Annual Research Report

1996

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4. Plant Pathology

1 ISLANDS REGION AGRONOMY

1.1 Introduction

1996 was a year of review and consolidation of the islands region agronomy program. Several staff changes occurred over the year that has led to improved management of the trials. The previous system of separating management of smallholder and formal trials was discontinued. Two new trials (126, 205) were established and treatments applied for the first time. A nursery fertiliser trial was established at Bebere to investigate the effect of sulphate of ammonia and urea on seedling growth. Leaf sampling of plantations was completed for all three companies involving the collection and dispatch of over 400 samples. A paper was presented at the International Society of Oil Palm Agronomists (ISOPA) meeting in Kuala Lumpur in September. Field days for New Ireland smallholders were conducted in March. Field days were planned for other project areas but due to changes in OPIC management in the Hoskins and Bialla schemes these field days were postponed until 1997.

1.1.1 Staff

Mr. Graham King joined OPRA in December 1995 as Islands Region Agronomist. Mr. Peter Navus resigned as Extension Agronomist at the end of January 1996. Mr. Joe Yambun transferred from Popondetta in May to take up the position of Assistant Agronomist at Kapiura. Ms. Doreen Piskot was appointed as Trainee Assistant Agronomist in June.

Mr. Tom Boala resigned as Field Supervisor in February. Mr. Jones Mole transferred to Dami from Kapiura and Mr. Abraham Mai was recruited as Field Supervisor at Kapiura.

1.1.2 Trial Management

Until Mr. Navus resignation smallholder research had been managed separately from the formal trial program. This was changed in 1996 so that formal and smallholder trials are managed together. Analysis of the data for all trials was completed in June and the annual report completed in September. Visits from biometricians from IACR - Rothamsted (Janet Riley) and Pacific Regional Agricultural Program (Dick Morton) were used to ensure that the correct analytical techniques were being used and to finalise designs of new trials. In 1996 the unopened spear leaves were counted in each trial at every harvest date to give an indication of water stress. The results of the analysis of this data are presented in this report for the first time.

1.1.3 Leaf Sampling

Plantation leaf sampling was completed for New Britain Palm Oil, Hargy Oil Palms and Poliamba. Samples cannot be taken within two months of fertiliser application and in 1996 sampling took place throughout the year with some results not available at year-end. These leaf and rachis analysis results are used to make fertiliser recommendations and as companies need to order well in advance to obtain their fertiliser for the following year plantation leaf sampling will be brought forward. In future all plantation leaf sampling will be completed by the end of March to ensure that fertiliser recommendations can be made by August each year.

1.1.4 Soil Surveys

DAL Land Utilisation Section conducted a survey of all trial sites in West New Britain to produce soil description data from all the trial sites.

1.1.5 Publications

A paper written by Allan Oliver and Graham King titled “Fertiliser research for sustained yield in Papua New Guinea” was presented at the International Conference on Sustainability of Oil Palm Plantations - Agronomic and Environmental Perspectives organised by ISOPA and PORIM and held in Kuala Lumpur in September 1996. A copy of this paper that emphasizes the potential for increased smallholder production with the addition of the correct fertiliser is included in the appendix. Allan Oliver and Graham King also attended the PIPOC conference organised by PORIM prior to the ISOPA meeting.

1.1.6 Smallholders

OPRA participated in field days for smallholders in New Ireland organised by OPIC. The main topic at these field days was fertiliser. The trials at Lossu and Paruai show quite clearly that with no application of muriate of potash palm growth is severely restricted and yields are very low. The 60 growers who attended these field days should now be aware of the need for the application of the correct fertiliser in New Ireland.

Field days were not held in either the Bialla or Hoskins project areas in 1996.

OPRA agronomists attended Local Planning Committee meetings at Nahavio, Bialla and New Ireland whenever possible.

Three radio programs were produced and broadcast on Radio West New Britain. The topics of these radio programs covered fertiliser and entomology issues.

1.1.7 Technical Recommendations

The following technical recommendations were made for the islands region in 1996.

- Nitrogen fertilisers should be applied to the frond pile to minimise losses due to erosion and leaching.
- EFB should not be applied at more than 60 t/ha/year.
- Immature phase fertiliser recommendations were reviewed. The main outcome was that application of nitrogen fertilisers should commence at planting and not three months after planting.
- The nursery fertiliser trial demonstrated that urea is not suitable for seedlings less than 6-months of age.

1.2 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 1-5 in each plot are from families with high bunch number (HBN) and palms 6-16 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, chlorine was used as a covariate rather than as a factor in the analysis of the 1996 data.

Frond 17 leaflet and rachis tissues were sampled for chemical analysis in 1996.

RESULTS

The average plot yield in Trial 107 in 1996 was 26.9 t/ha. This is considerably higher than the average plot yield recorded in 1994 (23.4 t/ha) and 1995 (23.0 t/ha). The mean number of bunches per hectare was 1050 in 1996 compared to only 951 in 1995 and 1756 in 1994. Mean single bunch weight was 26.0 kg in 1996 compared to 24.2 kg in 1995 and 13.6 in 1994.

Application of 2.0 kg of sulphate of ammonia led to a significant increase in yield ($p<0.001$) from 25.3 t/ha to 27.8 t/ha (Table 1.2). There was no extra advantage in applying 4.0 kg of sulphate of ammonia. In Table 1.3 yields recorded since 1986 show that the response to nitrogen has not been consistent. Figure 1.1 shows that yields peaked in 1990 followed by a marked decline in 1991, high yields in 1992 and 1993 and then a decline again in 1994 and 95. Yields increased again in 1996 but the interesting point is that even with plot isolation trenching in place yields in the N0 treatment also increased markedly. Figure 2 is a boxplot graph of plot yield recorded in each nitrogen treatment. This shows that factors (probably environmental) are having a greater effect on yield than nitrogen. Figure 3 is a boxplot graph of leaflet nitrogen against N level showing that although application of nitrogen elevates the mean leaflet nitrogen level some plots with no nitrogen applied also had very high leaflet nitrogen levels. Similarly, some plots receiving the highest level of sulphate of ammonia had very low leaflet nitrogen levels. This indicates that at this site applied nitrogen fertiliser is very mobile within the trial site even with plot isolation trenching in place.

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.

As expected high bunch number palms (HBN) produced significantly more bunches than those palms with medium sex ratio (MSR).

The aggregated data from January 1994 to December 1996 reflects the significant increase in FFB yield brought about by sulphate of ammonia application (Table 1.4).

Table 1.2 Main effects of N, P, K, Mg and progeny type on yield and yield components in 1996 adjusted for covariate (Trial 107).

	Nutrient element and level			Statistics		
				sig	sed	cv%
	N0	N1	N2			
Yield (t/ha/yr)	25.3	27.8	27.6	***	0.722	16.0
Bunches/ha	1022	1068	1061	ns	30.2	13.3
Bunch weight (kg)	25.3	26.3	26.3	**	0.368	6.6
	P0	P1	P2			
Yield (t/ha/yr)	26.7	27.0	27.0	ns	0.728	16.0
Bunches/ha	1049	1068	1034	ns	30.4	13.3
Bunch weight (kg)	25.7	25.9	26.4	ns	0.371	6.6
	K0	K1				
Yield (t/ha/yr)	27.5	26.3		*	0.586	16.0
Bunches/ha	1064	1036		ns	24.4	13.3
Bunch weight (kg)	26.1	25.9		ns	0.298	6.6
	Mg0	Mg1				
Yield (t/ha/yr)	27.1	26.7		ns	0.591	16.0
Bunches/ha	1058	1042		ns	24.7	13.3
Bunch weight (kg)	26.0	26.0		ns	0.302	6.6
	HBN	MSR				
Yield (t/ha/yr)	27.5	26.6		ns	0.629	16.0
Bunches/ha	1090	1032		*	26.3	13.3
Bunch weight (kg)	25.7	26.1		ns	0.321	6.6

Table 1.3 Effect of N on FFB yield and yield components from 1986 to 1996 (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)	22.6	23.5	24.1	1749	1714	1805	13.2	14.0	13.6
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

Figure 1.1: Yield in Trial 107 1986 - 1996

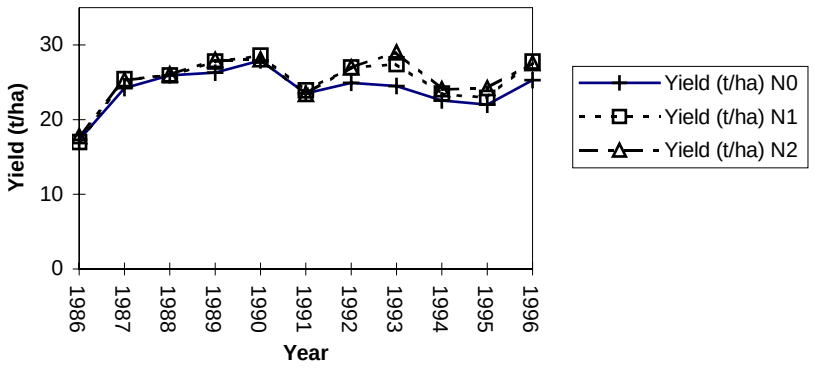


Figure 1.2: Relationship between plot yield and leaf nitrogen status

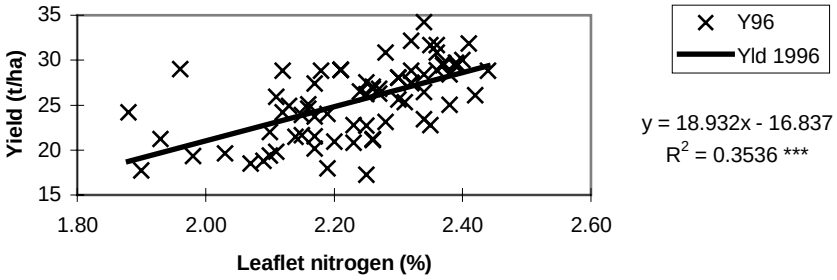


Figure 3: Boxplot of plot yield at N0, N1 and N2 in 1996.

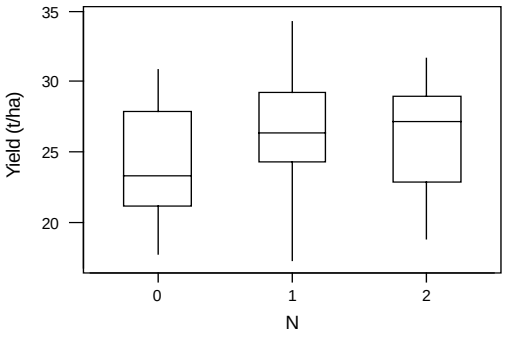


Figure 4: Boxplot of Leaflet Nitrogen at N0, N1 and N2 in 1996.

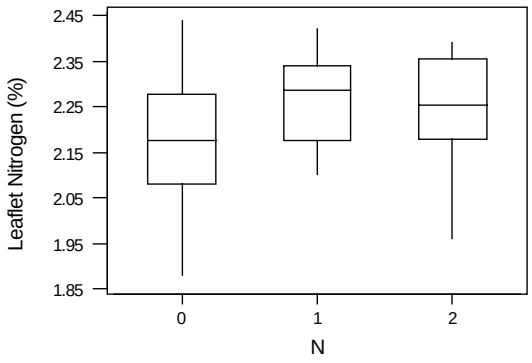


Table 1.4 Main effects of N, P, K, and Mg on yield and yield components from 1994 to 1996 adjusted for covariate (Trial 107).

	Nutrient element and level			Statistics		
				sig	sed	cv%
	N0	N1	N2			
Yield (t/ha/yr)	22.9	24.3	24.7	*	0.78	11.1
Bunches/ha	1227	1225	1267	ns	39.3	10.9
Bunch weight (kg)	20.3	21.4	21.2	*	0.39	6.4
	P0	P1	P2			
Yield (t/ha/yr)	24.1	23.7	24.0	ns	0.78	11.1
Bunches/ha	1229	1227	1263	ns	39.6	10.9
Bunch weight (kg)	20.7	20.9	21.3	ns	0.39	6.4
	K0	K1				
Yield (t/ha/yr)	24.1	23.8		ns	0.63	11.1
Bunches/ha	1245	1234		ns	31.9	10.9
Bunch weight (kg)	21.2	20.8		ns	0.32	6.4
	Mg0	Mg0				
Yield (t/ha/yr)	23.7	24.2		ns	0.64	11.1
Bunches/ha	1239	1240		ns	32.2	10.9
Bunch weight (kg)	20.8	21.1		ns	0.32	6.4

The results of leaflet nutrient analysis are given in Table 1.5. Application of sulphate of ammonia led to a significant reduction in leaflet calcium and magnesium content. Although leaflet nitrogen increased with application of sulphate of ammonia the increase was not significant. The leaflet nitrogen levels recorded here are still well below what is considered optimal (2.60%). One possible explanation for the lower than expected leaflet nitrogen levels is much of the nitrogen applied to a treated plot *escapes* to surrounding N0 plots. Figure 4 shows that leaflet nitrogen levels are elevated even in plots receiving no nitrogen fertiliser.

Application of Kieserite led to a significant increase in leaflet magnesium status however, there was no yield response. Application of triple super phosphate led to a significant increase in leaflet chlorine but no increase in leaflet phosphorus. Sulphate of potash application did not cause any change in leaflet nutrient status.

Analysis of the nutrient content of the rachis shows that phosphorus and magnesium concentrations increased with application of triple super phosphate and Kieserite but that application of sulphate of potash did not increase rachis potassium (Table 1.6). Application of sulphate of ammonia caused a significant reduction of rachis phosphorus.

Table 1.5 Treatment main effects on leaflet nutrient concentrations in 1996 adjusted for the covariate (Trial 107).

Element as % of dry matter	Nutrient element and level			Statistics		
				sig	sed	cv%
	N0	N1	N2			
Nitrogen	2.18	2.27	2.25	ns	0.041	6.2
Phosphorus	0.140	0.141	0.140	ns	0.001	2.6
Potassium	0.76	0.77	0.76	ns	0.015	6.6
Calcium	0.77	0.72	0.72	**	0.016	7.4
Magnesium	0.17	0.15	0.14	***	0.005	10.5
Chlorine	0.47	0.45	0.46	ns	0.018	13.3
	P0	P1	P2			
Nitrogen	2.23	2.22	2.24	ns	0.041	6.2
Phosphorus	0.139	0.140	0.141	ns	0.001	2.6
Potassium	0.75	0.76	0.77	ns	0.015	6.6
Calcium	0.73	0.74	0.73	ns	0.016	7.4
Magnesium	0.16	0.15	0.15	ns	0.005	10.5
Chlorine	0.43	0.46	0.48	*	0.018	13.3
	K0	K1				
Nitrogen	2.26	2.21		ns	0.033	6.2
Phosphorus	0.140	0.140		ns	0.001	2.6
Potassium	0.76	0.76		ns	0.012	6.6
Calcium	0.73	0.74		ns	0.013	7.4
Magnesium	0.15	0.16		ns	0.004	10.5
Chlorine	0.46	0.46		ns	0.014	13.3
	Mg0	Mg1				
Nitrogen	2.24	2.23		ns	0.033	6.2
Phosphorus	0.140	0.140		ns	0.001	2.6
Potassium	0.76	0.76		ns	0.012	6.6
Calcium	0.74	0.73		ns	0.013	7.4
Magnesium	0.14	0.17		***	0.004	10.5
Chlorine	0.45	0.47		ns	0.015	13.3

Table 1.6 Treatment main effects on rachis nutrient concentrations in 1996 (Trial 107).

Element as % of dry matter	Nutrient element and level			Statistics		
				sig	sed	cv%
	N0	N1	N2			
Nitrogen	0.25	0.26	0.26	ns	0.007	9.1
Phosphorus	0.128	0.105	0.090	**	0.012	36.8
Potassium	1.50	1.52	1.45	ns	0.034	7.9
Calcium	0.35	0.35	0.34	ns	0.012	12.0
Magnesium	0.04	0.04	0.04	ns	0.002	14.6
Chlorine	0.59	0.61	0.62	ns	0.047	26.7
	P0	P1	P2			
Nitrogen	0.26	0.26	0.25	ns	0.007	9.1
Phosphorus	0.092	0.105	0.124	*	0.012	36.8
Potassium	1.47	1.49	1.51	ns	0.035	7.9
Calcium	0.33	0.35	0.36	ns	0.012	12.0
Magnesium	0.04	0.04	0.04	ns	0.002	14.6
Chlorine	0.57	0.60	0.65	ns	0.048	26.7
	K0	K1				
Nitrogen	0.26	0.25		ns	0.006	9.1
Phosphorus	0.102	0.112		ns	0.009	36.8
Potassium	1.48	1.51		ns	0.028	7.9
Calcium	0.35	0.34		ns	0.010	12.0
Magnesium	0.04	0.04		ns	0.001	14.6
Chlorine	0.63	0.58		ns	0.038	26.7
	Mg0	Mg1				
Nitrogen	0.26	0.25		ns	0.006	9.1
Phosphorus	0.102	0.112		ns	0.009	36.8
Potassium	1.49	1.50		ns	0.028	7.9
Calcium	0.34	0.35		ns	0.010	12.0
Magnesium	0.04	0.05		***	0.001	14.6
Chlorine	0.59	0.63		ns	0.039	26.7

Trial 119 NITROGEN/ANION FERTILISER TRIAL AT MALILIMI PLANTATION.

PURPOSE

To investigate the response of oil palm to the application of various combinations of inorganic fertiliser with a view to providing information that will be useful in developing fertiliser recommendations.

DESCRIPTION

Site — Malilimi Plantation, Fields A7 and A8.

Soil — Young coarse textured freely draining soils formed on alluvially reworked andesitic pumiceous sands and gravel with some intermixed volcanic ash.

Palms — Dami commercial DxP crosses.
Planted in October 1985 at 135 palms/ha.
Treatments started in May 1989.

DESIGN

There are twelve treatments (Table 1.7) made up from muriate of potash or Kieserite (or neither of these) combined with nitrogen from one of three sources (or no nitrogen). The three nitrogen sources are: diammonium phosphate, sulphate of ammonia, and ammonium chloride. The twelve treatments are replicated in four randomised complete blocks, giving a total of 48 plots. Each plot has 36 palms of which the central 16 are recorded.

Table 1.7 Rates of fertilisers, and resulting combinations of elements used in Trial 119. (Treatment numbers are in brackets.)

	Nil		Muriate of potash		Kieserite	
Nil	---	(1)	K+Cl	(5)	Mg+S	(9)
Diammonium phosphate	N+P	(2)	N+P+K+Cl	(6)	N+P+Mg+S	(10)
Ammonium sulphate	N+S	(3)	N+S+K+Cl	(7)	N+2S+Mg	(11)
Ammonium chloride	N+Cl	(4)	N+2Cl+K	(8)	N+Cl+Mg+S	(12)

Diammonium phosphate	= 3.9 kg/palm/year
Ammonium sulphate	= 3.8 kg/palm/year
Ammonium chloride	= 3.0 kg/palm/year
Muriate of potash	= 4.2 kg/palm/year
Kieserite	= 3.7 kg/palm/year

RESULTS

The average plot yield in 1996 was high at 33.0 t/ha.

The overall treatment effects on bunch number were significant for both the 1996 data and the cumulative data for 1994 to 1996 (Table 1.8). There was a significant treatment effect on bunch weight in 1996. The treatments did not affect FFB yield in 1996 or for the period 1994-1996. The highest yield recorded in 1996 was 36.1 t/ha and this was from the treatment receiving muriate of potash and sulphate of ammonia.

Bunch weights were significantly higher in those treatments receiving chlorine-containing fertilisers (ammonium chloride, muriate of potash). Ammonium chloride gave a lower yield than either di-ammonium phosphate or sulphate of ammonia. The addition of muriate of potash with ammonium

chloride gave a higher yield than ammonium chloride alone but not as high as the muriate of potash and sulphate of ammonia treatment. Di-ammonium phosphate and sulphate of ammonia increased the number of bunches per hectare as compared to ammonium chloride (Table 1.9).

Although general conclusions are difficult due to the poor design of the trial, it would appear that i) chlorine containing fertilisers increase the single bunch weight, possibly by increasing bunch moisture content, ii) chlorine containing fertilisers especially ammonium chloride tend to reduce the numbers of bunches produced, iii) plot yields in this trial are high even in the control plots, and it is unlikely that there are any limiting nutrients at this site.

This trial was closed down at the end of 1996 as it has been replaced with a factorial fertiliser trial that will give better evidence of the response to nitrogen, potassium and chlorine at this site.

Table 1.8 Effect of fertiliser treatments on yield and yield components in 1996 and 1994 to 1996 (Trial 119).

Treatment		1996			1994 to 1996		
		Yield (t/ha/yr)	Bunch number/ha	Bunch weight (kg)	Yield (t/ha/yr)	Bunch number/ha	Bunch weight (kg)
1	Nil	31.3	1426	22.0	30.1	1429	21.1
2	DAP	33.2	1563	21.2	32.6	1621	20.1
3	SoA	34.8	1628	21.5	32.1	1587	20.3
4	AC	32.4	1291	25.1	31.3	1357	23.1
5	MoP	33.2	1356	24.5	31.8	1363	23.3
6	MoP + DAP	33.5	1415	23.7	33.5	1483	22.7
7	MoP + SoA	36.1	1508	24.0	32.4	1449	22.4
8	MoP + AC	34.8	1383	25.2	32.0	1355	23.7
9	Kies	28.1	1231	22.8	29.4	1367	21.5
10	Kies + DAP	34.1	1467	23.2	32.8	1488	22.0
11	Kies + SoA	33.3	1452	23.0	31.6	1510	21.0
12	Kies + AC	31.0	1245	25.0	31.0	1335	23.3
	significance	ns	ns	***	ns	*	***
	s.e.d	3.90	182.4	1.07	2.24	120.7	1.00
	cv%	11.8	12.9	4.5	7.0	8.3	4.5

Table 1.9 Treatment contrasts for yield and yield components in 1996 (Trial 119)

	CONTRAST	1996						1994 to 1996					
		Yield (t/ha/yr)		Bunch Number		SBW (kg)		Yield (t/ha/yr)		Bunch Number		SBW (kg)	
1	- N (- K & Mg)	31.2	ns	1426	ns	22.0	ns	30.1	ns	1429	ns	21.1	ns
	+ N (- K & Mg)	33.5		1494		22.6		32.0		1522		21.2	
2	DAP + SoA (- K & Mg)	34.0	ns	1596	**	21.3	***	32.3	ns	1604	**	20.5	***
	AmC (- K & Mg)	32.4		1291		25.1		31.4		1357		23.1	
3	DAP (- K & Mg)	33.2	ns	1563	ns	21.2	ns	32.6	ns	1621	ns	20.1	ns
	SoA (- K & Mg)	34.8		1628		21.5		32.1		1587		20.3	
4	- Mg (- N)	31.2	*	1426	*	22.0	ns	30.1	ns	1429	ns	21.1	ns
	+ Mg (- N)	28.1		1231		22.8		29.4		1367		21.5	
5	- Mg (+ N)	33.5	ns	1494	ns	22.6	**	32.0	ns	1522	ns	21.2	*
	+ Mg (+ N)	32.8		1388		23.7		31.8		1444		22.1	
6	- K (- N)	31.2	ns	1426	ns	22.0	*	30.1	ns	1429	ns	21.1	**
	+ K (- N)	33.2		1356		24.5		31.8		1363		23.3	
7	- K (+ N)	33.5	ns	1494	ns	22.6	**	32.0	ns	1522	ns	21.2	**
	+ K (+ N)	33.0		1435		24.3		32.6		1429		22.9	

Trial 120 NITROGEN/ANION FERTILISER TRIAL AT DAMI PLANTATION.

PURPOSE

To investigate the response of oil palm to the application of various combinations of inorganic fertiliser with a view to providing information that will be useful in developing fertiliser recommendations.

DESCRIPTION

Site — Dami Plantation, Field 9.

Soil — Young very coarse textured freely draining soils formed on alluvially reworked andesitic pumiceous sands and gravel.

Palms — Dami commercial DxP crosses.
Planted in 1983 at 135 palms/ha.
Treatments started in April 1989.

DESIGN

There are twelve treatments (Table 1.10) made up from muriate of potash or Kieserite (or neither of these) combined with nitrogen from one of three sources (or no nitrogen). The three nitrogen sources are: diammonium phosphate, ammonium sulphate, and ammonium chloride. The twelve treatments are replicated in four randomised complete blocks, giving a total of 48 plots. Each plot has 25 palms of which the central 9 are recorded. Plot isolation trenches were completed in February 1996.

Table 1.10 Rates of fertiliser and resulting combinations of elements used in Trial 120.

	Nil		Muriate of potash		Kieserite	
Nil	---	1	K+Cl	5	Mg+S (9)	9
Diammonium phosphate	N+P	2	N+P+K+Cl	6	N+P+Mg+S	10
Ammonium sulphate	N+S	3	N+S+K+Cl	7	N+2S+Mg	11
Ammonium chloride	N+Cl	4	N+2Cl+K	8	N+Cl+Mg+S	12

Diammonium phosphate	= 3.9 kg/palm/year
Ammonium sulphate	= 3.8 kg/palm/year
Ammonium chloride	= 3.0 kg/palm/year
Muriate of potash	= 4.2 kg/palm/year
Kieserite	= 3.7 kg/palm/year

RESULTS

The average plot FFB yield in 1996 was high at 29.7 t/ha/year.

The overall treatment effects for 1996 and the 1994 to 1996 cumulative data were not significant (Table 1.11). Despite this, partitioning of the treatment variance suggests that application of Kieserite in the presence of the nitrogen fertilisers increased the FFB yield by increasing the number of bunches produced (Table 1.12). The highest yield recorded in 1996 was from the treatment receiving both sulphate of ammonia and Kieserite (Table 1.11). This yield response was due to an increase in the number of bunches.

The treatment contrasts given in Table 1.12 show that ammonium chloride produces significantly larger bunches than di-ammonium phosphate and sulphate of ammonia. Although not significant, sulphate of ammonia gave a higher yield than di-ammonium phosphate. The addition of Kieserite in

the presence of nitrogen gave a significantly higher yield due to an increase in the number of bunches/ha.

Table 1.11 Effect of fertiliser treatments on yield and yield components in 1996 and 1994 to 1996 (Trial 120).

Treatment		1996			1994 to 1996		
		Yield (t/ha/yr)	Bunch number /ha	Bunch weight (kg)	Yield (t/ha/yr)	Bunch number /ha	Bunch weight (kg)
1	Nil	27.7	1125	24.6	27.6	1165	23.7
2	DAP	26.7	1136	23.6	28.3	1196	23.6
3	SoA	31.7	1296	24.5	28.4	1186	23.9
4	AC	31.4	1181	26.7	28.9	1168	24.8
5	MoP	30.6	1241	24.9	28.3	1163	24.4
6	MoP + DAP	29.0	1121	25.8	29.5	1178	25.1
7	MoP + SoA	28.9	1189	24.5	30.4	1277	23.9
8	MoP + AC	25.9	1020	25.4	27.9	1170	23.9
9	Kies	28.2	1133	25.0	27.4	1131	24.2
10	Kies + DAP	31.5	1301	24.3	29.1	1273	22.9
11	Kies + SoA	33.5	1346	24.9	30.7	1290	23.8
12	Kies + AC	31.1	1240	25.2	30.8	1250	24.7
	significance	ns	ns	ns	ns	ns	ns
	sed	2.49	124.7	1.06	1.55	79.4	0.78
	cv%	11.8	5.2	6.0	7.6	9.3	4.6

Table 1.12 Treatment contrasts for yield and yield components (Trial 120)

	Contrast	1996						1994 to 1996					
		Yield (t/ha/yr)		Bunch Number		SBW (kg)		Yield (t/ha/yr)		Bunch Number		SBW (kg)	
1	- N (- K & Mg)	27.7	ns	1125	ns	24.6	ns	27.6	ns	1165	ns	23.7	ns
	+ N (- K & Mg)	29.9		1204		24.9		28.5		1183		24.1	
2	DAP + SoA (- K & Mg)	29.2	ns	1216	ns	24.1	**	28.4	ns	1191	ns	23.8	ns
	AmC (- K & Mg)	31.4		1181		26.7		28.9		1168		24.8	
3	DAP (- K & Mg)	26.7	ns	1136	ns	23.6	ns	28.3	ns	1196	ns	23.6	ns
	SoA (- K & Mg)	31.7		1296		24.5		28.4		1186		23.9	
4	- Mg (- N)	27.7	ns	1125	ns	24.6	ns	27.6	ns	1165	ns	23.7	ns
	+ Mg (- N)	28.2		1133		25.0		27.4		1131		24.2	
5	- Mg (+ N)	29.9	*	1204	ns	24.9	ns	28.5	*	1183	*	24.1	ns
	+ Mg (+ N)	32.0		1296		24.8		30.2		1271		23.8	
6	- K (- N)	27.7	ns	1125	ns	24.6	ns	27.6	ns	1165	ns	23.7	ns
	+ K (- N)	30.6		1241		24.9		28.3		1163		24.4	
7	- K (+ N)	29.9	ns	1125	ns	24.9	ns	28.5	ns	1183	ns	24.1	ns
	+ K (+ N)	27.9		1110		24.8		29.3		1208		24.3	

Trial 122 NITROGEN AND CROP RESIDUE TRIAL AT KUMBANGO PLANTATION.

PURPOSE

To investigate the response of oil palm to applications of empty fruit bunches (EFB), palm kernel cake (PKC), pruned fronds and the combined application of these crop residues and inorganic nitrogen and magnesium fertiliser. It is hoped that by integrating the application of inorganic fertiliser and crop residue, the efficacy of nitrogen and magnesium fertiliser application will be improved.

DESCRIPTION

Site — Field number E12, Division II, Kumbango Plantation, Nr Kimbe, WNBP. The trial is situated about 1.5 km west of the Dagi River on its flat alluvial plain and about 6 km from the coast.

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 1978 at 120 palms/ha.
Trial was initiated in November 1991, treatment applications started in July 1992.

DESIGN

The trial consists of 13 treatments (Table 1.13) in 4 randomised complete blocks. 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 1.13 Treatments used in Trial 122.

Treatment Number	Crop Residue	Fertiliser Applied (kg/palm/yr)	Fertiliser Placement
1	Nil	3.0kg SoA & 3.0kg Kies	Weeded Circle
2	fronds	3.0kg SoA & 3.0kg Kies	Weeded Circle
3	fronds	3.0kg SoA & 3.0kg Kies	Frond Pile
4	fronds & EFB	3.0kg SoA & 3.0kg Kies	Weeded Circle
5	fronds & EFB	3.0kg SoA & 3.0kg Kies	Frond Pile
6	fronds & EFB	3.0kg SoA & 3.0kg Kies	EFB
7	fronds & PKC	3.0kg SoA & 3.0kg Kies	Weeded Circle
8	fronds & PKC	3.0kg SoA & 3.0kg Kies	Frond Pile
9	fronds & PKC	3.0kg SoA & 3.0kg Kies	PKC
10	Nil	Nil	Nil
11	fronds	Nil	Nil
12	fronds & EFB	Nil	Nil
13	fronds & PKC	Nil	Nil

The EFB is applied with a Giltrap EFB applicator at approximately 50 t/ha. The PKC was applied with a Kuhn spinning disc fertiliser spreader at a rate of 1.8 t/ha in previous years. However, this machine was no longer operational in 1996 so the PKC was applied by hand at the same rate of 1.8 t/ha.

RESULTS

Mean yield in 1996 was 24.3 t/ha. There was a significant treatment effect on yield in 1996 (Table 1.14) with the highest yield (28.3 t/ha) being recorded from the treatment receiving EFB with fertiliser applied in the weeded circle. Applying fertiliser to the EFB resulted in a yield of 27.5 t/ha. The mean yield from treatments receiving EFB was 26.7 t/ha compared to 22.7 t/ha from those treatments with fronds and fertiliser. PKC has had no effect on FFB yield. Although not significant the treatments receiving EFB all had higher bunch weights than any other treatment. The cumulative data for 1994 to 1996 shows that the highest yields have been recorded from the treatment receiving EFB and fertiliser applied to the frond pile though this is not statistically significant (Table 1.15).

In 1994 and 1995 EFB was applied at very high rates (120 t/ha), which led to a reduction in yield. In 1996 application rates were reduced to the recommended 50 t/ha. The 1996 yield results indicate that the high application rates have not had any long lasting effects.

The 1996 results also show that in the absence of EFB or PKC the application of fertiliser to the frond pile did not result in any decline in yield as compared with fertiliser applied to the weeded circle. The lowest plot yield in 1996 (20.3 t/ha) was recorded in the plot with no crop residue.

Table 1.14 Effects of treatments on yield and yield components in 1996 (Trial 122).

Treatment Number	Crop Residue	Fertiliser Applied	Fertiliser Placement	FFB Yield (t/ha/yr)	Number of Bunches/ha	Bunch weight (kg)
1	Nil	N + Mg	Weeded Circle	20.3	755	27.2
2	fronds	N + Mg	Weeded Circle	22.6	828	27.3
3	fronds	N + Mg	Frond Pile	22.8	817	27.9
4	fronds & EFB	N + Mg	Weeded Circle	28.3	923	30.8
5	fronds & EFB	N + Mg	Frond Pile	25.5	841	30.2
6	fronds & EFB	N + Mg	EFB	27.5	910	30.2
7	fronds & PKC	N + Mg	Weeded Circle	24.7	880	28.0
8	fronds & PKC	N + Mg	Frond Pile	22.8	798	28.5
9	fronds & PKC	N + Mg	PKC	22.9	790	29.1
10	Nil	Nil	Nil	24.8	851	29.1
11	fronds	Nil	Nil	23.3	835	28.1
12	fronds & EFB	Nil	Nil	25.6	808	31.7
13	fronds & PKC	Nil	Nil	24.6	853	28.9
			significance	*	ns	ns
			sed	1.94	74.3	1.36
			cv%	9.8	10.9	5.8

Table 1.15 Effects of treatments on yield and yield components for 1994 to 1996 (Trial 122).

Treatment Number	Crop Residue	Fertiliser Applied	Fertiliser Placement	FFB Yield (t/ha/yr)	Number of Bunches/ha	Bunch weight (kg)
1	Nil	N + Mg	Weeded Circle	25.5	1033	25.8
2	fronds	N + Mg	Weeded Circle	25.8	1045	25.3
3	fronds	N + Mg	Frond Pile	24.0	1057	24.5
4	fronds & EFB	N + Mg	Weeded Circle	27.4	1074	26.7
5	fronds & EFB	N + Mg	Frond Pile	29.3	1131	26.9
6	fronds & EFB	N + Mg	EFB	27.4	1059	26.6
7	fronds & PKC	N + Mg	Weeded Circle	25.5	1098	24.2
8	fronds & PKC	N + Mg	Frond Pile	26.1	1036	26.4
9	fronds & PKC	N + Mg	PKC	27.3	1093	26.4
10	Nil	Nil	Nil	27.2	1106	25.5
11	fronds	Nil	Nil	26.2	1065	25.6
12	fronds & EFB	Nil	Nil	27.2	1053	27.3
13	fronds & PKC	Nil	Nil	26.2	1087	25.2
			significance	ns	ns	ns
			sed	1.82	74.7	0.91
			cv%	8.4	8.5	4.3

Leaf and rachis tissues were not sampled in 1996. The area in which this trial is located is due to be replanted in 1998 and 1997 will be the last year of yield recording in this trial.

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 will start 36 months after planting.

DESIGN

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

There will be 15 fertiliser treatments in each replication and 3 control plots (Table 1.16). The 15 treatments will be replicated four times in a randomised complete block design. The three control plots will be plots on the edge of the trial from which yield will be recorded but the data will not be used in the analysis of variance. The mean yield from the control plots will be reported in the table of means as a comparison with the fertiliser treatments. 36 palm plots (6x6 palms) are used, the central 16 palms are recorded and the outer 20 palms are regarded as guard row palms. Each rate of fertiliser at the same level contains the same amount of nitrogen.

Table 1.16 Treatments used in Trial 125

Fertiliser	Level (kg/palm/year)		
	1	2	3
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

PROGRESS

This trial was approved in the PNGOPRA Scientific Advisory Board meeting in November 1993. The design was changed in February 1996. The site has been remapped and plot and palm labelling has been completed. Experimental fertiliser treatments will be started in August 1997 after pretreatment yield data has been collected. Until this time the palms will have received a standard immature palm fertiliser input. Frond 17 leaflet, rachis and cross-section sampling will be carried out prior to treatments being applied.

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 are to be 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 1.17). The 72 treatments will be replicated only once and will be divided among two blocks. The 3-factor interaction '2x2x2' will be confounded with blocks. Third and higher order interactions will 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 1.17 Fertiliser rates to be 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 ammonium and sulphate of potash will be split into two applications per year, while the other fertilisers are applied once per year.

PROGRESS

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.

Frond 17 leaflet sampling was carried out for each plot in December 1994, and subsequently analysed for nutrient element content (Table 1.18). Due to the delay in commencing fertiliser treatments frond 17 leaflet and rachis sampling was repeated in May 1996 (Table 1.19). These analyses will be used as pre-treatment data for the control of residual variance in later statistical analysis. It should be noted

that the whole site had been receiving a fertiliser schedule that comprises nitrogen and magnesium amelioration.

Table 1.18 Summary statistics for pre-treatment frond 17 leaflet tissue analysis - Dec 1994 (Trial 126).

Element	Values	Minimum	Maximum	Mean	Standard Deviation
Nitrogen	72	2.26	2.58	2.39	0.057
Phosphorus	72	0.138	0.152	0.146	0.003
Potassium	72	0.65	0.95	0.81	0.065
Magnesium	72	0.09	0.18	0.13	0.018
Calcium	72	0.68	1.04	0.85	0.075
Chlorine	72	0.28	0.45	0.34	0.037

Table 1.19 Summary statistics for pre-treatment frond 17 tissue analysis - May 1996 (Trial 126).

Element	Values	Minimum	Maximum	Mean	Standard Deviation
Leaflet					
Nitrogen	72	2.16	2.44	2.30	0.065
Phosphorus	72	0.135	0.152	0.141	0.004
Potassium	72	0.67	0.91	0.76	0.048
Calcium	72	0.63	0.93	0.81	0.065
Magnesium	72	0.10	0.17	0.13	0.016
Chlorine	72	0.22	0.38	0.27	0.028
Rachis					
Nitrogen	72	0.20	0.28	0.23	0.016
Phosphorus	72	0.028	0.054	0.041	0.004
Potassium	72	0.69	1.14	0.93	0.104
Calcium	72	0.30	0.45	0.37	0.038
Magnesium	72	0.02	0.04	0.03	0.002
Chlorine	72	0.07	0.18	0.11	0.021

Yields recorded in the six months from July to December 1996 are given in Table 1.20. As expected the fertiliser treatments applied in June had not had any effect on yield in this period.

Table 1.20 Yield recorded in Trial 126 for the six months from July - December 1996 (Trial 126).

	Nutrient element and level			Statistics	
				sig	sed
	N0	N1	N2		
Yield (t/ha/6 mths)	9.5	9.5	10.0	ns	0.823
Bunches/ha/6 mths	418	423	457	ns	36.5
Bunch weight (kg)	21.7	21.1	21.7	ns	0.547
	P0	P1			
Yield (t/ha/6 mths)	9.5	9.8		ns	0..551
Bunches/ha/6 mths	423	442		ns	23.8
Bunch weight (kg)	21.5	21.5		ns	0.447
	K0	K1	K2		
Yield (t/ha/6 mths)	10.3	9.6	9.1	ns	0.823
Bunches/ha/6 mths	457	433	404	ns	36.5
Bunch weight (kg)	22.0	21.0	21.4	ns	0.547
	Mg0	Mg1			
Yield (t/ha/6 mths)	10.0	9.3		ns	0.551
Bunches/ha/6 mths	447	418		ns	23.8
Bunch weight (kg)	21.7	21.3		ns	0.447
	Cl0	Cl1			
Yield (t/ha/6 mths)	9.5	9.8		ns	0.551
Bunches/ha/6 mths	423	437		ns	23.8
Bunch weight (kg)	21.5	21.5		ns	0.447

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 1996 at 120 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, which 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 1.21) will be arranged in a randomised complete block design with 4 replications.

