Annual Research Report

1998

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Papua New Guinea Oil Palm Research Association Inc.

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CONTENTS

Report by the Director of Research

to the

Annual General Meeting

August 1999

Oil palm research in Papua New Guinea commenced with the establishment of Dami Oil Palm Research Station by Harrisons and Crosfield in 1967. Plant breeding and subsequently seed production commenced with the introduction of elite breeding material to Dami from Malaysia in 1968. Dami has now developed into one of the most highly regarded seed production and plant breeding operations in the world. As other oil palm companies started operations in Papua New Guinea it was decided that the requirement for agronomy and crop protection research could best be met by forming a single research organisation to service all producers in Papua New Guinea. This initiative between the oil palm milling companies and the Government of Papua New Guinea is what led to the formation of the Papua New Guinea Oil Palm Research Association (PNGOPRA). The PNGOPRA was incorporated in 1980 as a non-profit making Association. To this day the PNGOPRA carries out all agricultural research, other than plant breeding, for all of Papua New Guinea's oil palm producers.

The research programme of the PNGOPRA is carefully structured to meet the needs of the industry as a whole. The PNGOPRA Research Advisory Committee, on which all Members are represented, meets annually to review and establish research priorities for the following year. To maintain PNGOPRA as a small, highly efficient research organisation, the Association is addressing only the most prominent constraints to the production of oil palm. By far the most serious factor limiting oil palm production is the ubiquitous presence of nutrient deficiency. This is regarded as the Association's most important research area. The Association's Agronomy Sections carry out research into crop nutrition and fertiliser management practices. The Association's Entomology Section conducts research into the control of insects and other pests, and the Plant Pathology Section is carrying out world leading research into the control of the Basal Stem Rot of oil palm caused by Ganoderma.

The main limiting factor to maximum oil palm growth in PNG is crop nutritional deficiency. The single highest cost involved in growing oil palm is fertiliser input. Much 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. In addition it is planned that specific research effort is directed towards more fundamental studies relating to magnesium, potassium deficiencies and to improving the efficiency of nitrogen amelioration. Nutritional problems are particularly serious among the smallholder growers and result in very large reductions in yield. In addition other technical, social and economic problems are confounded with the nutritional problems and result in the average smallholder yield being less than half of that of the plantations. PNGOPRA gives close technical support to the efforts of the extension service through a large network of smallholder block demonstration, farmer field days, and training for extension officers. PNGOPRA in conjunction with an external academic organisation is planning to develop a large-scale survey to study the smallholder production constraints with a view to assisting the development of management solutions. 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.

In 1999 it is planned to separate to a degree the responsibilities for the formal crop nutrition and agronomy research and the specific smallholder related work. A senior member of staff will be allocated the specific responsibility for all smallholder related work. This move will greatly improve the service through OPIC to the smallholder sector and will free the agronomy research units to focus more on the academically challenging crop nutritional problems.

The Entomology Section at PNGOPRA has made considerable progress in the development of integrated pest management (IPM) systems for the control of the major insect pests of oil palm in Papua New Guinea. These IPM systems use biological control as the principal management tool, and insecticide use is kept to an absolute minimum. This gives economically viable and environmentally acceptable pest management.

For the last 1-2 years our research effort has been directed towards the development of a naturally occurring parasitic insect (*Stichotrema dallatorreanum*) for the biological control of Sexava. This research shows considerable potential, and we are just about to start the second phase of the project, which will involve field trials with the parasite in West New Britain. The objective of this work is to attempt to establish the parasite in the oil palm agro-ecosystem in West New Britain as a biological control agent for Sexava IPM. We have also continued to rear and release the egg parasitoids (*Leefmansia bicolor* and *Doirania leefmansi*) for Sexava control. These biological control agents, along with a robust and efficient monitoring system have meant that Sexava populations have been kept well below economic thresholds in most areas.

We have continued to improve upon our IPM system for the Rhinoceros beetle (*Oryctes rhinoceros)* during 1998 and 1999. Our IPM system for Rhinoceros beetles involves the use of an aggregation pheromone to capture adult beetles, which are then infected with a naturally occurring viral pathogen and released back out into the field. Cultural practices are used to complement the biological control and chemical insecticides are only applied to control very high pest populations.

During the last year we have given recommendations for the control of a number of minor insect pests including bagworms, weevils, taro beetles, stick insects, Acria moth, grasshoppers and scale insects. We have also given advice on the control of rats at the Solomon Islands Plantations Ltd, and set up a series of trials to gather information in order to optimise rat control operations. We have on-going insect biodiversity studies in which we are particularly interested in the management of plantations to preserve and promote naturally occurring biological control agents and beneficial insects. Further research is planned to develop IPM control strategies for the control of the leafhopper causal agent of 'Finschhafen disorder' of coconuts, and for the control of Giant African Snail in Milne Bay Province. We also plan to become further involved in a conservation project for the Queen Alexandra Birdwing Butterfly in Oro Province, as well as initiating a long-term programme to investigate and improve insect pollination of oil palm in Papua New Guinea.

We have on-going training programmes in entomology for plantation workers and extension officers. This involves both formal and informal training, as well as field days and features on local radio. One of our Papua New Guinean Entomologists started a PhD in 1999; his studies involve the management and biological control of Giant African Snail.

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 was 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 industries 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 basiodiospores in the epidemiology of the disease. Following our initial research, all of which supported this hypothesis, control strategies were implemented.

With the start of PNGOPRA membership of the Solomon Islands Plantations Ltd, a further application was made for Stabex funding to support the research in the Solomon Islands. Research commenced in the Solomon Islands in October 1998. With the Solomon Islands Stabex funding, we were asked to work along side staff from the Plant Protection Laboratory at Dodo Creek with the aim of training their staff in a range of plant pathology techniques.

Considerable progress has been made in many areas. The most important being that a control strategy has been implemented. The extent of the progress is best illustrated by the fact that 14 papers have been published during the four years of the project. An enviable record for any research establishment especially one which has only been operating for four years.

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 build.

PNGOPRA remains small in size, particularly in relation to the size of the oil palm industry; however, the research output undoubtedly places PNGOPRA as one of the most effective research organisations in Papua New Guinea and the Solomon Islands. Over the last few years PNGOPRA has greatly increased both the quantity and quality of it's scientific output and increased the level of technical services and training provided to the industry. With input from the industry the organisation is constantly adapting to meet the needs of the industry it serves.

Despite the increase in output from PNGOPRA the true cost to the oil palm industry is considerably less than it was five years ago. In the years prior to 1994, the annual PNGOPRA levy was equivalent to about US$ 800,000. In 1999 the expenditure budget is equivalent to about US$ 600,000. The marked devaluation of the PNG Kina over the last three years has been particularly difficult for the organisation, however additional assistance from most of the Members has ensured that the functionality of PNGOPRA has been maintained. In the first half of 1999 there was some difficulty in establishing a new levy mechanism and rate to finance the approved expenditure budget. This caused some operational difficulties, however we are confident that a solution will be arrived at for the second half of the year.

Funding for PNGOPRA comprises about 55% levy from Association Members, and about 45% grant from Government and foreign aid sources. It is important that the grant funding which generally supports the direct research costs is maintained. A priority aim over the next several months is to secure further grant funding to support the continuation of the *Ganoderma* research and the entomology IPM research, and for the initiation of fundamental studies of the soil chemistry and plant nutritional constraints to oil palm production.

In March 1999, one of the Member companies announced its intention to withdraw its membership of PNGOPRA, no reason for this move was given. This is unfortunate because based on our knowledge and experience of the agriculturally related problems and risks faced in growing oil palm in this

particular environment; such a move is not in their interests and could place their long-term operations at risk. Hopefully if PNGOPRA can communicate the benefits of Membership more effectively this decision could be reversed.

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

The Members of the Papua New Guinea Oil Palm Research Association 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
July 1999

I. ISLANDS REGION AGRONOMY

(B Toreu & G. King)

AGRONOMY TRIALS

TRIAL 107 RESPONSE TO FERTILISER OF MATURE SECOND GENERATION PALMS AT BEBERE PLANTATION.

PURPOSE

To provide information about the responses of oil palm to fertiliser, that will be used in making fertiliser recommendations.

DESCRIPTION

Site: Fields D8 and D9, Bebere Plantation.

Soil: Young, coarse textured, freely draining, formed on alluvially redeposited pumiceous sands, gravel and volcanic ash.

Palms: 16 selected progenies - 5 from High Bunch Number (HBN) families and 11 from families with Medium Sex Ratios (MSR).
Planted in January 1983 at 135 palms/ha.
Treatments started in January 1984.

DESIGN

There are 72 treatments, comprising all factorial combinations of N and P at three levels and K, Mg and Cl each at two levels (Table 1.1). The recorded palms are 16 different selected progenies arranged in the same array in each plot. Plot isolation trenching was completed in 1995.

Table 1.1 Rates of fertiliser used in Trial 107.

	Feb 85 -Dec 88 Level			From Jan 89 Level		
	0	1	2	0	1	2
	(kg/palm/yr)			(kg/palm/yr)		
Sulphate of Ammonia (SoA)	0.0	1.0	2.0	0.0	2.0	4.0
Triple Superphosphate (TSP)	0.0	0.5	1.0	0.0	1.0	2.0
Sulphate of Potash (SoP)	0.0	1.8	-	0.0	3.6	-
Kieserite (Kies)	0.0	2.0	-	0.0	3.0	-
Sodium chloride (NaCl)	-	-	-	0.0	4.0	-

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

Sulphate of ammonia & sulphate of potash are applied as two equal doses per year. All other treatments are applied in a single dose.

There are 72 plots, each consisting of 36 palms of which the central 16 are recorded. The recorded palms are of 16 identified progenies arranged in a fixed spatial configuration in each plot. Palms 1 to 5 in each plot are from families with high bunch number (HBN) and palms 6 to 16 are from medium sex ratio families (MSR). The 72 treatments are replicated only once and are randomised amongst the 72 plots. High order interactions provide the error term in the statistical analysis.

At three months after planting all palms received 0.25 kg sulphate of ammonia and nothing else during the first twelve months. At 12 months (January 1984) half of the plots were given an application of sulphate of ammonia (1 kg/palm) as a treatment (establishment nitrogen). In September 1995, plantation labour mistakenly applied sulphate of ammonia to the entire trial at the rate of 1kg/palm.

The treatments that are described in Table 1.1 were started in February 1985 and modified in 1989. The sodium chloride treatment that was started in 1989 is applied orthogonally over the earlier establishment nitrogen treatment. Its purpose is to see whether a deficiency of chlorine is limiting the yield or affecting the response to other fertilisers. Detailed analysis of the 1996 data showed that chlorine was having no effect on yield and plot leaflet chlorine levels were elevated irrespective of whether sodium chloride had been applied or not. Consequently, on the advice of the consultant biometrician, further applications of sodium chloride were dropped. However, chlorine was used as a covariate rather than as a factor in the analysis of the subsequent data.

Frond 17 leaflet and rachis tissue was not sampled for chemical analysis in 1998.

RESULTS

The average plot yield in Trial 107 in 1998 was 25.4 t/ha. This is slightly lower than the average plot yield recorded in 1997 (26.5 t/ha) and in 1996 (26.9 t/ha). The mean number of bunches per hectare was 1038 in 1998 compared to 1070 in 1997. Mean single bunch weight was 24.5 kg in 1998 compared to 24.8 kg in 1997.

Application of sulphate of ammonia led to a significant increase in yield in 1998 caused by a significant increase in bunch weight (Table 1.2). Similarly yield for the period 1996-98 increased significantly with the application of sulphate of ammonia (Table 1.4). No other treatment had any effect on yield. In Table 1.3 yields recorded since 1986 are given showing that the response to nitrogen has not been consistent.

Plot isolation trenches were dug in 1995 to minimise interplot poaching of applied nutrients. The root pruning that occurred as a result of trenching has probably contributed to a reduction in yield in 1995 but yields have recovered in 1996 and 1997. 1998 yields were lower probably due to effect of the drought in 1997.

A decision was made at the 1998 SAC meeting that this trial be closed down at the end of 1998.

Table 1.2 Main effects of N, P, K, Mg on yield and yield components in 1998 adjusted for covariate (Trial 107).

	Nutrient element and level			Statistics		
				sig	sed	cv%
	N0	N1	N2			
Yield (t/ha/yr)	24.2	25.5	26.4	*	0.87	11.7
Bunches/ha	1020	1022	1071	ns	38.6	12.7
Bunch weight (kg)	23.7	25.0	24.7	*	0.43	6.1
	P0	P1	P2			
Yield (t/ha/yr)	24.6	25.7	25.9	ns	0.87	11.7
Bunches/ha	1009	1053	1051	ns	38.6	12.7
Bunch weight (kg)	24.4	24.4	24.6	ns	0.43	6.1
	K0	K1				
Yield (t/ha/yr)	24.7	26.1		ns	0.70	11.7
Bunches/ha	1010	1066		ns	31.3	12.7
Bunch weight (kg)	24.5	24.5		ns	0.35	6.1
	Mg0	Mg1				
Yield (t/ha/yr)	25.4	25.4		ns	0.70	11.7
Bunches/ha	1048	1028		ns	31.3	12.7
Bunch weight (kg)	24.3	24.7		ns	0.35	6.1

Table 1.3 Effect of N on FFB yield and yield components from 1986 to 1998 (Trial 107).

Year (age from planting)	Yield (t/ha)			Bunches/ha			Bunch Weight (kg)		
	N0	N1	N2	N0	N1	N2	N0	N1	N2
1986 (4)	17.3	17.0	17.8	2607	2624	2670	6.6	6.5	6.7
1987 (5)	24.2	25.4	25.3	2577	2647	2645	9.4	9.6	9.6
1988 (6)	25.9	25.9	26.1	1987	1903	1914	12.3	12.7	13.0
1989 (7)	26.3	27.8	28.0	1852	1941	1931	14.2	14.4	14.5
1990 (8)	27.9	28.6	28.1	1715	1746	1706	16.3	16.4	16.5
1991 (9)	23.5	23.9	23.4	1270	1270	1250	18.6	18.8	18.8
1992 (10)	24.9	27.0	27.0	1084	1175	1157	22.9	23.0	23.4
1993 (11)	24.5	27.4	29.0	1071	1175	1239	22.9	23.3	23.6
1994 (12)	21.1	22.0	23.0	928	932	999	23.3	24.2	23.8
1995 (13)	22.0	22.9	24.2	935	925	994	23.5	24.7	24.4
1996 (14)	25.3	27.8	27.6	1022	1068	1061	25.3	26.3	26.3
1997 (15)	26.1	26.7	26.7	1058	1078	1075	24.7	24.8	24.9
1998 (16)	24.2	25.5	26.4	1020	1022	1071	23.7	25.0	24.7

Table 1.4 Main effects of N, P, K, and Mg on yield and yield components from 1996 to 1998 adjusted for covariate (Trial 107).

	Nutrient element and level			Statistics		
				sig	sed	cv%
	N0	N1	N2			
Yield (t/ha/yr)	26.4	27.8	27.9	*	0.67	8.4
Bunches/ha	1086	1108	1115	ns	26.1	8.1
Bunch weight (kg)	24.3	25.1	25.1	*	0.36	5.0
	P0	P1	P2			
Yield (t/ha/yr)	26.9	27.6	27.6	ns	0.67	8.4
Bunches/ha	1088	1117	1104	ns	26.1	8.1
Bunch weight (kg)	24.7	24.8	25.1	ns	0.36	5.0
	K0	K1				
Yield (t/ha/yr)	27.3	27.4		ns	0.54	8.4
Bunches/ha	1096	1110		ns	21.1	8.1
Bunch weight (kg)	24.9	24.8		ns	0.30	5.0
	Mg0	Mg0				
Yield (t/ha/yr)	27.5	27.3		ns	0.54	8.4
Bunches/ha	1113	1093		ns	21.1	8.1
Bunch weight (kg)	24.7	25.0		ns	0.30	5.0

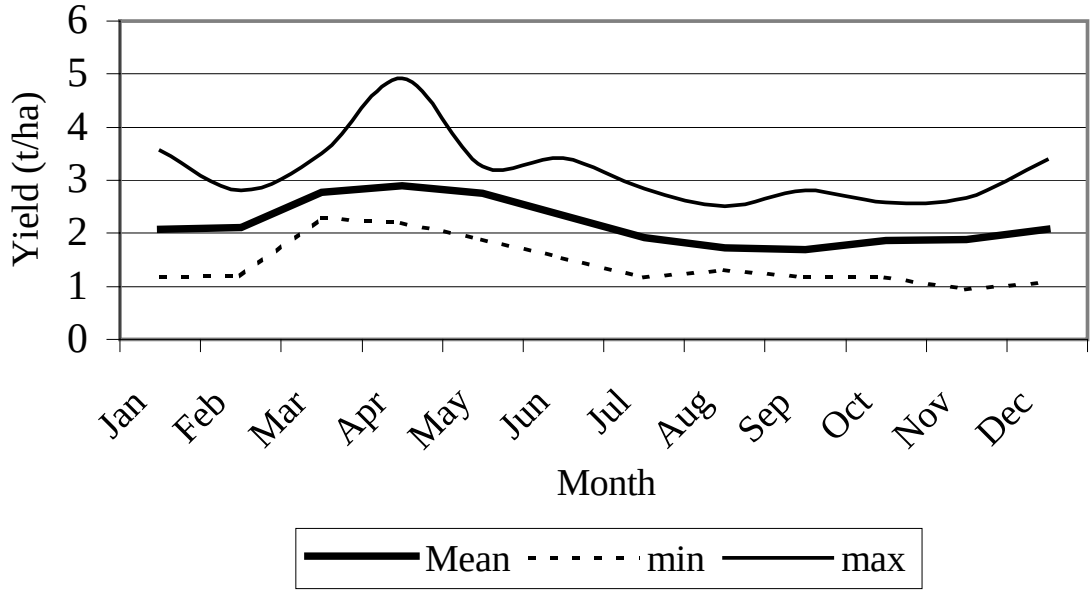
Plant tissue samples were not taken in 1998.

Table 1.5 gives the monthly yield data recorded in Trial 107. The mean annual yield for all years was 26.2 t/ha. Figure 1.1 shows the mean monthly yield with the minimum and maximum yields recorded in all months.

Table 1.5 Monthly yield (t/ha) from January 1987 to Dec 1998 (Trial 107).

Year	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1987	2.48	2.04	2.55	2.71	2.29	2.11	2.13	1.30	1.43	2.31	1.96	1.77
1988	2.13	1.20	3.47	2.65	3.00	1.78	1.17	1.56	1.90	2.31	2.66	2.66
1989	2.36	2.73	2.62	2.50	3.02	1.53	1.40	1.53	1.47	2.58	2.50	3.25
1990	3.55	2.80	2.67	3.10	2.58	2.33	2.01	1.32	1.31	2.37	1.95	1.74
1991	2.17	2.13	2.54	2.49	1.92	1.82	1.66	1.33	1.62	1.79	1.98	2.46
1992	1.99	2.16	2.85	2.23	1.88	2.67	1.88	1.41	1.94	2.00	2.15	3.38
1993	2.19	2.63	3.51	2.73	2.56	2.68	1.90	1.97	1.16	1.83	2.22	2.17
1994	1.87	2.16	2.77	2.20	2.92	2.00	1.48	1.81	1.47	1.49	1.92	1.63
1995	1.43	2.06	2.30	2.68	3.26	2.31	2.04	1.98	1.51	1.76	1.51	1.45
1996	1.76	2.32	2.53	4.92	3.27	2.63	2.84	1.90	2.80	1.26	1.26	1.08
1997	1.18	1.77	2.28	4.28	3.27	3.41	2.42	1.99	1.64	1.45	1.65	1.40
1998	1.72	1.35	3.28	2.22	3.12	2.84	2.02	2.52	2.05	1.16	0.95	2.00
Mean	2.07	2.11	2.78	2.89	2.76	2.34	1.91	1.72	1.69	1.86	1.89	2.08
s.e.	0.17	0.14	0.12	0.25	0.15	0.15	0.13	0.11	0.13	0.13	0.14	0.21
min	1.18	1.2	2.28	2.2	1.88	1.53	1.17	1.3	1.16	1.16	0.95	1.08
max	3.55	2.8	3.51	4.92	3.27	3.41	2.84	2.52	2.8	2.58	2.66	3.38

Figure 1.1: Mean Monthly Yield in Trial 107
1987 -1998



TRIAL 125 SOURCES OF NITROGEN FERTILISER TRIAL AT 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, nr. 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 1.6). The 15 treatments will be replicated four times in a randomised complete block design. Four “nil treatment” plots are located on the edge of each replicate 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 regarded as guard row palms.

Table 1.6 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
Sulphate of Ammonia	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 pretreatment 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.

RESULTS

Yield results and yield components for the full year (which is the first full year of yield recording since fertiliser treatments commenced) are presented in Table 1.7. The results show that type of fertiliser had a significant effect on yield but not on single bunch weight or bunch number. Fertiliser rate had a significant effect on yield, single bunch weight and bunch number.

Table 1.7 Yield and yield components in Trial 125 in 1998 (Trial 125).

Fertiliser Type	Yield (t/ha)	Single Bunch Wt (kg)	Number of Bunches/ha
Control	27.6	10.3	2664
Ammonium Chloride	28.3	11.0	2609
Sulphate of Ammonia	27.5	10.8	2571
Urea	27.6	10.6	2623
Ammonium Nitrate	27.8	10.9	2608
Di-Ammonium Phosphate	26.5	10.6	2532
sig. eff.	*	ns	ns
sed	0.60	0.25	70.8
cv (%)	5.3	5.6	6.7
Fertiliser Rate (gN/palm/year)	**Yield (t/ha)**	**Single Bunch Wt (kg)**	**Number of Bunches/ha**
520	26.8	10.8	2505
1040	27.9	10.5	2679
2080	27.8	11.0	2583
sig. eff.	*	*	*
sed	0.46	0.19	54.8
cv (%)	5.3	5.6	6.7

There was a significant Type x Rate interaction for yield and number of bunches. These interactions are given in Table 1.8 and Table 1.9 below. The interaction for bunch weight was not significant but details are given in Table 1.10 for comparison.

Table 1.8 Effect of Type of Fertiliser and Rate of Application on yield (t/ha) in 1998 (Trial 125).

Type of Fertiliser	Rate (gN/palm/year)		
	520	1040	2080
Ammonium Chloride	26.7	28.5	29.5
Sulphate of Ammonia	28.9	28.0	25.7
Urea	27.6	28.0	27.1
Ammonium Nitrate	26.1	27.8	29.7
Di-Ammonium Phosphate	25.0	27.1	27.3

$p<0.01$ sed = 1.04

Table 1.9 Effect of Type of Fertiliser and Rate of Application on bunch number in 1998 (Trial 125).

Type of Fertiliser	Rate (gN/palm/year)		
	520	1040	2080
Ammonium Chloride	2365	2679	2785
Sulphate of Ammonia	2624	2660	2430
Urea	2623	2796	2451
Ammonium Nitrate	2496	2639	2689
Di-Ammonium Phosphate	2415	2623	2559

$p<0.05$ sed = 122.6

Table 1.10 Effect of Type of Fertiliser and Rate of Application on bunch weight (kg) in 1998 (Trial 125).

Type of Fertiliser	Rate (gN/palm/year)		
	520	1040	2080
Ammonium Chloride	11.4	10.8	10.8
Sulphate of Ammonia	11.1	10.6	10.8
Urea	10.7	10.0	11.2
Ammonium Nitrate	10.5	10.7	11.4
Di-Ammonium Phosphate	10.5	10.5	10.8

Tissue analysis was conducted in 1998 and the results are given in Table 1.11. At this early stage there are no significant differences between fertiliser types. It should be noted, however, that leaflet chlorine was higher in the ammonium chloride treatment than with the other four fertiliser types. Rate of fertiliser did not have any effect in 1998. Leaflet micronutrient levels were also analysed in 1998, as there were obvious boron deficiency symptoms throughout the trial area. The results of this analysis are given in Table 1.12. Neither type of fertiliser or rate had any effect on micronutrient level.

Table 1.11 Leaflet N, P, K, Ca, Mg & Cl and Rachis K content in Trial 125 in 1998 (Trial 125).

Fertiliser Type	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	Cl (%)	Rachis K (%)
Control	2.51	0.156	0.72	0.93	0.18	0.49	1.56
Ammonium Chloride	2.46	0.154	0.73	0.92	0.19	0.55	1.65
Sulphate of Ammonia	2.45	0.156	0.76	0.90	0.18	0.49	1.58
Urea	2.51	0.155	0.74	0.89	0.19	0.50	1.65
Ammonium Nitrate	2.48	0.154	0.75	0.90	0.18	0.49	1.60
Di-Ammonium Phosphate	2.45	0.156	0.74	0.88	0.18	0.49	1.69
sig. eff.	ns	ns	ns	ns	ns	ns	ns
sed	0.034	0.002	0.020	0.022	0.008	0.018	0.060
cv (%)	3.3	2.7	6.5	5.9	10.1	8.7	8.9
Fertiliser Rate (gN/palm/year)							
520	2.48	0.156	0.75	0.88	0.18	0.50	1.68
1040	2.50	0.154	0.74	0.91	0.18	0.51	1.62
2080	2.44	0.155	0.74	0.90	0.19	0.50	1.61
sig. eff.	ns	ns	ns	ns	ns	ns	ns
sed	0.026	0.001	0.015	0.017	0.006	0.014	0.046
cv (%)	3.3	2.7	6.5	5.9	10.1	8.7	8.9

Table 1.12 Leaflet B, Cu, Fe, Mn & Zn content in Trial 125 in 1998 (Trial 125).

Fertiliser Type	B (ppm)	Cu (ppm)	Fe (ppm)	Mn (ppm)	Zn (ppm)
Control	12.9	4.9	81.7	95.7	44.9
Ammonium Chloride	12.7	4.6	80.8	92.1	62.7
Sulphate of Ammonia	12.1	4.6	83.1	87.1	41.3
Urea	12.6	4.6	76.7	85.1	41.5
Ammonium Nitrate	12.7	4.8	72.1	83.1	53.1
Di-Ammonium Phosphate	12.3	4.5	76.7	87.5	58.2
sig. eff.	ns	ns	ns	ns	ns
sed	0.31	0.22	4.38	4.98	12.7
cv (%)	6.0	11.9	13.8	14.0	60.4
Fertiliser Rate (gN/palm/year)					
520	12.4	4.6	78.1	83.7	53.6
1040	12.4	4.6	79.4	86.9	55.5
2080	12.6	4.6	76.1	90.3	45.1
Mean	12.5	4.6	77.9	87.0	51.4
sig. eff.	ns	ns	ns	ns	ns
sed	0.24	0.17	3.39	3.85	9.81
cv (%)	6.0	11.9	13.8	14.0	60.4

Mean B in the trial was 12.5ppm with the minimum-recorded B level at 10.6ppm and the highest at 14.7ppm. Optimum B level is assumed as being 15 – 25 ppm. Optimum Cu level is 5 – 8 ppm. Levels recorded in this trial are slightly below the optimum. Fe, Mn and Zn levels are adequate.

TRIAL 126 FACTORIAL FERTILISER TRIAL AT MALILIMI PLANTATION.

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, ie. 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 (K), sulphate of ammonia (N) each at three levels and Triple Superphosphate (P), Kieserite (Mg) and sodium chloride (Cl) each at two levels (Table 1.13). 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 1.13 Fertiliser rates used in Trial 126.

Fertiliser	Level (kg/palm/year)		
	0	1	2
Sulphate of potash	0.0	3.0	6.0
Sulphate of ammonia	0.0	3.0	6.0
Triple superphosphate	0.0	4.0	---
Kieserite	0.0	4.0	---
Sodium chloride	0.0	4.0	---

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

The sulphate of ammonia and sulphate of potash 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.

The trial was physically initiated in 1994. 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

An analysis of covariance was used to analyse the 1998 data with pre-treatment leaflet chlorine level as the covariate. Yields recorded in the twelve months from January to December 1998 are given in Table 1.14. Application of MoP resulted in a significant increase in yield due mainly to an increase in bunch weight. Chlorine application also led to a significant increase in yield as a result of an increase in single bunch weight. Application of TSP led to a reduction in yield.

Table 1.14 Main effects of N, P, K, Mg and Cl on yield and yield components in 1998 adjusted for covariate of pre-treatment chlorine (Trial 126).

	Nutrient element and level			Statistics		
				sig	sed	cv%
	N0	N1	N2			
Yield (t/ha/yr)	31.8	31.0	32.3	ns	0.63	5.9
Bunches/ha	1446	1412	1418	ns	39.0	8.0
Bunch weight (kg)	22.4	22.4	23.3	ns	0.54	7.0
	K0	K1	K2			
Yield (t/ha/yr)	30.2	33.4	31.6	***	0.56	5.9
Bunches/ha	1402	1500	1375	*	34.7	8.0
Bunch weight (kg)	22.0	22.8	23.4	*	0.48	7.0
	P0	P1				
Yield (t/ha/yr)	32.3	31.2		*	0.44	5.9
Bunches/ha	1454	1398		ns	27.3	8.0
Bunch weight (kg)	22.6	22.8		ns	0.38	7.0
	Mg0	Mg1				
Yield (t/ha/yr)	32.2	31.3		ns	0.44	5.9
Bunches/ha	1450	1401		ns	27.2	8.0
Bunch weight (kg)	22.6	22.8		ns	0.38	7.0
	Cl0	Cl1				
Yield (t/ha/yr)	31.2	32.3		*	0.48	5.9
Bunches/ha	1422	1429		ns	29.4	8.0
Bunch weight (kg)	22.3	23.1		ns	0.41	7.0

There was a significant NxK interaction recorded in 1998. Maximum yield was recorded at N0K1. Adding more N reduced yields. This is possibly due to antagonism between NH_4^+ and K^+ ions for exchange sites.

Table 1.15 Effect of N and K on yield in Trial 126 in 1998 (Trial 126).

Rate of Fertiliser	K0	K1	K2
N0	29.0	35.3	31.2
N1	29.8	32.7	30.6
N2	31.8	32.1	33.2
		P<0.01 sed=1.00	

The two year cumulative yield data also showed a significant response to both potassium and chlorine application.

Table 1.16 Main effects of N, P, K, Mg and Cl on cumulative yield and yield components for 1997 - 98 adjusted for covariate of pre-treatment chlorine (Trial 126).

	Nutrient element and level			Statistics		
				sig	sed	cv%
	N0	N1	N2			
Yield (t/ha/yr)	30.5	30.8	31.1	ns	0.54	7.0
Bunches/ha	1360	1385	1341	ns	36.9	8.0
Bunch weight (kg)	23.0	22.9	23.7	ns	0.52	6.6
	K0	K1	K2			
Yield (t/ha/yr)	30.3	31.6	30.6	*	0.48	7.0
Bunches/ha	1378	1395	1313	*	32.8	8.0
Bunch weight (kg)	22.5	23.3	23.8	*	0.47	6.6
	P0	P1				
Yield (t/ha/yr)	30.8	30.8		ns	0.38	7.0
Bunches/ha	1369	1355		ns	25.8	8.0
Bunch weight (kg)	23.1	23.2		ns	0.37	6.6
	Mg0	Mg1				
Yield (t/ha/yr)	31.0	30.7		ns	0.38	7.0
Bunches/ha	1370	1354		ns	25.8	8.0
Bunch weight (kg)	23.2	23.2		ns	0.37	6.6
	Cl0	Cl1				
Yield (t/ha/yr)	30.4	31.3		*	0.41	7.0
Bunches/ha	1350	1374		ns	27.9	8.0
Bunch weight (kg)	23.0	23.4		ns	0.40	6.6

Leaflet and rachis samples were analysed for nutrient content in 1998 and the results of this analysis are given in Tables 1.17 and 1.18. Application of sulphate of ammonia led to a significant increase in leaflet P and K. Application of sulphate of potash led to a significant increase in rachis K but a decrease in leaflet P. Triple super phosphate application increased both leaflet and rachis P. Kieserite application increased leaflet Mg and application of salt increased leaflet and rachis chlorine but decreased leaflet K.

Table 1.17 Treatment main effects on leaflet nutrient concentrations in 1998 at Malilimi (Trial 126).

Element as % of dry matter	Nutrient element and level			Statistics		
				sig	sed	cv%
	N0	N1	N2			
Nitrogen	2.29	2.27	2.32	ns	0.045	6.9
Phosphorus	0.145	0.148	0.148	**	0.0009	2.2
Potassium	0.66	0.71	0.74	*	0.027	13.2
Calcium	0.86	0.86	0.82	ns	0.020	8.1
Magnesium	0.16	0.15	0.16	ns	0.006	13.8
Chlorine	0.46	0.42	0.45	ns	0.028	21.6
	K0	K1	K2			
Nitrogen	2.31	2.30	2.27	ns	0.045	6.9
Phosphorus	0.148	0.148	0.145	**	0.0009	2.2
Potassium	0.68	0.72	0.72	ns	0.027	13.2
Calcium	0.85	0.84	0.85	ns	0.020	8.1
Magnesium	0.16	0.15	0.15	ns	0.006	13.8
Chlorine	0.44	0.45	0.44	ns	0.028	21.6
	P0	P1				
Nitrogen	2.29	2.30		ns	0.045	6.9
Phosphorus	0.146	0.149		**	0.0009	2.2
Potassium	0.70	0.71		ns	0.027	13.2
Calcium	0.84	0.85		ns	0.020	8.1
Magnesium	0.15	0.16		ns	0.006	13.8
Chlorine	0.43	0.46		ns	0.028	21.6
	Mg0	Mg1				
Nitrogen	2.30	2.29		ns	0.045	6.9
Phosphorus	0.146	0.148		ns	0.0009	2.2
Potassium	0.70	0.71		ns	0.027	13.2
Calcium	0.85	0.84		ns	0.020	8.1
Magnesium	0.15	0.16		*	0.006	13.8
Chlorine	0.44	0.45		ns	0.028	21.6
	Cl0	Cl1				
Nitrogen	2.28	2.31		ns	0.045	6.9
Phosphorus	0.147	0.147		ns	0.0009	2.2
Potassium	0.73	0.68		*	0.027	13.2
Calcium	0.83	0.86		ns	0.020	8.1
Magnesium	0.15	0.16		ns	0.006	13.8
Chlorine	0.41	0.48		**	0.028	21.6

Table 1.18 Treatment main effects on rachis nutrient concentrations in 1998 at Malilimi (Trial 126).

Element as % of dry matter	Nutrient element and level			Statistics		
				sig	sed	cv%
	N0	N1	N2			
Nitrogen	0.24	0.25	0.25	ns	0.007	9.5
Phosphorus	0.051	0.050	0.050	ns	0.0025	17.1
Potassium	1.25	1.25	1.26	ns	0.037	10.2
Calcium	0.42	0.41	0.39	ns	0.019	15.9
Magnesium	0.04	0.04	0.04	ns	0.002	20.3
Chlorine	0.53	0.47	0.50	ns	0.075	51.7
	K0	K1	K2			
Nitrogen	0.24	0.25	0.25	ns	0.007	9.5
Phosphorus	0.050	0.048	0.053	ns	0.0025	17.1
Potassium	1.16	1.29	1.30	**	0.037	10.2
Calcium	0.41	0.40	0.41	ns	0.019	15.9
Magnesium	0.04	0.04	0.04	ns	0.002	20.3
Chlorine	0.47	0.54	0.50	ns	0.075	51.7
	P0	P1				
Nitrogen	0.25	0.25		ns	0.006	9.5
Phosphorus	0.047	0.054		**	0.0020	17.1
Potassium	1.26	1.24		ns	0.030	10.2
Calcium	0.40	0.41		ns	0.015	15.9
Magnesium	0.04	0.04		ns	0.002	20.3
Chlorine	0.50	0.53		ns	0.061	51.7
	Mg0	Mg1				
Nitrogen	0.24	0.25		ns	0.006	9.5
Phosphorus	0.052	0.048		ns	0.0020	17.1
Potassium	1.28	1.23		ns	0.030	10.2
Calcium	0.41	0.41		ns	0.015	15.9
Magnesium	0.04	0.04		ns	0.002	20.3
Chlorine	0.50	0.50		ns	0.061	51.7
	Cl0	Cl1				
Nitrogen	0.24	0.25		ns	0.006	9.5
Phosphorus	0.050	0.051		ns	0.0020	17.1
Potassium	1.23	1.27		ns	0.030	10.2
Calcium	0.40	0.42		ns	0.015	15.9
Magnesium	0.04	0.04		ns	0.002	20.3
Chlorine	0.37	0.63		***	0.061	51.7

The height of palms was measured in this trial in February 1998. Average height of recorded palms was 8.26m giving an average annual increment of 0.69m.

TRIAL 129 CROP RESIDUE AND FERTILISER PLACEMENT TRIAL

PURPOSE

To provide information on the effect of fertiliser placement in the presence or absence of 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.
Treatment applications will start 36 months after planting.

DESIGN

This trial has been designed by biometricians from IACR - Rothamsted and the Pacific Regional Agricultural Program and will replace Trial 122 that is to be replanted in 1998. There will in fact be two separate trials side by side but the results will be reported together.

In Trial 129a there will be two EFB treatments (nil & 50 t/ha). The EFB will be applied on either side of the harvest path as per normal plantation practice. A standard fertiliser treatment of ammonium chloride and Kieserite will be applied to all plots receiving fertiliser. The fertiliser will be applied on either the weeded circle or on the frond pile. The six treatments (Table 1.19) will be arranged in a randomised complete block design with 4 replications.

Table 1.19 Treatments to be used in Trial 129a

Treatment Number	Crop Residue	Fertiliser Applied (kg/palm/yr)	Fertiliser Placement
1	EFB	3.0kg AC & 3.0kg Kies	Weeded Circle
2	EFB	3.0kg AC & 3.0kg Kies	Frond Pile
3	EFB	Nil	-
4	Nil	3.0kg AC & 3.0kg Kies	Weeded Circle
5	Nil	3.0kg AC & 3.0kg Kies	Frond Pile
6	Nil	Nil	-

In Trial 129b all plots will receive EFB at a rate of 50 t/ha. A standard fertiliser treatment of ammonium chloride and kieserite will be applied to all plots receiving fertiliser. The fertiliser will be applied on the weeded circle, the frond pile or the EFB (Table 1.20). The four treatments will be arranged in a randomised complete block design with 8 replications.

Table 1.20 Treatments to be used in Trial 129b.

Treatment Number	Crop Residue	Fertiliser Applied (kg/palm/yr)	Fertiliser Placement
1	EFB	3.0kg AC & 3.0kg Kies	Weeded Circle
2	EFB	3.0kg AC & 3.0kg Kies	Frond Pile
3	EFB	3.0kg AC & 3.0kg Kies	EFB
4	EFB	Nil	-

PROGRESS

This trial was approved in the PNGOPRA Scientific Advisory Board meeting in October 1996. The site has been identified and plot and palm labelling will be completed in 1998.

Experimental fertiliser treatments will be started in August 1999 after pre-treatment yield data has been collected. Until this time the palms will receive a standard immature palm fertiliser input. Frond 17 leaflet, rachis and cross-section sampling will be carried out prior to treatments being applied. The palms in this trial site suffered severe moisture stress in 1997. A survey of the site in July 1998 revealed that many of the palms were missing from the site and it was not suitable for trial purposes. A new trial site was established on Kumbango in the 1994 plantings and pre-treatment yield recording commenced in November 1998.

TRIAL 132 FACTORIAL FERTILISER TRIAL AT HAELLA PLANTATION.

PURPOSE

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

DESCRIPTION

Site: Haella Plantation, Road 6-7, Avenues 10-12

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

Palms: Dami commercial DxP crosses.
Planted in 1995 at 128 palms/ha.
Treatments to commence 1999.

DESIGN

There will be 81 treatments, comprising all factorial combinations of N, P, K and Mg each at three levels (Table 1.21).

Table 1.21 Rates of fertiliser to be used in Trial 132.

	Level (kg /palm/year)		
	0	1	2
Ammonium chloride	2.0	4.0	6.0
Triple Superphosphate	0.0	2.0	4.0
Muriate of potash	0.0	2.0	4.0
Kieserite	0.0	2.0	4.0

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

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 are divided among nine blocks each of nine plots.

PROGRESS

The Scientific Advisory Committee approved the trial in 1997 and the plots were marked out in December 1997. Pretreatment yield recording will continue until the end of 1998 and fertiliser treatments will commence in 1999. Leaflet samples were taken for analysis in 1998 and the results of this analysis are given in Table 1.22.

Table 1.22 Summary statistics for pre-treatment frond 17 leaflet tissue analysis.

Element (%)	Mean	Minimum	Maximum	Standard Deviation
Nitrogen	2.50	2.21	2.71	0.11
Phosphorus	0.158	0.151	0.169	0.003
Potassium	0.88	0.73	1.01	0.05
Calcium	0.89	0.70	1.03	0.06
Magnesium	0.21	0.17	0.28	0.02
Chlorine	0.59	0.46	0.70	0.05

TRIAL 135 EFFECT OF IMMATURE FERTILISER ON INCIDENCE AND SEVERITY OF CROWN DISEASE AT HAELLA AND KUMBANGO PLANTATION

PURPOSE

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

DESCRIPTION

Site Garu and Kumbango Plantation

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: Three selected Dami DxP progenies known to be susceptible to crown disease.

Progeny No.	Lot No.	Pedigree
1	9701815	714.604 x 742.307
2	9701608	711.619 x 742.307
3	9701129	711.808 x 742.207

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. This trial has been planned as an agro-genetic trial.

DESIGN

The three progenies will be planted in plots of 16 palms. There will be 3 nitrogen fertiliser regimes and two levels of Boron (0, 40g/palm). The 18 treatments will be planted as three replicates of a 3x3x2 factorial at Garu Plantation with treatments arranged in blocks of 6.

The plots receiving Boron will have 40g Borax/palm applied 3 months after planting.

The trials were planted in December 1998 and fertiliser application commenced in January 1999.

The nitrogen fertiliser schedules will be as follows:

1. High Rates (NBPOL standard practice since November 1996)

Timing	Fertiliser
At Planting	200 g TSP
At Planting	100 g AC or SoA
At Planting	250 kg EFB mulched in 1 palm circle
1 month	200 g AC or SoA
2 months	200 g AC or SoA
3 months	200 g AC or SoA
4 months	200 g AC or SoA
6 months	200 g AC or SoA
9 months	200 g AC or SoA
12 months	250 g AC or SoA + 0.5 kg Kieserite
18 months	1.0 kg AC or SoA

2. Medium Rate

Timing	Fertiliser
At Planting	200 g TSP
At Planting	100 g AC or SoA
At Planting	250 kg EFB mulched in 1 palm circle
1 month	100 g AC or SoA
2 months	100 g AC or SoA
3 months	100 g AC or SoA
4 months	100 g AC or SoA
6 months	100 g AC or SoA
9 months	100 g AC or SoA
12 months	200 g AC or SoA + 0.5 kg Kieserite
18 months	500 g AC or SoA

3. Low Rate

Timing	Fertiliser
At Planting	200 g TSP
At Planting	100 g AC or SoA
At Planting	250 kg EFB mulched in 1 palm circle
1 month	
2 months	
3 months	100 g AC or SoA
4 months	
6 months	100 g AC or SoA
9 months	100 g AC or SoA
12 months	200 g AC or SoA + 0.5 kg Kieserite
18 months	300 g AC or SoA

RECORDING

Scoring for severity of crown disease will be done monthly by OPRS once the palms reach 12 months of age. OPRA will be responsible for fertiliser application and leaflet samples for nutrient analysis including micronutrients will be taken at 6 monthly intervals. Yield recording will be done by OPRS.

TRIAL 136 MONTHLY LEAF SAMPLING INVESTIGATION

PURPOSE

The Scientific Advisory Board Meeting in 1997 approved that monthly leaf sampling be conducted in five locations in West New Britain. This was to give information on annual variations in leaf nutrient concentrations that will be used to help interpret the results of the annual plantation leaf sampling. This trial commenced in early 1998.

DESCRIPTION

Sampling sites are listed in Table 1.23.

Table 1.23 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

Leaflet and rachis tissue is sampled from frond 17, from approximately 40 palms from each field at the same time each month. Sampling intensity is 10 x 10 with different palms sampled on each date. Samples are collected and brought back to the station where they are dried according to standard procedures. Major nutrients; N, P and K with three secondary nutrients; Ca, Mg and Cl contents are determine in the dried samples by Applied Agricultural Research Laboratory, Malaysia.

RESULTS

Details of fertiliser application at each site in 1998 are given in Table 1.24.

Table 1.24 Application of fertiliser at five sampling sites in 1998 (Trial 136).

Plantation	Month	Fertiliser	Amount kg/palm
HAELLA	July	Ammonium Chloride	1.5
	August/Sept	Kieserite	2.0
	October	Ammonium Chloride	1.5
KUMBANGO	August	Ammonium Chloride	2.0
	September	Ammonium Chloride	2.0
MALILIMI			
BILOMI	March	Sulphate of ammonia	1.5
	March	Muriate of Potash	1.5
	Oct/Nov	Sulphate of ammonia	1.5
KAUTU	May	Ammonium Chloride	1.5
	August/Sept	Ammonium Chloride	1.5
	October	Ammonium Chloride	1.5

Results for the 12 months January to December 1998 are presented in the following tables. From November 1998 only K in the rachis was analysed. Leaflet Boron was analysed commencing November 1998. Some sites were not sampled in November 1998.

Table 1.25 Leaflet Nitrogen at 5 sites in 1998 (Trial 136).

Month	FERT	HAE	FERT	KUM	FERT	MAL	FERT	BIL	FERT	KAU
Jan		2.65		2.25		2.27		2.41		2.56
Feb		3.03		2.36		2.26		2.50		2.67
Mar		2.97		2.49		2.15	AS	2.26		2.35
Apr		2.54		2.38		2.35		2.25		2.75
May		2.56		2.46		2.26		2.47	AC	2.62
Jun		2.60		2.62		2.24		2.52		2.39
Jul	AC	2.57		2.41		2.33		2.27		2.36
Aug		2.53	AC	2.34		2.31		2.37	AC	2.28
Sep		2.57	AC	2.38		2.16		2.52		2.51
Oct	AC	2.51		2.21		2.31	AS	2.31	AC	2.48
Nov		N/A		N/A		N/A		2.27		2.26
Dec		2.27		2.25		2.25		2.29		2.28

Table 1.26 Rachis Nitrogen at 5 sites in 1998 (Trial 136).

Month	FERT	HAE	FERT	KUM	FERT	MAL	FERT	BIL	FERT	KAU
Jan		0.33		0.26		0.27		0.24		0.26
Feb		0.34		0.27		0.27		0.27		0.29
Mar		0.33		0.25		0.32	AS	0.24		0.26
Apr		0.34		0.27		0.27		0.27		0.26
May		0.25		0.3		0.28		0.24	AC	0.24
Jun		0.33		0.25		0.26		0.26		0.22
Jul	AC	0.32		0.26		0.25		0.23		0.22
Aug		0.23	AC	0.26		0.24		0.25	AC	0.27
Sep		0.27		0.26		0.23		0.28		0.27
Oct	AC	0.27	AC	0.24		0.22	AS	0.25	AC	0.26
Nov		N/A		N/A		N/A		N/A		N/A
Dec		N/A		N/A		N/A		N/A		N/A

Table 1.27 Leaflet P at 5 sites in 1998 (Trial 136).

Month	FERT	HAE	FERT	KUM	FERT	MAL	FERT	BIL	FERT	KAU
Jan		0.147		0.135		0.135		0.144		0.145
Feb		0.148		0.135		0.139		0.147		0.154
Mar		0.153		0.139		0.138		0.139		0.148
Apr		0.159		0.143		0.137		0.137		0.170
May		0.176		0.161		0.147		0.149		0.166
Jun		0.168		0.154		0.140		0.176		0.155
Jul		0.166		0.153		0.149		0.152		0.159
Aug		0.162		0.149		0.140		0.145		0.155
Sep		0.158		0.151		0.141		0.153		0.156
Oct		0.156		0.143		0.140		0.144		0.154
Nov		N/A		N/A		N/A		0.145		0.157
Dec		0.155		0.146		0.143		0.144		0.160

Table 1.28 Rachis P at 5 sites in 1998 (Trial 136).

Month	FERT	HAE	FERT	KUM	FERT	MAL	FERT	BIL	FERT	KAU
Jan		0.060		0.053		0.036		0.037		0.078
Feb		0.074		0.059		0.038		0.060		0.067
Mar		0.080		0.057		0.036		0.041		0.074
Apr		0.090		0.071		0.037		0.049		0.088
May		0.064		0.087		0.044		0.045		0.109
Jun		0.089		0.061		0.047		0.102		0.047
Jul		0.096		0.069		0.048		0.037		0.087
Aug		0.082		0.064		0.038		0.060		0.114
Sep		0.091		0.072		0.039		0.061		0.126
Oct		0.094		0.068		0.036		0.057		0.123
Nov		N/A		N/A		N/A		N/A		N/A
Dec		N/A		N/A		N/A		N/A		N/A

Table 1.29 Leaflet K at 5 sites in 1998 (Trial 136).

Month	FERT	HAE	FERT	KUM	FERT	MAL	FERT	BIL	FERT	KAU
Jan		0.69		0.57		0.57		0.65		0.59
Feb		0.71		0.55		0.69		0.61		0.79
Mar		0.55		0.49		0.71	MoP	0.57		0.55
Apr		0.79		0.63		0.61		0.59		0.73
May		0.87		0.69		0.73		0.75		0.73
Jun		0.87		0.71		0.67		0.77		0.73
Jul		0.95		0.79		0.67		0.75		0.75
Aug		0.93		0.79		0.71		0.61		0.69
Sep		0.83		0.73		0.67		0.73		0.77
Oct		0.85		0.89		0.75		0.55		0.75
Nov		N/A		N/A		N/A		0.61		0.79
Dec		0.83		0.75		0.63		0.67		0.75

Table 1.30 Rachis K at 5 sites in 1998 (Trial 136).

Month	FERT	HAE	FERT	KUM	FERT	MAL	FERT	BIL	FERT	KAU
Jan		1.32		1.52		0.83		1.34		1.12
Feb		1.42		1.67		0.95		1.93		1.24
Mar		1.36		1.34		0.95	MoP	1.26		0.99
Apr		1.28		1.52		1.01		1.88		1.42
May		1.60		1.52		1.20		1.83		1.37
Jun		1.26		1.62		1.24		1.62		1.72
Jul		1.37		1.57		1.24		1.37		1.30
Aug		1.28		1.32		1.07		1.34		1.07
Sep		1.34		1.37		1.03		1.26		1.01
Oct		1.30		1.34		0.89		1.67		1.30
Nov		N/A		N/A		N/A		0.97		1.26
Dec		1.22		1.66		1.10		1.34		0.93

Table 1.31 Leaflet Ca at 5 sites in 1998 (Trial 136).

Month	FERT	HAE	FERT	KUM	FERT	MAL	FERT	BIL	FERT	KAU
Jan		1.01		0.77		0.83		0.89		0.72
Feb		0.89		0.90		0.90		0.99		0.70
Mar		0.93		0.92		0.91		0.97		0.89
Apr		0.88		1.02		0.80		0.85		0.81
May		1.07		1.07		0.94		0.97		0.88
Jun		0.96		1.06		0.88		0.79		1.01
Jul		0.94		1.06		0.99		0.89		0.68
Aug		0.86		0.99		0.94		0.94		0.75
Sep		0.84		1.04		0.92		0.88		0.73
Oct		0.87		0.86		0.89		1.01		0.67
Nov		N/A		N/A		N/A		1.08		0.77
Dec		0.84		0.93		0.96		0.87		0.70

Table 1.32 Rachis Ca at 5 sites in 1998 (Trial 136).

