once. EFB applications started in mid 1993. EFB is applied with a Giltrap EFB applicator.

There are 72 plots, each plot consisting of 36 palms (6x6) of which the central 16 are recorded. The 72 treatments are replicated once and are grouped into two blocks. The 3 factor interaction '2x2x2' is confounded with blocks. High order interactions provide the error term in the statistical analysis.

RESULTS

The mean fresh fruit bunch (FFB) yield in 2000 over the trial was 31.6 t/ha (mean of 1336 bunches/ha and 24.1 kg/bunch). The only significant treatment effect was the positive effect of empty fruit bunch (EFB) on yield and number of bunches/ha, irrespective of other fertiliser treatments (Table 1.49).

Over the1998-2000 period, the mean annual FFB yield over the trial was 20.5 t/ha. There were no significant treatment effects on yield (Table 1.50). The mean number of bunches over the whole trial was 950/ha while the single bunch weight was at a mean of 21.4 kg/bunch. There was a positive effect of N on single bunch weight for the three-year period but this did not translate through to FFB yield.

The lack of response to N in 2000 and 1998-2000 was consistent with earlier results reported in the 1999 Agronomy Trials Report, and is discussed further in one of the proposed projects.

Tissue analysis results (leaf and rachis)
Most of the leaf nutrients were in the range of deficient to optimum levels except for Mg, which was deficient and Ca, which was in excess. Treatment effects are shown in Tables 1.51-1.52 and discussed below.

Nitrogen
In the absence of EFB, ammonium chloride increased leaf N. Where EFB was added leaf N was highest, and unaffected by ammonium chloride.

Phosphorus
In the absence of MOP, triple super phosphate increased leaf P. Where MOP was added; leaf P was moderate and unaffected by triple super phosphate application.

Potassium
Leaf K was highest in the presence of triple superphosphate and EFB.
Rachis K increased with the application of muriate of potash and EFB.

Magnesium
Leaf Mg increased with kieserite, irrespective of other treatments. As for interactions, leaf Mg was highest in the absence of muriate of potash and with zero or low levels of ammonium chloride.

Calcium
Leaf Ca was highest with added triple superphosphate but without Kieserite and EFB.

Boron
For Boron, there were several interactions between ammonium chloride, triple superphosphate and EFB.

Chlorine
Leaflet chlorine increased with all fertiliser types, but in the absence of these fertilisers, it tended to be higher with EFB applications.

CONCLUSION

During the whole period of the trial (10 years) there was no clear response to fertilisers. In 2000, there was a positive effect of EFB on yield irrespective of other fertilisers. While there were effects of fertilisers on leaf nutrients, this was not reflected in yields. The lack of response has not clearly been understood and is now part of a new proposal. This trial has closed and a final report will be written.

Table 1.49 Main effects of treatments on yield and yield components in 2000. P values for significant treatments are shown in bold (Trial 402).

	Treatment and level			p	s.e.d.	CV%
	AMC0	**AMC1**	**AMC2**			
Yield (t/ha)	30.8	32.0	32.0	0.282	2.8	9.0
Bunches/ha	1319	1354	1337	0.613	121	9.1
kg/bunch	23.8	24.0	24.4	0.306	1.3	5.4
	TSP0	**TSP1**	**TSP2**			
Yield (t/ha)	31.9	32.0	31.9	0.408	2.8	9.0
Bunches/ha	1344	1343	1322	0.789	121	9.1
kg/bunch	24.0	24.3	23.9	0.525	1.3	5.4
	MOP0	**MOP1**				
Yield (t/ha)	31.6	31.6		0.990	2.8	9.0
Bunches/ha	1345	1327		0.536	121	9.1
kg/bunch	23.9	24.3		0.234	1.3	5.4
	KIE0	**KIE1**				
Yield (t/ha)	31.8	31.3		0.442	2.8	9.0
Bunches/ha	1346	1327		0.503	121	9.1
kg/bunch	24.1	24.1		0.982	1.3	5.4
	EFB0	**EFB1**				
Yield (t/ha)	30.8	32.3		**0.045**	2.8	9.0
Bunches/ha	1301	1372		**0.022**	121	9.1
kg/bunch	24.2	24.0		0.497	1.3	5.4

Table 1.50 Main effect of Treatments on FFB and yield components in 1998-2000. P values for significant results are shown in bold (Trial 402).

	Treatment and level			p	s.e.d.	CV%
	AMC0	**AMC1**	**AMC2**			
Yield (t/ha)	19.9	20.6	20.6	0.199	1.5	7.2
Bunches/ha	933	951	942	0.642	64	6.8
kg/bunch	21.5	21.7	22.1	**0.007**	0.64	2.9
	TSP0	**TSP1**	**TSP2**			
Yield (t/ha)	20.5	20.6	20.0	0.255	1.5	7.2
Bunches/ha	951	948	927	0.378	64	6.8
kg/bunch	21.7	21.9	21.7	0.290	0.64	2.9
	MOP0	**MOP1**				
Yield (t/ha)	20.4	20.3		0.866	1.5	7.2
Bunches/ha	947	936		0.457	64	6.8
kg/bunch	21.7	21.8		0.311	0.64	2.9
	KIE0	**KIE1**				
Yield (t/ha)	20.7	20.1		0.097	1.5	7.2
Bunches/ha	955	928		0.087	64	6.8
kg/bunch	21.8	21.7		0.619	0.64	2.9
	EFB0	**EFB1**				
Yield (t/ha)	20.2	20.5		0.463	1.5	7.2
Bunches/ha	940	942		0.902	64	6.8
kg/bunch	21.6	21.9		0.113	0.64	2.9

Table 1.51. Main effects of treatments on tissue nutrient concentrations (based on dry matter) in 2000. Concentrations are in leaflets of frond 17, except for those designated "R", which are in the rachis of frond 17. Significant results ($p<0.05$) are shown in bold (Trial 402).

	Treatment and level			p	s.e.d.	CV%
	AMC0	AMC1	AMC2			
Ash (%)	15.9	15.8	16.1	0.216	0.58	3.6
N (%)	2.27	2.31	2.29	0.115	0.070	3.0
P (%)	0.148	0.149	0.148	0.448	0.005	3.4
K (%)	0.77	0.75	0.75	0.301	0.050	6.6
Mg (%)	0.15	0.15	0.14	0.499	0.016	10.6
Ca (%)	0.83	0.84	0.83	0.547	0.059	7.1
B (mg/kg)	11.8	11.8	11.6	0.620	0.868	7.4
Cl (%)	0.44	0.53	0.55	**<0.001**	0.033	6.5
R ash (%)	4.58	4.81	4.91	**0.077**		
R. K (%)	1.50	1.59	1.60	0.135	0.172	11.0
	TSP0	TSP1	TSP2			
Ash (%)	16.2	15.6	16.0	**0.012**	0.58	3.6
N (%)	2.30	2.31	2.28	0.316	0.070	3.0
P (%)	0.146	0.150	0.150	**0.019**	0.005	3.4
K (%)	0.74	0.77	0.76	0.116	0.050	6.6
Mg (%)	0.14	0.15	0.14	0.072	0.016	10.6
Ca (%)	0.83	0.82	0.83	0.248	0.059	7.1
B (mg/kg)	12.1	11.5	11.6	**0.053**	0.868	7.4
Cl (%)	0.50	0.51	0.52	0.247	0.033	6.5
R. ash (%)	4.93	4.64	4.74	0.134		
R K (%)	1.63	1.55	1.51	0.069	0.172	11.0
	MOP0	MOP1				
Ash (%)	16.0	16.0		0.385	0.58	3.6
N (%)	2.31	2.28		0.056	0.070	3.0
P (%)	0.149	0.147		0.101	0.005	3.4
K (%)	0.76	0.75		0.204	0.050	6.6
Mg (%)	0.15	0.14		**0.001**	0.016	10.6
Ca (%)	0.82	0.84		0.232	0.059	7.1
B (mg/kg)	11.9	11.6		0.116	0.868	7.4
Cl (%)	0.49	0.53		**<0.001**	0.033	6.5
R. ash (%)	4.67	4.87		0.107		
R K (%)	1.52	1.61		**0.033**	0.172	11.0
	KIE0	KIE1				
Ash (%)	16.0	15.9		0.250	0.58	3.6
N (%)	2.28	2.31		0.136	0.070	3.0
P (%)	0.149	0.148		0.466	0.005	3.4
K (%)	0.76	0.76		0.853	0.050	6.6
Mg (%)	0.14	0.16		**<0.001**	0.016	10.6
Ca (%)	0.86	0.81		**0.002**	0.059	7.1
B (mg/kg)	11.8	11.7		0.602	0.868	7.4
Cl (%)	0.51	0.51		0.750	0.033	6.5
R. ash (%)	4.81	4.73		0.489		
R. K (%)	1.58	1.55		0.422	0.172	11.0

Table 1.51 cont.

	EFB0	EFB1			
Ash (%)	16.2	15.7	**<0.001**	0.58	3.6
N (%)	2.25	2.33	**<0.001**	0.070	3.0
P (%)	0.147	0.150	**0.011**	0.005	3.4
K (%)	0.74	0.78	**0.002**	0.050	6.6
Mg (%)	0.15	0.15	0.710	0.016	10.6
Ca (%)	0.86	0.81	**<0.001**	0.059	7.1
B (mg/kg)	11.5	12.0	**0.029**	0.868	7.4
Cl (%)	0.49	0.52	**0.003**	0.033	6.5
R. ash (%)	4.60	4.94	**0.008**		
R. K (%)	1.47	1.66	**<0.001**	0.172	11.0

Table 1.52. Effects of treatments on tissue concentrations (based on dry matter) in 2000: significant three-way interactions (Trial 402).

Boron (mg/kg) AMC.MOP.KIE, p = **<0.001**, l.s.d. 1.0

	MOP 0		MOP 1	
	KIE 0	KIE 1	KIE 0	KIE 1
AMC0	13.1	11.2	10.5	12.4
AMC 1	11.6	12.2	12.2	11.2
AMC 2	11.9	11.4	11.4	11.7

Boron (mg/kg) TSP.MOP.KIE, p = **0.028** , l.s.d. 1.0

	MOP 0		MOP 1	
	KIE 0	KIE 1	KIE 0	KIE 1
TSP 0	13.2	11.7	11.4	12.1
TSP 1	11.4	11.6	11.7	11.3
TSP 2	12.0	11.5	11.1	11.9

Chlorine (%) AMC.TSP.KIE, p **= 0.033**, l.s.d. 0.05

	TSP 0		TSP 1		TSP 2	
	KIE 0	KIE 1	KIE 0	KIE 1	KIE 0	KIE 1
AMC 0	0.45	0.46	0.45	0.39	0.41	0.49
AMC 1	0.51	0.51	0.53	0.54	0.57	0.56
AMC 2	0.54	0.55	0.58	0.55	0.55	0.53

Chlorine (%) AMC.MOP.EFB, p = **<0.001**, l.s.d. 0.04

	MOP 0		MOP 1	
	EFB 0	EFB 1	EFB 0	EFB 1
AMC 0	0.28	0.48	0.50	0.51
AMC 1	0.52	0.55	0.55	0.51
AMC 2	0.57	0.53	0.55	0.56

Table 1.53. Effects of treatments on tissue concentrations (based on dry matter) in 2000: significant two-way interactions, not including those that are accounted for in significant three-way interactions in Table 1.52 (Trial 402).

Nitrogen (%), AMC.EFB, p = **0.036**, l.s.d. 0.06

	EFB 0	EFB 1
AMC 0	2.19	2.35
AMC 1	2.29	2.34
AMC 2	2.27	2.32

Phosphorus (%), TSP.MOP, p **= 0.011** , l.s.d. 0.004

	MOP 0	MOP 1
TSP 0	0.144	0.148
TSP 1	0.153	0.147
TSP 2	0.151	0.148

Potassium (%), TSP.EFB, p **= 0.004**, l.s.d. 0.043

	EFB 0	EFB 1
TSP 0	0.750	0.733
TSP 1	0.750	0.800
TSP 2	0.708	0.801

Magnesium (%) AMC.MOP, p = **0.035**, l.s.d. 0.013

	MOP 0	MOP 1
AMC 0	0.159	0.141
AMC 1	0.159	0.136
AMC 2	0.144	0.145

Ca (%), TSP.EFB, p = **0.006**, l.s.d. 0.050

	EFB 0	EFB 1
TSP 0	0.826	0.840
TSP 1	0.858	0.779
TSP 2	0.901	0.796

Ca (%), KIE.EFB, p = **0.027**, l.s.d. 0.041

	EFB 0	EFB 1
KIE 0	0.903	0.813
KIE 1	0.820	0.797

B (mg/kg) AMC.TSP, p = **0.007**, l.s.d. 0.9

	TSP 0	TSP 1	TSP 2
AMC 0	12.4	11.7	11.4
AMC 1	12.7	10.9	11.8
AMC 2	11.2	11.9	11.7

B (mg/kg) AMC.EFB, p = **0.018,** l.s.d. 0.7

	EFB 0	EFB 1
AMC 0	12.0	11.6
AMC 1	11.4	12.2
AMC 2	11.1	12.1

B (mg/kg) TSP.EFB, p = **0.003**, l.s.d. 0.7

	EFB 0	EFB 1
TSP 0	12.2	12.0
TSP 1	10.7	12.3
TSP 2	11.6	11.6

Cl (%) AMC.EFB, p = <**0.001**, l.s.d. 0.028

	EFB 0	EFB 1
AMC 0	0.392	0.492
AMC 1	0.535	0.530
AMC 2	0.558	0.542

Cl (%) TSP.EFB, p = **0.007**, l.s.d. 0.028

	EFB 0	EFB 1
TSP 0	0.468	0.534
TSP 1	0.503	0.508
TSP 2	0.513	0.521

Cl (%) MOP.EFB, p = **<0.001**, l.s.d. 0.023

	EFB 0	EFB 1
MOP 0	0.457	0.517
MOP 1	0.533	0.526

Cl (%) KIE.EFB, p = **0.001**, l.s.d. 0.048

	EFB 0	EFB 1
KIE 0	0.511	0.507
KIE1	0.478	0.535

Trial 403 Systematic Nitrogen Trial, Karausu

PURPOSE

To determine response to nitrogen fertiliser, using a layout designed to avoid possible poaching between plots

DESCRIPTION

This trial was approved at the 1999 SAC meeting. The trial design is shown below. Each plot is 4 rows of 15 palms. N rates (N 0 – N 8) vary systematically along the trial, and there are 8 replicates.

PROGRESS

The trial was laid out in 2000 in mature palms and treatments commenced in September 2000.

MAGNESIUM DEFICIENCY ON VOLCANIC ASH SOILS

(Dr. G. Gillman)

PURPOSE

To determine whether the widespread magnesium deficiency symptoms observed in West New Britain oil palm plantations are soil-related.

DESCRIPTION

The aim of the project was to determine the magnesium status of a range of volcanic ash soils, and more importantly, to ascertain what capacity they have to retain magnesium that may be applied in soluble form. PNGOPRA funded the project and the project leader, Dr. Gavin Gillman, CSIRO, carried out the analyses and interpretations. To date (August 2001), 151 samples have been examined for their cation exchange characteristics. They come from 18 profiles under oil palm in West New Britain, with 'low' to 'high' visual symptom deficiency ratings, as well as from 4 profiles under forest. In Oro Province, two sites under rainforest and three under oil palm were sampled. Analyses have included:

- Charge fingerprints (cation exchange capacity over a range of pH values)
- Exchangeable cation contents
- Cation exchange capacity (from charge fingerprints and using compulsive exchange method)

RESULTS

The results are surprising, and different to anything previously observed by the project leader. The cation exchange capacity (CEC) of the soils is completely occupied by exchangeable calcium, and in fact more calcium can usually be extracted than is necessary to saturate the cation exchange capacity. In other words, there are reserves of calcium that would tend to keep the CEC calcium-saturated for an indefinite period.

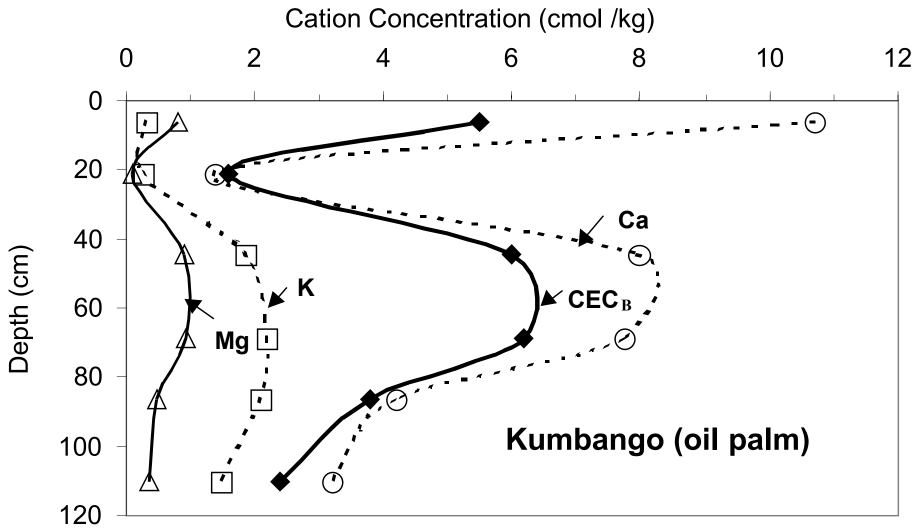
Figure 1.2a well illustrates the situation described above, and also shows the imbalance between calcium and magnesium throughout the profile at this plantation site. Such a state has not resulted from plantation management activities, because the same profile characteristics are evident at a nearby virgin rainforest site (Fig. 1.2b).

Contrast the above with what is observed at a rainforest location in Oro Province (Fig. 1.3b). Here we see that calcium and magnesium are in balance, and that the sums of cations extracted are roughly equal to the cation exchange capacity. In a nearby plantation location (Fig. 1.3a), an acceptable Ca:Mg ratio exists, and as magnesium contents become depleted by plant uptake, applications of soluble magnesium should have every chance of competing with calcium for cation exchange sites.

At all sites, retention of potassium will be problematic, though it appears that in the Ambogo plantation, fertiliser K applications have been retained in the surface, at least for now (or is this a result of recycling?).

CONCLUSION

In a range of volcanic ash soils, the cation exchange sites were completely dominated by calcium. Magnesium deficiency and lack of response to soluble magnesium fertilisers is most likely due to the inability of magnesium to compete with the calcium and be retained by the soil.



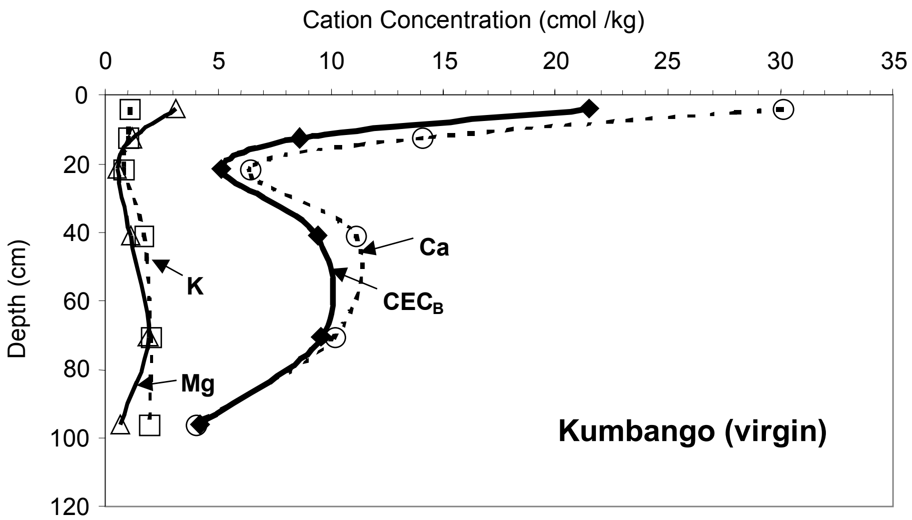


Figure 1.2. Exchangeable cations and basic cation exchange capacity (CEC_B) at Kumbango (West New Britain) in soil under oil palm (a) and forest (b).

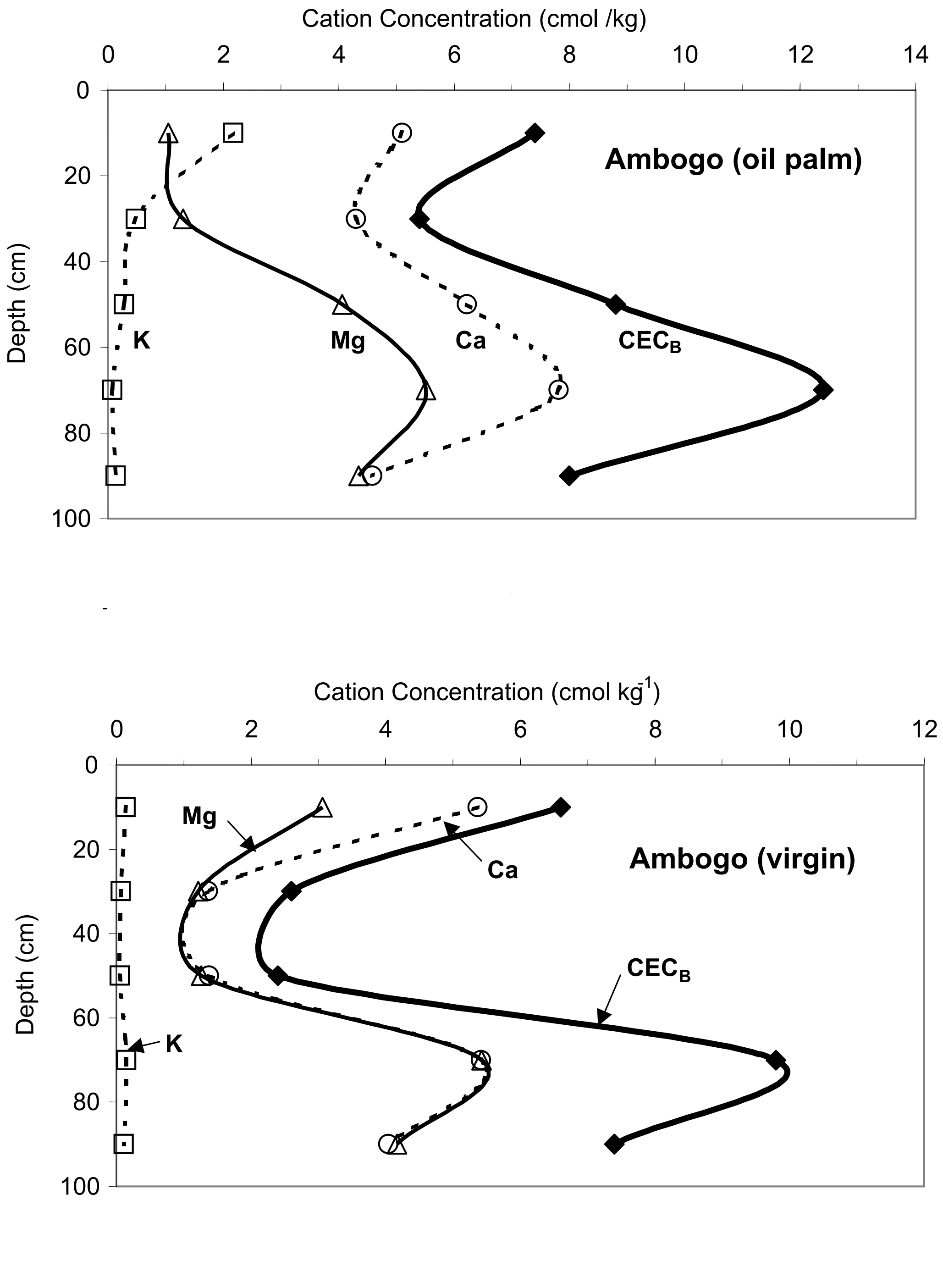


Figure 1.3. Exchangeable cations and basic cation exchange capacity (CEC$_B$) at Ambogo (Oro Province) in soil from between oil palms (a) and under forest (b).

AGRONOMY TRIALS IN ORO PROVINCE

(M. Banabas)

Trial 309 Potassium, Chlorine and Sulfur Trial, Ambogo Estate

PURPOSE

To test the response to potassium, chlorine and sulphur.

DESCRIPTION

Site Ambogo Estate Block 80H

Soil 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 planted in 1980 at 143 palms per hectare. Trial started in June 1990.

DESIGN

There are 25 plots each containing 16-core palms. The numbers and weights of bunches for each individual core palms are recorded at intervals of 14 days. In each plot the core palms are surrounded by at least one guard row and a trench.

The 25 plots are divided into five replicate blocks each containing five treatments (Table 1.54). The trial is laid down on the site of an earlier trial that was started in 1984 to test effects of EFB. Each treatment used in the present trial has a latin square design.

The treatments are combinations of fertilisers, one of which is bunch ash (BA). The right hand part of Table 1.54 shows the amount of each element that is applied to each treatment. The effect of an element is found by comparing the yields from two treatments; for example the effect of chlorine is found by comparing the yields from treatments 4 and 5.

The treatments that were used from January 1988 to June 1990 were similar treatments used from1991 to present, but there are some important differences. Treatment 3 now receives N and S, but used to receive only K. Treatment 2 now receives N and Cl, but used to receive K and Cl. Thus in comparison of a treatment with either 2 or 3 in order to test the effect of K.

Table 1.54 Types and amounts of fertiliser given in each treatment, and the corresponding amounts of nutrient element in Trial 309

Treatment No	Amount of fertiliser (kg/palm/yr)				Amount of Element (kg/palm/yr)			
	MOP	BA	AMS	AMC	N	K	Cl	S
1	-	-	-	-	-	-	-	-
2	-	-		3.2	0.80	-	2.1	-
3	-	-	4.0	-	0.84	-	-	0.96
4	4.4	-	4.0	-	0.84	2.3	2.1	0.96
5	-	8.8	4.0	-	0.84	2.2	-	0.96

RESULTS

Analysed yield data comparisons on the effects of N, S, K and Cl for 2000 and 1998-2000, are summarised in Table 1.55. In 2000 and 1998 - 2000 fertiliser treatments significantly affected yield, number of bunches per hectare and single bunch weight. Mean FFB yield was slightly lowered from 19.8 t/ha in 1999 to 18.4 t/ha/yr in 2000.