Table 1.21 Treatments to be used in Trial 129a.

Treatment Number	Crop Residue	Fertiliser Applied (kg/palm/yr)	Fertiliser Placement
1	EFB	3.0kg SoA & 3.0kg Kies	Weeded Circle
2	EFB	3.0kg SoA & 3.0kg Kies	Frond Pile
3	EFB	Nil	-
4	Nil	3.0kg SoA & 3.0kg Kies	Weeded Circle
5	Nil	3.0kg SoA & 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. The four treatments will be arranged in a randomised complete block design with 8 replications.

Table 1.22 Treatments to be used in Trial 129b

Treatment Number	Crop Residue	Fertiliser Applied (kg/palm/yr)	Fertiliser Placement
1	EFB	3.0kg SoA & 3.0kg Kies	Weeded Circle
2	EFB	3.0kg SoA & 3.0kg Kies	Frond Pile
3	EFB	3.0kg SoA & 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 1997.

Experimental fertiliser treatments will be started in August 1999 after pretreatment 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.

Trial 130 NURSERY FERTILISER TRIAL AT BEBERE

PURPOSE

To provide information which will be used to make nursery fertiliser recommendations

DESCRIPTION

Site Bebere Nursery

Palms Dami DxP crosses

DESIGN

The aim of the trial was to determine the maximum amount of urea or sulphate of ammonia that could be applied to seedlings of four ages. Seedlings 14, 20, 28 and 36 weeks of age were obtained from the nursery and arranged in a spare bed in the nursery in two blocks. Treatments were applied randomly to each seedling age but the seedlings of different ages were not randomised within blocks to avoid competition effects. The treatments are given in Table 1.22. Each plot contained 22 seedlings. Fertiliser was applied twice, once at the end of August 1996 and again 1 month later. Bole diameter, height and leaf numbers were recorded prior to treatments being applied and then fortnightly. Five seedlings of the three youngest ages were harvested from each plot at the end of October, separated into leaf, stem and root and oven dried at 70^{o}C for 24 hours to determine dry matter content. The oldest seedlings were too large to handle in the limited laboratory space at Dami.

Table 1.23 Fertiliser rates per seedling.

Fertiliser	Rate (g/seedling)			
	1	2	3	4
Urea	18.4	27.6	36.8	46.0
Sulphate of Ammonia	40.0	60.0	80.0	100.0

All the data were analysed using Minitab. The data for each age group was analysed separately.

RESULTS

Level of fertiliser whether sulphate of ammonia or urea had no effect on seedling growth. Type of fertiliser, however, had a significant effect on height, bole diameter and leaf number of 3½-month-old seedlings (Table 1.24). Sulphate of ammonia treated seedlings were taller, with thicker boles and had more leaves than those treated with urea.

Table 1.24 Effect of type of fertiliser on height, bole diameter and leaf number of 3.5 month old seedlings 2 and 4 weeks after the second dose of fertiliser.

Fertiliser	2 weeks			4 weeks		
	Height (cm)	Bole Diameter (cm)	Leaf Number	Height (cm)	Bole Diameter (cm)	Leaf Number
SoA	26.9	1.63	4.75	32.2	1.92	5.43
Urea	24.6	1.45	4.34	27.1	1.69	4.92
Sig.	***	***	*	***	*	*
sem	0.36	0.027	0.089	0.68	0.047	0.11

Application of urea to 5-month-old seedlings led to a reduction in leaf number (Table 1.25).

Table 1.25 Effect of type of fertiliser on leaf number of 5-month-old seedlings 2 weeks after the second application.

Fertiliser	Leaf Number
SoA	7.4
Urea	6.8
Sig.	*
sem	0.16

There was a significant interaction between type and rate of fertiliser for leaf number of 7-month-old seedlings (Table 1.26). At this age the lowest rate of urea resulted in a higher leaf number than the highest rate of sulphate of ammonia suggesting that urea is the better fertiliser once seedlings have reached 7 months of age.

Table 1.26 Effect of type and rate of fertiliser on leaf number of 7-month-old seedlings

Fertiliser	Level				
	1	2	3	4	Mean
SoA	8.75	9.09	9.11	9.45	9.10
Urea	9.52	9.18	9.13	8.06	8.97
Sig.			*		
sem			0.29		

Analysis of the fresh and dry weights of leaf, stem and root of 3.5 month seedlings showed that application of urea led to a reduction of weight of leaf, stem and root (Table 1.27).

Table 1.27 Effect of type of fertiliser on fresh and dry weight of leaf, stem and roots of 3½-month-old seedlings.

Fertiliser	Fresh Wt. Leaf (g)	Dry Wt. Leaf (g)	Fresh Wt. Stem (g)	Dry Wt. Stem (g)	Fresh Wt. Root (g)	Dry Wt. Root (g)
SoA	88.8	28.5	63.0	15.7	42.4	12.2
Urea	58.6	19.2	42.0	11.6	39.6	10.6
Sig.	**	***	**	*	ns	*
sem	5.6	1.3	4.1	1.0	4.3	0.7

There were no differences in fresh or dry weight of leaf, stem and root of older seedlings. Visual symptoms of root damage by urea were obvious in the younger seedlings. The primary roots were blackened as a result of urea application. The results of this experiment give strong evidence that urea should not be used for seedlings younger than 5-months of age. However, urea appeared to be the better fertiliser for palms 6 months and older. This observation will be tested in a second nursery fertiliser trial that will be established at Bebere nursery in 1997.

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 120 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 1.28).

Table 1.28 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 31.8 t/ha in 1996. This yield is considerably higher than the average plot yield recorded in the preceding three years, 20.2 t/ha in 1993, 23.3 t/ha in 1994 and 28.7 t/ha in 1995.

Ammonium chloride application increased FFB yield from 26.2 t/ha to 34.0 t/ha (N1) and 35.2 t/ha (N2) (Table 1.29). This increase was due to significant increases in both the number of bunches produced and the single bunch weight. The increase in yield due to ammonium chloride application is greater in 1996 than in 1995.

No other fertiliser had any effect on yield or the components of yield.

The cumulative data for the period 1994 to 1996 (Table 1.30) also shows a significant positive effect

of ammonia chloride application on FFB yield, which was caused by an increase in both number of, bunches and bunch weight.

Table 1.29 Main effects of N, P, K and Mg on yield and yield components in 1996 (Trial 204).

	Nutrient element and level			Statistics		
				sig	sed	cv%
	N0	N1	N2			
Yield (t/ha/yr)	26.2	34.0	35.2	***	1.07	11.6
Bunches/ha	1305	1439	1502	***	43.6	10.7
Bunch weight (kg)	20.1	23.7	23.5	***	0.42	6.5
	P0	P1	P2			
Yield (t/ha/yr)	31.8	31.0	32.6	ns	1.07	11.6
Bunches/ha	1399	1391	1456	ns	43.6	10.7
Bunch weight (kg)	22.7	22.2	22.3	ns	0.42	6.5
	K0	K1				
Yield (t/ha/yr)	31.9	31.7		ns	0.87	11.6
Bunches/ha	1418	1413		ns	35.6	10.7
Bunch weight (kg)	22.5	22.4		ns	0.34	6.5
	Mg0	Mg1				
Yield (t/ha/yr)	32.2	31.3		ns	0.87	11.6
Bunches/ha	1440	1391		ns	35.6	10.7
Bunch weight (kg)	22.4	22.5		ns	0.34	6.5

Table 1.30 Main effects of N, P, K and Mg on yield and yield components for 1994 to 1996 (Trial 204).

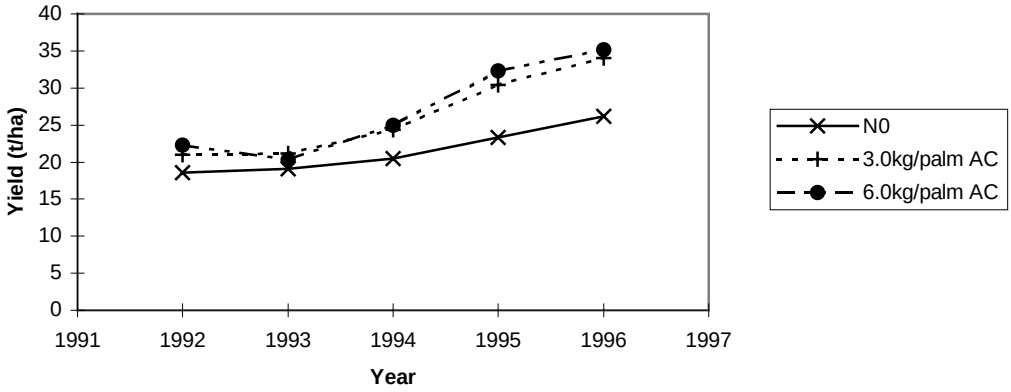
	Nutrient element and level			Statistics		
				sig	sed	cv%
	N0	N1	N2			
Yield (t/ha/yr)	23.3	29.6	30.8	***	0.69	8.5
Bunches/ha	1319	1440	1500	***	38.5	9.4
Bunch weight (kg)	17.8	20.7	20.6	***	0.35	6.2
	P0	P1	P2			
Yield (t/ha/yr)	28.0	27.3	28.4	ns	0.69	8.5
Bunches/ha	1404	1404	1451	ns	38.5	9.4
Bunch weight (kg)	20.0	19.5	19.6	ns	0.35	6.2
	K0	K1				
Yield (t/ha/yr)	27.9	28.0		ns	0.56	8.5
Bunches/ha	1426	1413		ns	31.4	9.4
Bunch weight (kg)	19.6	19.8		ns	0.29	6.2
	Mg0	Mg1				
Yield (t/ha/yr)	28.2	27.6		ns	0.56	8.5
Bunches/ha	1440	1399		ns	31.4	9.4
Bunch weight (kg)	19.6	19.7		ns	0.29	6.2

Table 1.31 gives the yield and components of yield for each year from 1992 to 1996. Figure 1.5 shows that yield has been increasing as a result of application of 3kg ammonium chloride since 1994 but that there has not been any advantage in applying 6kg of ammonium chloride.

Table 1.31 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

Figure 1.5: Effect of Nitrogen on Yield in Trial 204



The concentration of nitrogen in leaflet tissue increased significantly with application of ammonium chloride (Table 1.32). Application of ammonium chloride also led to increases in leaflet phosphorus and chlorine but decreases in leaflet potassium and magnesium. Application of Triple Superphosphate had no effect on leaflet nutrient concentration. Leaflet calcium and chlorine concentrations increased with application of muriate of potash but leaflet potassium did not change. Kieserite application led to an increase in leaflet magnesium but a decline in leaflet calcium.

Table 1.32 Treatment main effects on leaflet nutrient concentrations in 1996 (Trial 204).

Element as % of dry matter	Nutrient element and level			Statistics		
				sig	sed	cv%
	N0	N1	N2			
Nitrogen	2.18	2.35	2.41	***	0.025	3.7
Phosphorus	0.131	0.138	0.140	***	0.001	2.7
Potassium	0.72	0.67	0.67	***	0.015	7.4
Calcium	0.93	0.94	0.92	ns	0.020	7.6
Magnesium	0.20	0.17	0.15	***	0.007	14.2
Chlorine	0.36	0.54	0.57	***	0.016	11.4
	P0	P1	P2			
Nitrogen	2.31	2.32	2.31	ns	0.025	3.7
Phosphorus	0.135	0.136	0.138	ns	0.001	2.7
Potassium	0.71	0.68	0.67	ns	0.015	7.4
Calcium	0.92	0.93	0.94	ns	0.020	7.6
Magnesium	0.17	0.18	0.16	ns	0.007	14.2
Chlorine	0.50	0.49	0.49	ns	0.016	11.4
	K0	K1				
Nitrogen	2.33	2.29		ns	0.020	3.7
Phosphorus	0.137	0.136		ns	0.001	2.7
Potassium	0.69	0.68		ns	0.012	7.4
Calcium	0.90	0.96		***	0.017	7.6
Magnesium	0.18	0.17		ns	0.006	14.2
Chlorine	0.45	0.53		***	0.013	11.4
	Mg0	Mg1				
Nitrogen	2.31	2.31		ns	0.020	3.7
Phosphorus	0.136	0.136		ns	0.001	2.7
Potassium	0.69	0.68		ns	0.012	7.4
Calcium	0.95	0.91		*	0.017	7.6
Magnesium	0.16	0.18		**	0.006	14.2
Chlorine	0.49	0.50		ns	0.013	11.4

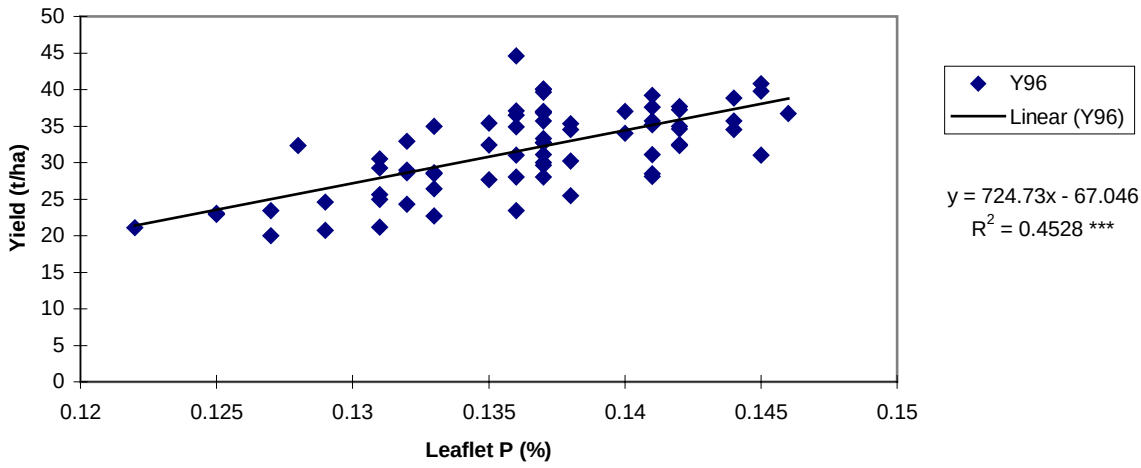
Application of ammonium chloride led to significant increases in rachis nitrogen, calcium, magnesium and chlorine but a decline in rachis phosphorus (Table 1.33). Rachis phosphorus increased with application of triple super phosphorus. Muriate of potash application led to a significant increase in both rachis phosphorus, chlorine and potassium.

Table 1.33 Treatment main effects on rachis nutrient concentrations in 1996 (Trial 204).

Element as % of dry matter	Nutrient element and level			Statistics		
				sig	sed	cv%
	N0	N1	N2			
Nitrogen	0.22	0.25	0.26	***	0.007	9.6
Phosphorus	0.085	0.071	0.059	***	0.004	20.0
Potassium	1.51	1.50	1.46	ns	0.051	11.7
Calcium	0.45	0.54	0.53	***	0.019	12.6
Magnesium	0.05	0.06	0.06	**	0.003	15.8
Chlorine	0.49	0.93	1.00	***	0.064	27.4
	P0	P1	P2			
Nitrogen	0.25	0.25	0.24	ns	0.007	9.6
Phosphorus	0.050	0.075	0.090	***	0.004	20.0
Potassium	1.54	1.45	1.49	ns	0.051	11.7
Calcium	0.50	0.51	0.52	ns	0.019	12.6
Magnesium	0.06	0.06	0.06	ns	0.003	15.8
Chlorine	0.86	0.78	0.78	ns	0.064	27.4
	K0	K1				
Nitrogen	0.25	0.24		ns	0.006	9.7
Phosphorus	0.068	0.075		*	0.003	20.0
Potassium	1.35	1.64		***	0.041	11.7
Calcium	0.50	0.51		ns	0.015	12.6
Magnesium	0.06	0..06		ns	0.002	15.8
Chlorine	0.72	0.89		**	0.052	27.4
	Mg0	Mg1				
Nitrogen	0.25	0.24		ns	0.006	9.7
Phosphorus	0.071	0.073		ns	0.003	20.0
Potassium	1.47	1.51		ns	0.041	11.7
Calcium	0.51	0.50		ns	0.015	12.6
Magnesium	0.06	0.06		ns	0.002	15.8
Chlorine	0.80	0.81		ns	0.052	27.4

A stepwise regression of all leaflet and rachis nutrient concentrations with yield revealed that leaflet phosphorus concentration is the best predictor of yield (Figure 1.6).

Figure 1.6: Effect of leaflet P on yield



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 1.34). 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 1.34 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 will be applied together.

RESULTS

The trial was planted in July and August 1993. The site was surveyed and mapped, and plot and palm labelling was carried out in 1993.

For the first 36 months, the palms received a standard immature palm fertiliser input. Pretreatment yield recording commenced in January 1996 and treatments were applied in August 1996. Leaflet samples were taken for analysis in May 1996 and a summary of the results of this analysis is given in Table 1.35. Fertiliser treatments had no effect on yield or the components of yield for the period August - Dec 1996 (Table 1.36). The EFB was tested for nutrient concentration and was found to contain 0.42%N, 0.042%P, 1.46%K, 0.27%Ca, 0.12%Mg and 0.16%Cl.

Table 1.35 Summary statistics for pre-treatment frond 17 leaflet tissue analysis -May 1996 (Trial 205)

Element	Values	Minimum	Maximum	Mean	Standard Deviation
Nitrogen	48	2.36	2.81	2.55	0.095
Phosphorus	48	0.139	0.160	0.150	0.004
Potassium	48	0.87	1.03	0.96	0.041
Magnesium	48	0.20	0.27	0.24	0.020
Calcium	48	0.98	1.18	1.08	0.053
Chlorine	48	0.12	0.22	0.18	0.003

Table 1.36 Yield and the components of yield Aug - Dec 1996 (Trial 205).

Treatment	Number of Bunches/ha	Single Bunch Weight (kg)	Yield (t/ha)
1	12.2	6.0	9.8
2	12.8	6.2	10.8
3	12.8	6.1	10.6
4	11.9	6.2	9.9
5	12.7	6.0	10.4
6	12.4	6.0	10.2
7	12.1	6.0	9.8
8	12.3	6.0	10.1
Mean	12.4	6.1	10.2
Sig.	ns	ns	ns
sed	0.611	0.16	0.58
cv%	8.5	4.6	9.8

There were large highly significant differences between progenies for yield and the components of yield in 1996 (Table 1.37).

Table 1.37 Yield and the components of yield for 16 selected progenies Jan - Dec 1996 (Trial 205).

Progeny	No. of bunches/ha	Single Bunch Wt. (kg)	Yield (t/ha)
1	3653	5.9	21.5
2	3431	5.7	19.7
3	3862	5.1	19.4
4	3448	5.3	18.2
5	3651	4.7	16.9
6	3243	4.4	14.7
7	2641	5.1	14.4
8	3566	5.4	18.8
9	3561	5.5	19.4
10	3462	5.3	18.2
11	3395	5.4	18.2
12	3862	5.3	20.2
13	3215	5.4	17.8
14	2728	5.3	15.0
15	3052	5.1	16.1
16	3538	4.8	16.7
Mean	3394	5.2	17.8
Sig.	***	***	***
sed	189.2	0.185	1.053
cv%	9.2	5.2	10.5

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 to start 36 months after planting.

DESIGN

There will be 81 treatments comprising all factorial combinations of sulphate of ammonia, Triple Superphosphate, muriate of potash and Kieserite each at three levels. There will be 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 will be replicated only once and will be divided among nine blocks each of nine plots (Table 1.38).

Table 1.38 Fertiliser used in Trial 209.

	Level (kg /palm/year)		
	0	1	2
Ammonium sulphate	0.0	3.0	6.0
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 a standard immature palm fertiliser input. Pretreatment yield recording will commence in January 1997 and treatments will be applied in July 1997. Leaflet samples will be taken for analysis in May 1997.

Trials 251 and 252 FACTORIAL FERTILISER TRIALS AT MARAMAKAS AND LUBURUA PLANTATIONS.

PURPOSE

To provide information on fertiliser responses on the principle soil type supporting oil palm in New Ireland.

DESCRIPTION

Sites — Trial 251: Fields 2B, 2C, 2D and 3A, Maramakas Plantation, Poliamba Pty Ltd.
Trial 252: Block 4, Luburua Plantation, Poliamba Pty Ltd.

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 soils are freely draining.

Palms — Dami commercial DxP crosses.
Planted in March 1989 (251) and September 1989 (252) at 120 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 1.39).

Table 1.39 Rates of fertiliser used in Trials 251 and 252.

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

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. A site factor is therefore included in the single analysis for these two trials.

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 about 1m from the base of each recorded palm on the side of the harvest path until the auger struck limestone. Soil depth was used as a concomitant variable in an analysis of covariance of the yield data from 1996 as well as the pooled 1994-1996 data. This analysis of covariance significantly reduced the residual mean square from 10.16 to 3.98 for the analysis of the 1996 yield data. Soil samples were taken for analysis in 1996.

RESULTS

The data recording of these trials commenced in June 1992.

The yield in these trials has been relatively low with the average plot yields ranging between 17.9 and 21.9 t/ha over the period 1993-6. The results for 1996 show that application of potassium led to a significant increase in single bunch weight and yield (Table 1.40). Application of 2.5 kg of muriate of potash led to an increase from 16.5 to 18.5 t/ha and to 20.0 t/ha with 5.0 kg of muriate of potash per palm. Bunch weight increased from 13.7kg with no potash to 15.7kg with 2.5kg muriate of potash. There was no further increase with 5.0kg of muriate of potash.

In 1996 Luburua gave higher yields than at Maramakas due to the significantly higher number of bunches produced at Luburua. Maramakas produced significantly heavier bunches but the resulting yield at Maramakas was 2.3t/ha less than that recorded at Luburua. This is the reversal of the 1995 result where yields were significantly higher at Maramakas and is surprising, as soil depth at Luburua is much shallower than at Maramakas. The site (Maramakas & Luburua) x fertiliser treatment interaction was not statistically significant in 1996 but this table of interactions shows that the yield at Luburua was higher possibly because of the higher leaflet potassium recorded in 1996 (Table 1.41).

Table 1.40 Main effects of N, P, K and Mg on yield and yield components for 1996 adjusted for covariate of soil depth (Trials 251 - Maramakas and 252 - Luburua).

	Nutrient element and level			Statistics		
				sig	sed	cv%
	N0	N1	N2			
Yield (t/ha)	17.8	18.5	18.7	ns	0.68	12.8
Bunches/ha	1222	1217	1231	ns	49.3	14.0
Bunch weight (kg)	14.6	15.3	15.4	ns	0.41	9.4
	K0	K1	K2			
Yield (t/ha)	16.5	18.5	20.0	***	0.68	12.8
Bunches/ha	1218	1186	1266	ns	49.4	14.0
Bunch weight (kg)	13.7	15.7	15.9	***	0.41	9.4
	P0	P1				
Yield (t/ha)	18.2	18.5		ns	0.55	12.8
Bunches/ha	1217	1230		ns	40.2	14.0
Bunch weight (kg)	15.1	15.1		ns	0.33	9.4
	Mg0	Mg1				
Yield (t/ha/yr)	18.2	18.5		ns	0.56	12.8
Bunches/ha	1213	1234		ns	40.7	14.0
Bunch weight (kg)	15.1	15.1		ns	0.34	9.4
	Maramakas	Luburua				
Yield (t/ha/yr)	17.2	19.5		***	0.58	12.8
Bunches/ha	1080	1367		***	42.4	14.0
Bunch weight (kg)	15.8	14.4		***	0.35	9.4

The applications of sulphate of ammonia had no effect on FFB yield or yield components in 1996 (Table 1.40) or for the three years 1994 to 1996 combined (Table 1.42). This lack of response to nitrogen is not surprising as the concentration of nitrogen in the leaflet tissue is relatively high (Table 1.45). The nitrogen concentration of the leaflet tissue in these trials is typical of those seen following routine tissue sampling and analysis of Poliamba Estates. The data suggest that there is no need to apply nitrogen fertiliser to much of Poliamba estates for the time being. This conclusion probably applies to the smallholder growers as well.

Table 1.41 Interactions between trial site and MoP by trial, yield from January 1994 to December 1996, and leaflet tissue sampled in 1996 (Trials 251 & 252).

	Yield (t/ha)		Leaflet K %	
	Maramakas	Luburua	Maramakas	Luburua
K0	18.2	17.8	0.51	0.59
K1	20.3	18.6	0.73	0.81
K2	21.0	20.5	0.76	0.83
Interaction significance	ns		ns	
sed	1.02		0.034	
cv%	12.6		11.6	

The analysis of the aggregated data for 1994 to 1996 shows a significant response to potassium. FFB yield at Maramakas is higher than in Luburua due to the significantly larger bunch weights at Maramakas (Table 1.42).

Table 1.42 Main effects of N, P, K and Mg on yield and yield components for January 1994 to December 1996 adjusted for covariate of soil depth (Trials 251 & 252).

	Nutrient element and level			Statistics		
				sig	sed	cv%
	N0	N1	N2			
Yield (t/ha)	19.0	19.5	19.7	ns	0.71	12.6
Bunches/ha	1583	1600	1611	ns	52.2	11.3
Bunch weight (kg)	12.0	12.1	12.2	ns	0.23	6.5
	K0	K1	K2			
Yield (t/ha)	18.1	19.4	20.7	**	0.71	12.6
Bunches/ha	1581	1574	1639	ns	52.2	11.3
Bunch weight (kg)	11.4	12.3	12.6	***	0.23	6.5
	P0	P1				
Yield (t/ha)	19.2	19.6		ns	0.58	12.6
Bunches/ha	1585	1611		ns	42.5	11.3
Bunch weight (kg)	12.1	12.1		ns	0.19	6.5
	Mg0	Mg1				
Yield (t/ha/yr)	19.2	19.6		ns	0.58	12.6
Bunches/ha	1596	1600		ns	43.0	11.3
Bunch weight (kg)	12.0	12.2		ns	0.19	6.5
	Maramakas	Luburua				
Yield (t/ha/yr)	19.8	19.0		ns	0.61	12.6
Bunches/ha	1573	1623		ns	44.8	11.3
Bunch weight (kg)	12.6	11.7		***	0.20	6.5

The application of muriate of potash increased the FFB yield by increasing the single bunch weight. Although the SITE x K interaction is not statistically significant, the two-way table (Table 1.41) shows that the yield response to 2.5kg muriate of potash (K1) was much greater at the Maramakas site compared to the Luburua site. However, the response to 5kg of muriate of potash (K2) was almost the same at both sites. Leaflet K levels were higher at Luburua than at Maramakas though not significantly. Luburua soils are shallower and higher rates of muriate of potash are required to obtain the same yield response. However, pretreatment soil sampling showed that soil potassium levels were higher at Luburua and this is reflected in the 1996 leaflet potassium levels that are higher at Luburua than at Maramakas. Unfortunately rachis tissue was not sampled in 1996. The conclusion from this data is that soil depth information should be used in conjunction with leaf and rachis analysis to make fertiliser recommendations in New Ireland.

In 1996 there was a significant interaction between phosphorus and trial site (Table 1.43). At Maramakas there was no response to phosphorus but at Luburua application of triple super phosphate led to an increase in yield from 18.8 to 20.3 t/ha. The leaflet P x site interaction was not significant. Analysis of the soil data does not show any significant effect of treatment or trial site.

Table 1.43 Interaction between P and Trial site for yield in 1996 (Trials 251 & 252).

	Yield (t/ha)	
	Maramakas	Luburua
P0	17.7	18.8
P1	16.6	20.3
Significance	*	
sed	0.78	
cv%	12.8	

The results of the soil analysis showed that application of muriate of potash had a significant effect on soil potassium. Soil K at K0 was 0.12 me% whilst at K1 and K2 soil K increased to 0.18 me%. There were no other significant results.

Yield and the components of yield for each year from 1992 - 1996 are given in Table 1.44.

Table 1.44 Effect of K on FFB yield and yield components from 1992 to 1996 (Trials 251 & 252).

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
Mean Yield	17.7	18.8	20.0						

In 1996 leaflet samples only were analysed and the results of this analysis are given in Table 1.45. Application of sulphate of ammonia led to a significant increase in leaflet nitrogen but had no effect on any other element tested. Leaflet nitrogen levels at N0 were 2.55% that is unlikely to limit yield. Muriate of potash application led to an increase in the concentration of nitrogen, potassium and chlorine in leaflet tissue. However, muriate of potash application also led to a decrease in leaflet magnesium status but as the magnesium levels were already at a high level this is not a concern.

Application of Triple Superphosphate led to a significant increase in leaflet nitrogen and leaflet phosphorus levels. Leaflet magnesium levels increased with application of Kieserite. Leaflet potassium levels were significantly higher at Luburua than at Maramakas.

Table 1.45 Treatment main effects on leaflet nutrient concentrations in 1996 (Maramakas and Luburua).

Element as % of dry matter	Nutrient element and level			Statistics		
				sig	sed	cv%
	N0	N1	N2			
Nitrogen	2.55	2.63	2.63	**	0.028	3.7
Phosphorus	0.160	0.162	0.161	ns	0.002	4.5
Potassium	0.70	0.72	0.70	ns	0.024	11.6
Calcium	1.13	1.09	1.10	ns	0.024	7.5
Magnesium	0.30	0.29	0.29	ns	0.012	14.4
Chlorine	0.59	0.61	0.62	ns	0.018	10.4
	K0	K1	K2			
Nitrogen	2.55	2.62	2.65	**	0.028	3.7
Phosphorus	0.160	0.162	0.162	ns	0.002	4.5
Potassium	0.55	0.77	0.79	***	0.024	11.6
Calcium	1.09	1.09	1.13	ns	0.024	7.5
Magnesium	0.38	0.26	0.24	***	0.012	14.4
Chlorine	0.53	0.63	0.66	***	0.018	10.4
	P0	P1				
Nitrogen	2.58	2.63		*	0.023	3.7
Phosphorus	0.158	0.164		**	0.002	4.5
Potassium	0.69	0.72		ns	0.019	11.6
Calcium	1.09	1.12		ns	0.020	7.5
Magnesium	0.30	0.29		ns	0.010	14.4
Chlorine	0.60	0.61		ns	0.015	10.4
	Mg0	Mg1				
Nitrogen	2.60	2.61		ns	0.023	3.7
Phosphorus	0.162	0.160		ns	0.002	4.5
Potassium	0.72	0.69		ns	0.020	11.6
Calcium	1.13	1.09		ns	0.020	7.5
Magnesium	0.28	0.31		**	0.010	14.4
Chlorine	0.60	0.61		ns	0.015	10.4
	Maramakas	Luburua				
Nitrogen	2.59	2.61		ns	0.024	3.7
Phosphorus	0.161	0.162		ns	0.002	4.5
Potassium	0.66	0.75		***	0.020	11.6
Calcium	1.12	1.09		ns	0.021	7.5
Magnesium	0.30	0.29		ns	0.011	14.4
Chlorine	0.60	0.61		ns	0.016	10.4

Figure 1.7 shows that at Maramakas soil depth has only a small not significant effect on yield. Soil depth at Luburua has a large significant effect on yield. The 1996 yield data (Figure 1.8) again demonstrates that potassium is the main factor limiting growth with soil depth the second limiting factor. With no applied potassium, soil depth has no effect on yield. However, with the addition of potassium fertiliser soil depth becomes limiting.

Figure 1.7: Relationship between plot yield and soil depth at Maramakas and Luburua in 1996.

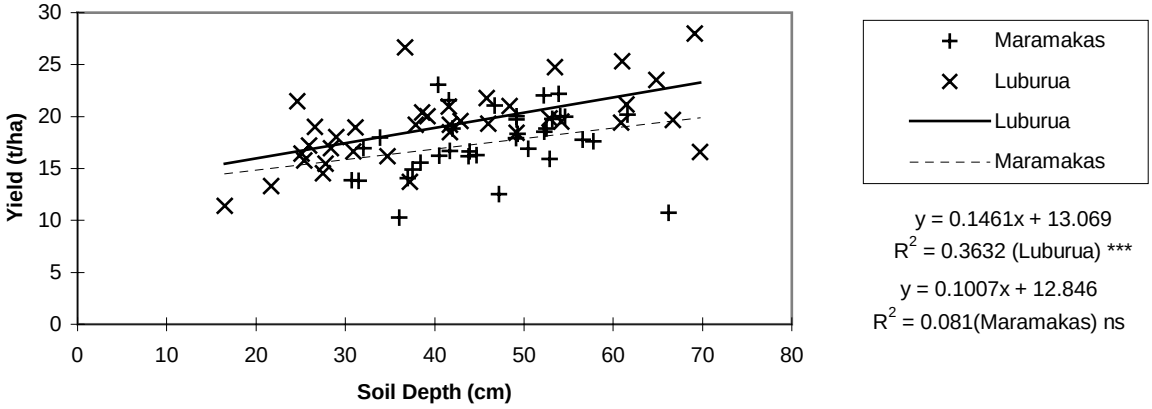


Figure 1.8: Relationship between plot yield and soil depth at K0, K1 & K2.

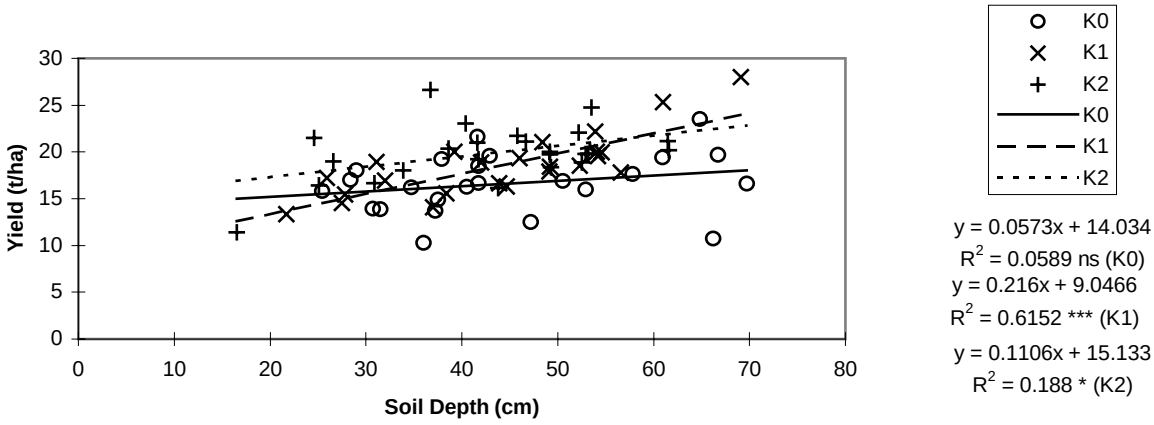


Figure 1.9: Effect of leaflet K on yield

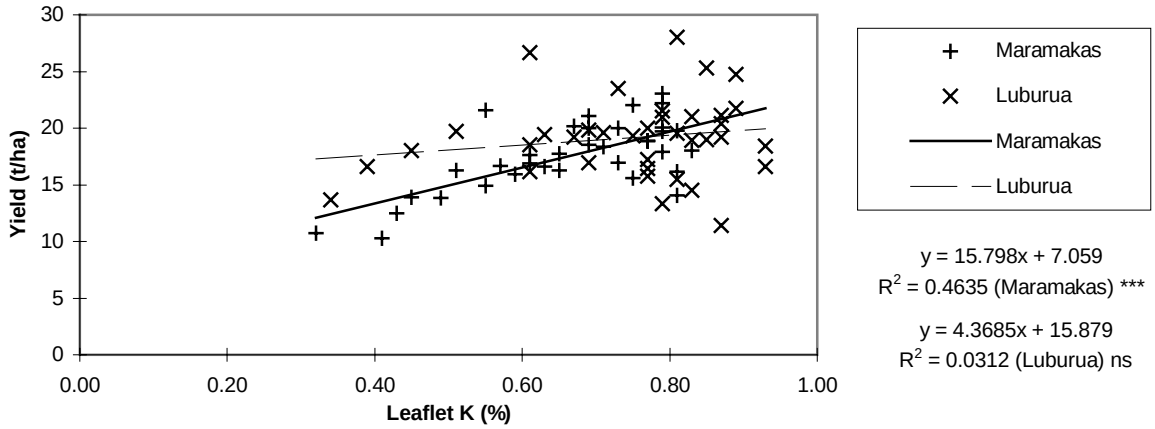
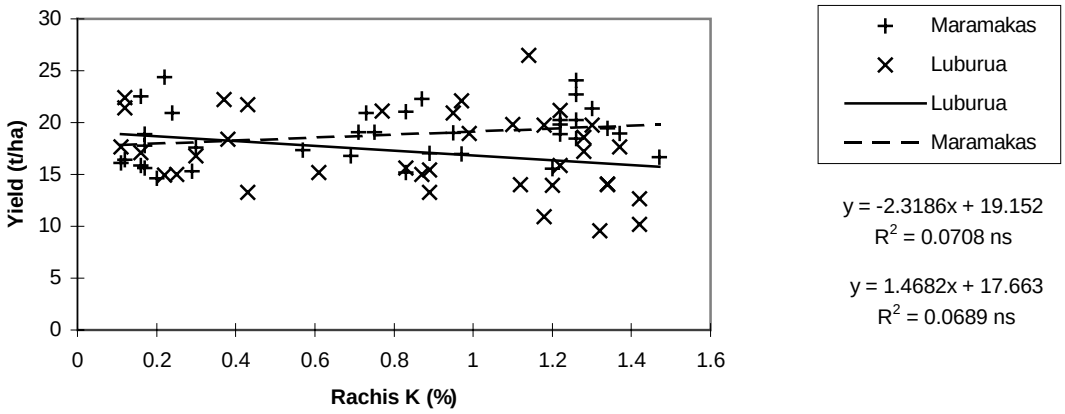


Figure 1.9 shows that leaflet potassium is a good indicator of potassium status on the deeper soils at Maramakas but is not a good indicator at Luburua on shallow soils. The relationship between soil depth and leaflet potassium was not significant at either site. Rachis samples were not analysed in 1996. However, the regression of rachis K in 1995 with 1995 yield was not significant (Figure 1.10). This indicates that some factor(s) other than potassium and soil depth are limiting yield at Poliamba.

Figure 1.10: Effect of rachis K on yield in 1995



Leaflet phosphorus, calcium, magnesium and chlorine were then regressed with yield. The regressions of phosphorus and chlorine were not significant but magnesium and calcium had a significant negative relationship with yield (Figures 1.11 and 1.12).

A stepwise regression of all the available leaf, rachis and soil analysis data with 1996 yield was then performed showing that the ratio of leaflet K:Ca, soil depth, leaflet Mg and K, rachis P, soil C/N and soil Ca explain 69% of variation in yield.

The resulting equation is:

$$y = 24.6 + 31.8KL{:}CaL + 0.05SD - 19.2MgL - 29.6KL + 53PR - 0.45C/N - 0.09CaS$$

with an $R^2 = 68.87\%$

where KL:CaL = Leaflet K: Leaflet Calcium
SD = Soil Depth
MgL = Leaflet Magnesium
KL = Leaflet Potassium
PR = Rachis Phosphorus
C/N = Soil Carbon: Nitrogen
CaS = Soil Calcium

Figure 1.11: Effect of leaflet magnesium on yield in 1996.