Month	FERT	HAE	FERT	KUM	FERT	MAL	FERT	BIL	FERT	KAU
Jan		0.51		0.47		0.39		0.44		0.37
Feb		0.54		0.54		0.39		0.55		0.33
Mar		0.54		0.56		0.43		0.41		0.35
Apr		0.52		0.59		0.38		0.44		0.36
May		0.58		0.56		0.42		0.48		0.53
Jun		0.47		0.57		0.43		0.32		0.43
Jul		0.51		0.57		0.46		0.40		0.35
Aug		0.41		0.46		0.40		0.46		0.37
Sep		0.43		0.46		0.43		0.38		0.30
Oct		0.48		0.45		0.39		0.42		0.31
Nov		N/A		N/A		N/A		N/A		N/A
Dec		N/A		N/A		N/A		N/A		N/A

Table 1.33 Leaflet Mg at 5 sites in 1998 (Trial 136).

Month	FERT	HAE	FERT	KUM	FERT	MAL	FERT	BIL	FERT	KAU
Jan		0.27		0.17		0.10		0.14		0.20
Feb		0.26		0.16		0.14		0.18		0.29
Mar		0.25		0.15		0.16		0.17		0.24
Apr		0.25		0.15		0.15		0.14		0.33
May		0.29		0.18		0.17		0.20		0.24
Jun		0.23		0.17		0.18		0.29		0.22
Jul		0.25		0.17		0.18		0.18		0.20
Aug	KIES	0.27		0.19		0.17		0.17		0.23
Sep		0.27		0.17		0.19		0.14		0.21
Oct		0.25		0.15		0.18		0.22		0.23
Nov		N/A		N/A		N/A		0.23		0.23
Dec		0.23		0.17		0.19		0.14		0.24

Table 1.34 Rachis Mg at 5 sites in 1998 (Trial 136).

Month	FERT	HAE	FERT	KUM	FERT	MAL	FERT	BIL	FERT	KAU
Jan		0.10		0.07		0.03		0.05		0.06
Feb		0.12		0.06		0.04		0.05		0.09
Mar		0.11		0.06		0.04		0.04		0.06
Apr		0.11		0.06		0.04		0.04		0.10
May		0.07		0.08		0.04		0.06		0.10
Jun		0.13		0.07		0.04		0.06		0.05
Jul		0.10		0.07		0.05		0.05		0.06
Aug	KIES	0.09		0.05		0.04		0.05		0.08
Sep		0.10		0.05		0.05		0.04		0.07
Oct		0.12		0.05		0.04		0.05		0.07
Nov		N/A		N/A		N/A		N/A		N/A
Dec		N/A		N/A		N/A		N/A		N/A

Table 1.35 Leaflet Cl at 5 sites in 1998 (Trial 136).

Month	FERT	HAE	FERT	KUM	FERT	MAL	FERT	BIL	FERT	KAU
Jan		0.62		0.65		0.37		0.57		0.47
Feb		0.63		0.56		0.47		0.69		0.54
Mar		0.56		0.50		0.44	MoP	0.59		0.47
Apr		0.65		0.50		0.49		0.50		0.45
May		0.80		0.62		0.51		0.63	AC	0.44
Jun		0.70		0.61		0.50		0.43		0.56
Jul	AC	0.79		0.63		0.44		0.70		0.45
Aug		0.81	AC	0.60		0.48		0.51	AC	0.44
Sep		0.65	AC	0.59		0.47		0.61		0.50
Oct	AC	0.72		0.61		0.47		0.55	AC	0.47
Nov		N/A		N/A		N/A		0.56		0.47
Dec		0.64		0.58		0.44		0.49		0.56

Table 1.36 Rachis Cl at 5 sites in 1998 (Trial 136).

Month	FERT	HAE	FERT	KUM	FERT	MAL	FERT	BIL	FERT	KAU
Jan		0.74		1.06		0.33		0.93		0.49
Feb		0.89		1.10		0.40		1.19		0.63
Mar		0.89		0.99		0.44	MoP	0.83		0.53
Apr		0.85		1.11		0.40		0.89		0.51
May		1.26		1.07		0.43		1.19	AC	0.55
Jun		0.80		1.20		0.47		0.53		1.02
Jul	AC	0.82		1.16		0.53		0.70		0.44
Aug		0.72	AC	0.89		0.52		0.77	AC	0.44
Sep		0.82	AC	0.85		0.40		0.65		0.36
Oct	AC	0.82		0.88		0.43		0.82	AC	0.39
Nov		N/A		N/A		N/A		N/A		N/A
Dec		N/A		N/A		N/A		N/A		N/A

DISCUSSION

From the results obtained from analysis of the leaflets, it can be seen that the level of each nutrient (Nitrogen, Phosphorous, Potassium, Calcium, Magnesium and Chlorine) at each site did not to a significant degree; this is illustrated in Table 1.37. In the first ten months it can be observed from the standard deviation that the level of each nutrient in each site varied only slightly. The variations in the concentration of some of these nutrients are associated with the physiological age of the palms and to a lesser extent with the variability in the nutrient supply of these nutrients from the soil. The range and mean percentage content of these nutrients were therefore highest in the youngest palms (Haella). In the older palms at Bilomi and Malilimi that are thirteen and fourteen years old respectively, the nutrient contents were lower.

Notes on observed nutrient concentrations follow:

Nitrogen: This nutrient was slightly lower in the sampling site at Malilimi with a mean content of 2.26% and was within optimal range in all other sites.

Phosphorous: Was slightly lower in Malilimi (0.141%) sampling site and possibly at Bilomi (0.148%).

Potassium: This nutrient is evidently low in all sampling sites when compared with the optimal range being in the order of about 0.9 to 1.2%. Mean values in all the sampling sites ranges from 0.66 to 0.81%.

Calcium: This nutrient is well supplied to a level well above the optimal range in all sampling sites.

Magnesium: This nutrient is needed in all sites. It is at near optimal range at Haella (0.26%) and Kautu (0.24%) sampling sites.

Chlorine: Most sampling sites have sufficient chlorine content. Malilimi and Kautu could be slightly lower and may need to be increased.

Table 1.37 Range of leaflet nutrient levels recorded at each site (Trial 136).

Nutrient	Site	Planting Year	Range (%)	Mean (%)	SD
Nitrogen	Haella	1995	2.27 – 3.03	2.62	0.21
	Kumbango	1993	2.21 – 2.62	2.38	0.12
	Malilimi	1985	2.15 – 2.35	2.26	0.06
	Bilomi	1987	2.25 – 2.52	2.37	0.11
	Kautu	1986	2.26 – 2.75	2.46	0.16
Phosphorus	Haella	1995	0.147 – 0.176	0.160	0.01
	Kumbango	1993	0.135 – 0.161	0.146	0.01
	Malilimi	1985	0.135 – 0.149	0.141	0.004
	Bilomi	1987	0.137 – 0.176	0.148	0.012
	Kautu	1986	0.145 – 0.170	0.157	0.007
Potassium	Haella	1995	0.55 – 0.95	0.81	0.12
	Kumbango	1993	0.49 – 0.89	0.69	0.12
	Malilimi	1985	0.57 – 0.75	0.67	0.05
	Bilomi	1987	0.55 – 0.77	0.66	0.08
	Kautu	1986	0.55 – 0.79	0.72	0.08
Calcium	Haella	1995	0.84 – 1.07	0.92	0.07
	Kumbango	1993	0.77 – 1.07	0.97	0.10
	Malilimi	1985	0.80 – 0.99	0.91	0.06
	Bilomi	1987	0.79 – 1.08	0.93	0.09
	Kautu	1986	0.67 – 1.01	0.78	0.10
Magnesium	Haella	1995	0.23 – 0.29	0.26	0.02
	Kumbango	1993	0.15 – 0.19	0.17	0.01
	Malilimi	1985	0.10 – 0.19	0.16	0.03
	Bilomi	1987	0.14 – 0.29	0.18	0.05
	Kautu	1986	0.20 – 0.33	0.24	0.04
Chlorine	Haella	1995	0.56 – 0.81	0.69	0.08
	Kumbango	1993	0.50 – 0.65	0.59	0.05
	Malilimi	1985	0.37 – 0.51	0.46	0.04
	Bilomi	1987	0.43 – 0.70	0.57	0.09
	Kautu	1986	0.44 – 0.56	0.49	0.04

The results seem to show a fairly stable level of nutrient irrespective of a number of these not being within the optimal range. Nutrient supply and maintenance then would depend entirely on the regular and proper use of fertilisers.

The nutrient concentration of the rachis tissue was characteristically lower for a number of nutrients compared to that of the leaflets. Leaflet nitrogen was about eight to nine times higher in the leaflet than the rachis. With phosphorous it was about two to three times higher in the leaflet. Potassium content was higher in the rachis than in the leaf. Rachis K to leaf K could be about 1.5 to 2 times higher in all the sites sampled as shown in the table below. Leaflet Calcium is slightly higher in the leaflet than in the rachis. Leaf Magnesium is about two to three times higher in the leaflet than the rachis. Chlorine content tends to be slightly higher in the rachis than in the leaf.

Table 1.38 Rachis K content range at 5 sites (Trial 136).

Nutrient	Site	Planting Year	Range (%)	Mean (%)	SD
Potassium (%)	Haella	1995	1.22 – 1.57	1.34	0.10
	Kumbango	1993	1.32 – 1.67	1.50	0.13
	Malilimi	1985	0.83 – 1.24	1.05	0.14
	Bilomi	1987	0.97 – 1.93	1.48	0.32
	Kautu	1986	0.93 – 1.72	1.22	0.23

From the data available there is a lack of clear evidence on how quickly or efficiently the palms are taking up fertilisers. Increases in the level of these nutrients from a low to a high level at different times (within that ten months period) do suggest however that nutrients have been replenished through fertiliser input as the main source. The effect of this may be prolonged due to other factors. Stability in the status of these nutrients would be too early to determine at this stage of the investigation.

TRIAL 137 SYSTEMATIC FERTILISER TRIAL

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.

Each plot will consist of 18 rows of 16 palms. Each of nine levels of N (N0, N1.....N8 kg/palm) should be applied to consecutive pairs of rows thus providing a systematic increase in N dosage. Thus in one plot the levels of N increase across the pairs of palm rows 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

Compared to a completely randomised or randomised block structure this systematic design has the following advantages:

a) A smaller experimental area can be used.
b) Treatment combinations will not be confounded with inherent soil variability as the long rows will cross a range of different fertility levels.

c) A greater range of N levels can be incorporated thus permitting detailed estimation of the N response.
d) A larger number of replications of the treatment combinations will be achieved.
e) The effect of spread of N fertiliser from treatment to treatment will be minimised because there is only one graduation in application to neighbouring plots (thus a heavy application of N will not occur next to a zero application).

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

TRIAL 138 PALM POISONING TRIAL

PURPOSE

Sodium arsenite is the recommended chemical for palm poisoning in PNG, as it is the cheapest and most efficacious product available. Sodium arsenite is highly toxic and its import is only permitted for oil palm poisoning by trained teams under the direct control of the importer. The product cannot be sold on to contractors. This poses a problem in some areas where replanting of smallholder oil palm is being delayed as the contractors are unable to purchase the recommended chemical. Plantation oil palm is mainly felled using an excavator but this is not practical for use on smallholder blocks. An alternative chemical for palm poisoning is required which is safer and cost effective.

BACKGROUND

Paraquat is the standard treatment in Malaysia and Indonesia. Glyphosate is also reported to be effective. In a previous palm poisoning trial conducted in 1997 neither glyphosate or paraquat killed the palms as effectively as sodium arsenite. MSMA was included in this trial and was the only other treatment that was as effective as sodium arsenite. Four weeks after treatment the paraquat and glyphosate treated palms were still green whereas all the sodium arsenite and MSMA treated palms were dead. The rates used in this trial were 120ml of neat paraquat per palm and 45ml of neat glyphosate (450g/l) per palm. The chemicals were poured into either 2 or 3 holes per palm. The holes were not plugged. It has been suggested that the procedures (no plugging) and rates used in this first trial may have led to the slow kill.

Milne Bay Estates are using glyphosate successfully at a rate of 60ml neat per palm in 3 holes. This is a higher rate than that used in the first trial in 1997.

Han (1979) reported on the results of three palm-poisoning trials conducted in Malaysia. He found that Paraquat and Glyphosate were equally effective but that Paraquat was cheaper at that time. Diquat was also found to be an effective palm-poisoning chemical but was not readily available and so was not recommended. The rates found to be effective were 22.7g a.i. per palm paraquat and 17.0g a.e. per palm glyphosate. This is equivalent to 115ml Gramoxone (200g/l a.i.) and 30ml Glyphosate CT (450g/l).

Nufarm representatives have suggested that diluting glyphosate 50/50 with water may result in better uptake. They also suggested that there should be no delay between drilling the hole and injection of chemical. Traditionally a chainsaw with a drill bit attachment has been used to drill the holes. This is very expensive and OPIC has requested that a treatment be included using a spike to make the holes in the palm.

DESIGN

Based on the results of the 1997 trial, the MBE experience and the report of Han (1979) the following treatments were used in a second trial.

A smallholder block at Sarakolok (Block 0812) was used for the trial. Treatments 1 – 9 were applied on 26/11/98. Treatment 10 (diquat) was applied 1 week later on 3/12/98, as the chemical did not arrive from Lae in time.

Each treatment was applied to 10 palms. After treatment each hole was plugged with a loose fruit. The palms were assessed weekly by rating the death of fronds and crown collapse.

Table 1.39 Treatments used in Trial 138.

Treat	Chemical	Rate/palm (ml)	Holes/Palm	Method	Dilution
1	Sodium Arsenite	60	2	Chainsaw	Neat
2	Glyphosate	30	2	Chainsaw	Neat
3	Glyphosate	30	2	Chainsaw	50/50
4	Glyphosate	60	3	Chainsaw	Neat
5	Glyphosate	60	3	Chainsaw	50/50
6	Glyphosate	60	3	Spike	Neat
7	Paraquat	120	2	Chainsaw	Neat
8	Paraquat	120	3	Chainsaw	Neat
9	Paraquat	160	3	Chainsaw	Neat
10	Diquat	120	3	Chainsaw	Neat

Sodium arsenite is the cheapest product available but the prices given below show that glyphosate at 58.26 toea per palm is much cheaper than either MSMA or Gramoxone. Using Glyphosate at 30ml per palm would be cheaper than sodium arsenite, however the first palm poisoning trial showed that this rate was not effective. The current practice of using a chainsaw to drill holes, although fast, is very expensive. If the treatment of glyphosate with the spike is effective then it is expected that the cost of palm poisoning with glyphosate will be significantly cheaper than poisoning with sodium arsenite.

Table 1.40 Cost of chemical in November 1998.

Chemical	Kina/l*	Rate	toea/palm
Sodium Arsenite	5.67	60	34.02
Glyphosate CT	9.71	30	29.13
Glyphosate CT	9.71	60	58.26
MSMA	10.06	90	90.54
Gramoxone	8.12	120	97.44

* Prices ex NBPOL Central Stores Nov 98

RESULTS

Chemicals were applied on 27/11/98 except Diquat that was applied on 3/12/98. On 14/12/98 the only chemical as effective as sodium arsenite was diquat even though the diquat had been applied 1 week later.

Assessment conducted on 14/12/98.

Treatment	**No. Dead**
Sodium arsenite	10/10
Glyphosate 30 ml neat	0
Glyphosate 30ml diluted	0
Glyphosate 60ml neat	0
Glyphosate 60ml diluted	0
Glyphosate 60ml spike	0
Paraquat 120ml 2 holes	0
Paraquat 120ml 3 holes	4/10
Paraquat 180ml 3 holes	7/10
Diquat 120ml 3 holes	10/10

Assessment conducted on 29/12/1998

Treatment	No. Dead
Sodium arsenite	10/10
Glyphosate 30 ml neat	0/10
Glyphosate 30ml diluted	0/10
Glyphosate 60ml neat	1/10
Glyphosate 60ml diluted	1/10
Glyphosate 60ml spike	2/10
Paraquat 120ml 2 holes	4/10
Paraquat 120ml 3 holes	8/10
Paraquat 180ml 3 holes	10/10
Diquat 120ml 3 holes	10/10

Using 120ml of paraquat application in 3 holes appears to be more effective than the 2 hole treatment. 180ml of Paraquat/palm is more effective than 120ml. At this stage the palms treated with Glyphosate were just beginning to turn yellow.

The final assessment was done on 2/2/99 and the results are as follows:

Treatment	No. Dead
Sodium arsenite	10/10
Glyphosate 30 ml neat	6/10
Glyphosate 30ml diluted	7/10
Glyphosate 60ml neat	10/10
Glyphosate 60ml diluted	10/10
Glyphosate 60ml spike	10/10
Paraquat 120ml 2 holes	7/10
Paraquat 120ml 3 holes	8/10
Paraquat 180ml 3 holes	10/10
Diquat 120ml 3 holes	10/10

This shows that 60ml of Glyphosate applied in 3 holes either with a chainsaw or spike will kill oil palms. The only disadvantage of this treatment is that palms take 2 months to die compared to the very rapid kill (14 days) with sodium arsenite and diquat. Diquat is not currently available in PNG and the cost of the product is not known at this stage. 180mls of paraquat are required to kill an oil palm. This is too expensive.

A further trial is planned to compare diquat at three rates (60, 90 and 120 ml per palm) and glyphosate at 2 rates (60 and 90 ml per palm) with sodium arsenite at the standard rate. All treatments will be applied with a spike in three holes per palm so that labour costs can be calculated.

Reference: Han, K.J. (1979). Some arboricide investigations on oil palms. *Planter* 55:371-376.

TRIAL 204 FACTORIAL FERTILISER TRIAL AT NAVO PLANTATION.

PURPOSE

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

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 1.41).

Table 1.41 Rates of fertiliser used in Trial 204.

	Level (kg /palm/year)		
	0	1	2
Ammonium chloride	0.0	3.0	6.0
Triple superphosphate	0.0	2.0	4.0
Muriate of potash	0.0	3.0	---
Kieserite	0.0	3.0	---

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

The average plot yield in this trial was 30.7 t/ha in 1998 compared to 25.7 t/ha in 1997 and 31.8 t/ha in 1996. As in previous years ammonium chloride application led to a significant increase in FFB yield from 26.0 t/ha (N0) to 32.4 t/ha (N1) and 33.9 t/ha (N2) (Table 1.42). This increase was due to a significant increase in single bunch weight and an increase in bunch number.

No other fertiliser had any main effect on yield or the components of yield. However, there was a significant interaction between N and K in 1998 and this is given in Table 43. This interaction was also present in 1997 and is not surprising, as potassium deficiency symptoms are quite apparent in those plots that are receiving high N inputs but no muriate of potash.

Table 1.42 Main effects of N, P, K and Mg on yield and yield components in 1998 (Trial 204).

	Nutrient element and level			Statistics		
				sig	sed	cv%
	N0	N1	N2			
Yield (t/ha/yr)	26.0	32.4	33.9	***	1.25	14.1
Bunches/ha	1304	1393	1445	ns	60.5	15.2
Bunch weight (kg)	19.9	23.4	23.6	***	0.40	6.1
	P0	P1	P2			
Yield (t/ha/yr)	30.9	30.1	31.3	ns	1.25	14.1
Bunches/ha	1370	1345	1426	ns	60.5	15.2
Bunch weight (kg)	22.6	22.3	21.9	ns	0.40	6.1
	K0	K1				
Yield (t/ha/yr)	30.9	30.6		ns	1.02	14.1
Bunches/ha	1383	1378		ns	49.4	15.2
Bunch weight (kg)	22.5	22.1		ns	0.32	6.1
	Mg0	Mg1				
Yield (t/ha/yr)	31.6	29.9		ns	1.02	14.1
Bunches/ha	1424	1337		ns	49.4	15.2
Bunch weight (kg)	22.2	22.3		ns	0.32	6.1

Table 1.43 Effect of N and K on yield in Trial 204 in 1998.

Rate of Fertiliser	K0	K1
N0	27.8	24.2
N1	31.4	33.4
N2	33.6	34.3
	P<0.05 sed 0.563	

The cumulative data for the period 1996 to 1998 (Table 1.44) also shows a significant positive effect of ammonia chloride application on FFB yield that was caused by an increase in both number of bunches and bunch weight. Table 1.45 gives the yield and components of yield for each year from 1992 to 1998.

Analysis of the three-year cumulative yield data shows that the response to nitrogen is quadratic (Figure 1.2) and that maximum yield is achieved with an application of approximately 5kg of ammonium chloride (Table 1.46). However, due to interplot poaching this response surface is flattened and is therefore an underestimate of the true response to ammonium chloride.

Table 1.44 Main effects of N, P, K and Mg on yield and yield components for 1996 to 1998 (Trial 204).

	Nutrient element and level			Statistics		
				sig	sed	cv%
	N0	N1	N2			
Yield (t/ha/yr)	24.7	31.4	32.5	***	0.85	10.0
Bunches/ha	1228	1357	1404	***	41.5	10.8
Bunch weight (kg)	20.1	23.2	23.2	***	0.35	5.5
	P0	P1	P2			
Yield (t/ha/yr)	29.5	28.9	30.2	ns	0.85	10.0
Bunches/ha	1316	1304	1370	ns	41.5	10.8
Bunch weight (kg)	22.4	22.1	22.0	ns	0.35	5.5
	K0	K1				
Yield (t/ha/yr)	29.6	29.5		ns	0.69	10.0
Bunches/ha	1330	1330		ns	33.9	10.8
Bunch weight (kg)	22.3	22.1		ns	0.29	5.5
	Mg0	Mg1				
Yield (t/ha/yr)	30.3	28.8		*	0.69	10.0
Bunches/ha	1364	1296		*	33.9	10.8
Bunch weight (kg)	22.2	22.2		ns	0.29	5.5

Table 1.45 Yield and components of yield for each year from 1992 to 1996 (Trial 204).

Year (age from planting)	Yield (t/ha)			Bunches/ha			Bunch Weight (kg)		
	N0	N1	N2	N0	N1	N2	N0	N1	N2
1992 (6)	18.6	21.0	22.3	1558	1617	1753	11.9	13.0	12.8
1993 (7)	19.1	21.2	20.3	1405	1447	1411	13.7	14.8	14.5
1994 (8)	20.5	24.4	25.0	1353	1452	1491	15.2	17.0	16.8
1995 (9)	23.3	30.4	32.3	1298	1427	1506	18.1	21.4	21.5
1996 (10)	26.2	34.0	35.2	1305	1439	1502	20.1	23.7	23.5
1997 (11)	21.7	27.2	28.1	1071	1218	1256	20.6	22.7	22.7
1998 (12)	26.0	32.4	33.9	1304	1393	1445	19.9	23.4	23.6

Figure 1.2: Yield in Trial 204 1996-1998

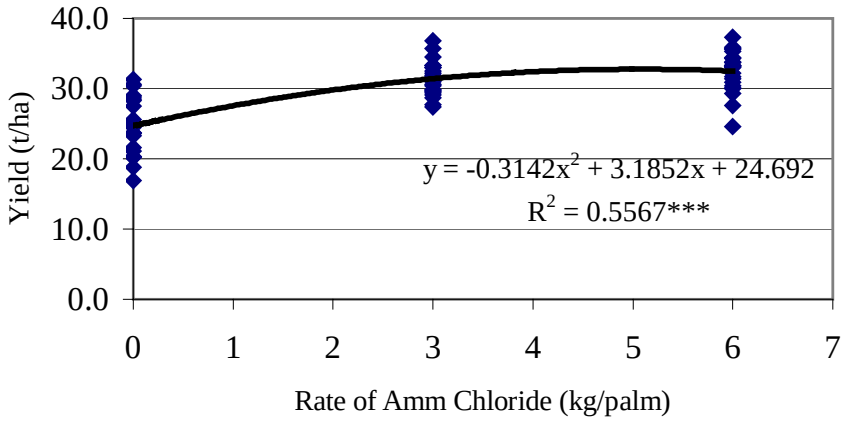


Table 1.46 Predicted yields (mean of 1996-98 yields) as determined by response curve in Figure 1.2.

	Rate of AC (kg/palm/year)						
	2	3	4	5	6	7	8
Yield (t/ha)	29.8	31.4	32.4	32.7	32.5	31.6	30.1

This shows that maximum yields are achieved at around 5kg per palm.

Samples were taken for tissue analysis in 1998 and the results are given below (Tables 1.47 and 1.48).

Samples were taken for tissue analysis in 1998. Full leaflet analysis was conducted but only rachis K analysis was conducted. The results are given below showing that application of Ammonium Chloride led to a significant increase in leaflet P and Cl but a decrease in leaflet Ca, Mg and rachis K. Leaflet N increased from 2.02 at N0 to 2,25 at N1 and 2.32 at N2 but this response was not significant. The relationship between leaflet N and yield is shown in Figure 1.3. This shows that the nature of the response is quadratic with a highly significant R^2 ($R^2 = 0.51$).

Application of TSP led to a significant increase in leaflet P.

Application of MoP led to a significant increase in leaflet Ca and Cl but no increase in leaflet K. Rachis K however, increased significantly with application of MoP.

Kieserite application led to a significant increase in leaflet K and Mg but a decrease in leaflet Ca.

There was a significant interaction between N and K as shown in Table 1.49. This is either a dilution effect of nitrogen application or that ammonium chloride application suppresses the uptake of K.

Table 1.47 Treatment main effects on leaflet nutrient concentrations in 1998 (Trial 204).

Element as % of dry matter	Nutrient element and level			Statistics		
				sig	sed	cv%
	N0	N1	N2			
Nitrogen	2.02	2.25	2.32	ns	0.033	5.2
Phosphorus	0.133	0.144	0.146	***	0.002	4.2
Potassium	0.64	0.62	0.65	ns	0.016	8.8
Calcium	0.93	0.88	0.84	***	0.018	7.1
Magnesium	0.21	0.17	0.16	***	0.007	13.3
Chlorine	0.37	0.49	0.51	***	0.016	12.4
	P0	P1	P2			
Nitrogen	2.19	2.18	2.22	ns	0.033	5.2
Phosphorus	0.138	0.144	0.146	**	0.002	4.2
Potassium	0.63	0.63	0.64	ns	0.016	8.8
Calcium	0.86	0.88	0.90	ns	0.018	7.1
Magnesium	0.18	0.18	0.18	ns	0.007	13.3
Chlorine	0.46	0.44	0.46	ns	0.016	12.4
	K0	K1				
Nitrogen	2.22	2.17		ns	0.027	5.2
Phosphorus	0.142	0.140		ns	0.001	4.2
Potassium	0.64	0.63		ns	0.013	8.8
Calcium	0.86	0.91		***	0.015	7.1
Magnesium	0.18	0.18		ns	0.006	13.3
Chlorine	0.42	0.49		***	0.013	12.4
	Mg0	Mg1				
Nitrogen	2.18	2.22		ns	0.027	5.2
Phosphorus	0.141	0.141		ns	0.001	4.2
Potassium	0.61	0.65		**	0.013	8.8
Calcium	0.91	0.86		***	0.015	7.1
Magnesium	0.17	0.19		***	0.006	13.3
Chlorine	0.45	0.46		ns	0.013	12.4

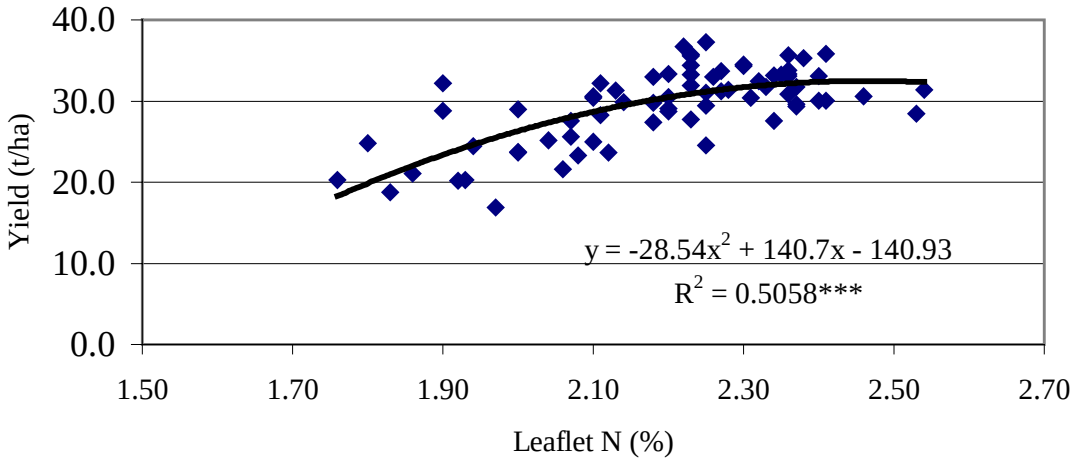
Table 1.48 Treatment main effects on rachis potassium concentrations in 1998 (Trial 204).

Element as % of dry matter	Nutrient element and level			Statistics		
				sig	sed	cv%
	N0	N1	N2			
Potassium	1.55	1.46	1.43	**	0.033	7.8
	P0	P1	P2			
Potassium	1.53	1.46	1.45	ns	0.033	7.8
	K0	K1				
Potassium	1.35	1.61		***	0.027	7.8
	Mg0	Mg1				
Potassium	1.46	1.50		ns	0.027	7.8

Table 1.49 Effect of N and K on rachis K in Trial 204 in 1998.

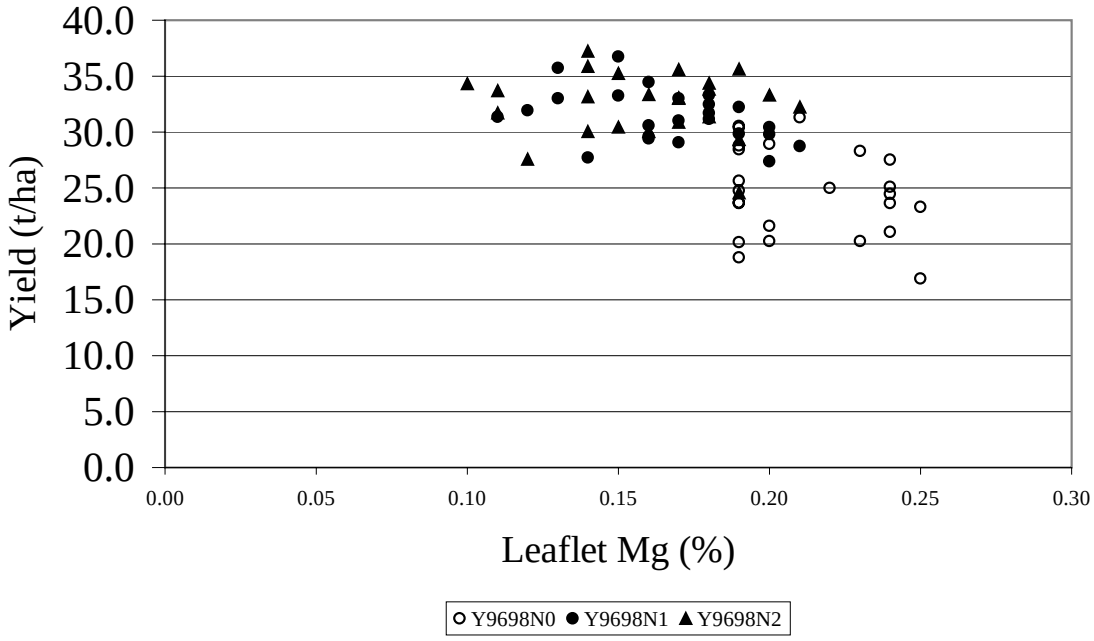
Rate of Fertiliser	K0	K1
N0	1.32	1.78
N1	1.39	1.53
N2	1.34	1.52
	sed 0.047 ***	

Figure 1.3: Cumulative yield 96-98 and Leaflet N in Trial 204



Initial interpretation of a stepwise regression analysis indicated that there was a negative relationship between leaflet Mg and yield. However, Figure 1.4 clearly shows that at N0 leaflet Mg levels are higher than at either N1 or N2 and that yield is much lower at N0. This is clearly a dilution effect.

Figure 1.4: Effect of leaflet Mg on yield at N0, N3 and N6



TRIAL 205 EFB/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 1.50). 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 as follows;

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

Table 1.50 Fertiliser and EFB treatments used in Trial 205.

Treatment	EFB (kg/palm/yr)	Triple Superphosphate (kg/palm/yr)	Kieserite (kg/palm/yr)
1	Nil	Nil	Nil
2	Nil	Nil	3.0
3	Nil	3.0	Nil
4	Nil	3.0	3.0
5	230	Nil	Nil
6	230	Nil	3.0
7	230	3.0	Nil
8	230	3.0	3.0

Where application of EFB and the inorganic fertilisers coincide, they are applied together.

RESULTS

1998 was the second full year of yield recording since fertiliser treatments were applied. The effect of fertiliser treatments on yield or the components of yield for the period Jan - Dec 1998 are given in Table 1.51). This shows that there was a significant response of yield to application of triple super phosphate and to EFB due to an increase in single bunch weight.

Table 1.51 Yield and the components of yield Jan - Dec 1998 (Trial 205).

Treatment	Yield (t/ha)	Number of Bunches/ha	Single Bunch Weight (kg)
EFB0	**28.3*** **	2995*	**9.6***
EFB1	**30.4**	3098	**9.9**
Mg0	29.3	3045	9.7
Mg1	29.4	3049	9.7
TSP0	**28.7***	3030	9.6
TSP1	**29.9**	3064	9.8
Mean	29.3	3047	9.7
sed	0.53	49.5	0.14
cv%	6.3	5.6	4.9

There were no significant interactions between EFB and Mg or between EFB and TSP in 1998 or in the 97-98 data (Table 1.52). The interaction of TSP and Mg was also not significant.

Table 1.52 Yield and the components of yield for 1997-1998 (Trial 205).

Treatment	Yield (t/ha)	Number of Bunches/ha	Single Bunch Weight (kg)
EFB0	**26.3****	2995	**8.1***
EFB1	**27.5**	3098	**8.3**
Mg0	26.8	3045	8.2
Mg1	27.0	3049	8.2
TSP0	**26.4***	3030	**8.1***
TSP1	**27.4**	3064	**8.3**
Mean	26.9	3047	8.2
sed	0.39	49.5	0.09
cv%	5.0	5.6	3.9

There were large highly significant differences between progenies for yield and the components of yield in 1998 (Table 1.53). There was a significant interaction between Mg and Progeny with Progenies A and I showing significant yield increases with the addition of Kieserite in the combined 1997-98 analysis. Yield of Progeny A increased from 28.9 t/ha to 32.5 t/ha with Kieserite and Progeny I yield increased from 29.3 t/ha to 32.1 t/ha with the addition of Kieserite.

Table 1.53 Yield and the components of yield for 16 selected progenies Jan - Dec 1998 (Trial 205).

Progeny	Yield (t/ha)	No. of bunches/ha	Single Bunch Wt. (kg)
A	32.4	3246	10.0
B	30.5	2897	10.6
C	29.0	3153	9.3
D	30.1	3185	9.5
E	24.7	2987	8.4
F	25.9	3153	8.3
G	27.3	2933	9.5
H	31.8	3063	10.4
I	33.8	3488	9.8
J	30.4	2998	10.3
K	28.6	2841	10.3
L	29.1	2987	9.9
M	29.2	2874	10.3
N	28.6	2866	10.1
O	29.7	2950	10.1
P	27.9	3125	9.0
Mean	29.3	3047	9.7
Sig.	***	***	***
sed	0.53	49.5	0.14
cv%	6.3	5.6	4.9

The results of the analysis of leaflet and rachis nutrient content in 1998 are given in Tables 1.54 and 1.55 respectively. Application of EFB led to a significant increase in leaflet P and K however, leaflet Mg decreased with application of EFB. Leaflet Mg increased significantly when Kieserite was applied. Application of TSP led to a significant increase in leaflet P but a decrease in leaflet K.

Table 1.54 Leaflet nutrient levels in 1998 (Trial 205).

Treatment	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	Cl (%)
EFB0	2.52	**0.154*** **	**0.86** **	1.02	**0.23*** **	0.40
EFB1	2.58	**0.161**	**0.89**	1.02	**0.21**	0.49
Mg0	2.53	0.158	0.88	1.02	**0.21***	0.43
Mg1	2.57	0.157	0.87	1.02	**0.22**	0.46
TSP0	2.53	**0.155*** **	**0.89** **	1.01	0.22	0.43
TSP1	2.56	**0.160**	**0.86**	1.03	0.22	0.46
Mean	2.55	0.157	0.87	1.02	0.22	0.44
sed	0.033	0.0009	0.009	0.014	0.004	0.015
cv%	4.5	1.9	3.4	4.6	5.7	11.9

Rachis N, P, K and Cl increased significantly with the application of EFB. Application of Kieserite led to a significant reduction in rachis N and TSP application led to a significant increase in rachis P.

Table 1.55 Rachis nutrient levels in 1998 (Trial 205).

Treatment	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	Cl (%)
EFB0	**0.24****	**0.052*****	**1.18*****	0.40	0.04	**0.27*****
EFB1	**0.25**	**0.084**	**1.47**	0.41	0.05	**0.44**
Mg0	**0.25***	0.069	1.33	0.41	0.05	0.37
Mg1	**0.24**	0.067	1.32	0.40	0.05	0.34
TSP0	0.24	**0.059*****	1.36	0.40	0.05	0.33
TSP1	0.25	**0.077**	1.29	0.41	0.05	0.38
Mean	0.24	0.068	1.33	0.41	0.05	0.35
sed	0.004	0.0033	0.043	0.008	0.001	0.032
cv%	5.3	16.7	11.3	6.5	8.4	31.3

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 sulphate of ammonia, Triple Superphosphate, muriate of potash 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 1.56).

Table 1.56 Fertiliser used in Trial 209.

	Level (kg /palm/year)		
	0	1	2
Sulphate of ammonia	2.0	4.0	8.0
Triple superphosphate	0.0	4.0	8.0
Muriate of potash	0.0	2.0	4.0
Kieserite	0.0	4.0	8.0

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 standard immature palm fertiliser input. Pre-treatment yield recording commenced in January 1997 and treatments were first applied in June 1998. Pre-treatment leaflet samples and rachis cross-sections were taken for analysis in May 1998.

The results of the pre-treatment leaflet analysis and rachis cross section are given in Table 1.57. The results of the analysis of the yield data for 1998 are given in Table 1.58.

Table 1.57 Summary statistics for pre-treatment frond 17 leaflet tissue analysis (Trial 209).

Element (%)	Mean	Minimum	Maximum	Standard Deviation
Nitrogen	2.47	2.22	2.69	0.11
Phosphorus	0.154	0.144	0.164	0.005
Potassium	0.95	0.83	1.14	0.07
Magnesium	0.22	0.17	0.27	0.02
Calcium	1.16	1.00	1.32	0.07
Chlorine	0.63	0.56	0.76	0.04

Table 1.58 Main effects of N, P, K and Mg on yield and yield components for 1998 (Trial 209).

	Nutrient element and level			Statistics	
				sig	sed
	N0	N1	N2		
Yield (t/ha/yr)	18.3	17.4	18.7	ns	0.52
Bunches/ha	2949	2867	2938	ns	65.1
Bunch weight (kg)	6.3	6.1	6.4	ns	0.06
	P0	P1	P2		
Yield (t/ha/yr)	18.4	17.7	18.4	ns	0.52
Bunches/ha	2956	2814	2985	ns	65.1
Bunch weight (kg)	6.3	6.3	6.2	ns	0.06
	K0	K1	K2		
Yield (t/ha/yr)	18.2	18.0	18.2	ns	0.52
Bunches/ha	2929	2887	2939	ns	65.1
Bunch weight (kg)	6.3	6.3	6.3	ns	0.06
	Mg0	Mg1	Mg2		
Yield (t/ha/yr)	18.0	18.3	18.2	ns	0.52
Bunches/ha	2872	2947	2936	ns	65.1
Bunch weight (kg)	6.3	6.2	6.3	ns	0.06

TRIALS 251 & 252 FACTORIAL FERTILISER TRIALS AT MARAMAKAS AND LUBURUA PLANTATIONS.

PURPOSE

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

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 1.59).

Table 1.59 Rates of fertiliser used in Trials 251 and 252.

	Level (kg /palm/year)		
	0	1	2
Sulphate of ammonia	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 fertiliser

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 for 1997 and 1998.

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 by drilling an auger hole beside each recorded palm until the auger struck limestone. Soil depth was used as a concomitant variable in an analysis of covariance of the yield data from 1998 as well as the pooled 1996-1998 data.

RESULTS

The data recording of these trials commenced in June 1992.

Mean yield in 1998 was 15.6 t/ha at Maramakas and 20.3 t/ha at Luburua. This was a dramatic decrease from the yield recorded in 1997 and can be attributed to the effect of the drought in 1997. At Maramakas application of 2.5kg of MoP per palm led to a significant increase in yield as a result of an increase in both bunch number and bunch weight. There was no further increase with an application of 5kg of MoP per palm. Application of SoA, TSP and Kieserite did not effect yield at Maramakas (Table 1.60). Similar responses were recorded for the three-year cumulative period 1996-1998 at Maramakas. Application of 2.5kg of MoP led to a significant increase in yield as a result of an increase in both bunch number and single bunch weight (Table 1.62).

Table 1.60 Main effects of N, P, K and Mg on yield and yield components for 1998 at Maramakas adjusted for covariate of soil depth.

	Nutrient element and level			Statistics		
				sig	sed	cv%
	N0	N1	N2			
Yield (t/ha)	15.0	15.9	16.0	ns	1.15	17.1
Bunches/ha	1047	1068	1085	ns	70.2	15.4
Bunch weight (kg)	14.0	14.7	14.4	ns	0.32	5.2
	K0	K1	K2			
Yield (t/ha)	9.7	18.4	18.8	**	1.30	17.1
Bunches/ha	855	1150	1195	*	79.2	15.4
Bunch weight (kg)	11.4	15.9	15.8	**	0.36	5.2
	P0	P1				
Yield (t/ha)	15.7	15.6		ns	0.94	17.1
Bunches/ha	1042	1092		ns	57.5	15.4
Bunch weight (kg)	14.8	13.9		ns	0.26	5.2
	Mg0	Mg1				
Yield (t/ha/yr)	16.0	15.3		ns	1.14	17.1
Bunches/ha	1066	1067		ns	69.7	15.4
Bunch weight (kg)	14.7	14.0		ns	0.32	5.2

The results at Luburua for 1998 show that there was a significant yield response to both nitrogen and potassium (Table 1.61). This is the second year in a row in which a response to nitrogen has been recorded. Application of 2.5 kg of SoA led to an increase in yield from 22.6 t/ha to 27.1 t/ha due to a significant increase in bunch weight. There was no further increase in yield with 5.0 kg of SoA per palm. Potassium application led to a significant increase in yield due to a significant increase in both bunch number and bunch weight.

Analysis of the cumulative data for 1996-1998 (Table 1.63) at Luburua shows that there was a significant increase in yield as a result of application of both SoA and MoP. Both the 1998 data and the cumulative 1996-98 data for Luburua show that there was a significant increase in bunch weight with application of TSP.

Table 1.61 Main effects of N, P, K and Mg on yield and yield components for 1998 at Luburua adjusted for covariate of soil depth.

	Nutrient element and level			Statistics		
				sig	sed	cv%
	N0	N1	N2			
Yield (t/ha)	17.9	22.2	20.9	*	1.09	12.7
Bunches/ha	1352	1570	1514	*	44.4	7.1
Bunch weight (kg)	12.8	14.0	13.5	*	0.24	4.2
	K0	K1	K2			
Yield (t/ha)	14.2	21.9	24.9	**	1.18	12.7
Bunches/ha	1221	1528	1687	**	47.8	7.1
Bunch weight (kg)	11.4	14.3	14.7	**	0.26	4.2
	P0	P1				
Yield (t/ha)	19.6	21.0		ns	0.86	12.7
Bunches/ha	1457	1500		ns	35.1	7.1
Bunch weight (kg)	13.1	13.9		*	0.19	4.2
	Mg0	Mg1				
Yield (t/ha/yr)	20.7	19.9		ns	0.88	12.7
Bunches/ha	1498	1459		ns	35.9	7.1
Bunch weight (kg)	13.5	13.4		ns	0.20	4.2

Table 1.62 Main effects of N, P, K and Mg on yield and yield components for January 1996 to December 1998 at Maramakas adjusted for covariate of soil depth.

	Nutrient element and level			Statistics		
				sig	sed	cv%
	N0	N1	N2			
Yield (t/ha)	20.5	21.6	22.1	ns	1.33	14.5
Bunches/ha	1379	1429	1435	ns	67.0	11.0
Bunch weight (kg)	14.7	14.9	15.2	ns	0.40	6.3
	K0	K1	K2			
Yield (t/ha)	15.5	23.9	24.8	*	1.50	14.5
Bunches/ha	1217	1497	1529	*	75.5	11.0
Bunch weight (kg)	12.5	16.0	16.3	**	0.45	6.3
	P0	P1				
Yield (t/ha)	21.6	21.1		ns	1.09	14.5
Bunches/ha	1399	1430		ns	54.8	11.0
Bunch weight (kg)	15.3	14.6		ns	0.33	6.3
	Mg0	Mg1				
Yield (t/ha/yr)	21.5	21.3		ns	1.32	14.5
Bunches/ha	1403	1426		ns	66.4	11.0
Bunch weight (kg)	15.2	14.7		ns	0.40	6.3

Table 1.63 Main effects of N, P, K and Mg on yield and yield components for January 1996 to December 1998 at Luburua adjusted for covariate of soil depth.

	Nutrient element and level			Statistics		
				sig	sed	cv%
	N0	N1	N2			
Yield (t/ha)	22.4	25.8	25.6	*	0.58	5.5
Bunches/ha	1756	1873	1903	*	45.2	5.8
Bunch weight (kg)	12.8	13.9	13.4	**	0.15	2.6
	K0	K1	K2			
Yield (t/ha)	20.6	25.8	27.5	**	0.62	5.5
Bunches/ha	1725	1854	1953	*	48.7	5.8
Bunch weight (kg)	12.0	14.0	14.1	***	0.16	2.6
	P0	P1				
Yield (t/ha)	23.9	25.3		ns	0.46	5.5
Bunches/ha	1830	1858		ns	35.7	5.8
Bunch weight (kg)	13.1	13.7		*	0.11	2.6
	Mg0	Mg1				
Yield (t/ha/yr)	25.0	24.2		ns	0.47	5.5
Bunches/ha	1870	1818		ns	36.5	5.8
Bunch weight (kg)	13.4	13.3		ns	0.12	2.6

There were significant NxP and KxP interactions for yield in the three year cumulative period recorded at Luburua (Tables 1.64 and 1.65).

Table 1.64 Effect of NxP on yield at Luburua in 1996-1998.

Treatment	P0	P1
N0	19.5	25.4
N1	25.8	25.9
N2	26.6	24.6
P<0.05 sed=0.82		

Table 1.65 Effect of KxP on yield at Luburua in 1996-1998.

Treatment	P0	P1
K0	18.6	22.5
K1	26.4	25.1
K2	26.8	28.2
P<0.05 sed=0.84		

Mean yields for the combined data for the 2 sites for the six years from 1992 to 1998 are given in Table 1.66.

Table 1.66 Effect of K on FFB yield and yield components from 1992 to 1998 at Luburua and Maramakas.

Year (age from planting)	Yield (t/ha)			Bunches/ha			Bunch Weight (kg)		
	K0	K1	K2	K0	K1	K2	K0	K1	K2
1992 (3)	16.2	17.1	18.4	2577	2596	2768	6.3	6.6	6.6
1993 (4)	17.9	18.6	19.5	2216	2275	2341	8.1	8.2	8.3
1994 (5)	20.4	22.2	23.1	1996	2113	2116	10.2	10.5	10.9
1995 (6)	17.3	17.5	19.1	1534	1424	1529	11.3	12.2	12.4
1996 (7)	16.5	18.5	20.0	1218	1186	1266	13.7	15.7	15.9
1997 (8)	18.9	26.3	26.9	1590	1852	1872	12.1	14.8	14.9
1998 (9)	12.2	20.2	21.5	1061	1340	1417	11.3	15.1	15.3
Mean Yield	17.1	20.1	21.2						

In 1998 both leaflet and rachis samples were analysed and the results of these analyses are given in Tables 1.67 and 1.71 for Maramakas and Tables 1.68 and 1.72 for Luburua.

Table 1.67 Treatment main effects on leaflet nutrient concentrations in 1998 at Maramakas.

Element as % of dry matter	Nutrient element and level			Statistics		
				sig	sed	cv%
	N0	N1	N2			
Nitrogen	2.51	2.50	2.55	ns	0.048	4.6
Phosphorus	0.172	0.168	0.170	ns	0.0028	4.1
Potassium	0.64	0.62	0.65	ns	0.018	7.0
Calcium	1.28	1.19	1.18	*	0.027	5.5
Magnesium	0.32	0.33	0.32	ns	0.016	11.9
Chlorine	0.65	0.67	0.71	ns	0.029	10.4
	K0	K1	K2			
Nitrogen	2.35	2.61	2.59	**	0.048	4.6
Phosphorus	0.163	0.173	0.173	*	0.0028	4.1
Potassium	0.43	0.73	0.76	***	0.018	7.0
Calcium	1.33	1.15	1.17	**	0.027	5.5
Magnesium	0.45	0.27	0.25	***	0.016	11.9
Chlorine	0.71	0.65	0.67	ns	0.029	10.4
	P0	P1				
Nitrogen	2.53	2.51		ns	0.039	4.6
Phosphorus	0.169	0.171		ns	0.0023	4.1
Potassium	0.64	0.64		ns	0.015	7.0
Calcium	1.22	1.22		ns	0.022	5.5
Magnesium	0.33	0.32		ns	0.013	11.9
Chlorine	0.65	0.70		ns	0.023	10.4
	Mg0	Mg1				
Nitrogen	2.53	2.51		ns	0.039	4.6
Phosphorus	0.171	0.169		ns	0.0023	4.1
Potassium	0.65	0.63		ns	0.015	7.0
Calcium	1.22	1.21		ns	0.022	5.5
Magnesium	0.30	0.34		*	0.013	11.9
Chlorine	0.66	0.69		ns	0.023	10.4

Table 1.68 Treatment main effects on leaflet nutrient concentrations in 1998 at Luburua.