Separations of effects on yield from different fertiliser treatments for 2000 and 1998 – 2000 are also presented in Table 1.55. In 2000, yields were highest in treatments 4, 5 and 3 (N & S), intermediate in treatment 2 (N & Cl) and lowest in treatment 1 (control). Similar effects are seen for the number of bunches per hectare and single bunch weight. For the 1998 – 2000 period similar effects to 2000 results are seen, except that treatment 5 was different from treatments 4 and 3.

In 2000, ammonium sulphate (N and S) applied at 4 kg/palm/yr produced high yields (>20 t/ha/yr) however addition of K and Cl either together or separately did not appear to further enhance yield (comparison of treatments 3, 4 and 5) (Table 1.55). On the other hand 1998 – 2000 mean yield data shows addition of Cl had a significant mean enhancement of 3 t/ha/yr. The positive mean yield difference due to addition of Cl started in 1996 (Tables 1.56 and 1.57). Addition of K tended to lower yield, the effect being significant in the 1998 – 2000 period.

K and Cl added to N and S enhanced yield from 1991 to 1994 but not after (Table 1.57). The difference in results seen from 1991 to 1994 and 1995 onwards may be due to residual effects of earlier treatments or another factor apart from the treatments becoming limiting.

Ammonia sulphate (effect of N and S), provided a yield difference of 12.4 t/ha/yr while ammonium chloride (effect of N and Cl) provided a yield difference of 8.0 t/ha/yr. It appears N is very important for high FFB yields in this particular soil type especially when applied with S anion.

Table 1.55 Effects of N, S, K, and Cl in different combinations on fresh fruit bunch (FFB) and yield components in 2000 and 1998-2000 (Trial 309).

Treatments	2000			1998 – 2000		
	Yield (t/ha)	BNO (/ha)	SBW (kg)	Yield (t/ha)	BNO (/ha)	SBW (kg)
4 N S K Cl	23.6a	926	26.6	21.5a	902	23.9
5 N S K	21.9a	829	27.7	18.5b	777	23.9
3 N S	22.0a	830	27.0	21.2a	899	23.7
2 N Cl	15.4b	743	20.4	16.2c	803	20.0
1 Nil	9.1c	668	14.2	8.2d	582	14.1
GM	18.4	799	23.2	17.1	793	21.1
Sig	***	**	***	***	***	***
SE	2.9	110	1.6	2.0	65	1.3
CV%	16.1	13.8	6.9	11.8	8.2	6.4

Table 1.56 Effects of N, S, K, and Cl, in different combinations on fresh fruit bunch yields in 1991-2000 (Trial 309)

	Yield (t/ha/yr)										
Treatments	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	98 –00
Age	11	12	13	14	15	16	17	18	19	20	Mean
4 N S K Cl	31.3	32.5	28.4	27.7	18.6	18.7	21.1	15.4	25.4	23.6	21.5
5 N S K	28.6	30.9	28.7	26.4	19.7	14.7	19.4	12.2	21.3	21.9	18.5
3 N S	28.5	27.8	25.2	24.2	28.6	15.1	18.7	17.3	24.4	22.0	21.2
2 N Cl	24.5	21.7	19.4	18.7	14.4	13.8	14.5	14.3	18.9	15.4	16.2
1 Nil	16.4	13.6	9.8	7.1	6.4	7.6	8.3	6.3	9.1	9.1	8.2
GM	25.9	25.3	22.3	20.8	17.5	14.0	16.4	13.1	19.8	18.4	17.1
Sig	**	***	***	***	***	Ns	***	**	***	***	***
SE									2.38	2.95	2.02
CV%	17.1	20.1	19.1	9.4	26.3	30.4	11.1	27.4	12	16.1	11.8

Table 1.57 Comparison of effects of N, S, K, and Cl, in different combinations on fresh fruit bunch yields in 1991-2000 (Trial 309)

Nutrient Element(s)	Treatment Comparisons	Yield (t/ha/yr)										
		1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	98-00
	Age	11	12	13	14	15	16	17	18	19	20	Mean
Cl	4 & 5	2.7	1.6	-0.7	0.3	-0.9	4.0	1.7	3.2	4.1*	1.7ns	3.0**
NKS	1 & 5	12.2	17.3	18.9	19.3	13.3	7.1	11.1	5.9	12.2***	12.8***	10.3***
NKClS	1 & 4	14.9	18.9	18.6	20.6	12.2	11.1	12.8	9.1	16.3***	14.5***	13.3***
K	3 & 5	0.1	3.1	3.5	2.2	-8.9	-0.4	0.1	-5.1	-3.1	-0.1ns	-2.7*
N Source	2 & 3	4.0	6.1	5.8	5.5	14.2	1.3	4.2	3.0	5.5	6.6*	5.0*

Leaf tissue analysis results for 2000 are presented in Table 1.58. For rachis tissues, only K was analysed. The fertiliser treatments had significant effects on all nutrient concentrations.

In the leaflets, N component of the fertilisers significantly increased N and P concentrations but had an opposite effect on the Mg concentration. Potassium component significantly increased K concentrations in both the leaflets and the rachis. Chlorine component significantly increased Cl and Ca concentrations but lowered K concentrations in the leaflet. The S component significantly increased S concentration in the leaflets.

Table 1.58 Effect of N, S, K and Cl in different fertiliser combinations, on the concentration of elements in leaf tissue of frond 17 in 2000 (Trial 309).

Treatments	Leaf Nutrient Levels (% DM)							
	N	P	K	Ca	Mg	Cl	S	Rachis K
4 N S K Cl	2.11	0.138	0.73	0.75	0.16	0.44	0.16	1.79
5 N S K	2.15	0.139	0.78	0.69	0.18	0.33	0.15	1.50
3 N S	2.13	0.135	0.72	0.64	0.18	0.24	0.15	0.98
2 N Cl	2.26	0.140	0.63	0.71	0.18	0.48	0.13	1.21
1 Nil	1.91	0.131	0.67	0.69	0.27	0.25	0.14	1.36
GM	2.11	0.136	0.70	0.69	0.19	0.35	0.14	1.37
Sig	**	**	***	**	***	***	**	***
SE	0.11	0.004	0.08	0.04	0.01	0.06	0.01	0.15
CV%	5.0	2.9	13.4	5.5	5.9	16.8	6.3	10.7

CONCLUSION

In the period 1998–2000, yields in this trial showed large positive responses to N and S, with little or no additional response to S, and a small or slightly negative response to K.

Trial 310 Potassium, Chlorine and Sulfur Trial, Ambogo Estate

PURPOSE

To test the response to potassium, chlorine and sulphur in the presence of nitrogen

DESCRIPTION

Site Ambogo Estate block 80D5

Soil Ambogo and Penderetta families. Silt loam over sandy loam, with mottling due to seasonally high water tables, derived from alluvially deposited volcanic ash.

Palms Dami commercial DxP crosses planted in 1980 at 143 palms per hectare. Trial started January 1986, but present treatments started in November 1990.

DESIGN

There are 35 plots each containing 16-core palms. The numbers and weights of bunches for each individual core palms are recorded at intervals of 14 days. In each plot the core palms are surrounded by at least one guard row, and a trench.

The 35 plots are divided into five replicate blocks each containing seven treatments that are randomised (Table 1.59). The treatments are a combination of fertilisers. The right half of Table 1.59 shows the amount of each element that is applied to each treatment. The effect of an element is found by comparing the yields from two treatments; for example the effect of chlorine in the absence of K and S is found by comparing treatments 3 and 1.

Table 1.59 Amount of each type of fertiliser, and each element, used for each treatment in Trial 310.

Treatment No	Amount of Fertiliser (kg/palm/yr)					Amount of Element (kg/palm/yr)			
	Urea	AMS	AMC	BA	MOP	N	K	Cl	S
1	1.8	-	-	-	-	0.81	-	-	-
2	-	4.0	-	-	-	0.84	-	-	0.96
3	-	-	3.2	-	-	0.80	-	2.10	-
4	-	4.0	-	4.4	-	0.84	1.10	-	0.96
5	-	-	3.2	4.4	-	0.80	1.10	2.10	-
6	-	4.0	-	-	2.2	0.84	1.04	1.1	0.96
7	-	2.0	1.6	-	-	0.82	-	1.1	0.48

RESULTS

Yield data for 2000 and the mean 3 for 1998 – 2000 are presented in Tables 1.60 and 1.61 respectively. In both periods, there were no statistically significant responses to fertiliser treatments by FFB yield or the number of bunches. However, there was a statistically significant response by single bunch weight ($p<0.001$). Fertiliser effects on single bunch weights were not reflected in FFB yields because of the corresponding opposite effect on the number of bunches. In addition, the FFB yield response was insignificant since 1991, except in 1992 and 1997 (Table 1.62).

Comparative results of the effects of fertilisers are presented in Table 1.63 though were not statistically significant. Comparison between treatments 1 and 2 gives effect of S, between 1 and 3 gives effect of Cl, between 2 and 4 gives effect of K and between 3 and 5 gives effect of K in the presence of Cl. Chlorine component in the fertilisers consistently maintained a high yield difference since 1991 (Treatments 3 and 1). There appears to be a fluctuation in the difference but it seems to coincide with yield cycle. Response to K though smaller than Cl appears to have stabilised after 1996 at between 1 and 2 tonnes. Response to K in the presence Cl was generally negative since 1991. This probably implies any response to KCl is due more to Cl component than to K.

Response to S appear to be inconsistent and negligible since 1995. Comparison of Cl and S anions suggest Cl better and mostly had a positive yield difference of greater than 2 tonnes since 1991.

A general comparison of N source (Treatments 1, 2 and 3) results suggests ammonium chloride a better N source than ammonium sulphate and Urea on ex - forest soils where OM levels are generally moderate to high.

Table 1.60 The effects of K, Cl and S on FFB yield and yield components in 2000 (Trial 310)

Treatment No	Elements Supplied	Element Missing	Yield (t/ha)	BNO (/ha)	SBW (kg)
6	N S K Cl	None	20.2	693	30.2
4	N K S	Cl	22.1	840	27.3
7	N Cl S	K	22.8	871	27.2
5	N K Cl	S	19.3	746	27.6
2	N S	K, Cl	19.9	821	25.6
3	N Cl	K, S	21.7	828	27.2
1	N (Urea)	K, Cl, S	18.8	847	23.3
GM			20.7	807	26.9
Sig			ns	ns	***
SE			2.7	118	1.8
CV%			13.1	14.6	6.8

Table 1.61 The effects of K, Cl and S on FFB yield and yield components in 1998-2000 (Trial 310)

Treatment No	Elements Supplied	Element Missing	Yield (t/ha)	BNO (/ha)	SBW (kg)
6	N S K Cl	None	24.2	903	27.5
4	N K S	Cl	24.3	967	25.6
7	N Cl S	K	25.9	999	26.3
5	N K Cl	S	23.0	880	26.8
2	N S	K, Cl	22.5	942	24.4
3	N Cl	K, S	24.5	936	26.5
1	N (Urea)	K, Cl, S	22.5	1020	22.4
GM			23.8	950	25.7
Sig			Ns	Ns	***
SE			2.133	98.7	1.287
CV%			8.9	10.4	5.0

Table 1.62 The effects of N, S, K and Cl in different combinations on FFB yield from 1991 to 2000 (Trial 310)

Treatment No	Elements Supplied	Element Missing	Years 1991 (11)	1992 (12)	1993 (13)	1994 (14)	1995 (15)	1996 (16)	1997 (17)	1998 (18)	1999 (19)	2000 (20)	1998 - 2000 Mean
6	N S K Cl	None	26.7	34.0	29.9	26.9	25.7	25.6	27.5	29.6	22.7	20.2	24.2
4	N K S	Cl	26.2	31.0	26.8	27.4	26.2	24.6	25.7	27.4	23.4	22.1	24.3
7	N Cl S	K	27.6	28.9	28.7	28.3	25.7	27.0	28.9	29.5	25.0	22.8	25.9
5	N K Cl	S	27.4	28.6	28.9	28.0	26.0	28.2	30.1	26.3	23.4	19.3	23.0
2	N S	K, Cl	26.5	29.6	29.9	30.4	22.8	23.7	24.4	26.0	21.6	19.9	22.5
3	N Cl	K, S	29.1	30.3	31.5	28.9	26.3	28.8	30.1	26.8	25	21.7	24.5
1	N (Urea)	K, Cl, S	25.3	25.6	28.1	27.1	22.7	24.5	26.9	27.0	21.3	18.8	22.5
GM			27.0	29.7	29.1	28.1	25.1	26.1	27.7	27.5	23.2	20.7	23.8
Sig			ns	**	ns	ns	ns	ns	*	ns	ns	ns	ns
SED							1.8	3.5	3.1	2.2			
SE											2.8	2.7	2.1
Lsd				3.4								3.5	
CV%				8.8	12.0	10.5	11.5	13.6	11.1	12.6	12.1	13.1	8.9

( ) = age

Table 1.63 The effects of S, Cl, K and K in the presence of Cl (K(Cl)) on FFB yield from 1991 to 2000 (Trial 310)

Effect of Nutrient Element	Treatment Comparisons	Years										
		1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	98-00 Mean
		(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	
S	2 and 1	1.2	4.0	1.8	3.3	0.1	-0.8	-2.5	-1.0	0.3	1.1	0.0
Cl	3 and 1	3.6	4.7	3.4	1.8	3.6	4.3	3.2	-0.2	3.7	2.9	2.0
K (-Cl)	4 and 2	-0.3	1.4	3.1	-3.0	3.4	0.9	1.3	1.4	1.8	0.4	1.8
K (+Cl)	5 and 3	-1.7	-1.7	-2.6	-0.9	-0.3	-0.6	0.0	-0.5	-1.6	-2.4	-1.5
NCl vs NS	2 and 3	2.6	0.7	1.6	-1.5	3.5	5.3	5.7	0.8	3.4	1.8	2.0

(..)Age

Leaf tissue analysis results for 2000 are presented in Table 1.64. For rachis tissues only K was analysed. The treatments had significant effects on Cl ($p<0.001$), leaflet K ($p<0.001$), S ($p=0.005$) and rachis K ($p<0.001$) concentrations. The Cl anion in the fertiliser treatments significantly increased Cl but lowered the leaflet K concentrations. Potassium supplied with Cl appeared to greatly improve the concentrations of rachis K (treatments 5 and 6) compared to K applied with S (treatment 4).

Table 1.64 The effects of N, S, K, and Cl in different combinations, on the concentrations of elements in leaf tissue of frond 17 in 2000 (Trial 310)

Treatment No	Elements Supplied	Element Missing	Leaf nutrient concentrations (% DM)							
			N	P	K	Ca	Mg	Cl	S	Rachis K
6	N S K Cl	None	2.14	0.141	0.67	0.76	0.15	0.44	0.12	1.45
4	N K S	Cl	2.20	0.144	0.76	0.67	0.15	0.22	0.12	1.19
7	N Cl S	K	2.20	0.142	0.67	0.72	0.16	0.49	0.14	1.17
5	N K Cl	S	2.18	0.148	0.69	0.83	0.15	0.49	0.12	1.31
2	N S	K, Cl	2.15	0.141	0.73	0.67	0.14	0.11	0.14	0.96
3	N Cl	K, S	2.17	0.146	0.66	0.78	0.15	0.49	0.12	1.17
1	N (Urea)	K, Cl, S	2.12	0.143	0.77	0.67	0.15	0.11	0.13	0.97
GM			2.17	0.144	0.71	0.73	0.15	0.34	0.13	1.17
Sig			ns	ns	***	ns	ns	***	**	***
SE			0.07	0.005	0.05	0.05	0.01	0.03	0.01	0.18
CV%			3.1	3.5	6.0	7.1	13	9.1	7.7	14.2

CONCLUSION

There is no statistically significant FFB yield response to fertiliser treatments. However, there is a consistent positive FFB yield difference due to Cl component in the fertilisers applied.

Trial 311 Nitrogen, Potassium, and EFB Trial, Isavene Estate

PURPOSE

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

DESCRIPTION

Site Isavene Estate Block 78A

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

Palms Dami commercial DxP crosses. Planted in 1978 at 128 palms/ha.

DESIGN

There are 32 plots each with a core of 16 palms. The number 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 at least one guard row and a trench.

The 32 plots are a single replicate containing 32 treatments, made up of all combinations of four levels each of N and K, and two levels of EFB (Table 1.65). Ammonium sulphate (AMS) is the source of nitrogen, and muriate of potash (MOP) is the source of potassium. The EFB is applied by hand as a mulch between the palm circles. The weights of EFB given in Table 1.65 are fresh weights ex-mill. When EFB was given for the first time in November 1988, the amount was 333 kg/palm. In September 1990 it was increased to 500 kg/palm and it is intended to apply this amount every two years.

Table 1.65 Amounts of fertiliser and EFB used in Trial 311.

Fertiliser	Amount (kg/palm/year)			
	Level 0	Level 1	Level 2	Level 3
AMS	0.0	2.0	4.0	6.0
MOP	0.0	2.0	4.0	6.0
	kg/palm/2 years			
EFB	0.0	500		

Note: *AMS and MOP have been applied twice a year since April 1988, and three times a year since 1995. The trial was trenched in 1995.*

RESULTS

Analysed yield data for 2000 is presented in Table 1.66. Ammonium sulphate significantly improved FFB yield ($p<0.001$) and this was due to a significant increase in both the bunch numbers ($p=0.014$) and single bunch weight ($p=0.002$). Empty fruit bunch also significantly increased FFB yield ($p<0.001$) and yield components ($p=0.01$) but there were no responses to muriate of potash. Similar responses to AMS and EFB are seen in the mean cumulative FFB yield and yield components data for 1998 – 2000 (Table 1.67).

In 2000 there were statistically significant interactions between AMS and EFB is seen for FFB yield ($p=0.023$) and number of bunches ($p=0.024$) (Tables 1.68 and 1.69). Ammonium sulphate significantly increased FFB yield and the number of bunches however the responses were influenced by the levels of EFB. A maximum yield of 37.4 t FFB/ha/yr was obtained with a combination of 6 kg AMS and 2 kg MoP averaged over all levels of EFB though the interaction here was not statistically significant (Table 1.67). A more realistic yield of 30 t/ha/yr was obtained with 4 kg AMS/palm/yr and 2 kg MoP/palm/yr based on the 1998 – 2000 data (Table 1.71). It appears that full benefit from high N rates (N2 and N3) is only seen in the presence of MOP. Nitrogen still is the major limiting nutrient. Ammonium sulphate and EFB combinations (2 kg AMS in the presence of EFB) produced a high FFB yield of 35.6 t in 2000 and 31 t FFB/ha/yr in 1998 – 2000. These combinations (N2 & K1 and N1 & EFB1) (Tables 1.56 and 1.60) produced more realistic yields even in the presence and absence of either K or EFB (Tables 1.58 and 1.61).

Table 1.66 Main effects of AMS, MOP and EFB on FFB yield and yield components in 2000 (Trial 311)

	Nutrient & Levels				Statistics		
					Sig	SE	CV%
	N0	N1	N2	N3			
Yield (t/ha)	22.4	29.9	29.9	33.9	***	3.3	11.4
BNO (/ha)	820	968	922	1041	**	105	11.2
SBW (kg)	27.7	31.4	34.1	33.4	**	2.5	7.7
	K0	K1	K2	K3			
Yield (t/ha)	26.9	28.3	29.7	31.1	n.s.	As above	As above
BNO (/ha)	881	898	963	1009	n.s.		
SBW (kg)	31.0	32.1	32.0	31.5	n.s.		
	EFB0	EFB1					
Yield (t/ha)	26.3	31.7			***	As above	As above
BNO (/ha)	883	992			*		
SBW (kg)	30.3	33.1			*		

Table 1.67 Effect of combinations of AMS and MOP, AMS and EFB on FFB yield (t/ha/yr) in 2000 (Trial 311)

	Level of ammonium sulphate			
Level of MOP	0	1	2	3
0	21.7	25.5	28.9	31.6
1	20.7	24.9	30.2	37.4
2	23.3	34.8	28.6	32.0
3	23.8	34.3	31.8	34.7

	Level of ammonium sulphate			
Level of EFB	0	1	2	3
0	19.0	24.1	30.6	31.4
1	25.7	35.6	29.1	36.4

GM = 23.8, s.e. = 3.317, AMS x EFB interaction p= 0.023)

Table 1.68 Effect of combinations of AMS and EFB on number of bunches per hectare in 2000 (Trial 311)

	Level of ammonium sulphate			
Level of EFB	0	1	2	3
0	779	822	975	955
1	861	1114	869	1126

GM = 938, s.e. = 105, AMS x EFB interaction p= 0.024

Table 1.69 Effect of combinations of AMS and MOP (absence of EFB) and AMS and EFB (absence of MOP) on FFB yield in 2000 (Trial 311)

	Level of ammonium sulphate (Absence of EFB)			
Level of MOP	0	1	2	3
0	14.1	18.5	29.6	27.1
1	15.0	15.9	30.4	35.2
2	23.3	31.7	27.0	32.0
3	23.6	30.5	35.6	31.3

	Level of ammonium sulphate (Absence of MOP)			
Level of EFB	0	1	2	3
0	14.1	18.5	29.6	27.1
1	29.2	32.6	28.3	36.2

Table 1.70 Main effects of AMS, MOP and EFB on FFB yield and yield components for 1998 – 2000 (Trial 311)

	Nutrient & Levels				Statistics		
					Sig	SE	CV%
	N0	N1	N2	N3			
Yield (t/ha)	19.2	26.9	29.7	32.1	***	3.0	11.3
BNO (/ha)	730	909	967	1028	***	68	7.5
SBW (kg)	26.1	29.6	31.3	31.5	***	2.0	6.7
	K0	K1	K2	K3			
Yield (t/ha)	25.5	26.5	27.7	28.1	n.s.	As above	As above
BNO (/ha)	878	881	924	951	n.s.		
SBW (kg)	28.8	29.8	30.2	29.6	n.s.		
	EFB0	EFB1					
Yield (t/ha)	24.4	29.5			***	As above	As above
BNO (/ha)	853	964			***		
SBW (kg)	28.3	30.9			**		

Table 1.71 Effect of combinations of AMS and MOP, AMS and EFB, and MOP and EFB on FFB yield (t/ha/yr) in 1998 – 2000 (Trial 311)

	Level of ammonium sulphate			
Level of MOP	0	1	2	3
0	18.4	24.9	28.4	30.3
1	18.5	22.9	29.7	34.9
2	19.6	30.8	28.3	32.2
3	20.1	29.0	32.4	30.9

	Level of ammonium sulphate			
Level of EFB	0	1	2	3
0	15.3	22.7	28.9	30.8
1	23.0	31.0	30.5	33.4

GM = 27.0, s.e = 3.044, AMS x EFB & AMS x MOP interactions n.s.

Table 1.72 Effect of combinations of AMS and MOP (absence of EFB) and AMS and EFB (absence of MOP) on FFB yield in 1998 – 2000 (Trial 311)

	Level of ammonium sulphate (Absence of EFB)			
Level of MOP	0	1	2	3
0	11.6	18.9	28.2	28.6
1	12.2	15.2	30.0	33.2
2	17.9	28.7	25.7	32.1
3	19.4	28.0	31.8	29.0

	Level of ammonium sulphate (Absence of MOP)			
Level of EFB	0	1	2	3
0	11.6	18.9	28.2	28.6
1	25.3	30.8	28.7	31.9

Nutrient contents of leaflets and rachis (K alone) are presented in Table 1.73. Ammonium sulphate significantly increased N ($p<0.001$), P ($p=0.002$) and Cl ($p=0.002$) concentrations all with significant linear components ($p<0.001$). MoP significantly increased the concentrations of Cl and rachis K ($p<0.001$) in a significant quadratic fashion ($p<0.001$). The concentrations of these 2 elements appear to level off at K2. EFB significantly increased N ($p=0.011$), P ($p=0.022$), Cl ($p=0.002$) and rachis K ($p=0.007$) concentrations.

In 2000 there were a number of significant fertiliser interaction effects on the concentration of nutrients. Ammonium sulphate and EFB had a significant interaction effect ($p=0.026$) on the concentration of N in the leaflets (Table 1.74). Ammonium sulphate significantly increased the N concentration but this was strongly influenced by EFB levels. Muriate of potash significantly increased the concentrations of Cl and rachis K but the increases were further enhanced by EFB (Tables 1.75 and 1.76). Though statistically not significant, the combined effect of N & K on Cl concentration is presented in Table 1.69. Muriate of potash increased Cl concentration but higher concentrations of Cl are realised in the presence of AMS.