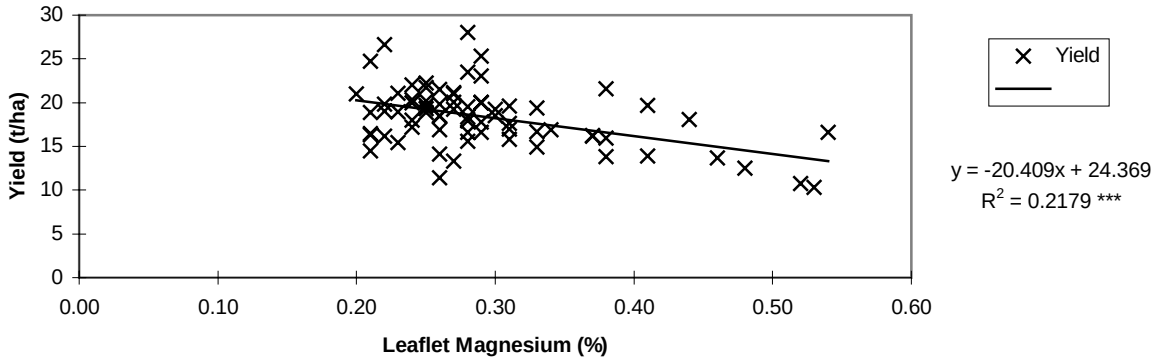


Figure 1.12: Relationship between leaflet calcium and yield

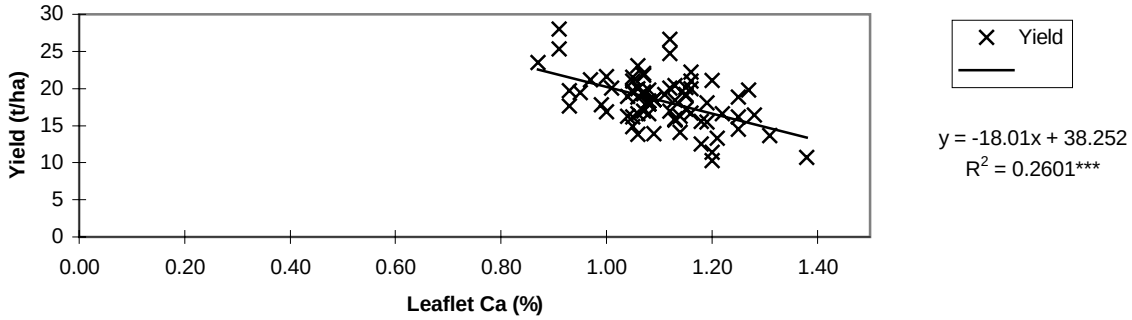
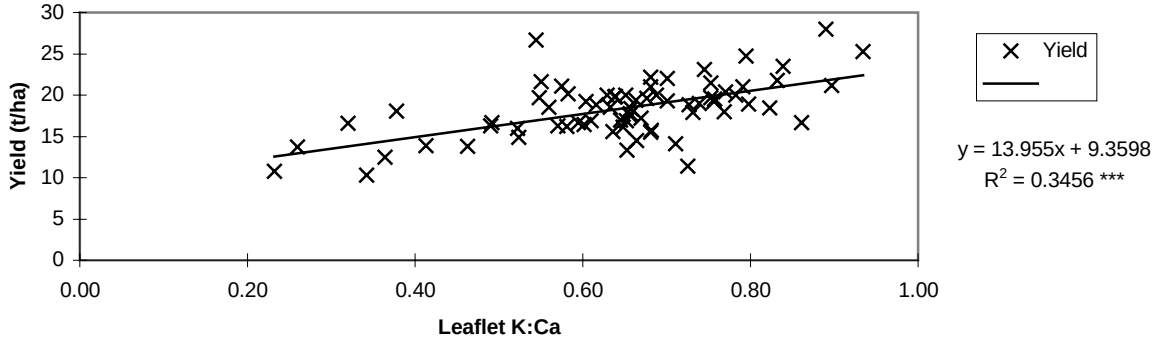


Figure 1.13: Relationship between Yield and Leaflet K:Ca in 1996.



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 1.46).

Table 1.46. 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

The average FFB yield in 1996 was higher than in the preceding 2 years at 26.4 t/ha/year. This is still considerably lower than the 1993 yield when 28.0 t/ha was recorded. Exploratory analysis of the 1996 data showed that mean yield was lower in block 1 than in block 2 but that the range of yields was higher in block 2 (Figure 1.14). Figure 1.15 shows that application of nitrogen leads to an increase in mean yield but that the range of yield increases with application of nitrogen. This suggests that there is a second factor other than nitrogen limiting yield in this field. Figure 1.16 shows that there is no correlation between leaflet nitrogen and yield whilst Figure 1.17 shows that application of nitrogen fertiliser has had no significant effect on leaflet nitrogen levels.

Figure 1.14 Box plot of FFB yield and block in 1996

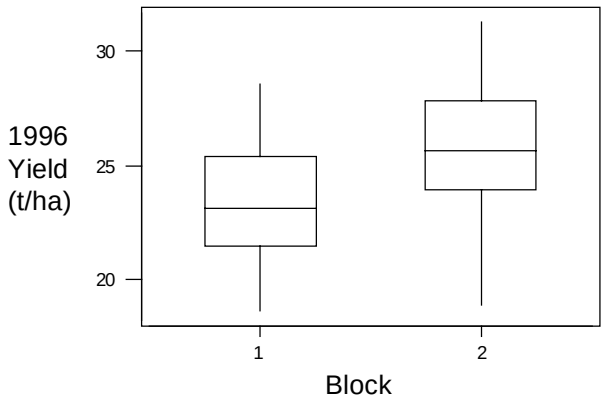


Figure 1.15 Boxplot of FFB yield and nitrogen in 1996

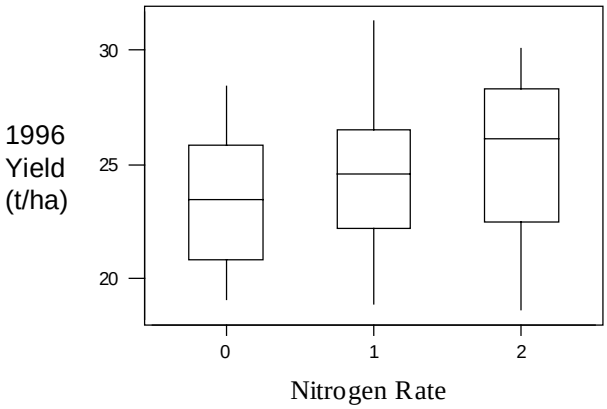


Figure 1.16: Effect of leaflet nitrogen on yield in 1996.

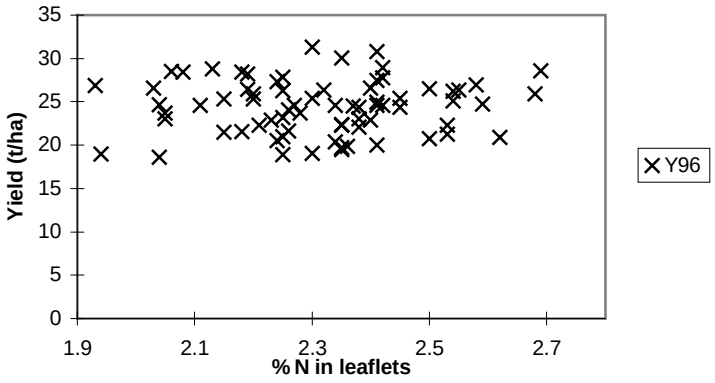
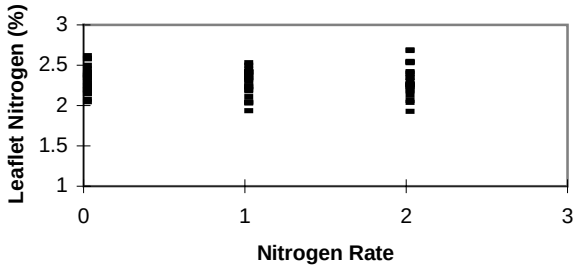


Figure 1.17: Effect of application of nitrogen on leaflet nitrogen levels



Analysis of the 1996 yield data showed that there was a significant yield increase due to ammonium chloride application (Table 1.47). This was due to an increase in both bunch number and bunch weight although these increases were not significant. Application of muriate of potash led to a significant decrease in FFB yield. However there was a significant interaction between nitrogen and potassium that is shown in Table 1.48. This shows that in the absence of nitrogen, potassium application results in a decrease in yield but that with application of ammonium chloride, muriate of potash application does not effect yield. Plot isolation trenches were constructed in 1995. Although the trenching will have minimised interplot poaching of nutrients, it appears that the trenching is having little effect in minimising movement of nitrogen fertiliser throughout the site. The water table in this site is high and mass flow of water through the plots must be carrying nitrogen from fertilised plots to non fertilised plots.

Application of Kieserite and triple super phosphate did not effect FFB yield in 1996 but the 1994 to 1996 cumulative data (Table 1.49) shows that Triple Superphosphate resulted in a significant increase in bunch number and that Kieserite application resulted in a significant increase in yield and bunch weight.

Table 1.47 Main effects of N, P, K and Mg on yield and yield components in 1996 (Trial 401).

	Nutrient element and level			Statistics		
				sig	sed	cv%
	N0	N1	N2			
Yield (t/ha/yr)	25.3	26.4	27.3	*	0.756	9.9
Bunches/ha	1185	1210	1224	ns	33.8	9.7
Bunch weight (kg)	21.6	21.9	22.4	ns	0.411	6.5
	P0	P1	P2			
Yield (t/ha/yr)	26.2	26.3	26.5	ns	0.756	9.9
Bunches/ha	1183	1209	1229	ns	33.8	9.7
Bunch weight (kg)	22.3	21.8	21.8	ns	0.411	6.5
	K0	K1				
Yield (t/ha/yr)	26.9	25.8		*	0.617	9.9
Bunches/ha	1229	1185		ns	27.6	9.7
Bunch weight (kg)	22.1	21.8		ns	0.336	6.5
	Mg0	Mg1				
Yield (t/ha/yr)	25.9	26.9		ns	0.617	9.9
Bunches/ha	1195	1219		ns	27.6	9.7
Bunch weight (kg)	21.8	22.1		ns	0.336	6.5

Table 1.48 Effect of nitrogen and potassium on yield in 1996 (Trial 401)

	Yield (t/ha/yr)	
	K0	K1
N0	26.7	23.7
N1	26.7	26.2
N2	27.1	27.5
Sig Effect	*	
sed	1.069	
cv%	9.9	

Table 1.49 Main effects of N, P, K and Mg on yield and yield components for 1994 to 1996 (Trial 401).

	Nutrient element and level			Statistics		
				sig	sed	cv%
	N0	N1	N2			
Yield (t/ha/yr)	22.7	23.5	23.6	ns	0.38	5.7
Bunches/ha	1117	1126	1091	ns	20.9	6.5
Bunch weight (kg)	20.4	21.0	21.7	**	0.35	5.8
	P0	P1	P2			
Yield (t/ha/yr)	23.0	23.4	23.5	ns	0.38	5.7
Bunches/ha	1079	1121	1133	*	20.9	6.5
Bunch weight (kg)	21.3	20.9	20.8	ns	0.35	5.8
	K0	K1				
Yield (t/ha/yr)	23.3	23.3		ns	0.31	5.7
Bunches/ha	1105	1117		ns	17.1	6.5
Bunch weight (kg)	21.1	20.9		ns	0.29	5.8
	Mg0	Mg1				
Yield (t/ha/yr)	22.9	23.7		*	0.31	5.7
Bunches/ha	1111	1111		ns	17.1	6.5
Bunch weight (kg)	20.7	21.3		*	0.29	5.8

The results of leaflet and rachis sampling in 1996 are given in Tables 1.50 and 1.51. Application of ammonium chloride led to a significant increase in both leaflet and rachis chlorine concentration but no increase in leaflet or rachis nitrogen. Application of Kieserite led to a significant reduction in leaflet nitrogen. Rachis potassium and magnesium increased significantly as a result of ammonium chloride application.

Table 1.50 shows that leaflet chlorine increases with application of ammonium chloride and that leaflet nitrogen concentration decreased with application of Kieserite.

Table 1.50 Treatment main effects on leaflet nutrient concentrations in 1996 (Trial 401).

Element as % of dry matter	Nutrient element and level			Statistics		
				sig	sed	cv%
	N0	N1	N2			
Nitrogen	2.34	2.30	2.34	ns	0.046	6.9
Phosphorus	0.147	0.160	0.147	ns	0.010	22.2
Potassium	0.73	0.71	0.73	ns	0.032	15.1
Calcium	0.84	0.89	0.84	ns	0.033	13.5
Magnesium	0.17	0.17	0.17	ns	0.007	14.7
Chlorine	0.45	0.61	0.56	***	0.032	20.8
	P0	P1	P2			
Nitrogen	2.36	2.26	2.35	ns	0.046	6.9
Phosphorus	0.160	0.146	0.148	ns	0.010	22.2
Potassium	0.73	0.70	0.74	ns	0.032	15.1
Calcium	0.85	0.86	0.85	ns	0.033	13.5
Magnesium	0.17	0.17	0.18	ns	0.007	14.7
Chlorine	0.52	0.55	0.55	ns	0.032	20.8
	K0	K1				
Nitrogen	2.29	2.36		ns	0.038	6.9
Phosphorus	0.147	0.156		ns	0.008	22.2
Potassium	0.71	0.73		ns	0.026	15.1
Calcium	0.84	0.87		ns	0.027	13.5
Magnesium	0.17	0.18		ns	0.006	14.7
Chlorine	0.52	0.56		ns	0.026	20.8
	Mg0	Mg1				
Nitrogen	2.37	2.27		*	0.038	6.9
Phosphorus	0.148	0.154		ns	0.008	22.2
Potassium	0.71	0.73		ns	0.026	15.1
Calcium	0.86	0.85		ns	0.027	13.5
Magnesium	0.17	0.18		ns	0.006	14.7
Chlorine	0.52	0.56		ns	0.026	20.8

Rachis potassium, chlorine and magnesium increased with application of ammonium chloride whilst rachis phosphorus and magnesium increased with application of Triple Superphosphate (Table 1.51). Stepwise regression of leaflet and rachis nutrient concentrations with yield showed that nutritional factors are not having any significant effects on yield in this trial.

Table 1.51 Treatment main effects on rachis nutrient concentrations in 1996 (Trial 401).

Element as % of dry matter	Nutrient element and level			Statistics		
				sig	sed	cv%
	N0	N1	N2			
Nitrogen	0.25	0.25	0.25	ns	0.006	8.7
Phosphorus	0.086	0.090	0.073	ns	0.006	26.1
Potassium	1.25	1.45	1.38	*	0.072	18.4
Calcium	0.37	0.40	0.40	ns	0.016	14.1
Magnesium	0.04	0.05	0.05	*	0.002	17.9
Chlorine	0.38	0.69	0.70	***	0.073	43.4
	P0	P1	P2			
Nitrogen	0.25	0.25	0.25	ns	0.006	8.7
Phosphorus	0.069	0.087	0.092	**	0.006	26.1
Potassium	1.36	1.35	1.37	ns	0.072	18.4
Calcium	0.40	0.39	0.39	ns	0.016	14.1
Magnesium	0.04	0.05	0.05	*	0.002	17.9
Chlorine	0.60	0.58	0.58	ns	0.073	43.4
	K0	K1				
Nitrogen	0.25	0.25		ns	0.005	8.7
Phosphorus	0.082	0.084		ns	0.005	26.1
Potassium	1.33	1.39		ns	0.059	18.4
Calcium	0.40	0.39		ns	0.013	14.1
Magnesium	0.04	0.04		ns	0.002	17.9
Chlorine	0.56	0.62		ns	0.060	43.4
	Mg0	Mg1				
Nitrogen	0.25	0.25		ns	0.005	8.7
Phosphorus	0.082	0.084		ns	0.005	26.1
Potassium	1.34	1.38		ns	0.059	18.4
Calcium	0.40	0.38		ns	0.013	14.1
Magnesium	0.04	0.05		ns	0.002	17.9
Chlorine	0.58	0.59		ns	0.060	43.4

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 1.52).

Table 1.52. 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 1996 was 26.6 t/ha/year. This is an increase from the 1995 (23.1 t/ha) but is still below that recorded in 1992 (31.0 t/ha) and 1993 (28.2 t/ha). In 1994 and 1995 EFB was applied at a rate of 120 t/ha whilst in 1996 this was reduced to the recommended level of 50 t/ha. It is likely that the high rates of EFB in 1994 and 1995 led to this reduction in yield.

Ammonium chloride application increased the single bunch weight in 1996 (Table 1.53) and in the cumulative data for 1994-96 (Table 1.54). Although not significant, the 1996 yield increased from

25.6 t/ha to 26.6 t/ha with 3.0 kg of ammonium chloride and to 27.6 t/ha with 6.0kg of ammonium chloride.

Application of triple super phosphate and muriate of potash did not effect yield or the components of yield. Application of Kieserite led to a significant increase in bunch weight.

Application of EFB started in mid 1993. Although the trial plan states that EFB would be applied at a rate of 50t/ha, the plantation practice in 1994 and 1995 was to apply almost 120 tonnes of EFB per hectare. Applying this much organic matter has most probably led to a reduction in yield as the large quantity of organic matter would most likely have tied up much of the applied nitrogen fertiliser. Anaerobic conditions would also have been created which would have limited root growth and uptake of nutrients.

In 1996 EFB was applied at a rate of 50t/ha and this has resulted in a significant increase in yield from 25.8t/ha to 27.4 t/ha. This increase in yield has occurred as a result of an increase in bunch number.

The only significant effect in the cumulative data (1994-1996) was a significant increase in bunch weight as a result of application of ammonia chloride (Table 1.45).

Table 1.53 Main effects of N, P, K and Mg on yield and yield components in 1996 (Trial 402).

	Nutrient element and level			Statistics		
				sig	sed	cv%
	N0	N1	N2			
Yield (t/ha/yr)	25.6	26.6	27.6	ns	0.88	11.5
Bunches/ha	1239	1234	1270	ns	35.9	10.0
Bunch weight (kg)	20.7	21.6	21.7	***	0.25	4.0
	P0	P1	P2			
Yield (t/ha/yr)	27.6	26.4	25.8	ns	0.88	11.5
Bunches/ha	1295	1223	1225	ns	35.9	10.0
Bunch weight (kg)	21.3	21.6	21.1	ns	0.25	4.0
	K0	K1				
Yield (t/ha/yr)	26.4	26.8		ns	0.72	11.5
Bunches/ha	1242	1253		ns	29.3	10.0
Bunch weight (kg)	21.3	21.4		ns	0.20	4.0
	Mg0	Mg1				
Yield (t/ha/yr)	26.7	26.5		ns	0.72	11.5
Bunches/ha	1267	1228		ns	29.3	10.0
Bunch weight (kg)	21.1	21.6		*	0.20	4.0
	EFB0	EFB1				
Yield (t/ha/yr)	25.8	27.4		*	0.72	11.5
Bunches/ha	1210	1286		*	29.3	10.0
Bunch weight (kg)	21.3	21.4		ns	0.20	4.0

Table 1.54 Main effects of N, P, K and Mg on yield and yield components from 1994 to 1996 (Trial 402).

	Nutrient element and level			Statistics		
				sig	sed	cv%
	N0	N1	N2			
Yield (t/ha/yr)	24.6	25.1	25.6	ns	0.48	6.7
Bunches/ha	1294	1273	1270	ns	31.0	8.4
Bunch weight (kg)	19.1	19.8	20.3	**	0.29	5.1
	P0	P1	P2			
Yield (t/ha/yr)	25.4	25.1	24.9	ns	0.48	6.7
Bunches/ha	1301	1266	1271	ns	31.0	8.4
Bunch weight (kg)	19.5	19.9	19.7	ns	0.29	5.1
	K0	K1				
Yield (t/ha/yr)	25.0	25.2		ns	0.39	6.7
Bunches/ha	1284	1275		ns	25.3	8.4
Bunch weight (kg)	19.6	19.8		ns	0.24	5.1
	Mg0	Mg1				
Yield (t/ha/yr)	25.2	25.1		ns	0.39	6.7
Bunches/ha	1290	1268		ns	25.3	8.4
Bunch weight (kg)	19.6	19.8		ns	0.24	5.1
	EFB0	EFB1				
Yield (t/ha/yr)	24.8	25.5		ns	0.39	6.7
Bunches/ha	1259	1299		ns	25.3	8.4
Bunch weight (kg)	19.7	19.7		ns	0.24	5.1

Table 1.55 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 application of 50 t/ha of EFB resulted in the same yield as 6.0 kg of ammonium chloride.

Table 1.55 Effect of N and EFB on FFB yield from 1992 to 1996 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

Application of ammonium chloride led to a significant increase in chlorine leaflet concentrations. Triple superphosphate application led to an increase in leaflet phosphorus whilst muriate of potash increased leaflet chlorine levels. Kieserite application led to an increase in leaflet magnesium but a decrease in leaflet calcium. EFB led to an increase in leaflet phosphorus and chlorine levels (Table 1.56).

Table 1.56 Treatment main effects on leaflet nutrient concentrations in 1996 (Trial 402).

Element as % of dry matter	Nutrient element and level			Statistics		
				sig	sed	cv%
	N0	N1	N2			
Nitrogen	2.47	2.49	2.52	ns	0.031	4.3
Phosphorus	0.151	0.149	0.151	ns	0.001	1.8
Potassium	0.82	0.79	0.80	ns	0.017	7.5
Calcium	0.87	0.88	0.87	ns	0.016	6.3
Magnesium	0.14	0.14	0.14	ns	0.004	10.0
Chlorine	0.49	0.58	0.61	***		
	P0	P1	P2			
Nitrogen	2.50	2.47	2.52	ns	0.031	4.3
Phosphorus	0.149	0.150	0.152	**	0.001	1.8
Potassium	0.81	0.80	0.80	ns	0.017	7.5
Calcium	0.87	0.88	0.87	ns	0.016	6.3
Magnesium	0.14	0.14	0.14	ns	0.004	10.0
Chlorine	0.56	0.56	0.55	ns	0.012	7.3
	K0	K1				
Nitrogen	2.51	2.48		ns	0.025	4.3
Phosphorus	0.150	0.150		ns	0.001	1.8
Potassium	0.81	0.80		ns	0.014	7.5
Calcium	0.87	0.88		ns	0.013	6.3
Magnesium	0.14	0.14		ns	0.003	10.0
Chlorine	0.53	0.58		***	0.010	7.3
	Mg0	Mg1				
Nitrogen	2.50	2.49		ns	0.025	4.3
Phosphorus	0.150	0.150		ns	0.001	1.8
Potassium	0.79	0.81		ns	0.014	7.5
Calcium	0.90	0.85		***	0.013	6.3
Magnesium	0.13	0.15		***	0.003	10.0
Chlorine	0.56	0.56		ns	0.010	7.3
	EFB0	EFB1				
Nitrogen	2.49	2.50		ns	0.025	4.3
Phosphorus	0.149	0.151		**	0.001	1.8
Potassium	0.80	0.81		ns	0.014	7.5
Calcium	0.88	0.87		ns	0.013	6.3
Magnesium	0.14	0.14		ns	0.003	10.0
Chlorine	0.52	0.60		***	0.010	7.3

Rachis potassium, calcium and chlorine increased with application of ammonium chloride whilst rachis phosphorus increased with application of Triple Superphosphate. Muriate of potash application led to a decrease in leaflet phosphorus but an increase in rachis potassium and chlorine. EFB application led to a significant increase in rachis phosphorus, potassium and chlorine (Table 1.57).

Table 1.57 Treatment main effects on leaflet nutrient concentrations in 1996 (Trial 402).

Element as % of dry matter	Nutrient element and level			Statistics		
				sig	sed	cv%
	N0	N1	N2			
Nitrogen	0.27	0.27	0.27	ns	0.006	7.4
Phosphorus	0.079	0.082	0.082	ns	0.004	18.1
Potassium	1.59	1.72	1.68	**	0.039	8.2
Calcium	0.41	0.45	0.46	**	0.012	9.1
Magnesium	0.04	0.04	0.04	ns	0.001	10.4
Chlorine	0.53	0.82	0.85	***	0.023	10.8
	P0	P1	P2			
Nitrogen	0.27	0.27	0.27	ns	0.006	7.4
Phosphorus	0.073	0.080	0.090	**	0.004	18.1
Potassium	1.70	1.67	1.62	ns	0.039	8.2
Calcium	0.44	0.45	0.44	ns	0.012	9.1
Magnesium	0.04	0.04	0.04	ns	0.001	10.4
Chlorine	0.76	0.73	0.71	ns	0.023	10.8
	K0	K1				
Nitrogen	0.27	0.27		ns	0.005	7.4
Phosphorus	0.077	0.085		*	0.003	18.1
Potassium	1.62	1.71		**	0.032	8.2
Calcium	0.43	0.45		ns	0.009	9.1
Magnesium	0.04	0.04		ns	0.001	10.4
Chlorine	0.65	0.82		***	0.018	10.8
	Mg0	Mg1				
Nitrogen	0.27	0.27		ns	0.005	7.4
Phosphorus	0.083	0.079		ns	0.003	18.1
Potassium	1.69	1.63		ns	0.032	8.2
Calcium	0.45	0.43		*	0.009	9.1
Magnesium	0.04	0.04		ns	0.001	10.4
Chlorine	0.74	0.73		ns	0.018	10.8
	EFB0	EFB1				
Nitrogen	0.26	0.27		ns	0.005	7.4
Phosphorus	0.075	0.087		***	0.003	18.1
Potassium	1.55	1.78		***	0.032	8.2
Calcium	0.44	0.45		ns	0.009	9.1
Magnesium	0.04	0.04		ns	0.001	10.4
Chlorine	0.62	0.84		***	0.018	10.8

1.3 **SMALLHOLDER DEMONSTRATION TRIALS.**

Trial 128 BENCHMARK/DEMONSTRATION OF RECOMMENDED MANAGEMENT AND FERTILISER APPLICATION ON OIL PALM SMALLHOLDINGS IN THE HOSKINS 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 128 is located on OPIC's Hoskins Smallholder Oil Palm. The 28 blocks selected in pairs are located at Sarakolok, Tamba, Kapore, Kavui, Buvussi, Mai, Kwalakesi, Gule and Kavutu. At Kavui and Buvusi there are 2 and 3 pairs respectively. Demonstration trials have also been established at Moramora Vocational School, Hoskins Secondary School and Ponini Vocational Centre. Details of each block are given in Table 58.

Palms Dami commercial DxP planting material.
Planted in various dates between 1972 and 1990 at 120 palms/ha.
Treatments started in July 1994.

DESIGN

Each of the 2 paired smallholder blocks represent a single replicate. There are three treatments (Table 1.58). With the first pair, half of the block will receive no fertiliser at all (control - RED) and the remaining half receive the recommended (demonstration - YELLOW) type and amount of fertiliser for the smallholder. With the second pair, half of the block will again receive no fertiliser at all (control - RED), and the remaining half will receive generous amounts (2kg) of <u>all</u> main types (N, P, K, MG - WHITE) of fertiliser. At the school blocks all three treatments are included in the one block.

Table 1.58 Treatments used in Trial 128

	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 by the block owner but the bunches from each treatment are put in separate nets and the weight of the nets from each colour code are recorded on the docket at the time of pick up. The OPRA recorders count the number of bunch stalks cut from each treatment. 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 1996.

Table 1.59 Details of 28 smallholder demonstration blocks in the Hoskins Smallholder Oil Palm Project areas of West New Britain Province in 1995.

Division	Sect	Owner	Block Number	Number of Palms		
				Red	Yellow	White
Kapore	3	H.T. Towakaken	010306	226	227	
Kapore	3	Joseph Pochei	010307	97		93
Tamba	2	A.T.T. Taul	20413	206	365	
Tamba	2	Hambakman	20414	250		240
Tamba	9	Usini Embi	20555	235		197
Tamba	9	Esther Sakius	20556	199	308	
Sarakolok*	5	Gima Bagera	30922	268	153	
Sarakolok	5	M. Hendry	30923	268		273
Buvussi*	6	Gumagoi Dogoba	41160	250		227
Buvussi*	6	Dombul Dekemba	41161	233	345	
Buvussi	5	Wamenvok Holbini	41193	376	332	
Buvussi	5	Vincent Kalaivi	41194	414		326
Buvussi	1	Simon Oleiuba	41399	341	353	
Buvussi*	1	Wai Aure	41418	238		566
Kavui	5	K. Tobubu	61682	221		257
Kavui	5	T. Tamaia	61681	188	192	
Kavui	8	Madau Tonatonok	61701	343	382	
Kavui	8	T. Todaungu	61702	358		344
Kwalakesi	VOP	Uba Kilu	130002	234	185	
Kwalakesi	VOP	Dominica Kaipu	130012	121		100
Mai*	VOP	Kulu Kuba	140019	120	112	
Mai*	VOP	Kenda Tavaperry	140091	130		106
Kavutu	VOP	Peter Magiap	330012	120		111
Kavutu	VOP	Misibil Irima	330037	109	122	
Gule	VOP	Timothy Tobubu	020007	135	86	
Gule	VOP	Mesunam Malalia	020008	118		123
		Moramora Vocational*				
		Hoskins Secondary*				
		Ponini Vocational*				

* trial blocks with unsatisfactory data during 1996

The data from blocks at Dire, Siki, Sarakalok, Mai and Buvusi (*) was unsatisfactory and blocks at Dire, Siki and Sarakolok were abandoned during 1996 due to the lack of cooperation from the block owner. The school blocks also were closed down during the year because the harvesting and recording systems were not reliable enough. Two new blocks were established at Gule as a result of a request by OPIC for more input on fertiliser research in VOP areas around Hoskins.

Table 1.59 Yield results for Trial 128 in 1996

Division	Sect	Block No.	No months harvesting recorded	Recorded Yield (t/ha/yr)		
				Control	N only	NPKMg
Kapore	3	10306	11	12.8	16.3	
Kapore	3	10307	7	16.3		23.7
Tamba	2	20413	9	12.6	22.6	
Tamba	2	20414	10	14.9		21.7
Tamba	5	20555	1	15.3		30.8
Tamba	5	20556	12	18.8	15.6	
Sarakolok	5	30922	5	2.6	5.1	
Sarakolok	5	30923	10	11.4		14.3
Buvussi	5	41193	1	13.0	17.0	
Buvussi	5	41194		11.7		21.1
Buvussi	1	41399		13.0	21.4	
Buvussi	6	41160	11	16.0		20.4
Buvussi	6	41161	11	16.7	14.6	
Kavui	5	61681		18.1	24.7	
Kavui	5	61682		12.9		15.2
Kavui	8	61701		16.4	19.4	
Kavui	8	61702		13.5		17.9
Mai	VOP	140019	7	15.3	10.3	
Mai	VOP	140091	9	12.0		18.7
Kwalakesi	VOP	130002		4.8	8.8	
Kwalakesi	VOP	130012		8.4		14.8
Kavutu	VOP	330012		18.4		21.4
Kavutu	VOP	330037		15.8	15.0	
			Mean	13.6	15.9	20.0
			Maximum	18.8	24.7	30.8
			Minimum	2.6	5.1	14.3
			s.e.	0.83	1.67	1.43

Once again yield recording in the smallholder trial blocks proved to be very difficult but was an improvement over 1995. Large coloured posts were placed at each market place and nets from each treatment were placed beside the post corresponding to the treatment. Recording of the weight of the nets from each colour on the field dockets by fruit truck drivers improved as a result but for many harvests throughout the year drivers did not bother to record the colour coding beside the net weight. The yields calculated from the available data are given in Table 1.59. The mean yield from fertilised plots was 16.0 t/ha in 1996, which is substantially higher than the mean yield recorded from fertilised plots in 1995 (14.0t/ha).

A number of the blocks had some of their palms poisoned in 1996 and yields from these blocks were lower in 1996 than in 1995. Some growers put bunches from the fertilised block with bunches from the control plot so the calculated yield figures given above should therefore be treated with some caution. Actual yields were not given this year as palm poisoning on many of the trial blocks has led to a reduction in yield. No yields were recorded in any of the school trials in 1996.

An informal survey of all the growers participating in the trial blocks in West New Britain was conducted in July 1996 to gauge growers views regarding the response of the palms on their block to the fertiliser applied. All the growers stated that the fertilised blocks produced higher yields due to an increase in both bunch number and bunch weight. The difference in leaf colour and rachis cross-

section between fertilised and unfertilised blocks was very marked. Several of the growers also stated that they did not want to continue with the trial as the control plot was costing them a lot of money through lost production. These growers, as leaders in their respective sections, were embarrassed that their palms were yellow compared to their neighbours. Instead of abandoning the trials the growers were allowed to put their own fertiliser evenly over the whole block whilst OPRA continued to apply fertiliser to half the block. This would allow OPRA to determine the difference if any between 2kg and 4kg of ammonium chloride.

Table 1.60 Descriptive statistics of leaflet and rachis nutrient concentrations (% on dry matter) from Trial 128 in 1996.

Nutrient	Treatment	Mean	Minimum	Maximum	Std Error
Leaflet N	Control	2.00	1.75	2.41	0.035
	N only	2.06	1.72	2.24	0.046
	N,P,K,Mg	2.11	1.89	2.30	0.035
Leaflet P	Control	0.13	0.115	0.142	0.002
	N only	0.13	0.120	0.138	0.002
	N,P,K,Mg	0.13	0.116	0.145	0.002
Leaflet K	Control	0.74	0.61	0.93	0.016
	N only	0.73	0.61	0.89	0.026
	N,P,K,Mg	0.70	0.63	0.83	0.016
Leaflet Ca	Control	0.86	0.63	1.07	0.022
	N only	0.89	0.66	1.12	0.037
	N,P,K,Mg	0.90	0.71	1.13	0.032
Leaflet Mg	Control	0.17	0.10	0.28	0.007
	N only	0.16	0.10	0.26	0.012
	N,P,K,Mg	0.15	0.09	0.19	0.008
Leaflet Cl	Control	0.23	0.10	0.46	0.019
	N only	0.33	0.22	0.49	0.027
	N,P,K,Mg	0.42	0.14	0.52	0.029
Rachis N	Control	0.20	0.16	0.24	0.004
	N only	0.21	0.18	0.27	0.007
	N,P,K,Mg	0.21	0.19	0.24	0.005
Rachis P	Control	0.068	0.031	0.134	0.007
	N only	0.066	0.029	0.156	0.013
	N,P,K,Mg	0.077	0.025	0.270	0.010
Rachis K	Control	1.16	0.42	1.77	0.057
	N only	1.25	0.67	1.72	0.088
	N,P,K,Mg	1.35	0.63	1.93	0.085
Rachis Ca	Control	0.35	0.27	0.30	0.012
	N only	0.41	0.23	0.38	0.022
	N,P,K,Mg	0.46	0.23	0.57	0.022
Rachis Mg	Control	0.04	0.03	0.09	0.003
	N only	0.04	0.03	0.07	0.003
	N,P,K,Mg	0.04	0.03	0.06	0.003
Rachis Cl	Control	0.13	0.03	0.54	0.023
	N only	0.31	0.09	0.56	0.045
	N,P,K,Mg	0.43	0.05	0.80	0.067

Leaf and rachis samples were taken from all the trial blocks in 1996. The summary statistics of this analysis are given in Table 1.60. Correlation and regression analysis did not show any significant relationships between yield and nutrient concentration. Other factors such as site, grower and palm age are most likely controlling yield and the number of trial plots is too small to be able to detect the true response to fertiliser application.

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 NBPOD's Kapiura Plantations Pty Ltd in the west to Noau and Hargy's Navo Plantation east of Bialla township. Details of the 23 selected blocks are given in Table 62.

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 1.61). With the first pair, half of the block will receive no fertiliser at all (control - RED) and the remaining half receive the recommended (demonstration - YELLOW) type and amount of fertiliser for the smallholder. With the second pair, half of the block will again receive no fertiliser at all (control - RED), and the remaining half will receive generous amounts (2kg) of <u>all</u> main types (N, P, K, MG - WHITE) of fertiliser.

Table 1.61 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 1996.

Table 1.62 Details of 28 smallholder demonstration blocks in the Bialla Smallholder Oil Palm Project areas of West New Britain Province in 1995.

Division	Sect	Owner	Block Number	Number of Palms		
				Red	Yellow	White
Bereme	VOP	Leo Lusi	254-04	79		96
Bereme	VOP	Mathais Avu	254-09	126	94	
Lavege	VOP	Emmanuel Moli	251-33	119		85
Lavege	VOP	Albert Vua	251-30	117	114	
Mamota	LSS	Maria Soima	240-0912-8	214		247
Mamota	LSS	Thomas Tingairo	240-0921-8	220	256	
Tarobi	VOP	Francis Lowa	257-023	110		146
Tarobi	VOP	Alphonse Tovili	257-07	108	121	
Salelebu	LSS	Samson Nata	240-447	153		138
Salelebu	LSS	Lou Ruku	240-450	115	114	
Lalopo	LSS	Anna Joram	1129			
Lalopo	LSS	Peni Lagoa	1108			
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	
Noau	VOP	Enoch Volele	0723	108		129
Noau	VOP	P. Malila	0714	116	116	
Soi	10	Raphael Moute	1653	125		126
Soi	10	Jan Moris	1651	124	120	
Matililiu	VOP	Raiman Vilale	1705	266		267
Matililiu	VOP	Mauli Vilale	1707	114	115	
		Bialla High School	13	99	120	120

RESULTS

1996 yield results for Trial 210 are given in Table 1.63.

Table 1.63 Yield results for Trial 210 in 1996

Division	Sect	Block No.	No months harvesting recorded	Calculated Yield (t/ha/yr)		
				Control	N only	NPKMg
Bereme	VOP	254-04	22	18.1		14.9
Bereme	VOP	254-09	19	10.2	13.9	
Lavege	VOP	251-33	15	14.3		21.8
Lavege	VOP	251-30	21	21.0	22.8	
Mamota	LSS	240-0912-8	22	19.9		24.8
Mamota	LSS	240-0921-8	21	22.0	21.0	
Tarobi	VOP	257-023	19	18.8		23.8
Tarobi	VOP	257-07	17	12.8	12.2	
Salelebu	LSS	240-447	4	-	-	-
Salelebu	LSS	240-450	4	-	-	-
Lalopo	LSS	1129	0	-	-	-
Lalopo	LSS	1108	0	-	-	-
Kiava	VOP	1122	6	-	-	-
Kiava	VOP	1123	4	-	-	-
Balima	LSS	1273	6	-	-	-
Balima	LSS	1274	4	-	-	-
Noau	VOP	0723	22	10.9	17.3	
Noau	VOP	0714	23	11.7		18.6
Soi	10	1653	28	20.9		25.2
Soi	10	1651	4	-	-	
Matililiu	VOP	1705	30	20.4	23.8	
Matililiu	VOP	1707	18	19.8		24.1
Bialla H.S.		13	15	22.5	24.8	28.3
			Mean	17.4	19.4	22.7
			Maximum	22.5	24.8	28.3
			Minimum	10.2	12.2	14.9
			s.e.	1.18	1.88	1.49

As with Trial 128 it has proven to be very difficult to ensure that the fruit truck drivers record the colour coding of the nets on the delivery docket. The calculated yield figures given above should therefore be treated with some caution.

The two blocks at Salelebu were established in 1995 and the first fertiliser applications were made in November 1995. Yield recording on these blocks commenced in late 1996. Block 1651 at Soi was planted in 1994 and had not commenced bunch production in 1995. The blocks at lalopo, Kiava and Balima were established in late 1996.

Tissue sampling was completed in October 1996 and the results are given in the Table 1.64.

Table 1.64 Descriptive statistics of leaflet and rachis nutrient concentrations (% on dry matter) from Trial 210 in 1996.