Element as % of dry matter	Nutrient element and level			Statistics		
				sig	sed	cv%
	N0	N1	N2			
Nitrogen	2.48	2.56	2.52	ns	0.055	5.4
Phosphorus	0.165	0.169	0.166	ns	0.0020	3.0
Potassium	0.62	0.65	0.63	ns	0.026	10.2
Calcium	1.25	1.20	1.24	ns	0.044	8.7
Magnesium	0.35	0.33	0.32	ns	0.018	13.7
Chlorine	0.69	0.70	0.70	ns	0.019	6.6
	K0	K1	K2			
Nitrogen	2.47	2.54	2.56	ns	0.055	5.4
Phosphorus	0.160	0.170	0.169	*	0.0020	3.0
Potassium	0.45	0.71	0.74	***	0.026	10.2
Calcium	1.24	1.22	1.22	ns	0.044	8.7
Magnesium	0.42	0.29	0.27	**	0.018	13.7
Chlorine	0.67	0.70	0.73	ns	0.019	6.6
	P0	P1				
Nitrogen	2.50	2.54		ns	0.045	5.4
Phosphorus	0.163	0.170		**	0.0016	3.0
Potassium	0.61	0.65		ns	0.022	10.2
Calcium	1.23	1.22		ns	0.036	10.2
Magnesium	0.34	0.32		ns	0.015	13.7
Chlorine	0.70	0.69		ns	0.015	6.6
	Mg0	Mg1				
Nitrogen	2.54	2.51		ns	0.045	5.4
Phosphorus	0.169	0.164		ns	0.0016	3.0
Potassium	0.64	0.62		ns	0.022	10.2
Calcium	1.25	1.21		ns	0.036	10.2
Magnesium	0.31	0.35		ns	0.015	13.7
Chlorine	0.70	0.70		ns	0.015	6.6

At Maramakas MoP application led to a significant increase in leaflet N, P, and K whilst leaflet Ca and Mg decreased. At Luburua MoP application led to a significant increase in leaflet P and K and a significant decrease in leaflet Mg. Although not significant leaflet N levels did increase with MoP application at Luburua. This increase in leaflet N at both sites was thought to be related to the increased vigour of legume cover crop that occurs when MoP is applied. To test these hypotheses the growth of legume cover crop was assessed. The cover crop was assessed in three ways: a) by scoring for % ground cover outside the weeded circle and harvest path at 4 locations within the plot on a 0-4 scale, b) scoring K deficiency symptoms on a 0-3 scale and c) rating the vigour of cover crop growth on a 1-3 scale.

The results of this assessment are given in Table 1.69 for Maramakas and Table 1.70 for Luburua. The analysis clearly shows that % ground cover and vigour increase whilst deficiency symptoms decrease with application of MoP. Mean % ground cover was less at Maramakas (mean score 2.85) than at Luburua (mean score 3.31). This is a possible explanation for the lower yields recorded at Maramakas. An interesting observation was that *Centrosema* sp. appeared to be less susceptible to K deficiency than *Calypogonium* sp. *Centrosema* sp tends to predominate in the low K plots in which plots *Calypogonium* sp. displays severe K deficiency symptoms and poor vigour.

Table 1.69 Effect of nutrients on legume ground cover at Maramakas (analysis of transformed data and back-transformed for % ground cover only).

	Nutrient element and level			Statistics		
				sig	sed	cv%
	N0	N1	N2			
% Ground cover (0-4)	3.08	3.22	3.11	ns	0.74	50.7
Deficiency score (0-3)	1.08	1.17	1.00	ns	0.41	91.7
Vigour score (0-3)	1.83	1.75	1.58	ns	0.47	66.7
	K0	K1	K2			
% Ground cover (0-4)	2.52	3.39	3.39	ns	0.74	50.7
Deficiency score (0-3)	1.83	0.83	0.58	ns	0.41	91.7
Vigour score (0-3)	1.17	1.92	2.08	ns	0.47	66.7
	P0	P1				
% Ground cover (0-4)	2.74	3.46		ns	0.61	50.7
Deficiency score (0-3)	1.06	1.11		ns	0.33	91.7
Vigour score (0-3)	1.61	1.83		ns	0.38	66.7
	Mg0	Mg1				
% Ground cover (0-4)	3.23	3.04		ns	0.61	50.7
Deficiency score (0-3)	0.89	1.28		ns	0.33	91.7
Vigour score (0-3)	1.83	1.61		ns	0.38	66.7

Table 1.70 Effect of nutrients on legume ground cover at Luburua (analysis of transformed data and back-transformed for % ground cover only).

	Nutrient element and level			Statistics		
				sig	sed	cv%
	N0	N1	N2			
% Ground cover (0-4)	3.78	3.62	3.71	ns	0.63	32.7
Deficiency score (0-3)	1.67	1.50	1.83	ns	0.16	23.5
Vigour score (0-3)	2.17	2.17	2.33	ns	0.08	9.2
	K0	K1	K2			
% Ground cover (0-4)	2.64	3.93	3.97	*	0.63	32.7
Deficiency score (0-3)	2.27	1.17	1.17	**	0.16	23.5
Vigour score (0-3)	1.33	2.50	2.83	***	0.08	9.2
	P0	P1				
% Ground cover (0-4)	3.76	3.67		ns	0.51	32.7
Deficiency score (0-3)	1.78	1.56		ns	0.13	23.5
Vigour score (0-3)	2.11	2.33		*	0.07	9.2
	Mg0	Mg1				
% Ground cover (0-4)	3.78	3.63		ns	0.51	32.7
Deficiency score (0-3)	1.56	1.78		ns	0.13	23.5
Vigour score (0-3)	2.33	2.11		*	0.07	9.2

Scoring System

% Ground cover
- 0 = no cover
- 1 = 25% cover
- 2 = 50% cover
- 3 = 75% cover
- 4 = 100% cover

Deficiency symptoms
- 0 = no symptoms
- 1 = some symptoms
- 2 = many symptoms
- 3 = severe symptoms

Vigour score
- 0 = dead
- 1 = poor vigour
- 2 = vigorous
- 3 = very vigorous

Rachis P, K and Cl increased significantly with application of MoP at Maramakas whilst rachis Ca and Mg decreased. Similarly at Luburua rachis P, K and Cl increased with application of MoP and rachis Ca and Mg decreased. The extremely low rachis K levels in the K0 treatments clearly show the reason for the yield response to applied potassium.

Table 1.71 Treatment main effects on rachis nutrient concentrations in 1998 at Maramakas.

Element as % of dry matter	Nutrient element and level			Statistics		
				sig	sed	cv%
	N0	N1	N2			
Nitrogen	0.25	0.28	0.28	ns	0.011	9.5
Phosphorus	0.093	0.077	0.077	*	0.003	10.5
Potassium	0.97	0.98	0.92	ns	0.057	14.6
Calcium	0.55	0.53	0.54	ns	0.018	8.0
Magnesium	0.16	0.15	0.16	ns	0.003	5.4
Chlorine	0.68	0.73	0.73	ns	0.059	20.2
	K0	K1	K2			
Nitrogen	0.29	0.25	0.27	ns	0.011	9.5
Phosphorus	0.065	0.087	0.095	**	0.003	10.5
Potassium	0.15	1.17	1.55	***	0.057	14.6
Calcium	0.63	0.50	0.50	**	0.018	8.0
Magnesium	0.27	0.11	0.09	***	0.003	5.4
Chlorine	0.35	0.84	0.94	**	0.059	20.2
	P0	P1				
Nitrogen	0.27	0.27		ns	0.009	9.5
Phosphorus	0.070	0.095		**	0.002	10.5
Potassium	0.97	0.94		ns	0.047	14.6
Calcium	0.54	0.54		ns	0.014	8.0
Magnesium	0.15	0.16		ns	0.002	5.4
Chlorine	0.71	0.71		ns	0.048	20.2
	Mg0	Mg1				
Nitrogen	0.27	0.27		ns	0.009	9.5
Phosphorus	0.084	0.081		ns	0.002	10.5
Potassium	0.98	0.93		ns	0.047	14.6
Calcium	0.56	0.52		ns	0.014	8.0
Magnesium	0.14	0.17		***	0.002	5.4
Chlorine	0.74	0.68		ns	0.048	20.2

Table 1.72 Treatment main effects on rachis nutrient concentrations in 1998 at Luburua.

Element as % of dry matter	Nutrient element and level			Statistics		
				sig	sed	cv%
	N0	N1	N2			
Nitrogen	0.28	0.27	0.29	ns	0.009	7.9
Phosphorus	0.082	0.074	0.076	ns	0.005	15.0
Potassium	0.96	1.01	0.92	ns	0.102	25.9
Calcium	0.53	0.52	0.51	ns	0.018	8.6
Magnesium	0.14	0.11	0.11	ns	0.012	23.5
Chlorine	0.77	0.85	0.75	*	0.025	7.8
	K0	K1	K2			
Nitrogen	0.30	0.27	0.27	*	0.009	7.9
Phosphorus	0.064	0.077	0.090	*	0.005	15.0
Potassium	0.18	1.19	1.52	***	0.102	25.9
Calcium	0.57	0.50	0.49	*	0.018	8.6
Magnesium	0.20	0.09	0.08	***	0.012	23.5
Chlorine	0.36	0.93	1.07	***	0.025	7.8
	P0	P1				
Nitrogen	0.29	0.27		ns	0.007	7.9
Phosphorus	0.069	0.085		*	0.004	15.0
Potassium	0.98	0.96		ns	0.083	25.9
Calcium	0.51	0.53		ns	0.015	8.6
Magnesium	0.13	0.12		ns	0.010	23.5
Chlorine	0.78	0.80		ns	0.021	7.8
	Mg0	Mg1				
Nitrogen	0.28	0.28		ns	0.007	7.9
Phosphorus	0.079	0.075		ns	0.004	15.0
Potassium	0.96	0.98		ns	0.083	25.9
Calcium	0.52	0.52		ns	0.015	8.6
Magnesium	0.11	0.13		ns	0.010	23.5
Chlorine	0.79	0.78		ns	0.021	7.8

As in 1996 and 1997 there continued to be a strong positive relationship ($R^2=0.46^{***}$) between yield and the ratio of leaflet K:Ca for the combined data (Fig 1.5) and at each site (Fig 1.6).

Figure 1.5: Relationship between yield and Leaflet K:Ca in 1998

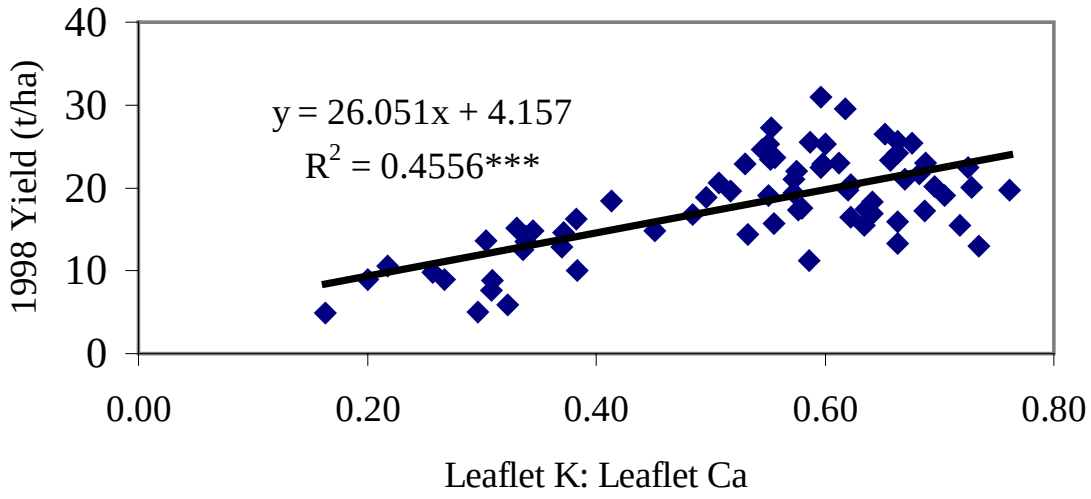
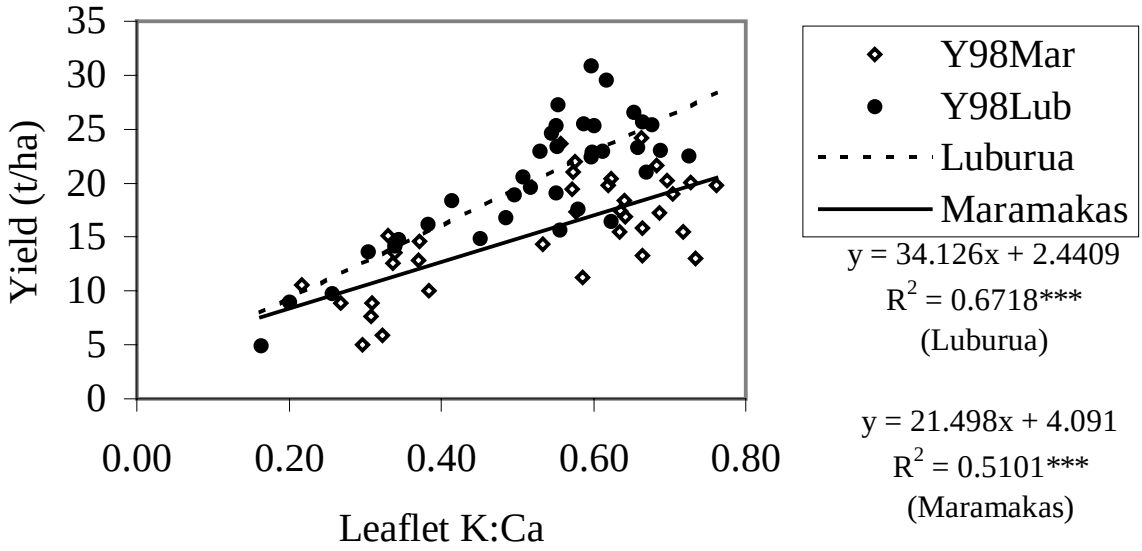


Figure 1.6: Yield and leaflet K:Ca at Maramakas and Luburua in 1998



Full vegetative measurements were recorded in 1998 as well as bunch analysis in selected plots. This data shows that at both sites potassium application led to a significant increase in dry frond weight, frond area, leaf area index and bunch index. Nitrogen application led to a significant increase in dry frond weight but not the other parameters (Tables 1.73 and 1.74).

Table 1.73 Vegetative growth parameters at Maramakas in 1998.

Growth Component	Nutrient element and level			Statistics		
				sig	sed	cv%
	N0	N1	N2			
Dry Frond Weight (kg)	2.73	2.83	2.91	**	0.022	1.9
Frond Area (m^2)	8.93	8.78	9.11	ns	0.289	7.9
Leaf Area Index	4.95	4.85	5.19	ns	0.104	5.1
Bunch Index	0.562	0.566	0.547	ns	0.018	8.1
	K0	K1	K2			
Dry Frond Weight (kg)	2.52	2.88	3.06	***	0.022	1.9
Frond Area (m^2)	8.02	9.15	9.65	*	0.289	7.9
Leaf Area Index	4.51	5.12	5.36	**	0.104	5.1
Bunch Index	0.501	0.594	0.580	*	0.018	8.1
	P0	P1				
Dry Frond Weight (kg)	2.83	2.82		ns	0.018	2.1
Frond Area (m^2)	8.97	8.91		ns	0.236	7.9
Leaf Area Index	4.96	5.03		ns	0.085	5.1
Bunch Index	0.556	0.561		ns	0.015	8.1
	Mg0	Mg1				
Dry Frond Weight (kg)	2.83	2.81		ns	0.018	2.1
Frond Area (m^2)	8.88	9.00		ns	0.236	7.9
Leaf Area Index	5.03	4.96		ns	0.085	5.1
Bunch Index	0.556	0.561		ns	0.015	8.1

Table 1.74 Vegetative growth parameters at Luburua in 1998.

Growth Component	Nutrient element and level			Statistics		
				sig	sed	cv%
	N0	N1	N2			
Dry Frond Weight (kg)	2.71	2.90	2.77	ns	0.129	11.3
Frond Area (m^2)	8.90	9.29	9.51	ns	0.406	10.8
Leaf Area Index	4.95	5.20	5.40	ns	0.223	10.5
Bunch Index	0.593	0.625	.0621	ns	0.013	5.3
	K0	K1	K2			
Dry Frond Weight (kg)	2.62	2.86	2.90	ns	0.129	11.3
Frond Area (m^2)	8.46	9.59	9.65	ns	0.406	10.8
Leaf Area Index	4.91	5.28	5.35	ns	0.223	10.5
Bunch Index	0.554	0.636	0.650	**	0.013	5.3
	P0	P1				
Dry Frond Weight (kg)	2.73	2.86		ns	0.106	11.3
Frond Area (m^2)	9.20	9.26		ns	0.332	10.8
Leaf Area Index	5.09	5.27		ns	0.182	10.5
Bunch Index	0.607	0.620		ns	0.011	5.3
	Mg0	Mg1				
Dry Frond Weight (kg)	2.79	2.80		ns	0.106	11.3
Frond Area (m^2)	9.21	9.26		ns	0.332	10.8
Leaf Area Index	5.16	5.21		ns	0.182	10.5
Bunch Index	0.619	0.608		ns	0.011	5.3

Table 1.75 Bunch Analysis results from 6 selected plots at Maramakas and Luburua.

Trial	Plot	K Level	No. of Bunches analysed	Kernel/Bunch (%)	Oil/Bunch (%)	Oil/Hectare (t/ha)
251	35	K0	23	5.47	25.4	2.46
251	14	K1	30	4.97	22.5	4.15
251	24	K2	30	5.50	21.9	4.12
252	26	K0	16	5.27	21.5	3.05
252	5	K1	30	5.37	23.1	5.05
252	32	K2	30	6.90	22.7	5.65
			Mean	5.58	22.9	

The bunch analysis data shows that average oil/bunch was 22.9% (Table 1.75). Due to the very low yields in the K0 a plot, only 23 and 16 bunches were sampled from Maramakas and Luburua respectively. This analysis will be repeated in 1999.

The height of the palms was measured in February 1998. The average palm height at Maramakas was 3.34m and at Luburua 3.02m. This gives an annual increment of 0.48m at Maramakas and 0.43m at Luburua. Annual height increment at Dami is between 0.70 and 0.80m indicating that palm height in New Ireland will not become limiting until the palms have reached 25 years or more. Annual frond production in the 12 months to August 1998 was 20.4 at Maramakas and 20.5 at Luburua. This is lower than expected but may be as a result of the drought.

TRIAL 401 FACTORIAL FERTILISER TRIAL AT KAUTU PLANTATION.

PURPOSE

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

DESCRIPTION

Site: Kapiura Estates, Kautu Plantation, Field 86T.

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

Palms: Dami commercial DxP crosses.
Planted in 1986 at 135 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 1.76).

Table 1.76 Rates of fertiliser used in Trial 401.

	Level (kg/palm/year)		
	0	1	2
Ammonium chloride	0	3.0	6.0
Triple superphosphate	0	2.0	4.0
Muriate of potash	0	3.0	---
Kieserite	0	3.0	---

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. Plot isolation trenching was completed in August 1995.

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' would be partially confounded with blocks. High order interactions provide the error term in the statistical analysis.

RESULTS

Yields declined sharply in this trial in 1998 with mean FFB yield at just 16.0 t/ha. This decline is probably due to the stress caused by the cyclone and drought in 1997. There were no differences in yield recorded between treatments in this trial in 1998 (Table 1.77). The only response detected in the 1996-98 cumulative data (Table 1.78) was a small increase in bunch weight as a result of nitrogen application.

Detailed examination of the data from Trial 401 has indicated two problems:

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

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 trial with this structure will not result in any changes to the patterns of response achieved so far.

Table 1.77 Main effects of N, P, K and Mg on yield and yield components in 1998 (Trial 401).

	Nutrient element and level			Statistics		
				sig	sed	cv%
	N0	N1	N2			
Yield (t/ha/yr)	15.9	16.2	15.8	ns	0.67	14.6
Bunches/ha	862	872	850	ns	32.2	13.0
Bunch weight (kg)	18.4	18.6	18.6	ns	0.26	4.8
	P0	P1	P2			
Yield (t/ha/yr)	15.7	15.8	16.4	ns	0.67	14.6
Bunches/ha	840	863	881	ns	32.2	13.0
Bunch weight (kg)	18.6	18.3	18.6	ns	0.26	4.8
	K0	K1				
Yield (t/ha/yr)	16.0	15.9		ns	0.55	14.6
Bunches/ha	862	860		ns	26.3	13.0
Bunch weight (kg)	18.5	18.5		ns	0.21	4.8
	Mg0	Mg1				
Yield (t/ha/yr)	15.8	16.2		ns	0.55	14.6
Bunches/ha	856	867		ns	26.3	13.0
Bunch weight (kg)	18.4	18.6		ns	0.21	4.8

Table 1.78 Main effects of N, P, K and Mg on yield and yield components for 1996 to 1998 (Trial 401).

	Nutrient element and level			Statistics		
				sig	sed	cv%
	N0	N1	N2			
Yield (t/ha/yr)	21.2	22.1	22.5	ns	0.52	8.3
Bunches/ha	1065	1086	1087	ns	25.6	8.2
Bunch weight (kg)	19.8	20.2	20.4	*	0.23	3.9
	P0	P1	P2			
Yield (t/ha/yr)	22.0	21.9	21.9	ns	0.52	8.3
Bunches/ha	1067	1082	1089	ns	25.6	8.2
Bunch weight (kg)	20.4	20.1	20.0	ns	0.23	3.9
	K0	K1				
Yield (t/ha/yr)	21.9	22.0		ns	0.43	8.3
Bunches/ha	1078	1080		ns	20.9	8.2
Bunch weight (kg)	20.1	20.2		ns	0.19	3.9
	Mg0	Mg1				
Yield (t/ha/yr)	21.7	22.2		ns	0.43	8.3
Bunches/ha	1075	1084		ns	20.9	8.2
Bunch weight (kg)	20.0	20.2		ns	0.19	3.9

Leaflet samples were taken for analysis in October 1998 and the results of this analysis are given in Table 1.79 below. These results show that leaflet N and Cl levels increased with the addition of ammonium chloride. However, the leaflet N levels are still low even at the highest rate of application. Leaflet P levels increased with application of TSP. MoP application led to a significant increase in leaflet Ca and Cl levels. Kieserite had no effect on leaflet nutrient levels.

Table 1.79 Treatment main effects on leaflet nutrient concentrations in 1998 (Trial 401).

Element as % of dry matter	Nutrient element and level			Statistics		
				sig	sed	cv%
	N0	N1	N2			
Nitrogen	2.24	2.31	2.27	*	0.028	4.3
Phosphorus	0.149	0.149	0.148	ns	0.001	3.1
Potassium	0.69	0.66	0.65	ns	0.018	9.5
Calcium	0.80	0.82	0.79	ns	0..017	7.1
Magnesium	0.19	0.20	0.18	ns	0.007	12.1
Chlorine	0.44	0.53	0.53	***	0.013	8.9
	P0	P1	P2			
Nitrogen	2.28	2.26	2.28	ns	0.028	4.3
Phosphorus	0.147	0.148	0.151	*	0.001	3.1
Potassium	0.66	0.65	0.68	ns	0.018	9.5
Calcium	0.81	0.80	0.80	ns	0..017	7.1
Magnesium	0.19	0.18	0.19	ns	0.007	12.1
Chlorine	0.51	0.49	0.49	ns	0.013	8.9
	K0	K1				
Nitrogen	2.27	2.27		ns	0.023	4.3
Phosphorus	0.149	0.149		ns	0.001	3.1
Potassium	0.68	0.65		ns	0.015	9.5
Calcium	0.79	0.82		*	0.013	7.1
Magnesium	0.19	0.19		ns	0.005	12.1
Chlorine	0.47	0.53		***	0.010	8.9
	Mg0	Mg1				
Nitrogen	2.27	2.27		ns	0.023	4.3
Phosphorus	0.149	0.148		ns	0.001	3.1
Potassium	0.67	0.66		ns	0.015	9.5
Calcium	0.81	0.79		ns	0.013	7.1
Magnesium	0.19	0.19		ns	0.005	12.1
Chlorine	0.50	0.49		ns	0.010	8.9

This trial was closed down at the end of 1998.

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 1.80).

Table 1.80 Rates of fertiliser used in Trial 402.

	Level (kg /palm/year)		
	0	1	2
Ammonium chloride	0.0	3.0	6.0
Triple Superphosphate	0.0	2.0	4.0
Muriate of potash	0.0	3.0	---
Kieserite	0.0	3.0	---
		(Tonnes/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 average plot yield in 1998 was only 16.1 t/ha. As with Trial 401 at Kautu the drop in yield can probably be attributed to the effects of the cyclone and drought in 1997.

The only significant response recorded in 1998 was an increase in bunch weight as a result of application of ammonium chloride, and EFB (Table 1.81). The 1996-1998 cumulative data (Table 1.82) shows a similar increase in bunch weight with the application of ammonium chloride.

Table 1.81 Main effects of N, P, K and Mg on yield and yield components in 1998 (Trial 402).

	Nutrient element and level			Statistics		
				sig.	sed	cv%
	N0	N1	N2			
Yield (t/ha/yr)	15.9	16.2	16.3	ns	0.64	13.7
Bunches/ha	838	849	833	ns	30.5	12.6
Bunch weight (kg)	18.9	19.1	19.6	*	0.20	3.6
	P0	P1	P2			
Yield (t/ha/yr)	16.4	16.0	15.9	ns	0.64	13.7
Bunches/ha	861	838	820	ns	30.5	12.6
Bunch weight (kg)	19.1	19.2	19.4	ns	0.20	3.6
	K0	K1				
Yield (t/ha/yr)	16.1	16.2		ns	0.52	13.7
Bunches/ha	844	836		ns	24.9	12.6
Bunch weight (kg)	19.1	19.3		ns	0.16	3.6
	Mg0	Mg1				
Yield (t/ha/yr)	16.4	15.8		ns	0.52	13.7
Bunches/ha	856	824		ns	24.9	12.6
Bunch weight (kg)	19.2	19.2		ns	0.16	3.6
	EFB0	EFB1				
Yield (t/ha/yr)	16.3	16.0		ns	0.52	13.7
Bunches/ha	856	824		ns	24.9	12.6
Bunch weight (kg)	19.0	19.4		*	0.16	3.6

As with Trial 107 and Trial 401 detailed examination of the data from Trial 402 has indicated two problems:

a) There is a distinct possibility that N and 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 trial with this structure will not result in any changes to the patterns of response achieved so far. However, the trial was trenched in 1997 and this may lead to a response sometime in the future. Application of EFB has led to a response in both 1996 and 1997 but there was no such response in 1998.

Table 1.82 Main effects of N, P, K and Mg on yield and yield components from 1996 - 98 (Trial 402).

	Nutrient element and level			Statistics		
				sig	sed	cv%
	N0	N1	N2			
Yield (t/ha/yr)	21.7	22.0	22.2	ns	0.55	8.6
Bunches/ha	1076	1064	1064	ns	25.6	8.3
Bunch weight (kg)	20.0	20.6	20.7	***	0.14	2.4
	P0	P1	P2			
Yield (t/ha/yr)	22.2	22.0	21.7	ns	0.55	8.6
Bunches/ha	1086	1060	1058	ns	25.6	8.3
Bunch weight (kg)	20.3	20.6	20.4	ns	0.14	2.4
	K0	K1				
Yield (t/ha/yr)	22.1	21.8		ns	0.45	8.6
Bunches/ha	1078	1058		ns	20.9	8.3
Bunch weight (kg)	20.4	20.5		ns	0.11	2.4
	Mg0	Mg1				
Yield (t/ha/yr)	21.8	22.1		ns	0.45	8.6
Bunches/ha	1069	1068		ns	20.9	8.3
Bunch weight (kg)	20.3	20.6		*	0.11	2.4
	EFB0	EFB1				
Yield (t/ha/yr)	21.6	22.3		ns	0.45	8.6
Bunches/ha	1058	1078		ns	20.9	8.3
Bunch weight (kg)	20.3	20.6		ns	0.11	2.4

Table 1.83 shows the yield figures recorded from this trial since yield recording commenced in 1991. These figures show that in most years there has been a small increase due to nitrogen. In 1994 and 1995 EFB had almost no effect on yield. However, in 1996 and 1997 application of 50 t/ha of EFB resulted in a significant increase in yield.

Table 1.83 Effect of N and EFB on FFB yield from 1992 to 1998 in Trial 402.

Year (age from planting)	Yield (t/ha)			Yield (t/ha)	
	N0	N1	N2	EFB0	EFB1
1991 (4)	22.4	23.4	22.2	-	-
1992 (5)	30.0	31.6	31.5	-	-
1993 (6)	27.2	28.6	28.9	-	-
1994 (7)	25.2	26.0	25.8	25.7	25.6
1995 (8)	23.2	22.6	23.5	22.8	23.4
1996 (9)	25.6	26.6	27.6	25.8	27.4
1997 (10)	21.3	21.7	20.9	20.9	21.7
1998 (11)	15.9	16.2	16.3	16.3	16.0

The main effect of adding fertiliser has been to increase leaflet and rachis Cl levels as can be seen from Table 1.84 and 1.85. Chlorine levels increased significantly with application of ammonium chloride, MoP and EFB. The significant increases in bunch weight with application of ammonium chloride and EFB are most likely due to the effect of chlorine.

Table 1.84 Treatment main effects on leaflet nutrient concentrations in 1998 (Trial 402).

Element as % of dry matter	Nutrient element and level			Statistics		
				sig	sed	cv%
	N0	N1	N2			
Nitrogen	2.37	2.36	2.36	ns	0.022	3.2
Phosphorus	0.154	0.155	0.154	ns	0.001	2.9
Potassium	0.73	0.72	0.72	ns	0.015	7.1
Calcium	0.80	0.82	0.80	ns	0.020	8.7
Magnesium	0.16	0.17	0.16	ns	0.005	11.6
Chlorine	0.48	0.54	0.53	*	0.019	12.8
	P0	P1	P2			
Nitrogen	2.42	2.33	2.35	**	0.022	3.2
Phosphorus	0.154	0.153	0.156	ns	0.001	2.9
Potassium	0.74	0.72	0.72	ns	0.015	7.1
Calcium	0.82	0.79	0.81	ns	0.020	8.7
Magnesium	0.16	0.16	0.16	ns	0.005	11.6
Chlorine	0.51	0.52	0.52	ns	0.019	12.8
	K0	K1				
Nitrogen	2.39	2.34		**	0.018	3.2
Phosphorus	0.156	0.153		*	0.001	2.9
Potassium	0.72	0.73		ns	0.012	7.1
Calcium	0.82	0.79		ns	0.016	8.7
Magnesium	0.16	0.16		ns	0.004	11.6
Chlorine	0.49	0.55		**	0.016	12.8
	Mg0	Mg1				
Nitrogen	2.37	2.36		ns	0.018	3.2
Phosphorus	0.156	0.153		*	0.001	2.9
Potassium	0.72	0.73		ns	0.012	7.1
Calcium	0.83	0.79		*	0.016	8.7
Magnesium	0.16	0.17		*	0.004	11.6
Chlorine	0.52	0.51		ns	0..016	12.8
	EFB0	EFB1				
Nitrogen	2.35	2.38		ns	0.018	3.2
Phosphorus	0.153	0.156		*	0.001	2.9
Potassium	0.72	0.74		ns	0.012	7.1
Calcium	0.82	0.79		ns	0.016	8.7
Magnesium	0.16	0.16		ns	0.004	11.6
Chlorine	0.50	0.53		*	0.016	12.8

Table 1.85 Treatment main effects on rachis nutrient concentrations in 1997 (Trial 402).

Element as % of dry matter	Nutrient element and level			Statistics		
				sig	sed	cv%
	N0	N1	N2			
Nitrogen	0.26	0.27	0.27	ns	0.005	6.3
Phosphorus	0.094	0.090	0.090	ns	0.004	15.2
Potassium	1.55	1.57	1.57	ns	0.045	9.9
Calcium	0.41	0.45	0.46	**	0.015	11.7
Magnesium	0.048	0.050	0.052	ns	0.0016	11.2
Chlorine	0.60	0.79	0.93	***	0.044	19.8
	P0	P1	P2			
Nitrogen	0.27	0.27	0.27	ns	0.005	6.3
Phosphorus	0.082	0.093	0.098	**	0.004	15.2
Potassium	1.58	1.62	1.48	*	0.045	9.9
Calcium	0.44	0.42	0.44	ns	0.015	11.7
Magnesium	0.048	0.053	0.050	*	0.0016	11.2
Chlorine	0.76	0.79	0.76	ns	0.044	19.8
	K0	K1				
Nitrogen	0.27	0.27		ns	0.004	6.3
Phosphorus	0.091	0.091		ns	0.003	15.2
Potassium	1.51	1.61		*	0.036	9.9
Calcium	0.44	0.44		ns	0.012	11.7
Magnesium	0.049	0.051		ns	0.0013	11.2
Chlorine	0.70	0.85		***	0.036	19.8
	Mg0	Mg1				
Nitrogen	0.27	0.27		ns	0.004	6.3
Phosphorus	0.096	0.086		**	0.003	15.2
Potassium	1.60	1.53		ns	0.036	9.9
Calcium	0.45	0.42		*	0.012	11.7
Magnesium	0.047	0.054		***	0.0013	11.2
Chlorine	0.79	0.75		ns	0.036	19.8
	EFB0	EFB1				
Nitrogen	0.26	0.28		***	0.004	6.3
Phosphorus	0.083	0.010		***	0.003	15.2
Potassium	1.48	1.64		***	0.036	9.9
Calcium	0.43	0.44		ns	0.012	11.7
Magnesium	0.051	0.049		ns	0.0013	11.2
Chlorine	0.71	0.83		**	0.036	19.8

The effect of EFB on leaflet and rachis K is shown in Figure 1.7. Rachis K increases with application of EFB but leaflet K is static. EFB actually contains very little chlorine but always has this effect. Figures 1.8 and 1.9 show that leaflet and rachis Cl increases with an increase in applied Chlorine. Even though chlorine is not a separate treatment there are four levels of chlorine applied depending on the rate of ammonium chloride or MoP applied to each plot. Leaflet N levels on the other hand do not increase with applied N (Fig 1.10) showing that applied chlorine remains in the plot in which it is applied but that applied N appears to move from plot to plot or is lost through leaching at this site. Plot isolation trenching was completed in 1997 and may have an effect over time in minimising this movement of N.

Figure 1.7: Effect of EFB on Leaflet and Rachis K

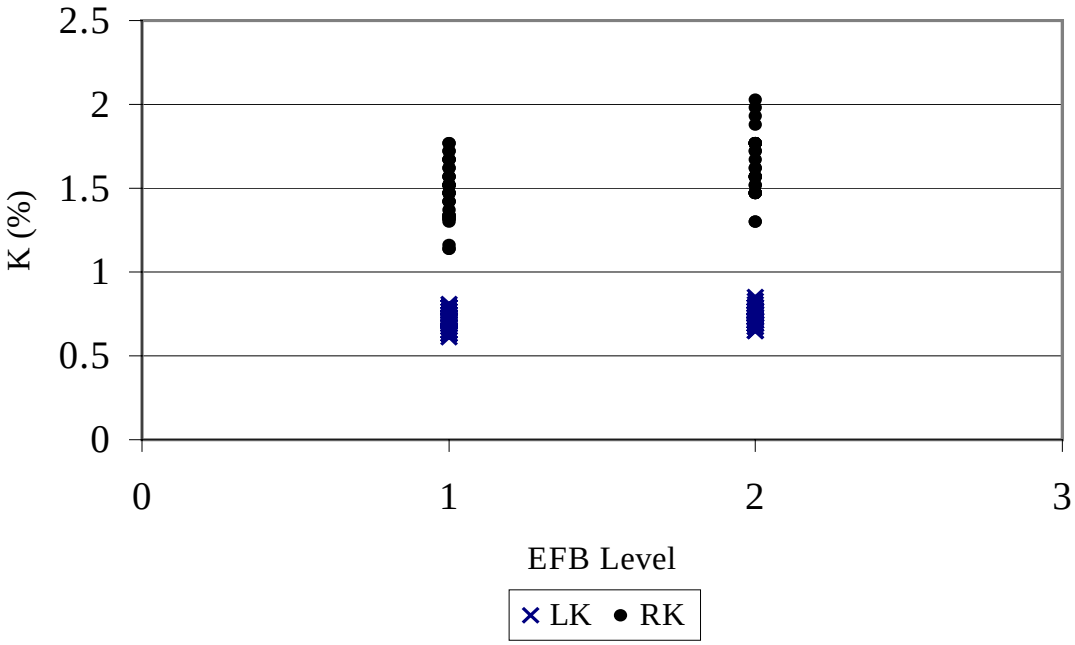


Figure 1.8: Rachis chlorine vs chlorine applied

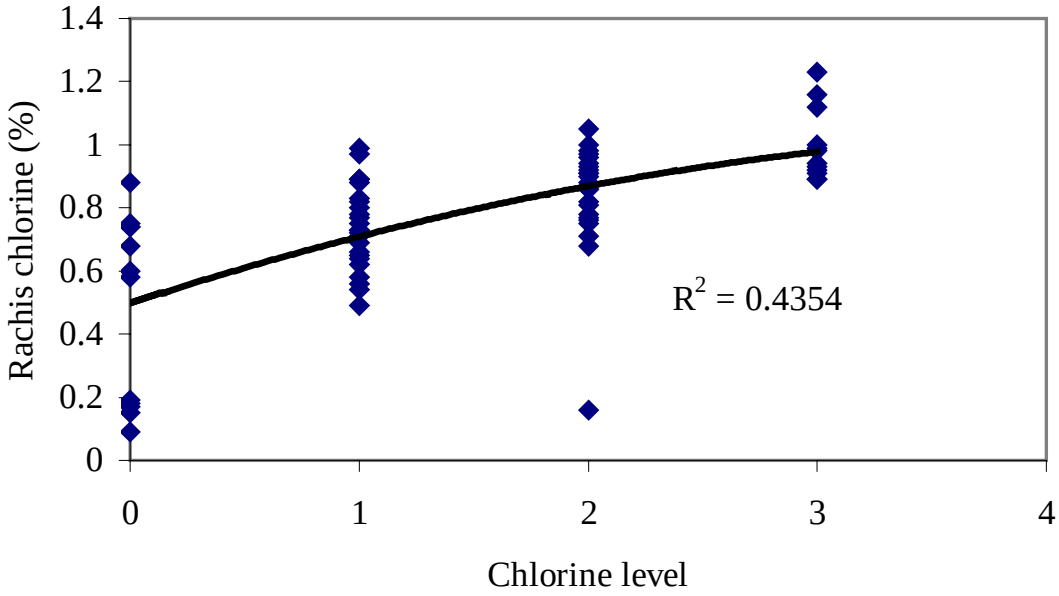


Figure 1.9: Leaflet chlorine vs chlorine applied

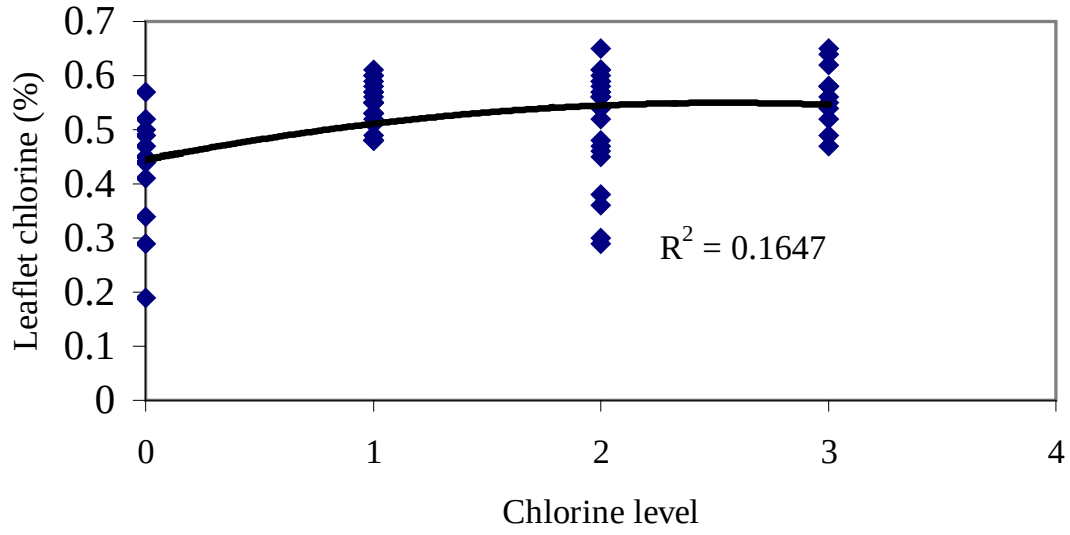
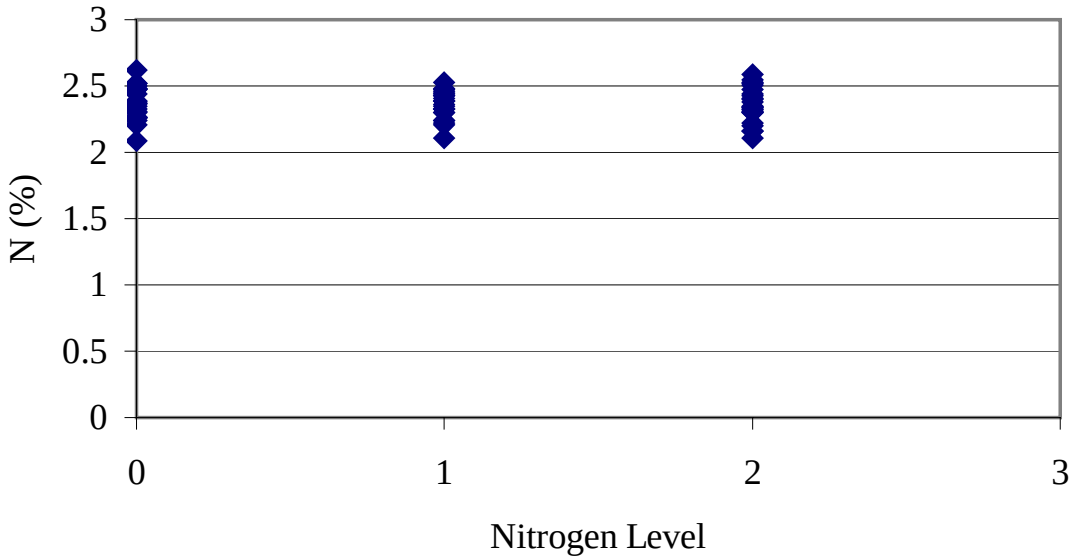


Figure 1.10: Leaflet Nitrogen



Bunch analysis was conducted in this trial in 1998. Bunches were taken from all plots and analysed in the bunch analysis laboratory at Kapiura. There were no significant effects of treatments on either Oil/Bunch (OB) or Kernel/Bunch (KB) (Table 1.86). Neither was there any correlation between leaflet and rachis chlorine, or leaflet and rachis potassium and OB or KB (Fig 1.11) even though bunch weights increase significantly with applied chlorine (Fig 1.12). The bunch analysis data does not show how this increase in bunch weight is produced. None of the bunch components showed any correlation with chlorine.

Table 1.86 Oil to Bunch and Kernel to Bunch in Trial 402 in 1998.

Component	Nutrient element and level			Statistics		
				sig	sed	cv%
	N0	N1	N2			
O/B (%)	25.6	25.0	24.9	ns	0.43	5.9
K/B (%)	5.6	5.7	6.0	ns	0.24	14.6
	P0	P1	P2			
O/B (%)	25.2	25.0	25.3	ns	0.43	5.9
K/B (%)	5.6	5.9	5.9	ns	0.24	14.6
	K0	K1				
O/B (%)	25.1	25.3		ns	0.35	5.9
K/B (%)	5.7	5.9		ns	0.20	14.6
	Mg0	Mg1				
O/B (%)	25.1	25.3		ns	0.35	5.9
K/B (%)	5.6	6.0		ns	0.20	14.6
	EFB0	EFB1				
O/B (%)	25.2	25.2		ns	0.35	5.9
K/B (%)	5.8	5.9		ns	0.20	14.6

Figure 1.11: Oil/Bunch and Leaflet Cl at 4 rates of Cl

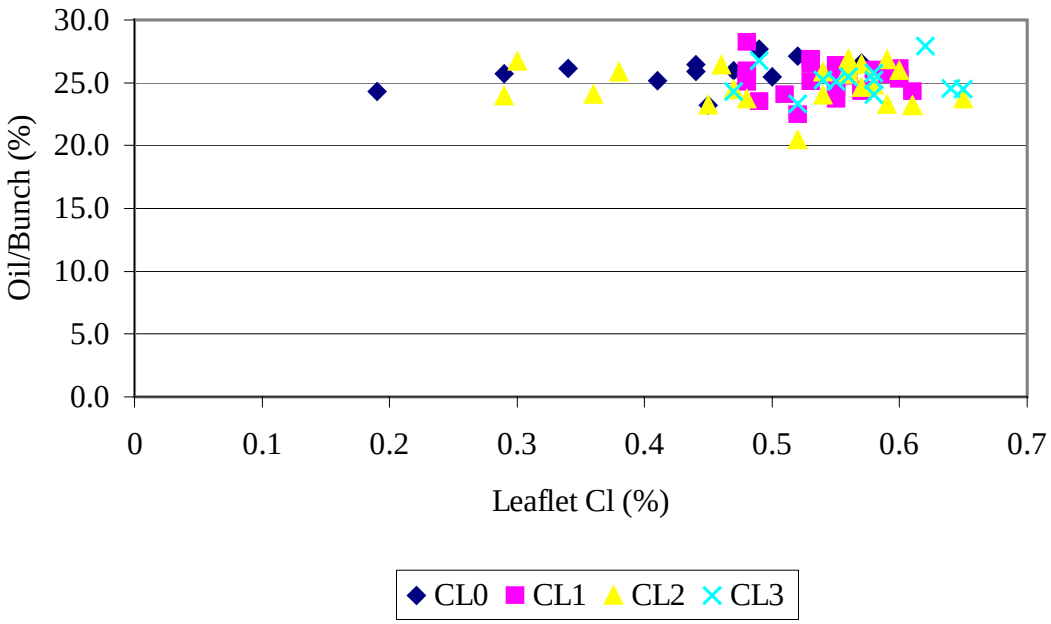
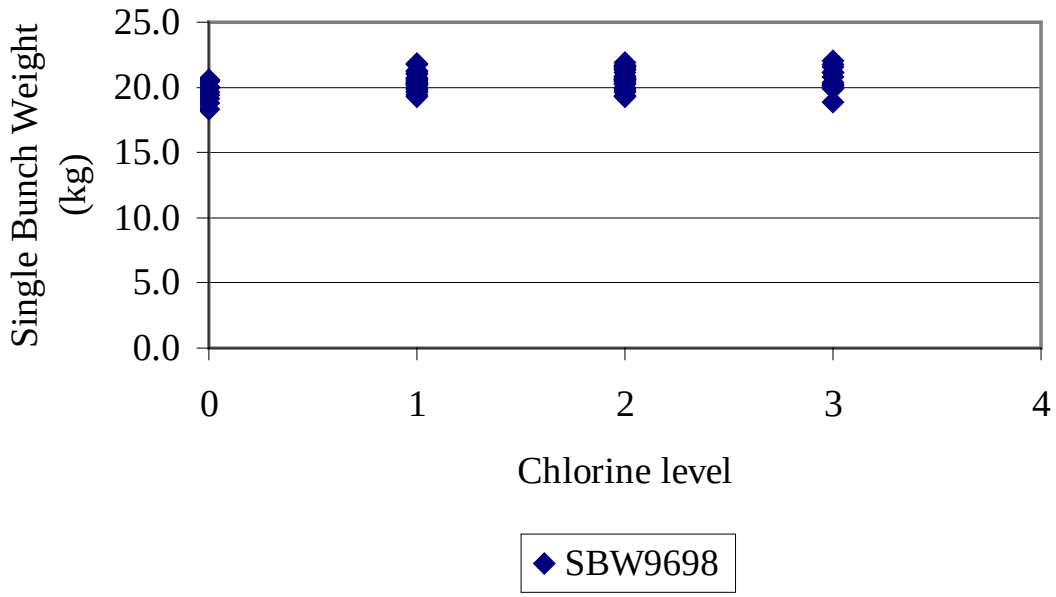


Figure 1.12: Effect of chlorine on single bunch weight (96-98)



2. MAINLAND REGION AGRONOMY

(M. Banabas)

AGRONOMY TRIALS

TRIAL 306 FERTILISER TRIAL AT AMBOGO ESTATE

PURPOSE

To test the response of oil palm to N, P, K and Mg in factorial combination on Ambogo and Penderetta soils.

DESCRIPTION

Site: Ambogo Estate, Block 79B.

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

Palms: Dami commercial DxP crosses planted in 1979 at 143 palms/ha. This trial started in 1982 and was closed at the end of 1998.

DESIGN

There are 81 plots each containing 16 core palms surrounded by at least one guard row, and a trench. The numbers and weights of bunches for individual core palms are recorded fortnightly.

The 81 plots are a single replicate containing 81 treatments, made up from all combinations of three levels of N, P, K and Mg (Table 2.1). The 81 treatments are divided into three blocks within the replicate, such that the effects of some high order interactions are confounded with block effects.

Table 2.1 Types and amount of fertiliser used in Trial 306.

		Amounts of fertiliser (kg/palm/year)		
Element	Type of fertiliser	Level 0	Level 1	Level 2
N	Sulphate of ammonia	0.0	3.0	6.0
P	Triple Superphosphate	0.0	0.5	1.0
K	Muriate of potash	0.0	2.5	5.0
Mg	Kieserite	0.0	0.75	1.5

Modifications: Until 1990 sulphate of ammonia rates were half those indicated.

RESULTS

Mean plot yield in 1998 was 17.6 t FFB/ha/yr, 26% lower than 1997 average crop (Table 2.2). The reduction in yield was mostly due to reduction in bunch numbers (Table 2.3). Reduction in both bunch numbers and FFB yield were more severe in N0 plots than in N fertilised plots (Tables 2.2 and 2.3).

Table 2.2 Mean Yield (t/ha/yr) at Different N levels in 1997 and 1998 (Trial 306).

N Rate	1997	1998	Difference	% Difference
N0	19.3	10.9	8.4	44
N1	25.4	20.9	4.5	18
N2	26.4	21.1	5.30	20
			Mean	26

Table 2.3 Mean Bunch Numbers/ha at Different N levels in 1997 and 1998 (Trial 306).

N Rate	1997	1998	Difference	% Difference
N0	833	541	292	35
N1	940	814	126	13
N2	962	803	159	17
			Mean	22

Yield and yield components results for 1998 and 1987-1998 are shown in Tables 2.4 and 2.6 respectively. Despite the reduction in overall yield, there has been a continued response ($p<0.001$) to sulphate of ammonia application in 1998 and between 1987-1998. The increase in yield was due to significant increases ($p<0.001$) in bunch numbers per hectare and single bunch weight. Sulphate of ammonia had strong linear and quadratic effects ($p<0.001$) on FFB yield and yield components in 1998 and 1987-1998.

Muriate of potash significantly increased single bunch weight ($p<0.001$) but this was not reflected in FFB yield because of corresponding declining bunch numbers. There were no responses to Triple-Superphosphate and Kieserite application.

The N and K treatment combinations are shown in Tables 2.5 and 2.7; the treatment interactions were statistically not significant. In 1998 because of a decrease in overall FFB yield, optimum combinations for maximum yield is not very clear but it does show that yields only increased with N levels (Table 2.5). For the period 1987 - 1998, a maximum yield of 24.7 t/ha was obtained with 6 kg of SoA alone but this was only a 2 tonne FFB increase from 3 kg SoA /palm/yr (Table 2.7).

The optimum fertiliser requirement appears to be at N1 (3kg SoA /palm/yr) (Figure 2.1).

The general FFB yield response pattern seen in 1998 is consistent and is similar for the mean cumulative yield data between 1987-1998. This suggests that N a major limiting nutrient in this particular environment. However responses are only seen up to N1 (3kg /palm/yr) after which another factor probably becomes limiting.

Table 2.4 Main effects of N, P, K, and Mg on yield and yield components in 1998 (Trial 306).