Table 1.73 Main effects of AMS, MOP and EFB on concentrations of elements (% of DM) in leaflets and rachis (K alone) in 2000 (Trial 311)

Nutrient & Levels					Statistics			
					GM	Sig	SE	CV%
	N0	N1	N2	N3				
N	1.99	2.16	2.24	2.33	2.18	***	0.08	3.5
P	0.130	0.133	0.138	0.142	0.136	**	0.004	3.3
K	0.70	0.67	0.71	0.71	0.70	n.s.	0.07	10.6
Ca	0.73	0.70	0.69	0.65	0.69	n.s.	0.05	7.3
Mg	0.18	0.14	0.14	0.13	0.15	*	0.02	14.0
Cl	0.37	0.41	0.43	0.46	0.42	**	0.03	8.0
S	0.13	0.15	0.15	0.15	0.14	n.s.	0.01	11.6
Rachis K	1.36	1.43	1.33	1.35	1.37	n.s.	0.14	10.8
	K0	K1	K2	K3				
N	2.20	2.17	2.16	2.19	2.18	n.s.	As	above
P	0.136	0.134	0.136	0.136	0.136	n.s.		
K	0.71	0.69	0.69	0.71	0.70	n.s.		
Ca	0.65	0.69	0.72	0.71	0.69	n.s.		
Mg	0.15	0.15	0.14	0.15	0.15	n.s.		
Cl	0.27	0.44	0.48	0.48	0.42	***		
S	0.15	0.15	0.15	0.15	0.14	n.s.		
Rachis K	1.10	1.36	1.52	1.50	1.37	***		
	EFB0	EFB1						
N	2.14	2.22			2.18	**	As	above
P	0.133	0.138			0.136	*		
K	0.69	0.71			0.70	n.s.		
Ca	0.69	0.69			0.69	n.s.		
Mg	0.15	0.14			0.15	n.s.		
Cl	0.39	0.44			0.42	**		
S	0.14	0.15			0.14	n.s.		
Rachis K	1.28	1.46			1.37	**		

Table 1.74 Effect of combinations of AMS and EFB on the concentration of leaf N (% of DM) in 2000 (Trial 311)

	Level of ammonium sulphate			
Level of EFB	0	1	2	3
0	1.91	2.07	2.20	2.37
1	2.07	2.25	2.29	2.29

GM = 2.18 AMS x EFB interaction p=0.026, s.e. = 0.076

Table 1.75 Effect of combinations of MoP and EFB on the concentration of rachis K (% of DM) in 2000 (Trial 311)

	Level of MOP			
Level of EFB	0	1	2	3
0	0.84	1.31	1.48	1.48
1	1.36	1.41	1.56	1.51

GM = 1.37, MoP x EFB interaction p=0.029, s.e. = 0.148

Table 1.76 Effect of combinations of AMS and MOP on Cl concentration (% of DM) in 2000 (Trial 311)

	Level of ammonium sulphate			
Level of MOP	0	1	2	3
0	0.20	0.29	0.28	0.32
1	0.39	0.40	0.45	0.52
2	0.47	0.48	0.48	0.51
3	0.42	0.47	0.51	0.52

	Level of MOP			
Level of EFB	0	1	2	3
0	0.21	0.42	0.48	0.47
1	0.33	0.46	0.49	0.49

GM = 0.42, MOP x EFB interaction p=0.028, AMS x MOP interaction n.s., s.e. = 0.033

CONCLUSION

Ammonium sulphate and EFB significantly increased FFB yields in 2000 and 1998 – 2000 periods. In addition in 2000, AMS significantly increased FFB yield but was influenced by EFB. This trial was closed at the end of 2000.

Trial 312 Nitrogen, Potassium and EFB Trial, Ambogo Estate

PURPOSE

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

DESCRIPTION

Site Ambogo Estate block 80E2

Soil Ambogo family, which is of recent alluvially reworked volcanic origin, with silty loam topsoil and sandy loam subsoil, with seasonally high water tables.

Palms Dami commercial DxP crosses. Planted 1980 at 143 palms/ha.

DESIGN

There are 32 plots each with a core of 16 palms. The number 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 at least one guard row, and a trench.

The 32 plots are a single replicate containing 32 treatments, made up from all combinations of four levels each of N and K, and two levels of EFB (Table 1.78). Ammonium sulphate (AMS) is the source of N, and muriate of potash (MOP) is the source of K. EFB is applied by hand as mulch between palm circles. The weights of EFB given in Table 1.78 are the fresh weights ex-mill. When EFB was given for the first time in November 1988 the amount was 333 kg/palm every two years. In September 1990 it was increased to 500 kg/palm, and it is intended to give this amount every two years.

Table 1.78 Amounts of fertiliser and EFB used in 2000 in Trial 312.

Type of Fertiliser or EFB	Amount (kg/palm/year)			
	Level 0	Level 1	Level 2	Level 3
AMS	0.0	2.0	4.0	6.0
MOP	0.0	2.0	4.0	6.0
	kg/palm/2 years			
EFB	0.0	500		

Notes: AMS and MOP have been applied twice a year since 1988, and three times a year since 1995. EFB has been applied once every two years.

RESULTS

Yield data for 2000 is presented in Table 1.79. Ammonium sulphate significantly increased FFB yields (p=0.017) in 2000. The increase in yield was mainly due to a significant increase in single bunch weight (p<0.001). Muriate of potash did not have any significant effect on yield or yield components. Empty fruit bunch applications significantly increased yield (p=0.041) and single bunch weight. The significant responses to ammonium sulphate and EFB seen in 2000 were similar to responses for 1998 –2000 however the responses were much stronger in the later (Table 1.83).

Single bunch weight was significantly affected by the interactions between AMS and EFB (p=0.006) in a significant linear fashion (p<0.001), but the effect did not translate through to yield (Table 1.70). There was a strong AMS effect on SBW but only in the presence of EFB. The interaction was also reflected in the FFB yields however statistically this was not significant. Though there were no significant interactions, two – way tables for 2000 results are presented in Tables 1.81 and 1.82 while for 1998 – 2000 in Tables 1.84 and 1.85.

A maximum FFB yield of 30.0 t /ha/yr was obtained with 6 kg AMS and 4 kg MOP averaged over all levels of EFB though a realistic yield of 28.6 t/ha/yr was obtained with 4 kg AMS and 2kg MOP. With AMS and EFB, a maximum yield of 29.8 t/ha/yr was obtained with 4 kg AMS and 500 kg EFB.

Table 1.79 Main effects of N, K and EFB on FFB yield and yield components in 2000 (Trial 312)

	Fertilisers & Levels				Statistics		
					sig	SE	CV%
	N0	N1	N2	N3			
Yield (t/ha)	18.5	24.3	26.4	25.9	*	4.0	17.1
BNO (/ha)	935	946	1061	1056	ns	202	20.3
SBW (kg)	20.2	26.3	26.0	25.8	***	1.5	6.2
	K0	K1	K2	K3			
Yield (t/ha)	23.1	23.4	24.0	24.5	ns	As	above
BNO (/ha)	955	1012	1019	1012	ns		
SBW (kg)	25.1	24.1	24.4	24.7	ns		
	EFB0	EFB1					
Yield (t/ha)	22.0	25.5			*	As	above
BNO (/ha)	966	1033			ns		
SBW (kg)	23.6	25.6			**		

Table 1.80 Effect of combinations of AMS and EFB on single bunch weight (kg) in 2000 (Trial 312)

	Level of ammonium sulphate			
Level of EFB	0	1	2	3
0	17.1	25.2	25.3	26.7
1	23.4	27.4	26.6	25.0

GM = 24.6 s.e = 1.533 and AMS x EFB interaction p = 0.006

Table 1.81 Effect of combinations of AMS and MOP, AMS and EFB on FFB yield in 2000 (Trial 312)

	Level of ammonium sulphate			
Level of MOP	0	1	2	3
0	17.4	24.3	25.3	25.3
1	16.1	25.2	25.2	27.2
2	20.0	23.4	26.4	26.1
3	20.4	24.2	28.6	24.9

	Level of ammonium sulphate			
Level of EFB	0	1	2	3
0	15.4	22.4	24.0	26.2
1	21.5	26.2	28.7	25.6

GM = 23.7 s.e = 4.065 and AMS x MOP and AMS x EFB = ns

Table 1.82 Effect of combinations of AMS and MOP, AMS and EFB on yield in presence/absence of K and EFB in 2000 (Trial 312)

	Level of ammonium sulphate (absence of EFB)			
Level of MOP	0	1	2	3
0	18.9	25.4	22.1	23.0
1	11.2	20.1	22.9	31.0
2	16.2	24.5	25.7	26.9
3	15.5	19.5	25.3	23.7

	Level of ammonium sulphate (absence of K)			
Level of EFB	0	1	2	3
0	18.9	25.4	22.1	23.0
1	16.0	23.2	28.4	27.5

Table 1.83. Main effects of AMS, MOP and EFB on FFB yield and yield components in 1998 – 2000 (Trial 312)

	Nutrient & Levels				Statistics		
					Sig	SE	CV%
	N0	N1	N2	N3			
Yield (t/ha)	18.5	24.2	27.9	27.9	***	2.8	11.5
BNO (/ha)	949	1007	1149	1165	*	109	10.2
SBW (kg)	19.4	24.3	24.7	24.5	***	2.8	3.5
	K0	K1	K2	K3			
Yield (t/ha)	23.6	24.8	25.6	24.6	ns	As	above
BNO (/ha)	1017	1094	1117	1040	ns		
SBW (kg)	23.4	22.9	23.1	23.5	ns		
	EFB0	EFB1					
Yield (t/ha)	22.4	26.9			**	As	above
BNO (/ha)	999	1135			**		
SBW (kg)	22.5	24.0			***		

Table 1.84 Effects of combinations of AMS and MOP, AMS and EFB and MOP and EFB on FFB yield in 1998 – 2000 (Trial 312)

Level of MOP	Level of ammonium sulphate 0	1	2	3
0	16.7	23.2	26.5	27.9
1	17.8	26.1	27.8	27.7
2	20.7	26.0	27.6	27.9
3	18.8	21.7	29.7	28.0

Level of EFB	Level of ammonium sulphate 0	1	2	3
0	14.2	21.8	25.5	28.2
1	22.8	26.7	30.4	27.6

GM = 24.6 s.e = 2.826 AMS x MOP & AMS x EFB = ns

Table 1.85 Effect of combinations of AMS and MOP and AMS and EFB on yield in presence/absence of MOP and EFB from 1998 to 2000 (Trial 312).

Level of MOP	Level of ammonium sulphate (absence of EFB) 0	1	2	3
0	15.1	22.3	23.8	26.1
1	11.9	21.5	26.8	30.8
2	16.4	25.0	26.0	28.9
3	13.5	18.4	25.4	27.3

Level of EFB	Level of ammonium sulphate (absence of MOP) 0	1	2	3
0	15.1	22.3	23.8	26.1
1	18.3	24.1	29.2	29.7

Nutrient contents of leaflets and rachis (K alone) are presented in Table 1.86. Ammonium sulphate significantly increased N ($p<0.001$) while lowering Ca ($p=0.0754$) and Mg ($p=0.011$) concentrations. Muriate of potash significantly increased Cl concentration ($p<0.001$) while EFB increased N ($p<0.001$), P ($p=0.013$), Cl ($p=0.033$) and rachis K ($p=0.021$) concentrations.

There was also a statistically significant interaction effect between AMS and EFB on leaflet N concentrations at $p=0.002$ with a strong linear component ($p=0.002$) (Table 1.87). Ammonium sulphate significantly increased N concentrations but this was strongly influenced by EFB. This effect was also reflected in FFB yields though statistically not significant.

Table 1.86 Main effects of N, K, and EFB on concentrations of elements in leaflet tissue (% of dry matter) of frond 17 in 2000 (Trial 312).

	Nutrient & Levels				Statistics		
					Sig	SE	CV%
	N0	N1	N2	N3			
N	2.00	2.11	2.19	2.28	***	0.04	1.8
P	0.139	0.141	0.144	0.143	ns	0.004	3.0
K	0.64	0.68	0.65	0.69	ns	0.06	9.5
Ca	0.86	0.75	0.72	0.70	*	0.08	10.0
Mg	0.16	0.15	0.14	0.15	*	0.01	7.0
Cl	0.43	0.47	0.46	0.45	ns	0.03	9.7
S	0.12	0.12	0.13	0.12	ns	0.01	10.0
Rachis K	1.58	1.64	1.69	1.61	ns	0.19	11.8
	K0	K1	K2	K3			
N	2.13	2.15	2.14	2.16	ns	As	above
P	0.140	0.143	0.141	0.142	ns		
K	0.68	0.65	0.67	0.66	ns		
Ca	0.69	0.78	0.79	0.77	ns		
Mg	0.14	0.15	0.16	0.15	ns		
Cl	0.37	0.49	0.48	0.48	***		
S	0.12	0.12	0.12	0.12	ns		
Rachis K	1.44	1.71	1.66	1.70	(*)		
	EFB0	EFB1					
N	2.09	2.20			***	As	above
P	0.139	0.144			*		
K	0.66	0.67			ns		
Ca	0.79	0.73			ns		
Mg	0.15	0.15			ns		
Cl	0.44	0.47			*		
S	0.12	0.12			ns		
Rachis K	1.53	1.73			*		

Table 1.87 Effect of combinations of AMS and EFB on Leaflet N concentration (% of DM) in 2000 (Trial 312)

	Level of N			
Level of K	N0	N1	N2	N3
EFB0	1.92	2.02	2.11	2.30
EFB1	2.07	2.19	2.27	2.27

GM = 2.14, AMS x EFB interaction p= 0.002, s.e. = 0.0383

CONCLUSION

Ammonium sulphate and EFB significantly improved FFB yields in 2000 and 1998 – 2000 periods. In addition to FFB yields, AMS and EFB also improved N concentration in the leaflets. Combined effect suggests AMS effect on N concentrations was strongly influenced by EFB.

Trial 324 Nitrogen Source Trial on Higaturu Soils, Sangara Estate

PURPOSE

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

DESCRIPTION

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

N sources to be tested are ammonia sulphate (AMS), ammonium chloride (AMC), ammonium nitrate (AMN), urea and diammonium phosphate (DAP).

The design is similar to Trial 125 at Kumbango (WNB). Five N sources are tested at 3 different rates of equivalent N contents and in 4 replicates. There are 15 treatments per replicate. A total of 60 plots are used in this experiment. There are also 4 zero fertiliser plots at the edge of the trial but data collected from these plots will not be used for ANOVA. Each of the plots consists of 36 palms; the central 16 are experimental palms from which data recording is done. Fertiliser treatments levels are shown in Table 1.88. Trial started in January 2001. This trial is the same design as Trial 325 in Oro and Trial 125 in West New Britain.

Table 1.88 Nitrogen source treatments and levels

Nitrogen Source	Level (kg/palm/yr)		
	1	2	3
Ammonium sulphate (21% N)	2.0	4.0	8.0
Ammonium chloride (26 % N)	1.6	3.2	6.4
Urea (46% N)	0.9	1.8	3.6
Ammonium nitrate (35% N)	1.2	2.4	4.8
Diammonium phosphate (18 % N)	2.3	4.6	9.2
g N /palm/yr	420	840	1680

RESULTS

Following activities were done in 2001; yield recording, physiological measurements, leaf tissue sampling soil sampling from each of the 4 replicates, soil profile description and fertiliser treatment applications.

Trial 325 Nitrogen Source Trial on Ambogo/Penderretta soils, Ambogo Estate

PURPOSE

To test relative effectiveness of different nitrogen fertilisers on Ambogo / Penderretta soils (Outwash plains).

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 to be replanted in 2001/2002 at 135 palms per hectare.

DESIGN

N sources to be tested are ammonia sulphate (AMS), ammonium chloride (AMC), ammonium nitrate (AMN), urea and diammonium phosphate (DAP).

The design is the same design as Trial 324 at Sangara, and Trial 125 at Kumbango (WNB). Five N sources are tested at 3 different rates of equivalent N contents and in 4 replicates. There are 15 treatments per replicate. A total of 60 plots are used in this experiment. There are also 4 zero fertiliser plots at the edge of the trial but data collected from these plots will not be used for ANOVA. Each of the plots consists of 36 palms; the central 16 are experimental palms from which data recording is done. Fertiliser treatments levels are shown in Table 1.89. Trial to start 36 – 48 months after replanting.

Table 1.89 Nitrogen source treatments and levels in trial 325.

Nitrogen Source	Level (kg/palm/yr)		
	1	2	3
AMS (21% N)	2.0	4.0	8.0
AMC (26 % N)	1.6	3.2	6.4
Urea (46% N)	0.9	1.8	3.6
AMN (35% N)	1.2	2.4	4.8
DAP (18 % N)	2.3	4.6	9.2
g N /palm/yr	420	840	1680

RESULTS

In progress.

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

DESCRIPTION

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. Trial to start in 2002.

DESIGN

It is proposed here to have 4 levels of N (ammonium sulphate) and 3 of EFB in factorial combinations in 5 Blocks (randomised complete block design) (Table 1.90). The trial will consist of 60 plots. Each plot will have 36 palms; 20 of the palms will provide the guard row while recordings will be done from the 16 core palms. The plots will also be surrounded by a trench to prevent plot-to-plot poaching. EFB treatments will be given once a year.

Table 1.90 Fertiliser treatments and levels in Trial 326.

Fertiliser type	Levels (kg/palm/yr)			
	1	**2**	**3**	**4**
AMS	0	2.5	5.0	7.5
EFB	0	130	390	

RESULTS

In progress.

Trial 327 Nitrogen x EFB Trial on Ambogo/Penderretta Soils, Ambogo Estate

PURPOSE

To provide information on the minimum EFB requirements of palms to help formulate fertiliser recommendations for soils of the outwash plains.

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 to be replanted in 2001/2002 at 135 palms per hectare. Trial to start 36 – 48 months after replant.

DESIGN

It is proposed here to have 4 levels of N (ammonium sulphate) and 3 of EFB in factorial combinations in 5 Blocks (randomised complete block design) (Table 1.91). The trial will consist of 60 plots. Each plot will have 36 palms; 20 of the palms will provide the guard row while recordings will be done from the 16 core palms. The plots will also be surrounded by a trench to prevent plot-to-plot poaching. EFB treatments will be given once a year.

Table 1.91 Fertiliser treatments and levels in Trial 327.

Fertiliser	Levels (kg/palm/yr)			
	1	2	3	4
AMS	0	2.5	5.0	7.5
EFB	0	130	390	

RESULTS

In progress.

Trial 328 Nitrogen, Phosphorus and Magnesium Trial on Ohita Soils, Sumbiripa Estate

PURPOSE

To provide information/data for fertiliser recommendations to both estate and smallholders on Ohita Soil Family.

DESCRIPTION

Site Sumbiripa Estate

Soil Ohita family, Soils are formed from several shallow recently deposited volcanic ash falls overlying older alluvial surface and are found on the lower terraces. Many of the lower terraces are also mixed with alluvial materials from the Higaturu Soils Family. The topsoil is moderately to strongly developed structure and have rapid permeabilities and excellent physical properties.

Palms Dami commercial DxP crosses to be replanted at 135 palms per hectare. Trial to start in 36 – 48 months after replant.

DESIGN

It is proposed to have a 3 x 3 x 3 non-confounded factorial in randomised complete block design. Fertilisers will be ammonium sulphate (AMS), triple superphosphate (TSP) and kieserite (KIES). Muriate of potash will be applied to all plots. There will be a single replicate of 3 blocks of 27 plots each totalling 81 plots. Each plot will have 36 palms; 20 of the palms will provide the guard row while recordings will be done from the 16 core palms. The plots will also be surrounded by a trench to prevent plot-to-plot poaching.

Table 1.92 Fertiliser treatments and levels in Trial 328.

Fertiliser	Levels (kg/palm/yr)		
	1	2	3
AMS (N)	2.0	4.0	6.0
TSP (P)	0	2.0	4.0
KIES (Mg)	0	2.0	4.0

RESULTS

In progress.

Trial 329 Nitrogen, P, K and Mg Trial on Mamba Soils, Mamba Estate

PURPOSE

To provide information/data for fertiliser recommendations to both estate and smallholders in the Kokoda Valley and Ilimo/Papaki Areas on soils that are cation depleted and have 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 2x3x3x 3 confounded factorial of single replicate of 3 blocks of 18 treated plots each totalling 54 plots altogether (Table 1.93). Fertilisers to be used are ammonium sulphate (AMS), triple superphosphate (TSP), muriate of potash (MOP) and kieserite (KIES). 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. Trial to start in 2001.

Table 1.93 Fertiliser treatments and levels in Trial 329.

Fertiliser	Levels (kg/palm/yr)		
	1	2	3
AMS (N)	2	4	
TSP (P)	0	2	4
MOP (K)	0	2	4
KIES (Mg)	0	2	4

RESULTS

The plots have been selected, marked and numbered. Compound soil samples from each of the 3 replicates have taken and soil profile description done. The trial is due for fertiliser treatments and yield recording to commence in August 2001.

Trial 330 Grassland Sulphur Trial on Outwash Plains, Parahe Mini Estate

PURPOSE

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

DESCRIPTION

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. Trial to start in 2002.

DESIGN

It is proposed to have a 4 x 3 Urea x Sulphur factorial in randomised complete blocks. Each plot will have 64 palms; 48 of the palms will provide double guard rows while recordings will be done from the 16 core palms. There will be no need for trenches to prevent 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.

Table 1.94 Fertiliser treatments and levels in Trial 330.

Fertiliser	Levels (kg/palm/yr)			
	1	**2**	**3**	**4**
Elemental Sulphur (S)	0	0.15	0.30	
Urea (N)	0.5	1.5	2.5	3.5

RESULTS

In progress.

Trial 331 Spacing and Thinning For Mechanical In-field Collection Trial, Ambogo Estate

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 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. Trial to start in 36 – 48 months after replant.

DESIGN

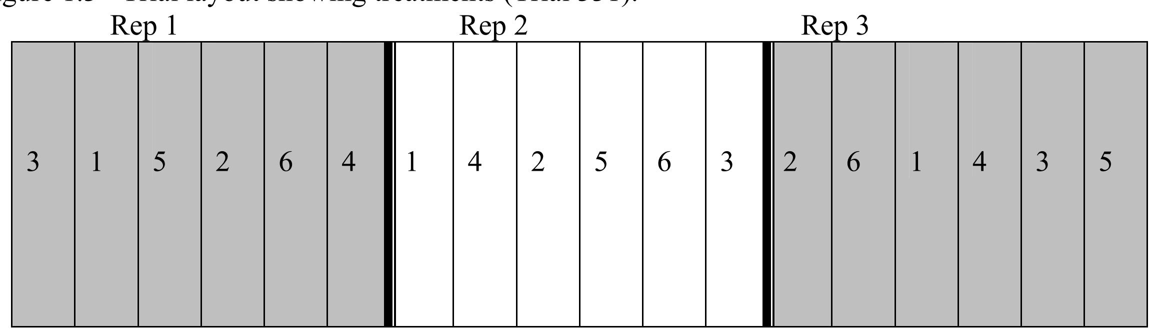
There are 6 treatments initially of different planting densities but of equilateral triangular spacing (Table 1.95). Every third row (33%) in treatments 4, 5 and 6 will be thinned at year 5 after planting while treatments 1, 2 and 3 will remain. The final densities of treatments 4, 5 and 6 will be similar 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. Treatment 2 will be used as a control because this is the density at which the plantation is planting. Treatments 1 and 3 are provided for comparisons with treatments 4 and 6 respectively to see the effects from thinning and increased avenue widths.

Table 1.95 Treatment allocations in Trial 331.

Treatment No	Initial Density (palms/ha)	Triangular spacing (m)	Density after thinning (palms/ha)	Avenue width (m)	Number of Rows*
1	128	9.5	------	8.23	7
2	135	9.25	------	8.01	7
3	143	9.0	------	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

Figure 1.3 Trial layout showing treatments (Trial 331).



There are 6 treatments of 3 replicates, totalling 18 plots (Figure 1.3). Each plot is approximately 1.25 ha therefore a total of 25 ha is used. In each replicate, the treatments are allocated randomly. Plots are separated from each other by 2 rows of palms, however, the avenue widths on either side of the rows will be that of the plot they are surrounding. The avenue width of guard rows of adjacent plots is the average width of the 2 adjacent plots. Within each plot there are 4 - 6 subplots of different cover crops randomly allocated and planted across the plot field. The trial should be able to fit into a block size of 50 ha.

RESULTS

In progress.

A list of possible cover crop species has been obtained from Farmset Ltd, but possibility of importation needs to be investigated with Quarantine. Enquiries with pasture agronomists in DAL have not yet been successful.

AGRONOMY TRIALS IN MILNE BAY PROVINCE

(M. Banabas)

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.

Site Dami commercial DxP crosses. Planted 1986 at 127 palms/ha. Trial started in 1994.

DESIGN

Trial 502B relocation is a single replicate split into four blocks, each comprising factorial applications of 4x4x2x2 N, P, K and EFB treatments. There are 64 plots each containing 16-core palms. The numbers and weights of bunches of each individual core palm are recorded at intervals of 14 days. In each plot the core palms are surrounded by one guard row and a trench.

The 64 treatments are made up from all combinations of four levels of AMS and MOP, and two levels of TSP and EFB (Table 1.96). EFB is applied by hand as mulch between palm circles.

Table 1.96 Amount of fertiliser and EFB used in 2000 (Trial 502b)

Type of Fertiliser or EFB	Amounts (kg/palm/year)			
	Level 0	Level 1	Level 2	Level 3
AMS	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		

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.

RESULTS

FFB yield results for 2000 are presented in Table 1.97. The average plot yield in 2000 was 34.7 t/ha/yr, an increase of 11.3 t/ha/yr from 23.4 t/ha in 1999. The crop has fully recovered from the low levels experienced in 1998 and 1999.

In 2000 ammonium sulphate significantly increased FFB yield ($p<0.001$) with a significant quadratic component ($p<0.001$) and number of bunches ($p=0.003$) but did not have any effect on single bunch weight. Muriate of potash slightly increased FFB yield while EFB significantly increased FFB yield ($p=0.016$) and single bunch weight ($p=0.012$). Empty fruit bunch also increased the number of bunches however the effect was statistically not significant. TSP application did not affect yield or yield components. Similar though much stronger responses than 2000 are reported for 1998 – 2000 period (Table 1.100).

In 2000 no statistically significant interactions between the fertiliser treatments are reported however 2 way tables showing effects of AMS & MOP and AMS & EFB fertilisers combinations on FFB yield are presented (Tables 1.98 and 1.99). The results indicate very good FFB yield responses to AMS fertiliser but strongly influenced by the presence of MOP or EFB.