Nutrient	Treatment	Mean	Minimum	Maximum	Std Error
Leaflet N	Control	2.31	1.92	2.68	0.052
	N only	2.31	2.08	2.68	0.068
	N,P,K,Mg	2.37	2.03	2.64	0.061
Leaflet P	Control	0.142	0.120	0.167	0.003
	N only	0.144	0.130	0.162	0.004
	N,P,K,Mg	0.144	0.126	0.162	0.003
Leaflet K	Control	0.83	0.47	1.03	0.031
	N only	0.76	0.61	1.01	0.041
	N,P,K,Mg	0.76	0.55	0.95	0.038
Leaflet Ca	Control	0.90	0.64	1.13	0.026
	N only	0.95	0.60	1.16	0.048
	N,P,K,Mg	0.94	0.71	1.10	0.042
Leaflet Mg	Control	0.22	0.14	0.42	0.017
	N only	0.22	0.14	0.35	0.019
	N,P,K,Mg	0.21	0.11	0.38	0.024
Leaflet Cl	Control	0.19	0.08	0.35	0.016
	N only	0.42	0.08	0.62	0.055
	N,P,K,Mg	0.45	0.08	0.69	0.053
Rachis N	Control	0.23	0.19	0.27	0.005
	N only	0.24	0.19	0.31	0.012
	N,P,K,Mg	0.24	0.18	0.29	0.011
Rachis P	Control	0.045	0.020	0.100	0.004
	N only	0.048	0.027	0.079	0.005
	N,P,K,Mg	0.065	0.020	0.122	0.010
Rachis K	Control	1.15	0.17	1.47	0.058
	N only	1.10	0.63	1.52	0.074
	N,P,K,Mg	1.25	0.22	1.67	0.112
Rachis Ca	Control	0.35	0.19	0.56	0.017
	N only	0.41	0.21	0.56	0.032
	N,P,K,Mg	0.44	0.27	0.56	0.030
Rachis Mg	Control	0.05	0.03	0.21	0.009
	N only	0.05	0.03	0.11	0.007
	N,P,K,Mg	0.06	0.04	0.16	0.011
Rachis Cl	Control	0.08	0.03	0.29	0.013
	N only	0.30	0.02	0.69	0.068
	N,P,K,Mg	0.46	0.03	0.92	0.077

As with Trial 128 there was no significant correlation between yield and nutrient concentration.

Trial 253: BENCHMARK/DEMONSTRATION OF RECOMMENDED MANAGEMENT AND FERTILISER PRACTICES ON OIL PALM SMALLHOLDINGS IN THE NEW IRELAND SCHEME.

PURPOSE

To carry out basic investigations into requirement for fertiliser input in smallholdings and if so determine the type of fertiliser required. This is a missing element trial on village oil palm.

DESCRIPTION

Sites. Experiment 253 is located on OPIC's New Ireland Smallholder Oil Palm The two blocks in which the trials have been established are located at Lossu at South village oil palm (VOP), and Paruai in the North VOP area. Both these blocks are on the East Coast of New Ireland.

Palms Dami commercial DxP crosses.
Planted in 1992/93.

DESIGN

Each smallholder block provides a single replicate consisting of 2 hectares. Within this 2 ha there are 6 different treatments in 6 plots (Table 1.64). The fertiliser types and rates used are given in Table 1.65.

Table 1.64 Fertiliser types used in Trial 253.

Fertiliser type	Plot No	Treatment
AS + TSP + MoP + KIE	1	Complete: N+P+K+Mg
TSP + MoP + KIE	2	Complete minus N
AS + MoP + KIE	3	Complete minus P
AS + TSP + KIE	4	Complete minus K
AS + TSP + MoP	5	Complete minus Mg
NIL	6	NIL

AS = ammonium sulphate,
TSP = Triple Superphosphate,
MoP = muriate of potash,
KIE = Kieserite

Table 1.65 Rates of fertiliser applied in Trial 253.

Treatment	Amount of fertiliser (kg/palm/yr)			
	Ammonium Sulphate	Triple Superphosphate	Muriate of Potash	Kieserite
1	2	2	2	2
2	0	2	2	2
3	2	0	2	2
4	2	2	0	2
5	2	2	2	0
6	0	0	0	0

Fertiliser application currently follows plantation (Poliamba Pty Ltd) practice. The whole block is harvested in the normal way for a smallholder block and the weight of the fruit is recorded by OPRA. Leaflets and rachis of frond 17 are sampled each year.

The palms at Lossu started bearing fruit in 1996. A few harvests were recorded late in 1996. The palms at Paruai had still not commenced harvesting at the end of 1996.

The results of tissue sampling carried out in September 1996 are given in Table 1.66 for leaflet and Table 1.67 for rachis.

Table 1.66 Leaflet nutrient content in Trial 253 in 1995.

Site	Treatment	Ash	N	P	K	Ca	Mg	Cl
Paruai	N,P,K,Mg	9.10	2.04	0.132	0.61	0.87	0.48	0.70
	- N	10.03	1.97	0.116	0.49	0.99	0.55	0.79
	- P	8.51	2.08	0.087	0.87	0.59	0.45	0.59
	- K	7.97	2.10	0.118	0.32	0.91	0.75	0.86
	- Mg	7.56	1.89	0.119	0.59	0.85	0.53	0.76
	Nil	8.26	2.15	0.094	0.37	0.88	0.58	0.74
Lossu	N,P,K,Mg	7.22	2.75	0.166	0.75	1.15	0.34	0.69
	- N	7.50	2.67	0.173	0.75	1.07	0.34	0.66
	- P	6.87	2.70	0.163	0.79	1.29	0.32	0.75
	- K	6.29	2.60	0.171	0.45	0.99	0.46	0.51
	- Mg	6.67	2.72	0.167	0.77	1.17	0.29	0.71
	Nil	7.25	2.29	0.154	0.39	1.22	0.50	0.69

The palms at the Paruai site were planted on Kunai whereas the palms at Lossu were planted in an area of old garden land. At both sites leaflet K was very low in the minus K and control plots. Leaflet nitrogen increased with the application of ammonium sulphate but at Paruai nitrogen levels are still very low. At the Paruai site phosphorus levels are very low and addition of Triple Superphosphate has increased leaflet phosphorus levels.

The analysis of rachis given in Table 1.67 also demonstrates that potassium levels are very low. Rachis N and P are very low in the minus P plot at Paruai indicating that phosphorus is limiting at this site.

Table 1.67 Rachis nutrient content in Trial 253 in 1995.

Site	Treatment	Ash	N	P	K	Ca	Mg	Cl
Paruai	N,P,K,Mg	2.18	0.19	0.039	0.73	0.24	0.12	0.45
	- N	2.39	0.19	0.029	0.75	0.25	0.18	0.64
	- P	2.17	0.07	0.014	0.69	0.19	0.17	0.33
	- K	1.57	0.24	0.029	0.12	0.22	0.21	0.20
	- Mg	2.07	0.27	0.036	0.56	0.20	0.18	0.39
	Nil	1.74	0.20	0.016	0.49	0.17	0.14	0.34
Lossu	N,P,K,Mg	2.43	0.30	0.063	0.56	0.40	0.14	0.51
	- N	2.81	0.30	0.060	0.75	0.48	0.12	0.71
	- P	2.44	0.27	0.057	0.52	0.56	0.10	0.47
	- K	2.87	0.29	0.079	0.10	0.69	0.34	0.54
	- Mg	2.68	0.32	0.060	0.45	0.54	0.12	0.50
	Nil	2.91	0.32	0.091	0.10	0.74	0.34	0.49

2 MAINLAND REGION AGRONOMY

2.1 Introduction

1996 was a difficult year for the Mainland Agronomy Programme, mainly due to staff changes. Training of three new assistant Agronomists took up much of the year, with the Regional Agronomist having to spend more time in Milne Bay during the early part of 1996. Problems with software resulted in delays in the production of the 1995 Annual Research Report. No major new trials were setup apart from 8 smallholder demonstration blocks. Tissue sampling was completed for both Higaturu Oil Palms and Milne Bay Estates, involving over 600 samples. Field days for Oro smallholders were conducted during the year but only one was organised for Milne Bay smallholders.

2.1.1 Staff

Joe Yambun transferred from Popondetta in May to take up the position of assistant Agronomist at Kapiura. Murom Banabas left in January 1996 to start a two-year MSc in Soil Science at Massey University, New Zealand. At Higaturu, two trainee assistant Agronomists were recruited. Josephine Papah joined in January and Peter Taramurray in June. In Milne Bay, Mr. Winston Eremu, another new trainee, was recruited to manage trials during Mr. Banabas's study leave.

2.1.2 Trial Management

Analyses of trials were not completed due to problems with the statistical software. All trials were managed well except for the two trials at Mamba where 1996 yield data are incomplete die to missed harvests during the year.

2.1.3 Tissue Sampling

Leaf sampling of trials at Higaturu and Milne Bay were both completed. In both locations, training sessions on leaf sampling were conducted for Supervisors, assistant Managers and Managers. Some results were not available by the end of the year.

2.1.4 Smallholders

PNGOPRA participated in field days for smallholders in Popondetta and Milne Bay, jointly organised by OPIC and PNGOPRA. The main topic covered was the need and benefits of fertiliser. The smallholder trials clearly indicate the need for applications of ammonium sulphate, which if not applied severely limits production. Only one field day was held in Milne Bay. The PNGOPRA Regional Agronomist attended OPIC Local Planning Committee meetings in Popondetta and Alotau.

2.2 AGRONOMY TRIALS

Trial 305 FERTILISER TRIAL AT AREHE ESTATE

PURPOSE

To test the response to N, P, K, and Mg in factorial combination on Higaturu soil.

DESCRIPTION

Site Arehe Estate, block 78F.

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

Palms Dami commercial DxP crosses. Planted in 1978 at 130 palms/ha. Trial started in 1981.

DESIGN

There are 72 plots, each with a core of 16 palms. The numbers and weights of bunches from each individual core palm are recorded at intervals of 14 days. In each plot the core palms are surrounded by at least one guard row, which was trenched in 1995.

The 72 plots are divided into two replicates. In each replicate there are 36 treatment combinations, made up from all combinations of three levels each of N and K, and two levels each of P and Mg (Table 2.1).

Table 2.1 Types of fertiliser and amounts used in Trial 305.

		Amount of fertiliser (kg/ha/yr)		
Element	Type of Fertiliser	Level 0	Level 1	Level 2
N	SoA	0.0	2.0	4.0
P	TSP	0.0	2.0	-
K	MoP	0.0	2.0	4.0
Mg	Kies	0.0	1.0	-

RESULTS

Mean yield was low in 1996, with an average plot yield of 21.7 tonnes FFB/ha/yr. There has been a continued major response to SoA. The increase in yield was made up from an increase in the number of bunches per hectare and single bunch weight. Muriate of potash (MoP) did not have any major effects on yield, although there were statistically significant increases in single bunch weights. Responses to TSP alone were absent and there was a significant decrease in bunch numbers due to Kieserite in 1996 (Table 2.2). Over the 9-year period 1987-1996, the trend is the same as seen in 1996 (Table 2.4).

N and K treatment combinations are given in Table 2.3 and 2.5. Though the interactions were not significant, the highest yielding treatment combination in both 1996 and 1987-96 was obtained with an application of 4kg of ammonium sulphate and 2kg of muriate of potash per palm

Table 2.2 Main effects of N, P, K, and Mg on yield and yield components in 1996 (Trial 305).

	Nutrient element and level			Statistics		
				sig	cv%	sed
	N0	N1	N2			
Yield (t/ha/yr)	18.3	22.3	24.4	***	14.8	0.93
Bunches/ha	768	821	868	**	13.0	30
Bunch weight (kg)	23.6	27.3	28.2	***	9.0	0.69
	P0	P1				
Yield (t/ha/yr)	21.6	21.8		ns	14.8	0.76
Bunches/ha	815	823		ns	13.0	25
Bunch weight (kg)	26.4	26.4		ns	9.0	0.56
	K0	K1	K2			
Yield (t/ha/yr)	20.8	22.5	21.7	ns	14.8	0.93
Bunches/ha	845	817	796	ns	13.0	30
Bunch weight (kg)	24.5	27.6	27.1	***	9.0	0.69
	Mg0	Mg1				
Yield (t/ha/yr)	22.2	21.1		ns	14.8	0.76
Bunches/ha	845	793		*	13.0	25
Bunch weight (kg)	26.3	26.5		ns	9.0	0.56

Table 2.3 The effect of N on yield at different levels of K in 1996 (Trial 305)

	Yield (t/ha/yr)		
	K0	K1	K3
N0	16.9	19.4	18.5
N1	22.0	22.4	22.6
N2	23.5	25.8	24.0
Grand mean	21.7	sed	1.61

Table 2.4 Main effects of N, P, K, and Mg on yield and yield components in 1987 – 1996 (Trial 305)

	Nutrient element and level			Statistics sig	cv%	sed
	N0	N1	N2			
Yield (t/ha/yr)	19.5	25.3	28.1	***	13.1	1.01
Bunches/ha	859	977	1067	***	11.4	36
Bunch weight (kg)	22.5	26.0	26.4	***	8.2	0.57
	P0	P1				
Yield (t/ha/yr)	24.1	24.5		ns	13.1	0.83
Bunches/ha	960	975		ns	11.4	30
Bunch weight (kg)	24.9	25.0		ns	8.2	0.46
	K0	K1	K2			
Yield (t/ha/yr)	23.2	25.1	24.5	ns	13.1	1.01
Bunches/ha	1000	960	942	ns	11.4	36
Bunch weight (kg)	23.1	26.0	25.8	ns	8.2	0.57
	Mg0	Mg1				
Yield (t/ha/yr)	24.7	23.8		ns	13.1	0.83
Bunches/ha	989	946		ns	11.4	30
Bunches weight (kg)	24.8	25.1		ns	8.7	0.47

Table 2.5 The effect of N on yield at different levels of K in 1987-1996 (Trial 305).

		Yield (t/ha/yr)		
		K0	K1	K2
	N0	18.5	20.3	19.7
	N1	24.8	25.6	25.5
	N2	26.5	29.5	28.2
Grand mean	24.3	Standard error		1.56

The poorer treatment combinations yielded well below 20t/ha, the lowest was 12.7t/ha especially when nitrogen was absent. In comparison, with high fertilizer inputs of 4 kg of SoA per palm yields were high around 30t/ha (Table 2.6).

Table 2.6 Yields for treatment combinations giving highest and lowest yields 1987-1996. (Trial 305)

Maximum Yield Combination					Minimum Yield Combination				
Yield (t/ha)	N	P	K	Mg	Yield (t/ha)	N	P	K	Mg
32.8	2	0	1	1	12.7	0	1	0	1
31.5	2	1	1	0	13.1	0	1	1	0
31.1	2	0	2	0	13.4	0	0	2	0
30.6	2	0	1	0	13.7	0	1	2	1
30.5	2	1	2	1	14.7	0	0	0	1
30.4	2	0	2	1	14.9	0	0	0	0
30.3	2	1	1	1	15.3	0	1	2	0
30.3	2	1	1	1	15.4	0	0	0	1
29.8	2	1	0	0	15.7	0	0	1	0
29.6	1	0	1	0	16.6	1	0	2	1
29.3	1	1	2	0	17.3	0	0	1	1
28.6	2	0	1	0	17.4	0	1	0	0
28.4	2	0	2	0	19.0	0	1	1	1

Trial 306 **FERTILISER TRIAL AT AMBOGO ESTATE**

PURPOSE

To test the response 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 seasonally high water table, derived from alluvially deposited volcanic ash.

Palms — Dami commercial DxP crosses planted in 1979 at 143 palms/ha. Trial started 1982.

DESIGN

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

The 81 plots are in a single replicate containing 81 treatments, made up from all combinations of three levels each of N, P, K, and Mg (Table 2.6). The 81 treatments are divided into three blocks within the replicate, such that some high order interactions are confounded with block effects.

Table 2.7 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	SoA	0.0	3.0	6.0
P	TSP	0.0	0.5	1.0
K	MoP	0.0	2.5	5.0
Mg	Kies	0.0	0.75	1.5

Modifications: Until 1990 SoA rates were half those indicated.

RESULTS

The average plot yield in 1996 was 25.2 t FFB/ha/yr. There has been a continued major response to ammonium sulphate in 1996. The increase in yield was made up from increases in bunch numbers per hectare (Table 2.8) and single bunch weight. Muriate of potash did not have any major effects on yield, but there was a significant increase in single bunch weight. There were no responses to Triple-Superphosphate or Kieserite.

The trend is similar for the cumulative data between 1987-1986 (Table 2.10). N and K treatment combinations are shown in Tables 2.9 and 2.11. In 1996 maximum yield of 29.5 t/ha was obtained with 3 kg of SoA alone. Between 1987-96 the highest yielding treatment combination was 6kg SoA and 2.5kg MoP, giving 28.0 t/ha.

Table 2.8 Main effects of N, P, K, and Mg on yield and yield components in 1996 (Trial 306).

	Nutrient element and level			Statistics		
				sig	cv%	sed
	N0	N1	N2			
Yield (t/ha/yr)	19.4	27.8	28.3	***	19.7	1.35
Bunches/ha	789	955	964	***	17.6	43
Bunch weight (kg)	24.6	29.1	29.6	***	8.6	0.65
	P0	P1	P2			
Yield (t/ha/yr)	25.8	24.1	25.6	ns	19.7	1.35
Bunches/ha	927	882	897	ns	17.6	43
Bunch weight (kg)	27.6	27.2	28.3	ns	8.6	0.65
	K0	K1	K2			
Yield (t/ha/yr)	25.6	24.1	25.4	ns	19.7	1.35
Bunches/ha	964	849	893	*	17.6	43
Bunch weight (kg)	26.4	28.5	28.2	**	8.6	0.65
	Mg0	Mg1	Mg2			
Yield (t/ha/yr)	24.1	26.0	25.5	ns	19.7	1.35
Bunches/ha	879	927	900	ns	17.6	43
Bunch weight (kg)	27.2	27.9	28.1	ns	8.6	0.65

Table 2.9 The effects of N on yield at different levels of K in 1996

	Yield (t/ha/yr)		
	K0	K1	K2
N0	20.0	18.5	19.7
N1	29.5	26.4	27.5
N2	27.4	28.4	29.2
Grand mean	25.2	Standard error 2.34	

Table 2.10 Main effects of N, P, K, and Mg on yield an dyield components in 1987-96 (Trial 306).

	Nutrient element and level			Statistics sig	cv%	sed
	N0	N1	N2			
Yield (t/ha/yr)	19.7	25.7	27.3	***	13.4	0.88
Bunches/ha	848	940	994	***	11.1	27
Bunch weight (kg)	23.2	27.3	27.5	***	7.6	0.54
	P0	P1	P2			
Yield (t/ha/yr)	24.7	23.2	24.7	ns	13.4	0.88
Bunches/ha	951	902	929	ns	11.1	27
Bunch weight (kg)	25.9	25.7	26.5	ns	7.6	0.54
	K0	K1	K2			
Yield (t/ha/yr)	24.2	24.1	24.3	ns	13.4	0.88
Bunches/ha	978	896	909	ns	11.1	27
Bunch weight (kg)	24.6	26.8	26.6	***	7.6	0.54
	Mg0	Mg1	Mg2			
Yield (t/ha/yr)	23.2	24.9	24.6	ns	13.4	0.88
Bunches/ha	909	949	924	ns	11.1	27
Bunch weight (kg)	25.3	26.2	26.4	ns	7.6	0.54

Table 2.11 The main effects of N on yield at different levels of K in 1987-1996 (Trial 306).

		Yield (t/ha/yr)		
		K0	K1	K2
	N0	20.3	19.3	19.5
	N1	26.3	25.1	25.8
	N2	26.1	28.0	27.7
Grand mean	24.2	Standard error	1.52	

No tissue sampling was carried out in 1996.

Trial 309 **POTASSIUM, CHLORINE AND SULPHUR TRIAL AT AMBOGO ESTATE**

PURPOSE

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

DESCRIPTION

Site — Ambogo Estate, block 80H

Soil — Penderetta family. Thin dark sandy loam topsoil over sandy loam subsoil, derived from alluvially deposited volcanic ash. Mottling due to seasonally high water tables.

Palms — Dami commercial DxP crosses planted in 1980 at 143 palms per hectare. Trial started January 1988, but present treatments started in June 1990.

DESIGN

There are 25 plots each containing 16 core palms. The numbers and weights of bunches for each individual core palms are recorded at intervals of 14 days. In each plot 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 in a Latin Square design (Table 2.12). The trial is laid down on the site of an earlier trial that was started in 1984 to test effects of EFB.

The treatments are combinations of fertilisers, one of which is bunch ash (BA). The right hand part of Table 2.12 shows the amount of each element that is applied to each treatment. The effect of an element is estimated 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.

Table 2.12 Types and amounts of fertiliser given in each treatment, and the corresponding amounts of nutrient element in Trial 309.

	Amounts of fertiliser (kg/palm/year)				Amount of element (kg/palm/year)			
Treatment No.	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

RESULTS

Yield data comparisons on the effects of N, S, K, and Cl for 1994 and 1995, are summarised in Table 2.13.

In 1996 yields have fallen below 20 t/ha. The first time that yields have fallen despite receiving nitrogen rates that have the same on the estates was in 1995. A possible explanation for the drop in yield would have been the effect of plot isolation trenching that was carried out in 1995.

Despite the drop in yield, major responses have been recorded with nitrogen, sulphur, potassium and a small response to chlorine. Treatment effects were not significantly different in 1996 as compared to previous years (Table 2.14). In separating out the effects of different elements and their combinations over the six years (Table 2.15), there was a continued response to both potassium and sulphur.

Table 2.13 Effects of N, S, K, and Cl in different combinations on yield and yield components in 1995-1996 (Trial 309)

Treatment	1995			1996		
	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	18.7	746	25.2	18.7	769	24.1
5 N S K	19.7	876	22.4	14.7	665	21.4
3 N S	18.6	817	22.4	15.1	722	20.7
2 N Cl	14.4	710	20.5	13.8	683	20.4
1 Nil	6.4	436	14.1	7.6	466	16.1
sig	***	***	***	ns	ns	***
sed	4.09	1.56	2.86	2.69	94	1.35

Table 2.14 Effects of N, S, K, and Cl, in different combinations, on yield trends from 1991 – 1995 (Trial 309).

	Yields (Tonnes per hectare per year)					
	1991	1992	1993	1994	1995	1996
Age	11	12	13	14	15	16
Treatment						
4 N S K Cl	31.3	32.5	28.4	27.7	18.7	18.7
5 N S K	28.6	30.9	28.7	26.4	19.7	14.7
3 N S	28.5	27.8	25.2	24.2	18.6	15.1
2 N Cl	24.5	21.7	19.4	18.7	14.4	13.8
1 Nil	16.4	13.6	9.8	7.1	6.4	7.6
Sig	**	***	***	***	***	***
cv%	17.1	20.1	19.1	9.4	26.3	30.4

Table 2.15 Mean yield for 1991-1996, and difference in yield for selected comparisons (Trial 309).

Mean Yield 1991 - 1996		Selected Comparisons		
Treatment	Yield (t/ha/yr)	Comparisons	Difference (t/ha/yr)	Sig
4 N S K Cl	23.2	4-2 (effect of K and S)	6.4	***
5 N S K	20.8	3-2 (substituting S for Cl)	3.2	***
3 N S	20.0	4-3 (effect of K and Cl)	3.2	***
2 N Cl	16.8	4-5 (effect of Cl)	2.4	**
1 Nil	9.1	5-3 (effect of K)	0.8	ns
		3-1 (effect of N and S)	10.9	***
		2-1 (effect of N and Cl)	7.7	***

F sig ***, cv% = 18.3, sed = 2.08

Analysis of leaf and rachis in 1996 are shown in Table 2.16 and 2.17. There were no significant differences in leaf and rachis nitrogen. These leaf N levels indicate the low yields in the trial. In 1995 all leaf N levels were below 2% except for treatment 2, which was receiving ammonium chloride. Applications of bunch ash and ammonium sulphate provided 0.83% leaf K and 1.62% K in the rachis. Significant differences between treatments were recorded for leaf P, K, Ca, and Cl, whilst in the rachis only Ca and Cl were recorded.

Table 2.16 Effects of N, S, K, and Cl in different combinations, on the concentration of elements in leaf tissue of frond 17 in 1996 (Trial 309)

		Concentrations of elements (% of dry matter)						
Treatment		N	P	K	Ca	Mg	Cl	S
4	N S K Cl	2.04	0.128	0.75	0.70	0.22	0.44	
5	N S K	2.05	0.130	0.83	0.67	0.24	0.30	
3	N S	2.06	0.126	0.78	0.60	0.22	0.21	
2	N Cl	2.11	0.135	0.70	0.69	0.24	0.42	
1	Nil	1.97	0.125	0.76	0.61	0.27	0.23	
	sig	ns	**	**	**	ns	***	
	cv%	3.9	2.5	5.4	5.7	13.1	17.4	
	sed	0.05	0.002	0.03	0.02	0.02	0.04	

Table 2.17 Effects of N, S, K, and Cl in different combinations, on the concentration of elements In the rachis in 1995 (Trial 309).

Treatment		Concentrations of elements (% dry matter)						
		N	P	K	Ca	Mg	Cl	S
4	N S K Cl	0.24	0.133	1.73	0.32	0.07	1.02	
5	N S K	0.24	0.149	1.62	0.25	0.06	0.30	
3	N S	0.23	0.114	1.27	0.22	0.06	0.16	
2	N Cl	0.28	0.132	1.28	0.28	0.09	0.88	
1	Nil	0.25	0.125	1.15	0.22	0.08	0.27	
	sig	ns	ns	ns	**	ns	***	
	cv%	13.4	18.3	17.3	12.4	18.3	16.3	
	sed	0.02	0.015	0.15	0.02	0.01	0.05	

Trial 310 POTASSIUM, CHLORINE AND SULPHUR TRIAL AT AMBOGO ESTATE

PURPOSE

To test the response of oil palm to fertiliser applications of 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 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 (Table 2.18). The lower half of Table 2.18 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 Cl in the absence of K and S is found by comparing treatments 3 and 1.

Table 2.18 Amount of each type of fertiliser, and each element, used for each treatment in Trial 310.

Type of fertiliser	Treatment number (kg fertiliser/palm/year)						
	1	2	3	4	5	6	7
Urea	1.8	-	-	-	-	-	-
SoA	-	4.0	-	4.0	-	4.0	2.0
AmC	-	-	3.2	-	3.2	-	1.6
BA	-	-	-	4.4	4.4	-	-
MoP	-	-	-	-	-	2.2	-
Element	**(kg 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	-	-	-	-	-	2.2	-

RESULTS

There were no significant differences in yield between the treatments in 1996 (Table 2.19) or during 1991-96 (Table 2.21).

There were no significant differences between treatments in terms of FFB yield. However, there were significant differences between treatments in single bunch weight (Table 2.20). It appears that

treatments lacking chlorine have significantly lower bunch weight. Bunch analysis is required to determine which component has been increased by the chlorine applications.

Table 2.19 The effects of K, Cl and S on yield in 1996 (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	25.6	0.0	0.0
4	N, K, S	Cl	24.6	-1.0	-3.9
7	N, Cl, S	K	27.0	+1.4	+5.5
5	N, K, Cl	S	28.2	+2.6	+10.2
2	N, S	K, Cl	23.7	-1.9	- 7.4
3	N, Cl	K, S	28.8	+3.2	+12.5
1	N (Urea)	K, Cl, S	24.5	-1.1	-4.3
		sig	ns		
		cv%	13.6		
		sed	3.54		

Table 2.20 The effects of K, Cl and S on single bunch weight in 1996 (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	27.3	0.0	0.0
4	N, K, S	Cl	26.1	-1.2	-4.6
7	N, Cl, S	K	27.1	-0.2	-0.7
5	N, K, Cl	S	29.5	+2.2	+7.5
2	N, S	K, Cl	23.7	-3.6	-15.1
3	N, Cl	K, S	28.5	+1.2	+4.2
1	N (Urea)	K, Cl, S	25.3	-2.0	-7.9
		sig	***		
		cv	5.4		
		Sed	0.91		

Table 2.21 The effect of K, Cl and S on yield for the period 1991-1996 (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	26.3	0.0	0.0
4	N, K, S	Cl	25.8	-0.5	-1.9
7	N, Cl, S	K	26.7	0.4	-1.5
5	N, K, Cl	S	27.7	1.4	+5.3
2	N, S	K, Cl	24.9	-1.4	-5.3
3	N, Cl	K, S	28.4	+2.1	+8.0
1	N (Urea)	K, Cl, S	24.6	-1.7	-6.5
		Sig	ns		
		cv	9.5		
		lsd	1.6		

Table 2.22 The effects of N, S, K, and Cl in different combinations, on the concentrations of leaf tissues of frond 17 in 1996 (Trial 310).

Treatment	Concentrations of elements (% of dry matter) N	P	K	Ca	Mg	Cl
6 N S K Cl	2.11	0.133	0.79	0.71	0.18	0.44
4 N S K	2.23	0.138	0.89	0.61	0.17	0.23
7 N S Cl	2.27	0.139	0.79	0.68	0.17	0.48
5 N K Cl	2.31	0.139	0.82	0.70	0.16	0.49
3 N Cl	2.21	0.139	0.82	0.68	0.19	0.20
2 N S	2.30	0.140	0.80	0.66	0.17	0.43
1 N (Urea)	2.31	0.144	0.91	0.65	0.17	0.14
sig	**	**	**	ns	(ns)	***
cv	3.4	2.5	9.3	6.2	8.7	30.7
sed	0.05	0.002	0.03	0.04	0.01	0.07

Table 2.23 Effects of N, S, K and Cl in different combinations, on the concentrations of elements in rachis of frond 17 in 1996 (Trial 310).

Treatment		Concentrations of elements (% dry matter) N	P	K	Ca	Mg	Cl
6	N S K Cl	0.25	0.203	1.58	0.40	0.06	0.88
4	N S K	0.27	0.175	1.41	0.30	0.05	0.32
7	N S Cl	0.30	0.145	1.30	0.42	0.07	0.83
5	N K Cl	0.30	0.175	1.44	0.39	0.05	0.98
3	N Cl	0.29	0.144	1.19	0.34	0.05	0.29
2	N S	0.30	0.169	1.31	0.36	0.06	0.63
1	N (Urea)	0.30	0.129	1.03	0.29	0.04	0.07
	sig	*	****	****	***	(ns)	****
	cv	8.4	14.9	11.7	14.9	23.0	55.3
	sed	0.02	0.02	0.10	0.03	0.008	0.20

Leaf and rachis tissue analyses are shown in Tables 2.22 and 2.23. Significant differences between treatments were recorded for leaf and rachis N, P, K, and Cl. Application of urea and ammonium chloride produced the highest leaf N levels respectively, whilst treatment 6 which receives ammonium sulphate and muriate of potash shown leaf N of 2.11%.

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

PURPOSE

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

DESCRIPTION

Site — Isavene Estate block 78A

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

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

DESIGN

There are 32 plots each with a core of 16 palms. The number and weights of bunches from each individual core palm are recorded at intervals of 14 days. In each plot at least one guard row and a trench surround the core palms.

The trial has a single replicate containing 32 treatments, made up of all combinations of four levels each of N and K, and two levels of EFB (Table 2.24). 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 a mulch between the palm circles. The weights of EFB given in Table 2.24 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 is applied every two years.

Table 2.24 Amounts of fertiliser and EFB used in Trial 311.

Type of fertiliser or EFB	Amount (kg/palm/year)			
	Level 0	Level 1	Level 2	Level 3
SoA	0.0	2.0	4.0	6.0
MoP	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 1996 and the 7-year period are shown in Tables 2.25 and 2.27. In 1990, applications of ammonium sulphate produced a statistically significant response in yield. The increase in yield was due to increases in bunch numbers and single bunch weights. There were no significant increases due to applications of muriate of potash, despite a 4.5 tonne increase with 6 kg of MoP, as shown in Table 2.25. Empty fruit bunch, averaged over all fertiliser treatments, increased yield by 5.0 tonnes, again due to an increase in bunch numbers and single bunch weight.

Table 2.26 shows the two-way tables for N, K, and EFB. The interactions were not significant but a maximum yield of 37.8 FFB t/ha is obtained with 6 kg/palm of SoA and 2 kg/palm of MoP, a 17.6 tonnes increase from the control yield of 20.2 tonnes. Response to both N and K fertiliser improved in the presence of EFB..

Table 2.25 Main effects of N, K, EFB on yield and yield components in 1996 (Trial 311).

	Level of nutrient element or EFB				Statistics		
	N0	N1	N2	N3	sig	cv%	sed
Yield (t/ha/yr)	**23.8**	**26.9**	**29.0**	**32.6**	**	12.8	1.80
Bunches/ha	**845**	**946**	**933**	**1033**	*	11.9	55
Bunch weight (kg)	**28.1**	**28.2**	**31.1**	**31.6**	*	7.2	1.06
	K0	K1	K2	K3			
Yield (t/ha/yr)	26.5	27.4	27.4	31.0	ns	12.8	1.80
Bunches/ha	890	923	914	1030	ns	11.9	55
Bunch weight (kg)	29.5	29.1	30.2	30.1	ns	7.2	1.06
	EFB 0	EFB 1					
Yield (t/ha/yr)	**25.6**	**30.6**			**	12.8	1.28
Bunches/ha	**887**	**992**			*	11.9	39
Bunch weight (kg)	**28.6**	**30.9**			**	7.2	0.75

Table 2.26 Main effects of N, K, and EFB on yield and yield components for 1989 – 1996 (Trial 311)

	Level of nutrient element or EFB				Statistics		
	N0	N1	N2	N3	Sig	cv%	sed
Yield (t/ha/yr)	25.4	29.2	30.8	33.6	***	7.9	1.17
Bunches/ha	937	1060	1055	1148	*	8.0	41
Bunch weight (kg)	27.0	27.4	29.2	29.3	*	5.4	0.76
	K0	K1	K2	K3			
Yield (t/ha/yr)	**28.4**	**29.1**	**29.4**	32.1	*	7.9	1.17
Bunches/ha	**1025**	**1025**	**1027**	1123	ns	8.0	41
Bunch weight (kg)	**27.5**	**28.0**	**28.8**	28.6	ns	5.4	0.76
	EFB 0	EFB 1					
Yield (t/ha/yr)	27.8	31.7			***	7.9	0.83
Bunches/ha	1010	1090			*	8.0	29
Bunch weight (kg)	27.3	29.1			**	5.4	0.54

Table 2.27 Effect of combinations of N and K, N and EFB, and K and EFB in 1996 (Trial 311).

Yield (t/ha/yr)

	Level of N			
Level of K	N0	N1	N2	N3
K0	20.2	25.3	30.0	30.7
K1	22.4	22.1	27.4	37.8
K2	25.0	29.6	26.2	28.8
K3	27.7	30.8	32.3	33.2
Level of EFB				
EFB0	22.2	22.6	27.5	30.1
EFB1	25.5	31.3	30.5	35.2

	Level of K			
	K0	K1	K2	K3
Level of EFB				
EFB0	24.4	22.6	26.6	28.8
EFB1	28.6	32.3	28.2	33.3

Grand mean: 28.1 Standard error: NxK=3.61, NxEFB & KxEFB=2.55.

Table 2.28 Effect of combinations of N and K, N and EFB, K and EFB on yield for 1989 – 1996 (Trial 311).

Level of K	Yield (tonnes/ha/yr) Level of N			
	N0	N1	N2	N3
K0	22.8	27.8	31.1	31.8
K1	23.6	25.1	30.0	37.7
K2	26.6	31.3	28.7	31.1
K3	28.5	32.5	33.3	34.0
Level of EFB				
EFB 0	23.9	25.6	29.8	31.8
EFB 1	26.9	32.7	31.7	35.4
	Level of K			
	K0	K1	K2	K3
EFB 0	26.4	24.9	28.8	31.0
EFB 1	30.4	33.4	30.0	33.1

Grand mean: 29.7 Standard error: NxK=2.34, NxEFB & KxEFB=1.66

Table 2.29 Main effects of N, K, and EFB on concentrations of elements in leaflet tissue in 1996 (Trial 311).

	Level of nutrient Element or EFB				Statistics sig	cv%	sed.
	N0	N1	N2	N3			
N%	1.99	2.19	2.23	2.36	****	4.3	0.05
P%	0.124	0.131	0.132	0.137	*	5.6	0.004
N/P	16.1	16.7	16.9	17.0			
K%	0.76	0.75	0.77	0.76	ns	7.4	0.03
Ca%	0.66	0.66	0.66	0.64	ns	7.8	0.02
Mg%	0.18	0.18	0.18	0.16	ns	10.3	0.009
Cl%	0.44	0.51	0.53	0.53	ns	24.1	0.06
	K0	K1	K2	K3			
N%	2.26	2.16	2.15	2.21	ns	4.3	0.05
P%	0.133	0.131	0.130	0.131	ns	5.6	0.004
K%	0.80	0.75	0.75	0.74	ns	7.4	0.03
Ca%	0.62	0.68	0.65	0.65	ns	7.8	0.02
Mg%	0.18	0.18	0.17	0.17	ns	10.3	0.006
Cl%	0.45	0.48	0.52	0.56	ns	24.1	0.06
	EFB0	EFB1					
N%	2.16	2.23			(ns)	4.3	0.03
P%	0.129	0.134			ns	5.6	0.003
N/P	16.7	16.6					
K%	0.75	0.77			ns	7.4	0.02
Ca%	0.66	0.65			ns	7.8	0.02
Mg%	0.18	0.17			ns	10.3	0.006
Cl%	0.46	0.54			ns	24.1	0.04

Ammonium sulphate significantly increased N, and P levels in the leaflets. Muriate of potash reduced leaf K but was not significant. Empty fruit bunch increased leaflet N that was almost significant. There were also increases in leaf P, K and Cl but was not significant.

Table 2.30 Main effects of N, K, and EFB on concentrations of elements in rachis in 1996 (Trial 311).

	Level of nutrient Element or EFB				Statistics		
					sig	cv%	sed.
	N0	N1	N2	N3			
N%	0.24	0.26	0.27	0.29	**	7.2	0.01
P%	0.085	0.086	0.072	0.087	ns	20.4	0.008
K%	1.36	1.52	1.36	1.49	*	8.2	0.06
Ca%	0.41	0.41	0.40	0.39	ns	8.7	0.02
Mg%	0.07	0.06	0.06	0.06	**	9.3	0.003
Cl%	0.78	0.92	0.89	0.87	ns	16.1	0.07
	K0	K1	K2	K3			
N%	0.28	0.26	0.26	0.27	ns	7.2	0.01
P%	0.078	0.081	0.078	0.093	ns	20.4	0.008
K%	1.17	1.46	1.47	1.62	***	8.2	0.06
Ca%	0.37	0.41	0.41	0.42	ns	8.7	0.02
Mg%	0.06	0.06	0.07	0.06	(ns)	9.3	0.003
Cl%	0.41	0.92	1.03	1.10	***	16.1	0.07
	EFB0	EFB1					
N%	0.26	0.27			ns	7.2	0.01
P%	0.074	0.091			*	20.4	0.006
K%	1.36	1.51			**	8.2	0.04
Ca%	0.40	0.40			ns	8.7	0.01
Mg%	0.07	0.06			**	9.3	0.002
Cl%	0.82	0.92			(ns)	16.1	0.05

Ammonium sulphate increased rachis N. Rachis K although was significantly variable and rachis Mg was significantly reduced. Muriate of potash increased rachis K and Cl, whilst empty fruit bunch increased levels of P and K and Cl, but reduced Mg levels in the rachis.

Trial 312 NITROGEN, POTASSIUM, AND EMPTY FRUIT BUNCH TRIAL AT ISAVENE ESTATE.

PURPOSE

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

DESCRIPTION

Site — Ambogo Estate, block 80E2.

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

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

DESIGN

There are 32 plots each with a core of 16 palms. The number and weights of bunches from each individual core palm are recorded at intervals of 14 days. In each plot at least one guard row and a trench surround the core palms.