	Nutrient element And level			Statistics sig	cv%	sed
	N0	N1	N2			
Yield (t/ha/yr)	10.9	20.9	21.1	***	27.2	1.30
Bunches/ha	541	814	803	***	24.9	48.8
Bunch weight (kg)	19.7	25.6	26.1	***	7.6	0.49
	P0	P1	P2			
Yield (t/ha/yr)	17.4	17.4	18.1	ns	27.2	1.30
Bunches/ha	722	721	715	ns	24.9	48.8
Bunch weight (kg)	23.4	23.6	24.3	ns	7.6	0.49
	K0	K1	K2			
Yield (t/ha/yr)	17.8	17.2	17.9	ns	27.2	1.30
Bunches/ha	774	670	715	ns	24.9	48.8
Bunch weight (kg)	22.4	24.7	24.4	***	7.6	0.49
	Mg0	Mg1	Mg2			
Yield (t/ha/yr)	17.8	17.9	17.2	ns	27.2	1.30
Bunches/ha	738	726	694	ns	24.9	48.8
Bunch weight (kg)	23.5	23.9	24.0	ns	7.6	0.49

Table 2.5 The effects of N on yield at different levels of K in 1998 (Trial 306).

	Yield (t/ha/yr)		
	K0	K1	K2
N0	12.6	9.0	11.0
N1	19.5	20.5	22.6
N2	21.2	22.0	20.1
Grand mean	17.6	Standard error	4.78

Table 2.6 Main effects of N, P, K and Mg on yield and yield components in 1987-1998 (Trial 306).

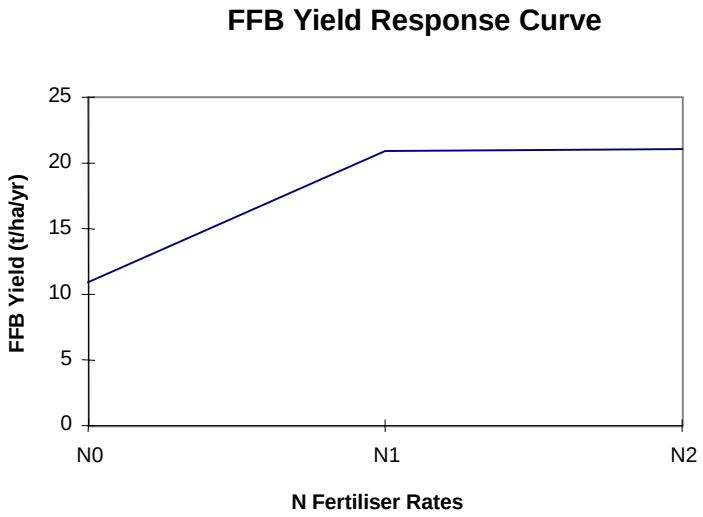
	Nutrient element and level			Statistics		
				sig	cv%	sed
	N0	N1	N2			
Yield (t/ha/yr)	15.1	23.2	23.8	***	15.6	0.89
Bunches/ha	833	940	962	***	13.2	29.3
Bunch weight (kg)	23.1	27.0	27.6	***	6.9	0.47
	P0	P1	P2			
Yield (t/ha/yr)	20.9	20.2	21.0	ns	15.6	0.89
Bunches/ha	828	808	811	ns	13.2	29.3
Bunch weight (kg)	24.7	24.6	25.3	ns	6.9	0.47
	K0	K1	K2			
Yield (t/ha/yr)	21.1	20.2	20.8	ns	15.6	0.89
Bunches/ha	873	771	803	*	13.2	29.3
Bunch weight (kg)	23.7	25.5	25.4	***	6.9	0.47
	Mg0	Mg1	Mg2			
Yield (t/ha/yr)	20.4	21.2	20.4	ns	15.6	0.89
Bunches/ha	819	830	798	ns	13.2	29.3
Bunch weight (kg)	24.5	25.0	25.1	ns	6.9	0.47

Table 2.7 Effects of N on yield at different levels of K in 1987-1998 (Trial 306).

	Yield (t/ha/yr)		
	K0	K1	K2
N0	16.4	14.0	15.0
N1	22.7	22.6	24.2
N2	24.7	20.0	20.8

Grand mean 20.7 Standard error 3.23

Figure 2.1 FFB Yield Response Curve at Different N Levels in 1998 (Trial 306).



Leaflets and rachis tissue analysis results for 1998 are shown in Tables 2.6 and 2.7 respectively.

Sulphate of ammonia application significantly ($p<0.001$) increased leaflet N and P concentrations (Table 2.8). The significant increase in concentrations of these 2 elements increased the N/P ratio from 14.1 to 15.7 but was lower than the assumed optimum of 16. The ratio was low because of a large increase in P concentration relative to N concentrations. It appears that N content and probably uptake is limited by some other factor.

Muriate of potash application significantly ($p<0.001$) reduced K and Mg concentrations while increasing Ca ($p=0.045$) and Cl ($p<0.001$). The Ca levels probably caused reduced K and Mg contents. The changes in leaflet levels due to muriate of potash were not translated to yield though it has been shown to increase single bunch weight.

Triple Superphosphate application did not change any of the nutrient levels in the leaflets.

Kieserite application increased magnesium levels ($p<0.001$) in the leaflets but only at level 2; this pattern was also seen last year. However the response to Kieserite is not reflected as a yield response.

Mean nutrient levels in the leaflets seem to have recovered from effects of drought to normal or expected levels in 1998 (Table 2.9). Nutrient contents were generally reduced to low levels in 1997 from 1995 but increased after the draught in 1998. Soil moisture is very important in nutrient movement from soil solutions to root surfaces for uptake and metabolic activities in plants.

Table 2.8 Main effects of N, P, K and Mg on the concentrations of elements in the leaflet tissue in 1998 (Trial 306).

Element	Level of nutrient			Statistics sig	cv%	sed
	N0	N1	N2			
N%	1.86	2.06	2.18	***	5.5	0.03
P%	0.132	0.136	0.139	***	4.0	0.001
K%	0.68	0.69	0.68	ns	6.6	0.01
Ca%	0.71	0.70	0.72	ns	10.3	0.02
Mg%	0.25	0.24	0.24	ns	11.3	0.007
Cl%	0.39	0.40	0.39	ns	20.7	0.02
S%	0.11	0.12	0.12	ns	9.3	0.003
	P0	P1	P2			
N%	2.03	2.02	2.05	ns	5.5	0.03
P%	0.135	0.136	0.135	ns	4.0	0.001
K%	0.69	0.68	0.68	ns	6.6	0.01
Ca%	0.71	0.72	0.69	ns	10.3	0.02
Mg%	0.23	0.25	0.23	ns	11.3	0.007
Cl%	0.40	0.39	0.39	ns	20.7	0.02
S%	0.11	0.11	0.12	ns	9.3	0.003
	K0	K1	K2			
N%	2.04	2.02	2.04	ns	5.5	0.03
P%	0.135	0.135	0.136	ns	4.0	0.001
K%	0.72	0.66	0.68	***	6.6	0.01
Ca%	0.67	0.73	0.72	*	10.3	0.02
Mg%	0.26	0.24	0.23	***	11.3	0.007
Cl%	0.21	0.48	0.49	***	20.7	0.02
S%	0.12	0.12	0.11	ns	9.3	0.003
	Mg0	Mg1	Mg2			
N%	2.00	2.04	2.07	ns	5.5	0.03
P%	0.135	0.135	0.136	ns	4.0	0.001
K%	0.69	0.69	0.68	ns	6.6	0.01
Ca%	0.70	0.71	0.71	ns	10.3	0.02
Mg%	0.23	0.23	0.26	***	11.3	0.007
Cl%	0.37	0.42	0.39	ns	20.7	0.02
S%	0.11	0.12	0.12	ns	9.3	0.003

Table 2.9 Mean Leaflet Nutrient Concentrations 1995 – 1998 (Trial 306).

Leaflet Nutrient (%)	Year		
	1995	**1997**	**1998**
N	2.12	1.99	2.04
P	0.140	0.120	0.136
K	0.85	0.73	0.69
Ca	0.62	0.62	0.71
Mg	0.21	0.19	0.24
Cl	0.39	0.35	0.39
S			0.12

In the rachis, SoA significantly increased N concentration ($p<0.001$) while reducing P ($p<0.001$), K ($p=0.036$) and Mg ($p<0.001$) concentrations (Table 2.10). Triple Superphosphate increased P concentration ($p<0.001$) though this was not seen in the leaflets; suggesting P uptake is independent

from N influence but its movement from the vacuoles into the leaflets for metabolic activities is affected by N levels. Decreasing P concentrations in the rachis due to increasing N concentrations also supports this point that increased metabolic activities in the leaves draw P (and Mg) from the rachis thus reducing the levels in the rachis. Muriate of potash application significantly ($p<0.001$) increased P, K, Ca and Cl concentrations. The increased nutrient contents did not affect FFB yield but it did increased single bunch weight. Kieserite application increased Mg concentrations ($p=0.021$) the levels do not appear to be large.

Table 2.10 Main effects of N, P, K and Mg on the concentrations of elements in the rachis in 1998 (Trial 306).

	Level of nutrient			Statistics		
Element				sig	cv%	sed
	N0	N1	N2			
N%	0.23	0.26	0.29	***	9.8	0.007
P%	0.297	0.184	0.118	***	21.7	0.012
K%	1.67	1.59	1.57	*	9.0	0.04
Ca%	0.29	0.31	0.31	ns	13.5	0.01
Mg%	0.09	0.08	0.07	***	16.0	0.004
Cl%	0.77	0.76	0.72	ns	22.1	0.04
S%	0.04	0.04	0.04	ns	23.1	0.002
	P0	P1	P2			
N%	0.26	0.27	0.26	ns	9.8	0.007
P%	0.174	0.201	0.224	***	21.7	0.012
K%	1.63	1.61	1.58	ns	9.0	0.04
Ca%	0.30	0.32	0.30	ns	13.5	0.01
Mg%	0.08	0.08	0.08	ns	22.0	0.004
Cl%	0.76	0.72	0.76	ns	25.7	0.05
S%	0.04	0.04	0.04	ns	23.1	0.002
	K0	K1	K2			
N%	0.26	0.26	0.26	ns	9.8	0.007
P%	0.169	0.203	0.227	***	21.7	0.012
K%	1.32	1.68	1.83	***	9.0	0.04
Ca%	0.27	0.33	0.33	***	13.5	0.01
Mg%	0.08	0.09	0.08	*	22.0	0.004
Cl%	0.24	0.94	1.06	***	25.7	0.05
S%	0.04	0.04	0.04	ns	23.1	0.002
	Mg0	Mg1	Mg2			
N%	0.26	0.26	0.27	ns	9.8	0.007
P%	0.200	0.196	0.203	ns	21.7	0.012
K%	1.62	1.60	1.61	ns	9.0	0.04
Ca%	0.31	0.31	0.31	ns	13.5	0.01
Mg%	0.08	0.08	0.09	*	22.0	0.004
Cl%	0.70	0.79	0.76	ns	25.7	0.05
S%	0.04	0.04	0.04	ns	23.1	0.002

Vegetative measurements were carried out in May 1998 while leaflet samples were taken for leaf nutrient analysis. The vegetative measurements and estimated physiological growth parameters are shown in Table 2.11.

Sulphate of ammonia significantly increased all estimated vegetative parameters ($p<0.001$). VDM increased in a linear fashion (linear $p<0.001$) while BDM increased curvilinearly ($p<0.001$). The strong quadratic effect on BDM suggests a limiting factor to BDM production while VDM is not being limited by some other factor. A possible limiting factor to BDM is high LAI due to the high planting density at this site (143 points /ha). Though fractional energy interception and energy conversion have been significantly improved ($p<0.001$) by N fertiliser, a greater proportion of photosynthates seem to have been diverted to vegetative production for inter-palm competition for light. This is partly shown by the low BI figures of less than 0.500 (mean of 0.398). Another reason could have been the overall reduction in FFB yield due to the long dry season in 1997.

TSP and MoP did not affect any of the vegetative growth parameters but Kieserite significantly ($p=0.002$) increased LAI and FEI. Effects of Kieserite were mostly due to significant increases in frond area ($p=0.025$).

Table 2.11 Trial 306 Physiological Growth Parameters, 1998.

	FW kg	FDM (t/ha/yr)	VDM (t/ha/yr)	BDM (t/ha/yr)	TDM (t/ha/yr)	BI	LAI	FEI	Con.eff
N0	**4.40**	**15.1**	**17.8**	**8.9**	**26.7**	**0.319**	**5.59**	**0.862**	**0.98**
N1	**5.04**	**17.3**	**21.1**	**17.1**	**38.2**	**0.445**	**6.33**	**0.893**	**1.37**
N2	**5.53**	**19.0**	**23.1**	**17.7**	**40.7**	**0.430**	**6.49**	**0.900**	**1.45**
	***	***	***	***	***	***	***	***	***
P0	4.87	16.7	20.1	14.2	34.4	0.400	6.01	0.881	1.24
P1	4.94	17.0	20.5	14.6	35.1	0.405	6.02	0.879	1.28
P2	5.16	17.7	21.3	14.9	36.2	0.390	6.38	0.895	1.29
	ns	ns	ns	ns	ns	ns	ns	ns	ns
K0	4.83	16.6	20.0	14.6	34.6	0.405	6.17	0.887	1.25
K1	5.05	17.3	20.8	14.1	34.9	0.385	6.29	0.891	1.25
K2	5.09	17.5	21.1	15.1	36.2	0.404	5.95	0.878	1.32
	ns	ns	ns	ns	ns	ns	ns	ns	ns
Mg0	4.86	16.7	20.2	14.6	34.8	0.401	**5.84**	**0.873**	1.27
Mg1	5.18	17.8	21.4	14.7	36.0	0.394	**6.31**	**0.892**	1.29
Mg2	4.92	16.9	20.4	14.5	34.8	0.400	**6.26**	**0.890**	1.25
	ns	ns	ns	ns	ns	ns	*	*	ns
GM	4.99	17.1	20.6	14.6	35.2	0.398	6.14	0.885	1.27
SED	0.184	0.63	0.745	1.03	1.51	0.0177	0.177	0.0128	0.054
cv %	13.6	13.6	13.3	26.1	15.8	16.4	10.6	2.9	15.7

Bunch analysis was carried out over a 2-month period from selected plots to investigate the effects of N and K fertilisers on oil palm bunch components. From each of the plots, 30 bunches were used for the analysis. The bunch analysis results are shown in Table 2.12.

Nitrogen fertiliser appears to increase all of the bunch components ratios whilst depressing kernel/fruit, kernel/bunch and Fruit/bunch ratios. Oil/bunch ratio was generally high even in the N0 plot but oil/ha increased with N rates because of FFB yield response. FFB yield per ha appears to be the major factor determining the overall oil produced per ha. K fertiliser does not appear to have any significant effect on the bunch components and as a result exhibits no effect on oil produced per ha.

Table 2.12 Trial 306 Bunch Analysis Results - 1998

Treatments	BNO	Frt/Bunch	WM/Frt	DM/Frt	Oil/WM	K/Frt	K/Bunch	Oil/Bunch	Yield t/ha	Oil/ha
N0	30	66.2	77.13	50.48	52.9	32.26	21.46	26.81	10.9	2.9
N1	30	64.22	77.4	55.82	59.13	30.14	19.4	29.59	20.9	6.2
N2	30	62.89	80.22	54.19	54.89	28.1	17.91	27.42	21.1	5.8
K0	30	66.2	77.13	50.48	52.9	32.26	21.46	26.81	17.8	4.8
K1	30	69.34	79.34	51.68	52.04	37.02	25.72	28.71	17.2	4.9
K2	30	64.7	79.21	50.63	51	34.39	22.27	26.05	17.9	4.7
GM		65.47	78.66	52.56	53.99	32.38	21.35	27.72	17.6	4.9
Min		41.31	59.84	38.36	32.39	13.11	7.33	16.36		
Max		97.28	107.2	85.4	86.53	67.39	44.31	50.08		
SEM		0.66	0.69	0.64	0.67	0.68	0.53	0.49		
cv%		12.4	10.8	14.9	15.2	25.7	30.4	21.8		

Soils samples were taken from selected plots in December 1998 just after the trial was closed to investigate the effects of fertilisers on soil chemical properties. From each plot, the samples were taken from 5 points and at 4 depths, 0 - 10, 10 - 20, 20 - 30 and 30 - 60 cm. The samples were then air-dried and a sub-sample was sent to DAL (NARI) Lab for analysis. Analysed results are presented in Table 2.13.

In all the plots the soil pH in water was reduced at 0 - 10 cm depth to values less than 5.3. With an increase in N fertiliser application rates, the pH dropped further to less than 5.0 (4.2 - 4.8). Also with increasing N fertiliser rates, pH at depths down to 30 cm was reduced. The lowered pH values are also reported from soil samples taken from the estates prior to replanting. Similar effects are seen in the pH in 1M KCl solution.

P in TSP fertilised plots has accumulated, mostly at 0 - 10 cm depth. At greater depths, P values are higher than non-fertilised plots probably due to P being leached/moved in particulate forms or in soluble organic matter and accumulated at depths.

C and N have accumulated in N fertilised plots at 0 - 10 cm depth. Fe levels in the soils have greatly increased as a result of application of N fertilisers; down to 30 cm depth this is closely related to the pH change discussed above.

Table 2.13 Soils Results From Selected Plots - December 1998 (Trial 306).

Treatments	Depth	pH	P	Ca	Mg	K	Na	CEC	C	N	Fe	Mn	Zn	Cu	Sand	Silt	Clay	PRET	Al	pH in KCl
NPKMg	cm		mg/Kg	me%	me%	me%	me%	me%	%	%	ppm	ppm	ppm	ppm	%	%	%	%	me%	
OOOO	0-10	5.3	12.4	4.2	0.94	0.24	0.04	9.6	0.81	0.08	63	51	1	1	72	14	14	15	0.7	4.2
	10-20	6.7	1.9	6.6	4.15	0.04	0.09	11.8	0.51	0.03	24	8	1	1	55	26	18	7	0	5.1
	20-30	6.5	1.5	11	5.57	0.07	0.12	17.6	1.06	0.09	33	21	1	2	39	35	27	9	0	5
	30-60	6.4	3.8	2.6	1.64	0.03	0.05	6	0.1	0.01	17	4	1	1	90	2	8	6	0	5.3
1000	0-10	5.1	8.9	10.7	2.59	0.44	0.1	22.1	2.96	0.23	181	21	1	1	37	33	30	24	0.9	4.1
	10-20	5.7	4.8	11.7	3.92	0.15	0.13	18.9	1.44	0.12	100	18	1	2	44	24	32	14	0	4.5
	20-30	6.2	2.7	8.1	3.6	0.08	0.12	13.9	0.65	0.04	38	11	1	1	59	18	22	5	0	4.9
	30-60	6.3	3	3.5	1.46	0.05	0.06	6.4	0.22	0.02	21	5	1	1	84	6	10	2	0	5
2201	0-10	4.2	50.8	5.5	1.23	0.05	0.1	18.7	2.18	0.18	201	14	1	1	40	33	28	28	5	3.6
	10-20	5.7	8.4	10.1	3.11	0.03	0.15	14.5	0.94	0.09	81	13	1	1	54	22	24	15	0	4.6
	20-30	6.3	5.3	6	2.36	0.02	0.1	8.5	0.27	0.03	29	5	1	1	75	10	15	6	0	5.2
	30-60	6.3	4	3.2	1.35	0.02	0.05	5	0.08	0.01	15	3	1	1	93	4	3	1	0	5.3
1111	0-10	4.8	30.8	1.4	0.35	0.22	0.04	11.9	2.54	0.22	178	6	1	1	78	8	14	23	2.6	3.9
	10-20	5.2	7.9	2.9	0.43	0.31	0.04	9.3	1.72	0.13	111	5	1	1	72	16	12	20	1.5	4.3
	20-30	5.9	2.9	2.7	0.49	0.33	0.04	5.7	0.65	0.04	32	5	1	1	88	6	6	6	0	4.9
	30-60	6.3	0.2	2.9	0.59	0.12	0.04	5.5	0.07	0.02	15	5	1	1	90	4	6	1	0	5.4
2222	0-10	4.8	50.5	2.3	0.63	0.33	0.05	12.2	2.07	0.16	167	37	1	1	69	14	16	19	2.4	3.8
	10-20	5.9	5.1	11.6	4.38	0.15	0.09	19.7	2.96	0.2	96	24	1	1	26	47	27	12	0	4.9
	20-30	5.8	8.5	3.6	0.79	0.24	0.04	6.9	0.42	0.03	31	30	1	1	80	10	10	6	0	4.5
	30-60	6.3	8.4	3.8	1.17	0.11	0.04	6.5	0.11	0.02	35	24	1	7	84	6	10	6	0	4.9

TRIAL 309 POTASSIUM, CHLORINE AND SULPHUR TRIAL AT AMBOGO ESTATE

PURPOSE

To investigate the response of oil palm to potassium, chlorine and sulphur fertiliser applications.

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 is present due to seasonally high water tables.

Palms: Dami commercial DxP crosses planted in 1980 at 143 palms per hectare. The trial started in June 1990.

DESIGN

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

The 25 plots are divided into five replicate blocks each containing five treatments (Table 2.14). 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 been paid down as part of a latin square design.

The treatments are combinations of fertilisers, one of which is bunch ash (BA). The right hand part of Table 2.14 shows the amount of each element that is applied to each treatment. The effects of an element are found by comparing the yields from two treatments; for example the effect of chlorine is found by comparing the yields from treatment 4 and 5.

The treatments that were used from January 1988 to June 1990 were similar, 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 2.14 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	SoA	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

RESULT

Yield data comparisons on the effects of N, S, K and Cl for 1998 and 1991-1998, are summarised in Table 2.15. In 1998 there was on average 20% yield decline from 1997 yield due to the effect of the long dry season in 1997 (Table 2.17).

Despite the overall yield decline, fertiliser treatment effects on FFB yield and yield components were significantly different both in 1998 and 1991 - 1998 (Table 2.15).

Separations of effects for different elements and their combinations on FFB yield over the 8 years are presented in Table 2.16. Treatments 2, 3, 5 and 4 are significantly different to treatment 1. However treatment 4 is not different from treatments 5 and 3 but is different from treatment 2.

SoA (effect of N and S) produced a yield difference of 10.8 tonnes/ha/yr while AmC (effect of N and Cl) produced a yield difference of 7.5 tonnes FFB. It appears N is important for high FFB yields in this particular soil type but only when applied with S. The effect of K and Cl either applied together or separately (excluding N and S) produced very low yield differences of less than 2.7 tonnes FFB compared to the control.

A comparison of N source indicates sulphate of ammonia (NS) is better than ammonium chloride (NCl) by a difference of 3 tonnes though statistically the difference was not significant (Table 2.15 and 2.17).

Table 2.15 Effects of N, S, K, and Cl in different combinations on yield and yield components in 1998 and 1991-98 (Trial 309).

Treatment	1998			1991-1998		
	Yield (t/ha/yr)	Bunches (No/ha)	Bunch wt (kg)	Yield (t/ha/yr)	Bunches (No/ha)	Bunch wt (kg)
4 N S K Cl	15.3	735	20.8	18.8	866	21.6
5 N S K	12.2	596	20.5	16.1	770	20.9
3 N S	17.3	844	20.3	18.3	884	20.6
2 N Cl	14.3	782	18.1	15.0	798	18.7
1 Nil	6.3	452	13.6	7.5	522	14.1
Grand Mean	13.1	682	18.7	15.1	768	19.2
Sig	**	**	***	***	***	***
Sed	2.27	86	1.09	1.69	67	0.714
cv%	27.4	19.9	9.2	17.6	13.9	5.9

Table 2.16 Mean FFB yield for 1991-1998, and difference in yield for selected comparisons (Trial 309).

	Mean Yield 91 – 98		Selected comparisons		
Treatment	Treatment Mean Sep	Yield (t/ha/yr)	comparison	Difference (t/ha/yr)	sig.
4 N S K Cl	a	18.8	4-2 (effect of K and S)	3.8	*
5 N S K	ab	16.1	3-2 (substituting S for Cl)	3.3	ns
3 N S	ab	18.3	4-3 (effect of K and Cl)	0.5	ns
2 N Cl	b	15.0	4-5 (effect of Cl)	2.7	ns
1 Nil	c	7.5	5-3 (effect of K)	-2.2	ns
			3-1 (effect of N and S)	10.8	**
			2-1 (effect of N and Cl)	7.5	**
	cv%: 17.6 sed=1.69 lsd (2.5%) = 3.68				

Table 2.17 Effects of N, S, K, and Cl, in different combinations on yield trends in 1991-1998 (Trial 309).

	Yield (t/ha/yr)							
	1991	1992	1993	1994	1995	1996	1997	1998
Treatment	11	12	13	14	15	16	17	18
4 N S K Cl	31.3	32.5	28.4	27.7	18.6	18.7	21.2	15.4
5 N S K	28.6	30.9	28.7	26.4	19.7	14.7	19.4	12.2
3 N S	28.5	27.8	25.2	24.2	18.6	15.1	18.7	17.3
2 N Cl	24.5	21.7	19.4	18.7	14.4	13.8	14.5	14.3
1 Nil	16.4	13.6	9.8	7.1	6.4	7.6	8.3	6.3
Sig.	**	***	***	***	***	ns	***	**
cv%	17.1	20.1	19.1	9.4	26.3	30.4	11.1	27.4

Leaflets and rachis nutrient analysis results in 1998 are presented in Tables 2.18 and 2.19 respectively. The treatments had significant effects on P, K, Ca and Cl levels both in the leaflets and rachis.

In the leaflets, fertilised plots maintained high P levels while Cl application increased Cl and Ca concentrations. A K component in the applied fertiliser increased K concentrations but only in the absence of Cl.

In the rachis, K (5) maintained high K concentrations while Cl (2 and 5) maintained both Ca and Cl at high levels.

N the major limiting nutrient in this particular soil failed to produce an increase in N concentration in both the leaflets and rachis tissue. The N concentration in the leaflet tissue was below 2.00%.

Table 2.18 Effect of N, S, K and Cl in different combinations, on the concentration of elements in leaf tissue of frond 17 in 1998 (Trial 309).

		Concentrations of elements (% of dry matter)						
Treatment		N	P	K	Ca	Mg	Cl	S
4	N S K Cl	1.78	0.129	0.64	0.77	0.26	0.44	0.13
5	N S K	1.89	0.129	0.69	0.69	0.26	0.34	0.15
3	N S	1.92	0.133	0.73	0.61	0.25	0.23	0.16
2	N Cl	1.97	0.136	0.64	0.71	0.26	0.41	0.14
1	Nil	1.78	0.123	0.62	0.69	0.30	0.31	0.14
	Grand Mean	1.87	0.130	0.66	0.69	0.27	0.35	0.15
	sig.	ns	**	**	**	ns	*	ns
	cv%	5.7	3.1	5.0	6.8	15.0	26.0	8.9
	sed	0.07	0.003	0.02	0.03	0.03	0.06	0.008

Table 2.19 Effect of N, S, K, and Cl in different combinations on the concentration of elements in the rachis of frond 17 in 1997 (Trial 309).

		Concentrations of elements (% of dry matter)						
Treatment		N	P	K	Ca	Mg	Cl	S
4	N S K Cl	0.25	0.163	1.99	0.40	0.09	1.26	0.06
5	N S K	0.23	0.197	1.87	0.30	0.07	0.48	0.06
3	N S	0.27	0.108	1.35	0.31	0.08	0.38	0.07
2	N Cl	0.23	0.160	1.39	0.34	0.10	0.98	0.06
1	Nil	0.21	0.174	1.34	0.27	0.10	0.54	0.05
	Grand Mean	0.24	0.161	1.59	0.32	0.09	0.73	0.06
	Sig	(ns)	*	***	***	(ns)	*	ns
	Cv%	12.1	21.7	7.6	10.8	20.3	53.1	18.6
	Sed	0.02	0.019	0.07	0.02	0.01	0.24	0.007

Physiological growth parameters were estimated from vegetative measurements carried out in June 1998 while leaf sampling was carried out for leaf tissue analysis. The results are presented in Table 2.20.

Fertiliser treatments had significant effects on all the growth parameters estimated. For FW, FDM and VDM, treatments 4, 5 and 3 were significantly different from treatments 2 and 1, however treatment 2 was also different from 1. VDM production (estimated from FW and FDM) was high in plots receiving N but increased further with the addition of S. Inclusion of Cl and K to N and S either together or separately did not affect VDM production.

For BDM, TDM, LAI, FEI and Con eff, treatments 2, 3, 5 and 4 were significantly different from treatment 1. N appears to be the major limiting nutrient element which is affecting the differences in the DM production. The effect of drought in 1997 causing an overall yield decline seems to have an overriding effect on S, K and Cl and therefore their individual effects cannot be separated. BI values are low and less than 0.500 indicating high production of VDM relative to BDM. A major

contributing factor to the overall yield decline both in 1998 and probably also the overall yield decline since 1993/1994.

Table 2.20 Effect of N, S, K, and Cl in different combinations on physiological growth parameters in 1998 (Trial 309).

		Physiological Growth Parameters								
Treatment		FW kg	FDM	VDM t/ha/yr	BDM	TDM	BI	LAI	FEI	Con eff
4	N S K Cl	3.50	12.0	14.7	12.6	27.3	0.459	5.47	0.855	1.02
5	N S K3.56	12.2	14.7	10.0	24.7	0.402	4.72	0.802	1.00	
3	N S	3.45	11.8	14.7	14.2	28.9	0.484	5.19	0.843	1.10
2	N Cl	2.89	9.9	12.3	11.7	24.0	0.485	4.53	0.802	0.96
1	Nil	2.09	7.2	8.5	5.2	13.7	0.364	3.59	0.714	0.61
	Grand Mean	3.10	10.6	13.0	10.7	23.7	0.439	4.70	0.803	0.94
	Sig	***	***	***	**	***	**	*	*	**
	Cv%	7.8	7.8	8.9	27.4	16.6	11.5	16.8	7.1	15.6
	Sed	0.15	0.52	0.74	1.86	2.49	0.032	0.50	0.036	0.09
	Lsd	0.33	1.14	1.60	4.05	5.43	0.0699	1.09	0.0786	0.201

Bunch analysis in Trial 309 was carried out over a period of 2 months from selected plots. From each plot 30 bunches were analysed, except for nil fertiliser plot in which only 8 bunches were used because of low number of bunches produced during the period. The bunch analysis results are shown in Table 2.21.

Fertiliser combinations appear to reduce fruit/bunch, WM/fruit, DM/fruit and oil/bunch while increasing kernel/fruit and kernel/bunch ratios. Effects of individual elements do not appear to be clear but it appears the N and S combination produces high oil per ha which is mostly due to high FFB yields.

Table 2.21 Trial 309 1998 Bunch Analysis Results, 1998.

Treatments	BNO	Frt/Bunch	WM/Frt	DM/Frt	Oil/WM	K/Frt	K/Bunch	Oil/Bunch	Yield t/ha	Oil/ha
N S K Cl	30	64.34	73.46	41.92	44.52	41.48	26.59	20.52	15.3	3.1
N S K	30	61.82	76.85	47.43	48.89	40.09	24.79	22.99	12.2	2.8
N S	30	65.87	68.8	40.31	45.81	36.44	24.12	20.54	17.3	3.6
N Cl	30	65.08	73.8	41.08	43.51	52.11	34.00	20.46	14.3	2.9
Nil	8	65.94	79.20	46.63	49.83	34.43	22.50	25.96	6.3	1.6
GM		64.38	73.6	43.12	45.94	42.02	27.07	21.43	13.1	2.8
Min		34.66	56.21	24.77	14.11	21.03	13.83	10.8		
Max		83.82	115.47	57.02	63.73	70.94	47.24	33.44		
SEM		0.64	0.8	0.62	0.8	0.93	0.67	0.38		
cv%		11.27	12.3	16.28	19.72	24.94	28.12	19.79		

TRIAL 310 POTASSIUM, CHLORINE AND SULPHUR TRIAL AT AMBOGO ESTATE

PURPOSE

To test the response to potassium, chlorine and sulphur

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 recorded core palms. The numbers and weights of bunches for each individual core palms are recorded at intervals of 14 days. In each plot at least one guard row and a trench surround the core palms.

The 35 plots are divided into five replicate blocks each containing seven treatments that are randomised (Table 2.22). The treatments are a combination of fertilisers. The lower half of the Table 2.22 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 2.22 Amount of each type of fertiliser, and each element, used for each treatment in Trial 310.

	Treatment number (kg of fertiliser/palm/year)						
Type of Fertiliser	1	2	3	4	5	6	7
Urea	1.8	-	-	-	-	-	-
Sulphate of ammonia	-	4.0	-	4.0	-	4.0	2.0
Ammonium chloride	-	-	3.2	-	3.2	-	1.6
Bunch ash	-	-	-	4.4	4.4	-	-
Muriate of potash	-	-	-	-	-	2.2	-
Element	(kg of element/palm/year)						
N	0.81	0.84	0.80	0.84	0.80	0.84	0.82
K	-	-	-	1.1	1.1	1.04	-
S	-	0.96	-	0.96	-	0.96	0.48
Cl	-	-	2.1	-	2.1	1.1	1.1

RESULT

Yield results for 1998 are presented in Table 2.23. The effect of an element is found by comparing two treatment combinations. However, in 1998 there were no significant differences between the treatment means and therefore comparisons will not be valid. Treatment effects were generally insignificant since 1991 (Tables 2.23 and 2.24).

There were no significant differences between treatments for mean bunch numbers (Table2.24) but there were differences in single bunch weights ($p<0.001$) (Table 2.25). Although there were differences in single bunch weights, FFB yields were not affected because of declining bunch numbers.

Table 2.23 The effects of K, Cl and S on yield in 1998 (Trial 310).

Treatment No.	Elements Supplied	Elements missing	Yield (t/ha/yr)	Differences from Treatment No. 6 t/ha/yr	%
6	N, K, Cl, S	None	29.6	0.0	0.0
4	N, K, S	Cl	27.4	-2.2	-7.0
7	N, Cl, SK	29.5	-0.1	0.0	
5	N, K, Cl	S	26.3	-3.3	-11.0
2	N, S	K, Cl	26.0	-3.0	-10.0
3	N, Cl	K, S	26.8	-2.8	-9.0
1	N (Urea)	K, Cl, S27.0	-2.6	-9.0	
		Grand mean	27.5		
		sig	ns		
		cv%	12.6		
		sed	2.19		

Table 2.24 The effects of K, Cl and S on bunch numbers in 1998 (Trial 310).

Treatment No.	Elements Supplied	Elements missing	Bunches (No/ha/yr)	Differences from Treatment No. 6 No/ha/yr	%
6	N, K, Cl, S	None	1162	0	0.0
4	N, K, S	Cl	1128	-34	-3.0
7	N, Cl, SK	1139	-23	-2.0	
5	N, K, Cl	S	1019	-143	-12.0
2	N, S	K, Cl	1087	-75	-6.0
3	N, Cl	K, S	1037	-125	-11.0
1	N (Urea)	K, Cl, S1201	+39	+3.0	
		Grand mean	1110		
		sig	ns		
		cv%	13.8		
		sed	96.6		

Table 2.25 The effects of K, Cl, and S on single bunch weights in 1998 (Trial 310).

Treatment No.	Elements Supplied	Elements missing	Single bunch weight (kg)	Differences from Treatment No. 6 wt (kg)	%
6	N, K, Cl, S	None	25.7	0.0	0.0
4	N, K, S	Cl	24.3	-1.4	-5.0
7	N, Cl, SK		25.9	+0.2	+1.0
5	N, K, Cl	S	25.9	+0.2	+1.0
2	N, S	K, Cl	24.0	-1.7	-7.0
3	N, Cl	K, S	25.8	+0.1	0.0
1	N (Urea)	K, Cl, S	22.6	-3.1	-12
		Grand mean	24.9		
		Sig	***		
		Cv%	4.5		
		Sed	0.71		

Table 2.26 The effect of K, Cl and S on yield for the period 1991-1998 (Trial 310).

Treatment No.	Elements Supplied	Elements Missing	Yield (t/ha/yr)	Differences from Treatment No. 6 t/ha/yr	%
6	N, K, Cl, S	None	28.3	0.0	0.0
4	N, K, S	Cl	26.6	-1.7	-6.0
7	N, Cl, SK		28.7	+0.4	+1.0
5	N, K, Cl	S	27.6	-0.7	-2.0
2	N, S	K, Cl	25.3	-3.0	-11
3	N, Cl	K, S	28.0	-0.3	-1.0
1	N (Urea)	K, Cl, S	26.4	-1.9	-7.0
		Grand mean	27.3		
		Sig	ns		
		Cv%	8.1		
		Sed	1.39		

Table 2.27 The effects of N, S, K, and Cl in different combinations FFB yield from 1991 to 1998 (Trial 310).

	Yield (t/ha/yr)							
Treatment	1991	1992	1993	1994	1995	1996	1997	1998
	11	12	13	14	15	16	17	18
6 N S K Cl	26.7	34.0	29.9	26.9	25.7	25.6	27.5	29.6
4 N S K	26.2	31.0	26.8	27.4	26.2	24.6	25.7	27.4
7 N S Cl	27.6	28.9	28.7	28.3	25.7	27.0	28.9	29.5
5 N K Cl	27.4	28.6	28.9	28.0	26.0	28.2	30.1	26.3
2 N S	26.5	29.6	29.9	30.4	22.8	23.7	24.4	26.0
3 N Cl	29.1	30.3	31.5	28.9	26.3	28.8	30.1	26.8
1 N (Urea)	25.3	25.6	28.1	27.1	22.7	24.5	26.9	27.0
GM	27.0	29.7	29.1	28.1	25.1	26.1	27.7	27.5
Sig	ns	**	ns	ns	ns	ns	*	ns
Cv%		8.8	12.0	10.5	11.5	13.6	11.1	12.6
Sed					1.82	3.54	3.06	2.19
Lsd		3.4						

Leaf and rachis analysis results for 1998 are presented in Tables 2.28 and 2.29 respectively. The treatments had significant effects on Cl concentration ($p<0.001$) in the leaflets and K ($p=0.004$), Mg ($p=0.014$) and Cl ($p=0.022$) concentrations in the rachis.

Table 2.28 The effects of N, S, K, and Cl in different combinations, on the concentrations of elements in leaf tissue of frond 17 in 1998 (Trial 310).

	Concentration of elements (% dry matter)						
Treatment	N	P	K	Ca	Mg	Cl	S
6 N S K Cl	2.12	0.142	0.72	0.74	0.20	0.48	0.14
4 N S K	2.13	0.144	0.80	0.66	0.19	0.25	0.14
7 N S Cl	2.22	0.146	0.75	0.70	0.21	0.52	0.14
5 N K Cl	2.12	0.146	0.75	0.73	0.18	0.51	0.15
2 N S	2.12	0.143	0.77	0.65	0.20	0.14	0.14
3 N Cl	2.12	0.148	0.73	0.73	0.21	0.55	0.14
1 N (Urea)	2.12	0.147	0.79	0.68	0.19	0.13	0.15
GM	2.14	0.147	0.76	0.70	0.20	0.37	0.14
Sig	ns	ns	ns	ns	ns	***	ns
Cv%	4.2	2.4	6.6	9.7	7.6	7.1	8.2
Sed	0.06	0.002	0.03	0.04	0.09	0.02	0.02

Table 2.29 Effects of N, S, K and Cl in different combinations, on the concentrations of elements in rachis of frond 17 in 1998 (Trial 310).

	Concentrations of elements (%dry matter)						
Treatment	N	P	K	Ca	Mg	Cl	S
6 N S K Cl	0.28	0.169	1.50	0.40	0.07	0.80	0.06
4 N S K	0.30	0.173	1.31	0.36	0.08	0.67	0.06
7 N S Cl	0.29	0.117	1.36	0.40	0.07	0.89	0.06
5 N K Cl	0.30	0.179	1.40	0.36	0.07	0.85	0.05
2 N S	0.28	0.118	1.06	0.31	0.05	0.08	0.05
3 N Cl	0.30	0.179	1.31	0.42	0.09	0.98	0.05
1 N (Urea)	0.28	0.148	1.13	0.34	0.06	0.33	0.04
GM	0.29	0.155	1.30	0.37	0.07	0.66	0.05
Sig	ns	ns	**	ns	*	*	ns
Cv%	12.0	25.4	12.7	17.7	24.6	64.2	17.3
Sed	0.02	0.02	0.10	0.04	0.011	0.27	0.006

The results of the calculated physiological growth parameter are presented in Table 2.30. The treatments did not have any significant effect on all of the parameters estimated.

Table 2.30 Effects of N, S, K and Cl in different combinations, on physiological growth parameters in 1998 (Trial 310).

	Physiological Growth Parameters								
Treatment	FW kg	FDM	VDM t/ha/yr	BDM	TDM	BI	LAI	FEI	Con. eff
6 N S K Cl	4.60	15.8	20.2	24.3	44.5	0.545	6.23	0.889	1.60
4 N S K	4.66	16.0	20.3	22.4	42.7	0.524	6.13	0.888	1.54
7 N S Cl	5.10	17.5	22.2	24.2	46.4	0.521	6.51	0.902	1.65
5 N K Cl	4.84	16.6	20.8	21.6	42.4	0.510	6.04	0.885	1.53
2 N S	4.43	15.2	19.3	21.4	40.6	0.525	6.61	0.902	1.45
3 N Cl	4.68	16.1	20.3	21.9	42.2	0.518	6.80	0.911	1.49
1 N (Urea)	4.46	15.3	19.5	22.2	41.6	0.533	6.42	0.867	1.49
GM	4.68	16.1	20.4	22.6	42.9	0.525	6.39	0.896	1.54
Sig	ns	ns	ns	ns	ns	ns	ns	ns	ns
Cv%	11.3	11.3	10.1	12.6	9.0	6.8	11.3	3.0	8.8
Sed	0.33	1.15	1.30	1.79	2.44	0.023	0.455	0.0167	0.085

Bunch analysis in trial 310 was done over a period of 2 months from selected plots to see the effect of Cl, S and K in combinations with N. From each plot, 30 bunches were analysed. The bunch analysis results are shown in Table 3.

Effect of N appears to have the major effect on the bunch components thus overshadowing the effects of the other 3 elements, however, N in combinations with the 3 elements shows increases in kernel/fruit and kernel/bunch ratios. A general picture seen here also is that where K and Cl are together, bunch components ratios are reduced. However where the 2 elements are separated and added to N and S, the bunch components are increased.

Table 2.31 Trial 310 Bunch analysis results for 1998.

Treatments	BNO	Frt/Bunch	WM/Frt	DM/Frt	Oil/WM	K/Frt	K/Bunch	Oil/Bunch	Yield t/ha	Oil/ha
N K Cl S	30	61.88	68.57	42.25	48.66	35.20	21.76	20.56	29.6	6.1
N K S	30	64.29	73.39	47.30	51.62	28.79	18.61	24.20	27.4	6.6
N Cl S	30	63.73	73.05	47.19	51.56	37.42	23.89	24.06	29.5	7.1
N K Cl	30	64.09	68.77	45.42	53.38	34.82	22.41	23.35	26.3	6.1
N S	30	66.78	73.18	48.57	53.61	31.82	21.24	26.04	26.0	6.8
N Cl	30	65.40	70.20	44.07	49.77	34.72	22.61	22.87	26.8	6.1
N (Urea)	30	62.34	70.90	46.35	52.45	28.58	17.87	23.33	27.0	6.3
GM		64.07	71.15	45.88	51.58	33.05	21.20	23.49	27.5	6.5
Min		30.56	48.67	24.32	22.23	17.29	8.79	8.56		
Max		95.06	101.58	88.38	84.84	67.21	45.51	46.83		
SEM		0.48	0.56	0.59	0.68	0.52	0.38	0.4		
cv%		10.77	11.43	18.47	19.16	22.94	26.07	24.35		

TRIAL 311 NITROGEN, POTASSIUM, AND EMPTY FRUIT BUNCH TRIAL AT ISAVENE ESTATE

PURPOSE

To test the response of oil palm 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 recorded palms. The number and weights of bunches from each individual core palm are recorded at intervals of 14 days. In each plot at least one guard row and a trench surround the core palms.

The 32 plots comprise a single replicate containing 32 treatments, made up of all factorial combinations of four levels each of N and K, and two levels of EFB (Table 2.32). Sulphate of ammonia (SoA) is the source of nitrogen, and muriate of potash (MoP) is the source of potassium. The EFB is applied by hand as mulch between the palm circles. The weights of EFB given in Table 2.32 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 2.32 Amounts of fertiliser and EFB used in Trial 311.

Type of fertiliser	Amount (kg/palm/year)			
Or EFB	Level 0	Level 1	Level 2	Level 3
Sulphate of ammonia	0.0	2.0	4.0	6.0
Muriate of potash	0.0	2.0	4.0	6.0
		Kg per palm per two years		
EFB	0.0	500		

Note: SoA 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

Yield data for 1998 is shown in Table 2.33. Sulphate of ammonia significantly ($p<0.001$) improved FFB yield and this was due to significant increases ($p<0.001$) in bunch numbers and single bunch weights. A similar response is seen for mean cumulative FFB yield and yield components for the period 1991 - 1998 (Table 2.36).

Although interactions between the 3 fertiliser treatments were not significant, the 1998 yield results are presented in two-way tables in Tables 2.34 and 2.35. A maximum FFB yield of 39.5 t/ha/yr was obtained with a combination of 4 kg SoA and 6 kg MoP averaged over all levels of EFB (Table 2.34). A more realistic yield of 34 tonnes FFB was obtained with 4 kg SoA and 2 kg MoP. The combination of SoA and EFB produce a high yield of 29.7 t FFB/ha/yr (2 kg SoA in the presence of EFB). These combinations (N2 & K1 and N1 & EFB1) averaged over all levels of EFB also produced high and realistic yields for the period 1991 - 1998 (Table 2.37) and even in the presence and absence of either K or EFB (Tables 2.35 and 2.38).

Application of empty fruit bunch appears to greatly improve the utilisation of N (probably S as well) in this particular soil type.

Table 2.33 Main effects of N, K, EFB on yield and yield components in 1998 (Trial 311).

	Level of nutrient element or EFB				Statistics		
					Sig.	cv%	sed
	N0	N1	N2	N3			
Yield (t/ha/yr)	16.9	28.9	34.5	33.7	***	13.0	1.85
Bunches/ha	658	1010	1140	1105	***	9.3	45
Bunch weight (kg)	25.2	28.4	30.3	30.5	***	6.4	0.91
	K0	K1	K2	K3			
Yield (t/ha/yr)	27.0	28.2	29.3	29.5	ns	13.0	1.85
Bunches/ha	961	952	970	1030	ns	9.3	45
Bunch weight (kg)	27.5	28.9	29.6	28.3	ns	6.4	0.91
	EFB0	EFB1					
Yield (t/ha/yr)	25.4	31.6			***	13.0	1.31
Bunches/ha	899	1057			***	9.3	32
Bunch weight (kg)	27.4	29.7			**	6.4	0.64

Table 2.34 Effect of combinations of N and K, N and EFB, and K and EFB in 1998 on FFB yield (Trial 311).

		Level of N		
Level of K	N0	N1	N2	N3
K0	16.7	28.1	30.1	33.0
K1	17.7	25.9	34.5	34.7
K2	16.0	31.4	33.8	35.9
K3	17.3	30.1	39.5	31.0
Level of EFB				
EFB 0	22.8	27.1	29.4	30.5
EFB 1	27.6	29.7	31.1	30.6
		Level of K		
Level of EFB	K0	K1	K2	K3
EFB 0	22.7	24.1	26.6	28.0
EFB 1	31.2	32.3	32.0	30.9

Grand mean: 28.5 SED: NxK=3.71, NxEFB & KxEFB=2.62

Table 2.35 Effect of combinations of N and K (absence of EFB) and N and EFB

(absence of K) in 1998 (Trial 311).

	Yield (t/ha/yr)			
		Level of N (absence of EFB)		
Level of K	N0	N1	N2	N3
K0	10.9	21.5	28.7	30.0
K1	10.1	18.2	34.8	33.2
K2	11.4	28.9	30.8	35.1
K3	14.6	31.7	35.3	30.6
Level of EFB		Level of N (absence of K)		
	N0	N1	N2	N3
EFB 0	10.9	21.5	28.7	30.0
EFB 1	22.4	34.7	31.6	36.0

Table 2.36 Main effects of N, K and EFB on yield and yield components for 1989 – 1998 (Trial 311).

	Level of nutrient Element or EFB				Statistics		
					sig	cv%	sed
	N0	N1	N2	N3			
Yield (t/ha/yr)	19.4	28.7	32.2	33.7	***	10.7	1.52
Bunches/ha	741	1021	1074	1109	***	6.8	33
Bunch wt (kg)	26.7	28.0	30.1	30.4	***	6.0	0.85
	K0	K1	K2	K3			
Yield (t/ha/yr)	27.6	28.1	28.4	29.9	ns	10.7	1.52
Bunches/ha	977	960	963	1044	ns	6.8	33
Bunch wt (kg)	27.7	28.7	29.3	28.5	ns	6.0	0.85
	EFB0	EFB1					
Yield (t/ha/yr)	25.8	31.2			***	10.7	1.08
Bunches/ha	920	1051			***	6.8	24
Bunch wt (kg)	27.4	29.6			**	6.0	0.60

Table 2.37 Effect of combinations of N and K, N and EFB, and K and EFB, on yield from 1989 to 1998 (Trial 311).

		Yield (t/ha/yr)		
		Level of N		
Level of K	N0	N1	N2	N3
K0	18.8	27.7	30.7	33.0
K1	19.9	24.3	32.6	35.5
K2	18.1	31.5	30.1	34.1
K3	20.5	31.5	35.5	32.1
Level of EFB				
EFB 0	15.5	24.9	30.5	32.1
EFB 1	23.2	32.6	34.0	35.2
		Level of K		
Level of EFB	K0	K1	K2	K3
EFB 0	25.3	23.7	27.2	28.3
EFB 1	30.9	32.1	28.0	32.5
Grand mean:	28.5	SED NxK=3.05, NxEFB & KxEFB=2.16		

Table 2.38 Effect of combinations of N and K (absence of EFB) and N and EFB (absence of K) from 1989 to 1998 (Trial 311).

		Yield (t/ha/yr)		
		Level of N (absence of EFB)		
Level of K	N0	N1	N2	N3
K0	13.4	21.6	29.6	31.6
K1	13.4	16.9	32.5	32.9
K2	16.4	30.2	27.3	33.6
K3	18.9	30.8	32.4	30.5
Level of EFB		Level of N (absence of K)		
	N0	N1	N2	N3
EFB 0	13.4	21.6	29.6	31.6
EFB 1	24.3	33.7	31.9	34.4

Leaflet and rachis tissue analysis results are presented in Tables 2.39 and 2.40 respectively. Sulphate of ammonia significantly increased N concentration (p=0.025) in the leaflet tissue. P concentrations were also increased but these were statistically not significant. SoA while increasing N and P concentrations lowered Mg concentrations (p=0.004).

Muriate of potash application did not affect the leaf nutrient concentrations though it does suggest increases in Cl and Ca concentrations. EFB also did not statistically affect leaf nutrient concentrations.

In the rachis (Table 2.40), SoA significantly increased N (p=0.013) whilst lowering Mg (p=0.011) concentrations. Muriate of potash increased K (p=0.008) and Cl (p=0.003) concentrations while EFB did not affect any of the nutrient concentrations.

The general lack of responses in the nutrient contents in 1998 is probably due to improved soil moisture conditions after the draught in 1997. Also, in most cases, the nutrient concentrations have improved to normal levels from 1997 levels.

Table 2.39 Main effects of N, K, and EFB on concentrations of elements in leaflet tissue in 1998 (Trial 311).