For accumulated mean FFB yield for 1998 – 2000 period, there were statistically significant interactions between AMS & MOP ($p=0.014$) and MOP & EFB ($p=0.001$) with a significant linear component ($p<0.001$) (Tables 1.101 and 1.103). Effect of AMS and EFB on FFB yield was not statistically significant however results are presented (Table 1.102). There were very good responses to AMS however much higher yields were realised in the presence of MOP and EFB. Muriate of potash also significantly improved yields however the response was strongly influenced by EFB. Optimum combination of AMS and MOP is between 2 and 4 kg AMS and 2.5 and 5 kg MOP.

Table 1.97 Main effects of AMS, TSP, MOP and EFB on FFB yield and yield components in 2000 (Trial 502b)

	Nutrient & Levels				Statistics		
					Sig	SE	CV%
	N0	N1	N2	N3			
Yield (t/ha)	29.3	36.7	37.5	35.6	***	3.4	9.9
BNO (/ha)	1229	1491	1531	1510	**	179	12.4
SBW (kg)	24.4	25.1	24.9	24.3	ns	1.3	5.2
	P0	P1					
Yield (t/ha)	34.8	34.7			ns	As	above
BNO (/ha)	1429	1452			ns		
SBW (kg)	25.0	24.3			ns		
	K0	K1	K2	K3			
Yield (t/ha)	33.4	33.6	35.1	36.9	(*)	As	above
BNO (/ha)	1408	1408	1440	1505	ns		
SBW (kg)	25.2	24.7	24.8	25.0	ns		
	EFB0	EFB1					
Yield (t/ha)	33.5	36.0			*	As	above
BNO (/ha)	1417	1464			ns		
SBW (kg)	24.2	25.2			*		

Table 1.98 Effects of combinations of AMS and MOP fertilisers on FFB yield in 2000 (Trial 502b)

Level of MOP	Level of ammonium sulphate 0	1	2	3
0	28.8	35.5	35.0	34.2
1	28.2	36.0	34.9	35.2
2	29.3	35.9	38.6	36.7
3	30.8	39.2	41.3	36.2

GM = 34.7 AMS x MOP interaction ns s.e = 3.447

Table 1.99 Effects of combinations of AMS and EFB fertilisers on FFB yield in 2000 (Trial 502b)

Level of EFB	Level of ammonium sulphate 0	1	2	3
0	27.2	35.0	37.3	34.3
1	31.4	38.3	37.6	36.8

GM = 34.7 AMS x EFB interaction ns s.e = 3.447

Table 1.100 Main effects of N, P, K and EFB on FFB yield and yield components in 1998-2000 (Trial 502b)

	Nutrient & Levels				Statistics Sig	SE	CV%
	N0	N1	N2	N3			
Yield (t/ha)	22.7	25.8	26.0	25.6	***	0.8	3.2
BNO (/ha)	1000	1063	1081	1087	***	41	3.9
SBW (kg)	22.7	24.3	24.0	23.7	**	0.8	3.5
	P0	P1					
Yield (t/ha)	25.2	24.9			ns	As	above
BNO (/ha)	1054	1061			ns		
SBW (kg)	24.0	23.4			*		
	K0	K1	K2	K3			
Yield (t/ha)	24.1	24.7	25.4	25.8	***	As	above
BNO (/ha)	1043	1041	1067	1079	ns		
SBW (kg)	23.1	23.9	23.8	23.9	*		
	EFB0	EFB1					
Yield (t/ha)	23.9	26.2			***	As	above
BNO (/ha)	1031	1085			***		
SBW (kg)	23.2	24.2			***		

Table 1.101 Effects of combinations of AMS and MOP fertilisers on FFB yield in 1998 – 2000 (Trial 502b)

Level of K	Level of ammonium sulphate 0	1	2	3
0	22.1	25.5	24.9	24.0
1	21.8	26.5	24.9	25.7
2	23.1	25.0	26.6	26.9
3	23.9	26.3	26.9	25.6

Gm = 25.0 AMS x MOP interaction p = 0.014 s.e. = 0.796

Table 1.102 Effects of combinations of AMS and EFB fertilisers on FFB yield in 1998 – 2000 (Trial 502b)

Level of EFB	Level of ammonium sulphate 0	1	2	3
0	21.4	24.5	25.1	24.5
1	24.0	27.2	26.8	26.7

GM = 25.0, AMS x EFB interaction = ns, s.e. = 0.796

Table 1.103 Effects of combinations of MOP and EFB fertilisers on FFB yield in 1998 – 2000 (Trial 502b)

Level of EFB	Level of muriate of potash 0	1	2	3
0	22.3	23.1	24.6	25.5
1	26.0	26.4	26.2	26.2

GM = 25.0, MOP x EFB interaction p = 0.001, s.e. = 0.796

Leaf tissue analysis results are presented in Table 1.104. For rachis tissues, only K was analysed. Ammonium sulphate significantly increased N concentration ($p<0.001$) with a significant linear component ($p<0.001$). Ammonium sulphate, on the other hand significantly depressed the Ca ($p<0.001$), Mg ($p=0.018$) and rachis K ($p=0.059$) concentrations. Muriate of potash significantly increased leaflet K ($p=0.053$), Cl ($p=0.002$) and rachis K ($p<0.001$) but lowered Mg ($p=0.031$) concentrations. Triple superphosphate had no effect on the nutrient concentrations. Empty fruit bunch significantly increased both leaflet K ($p=0.009$) and rachis K ($p<0.001$) but lowered Ca ($p=0.009$) and Mg ($p=0.020$) concentrations. Empty fruit bunch also increased N concentration but this was not statistically significant.

Two way tables showing effect of MOP and EFB on leaflet K and rachis K concentrations are presented in Tables 1.105 and 1.106 respectively. Though there was a statistically significant interaction between MOP and EFB on leaflet K in 1999 ($p=0.001$), there was none in 2000 but there was still a significant interaction effect on rachis K ($p<0.001$) concentration. In both cases, EFB significantly improved the uptake of K from MOP treatments.

Table 1.104 Main effects of N, P, K and EFB on the concentration of nutrient elements in the leaflets and rachis K (% of DM) of frond 17 in 2000 (Trial 502b)

Level of nutrient Element or EFB					Statistics			
					GM	Sig	SE	CV%
	N0	N1	N2	N3				
N	2.19	2.27	2.30	2.33	2.27	***	0.06	2.9
P	0.153	0.155	0.155	0.156	0.155	ns	0.006	3.7
K	0.55	0.54	0.54	0.56	0.55	ns	0.06	11.7
Ca	0.83	0.77	0.74	0.74	0.77	***	0.04	5.1
Mg	0.36	0.34	0.33	0.32	0.34	*	0.03	8.5
Cl	0.44	0.43	0.43	0.45	0.44	ns	0.02	5.1
Rachis K	1.35	1.23	1.19	1.11	1.22	(*)	0.21	17.4
	K0	K1	K2	K3				
N	2.28	2.29	2.24	2.28	2.27	ns	As	above
P	0.156	0.155	0.153	0.154	0.155	ns		
K	0.52	0.54	0.56	0.57	0.55	*		
Ca	0.76	0.78	0.77	0.78	0.77	ns		
Mg	0.36	0.34	0.33	0.32	0.34	*		
Cl	0.41	0.45	0.44	0.44	0.44	**		
Rachis K	0.77	1.17	1.45	1.49	1.22	***		
	P0	P1						
N	2.27	2.28			2.27	ns	As	above
P	0.154	0.155			0.155	ns		
K	0.55	0.54			0.55	ns		
Ca	0.76	0.78			0.77	ns		
Mg	0.34	0.33			0.34	ns		
Cl	0.43	0.44			0.44	ns		
Rachis K	1.22	1.22			1.22	ns		
	EFB0	EFB1						
N	2.26	2.29			2.27	ns	As	above
P	0.153	0.156			0.155	ns		
K	0.52	0.57			0.55	**		
Ca	0.79	0.75			0.77	**		
Mg	0.35	0.33			0.34	*		
Cl	0.43	0.44			0.44	ns		
Rachis K	1.03	1.41			1.22	***		

Table 1.105 Effects of combinations of MOP and EFB on leaflet K concentrations (% of DM) in 2000 (Trial 502b)

	Levels of muriate of potash			
Levels of EFB	0	1	2	3
0	0.46	0.50	0.56	0.55
1	0.58	0.58	0.56	0.58

GM = 0.55, MOP X EFB interaction = ns, s.e. = 0.06

Table 1.106 Effects of combinations of MOP and EFB on Rachis K concentrations (% of DM) in 2000 (Trial 502b)

Levels of EFB	Levels of muriate of potash			
	0	1	2	3
0	0.35	0.96	1.38	1.43
1	1.20	1.38	1.53	1.56

GM = 1.22, MOP X EFB interaction p<0.001, s.e. = 0.21

CONCLUSION

Ammonium sulphate, MOP and EFB significantly increased FFB yield in 2000 and 1998 – 2000 periods. Muriate of potash significantly increased rachis K but this was strongly influenced by EFB and this was also reflected by FFB yields in 1998 – 2000.

Trial 504 Mature Phase Fertiliser 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.

Palm Special Dami DxP crosses of 16 progenies that were randomised within each plot. The palms were planted in January 1991 at 127 palms/ha. Trial started in 1994.

DESIGN

There are 64 plots, each with a core of 16 palms. The numbers and weights of bunches from each individual core palm are recorded at intervals of 14 days. In each plot the core palms are surrounded by a guard row and a trench.

The 64 plots are divided into two replicates of 32 plots each. In each replicate there are 32 treatments, made up from all combinations of four levels each of N and K, and two levels of an additional treatment, which is currently vacant (Table 1.107).

Table 1.107 Types of treatment fertiliser and rates used in Trial 504.

	Levels and application rates (kg/palm/year)			
Type of Fertiliser	**0**	**1**	**2**	**3**
Ammonium sulphate	0.0	2.0	4.0	6.0
Muriate of Potash	0.0	2.5	5.0	7.5
Vacant Treatment	-	-	-	-

RESULTS

Analysed FFB yield and yield component results for 2000 and 1998 – 2000 are presented in Tables 1.108 and 1.110 respectively. In 2000 and 1998-2000, AMS significantly increased FFB yield at p=0.050 and p=0.028 respectively. Muriate of potash significantly increased FFB yield both in 2000 (p=0.027) and 1998 – 2000 at p<0.001 with a strong linear component (p<0.001). The effect of MOP on single bunch was apparent in 1998 – 2000 but not in 2000. Mean FFB yield for all the plots in 2000 was 42.6 t/ha/yr, an increase of 21.6 tonnes from 21.0 t/ha/yr in 1999.

Effects of combinations of AMS and MOP on FFB yield in 2000 and 1998 – 2000 are presented in Tables 1.109 and 1.111 respectively. There was a statistically significant interaction at p=0.041 for mean yield data in 1998 - 2000 but not in 2000. It appears high yields were obtained at between 2 and 4 kg AMS and 5kg MOP per palm per year.

Table 1.108 Main effects of N and K on FFB yield and yield components in 2000 (Trial 504).

	Nutrient & Levels				Statistics		
					sig	SE	CV%
	N0	**N1**	**N2**	**N3**			
Yield (t/ha)	40.6	42.8	43.8	43.1	*	3.3	7.7
BNO (/ha)	1841	1907	1947	1915	ns	150	7.9
SBW (kg)	22.5	22.9	22.8	22.9	ns	1.2	5.3
	K0	**K1**	**K2**	**K3**			
Yield (t/ha)	40.4	42.9	44.0	43.0	*	As	above
BNO (/ha)	1858	1927	1919	1905	ns		
SBW (kg)	22.2	22.6	23.3	23.0	ns		

Table 1.109 Effect of AMS and MOP combinations on FFB yield in 2000 (Trial 504).

Level of MOP	Level of ammonium sulphate			
	0	**1**	**2**	**3**
0	39.2	39.3	40.8	42.5
1	41.1	43.0	43.2	44.3
2	42.0	43.7	46.8	43.5
3	40.2	45.1	44.3	42.3

GM = 42.6, AMS x MOP interaction ns, s.e = 3.3

Table 1.110 Main effects of N and K on FFB yield and yield components in 1998-2000 (Trial 504).

	Nutrient & Levels				Statistics		
					Sig	SE	CV%
	N0	**N1**	**N2**	**N3**			
Yield (t/ha)	26.7	28.3	27.9	27.7	*	1.5	5.5
BNO (/ha)	1467	1527	1515	1489	ns	92	6.1
SBW (kg)	18.2	18.5	18.3	18.5	ns	0.8	4.4
	K0	**K1**	**K2**	**K3**			
Yield (t/ha)	26.0	27.7	28.9	28.1	***	As	above
BNO (/ha)	1452	1502	1544	1501	ns		
SBW (kg)	17.9	18.4	18.6	18.6	*		

Table 1.111 Effect of AMS and MOP combinations on FFB yield in 1998 - 2000 (Trial 504)

Level of MOP	Level of ammonium sulphate			
	0	**1**	**2**	**3**
0	24.7	25.0	26.7	27.8
1	26.5	28.5	27.8	28.0
2	28.7	29.6	29.1	28.2
3	27.0	30.3	28.2	27.0

GM = 27.7, AMS x MOP interaction p=0.041, s.e = 1.5

Leaf tissue analysis results are presented in Table 1.112. For rachis, only K was analysed. Ammonium sulphate significantly increased N ($p=0.005$) with a strong linear component ($p<0.001$) and P (p=0.044) concentrations. Muriate of potash significantly increased Ca (p=0.012) and Cl and rachis K concentrations both at p<0.001.

Table 1.112 Main effects of N and K on the concentration of nutrient elements in the leaflets and rachis K (% of DM) of frond 17 in 2000 (Trial 504)

					Statistics			
	Nutrient & Levels				GM	Sig	SE	CV%
	N0	**N1**	**N2**	**N3**				
N	2.38	2.44	2.46	2.47	2.44	**	0.07	3.2
P	0.160	0.163	0.164	0.162	0.162	*	0.004	2.7
K	0.61	0.63	0.63	0.63	0.62	ns	0.05	8.1
Ca	0.75	0.75	0.74	0.74	0.74	ns	0.06	8.0
Mg	0.34	0.33	0.34	0.33	0.33	ns	0.03	9.5
Cl	0.49	0.49	0.49	0.49	0.49	ns	0.04	7.4
Rachis K	1.09	1.04	0.99	0.99	1.03	ns	0.18	17.4
	K0	**K1**	**K2**	**K3**				
N	2.46	2.44	2.44	2.41	2.44	ns	As	above
P	0.163	0.163	0.163	0.162	0.162	ns		
K	0.62	0.63	0.61	0.63	0.62	ns		
Ca	0.70	0.76	0.75	0.76	0.74	**		
Mg	0.33	0.34	0.33	0.33	0.33	ns		
Cl	0.37	0.51	0.53	0.54	0.49	***		
Rachis K	0.60	1.00	1.21	1.32	1.03	***		

CONCLUSION

Ammonium sulphate and MOP significantly improved FFB yields. Muriate of potash appears to have a stronger effect on FFB yield though slightly influenced by AMS.

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. Trial started in 1994.

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.

The 64 plots is a single replicate split into four blocks, comprising factorial applications of 4x2x4x2 of N, P, K and EFB treatments. The treatments are made up from all combinations of four levels each of N and K and two levels each of P and EFB (Table 1.102). EFB is applied by hand as mulch between palm circles.

Table 1.113 Amounts of fertiliser and EFB used in Trial 511.

Type of Fertiliser or EFB	Amounts (kg/palm/year)			
	Level 0	Level 1	Level 2	Level 3
AMS	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

Analysed yield results for 2000 are presented in Table 1.114. The mean plot FFB yield in 2000 was 25.5 t/ha/year, an increase of 8.6 t from 16.9 t FFB/ha/year in 1999. Ammonium sulphate significantly increased FFB yield, number of bunches and single bunch weight ($p < 0.001$) all with strong linear components ($p<0.001$). Triple-superphosphate also significantly increased FFB yield and the number of bunches ($p<0.001$) but did not affect single bunch weight. Muriate of potash did not have any effect on FFB yield and yield components while EFB significantly increased FFB yield, bunch number and single bunch weight ($p<0.001$). Similar responses are seen for mean FFB yield in 1998 – 2000 (Table 1.119).

In 2000 and 1998 – 2000, there were no statistically significant interactions between the different fertiliser treatments combinations, however, 2 way tables for different combinations of AMS, TSP and EFB are presented (Tables 1.115, 1.116, 1.117, 1.118, 1.120, 1.121, 1.122 and 1.123). The FFB yields for both 2000 and 1998 – 2000 indicate very good responses to nitrogen fertiliser (AMS) but were strongly influenced by the presence of TSP or EFB.

Table 1.114 Main effects of N, P, K, and EFB on FFB yield and yield components in 2000 (Trial 511).

	Nutrient & Levels				Statistics		
					sig	SE	CV%
	N0	N1	N2	N3			
Yield (t/ha)	14.9	24.1	29.5	33.4	***	5.7	22.5
BNO (/ha)	765	1080	1201	1412	***	201	18.1
SBW (kg)	19.3	22.1	24.5	23.7	***	2.1	9.5
	P0	P1					
Yield (t/ha)	21.8	29.2			***	As	above
BNO (/ha)	969	1260			***		
SBW (kg)	21.9	23.0			ns		
	K0	K1	K2	K3			
Yield (t/ha)	24.9	25.1	25.4	26.5	ns	As	above
BNO (/ha)	1080	1129	1098	1150	ns		
SBW (kg)	22.6	21.6	22.7	22.7	ns		
	EFB0	EFB1					
Yield (t/ha)	20.0	30.9			***	As	above
BNO (/ha)	923	1306			***		
SBW (kg)	20.8	24.1			***		

Table 1.115. Effects of combinations of AMS and TSP fertilisers on FFB yield in 2000 (Trial 511)

	Level of ammonium sulphate			
Level of TSP	0	1	2	3
0	14.3	21.2	24.7	26.9
1	15.5	27.0	34.3	39.9

GM = 25.5, AMS x TSP Interaction ns, s.e = 5.7

Table 1.116 Effects of combinations of AMS and TSP fertilisers on FFB yield in 2000 (Absence of EFB) (Trial 511)

	Level of ammonium sulphate			
Level of TSP	0	1	2	3
0	8.2	15.4	14.8	22.6
1	9.5	19.1	31.1	39.2

GM = 25.5, s.e = 5.7

Table 1.117 Effects of combinations of AMS and EFB fertilisers on FFB yield in 2000 (Trial 511)

	Level of ammonium sulphate			
Level of EFB	0	1	2	3
0	8.8	17.3	23.0	30.9
1	21.0	30.9	36.0	35.9

GM = 25.5, AMS x EFB interaction ns, s.e = 5.7

Table 1.118 Effects of combinations of AMS and TSP fertilisers on FFB yield in 2000 (Absence of TSP) (Trial 511)

	Level of ammonium sulphate			
Level of EFB	0	1	2	3
0	8.2	15.4	14.8	22.6
1	20.4	27.0	34.5	31.2

GM = 25.5, s.e = 5.7

Table 1.119 Main effects on N, P, K and EFB on FFB yield and yield components in 1998-2000 (Trial 511).

	Nutrient & Levels				Statistics		
					Sig	SE	CV%
	N0	N1	N2	N3			
Yield (t/ha)	14.0	18.5	20.6	23.2	***	3.0	15.7
BNO (/ha)	810	918	952	1075	**	130	13.8
SBW (kg)	17.3	19.9	21.3	21.4	**	2.2	10.9
	P0	P1					
Yield (t/ha)	17.3	20.8			***	As	above
BNO (/ha)	882	995			**		
SBW (kg)	19.3	20.6			*		
	K0	K1	K2	K3			
Yield (t/ha)	18.9	18.5	18.9	19.9	ns	As	above
BNO (/ha)	934	927	928	965	ns		
SBW (kg)	20.0	19.5	20.0	20.4	ns		
	EFB0	EFB1					
Yield (t/ha)	16.2	21.9			***	As	above
BNO (/ha)	844	1033			***		
SBW (kg)	18.9	21.1			**		

Table 1.120 Effects of combinations of AMS and TSP fertilisers on FFB yield in 1998 - 2000 (Trial 511)

	Level of ammonium sulphate			
Level of TSP	**0**	**1**	**2**	**3**
0	13.7	16.9	18.2	20.5
1	14.3	20.0	23.0	25.9

GM = 19.1, AMS x TSP interaction ns, s.e = 3.001

Table 1.121 Effects of combinations of AMS and TSP fertilisers on FFB yield in 1998 - 2000 (Absence of EFB) (Trial 511)

	Level of ammonium sulphate (absence of EFB)			
Level of TSP	**0**	**1**	**2**	**3**
0	10.3	13.5	13.8	18.1
1	11.2	16.0	21.4	25.4

GM = 19.1, s.e = 3.001

Table 1.122 Effects of combinations of AMS and EFB on FFB yield in 1998 - 2000 (Trial 511)

	Level of ammonium sulphate			
Level of EFB	**0**	**1**	**2**	**3**
0	10.8	14.8	17.6	21.7
1	17.2	22.1	23.6	24.7

GM = 19.1 AMS x EFB interaction ns s.e = 3.0

Table 1.123 Effects of combinations of AMS and EFB on FFB yield in 1998 – 2000 (Absence of TSP) (Trial 511)

	Level of ammonium sulphate (absence of TSP)			
Level of EFB	**0**	**1**	**2**	**3**
0	10.3	13.5	13.8	18.1
1	17.1	20.3	22.6	22.9

GM = 19.1 s.e = 3.0

Leaf tissue analysis results are presented in Table 1.124. For rachis nutrients, only K was analysed. Ammonium sulphate significantly increased N ($p<0.001$) with a strong linear component ($p<0.009$) and P ($p=0.009$) whilst lowering Mg ($p<0.001$) and rachis K ($p=0.027$) concentrations. MoP significantly increased Cl ($p=0.003$) and rachis K ($p<0.001$) concentrations while TSP significantly increased P ($p<0.001$) concentrations. EFB significantly increased N ($p<0.001$), P ($p<0.001$), K ($p=0.009$) and rachis K ($p<0.001$) but lowered Mg ($p<0.001$) concentrations. The significant reduction in Mg concentration caused by AMS and EFB treatment applications is probably due dilution effect.

Two-way tables showing combined effects of TSP and EFB on leaflet P concentrations and MoP and EFB on rachis K concentrations are presented in Tables 1.118 and 1.119 respectively. Triple superphosphate and EFB fertiliser treatments combinations had a significant effect ($p=0.001$) on P concentration in the leaflets. There was a strong response to TSP fertiliser however this response was strongly influenced by EFB treatments. In the rachis MoP and EFB fertiliser treatments combinations had a significant effect ($p = 0.015$) on the concentration of K. Muriate of phosphate significantly improved K concentration but this was further enhanced in the presence EFB fertilisers.

Table 1.124 Main effects of N, P, K and EFB on the concentration of nutrient elements (% of DM) in the leaflets and rachis K of frond 17 in 2000 (Trial 511)

Nutrient & Levels					Statistics			
					GM	Sig	SE	CV%
	N0	N1	N2	N3				
N	2.05	2.10	2.28	2.29	2.18	***	0.11	5.5
P	0.139	0.140	0.144	0.145	0.142	**	0.004	2.9
K	0.61	0.62	0.61	0.62	0.61	ns	0.08	13.0
Ca	0.78	0.80	0.74	0.70	0.76	*	0.08	10.8
Mg	0.39	0.36	0.33	0.30	0.34	***	0.03	9.0
Cl	0.53	0.51	0.51	0.49	0.51	ns	0.05	10.1
Rachis K	1.52	1.42	1.25	1.37	1.39	*	0.20	14.5
	K0	K1	K2	K3				
N	2.22	2.13	2.18	2.19	2.18	ns	As	above
P	0.144	0.141	0.141	0.143	0.142	ns		
K	0.62	0.60	0.62	0.62	0.61	ns		
Ca	0.75	0.77	0.74	0.76	0.76	ns		
Mg	0.36	0.35	0.34	0.33	0.34	ns		
Cl	0.44	0.52	0.53	0.53	0.51	**		
Rachis K	1.09	1.39	1.54	1.54	1.39	***		
	P0	P1						
N	2.17	2.20			2.18	ns	As	above
P	0.138	0.147			0.142	***		
K	0.62	0.61			0.61	ns		
Ca	0.75	0.76			0.76	ns		
Mg	0.35	0.34			0.34	ns		
Cl	0.49	0.52			0.51	ns		
Rachis K	1.43	1.35			1.39	ns		
	EFB0	EFB1						
N	2.07	2.29			2.18	***	As	above
P	0.136	0.149			0.142	***		
K	0.58	0.65			0.61	**		
Ca	0.78	0.74			0.76	ns		
Mg	0.37	0.32			0.34	***		
Cl	0.50	0.52			0.51	ns		
Rachis K	1.25	1.53			1.39	***		

Table 1.125 Effects of combinations of TSP and EFB fertilisers on leaflet P concentrations (% of DM) in 2000 (Trial 511)

	Levels of triple superphosphate	
EFB Levels	**0**	**1**
0	0.129	0.143
1	0.147	0.151

GM = 0.142, TSP x EFB interaction p=0.001, s.e. 0.004

Table 1.126 Effects of combinations of MOP and EFB fertilisers on rachis K concentrations (% of DM) in 2000 (Trial 511)

	Levels of muriate of potash			
EFB Levels	**0**	**1**	**2**	**3**
0	0.78	1.26	1.44	1.53
1	1.40	1.52	1.64	1.56

GM = 1.39, MOP x EFB interaction p=0.015, s.e. 0.20

CONCLUSION

Ammonium sulphate, TSP and EFB significantly improved FFB yields in 2000 and 1998 – 2000 periods. It is also apparent from the results that though statistically not significant, FFB yield responses to AMS were strongly influenced by TSP or EFB treatments.

ORO MAPPING PROJECT

Introduction

The Oro Mapping Project commenced in 1999 and is funded as part of the World Bank financed Oro Smallholder Oil Palm Expansion Project. The mapping project is a collaborative one between the PNGOPRA, the Oil Palm Industry Corporation and the Oro Conservation Project. The World Bank project objectives are:

1) To facilitate the protection the Queen Alexandrae Birdwing Butterfly (QABB) and
2) To monitor the expansion of the oil palm development in Oro Province.