The trial has a single replicate containing 32 treatments, made up of all combinations of four levels each of N and K, and two levels of EFB (Table 2.31). 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 2.31 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 applied every two years.

Table 2.31 Amounts of fertiliser and EFB used in Trial 312.

Type of fertiliser or EFB	Amount (kg/palm/year)			
	Level 0	Level 1	Level 2	Level 3
SoA	0.0	2.0	4.0	6.0
MoP	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.

EFB has been applied once every two years.

RESULTS

Yield data for 1996, and 1989-1996 are shown in Tables 2.32 and 2.34. Ammonium sulphate significantly increased yields in 1996. These were made up of increases in bunch numbers and single bunch weight. Muriate of potash did not have any significant effect on yield. Empty fruit bunch applications significantly increased yield and it's components in 1996.

The two-way tables for N, K, and EFB are shown in Table 2.33 and 2.35. The interactions were not significant, but there are some notable trends. The maximum yield of 34 FFB t/ha is achieved with 6 kg /palm of SoA and 2 kg/palm of MoP. This combination is the same in Trial 311. SoA applied with the combination of EFB provided a further benefit in yield. EFB applied with MoP seems to reduce yields. Applications of EFB increased yield when applied alone or with SoA.

In 1989-1996 the trend is similar. Yield increase due to EFB is now apparent as compared to 1995 yield data.

Table 2.32 Main effects of N, K, EFB on yield and yield components in 1996 (Trial 312).

	Level of nutrient element or EFB				Statistics		
	N0	N1	N2	N3	sig	cv%	sed
Yield (t/ha/yr)	**229**	**26.6**	**30.0**	31.8	**	11.1	1.54
Bunches/ha	968	**1026**	1146	1221	ns	12.2	67
Bunch weight (kg)	**23.2**	**25.8**	**26.2**	**26.2**	***	7.6	0.97
	K0	K1	K2	K3			
Yield (t/ha/yr)	27.7	28.9	28.1	26.7	ns	11.1	1.09
Bunches/ha	1084	1145	1124	1026	ns	12.2	47
Bunch weight (kg)	25.3	25.1	25.0	26.0	ns	7.6	0.68
	EFB 0	EFB 1					
Yield (t/ha/yr)	**24.8**	**30.9**			***	11.1	1.09
Bunches/ha	1017	1173			*	12.2	67
Bunch weight (kg)	**24.3**	**26.4**			*	7.6	0.68

Table 2.33 Main effects of N, K, and EFB on yield and yield components for 1989-1995 (Trial 312).

	Level of nutrient element or EFB				Statistics		
	N0	N1	N2	N3	sig	cv%	sed
Yield (t/ha/yr)	**25.0**	**28.8**	31.7	32.8	***	7.8	1.15
Bunches/ha	**1196**	**1228**	**1343**	**1395**	*	8.9	57
Bunch weight (kg)	**20.8**	**23.5**	**23.6**	**23.5**	**	4.9	0.56
	K0	K1	K2	K3			
Yield (t/ha/yr)	29.4	30.0	29.0	28.9	ns	7.8	1.54
Bunches/ha	1289	1316	1312	1246	ns	8.9	57
Bunch weight (kg)	22.8	22.7	22.7	23.3	ns	4.9	0.56
	EFB 0	EFB 1					
Yield (t/ha/yr)	**27.7**	31.4			**	7.8	0.82
Bunches/ha	**1250**	1331			(ns)	8.9	40
Bunch weight (kg)	**22.1**	23.6			**	4.9	0.40

Table 2.34 Effect of combinations of N and K, N and EFB on yield in 1996 (Trial 312).

Yield (t/ha/yr)

	Level of N			
Level of K	N0	N1	N2	N3
K0	21.9	27.5	30.7	30.6
K1	21.7	27.0	33.1	34.0
K2	25.0	27.8	28.5	30.9
K3	23.3	24.1	27.7	31.6
Level of EFB				
EFB0	19.7	21.2	27.9	30.4
EFB1	26.2	32.0	32.1	33.2

	Level of K			
Level of EFB	K0	K1	K2	K3
EFB0	22.8	27.5	24.5	24.4
EFB1	32.6	30.3	31.6	28.9

Grand mean: 27.8, Standard errors: NxK=3.1, NxEFB & KxEFB=2.18.
Interactions were not significant.

Table 2.35 Effects of combinations of N and K, N and EFB and K and EFB on yield in 1989-1996 (Trial 312).

	Yield (t/ha/yr)			
		Level of N		
Level of K	N0	N1	N2	N3
K0	23.9	29.6	32.6	31.6
K1	24.4	29.2	33.2	33.3
K2	25.5	30.2	30.7	33.0
K3	26.0	26.3	30.3	33.1
Level of EFB				
EFB0	22.6	26.2	30.0	32.2
EFB1	27.3	31.5	33.4	33.3
		Level of K		
Level of EFB	K0	K1	K2	K3
EFB0	27.2	28.3	27.7	27.9
EFB1	31.8	31.7	32.0	30.0

Table 2.36 Main effects of N, K, and EFB on concentrations of elements in leaflet tissue of frond 17 in 1996 (% dry matter).

	Level of nutrient Element or EFB				Statistics		
					sig	cv%	sed
	N0	N1	N2	N3			
N%	2.14	2.18	2.21	2.2	ns	9.1	0.10
P%	0.135	0.136	0.139	0.142	ns	4.8	0.003
N/P	15.9	16.0	15.9	15.5			
K%	0.79	0.79	0.80	0.80	ns	8.1	0.03
Ca%	0.69	0.68	0.67	0.64	ns	8.5	0.03
Mg%	0.02	0.20	0.18	0.18	ns	12.5	0.01
Cl%	0.41	0.47	0.47	0.47	ns	12.3	0.03
	K0	K1	K2	K3			
N%	2.17	2.19	2.17	2.21	ns	9.1	0.10
P%	0.137	0.140	0.137	0.137	ns	4.8	0.003
K%	0.81	0.80	0.78	0.78	ns	8.1	0.03
Ca%	0.64	0.67	0.69	0.67	ns	8.5	0.03
Mg%	0.19	0.19	0.19	0.19	ns	12.5	0.01
Cl%	0.40	0.47	0.49	0.45	(ns)	12.3	0.03
	EFB0	EFB1					
N%	2.10	2.27			*	9.1	0.07
P%	0.135	0.141			*	4.8	0.002
K%	0.77	0.82			*	8.1	0.02
Ca%	0.70	0.64			**	8.5	0.02
Mg%	0.20	0.18			ns	12.5	0.008
Cl%	0.46	0.45			ns	12.3	0.02

Applications of ammonium sulphate did not have any significant effects on leaf levels of all elements.

There is an increase in leaf N and P as shown in Table 2.36. Empty fruit bunches significantly improved leaflet N, P, K and reduced leaf Ca. The reduction in Ca could possibly be due to K/Ca antagonism effects.

Table 2.37 Main effects of N, K, and EFB on concentrations of elements in the rachis in 1996 (% dry matter).

	Level of nutrient Element or EFB				Statistics		
					sig	cv%	sed.
	N0	N1	N2	N3			
N%	0.26	0.24	0.26	0.26	ns	11.7	0.02
P%	0.182	0.153	0.144	0.125	*	15.9	0.01
K%	1.66	1.64	1.68	1.55	ns	7.0	0.06
Ca%	0.30	0.32	0.34	0.32	ns	9.0	0.01
Mg%	0.05	0.05	0.05	0.05	ns	15.9	0.004
Cl%	0.73	0.81	0.88	0.85	(ns)	12.6	0.05
	K0	K1	K2	K3			
N%	0.24	0.27	0.26	0.24	ns	11.7	0.02
P%	0.149	0.150	0.142	0.163	ns	15.9	0.01
K%	1.45	1.78	1.62	1.68	**	7.0	0.06
Ca%	0.29	0.34	0.33	0.34	*	9.0	0.01
Mg%	0.05	0.05	0.05	0.06	ns	15.9	0.004
Cl%	0.51	0.94	0.89	0.94	***	12.6	0.05
	EFB0	EFB1					
N%	0.24	0.26			(ns)	11.7	0.01
P%	0.148	0.154			ns	15.9	0.008
K%	1.55	1.72			**	7.0	0.01
Ca%	0.33	0.31			*	9.0	0.01
Mg%	0.05	0.05			ns	15.9	0.003
Cl%	0.79	0.85			ns	12.6	0.04

Ammonium sulphate significantly reduced rachis P. Muriate of potash increased rachis K, Ca and Cl, whilst EFB improved N and K. P and Cl levels were also increased but were not significant.

Trial 317 FERTILISER TRIAL ON LOWER TERRACE KOMO ESTATE MAMBA.

PURPOSE

To test the response to N, P, K, and Mg in factorial combination on Mamba soil, to get information that will help in making fertiliser recommendations.

DESCRIPTION

Site Komo Estate, block 27.

Soil Dark sandy loam, derived from airfall ash.

Palms Dami commercial DxP crosses. Planted 1985 at 130 palms/ha. Trial started in May 1990.

DESIGN

There are plots, each with a core of 10 palms. The numbers and the weights of bunches from each individual core palms are recorded at intervals of 14 days. Trenches (one meter deep) to separate them from adjoining plots surround the core palms.

The 36 plots are a single replicate containing 36 treatments, made up from all combinations of three levels of N and K and two levels of P and Mg (Table 2.38).

Table 2.38 Amounts of fertiliser used in Trial 317.

Type of fertiliser		Amount (kg/palm/year)		
	Element	Level 0	Level 1	Level 2
SoA	N	0.0	2.5	5.0
TSP	P	0.0	2.5	-
MoP	K	0.0	2.5	5.0
KIES	Mg	0.0	2.5	-

RESULTS

Yield data for 1996 were not complete. There were six harvests that were not recorded and also harvests that were accumulated, this has affected the data presented here. This results in yields that are apparently low in 1996.

Over the 1991-1996 period, cumulative data showed a significant increase in yield and single bunch weight due to the application of Kieserite.

There were no responses to ammonium sulphate, Triple-Superphosphate and muriate of potash.

Table 2.39 Main effects of N, P, K, and Mg on yield and yield components in 1996 (Trial 317).

	Level of nutrient element			Statistics		
	N0	N1	N2	sig	cv%	sed
Yield (t/ha)	10.8	12.4	10.5	ns	30.6	1.40
Bunches/ha	386	424	392	ns	25.3	41
Bunch weight (kg)	27.4	29.1	25.4	ns	15.8	1.76
	K0	K1	K2			
Yield (t/ha)	10.5	11.0	12.1	ns	30.6	1.40
Bunches/ha	406	378	418	ns	25.3	41
Bunch weight (kg)	25.4	27.9	28.7	ns	15.8	1.76
	P0	P1				
Yield (t/ha)	11.0	11.4		ns	230.6	1.14
Bunches/ha	399	402		ns	25.3	33
Bunch weight (kg)	26.4	28.2		ns	15.8	1.44
	Mg0	Mg1				
Yield (t/ha)	10.4	12.0		ns	30.6	1.14
Bunches/ha	282	419		ns	25.3	33
Bunch weight (kg)	26.3	28.4		ns	15.8	1.44

Table 2.40 Main effects of N, K, and EFB on yield and yield components for 1991 – 1996 (Trial 317).

	Level of nutrient element			Statistics		
	N0	N1	N2	sig	cv%	sed
Yield (t/ha/yr)	17.1	18.5	16.3	ns	16.1	1.14
Bunches/ha	722	764	705	ns	15.0	44
Bunch weight (kg)	23.6	24.4	23.0	ns	10.9	1.05
	K0	K1	K2			
Yield (t/ha/yr)	16.2	17.2	18.6	ns	16.1	1.14
Bunches/ha	721	699	771	ns	15.0	44
Bunch weight (kg)	22.3	24.5	24.2	ns	10.9	1.05
	P0	P1				
Yield (t/ha/yr)	17.0	17.6		ns	16.1	0.93
Bunches/ha	734	726		ns	15.0	36
Bunch weight (kg)	23.1	24.2		ns	10.9	0.86
	Mg0	Mg1				
Yield (t/ha/yr)	16.2	18.5		ns	16.1	0.93
Bunches/ha	712	748		ns	15.0	36
Bunch weight (kg)	22.6	24.7		ns	10.9	0.86

Table 2.41 Main effects of N, P, K, and Mg on concentrations of elements in the leaf tissues of frond 17 in 1996 (Trial 317)

	Nutrient element and level			Statistics		
				sig	cv%	sed
	N0	N1	N2			
N%	2.50	2.50	2.47	ns	7.9	0.08
P%	0.165	0.162	0.156	(ns)	4.6	0.003
K%	0.73	0.82	0.78	ns	11.6	0.04
Ca%	0.97	0.89	0.88	ns	16.1	0.06
Mg%	0.21	0.18	0.15	*	21.4	0.02
Cl%	0.49	0.51	0.49	ns	14.6	0.03
	P0	P1				
N%	2.50	2.48		ns	7.9	0.06
P%	0.159	0.163		ns	4.6	0.002
K%	0.78	0.77		ns	11.6	0.03
Ca%	0.86	0.96		(ns)	16.1	0.05
Mg%	0.18	0.19		ns	21.4	0.01
Cl%	0.51	0.48		ns	14.6	0.02
	K0	K1	K2			
N%	2.52	2.38	2.57	ns	7.9	0.08
P%	0.161	0.156	0.165	*	4.6	0.002
K%	0.70	0.76	0.86	**	11.6	0.04
Ca%	0.90	0.99	0.85	ns	16.1	0.06
Mg%	0.21	0.17	0.16	*	21.4	0.02
Cl%	0.37	0.54	0.58	***	14.6	0.03
	Mg0	Mg1				
N%	2.46	2.52		ns	7.9	0.06
P%	0.160	0.161		ns	4.6	0.002
K%	0.83	0.72		**	11.6	0.03
Ca%	0.92	0.91		ns	16.1	0.05
Mg%	0.12	0.24		***	21.4	0.01
Cl%	0.50	0.49		ns	14.6	0.02

Leaf nitrogen was not affected by application of ammonium sulphate, but levels have remained high with a mean level of 2.49 % of dry matter. SoA have also significantly depressed leaf P, Mg and rachis Ca and Mg. Triple-Superphosphate increased calcium levels in the leaf and P levels in the rachis, whilst levels of K in the rachis were significantly reduced.

Muriate of Potash improved plant K, Cl and leaf P, whilst having a depressing effect on plant Mg, rachis N and Ca significantly. Kieserite increased plant Mg and depressed plant K.

Table 2.42 Main effects of N, P, K, and Mg on concentrations of elements in the rachis of frond 17 in 1996 (Trial 317).

	Nutrient element and level			Statistics		
				sig	cv%	sed
	N0	N1	N2			
N%	0.28	0.29	0.28	ns	12.3	0.01
P%	0.073	0.067	0.061	ns	19.1	0.005
K%	0.80	0.73	0.80	ns	29.3	0.09
Ca%	0.45	0.41	0.32	*	22.5	0.04
Mg%	0.08	0.06	0.04	*	46.8	0.01
Cl%	0.53	0.40	0.46	ns	32.2	0.06
	P0	P1				
N%	0.29	0.27		ns	12.3	0.01
P%	0.058	0.076		**	19.1	0.004
K%	0.86	0.69		(ns)	29.3	0.08
Ca%	0.38	0.41		ns	22.5	0.03
Mg%	0.06	0.05		ns	46.8	0.009
Cl%	0.47	0.46		ns	32.2	0.05
	K0	K1	K2			
N%	0.31	0.25	0.29	*	12.3	0.01
P%	0.063	0.066	0.072	ns	19.1	0.005
K%	0.44	0.69	1.21	***	29.3	0.09
Ca%	0.42	0.45	0.31	*	22.5	0.04
Mg%	0.070	0.06	0.04	(ns)	46.8	0.01
Cl%	0.18	0.55	0.65	***	32.2	0.06
	Mg0	Mg1				
N%	0.29	0.27		(ns)	12.3	0.01
P%	0.066	0.068		ns	19.1	0.004
K%	0.88	0.68		*	29.3	0.08
Ca%	0.40	0.40		ns	22.5	0.03
Mg%	0.03	0.08		**	46.8	0.009
Cl%	0.47	0.46		ns	32.2	0.05

Trial 318 FERTILISER TRIAL ON RIVER TERRACE KOMO ESTATE MAMBA.

PURPOSE

To test the response to N, P, K, and Mg in factorial combination on Mamba soil.

DESCRIPTION

Site Komo Estate, block 39.

Soil Dark sandy loam.

Palms Dami commercial DxP crosses. Planted 1985 at 130 palms/ha. Trial started in May 1990.

DESIGN

There are 36 plots, each with a core of 9 palms. The numbers and the weights of bunches from each individual core palms are recorded at intervals of 14 days. Trenches (one meter deep) to separate them from adjoining plots surround the core palms.

The 36 plots are a single replicate containing 36 treatments, made up from all combinations of three levels of N and K and two levels of P and Mg (Table 2.43).

Table 2.43 Amounts of fertiliser used in Trial 318.

Type of fertiliser		Amount (kg/palm/year)		
	Element	Level 0	Level 1	Level 2
SoA	N	0.0	2.5	5.0
TSP	P	0.0	2.5	-
MoP	K	0.0	2.5	5.0
Kieserite	Mg	0.0	2.5	-

RESULTS

Yield data for 1996 was not complete. There were 9 harvests that were not recorded; this has resulted in the very low yields shown in Table 2.44. The cumulative data for 1991-1996 is shown in Table 2.45.

Treatments had no significant effect on yield, however application of Kieserite had increased yield by 2 tonnes over the period 1991-1996, which was close to being statistically significant (Table 2.45).

Table 2.44 Main effects of N, P, K, and Mg on yield and yield components in 1996 (Trial 318).

	Level of nutrient element			Statistics		
	N0	N1	N2	sig	cv%	sed
Yield (t/ha)	8.01	8.98	8.92	ns	44.6	1.57
Bunches/ha	332	340	361	ns	35.6	50
Bunch weight (kg)	23.2	26.0	24.3	ns	20.7	2.07
	K0	K1	K2			
Yield (t/ha)	7.19	9.75	8.99	ns	44.6	1.57
Bunches/ha	295	381	356	ns	35.6	50
Bunch weight (kg)	23.6	25.4	24.5	ns	20.7	2.07
	P0	P1				
Yield (t/ha)	8.90	8.38		ns	44.6	1.28
Bunches/ha	345	343		ns	35.6	40
Bunch weight (kg)	25.3	23.7		ns	20.7	1.69
	Mg0	Mg1				
Yield (t/ha)	8.53	8.75		ns	44.6	1.28
Bunches/ha	331	358		ns	35.6	40
Bunch weight (kg)	24.9	24.1		ns	20.7	1.69

Table 2.45 Main effects of N, P, K, and Mg on yield and yield components for 1991 - 1996 (Trial 318).

	Level of nutrient element			Statistics		
	N0	N1	N2	sig	cv%	sed
Yield (t/ha/yr)	14.1	15.4	14.9	ns	32.9	1.99
Bunches/ha	6809	676	691	ns	22.4	62
Bunch weight (kg)	20.2	22.4	21.3	ns	18.3	1.59
	K0	K1	K2			
Yield (t/ha/yr)	12.6	15.9	15.8	ns	32.9	1.99
Bunches/ha	618	712	717	ns	22.4	62
Bunch weight (kg)	20.7	22.2	21.6	ns	18.3	1.59
	P0	P1				
Yield (t/ha/yr)	15.1	14.4		ns	32.9	1.62
Bunches/ha	689	675		ns	22.4	50
Bunch weight (kg)	21.7	20.8		ns	18.3	1.30
	Mg0	Mg1				
Yield (t/ha/yr)	13.6	15.9		**ns**	32.9	1.62
Bunches/ha	635	730		**(ns)**	22.4	50
Bunch weight (kg)	21.0	21.6		ns	20.7	1.69

The men leaf N in 1996 was 2.48% of dry matter. Applications of ammonium sulphate did not have any effects on other elements, except by increasing rachis N. Triple-Superphosphate increased plant P and rachis ca. Muriate of potash increased levels of plant K, but depressed all other bases. Kieserite on the other hand increased magnesium levels and reduced leaflet P and K.

Table 2.46 Main effects of N, P, K, and Mg on concentrations of elements in the leaf tissues of frond 17 in 1996 (Trial 318)

	Nutrient element and level			Statistics		
				sig	cv%	sed
	N0	N1	N2			
N%	2.44	2.44	2.55	ns	10.6	0.11
P%	0.162	0.160	0.158	ns	5.1	0.003
K%	0.93	0.86	1.04	ns	22.6	0.09
Ca%	0.85	0.80	0.72	(ns)	15.9	0.05
Mg%	0.20	0.21	0.16	ns	36.2	0.03
Cl%	0.50	0.54	0.56	ns	24.6	0.05
	P0	P1				
N%	2.46	2.50		ns	10.6	0.09
P%	0.157	0.163		*	5.1	0.003
K%	1.00	0.88		ns	22.6	0.07
Ca%	0.78	0.81		ns	15.9	0.04
Mg%	0.18	0.20		ns	36.2	0.02
Cl%	0.54	0.54		ns	24.6	0.04
	K0	K1	K2			
N%	2.47	2.48	2,48	ns	10.6	0.11
P%	0.164	0.157	0.159	ns	5.1	0.003
K%	0.74	0.94	1.14	**	22.6	0.09
Ca%	0.86	0.79	0.73	(ns)	15.9	0.05
Mg%	0.24	0.17	0.17	*	36.2	0.03
Cl%	0.47	0.57	0.57	ns	24.6	0.05
	Mg0	Mg1				
N%	2.48	2.47		ns	10.6	0.09
P%	0.161	0.159		*	5.1	0.003
K%	1.08	0.80		***	22.6	0.07
Ca%	0.81	0.77		ns	15.9	0.04
Mg%	0.11	0.27		***	27.3	0.02
Cl%	0.54	0.53		ns	24.6	0.04

Table 2.47 Main effects of N, P, K, and Mg on concentrations of elements in the rachis of frond 17 in 1996 (Trial 318).

	Nutrient element and level			Statistics		
				sig	cv%	sed
	N0	N1	N2			
N%	0.26	0.28	0.30	*	10.3	0.01
P%	0.088	0.76	0.83	ns	37.3	0.01
K%	0.95	1.12	1.22	ns	31.7	0.14
Ca%	0.31	0.31	0.29	ns	23.8	0.03
Mg%	0.06	0.10	0.06	ns	118.7	0.04
Cl%	0.60	0.65	0.68	ns	50.6	0.13
	P0	P1				
N%	0.28	0.27		ns	10.3	0.009
P%	0.069	0.96		*	37.3	0.01
K%	1.18	1.02		ns	31.7	0.11
Ca%	0.27	0.34		*	23.8	0.03
Mg%	0.08	0.07		ns	118.7	0.04
Cl%	0.65	0.64		ns	50.6	0.11
	K0	K1	K2			
N%	0.27	0.29	0.27	ns	10.3	0.01
P%	0.068	0.090	0.089	ns	37.3	0.01
K%	0.57	1.26	1.46	***	31.7	0.14
Ca%	0.36	0.29	0.27	*	23.8	0.03
Mg%	0.09	0.09	0.04	ns	118.7	0.04
Cl%	0.46	0.68	0.80	(ns)	50.6	0.13
	Mg0	Mg1				
N%	0.29	0.270		(ns)	28.9	0.009
P%	0.086	0.079		ns	37.3	0.01
K%	1.14	1.06		ns	31.7	0.11
Ca%	0.33	0.28		ns	23.8	0.02
Mg%	0.06	0.09		ns	118.7	0.04
Cl%	0.63	0.66		ns	50.6	0.13

Trial 502b **FERTILISER TRIAL AT WAIGANI ESTATE**

PURPOSE

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

DESCRIPTION

Site Waigani Estate, Field 6503 and 6504.

Soil Plantation family, which of recent alluvial origin.

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

DESIGN

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

The 64 treatments are made up from all combinations of four levels of N and K, and two levels of TSP and EFB (Table 2.48). EFB is applied by hand as mulch between palm circles.

Table 2.48 Amount of fertiliser and EFB used in 1996.

Type of fertiliser or EFB	Amount (kg/palm/year)			
	Level 0	Level 1	Level 2	Level 3
SoA	0.0	2.0	4.0	6.0
MoP	0.0	2.5	5.0	7.5
TSP	0.0	2.0	-	-
EFB	0.0	500	-	-

Trenching was completed in 1995, and the first dose of fertilizer was applied in the fourth quater of 1994.

RESULTS

The average plot yield in 1996 was 22.6 t/ha/year. The trial has not shown any significant responses in yield from applications of ammonium sulphate or muriate of potash, although a linear trend is developing. Ammonium sulphate increased single bunch weight, which was accompanied by the decrease in bunch numbers.

Applications of EFB started in August 1995. Applying the mulch has led to a small but almost significant reduction in yield. The reductions in yield are not known for certain at this early stage of the Trial.

Table 2.50 shows the two-way table of N and K. A maximum yield of 25.3 t/ha/yr was achieved with 6 kg of ammonium sulphate and 4 kg of muriate of potash.

Table 2.49 Main effects of N, P, K, and Mg on yield and yield components in 1996 (Trial 502b).

	Nutrient element and level				Statistics sig	cv	sed
	N0	N1	N2	N3			
Yield (t/ha/yr)	22.0	22.5	22	23.6	ns	8.7	0.70
Bunch/ha	1005	971	947	997	ns	8.8	30
Bunch wt (kg)	21.6	23.2	23.4	23.7	***	4.9	0.40
	K0	K1	K2	K3			
Yield (t/ha/yr)	22.2	22.0	22.9	23.0	ns	8.7	0.70
Bunch/ha	962	968	989	1001	ns	8.8	30
Bunch wt (kg)	23.1	22.8	23.2	23.0	ns	4.9	0.40
	P0	P1					
Yield (t/ha/yr)	22.8	22.3			ns	8.7	0.49
Bunch/ha	993	967			ns	8.8	21
Bunch wt (kg)	23.0	23.0			ns	6.6	0.28
	EFB0	EFB1					
Yield (t/ha/yr)	23.0	22.0			ns	8.7	0.49
Bunch/ha	988	972			ns	8.8	21
Bunch wt (kg)	23.3	22.8			ns	4.9	0.28

Table 2.50 Effects of combinations of N and K fertilisers in 1996 (Trial 502b).

		Level of N		
Level of K	N0	N1	N2	N3
K0	22.6	20.9	21.4	23.8
K1	21.8	23.9	20.8	21.6
K2	22.3	21.9	22.2	25.3
K3	21.5	23.3	24.0	23.5
Mean	22.5	Standard error		1.39

Table 2.51 Main effects of N, P, K and EFB on yield and yield components in 1995-1996 (Trial 502b).

	Level of nutrient Element or EFB				Statistics sig	cv%	sed.
	N0	N1	N2	N3			
Yield (t/ha/yr)	20.6	20.7	20.4	20.9	ns	6.3	0.46
Bunches/ha	987	953	941	961	ns	7.2	24
Bunch weight (kg)	20.9	21.8	21.8	21.8	*	4.5	0.34
	K0	K1	K2	K3			
Yield (t/ha/yr)	20.7	20.6	20.8	20.6	ns	6.3	0.46
Bunches/ha	962	967	962	952	ns	7.2	24
Bunch weight (kg)	21.6	21.4	21.7	21.6	ns	4.5	0.34
	P0	P1					
Yield (t/ha/yr)	20.9	20.5			ns	6.3	0.33
Bunches/ha	968	954			ns	7.2	17
Bunch weight (kg)	21.6	21.5			ns	4.5	0.24
	EFB0	EFB1					
Yield (t/ha/yr)	20.8	20.6			ns	6.3	0.33
Bunches/ha	965	957			ns	7.2	17
Bunch weight (kg)	21.6	21.5			ns	4.5	0.34

Leaflet tissue analysis shown in Table 2.52. Leaf N, P, K and rachis N were increased due to applications of ammonium sulphate, but there was a reduction in rachis P (Table 2.53). Muriate of potash depressed leaflet P and rachis Mg, but significantly increased leaf Cl, rachis K, P and Cl.

Triple-Superphosphate increased levels of P both in the leaf and rachis. EFB applications also improved levels of K and P on both the leaf and rachis.

Table 2.52 Main effects of N, P, K, and EFB on the concentrations of nutrients in leaf tissues of frond 17 in 1996 (% dry matter).

	Nutrient Element and Level				Statistics		
					sig	cv%	sed.
	N0	N1	N2	N3			
N%	2.43	2.48	2.49	2.57	**	4.2	0.04
P%	0.151	0.152	0.149	0.154	**	2.2	0.001
N/P	16.1	16.3	16.7	16.7			
K%	0.66	0.67	0.69	0.69	(ns)	5.5	0.01
Ca%	0.78	0.77	0.73	0.74	ns	7.4	0.02
Mg%	0.31	0.31	0.30	0.30	ns	5.8	0.009
Cl%	0.45	0.46	0.44	0.45	ns	5.9	0.009
	K0	K1	K2	K3			
N%	2.55	2.46	2.49	2.46	ns	4.2	0.04
P%	0.154	0.151	0.150	0.150	**	2.2	0.001
K%	0.68	0.68	0.67	0.69	ns	5.5	0.01
Ca%	0.73	0.77	0.76	0.76	ns	7.4	0.02
Mg%	0.30	0.31	0.31	0.30	ns	5.8	0.009
Cl%	0.41	0.46	0.46	0.47	***	5.9	0.009
	P0	P1					
N%	2.49	2.50			ns	4.2	0.03
P%	0.150	0.152			*	2.2	0.001
N/P	16.6	16.5					
K%	0.68	0.68			ns	5.5	0.009
Ca%	0.76	0.75			ns	7.4	0.014
Mg%	0.31	0.30			ns	5.8	0.006
Cl%	0.45	0.45			ns	5.9	0.007
	EFB0	EFB1					
N%	2.47	2.51			ns	4.2	0.03
P%	0.151	0.152			(ns)	2.2	0.001
N/P	16.4	16.5					
K%	0.67	0.69			*	5.5	0.009
Ca%	0.75	0.76			ns	7.4	0.014
Mg%	0.30	0.31			ns	5.8	0.006
Cl%	0.45	0.45			ns	5.9	0.007

Table 2.53 Main effects of N, P, K, and EFB on the concentration of elements in the rachis of frond 17 in 1996 (% dry matter).

	Nutrient Element and Level				Statistics		
					sig.	cv%	sed.
	N0	N1	N2	N3			
N%	0.27	0.28	0.29	0.30	***	7.2	0.007
P%	0.119	0.108	0.097	0.089	***	13.4	0.005
K%	1.18	1.18	1.14	1.12	ns	13.2	0.05
Ca%	0.33	0.33	0.33	0.34	ns	7.3	0.009
Mg%	0.13	0.13	0.13	0.12	ns	3.6	0.004
Cl%	0.64	0.63	0.61	0.62	ns	10.4	0.02
	K0	K1	K2	K3			
N%	0.29	0.29	0.27	0.29	(ns)	7.2	0.007
P%	0.094	0.101	0.103	0.115	***	13.4	0.005
K%	0.89	1.06	1.26	1.41	***	13.2	0.05
Ca%	0.33	0.35	0.32	0.34	*	7.3	0.009
Mg%	0.13	0.14	0.12	0.12	*	3.6	0.004
Cl%	0.46	0.61	0.68	0.75	***	10.4	0.02
	P0	P1					
N%	0.28	0.29			ns	7.2	0.007
P%	0.096	0.111			***	13.4	0.003
K%	1.14	1.16			ns	13.2	0.05
Ca%	0.34	0.33			ns	7.3	0.006
Mg%	0.13	0.13			ns	3.6	0.003
Cl%	0.63	0.62			ns	10.4	0.016
	EFB0	EFB1					
N%	0.28	0.29			ns	7.2	0.005
P%	0.094	0.113			***	13.4	0.003
K%	1.03	1.27			***	13.2	0.04
Ca%	0.34	0.33			ns	7.3	0.006
Mg%	0.13	0.13			ns	3.6	0.003
Cl%	0.61	0.64			*	10.4	0.016

Trial 504 MATURE PHASE FERTILISER TRIAL AT SAGARAI ESTATE

PURPOSE

To test the response of oil palm to fertiliser applications of N and K on the main soil type at Sagarai.

DESCRIPTION

Site — Sagarai Estate, Field 0610, 0611 and 0612.

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

Palm — Identified 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 1994.

DESIGN

There are 64 plots, each with a core of 16 palms. The numbers and weights of bunches from each individual core palm are recorded at intervals of 14 days. In each plot 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 all combinations of four levels each of N and K, and two levels of an additional treatment, which is currently vacant (Table 2.54) and therefore functions as an additional replicate.

Table 2.54 Types of fertiliser and amounts used in Trial 504.

Type of fertiliser	Amount (kg/palm/year)			
	Level 0	Level 1	Level 2	Level 3
SoA	0.0	2.0	4.0	6.0
MoP	0.0	2.5	5.0	7.5
Vacant	vacant	vacant		

RESULT

In 1996 and in 1995-1996 there were no significant responses to application of ammonium sulphate or muriate of potash. Yields were high even in the control plots and the mean yield was 28.3 t/ha. A maximum yield of 29.9 FFB t/ha was achieved with 4 kg/palm of SoA and 2.5 kg /palm of MoP. The trend is the same for the period 1995-1996.

Table 2.55 Main effects of N and K on yield and yield components in 1996 (Trial 504).

	Nutrient element and level				Statistics sig	cv	sed
	N0	N1	N2	N3			
Yield (t/ha/yr)	27.7	28.7	28.9	27.8	ns	7.9	0.79
Bunches/ha	2400	2389	2462	2313	ns	7.0	59
Bunch wt (kg)	11.6	12.0	11.8	12.0	ns	5.7	0.24
	K0	K1	K2	K3			
Yield (t/ha/yr)	28.3	28.8	28.8	27.2	ns	7.9	0.79
Bunches/ha	2404	2400	2441	2320	ns	7.0	59
Bunch wt (kg)	11.8	12.0	11.8	11.7	ns	5.7	0.24

Table 2.56 Effect of N and K in combinations, on yield in 1996 (Trial 504).

		Level of N			
Level of K	N0	N1	N2	N3	
K0	27.5	28.1	29.2	28.3	
K1	27.4	29.4	29.9	28.7	
K2	28.7	29.4	28.8	28.5	
K3	27.2	28.0	27.8	25.6	
Mean 28.3	Standard error	1.58			

Table 2.57 Main effects of N and K on yield and yield components in 1995-1996 (Trial 504).

	Level of nutrient Element				Statistics sig.	cv%	sed.
	N0	N1	N2	N3			
Yield (t/ha/yr)	24.9	25.2	25.1	25.0	ns	8.9	0.79
Bunches/ha	2289	2255	2274	2227	ns	7.8	62
Bunch weight (kg)	10.9	11.2	11.1	11.3	ns	6.6	0.26
	K0	K1	K2	K3			
Yield (t/ha/yr)	24.8	25.7	25.3	24.3	ns	8.9	0.79
Bunches/ha	2244	2292	2288	2221	ns	7.8	62
Bunch weight (kg)	11.1	11.3	11.1	11.0	ns	6.6	0.26

Table 2.58 Effects of N and K in combinations on yield in 1995-1996 (Trial 504).

		Level of N			
Level of K	N0	N1	N2	N3	
K0	23.8	23.9	24.9	26.7	
K1	26.2	25.2	25.8	25.7	
K2	25.1	24.9	26.2	25.0	
K3	24.3	26.6	23.5	22.8	
Mean 25.0	Standard error	1.58			

Table 2.59 Main effects of N and K on the concentration of elements in leaf tissue of frond 17 (% dry matter) in 1996 (Trial 504).

	Nutrient element and level				Statistics sig.	cv%	sed.
	N0	N1	N2	N3			
N%	2.54	2.55	2.57	2.60	ns	3.4	0.03
P%	0.155	0.154	0.156	0.154	(ns)	2.3	0.001
K%	0.72	0.73	0.71	0.75	ns	6.2	0.02
Ca%	0.95	0.94	0.95	0.95	ns	4.3	0.01
Mg%	0.34	0.32	0.33	0.33	ns	7.1	0.008
Cl%	0.59	0.60	0.58	0.61	ns	7.0	0.02
	K0	K1	K2	K3			
N%	2.57	2.58	2.58	2.53	ns	3.4	0.03
P%	0.155	0.155	0.155	0.154	ns	2.3	0.001
K%	0.76	0.72	0.71	0.72	*	6.2	0.02
Ca%	0.90	0.95	0.99	0.96	***	4.3	0.01
Mg%	0.32	0.33	0.34	0.33	ns	7.1	0.008
Cl%	0.54	0.60	0.62	0.63	***	7.0	0.02

Table 2.60 Main effects of N and K on the concentrations of elements in the rachis of frond 17 in 1996 (% dry matter).

	Nutrient element and level				Statistics sig.	cv%	sed.
	N0	N1	N2	N3			
N%	0.31	0.31	0.32	0.32	ns	7.4	0.008
P%	0.143	0.135	0.122	0.131	***	10.5	0.005
K%	1.34	1.37	1.30	1.39	ns	12.4	0.06
Ca%	0.47	0.46	0.47	0.48	ns	7.3	0.01
Mg%	0.18	0.16	0.17	0.17	ns	10.9	0.006
Cl%	0.83	0.80	0.83	0.87	ns	19.0	0.06
	K0	K1	K2	K3			
N%	0.31	0.32	0.32	0.32	ns	7.4	0.08
P%	0.121	0.134	0.137	0.139	**	10.5	0.005
K%	1.14	1.34	1.45	1.48	***	12.4	0.06
Ca%	0.44	0.48	0.49	0.47	**	7.3	0.01
Mg%	0.16	0.18	0.17	0.16	**	10.9	0.006
Cl%	0.54	0.84	0.97	0.98	***	19.0	0.06

Muriate of potash reduced leaf K and increased leaf Ca and Cl significantly. Application of SoA had no significant effect on the elements in the leaflet tissue. SoA reduced rachis P, whilst MoP increased rachis P, K, Ca, and Cl.

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

PURPOSE

To investigate the response of oil palm to applications of ammonium sulphate, Triple Super-phosphate, muriate of potash and empty fruit bunch on interfluve terrace soils at Milne Bay Estates.

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. Ironstone gravel maybe cemented into massive blocks of laterite. Soil dominantly poorly drained. Although these soils are dominantly poorly drained, somewhat imperfectly drained variants with olive grey subsoil have been included into this family. Mostly on gently sloping terraces, but also found on spur crest of hilly terrain.

Palms — Dami commercial DxP crosses. Planted in 1988 at 127 palms/ha. Trial started 1994.

DESIGN

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

The 64 plots is a single replicate split into four blocks, comprising factorial applications of 4x4x2x2 of N, K, P and EFB treatments. The treatments are made up from all combinations of four levels each of N and K and two levels each of P and EFB (Table 2.61). EFB is applied by hand as mulch between palm circles.

Table 2.61 Amounts of fertiliser and EFB used in Trial 511.

Type of fertiliser or EFB	Amounts of fertiliser (kg/palm/ha) Level 0	Level 1	Level 2	level3
SoA	0.0	2.0	4.0	6.0
MoP	0.0	2.5	5.0	7.0
TSP	0.0	2.0		
	Kg/palm/year			
EFB	0.0	300		

RESULTS

Yield data for 1996 and 1995-1996 are shown in Table 2.62 and 2.63. There was a significant response to ammonium sulphate on yield, number of bunches and single bunch weight in both periods. Triple-Superphosphate significantly increased single bunch weight only in 1996. There were no responses to muriate of potash or empty fruit bunches.

Table 2.62 Main effect of N, P, K, and EFB on yield and yield components in 1996 (Trial 511).