	Level of nutrient Element or EFB				Statistics sig.	cv%	sed
	N0	N1	N2	N3			
N%	1.93	2.05	2.19	2.20	*	7.7	0.08
P%	0.132	0.139	0.139	0.144	ns	8.6	0.006
K%	0.64	0.67	0.68	0.70	ns	8.1	0.03
Ca%	0.75	0.74	0.70	0.67	ns	8.8	0.03
Mg%	0.23	0.21	0.20	0.21	**	6.4	0.007
Cl%	0.44	0.39	0.45	0.42	ns	36.9	0.07
S%	0.14	0.15	0.15	0.15	ns	13.8	0.01
	K0	K1	K2	K3			
N%	2.13	2.06	2.04	2.14	ns	7.7	0.08
P%	0.143	0.131	0.139	0.141	ns	8.6	0.006
K%	0.69	0.66	0.65	0.68	ns	8.1	0.03
Ca%	0.71	0.71	0.73	0.75	ns	8.8	0.03
Mg%	0.21	0.21	0.21	0.21	ns	6.4	0.007
Cl%	0.40	0.42	0.44	0.44	ns	36.9	0.07
S%	0.15	0.15	0.15	0.15	ns	13.8	0.01
	EFB 0	EFB 1					
N%	2.07	2.10			ns	7.7	0.06
P%	0.136	0.140			ns	8.6	0.004
K%	0.66	0.68			ns	8.1	0.02
Ca%	0.73	0.72			ns	8.8	0.02
Mg%	0.21	0.22			ns	6.4	0.005
Cl%	0.43	0.42			ns	36.9	0.05
S%	0.15	0.15			ns	13.8	0.007

Table 2.40 Main effects of N, K, and EFB on concentrations of elements in Rachis in 1997 (Trial 311).

	Level of nutrient Element or EFB				Statistics sig	cv%	sed
	N0	N1	N2	N3			
N%	0.25	0.28	0.29	0.33	*	12.9	0.019
P%	0.092	0.086	0.066	0.079	ns	28.1	0.01
K%	1.42	1.57	1.40	1.50	ns	12.1	0.09
Ca%	0.39	0.42	0.38	0.40	ns	11.6	0.02
Mg%	0.08	0.06	0.06	0.06	**	11.5	0.004
Cl%	0.87	0.96	0.94	0.96	ns	22.5	0.10
S%	0.07	0.07	0.06	0.06	ns	22.8	0.007
	K0	K1	K2	K3			
N%	0.30	0.30	0.28	0.28	ns	12.9	0.019
P%	0.069	0.073	0.091	0.091	ns	28.1	0.01
K%	1.22	1.50	1.57	1.59	**	12.1	0.09
Ca%	0.39	0.41	0.40	0.39	ns	11.6	0.02
Mg%	0.06	0.07	0.07	0.06	ns	11.5	0.004
Cl%	0.57	1.05	1.05	1.06	**	22.5	0.10
S%	0.06	0.07	0.07	0.07	ns	22.8	0.007
	EFB 0	EFB 1					
N%	0.29	0.29			ns	12.9	0.013
P%	0.080	0.082			ns	28.1	0.008
K%	1.42	1.53			(ns)	12.1	0.06
Ca%	0.40	0.40			ns	11.6	0.01
Mg%	0.07	0.07			ns	11.5	0.003
Cl%	0.86	1.01			ns	22.5	0.07
S%	0.07	0.06			ns	22.8	0.005

Physiological growth parameters estimated from vegetative measurements are presented in Table 2.41. Sulphate of ammonia and EFB significantly improved dry matter production, bunch index and CE. Effect of SoA on VDM was strongly linear (p=0.001) while strong quadratic effect (p=0.001) is seen with BDM production.

Table 2.41 Effect of N, K and EFB on physiological growth parameters in 1998 (Trial 311).

	FW kg	FDM t/ha/yr	VDM t/ha/yr	BDM t/ha/yr	TDM t/ha/yr	BI	LAI	FEI	CE
N0	**4.17**	**13.0**	**16.0**	**13.9**	**29.9**	**0.454**	5.79	0.870	**1.10**
N1	**4.66**	**14.6**	**18.8**	**23.7**	**42.5**	**0.553**	6.27	0.891	**1.54**
N2	**5.18**	**16.2**	**21.1**	**28.3**	**49.4**	**0.571**	6.33	0.893	**1.78**
N3	**5.65**	**17.6**	**22.7**	**27.6**	**50.3**	**0.549**	6.92	0.916	**1.76**
	***	***	***	***	***	***	ns	ns	***
K0	4.85	15.1	19.3	22.1	41.4	0.524	6.44	0.897	1.47
K1	4.97	15.5	19.8	23.1	42.9	0.526	6.54	0.904	1.52
K2	4.96	15.5	19.9	24.0	43.9	0.536	6.38	0.892	1.57
K3	4.88	15.2	19.6	24.2	43.8	0.542	5.95	0.877	1.60
	ns	ns	ns	ns	ns	ns	ns	ns	ns
EFB0	**4.66**	**14.5**	**18.5**	**20.8**	**39.3**	**0.513**	6.27	0.888	**1.41**
EFB1	**5.17**	**16.1**	**20.8**	**25.9**	**46.7**	**0.550**	6.38	0.897	**1.67**
	*	*	**	***	***	***	ns	ns	**
GM	4.92	15.3	19.6	23.4	43.0	0.532	6.33	0.892	1.54
cv%	9.5	9.5	9.7	13.0	11.1	3.3	12.0	3.5	12.4
SEDa	0.23	0.73	0.95	1.52	2.39	0.009	0.38	0.0155	0.095
SEDb	0.17	0.52	0.67	1.08	1.69	0.006	0.268	0.0109	0.067

SEDa = standard error of difference for N and K
SEDb = standard error of difference for EFB

Bunch analysis in trial 311 was carried out over a period of 2 months from selected plots to investigate the effects of N, K and EFB on bunch components. From each plot 30 bunches were analysed, however, in several of the plots less than 30 bunches were analysed because there were less numbers of bunches harvested during the period. The bunch analysis results are presented in Table 2.42.

N fertiliser application appears to have major effects on the estimated bunch components. Fruit/bunch, WM/fruit, DM/fruit and oil/bunch ratios were all reduced with N application whilst kernel/fruit and kernel/bunch were increased. Despite the reduction in oil/bunch, oil per ha increase with N rates and this is due to N increasing overall FFB yield per ha.

K fertiliser application had a similar effect on the bunch components as the N fertiliser. However oil/ha is not affected because there is no FFB yield response to K fertiliser application.

Table 2.42 Trial 311 1998 Bunch Analysis Results (Trial 311).

Treatments	BNO	Frt/Bunch	WM/Frt	DM/Frt	Oil/WM	K/Frt	K/Bunch	Oil/Bunch	Yield t/ha	Oil/ha
N0	25	64.64	72.52	50.48	57.06	35.15	22.71	26.36	16.9	4.5
N1	30	64.31	77.62	48.09	48.94	34.97	22.50	24.42	28.9	7.1
N2	11	66.20	78.11	44.26	43.94	39.73	26.21	22.49	34.5	7.8
N3	30	65.30	75.61	46.03	47.73	37.56	24.54	23.57	33.7	7.9
K0	25	64.64	72.52	50.48	57.06	35.15	22.71	26.36	27	7.1
K1	30	65.58	74.85	48.01	51.83	34.84	22.87	25.14	28.2	7.1
K2	30	64.91	79.48	47.00	46.51	36.93	24.16	23.71	29.3	6.9
K3	30	66.81	76.47	45.28	46.76	40.57	27.12	23.52	29.5	6.9
EFB0	25	64.64	72.52	50.48	57.06	35.15	22.71	26.36	25.4	6.7
EFB1	25	66.65	75.03	43.82	45.37	37.12	24.71	22.71	31.6	7.2
N0 K0	25	64.64	72.52	50.48	57.06	35.15	22.71	26.36	10.9	2.9
N2 K2	30	67.31	74.14	43.22	46.00	31.59	21.23	22.62	30.8	7.0
N0 EFB0	25	64.64	72.52	50.48	57.06	35.15	22.71	26.36	10.9	2.9
N2 EFB1	27	66.65	75.03	43.82	45.37	37.12	24.71	22.71	31.6	7.2
GM		65.38	76.54	46.14	47.77	35.87	23.48	23.61	28.5	6.7
Min		44.73	42.83	26.44	18.35	12.89	9.04	11.08		
Max		88.37	136.57	78.79	81.03	68.8	44.96	42.06		
SEM		0.34	0.56	0.45	0.61	0.48	0.35	0.3		
cv%		8.42	12.03	16.01	20.95	22.1	24.57	20.55		

TRIAL 312 NITROGEN, POTASSIUM, AND EMPTY FRUIT BUNCH TRIAL AT AMBOGO ESTATE

PURPOSE

To test the response of oil palm 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 recorded palms. The number and weights of bunches from each individual core palm are recorded at intervals of 14 days. In each plot at least one guard row and a trench surround the core palms.

The 32 plots comprise a single replicate containing 32 treatments, these are made up of all factorial combinations of four levels each of N and K, and two levels of EFB (Table 2.43). Sulphate of ammonia (SoA) 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 2.43 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 2.43 Amounts of fertiliser and EFB used in 1998.

Type of fertiliser	Amount (kg/palm/year)			
Or EFB	Level 0	Level 1	Level 2	Level 3
Sulphate of ammonia	0.0	2.0	4.0	6.0
Muriate of potash	0.0	2.0	4.0	6.0
	kg/palm/two years			
EFB	0.0	500		

Notes: SoA 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 1998 is presented in Table 2.44. Sulphate of ammonia significantly increased yields ($p<0.001$) in 1998. The increase in yield was due to significant increases ($p<0.001$) in bunch numbers and single bunch weight. Muriate of potash did not have any significant effect on yield. Empty fruit bunch applications significantly increased FFB yield and it's components ($p<0.001$) in 1998. The significant responses to sulphate of ammonia and EFB seen in 1998 were also similar to responses observed for the period 1989 - 1998 (Table 2.49).

There were significant treatment interactions for FFB yield (p=0.003 (linear component, p<0.001), bunch numbers (p=0.025, linear p=0.007) and single bunch weight (p<0.001, linear p=0.001) between sulphate of ammonia and EFB. While there were significant interactions between SoA and EFB, there was none between SoA and MoP or EFB and MoP. Two-way tables for 1998 are presented in Tables 2.45, 2.46, 2.47 and 2.48 while for 1989 - 1998 in Tables 2.50, 2.51, 2.52 and 2.53.

A maximum FFB yield of 33.0 t/ha/yr was obtained with 4kg SoA and 6 kg MoP averaged over all levels of EFB, though a more realistic yield of 29.7 t/ha/yr was obtained with 4 kg SoA and 2kg MoP. With SoA and EFB, a maximum yield of 32.5 t/ha/yr was obtained with 4 kg SoA and EFB1. In the absence of either K or EFB, optimum yields appear to be at N1 and EFB1 levels.

Table 2.44 Main effects of N, K, and EFB on yield and yield components in 1998 (Trial 312).

	Level of nutrient Elements or EFB				Statistics		
					sig	cv%	sed
	N0	N1	N2	N3			
Yield (t/ha/yr)	18.2	25.7	30.1	29.3	***	9.3	1.20
Bunches/ha	950	1128	1267	1145	***	9.7	55
Bunch weight (kg)	18.6	22.9	23.9	22.3	***	3.6	0.40
	K0	K1	K2	K3			
Yield (t/ha/yr)	25.1	25.9	26.5	26.0	ns	9.3	1.20
Bunches/ha	1118	1171	1176	1116	ns	9.7	55
Bunch weight (kg)	22.1	21.9	22.4	22.7	ns	3.6	0.40
	EFB 0	EFB 1					
Yield (t/ha/yr)	23.1	28.6			***	9.3	0.85
Bunches/ha	1042	1249			***	9.7	39.1
Bunch weight (kg)	21.6	22.9			***	3.6	0.28

Table 2.45 Effect of combinations of N and K, N and EFB on FFB yield in 1998 (Trial 312).

Yield (t/ha/yr):

		Level of N		
Level of K	N0	N1	N2	N3
K0	16.7	24.3	28.1	31.3
K1	19.7	27.3	29.7	26.8
K2	19.8	28.5	29.7	27.9
K3	16.8	22.8	33.0	31.3
Level of EFB				
EFB 0	11.7	23.1	27.8	29.9
EFB 1	24.7	28.3	32.5	28.8

		Level of K		
Level of EFB	K0	K1	K2	K3
EFB 0	22.8	22.5	24.5	22.7
EFB 1	27.4	29.3	28.5	29.2

Grand Mean: 25.9 Sed: NxK=2.40, NxEFB & KxEFB=1.69

Table 2.46 Effect of combinations of N and K, N and EFB on yield in present/absence of K and EFB in 1998 (Trial 312).

Yield (t/ha/yr) (absence of EFB):

		Level of N		
Level of K	N0	N1	N2	N3
K0	10.1	21.3	28.6	31.4
K1	11.2	23.5	27.5	27.7
K2	15.0	26.9	27.5	28.6
K3	10.6	20.9	27.5	32.0

Yield (t/ha/yr) (absence of K):

		Level of N		
Level of EFB	N0	N1	N2	N3
EFB 0	10.1	21.3	28.6	31.4
EFB 1	23.3	27.4	27.6	31.2

Table 2.47 Effect of combinations of N and EFB on Bunch numbers in 1998 (Trial 312).

Bunch numbers/ha:

		Level of N		
Level of EFB	N0	N1	N2	N3
EFB 0	733	1039	1160	1238
EFB 1	1166	1216	1374	1238

Grand Mean: 1145 Sed: NxEFB=78

Table 2.48 Effect of combinations of N and EFB on Single Bunch Weight in 1998 (Trial 312).

Single Bunch Weight (kg/bunch/yr):

			Level of N		
Level of EFB	N0		N1	N2	N3
EFB 0	15.9		22.3	23.9	24.2
EFB 1	21.3		23.4	23.8	23.2
Grand Mean:	22.3	Sed:	NxEFB =0.566		

Table 2.49 Main effects of N, K, and EFB on yield and yield components in 1989 – 1998 (Trial 312).

	Level of nutrient Elements or EFB				Statistics		
					sig	cv%	sed
	N0	N1	N2	N3			
Yield (t/ha/yr)	21.4	27.4	30.9	31.4	***	6.5	0.91
Bunches/ha	1063	1179	1291	1316	***	5.9	36
Bunch weight (kg)	19.7	23.2	24.0	23.9	***	3.2	0.36
	K0	K1	K2	K3			
Yield (t/ha/yr)	27.2	28.2	28.2	27.4	ns	6.5	0.91
Bunches/ha	1187	1252	1238	1172	ns	5.9	36
Bunch weight (kg)	22.6	22.3	22.7	23.1	ns	3.2	0.36
	EFB 0	EFB 1					
Yield (t/ha/yr)	25.4	30.1			***	6.5	0.64
Bunches/ha	1141	1284			***	5.9	25
Bunch weight (kg)	21.9	23.5			***	3.2	0.25

Table 2.50 Effects of combinations of N and K, N and EFB and K and EFB on yield in 1989-1998 (Trial 312).

Yield (t/ha/yr):

		Level of N		
Level of K	N0	N1	N2	N3
K0	19.8	26.6	30.4	32.1
K1	22.5	28.6	31.6	30.2
K2	22.1	29.4	29.9	31.8
K3	21.1	24.9	31.8	31.7
Level of EFB				
EFB0	16.5	24.8	28.9	31.6
EFB1	26.3	30.0	32.9	31.2

		Level of K		
Level of EFB	K0	K1	K2	K3
EFB0	24.9	25.4	26.5	25.0
EFB1	29.6	31.1	30.0	29.7

Grand mean = 27.8 Sed NxK=1.82, NxEFB & KxEFB=1.29

Table 2.51 Effect of combinations of N and K and N and EFB on yield in present/absence of K and EFB from 1989 to 1998 (Trial 312).

Yield (t/ha/yr) (absence of EFB):

	Level of N			
Level of K	N0	N1	N2	N3
K0	14.9	23.5	29.4	31.6
K1	15.7	24.9	30.3	30.6
K2	19.2	28.0	27.2	31.6
K3	16.1	22.7	28.7	32.7

Yield (t/ha/yr) (absence of K):

	Level of N			
Level of EFB	N0	N1	N2	N3
EFB 0	14.9	23.5	29.4	31.6
EFB 1	24.8	29.7	31.3	32.7

Table 2.52 Effect of combinations of N and EFB on Bunch Numbers from 1989 to 1998 (Trial 312).

Bunch numbers/ha:

	Level of N			
	N0	N1	N2	N3
EFB 0	934	1102	1218	1309
EFB 1	1192	1257	1363	1322
Grand Mean:	1212	Sed:	NxEFB=51	

Table 2.53 Effect of combinations of N and EFB on Single Bunch Weight from 1989 to 1998 (Trial 312).

Single Bunch Weight (kg/bunch/yr):

	Level of N			
	N0	N1	N2	N3
EFB 0	17.3	22.5	23.8	24.2
EFB 1	22.1	23.9	24.3	23.6
Grand Mean:	22.7	Sed:	NxEFB =0.506	

Leaflet and rachis tissue analysis results are presented in Tables 2.54 and 2.55 respectively.

In the leaflets tissue SoA significantly increased N ($p<0.001$), P ($p=0.025$) and Ca ($p=0.014$) whilst lowering Mg concentrations ($p=0.009$). Muriate of potash application increased only Ca concentrations ($p=0.027$). EFB significantly increased N ($p=0.008$), P ($p=0.002$), K ($p=0.004$) and Mg ($p=0.048$) concentrations.

In the rachis tissue SoA significantly increased N ($p=0.003$) and Cl (0.011) concentrations whilst lowering P ($p<0.001$) concentrations. Muriate of potash significantly increased P($p=0.023$), K ($p<0.001$), Ca ($p=0.011$) and Cl ($p<0.001$) concentrations. EFB application had significant effect on the N ($p=0.044$), P ($p<0.001$), K ($p<0.001$), Ca ($p=0.026$) and Cl ($p=0.025$) concentrations.

Table 2.54 Main effects of N, K, and EFB on concentrations of elements in leaflet tissue of frond 17 in 1998 expressed as % of dry matter (Trial 312).

	Level of nutrient Element or EFB				Statistics sig.	cv%	sed
	N0	N1	N2	N3			
N%	1.97	2.13	2.19	2.35	***	5.0	0.05
P%	0.137	0.144	0.144	0.146	*	3.2	0.002
K%	0.67	0.66	0.69	0.72	ns	8.0	0.027
Ca%	0.81	0.75	0.69	0.72	*	7.5	0.03
Mg%	0.19	0.17	0.16	0.17	**	7.0	0.006
Cl%	0.51	0.48	0.46	0.50	ns	15.7	0.04
S%	0.11	0.12	0.12	0.12	ns	7.7	0.005
	K0	K1	K2	K3			
N%	2.12	2.19	2.11	2.17	ns	5.0	0.05
P%	0.141	0.145	0.140	0.144	ns	3.2	0.002
K%	0.68	0.68	0.67	0.71	(ns)	8.0	0.027
Ca%	0.69	0.77	0.74	0.77	*	7.5	0.03
Mg%	0.16	0.18	0.17	0.18	ns	7.0	0.006
Cl%	0.42	0.52	0.49	0.53	(ns)	15.7	0.04
S%	0.12	0.12	0.12	0.12	ns	7.7	0.005
	EFB0	EFB1					
N%	2.09	2.23			**	5.0	0.05
P%	0.139	0.146			**	3.2	0.002
K%	0.65	0.72			**	8.0	0.027
Ca%	0.75	0.74			ns	7.5	0.03
Mg%	0.17	0.18			*	7.0	0.006
Cl%	0.48	0.50			ns	15.7	0.04
S%	0.12	0.12			ns	7.7	0.003

Table 2.55 Main effects of N, K, and EFB on concentrations of elements in the rachis in 1998 expressed as % of dry matter (Trial 312).

	Level of nutrient				Statistics		
	Element or EFB				sig	cv%	sed
	N0	N1	N2	N3			
N%	0.24	0.28	0.29	0.32	**	9.2	0.01
P%	0.186	0.154	0.133	0.114	***	8.8	0.007
K%	1.65	1.66	1.62	1.66	ns	6.7	0.06
Ca%	0.36	0.38	0.37	0.37	ns	8.9	0.01
Mg%	0.07	0.06	0.05	0.05	ns	17.0	0.005
Cl%	0.89	0.94	0.92	1.06	**	8.5	0.04
S%	0.04	0.04	0.04	0.04	ns	21.4	0.004
	K0	K1	K2	K3			
N%	0.30	0.29	0.28	0.27	ns	9.2	0.01
P%	0.133	0.158	0.145	0.152	*	8.8	0.007
K%	1.40	1.75	1.69	1.76	***	6.7	0.06
Ca%	0.32	0.39	0.39	0.37	**	8.9	0.01
Mg%	0.05	0.06	0.06	0.06	ns	17.0	0.005
Cl%	0.50	1.12	1.10	1.10	***	8.5	0.04
S%	0.04	0.04	0.03	0.04	ns	21.4	0.004
	EFB 0	EFB 1					
N%	0.27	0.29			*	9.2	0.01
P%	0.164	0.130			***	8.8	0.005
K%	1.53	1.76			***	6.7	0.04
Ca%	0.38	0.35			**	8.9	0.01
Mg%	0.06	0.05			ns	17.0	0.003
Cl%	0.92	0.99			*	8.5	0.03
S%	0.04	0.04			ns	21.4	0.004

Physiological growth parameters, estimated from vegetative measurements carried out in June 1998 while leaf tissue samples were taken for analysis are shown in Table 2.56. Sulphate of ammonia significantly increased all the growth parameters while EFB increased BDM and parameters derived from it.

Table 2.56 Effects of N, K and EFB on physiological growth parameters - 1998 (Trial 312).

	FW (kg)	FDM t/ha/yr	VDM t/ha/yr	BDM t/ha/yr	TDM t/ha/yr	BI	LAI	FEI	Con.ef
N0	**4.39**	**15.1**	**18.4**	**14.9**	**33.4**	**0.433**	**5.72**	**0.867**	**1.23**
N1	**4.92**	**16.9**	**21.1**	**21.1**	**42.2**	**0.500**	**6.73**	**0.910**	**1.49**
N2	**5.34**	**18.3**	**23.1**	**24.7**	**47.8**	**0.516**	**6.49**	**0.896**	**1.71**
N3	**5.84**	**20.1**	**25.0**	**24.0**	**49.0**	**0.492**	**6.78**	**0.912**	**1.73**
	*	*	**	***	***	**	**	*	***
K0	4.77	16.4	20.5	20.6	41.1	0.492	5.96	0.878	1.50
K1	5.57	19.1	23.6	21.2	44.8	0.470	6.67	0.903	1.59
K2	5.09	17.5	21.8	21.7	43.6	0.496	6.49	0.899	1.55
K3	5.07	17.4	21.7	21.3	43.0	0.483	6.61 (ns)	0.905	1.52
EFB0	4.93	16.9	20.9	**19.0**	**39.9**	**0.465**	**6.16**	**0.885**	**1.44**
EFB1	5.32	18.3	22.9	**23.4**	**46.3**	**0.505**	**6.70**	**0.908**	**1.64**
				***	***	**	**	*	**
GM	5.13	17.6	21.9	21.2	43.1	0.485	6.43	0.896	1.54
cv%	15.2	15.2	13.7	9.3	8.9	7.6	7.6	2.5	9.4
SEDa	0.39	1.33	1.50	0.98	1.92	0.0184	0.25	0.0112	0.07
SEDb	0.28	0.94	1.06	0.70	1.36	0.0130	0.17	0.0080	0.05

SEDa = standard error for N and K
SEDb = standard error for EFB

TRIAL 502B FERTILISER TRIAL AT WAIGANI ESTATE

PURPOSE

To test the response of oil palm to the application of 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 comprises a single replicate of 64 treatments split into four blocks. Treatments comprise of all factorial combinations of N and K at 4 levels and P and EFB at 2 levels (Table 2.57). There are 64 plots each containing 16 core recorded palms. The numbers and weights of bunches of each individual core palm are recorded at intervals of 14 days. In each plot one guard row and a trench surround the core palms. EFB is applied by hand as mulch between palm circles.

Table 2.57 Amounts of fertiliser and EFB used in 1998.

Type of fertiliser Or EFB	Amounts (kg/palm/year) Level 0	Level 1	Level 2	Level 3
Sulphate of ammonia	0.0	2.0	4.0	6.0
Muriate of potash	0.0	2.5	5.0	7.5
Triple Superphosphate	0.0	2.0		
	Kg/palm/year			
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

The average plot yield in 1998 was 16.9 t/ha/yr, a reduction of 9.6 t/ha/yr (36%) from 26.5 t/ha in 1997 (Table 2.58). The reduction was common to all treatments and has overshadowed the effects of fertilisers that were seen in the 1997 data. The reduction in crop was mostly due to a reduction in bunch numbers that probably resulted from abortions during the drought in 1997.

Sulphate of ammonia application increased single bunch weight ($p=0.006$) but did not have an effect on FFB yield. Muriate of potash and Triple Superphosphate application did not have an effect on FFB yield and yield components. EFB application significantly increased the number of bunches ($p=0.04$) and this caused an increase in FFB yield ($p=0.014$). The effect of EFB on yield was absent in 1997 but is seen in 1998. It appears that EFB promotes the growth of feeder roots by keeping the soil moist and this allowed both nutrients and water to be taken up by the palms

Tables 2.59 and 2.60 show the two-way tables for N&K and N&EFB respectively, though the interactions were not statistically significant. The maximum yield from combinations of N & K cannot be determined clearly because of the overriding effect of drought in 1997. The same is observed for 1996 - 1998 (Table 2.62). However with N & EFB in 1998, high yields are only seen in the presence of EFB (Table 2.60) but not for 1996 - 1998 (Table 2.63).

Accumulated mean yield data for the period 1996 - 1998 is presented in Table 2.61. The effects of fertiliser are partly overshadowed by effect of drought in 1997. Muriate of potash significantly increased FFB yield ($p=0.0016$) by a maximum of 2 tonnes only. The increase in yield was due to an increase in bunch numbers ($p=0.048$). Sulphate of ammonia significantly increased single bunch weight ($p<0.001$), however FFB yield was not affected because of reduced bunch numbers.

Table 2.58 Main effects of N, P, K, and Mg on yield and yield components in 1998 (Trial 502b).

	Nutrient element and level				Statistics sig.	cv %	sed
	N0	N1	N2	N3			
Yield (t/ha/yr)	16.9	17.1	16.8	16.8	ns	17.1	2.32
Bunch/ha	860	782	778	778	ns	16.5	47
Bunch wt (kg)	19.8	22.0	21.6	21.7	**	6.6	0.50
	K0	K1	K2	K3			
Yield (t/ha/yr)	16.9	16.7	17.3	16.7	ns	17.1	2.32
Bunch/ha	820	764	820	794	ns	16.5	47
Bunch wt (kg)	20.7	21.8	21.3	21.3	ns	6.6	0.50
	P0	P1					
Yield (t/ha/yr)	17.3	16.5			ns	17.1	0.73
Bunch/ha	1251	1255			ns	16.5	33
Bunch wt (kg)	21.4	20.9			ns	6.6	0.35
	EFB0	EFB1					
Yield (t/ha/yr)	15.8	18.0			*	17.1	0.73
Bunch/ha	761	838			ns	16.5	33
Bunch wt (kg)	20.9	21.6			*	6.6	0.35

Table 2.59 Effects of combinations of N and K fertilisers in 1998 (Trial 502b).

Yield (t/ha/yr):

	Level of N			
Level of K	N0	N1	N2	N3
K0	17.0	18.0	16.1	16.6
K1	16.9	17.6	16.6	16.6
K2	17.4	16.8	16.4	18.9
K3	17.5	16.0	18.2	15.2

Mean 16.9 SED 2.05

Table 2.60 Effects of combinations of N and EFB fertilisers in 1998 (Trial 502b).

Yield (t/ha/yr):

		Level of N			
Level of EFB		N0	N1	N2	N3
	EFB0	17.2	15.6	15.3	15.1
	EFB1	16.7	18.6	18.3	18.5
Mean	16.9	SED	1.45		

Table 2.61 Main effects of N, P, K and EFB on yield and yield components in 1996-1998 (Trial 502b).

	Level of nutrient Element or EFB				Statistics		
					sig	cv%	sed.
	N0	N1	N2	N3			
Yield (t/ha/yr)	21.2	22.0	22.4	22.4	ns	6.5	0.51
Bunches/ha	1028	998	1015	1002	ns	6.8	24
Bunch weight (kg)	20.6	22.2	22.1	22.4	***	4.4	0.34
	K0	K1	K2	K3			
Yield (t/ha/yr)	21.2	21.3	22.3	23.1	*	6.5	0.51
Bunches/ha	989	979	1022	1054	*	6.8	24
Bunch weight (kg)	21.5	21.9	21.9	22.0	ns	4.4	0.34
	P0	P1					
Yield (t/ha/yr)	22.3	21.6			ns	6.5	0.36
Bunches/ha	1018	1004			ns	6.8	17
Bunch weight (kg)	22.0	21.7			ns	4.4	0.24
	EFB0	EFB1					
Yield (t/ha/yr)	21.7	22.2			ns	6.5	0.36
Bunches/ha	1007	1015			ns	6.8	17
Bunch weight (kg)	21.7	22.1			ns	4.4	0.24

Table 2.62 Effects of combinations of N and K fertilisers in 1996 - 1998 (Trial 502b).

Yield (t/ha/yr):

		Level of N			
Level of K		N0	N1	N2	N3
	K0	20.6	21.2	21.7	21.4
	K1	20.5	22.4	20.7	21.6
	K2	21.1	21.6	22.7	23.8
	K3	22.3	22.8	24.5	22.6
Mean	22.0	SED	1.015		

Table 2.63 Effects of combinations of N and EFB fertilisers in 1996 - 1998 (Trial 502b).

Yield (t/ha/yr):

		Level of N			
Level of EFB		N0	N1	N2	N3
	EFB0	21.0	21.6	22.0	22.3
	EFB1	21.3	22.4	22.8	22.5
Mean	22.0	SED	0.718		

Leaflet tissue analysis results are presented in Table 2.64. Generally there was no response to inorganic fertiliser treatments. The exception is muriate of potash that caused an increase in Cl concentration (p=<0.001). EFB, on the other hand, significantly affected K (p=0.005), Ca (p=0.007) and Mg (p=0.003) concentrations.

Mean leaflet nutrient concentrations for 1996 (before drought), 1997 (during drought) and 1998 (after drought) are presented in Table 2.65. Mean Ca, Mg and Cl concentrations have increased while K is lowered and N and P levels remain unchanged in 1998. The lack of change in N and P concentrations cannot be explained. Leaflet sampling in 1999 will show more reliably if N and P concentrations have changed.

In the rachis tissue, sulphate of ammonia significantly increased N concentration while the P content was reduced (p=<0.001)(Table 2.66). Muriate of potash application increased rachis K and Cl (p=<0.001) contents. There was no response to Triple Superphosphate application. Empty fruit bunch significantly increased K but also reduced Ca and Mg concentrations (p=<0.001). K released from the breakdown of empty fruit bunch is probably readily available for plant uptake. The reduction of Ca and Mg is probably due to the antagonistic effect of K.

Table 2.64 Main effects of N, P, K, and EFB on the concentrations of nutrients in leaf tissues of frond 17 in 1998 expressed as % dry matter (Trial 502b).

	Nutrient Element and Level				Statistics		
					sig	cv%	sed.
	N0	N1	N2	N3			
N%	2.23	2.25	2.26	2.30	ns	4.0	0.03
P%	0.148	0.146	0.145	0.147	ns	2.2	0.001
K%	0.66	0.65	0.65	0.64	ns	12.1	0.03
Ca%	0.80	0.79	0.81	0.77	ns	7.9	0.02
Mg%	0.36	0.35	0.35	0.33	ns	9.4	0.01
Cl%	0.62	0.66	0.65	0.64	ns	7.6	0.014
B (ppm)	9.07	9.11	9.16	9.53	ns	11.3	0.37
	K0	K1	K2	K3			
N%	2.29	2.23	2.25	2.26	ns	4.0	0.03
P%	0.147	0.144	0.146	0.148	*	2.2	0.001
K%	0.62	0.62	0.66	0.69	(ns)	12.1	0.03
Ca%	0.77	0.79	0.80	0.80	ns	7.9	0.02
Mg%	0.35	0.34	0.35	0.34	ns	9.4	0.01
Cl%	0.58	0.65	0.67	0.68	***	7.6	0.014
B (ppm)	9.61	8.94	9.34	8.97	ns	11.3	0.37
	P0	P1					
N%	2.26	2.26			ns	4.0	0.02
P%	0.147	0.146			ns	2.2	0.002
K%	0.65	0.64			ns	12.1	0.02
Ca%	0.79	0.80			ns	7.9	0.02
Mg%	0.35	0.35			ns	9.4	0.01
Cl%	0.64	0.64			ns	7.6	0.012
B (ppm)	9.27	9.17			ns	11.3	0.59
	EFB0	EFB1					
N%	2.25	2.27			ns	4.0	0.02
P%	0.146	0.146			ns	2.2	0.002
K%	0.61	0.68			**	12.1	0.02
Ca%	0.82	0.77			**	7.9	0.02
Mg%	0.36	0.33			**	9.4	0.01
Cl%	0.64	0.65			ns	7.6	0.012
B (ppm)	9.44	8.99			ns	11.3	0.59

Table 2.65 Mean leaflet tissue nutrient concentrations from 1996 to 1998 (Trial 502b).

Nutrient Element	**1996**	**1997**	**1998**
N%	2.49	2.29	2.26
P%	0.151	0.146	0.146
K%	0.68	0.72	0.65
Ca%	0.75	0.66	0.79
Mg%	0.31	0.31	0.35
Cl%	0.45	0.54	0.64

Table 2.66 Main effects of N, P, K and EFB on the concentration of elements in the rachis of frond 17 in 1998 expressed as % dry matter (Trial 502b).

	Nutrient Element and Level				Statistics		
					sig.	cv%	sed.
	N0	N1	N2	N3			
N%	0.30	0.32	0.34	0.35	***	6.6	0.007
P%	0.104	0.082	0.074	0.066	***	17.9	0.005
K%	1.14	1.08	1.20	1.09	ns	17.6	0.07
Ca%	0.38	0.38	0.38	0.39	ns	8.3	0.011
Mg%	0.19	0.18	0.17	0.17	ns	14.3	0.009
Cl%	1.05	1.00	1.05	0.97	ns	10.4	0.04
B (ppm)	5.39	5.54	5.60	5.70	ns	5.0	0.10
	K0	K1	K2	K3			
N%	0.32	0.32	0.33	0.34	*	6.6	0.007
P%	0.078	0.076	0.087	0.085	ns	17.9	0.005
K%	0.73	1.01	1.35	1.41	***	17.6	0.07
Ca%	0.38	0.40	0.37	0.39	ns	8.3	0.011
Mg%	0.19	0.19	0.17	0.16	*	14.3	0.009
Cl%	0.71	0.99	1.19	1.18	***	10.4	0.04
B (ppm)	5.71	5.64	5.45	5.43	ns	5.0	0.10
	P0	P1					
N%	0.33	0.33			ns	6.6	0.002
P%	0.076	0.086			ns	17.9	0.005
K%	1.14	1.12			ns	17.6	0.05
Ca%	0.39	0.39			ns	8.3	0.008
Mg%	0.18	0.18			ns	14.3	0.006
Cl%	1.03	1.01			ns	10.4	0.02
B (ppm)	5.43	5.68			ns	5.0	0.07
	EFB0	EFB1					
N%	0.32	0.33			ns	6.6	0.002
P%	0.078	0.085			ns	17.9	0.005
K%	0.97	1.28			***	17.6	0.05
Ca%	0.40	0.37			***	8.3	0.008
Mg%	0.20	0.16			***	14.3	0.006
Cl%	0.99	1.04			ns	10.4	0.02
B (ppm)	5.53	5.58			*	5.0	0.15

TRIAL 504 MATURE PHASE FERTILISER TRIAL AT SAGARAI ESTATE

PURPOSE

To test the response of oil palm to N and K fertiliser application at Sagarai Estate, the trial design makes allowance made for one additional treatment.

DESCRIPTION

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

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

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

DESIGN

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

The 64 plots are divided into two replicates of 32 plots each. In each replicate there are 32 treatments, made up from factorial combinations of four levels each of N and K, and two levels of an additional treatment, which is currently vacant (Table 2.67).

Table 2.67 Type of fertiliser and amounts used in Trial 504.

Element	Type of fertiliser	Amounts and levels of fertiliser Level 0	Level 1	Level 2	Level 3
N	Sulphate of ammonia	0.0	2.0	4.0	6.0
K	Muriate of potash	0.0	2.5	5.0	7.0
?	?	?	?	?	?

RESULT

In 1998 and in the period 1996-1998 there were no significant responses to application of sulphate of ammonia (Tables 2.68 and 2.69). Muriate of potash significantly increased FFB yield ($p=0.035$) up to level K2 (5.0 kg/palm) but not further, this effect was observed both in 1998 and 1996 - 1998. The average FFB yield for all the plots in 1998 was 19.4 t/ha/yr., a decrease of 13.1 tonnes (40%) from the 32.5 t/ha/yr in 1997. The reduction in yield is mostly due to a reduction in the number of bunches caused by the 1997 dry season.

Table 2.68 Main effects of N and K on yield and yield components in 1998 (Trial 504).

	Nutrient element and levels				Statistics sig.	cv%	sed
	N0	N1	N2	N3			
Yield (t/ha/yr)	19.5	19.8	19.5	18.9	ns	9.2	0.63
Bunches/ha	1461	1446	1483	1399	ns	9.0	46
Bunch wt (kg)	13.4	13.7	13.2	13.5	ns	6.2	0.29
	K0	K1	K2	K3			
Yield (t/ha/yr)	18.3	19.7	20.2	19.5	*	9.2	0.63
Bunches/ha	1408	1464	1492	1425	ns	9.0	46
Bunch wt (kg)	13.0	13.5	13.6	13.7	ns	6.2	0.29

Table 2.69 Main effects of N and K on yield and yield components in 1996-1998 (Trial 504).

	Nutrient element and levels				Statistics sig.	cv%	sed.
	N0	N1	N2	N3			
Yield (t/ha/yr)	26.4	27.1	26.9	26.5	ns	5.0	0.47
Bunches/ha	2149	2126	2162	2103	ns	5.8	44
Bunch weight (kg)	12.5	12.9	12.6	12.7	ns	4.7	0.21
	K0	K1	K2	K3			
Yield (t/ha/yr)	26.3	27.0	27.5	26.3	*	5.0	0.47
Bunches/ha	2145	2156	2154	2085	ns	5.8	44
Bunch weight (kg)	12.4	12.7	12.9	12.8	ns	4.7	0.21

Leaflet and rachis analysis results are presented in Tables 2.70 and 2.71. In the leaflets, sulphate of ammonia application did not affect any of the nutrient contents however in the rachis tissue P was reduced significantly ($p<0.001$). Muriate of potash significantly increased Ca ($p=0.011$) and Cl ($p<0.001$) concentrations in the leaflets. In the rachis P, K, Ca and Cl were all increased ($p<0.001$) by application of muriate of potash.

Table 2.70 Main effects of N and K on the concentration of elements in leaf tissue of frond 17 expressed as % dry matter in 1998 (Trial 504).

	Nutrient element and level				Statistics		
					sig.	cv%	sed.
	N0	N1	N2	N3			
N%	2.23	2.27	2.27	2.30	ns	3.9	0.03
P%	0.143	0.144	0.144	0.144	ns	2.1	0.001
K%	0.58	0.59	0.57	0.58	ns	8.9	0.02
Ca%	0.93	0.93	0.93	0.93	ns	5.8	0.02
Mg%	0.36	0.35	0.35	0.35	ns	7.6	0.010
Cl%	0.62	0.63	0.65	0.64	ns	5.7	0.01
B (ppm)	9.94	9.93	9.77	9.85	ns	7.8	0.27
	K0	K1	K2	K3			
N%	2.30	2.25	2.27	2.27	ns	3.9	0.03
P%	0.143	0.143	0.143	0.145	ns	2.1	0.001
K%	0.58	0.57	0.57	0.60	ns	8.9	0.02
Ca%	0.90	0.93	0.94	0.96	**	5.8	0.02
Mg%	0.36	0.35	0.35	0.35	ns	7.6	0.010
Cl%	0.52	0.64	0.69	0.69	***	5.7	0.01
B (ppm)	9.87	10.03	9.52	10.06	ns	7.8	0.27

Table 2.71 Main effects of N and K on the concentrations of elements in the rachis of frond 17 in 1998 expressed as % dry matter (Trial 504).

	Nutrient element and levels				Statistics		
					sig.	cv%	sed.
	N0	N1	N2	N3			
N%	0.28	0.29	0.29	0.29	ns	7.0	0.009
P%	0.084	0.067	0.065	0.064	***	11.9	0.003
K%	1.01	1.08	1.04	1.02	ns	16.2	0.06
Ca%	0.42	0.40	0.42	0.41	ns	8.4	0.01
Mg%	0.18	0.17	0.18	0.18	ns	13.1	0.008
Cl%	0.84	0.80	0.87	0.86	ns	13.9	0.04
B (ppm)	4.55	4.69	4.52	4.40	ns	9.0	0.14
	K0	K1	K2	K3			
N%	0.29	0.29	0.29	0.29	ns	7.0	0.009
P%	0.063	0.068	0.070	0.077	***	11.9	0.003
K%	0.78	1.02	1.09	1.26	***	16.2	0.06
Ca%	0.38	0.42	0.43	0.42	***	8.4	0.01
Mg%	0.17	0.18	0.19	0.17	ns	13.1	0.008
Cl%	0.44	0.85	1.00	1.07	***	13.9	0.04
B (ppm)	4.54	4.60	4.52	4.50	ns	9.0	0.14

TRIAL 511 FERTILISER TRIAL ON INTERFLUVE TERRACES SOILS AT WAIGANI ESTATE.

PURPOSE

To investigate the response of oil palm to applications of sulphate of ammonia, Triple Super-phosphate, muriate of potash and empty fruit bunch on interfluve terrace 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 topsoil. 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. The trial started in 1994.

DESIGN

There are 64 plots each containing 16 core recorded palms. The numbers and weights of bunches for each individual core palm are recorded at intervals of 14 days. In each plot a guard row and a trench surround the core palms.

The 64 plots comprise a single replicate split into four blocks. The trial contains 63 treatments comprising all factorial combinations of N and K at 4 levels, and P and EFB at 2 levels (Table 2.72). EFB is applied by hand as mulch between palm circles.

Table 2.72 Amounts of fertiliser and EFB used in Trial 511.

Type of fertiliser	Amounts of fertiliser (kg/palm/ha)			
or EFB	Level 0	Level 1	Level 2	Level3
Sulphate of ammonia	0.0	2.0	4.0	6.0
Muriate of potash	0.0	2.5	5.0	7.5
Triple Superphosphate	0.0	2.0		
		kg/palm/year		
EFB	0.0	315		

RESULTS

Yield data for 1998 is presented in Table 2.73. There were significant responses to application of sulphate of ammonia for FFB yield (p=0.015) and single bunch weight (p=0.004). Triple Superphosphate and muriate of potash application did not have an effect on FFB yield and yield components. EFB application significantly increased FFB yield (p=0.01) and single bunch weight (p=0.015).

Accumulated mean yield data for the period 1996 to 1998 is presented in Table 2.75. Sulphate of ammonia application significantly increased FFB yield and all yield components. TSP application increased FFB yield and single bunch weight. EFB only increased FFB yield.

Though treatment interactions both in 1998 and 1996 - 1998 were not statistically significant, yield two way tables indicate that higher responses to sulphate of ammonia are only seen in the presence of either P or EFB (Tables 2.74 and 2.76).

Table 2.73 Main effect of N, P, K, and EFB on yield and yield components in 1998 (Trial 511).

	Level of nutrient Element					Statistics	
					sig.	cv%	sed.
	N0	N1	N2	N3			
Yield (t/ha/yr)	12.1	14.9	15.4	17.1	**	23.1	1.21
Bunches/ha	823	908	898	967	ns	22	70
Bunch weight (kg)	14.6	16.4	17.2	17.9	**	10.9	0.64
	K0	K1	K2	K3			
Yield (t/ha/yr)	15.0	14.1	15.0	15.3	ns	23.1	1.21
Bunches/ha	926	865	896	909	ns	22	70
Bunch weight (kg)	16.3	16.2	16.6	16.9	ns	10.9	0.64
	P0	P1					
Yield (t/ha/yr)	14.3	15.5			ns	23.1	0.56
Bunches/ha	885	912			ns	22	50
Bunch weight (kg)	16.1	17.0			ns	10.9	0.45
	EFB0	EFB1					
Yield (t/ha/yr)	13.5	16.2			**	23.1	0.56
Bunches/ha	852	946			ns	22	50
Bunch weight (kg)	15.8	17.2			**	10.9	0.45

Table 2.74 FFB yield (t/ha/yr) two-way tables 1998 (Trial 511).

(a) NxP

		Level of N			
		N0	N1	N2	N3
Level of P	P0	11.4	14.5	15.1	16.0
	P1	12.7	15.2	15.6	18.3

Grand mean 14.9, Sed =1.71

(b) NxEFB

		Level of N			
		N0	N1	N2	N3
Level of EFB	EFB0	10.1	12.8	14.0	16.9
	EFB1	14.0	16.9	16.7	17.4

(c) NxP (absence of EFB) Sed = 2.42

		Level of N			
		N0	N1	N2	N3
Level of P	P0	9.9	12.2	14.3	14.5
	P1	10.4	13.4	13.8	19.3

(d) NxEFB (Absence of P)

		Level of N			
		N0	N1	N2	N3
Level of EFB	EFB0	9.9	12.2	14.3	14.5
	EFB1	12.9	16.8	15.9	17.6

Table 2.75 Main effects on N, P, K and EFB on yield and yield components in 1996-1998 (Trial 511).

		Level of nutrient and Element			Statistics		
					sig.	cv%	sed.
	N0	N1	N2	N3			
Yield (t/ha/yr)	14.1	17.3	19.5	20.7	***	12.4	0.79
Bunches/ha	977	1073	1121	1181	*	15.5	60
Bunch weight (kg)	14.5	16.3	17.5	17.7	***	8.6	0.50
	K0	K1	K2	K3			
Yield (t/ha/yr)	17.5	17.7	18.2	18.1	ns	12.4	0.79
Bunches/ha	1054	1112	1106	1079	ns	15.5	60
Bunch weight (kg)	16.6	16.0	16.5	16.8	ns	8.6	0.50
	P0	P1					
Yield (t/ha/yr)	17.1	18.7			*	12.4	0.56
Bunches/ha	1069	1107			ns	15.5	42
Bunch weight (kg)	16.0	16.9			*	8.6	0.35
	EFB0	EFB1					
Yield (t/ha/yr)	17.0	18.8			*	12.4	0.56
Bunches/ha	1050	1126			ns	15.5	42
Bunch weight (kg)	16.2	16.8			ns	8.6	0.35

Table 2.76 FFB yield (t/ha/yr) two-way tables 1996 - 1998 (Trial 511).

(a) NxP

		Level of N			
		N0	N1	N2	N3
Level of P	P0	13.6	16.2	18.9	19.7
	P1	14.6	18.4	20.1	21.6

Grand mean 17.9, Sed =1.11

(b) NxEFB

		Level of N			
		N0	N1	N2	N3
Level of EFB	EFB0	13.3	16.2	18.7	19.9
	EFB1	15.0	18.4	20.2	21.4

(c) NxP (absence of EFB) Sed = 1.57

		Level of N			
		N0	N1	N2	N3
Level of P	P0	13.0	15.3	17.8	18.3
	P1	13.6	17.0	19.6	21.5

(d) NxEFB (Absence of P) Sed = 1.57

		Level of N			
		N0	N1	N2	N3
Level of EFB	EFB0	13.0	15.3	17.8	18.3
	EFB1	14.3	17.1	19.9	21.1

Leaflet tissue analysis results are presented in Table 2.77. Sulphate of ammonia significantly increased leaflet N ($p<0.001$) and K ($p=0.007$) concentrations while lowering Ca ($p=0.03$) and Mg ($p=0.007$) concentrations. Muriate of potash increased Cl ($p=0.002$) and Ca ($p=0.023$) concentrations. Triple Superphosphate increased leaflet P ($p=0.008$) and Cl ($p=0.012$) while reducing K ($p=0.0012$) concentrations. EFB increased N ($p=0.003$), P ($p=0.003$) and K ($p=0.006$) concentrations.

In rachis tissue, sulphate of ammonia increased N but lowered P, Mg and Cl concentrations (Table 2.78). Muriate of potash increased rachis K, Ca and Cl concentrations. Triple Superphosphate increased rachis P concentration. EFB increased N, P and K but lowered Ca and Mg concentrations.

Table 2.77 Main effects of N, P, K, and EFB on the concentrations of elements in leaflet tissue of frond 17 in 1997 (Trial 511).

	Level of nutrient Element or EFB				Statistics sig.	cv%	sed.
	N0	N1	N2	N3			
N%	214	2.26	2.34	2.35	***	4.1	0.03
P%	0.135	0.138	0.139	0.140	ns	3.5	0.002
K%	0.65	0.66	0.70	0.73	**	7.9	0.02
Ca%	0.85	0.82	0.81	0.80	*	4.9	0.01
Mg%	0.38	0.36	0.33	0.31	**	12.8	0.02
Cl%	0.55	0.57	0.59	0.58	ns	9.0	0.02
B (ppm)	10.17	9.94	9.66	9.69	ns	7.0	0.25
	K0	K1	K2	K3			
N%	2.29	2.27	2.27	2.27	ns	4.1	0.03
P%	0.138	0.138	0.137	0.138	ns	3.5	0.002
K%	0.66	0.69	0.70	0.68	ns	7.9	0.02
Ca%	0.79	0.84	0.82	0.83	*	4.9	0.01
Mg%	0.35	0.36	0.34	0.33	ns	12.8	0.02
Cl%	0.51	0.60	0.60	0.58	**	9.0	0.02
B (ppm)	10.11	9.88	9.81	9.67	ns	7.0	0.25
	P0	P1					
N%	2.27	2.27			ns	4.1	0.02
P%	0.136	0.140			**	3.5	0.001
K%	0.70	0.66			**	7.9	0.01
Ca%	0.81	0.83			ns	4.9	0.01
Mg%	0.34	0.35			ns	12.8	0.01
Cl%	0.55	0.59			**	9.0	0.01
B (ppm)	9.86	9.87			ns	7.0	0.17
	EFB0	EFB1					
N%	2.22	2.32			**	4.1	0.02
P%	0.135	0.140			**	3.5	0.001
K%	0.66	0.71			**	7.9	0.01
Ca%	0.82	0.81			ns	4.9	0.01
Mg%	0.35	0.34			ns	12.8	0.01
Cl%	0.56	0.58			ns	9.0	0.01
B (ppm)	9.98	9.75			ns	7.0	0.17

Table 2.78 Main effects of N, P, K, and EFB on the concentration of elements in the rachis of frond 17 in 1998.