Background

The World Bank mission which visited the Oro Province from February1998 followed up on earlier observations by the Bank Forestry mission on possible effects of Oil Palm development on the conservation of primary rain forests and the endangered Queen Alexandrae Birdwing Butterfly (QABB). The mission then discussed and agreed with various stakeholders that it would be necessary to ensure that smallholder development in the province should be consistent with the protection and conservation of the provinces rich forestry resources and the endangered Queen Alexandrae Birdwing Butterfly. The project had already programmed resources for the development of a Geographic Information System, with the PNG Oil Palm Research Association. It was then agreed the scope of this activity be expanded to develop broad-based and supportive GIS capabilities in the Provincial government, OPIC, PNGOPRA and Conservation Communities.

Also during the visit the mission discussed with Mr. David Freyne, Team leader for ACLMP in Port Moresby, for assistance in the design and implementation of the program.

GIS description

MapInfo, a simple desktop mapping tool is the software recommended for the Oro Mapping Project. It enables linkages between spatial data and database information and performs some geographical analysis. In addition MapInfo is the most widely used mapping software in PNG with a local distributor.

A MapInfo format spatial database is made up of series of layers that contain polygon and database information relating to a particular spatial dataset i.e. soils, vegetation etc. It was necessary to obtain data from a number of sources and to involve personnel from supplying organisations in the process of conversion of data to an appropriate digital format. Following are the layers that formed the initial database covering the Kokoda Valley and the Popondetta plains.

1. A raster layer of geo-referenced SPOT Panchromatic and LandSat TM imagery
2. Existing road information captured from satellite image and GPS road surveys
3. Digitized 1:100 000 scale contour and drainage information
4. Locations of oil palm small holder blocks
5. Soil survey information
6. Forestry inventory Mapping
7. Social information such as villages, health services, schools etc.
8. Digital elevation model

Current status of the project

With the initial database and the acquisition of the Magellan Global Positioning unit the following activities were achieved as a measure to protect the QABB.

1. All QABB sightings are identified and mapped. Tagged onto the sightings layer is the following information:
   a) The name of the nearest village,
   b) The date the QABB was sighted,
   c) The life stage of the butterfly when sighted,
   d) The type of vegetation where the QABB was sighted and
   e) the name of the person that reported the sighting

2. The registered and proposed Wild Life Management Areas (WMA) are then surveyed using the Global Positioning System. These areas are mapped out at the request of the landowners through the Oro Conservation Office. Currently the only registered Wild Life Management Area is mapped, including five proposed Wild Life Management Areas.

The second objective of the Oro Mapping Project is to monitor the expansion of oil palm development in the Oro Province. Since acquiring the Global Positioning System the following activities were achieved:

a) 3,774 small holder blocks out of 6,000 have been mapped using the GPS
b) 95% of the existing roads in the project area have also been mapped and identified and
c) the Management Information System that OPIC had established since 1999 is then tagged onto all GPS'd locations of the small holder blocks. This would allow for the database to be queried.

Mapping of roads and smallholder plantings have proved very useful to extension officers who are with the OPIC or with the Small Holder Unit of Higaturu Oil Palms. This information is very helpful in the delivery of tools etc. and similarly management of smallholder production is made more efficient.

Conclusion

With the rapid expansion of oil palm development in the Oro Province, the Oro Mapping Project is seen as a tool to integrate the conservation of the endangered Queen Alexandrae Birdwing Butterfly into the development of the Oil Palm industry.

All measures taken by the different stakeholders involved in the conservation of the QABB, with activities like informing landowners about the options for development, and conservation, assisting landowners in the process of registering their land as Wildlife Management areas, and all other activities as carried out by the Oro Mapping Project are purposely for the conservation of the QABB.

Also with the Oro Mapping Project monitoring the expansion of oil palm in the province, areas identified as no-go zones for oil palm planting are avoided. Roads and smallholder blocks are mapped out to ensure they do not enter Wildlife Management areas. Similarly the information collected by the Oro Mapping Project is also used to make production of oil palm more efficient.

2. SMALLHOLDER STUDIES

(Dr. G. Curry[1], G. Koczberski[1] and Prof. K. Gibson[2])

See attached Annual Research Report Supplement

EXECUTIVE SUMMARY

The oil palm industry is one of the more successful rural developments in Papua New Guinea. Oil Palm is grown in five areas: Hoskins and Bialla in West New Britain, Popondetta, Milne Bay and New Ireland, with over 14,500 smallholder oil palm blocks. In 2000, smallholders produced approximately 531,263 tonnes of FFB (worth K36.5 million), which accounted for 33.4% of total production, the company estates producing the balance. Last year oil palm exports accounted for 32% of the total value of Papua New Guinea's agricultural exports, and 5% of total Papua New Guinea exports. In the same year the value of oil palm exports exceeded coffee, "traditionally" the most important commodity crop in terms of foreign exchange earnings.

Whilst there have been large increases in production and the area planted by smallholders, improving smallholder productivity remains the industry's major challenge. Smallholder productivity is much lower than the estate plantation, and village oil palm (VOP) productivity is consistently lower than the land settlement schemes (LSS) (except for Popondetta).

In 1999 project funding was approved by ACIAR to research the biophysical and socio-economic interactions of factors affecting productivity among oil palm smallholders in Hoskins and Popondetta. The primary aim of the research was to help improve smallholder oil palm productivity. The main objectives of the project were to:

- Gain an understanding of the socio-economic constraints upon smallholder production;
- Evaluate the Loose Fruit Mama Scheme;
- Develop strategies for more effective extension interventions;
- Make recommendations for change that might result in further increases in smallholder productivity, and
- Produce a work manual for extension officers.

Research was undertaken at the Hoskins and Popondetta schemes with smallholders the focus of data collection. Other key stakeholders that participated in the research included OPIC, NBPOL, HOPL, customary landowners, and industry associations, such as the oil palm growers associations. The research employed semi-structured interviews, case studies, questionnaire surveys, workshops, focus groups, analysis of industry smallholder databases and the review of relevant reports and published literature.

At the beginning of the data collection phase, workshops with extension officers at Hoskins and Popondetta identified the key variables explaining variation in smallholder production as: physical factors; agronomic and farm management practices; intra-household relations and decision-making; income distribution; time and cash management skills; tenure security; economic necessity to harvest; level of interest in oil palm harvesting; and, the personal characteristics of growers. Building on this knowledge and working closely with smallholders, the study identified the following socio-economic factors affecting production and, more importantly influencing the everyday activities and decisions of smallholders.

[1] Curtin University, Perth, Australia
[2] Australian National University, Canberra

Smallholder Livelihood strategies

- In addition to oil palm, smallholders are involved in a diverse range of economic activities that we define as livelihood strategies. Smallholder livelihood strategies promote household economic and social security by increasing income and diversifying income sources, strengthening people's capacity to meet their needs, increasing the range of options and choices available to households, increasing food security and reducing household risks.
- The main smallholder livelihood strategies include managing a range of cash crops, wage employment, small business enterprises, garden production for home consumption and local markets, and indigenous exchange. These non-oil palm labour and time demands sometimes compete with oil palm production; at other times they have a positive influence where they contribute to livelihood security thereby adding to social stability on the schemes.
- For many smallholders, access to alternative income sources is often necessary to meet household needs, especially on highly populated LSS blocks and/or during times of depressed oil palm prices. An important reason why smallholders pursue income diversification is to lower income risks by reducing their vulnerability to the fluctuating price of oil palm.
- For many VOP smallholders in Hoskins and Popondetta, entry into oil palm production is relatively recent and many retain holdings of other export cash crops, especially cocoa and copra. In a survey of 100 VOP and LSS smallholder blocks at Hoskins, 72% and 26% respectively had access to other export cash crops. Of the Hoskins VOP blocks with cash crops, 83.5% had two or more types of cash crops in addition to oil palm.
- The oil palm plantation estates provide opportunities for short-term casual employment and long-term employment of smallholders. The former often provides temporary financial relief for block residents during peak cash demands such as payment of school fees, bride-prices or other customary obligations.
- Access to off-block wage employment can add significantly to material standards of living on smallholder blocks. The association between off-block or self employment adversely affecting oil palm production requires further research, although evidence suggest that off-block employment is only a problem when it limits the labour availability at harvest times. On the more heavily populated blocks at Hoskins, off-block employment provides very important supplementary income, and relieves some of the economic and population pressures on the block.
- Food garden production is extremely important for LSS and VOP smallholders in terms of labour demands and meeting household consumption requirements. At Hoskins labour allocated to gardening exceeds that allocated to oil palm and is the dominant activity carried out by smallholders. This is most notable among women who allocate almost 2.5 times as much of their labour to gardening than to oil palm; for Hoskins men, gardening and oil palm are of about equal importance in terms of the amounts of time allocated to each activity. At Popondetta, men spend more time in oil palm related work than gardening, and women spend considerably more time in gardens than in oil palm.
- Approximately 80% of meal ingredients at Kavui LSS and Popondetta were from gardens compared with about 50% of meal ingredients from food gardens at Gaungo VOP. The balance at Gaungo is made up of store foods, (mostly tinned fish and rice) and fresh fish and meat. The higher protein diets of VOP smallholders at Hoskins are partly a reflection of the wider range of income choices available to VOP smallholders and the greater population pressure on LSS blocks, where falling per capita incomes from oil palm are increasing settlers' dependence on subsistence food production.
- The marketing of food crops, coconuts, betel nut, tobacco, processed foods and manufactured items at local markets provides a regular additional income for women at Hoskins and Popondetta. At Hoskins, market income is especially important for women

from the LSS schemes. A survey of women selling at several markets around Kimbe and Hoskins, revealed that 54% of sellers were from LSS schemes and 8% were settlers residing on village land, and LSS women were disproportionately over-represented in local markets in terms of the values of items for sale, especially garden produce. At Hoskins, VOP women are not as heavily involved in marketing garden produce. Average earnings per market visit were K10.91 at Hoskins and K4.64 at Popondetta.

- Most smallholders are involved in various forms of indigenous production and exchange, especially VOP producers. For many VOP smallholders, the motivation to harvest is not so much concerned with accumulating savings for capital investments or consumption in the market economy, but with redistributing wealth through kin exchange. Some smallholders with intermittent involvement in oil palm production may not harvest for several months but will do so to contribute to a communal feast or exchange. For more regular VOP producers, oil palm production may increase significantly when the demands of the indigenous economy are unusually high. Thus, the requirements of indigenous exchange can drive people's involvement in oil palm production.

Smallholder household type and oil palm production strategies

- A major feature of the LSS and VOP subdivisions is the diversity of smallholder household types and oil palm production strategies.
- Smallholder households can be divided into four different types according to household type and oil palm production strategies:
  1. Single household (wok bung), where all or most adult family members participate in harvesting.
  2. Caretaker household, usually single household working together (wok bung).
  3. Multiple household (mixed), where most adult members from each household participate in FFB harvesting and adult women rotate the collection of loose fruit and loose fruit income between households.
  4. Multiple household (rotate), where harvesting and loose fruit collection and the associated incomes are rotated monthly between different households co-resident on the block.
- The type of smallholder household production unit present on a block reveals much about household labour supply and organisation, decision making, income distribution, family/gender relations, the range of livelihood strategies pursued and production motivation. These factors affect oil palm production.
- Single household blocks are largely found on VOPs, except in Popondetta where population pressure is less on the LSSs. The various types of household production units reflect a transition on the older LSS schemes such as Hoskins where single households are being replaced by multiple families co-residing on a block. As a consequence, labour arrangements, harvesting practices and methods of payment are changing in a variety of ways. These multiple household blocks are complex economic and social units and far more heterogeneous in terms of labour and income strategies than the nuclear single families that first settled on the scheme in the 1970s.
- At Hoskins, some blocks have moved away from a multiple household mixed production unit where most adults from all co-resident households contribute to harvesting, to more individualised units of production where harvesting is rotated between co-resident households with less shared inter-household labour harvesting. This system of production usually emerges as a response to the increasing number of co-resident households on blocks. However, the rotation production system, which appears to be increasing, may be a less efficient oil palm production system than shared family labour harvests. There is some evidence to suggest that oil palm productivity is lower on highly populated that employ a

rotation system than on highly populated blocks that continue to practice shared family labour harvesting where more adults tend to participate in harvesting. Also under a rotation system there is a higher probability that block maintenance will be neglected or disputed, replanting will be delayed and that there will be problems with loan repayments.

- Multiple household rotation production units are predominantly on the LSS schemes at Hoskins where up to five or six households reside on one block. The shift to a rotation system on highly populated blocks where households are operating more like independent nuclear family units is a major socio-agronomic transformation occurring on the land settlement schemes at Hoskins (and possibly at Bialla). At Popondetta this study did not record the rotation system operating among smallholders, and OPIC officers could recall only a small number of blocks that had adopted the rotation system.

Population growth and second-generation issues

- Population pressure is beginning to emerge at the older LSS schemes such as Hoskins (and possibly Bialla) as second generation marry and establish their own households on the block. Many blocks are now supporting multiple families. The presently high numbers of households per LSS block at Hoskins partly reflect the difficulty settlers now face in returning to their “home” villages or acquiring land or employment in WNB or elsewhere in Papua New Guinea.
- Acquiring additional land is the primary desire of most smallholders experiencing population pressure on their blocks. However, opportunities for second-generation smallholders to purchase LSS blocks are becoming constrained by limited savings potential and the rapid inflation of LSS block prices. In response, some LSS settlers are “purchasing land” land from customary landowners, squatting illegally on government or private land, seeking land in another province or moving into an informal (squatter) settlement in an urban centre.
- Growing number of smallholders illegally residing on government or company land, or “purchasing” insecure VOP land are important issues that have the potential to seriously undermine social stability in the future.
- Social instability and conflict is associated with heavily populated blocks. Many multiple household rotation blocks experience economic and population pressure, and disputes and violence often occur on payday over the distribution of oil palm income. Inter- and intra-household disputes reduce social harmony and can sometimes lead to significant disruptions to oil palm production and in the longer term are a disincentive for smallholder investment.
- Economic pressure on populated blocks is leading to the development of supplementary income sources to maintain household livelihoods. The trend to increased reliance on non-oil palm income sources is likely to continue as population grows and as it becomes more difficult through time for second-generation settlers to return home.
- There are increasing numbers of under-employed people on blocks, especially youth, who are unable to participate fully in oil palm production. They are an under utilised resource for the industry, and in the longer term may pose a threat to the social sustainability of the schemes as they become more disaffected and alienated.
- With population it appears LSS smallholders are becoming more reliant on gardens, although the Mama Lus Frut Scheme may have offset this reliance in Hoskins. Those blocks with high population and which do not have alternative sources of income are reverting to more subsistence lifestyles in which garden production is becoming much more important.

Conflicts over land tenure

- Land conflicts take many forms in the oil palm smallholder sector, from the large compensation claims demanded by customary landowners for land alienated for estate plantations and land settlement schemes to inter- and intra-household disputes over block ownership.
- Land conflicts are critical production issues. Land disputes reduce smallholder productivity by removing disputed stands of oil palm from production and lowering smallholder incentives to investment in their long-term futures (e.g. replanting or fertiliser uptake). Also, insecure tenure undermines smallholder confidence in and commitment to oil palm, and deters economic development.
- Land conflicts on both VOP and LSS blocks are particularly serious in Popondetta and are a major constraint on and challenge to improving smallholder production.
- The "sale" of customary land at Hoskins is leading to land disputes between settlers and some landowning clan members, especially younger clan members who perceive future land shortages for clan members. These disputes are undermining the future tenure security of settlers "owning" VOP blocks.
- At Hoskins and Popondetta there is growing intolerance and resentment towards settlers that is partly linked with wider feelings of unease held by indigenous landowners and a new generation of young landowners who see "outsiders" as the cause of growing land shortages in the area.

Industry and OPIC Interventions

- In all project areas VOP plantings are increasing. Popondetta's VOP expansion programme under the Oro Expansion Project funded by the World Bank has increased by over 7,840 hectares since the project commenced in 1993, far exceeding the initial project target of 3,500 hectares.
- Oil palm mini-estates (based on lease, lease-back arrangements) are a recent phenomenon and undergoing rapid expansion, yet the long-term socio-economic impacts are little understood and difficult to predict. A particular concern is how to ensure that the benefits from mini-estate development flow to women and groups holding secondary rights in the resource.
- The Mama Lus Frut Scheme introduced at Hoskins in 1997 has provided substantial financial benefits for the company and women. In 2000, women earned K1, 443. Women spend a high proportion of their oil palm income on food and family needs and this partly explains why smallholders view the scheme as significantly improving the social environment and general quality of life on the blocks.
- The mama card has helped households meet their needs and strengthened livelihoods through improving income distribution and labour arrangements within households, reducing reliance on garden income, enabling households to meet short-term cash demands and social obligations, and, opening up new avenues for men to contribute to the household economy.
- The success of the mama card can be explained partly by the way it was introduced, the employment of female extension officers in OPIC, and the high level of committed support of the scheme by OPIC and NBPOL. Also there were few structural/cost barriers to participation in the scheme, and loose fruit collection was easily incorporated into existing gendered work roles and patterns. Most importantly, it strengthened household livelihood security through increased financial and social benefits for women.
- Replanting programmes at Hoskins and Popondetta are challenged with a reluctance by smallholders to replant. At Popondetta, smallholders are reluctant to replant for several reasons including high debt levels, loss of income, low oil palm prices, tenure insecurity,

rental arrears, poor road conditions and a view by some smallholders that replanting is unnecessary.

- Despite problems with debt avoidance, interest-free in-kind credit to smallholders at Hoskins and Popondetta remains very important for maintaining and enhancing smallholder productivity, social harmony, and for ensuring the future growth of the smallholder sector.
- In a process of weighing up an industry or OPIC intervention, smallholders are often focusing on how a proposed intervention fits into and strengthens their existing livelihood strategies and their objectives. Smallholder initiatives are more likely to be successful if they are compatible with household livelihood strategies that smallholders see as important in maintaining economic and social well being.

Recommendations

- Smallholder initiatives to increase smallholder production or productivity should aim to promote sustainable livelihoods through increasing household choices, income, land security and social harmony.
- Develop more flexible payment systems to encourage greater labour mobility and more equitable distribution of income between co-resident households.
- Encourage the development of supplementary income sources that do not interfere or conflict with oil palm production. This will help relieve some of the economic pressure on smallholder LSS blocks at Hoskins.
- Maintain and support food security by encouraging strategies of sustainable food garden production.
- Examine land issues to ensure future land security and social stability.
- Develop strategies for overcoming the reluctance to replant by smallholders.
- Continue interest free credit schemes currently provided to smallholders by the oil palm companies. The value of these schemes to smallholders could be enhanced significantly by making repayment rates more flexible to take account of fluctuations in oil palm prices.

3. ENTOMOLOGY
(Dr. R. Caudwell)

INTEGRATED MANAGEMENT OF SEXAVA PESTS OF OIL PALM

Introduction

The principal pests of oil palm in PNG are a group of species from the Tettigoniidae family (Orthoptera), collectively known as Sexava. Four species of Sexava are pests of oil palm in PNG, *Segestes decoratus* Redtenbacher and *Segestidea defoliaria defoliaria* Uvarov in West New Britain Province, *Segestidea novaeguineae* Brancsik in Oro Province, and *Segestidea gracilis* in New Ireland Province. These insects cause damage by feeding on the oil palm fronds and defoliation levels can be very severe where high population densities occur. During the last five years an integrated pest management (IPM) system has been developed for Sexava. This IPM system has the following components: (1) a knowledge of the biology and ecology of the pest, (2) economic thresholds, (3) monitoring system for the pest, (4) precise targeting of chemical control agents, (5) biological control and (6) cultural control.

The work undertaken as part of the development and implementation of the Sexava IPM system has been reported by: Caudwell and Orrell (1996), Caudwell and Orrell (1997), Kathirithamby *et al*. (1998), Caudwell, Kathirithamby and Solulu (1998), Caudwell (2000), Kathirithamby *et al* (2000), Caudwell (2000), Caudwell (2001a), and Caudwell (2001b). The IPM system is illustrated in Figure 1. The further developments of this IPM system that were undertaken during 2000 are described below with conclusions drawn about its effectiveness and future role in oil palm cultivation.

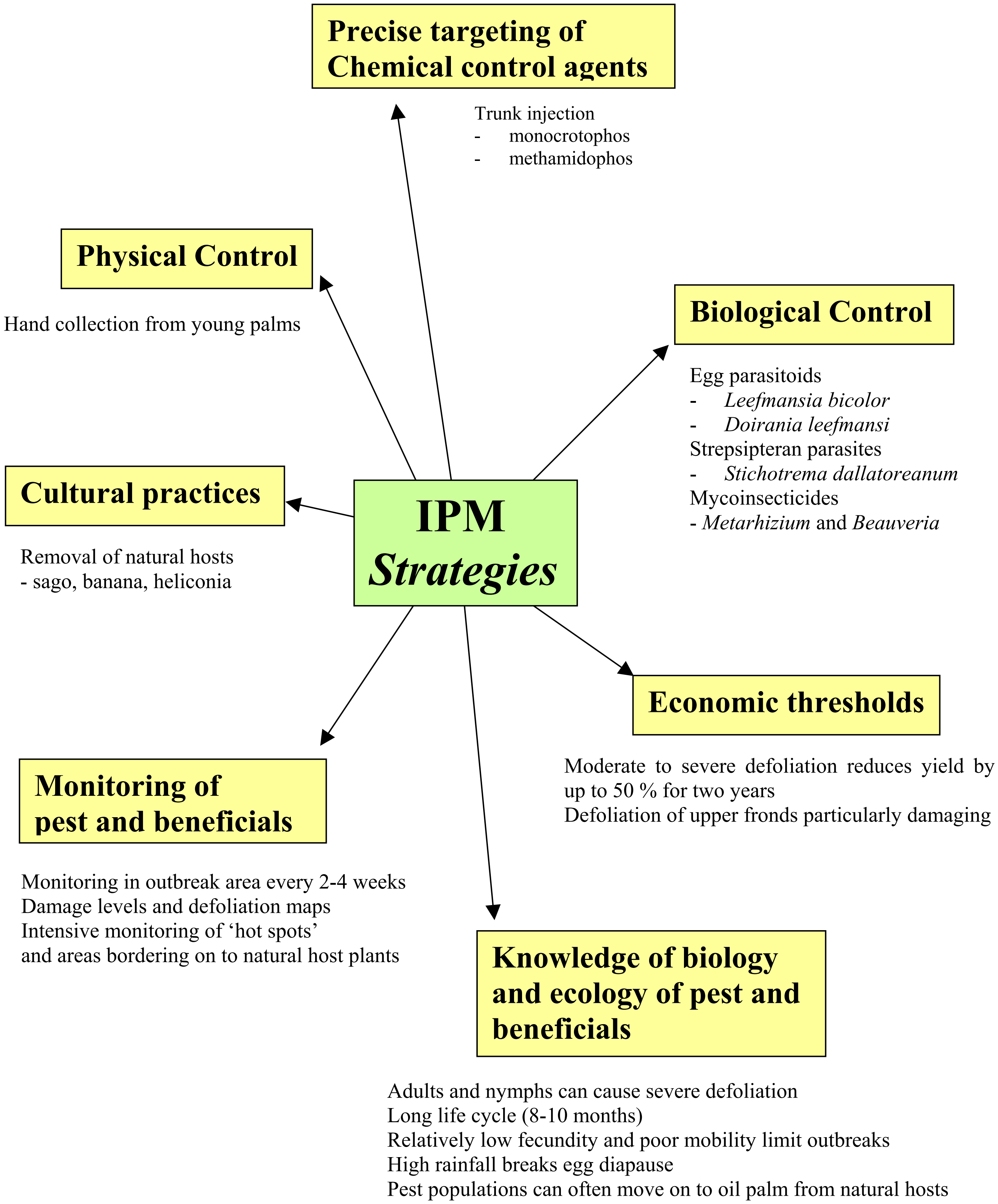
Knowledge of the biology and ecology of the pest

Young (1985) described the basic biology and life cycles of the group of insects collectively known as Sexava. Adult Sexava lay the majority of their eggs in the soil at the base of oil palm trees, but a small proportion may be laid in the roots of epiphytes on the oil palm trunk and in the butts of necrotic palm fronds. Oviposition occurs at night, and eggs are usually laid singly, although one female may lay three or four in succession. A female Sexava can lay up to 100 eggs in a lifetime. The period from egg deposition to hatching varies between 40-100 days. After hatching, the first instar nymphs climb up to the crown of the palm and start to feed on the fronds. The newly emerged nymphs are dark green in colour. The juvenile stages and the moult to the adult stages are completed in the crown of the palm. The number of moults is reported to be six in the male and seven in the female. Females take approximately 21-26 weeks to reach the adult stage, and males approximately 20-22. Adults are usually green in colour, although brown variants often occur. The adults tend only to leave the crown of the oil palm to oviposit or if there is a shortage of food. Sexava populations appear to be higher during the rainy season (October to April in West New Britain). There is little published literature available on this subject, but it is considered that the onset of the rains may result in increased and synchronous emergence of Sexava nymphs.

Monitoring system for the pest

Up until 1995 poor monitoring meant that pest damage was usually not found until it had become severe, and subsequent control operations then occurred too late to prevent significant economic yield losses. During 1995-96 a similar monitoring system to the one described by Wood (1976) as set up, whereby the initial detection component of the monitoring system, or alert stage, be undertaken by plantation workers and smallholder growers.

Figure 3.1 A summary of the IPM system that has been developed for Sexava pests of oil palm



Since 1995 a regular programme of training in entomology has been conducted for plantation workers, smallholder growers, and extension officers. This has involved both formal and informal training, as well as features on rural radio stations. The result is that most people that are directly associated with oil palm growing in West New Britain Province are now able to recognize the very early signs of insect damage. The training programme that was undertaken in 2000 is given in Table 3.1.