	Level of nutrient Element				Statistics		
					sig.	cv%	sed.
	N0	N1	N2	N3			
Yield (t/ha/yr)	17.7	20.3	22.6	22.8	***	11.8	0.87
Bunches/ha	1243	1313	1352	1393	(ns)	12.2	57
Bunch weight (kg)	14.3	15.5	16.9	16.4	***	10.0	0.56
	K0	K1	K2	K3			
Yield (t/ha/yr)	21.0	20.9	20.7	20.8	ns	11.8	0.87
Bunches/ha	1294	1371	1330	1306	ns	12.2	57
Bunch weight (kg)	16.2	15.3	15.6	16.0	ns	10.0	0.56
	P0	P1					
Yield (t/ha/yr)	20.5	21.2			ns	11.8	0.61
Bunches/ha	1331	1319			ns	12.2	40
Bunch weight (kg)	15.4	16.2			(ns)	10.0	0.39
	EFB0	EFB1					
Yield (t/ha/yr)	20.7	21.0			ns	11.8	0.61
Bunches/ha	1289	1361			ns	12.2	40
Bunch weight (kg)	16.0	15.5			ns	10.0	0.3

Table 2.63 Main effects on N, P, K, and EFB on yield and yield components in 1995-1996 (Trial 511)

	Level of nutrient and Element				Statistics sig.	cv%	sed.
	N0	N1	N2	N3			
Yield (t/ha/yr)	21.2	22.2	23.2	24.2	**	9.4	0.75
Bunches/ha	1493	1478	1491	1602	(ns)	9.4	50
Bunch weight (kg)	14.2	15.0	15.7	15.1	*	9.0	0.48
	K0	K1	K2	K3			
Yield (t/ha/yr)	22.2	22.3	23.2	23.0	ns	9.4	0.75
Bunches/ha	1449	1524	1577	1514	ns	9.4	50
Bunch weight (kg)	15.4	14.7	14.7	15.3	ns	9.0	0.48
	P0	P1					
Yield (t/ha/yr)	22.3	23.0			ns	9.4	0.53
Bunches/ha	1507	1524			ns	9.4	35
Bunch weight (kg)	14.8	15.2			ns	9.0	0.34
	EFB0	EFB1					
Yield (t/ha/yr)	22.6	22.8			ns	9.4	0.53
Bunches/ha	1498	1533			ns	9.4	35
Bunch weight (kg)	15.2	14.9			ns	9.0	0.34

Table 2.64 Main effects of N, P, K, and EFB on the concentrations of elements in leaflet tissue of frond 17 in 1996 (Trial 511).

	Level of nutrient Element or EFB				Statistics sig.	cv%	sed.
	N0	N1	N2	N3			
N%	2.17	2.22	2.29	2.33	***	3.9	0.03
P%	0.132	0.135	0.138	0.135	**	3.6	0.002
N/P	16.4	16.4	16.6	17.3			
K%	0.68	0.73	0.77	0.78	**	9.1	0.02
Ca%	0.82	0.78	0.76	0.74	*	9.1	0.02
Mg%	0.33	0.31	0.30	0.29	**	9.9	0.01
Cl%	0.53	0.52	0.53	0.52	ns	6.8	0.01
	K0	K1	K2	K3			
N%	2.22	2.27	2.26	2.26	ns	3.9	0.03
P%	0.134	0.134	0.135	0.137	ns	3.6	0.002
K%	0.73	0.75	0.74	0.73	ns	9.1	0.02
Ca%	0.74	0.78	0.78	0.80	ns	9.1	0.02
Mg%	0.30	0.31	0.31	0.30	ns	9.9	0.01
Cl%	0.48	0.53	0.54	0.55	***	6.8	0.01
	P0	P1					
N%	2.24	2.27			ns	3.9	0.03
P%	0.134	0.137			*	3.6	0.002
N/P	16.7	16.6					
K%	0.75	0.73			ns	9.1	0.02
Ca%	0.78	0.78			ns	9.1	0.02
Mg%	0.31	0.30			ns	9.9	0.01
Cl%	0.52	0.53			ns	6.8	0.01
	EFB0	EFB1					
N%	2.23	2.28			*	3.9	0.03
P%	0.134	0.136			ns	3.6	0.002
N/P	16.6	16.8					
K%	0.74	0.74			ns	9.1	0.02
Ca%	0.78	0.77			ns	9.1	0.02
Mg%	0.31	0.30			ns	9.9	0.01
Cl%	0.52	0.52			ns	6.8	0.01

Ammonium sulphate increased leaf N, P, and K, but reduced leaf Ca and Mg. Muriate of potash only increased leaf Cl. Triple-Superphosphate increased leaf P whilst empty fruit bunch increased leaflet N.

Table 2.65 Main effects of N, P, K, and EFB on the concentration of elements in the rachis of frond 17 in 1996 (Trial 511).

	Level of nutrient Element or EFB				Statistics sig.	cv%	sed.
	N0	N1	N2	N3			
N%	0.24	0.24	0.26	0.26	*	7.0	0.006
P%	0.092	0.081	0.077	0.070	*	21.7	0.006
K%	1.58	1.62	1.55	1.50	*	7.4	0.04
Ca%	0.33	0.33	0.33	0.32	ns	9.3	0.01
Mg%	0.12	0.11	0.10	0.10	***	8.9	0.003
Cl%	1.01	0.95	0.87	0.86	**	13.2	0.04
	K0	K1	K2	K3			
N%	0.25	0.24	0.26	0.25	*	7.0	0.006
P%	0.075	0.079	0.084	0.083	ns	21.7	0.006
K%	1.45	1.56	1.62	1.62	***	7.4	0.04
Ca%	0.31	0.33	0.32	0.34	ns	9.3	0.01
Mg%	0.10	0.10	0.11	0.11	ns	8.9	0.003
Cl%	0.79	0.96	0.97	0.98	***	13.2	0.04
	P0	P1					
N%	0.25	0.25			ns	7.0	0.006
P%	0.064	0.096			***	21.7	0.004
K%	1.57	1.55			ns	7.4	0.029
Ca%	0.32	0.33			ns	9.3	0.01
Mg%	0.10	0.11			ns	8.9	0.002
Cl%	0.93	0.91			ns	13.2	0.03
	EFB0	EFB1					
N%	0.25	0.26			*	7.0	0.006
P%	0.067	0.094			***	21.7	0.004
K%	1.50	1.62			***	7.4	0.029
Ca%	0.32	0.33			ns	9.3	0.01
Mg%	0.10	0.11			ns	8.9	0.002
Cl%	0.91	0.93			ns	13.2	0.03

In the rachis tissue, levels of N increased whilst all other elements were reduced when SoA was applied. MoP increased rachis N, K and Cl. P was also increased with application of TSP whilst EFB improved N, P, and K levels.

3. Entomology

Introduction

As a result of the quality of research that is now being undertaken by PNGOPRA and our collaborative partners the entomology research report for 1996 is presented as a series of formal scientific papers. These have been or are soon to be published in international scientific journals. Accounts of pest outbreaks and other significant events of 1996 are also given.

The Sexava situation was relatively quiet during 1996, with approximately 910 hectares requiring chemical treatment. We continued to rear two species of Sexava egg parasitoids at our Dami and Hargy research centres. A total of almost two million of these were released into various oil palm growing areas during the year. The relatively low levels of Sexava damage for 1996 was probably due to (1) the timely release of egg parasitoids, (2) the low annual rainfall, and (3) an improved monitoring system for the pest. A series of entomology training courses has resulted in an improved awareness of insect pests, and Sexava outbreaks are now being reported well before they research economic thresholds.

We have also had isolated outbreaks of Bagworms and Rhinoceros beetles during 1996, and details of these are given in this report. Of particular significance is the development of an integrated pest management system for Rhinoceros beetle pheromone and baculovirus, as well as the development of good cover crop, and the elimination of breeding sites.

Our research effort has been significantly enhanced by the donation of 822,000 kina by the European Union to fund investigations into Sexava biocontrol and integrated pest management. As part of this project we are undertaking collaborative research with scientists from Oxford University and the International Institute of Biological Control. The main objectives being to investigate the potential of the parasite Stichotrema dallatorreanum and fungal pathogens as Sexava biocontrol tools, and how they can be incorporated into our existing IPM system for Sexava. This EU-funded project is expected to continue until the end of 1998, by which time we will have made considerable progress towards the further improvement of our Sexava IPM system.

Another important achievement for 1996 was Takis Solulu's completion of his Masters Degree at Oxford University.

Pest reports and results of fruitset studies for 1996

Sexava

The oil palm growing areas in West New Britain that required chemical treatment in 1996 for economically significant levels of Sexava damage are shown in Table 3.1.

Table 3.1 The oil palm growing areas in West New Britain that required chemical treatment in 1996 for economically significant levels of Sexava damage

Date	Plantation / Smallholders	Site	Approx area treated (ha)	Volume of formulation (litres)
4 Jan	Hoskins smallholders	Kavui	8	20
25 Jan	Hoskins smallholders	Galai division 11	44	110
6 Feb	NBPOL Mosa	Dami plantation	100	250
1 Mar	NBPOL Kapiura	Malilimi plantation	72	180
20 Mar	NBPOL Mosa	Navarai plantation	110	275
29 Mar	NBPOL Mosa	Dami plantation	30	75
16 May	Hoskins smallholders	Buvussi section 1	56	140
21 May	Hoskins smallholders	Kavui	8	20
10 July	NBPOL Kapiura	Bilomi plantation	22	55
3 Aug	Hoskins smallholders	Buvussi section 3	20	50
3 Aug	Hoskins smallholders	Galai div 1 and 11	20	50
12 Aug	NBPOL Mosa	Bebere division 11	25	63
12 Nov	Bialla smallholders	Balima	4	10
6 Dec	Salilubu smallholders	Silanga	20	50
6 Dec	Salilubu smallholders	Uasilau	15	38
13 Dec	Bialla smallholders	Balima	56	140
20 Dec	Bialla smallholders	Balima	40	100
27 Dec	Bialla smallholders	Wilelo	260	650
		Approximate total	910 ha	2276 litres
Percentage of WNBP oil palm growing areas treated				2.75
Insecticide costs - monocrotophos (Nuvacron / Azodrin K18.6 per litre)				K42,330

Field releases of egg parasitoids for Sexava control in 1996

The oil palm growing areas in West New Britain in which Sexava egg parasitoids were release during 1996 are shown in Table 3.2.

Table 3.2 The oil palm growing areas in West New Britain in which Sexava egg parasitoids were release during 1996

	Number of adult egg parasitoids released	
Location	*Leefmansia bicolor*	*Doirania leefmansia*
1. NBPOL Plantations		
Dami Research Station	153,690	768,500
Kumbango plantation	26,310	276,250
Navarai plantation	24,900	73,500
Malilimi plantation	17,130	158,750
2. VOP Blocks Hoskins		
Banaule VOP	63,690	165,000
3. District (Coconut blocks)		
Cape Gloucester	26,610	164,500
Kandrain	25,680	24,750
Total	338,010	1,631,250
Grand total	1,969,260	

Bagworms

Economically significant levels of Bagworm (*Mahasena corbetti)* damage occurred at Kautu and Kaurausu plantations (NBPOL, Kapiura) during the early part of 1996. Approximately 150 ha at Kautu and 60 ha at Kaurausu received chemical treatment (trunk injection with monocrotophos).

Low-level populations of Bagworms were reported in other areas of Kautu and Kaurausu later in the year, but these did not reach economic thresholds during 1996.

Low-level populations of Bagworms were also reported at Embi plantation (Higaturu Oil Palms). Damage levels however remained extremely low during 1996.

No other outbreaks of Bagworms were reported during 1996.

Rhinoceros Beetle

Oryctes rhinoceros continued to cause economically significant damage at Numondo plantation (NBPOL, Garu) during 1996. Management of this pest is described in a separate research paper contained within this report.

Scapanes australis caused light damage to new plantings at Hargy Oil Palms. Most of the damage was however very light, and controlled by hand collecting of the adult beetles. One block (approx 12 ha) required chemical treatment (Furadan granules applied to leaf axils).

Other Pests

Cockchafer beetles (*Dermolepida* sp) were reported to be causing light damage at Embi plantation (Higaturu oil palms). The damage levels remained extremely light during 1996, and were of no economic significance.

Leafhoppers (*Zophiuma lobulata*) were reported on coconut and betel nut palms at Mosa and Dami station (New Britain Palm Oil) in August 1996. These palms were recommended for immediate chemical treatment (trunk - injected monocrotophos).

Leaf-eating caterpillars (*Acria* sp) were reported to be causing damage to young seedlings at Kapiura nursery (New Britain Palm Oil Ltd) in May 1996. High populations of early instar caterpillars were causing moderate to severe levels of defoliation throughout the nursery. Immediate chemical treatment was therefore recommended (Monocrotophos, 150ml/100 litres applied using knapsack sprayers).

Fruitset study

Brief summary of methodology

For a number of years now OPRA has conducted a fruitset study at Kapiura plantations, NBPOL. For this study observations are made in experimental plots located in Kautu division one, Kautu division 2, Bilomi and Kaurausu. In each location two plots are monitored, one plot contains a group of 20 palms and the other plot consists of 120, 115,115 and 116 palms respectively at Kautu 1, Kautu 2, Bilomi and Kaurausu. The following observations are made at each plot:

1. The number of receptive female and male inflorescences at anthesis
2. Number of *Elaeidobius* emerging from 5 sets of 20 male spikelets
3. Percentage fruitset and physical analysis on pre-ripened bunches

The 1996 results for this study are shown in figures 3.1 and 3.2.

Figure 3.1 The percentage fruitset each month at the 4 experimental plots during 1996

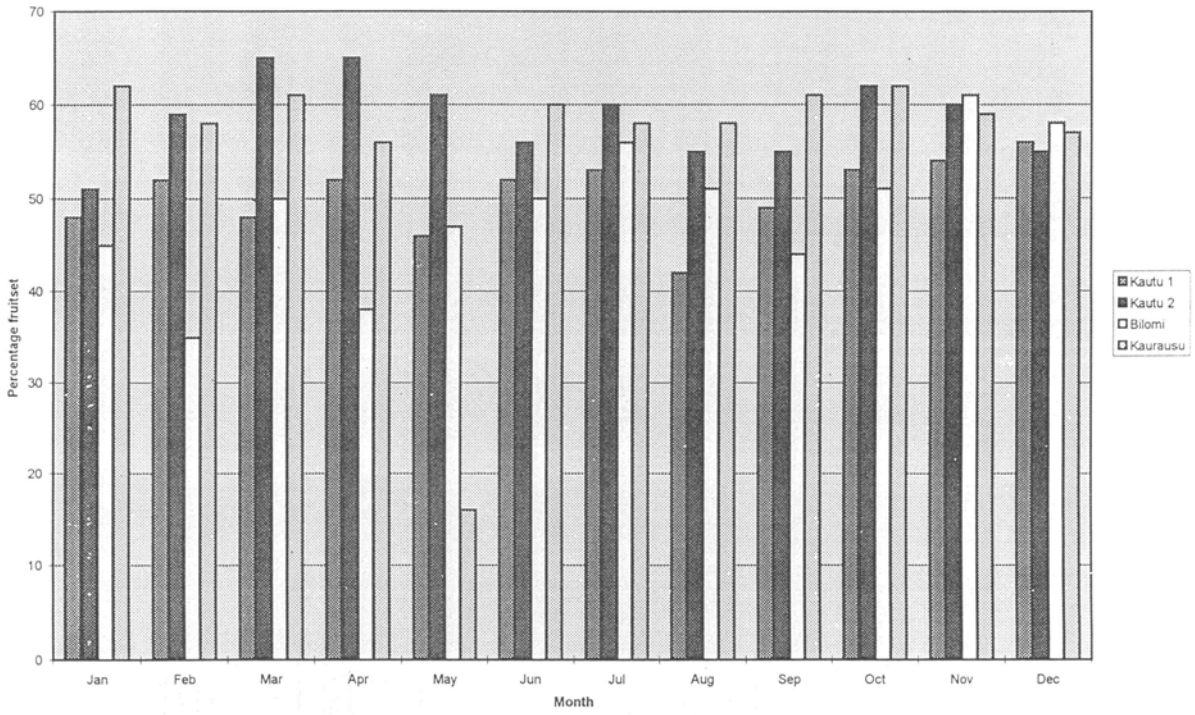
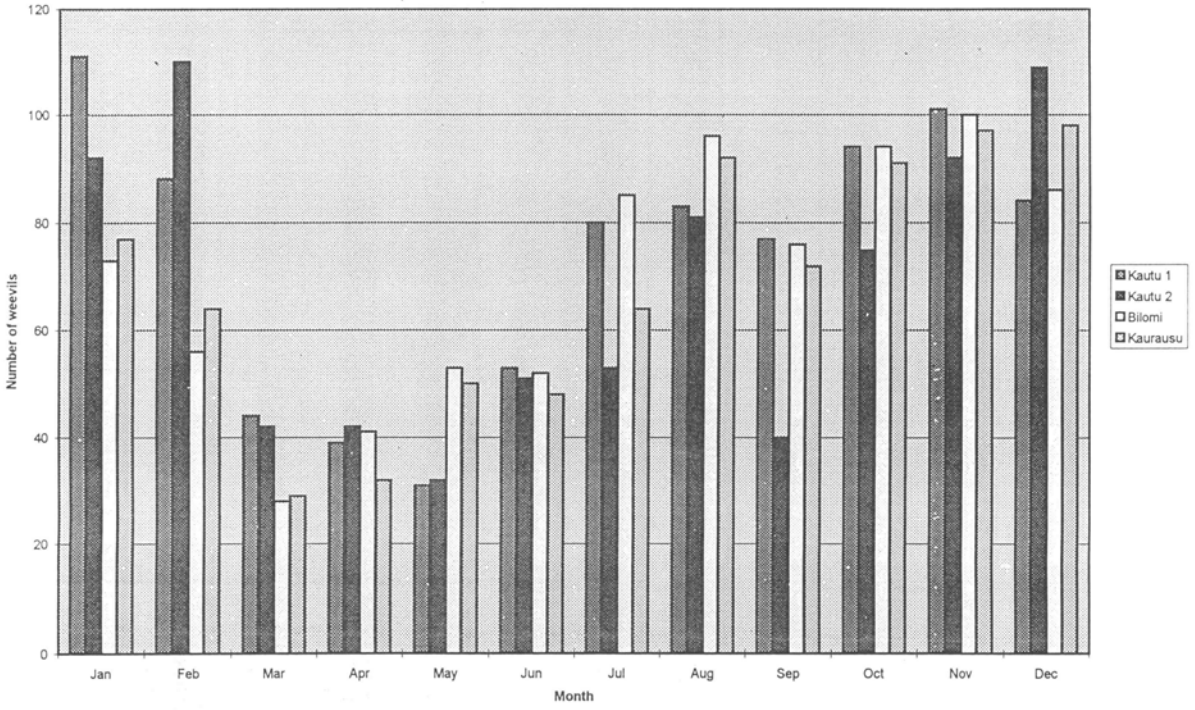


Figure 3.2 The number of Elaeidobius emerging from 5 sets of 20 male spikelets each month at the 4 expermental plots during 1996



Other significant events

Training

Takis Solulu completed his MSc at the Department of Zoology, Oxford University in November 1996. His is currently working on the EU-funded Sexava biocontrol project, and is based at our Higaturu Research Centre.

Rob Caudwell completed a series of entomology training courses for plantation assistants and extension officers. About twenty courses were held throughout the oil palm growing areas of West New Britain.

Dr David Moore, an insect pathologist from the International Institute of Biological Control, gave 8 days on-the-job training in insect pathology to staff from OPRA's entomology section.

Conferences

Rob Caudwell and Takis Solulu attended the World Entomology Congress held at Florence in August 1996. A Poster presentation was given by Takis Solulu.

PORIM Oil Palm Congress at Kuala Lumpur was attended by Rob Caudwell in September 1996, and a poster presentation given.

Visitors

Dr David Moore, from the International Institute of Biological Control, visited West New Britain in November 1996. This 10-day visit was the first part of the mycopesticide component of the EU-funded Sexava biocontrol project.

Projects

In October 1996 the European Union delegate, Dr David MacRae, and the Director of PNGOPRA, Mr Ian Orrell, signed an agreement for EU-Stabex funding for the Sexava biocontrol project. The EU agreed to provide a total grant of K822,000 to PNGOPRA to fund the project.

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Integrated pest management for oil palm in Papua New Guinea

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The global production of palm oil has increased very rapidly, more than doubling between 1970 and 1980. Oil palm is the second most important cash crop in Papua New Guinea (PNG), and in 1995 its export value was US$128 million. The principal pests of oil palm in PNG are a group of tettigonids, collectively known as Sexava, which cause damage by defoliating the oil palm tree. Severe defoliation causes reductions in photosynthesis and fruit production, resulting in yield losses. Control of these pests is currently reliant upon the use of trunk-injected monocrotophos. Because of difficult application methods, poor monitoring procedures, and the difficult environment, chemical control usually occurs too late to prevent significant yield losses. Furthermore the application of chemicals is expensive and environmentally undesirable. There is enormous potential to improve the current pest management practices, and several biological control agents could be used in an integrated pest management (IPM) system. Agronomic practices directed towards developing biodiversity within the oil palm cropping system, and improved pest monitoring and surveying could also be components of this IPM scheme.

Keywords: Integrated pest management; biological control; oil palm; tettigonids.

Introduction

THE DEVELOPMENT OF THE OIL PALM INDUSTRY

Collectively, oil crops and their products are the second most valuable commodity being traded on global markets (Röbbelen *et al*. 1989). Production and trade in these commodities has expanded rapidly in response to an increasing world population and improved living standards. Technological advances have resulted in higher production levels, and improvements in production quality and versatility. The global production of palm oil has increased very rapidly, more than doubling between 1970 and 1980. In 1980, palm oil became the world's second most important vegetable oil after soybean.

The oil palm, *Elaeis guineenis* Jacq. is a monocotyledon of the order Spadiciflotae. It is from the Palmae family and the Cocoineae tribe. It originated in Africa, and its natural habitat is in the humid tropics, 15° on either side of the equator. Oil palm produces the most oil per unit area of all the oil-bearing plants, with current yield averaging between five and seven tonnes of oil per hectare per year. Hartley (1988) and Gascon *et al*. (1989) provide comprehensive accounts of all aspects of oil palm botany and cultivation, as well as details of palm oil processing and its uses.

Gascon *et al*. (1989) reported that in 1977, 78% of the palm oil production came from South–East Asia (Malaysia and Indonesia), 17% from Africa and 5% from South America. More recently very rapid development of the oil palm industry has taken place in Indonesia. The oil palm industry is relatively new in Papua New Guinea, with the first development starting in West New Britain Province in 1967, following a World Bank recommendation. Rapid expansion occurred, and by 1985 PNG was producing 140 000 tonnes of palm oil and 48 800 tonnes of palm kernels per year (1.8% of world production). In 1995 oil palm became PNG's second largest agricultural industry behind coffee, with an export value of US$128 million. Approximately 63 thousand hectares of oil palm are currently being cultivated in PNG.

The oil palm industry in PNG has successfully developed under the nucleus estate system. Under this system the projects are divided into two parts: the nucleus estate, and smallholder schemes. The nucleus estates are large central plantations, run as joint ventures between the government and private enterprise. Each estate has its own processing mill and exporting facilities. Around the nucleus estate smallholders grow oil palm on small (4–5 hectare) blocks. Smallholders are either villagers living in the area, or settlers brought in from other areas. The nucleus estate is therefore a stable business, growing, processing, and exporting palm oil. The estate also provides the smallholders with services such as planting material, technical and management advice, marketing, processing and export facilities. Over the past 30 years the oil palm industry in PNG has developed into a dynamic and successful agricultural enterprise. During this period it has been the only agricultural industry in PNG that has had continual investment for expansion and development. It is soon expected to overtake coffee as PNG's most important agricultural industry.

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INSECT PESTS OF OIL PALM

Worldwide there are a number of insect pests that affect the oil palm at all stages of its development. The majority of these are leaf feeders, and cause damage by defoliating the oil palm tree. Severe defoliation reduces photosynthesis and fruit production, resulting in yield losses. The most important of these pests include insects from the orders Lepidoptera, Coleoptera, Orthoptera, and Hemiptera (Hartley, 1988). The Lepidoptera that cause damage to oil palm are mainly from the Cochlidiidae or Limacodidae family (slug or nettle caterpillars), or from the Psychidae family (bagworms). The beetles that damage oil palm belong to three distinct groups: (1) the Chrysomeloidea, of which the Hispid leaf miners are of greatest importance; (2) the Curculionidae or true weevils; and (3) the Scarabeoidea, of which the Dynastid 'Rhinoceros' beetles form the most damaging group. Rhinoceros beetles are not leaf feeders, but damage oil palm by boring into young trees and feeding from soft tissues around the growing point. Orthopteran pests of oil palm include insects from the Acridoidea (grasshoppers) and Tettigoniidae (treehoppers or bush crickets) families. Important Hemipteran pests include insects from the families Aphididae (aphids) and Coccidae (mealybugs and scale insects) (Hartley, 1988).

A variety of chemical and biological control agents have been used to control these insect pests (Hartley, 1988). There has recently been a trend towards reducing pesticide inputs for oil palm pest management, and many alternative biological control agents have been developed. These include the use of pheromone traps and insect baculoviruses to control Rhinoceros Beetle (*Oryctes rhinoceros*) and the Black Palm Weevil (*Rhynchophorus palmarum*) (Oehlschlager *et al*. 1993; Mohen and Pillai, 1993; Dhileepan, 1994a), and the use of entomopathogenic viruses and insect growth regulators for the control of leaf-eating lepidoptera (Mariau and de Chenon, 1990; de Chenon *et al*., 1988; Cruz and Reyes, 1991). There has also been an improved understanding of the importance of management practices in reducing pest populations. This includes the need to preserve naturally occurring biological control agents, as well as general levels of biodiversity within the oil palm cropping system. For example, Basri *et al*. (1995) reported that natural enemy levels affect host population regulation in bagworms (*Metisa plana*). These authors concluded that *M. plana* populations were affected by both primary and secondary parasitoids and predators. A hypothetical life table was used to demonstrate that natural enemies played a key role in suppressing bagworm populations. The presence of beneficial soft weeds and herbaceous plants, that provide a source of food for numerous parasitic Diptera and Hymenoptera, helps to maintain a balance between insect pests and their natural biological control agents within oil palm plantations (Chung *et al*. 1995a).

The principal pests of oil palm in PNG are a group of species from the tettigoniidae family (Orthoptera), known as bush crickets, long-horned grasshoppers or treehoppers. This group of species are collectively called Sexava. Three species of Sexava are pests of oil palm in PNG, *Segestes decoratus, Segestidea defoliaria*, and *Segestidea novaeguinea*. These insects cause damage by feeding on oil palm fronds, and defoliation levels can be very severe where high population densities occur.

Young (1985) described the basic biology and life cycles of this group of species. Adult Sexava lay the majority of their eggs in the soil at the base of oil palm trees, but a small proportion may be laid in the roots of epiphytes on the palm trunk and in the butts of necrotic palm fronds. Oviposition occurs at night, and the eggs are laid singly, although three or four may be laid in succession by one female. A female Sexava can lay up to 40 eggs in a lifetime. The period from egg deposition to hatching varies between 40–100 days. After hatching, the first instar nymphs climb up to the crown of the palm, and start to feed on the fronds. The newly emerged nymphs are dark green in colour. The juvenile stages and moult to the adult stages are completed in the crown of the palm. The number of moults is reported to be six in the male and seven in the female (Froggatt, 1935). Females take approximately 21–26 weeks to reach the adult stage, and males approximately 20–22. The adults are usually green in colour, although brown variants often occur. The adults only leave the crown to oviposit if there is a shortage of food. Sexava populations appear to be more active during the rainy season (October to April in West New Britain). There is little literature available on this subject, but it is considered that the onset of the rains may result in increased emergence of Sexava nymphs. Adult Sexava also appear to be more active during the rainy season, and it is possible that food consumption increases during this period.

Most of PNG's oil palm is grown in West New Britain (70%), and during 1994–95 there was a significant increase in Sexava populations in this area. Damage levels were probably the worst on record up to that time, with large areas of oil palm plantations affected by high populations of *Segestes decoratus* and *Segestidea defoliaria*. Control is currently reliant upon the use of trunk injected monocrotophos (Nuvacron or Azodrin) (Sarjit, 1986; Matthews, 1992). Monocrotophos (10 ml of 400 ml ai/l formulation) is injected into a single 1.5 cm diameter hole, 15 cm deep and drilled at a 45° angle into the trunk, 1 m above the ground. The monocrotophos persists for approximately 60 days in the leaf tissue of the palm, and provides good field control of Sexava. A follow up treatment is required after approximately 12 weeks to coincide with the emergence of nymphs from eggs laid by the original pest population. This method of pesticide application is effective if performed properly. It confines

the insecticide to the tree and therefore has a negligible effect on non-target organisms. Treatment is however very time consuming, especially when large areas of plantation are affected by high Sexava populations. Treatment of remote areas is also difficult, and control operations are severely disrupted during the rainy season. These application difficulties, along with generally poor monitoring procedures, usually means that chemical control often occurs too late to prevent significant yield losses, particularly for the smallholder crop. Furthermore the application of chemicals is very expensive. The trunk injection technique targets pesticide application to within the plant tissue, and is therefore more environmentally desirable than other application techniques, such as spraying. However it does result in user hazard, and our current research effort is directed towards reducing pesticide use on oil palm.

In PNG spraying of insecticides to control insect pests of oil palm is confined to nurseries. The majority of the rural population, particularly in smallholder areas, use creeks and rivers for washing and drinking water. Pesticide application methods have therefore been restricted to prevent possible contamination of this water. The African pollinating weevil (*Elaeidobius kamerunicus*) has been introduced into most oil palm growing regions of the world, including PNG. This weevil has dramatically increased pollination levels and fruitset rates, and improved palm oil yields (Dhileepan, 1994b). In PNG, restricting pesticide application to trunk injection also reduces the possibility of the weevil population being adversely affected by the indiscriminate use of pesticides.

A number of biological control agents, including Strepsipteran parasites, hymenopteran egg parasitoids, and fungal pathogens have potential for use in an integrated pest management system for Sexava. Agronomic practices directed towards developing biodiversity within the oil palm cropping system, to maximize the presence of naturally occurring parasites and pathogens of the pest species may also reduce pest populations. Improved pest monitoring and surveying procedures could also be used in this IPM system.

Development of an integrated pest management scheme

AGRONOMIC PRACTICES

Preservation of biodiversity within oil palm plantations is very important. Beneficial soft weeds and herbaceous plants provide a source of food for numerous parasitic Diptera and Hymenoptera, and help to maintain a balance between insect pests, and natural biological control agents (Chung *et al*. 1995a). The preservation of these natural biological control agents could play an important role in the development of a sustainable pest management scheme for Sexava. Prior (1988) reported that Sexava adults and nymphs are parasitized by tachinid flies (*Exorista notabilis*) and Strepsiptera (*S. dallatorreanum*). He also listed the following predators of Sexava: crows (*Covus orrus*), kites (*Haliastur indus*), flycatchers (*Rhipidura leucophrys*), the cane toad (*Bufo marinus*), and various native frogs, lizards, gekkos, skinks and scorpions. Sexava oothecae were reported to be parasitized by Encyrtidae (*Leefmansi bicolor*), Trichogrammatidae (*Doirania leefmansi*), Mymaridae (*Anaphes* sp., *Anaphes* sp., *Stethynium* sp., *Anneckia oophaga*, and *Platypatasson fransseni*), Eulophidae (*Tetrastichus* nr *dubius*), and Scelionidae (*Triteleia atrella*) (Prior, 1988). Care must therefore be taken to ensure that populations of these naturally occurring biological control agents are maintained within oil palm plantations.

The use of herbicides for the maintenance of harvesting paths between rows of palms, and harvesting circles around the bases of palms, is an important management practice in oil palm plantations. However, in PNG there has recently been a tendency towards the over use of herbicides, and there has been a significant loss of ground cover in some plantations. Herbicides have also been used for intensive epiphyte spraying programmes. Field studies will be undertaken to determine levels of biodiversity within oil palm blocks, and to assess whether current management practices influence the presence and abundance of Sexava natural enemies. The results of these studies will then be used to advise plantation managers on how to adjust their agronomic practices in order to maintain populations of naturally occurring biological control agents of Sexava.

MONITORING AND SURVEYING

In PNG poor monitoring has meant that pest damage is often not found until it has become severe, and subsequent control operations then occur too late to prevent significant economic yield losses. In other oil palm growing countries, particularly Malaysia, very effective monitoring and surveillance systems have been developed for use in the management of insect pests (Chung *et al*. 1995b). Wood (1976) describes a monitoring and surveillance system that is divided into three stages: alert, census and action. This system has been used in Malaysia for many years, and improvements have included computerized data processing and the generation of colour coded maps to facilitate decision making in IPM.

The alert stage requires the training of plantation workers to recognize early damage symptoms, and then to report them to plantation managers, who then inform specialist entomology units. In PNG a training programme has been undertaken to teach plantation workers to recognize early signs of insect damage. This should enable the early detection of Sexava populations. This plantation level monitoring is carried out as part of normal work routines. Each oil palm block is visited at least every

fortnight for fruit harvesting. Harvesting supervisors have been trained to look for early signs of insect pest damage to oil palms in their blocks, and then to promptly report it to plantation managers.

The census stage is activated once the damage is reported by the plantation manager to the entomology unit, and involves field studies to determine the pest species, developmental stage, pest numbers, and natural enemy levels. Census for oil palm pests is made difficult by the height of the canopy, and it is often impossible to see insect pests from ground level observations. In other oil palm growing countries, census for lepidopteran pests usually involves the cutting down a predetermined frond from a number of trees in each plantation block that have been selected using a grid matrix or some other method (Chung *et al*. 1995b). The numbers of leaf-eating caterpillars on each frond is then used to determine the overall population levels.

Pest enumeration is difficult for Sexava due to their nocturnal behaviour and their feeding habits. Sexava tend to move onto the oil palm fronds from the central spear cluster at night to feed. Cutting off of fronds from affected areas would enable defoliation levels to be quantitatively assessed, but it would not be possible to make accurate assessments of pest numbers. Possible alternative sampling methods include the use a mistblower to apply short-lived pyrethroid insecticides to the canopy, and then collecting Sexava in trays or on sheets placed underneath the tree (Springate and Basset, 1996).

Smith and van den Bosch (1967) however argued that economic thresholds should be based on actual damage rather than pest numbers, in which case defoliation levels rather than Sexava numbers would be used for the census stage. Current field techniques involve the use of binoculars to assess feeding damage, and then qualitative scoring into three damage categories (light, moderate, or severe). This is a subjective technique, but has a number of inherent advantages. It allows the observer to view the entire tree, rather than basing assessments on a single frond. Damage to the newer fronds in the upper part of the leaf canopy has a greater impact on the productivity of the palm than damage to older fronds in the lower part of the canopy, and it is important that this is taken into account when assessments are made. This survey technique also enables large areas to be surveyed within each plantation block, rather than confining the damage assessment to a predetermined tree, and allows the observer to use his/her knowledge of the pest's behaviour to improve the reliability of the assessment. Sexava adults and nymphs tend to move into the edges of oil palm blocks from their natural hosts, these include wild sago and banana palms, and heliconia. It is often possible to detect early signs of damage in areas of plantations that border onto these plants.

Once damage levels have been assessed defoliation maps can be drawn up to show levels of insect damage over large areas (Mariau, 1994). Satellite imagery could also be used to detect signs of damage over extensive areas. This would be dependent upon achieving the required level of image resolution to be able to detect signs of damage. The use of satellite imagery for the detection of Sexava feeding damage is currently being investigated by the Oil Palm Research Association in PNG.

An improved knowledge of Sexava feeding behaviour and population dynamics may enable likely Sexava hot spots to be located. These would be locations where the risk of Sexava outbreaks were high, and these areas could be surveyed more frequently in an effort to detect early signs of damage.

STREPSIPTERAN PARASITES

Strepsiptera are entomophagous parasites of cosmopolitan distribution (Kathirithamby, 1989; 1991). They are exclusively parasitic in about 34 families of Insecta in six orders, and have extreme sexual dimorphism combined with an unusual life cycle. The males are free-living, and short-lived insects. The females in contrast are permanently endoparasitic, and as adults appear as sacs bloated with eggs (Kathirithamby, 1989). The female normally parasitizes the same host as the male. However, of the 574 described species of Strepsiptera, the host is often unknown, and most of the species have been described from flying males collected from light traps.

O'Connor (1959) reported that Sexava adults and nymphs were parasitized by a Strepsipteran, *Stichotrema dallatorreanum*. This species belongs to the family Myrmecolacidae, and Kathirithamby (1989, 1991) reported that the males of this family parasitize a different host from the female. In PNG, female *S. dallatorreanum* parasitize Sexava, and males are thought to parasitize larva of the ant, *Camponotus papua* (Young, 1987a). High levels of parasitism of *S. novaeguinea* by *S. dallatorreanum* occurs in oil palm growing areas in mainland PNG, and chemical treatment of Sexava has not been required on plantations in these areas for many years. Young (1987b) concluded that *S. dallatorreanum* contributed to the control of Sexava in areas with an evenly distributed rainfall, and suggested that the parasite had potential for use as a biological control agent in areas where it is not endemic against pest species of Sexava. However, very little is known about this species of Strepsiptera, and the biological interaction with its Sexava host.

Wigley *et al*. (1989) reported that *S. dallatorreanum* was found parasitizing *Sexava nubile* in Irian Jaya, and subsequently attempted to introduce it into the Talaud Islands to control Sexava pests of coconuts. These attempts failed, largely because insufficient information was available regarding the basic biology and ecology of the parasite, and its interaction with the Sexava host. These authors stressed the importance of undertaking studies to

determine the biology of the parasite and the host-parasite relationship, before attempting to use *S. dallatorreanum* as an introduced biological control agent for Sexava pests.

A collaborative research programme has recently been set up between the Oil Palm Research Association in PNG and Oxford University in the UK to develop the use of *S. dallatorreanum* in an integrated pest management scheme for Sexava. Basic life history studies will be undertaken, and attempts will be made to locate and identify the male *S. dallatorreanum*. The first instar larva and the adult male are the only free-living stages of the parasite, and they constitute its host-seeking stages. It is not clear whether the first instars are sexually dimorphic, and this will be clarified using electron microscopy. The females of the parasite may be parthenogenetic, or may express this mode of reproduction under certain conditions. The neotenic female lays over a million eggs, and all of these develop into first instar larvae. Female *S. dallatorreanum* will be bred in the laboratory to investigate whether they are parthenogenetic. When a Sexava host is infected its entire abdomen is occupied by the parasite. The digestive and reproductive system of the host are pushed against the body wall, leaving little room for effective host nutrition or reproduction. Infection by *S. dallatorreanum* has been found to affect the physiology and behaviour of the Sexava host (Solulu, personal communication), and further studies will be undertaken to determine the effects of infection on host feeding, longevity and fecundity.

When the detailed life history of the *S. dallatorreanum* parasitizing Sexava on mainland PNG has been determined, infectivity trials will be undertaken to assess whether it will infect Sexava from oil palm growing areas of New Britain. Field trials will be undertaken once the efficacy and environmental impact of *S. dallatorreanum*-based control has been determined. It is an imperative that the detailed life history of *S. dallatorreanum*, and the precise nature of the host–parasite interaction be rigorously studied before any such trials are attempted.

MICROBIAL INSECTICIDES

For an entomopathogen to have potential as a microbial insecticide it must have the following characteristics – virulence, predictability of control, ease of application, ease of production, environmental acceptability, and it must be also able to reduce pest populations to below economic thresholds (Burgess and Hussey, 1971). These are all attributes of chemical insecticides with which microbial insecticides have to compete.