	Level of nutrient Element or EFB				Statistics sig.	cv%	sed.
	N0	N1	N2	N3			
N%	0.26	0.27	0.28	0.29	*	9.3	0.009
P%	0.082	0.061	0.051	0.049	***	28	0.006
K%	1.67	1.69	1.59	1.63	ns	13	0.08
Ca%	0.35	0.37	0.36	0.35	ns	6.4	0.01
Mg%	0.16	0.14	0.14	0.12	***	14.3	0.007
Cl%	1.29	1.27	1.18	1.17	*	9.5	0.04
B (ppm)	4.99	5.06	5.17	5.03	ns	5.4	0.10
	K0	K1	K2	K3			
N%	0.27	0.28	0.27	0.28	ns	9.3	0.009
P%	0.059	0.063	0.060	0.061	ns	28	0.006
K%	1.39	1.62	1.77	1.80	***	13	0.04
Ca%	0.35	0.37	0.35	0.36	*	6.4	0.08
Mg%	0.15	0.14	0.14	0.13	ns	14.3	0.007
Cl%	0.93	1.27	1.35	1.36	***	9.5	0.04
B (ppm)	5.07	5.11	4.97	5.10	ns	5.4	0.10
	P0	P1					
N%	0.27	0.28			ns	9.3	0.006
P%	0.044	0.077			***	28.0	0.004
K%	1.67	1.62			ns	13.0	0.05
Ca%	0.35	0.36			ns	6.4	0.01
Mg%	0.14	0.14			ns	14.3	0.005
Cl%	1.24	1.21			ns	9.5	0.03
B (ppm)	5.10	5.03			ns	5.4	0.07
	EFB0	EFB1					
N%	0.27	0.28			*	9.3	0.006
P%	0.054	0.067			**	28.0	0.004
K%	1.51	1.78			***	13.0	0.05
Ca%	0.37	0.35			**	6.4	0.01
Mg%	0.15	0.13			*	14.3	0.005
Cl%	1.21	1.24			ns	9.5	0.03
B (ppm)	5.10	5.03			ns	5.4	0.07

3. SOLOMON ISLANDS AGRONOMY

(A. Oliver)

Introduction

PNG Oil Palm Research assumed responsibilities for agricultural research and technical work in August 1998. One of PNGOPRA's primary responsibilities was to continue monthly ***Ganoderma*** census throughout SIPL plantations and to assist the sanitation program in collaborating with the SIPL Field Department. Two factorial fertiliser trials at Ngalimbiu and Mbalasuna continue to be managed.

A major issue towards the end of 1998, was the low extraction rates, and the high incidence of rat damage affecting palms (both fruits and seedlings. A series of observations commenced in December to establish whether rat damage was causing reductions in OER. This resulted in the setting up 18 observation plots through out SIPL. The work program has expanded. Other services were inherited from the previous FSD, and these include; Leaf sampling, soil sampling, and water sampling.

Staff

Total SIPL staff on seconded to OPRA is 13, consisting of 11 recorders, 1 senior field supervisor, Mr. Paul Awaikera and Helen Kasile, as Office supervisor. Mr. Allan Oliver, a Papua New Guinean is OPRA's Officer-in-Charge. He took up this position in mid August 1998.

Agronomy

Management of the two fertiliser trials continue as in the past, yield data for 1998 has been analysed and reported in this document.

- Trial 701 at Ngalimbiu has not shown a response to either sulphate of ammonia or muriate of potash application. The yield from the zero plots is higher than would be expected. The trial data suggests there is no benefit from fertiliser application. Poaching causes this lack of response, we believe. Our intention is to dig plot isolation trenches in the trial; this work is currently in progress.
- Trial 702 at Mbalasuna has shown yield responses to all three fertilisers applied; sulphate of ammonia, muriate of potash and Triple Superphosphate. Plot isolation trenches are also planned for this trial.
- Leaf sampling was carried out in April from selected plots only and bulked together under the same treatment. It is our intention to sample all plots commencing 1999.
- Fortnightly yield recording continued as scheduled.
- Vegetative measurement have not been carried out previously, this will commence in 1999. Included will be petiole WxT, full frond measurement and frond production counts.
- Fertiliser applications continue to be applied twice a year.

Pathology

A major activity for OPRA in the Solomon Islands is carry out research into Basal Stem Rot caused by Ganoderma. The European Union under the Stabex funding mechanism largely funds this research. The main thrust of the Ganoderma research is to develop effective strategies to control the disease. As part of this work, OPRA carries out disease census, this included 6 monthly surveys, covering the whole plantation, and 3 monthly surveys carried out in blocks where the highest incidences of *Ganoderma* have been recorded. A felling and sanitation programme follows the census, as a strategy to minimise the spread of the disease. This has worked well but can still be improved. The OPRA team is responsible for all the census work, while SIPL field department is responsible for all felling and sanitation work. Towards the end of 1998, SIPL purchased a total of 7 chainsaws and a major clean up of all backlogged sanitation work from past surveys was completed.

Entomology and other services

A major concern towards the end of 1998 was the low oil extraction rates being recorded. A number of investigations commenced to look into factors that may be causing low OER. A total of 18 observation plots were established to collect a data from which to determine the causes. Included in this data collection were rat trapping, weevil emergence counts, and observations of bunch characteristics. Dr Rob Caudwell, PNGOPRA and Professor Menzies, University of PNG made visits, to determine the rat species involved in damaging both young seedlings and fruit bunches.

TRIAL 701 NITROGEN AND POTASSIUM FACTORIAL TRIAL AT NGALIMBIU DIVISION

PURPOSE

To investigate the response of oil palm to applications of N and K fertiliser.

DESCRIPTION

Site: Ngalimbiu Division block 22

Soil: Metapona soil system, which is of recent alluvial deposit, with silty clay loam over loam.

Palms: Dami commercial DxP crosses. Planted 1989 at 120 palms/ha. Trial commenced in 1996.

DESIGN

There are 48 plots each with a core of 16 recorded 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.

The 48 plots are divided into three replicates each containing 16 treatments made up from all factorial combinations of four levels each of N and K (Table 3.1). Sulphate of ammonia (SoA) is the source of N, and muriate of potash (MoP) is the source of K.

Table 3.1 Amounts of fertiliser used in Trial 701 in 1998.

Type of fertiliser	Amount (kg/palm/year)			
	Level 0	Level 1	Level 2	Level 3
Sulphate of ammonia	0.0	2.0	4.0	6.0
Muriate of potash	0.0	2.0	4.0	6.0

Notes: SoA and MoP have been applied twice a year since 1996.

RESULTS

The average FFB yield for all plots in the trial in 1998 was 30.1 t/ha as compared to 31.7 t/ha in 1997. Over the last three years an average yield of 25.5 t/ha was recorded.

There were no responses to either sulphate of ammonia or muriate of potash application. FFB yields in the trial were high in 1998, mostly above 30t/ha. Yields are high even in the control plots, and it appears that there is no benefit from the fertiliser applied. It is felt that inter-plot poaching of applied nutrients may be responsible for the lack of observable response. Plot isolation trenches are being put in place in order to isolate treatment effects.

Tables 3.3 and 3.5 illustrate the N x K interactions, but these were not statistically significant in 1998 or for the three year period 1996-1998.

Table 3.2 Main effects of N and K on yield and yield components in 1998 (Trial 701).

	Nutrient Element and level				Statistics		
					sig.	Cv%	Sed
	N0	N1	N2	N3			
Yield (t/ha/yr)	30.5	29.3	29.3	31.4	ns	13.5	1.66
Bunches/ha	1366	1346	1350	1475	ns	16.7	94
Bunch weight (kg)	22.5	21.8	21.7	21.7	ns	7.7	0.69
	K0	K1	K2	K3			
Yield (t/ha/yr)	30.1	30.5	30.1	29.8	ns	13.5	1.66
Bunches/ha	1353	1392	1466	1324	ns	16.7	94
Bunch weight (kg)	22.3	22.0	20.9	22.6	ns	7.7	0.69

Table 3.3 Effect of combinations of N and K on yield in 1998 (Trial 701).

	FFB Yield (t/ha/yr)			
	Level of N			
Level of K	**N0**	**N1**	**N2**	**N3**
K0	27.2	28.7	32.8	31.8
K1	31.6	30.4	27.6	32.3
K2	30.5	29.2	29.4	31.1

Grand Mean: 30.1 Standard Error: NxK=3.31
All interactions were not significant.

Table 3.4 Main effects of N and K on yield and yield components in 1996 – 1998 (Trial 701).

	Nutrient Element and level				Statistics		
					sig	Cv%	Sed
	N0	N1	N2	N3			
Yield (t/ha/yr)	25.6	25.2	25.2	26.1	ns	8.4	0.87
Bunches/ha	1223	1182	1192	1272	ns	11.7	58
Bunch weight (kg)	21.1	21.5	21.1	20.7	ns	6.4	0.55
	K0	K1	K2	K3			
Yield (t/ha/yr)	25.4	25.6	25.7	25.4	ns	8.4	0.87
Bunches/ha	1180	1224	1276	1189	ns	11.7	58
Bunch weight (kg)	21.6	21.0	20.4	21.4	ns	6.4	0.55

Table 3.5 Effects of combinations of N and K on yield in 1996-1998 (Trial 701).

	Yield (t/ha/yr)			
	Level of N			
Level of K	**N0**	**N1**	**N2**	**N3**
K0	23.8	24.3	26.8	26.5
K1	26.7	25.8	23.8	26.2
K2	25.9	25.6	25.2	26.2
K3	26.1	25.1	24.8	25.7

Grand mean = 25.5 Standard error NxK=1.74
Interactions were not significant.

Leaflet tissue sampling was carried out in March 1998, from the 00, 11, 22, 33 treatment combinations (Table 3.6). These were bulk together and sent for analysis.

Table 3.6 Treatment combination effects on leaflet nutrient concentrations in 1998 (Trial 701).

Elements as %	Nutrient Element and Level			
of dry matter	N0K0	N1K1	N2K2	N3K3
Nitrogen	2.28	2.32	2.44	2.48
Phosphorus	0.160	0.156	0.159	0.159
Potassium	0.77	0.72	0.70	0.70
Calcium	0.91	0.92	0.96	1.00
Magnesium	0.33	0.32	0.32	0.32
Sulphur	0.16	0.16	0.17	0.17

TRIAL 702 NITROGEN, PHOSPHATE AND POTASSIUM FACTORIAL TRIAL AT MBALASUNA DIVISION

PURPOSE

To investigate the response of oil palm to N, P and K fertilisers

DESCRIPTION

Site: Mbalasuna Division, Block 70.

Soil: Kongga soil system; Typic Haplustalf Pleistocene sediments mostly derived from basic volcanic material. Most stony red lateritic soil

Palms: Dami commercial DxP crosses. Planted 1988 at 136 palms/ha. Trial commenced in 1996.

DESIGN

There are 54 plots each with a core of 16 recorded 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.

The 54 plots are divided into two replicates each containing 27 treatments made up from all factorial combinations of three levels each of N, P and K (Table 3.7). Sulphate of ammonia (SoA) is the source of N, Triple Superphosphate (TSP) is the source of P and muriate of potash (MoP) is the source of K.

Table 3.7 Amounts of fertiliser applied in Trial 702 in 1998.

Type of fertiliser	Amount (kg/palm/year)		
	Level 0	Level 1	Level 2
Sulphate of ammonia	0.0	2.0	4.0
Triple Superphosphate	0.0	2.0	4.0
Muriate of potash	0.0	2.0	4.0

Notes: SoA, TSP and MoP have been applied twice a year since 1996.

RESULTS

The average plot yield in 1998 was 18.2 t/ha.

There were significant responses to sulphate of ammonia, Triple Superphosphate and muriate of Potash application which resulted in increased FFB yield, single bunch weight and bunch number in 1998.

The effects of combinations of N and K fertiliser are presented in Table 3.8. A maximum yield of 21.6 tons/ha with 4 kg of SoA and 2 kg of MoP was achieved in 1998.

The cumulative data for the period 1996 to 1998 also shows a significant effect of sulphate of ammonia, Triple Superphosphate and muriate of potash that was caused by increases in both bunch number and single bunch weight. In 1997 only responses to nitrogen fertiliser were observed. Yield data shows that the response to all three fertilisers is linear, and a maximum yield of 16.7 t/ha is achieved with application of 4kg of sulphate of ammonia and 4 kg of muriate of potash. The yield is low even under a high fertiliser input regime.

Table 3.9 Main effects of N, P and K on yield and yield components in 1998 (Trial 702).

	Level of nutrient elements			Statistics		
				sig	Cv%	Sed
	N0	N1	N2			
Yield (t/ha/yr)	16.1	18.5	20.1	*	22.4	1.36
Bunches/ha	1105	1236	1281	*	22.6	90
Bunch weight (kg)	14.5	15.0	15.9	*	15.2	0.77
	P0	P1	P2			
Yield (t/ha/yr)	15.9	19.3	19.5	**	22.4	1.36
Bunches/ha	1129	1236	1257	ns	22.6	90
Bunch weight (kg)	14.0	15.7	15.6	*	15.2	0.77
	K0	K1	K2			
Yield (t/ha/yr)	15.9	19.3	19.4	**	22.4	1.36
Bunches/ha	1082	1274	1266	**	22.6	90
Bunch weight (kg)	14.7	15.1	15.5	ns	15.2	0.77

Table 3.10 Effect of combinations of N and K on yield in 1998 (Trial 702).

	Yield (t/ha/yr)		
Level of K	Level of N		
	N0	N1	N2
K0	13.8	16.7	17.3
K1	16.5	19.6	21.6
K2	17.9	19.2	21.3

Grand Mean: 18.2 Standard Error: NxK=2.35
Interactions were not statistically significant.

Table 3.11 Main effects of N, P and K on yield and yield components in 1996 – 1998 (Trial 702).

	Level of nutrient elements			Statistics		
				Sig.	Cv%	Sed
	N0	N1	N2			
Yield (t/ha/yr)	13.2	15.2	16.1	**	19.0	0.94
Bunches/ha	989	1102	1127	*	18.0	64
Bunch weight (kg)	13.2	13.8	14.5	*	13.5	0.62
	P0	P1	P2			
Yield (t/ha/yr)	13.4	15.3	15.8	**	19.0	0.94
Bunches/ha	1027	1087	1104	ns	18.0	64
Bunch weight (kg)	13.0	14.2	14.3	*	13.5	0.62
	K0	K1	K2			
Yield (t/ha/yr)	13.5	15.4	15.5	*	19.0	0.94
Bunches/ha	997	1105	1116	*	18.0	64
Bunch weight (kg)	13.6	13.9	14.0	ns	13.5	0.62

Table 3.12 Effects of combinations of N and K on yield in 1996-1998 (Trial 702).

	Yield (t/ha/yr)		
Level of K	Level of N		
	N0	N1	N2
K0	12.2	14.2	14.2
K1	13.1	15.8	15.6
K2	14.2	15.6	16.7

Grand mean = 14.8 Standard error NxK=1.62
Treatment interactions were not statistically significant.

Leaflet tissue sampling was carried out in 1998 and samples were bulked together under the three treatment combinations; 000, 111 and 222 (NPK).

Applications each of the three fertilisers increased leaflet concentrations of nitrogen, phosphorus and potassium.

Table 3.13 Treatment main effects on leaflet nutrient concentrations in 1998 (Trial 702).

Element as % of	Nutrient element and levels		
Dry matter	N0P0K0	N1P1K1	N2P2K2
Nitrogen	2.16	2.16	2.40
Phosphorus	0.147	0.155	0.159
Potassium	0.45	0.56	0.66
Calcium	0.94	0.92	0.92
Magnesium	0.53	0.49	0.40
Sulphur	0.15	0.16	0.16

4. SMALLHOLDER DEMONSTRATION TRIALS.

ISLANDS REGION

(G. King)

TRIAL 210 BENCHMARK/DEMONSTRATION OF RECOMMENDED MANAGEMENT AND FERTILISER APPLICATION ON OIL PALM SMALLHOLDINGS IN THE BIALLA SCHEME

PURPOSE

To determine if there is a requirement for fertiliser input and if so determine the type of fertiliser required. To demonstrate that good agronomic management and correct use of fertilisers can increase or maintain relatively high levels of FFB production.

DESCRIPTION

Site: Experiment 210 is located on OPIC's Bialla Smallholder Oil Palm Project covering areas between Bereme and NBPOL's Kapiura Plantations Pty Ltd in the west to Noau and Hargy's Navo Plantation east of Bialla township. Initially there were 23 selected blocks in this trial. However, the trials in the Kapiura area of the project were closed down at the end of 1997 as these growers were all receiving fertiliser from the milling company and no longer wanted to participate in the trial. Sites were maintained at Balima, Kiava and Soi only in 1998. These are areas that were not receiving fertiliser from the milling companies.

Palms: Dami commercial DxP planting material.
Planted in various dates the between 1984 and 1991 at 120 palms/ha.
Treatments started in July 1994.

DESIGN

Each of the 2 paired smallholder blocks provides a single replicate. There are three treatments (Table 4.1). With the first pair, half of the block received no fertiliser at all (control - RED) and the remaining half received the recommended (demonstration - YELLOW) type and amount of fertiliser for the smallholder. With the second pair, half of the block again received no fertiliser at all (control - RED), and the remaining half received generous amounts (2kg) of <u>all</u> main types (N, P, K, Mg - WHITE) of fertiliser.

Table 4.1 Treatments used in Trial 210

	Type of Fertiliser (kg/palm/year)			
Treatment Colour Code	Ammonium Chloride	Triple Superphosphate	Muriate of Potash	Kieserite
Red	0	0	0	0
Yellow	2	0	0	0
White	2	2	2	2

Fertiliser is applied twice a year in May and November. The whole block is harvested in the normal way for a smallholder block and the weight of the fruit recorded by the transport company in each project at the time of pick up. Trenches are dug between the two fertiliser treatments to minimise fertiliser poaching by palms in the untreated blocks. Frond 17 leaflet and rachis samples were taken

for analysis in 1998.

As in the other smallholder trial areas the yield recording system collapsed once the growers started receiving fertiliser under the milling company sponsored credit scheme. Yield data was collected from 6 blocks only in 1998 and even then not for the whole year. As explained in previous annual reports it was almost impossible to collect reliable yield data as the fruit truck operators rarely put the colour codes on the field docket.

Table 4.2 Details of 6 smallholder demonstration blocks in the Bialla Smallholder Oil Palm Project area of West New Britain Province in 1998.

Division	Sect	Owner	Block Number	Number of Palms		
				Red	Yellow	White
Kiava	VOP	Monais Taba	1122	116		133
Kiava	VOP	Laili Taga	1123	131	132	
Balima	LSS	Benedict Ikinaka	1273	241		262
Balima	LSS	Augustus Eremas	1274	259	247	
Soi	10	Jan Moris	1651	124	120	
Soi	10	Raphael Moute	1653	125		126

RESULTS

1998 yield results for Trial 210 are given in Table 4.3.

Table 4.3 Yield results for Trial 210 in 1997

Division	Sect	Block No.	No months harvesting recorded	Calculated Yield (t/ha/yr)		
				Control	N only	NPKMg
Kiava	VOP	1122	4	15.2		22.6
Kiava	VOP	1123	4	19.3	26.6	
Balima	LSS	1273	5	12.6		14.9
Balima	LSS	1274	5	6.92	10.9	
Soi	10	1651	5	14.5	20.4	
Soi	10	1653	4	30.5		37.2
			Mean	16.5	19.3	24.9

The calculated yield figures given above should be treated with some caution as they have been extrapolated from only 4 or 5 months data. They do however show quite clearly that yields increase with addition of nitrogen as well as to the complete nitrogen, phosphorus, potassium and magnesium treatment.

Tissue sampling was completed in October 1998 and the results are given in the Table 4.4. These results show that leaflet N increased with application of ammonium chloride but levels are still well below optimum.

Leaflet and rachis K levels in the control plots at Balima and Soi were very low. Addition of K led to an increase in both leaflet and rachis K. It is likely that a yield response to K could be expected at these sites.

Leaflet P increased slightly with the addition of TSP. Leaflet Mg levels were generally adequate. Chlorine levels increased with the addition of chloride fertilisers.

Rachis K increased with the addition of ammonium chloride and with muriate of potash. Rachis chlorine increased with the addition of chloride.

Table 4.4 Leaflet and rachis nutrient concentrations (% on dry matter) from Trial 210 in 1998.

Block No.	Treat	Leaflet						Rachis
		N	P	K	Ca	Mg	Cl	K
1122	Control	2.03	0.138	1.01	0.72	0.13	0.15	1.34
1122	NPKMg	2.35	0.149	0.83	0.81	0.15	0.52	1.52
1123	Control	2.22	0.148	1.05	0.72	0.25	0.18	1.18
1123	N only	2.31	0.145	0.91	0.88	0.18	0.47	1.28
1273	Control	2.06	0.141	0.83	0.67	0.27	0.32	0.93
1273	NPKMg	2.18	0.144	0.55	0.70	0.30	0.60	0.85
1274	Control	2.20	0.122	0.41	0.79	0.45	0.60	0.22
1274	N Only	2.25	0.136	0.65	0.59	0.32	0.45	0.55
1651	Control	2.23	0.149	0.91	0.99	0.25	0.18	1.07
1651	N only	2.48	0.159	0.81	1.13	0.24	0.62	0.91
1653	Control	2.22	0.145	0.99	0.74	0.19	0.29	1.07
1653	NPKMg	2.44	0.160	0.81	0.98	0.21	0.71	1.47

TRIAL 255 SMALLHOLDER SURVEY IN NEW IRELAND PROVINCE

PURPOSE

To determine nutrient status of smallholder oil palm in New Ireland

BACKGROUND

Smallholder FFB production in New Ireland has been very poor to date. The factorial trials on the estates at Poliamba show very clearly that potassium is the main limiting nutrient and that quite high yields can be achieved with the application of muriate of potash. For a number of mainly administrative reasons smallholders in New Ireland have not had access to fertiliser since their palms were planted. Up until the end of 1997 PNGOPRA had two fertiliser trials on smallholder blocks. These trials clearly showed the benefits of application of potassium. The trials also indicated that there was also a response to phosphorus. These trials were closed down at the end of 1997 so that resources could be put into smallholder surveys that would provide more information regarding the nutritional status of smallholder oil palms in New Ireland.

DESIGN

There are over 450 smallholder growers in New Ireland with approximately 1,100ha planted. A database of growers was available from OPIC giving information on the grower and date of planting for each smallholder. It was decided to sample 50 growers from the project and this sample was selected by taking a 1 in 6 sample from the list of 300 growers who had planted oil palm in 1991, 92, 93 or 94. These blocks were all visited over a 3-month period in 1998 and leaflet and rachis samples were collected for analysis from 47 of the 50 selected blocks. The three blocks not sampled were severely damaged by fire in 1997 and had not sufficiently recovered to be able to take tissue samples. Information on fertiliser application and road access was obtained from OPIC records and 1998 production and income records were obtained from Poliamba Ltd. records.

RESULTS

Mean leaflet and rachis nutrient concentrations are given in Tables 4.5 and 4.6. Leaflet N, P, Ca, Mg and Cl levels were adequate. Leaflet K levels are low. Mean rachis K level was only 0.29%. This is very low. The lowest level of rachis K recorded was just 0.10%.

Table 4.5. Leaflet nutrients recorded in 47 smallholder blocks in New Ireland.

	Nutrient Level (%)						
	Ash	N	P	K	Ca	Mg	Cl
Mean	7.58	2.43	0.165	0.58	1.14	0.39	0.60
SE	0.13	0.02	0.002	0.02	0.02	0.01	0.02
Min	5.91	2.20	0.126	0.28	0.71	0.26	0.30
Max	9.96	2.76	0.178	1.03	1.41	0.56	0.85

Table 4.6. Rachis nutrient levels in 47 smallholder blocks in New Ireland.

	Nutrient Level (%)						
	Ash	N	P	K	Ca	Mg	Cl
Mean	2.65	0.26	0.086	0.29	0.52	0.17	0.28
SE	0.05	0.003	0.004	0.03	0.02	0.01	0.02
Min	1.7	0.21	0.040	0.10	0.28	0.09	0.06
Max	3.71	0.31	0.150	1.10	0.78	0.30	0.82

There are 4 divisions in the New Ireland smallholder project. Mean leaflet and rachis nutrient levels for each division are given in Tables 4.7 and 4.8.

There is very little variation between divisions. Potassium levels were lowest in Notsi division and highest in the West Coast division.

Table 4.7. Mean leaflet nutrient levels in each of the 4 divisions in New Ireland

	Division			
Nutrient (%)	Kara	Nalik	Notsi	West Coast
Ash	7.74	7.53	7.90	6.65
N	2.38	2.46	2.40	2.56
P	0.160	0.170	0.166	0.166
K	0.60	0.58	0.48	0.70
Ca	1.11	1.12	1.19	1.10
Mg	0.38	0.38	0.43	0.38
Cl	0.57	0.65	0.68	0.44
Count	19	12	11	5

Table 4.8. Mean rachis nutrient levels in each of the 4 divisions in New Ireland

	Division			
Nutrient (%)	Kara	Nalik	Notsi	West Coast
Ash	2.75	2.51	2.68	2.42
N	0.26	0.26	0.26	0.24
P	0.078	0.092	0.092	0.093
K	0.36	0.24	0.18	0.41
Ca	0.55	0.54	0.59	0.46
Mg	0.17	0.17	0.20	0.13
Cl	0.31	0.29	0.26	0.14
Count	19	12	11	5

Production data for the 47 blocks is summarised in Table 4.9. Mean yield for all blocks was 4.34 t/ha. Nalik division had the highest mean yield of 7.06 t/ha. These low yields reflect the poor potassium status of the smallholder palms in New Ireland.

Table 4.9. FFB production for 47 smallholder blocks in New Ireland in 1998

	All Sites		Kara		Nalik		Notsi		West Coast	
	Total T FFB	Yield (t/ha)	Total t FFB	Yield (t/ha)	Total t FFB	Yield (t/ha)	Total t FFB	Yield (t/ha)	Total t FFB	Yield (t/ha)
Mean	9.93	4.34	8.64	4.05	17.6	7.06	6.02	2.54	5.00	2.84
Min	0	0	0	0	1.73	0.87	0	0	0.50	0.25
Max	48.65	14.63	42.23	14.08	48.65	14.63	12.1	6.05	6.45	5.52
SE	1.68	0.59	2.78	1.01	4.10	1.28	1.40	0.56	1.14	0.85
Count	47	47	19	19	12	12	11	11	5	5

Smallholder income data for 1998 was obtained from the milling company for each of the 47 blocks. Mean income per hectare in 1998 was K614. Income was highest in the Nalik division where the mean income for the 12 growers surveyed was K1016.

Table 4.10. Income from oil palm for 47 smallholder blocks in New Ireland in 1998

	All Sites		Kara		Nalik		Notsi		West Coast	
	Total Kina	K/Ha	Total Kina	K/Ha	Total Kina	K/Ha	Total Kina	K/Ha	Total Kina	K/Ha
Mean	1409	614	1213	567	2537	1016	831	349	718	409
Min	0	0	0	0	277	138	0	0	77	38
Max	7239	2062	5725	1908	7239	2062	1603	798	917	800
SE	240.7	83.8	386.5	140.6	600.5	185	191	75.1	161.7	124.0
Count	47	47	19	19	12	12	11	11	5	5

The production levels in Nalik division are much higher than in any other division. The best growers in New Ireland are found in one village within Nalik division. At Kafkaf village 21 growers produced 467.7 tonnes of FFB worth a total of K67,548. Total production in the New Ireland project in 1998 was only 2,400 tonnes of FFB. The best grower in New Ireland also came from Kafkaf village. He produced 70.27 tonnes of FFB from 5 ha in 1998 giving that grower a total income of K9907.89 for the year or K1982 per hectare. This compares with an average income per hectare of K2189 in the Hoskins scheme in 1998.

Yield and income figures were calculated for each of the 47 blocks depending on road access and whether fertiliser was applied in 1998. This information is given in Table 4.11 showing that road access and fertilisers are the major limiting factors affecting FFB production in New Ireland.

Table 4.11. Production and income from 47 blocks in New Ireland – Road access and fertiliser.

	Yield (t/ha)	Income (K/ha)
Road Access		
No Road	1.99	278
Poor	1.85	260
Good	5.93	842
Fertiliser		
None	2.37	330
Applied	7.24	1031
Good Road & No Fertiliser	3.41	474
Good Road & Fertiliser Applied	8.11	1160

TRIAL 314 SMALLHOLDER DEMONSTRATION TRIALS – POPONDETTA/ORO EXPANSION PROJECTS.

PURPOSE

To demonstrate the correct use of fertilisers to improve and maintain yield.

DESCRIPTION

Site: Experiment 314 is located on OPIC's Popondetta and Oro Expansion Oil Palm projects. The 10 blocks are located at Sorovi, Aeka and Illimo divisions. Details of each block are given in Table 4.13.

Palms: Dami commercial DxP planting material at 130 palms/ha.
Planted between 1979 and 1993.
Treatments commenced between 1994 and1997.

DESIGN

Each of the Smallholder blocks was divided in two halves. Half of the block (demonstration - RED) receives the recommended type and amount of fertilizer (3kg/palm/year - SoA) while the other half (control - YELLOW) does not (Table 4.12)

Table 4.12 Treatments used in Trial 314

Treatment	Type of Fertiliser (kg/palm/year) Sulphate of ammonia
Treated (Red)	3.0
Control (Yellow)	0.0

Fertilizer was applied three times a year in February, July and December. A trench was dug between the two plots to minimise fertilizer poaching by palms from the untreated plot. Initially yields were recorded by weighing individual bunches harvested during each round. The whole block was harvested during the normal transport schedule but the bunches were left under the trees in each plot. OPRA recorders then recorded the weights of the bunches from both plots before the owner loaded the bunches onto the nets, ready for pickup by transport. This system did not work and a simpler system was introduced during 1998. At each harvest, the block owner harvests and removes the bunches to the nets ready for pick up. The numbers of stalks are counted by OPRA from each half block. Bunch weights are recorded four times a year only. The weight of nets recorded by the Transport Company is then apportioned to each half block depending on the number of stalks and average bunch weight.

Even this system did not always work as it all depends on the cooperation of the grower and the Transport Company.

Table 4.13 Details of 10 smallholder demonstration sites in the Popondetta Smallholder Oil Palm Project areas of Oro Province.

Division	Owner	Block number	Number of palms	
			Red	Yellow
Sorovi	Bray Kivigi	260002	250	232
Sorovi	Hamilton Bakovo	121779	253	231
Sorovi	Richie Abraham	610047	61	60
Sorovi	Nathaniel Aiga	610024	131	128
Sorovi	Manauwe Amitake	040266	117	124
Isavene	Nelson Mungeron	580007	236	246
Igora	Johnson Ejavo	111578	324	155
Saiho	Kingsford Penunu	390001	281	204
Illimo	Kingsley Isoro	670014	148	118
Illimo	Allen Jirekari	670015	135	120

Yields recorded in 1998 are reported in Table 4.14. Even though the recording system failed in most cases, yields are higher in the treated (RED) blocks at every site. As in West New Britain each grower involved in the trial testifies that the fertilised side of his block gives higher yields than the side with no fertiliser.

Table 4.14 Yield results for Trial 314 in 1998.

Division	Block number	No harvest recorded	Recorded Yield (t/ha/yr)	
			Red	Yellow
Sorovi	260002	4	2.8	0.3
Sorovi	121779	8	11.9	9.0
Sorovi	610047	0		
Sorovi	610024	0		
Sorovi	040266	6	13.8	7.0
Isavene	580007	10	15.8	8.3
Igora	111578	6	4.6	3.4
Saiho	390001	21	21.5	11.6
Illimo	670014	0		
Illimo	670025	0		
		Mean	11.73	6.60
		Maximum	21.50	11.60
		Minimum	2.80	0.30
		s.e.	2.87	1.67

Leaflet and rachis samples were taken from each block and analysed for nutrient content in 1998. The results of this analysis are given in Table 4.15 below. These results show that leaflet N, P, K and Cl and rachis K and Cl increased with application of SoA. Leaflet Ca and Mg decreased. Leaflet N levels are still very low even after several years of N application. K levels are also very low in some cases and it would be expected that application of MoP in these areas would result in an increase in yield. Chlorine levels are also low.

Table 4.15 Descriptive statistics of leaflet and rachis nutrient concentration (% of dry matter).

Nutrient	Treatment	Mean	Minimum	Maximum	Std Error
Leaflet N	Control	1.96	1.60	2.35	0.07
	N only	2.10	1.88	2.35	0.05
Leaflet P	Control	0.126	0.115	1.143	0.091
	N only	0.139	0.129	0.155	0.002
Leaflet K	Control	0.62	0.41	0.83	0.038
	N only	0.66	0.43	0.83	0.038
Leaflet Ca	Control	0.78	0.63	0.93	0.030
	N only	0.75	0.56	0.92	0.036
Leaflet Mg	Control	0.26	0.18	0.39	0.017
	N only	0.24	0.16	0.36	0.020
Leaflet Cl	Control	0.27	0.12	0.39	0.021
	N only	0.33	0.13	0.43	0.027
Rachis K	Control	0.90	0.14	1.47	0.138
	N only	0.97	0.13	1.52	0.146
Rachis Cl	Control	0.24	0.06	0.55	0.047
	N only	0.29	0.05	0.67	0.056

The results from 10 blocks cannot be extrapolated to the whole scheme, as 10 are not a sufficiently representative sample of over 4000 growers. The results that have been obtained strongly suggest that continued N amelioration is essential for smallholder oil palm production in Oro Province. However, it is impossible to determine whether P, K, Mg or Cl is also limiting yield. The leaf and rachis analysis results suggest that K and Cl are limiting but as these results are only from 10 blocks it is not possible to make any recommendations for these elements.

TRIAL 506 SMALLHOLDER DEMONSTRATION TRIALS - MILNE BAY PROVINCE

PURPOSE

To demonstrate the importance of fertiliser application to smallholder growers in Milne Bay Province.

DESCRIPTION

There are 6 blocks chosen with the help of OPIC extension officers for use as demonstration blocks for other growers. Block details are summarised in Table 4.16 below.

Table 4.16 Details of Demonstration Sites

Location	Block Number	Site Description	Density & Ha
Waima	07020	On footslope	127
Giligili	05006	Alluvial Plain	127
Kerakera	01022	Alluvial Plain	127
Naura	04016	Alluvial Plain	127
Ata ata	17009	On footslope	127
Sagarai	22001	Alluvial Plain	120

The demonstration blocks were started in 1995 and were trenched dividing the block into 2 with half receiving the recommended fertilisers application rate (1.5 kg SoA and 2.0 kg MoP) (Demo plot) and the other half receiving nil fertiliser (Control plot). The rates were increased to 2 kg SoA and 2.5 kg MoP per palm per year in 1998. Yield recordings are done fortnightly and done separately for fertilised and unfertilised plots by the milling company and OPIC. Leaf and rachis tissues have been taken annually for analysis.

RESULTS

As with the smallholder trials in other project areas accurate yield recording has not been possible. Bunch weights were either not recorded properly or the bunches from the control plots were mixed with those from the demo plots by the growers or a combination of both. Bunch numbers were determined by going through the blocks after every harvest and counting the cut stalks on each palm in a block. A summary of records is shown in Table 4.17. 1996 was the first year after treatments were first applied and although yield data were accurately recorded in that year it is unlikely that the fertiliser treatments would have had any effect at such an early stage. The very low bunch number recorded in 1998 is due to the low crop experienced during the year following on from the drought in 1997.

From 1997 to 1998 bunch weight recordings were not done and only bunch numbers records were collected. Results for 1996 to 1998 are shown in Table 4.18. The number of bunches in all the blocks for the 3 years were higher in fertilised plots than in control plots. In 1998 bunch numbers were markedly reduced both in the fertilised and non-fertilised plots. However, bunch numbers in fertilised plots were still higher than in the control plots indicating the importance of fertilisers in maintaining higher yields even after long dry periods. The reduced crop was also reported from estate plantings and estate formal trials in both Gumini and Sagarai Valleys.

Table 4.17 Records of Bunch numbers and Yield Recordings.

Year	Number of Records	
	Bunch Number	Bunch Weight
1996	65 (100%)	56 (86%)
1997	62 (95%)	8 (12%)
1998	47 (72%)	0 (0%)

Table 4.18 Yield Records for 1996 to 1998.

Block	1996				1997		1998	
	Control		Demo		Control	Demo	Control	Demo
	BN/Ha	Y (t/ha)	BN/Ha	Y (t/ha)	BN/Ha	BN/Ha	BN/Ha	BN/Ha
1022	1075	12.3	1218	12.9	856	961	316	433
4016	786	9.6	816	10.9	679	710	294	340
5006	1101	13.1	1170	13.5	937	1175	640	688
7020	567	1.7	721	4.3	429	536	341	359
17009	697	10.4	1058	15.9	896	1101	332	623
22001	1229	16.7	1200	15.6	1635	1725	1032	916
Mean	909	9.11	1030	10.44	905	1035	493	560
Min	567	1.7	721	4.3	429	536	294	340
Max	1229	16.7	1218	15.9	1635	1725	1032	916
s.e.	107.1	3.0	86.8	1.8	164.7	169.3	120.0	91.7

Leaf and rachis tissue analysis from the demonstration sites were done in 1995, 1996, 1997 and 1998 and the results are presented in Tables 4.19, 4.20, 4.21 and 4.22 respectively.

Blocks 01022 (Kerakera) and 04016 (Naura) are located on alluvial flood plains in the Gumini Valley and are old systematic trial sites. These sites therefore have received fertilisers of varying amounts prior to the new design being imposed on them. Palms sampled randomly in either of the plots may have previously been receiving varying rates of fertilisers and therefore results are not comparable especially for tissue analysis done in 1996 and probably in 1997 as well.

Blocks 17009 (Ata ata) and 07020 (Waima) are located in the seepage zones a the base of the slopes and the therefore presence of water logged conditions is a major limiting factor. Blocks 05006 (Giligili) and 22001 (Sagarai) are on alluvial plains and on sites that have high fertility.

Leaf N and K levels in both unfertilised and fertilised plots in blocks located in the seepage zones generally are lower than those on the alluvial plains. Water logged conditions appear to be the major limiting factor. Drainage at these sites will be of little help because the sites are located on the footslopes of hills where water seepage is a major characteristic.

In 1996 and 1997, K levels in the both the leaflets and rachis was low and did not seem to respond to K fertiliser, however, responses are seen in the rachis. In 1998 the mean nutrient levels were low and there appears to be no response to the fertilisers.

On the whole leaf nutrient levels were low in 1998 indicating palms were still probably recovering from the long dry season experienced in 1997 and early 1998.

Table 4.19 1995 Tissue Analysis Results (%DM).

Block	Leaflet												Rachis	
	N %		P%		K%		Ca%		Mg%		Cl%		K%	
	C	D	C	D	C	D	C	D	C	D	C	D	C	D
1022	2.34	2.46	0.160	0.160	0.73	0.71	0.96	0.97	0.42	0.42	0.53	0.53	0.63	0.85
4016	2.64	2.48	0.171	0.159	0.75	0.75	0.99	0.92	0.41	0.38	0.51	0.54	0.79	0.81
5006	2.58	2.67	0.143	0.163	0.69	0.79	0.87	0.93	0.38	0.43	0.59	0.66	0.79	0.63
17009	2.37	2.59	0.139	0.160	0.69	0.79	0.95	0.98	0.43	0.48	0.68	0.66	0.67	0.67
7020	2.19	2.08	0.145	0.141	0.75	0.79	0.93	0.95	0.42	0.43	0.43	0.45	0.79	0.99
22001	2.72	2.69	0.172	0.162	0.93	0.85	0.98	0.94	0.29	0.30	0.54	0.59	1.20	1.34
Mean	2.47	2.50	0.155	0.158	0.76	0.78	0.95	0.95	0.39	0.41	0.55	0.57	0.81	0.88
Min	2.19	2.08	0.139	0.141	0.69	0.71	0.87	0.92	0.29	0.30	0.43	0.45	0.63	0.63
Max	2.72	2.69	0.172	0.163	0.93	0.85	0.99	0.98	0.43	0.48	0.68	0.66	1.20	1.34
se	0.08	0.09	0.006	0.003	0.04	0.02	0.02	0.01	0.02	0.02	0.03	0.03	0.08	0.11

Table 4.20 1996 Leaf Tissue Results (% DM).

Block	Leaflet												Rachis	
	N %		P%		K%		Ca%		Mg%		Cl%		K%	
	C	D	C	D	C	D	C	D	C	D	C	D	C	D
1022	2.36	2.37	0.150	0.153	0.65	0.77	0.74	0.79	0.34	0.36	0.47	0.48	0.71	0.97
4016	2.41	2.41	0.147	0.149	0.63	0.71	0.74	0.76	0.35	0.34	0.50	0.50	0.91	0.73
5006	2.30	2.42	0.15	0.15	0.75	0.75	0.77	0.82	0.37	0.42	0.58	0.59	0.81	0.71
17009	2.01	2.03	0.131	0.138	0.61	0.71	0.82	0.80	0.42	0.45	0.57	0.58	0.61	0.75
7020	2.12	2.29	0.140	0.145	0.63	0.73	0.79	0.79	0.40	0.39	0.45	0.50	0.83	0.85
22001	2.65	2.81	0.154	0.163	0.81	0.81	0.78	0.82	0.27	0.31	0.44	0.55	1.22	1.34
Mean	2.31	2.39	0.145	0.150	0.68	0.75	0.77	0.80	0.36	0.38	0.50	0.53	0.85	0.89
Min	2.01	2.03	0.131	0.138	0.61	0.71	0.74	0.76	0.27	0.31	0.44	0.48	0.61	0.71
Max	2.65	2.81	0.154	0.163	0.81	0.81	0.82	0.82	0.42	0.45	0.58	0.59	1.22	1.34
se	0.09	0.10	0.003	0.003	0.03	0.02	0.01	0.01	0.02	0.02	0.02	0.02	0.09	0.10

Table 4.21 1997 Leaf Tissue Results (% DM)

Block	Leaflet												Rachis	
	N %		P%		K%		Ca%		Mg%		Cl%		K%	
	C	D	C	D	C	D	C	D	C	D	C	D	C	D
1022	2.28	2.18	0.149	0.148	0.67	0.67	0.76	0.74	0.41	0.33	0.44	0.51	0.55	0.95
4016	2.28	2.13	0.141	0.146	0.65	0.75	0.82	0.79	0.37	0.37	0.40	0.48	0.77	0.89
5006	2.43	2.34	0.137	0.140	0.63	0.61	0.69	0.75	0.40	0.40	0.58	0.40	0.67	0.63
17009	2.28	2.13	0.128	0.136	0.51	0.55	0.85	0.76	0.49	0.43	0.50	0.58	0.54	0.81
7020	2.22	2.28	0.148	0.148	0.63	0.73	0.82	0.80	0.42	0.40	0.37	0.46	0.69	0.89
22001	2.06	2.47	0.148	0.150	0.89	0.77	0.68	0.78	0.30	0.31	0.45	0.57	0.97	1.14
Mean	2.26	2.26	0.142	0.145	0.66	0.68	0.77	0.77	0.40	0.37	0.46	0.50	0.70	0.89
Min	2.06	2.13	0.128	0.136	0.51	0.55	0.68	0.74	0.30	0.31	0.37	0.40	0.54	0.63
Max	2.43	2.47	0.149	0.150	0.89	0.77	0.85	0.80	0.49	0.43	0.58	0.58	0.97	1.14
se	0.05	0.06	0.003	0.002	0.05	0.04	0.03	0.01	0.03	0.02	0.03	0.03	0.07	0.07

Table 4.22 1998 Leaf Tissue Results (% DM).

Block	Leaflet												Rachis	
	N %		P%		K%		Ca%		Mg%		Cl%		K%	
	C	D	C	D	C	D	C	D	C	D	C	D	C	D
1022	2.26	2.26	0.145	0.143	0.53	0.51	0.80	0.77	0.36	0.38	0.54	0.44	0.77	0.43
4016	2.20	2.28	0.145	0.143	0.53	0.55	0.76	0.82	0.39	0.35	0.37	0.49	0.61	0.85
5006	2.25	2.22	0.138	0.140	0.51	0.53	0.87	0.86	0.42	0.42	0.48	0.56	0.50	0.53
17009	2.06	2.20	0.135	0.148	0.51	0.51	0.90	0.93	0.53	0.49	0.55	0.63	0.71	0.42
7020	2.12	2.18	0.143	0.146	0.53	0.63	0.81	0.87	0.44	0.36	0.39	0.50	0.61	1.05
22001	2.21	2.37	0.143	0.148	0.75	0.63	0.78	0.91	0.25	0.32	0.38	0.50	0.95	0.91
Mean	2.18	2.25	0.142	0.145	0.56	0.56	0.82	0.86	0.40	0.39	0.45	0.52	0.69	0.70
Min	2.06	2.18	0.135	0.140	0.51	0.51	0.76	0.77	0.25	0.32	0.37	0.44	0.50	0.42
Max	2.26	2.37	0.145	0.148	0.75	0.63	0.90	0.93	0.53	0.49	0.55	0.63	0.95	1.05
se	0.03	0.03	0.002	0.001	0.04	0.02	0.02	0.02	0.04	0.02	0.03	0.03	0.06	0.11

The leaflet samples were tested for Boron content in 1997 and 1998 and the results of this analysis are given in Table 4.23 below. These levels are low though caution should taken when interpreting these results, as frond 17 is not the best frond to assess Boron levels.

Table 4.23 Leaflet B (ppm) in 1997 and 1998.

Block	1997 B ppm		1998 B ppm	
	C	D	C	D
1022	9.8	8.7	7.9	10.1
4016	11.7	9.2	8.6	11.1
5006	10.3	9.7	9.8	9.9
17009	12.8	11.3	11.4	11.0
7020	9.6	8.2	8.4	9.9
22001	9.4	9.4	7.3	8.9
Mean	10.6	9.42	8.90	10.15
Min	9.40	8.20	7.30	8.90
Max	12.80	11.30	11.40	11.10
se	0.55	0.43	0.60	0.33

5. ENTOMOLOGY

(R.W. Caudwell, T. Solulu, R. Safitoa)

PNG ISLANDS PEST REPORT

Sexava (Orthoptera: Tettigonniidae)

Segestes decoratus Redtenbacher and *Segestidea defoliaria* Uvarov are the principal insect pests of oil palm in West New Britain Province. Control of these insects currently involves the use of trunk-injected monocrotophos and the release of hymenopteran egg parasitoids.

The areas of West New Britain that required chemical treatment for economically significant levels of Sexava damage during 1998 are shown in Table 5.1. From the table it can be seen that there were 2 outbreaks during the year, and that the total area treated was approximately 36 ha. This represents about 0.09% of the total oil palm growing area in West New Britain Province. The insecticide costs for the treatment were approximately 2,043 Kina. During 1996 approximately 910 ha were treated for Sexava damage at an insecticide cost of 42,330 Kina, and during 1997 about 215 ha were treated at an insecticide cost of 13, 819 Kina. This information is summarised in Table 5.2.

It is apparent that the Sexava situation in West New Britain was even quieter in 1998 than in 1997. This extremely low level of damage was probably due to: (1) the effects of the drought experienced during the previous year, (2) the timely release of egg parasitoids, and (3) a robust and efficient monitoring system for the pest. Our training programmes for plantation workers, OPIC extension officers, and smallholder growers have continued during 1998. This has resulted in an improved and sustained awareness of the importance of insect pests, and consequently Sexava outbreaks are still being reported well before they reach economic levels.

The mass rearing and release of Sexava egg parasitoids (*Leefmansia bicolor* and *Doirania leefmansia*) continued at Dami Research Station throughout 1998. Table 5.4 gives details of the number of parasitoids reared for biocontrol and the areas where they were released. From the table it can be seen that we released a total of 7,915 parasitized eggs in West New Britain during 1998. From these eggs we would expect approximately 158,300 parasitoids to emerge. During 1996 we released a total of approximately 1, 969,260 parasitoids, and during 1997 we released a total of approximately 701,300. The low rainfall during 1997 meant that it was still difficult to find sufficient Sexava for our breeding cultures for the first half of 1998. This made breeding the parasitoids very difficult, hence the relatively low numbers that were reared and released.

Our EU-funded Sexava research programme continued throughout 1998, with progress during the year documented in the research reports. Field trials of the parasite in West New Britain are scheduled to commence in 1999.

Our integrated pest management system for Sexava is illustrated in Figure 5.1.

Figure 5.1 Strategies for Sexava IPM.

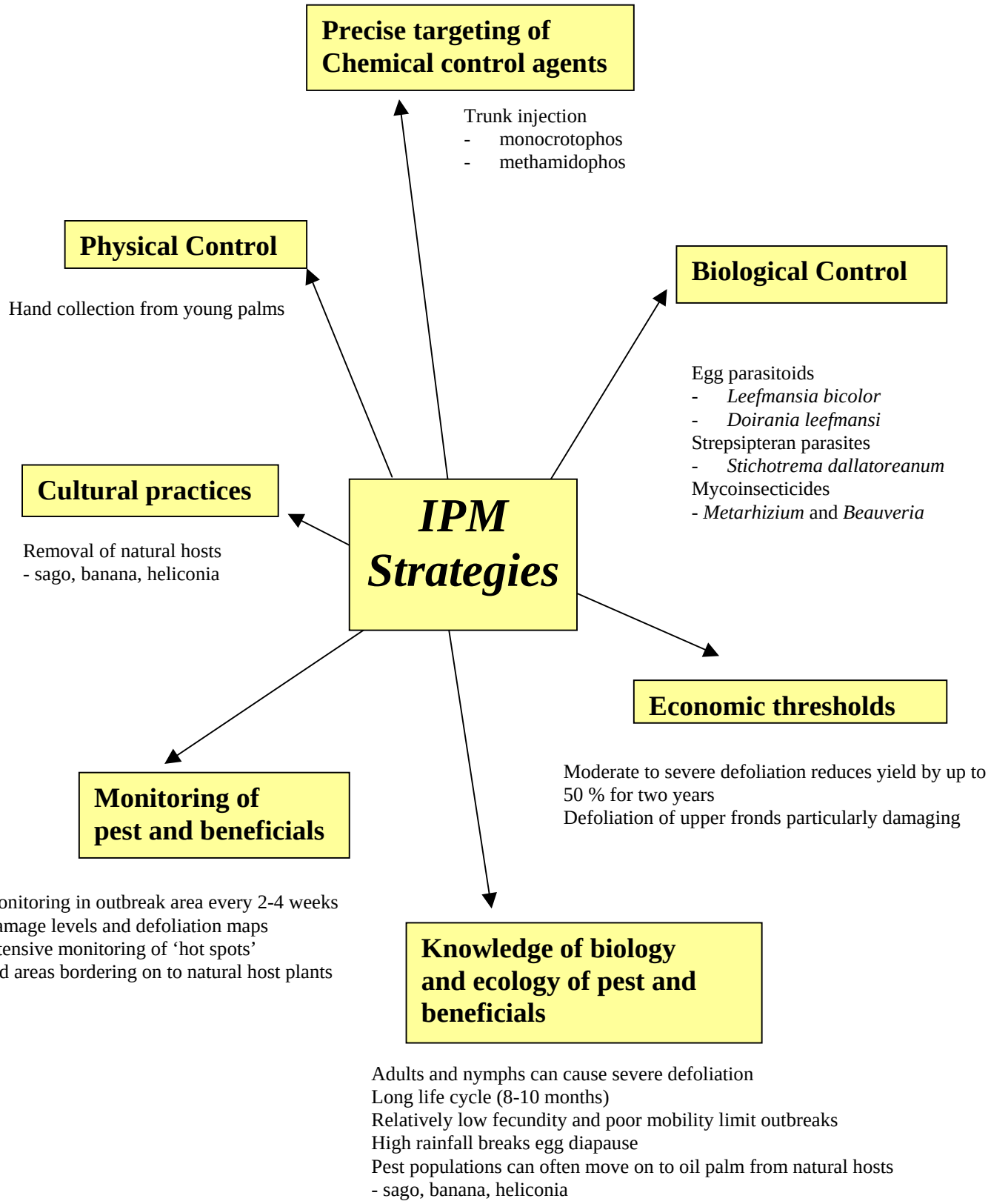


Table 5.1 The oil palm growing areas in West New Britain that required chemical treatment for economically significant levels of Sexava damage in 1998.