A census stage has been developed that involves the visual assessment of feeding damage, using binoculars or the naked eye, and then qualitative scoring into three damage categories (light, moderate, or severe). This technique allows large areas to be surveyed within each oil palm block, rather than confining the damage assessment to a predetermined tree. Furthermore, it allows the trained observer to use his/her knowledge of the pest's behaviour to improve the reliability of the assessment. Once damage levels have been assessed defoliation maps can be drawn up to show levels of pest damage over large areas.

Precise targeting of chemical control agents

The control of a large and rapidly increasing Sexava population is dependent on the use of precisely targeted chemical control agents. This involves the use of trunk-injected monocrotophos (Nuvacron or Azodrin) (Matthews, 1992). The control of Sexava using trunk injection involves the application of monocrotophos (10mls of 40% SL monocrotophos) into a single 1.5cm diameter hole, 15cm deep and drilled at a 45^o angle into the trunk, 1m above the ground. The active ingredient persists for approximately 60 days in the leaf tissue of the palm. A follow up treatment is required after approximately 12 weeks to coincide with the emergence of nymphs from eggs laid by the original pest population. This application technique, by confining the insecticide to the palm, has no impact on other non-target organisms, including beneficial insects (and reduces exposure of workers to these toxic insecticides). This method of pesticide application is very effective if performed properly. Treatment is however very time consuming, especially when very large areas of plantation are affected by high Sexava populations. Treatment of remote areas can be difficult, and control operations are often disrupted during the rainy season.

The improved monitoring system that has been developed over the last 4-5 years as a component of the IPM system has resulted in Sexava outbreaks being reported very early, and has therefore enabled chemical treatment to be undertaken before the populations have had time to spread and affect large areas of oil palm. The oil palm growing areas in West New Britain that required chemical treatment for economically significant levels of Sexava damage during 2000 are shown in Table 3.2. From Table 3.2 it can be seen that during the year there were 15 outbreaks that were recommended for chemical treatment, with a total area of approximately 1981 ha. Approximately 4951 litres of monocrotophos were used for these treatments, at a total insecticide cost of 134,079 Kina and a unit insecticide cost of 67.7 Kina/ha.

The oil palm growing areas in West New Britain that required chemical treatment for economically significant levels of Sexava damage during 1996, 97,98, 99, and 2000 are shown in Table 3.3. From Table 3.3 it can be seen that during 1996 a total of 910 ha were treated at an insecticide cost of 42,330 Kina, during 1997 215 ha were treated at a cost of 13,819 Kina, during 1998 36 ha were treated a cost of 2,043 Kina, during 1999 548 ha were treated at a cost of 37,100 kina, and during 2000 2,592 ha were treated at a cost of 175,512 Kina.

Table 3.1. A summary of the entomology training schedule for 2000

Month	Plantation / smallholder group	Activity
January	Sarakolok smallholders	Course in trunk injection methodology
February	OPIC, Popondetta project	Smallholder field day
March	OPIC, Popondetta project	Smallholder field day
April	OPIC, Popondetta project	Smallholder field day
May	OPIC, Popondetta project	Smallholder field day
May	Soi smallholders	Course in trunk injection methodology
June	OPIC, Popondetta project	Smallholder field day
July	OPIC, Popondetta project	Smallholder field day
August	OPIC, Popondetta project	Smallholder field day
September	Numundo Group, NBPOL	Entomology training course
September	Numundo Group, NBPOL	Entomology training course
September	OPIC, Hoskins project	Entomology training course
September	OPIC, Hoskins project	Entomology training course
September	OPIC, Hoskins project	Entomology training course
September	OPIC, Hoskins project	Entomology training course
September	Kapiura Group, NBPOL	Entomology training course
September	Mosa Group, NBPOL	Entomology training course
October	OPIC, Popondetta project	Smallholder field day
December	Malilimi, NBPOL	Entomology training course

Table 3.2. The oil palm growing areas in West New Britain that required chemical treatment for economically significant levels of Sexava damage in 2000

Date	Plantation / Smallholders	Site	Approximate Area (ha)	Volume of formulation (l)
6 January	Hoskins Smallholders	Sarakolok	4.5	11.25
28 January	Hoskins Smallholders	Sarakolok	38	95.00
12 February	Hoskins Smallholders	Sarakolok	19	47.50
18 February	Hargy Oil Palms	Navo	833	2082.5
7 March	Hoskins Smallholders	Sarakolok	192	480
17 March	Bialla Smallholders	Soi	300	750
25 May	Hoskins Smallholders	Sarakolok	13	32.5
30 May	NBPOL Mosa Group	Togulo	34	85
15 June	NBPOL Mosa Group	Togulo	19	47.5
15 June	Hoskins Smallholders	Siki VOP	64	160
25 June	Hargy Oil Palms	Area 2	200	500
18 Sept	Hoskins Smallholders	Kavui/Tamba	51	127.5
4 October	NBPOL Kapiura Group	Bilomi	145	362.5
4 October	Hargy Oil Palms	Balaha	25	62.5
15 October	Hoskins Smallholders	Kavui	43	107.5
9 December	Hoskins Smallholders	Roka	20	50
7 December	NBPOL Kapiura Group	Malilimi	522	1305
19 December	Poliamba, New Ireland	Wanup Estate	70	175
		Total	2,592.5	6,481.25
Percentage of WNBP and NI oil palm growing area treated				4.08 %
Insecticide costs – Nuvacron/Azodrin K27.08/l				175,512 kina
Unit insecticide costs – per hectare				67.7 kina/ha

Table 3.3. The oil palm growing areas in West New Britain that required chemical treatment for economically significant levels of Sexava damage in 1996, 97,98 and 99

Year	Approx. area (ha)	Volume of formulation (l)	Insecticide cost (kina)	Unit insecticide cost (K/ha)
1996	910	2,275	42,330	46.5
1997	215	538	13,819	64.27
1998	36	90	2,043	56.75
1999	548	1370	37,100	67.7
2000	2,592	6,481	175,512	67.7

It is apparent that there was a relatively large area treated for Sexava damage during 2000. This was in fact the largest area that has been treated for since the beginning of the development of the Sexava IPM system in 1996. However, a more detailed examination of the outbreaks demonstrates that much of the increase in the area treated was due to management, rather than biological reasons.

For example, the Sexava outbreak at Navo Plantation was recommended for chemical treatment as early as May 1999. At this time only about 30-40 hectares of plantation where infested with Sexava, and the treatment of this small area would have been extremely cheap. Unfortunately the management of Hargy Oil Palms were unwilling to carry out the chemical treatment at that stage. Subsequently the outbreak increased in area, further recommendations were given for chemical control, but this advice was again ignored. Furthermore, the treatment that was undertaken was done to a very poor standard, with a lot of areas only receiving a single treatment. A significant proportion of this area remained untreated at the end of December 2000, some 19 months after the original outbreak was surveyed.

In addition to this, the 300 hectares that were recommended for treatment at Soi were probably the result of a build up on low-level Sexava populations over the previous 2-3 years. Add to this the 522 hectares that were recommended for treatment at Malilimi, which was the result of an outbreak that went undetected for several months before, and the resulting area of ‘normal’ outbreaks is somewhat different. A more realistic figure would be somewhere around 900 hectares, rather than the 2,526 that resulted from the above factors. An area of 900 hectares, although relatively large, is more in-line with the magnitude of Sexava outbreaks since 1996. Furthermore, it is considered that in the long-term the annual outbreak area will be significantly reduced by the introductions of the Sexava parasite, *Stichotrema dallatorreanum* into West New Britain. Details of this are given in the next section.

Biological Control

Egg parasitoids

The first recorded use of Sexava egg parasitoids in PNG was in 1933, when the Hymenopteran egg parasitoids *Leefmansia bicolor* and *Doirania leefmansi* were introduced from Amboina in the Moluccas and established in a number of coconut growing areas on New Hanover Island (Froggatt, 1935).

PNGOPRA has reared these two parasitoids in the laboratory for several years. They are reared on Sexava eggs and then released into oil palm growing areas where low-level Sexava populations are present. Several million of these egg parasitoids are usually released into the field each year.

Table 3.4 gives details of the releases of egg parasitoids during 2000. From the table it can be seen than a total of 5,648 parasitised eggs were released during the year. From these eggs a total of approximately 112,960 adult parasites would be expected to emerge. It can be seen that parasitised eggs were released in oil palm plantations, as well as in smallholder and village oil palm. Small numbers were also released on to coconuts in Madang Province, in collaboration with CCRI.

Strepsipteran parasites

In PNG, female *Stichotrema dallatorreanum* Hofeneder (Myrmecolacidae) parasitize Sexava (Young, 1987). High levels of parasitism (30-40%) of the Sexava species, *S. novaeguineae* by *S. dallatorreanum* occurs in oil palm growing areas in mainland PNG (Kathirithamby *et al.,* 1998) and chemical control has not been required on plantations in these areas for many years. By contrast, in West New Britain regular intervention has been required to control *S. defoliaria* and *S. decoratus. S. dallatorreanum* has not been reported from these two species of Sexava in West New Britain.

Kathirithamby *et al.* (1998) reported that when a Sexava host is infected by *S. dallatorreanum,* the first instar larva of the parasite enters the host and moults the cuticle to become an apodous second instar larva. There are three endoparasitic larval instars, and the process of moulting is the occurrence of apolysis, which is not followed by ecdysis, so that the endoparasitic larval instars therefore remain enveloped by the old cuticles (Kathirithamby *et al.*,1998). The neotenic female *S. dallatorreanum* produces over a million eggs which develop viviparously, and the first instar larvae emerge to the exterior via the cephalothorax to seek and infect new hosts (Kathirithamby *et al.*, 1998).

A quantitative study into the effect of parasitism by *S. dallatorreanum* on the performance of the *S. novaeguineae* host was undertaken by Solulu *et al.* (1998) in Oro Province, on the mainland Papua New Guinea. Solulu *et al.* (1998) reported that the morphological consequences of infection by *S. dallatorreanum* included reduced wing, ovipositor and digestive tract lengths in the host. Solulu et al. (1998) also reported that feeding activity, ovarian development, egg number and gonadal weight were significantly reduced in parasitized hosts. Solulu *et al.* (1998) concluded that the consequent reduction in host fecundity indicated *S. dallatorreanum* may have potential as a biological control agent for use in a Sexava IPM system.

A series of infectivity trials were undertaken in the laboratory to assess whether the parasite would infect the two species of Sexava that are pests of oil palm in West New Britain. Nymphs (2^{nd} and 3^{rd} instar) of the two species were exposed to first instar S. *dallatorreanum* in replicated and controlled cage experiments. The infection levels in test insects from the two species ranged from approximately 70-90%, relative to the healthy control insects. Field studies were also undertaken to survey for male *S. dallatorreanum* in Oro Province on the mainland of Papua New Guinea. However, relatively few males of the parasite were found during the study period and the role of the males in the life history of the parasite remains unclear. Kathirithamby (personnel communication) suggests that the female S. *dallatorreanum* that infect *S. novaeguineae* in the oil palm growing areas of mainland PNG may be facultatively parthenogenetic

Table 3.4. The oil palm growing areas in West New Britain in which Sexava egg parasitoids were released during 2000

Location	Number of Sexava eggs parasitised by *L.bicolor*	Number of adult *L.bicolor* expected to emerge
Plantations		
Dami Research Station, NBPOL	210	4,200
Bebere Div 2, NBPOL	310	6,200
Bilomi Div 1, NBPOL	338	6,760
Malilimi Div 1, NBPOL	870	17,400
Navarai, NBPOL	210	4,200
Numundo, NBPOL	580	11,600
Togulo Div 2, NBPOL	350	7,000
Area 2, Hargy Oil Palms	220	4,400
Navo Plantation, Hargy Oil Palms	450	9,000
Luburua, Poliamba	60	1,200
Warup, Poliamba	140	2,800
Smallholders		
Kavui	330	6,600
Kapore	320	6,400
Siki	210	4,200
Sarakolok	400	8,000
Tamba	110	2,200
Soi	120	2,400
Village Oil Palm		
Banaule	110	2,200
Coconuts		
Stewart Research Station, Medang	310	6,200
Total	5,648	112,960

Table 3.5. Details of the field introductions made during 2000 of *S. defoliaria* and *S. decoratus* infected with *S. dallatorreanum.*

Trial Site	Dates of releases	Number of infected Sexava released
Siki smallholders	February - June	593
Dami plantation	February - June	668
Kapore smallholders	June - August	606
Navo plantation	June – December	1253
Kavui smallholders	September - December	499
	Total number released	3619

The parasite has now been introduced into the oil palm growing areas of West New Britain in an attempt to get it established in field populations of *S. defoliaria* and *S. decoratus.* The nymphs of the two species have been infected with *S. dallatorreanum* in the laboratory, using the methodology developed during the infectivity trials. Infected Sexava have then been released at regular intervals into a series of release areas, located throughout the oil palm growing areas of West New Britain Province. The introductions have now been taking place for a period of 12 months, and are set to run for approximately 2-3 years, this is detailed in Table 3.5. Surveys have been undertaken in the release areas to determine the degree of infection by the parasite in subsequent generations of Sexava populations.

Data gathered from the release sites have shown that *S. dallatorreanum* can complete its life cycle in the field populations of *S. defoliaria* and *S. decoratus* in West New Britain. There is also evidence to suggest that the parasite is spreading from the original release sites to infect *S. defoliaria* and *S. decoratus* in surrounding areas. The data indicates that there is a good chance of successfully establishing S. dallatorreanum in West Britain and that the parasite will have a significant impact on populations of Sexava.

Conclusions

A summary of the IPM system that has been developed for Sexava is shown in Figure 3.1. The knowledge of the biology and ecology of the main pest, although far from complete, is enough to enable effective decision making in the other components of the IPM system. The impact of the pest on the yield components of the crop is sufficiently well understood to enable economic thresholds to be determined. The economic thresholds are effective at a field level, and can be used in the area-wide monitoring system for the pest. Pest monitoring is efficient, as evidenced by the regular detection of low-level pest damage, and it requires a relatively small input from specialist entomologists. There is no indiscriminate use of insecticides, with the trunk-injection technique providing precise targeting of chemical control agents, thus preventing contamination of the environment and workers, as well as preserving beneficial and non-target organisms.

The successful introduction of the *S. dallatorreanum* into the oil palm growing areas of West New Britain and New Ireland will have a significant impact on the pest status of the two species of Sexava in these areas. This is likely to result in further reductions in the use of insecticides, and therefore provide further cost benefits to the oil palm industry in PNG. The information from the field trials suggests that *S. dallatorreanum* is establishing in the populations of *S. defoliaria* and *S. decoratus* in West New Britain. Further releases during the next 1-2 years will mean that this is an increasingly likely event

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INSECT POLLINATION OF OIL PALM

Introduction

E. kamerunicus was introduced into Papua New Guinea in 1982. This resulted in significant improvements to oil palm pollination, resulting in improved fruitset levels and oil extraction ratios, and hence increased yields. The introductions of the pollinating weevil made a significant contribution to the economic viability of the oil palm industry in PNG, and was particularly helpful to the smallholder sector because yields were significantly increased with no direct cost to the farmers, and this continued in the medium to long term.

Recently, Ming (1999) highlighted concerns regarding the periodic occurrence of poor pollination and yield (drop by as much as 30%) in certain locations in Malaysia. Ming (1999) reported that low weevil populations have been observed to be associated with the problem and suggested that this may be caused by the direct or indirect effects of weather, or due to parasitism by the nematodes *Aphelenchoides bicaudatus* and *Cylindrocorpus* sp. enhanced by weather change. Ming (1999) also suggested that a second pollinator, e.g. *E. subvittatus* may be able to overcome this situation, and hence complement *E. kamerunicus.* Ming (1999) concluded that a thorough study on this subject is of the utmost urgency.

Rao and Law (1998) reported on the problem of poor fruitset in parts of East Malaysia. These authors highlighted that large sums of money are being lost each year because of seasonal reductions in FFB, OER and KER because of poor fruitset. The poor fruitset is reported to be due to poor pollination five months earlier when weevil numbers are drastically low. The authors suggest that poor pollination could be due to (1) insufficient viable pollen, (2) reduced pollinating activity by the pollinating weevil, and (3) combinations of (1) and (2). Research undertaken at Pamol since 1992 has ruled out low pollen viability as a likely cause of poor fruitset. It was found that the seasonal low fruitset is due to poor pollination because of insufficient weevils (Rao and Law, 1988). Weevil numbers fell dramatically when their breeding sites, the male inflorescences, became less abundant, and this was coincident with extensive infection by parasitic nematodes and unfavourable weather. Rao and Law (1998) regarded the nematode infection of weevils as an intractable problem. They suggested that the present weevil populations, derived from only a few pairs, may be suffering inbreeding depression, and hence more rapidly succumb to nematode parasitism. Furthermore, it is suggested that these weevils lacked the features necessary for adaptation to wet conditions. Syed has suggested the immediate action of importing *E. kamerunicus* from Peninsular Malaysia and, subsequently, other *Elaeidobius* species from Africa. Rao and Law (1998) considered that a complex of pollinating insects, some of whose niche is not the oil palm inflorescence may eventually be necessary.

Rao and Law (1998) highlighted that suggestions of importing fresh batches of *E. kamerunicus* or indeed other species of pollinating insects from Cameroon requires some priority research into some key issues. For instance, in their native Cameroon, weevil populations were also observed to decline in the rainy season but the reduction was less pronounced. It would therefore be useful to determine the cause of the decline in native Cameroon. A high proportion of the dead pupae and weevils of the original importation into Malaysia were nematode infected (Kang *et al.*, 1982) and hence destroyed. So the nematodes that are now causing the problems were probably brought in with the original populations.

Rao and Law (1998) considered that the suggestion of inbreeding depression, or extreme homozygosity, raises the question of why the effects were not manifested sooner after the introduction given the weevil's short generation time. Furthermore, populations at other localities, some experiencing seasonal wet weather, also grew from a limited number of mating pairs. They suggest that it would therefore be interesting to find out how potentially serious the nematode parasitism is in these areas. Rao and Law (1998) concluded that containing nematode parasitism requires an understanding of the manner of parasitism and the predisposing factors favouring the rise in nematode parasitism in the weevil population. They also highlighted that the introduction of new weevils into a given area requires the predetermination of levels of resistance, or at least heterozygosity, in sub groups if they exist and in different species on the weevil in the genera.

Insect pollination of oil palm in Papua New Guinea

The oil palm industry in Papua New Guinea is should take the matter of the long-term viability and sustainability of *E. kamerunicus* very seriously. Although excellent levels of fruitset are being achieved in most project areas within PNG it is considered that urgent action is necessary to address the sustainability of the current levels of insect pollination, as well as to possibly make improvements for the future.

The current population of pollinating weevils within Papua New Guinea is derived from a relatively small number of weevil individuals introduced from West Africa in 1982. It is therefore apparent that the oil palm industry in PNG faces the same problems as in other areas of South East Asia, that the narrow genetic base of the weevil population poses a very significant risk to viable and sustainable production.

An initial, two-year research project was approved for funding by the European Union in July 2000, with a grant of almost kina 500,000. This will involve collaboration between the Oil Palm Research Association in Papua New Guinea and CABI Biosciences in the UK.

The objectives of the pollination project

The objectives of the project are:

(1) To screen the existing *E. kamerunicus* populations within PNG for evidence of infection by the nematodes *Aphelenchoides bicaudatus* and *Cylindrocorpus* sp., or any other species of nematode, or other parasites and pathogens. This will involve the season monitoring of infection levels, as well as detailed laboratory studies to assess the impact that the nematode infections might be having on the fitness, vigour, and fecundity of the weevil population and consequently fruitset levels.

(2) To determine the degree of genetic separation between weevil populations in Papua New Guinea and natural populations in West Africa. Molecular markers are being increasingly used to characterize plant and animal populations. Markers can be used to evaluate levels of genetic diversity and phylogenetic relationships within and between species, and to identify particular races. Several different types of markers have been developed, including isozyme, RFLP, RAPD, and AFLP. AFLP (Amplified fragment length polymorphism) is a novel DNA fingerprinting technique (Vos *et al.*, 1995). The AFLP technique has many of the characteristics of an ideal system for detecting genetic variation (Majer *et al.*, 1996). For example, variability is assessed at a large number of independent loci, AFLP markers are 'neutral' (i.e. not subject to natural selection), variation is revealed in any part of the genome, data are obtained very quickly and are extremely reproducible (Majer *et al.*, 1996).

The AFLP technique is based on the selective PCR amplification of restriction fragments from a total digest of genomic DNA. The technique involves three steps: (1) restriction of the DNA and ligation of oligonucleotide adapters, (2) selective amplification of sets of restriction fragments, and (3) gel analysis of the amplified fragments. PCR amplification of restriction fragments is achieved by using the adapter and restriction site sequence as target sites for primer annealing. The selective amplification is achieved by use of primers that extend into the restriction fragments, amplifying only those fragments in which the primer extensions match the nucleotides flanking the restriction sites. Using this method, sets of restriction fragments may be visualized by PCR without knowledge of nucleotide sequence. The method allows the specific co-amplification of high numbers of restriction fragments. The number of fragments that can be analyzed simultaneously is dependent on the resolution of the detection system. Typically 50-100 restriction fragments are amplified and detected on denaturing polyacrylamide gels.

The AFLP technique will be used to compare the degree of genetic separation between populations of introduced weevils in PNG and natural weevil populations in West Africa. Field studies will also be undertaken to determine the interaction between genetic diversity and the degree and impact of nematode infection at the population level. Rao and Law's (1998) suggestion that the narrow genetic base may mean that existing weevil populations are more susceptible to nematode parasitism will be evaluated.

(3) To assess the potential to improve the genetic base of the existing population of *E. kamerunicus* within Papua New Guinea as well as on a regional level. This could be done by the introduction of fresh batches of the same weevil species, or possibly by the introduction of one or a number of new species of pollinating insects from West Africa or South America.

Work on the project during the later part of 2000 has involved sampling *E. kamerunicus* in oil palm growing areas within PNG and Ghana.

The following sites have been sampled in PNG:

1. Area 9, Hargy Oil Palms, West New Britain Province
2. Kautu Plantation, NBPOL, West New Britain Province
3. Kavu Gara Plantation, NBPOL, West New Britain Province
4. Kumbango Plantation, NBPOL, West New Britain Province
5. Dami Plantation, NBPOL, West New Britain Province
6. Poliamba Limited, New Ireland Province
7. Milne Bay Estates, Milne Bay Province
8. Higaturu Oil Palms, Oro Province

The following sites have been sampled in Ghana:

1. Kade, Eastern Region
2. Ajukato, Eastern Region
3. Benso Oil Palms, Western Region
4. Sekondi school, Western Region
5. Twifo Oil Palms, Central Region
6. Between Twifo and Cape Coast, Central Region
7. Assin Dadieso, Central Region
8. Egyirkrom, Central Region
9. Ewusi, Western Region

Further work on the project to date has involved the screening of sampled of weevils from PNG and Ghana for evidence of infection by the nematodes *Aphelenchoides bicaudatus* and *Cylindrocorpus* sp., or any other species of nematode, or other parasites and pathogens. Work has also been undertaken to on these samples to determine the degree of genetic separation between weevil populations in PNG and natural populations in West Africa. Adequate amounts of high quality DNA have been extracted from the samples from each of the sites. During the first half of 2001 the AFLP technique will be carried out using these DNA samples. It should then be possible to determine the degree of genetic separation between weevil populations in PNG and natural populations in West Africa.

During the first half of 2001 further field sampling has been undertaken in Indonesia and Costa Rica. During this visit weevils have been sampled from PTPP London Sumatra in Indonesia and from ASD Oil Palms in Costa Rica. The samples from these two locations will be used as out groups in both the nematode screening and AFLP work.

All of the above work will be described in the 2001 Annual Report.

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MINOR INSECT PESTS OF OIL PALM DURING 2000

PNG Islands

1. Bagworms (Lepidoptera: Psychidae)

There were only two minor outbreaks of Bagworm damage during 2000 that required chemical treatment, one at close to the nursery and the other close to the mill, both at Kautu Plantation (Kapiura Group, NBPOL). The overall area treated was however less than five hectares.

There were also isolated outbreaks of Bagworms at Bebere and Kautu nursery. Chemical treatment was not required for these outbreaks.

2. Leafhoppers (Hemiptera: Cicadelloidea)

Feeding by *Zophiuma lobulata* causes Finschhafen disorder of coconuts and oil palm. The prevalence of Finschhafen disorder in West New Britain seemed to increase slightly during 2000, with a number of small areas of oil palm requiring chemical treatment, including about 20 palms at Dami Research Station, and a similar number of palms adjacent to the nursery at Kautu Plantation.

3. Rhinoceros beetles (Coleoptera: Scarabaeidae)

During 2000 there was an outbreak of the common rhinoceros beetle, *Scapanes australis*, at Suma Estate, Poliamba Ltd, New Ireland Province. The eggs of this species of beetle are laid in rotting plant materials including tree trunks and stumps, compost heaps, dung hills etc. The overall development cycle of the beetle exceeds one year. Eggs hatch after about 32 days and the entire larval stage is spent inside the breeding medium. The larvae usually live in isolation from each other and mine galleries in the soil.

The adult beetles feed on the growing points of coconut and oil palms and this is the primary cause of crop damage leading to loss of yield and death in young palms. On oil palms, *S. australis* bores into the cluster of spears, boring through petiole bases into the central unopened leaves. This causes tissue maceration and the presence of a fibrous frass inside the feeding hole is an indication of its activity within. In young palms where the spears are narrower and penetration may occur lower down, the effects of damage can be much more severe than in older palms. The young palms affected by the beetle damage have a delayed immaturity period. Thus, early oil palm yields are considerably reduced after a prolonged and serious rhinoceros beetle attack.