There has been relatively little research done to investigate the potential of microbial insecticides for Sexava control. Henry and Hosang (1987) and Hosang and Wigley (1989) surveyed Sexava populations in coconut growing areas on Indonesian Islands around North Sulawesi for the presence of pathogenic microorganisms, and subsequent laboratory bioassays focused on the testing of protozoan pathogens against *Sexava coriaca* and *Sexava nubile*. Attempts were also made to release protozoan microorganisms into *S. nubile* populations of the Talaud Islands (Hosang *et al*. 1988). The results of these studies were however inconclusive, although these authors suggested that Sexava are potentially excellent candidates for microbial control.

A variety of microbial insecticides have been tested against Orthopteran pests in Africa and North America (Prior and Lomer, 1992). Potential control agents include microsporida (Henry, 1971), nematodes (Capinera and Hibbard, 1987), entomopoxviruses (Street and McGuire, 1988), and fungi (Prior, 1992). The deuteromycetes fungi *Metarhizium* and *Beauveria* show great potential as microbial insecticides for short-horn grasshoppers and locusts (Moore *et al*. 1992; Bateman *et al*. 1993a; Bateman *et al*. 1993b; Lomer *et al*. 1993; Jenkins and Thomas, 1996; Moore *et al*. 1996). Fungi from these genera may also have potential to be used as microbial insecticides against Sexava.

Entomopathogenic fungi infect the host through the cuticle, and pathogenesis begins with adhesion of the conidia to the host cuticle. This is followed by germination and penetration. The fungus then develops inside the host, eventually resulting in host death. Fungi are alone among insect pathogens in being able to invade actively through the cuticle (Charnley, 1992). This contact action avoids problems of inactivation, caused by adverse environmental conditions, while waiting for the pest to ingest the pathogen, which is a critical limitation for viruses, bacteria and protozoa.

Beauveria and *Metarhizium* have virulent strains that are host specific (Prior, 1992), can be formulated and applied in the same manner as chemical insecticides (Bateman, 1993; Batemen *et al*. 1993a; Batemen *et al*. 1993b), can be produced cheaply using artificial media (Goettel and Roberts, 1992), are environmentally acceptable (Goettel and Johnson, 1992), and are able to reduce pest populations to below economic thresholds (Batemen *et al*. 1993b; Lomer *et al*. 1993; Johnson and Goettel, 1993). These genera of entomopathogenic fungi therefore have all the necessary characteristics of a microbial insecticide as described by Burgess and Hussey (1971).

The Entomology Section at the Oil Palm Research Association in PNG has recently initiated a joint project with the Grasshopper and Locust Biocontrol Group at the International Institute of Biological Control, UK to investigate the use of entomopathogenic fungi for Sexava control. The first phase of this project will involve exploration for fungal pathogens virulent against Sexava. When suitable strains of *Beauveria* or *Metarhizium* have been found, they will be tested against Sexava in laboratory and field bioassays. The deuteromycetes *Beauveria* and *Metarhizium* have lipophilic conidia which

are easily mixed with oil, and Prior *et al*. (1988) reported that *Beauveria bassiana* conidia were thirty times more effective when they were formulated in vegetable oil rather than water. Batemen *et al*. (1993a) also found that in laboratory bioassays using *Schistocerca gregaria*, formulations of *Metarhizium flavoviride* conidia in cottonseed oil showed superior performance to water-based suspensions, and that this was especially pronounced at low humidities (35% RH). The LD_{50}s for oil and water suspensions for adult *S. gregaria*, inoculated with 2 μl of conidial suspension beneath the pronotum shield, were 8.9×10^3 and 1.3×10^6 conidia/insect respectively (at five days post treatment). Virulent strains of *Beauveria* or *Metarhizium* conidia will therefore be formulated in vegetable or mineral oil-based suspensions and tested against Sexava.

Vegetable oil-based suspensions of fungal conidia virulent against Sexava could be applied using aerial and ground ultra-low volume spraying technology, this could enable very large areas to be treated using relatively low volumes of formulation (1–2 litres/ha). Maximization of coverage at low volumes would require the production of large numbers of small droplets, however not so small that they do not deposit on their targets. ULV formulations of myco-insecticides have been developed that have satisfactory atomization characteristics with standard ULV spraying equipment, with a substantial proportion of spray droplets within a size range appropriate for the target (e.g. 80% of the total volume between 50–100 μm) (Bateman, 1993). Conidia virulent against Sexava will be formulated in low viscosity vegetable oils so that the suspension will flow satisfactorily through ULV equipment, and at least some of the mixture should have low volatility, so that small droplets maintain sufficient size to impact on the target.

It is considered that the wet and humid environment in Papua New Guinea would provide ideal conditions for fungal pathogens. The humid environment of the oil palm growing areas in PNG, together with the protection against ultra-violet radiation provided by the oil palm canopy, and the permanent nature of the cropping system, should provide an ideal opportunity for successful insect control using a fungal biopesticide.

EGG PARASITOIDS

The first recorded use of Sexava egg parasitoids in PNG was in 1933, when the Hymenopteran egg parasitoids *Leefmansia bicolor* and *Doirania leefmansi* were introduced from Amboina in the Maluccas and established in a number of coconut growing area on New Hanover Island (Froggatt, 1935). The PNG Oil Palm Research Association has reared these two egg parasitoids in the laboratory for several years. The parasitoids have been reared on Sexava eggs and then released into oil palm growing areas where Sexava populations are present. Several million egg parasitoids are usually released each year. Unfortunately the efficacy of the egg parasitoids for the control of Sexava populations has never been properly determined. The vast majority of Sexava eggs are laid in the soil at the base of oil palm trees (Young, 1985). However, Froggatt and O'Conner (1940) reported that the highest levels of parasitism by *L. bicolor* and *D. leefmansi* occurs in eggs laid on the trunks, and in fibres and crowns, and that it is relatively low in eggs laid in the soil. It is therefore questionable whether the egg parasitoids that are released to control Sexava pests actually parasitize the majority of Sexava eggs which are laid in the soil.

If egg parasitoids are to be used in an integrated pest management system for Sexava it is important that their field performances are rigorously evaluated. The following aspects of the existing mass release programme should be determined – dispersal of parasitoids after release (walking, flight), habitat location, host location (perception of sensory cues), synchronization with the population dynamics of the host, density dependent population dynamics, and the intrinsic rate of population increase. If this evaluation shows that the egg parasitoids are exerting an influence on Sexava populations then improvements should be made to their mass rearing. These could possibly involve the use of synthetic or semi-synthetic media, the stimulation of egg laying, adjustment to and/or control of physical and chemical conditions within the rearing system, cooling or freezing (to delay development), and optimization of the age of host eggs that are used for rearing.

Conclusions

There is enormous potential for improvement to the current pest management practices for oil palm in Papua New Guinea. Agronomic practices should be directed towards developing biodiversity within the oil palm cropping system, to maximize the presence of naturally occurring parasites and pathogens of the pest species. Improved pest monitoring and surveying would enable the early detection of pest outbreaks, and improve the efficacy of control operations. A number of biological control agents, including Strepsipteran parasites, hymenopteran egg parasitoids, and fungal pathogens have potential for use in an integrated pest management system for Sexava. The potential of each of these components for use in the IPM system will become apparent as our research programme develops. The resulting pest management scheme may include some, or all of these components, for the integrated control of Sexava. This IPM system would be sustainable, low input, cost effective, and environmentally acceptable.

As Sexava are the only economically significant pest of oil palm in PNG success in this project will lead to reductions in, or complete elimination of, chemical treatment. This will result in consequent savings in both

the costs of importing chemical insecticides, and in treatment costs. Such a system would eliminate the problems associated with existing control operations, and improve the economic viability of PNG's oil palm.

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Some effects of stylopization by *Stichotrema dallatorreanum* (Strepsiptera: Myrmecolacidae) on its host, *Segestidea novaeguineae* (Orthoptera: Tettigoniidae) in Oro Province.

(Takis M. Solulu MSc)

Introduction

Stichotrema dallatorreanum Hofeneder is an unusual entomophagous parasite. Like the other known members of the family Myrmecolacidae, the male is thought (although not yet confirmed) to be parasitic on species of ants, while the female parasitizes orthopteran hosts. In Papua New Guinea (PNG), the female strepsipteran is recorded to parasitize species of foliovorous tettigoniids, commonly known as 'sexavae', which are economic pests of oil palm, *Elaeis guineensis* Jacq. (Palmae) and also coconuts. Two species, *Segestes decoratus* Redtenbacher and *Segestidea novaeguineae* (Brancsik) have been recorded as being parasitized by *S. dallatorreanum* in the mainland of PNG (O'Connor, 1959). This strepsipteran appears to be effective in keeping the numbers of these two species of sexavae in check in the mainland where it occurs, hence might be a potential biological control agent (BCA) on similar related pest species in the island region where it is absent, particularly West New Britain where infestation by *Segestidea defoliaria* Uvarov recurs annually.

Although studies involving *S. dallatorreanum* have been done (PNGOPRA Annual Reports, 1983-85; Young, 1987a, 1987b; O'Connor, 1959), much of these work had been concerned with life histories of the stylops. Even then, much is not known about the biology of the stylops, including the yet uknown male and its host. There is, however, no information on the stylops-host relationship, relating to changes in morphology, behaviour or physiology in the hosts due to stylopization. Therefore, this study was undertaken to assess the impact of stylopization by *S. dallatorreanum* on the body characters, gut content, some reproductive variables and body composition of field-collected adults of the host *S. novaeguineae*. The study presents and discusses some of these findings.

Field studies were carried out at Higaturu in the Oro Province, while biochemical assays and data analyses were performed at the Zoology Department, University of Oxford, UK.

Materials and Methods

Field collection of adult *Segestidea novaeguineae*

A total of 180 adults of *S. novaeguineae* was sampled and analyzed during the study. These represented 59 (29 males and 30 females) healthy specimens ("treatment" 1), 54 (28 males and 26 females) stylopized ("treatment" 2) and 67 (33 males and 34 females) specimens which were simultaneously parasitized by *S. dallatorreanum*, and a parasitic tachinid fly, *Exorista notabilis* Walker ("treatment" 3). Adult sexavae were manually collected around Higaturu from infested oil palm fields, from vegetation around the base of palms, on ferns and epiphytes along palm trunks, and/or from the lowermost fronds of mature palms in the early hours (0700 to 1100h) of the day, and placed into a large collecting cage containing fresh palm leaves as a source of food and brought to the laboratory.

Observation on body characters and gut content

Live specimens were individually removed from the collecting cage and immediately placed in a large killing jar (250ml) containing cotton wool soaked in chloroform, removed after 5-10s and kept in a refrigerator (3-4^{o}C). These were then individually taken from the refrigerator and the following body characters measured: length of antennae, forewings and, in females, length of ovipositor, to ± 0.1cm

(using a ruler). Following these measurements, each sexava specimen was cut ventro-longitudinally, from the prothoracic sternum to the terminal end of the abdomen. Qualitative observations were then made on the digestive tract and reproductive structures for abnormalities and/or signs of damage due to stylopization. The same specimens were used for subsequent measurememnt. The number of stylops and *E. notabilis* inside each host was also recorded for the parasitized hosts (121 specimens). While both adults and larvae of the female strepsipteran were found inside the hosts, majority of the multiparasitized specimens (53/67) did not contain larval tachinids, but had only remains of larval exuviae. When the parasites had been removed, the alimentary canal with content was removed and the whole length of each was straightened and measured to ± 0.1cm (using a ruler). The content of each gut were removed, oven-dried at 50^{o}C and weighed to ± 0.001g (using an electronic balance) after 24h.

Observation on reproductive organs/variables

The male gonads were observed for signs of damage due to stylopization, and then removed from the carcass, blotted and fresh weighed to ± 0.001g. These were then dried in an oven at 50^{o}C and reweighed after 24h. The appearance of ovaries in both healthy and parasitized female *S. novaeguineae* was noted. Gonads which appeared reduced in size, lacking distinct stages of egg development and having distorted immature eggs in the ovarioles were scored as being abnormal. Normal forms were typical of orthopteran ovaries and were contrary to these descriptions. The appearance of immature eggs, (i.e. developing eggs in the ovarioles) of healthy and parasitized female sexavae was recorded. These were scored as normal when the developing eggs appeared yellow-orange in colour, sausage-shape and varying uniformly at different stages of their development along the ovarioles. Abnormal forms were contrary to these descriptions. In most instances, abnormal eggs appeared purplish-black in colour, more rounded than 'sausage-like' and had irregular or distorted stages of egg development. Female gonads were then removed from the carcasses, blotted and fresh weighed to ± 0.001g and were examined (using a stereomicroscope) for effects on the ovariole structures and numbers. The number of mature eggs (i.e. developed eggs in the calyces/oviduct awaiting oviposition) in both healthy and parasitized female specimens was recorded. Appearance, size and deformities in developed eggs were also recorded. Developed eggs recorded as being abnormal were those which appeared darker (black or purplish black) in colour and varying more in shape, size and length (8-11mm) than did the normal form, which were uniformly elongated, light brown in colour and 12-13mm in length. A particularly notable abnormal form was that in which the egg had ballooned out to form a bizarre structure. Samples of 128, 114 and 120 mature eggs respectively were obtained from healthy, stylopized and multiparasitized specimens and their lengths measured to ± 0.1mm (using a ruler).

Biochemical assay

When the digestive and internal reproductive organs had been removed, the empty carcass, including head and antennae, was fresh weighed (to ± 0.001g) and then oven dried at 50^{o}C for 3-5 days for each carcass to attain a constant dry weight. Lipid content was extracted by soaking each carcass in chloroform for 24h. The chloroform was decanted and replaced. This was repeated three times for each specimen. After the third rinse, each specimen was placed in a Petri dish, redried in the oven at 50^{o}C for 24h and reweighed. The lipid content of each specimen was calculated as the difference in dry weight before and after lipid extraction. Each carcass specimen was then crushed in a pestle and mortar to a powder, and placed in a vial for nitrogen determination, which was determined using standard microKjeldahl procedures at the Zoology Department, University of Oxford.

Monitoring of parasitism levels

Additionally, the level of parasitism by *S. dallatorreanum* and *E. notabilis* was monitored from January to December 1995 on four selected sites, one each at Awowota, Dobuduru, Igora and Iseveni localities. The size of each site varied between 2-4ha, with an average of 270 mature oil palm stand

per plot. Monitoring was done fortnightly and carried out between 0700-1100h which involved walking through each block and thoroughly checking each palm for sexavae from ground level. Adult sexavae when spotted were caught and observed for external evidence of the stylops (protruding cephalothorax from the host cuticle) and tachinid (injury markings due to emergence of larva for pupation in soil and larval breathing funnels on host cuticle). These were then scored, marked and then released back into the field.

Statistical analysis of data

All parametric statistical analyses were generated using the SPSS for Windows statistical package (Release 6.1). The main parametric procedures used were analysis of variance (ANOVA) and analysis of covariance (ANCOVA), using carcass dry weight as a covariate. Additionally, chi-squared contingency tests were performed for categorical data sets.

Results

All data are summarized and presented in Tables of means, ANCOVA and followed by figures. Data in the graphs are from unparasitized hosts (denoted by "0" stylops) and from hosts parasitized *only* by *S. dallatorreanum* (i.e. 'treatments' 1 and 2). "Treatment" in the analyses refers to whether the hosts were healthy ('treatment' 1); stylopized *only* ('treatment' 2) or multiparasitized ('treatment' 3). Throughout all analyses, treatments 2 and 3 did not differ significantly, so the results refer to "stylopization" as indicating only the presence of stylops, or presence of both stylops and tachinid parasites. The number of *Stichotrema* found inside each host ranged from 1-6 in male and 1-9 in female *Segestidea*, while total of both stylops and tachinid parasites was 2-8 and 2-11 respectively.

Influence of stylopization on body characters

The wing length and gut length were significantly longer in female *S. novaeguineae* than in males (Table 1, column a).

Table 1 Relative values (Mean ± SEM) of (a) body characters and (b) gut contents of *S. novaeguineae*.

		(a) *Morphological characters*			
	(n)	Antennal length (cm)	Wing length (cm)	Gut length (cm)	(b) Dry *gut content* (g)
Female Host					
Healthy	(30)	18.1 ± 0.16	9.1 ± 0.07	22.4 ± 0.19	0.40 ± 0.017
Stylopized	(26)	18.1 ± 0.22	8.9 ± 0.07	21.0 ± 0.33	0.27 ± 0.024
Parasitism*	(34)	17.8 ± 0.24	8.5 ± 0.10	21.5 ± 0.27	0.29 ± 0.014
Male Host					
Healthy	(29)	20.2 ± 0.22	7.4 ± 0.05	17.5 ± 0.18	0.15 ± 0.010
Stylopized	(28)	20.5 ± 0.24	7.4 ± 0.07	16.8 ± 0.19	0.15 ± 0.008
Parasitism*	(33)	19.9 ± 0.36	7.0 ± 0.07	16.6 ± 0.18	0.14 ± 0.009

* That is, simultaneous parasitizism by stylops & tachinid parasites.

Table 2 Summarized ANCOVA table showing F values for variables in Table 1.

Source	df	*F values* Antennal length	Wing length	Gut length	Dry gut content
Covariate	1	0.16	66.25***	59.53***	3.51 2
Treatment	2	1.38	10.81***	6.29**	8.79***
Sex	1	47.89***	144.89***	156.21***	61.96***
Treat * Sex	2	0.36	1.07	2.39	13.07***

Covariate = dry carcass weight (g). Significance level: * $p<0.05$; ** $p<0.01$ and *** $p<0.001$

Stylopization by *S. dallatorreanum* was found to have significantly reduced wing length ($p<0.001$) and gut length ($p<0.01$) in female hosts, but was not associated with a significant difference in the antennal length of either sex. Reduction in wing length and gut length persisted even when a covariate (carcass dry weight) was used in the analyses (Table 2). A gradual decline in wing length was seen in females with increasing numbers of stylops per host, but this was not apparent in male sexavae (fig 1). However, increasing numbers of stylops inside the host was associated with a progressive reduction in gut length in both sexes (fig 2).

Influence of stylopization on gut content (dry matter)

The amount of solid food material (ie. oil palm leaf tissues) analysed from healthy and parasitized *S. novaeguineae* showed that female sexavae had significantly more gut content than males (Table 1, column b). On average, healthy female sexava had 63.4% more solid food material in the digestive tract than an equivalent male. Stylopization was associated with a significant decline in the amount of solid plant material in the gut of female sexavae, however in males stylopization was associated with no change in gut content. Hence, the interaction term sex by treatment was highly significant (Table 2). The presence of two or more stylops per host had the greatest effect in lowering gut content in females (fig 3).

Influence of stylopization on reproductive organs/variables

The following variables: ovipositor length, ovary wet weight, egg development, number of ovarioles, number of developed eggs and testes weight were measured to elucidate possible impact of stylopization on reproductive performance in *S. novaeguineae*. Tables 3 gives the mean values of some reproductive variables measured. The analysis of covariance (Table 4) indicated a significant effect of stylopization on ovipositor length, ovary wet weight, mature egg numbers and testes dry weight in *S. novaeguineae*.

Table 3 Relative values (Mean ± SEM) of various reproductive variables in *S. novaeguineae*.

		Reproductive organs/variables				
	(n)	Testes dry weight (g)	Ovipositor length (cm)	Ovary wet weight (g)	Ovariole number	Mature egg number
Female Host						
Healthy	(30)	-	4.8 ± 0.04	0.98 ± 0.095	31.2 ± 0.65	13.5 ± 1.61
Stylopized	(26)	-	4.7 ± 0.04	0.52 ± 0.074	30.6 ± 0.56	6.5 ± 1.42
Parasitism*	(34)	-	4.5 ± 0.05	0.43 ± 0.055	30.1 ± 0.56	4.4 ± 1.05
Male Host						
Healthy	(29)	0.05 ± 0.004	-	-	-	-
Stylopized	(28)	0.05 ± 0.005	-	-	-	-
Parasitism*	(33)	0.04 ± 0.113	-	-	-	-

* That is, simultaneous parasitizism by stylops & tachinid parasites.

Table 4 Summarized ANCOVA table showing *F values* of various reproductive variables.

Source	df	Ovipositor length	Ovary wet weight	Ovariole number	Egg number	Testes wet weight	Testes dry weight
Covariate	1	14.16***	62.68***	0.270	30.68***	46.13***	58.67***
Treatment	2	8.37***	8.80***	0.44	5.70*	1.34	3.25*

covariate = dry carcass weight (g). Significance levels: * $p<0.05$, ** $p<0.01$ and *** $p<0.001$

Effect on the ovipositor length

Stylopization by *S. dallatorreanum* was associated with a significantly reduced length of the ovipositor in female *S. novaeguineae* (Table 4). This effect was over and above that due to differences in overall body size. Presence of two or more stylops per host appeared to have had a greater impact than just one stylops (fig 4).

Effects on ovary development and wet weight

Stylopization was observed to have affected the development and structure of the ovaries in stylopized and multiparasitized female sexavae. The ovary wet-weight, including weights of eggs, was significantly reduced in stylopized as compared to healthy hosts (Table 3). Affected female gonads appeared reduced in size with slightly thickened walls of the oviduct and abnormally developing eggs in some ovarioles relative to those found in healthy females. Increasing stylops density per host body strongly affected the weight of the female gonads (fig 5). As can be seen (fig 5), there were two distinct groups of healthy sexavae, those with ovary wet-weight between 0.9 and 1.5g and those with ovaries less than 0.5g in weight. Presumably these represent mature and immature females, respectively.

Effects on the number of ovarioles

Stylopization by *S. dallatorreanum*, as well as increasing stylops density per host had no significant impact on the number of ovarioles present in the ovaries of female *S. novaeguineae*. The average was found to be 31.2 ± 0.65 per ovary (mode of 33 per ovary), hence 64-66 ovarioles per female sexava (Table 3). While stylopization did not affect the number of ovarioles, it was observed to be associated

with alteration in the structure of the ovariole tubes, which appeared comparatively thinner and shorter than those from healthy female sexavae. Such ovarioles were found to have fewer, or in heavily infected female hosts, no mature or developing oocytes in them.

Effects on egg development, mature egg numbers and forms

Stylopized female hosts were observed to have suppressed egg development and formation. Affected immature eggs appeared rounded and black, or purplish-black in colour rather than elongated ('sausage-like') and yellow (yolky) in normal developing eggs. The number of developed eggs was lower in stylopized than in healthy females (Table 3). A number of stylops in excess of two per host had the greatest effect in lowering mature egg numbers (fig 6). The influence of stylopization on egg formation and development at the early stage was manifested later by the varied degree of abnormality observed in the colour, size and form of the developed eggs. Affected eggs appeared darker, varying in forms and less than 12mm in length, and with an unusual flocculent coating over the egg shell, thus concealing the distinctive putative hatching lines which in normal eggs runs dorsally and ventrally along the egg's plane. The normal eggs are uniformly light brown, slender and elongated (12-13mm in length). The most extremely affected eggs had a bizarre balloon-like structure. Calculated chi-squared tests (^{2}= 75.22) at 2 degrees of freedom was much greater than the tabular value (5.991) at the 5% level, thus indicating a highly significant difference ($p<0.001$) in mature egg form (i.e. normal verses abnormal appearance) between healthy and parasitized sexavae.

Effects on the testes wet and dry weights

The testes wet weight in male *Segestidea* was not affected by the presence of *Stichotrema*, though a weakly significant reduction was observed in dry weight (Table 3). Increasing stylops density per male host had no influence on the testes weight. It was also observed that the male gonads appeared near normal in stylopized males, thus suggesting that stylopization may have had a lesser effect on the male than the female gonads.

Influence of stylopization on body composition

Table 5 gives the relative effect of stylopization by *S. dallatorreanum* on body composition of *S. novaeguineae*: carcass dry-weight, absolute carcass nitrogen, % lipid and % nitrogen. Each determined body component was expressed as a percentage of each respective individual carcass weight. Carcass dry weight excludes weights of parasites, digestive and reproductive organs.

Table 5 Relative values (Mean ± SEM) of various body composition of *S. novaeguineae*.

		Body composition			
	(n)	Carcass dry weight (g)	Absolute Carcass nitrogen (g)	% lipid	% nitrogen
Female Host					
Healthy	(30)	1.80 ± 0.052	0.24 ± 0.007	4.1 ± 0.30	13.2 ± 0.03
Stylopized	(26)	1.68 ± 0.057	0.22 ± 0.007	3.0 ± 0.39	13.2 ± 0.06
Parasitism*	(34)	1.49 ± 0.049	0.20 ± 0.006	3.0 ± 0.34	13.1 ± 0.05
Male Host					
Healthy	(29)	1.20 ± 0.026	0.16 ± 0.003	4.2 ± 0.29	13.0 ± 0.04
Stylopized	(28)	1.08 ± 0.038	0.14 ± 0.005	2.4 ± 0.25	13.1 ± 0.05
Parasitism*	(33)	0.97 ± 0.031	0.13 ± 0.004	2.0 ± 0.15	13.0 ± 0.05

* That is, simultaneous parasitizism by stylops & tachinid parasites.

Table 6 Summarized ANCOVA table showing F values of various carcass compositions.

Source	df	% Lipid	% Nitrogen
Covariate	1	15.96***	19.45***
Treatment	2	9.86***	3.86*
Sex	1	3.34	27.19***
Treat * Sex	2	3.15*	0.97

Covariate = dry carcass weight (g). Significance levels: * $p<0.05$, ** $p<0.01$ and *** $p<0.001$.

Effects on carcass dry weight

Stylopization was associated with a highly significant effect ($p>0.001$) on the carcass dry weight of *Segestidea*. A decrease in the host carcass dry weight was observed in both male and female hosts (Table 4), with a progressive reduction in carcass dry weight with increasing stylops density per host (fig 7).

Effects on % lipid content in the carcass

The carcass lipid content was similar in both healthy female and male *S. novaeguineae* (Table 5). Stylopization by *S. dallatorreanum* was associated with a highly significant reduction in lipid levels in the carcass of both sexes (Table 5 and 6). Presence of more than one stylops per host was correlated with a marked decrease in carcass lipid content (fig 8).

Effects on % nitrogen content in the carcass

Percent nitrogen in the carcass was significantly higher in female than in male *Segestidea*. Stylopization by *S. dallatorreanum* was associated with a slightly elevated level of carcass nitrogen (Table 6). The numbers of stylops inside the host body had a complex influence on nitrogen levels in the carcass of both male and female sexavae (fig 9). The absolute value for carcass nitrogen however was much lower in parasitized as compared to unparasitized sexavae (Table 5).

Seasonal occurrence of external evidence of parasitism

Monthly monitoring figures for the four monitoring sites were combined to give respective rates of stylopization and parasitization by *S. dallatorreanum* and *E. notabilis* (fig 10). Th rate of stylopization ranged from 11-58% while parasitism by the tachinid fly was from 23-63%, with an annual average of 34% and 49% respectively. The level of stylopization would have been an underestimate of the actual occurrence since they were based on external evidence. Some sexavae may have had stylops larvae developing in them (as observed during dissections of some specimens which appeared healthy) but were not accounted during monitoring.

Discussion

The effects of stylopization on the morphology of hosts in the Hymenoptera and Hemiptera have been well studied, while knowledge of the stylops-induced alterations in feeding, body composition and reproductive performance in hosts is very scanty. The present study presents for the first time, data on gut content, body composition and certain reproductive variables involving a strepsipteran (*S. dallatorreanum*)-orthopteran (*S. novaeguineae*) association

Effects of Stylopization on Host Body Characteristics

Adult *Segestidea* have wings longer than body length, but are poor fliers. Movement between palms is normally by walking and crossing over between overlapping fronds. Unless disturbed, they are rarely seen flying or even jumping between palms, even at night when they are most active. Hence, although the wing length was reduced in stylopized hosts, it would probably have minimal impact on their mobility. Decreased power of flight due to stylopization has, however, been noted in smaller stylopized hosts such as Hymenoptera and Hemiptera.

The length of the digestive tract was significantly reduced in both stylopized male and female *Segestidea*. When there was only a single stylops, the females were large (occupying over 75% of the host's abdominal cavity), and were found to push the foregut towards the thoracic sternum. The midgut, however rather than being pushed against the body wall passed through the median region of the stylops' abdomen, which wrapped in a corkscrew-shape around the gut. These portions of the mid-gut of the host were usually empty, thinner and more transparent than those areas which did not pass between the stylops' abdominal region. No sign of direct injury to the digestive tract of the host was inflicted by the stylops, although no histological studies have been undertaken.

Except for the corkscrew effect, similar effects on the digestive tract have been examined in stylopized Hymenoptera (examples in Salt, 1927). Strepsipteran parasites are thought to acquire their nourishment by absorption of nutrients from the host's haemolymph (Salt, 1927; Askew, 1971), or by abstracting from the host's integument (Clausen, 1972), hence, there is no physical injury to host tissue. Perhaps the corkscrew-like wrapping around the host mid-gut involves direct absorption of nutrients across the mid-gut wall by the stylops. Studies involving the larval and adult stages of this stylops species are required to establish the exact mode and site of feeding within the host. The effect on the digestive tract and the presence of high numbers of the large stylops (a maximum of 6 and 9 stylops per male and female hosts, respectively, were recorded) would be expected to have some influence on the feeding behaviour and post-ingestive physiology (amount and perhaps type of food eaten, and efficiency of digestion and nutrient utilization) in *Segestidea*.

Female *Segestidea* were found to have 63% more oil palm leaf tissues (0.252-0.582g) in the gut when healthy, and 43% more when stylopized, than did healthy males (0.058-0.331g), thus indicating that adult female sexavae consume more food than males do. Based on data from the gut contents, stylopization by *Stichotrema* would appear to have a marked influence on the feeding behaviour of female, but not male *Segestidea*. Stylopized female hosts were found to have significantly reduced amount of solid food material in the gut, with two or more stylops being associated with a 50% reduction. This preliminary result, therefore, could indicate that *Stichotrema* significantly reduced food consumption in *Segestidea*, hence indicating its potential use in pest management of the tettigoniid (and related species of sexavae). It is important, however, to show directly that stylopization actually reduced food consumption in females; that is, whether the reduced gut content in females indicated lowered food consumption rather than simply the redistribution of host feeding patterns, such that the same amount of food over a given time period was eaten but in more frequent, smaller meals (see Simpson, 1995).

The effects of stylopization on host reproduction include reduction of external (secondary) sexual characters, internal (primary) sexual organs and sexual behaviour. These effects by strepsipteran parasites are very well known in the Hymenoptera, while studies in Hemiptera have also reported profound impact by various strepsipteran species on reproductive characters. The present findings on Orthoptera stylopized by *S. dallatorreanum* was no exception and was associated with reduced ovipositor length, gonadal weight and structure, egg development and numbers, and alterations of mature egg forms in *S. novaeguineae*.

Stylopization by *Stichotrema* significantly reduced the length of the ovipositor in female *Segestidea*. Female hosts with high stylops numbers (3 per host) were found to have shorter ovipositors than

those with two or fewer. This reduction in ovipositor length in *Segestidea* could affect the behaviour of females during oviposition, especially the depth at which eggs are laid. The presence of mature eggs in the oviduct and along the ovipositor indicated that at least some stylopized female sexavae might oviposit.

Although stylopized male *Segestidea* were found to have reduced testes weight, their gonadal structures appeared normal, some of which were indistinguishable from those of unstylopized hosts. Some stylopized male sexavae were observed to have a large mass of spermatophore attached to their external genitalia. This might suggest that stylopized male *Segestidea* do produce spermatozoa. Ovarian development, size and wet weight were significantly reduced in stylopized female *Segestidea*. These effects were more pronounced in heavily infested hosts. Affected gonads mainly showed atrophic signs, rather than any direct injury to the gonadal tissues, thus possibly indicating a nutritional effect and/or endocrine effect of the stylops. Apart from the reduced size of the female gonads, the inner walls of the oviduct appeared slightly thickened, while an unusually large or swollen spermatheca was also notable in stylopized as compared to healthy females. The number of ovarioles was unaffected in stylopized female hosts, but these were thinner and reduced in size relative to those in healthy hosts. A marked reduction in oocyte numbers was also observed in stylopized female sexavae as compared to healthy female host,while in some heavily stylopized specimens a large number of ovarioles had no oocytes. Suppressed oocyte numbers and development due to parasitism have been reported in strepsipteran-infected Hymenoptera (reviewed in Salt, 1927), and in many other parasitic relationships (see Thompson, 1983 for examples).

Female *Segestidea* stylopized by *Stichotrema* exhibited marked interference to egg development. A large number of stylopized female sexavae had some immature eggs (in the ovarioles) that were darker and more rounded in appearance, as compared to the normal yellow and uniformly sausage-like forms. Whether such eggs ever complete their development, or whether they are reabsorbed by the host is not known. A significantly reduced number of mature eggs (in the calyces/oviduct) were found in female *Segestidea* due to stylopization, namely 52% fewer mature eggs in stylopized than in healthy female hosts; a similar reduction to that reported in stylopized *S. decoratus* (Young, 1987a). Observations suggest that parasitized female *Segestidea* can produce normal eggs, athough fewer than in unparasitized hosts. A further rather unusual impact by *Stichotrema* was seen on the morphology of mature eggs. Over 50% of mature eggs sampled from stylopized female *Segestidea* exhibited the following abnormalities: reduction in overall length (<12mm), variations in form and colour, an unusual flocculent coating over the eggshell, and a bizzare balloon-like structure on some severely affected eggs. The physiological mechanism responsible for this phenomenon is not known thus requires further study.

The effects on reproductive characters in *Segestidea* due to stylopization by *Stichotrema*, together exhibit the symptoms of ‘parasitic castration’ or ‘stylopization syndrome’, a well-known phenomenon in stylopized Hymenoptera and Hemiptera. This castrative effect on the host’s reproductive characters can be viewed as a parasite survival strategy (Baudoin, 1975), which has been suggested to remove potential competition for glycogen and lipid reserves (Reed-Larson & Brown, 1990) and/or to reduce reproduction in hosts which would otherwise shorten the host’s lifespan (Thompson, 1983; Barnard, 1990). These effects may result from withdrawal of nutrients required by the host for reproduction (Baudoin, 1975; Reed-Larson & Brown, 1990), active suppression by the parasite of oocyte maturation (Thompson, 1983; Hurd, 1993), or from secretion of castrative hormone by the parasite (Baudoin, 1975), so that nutrients from the target organs can be made available to sustain host longevity and parasite development. Hurd (1993) suggested three categories of impact of parasites on host reproductive performance: (i) inhibition of host mating due to morphological or behavioural changes, (ii) destruction of host reproductive tissue, and (iii) reduction of egg output due to malfunction of ovarian yolk sequestration. The evidence presented here would indicate that reduced reproductive performance in *Segestidea* due to stylopization by *Stichotrema* could fall into catergories (ii) and (iii). The first may also have occurred, although mating has been observed (Solulu, 1996) among stylopized hosts. The reduced fecundity and reproductive efficiency due to parasitic castration

in *Stichotrema*-infected *Segestidea* would appear to have important implications for a biological control strategy.

The host carcass dry weight, excluding weight of parasites, digestive and reproductive organs, was found to have been significantly reduced in stylopized male and female sexavae as compared to unstylopized hosts. I is likely that this reduction relative to measure of wet weight (which did not defer between healthy and parasitized hosts) largely resulted from weight loss due to removal of the parasites.

Significantly reduced lipid levels were found in the carcass of stylopized *Segestidea* as compared to unstylopized hosts. The presence of one stylops reduced lipid levels by almost 54 % in males; while in females a slight increase was seen. However, at increased stylops density per host, lipid levels decreased considerably in both sexes. For instances, a 65% reduction in carcass lipid was found when stylops numbers were more than 3 per host in both sexes. Utilization of host lipid by endoparasitic insects has been reported in the literature (eg. Hawlitzky & Mainguent, 1976). It seems that stichotrema was either absorbing and digesting its nutritional lipid requirement from its host tissues, hence the reduced levels in the carcass, or more likely, the strain on host nutrition provided by the parasite either in the form of reduced intake or sequestering of hosts nutrients led to depletion by the host of it's lipid storage tissues.

Stylopization was associated with elevated % nitrogen in the carcass of both male and female *Segestidea*. Presence of one stylops increased % nitrogen in female sexavae, but this was not obvious in stylopised males. When there were more than one stylops per host, females showed a relative decline, while males had an increase in carcass % nitrogen. However, at higher stylops density ($\geq$ 4 per host) females also exhibited appreciable increase in carcass % nitrogen. When absolute carcass nitrogen was considered, however, levels were significantly lower for parasitized hosts, indicating that the rise in % carcass nitrogen was the result of an even more pronounced decline in carcass lipid content. Perhaps, however, stylopised *Segestidea* may have accumulated and converted relatively more food nitrogen into their body tissues than did unstylopized hosts.

The reduced feeding and reproductive performance in *S. novaeguineae* parasitized by *S. dallatorreanum* signifies the enormous potential of the strepsipteran as an effective BCA against species of sexavae in PNG. These results may have also provided, for the first time, possible explanation to the non-economic level of sexavae infestation on the mainland of PNG, where the endoparasite is found. Circumstantial evidence from Oro (a mainland province) also supports this inference and includes: the relatively high incidence of the external evidence of stylopization, 34% per year (range of 11 - 58 %); the fact that no chemicals have been applied to treat S. *novaeguineae* infestation since 1987 (PNGOPRA Records), and the low level of damage to oil palm foliage observed annually in the area, despite S. *novaeguinea*e being phenotypically larger and ingesting more plant material per insect, as compared to S. *decoratus* and *S. defoliaria* (Solulu, 1996). The impact by the strepsipteran on feeding and reproductive performance, including effects on morphology and biochemistry of S. *novaeguineae*, thus provides essential information for assessing the potential of *Stichotrema* as a BCA against similar species of sexavae in the island region, particularly S. *defoliaria* and *S. decoratus* in West New Britain. Although captive rearing of S. *dallatorreanum* until the entrusion of the cephalothorax had been reported in *S. defoliaria* (O' Connor, 1959; Prior, 1987) and *Segestidea uniformis* (Willemse) (J.Ardley, cited in Young, 1978a), further development and establishment of the stylops on these host species was unsuccessful. This was mainly due to the lack of basic biological information about the stylops, especially its life history, mode of reproduction and interaction with the hosts, hence indicating that basic research remains to be done before any attempts can be made to infect other species of sexavae with the strepsipteran. A more thorough understanding of the physiology of the sexavae-stylops interaction, relating to feeding, reproduction, nutritional biochemistry and behaviour is essential to effectively utilize and engage S. *dallatorreanum* as a BCA in a more sustainable IPM system for control of sexavae.

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Integrated control of *Oryctes rhinoceros*, a pest of oil palm in Papua New Guinea

(Ross Safitoa)

Introduction

The Asiatic Rhinoceros beetle, *Oryctes rhinoceros* (L) (Coleoptera: Scarabaedae - Dynastidae) is an important pest of palms, particularly coconut (*Cocos nucifera*) and oil palm (*Elaeis guineensis)* in Southeast Asia and the Pacific region. In Papua New Guinea (PNG) attacks to coconut palms were recorded in Manus, New Ireland, East New Britain and West New Britain provinces. Although not much information is known about the levels of damage and occurrence of *O. rhinoceros* on oil palm plantings in PNG, Solulu (unpublished data) first recorded attacks on younger plantings (1-2 years) at Numondo plantation in West New Britain province.

Damage is caused by the adults boring through young leaf base and feeding on the succulent spear and soft tissues within. Prolonged and serious *Oryctes* damage can result in considerable loss of early yield. About 40% of the first years crop can be lost; with another 10% of the second years, making it about 25% loss of the two years crop (Suan and Alwi, 1991).