Date	Plantation/ Smallholders	Site	Approx. Area (ha)	Volume of formulation (l)
10-Feb	Salalubu smallholders	Uasilau	12	30
18-Apr	Hoskins Smallholders	Siki	24	60
		TOTAL	36	90
% WNBP oil palm growing area treated				0.09%
Insecticide costs - Nuvacron/Azodrin K22.70/l				2,043 Kina

Table 5.2 The oil palm growing areas in West New Britain that required chemical treatment for economically significant levels of Sexava damage in 1996, 97 and 98.

Year	Approx. Area (ha)	Volume of formulation (L)	Insecticide cost (Kina)
1996	910	2,275	42,330
1997	215	538	13,819
1998	36	90	2,043

Table 5.3 The oil palm growing areas in West New Britain that required chemical treatment of economically significant levels of Bagworm damage in 1996, 97 and 98.

Year	Approx. Area (ha)	Volume of formulation (L)	Insecticide cost (Kina)
1996	210	263	4,892
1997	340	425	10,926
1998	0	0	0

Table 5.4 The oil palm growing areas in West New Britain in which Sexava egg parasitoids were released during 1998.

Location	Number of parasitised eggs		Number of adult parasitoids	
	L. bicolor	*D. leefmansia*	*L. bicolor*	*D. leefmansia*
Plantations				
Dami Research Station	620		12,400	
Haella Plantation	100		2,000	
Navarai Plantation	1,845		36,900	
Navarai Plantation	1,100		22,000	
Smallholder blocks				
Buvussi	620		12,400	
Galai	110		2,200	
Kapore	670		13,400	
Sarakolok	870		17,400	
Siki	790		15,800	
Tamba	110		2,200	
Village Oil Palm				
Banaule	860		17,200	
Ganeboku	110		2,200	
Patanga	110		2,200	
Total	**7,915**		**158,300**	

Bagworms (Lepidoptera: Psychidae)

There were no economically significant outbreaks of Bagworm damage during 1998. With the areas at Kautu and Kaurausu Plantations (NBPOL) that had experienced persistent Bagworm outbreaks during 1996 and 1997 remaining quiet during the year.

Table 5.3 gives a comparison of the oil palm growing areas in West New Britain that required chemical treatment for economically significant levels of Bagworm damage during 1996, 1997 and 1998.

A section of our research reports describe trials that we undertook during 1998 to determine the effect of plantation management practices on general levels of biodiversity, and on the population levels of Bagworm natural enemies.

Our integrated pest management system for Bagworms is illustrated in Figure 5.2.

Figure 5.2 Strategies for Bagworm IPM

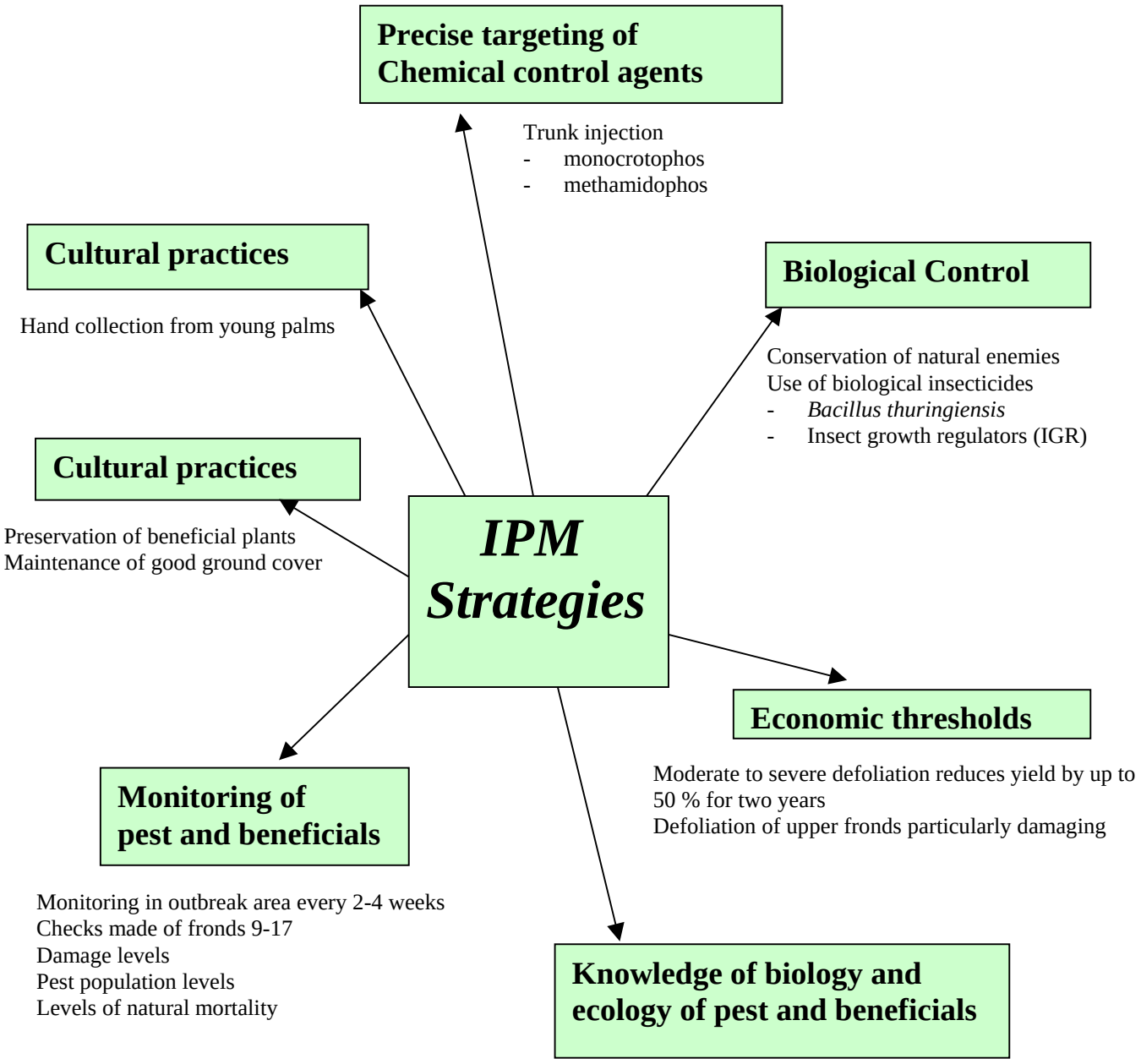
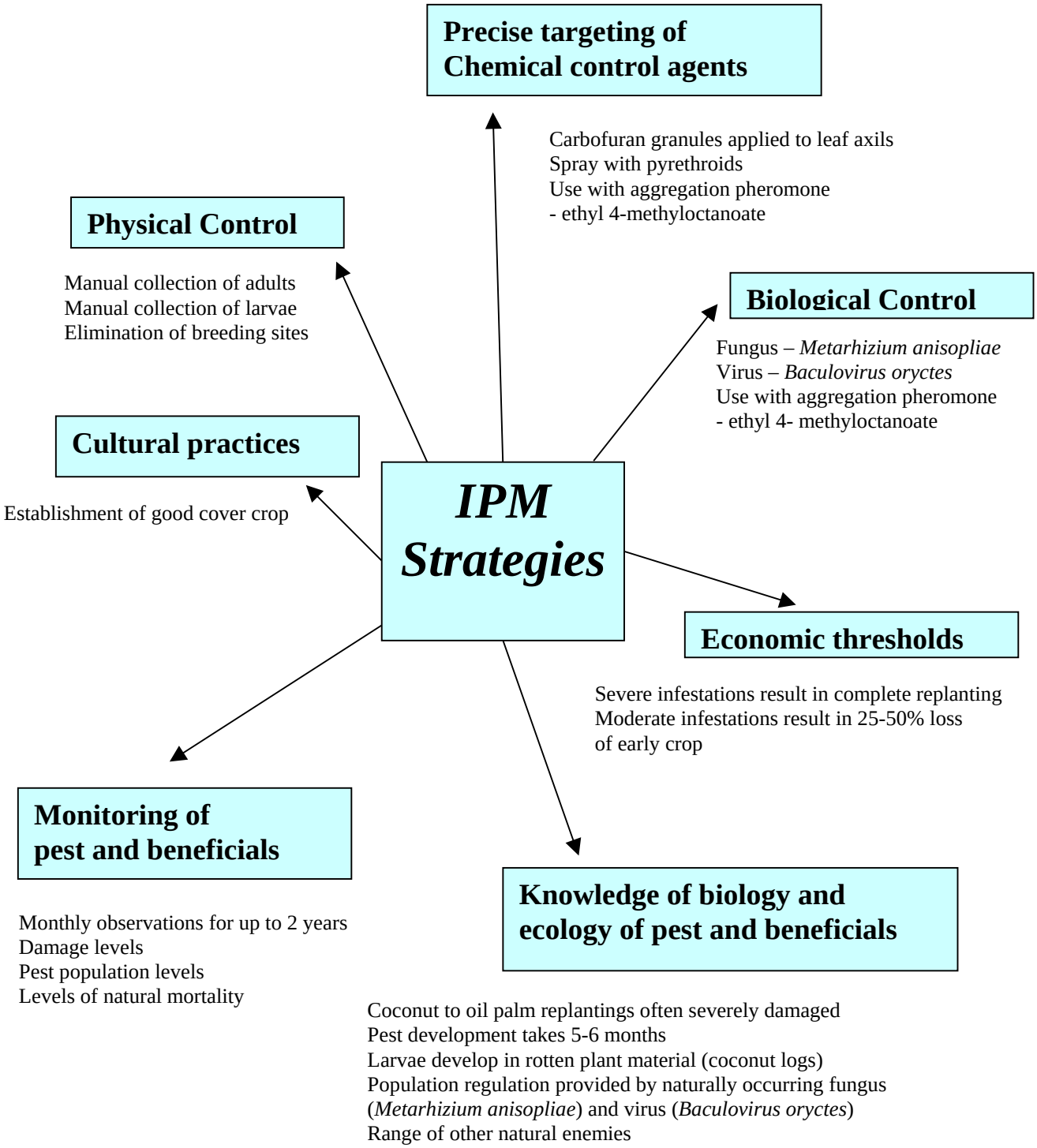


Figure 5.3 Strategies for Rhinoceros Beetle IPM



Rhinoceros beetles (Coleoptera: Scarabaeidae)
There were no new outbreaks of *Oryctes rhinoceros* during 1998. Our mass trapping and release programme for *Oryctes rhinoceros* at Numundo plantation finished 1997. This programme seems to have been very successful, there are high levels of baculovirus in the field, and the population of *O. rhinoceros* is under good control at Numundo. We continued surveying throughout 1998, and found no evidence of renewed population growth at Numundo, and no evidence of the spreading of the beetle population into other areas. Our integrated pest management system for *Oryctes rhinoceros* is illustrated in Figure 5.3.

There were localised outbreaks of *Scapanes australis* at Garu Plantation. Beetles were found to be attacking young plantings at the edges of the plantation. However, a combination of hand collection, the removal of breeding sites and the development of good cover crop gave good control.

Weevils (Coleoptera: Curculionoidea)
Two species of weevil were reported to be causing defoliation to young plantings at Haella Plantation during 1997. These were identified as *Lophothetes pencilliger* and *Rhinoscapha schmeltzi* and the outbreak was documented in the 1997 Annual Report. Damage levels were light and very localised during 1997, and no chemical treatment was recommended. The outbreak was probably caused by a temporary breakdown in natural control following the clearing of food gardens for oil palm development. Good cover crop was established within a few months of the outbreak, and there were no further problems with the weevils during the remainder of 1997 and throughout 1998.

Taro Beetle (Coleoptera: Scarabaedae)
Taro beetles (*Papuana huebneri* Fairmaire) were reported to be causing damage to seedlings at Garu nursery during 1997. Adult beetles were found to be boring into the base of seedlings and feeding from soft tissue just below soil level. Damage levels were however very light, with less than 1% of the seedlings showing symptoms. Hand collection of beetles was recommended, and this was done throughout the nursery at fortnightly intervals. After two rounds of hand collection a layer of mill fiber was fitted around the base of each seedling to prevent access by the Taro beetles.

There were no further outbreaks of Taro Beetles in the nursery during 1998, although some hand collection was undertaken to ensure that the population remained at low levels.

Leafhoppers (Hemiptera: Cicadelloidea)
Finschhafen disorder was first observed on coconut palms near to Finschhafen in Morobe Province, Papua New Guinea in 1960. Early symptoms of the disorder include a yellow bronzing from the tip of coconut leaflets, with the bronzing later extending towards the petiole. As the condition advances the leaflet tips become necrotic, with advanced symptoms appearing as senescence of leaves, with accelerated and pronounced yellowing and necrosis. In coconuts this disorder results in reduction of yields, slowing of growth rates and occasionally, the death of young palms.

Feeding by a small brown leafhopper (*Zophiuma lobulata* Ghauri) causes Finschhafen disorder of coconuts. It is most probable that the symptoms are caused by a localised toxic reaction to *Z. lobulata* feeding on the coconut fronds. Control of the disorder is therefore dependent on the management of *Z. lobulata* populations.

In March 1994, Finschhafen disorder was observed on coconuts in West New Britain Province. At this time the outbreak was localised and confined to a very small area. The leafhopper, *Z. lobulata* was confirmed as the causal agent of the disorder. Betelnut and oil palms were also affected by the disorder, but to a much lesser extent. Since 1994, Finschhafen disorder of coconuts has spread throughout the Kimbe area and has been observed as far as Talasea in the north and Ulamona in the east. Damage levels are currently very high in all these areas, and the disorder has resulted in a loss of

coconut production in the West New Britain region. In addition to this, the disorder is now being observed with increasing frequency on oil palm.

Treatment is by targeting the leafhopper vector of the disease, using trunk-injected monocrotophos. For a number of reasons we are reluctant to recommend such treatments for subsistence coconut growing. The spread of the disorder to oil palm was very slow and localised during 1995, 1996 and 1997, with affected palms showing very weak symptoms. However, during 1998 there were outbreaks of the disorder on oil palms at Dami, Kaurausu, and Numundo Plantations, as well as on oil palms in smallholder blocks throughout the Hoskins and Kimbe project. Some areas of oil palm, especially in the vicinity of affected coconuts, were treated by trunk-injection of monocrotophos during the year.

During 1999 and 2000 we are planning a concerted effort to control the leafhopper on oil palm and coconuts in the West New Britain area. This will probably be a collaborative project with scientists from the Coconut and Cocoa Research Institute. We have observed a high prevalence of naturally occurring fungal pathogens in field populations of the leafhoppers (*Metarhizium* and *Beauveria* sp). We have also been able to isolate and rear populations of hymenopteran egg parasitoids, the identity of which are yet to be established. These two biocontrol agents will form the basis of an integrated pest management system for the leafhopper.

The primary objective of the project will be to develop an integrated pest management system for the control of *Z. lobulata*, the causal agent of Finschhafen disorder, and therefore to safeguard the production of copra and oil palm in West New Britain. The project aims to determine:-

1. The extent of the Finschhafen disorder in West New Britain.
2. The susceptibility of different varieties of coconut and of commercial oil palm to Finschhafen disorder.
3. The general biology, ecology and pest status of Z. *lobulata.*
4. The role of biological control agents in the population regulation of *Z. lobulata* and in the possible suppression of Finschhafen disorder.

Using the information gained from these studies an integrated pest management system will be implemented for *Z. lobulata* that is appropriate to the needs of the copra and oil palm industries in West New Britain. This IPM system will be sustainable, cost effective and environmentally acceptable.

PNG MAINLAND PEST REPORT

Sexava (Orthoptera: Tettigoniidae)

Segestidea novaeguineae Brancsik is the largest species of Sexava found in PNG. It is a potential pest of oil palm in Oro Province, but has not caused any economic damage since 1983. There were no economic outbreaks of *S. novaeguineae* in Oro Province during 1998. Adequate population regulation is provide by a number of naturally occurring biological control agents, including the strepsipteran, *Stichotrema dallatorreanum*; and the dipteran, *Exorista notabilis*; as well as various predators (ants, ground beetles, centipedes) and fungal agents.

There is no record of Sexava attacking oil palm in Milne Bay Province.

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. Damage by this pest usually occurs in conjunction with Sexava damage, however recent observations have demonstrated that stick insects alone are capable of causing economic damage to oil palm.

There seems to have been an increased incidence of stick insect damage to oil palm in Oro Province during the last 2-3 year. During 1997 there was 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. Chemical treatment is by trunk injection of monocrotophos (Nuvacron or Azodrin) in the same way as is undertaken for Sexava control, although only a single application is required for stick insect control.

There is no record of stick insects attacking oil palm in Milne Bay Province.

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 1998, in both Milne Bay and Oro Provinces. The occurrence of field populations was sporadic and isolated, with light damage of no economic significance.

***Acria* moth (Xyloryctidae)**
Acria moth is widespread throughout Milne Bay Estates from Giligili to Hagita, Waigani and Sagarai. During 1998 significant 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. These include a number of species of parasitic wasp, as well as several pathogens of both the larvae and pupa. Population outbreaks seem to occur during the dry season, when regulation by natural enemies seems to break down. A severe drought was experienced during 1997, but a return to normal rain patterns during 1998 seems to have improved the population regulation of this pest. No chemical control was during 1998 recommended, but regular population monitoring was undertaken.

There is no record of *Acria* moth attacking oil palm in Oro Province.

Rhinoceros beetles (Coleoptera: Scarabaeidae)
The common rhinoceros beetle, *Scapanes australis*, is the only species that attacks oil palm in Milne Bay and Oro Provinces. During 1998 damage by this beetle was sporadic and infrequent, and of no economic significance.

There is no record of *Oryctes rhinoceros* attacking oil palm in Milne Bay and Oro Provinces.

Sugarcane weevil (Coleoptera: Curculonidae)
The sugarcane weevil, *Rhabdocelis obscurus* is widespread in PNG, and is well known to attack other crops, notably sugarcane. In oil palm it is usually associated with freshly pruned fronds, damaged areas, and rotten bunches. Recently however the weevil has been reported to be causing damage to developing oil palm bunches.

During 1997 the sugarcane weevil was reported to be damaging black bunches at Mamba Estate (Higaturu Oil Palms). The weevil larvae were found to be tunneling into both the bunch stalk and spikelets. The relatively high incidence of rotten bunches during that period (possibly due to bunch failure and/or poor pollination) probably attracted large numbers of sugarcane weevils and increased

overall population levels. The situation is now under control and there no further outbreaks of this pest reported during 1998.

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 1998. 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.

Longicorn beetles (Coleoptera: Cerambycidae)
Longicorn beetles (*Mulciber* sp.) were found at Embi Plantation during 1997. Damage levels were light during 1998, with no treatment recommended. We are however conducting monthly monitoring of this insect.

Grasshoppers (Orthoptera: Acrididae)
During 1998 short-horned grasshoppers from the family Acrididae were reported to be causing damage to young palms (1997 plantings) at Mamba Estate, Higaturu Oil Palms. Species of *Valanga* were the most abundant of these grasshoppers, with adults and nymphs feeding on the foliage of the young palms as well as the legume cover crop. However, the damage levels were generally light and no control action recommended.

Scale Insect (Hemiptera: Diaspididae)
During 1998 low levels of scale insect were found along some of the road oil palm blocks at Sagarai Estate, Milne Bay Estates. It is probable that this damage is being caused by the coconut scale insect, *Aspidiotus destructor*. If it is not this species, then it is one that is taxonomically very similar.

Damage levels are however very light, and the only control recommendation was the removal and burning of affected fronds (which were mainly at the bottom of the frond canopy). We are conducting monthly monitoring in these areas.

Rats
Damage to oil palm by rats was reported in Milne Bay and Oro Province during 1997. Rats cause damage to seedlings in nurseries by chewing through frond bases. In mature palms they feed on fruit bunches (ripe and black bunches) and also damage male inflorescences whilst searching for larvae of the pollinating weevil.

There were no further outbreaks of rats reported from Milne Bay or Oro Province during 1998.

Giant African Snails
The introduced Giant African Snail, *Achatina fulica* feeds on leguminous covercrops in the oil palm agroecosystem. This snail is now widespread throughout Milne Bay Estates from Giligili to Hagita, Waigani and Sagarai, with some areas having had their cover crop stripped bare.

The control of Giant African Snail in and around confined areas such as nurseries is relatively straightforward, using a combination of physical barriers, baiting with metaldyde and hand collection. Control using these methods is feasible on a small scale, but would not be practical on a large, area-wide scale. The economic value of cover crop is difficult to define, but certainly does not justify the large-scale implementation of physical barriers, baiting and hand collection on a plantation level.

In 1997 there were instances of Giant African Snails attacking newly planted palms in oil palm developments in the Kimbe area. There is therefore a risk that when Milne Bay Estates is replanted the high population of snails may cause a great deal of damage to young plantings.

At this time there is no feasible biological control agent for the snail. A number of projects have attempted to develop biocontrol for the snail, but to date none have been successful. The biology and control of Giant African Snail is to be the subject of Takis Solulu's PhD Research. It is hoped that this work will provide valuable insights into potential control methods for this pest.

Giant Sensitive Plant (GSP)
Mimosa invisa Mart, commonly known as the Giant Sensitive Plant (GSP) is widespread throughout the oil palm agroecosystem in Papua New Guinea. It is a serious weed that can hinder field operations, particularly in young plantings (3-5 years old).

During 1997 we obtained a batch of the psyllid, *Heteropsylla spinulosa* (Homoptera: Psyllidae) from Ramu Sugar Limited . This insect has been demonstrated to give good field control of GSP. It is a sap-sucking bug (2-3mm long) introduced into PNG in 1992 from Queensland, Australia. The psyllid is known to be effective in controlling *Mimosa invisa* in areas where it has been released, especially in sugarcane fields at Ramu. The adults and nymphs of the bug suck sap from leaflets, leaf stems and growing tips of the weed, thus causing distortion and deformed growth of GSP. Flowering and seed production can also be adversely effected by the feeding behaviour of the psyllid, with a reduction of 98% GSP seed production demonstrated at Ramu Sugar Limited.

We released the first batch of psyllids into clumps of GSP at Higaturu Oil Palms in 1997. Further collections and releases were planned for 1998. However subsequent investigations revealed that this psyllid, or one that is taxonomically very similar, seems to be already present throughout most of the oil palm growing regions of Oro Province.

Samples of these psyllids were sent to the International Institute of Entomology for identification. Where it was confirmed that all the specimens were in fact *Heteropsylla spinulosa.* So it would seem that our original introductions have been successful, and that the *Mimosa* biological control agent is now present throughout the oil palm growing areas of Oro Province.

***Mitracarpus hiryus* (villosus)**
This weed was reported to be causing serious problems in new oil palm plantings at Mamba Estate, HOPPL, Oro Province. It is likely that there is a high soil seed load of this weed at Mamba and any control measures, chemical or otherwise, are proving expensive, time consuming and ineffective.

We are currently investigating the potential for the biological control of this weed. This weed has however never been the subject of any biological control programme. It is a neotropical species that appears to be only a minor, ruderal weed in Trinidad and Brazil. Weed scientists at the International Institute for Biological Control have indicated that this weed may be an excellent target for the classical biological control a strategy.

We will continue with these investigations, with a view to possibly setting up a biological control project for the weed.

SOLOMON ISLANDS PEST REPORT

Solomon Islands Plantations Ltd. (SIPL) became a member of the Papua New Guinea Oil Palm Research Association in 1998. OPRA established a base at SIPL in August 1998, and the first visit by OPRA entomology staff took place in October.

Damage by the Black Rat, *Rattus rattus* is widespread throughout the oil palm plantations in the Solomon Islands. The rat is reported to be causing damage to bunches by feeding on mesocarp and kernel, as well as damage to male flowers and subsequent loss of pollination by feeding on the pollinating weevils. Despite attempts at control, mainly through baiting campaigns (using Matikus and Klerat), the rat populations appear to be very high. These high rat populations have been implicated in causing a loss of oil extraction (OER) and kernal oil extraction (KER) at the mill. Since July 1996 the OER at SIPL has been 20-21%, compared to a long term mean value of 22%. This 1% loss in OER equates to 1300 tonnes of lost crude palm oil (CPO). At $US580 per tonne of CPO, this equates to $US754,000.

There has been much debate concerning the rat problem at SIPL, with differing management recommendations being given by different specialists and different times during the 1996 and 1997. Baiting is expensive and logistically difficult, but at present there seems to be no other viable control method. Furthermore the efficacy of baiting campaigns has been brought into question because of the need to undertake large numbers of repeat applications, sometimes 8-10 rounds, before acceptance levels are significantly reduced.

Based on this information and the experience gained during our first visit a set of formal experimental trials have been set up to enable a rigorous evaluation of the extent of the rat problem at SIPL, and to assess the impact of future control campaigns. A total of 18 experimental plots have been established, spread throughout the SIPL estate. Each plot is about 10 hectares in size. The following data will be collected from each of these plots:

1. Assessment of rat damage to bunches and loose fruit.
2. Assessment of rat populations.
3. Assessment of the populations of pollinating weevils.
4. Assessments of rat damage to male flowers.

Work on these trials commenced at the beginning of 1999 and the results will be presented in the 1999 Annual Report.

RESEARCH REPORT – POLLINATION STUDY AT MAMBA ESTATE, ORO PROVINCE.

Introduction

An investigative study into pollination commenced in 1998 at Mamba Estate, HOPPL, Oro Province. This followed concerns regarding low yields and poor fruitset experienced in 1997 from 1993 plantings at Mamba.

The following observations were proposed at the beginning of the study:

- Number of receptive female and male inflorescences at anthesis
- Number of *Elaeidobius* emerging from 5 sets of 20 spikelets
- Percentage fruitset levels
- Pollen viability testing
- Trials with insect-assisted pollination

It was proposed that these observations be made in three separate experimental plots, with each site consisting of 135 palms per plot (i.e. the planting density at Mamba). The sites were located as follows:

Division	Field	Year of planting
Komo	93 C	1993
Saga	95 E	1995
Saga	96 AI	1996

Preliminary Results in 1998

During 1998 we made observations on the number of receptive female and male inflorescences at anthesis, the number of *Elaeidobius* emerging from males spikelets, and fruitset levels, as well as pollen viability testing.

The initial data collected during 1998 is shown in Figures 5.4, 5.5, 5.6 and 5.7. Figures 5.4 and 5.5 give the numbers of anthesing male and receptive female inflorescences respectively for each of the three plots. Figure 5.6 shows the mean number of *Elaeidobius* progency emerging from 5 sets of 20 spikelets for all three plots during 1998. The percentage fruitset for the plots at Komo and Saga 95 are shown in Figure 5.7.

Generally, it can be seen that the preliminary data obtained in 1998 indicates a low number of male inflorescences, low weevil populations. This in turn would result in an inadequate quantity of pollen and poor pollination. Hence the high incidence of poor fruitset and low yields observed at Mamba Estate during the year.

Incidence of undisturbed pollen was observed on anthesing male inflorescences from July/August until the end of 1998, and this was particularly apparent at Komo division. Such inflorescences had very few pollinating weevils attending to them, as well as rapid colonisation by moulds at the post-anthesis stage. When samples were taken for pollen viability testing, these inflorescences were found to have a low quantity of pollen. Pollen viability testing commenced in October 1998. The results from October to the end of the year indicated low pollen viability, which was in the range of 15-43%.

Figure 5.4 The number of male flowers at anthesis (average/day/135 palms) in the three trial plots at Mamba Estate, Oro Province.

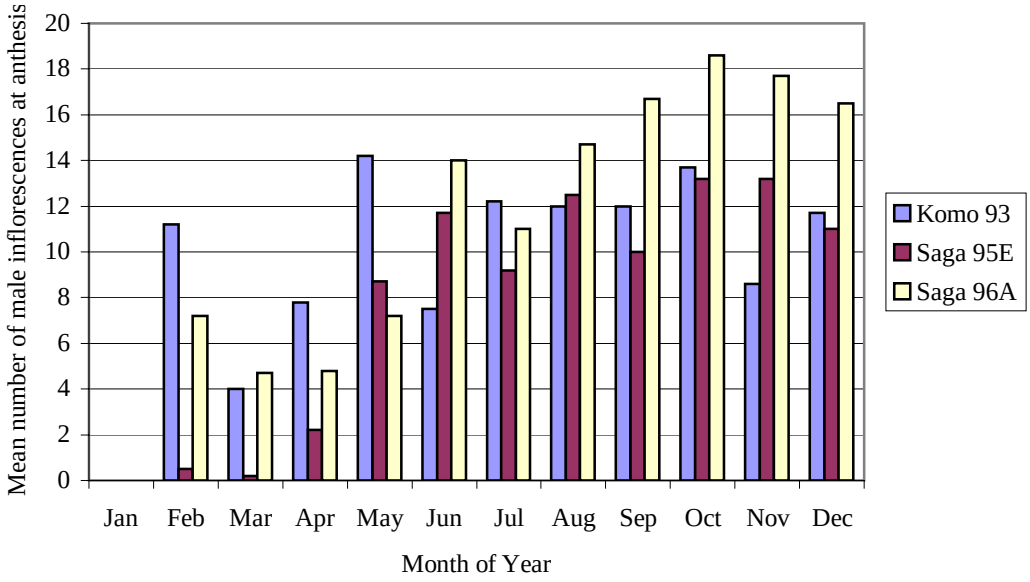


Figure 5.5 The number of female flowers at the receptive stage (average/day/135palms) in the three trial plots at Mamba Estate, Oro Province.

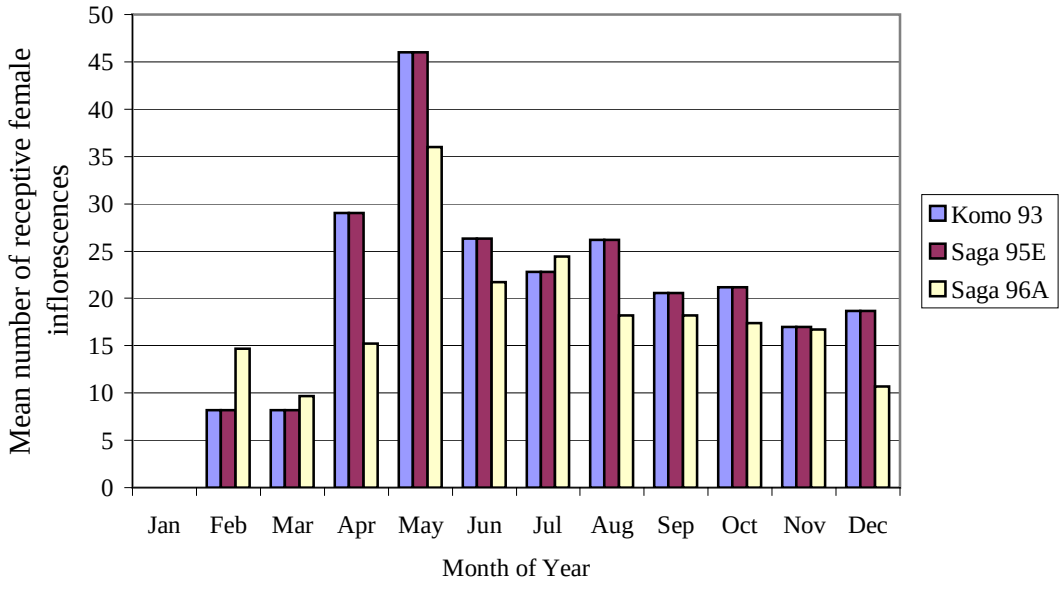


Figure 5.6 The mean number of weevil progency emerging from each spikelet from the trial plots at Mamba Estate, Oro Province.

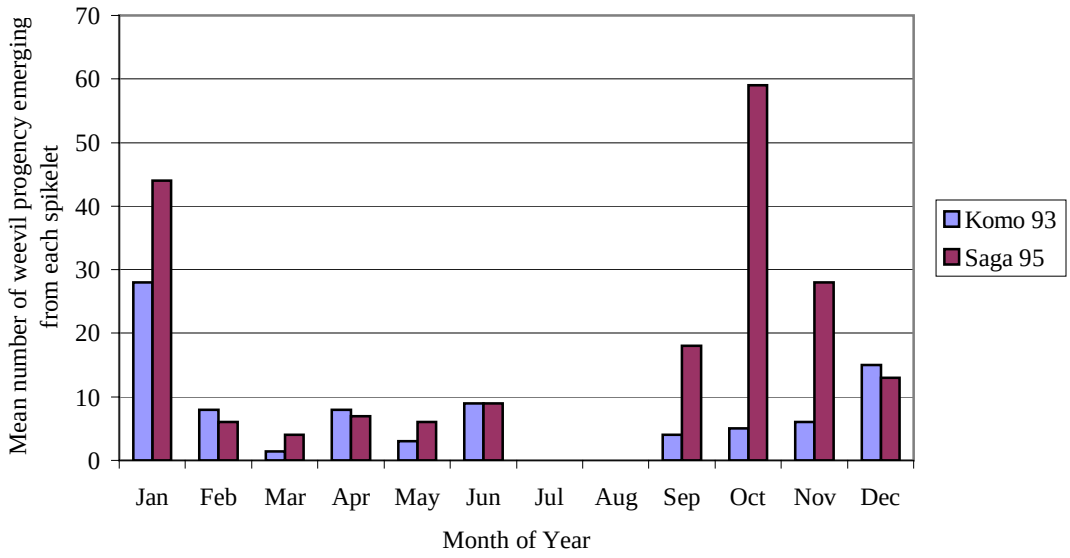
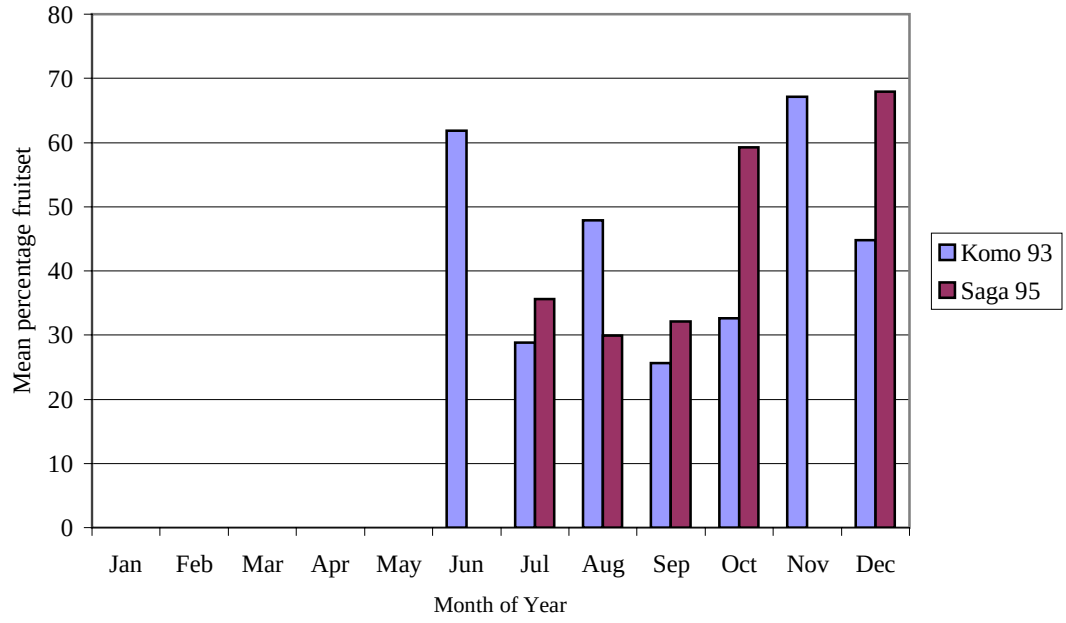


Figure 5.7 The mean percentage fruitset for the trial plots at Mamba Estate, Oro Province.



The calculation of percentage fruitset commenced in July for site at Komo and one at Saga. Ten harvestable bunches (ripe with no loose fruits) were randomly selected from the field at the Komo and Saga sites each fortnight and percentage fruitset determined. The range of percentage fruitset showed considerable non-uniformity for the 118 bunches analysed during this test period. An average of 44% and 45% fruitset was recorded for the six months at Koma and Saga respectively. Just over 37% of the bunches analysed gave fruitset levels of over 51%, while the remaining bunches gave values below 51% fruitset.

We plan to continue with these pollination studies for the foreseeable future. A more thorough account of this work will be presented in the 1999 annual report, by which time we will have 18-24 months of experimental data from the trial plots.

RESEARCH REPORT – POLLINATION STUDY AT KAPIURA PLANTATION, WEST NEW BRITAIN PROVINCE.

The results of this study for 1998 are shown in Figures 5.8, 5.9, 5.10 and 5.11.

Figure 5.8 The number of male flowers at anthesis in the four trial plots at Kapiura Plantation, West New Britain Province.

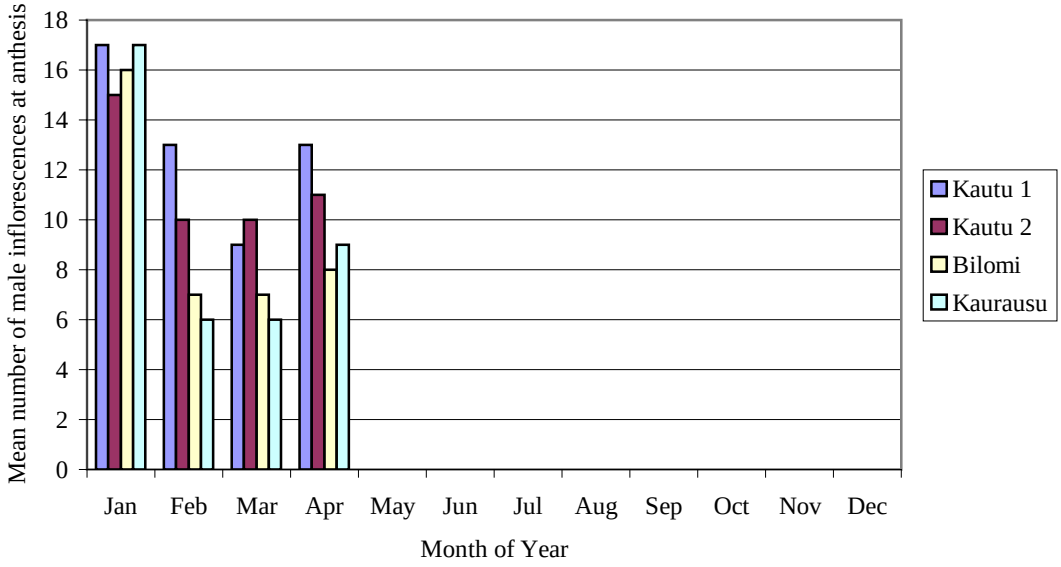


Figure 5.9 The number of female flowers at a receptive stage in the four trial plots at Kapiura Plantation, West New Britain Province.

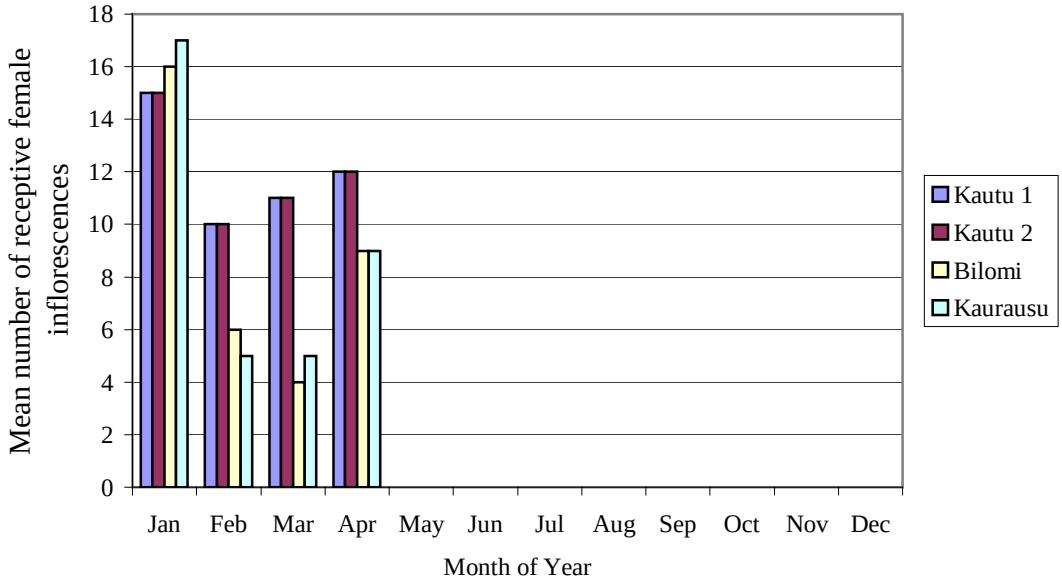


Figure 5.10 The mean number of weevil progency emerging from each spikelet from the trial plots at Kapiura Plantation, West New Britain Province.

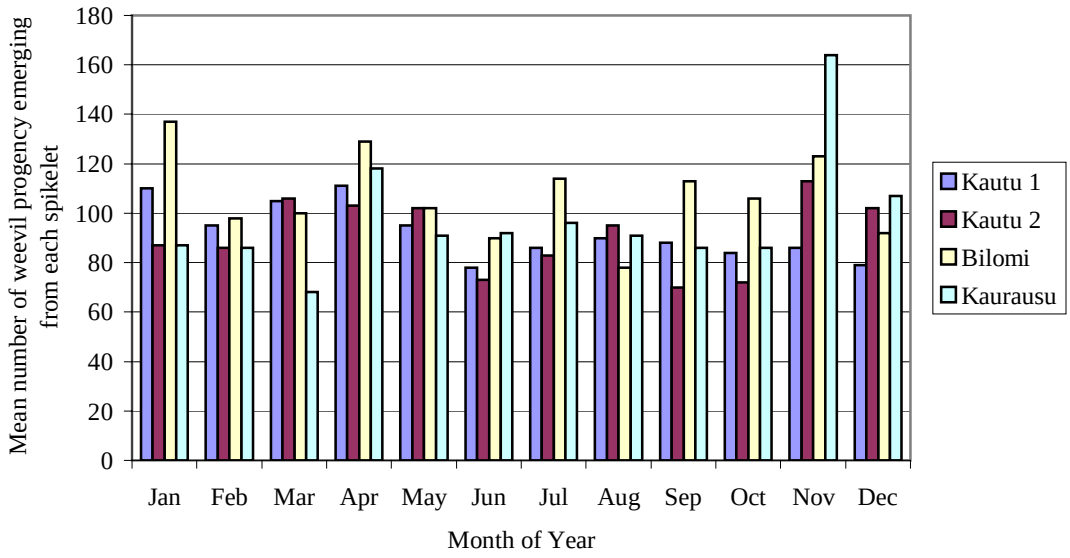
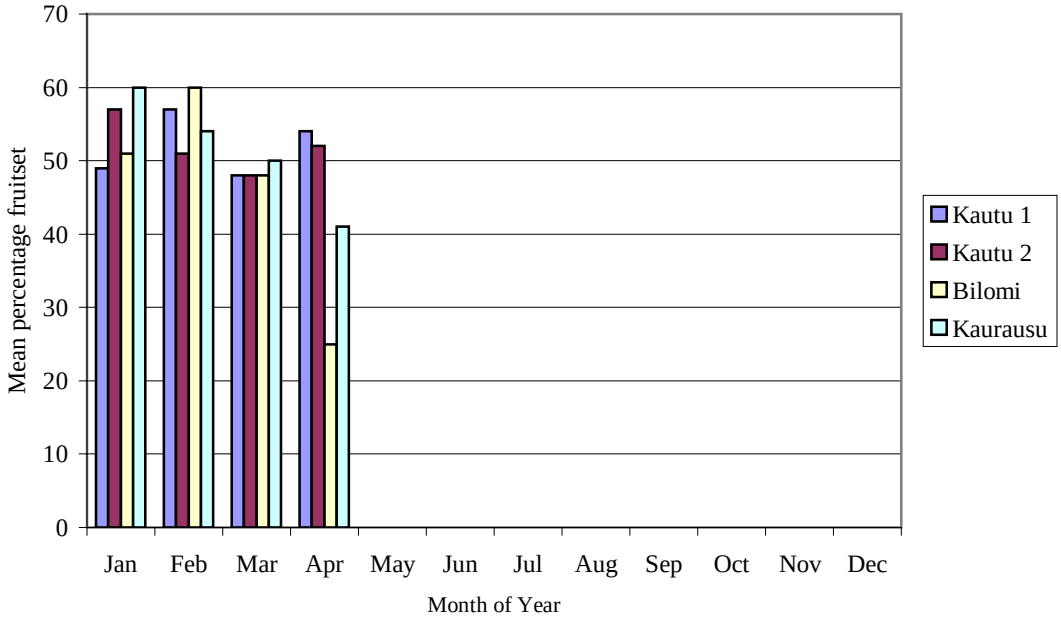


Figure 5.11 The mean percentage fruitset for the trial plots at Kapiura Plantation, West New Britain Province.



RESEARCH REPORT – SEXAVA BIOLOGICAL CONTROL

Experiment 1 - Life history studies

Objectives

1. To investigate the biology of *Segestidea novaeguineae*
2. To determine the possible effects of infection by *Stichotrema dallatorreanum* on the life history and development of its host, *S. novaeguineae*.

Materials and methods

This experiment supplements the results presented in the 1997 Annual Report.

During 1998 a total of 80 first and second instar *S. novaeguineae* were collected from the oil palm agro-ecosystem in Oro Province, and reared at OPRA Higaturu. The test insects were colour coded, using a permanent marker, then placed in large walk-in cages. These cages were 1.83m x 1.86m x 1.83m in size, with 32 x 32 Lumite mesh screen. Each cage was partitioned into two sections, and ten test insects housed in each section. Nursery seedlings were provided as a food source for the test insects (3 seedlings per section).

Growth rates, moulting increment and the inter-moult period were recorded for each of the 80 test insects. Observations were also undertaken to assess unusual or abnormal behaviour. The test insects in this part of the study were field collected, and could therefore have been either healthy or infected by *S. dallatorreanum*. Therefore during the study each test insect was examined daily for evidence of infection, particularly for signs of protrusion of the cephalothorax of the parasite through the abdomen of the host.

Additionally, samples of late instar nymphs (5^{th} to 7^{th} instars) of *S. novaeguineae* were collected from the field and placed in breeding aluminium cages (30cm x 30cm x 60cm, with fly wire screen). Fresh oil palm leaflets were provided as food. These insects were observed for protrusion of mature female *S. dallatorreanum* after the host had moulted to adult.

Results

Of the 80 field collected nymphs of *S. novaeguineae* reared in walk in cages, 44 (23 males and 21 females) successfully reached the adult stage while the remaining 36 nymphs died in captivity. All 44 of the surviving adults were confirmed as healthy and not infected by *S. dallatorreanum*. The mean values of the two growth components for the 44 nymphs that successfully moulted to adult are presented in Table 5.5, while the mean adult characters of the same individuals are shown in Table 5.6.

A total of five individually caged and healthy *S. novaeguineae* females were observed to have laid normal eggs without being exposed to or mated by a male. The number of eggs laid ranging from 35 to over 50 per female. It took between 66 – 95 days between each female moulting into adult and the beginning of oviposition.

Six adults (4 females and 2 males), from the sample of late instars of *S. novaeguineae* reared in cages that successfully moulted to adults, had cephalothorax of mature female *S. dallatorreanum* protruding from their cuticle. Protrusion of the cephalothoracea was observed 8 - 34 days after the host had reached the adult stage. One male host had two *S. dallatorreanum*, the first emerging 11 days and the second 13 days after the host had turned adult.

Table 5.5 The mean length attained at each nymphal instar (a), and the mean number of days between successive moults (b) for 23 males and 21 female nymphs of *S. novaeguineae* (n values denoting the number of insects moulting to adult from previous instar).

(a) Nymphal lengths (mm)			(b) Instar duration (days)		
Instar	*Males*	*Females*	*Stadium*	*Males*	*Females*
1st	-	-	1st – 2nd	-	-
2nd	18	18	2nd – 3rd	14	14
3rd	23	23	3rd – 4th	16	15
4th	29	29	4th – 5th	17	15
5th	30	35	5th – 6th	20	18
6th	42	42	6th – adult	24 (18)	28 (2)
7th	43	49	6th – 7th	21	21
8th	-	51	7th – adult	25 (5)	25 (17)
			7th – 8th	-	20
			8th – adult	-	29 (2)

Table 5.6 The mean (± SE) adult body characters of 24 males and 21 females of *S. novaeguineae* (measured one day after each individual insect had moulted to adult).

	Mean (± SE) lengths (cm)	
Adult body characters	**Males**	**Females**
Body	4.9 ± 0.08	5.6 ± 0.08
Antenna	20.4 ± 0.32	18.9 ± 0.21
Forewing	6.7 ± 0.07	8.2 ± 0.08
Ovipositor	-	4.5 ± 0.14
Subgenital plate	0.9 ± 0.02	-

There was no apparent difference in the moult increment and instar duration at each instar between sexes of *S. novaeguineae*. The obvious difference seen was that the larger females tend to increase in size towards the end of their development, and have an extra nymphal stage (7 - 8th instar) as compared to the male Sexava (6th – 7th instar).

Discussion

Female *S. novaeguineae* are morphologically larger, and therefore require a slightly longer time to develop into adults from 1st instar nymph than males. The majority of females (80% from this study) attain the 7th instar before becoming adults, however some became adults from early as the 6th instar (10%) or even up to the 8th instar (10%) before reaching the adult stage. Males however usually attains 6th or 7th instar prior to reaching the adult stage, with most becoming adults from 6th nymphal stage (78%).

Reproduction in *S. novaeguineae* is normally thought to be achieved sexually, that is resulting from mating between the opposite sexes. Females lay fertilised eggs into the soil some time after mating, which then hatch into young nymphs and later develop into adults. Hitherto, parthenogenesis (ie. production and oviposition of eggs without fertilisation) in this species of Sexava was not known. The results from this study, however showed that female *S. novaeguineae* can also lay fairly large number of presumably viable eggs (35 to over 50 eggs per female) without being mated, or parthenogenetically. It was also observed that some time period (gestation or maturity period) would have to elapse before a female can lay her eggs (in this study, 66 – 95 days from moulting to adult).

We have therefore established that *S. novaeguineae* can reproduce both sexually and parthenogenetically, and oviposite only after it reaches a certain stage of reproductive maturity.

The developmental time of female *S. dallatorreanum* from the time of entry (ie. host penetration by free-living 1st instar larvae or triungulins) to protrusion of cephalothorax of mature female stylops from host cuticle is yet not known. Results obtained from this study showed protrusion of fully developed cephalothorax (i.e. the chitinized fused head-anal region of the female) from host cuticle to take between 8 – 34 days after the host has turned adult.

This would support the view that developmental time of *S. dallatorreanum* from entry to maturity takes longer than the development time of its host. The observed variation in 'protrusion time' by mature *S. dallatorreanum* in adults of known age could possibly explain the question of when, and at which nymphal stage of the host the triungulins had entered. For instance, protrusion time of < 13 days could imply that host entry was at an early nymphal stage (1st – 2nd instars), while > 13 days infection could have occurred at later stages.