The damage levels at Suma were found to be very high. Damage assessments were undertaken on 300 palms across two transects from one side of the estate to the other, with one transect located on either side of the main highway. A total of 24.6% of palms were found to have spear cluster damage, which is regarded as primary damage symptoms. A significant proportion of these palms, particularly those close to the boundaries of the estate, were found to be seriously damaged.

Chemical treatment was recommended for all affected areas within Suma. This was done by the application of carbofuran granules (‘furadan’) into the leaf axils of the palms. This is a systemic insecticide with predominately contact and stomach action that has been used routinely for rhinoceros beetle control on oil palm for many years. A second application of insecticide was undertaken two months after the first.

A trial of the *Scapanes* pheromone, developed at CCRI/CIRAD was also undertaken at Suma Estate. This was done using bucket traps, each containing two lengths of freshly cut sugar cane and three slow release formulations of *Scapanes* aggregation pheromone. The pheromone contains a mixture of 2-butanol, 3-hydroxy-2-butanone, and 2,3-butanediol. The mixture of these components exhibits pheromone activity, which French researchers suggest is a sex pheromone. It is thought that male beetles have evolved to respond to their own sex signal to gain possession of a suitable mating and feeding site by fighting with other males. French researchers report that male beetles perform a peculiar calling behaviour during the early evening, by raising their abdomens and emitting a rectal liquid secretion, which reported to be rhythmically smeared by crossing of the hind legs. It is from this rectal secretion that the French have been able to develop the synthetic pheromone.

The pheromone traps have been very effective at reducing *Scapanes* damage to coconuts in East New Britain. However they were found to be not effective at Suma Estate, the reason for which remains unclear.

There were no further outbreaks of *Oryctes rhinoceros* during 2000.

PNG Mainland

4. Stick insects (Phasmatodea: Phasmidae)

Species of stick insects, *Eurycantha* species, have previously been recorded as important pests of oil palm in Oro Province, with the first economic damage reported in 1986. Further economic damage was reported in 1989 and 1990. There was an increased incidence of stick insect damage to oil palm in Oro Province during between 1996 and 1999. During 1997 there were a total of 4 smallholder blocks at Koropata division that were recommended for chemical treatment for the control of stick insects. A further 7 smallholder blocks in the same division were recommended for treatment in 1998, and 34 blocks during 1999. The 1999 outbeaks were at Koropata (18 blocks) and New Warisota VOP (16 blocks). There were however no new outbreaks of Stick insects during 2000.

5. Bagworms (Lepidoptera: Psychidae)

Damage by bagworms, *Mahasena corbetti* (rough bagworm), *Clania* species (smooth bagworm), and the 'ice-cream cone' bagworm remained low and of no economic significance throughout 2000, in both Milne Bay and Oro Provinces. The occurrence of field populations was sporadic and isolated, with light damage of no economic significance.

6. *Acria* moth (Xyloryctidae)

Acria moth is widespread throughout Milne Bay Estates from Giligili to Hagita, Waigani and Sagarai. During 2000 some damage to oil palm was observed in areas throughout these locations. Although this pest has been causing damage, no control measures have been recommended since 1994. There appears to be a wide range of naturally occurring biological control agents that usually provided adequate population regulation.

7. Chafer beetles (Coleoptera: Melonothinae)

Chafer beetles are widespread throughout the oil palm growing areas of Oro Province. Population levels are however usually very low, and damage levels light.

Light to moderate levels of Chafer beetle damage occurred at Embi Plantation (Higaturu Oil Palms) during 2000. This was caused by two species (*Dermolopida* sp and *Litura* sp). No control measures were recommended and the population subsequently declined during the second half of the year, a similar pattern to that observed in previous years. We continue a programme of monthly population and damage monitoring at Embi Plantation.

POLLINATION TRIALS

The number of male flowers at anthesis and the number of female flowers at the receptive stage in the three trial plots at Mamba Estate, HOPPL are shown in Figures 3.2 and 3.3.

The mean number of weevil progency emerging from each spikelet and the mean percentage fruitset in the three trial plots at Mamba Estate, HOPPL are shown in Figures 3.4 and 3.5.

The mean number of weevil progency emerging from each spikelet in the four trial plots at Kapiura Plantation, NBPOL is shown in Figure 3.6.

The number of male flowers at anthesis and the number of female flowers at the receptive stage in the four trial plots at Garu and Haella, NBPOL are shown in Figures 3.7 and 3.8.

The mean number of weevil progency emerging from each spikelet in the four trial plots at Garu and Haella, NBPOL are shown in Figure 3.9.

Figure 3.2. The number of male flowers at anthesis (average/day/135 palms) in the three trial plots at Mamba Estate, HOPPL, Oro Province during 2000

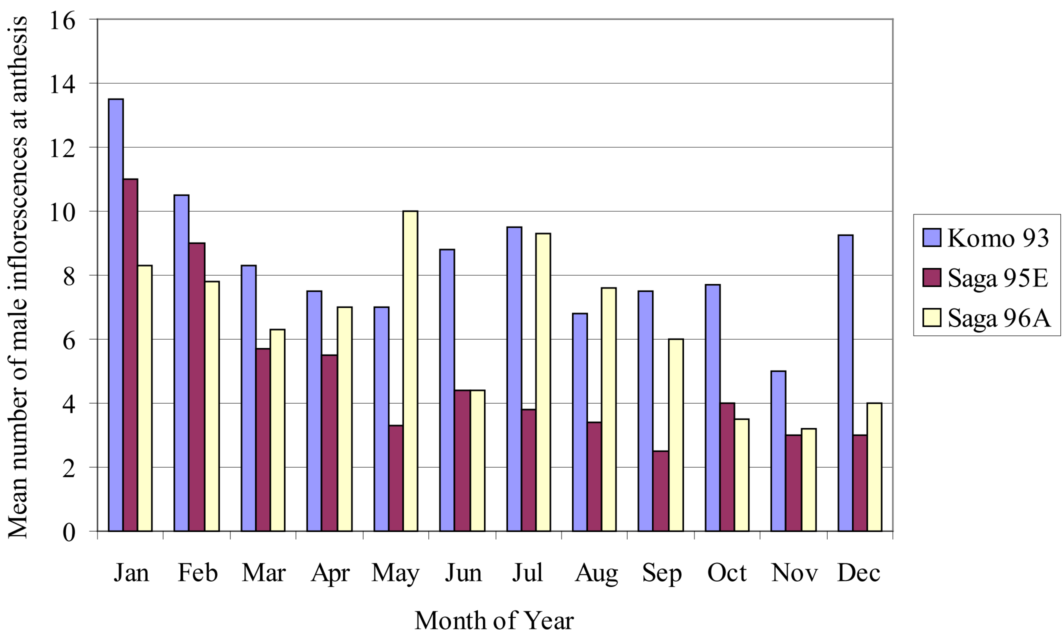


Figure 3.3. The number of female flowers at receptive stage (average/day/135 palms) in the three trial plots at Mamba Estate, HOPPL, Oro Province during 2000

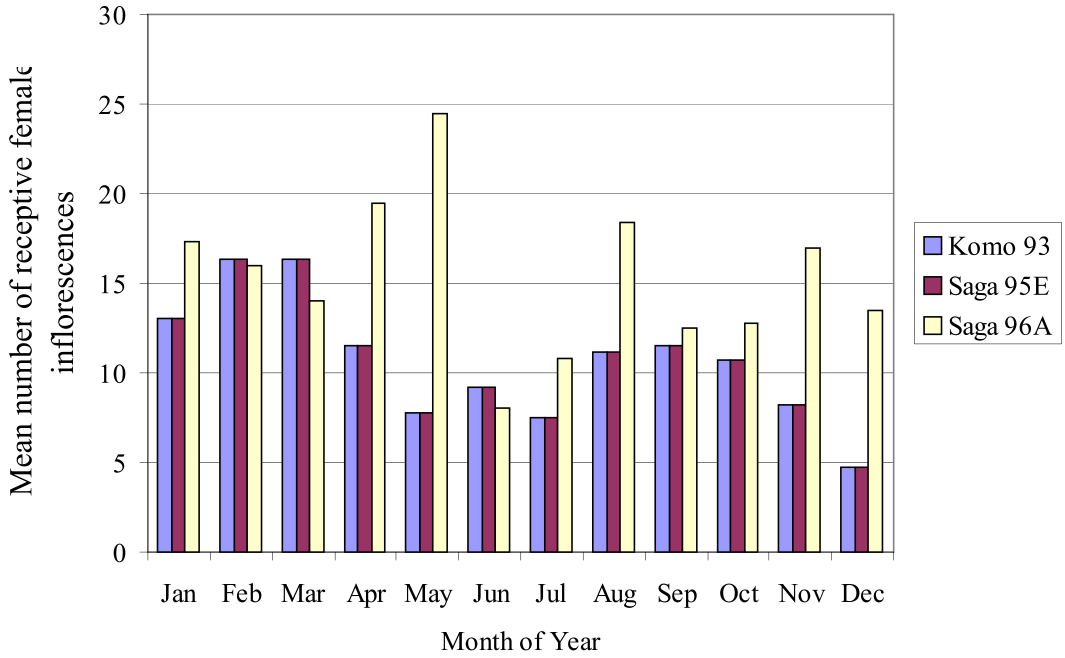


Figure 3.4. The mean number of weevil progency emerging from each spikelet from the trial plots at Mamba Estate, HOPPL, Oro Province during 2000

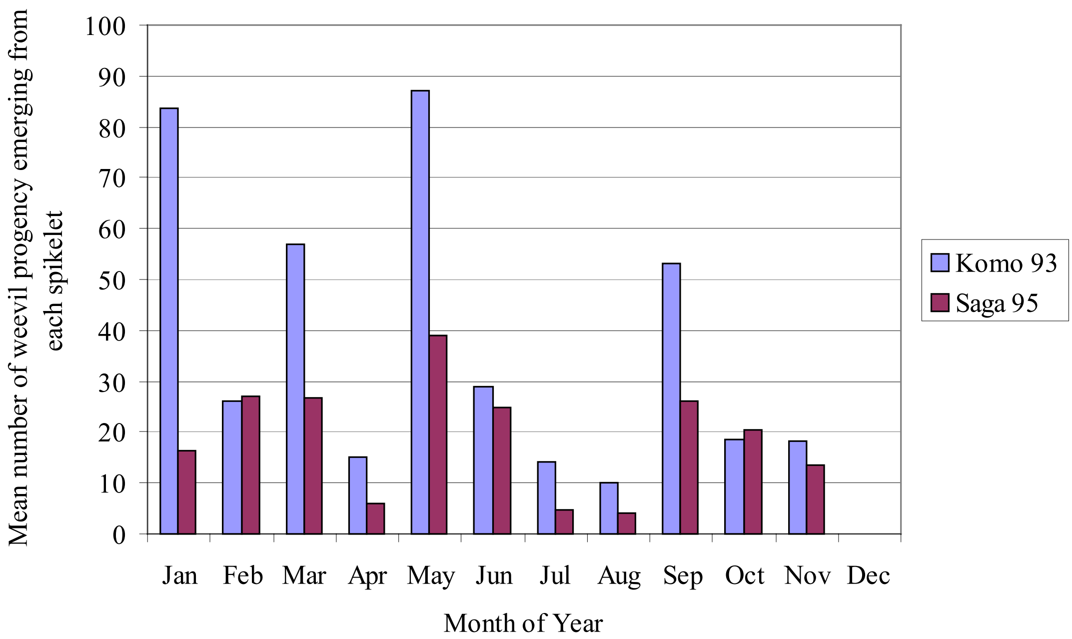


Figure 3.5. The mean percentage fruitset for the trial plots at Mamba Estate, HOPPL, Oro Province during 2000

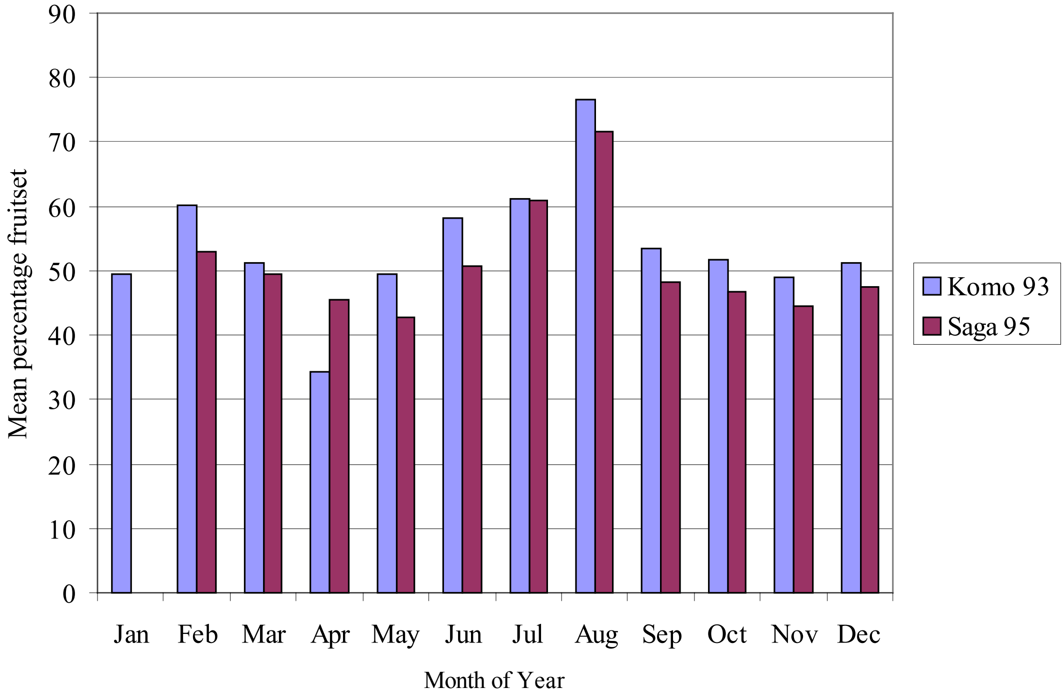


Figure 3.6. The mean number of weevil progency emerging from each spikelet from the trial plots at Kapiura Plantation, NBPOL, West New Britain Province during 2000

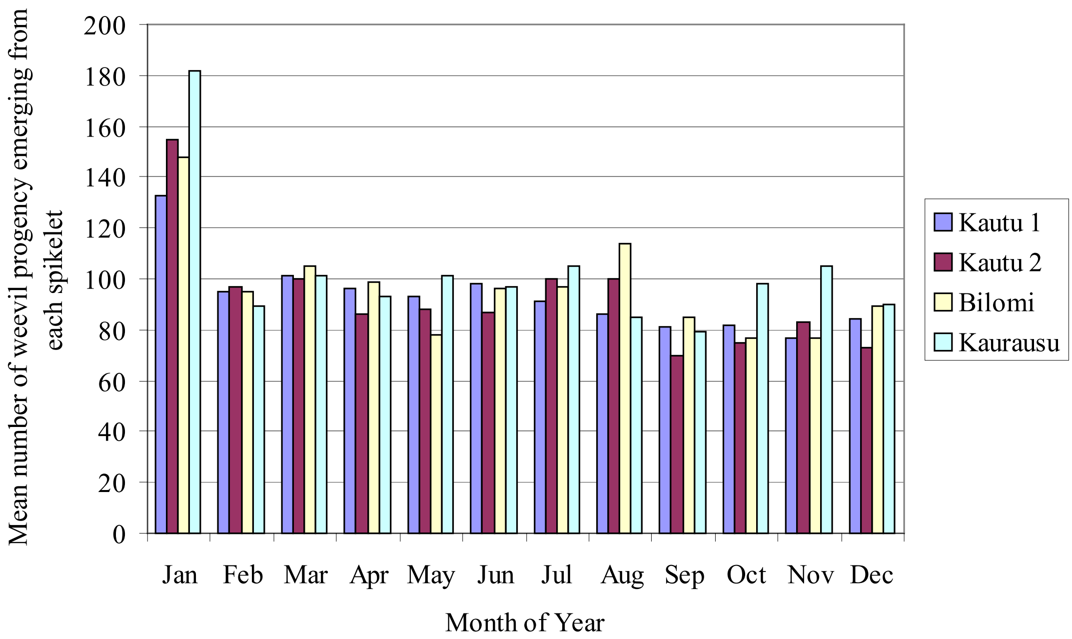


Figure 3.7. The number of male flowers at anthesis (average/day/135 palms) in the four trial plots at Garu and Haella, NBPOL, WNBP during 2000

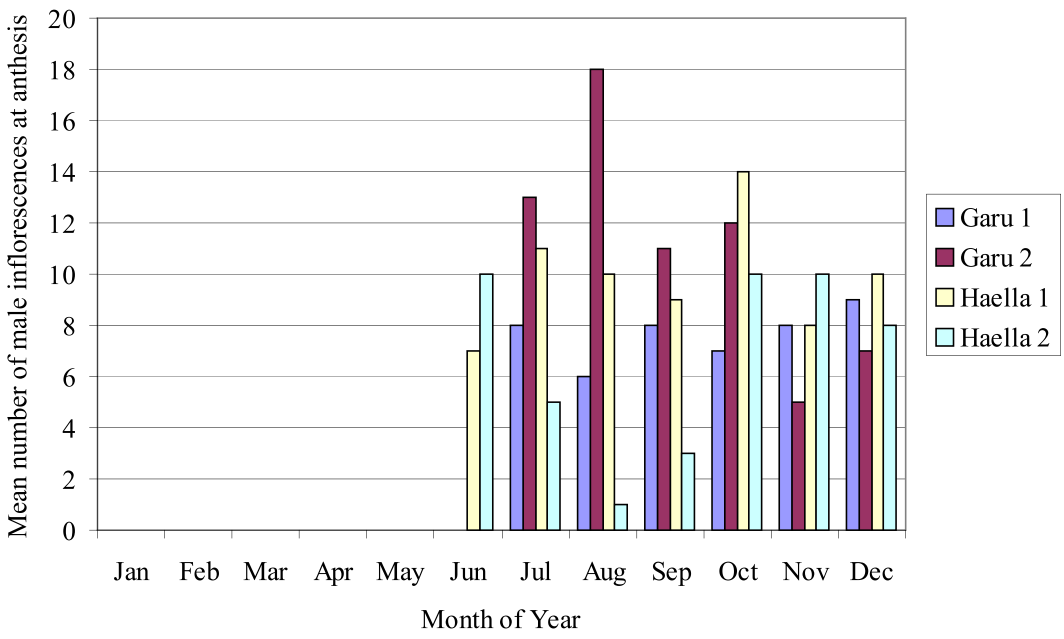


Figure 3.8. The number of female flowers at receptive stage (average/day/135 palms) in the four trial plots at Garu and Haella, NBPOL, WNBP during 2000

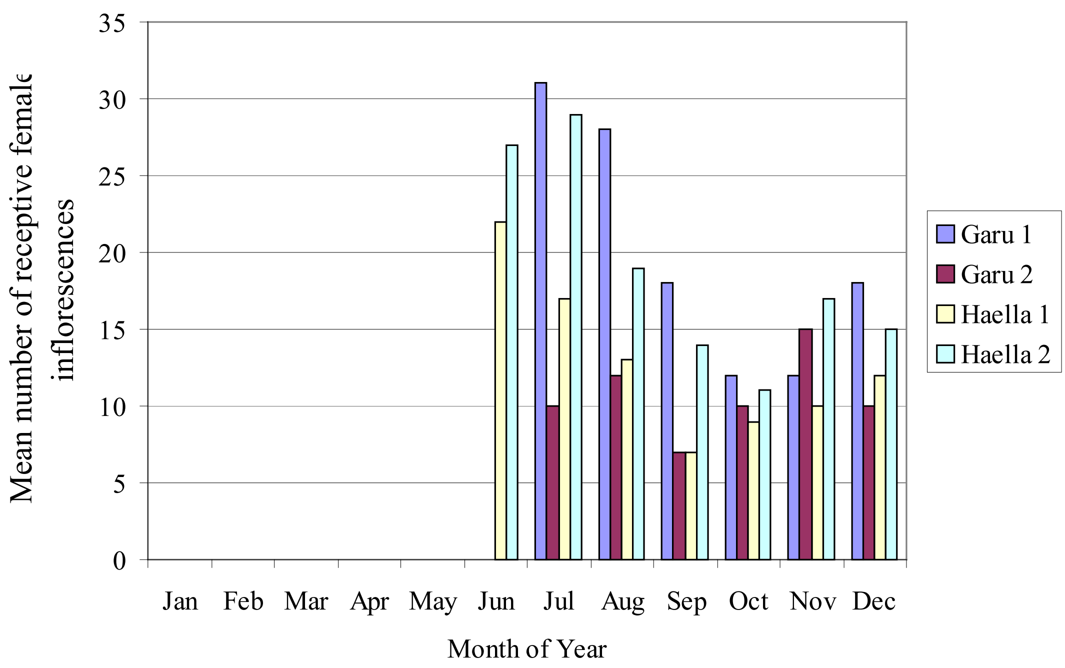
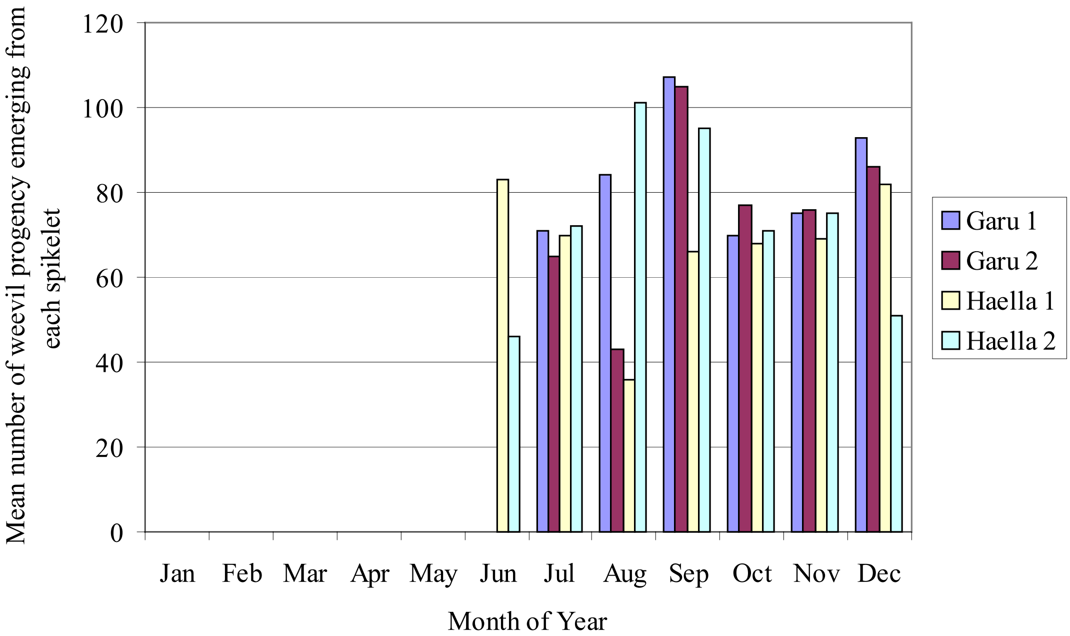


Figure 3.9. The mean number of weevil progency emerging from each spikelet from the trial plots at Garu and Haella, NBPOL, West New Britain Province during 2000



PUBLICATIONS, CONFERENCES, CONSULTANTS, AND STAFF

The paper entitled 'The successful development and implementation of an integrated pest management system for oil palm in Papua New Guinea' by R.W. Caudwell was accepted for publication in Integrated Pest Management Reviews.

The paper entitled 'Insect pollination of oil palm - time to evaluate the long-term viability and sustainability of *Elaeidobius kamerunicus*?' by R.W. Caudwell was accepted for publication in The Planter.

A total of 2 papers are currently being prepared with collaborators at Oxford University and 5 with collaborators at CABI Biosciences. These should be ready for submission during 2001.

Dr Kathirithamby continues to advise as part of the Sexava biocontrol project. She will be retained throughout 2000 and 2001, but will not be visiting PNG as part of this work.

Drs Alex Reid and David Hunt at CABI Biosciences, and Dr Ben Mensah at University of Cape Coast Ghana, are currently working as collaborators as part of the EU-funded pollination project.

Takis Solulu continues his PhD programme at University of Queensland.

The improvements to the entomology facility at Dami are now complete.

4. PLANT PATHOLOGY

(Dr. F. R. Sanderson & Dr. C. A. Pilotti)

CHARACTERIZATION OF GANODERMA POPULATIONS

Species of Ganoderma associated with oil palm

It was established in 1998 that two species of *Ganoderma* normally colonise coconut logs and poisoned palms. *Ganoderma* species have also been located on hardwood stumps in ex-forest areas that are now planted with oil palm. One species has a shiny (laccate) upper surface and was formerly designated as Type I and the other has a dull (non-laccate) upper surface and was designated Type II.

Identification of species

During 1998 – 1999 numerous collections were made of *Ganoderma* specimens on all three hosts. Collections were examined and details of basidiome morphology, spore morphology and mycelial characteristics were recorded for over 100 specimens. Four species of *Ganoderma* have been separated but only two have been identified. The major pathogen on oil palm has been identified as *G. boninense* (formerly designated Type I) with *G. tornatum* (formerly designated Type II) being found in the wood of a small percentage of live palms. Two other species found as saprophytes on coconut have not been positively identified.

Table 4.1. Summary of the morphological characteristics of the different species found in association with oil palm.