Male and female *S. novaeguineae* take 136 and 146 days respectively to develop from 1st instar into adults. Hence, it is evident that from entry *S. dallatorreanum* would require approximately 140 – 160 days (or 5 to 6 months of developmental time) to develop into an adult. To verify this hypothesis on developmental time of *S. dallatorreanum*, a trial on exposure period (i.e. exposing *S. novaeguineae* nymphs to *S. dallatorreanum* for a specific number of days) is desirable. Obviously *S. dallatorreanum* will not develop fully in hosts having shorter life span than it requires for its development, and this would in turn have a bearing on the success of the parasite as a biocontrol agent. Experiments to address this matter are currently being undertaken.

Experiment 2 Infectivity trials

Objectives

1. To infect *Segestidea defoliaria* and *Segestes decoratus* with *Stichotrema dallatorreanum*.
2. To observe the development of the parasite, and determine the effect that it has on the development of its host.

Materials and methods

Further batches of field collected eggs of *Segestidea defoliaria* and *Segestes decoratus* were sent from Dami Research Station, West New Britain to OPRA Higaturu during 1998. These eggs were kept in the laboratory until hatching. Upon hatching each test insect was measured and colour coded with a permanent marker. Five test insects were placed in one cage ($0.6m^3$), and this defined as one experimental replicate.

The five test insects were then infected with triungulins (free-living, first instar larvae of *S. dallatorreanum*). This was done by the introduction of an infected *S. novaeguineae*, with emerging triungulins into the cage containing the test insects. Fresh oil palm leaves and moisture were provided daily for both the test insects and the infected host in each cage.

The test insects were exposed to emerging triungulins from the 1st and up to the 4th nymphal stage. There was no further exposure of test insects to triungulins ceased for the 5th instar until adulthood. Moult increment and inter-moult period were determined for each test insect as described in Experiment 1.

Ten replicates of infected and control treatments (not exposed to *S. dallatorreanum*) of *S. defoliaria*, and 8 of infected and 3 controls for *S. decoratus* were undertaken during 1998. No further replicates were undertaken for the latter species during the year due to lack of eggs.

Results

Of the 50 first instar nymphs of *S. defoliaria* exposed to *S. dallatorreanum*, 44 insects (88%) were confirmed to have triungulins clinging onto various body parts and/or had triungulins penetrating the host cuticle (15 insects), or actual stylops developing inside (29 insects). The number of stylops observed after the dissection of dead test insects ranged from 2–100 developing larvae per infected specimen, with an average of 22 stylops/insect. In *S. decoratus*, 35 insects (70% of the 50 exposed nymphs) were confirmed infected, with 21 insects having stylops larvae developing in them. The number of stylops observed per infected specimen ranged from 1-18, with an average of 5 stylops/insect.

Cage mortality was observed to be very high in both *S. defoliaria* and *S. decoratus*. A mortality level of 100% was observed for the test insects (both control and infected sample) in *S. defoliaria*, while 90% and 94% respectively were observed in *S. decoratus*. Comparatively more test insects successfully reached the adult stage in *S. decoratus* (18% success) than *S. defoliaria* (2%) (Table 5.7). As illustrated in Figure 5.11 fewer *S. defoliaria* in the control treatments died between 2^{nd} – 4^{th} nymphal stages (20% death) than in the infected group (56% death) at the same age. The converse occurred at the later developmental stages (5^{th} – 7^{th} instars), where 64% and 28% mortality were recorded.

Table 5.7 Summary of observations from the infectivity trial.

Observations	*Segestidea defoliaria*		*Segestes decoratus*	
	Control	Treated	Control	Treated
Number of replicates	10	10	10	10
Number of test insects/replicate	5	5	5	5
Number of replicates done 1997-98	10	10	2	10
Number died before reaching adult	49	49	5	40
Number moulting to adult stage	1	1	5	6
Total deaths in captivity	50	50	9	47
Number having parasite development		44		35
Number of parasites/test insect		2-100		1-18
Percentage of test insects infected		88%		70%
Percentage mortality in captivity	100%	100%	90%	94%

Figure 5.11 Frequency of death at the various life stages in test *Segestidea defoliaria* nymphs.

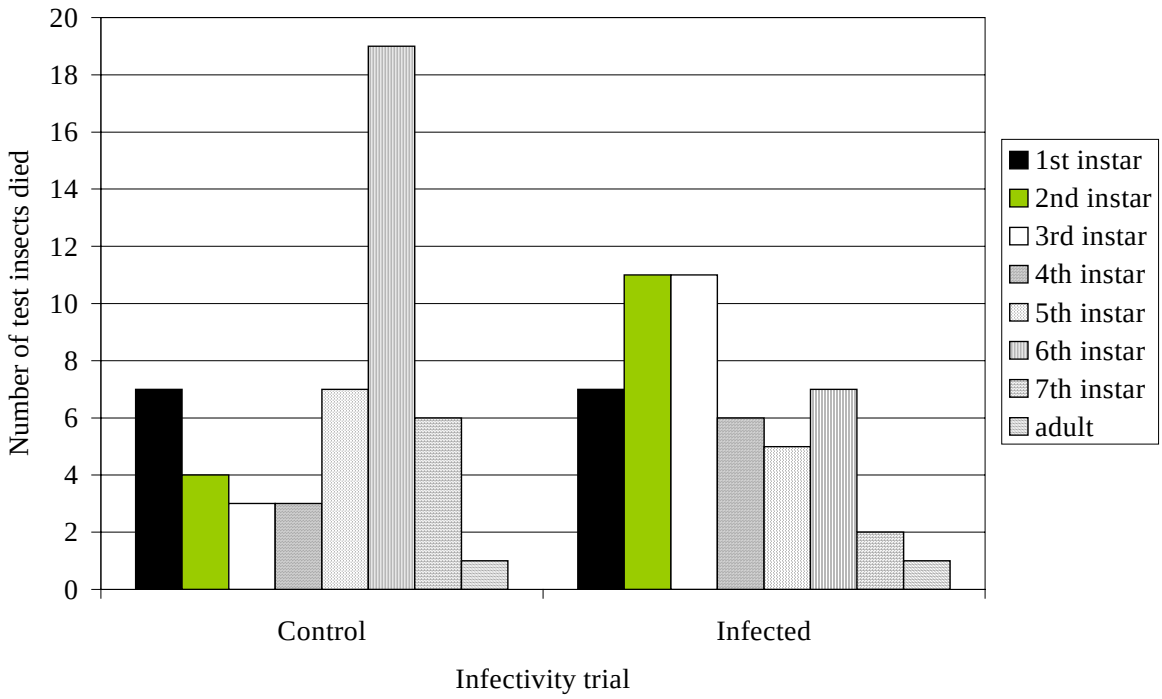


Table 5.8 The mean length (mm) attained at each nymphal instar in the *S. defoliaria* and *S. decoratus* test insects used in the infectivity trials.

Instar	*Segestidea defoliaria*				*Segestes decoratus*	
	Control		Infected		Control	Infected
	Male	Female	Male	Female	(females only)	
1st	12	12	11	12	13	13
2nd	17	17	16	16	18	17
3rd	20	21	21	21	23	23
4th	24	26	27	26	27	28
5th	30	31	33	32	34	33
6th	35	36	41	37	41	41
7th	38	42	-	45	46	46

From Table 5.8 it can be seen that there was no apparent difference in body lengths attained at each nymphal instar within and between sexes or between the control and infected insects in both *S. defoliaria* and *S. decoratus*.

Table 5.9 The mean number of days between successive moults in *S. defoliaria* and *S. decoratus.*

Instar	*Segestidea defoliaria*				*Segestes decoratus*	
	Control		Infected		Control	Infected
	Male	Female	Male	Female	(females only)	
$1^{st} – 2^{nd}$	15	14	14	15	15	12
$2^{nd} – 3^{rd}$	14	12	13	12	12	14
$3^{rd} – 4^{th}$	13	15	14	12	12	15
$4^{th} – 5^{th}$	14	15	13	14	16	17
$5^{th} – 6^{th}$	18	21	21	17	18	21
6^{th} – adult	30	-	-	-	24	32
$6^{th} – 7^{th}$	17	30	-	21	23	22
7^{th} – adult	-	-	-	26	21	28
Days to adult						
6^{th} – adult:	104	-	-	-	97	111
6^{th} – adult:	-	-	-	117	141	161

From Table 5.9 it can be seen that infected *S. decoratus* appear to take more days to reach the adult stage from 1^{st} instar nymph (111 – 161 days) relative to the controls (97 – 141 days), thus suggesting possible influence by *S. dallatorreanum* in delaying the hosts' developmental time. Differences in *S. defoliaria* could not be determined due to pre-adult deaths to nearly all test insects.

Table 5.10 Comparative mean (± SE) developmental time (days) in three species of Sexava

	N	Developmental time (d)	Range (d)
Female			
Segestidea novaeguineae	8	136 ± 6.6	102 – 159
Segestidea defoliaria	9	112 ± 5.1	87 – 139
Segestes decoratus	4	100 ± 5.1	89 – 114
Male			
Segestidea novaeguineae	10	109 ± 5.9	85 – 146
Segestidea defoliaria	6	88 ± 5.9	69 – 111

From Table 5.10 it can be seen that the mean number of days required to reach the adult stage indicates an apparent difference between the 3 species of sexavae. The larger *S. novaeguineae* appear to take longer to reach adulthood relative to the other two species.

Discussion

The infectivity trial demonstrated that *S. dallatorreanum* from its natural host *S. novaeguineae* will infect both test hosts *S. defoliaria* and *S. decoratus* from West New Britain. This was confirmed from the high infection rates of 88% and 70% observed respectively in *S. defoliaria* and *S. decoratus* samples exposed to *S. dallatorreanum*. Infected insects included those found having either the stylops larvae developing inside them and/or triungulins that had penetrated into the host cuticle. Host entry was observed through the permeable surface of the insects, including the tibia, femur and coxae of fore-, mid- and hind legs; thoracic region, and the abdominal surfaces.

Development of stylops larvae was confirmed in 29 *S. defoliaria* and 21 *S. decoratus* nymphs. However, complete development of the parasite to maturity, that is, protrusion of the cephalothorax through the host cuticle was not achieved. This was because most infected insects died before reaching the adult stage. Although one specimen each of *S. defoliaria* with 12 stylops and *S. decoratus* with 1 large stylops did successfully moulted to adult, both also died within four days from turning adult and without the protrusion of the cephalothoraces.

The number of parasites found inside each infected insect varied greatly between the species tested, with the highest numbers found in *S. defoliaria* (average of 22 parasites/insect and ranging from 2-100/insect) than in *S. decoratus* (5 parasites/insect and 1-18/insect, respectively). Consequently, the high incidence of death observed in the exposed insects as compared to the controls, particularly deaths occurring at the early nymphal stages of the trial may be attributed to overparasitism. However, the high cage mortality also seen in the control sample may indicate that sexavae are sensitive insects and may prove difficult to rear in captivity. This may also suggest that further cage/lab based infectivity trial may prove difficult and/or yield similar results.

Development of *S. dallatorreanum* appeared to have negligible effect on the nymphal body lengths attained at each instar in both *S. defoliaria* and *S. decoratus*. However, the presence of the strepsipteran appeared to have had some influence on the developmental time in *S. decoratus*. This was seen in the increased number of days required between successive ecdysis, thus possibly suggesting that *S. dallatorreanum* would prolong its hosts' life cycle or lifespan to complete its own development. Such a manipulation was not seen in *S. defoliaria* mainly because of premature deaths of the test samples.

Experiment 3 Field Studies

Objectives

1. To monitor the levels of stylopization in the oil palm agroecology in Oro Province.
2. To survey for the free-living stages of male *S. dallatorreanum*.

Materials and methods

Two new sites, one each at Ambogo and Sangara estates (HOPPL) were selected for monitoring in 1998. These replaced the smallholder block at Dobuduru which had approximately a quarter of palms destroyed by fire during the drought in 1997. Monitoring of the infection levels of *S. novaeguineae* by *S. dallatorreanum* was carried out fortnightly for each site. This monitoring coincided with the harvesting rounds at each estate. During harvesting, a large number of *S. novaeguineae* are dislodged from the fronds and fall to the ground, and are thus easily spotted and caught. This method gives a large number of sampled insects per unit area each fortnight. Individual *S. novaeguineae* are caught, observed for evidence of infection by *S. dallatorreanum* (i.e cephalothorax of mature parasite protruding from the host cuticle) and recorded. The captured individuals are then released back into the field.alaise and light traps were used to survey for the yet unknown free-living stages of male *S. dallatorreanum* during 1998, both in Oro and West New Britain Provinces.

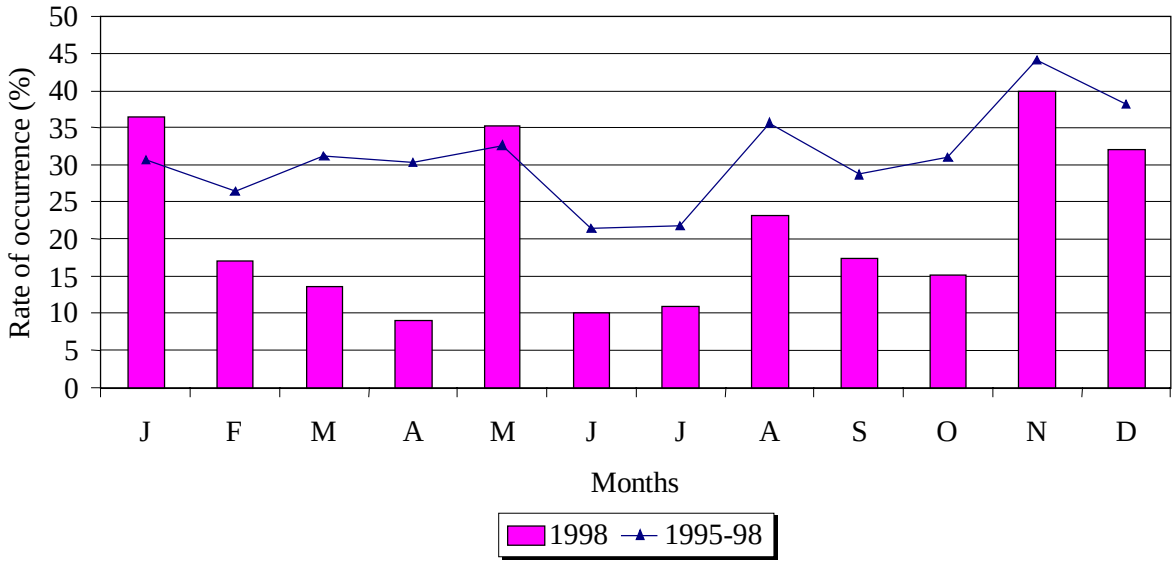
Results

An average of 22% level of stylopisation (external evidence) in *S. novaeguineae* by *S. dallatorreanum* was observed in during 1998, while the mean for a 4 year period (1995 – 98) was 31% (range of 20 – 45% level).

The trend in seasonal fluctuation of stylopisation levels during 1998 appears to be similar to those for the means over the entire observation period (1995-98). See Figure 5.12.

During 1998, no free-living males of *S. dallatorreanum* were captured in the malaise or light traps in Oro Province.

Figure 5.12. Mean external evidence of stylopisation levels in *S. novaeguineae* by *S. dallatorreanum* in Oro Province, 1995-98 (1995/96 figures from T. Solulu MSc data).



Discussion

A relatively high level of infection in *S. novaeguineae* by *S. dallatorreanum* is occurring naturally where both the parasite and host coexists, and hence the effective regulation of the pest population by the parasite as observed annually in mainland PNG.

It should be noted that the level of infection recorded in Oro Province would have been an underestimate of the actual occurrence, since monitoring was based only on the external evidence. That is, the rate of occurrence is not quite the same as the actual level of parasitism. Hence, it is possible that actual level of parasitism may be higher still in the field.

PROJECT REPORT - European Union Stabex Project Number 4.5

Research in the biological control of Sexava at the Papua New Guinea Oil Palm Research Association

Project Completion Report – November 1996 to December 1998

1. Activities / Inputs

1.1 Research

When the project began in November 1996 virtually nothing was known about the group of long-horned grasshoppers, collectively known as Sexava, that are the principal pests of oil palm in Papua New Guinea. Furthermore very little was known about the potential for the biological control of these insect pests. Two biological agents were targeted as having potential for Sexava biocontrol: a strepsipteran parasite of Sexava, and fungal pathogens virulent against the pest. Since November 1996 we have focussed our efforts towards developing the use of these as agents for Sexava biological control.

Research involving the strepsipteran parasite has been linked to, and supported through collaborative work at the Department of Zoology at Oxford University, UK.

Work involving the development of fungal pathogens has been carried out in conjunction with the International Institute of Biological Control (IIBC), UK.

The following activities have been undertaken:

(a) Basic life history studies have been carried out at our Higaturu Research Centre, Popondetta. Walk-in cages have been used for rearing large numbers of test insects. This has enabled us to determine the life history of the Sexava host and the strepsipteran parasite. These studies have given us a good insight into a number of biological parameters, and we continued with them throughout 1997 and 1998. The cultures also served as a source of fresh material for ultrastructural studies (b) and infectivity trials (d). The prolonged drought experienced in Papua New Guinea during 1997 meant that it was difficult to collect sufficient live material for these studies and for the insect cultures in general. Progress was therefore slow for the last 6-8 months of 1997. Fortunately we managed to make good progress throughout 1998 and all of the work that was planned at the beginning of the project has now been completed.

(b) Throughout the duration of the project material has been sent to Dr Kathirithamby at Oxford University.

During 1997 Dr Kathirithamby used electron microscopy to study the ultrastructure of the host and parasite. She has found that the parasite reproduces using a combination of polyembryony, parthenogenesis and vivaparity. She also investigated the influence of the parasite on host fecundity, particularly with regard to the development of abnormal eggs. In addition to this, she identified material caught in our field studies (c), and analysed material resulting from our infectivity trials (d).

During 1998 Dr Kathirithamby's work focused on two important aspects of the biology of the Sexava parasite, *Stichotrema dallatorreanum*, feeding and reproduction. She found that the late instar and mature female *S.dallatorreanum* have no mouth opening, and feed using a region analogous to the peritropic matrix which is formed on the ventral surface. The peritrophic matrix is normally found only in the midgut of Arthropods, and is a structure that surrounds the food and aids in food

absorption. This is the first time that the matrix has been found on the outside cuticle of an arthropod. It appears to be modified in Strepsiptera, where the food is the host haemolymph.

Sections of young females from the infectivity trials (d) were been examined and they it was found that they seem to be secreting this matrix via the microvillate cells. Although it can only be confirmed that the matrix is formed when late fourth instar females become available for examination. It is important for the female to have such a matrix for food absorption during development in the altered host.

During 1998 Dr Kathirithamby has found that in *S. dallatorreanum* there is no egg stage, so that the development of the immature parasite passes from germ cell to embryo. She has also discovered that embryos are connected to other embryos by putative nutritive chords. As there is no fat body, nutrients are passed to the developing embryos via these chords. The origin and function of the chords is now being determined. Similar investigations are to be undertaken for the material resulting from the infectivity trials (d).

c) Light and malaise traps have been used in PNG to attempt to locate the free-living stages of the parasite. We trapped for the duration of the project, and this has given us two years of taxonomic and ecological data. This in turn has given a good insight into the presence and abundance of the free-living stages of the parasite, as well as some knowledge of its population dynamics. The material caught in the traps was sent to Dr Kathirithamby at Oxford University for identification, and we are currently working on a joint publication from this data.

(d) In May 1997 we started the first stages of infectivity trials with the parasite and species of Sexava from West New Britain. Progress was slow during 1997 because of the drought and the resulting problems with getting sufficient live material for the insect cultures. However by the end of 1997 we had made a major breakthrough in demonstrating that the parasite would infect both species of Sexava from West New Britain. Further large-scale cage trials were undertaken throughout 1998, and most of this work was completed by the end of the year.

We have therefore fulfilled our original objectives. However, although we have shown infectivity and partial development, we are still to demonstrate complete development of the parasite within Sexava hosts from WNB and the subsequent development of a second generation of parasites from within these altered hosts. This aspect of our research will be addressed in the next phase of the project, which will involve field trials with the parasite in West New Britain during 1999 and 2000.

(e) If the field trials with the parasite are successful, then its use will be incorporated into our integrated pest management system for Sexava in West New Britain. This IPM system will be sustainable, environmentally acceptable and economically viable. It will benefit both plantation and smallholder oil palm growers in the islands region of Papua New Guinea.
(f) Surveys for fungal pathogens of Sexava, using two separate methods, were undertaken from November 1996 onwards: (1) surveying from individual Sexava hosts, and (2) surveying soil samples collected from the oil palm agro-ecosystem. We were unable to find pathogens from Sexava hosts, but 49 pathogens were isolated from soil samples. These were tested against Sexava in the laboratory, but none showed much potential. Partial biological characterisation of these isolates was undertaken, and we continued with surveys to find an isolate from infected Sexava hosts throughout 1997 and 1998 but with no success.

1.2 Training

(a) Takis Solulu, the assistant entomologist completed his MSc. at Oxford University, UK in December 1996.

(b) A second assistant entomologist, Ross Safitoa, was recruited to the project in January 1997. He was to be registered for a MSc. in Applied Entomology at Imperial College, University of London, UK for 1999. Unfortunately Ross was seriously ill for a large part of 1998, and spent seven months in Australia undergoing medical treatment. Our plans for him to go for training overseas in 1999 have therefore had to be altered, and we are now looking for him to start on his MSc during 2000 or 2001.

(c) Takis Solulu has recently been awarded an Australian Development Scholarship to study for a PhD in Crop Protection at the University of Queensland in Brisbane. This overseas training will commence in June 1999 and last for three years.

(d) The entomology supervisor, Simon Makai, has been given on-the-job training by the OPRA senior entomologist, as well as by our collaborating scientists: Dr David Moore (International Institute of Biological Control) and Dr Jeya Kathirithamby (Department of Zoology, Oxford University).

(e) Staff from the International Institute of Biological Control conducted a two-week training course in insect pathology for three OPRA entomologists in May 1997.

(f) A series of training courses for agricultural extension officers (from OPIC) and plantation managers / supervisors started in 1996. These courses continued throughout 1997 and 1998. During this time we have also done a series of training courses in entomology for smallholder oil palm growers in West New Britain Province.

(g) We have produced entomology fact sheets for smallholder oil palm growers, and have done a series of programmes about entomology on local radio in West New Britain.

2. Results / Outputs

(a) Dissemination

All research findings have been disseminated in international scientific journals and conferences, as well as OPRA Annual Reports. Project dissemination between 1996 and 1998 includes the following:

Caudwell, R.W and Orrell, I. 1996
A sustainable integrated pest management scheme for oil palm in Papua New Guinea
Proceedings of the PORIM International Oil Palm Conference **1996,** 476-482

Caudwell, R.W and Orrell, I. 1997
Integrated pest management for oil palm in Papua New Guinea
Integrated Pest Management Reviews **2,** 1-8

Moore, D. and Caudwell, R.W. 1997
Formulation of entomopathogens for the control of grasshoppers and locusts
Memoirs of the Entomological Society of Canada **171,** 49-66

Annual Report of the Papua New Guinea Oil Palm Research Association. 1997
Entomology Section.

Kathirithamby, J., Simpson, S.J., Solulu, T.M. and Caudwell, R.W. 1998
Strepsipteran parasites – novel biocontrol tools for oil palm integrated pest management in Papua New Guinea
International Journal of Pest Management **44 (3),** 127-133

Solulu, T.M., Kathirithamby, J. and Simpson, S.J. 1998
The effect of strepsipteran parasitism on a Tettigoniidae pest of oil palm in Papua New Guinea.
Physiological Entomology **23,**

Kathirithamby, J.1998.
Host parasitoid associations of Strepsiptera: anatomical and developmental consequences.
International Journal of Insect Morphology and Embryology Series on Strepsiptera. **27,** 39-51

Kathirithamby, J. Caudwell, R.W., and Solulu, T. 1998
Biological control agents for oil palm IPM in Papua New Guinea
*Proceedings of the IOPRI International Oil Palm Conference **1998***

Annual Report of the Papua New Guinea Oil Palm Research Association. 1998
Entomology Section.

Caudwell, R.W. and Solulu, T.M. 1999
Strepsipteran parasites – potential biocontrol tools for oil palm IPM in Papua New Guinea
Crop Protection In Prep

Kathirithamby, J. and Caudwell, R.W. 1999
A survey of male Strepsiptera found in the oil palm agroecosytem in Papua New Guinea
Bulletin of Entomological Research In Prep

(b) Knowledge of the biology of the parasite

Resulting from our research during 1997 and 1998 we have acquired an in-depth knowledge of the biology of the strepsipteran parasite and its Sexava host. This will be further developed during the second stage of the project in 1999 and 2000.

(c) Potential of parasite for use as a biocontrol agent

We have determined the potential of the parasite as a biological control agent in an analytical and scientific manner. Our research has involved both detailed laboratory studies and carefully planned field work. We have good evidence that *S. dallatorreanum* will infect both pest species of Sexava from West New Britain. We have elucidated key components of the host – parasite relationship, and have developed a good knowledge regarding the effect of the parasite on the fitness and fecundity of its Sexava host.

(d) Use of parasite as a biocontrol agent

We would like to undertake field trials with the parasite in West New Britain during 1999 and 2000. Depending on the success of these, the use of parasite will be incorporated into our integrated pest management system for Sexava. The use of the parasite as a biocontrol tool in Sexava IPM will be will be sustainable, environmentally acceptable and economically viable. It will benefit both plantation and smallholder oil palm growers in the islands region of Papua New Guinea.

(e) Collection of fungal pathogens

A collection of fungal pathogens has been obtained from the oil palm agro-ecosystem in West New Britain. Partial biological characterisation and screening of these isolates against Sexava have been carried out.

(f) Potential of fungal pathogens for use as biocontrol agents

A project report has been produced by PNGOPRA and IIBC on the feasibility of developing a biological control strategy for Sexava based on fungal pathogens.

(g) Infrastructure

Most of the capital items for the project was purchased during 1997. These included a four-wheel drive vehicle for the senior entomologist and two motorcycles (for the assistant entomologist and entomology supervisor). Houses for the assistant entomologist and supervisor were constructed at Hargy Oil Palms, Bialla, West New Britain. Large amounts of general laboratory and field equipment were also purchased. These included the following: three microscopes (one located at Oxford University), a camera and video system for one of the microscopes, a portable computer for the senior entomologist, a fridge, breeding and experimental cages, light and malaise traps for field collecting, and two cabinets for our insect collections.

By the end of 1997 we had fully functioning entomology laboratories at our Dami, Higaturu and Hargy Research Centres. With each laboratory set up with the required equipment and manpower to undertake specific research tasks under the project, as well as to undertake the routine research work that we do for the oil palm industry. We had 2-3 staff at each laboratory, each with the required level of knowledge and training to conduct the experiments being undertaken for the project at that location.

In May 1998 Hargy Oil Palms, the landlord of our research centre in Bialla, gave us notice to vacate our rented property there. This meant that our entomology research unit at Bialla was closed down in May 1998. The senior entomologist was transferred to Popondetta, and the assistant entomologist was at that time in Australia undergoing urgent medical treatment. The equipment from our Bialla centre was relocated to Popondetta and Dami. The assistant entomologist resumed duties at Dami in January 1999, and the senior entomologist is to be transferred back to Dami later in 1999.

During the project we have therefore developed a robust infrastructure of equipment, knowledge and training within the entomology section of PNGOPRA. This has enabled the objectives of the project to be fulfilled within the required time frame. This infrastructure will also be sustainable in the long term, and will serve our future research requirements.

6. PLANT PATHOLOGY

(F R Sanderson & C A Pilotti)

FIELD RESEARCH

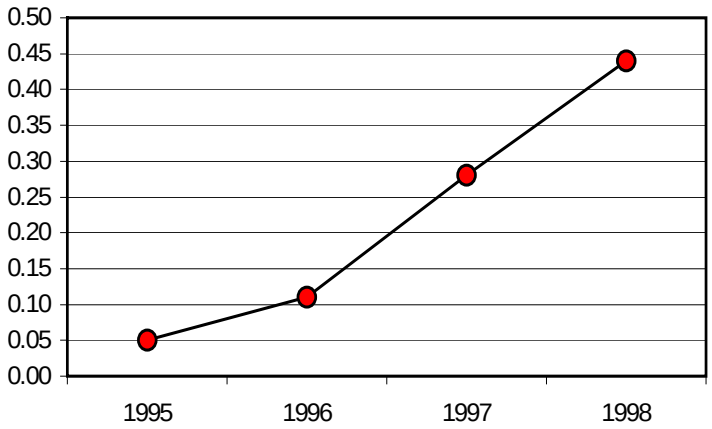
SURVEYS

There were two reasons for implementing of the surveys. The first was to obtain an insight into the epidemiology of the disease, and second to providing information on the incidence, range of symptoms. More importantly, however, the surveys have given us the opportunity to develop and implement the control strategy.

1998 Surveys

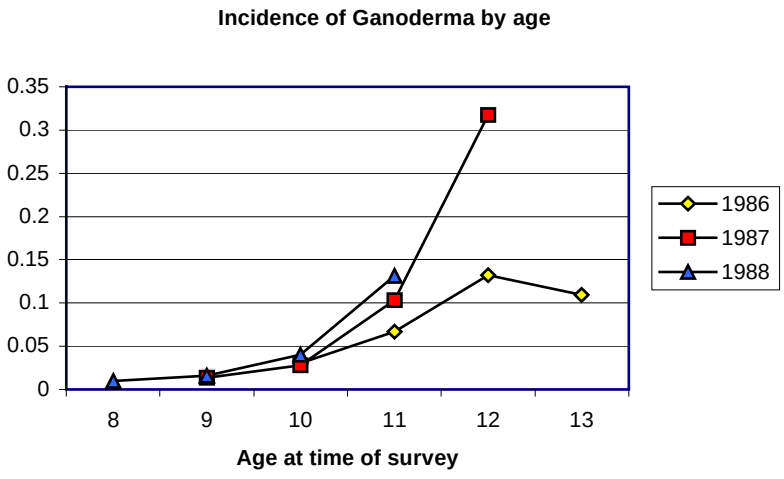
Two surveys were conducted during 1998. The incidence of infection has been increasing steadily over the 4 years starting at 0.05% in 1995, increasing to 0.11% in 1996, 0.28% in 1997 and to 0.44% in 1998. During the four years we have recorded and checked just under 3,000 palms.

Figure 6.1 Incidence of infection for all blocks planted in 1986, 87 and 88, as recorded during the 1995, 96 and 97 surveys.



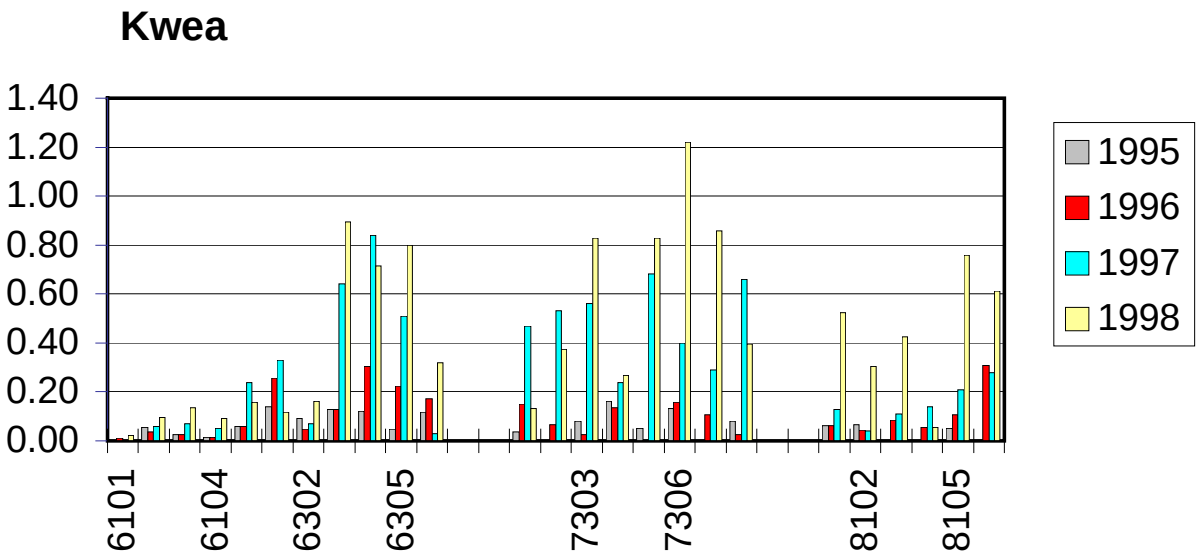
The lack of infection in the older plantations around PNG suggests that there was little secondary spread within these plantations. We have therefore been predicting that the current increase in the incidence of infection in Milne Bay is likely to slow down.

Figure 6.2 Incidence of infection by age at each survey.

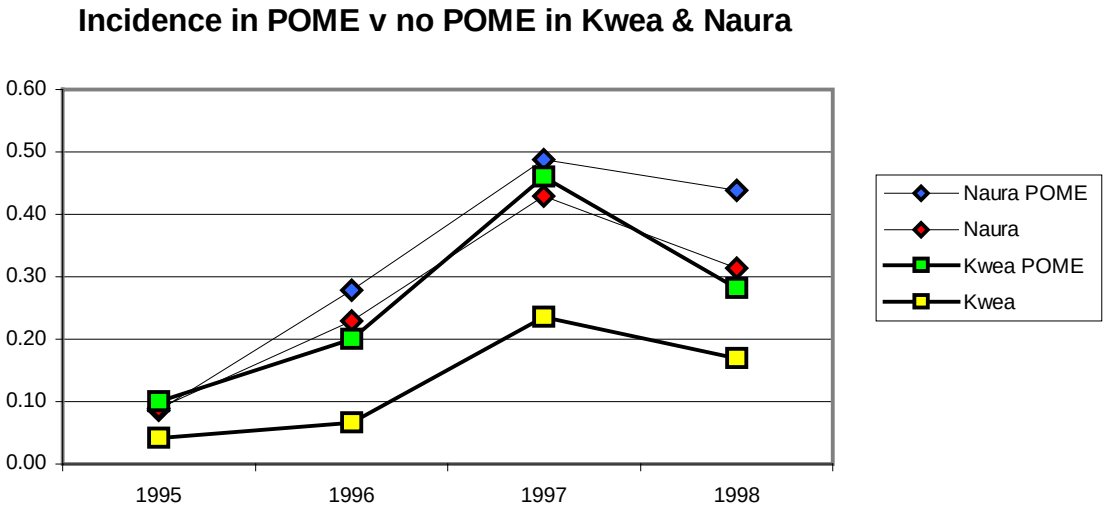


As in previous surveys and discussed at greater length last year, the differences between blocks mask any trends due to factors such as age, whether the previous cover was coconut or forest, or the suggested effect of POME on incidence.

Figure 6.3 Incidence of infection for the four years of surveys shown by blocks and grouped into 6--- series planted in 1986, 7--- series planted in 1987 and 8--- series planted in 1988. Differences between blocks completely mask any effect due to age on incidence.

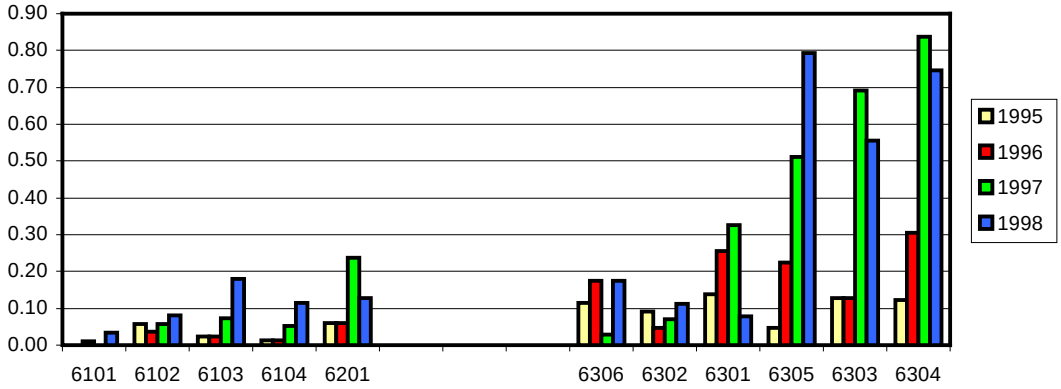


As with last year if we bulk the data for all POME blocks for both Kwea and Naura we are starting to get a clear difference between POME and NO POME in both plantations.



If we take the 1986 plantings from Kwea the picture becomes even clearer.

Incidence in no POME v POME 1986 planted blocks. Kwea



CONTROL STRATEGY

Our current recommendation:

- Surveys to identify infected palms which are marked as either
  - Infected without brackets.
  - Infected with brackets.
- Palms without brackets are left, harvested, and monitored for future development of brackets.
- Palms with brackets are felled and any infection at the base of the trunk cut up and removed from the block.
- The root ring and trunk base is removed to a depth of 10 - 15 cm below ground level and the hollow filled with soil. As long as the infected palm base and roots are covered with soil, the infected stem base and roots are of little consequence as brackets cannot form and they are soon invaded by a host of other wood decaying organisms.

A change in the basic strategy is required at replanting. Every effort must be made to identify and remove all infected palms, so that at replanting, the only old trunks left in the field are of healthy wood and not likely to be a source of brackets.

Implementation of the control in Milne Bay Estates

During the 1996 and 97 surveys, the removal team got further and further behind in removing infected palms. To compensate we implemented bracket removal teams then looked at fungicide control. For 1998 it was decided to firstly catch up with the backlog then for the second survey implement a system so that the removal teams could keep up with the survey teams.

An Access programme was developed so that the data could be entered daily and a weekly Report produced that identified Palms for Removal. Four chain saw gangs would then remove these palms during the week.

The backlog was cleared by June 1998, however, we were completely frustrated by the computer network of MBE not being compatible with the OPRA PC. Photocopying the forms and again putting into the OPRA computer separately at a later date eventually did the job.

Implementation of the control in other Plantations

Three training courses were conducted to instruct staff from other plantations and OPIC on the skills required implementing the control strategy. These were conducted under the auspices of the training officer at Milne Bay Estates and OPRA staff.

Arthur Senuar, the Ganoderma Field Supervisor from MBE then spent 2 – 3 days with each of the Ganoderma teams on the different Estates.

A further follow-up will be conducted during the next few months.

FUNGICIDE TRIALS

Five conazole fungicides were tried:

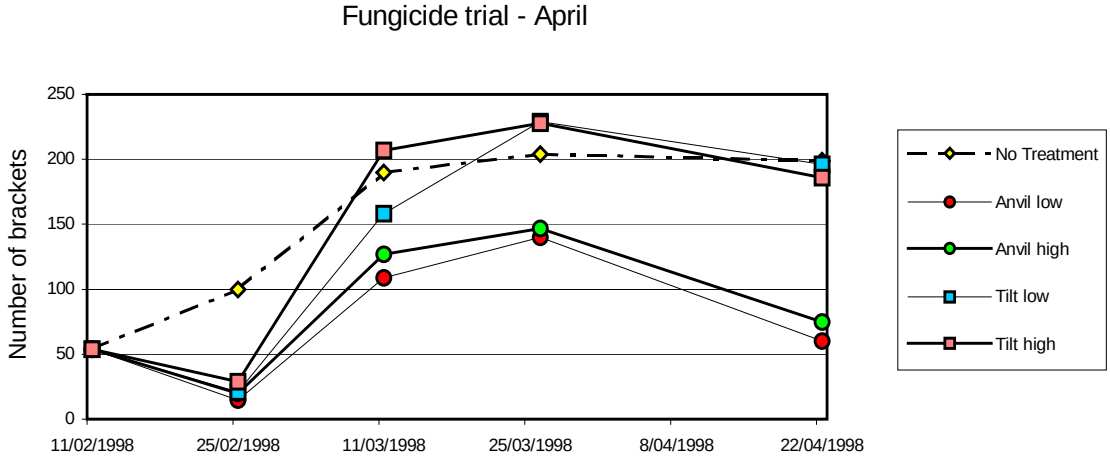
- Cyproconazole Alto 100 SL
- propoconazole Tilt 250 EC
- hexaconazole Anvil 50 EC
- difenconazole Bogard 100 WP
- penconazole Topas 100 EC

Following two small trials three of the chemicals were rejected leaving only:

- hexaconazole Anvil 50 EC 5 & 15 ml/palm
- propoconazole Tilt 250 EC 1 & 3 ml/palm

Ten palms were sprayed per treatment including a control giving a total of 5 treatments. Palms were grouped so that each treatment had a total of 54 brackets. Sprays were applied on the 11/3/98, 11/4/98 & 25/4/98.

Two weeks after the first application both chemicals had reduced bracket numbers from 4 – 5 per palm down to 2 – 3 per palm while the numbers on the unsprayed had risen to 10 per palm. At this point the long dry spell broke and we had our first rains. Two weeks later the numbers had risen to 12 – 21 brackets per palm with 19 per palm on the unsprayed. A second application was made on the 11/4 and a third on the 25/4. By the end of the trial the number of brackets for the two treatments of hexaconazole (Anvil) was 6 & 7, while that for propoconazole (Tilt) and the untreated was 19 & 20. Although hexaconazole does have activity against the Ganoderma it is insufficient to be considered for this purpose.



WOOD DEGRADING FUNGI

During 1997 Dr. Roland True spent six weeks in the Milne Bay Laboratory during March and April. During this time he isolated 29 wood degrading fungi that were inoculated into felled oil palm trunks. Although some wood degrading activity was demonstrated in the majority of isolates, in all cases it was limited to less than 3 cm of the inoculation point after about four months. The most impressive is a black soft rot complex that rapidly breaks down the soft woody cells. Although the vascular tissue is left intact, the process completely breaks down the structure of the wood.

A visit by Mrs Barbara Ritchie in March 1998 focused on the black soft rot complex. It was quickly demonstrated that the rapid decay was the result of the single fungus *Ceratocystis*. Inoculations were made in both the laboratory and in the field that confirmed this.

AEROPONICS

The shade house was completed late last year and the aeroponics unit commissioned in May this year. 250 seedlings were transplanted from the field then a further 750 from DAMI. After 3 months the Dami seedlings have caught up with those transplanted and will no doubt soon outgrow them.

FOREST STRAINS OF GANODERMA

In May this year (1998) a request was made to look at *Ganoderma* brackets which had developed on poisoned oil palms in the Kapiura plantation of NBPOL. On visiting the site it was noted that although the brackets were similar to those on living oil palm there did appear to be some slight differences. They were also similar to brackets on several of the decaying forest stumps fund within the area of poisoned oil palms. The brackets were also similar to those seen on old forest stumps in Milne Bay.

Spore prints were collected from brackets from both the poisoned oil palms and the forest stumps. Three sibling families were germinated on agar and crosses made within and between the three families. Crosses were made between two Kapiura families and two forest types from Milne Bay, and between the same two Kapiura families and a complete set of four mating types from one oil palm family.

The results were interesting in that:

1. The crosses between the Kapiura families, even the outcrosses, all behaved in a typical tetrapolar fashion, indicating that the isolates from the two poisoned oil palms and the old forest stump were the same family. The palms and stump were in an area of about 100 metres square. The only instances where we have different siblings families from oil palm behaving in this manner, is when they are from the same palm, never from different palms.
2. The outcrosses between the forest types from Kapiura and the forest types from Milne Bay all produced clamps, demonstrating that they are from the same mating population and therefore the same species.
3. None of the outcrosses between the Kapiura forest types and the oil palm type produced clamps, indicating that they are different species.

This work has frustrating implications as although the original impression was that the two types of brackets were different, on a study of the wide range of brackets kept in the laboratory, the bracket form of both types overlaps. This is therefore not a reliable criteria to use to distinguish the two types.

We will therefore have to develop other methods to distinguish the forest and palm types of *Ganoderma*.

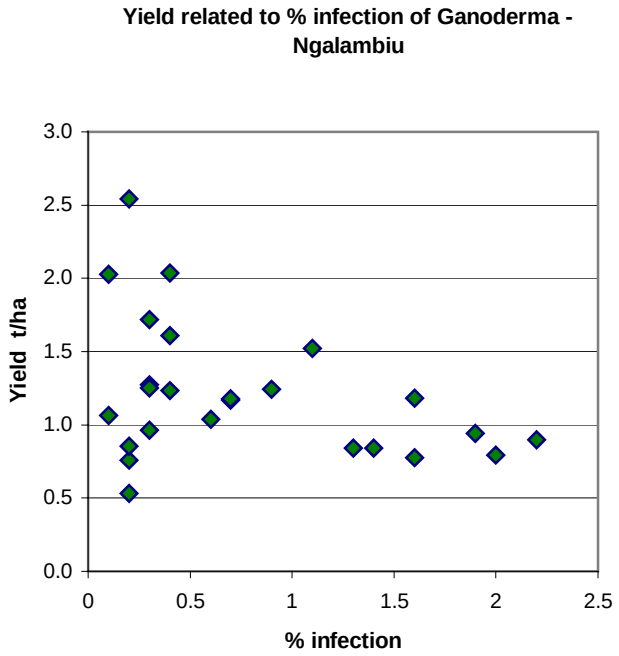
SOLOMON ISLANDS

Background

Like most diseases there are two distinct phases: The primary infection and the secondary spread. With Ganoderma the primary infection occurs at replanting (seen as infected palms from years 6 onwards), the secondary spread within the cropping cycle is seen as upper stem rot. For oil palm it is normally only the primary infection cycle, which is of any significance.

At SIPL this was dramatically changed when the cyclone devastated the area during 1986. The result was a dramatic increase in the importance of the secondary spread of the disease. This resulted in the high levels of Ganoderma in the older stands now being replanted.

Of interest are the blocks in Ngalimbiu (Fields A, B, & C) which were replanted during the three years following the cyclone, which now have incidences of Ganoderma up to 2.2%. The appended graph suggests that this level of infection could be reducing yields by as much as 0.75 tonnes per hectare.



Current Situation:

Surveys

These are well implemented and excellent data is being collected. However, the same situation has developed at SIPL as occurred at Milne Bay. The felling team raced away from the removal team.

The basal plate is removed from the soil. This is being well done. A chain saw is used to remove the basal infection from the felled trunk, and the infected material is removed to the roadside. Unfortunately this is not being well done. In most instances the trunk is not cut back to healthy tissue, leaving a much larger area for bracket production. Secondly in the Divisions of Tetere and Ngalimbiu, the infected material is still on the roadside, again a source of brackets.

As the removal team gets further behind and the felled trunk becomes covered with ground cover then the felled palm is left *in situ.*

In Milne Bay this problem was overcome by the establishment of a Ganoderma team which is responsible for both the surveys and for the control. The size of both groups is regulated so that the whole Estate is surveyed and control implemented over a period of six months. The two chain saw gangs keep pace with the survey team. The removal of the infected material is the responsibility of this section.

Replanting
The plan was to push over all infected palms two years before replanting. Dig out the root ball, cut the infection from the trunk base with a chain saw and remove this material from the site.

In practice this has proved to be unworkable. Currently Mberande Block B has been sanitised. That is the infected/suspected palms have been pushed over and placed in the frond pile and the root ball removed and broken up. There is no removal of the infection at the base of the fallen trunk. Block A is currently being worked and Tetere Field F is to follow. Once this is completed the rest of the palms will be pushed over prior to planting the blocks.

Where to from here?
We have to get the replanting cycle right. Currently there is a gap between what we perceive as being ideal and what, because of a number of reasons, was achieved. An effective compromise has to be reached. To leave the infected trunk material in the field goes against all current thinking regarding Ganoderma control.

I. The immediate priority therefore is to determine the extent of the infection in Tetere Fields A, B, and C so we can assess the risks from the actions already taken. OPRA will do this as part of their research programme.

II. During our next visit a meeting should be held (James Joe OPRA) to discuss the results of this survey and determine what action should be taken in these fields.

III. Every effort should be made to remove the infected trunk bases from the Mberande and Tetere blocks currently being cleared for replanting.

IV. As the future surveys will be carried out by OPRA, the reorganisation of the Ganoderma control to a central Ganoderma team would be preferable to OPRA liasing with each Divisional Manager. It would mean that survey and removal times could be co-ordinated and also mean a more rigid control over the removal of infected plant material.

V. A study should be implemented of the Ngalimbiu Fields A, B, & C to see if it is possible to get some handle on yield losses through Ganoderma. See appended table.

1998 CONFERENCES

Workshop at Egham organised by CABI Biosciences. 5th – 6th August

Understanding variations in Ganoderma.

This was a very valuable workshop for both Carmel and I as it gave us a very good opportunity to become informed and assess the research being carried out by other groups in this field. It also gave us the opportunity to participate in formulating an application for joint funding for all future Ganoderma research.

International Plant Pathology Congress, Edinburgh. 9th – 16th August.

Mark Holderness presented an invited paper on the Ganoderma research and Mrs. Carmel Pilotti and Dr. Pim Sanderson presented two posters.

Again this was an invaluable conference as it gave us both the opportunity to become aware of the latest research into host/pathogen genetics, the area where this project must aim over the next couple of years. It was a great pity that Paul Bridge did not attend this meeting.

PAPERS PRESENTED DURING THE YEAR

Variability of Ganoderma sp. in Papua New Guinea.
Pilotti, Sanderson Aitken and Bridge

ITS-based Detection Methods for Use with Ganoderma.
Bridge, O'Grady, Pilotti and Sanderson

Spores As A Mechanism for Variation in the Host/Pathogen Interaction.
Sanderson

Mating and Vegetative Compatibility Studies On *Ganoderma Boninense*.
Pilotti and Sanderson

A New Approach to the Control of Basal Stem Rot of Oil Palm.
Sanderson Pilotti and Bridge

Ganoderma Disease Of Perennial Crops.
Holderness, et al.

CONSULTANTS

Ms. Barbara Ritchie, CABI Biosciences. 22nd March – 12th April.

Dr Paul Bridge, CABI Biosciences, 22nd April – 29th April.

Appendix 1

Meteorological Data – 1998

Rainfall (mm)

Month	NBPOL (Dami)	Hargy	Poliamba (Lakurumau)	Milne Bay (Waigani)	Higaturu (PNGOPRA)	SIPL (Ngalimbiu)
Jan	638	594	242	159	226	188
Feb	850	556	525	116	369	331
Mar	569	614	242	291	461	320
Apr	468	194	344	80	115	112
May	345	114	163	245	165	177
Jun	352	348	280	110	72	74
Jul	175	246	241	256	176	41
Aug	145	110	203	302	53	98
Sep	95	132	216	238	139	237
Oct	288	322	185	202	178	50
Nov	288	157	274	292	263	253
Dec	245	940	192	204	415	287
Total	**4,456**	**4,325**	**3,107**	**2,495**	**2,632**	**2,165**

Sunshine Hours

Month	NBPOL (Dami)	Hargy	Poliamba (Kavieng)	Milne Bay (Bomata)	Higaturu (PNGOPRA)	SIPL (Ngalimbiu)
Jan	72	112		178	121	131
Feb	100	115		194	162	138
Mar	86	88		148	171	142
Apr	156	191		245	217	224
May	145	184		116	174	172
Jun	146	137		163	185	181
Jul	146	135		166	176	203
Aug	186	182		138	205	243
Sep	187	199		192	110	210
Oct	177	222		258	131	242
Nov	149	233		193	142	218
Dec	129	209		141	62	187
Total	**1,676**	**2,007**		**2,132**	**1,856**	**2,290**