HOST	HABIT	PILEUS SURFACE	PORE SHAPE/ INDEX	PORE SURFACE COLOUR	SPORE COLOUR	SPORE SHAPE (INDEX)	NAME ASIGNED
Oil palm	Stipitate or pileate	laccate	Round to angular	Cream to pale yellow	brown	Narrowly ellipsoid (2.0)	*G. boninense*
Coconut	Stipitate or pileate	laccate	Round to angular	Cream to pale yellow	brown	Narrowly ellipsoid	*G. boninense*
Hardwood	Stipitate, pileate or sessile	Non-laccate	round	White to cream to grey	brown	Ovoid (1.4 -1.6)	*G. tornatum*
Coconut	Pileate or sessile	Non-laccate	round	White to cream to grey	brown	Ovoid (1.5 -1.6)	*G. tornatum*
Coconut/ Hardwood	stipitate	Sub-non-laccate	round	White to brown	brown	Elliosoid to ovoid	*G. mastosporum.*
Coconut/wild palm	Stipitate or sessile	Sub-non-laccate	round	Cream to tan	brown	Ellipsoid (1.7)	*G. sp.*

Cross infection from previous crop

Using mating tests, *G. boninense* isolates on oil palm have been found to be the same as those occurring as saprophytes on coconut. In addition, *G. tornatum* isolates growing as saprophytes on hardwoods and coconut have crossed with those found to occur on oil palm and hence, assumed to be the same species

Table 4.2. Interfertility tests amongst non-laccate (*G. tornatum*) and laccate (*G. boninense)* specimens obtained from various hosts.

			NON-LACCATE																				LACCATE															
			Wild palm				Hardwood								Coconut				Oil Palm				Coconut												Oil Palm			
			342A	342B	342O	342G	344L	344D	344H	344J	370B	370G	370H	370O	396A	396B	396C	396E	463A	463B	463C	463G	392A	392B	392D	392G	394J	394K	394N	394A	233D	233E	233F	233H	182B	182D	182G	182I
NON-LACCATE	hardwood	344L	-	-	-	-		-	-	+																												
		344G	-	-	-	-			+	-																												
		344H	-	-	-	-				-																												
		344J	-	-	-	-																																
		370B	-	-	-	-	+	+	+	+		-	-	+																								
		370G	-	-	-	-	+	+	+	+			+	-																								
		370H	-	-	-	-	+	+	+	+				-																								
		370O	-	-	-	-	+	+	+	+																												
	coconut	396A	-	-	-	-	+	+	+	+	+	+	+	+		-	+	-																				
		396B	-	-	-	-	+	+	+	+	+	+	+	+			-	+																				
		396C	-	-	-	-	+	+	+	+	+	+	+	+				-																				
		396E-	-	-	-	-	+	+	+	+	+	+	+	+																								
	oil palm	463A	-	-	-	-	+	+	+	+	+	+	+	+	+	+	+	+		-	+	-																
		463B	-	-	-	-	+	+	+	+	+	+	+	+	+	+	+	+			-	+																
		463C	-	-	-	-	+	+	+	+	+	+	+	+	+	+	+	+				-																
		463G	-	-	-	-	+	+	+	+	+	+	+	+	+	+	+	+																				
LACCATE	coconut	392A	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		-	+	-												
		392B	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-			-	+												
		392D	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-				-												
		392G	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-																
		394J	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+	+		+	-	-								
		394K	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+	+			-	-								
		394N	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+	+				+								
		394A	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+	+												
		233D	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+	+	+	+	+	+		-	-	+				
		233E	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+	+	+	+	+	+			+	-				
		233F	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+	+	+	+	+	+				-				
		233H	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+	+	+	+	+	+								
	Oil palm	182B	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+	+	+	+	+	+	+	+	+	+		-	-	+
		182D	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+	+	+	+	+	+	+	+	+	+			+	-
		182G	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+	+	+	+	+	+	+	+	+	+				-
		182I	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+	+	+	+	+	+	+	+	+	+				

Seven palms containing *G. tornatum* brackets were sampled, and the isolates from the palm wood were plated together with the isolate from the bracket on the same palm. In five of the seven, at least one of the isolates from the wood was vegetatively compatible with that from the associated bracket. In four cases, at least one of the isolates did not match the brackets and it is assumed that the pathogen was *G. boninense* rather than *G. tornatum*. These results indicate that cross infection from saprophytic *Ganoderma* species on different hosts can occur.

This is evidence for cross-infection from hardwood debris and suggests that saprophytic species are capable of pathogenicity given favorable conditions.

Table 4.3. Dikaryons of *G. tornatum* isolated from seven palms in the field.

BASIDIOME ISOLATE	Dikaryons isolated from palm wood		
	1	**2**	**3**
505	barrier	-	-
601	none	none	none
612	none	none	none
633	barrier	-	-
635	barrier	none	-
636	none	-	-
637	none	barrier	barrier

G. boninense ***on oil palm***

The population of *G. boninense* in several blocks within the Milne Bay Estates plantation were studied. Two blocks were selected in Giligili and four blocks in Waigani Estate. All palms in these blocks which were identified in the 1999 survey as containing brackets were sampled and spore prints were obtained. Mating tests were used to assess the relationships amongst isolates within and between blocks. A total of 8,336 crosses were carried out between the different isolates.

Mating tests between isolates within a block, between blocks and between estates revealed a total of 81 **A** and 81 **B** mating alleles in the current population. Chi-square contingency tests showed that these alleles were randomly distributed throughout the plantation. Mating alleles were common in some isolates from Giligili and Waigani Estates indicating long range dispersal of basidiospores after each successive breeding cycle either by wind or vector. This is the first scientifically based evidence supporting the hypothesis that basidiospores are important in the spread of basal stem rot. The current population on oil palm in Milne Bay is comprised of many genotypes. These findings indicate that out-crossing between monokaryotic isolates in the founder population has occurred prior to colonization of oil palm. They also indicate that the population is derived from primary inoculum. No evidence for secondary spread of *Ganoderma* between palms either by root contact or by basidiospores has been found in the current population.

Table 4.4. Mating alleles found amongst isolates within the Milne Bay plantation.

ALLELE	Frequency	ALLELE	Frequency	ALLELE	Frequency	ALLELE	Frequency	ALLELE	Frequency	ALLELE	Frequency
A1	3	A33	1	A65	1	*B1	2	B33	1	B65	1
A2	1	A34	1	A66	1	B2	1	B34	1	B66	1
A3	2	A35	1	A67	1	B3	1	B35	1	B67	1
A4	1	A36	3	A68	1	B4	1	B36	1	B68	1
A5	2	A37	1	A69	1	B5	2	B37	1	B69	2
A6	1	A38	1	A70	2	*B6	2	B38	1	B70	1
A7	3	A39	1	A71	1	B7	2	B39	1	B71	1
*A8	3	A40	3	A72	1	*B8	2	B40	3	B72	1
A9	2	A41	3	A73	1	B9	1	B41	3	B73	1
A10	1	A42	1	A74	2	B10	1	B42	1	B74	1
A11	2	A43	1	A75	1	B11	1	B43	1	B75	1
A12	2	A44	1	A76	1	B12	1	B44	1	B76	1
A13	1	A45	3	A77	1	B13	1	B45	1	B77	1
A14	1	A46	1	A78	1	B14	1	B46	2	B78	1
A15	1	A47	1	A79	1	B15	1	B47	1	B79	1
A16	1	A48	1	A80	1	B16	1	B48	1	B80	1
A17	1	A49	1	A81	1	B17	1	B49	1	B81	1
A18	1	A50	1	A82		B18	1	B50	2	B82	
*A19	2	A51	1	A83		B19	2	B51	1	B83	
*A20	2	A52	1	A84		*B20	2	B52	1	B84	
A21	1	A53	1	A85		B21	1	B53	2	B85	
A22	1	A54	1	A86		B22	1	B54	1	B86	
A23	0	A55	2	A87		B23	1	B55	2	B87	
A24	1	A56	1	A88		B24	1	B56	1	B88	
A25	1	A57	1	A89		B25	2	B57	1	B89	
A26	1	A58	1	A90		B26	1	B58	1	B90	
A27	1	A59	1			B27	1	B59	1		
A28	1	A60	1			B28	1	B60	2		
A29	1	A61	1			B29	2	B61	1		
A30	1	A62	1			*B30	2	B62	1		
A31	1	A63	1			B31	1	B63	1		
A32	2	A64	1			B32	1	B64	1		

Multiple locations in Giligili = red; Multiple locations in Waigani = blue; In both Giligili and Waigani = Yellow

Implications for the field control of basal stem rot

The results from the population studies indicate that basal stem rot can only be minimized but not completely eliminated. Initial colonisation of plantation debris by *Ganoderma* basidiospores will occur on replant if crop debris is left in the fields. This inoculum will subsequently invade planted palms if they are planted sufficiently close to infected stumps and logs.

In areas planted from ex-forest, we will expect to find low levels of *G. boninense* and probably *G. tornatum* causing basal stem rot when the oil palm are between 8 – 12 years of age. In areas planted from ex-coconut, we would expect the majority of isolates on oil palm to be *G. boninense*. The fact that out-crossing occurs in the founder population indicates that selection will occur for 'palm specific' isolates and levels of *G. boninense* may increase in areas planted from coconut and oil palm and in subsequent replants of the same crop. It is therefore important that inoculum levels are minimized on replant through adequate sanitation.

DEVELOPMENT OF MOLECULAR MARKERS

Due to financial constraints at the beginning of 1999, this work could not proceed and was abandoned.

IMPLEMENTATION OF THE CONTROL STRATEGY

Milne Bay Estates

This year has seen an interesting glitch, the result of:

- The implementation of a recording and data handling system based on an Access programme,
- A visit by Paul Aiwakera from the Solomon Islands who introduced a completely new method of recording in the field
- The introduction of the two GPS units for collecting the field data.

The net result of these three factors was that the data handling team in the office found it easier to use the data from Paul's hand written sheets from the field, rather than master the apparently complex steps required to transfer files from MapInfo through Excel to Access. Each GPS unit generated one map file a day that subsequently has to be transferred to text file.

Mr. Quentin McKain is currently developing a central database into which the field data is entered and from which queries regarding correlations such as palm oil mill effluent and Ganoderma stem rot can be generated.

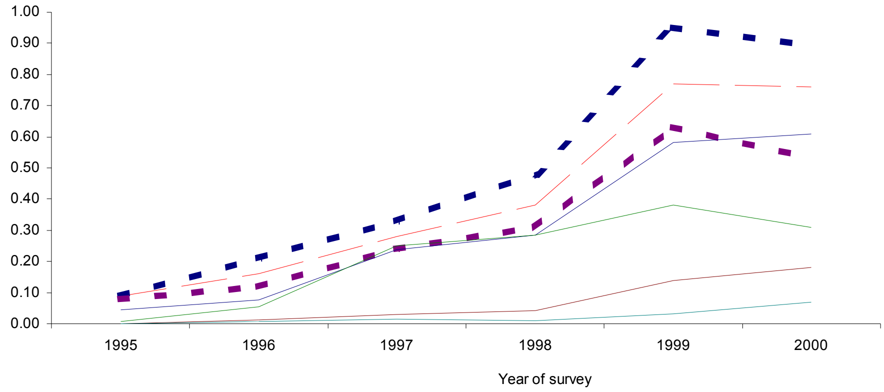
Results

For the first time, the annual incidence of *Ganoderma* stem rot has remained about the same as that for the previous year. As this trend applies to all but the youngest palms it is not possible to attribute a cause.

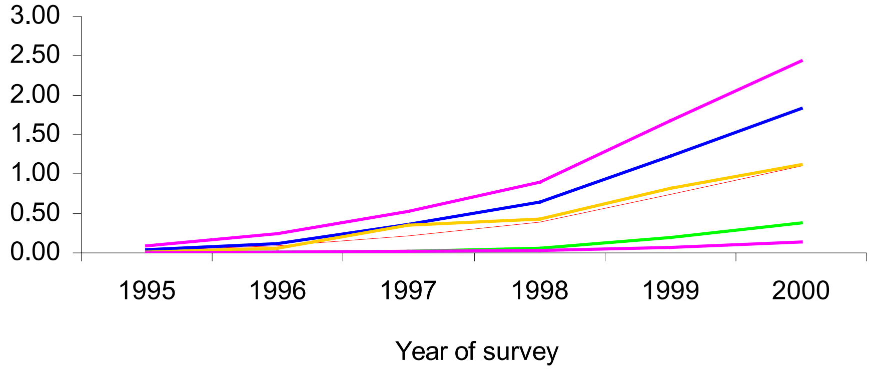
One trend that should be noted, however, is the higher levels of *Ganoderma* basal stem rot in those POME blocks

.

Incidence of Ganoderma recorded each year



Total incidence of Ganoderma by year of planting



Poliamba Ltd

A second year of surveys has been completed and currently infected palms are being felled and all infection removed using an axe and harvesting chisel. Three winches have been ordered to speed up the process of removal.

Division	1999	2000	1999	2000
Nalik	825	914	**0.36**	**0.40**
Notsi	476	393	**0.31**	**0.26**
Kara	301	420	**0.18**	**0.25**
Total	3204	3454	**0.29%**	**0.32%**

A further year of survey data will be required before any trends can be seen as the first years data is a bulk sample of all old infections from previous years.

New Britain Palm Oil Limited

As with Poliamba, two surveys have been conducted in the 1994 plantings and sanitation is currently being carried out. Thirteen palms have been recorded in the 1995 plantings during the last census round.

Block	Nov-99	Apr-00	Total	% Ganoderma	Live palms
E1	0	5	5	0.08	97.25
E2	2	1	3	0.05	96.41
E3	6	17	23	0.37	95.66
E4	1	34	35	0.94	94.56
E5	0	48	48	1.52	90.01
	9	105	114	**0.45%**	**95.30%**

Higaturu Oil Palm Ltd.

The latest information suggests that Embi is being surveyed monthly with surgery the main approach and that felling of infected palms is being used as a last resort.

Embi:

Block	Total	% Ganoderma
89A	10	0.15
89B	22	0.24
89C	69	0.73
89D	28	
89E	1	0.01
89F	1	0.01
90C	2	0.05
	133	**0.22**

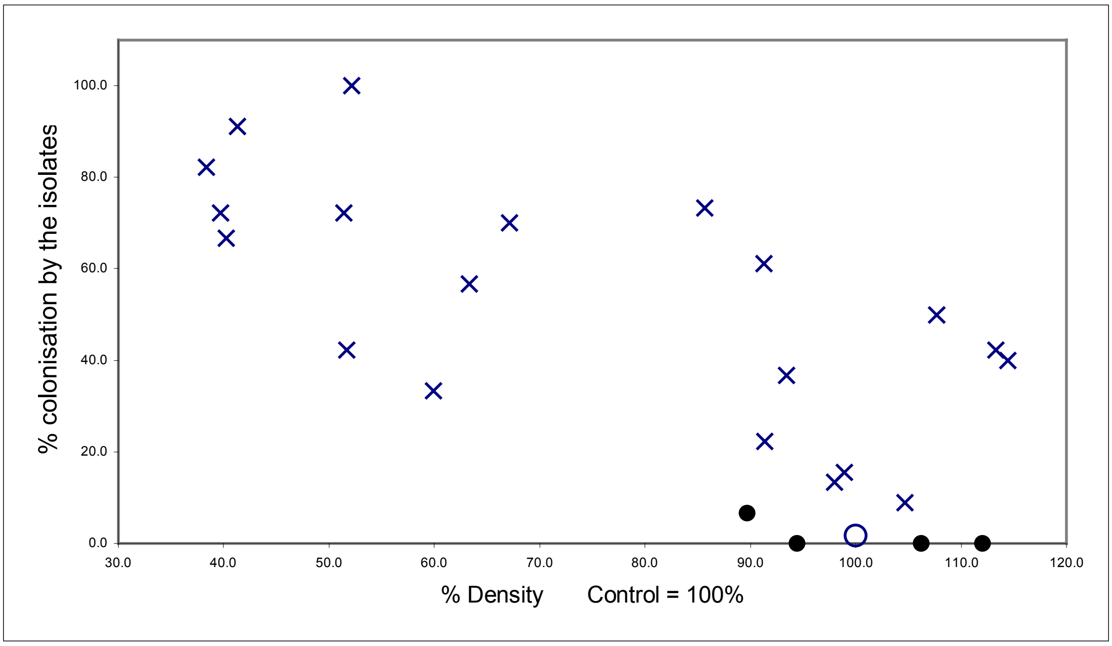
RAPID DEGRADATION OF OIL PALM WOOD

This is a co-operative project with CABI Bioscience and Birkbeck College, and Ms Barbara Ritchie spent three weeks at Milne Bay in June. During her visit a further 25 isolates were collected and two trials carried out to test the efficacy of these isolates. Results were inconsistent mainly through contamination by airborne inoculum. Bags have to be opened after 2 days because of the very rapid growth rate of the fungus. Inoculations of 9-month-old oil palm seedlings growing in the aeroponics system and 12-month-old seedlings growing in poly-bags were also carried out using two of the isolates.

Over the following three months two further trials were carried out. As in previous trials, 10x10x10cm blocks of oil palm wood cut from the base of a palm were used. These were cut in the field using a chain saw. Blocks were then dipped into a container holding 1.4l of Benlate (0.125g a.i. per l water), and 0.5cm cut off each end. The cut ends were then inoculated with the agar from ¼ of a petri dish containing the various isolates. Inoculated blocks were placed inside a sealed zip-lock plastic bag for two day before being opened. The coverage of the block by isolates was measured after 4 days and 11 days. The blocks were then removed from their plastic bags and left in a warm dry room for three weeks before weighing. The original volume of each block was obtained by measuring the Benlate remaining in the container after dipping. The density of the blocks at the end of the drying period could then be calculated following weighing.

Results

Two points are obvious from the diagram below. Firstly there is a wide range of activities between isolated and secondly, the active strains have the ability to reduce the density of the oil palm wood by half within three weeks. At the end of this period only the vascular tissue remains intact.



Taxonomy of Ceratocystis (What's in a name?)

Ceratocystis is a member of the Ascomycetes. Unlike the Basidiomycetes, which have a macro structure such as the bracket as part of the sexual phase, the sexual stage of the Ascomycetes is a microscopic sac containing 8 spores called an ascus. Unfortunately these are infrequently seen and as a result the identification of most Ascomycetes is done on the shape etc of the asexual conidia. In practice, until the sexual stage of an Ascomycete is identified they are conveniently assigned taxonomic names within the Fungi Imperfecti, related to the structure of the asexual spores. However, once the sexual stage is found, the imperfect name no longer has any validity and a taxonomic name is assigned within the correct group of Ascomycetes. In theory this is fine. Unfortunately in practice it leads to confusion. The case in point. *Ceratocystis*; if you look at the proceedings of the 1997 Oil Palm conference in Cartagena, on page 23, there is the paper Monitoring and Distribution of *Theilaviopsis paradoxa*, causal agent of Bud Rot in oil palm. On page 25 the paper Importance and distribution of stem rots in the Northern and Central oil palm areas in Colombia. In this we learn that the second most important stem rot is the dry stem rot caused by *Ceratocystis paradoxa*. On page 19, in the paper Pathogenicity of *Theilaviopsis paradoxa* causal agent of bud rot in oil palm, the relationship of the two fungi is made clear. This fungus (*Theilaviopsis paradoxa*) has been found in palm tissues and in waste material associated with its sexual phase *Ceratocystis paradoxa*.

This last statement is a very good example of a widely held misconception that such fungi have two taxonomic names, one associated with each of its two sexual phases. This is nonsense. The fungus is classified as *Ceratocystis* because it has asci whose characteristics put it in the genus *Ceratocystis*.

Taxonomy (Birkbeck College & CABI Bioscience)

The candidate fungus that causes the rapid degradation was tentatively identified as a *Thielaviopsis* sp., an imperfect fungus that may form the perfect state *Ceratocystis.* As *Ceratocystis paradoxa* has been associated with a number of palm disease including basal trunk and bud rots in Colombia and the apparent association of the same fungus with upper stem rot in Indonesia, Malaysia and PNG, it is important to identify and also determine if there could be any risk of such diseases from the candidate species. A number of isolates of *Thielaviopsis* have been obtained at Birkbeck College, and further specimens are available at RBG, Kew. These collections include examples associated with upper stem rot and bud rot of palms. A programme of molecular screening based on ITS sequences will be undertaken for these isolates during 2001, enabling direct identifications to be made. This work will be undertaken in association with CABI Bioscience to ensure that all candidate organisms can be identified.

Upper Stem Rot

During two weeks in North Sumatra and Johor I was shown many examples of what is generally referred to as upper stem rot. These areas were an enigma; 1) because they were often confined within obvious areas, 2) there was *G. boninense*, both as a wood rot and brackets associated with the collapsed upper trunk, and 3) of more interest were extensive areas of a soft rot, which had weakened the stem to the point of collapse (the trunk had collapsed, not broken). This soft rot was characterised by the collapse of the soft woody tissue leaving only the vascular strands. This is typical of what we have become to associate with *Ceratocystis* rot in the laboratory and hence by association, in the field.

The most striking feature of this problem is that it occurs in reasonably well-defined areas. This is unlikely to occur with *Ganoderma*; on the other hand it is characteristic of *Ceratocystis*, which many have suggested is associated with soil related stress.

Conclusion

The core study, the rapid degradation of oil palm wood, is progressing well, unfortunately the association of *Ceratocystis* with other oil palm problems means we have to tread carefully. It is important to realise, our objective is to simply improve on what is already occurring. We are not introducing a new organism but working with one that is already well established.

HASSAN AND TURNER TRIALS.

In 1998 30 palms were felled leaving stumps of about 1 metre. Ten palms had severe basal rot, 10 *Ganoderma* stem rot with brackets but no obvious basal stem rot, and 10 were sterile palms. By the end of 12 months it was obvious that there was a strong correlation between both the *Ganoderma* stem rot and the age of the seedlings at the time of transplant and the level of infection. Infection being greatest in the young seedlings planted next to those stumps with basal stem rot.

A second trial was planted in 1999 again around stumps with basal rot, bracket and sterile stumps. For this trial, 6-month, 8 month and 13-month-old seedlings were used.

After 12 months there was again the correlation between age of seedlings and plant death but this was not related to the type of stump.

During a visit in which 4 days was spent with Yonnes Hassan, it became apparent that he has become very proficient at setting up these trials. Both the distance from the stump and the age of seedlings is critical to the success. Seedlings must be no older than 6 months and planted within 50 cm of the stump.

EPIDEMIOLOGY OF BASAL STEM ROT USING GanET

The efficiency of the Polymerase Chain Reaction (PCR) primer developed previously in the programme was tested with fresh samples obtained during a field visit to Milne Bay and West New Britain in May/June 2000. The PCR primer was developed during 1997/98 to be specific to a short sequence located near the 3' terminus of the second internally transcribed spacer (ITS2) region of the ribosomal RNA (rRNA) gene cluster. This specific primer (GanET) was used in a PCR together with a universal primer located at the 3' terminus of the 5.8S rRNA gene. In previous testing this primer combination has been shown to give a PCR product of 160bp, corresponding to the ITS2 region, from isolates of *Ganoderma boninense* taken from infected oil palms. Previous screening in 1998 showed that this PCR product was not obtained from other fungi associated with oil palms, and that the GanET target sequence did not occur in any other species of *Ganoderma.*

All previous studies had been undertaken with material from Milne Bay, and in the current phase of the programme field samples were obtained from infected oil palms in West New Britain. Samples were taken from *Ganoderma* fruiting bodies on palms, from mycelium within infected palms, from frond bases immediately behind fruiting bodies, and from degraded palm tissue of cut frond bases on apparently healthy palms. Samples (<5g) were collected in the field, and preserved in propan-2-ol before testing in the laboratory. Laboratory testing involved a simple total DNA extraction from the samples after they had been partially freeze dried. All samples taken from fruiting bodies, and from areas known to be infected, gave positive results in that the expected PCR product was obtained. Control samples from uninfected palms and from some material of other *Ganoderma* species held at Royal Botanic Gardens, Kew, all gave negative results.

In order to consider the hypothesis that *G. boninense* may enter the oil palm through cut frond bases, two series of samples were obtained from West New Britain and Milne Bay (60+ samples in total). Samples were obtained by removing the outer layer of recently cut frond bases, and taking palm material from the newly exposed tissue. A high proportion of the newly exposed tissue in palms at West New Britain showed a brown rot, whereas this was only seen in occasional samples from Milne Bay. PCR screening was carried out on the frond base samples in the same way as for the infected tissue. The characteristic PCR product was not obtained from any sample. Limited samples showing the brown rot will be further tested with more general molecular methods in order to determine if the rot may be fungal in origin.

Conclusion. The GanET PCR system is able to detect *G. boninense* in samples of infected palms collected under field conditions. The negative result for the frond base material is, however, inconclusive. If the hypothesis of spore spread is correct, it could be reasonably expected that there would only be a small amount of fungal material present at the site of entry. Spores are unlikely to establish fungal growth in all cases, as this would lead to multiple infections on all palms. Under these conditions it is likely that there will be a small amount of infective material in a small number of frond bases and so in order to categorically test the hypothesis it will be necessary to test multiple samples from a defined block of palms.

IDENTIFICATION OF OTHER *GANODERMA* SPECIES

Recent work conducted by Palm Oil Research Institute of Malaysia (PORIM) has suggested that two further species of *Ganoderma* may also occur on oil palm. This study suggested that these species may be either weakly pathogenic or saprobic, but did not conclusively identify the species. The species as described by the PORIM work would be placed into a different section of the genus *Ganoderma*, on the basis of having non-laccate (non-shiny) fruiting bodies. Non-laccate fruiting bodies have been observed on oil palm in Papua New Guinea, and the identity of these in relation to the PORIM study is not known. Work has commenced on a brief molecular screening of collections of non-laccate fruiting bodies held at RBG, Kew. This will provide a framework for the identification of the PNG collections. An additional aspect of this programme is that it will include a large number of collections made in SE Asia and Oceania before the introduction of oil palm, and so inclusion of laccate specimens will give information of the original presence of *G. boninense* in the region.

Consultancies

Professor Paul Bridge, Birkbeck College. 22nd May – 15th June
Mrs Barbara Ritchie, CABI Bioscience. 12th June – 25th June

Visits

F R Sanderson, Bah Lias, North Sumatra, Indonesia, and EPA Management SDN BHS Johor Malaysia. 21st August – 1st September.

Conferences

F R Sanderson Intentional Planters Conference, KL 17 – 20 May 2000

C A Pilotti International Symposium on Oil Palm Genetic Resources and Utilization