Control methods of *Oryctes rhinoceros* (L) damage to oil palms have concentrated on physical, chemical and biological means. For the former, destruction of breeding grounds by clear burning of stems and decomposing organic matter is effective. But because of agronomic, economic and practical benefits only partial burning and trunk shredding operations have been selectively employed. Rhinoceros beetles also breed in partially burnt and shredded palm trunks, but the decomposition period is much shorter resulting in reduced damage compared to under planting technique. Palm disposal operations in either an oil palm to oil palm or coconut to oil palm replanting situations augment pest population levels, particularly where poisoned unfelled stems or poisoned felled stems are exposed to entry. Moreover, empty fruit bunches in large heaps in immature plantations are suitable breeding sites for *Oryctes*, and young plantings on sites previously infested are also susceptible to *Oryctes* attack. Creeping legume plants (cover crops) are planted to cover felled palms, and therefore act as a "vegetative barrier" which suppresses the activities of the pest in immature plantations (Wood, 1968).

The release of the adult Rhinoceros beetle infected with entomopathogenic organism, a virus *Oryctes baculovirus*, as biocontrol agent is another useful control tool. The viral *O. baculovirus* was introduced into several of the Pacific Islands, including PNG in 1978 - 1979 (Gorick, 1980) to control the coconut pest. The viruses infect both the larvae and the adult by entering the gut tissue causing white, swollen and milky mucoid fluid to develop within.

The potential use of the aggregation pheromone (AP) to control *Oryctes rhinoceros* (L) has been reported (Anon, 1996). The AP, ethyl 4-methyloctanoate, can be used to capture adult *Oryctes*, and it is then possible to infect them with an entomopathogen and release them back into the field.

The objective of our work was to control Rhinoceros beetle (*Oryctes rhinoceros*) populations, and hence to prevent damage to young oil palms at Numondo plantation, West New Britain Province.

To achieve these objectives we used a combination of cross-vane traps, Sime RB aggregation pheromone (ethyl 4-methyloctanoate) and the Rhinoceros beetle virus Oryctes *baculovirus*, in combination with regular population monitoring and the establishment of good leguminous cover crop, in an integrated pest management scheme.

Materials and methods

Description of Numondo Plantation

Numondo Oil palm plantation is located approximately 10 km north of the Township of Kimbe, West New Britain Province (Fig. 1). The site was covered with coconut palms that were severely infested by *Oryctes rhinoceros*. After the acquisition of the area by New Britain Palm Oil Limited (NBPOL) part of the northern tip of the area was planted with oil palm in 1994 and 1995. The Talasea Highway runs through the plantation dividing the oil palm plantings (474.3 ha) to the east towards the coastline and the coconut plantation (901.3 ha) to the west (Figure 1).

Cross-vane traps

Each trap was made up of a Sime RB pheromone sachet, a plastic bucket, a 2 metre long wooden stilt and a black painted cross-vane. The vane was 46 cm in length and shaped in such a way that the bottom end fitted into the taper end of the bucket. This left the top half of the vane (23cm) sticking out of the bucket. The bucket was 30cm in height so that the bottom end off the cross-vane did not touch the bottom of the bucket. Holes were punched into the bottom of the bucket to drain out water. The trap was placed on a two metre wooden stilt erected firmly off the ground. A wooden pole wedged at the tip was used to lower and place the trap back up (see figure 2).

Cross-vane trapping methodology

The traps were set up on two different occasions. On the first occasion from 1 August to the 9 October 1996, and the second from 14 January to 13 August 1997. The studies lasted 10-weeks and 30-weeks respectively.

On 1 August 1996 a total of 10 traps were set up in the older plantings at a spacing of approximately one trap per two hectares. The traps were placed parallel to the Highway and were emptied every week. Of the total insects caught, 100 rhinoceros beetles were selected, infected with baculovirus, painted white and then released back into the field. The remaining beetles were killed.

For the second trial starting on 14 January 1997, a total of 44 traps were set up at Numondo plantation. The traps were spaced at approximately one every two hectares and positioned in the 1995 plantings. A total of 24 traps were placed parallel to the main road and positioned 12 to 15 palms back from it. Another 9 traps were erected in the first block of the new plantings (on top and around the base of the hill), and 4 traps were positioned at each corner of an experimental block (coconut logs exposed for an OPRA Ganoderma survey). The remaining 7 traps were put out in the coconut plantation, parallel to the main road and 20 meters back from it.

Figure 1. Map of Numundo plantation showing the areas of young oil palm planted since 1994/95 and the coconut plantation.

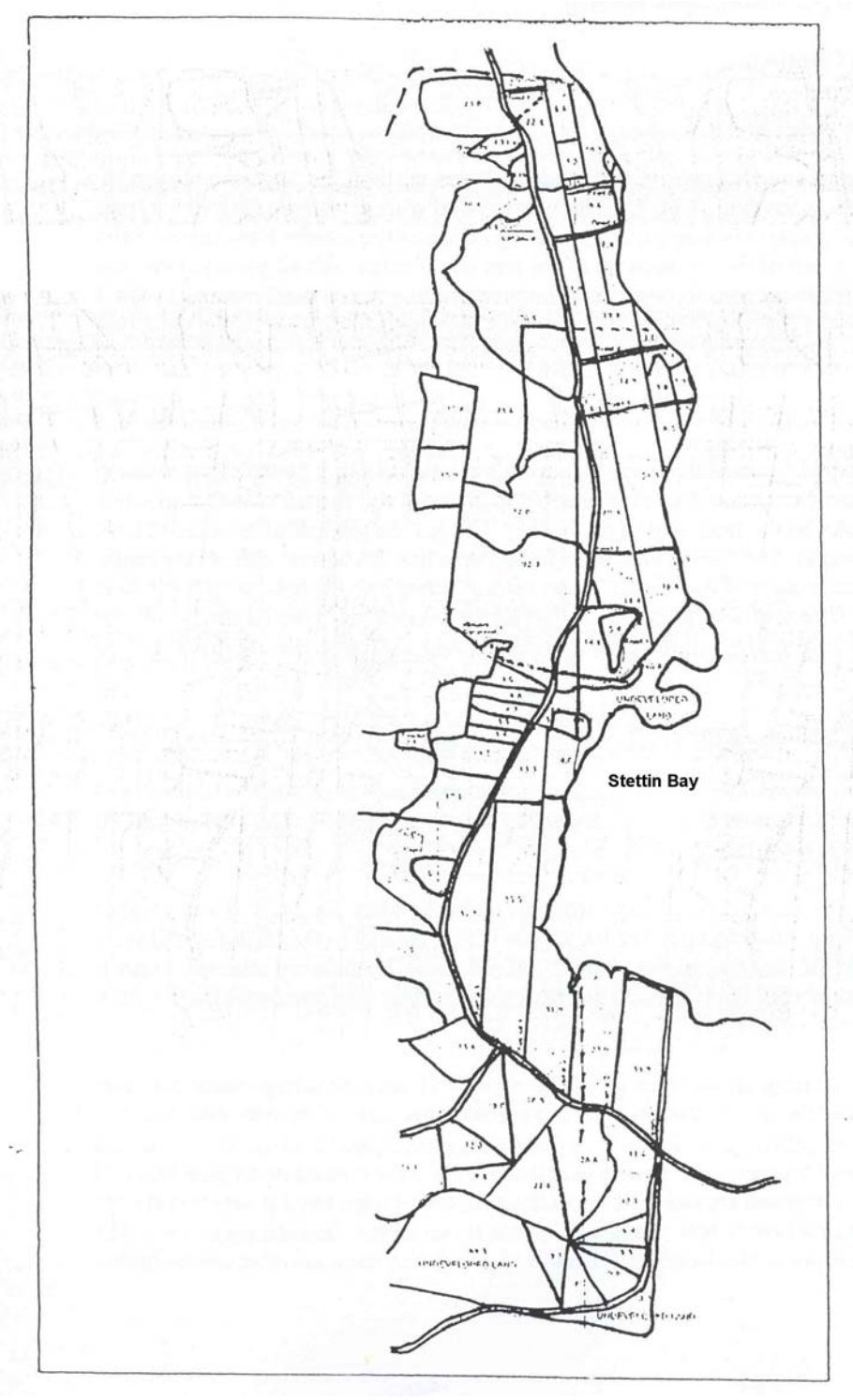
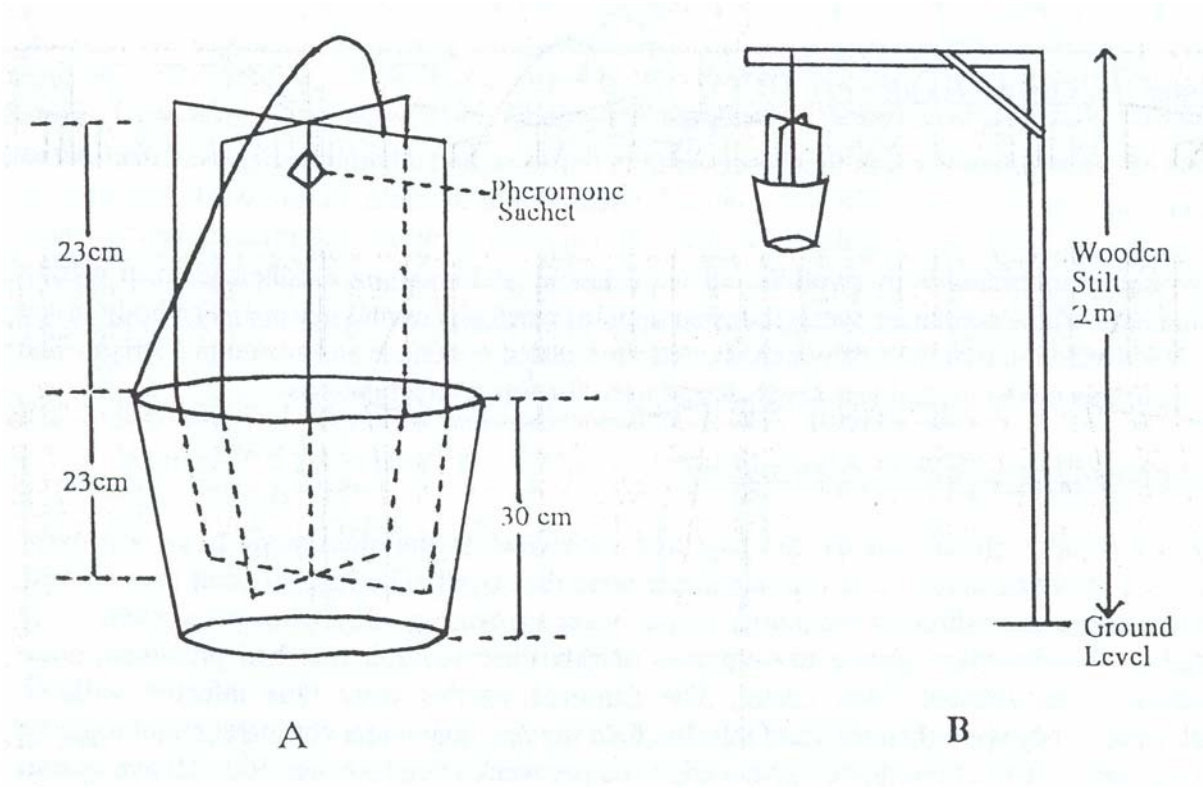


Figure 2. Rhinoceros beetle traps - design of (A) cross-vane in a bucket and (B) bucket on a wooden stilt.



Use of *Oryctes rhinoceros* aggregation pheromone

The *O. rhinoceros* aggregation pheromone was made by Chem Tica International (CTI) S.A. of Costa Rica. This was initially supplied in heat-sealed polymer membrane bag devices that release the formulation over a 10-week period. A pheromone sachet was securely placed at the tip of each cross-vane bucket and positioned the locations within the plantations as described previously.

Screening for *Oryctes baculovirus*

In 1995 *Oryctes rhinoceros* was first discovered in this area, and a batch of *Oryctes baculovirus* inoculum was obtained from CCRI Keravat and released into the field. Future work then utilised the virus present in the field population to infect the captured adult beetles. Infected larvae, which were visually identified with swollen and black/brown abdomens were collected from rotting coconut logs. These specimens were chopped into small pieces and mashed. The body tissue was then divided in two, half of which was put in a sealed container and stored in a fridge. The other half was mixed in soil and sawdust and used for future inoculations.

Inoculation of beetles with *O. baculovirus*

Of the total adult rhinoceros beetles captured each week in the pheromone traps, 100 were selected and divide in half, and the remainder were destroyed. The first 50 adult beetles were upturned and infected through the mouth with a water suspension of the virus via a pipette. The second 50 beetles were placed in container of saw dust and soil that had previously been inoculated with infected body tissue. The captured beetles were thus infected with *O. baculovirus*. They were then released into the

field the next day under rotting coconut logs. In some instances the total number of adults captured per week were less than 100. All live beetles in this case were infected.

Results

The results of the pheromone experiments are shown in Figures 3 and 4.

In the first trial (Figure 3) a peak total of 270 adult rhinoceros beetles (both male and female) were captured in the first week. There was then a gradual decrease from week 1 to week 5, and then after that an almost constant gradient to week 10. A similar trend can be seen in the second trial (Fig 4). The highest number of adult beetles were captured in the trail were during week 3 (N= 578) and the lowest during week 10 (N=14). After changing the pheromone sachets during week 10 the total number of captured adults increased during week 11 (N=534) and then dropped for the next 9 weeks. A similar pattern is apparent from weeks 20 to 30.

It can be seen that the pheromone attracts adults of both male and female rhinoceros beetles.

The trapping intensity in the older plantings (August - October, 1996) was 10 traps for 20 hectares, while in the younger plantings it was 44 traps for 88 hectares. Although these figures vary, a comparison can be made between the average numbers of adults caught per week for each study. In the first trial, from August to October 1996, an average of 97 adult rhinoceros beetles were caught per week. In the second trial, which ran from January to August 1997, an average of 293 adults were captured per week.

In the second trial a number of traps fell during weeks 8 to 10, and this contributed to the steep reduction in beetles caught during this period. A total of 35 traps were left for the remainder of the trial.

Figure 3. Mean number of adult Oryctes rhinoceros caught per RB pheromone trap at Numundo Plantation (1 trap/2 ha)

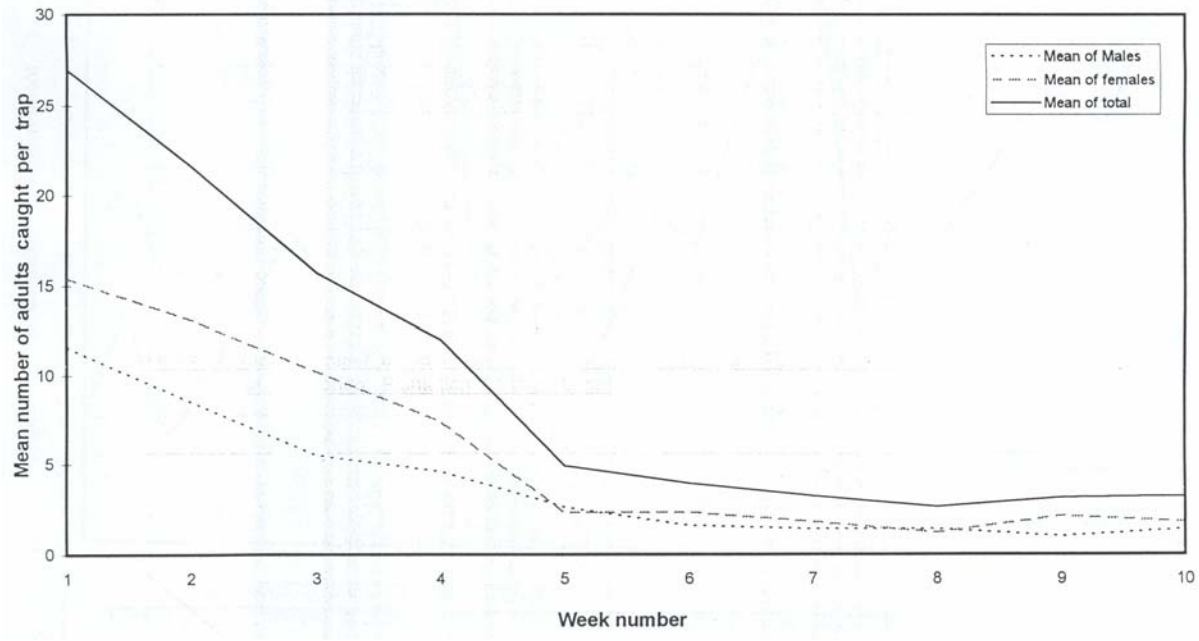
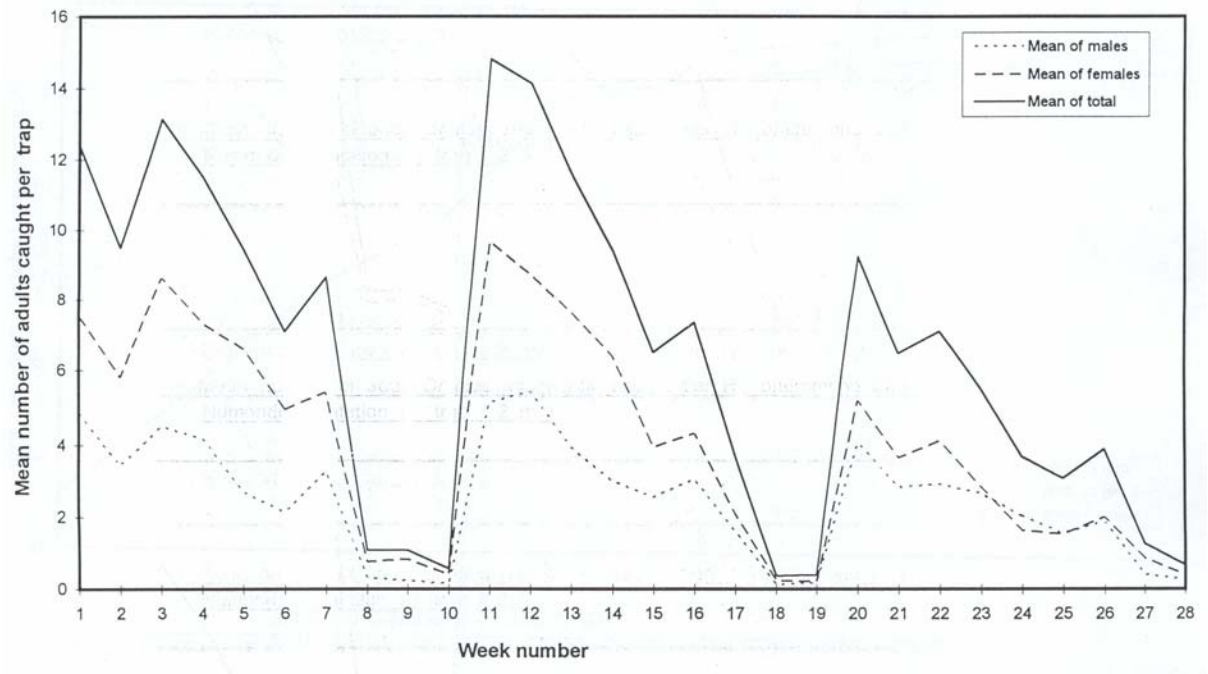


Figure 3. Mean number of adult Oryctes rhinoceros caught per RB pheromone trap at Numundo Plantation (1 trap/2 ha)



Discussion

Luring adult rhinoceros beetles by use of a pheromone can help suppress O. rhinoceros population biologically and physically. Releasing a portion of the captured beetles infected with Oryctes baculovirus helps spread the disease into the wild pest population, while the other portion can be destroyed physically.

A total of approximately 600 and 2000 virus-infected adults (both males and females) were released at Numondo plantation by the end of October 1996 and August 1997 respectively. This number of infected adult beetles should be sufficient to spread the disease and suppress pest population throughout the whole plantation within two to three years. The virus is usually well established itself about 9 months after introduction, and then maintains a low level of the pest for 3-4 years afterwards (Mohan and Pillai, 1993).

Although the damage caused by adult rhinoceros beetles was serious in both the 94 and 95 plantings, high populations were concentrated on the younger plantings (1-2 years old). This probably resulted from the presence of felled coconut logs that were yet to be covered by the leguminous crop. Whereas in the older plantings these logs were well covered by the legume, and the breeding sites were therefore not accessible.

Conclusion

Large numbers of adult *O. rhinoceros* have been trapped at Numondo Plantation, and some of these have been infected with *Oryctes baculovirus* and released back into the field. Trapping has provided short term suppression of the beetle population, and the introduction of the virus will result in long term population management. These factors together with a good establishment of cover crop, and the rapid development of the oil palm seedlings will provide effective integrated pest management for *O. rhinoceros* at Numondo Plantation.

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Fungal pathogens for the control of insect pests of oil palm in Papua New Guinea

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Abstract

Oil palm is the second most important cash crop in Papua New Guinea, and in 1995 its export value was US$128 million. The principal pests of oil palm in PNG are a group of tettigonids, collectively known as Sexava, which cause damage by defoliating the oil palm tree. Severe defoliation causes reductions in photosynthesis and fruit production, resulting in yield losses. Control of these pests is currently reliant upon the use of trunk-injected monocrotophos. Because of difficult application methods, poor monitoring procedures, and the difficult environment, chemical control usually occurs too late to prevent significant yield losses. Furthermore the application of chemicals is expensive and environmentally undesirable. This paper describes the first phase of a project to develop the use of fungal entomopathogens as control agents for use against Sexava. Surveys were undertaken in the oil palm agroecosystem to find fungal pathogens virulent against the target pest. Forty-nine fungal isolates were found, and these were tested in laboratory bioassays for virulence against Sexava. The results of these studies are presented in this paper.

Introduction

The development of the oil palm industry

The oil palm industry in PNG has successfully developed under the nucleus estate system. Under this system the projects are divided into two parts: the nucleus estate, and smallholder schemes. The nucleus estates are large central plantations, run as joint ventures between the government and private enterprise. Each estate has its own processing mill and exporting facilities. Around the nucleus estate smallholders grow oil palm on small (4-5 hectare) blocks. Smallholders are either villagers living in the area, or settlers brought in from other areas. The nucleus estate is therefore a stable business, growing, processing, and exporting palm oil. The estate also provides the smallholders with services such as planting material, technical and management advice, marketing, processing and export facilities. Over the past 30 years the oil palm industry in PNG has development into a dynamic and successful agricultural enterprise. During this period it has been the only agricultural industry in PNG that has had continual investment for expansion and development. In 1995 oil palm became PNG's second largest agricultural industry behind coffee, with an export value of US$128 million. Approximately 63 thousand hectares of oil palm are currently being cultivated in PNG.

Insect pests of oil palm

The principal pests of oil palm in PNG are a group of species from the tettigoniidae family (Orthoptera), known as bush crickets, long-horned grasshoppers or treehoppers. This group of species are collectively called Sexava. Three species of Sexava are pests of oil palm in PNG, *Segestes decoratus*, *Segestidea defoliaria*, and *Segestidea novaeguinea*. These insects cause damage by feeding on oil palm fronds, and defoliation levels can be very severe where high population densities occur. Young (1985) described the basic biology and life cycles of this group of species.

Sexava control is currently reliant upon the use of trunk-injected monocrotophos (Nuvacron or

Azodrin) (Sarjit, 1986; Matthews, 1992). Monocrotophos (10ml of 400ml ai/l formulation) is injected into a single 1.5cm diameter hole, 15cm deep and drilled at a 45^{o} angle into the trunk, 1m above the ground. The monocrotophos persists for approximately 60 days in the leaf tissue of the palm, and provides good field control of Sexava. A follow up treatment is required after approximately 12 weeks to coincide with the emergence of nymphs from eggs laid by the original pest population.

This method of pesticide application is effective if performed properly. It confines the insecticide to the tree and therefore has a negligible effect on non-target organisms. Treatment is however very time consuming, especially when high Sexava populations affect large areas of plantation. Treatment of remote areas is also difficult, and control operations are severely disrupted during the rainy season. These application difficulties, along with generally poor monitoring procedures, usually means that chemical control often occurs too late to prevent significant yield losses, particularly for the smallholder crop. Furthermore the application of chemicals is very expensive and our current research effort is directed towards reducing pesticide inputs. We are therefore undertaking research to develop alternative methods for Sexava control.

Microbial insecticides

For an entomopathogen to have potential as a microbial insecticide it must have the following characteristics; virulence, predictability of control, ease of application, ease of production, environmental acceptability, and it must be also able to reduce pest populations to below economic thresholds (Burgess and Hussey, 1971). These are all attributes of chemical insecticides with which microbial insecticides have to compete.

A variety of microbial insecticides have been tested against Orthopteran pests in Africa and North America (Prior and Lomer, 1992). Potential control agents include microsporida (Henry, 1971), nematodes (Capinera and Hibbard, 1987), entomopoxviruses (Street and McGuire, 1988), and fungi (Prior, 1992). The deuteromycetes fungi *Metarhizium* and *Beauveria* show great potential as microbial insecticides for short-horn grasshoppers and locusts (Moore *et al.*, 1992; Bateman *et al.*, 1993a; Bateman *et al.*, 1993b; Lomer *et al.*, 1993; Jenkins and Thomas, 1996; Moore *et al*., 1996), and are currently being developed for field use by the International Institute of Biological Control (IIBC) in the UK and the International Institute of Tropical Agriculture (IITA) in West Africa. This paper describes the preliminary findings of a collaborative research programme between the Oil Palm Research Association in PNG and IIBC in the UK. The objective being to develop fungal entomopathogens for Sexava control.

Materials and Methods

Surveying for fungal pathogens in the oil palm agroecosystem

Surveys for fungal pathogens of Sexava were undertaken from November 1996 until May 1997. Two separate methods were used for the surveys:

1. Surveying for fungal pathogens from individual Sexava hosts
2. Surveying soil samples collected from the oil palm agroecosystem for fungal pathogens

During the study several thousand Sexava were collected from the field in West New Britain Province, and stored in large walk in insectaries located at the Oil Palm Research Association's Dami and Hargy Research bases. Young oil palm seedlings were put into the insectaries to provide food for the captive insects. The insectaries were checked daily for dead Sexava. Cadavers were collected and placed in small plastic food containers and sprayed with water to provide the high humidity necessary for the development of entomopathogenic fungus within the insect host. The boxes were opened each day and the cadavers checked for external signs of fungal sporulation. Surveying work also included scouting for Sexava cadavers in areas of high pest populations. The cadavers were collected, brought

back to the laboratory, and again placed in plastic food containers to provide the necessary humidity required for fungal sporulation. Unfortunately no evidence of fungal pathogens was found from the Sexava cadavers collected from the laboratory cultures or from the field during these surveys. We therefore used a soil isolation technique to survey for potential fungal pathogens.

In November 1996 several hundred soil samples were taken from the oil palm agroecosystem in West New Britain Province (approximately 5g of soil for each sample). These samples were then taken back to the International Institute of Biological Control in the UK and screened for the presence of fungal pathogens with potential virulence against Sexava.

Isolation and culturing of pathogens in the laboratory

Fungal isolates were obtained from the soil samples by baiting with Greater Wax Moth larvea, *Galleria mellonella* (Lepidoptera: Pyralidae), which are highly susceptible to pathogens. Two larvea per soil sample were placed in a polythene minigrip bag and stored in the dark at 25^{o}C. The samples were observed daily and the soil was kept moist by adding small quantities of distilled water. Dead *G. mellonella* were removed daily, and surface sterilised by washing in 70% alcohol followed by rinsing in sterile distilled water.

The cadavers were divided into three groups. The first group had suspected mycosis and the cadavers had characteristic pink coloured bodies. These cadavers were placed onto damp filter paper scaled in a 30mm petri dish and stored at 25^{o}C to encourage external sporulation of the fungus. The second group of cadavers had soft and natural coloured bodies, with death possibly being due to nematode infections. To extract the nematodes from the cadavers a 55mm filter paper was mounted on a 30mm petri dish lid placed inside a 90mm petri dish and sterile distilled water was poured into the larger dish. This allowed the edge of the filter paper to touch the water and become damp while keeping the cadaver out of the water. Nematodes leaving the cadaver could therefore enter the water via the filter paper. If the cadavers did not fall into the first two groups they were assumed to have died from other causes and no further investigations were carried out.

Any cadavers exhibiting signs of external sporulation were removed and samples of spores streaked onto potato carrot agar containing antibiotics (PCA + Ab) to remove any contaminants and to allow separation of the different types of fungus. The different isolates were then stored in the IIBC culture collection. A total of 49 fungal isolates were found using this method. Figure 1 shows the oil palm growing areas in West New Britain were the soil containing these isolates were collected, and details of the type of fungus found are given in Table 1.

Any cadavers exhibiting nematode infection were sent to the International Institute of Parasitology (UK), along with the relevant soil samples, to be identified. No further work was done on these during this study, but the specimens will be kept for possible work in the future.

Bioassay of isolates against target pest

Bioassays of 49 fungal isolates extracted from the soil samples were undertaken in Papua New Guinea in May 1997. Conidial suspensions of the isolates were obtained by pouring approximately 3ml of kerasene oil onto the culture plates and scraping the fungus away from the agar. The resultant suspension was then filtered through a 75um sieve and shaken vigorously. For the bioassays two micro litres of condial suspension was placed under the pronotum of each adult *S. defolaria*. Five test insects were used for each of the 49 fungal isolates and a control group was dosed with pure kerosene oil only (no fungus). After treatment the five adults for each group were placed in a plastic container (30x20x10cm) and monitored for seven days. The test insects were given fresh oil palm leaves each day, and any cadavers removed and put into clean boxes to encourage external.

Results and Discussion

Details of the source of each of the 49 fungal isolates, the types of fungus that were found, and the accumulated daily mortalities resulting from laboratory bioassays using adult *S. defolaria* are given in Table 1. Most of the identified entomopathogens were *Metarhizium* sp, probably *anisopliae*, but there were also several isolates of *Paecilomyces lilacinus*. In the bioassays control mortality was high and although a few isolates achieved 100% mortality, no cadavers exhibited signs of external sporulation.

All the isolated used in the bioassay were extracted from soil samples baited with larvae of *G. mellonella*, which are highly susceptible to pathogens. However the most effective way of finding pathogen susceptible to the target organism, i.e. Sexava, is by isolation from infected individuals. To date no infected Sexava adults have been obtained. However, eggs infected with *Metarhizium* and *Paecilomyces* have been found. These need to be bioassayed to check susceptibility against Sexava adults, and to determine pathogenicity. The isolates may have come from external growth from soil contaminants, or may be only effective against eggs.

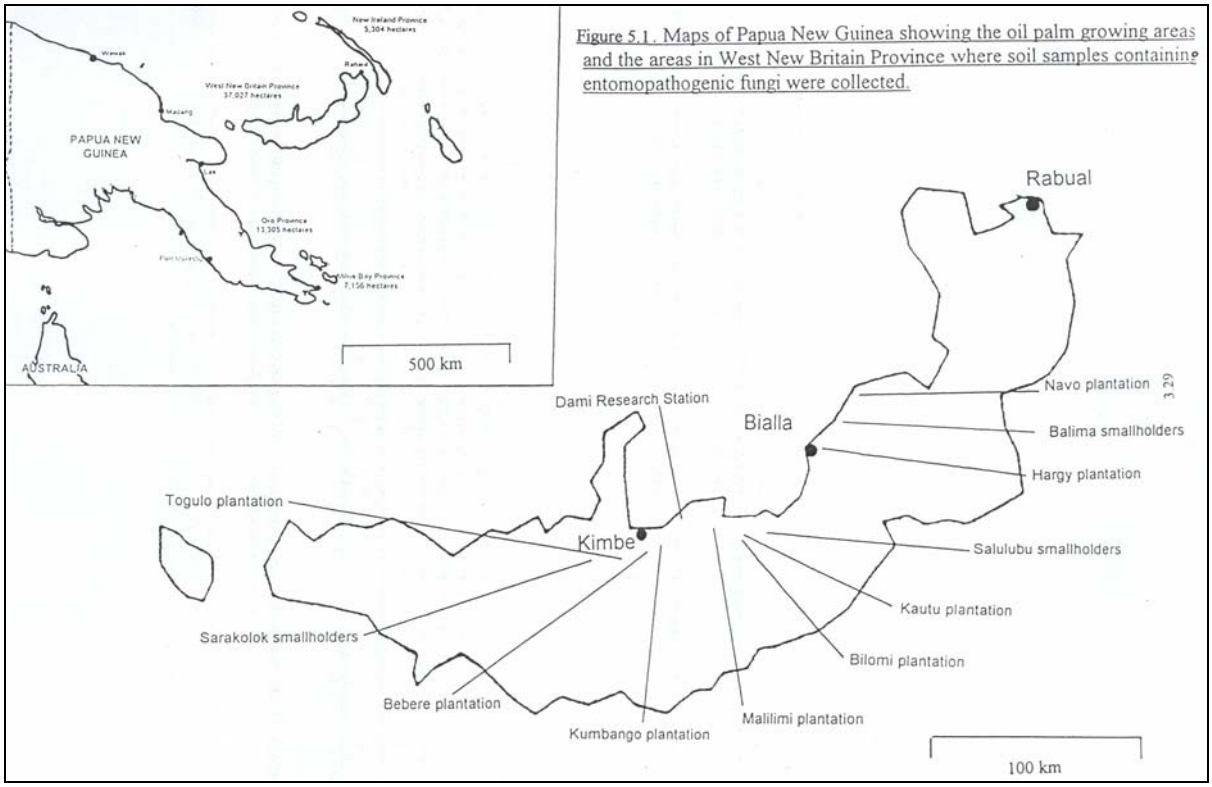

Figure 5.1. Maps of Papua New Guinea showing the oil palm growing areas and the areas in West New Britain Province where soil samples containing entomopathogenic fungi were collected.

Other techniques are required for obtaining suitable pathogens. Kooyman and Shah (1992) suggest site monitoring and point surveys as direct methods to find infected specimens. Furthermore, it is more likely to find infected individuals in high populations. This could simply be achieved by allowing some oil palms to become heavily infected during an outbreak. The population would become stressed due to high densities and, ultimately, food shortages. Disease expression would be more likely under those conditions, thus, increasing the likelihood of finding infected specimens.

The bioassay controls also need attention. Many of the Sexava died due to the stresses of handling, cramped conditions, and being sprayed with water. To overcome these problems larger individual boxes for the Sexava, plus less handling, and no spraying would create a less stressful environment for the test insects. This would prolong their lives, and allow the fungus to establish itself effectively.

Table 1. Details of the source of each of the fungal isolates, and the accumulated daily mortalities resulting from laboratory bioassays using adult *Segestes defoliaria*

Bioassay Number	Source of soil sample	Type of fungus isolated	Accumulated daily mortality (%)							
			Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Sporulation
1	Control	Blank oil	0	20	20	40	60	80	100	no
2	Navo plantation	*Metarhizium* sp.	0	0	0	20	60	100	100	no
3	Malilimi plantation	*Metarhizium* sp.	0	0	20	20	40	40	60	no
4	Area 4, Hargy plantation	*Metarhizium* sp.	0	0	0	40	60	80	80	no
5	Sarakolok smallholders	*Metarhizium* sp.	0	0	0	20	40	60	60	no
6	Bilomi plantation	*Metarhizium* sp.	20	20	20	20	40	100	100	no
7	Balima smallholders	*Metarhizium* sp.	0	0	0	0	20	40	40	no
8	Area 7, Hargy plantation	*Metarhizium* sp.	0	0	0	0	20	80	100	no
9	Area 9, Hargy plantation	*Metarhizium* sp.	0	0	0	40	60	60	80	no
10	Area 2, Hargy plantation	*Metarhizium* sp.	0	0	0	0	0	20	60	no
11	Bilomi plantation	*Metarhizium* sp.	0	0	0	20	20	20	60	no
12	Malilimi plantation	*Metarhizium* sp.	0	0	0	20	40	60	60	no
13	Balima smallholders	*Metarhizium* sp.	0	40	40	40	60	60	80	no
14	Sarakolok smallholders	*Metarhizium* sp.	0	0	0	0	20	20	60	no
15	Area 2, Hargy plantation	*Metarhizium* sp.	0	0	0	0	0	20	20	no
16	Area 6, Hargy plantation	*Paecilomyces* sp.	0	0	0	0	20	40	60	no
17	Area 6, Hargy plantation	*Paecilomyces* sp.	0	0	0	0	20	40	100	no
18	Dami Research Station	*Metarhizium* sp.	0	0	0	0	0	20	80	no
19	Kautu plantation	*Paecilomyces* sp.	0	0	0	20	20	20	20	no
20	Area 4, Hargy plantation	*Paecilomyces* sp.	0	0	0	40	40	40	60	no
21	Area 2, Hargy plantation	*Metarhizium* sp.	0	0	0	40	40	40	40	no
22	Kumbango plantation	*Paecilomyces* sp.	20	20	20	20	40	40	80	no
23	Area 4, Hargy plantation	*Paecilomyces* sp.	0	0	0	0	0	60	60	no
24	Malilimi plantation	*Paecilomyces* sp.	0	0	0	20	20	20	20	no
25	Sarakolok smallholders	*Metarhizium* sp.	0	0	0	60	60	80	80	no
26	Togulo plantation	*Metarhizium* sp.	0	0	0	40	40	60	80	no
27	Salulubu smallholders	*Metarhizium* sp.	0	0	0	20	60	60	80	no
28	Dami Research Station	*Metarhizium* sp.	0	0	20	20	20	40	60	no
29	Malilimi plantation	*Metarhizium* sp.	0	0	0	20	20	40	60	no
30	Navo plantation	*Metarhizium* sp.	0	0	0	0	0	20	60	no
31	Kautu plantation	*Metarhizium* sp.	0	0	20	40	40	60	60	no
32	Kautu plantation	*Metarhizium* sp.	0	0	20	80	100	100	100	no
33	Balima smallholders	*Metarhizium* sp.	0	0	0	40	40	60	80	no
34	Balima smallholders	*Metarhizium* sp.	0	0	0	0	0	0	0	no
35	Area 2, Hargy plantation	*Metarhizium* sp.	0	0	0	20	20	40	60	no
36	Navo plantation	*Metarhizium* sp.	0	0	0	0	0	20	80	no
37	Area 11, Hargy plantation	*Metarhizium* sp.	0	0	0	40	60	60	80	no
38	Area 4, Hargy plantation	*Paecilomyces* sp.	20	20	20	20	20	20	40	no
39	Balima smallholders	*Metarhizium* sp.	0	0	0	20	40	40	80	no
40	Togulo plantation	*Metarhizium* sp.	0	0	0	0	0	80	80	no
41	Salulubu smallholders	*Metarhizium* sp.	0	0	0	0	0	40	60	no
42	Bebere plantation	*Metarhizium* sp.	0	0	0	20	20	60	100	no
43	Bilomi plantation	*Metarhizium* sp.	0	0	0	0	20	40	100	no
44	Kautu plantation	*Metarhizium* sp.	0	0	0	0	0	0	20	no
45	Area 11, Hargy plantation	*Metarhizium* sp.	0	0	0	60	60	100	100	no
46	Bilomi plantation	*Metarhizium* sp.	0	0	0	40	40	80	100	no
47	Balima smallholders	*Metarhizium* sp.	0	0	0	20	20	20	60	no
48	Navo plantation	*Metarhizium* sp.	0	0	20	80	80	80	80	no
49	Area 6, Hargy plantation	*Metarhizium* sp.	0	0	20	60	80	100	100	no
50	Bilomi plantation	*Metarhizium* sp.	0	0	0	20	20	40	40	no

The wide occurrence of the entomopathogenic fungus around the oil palm plantations was encouraging, and indicated that the agricultural techniques used on the estate do not inhibit the survival of pathogens. The microenvironment in the oil palm crown itself appears to be very amenable to fungal entomopathogens, as it is well shaded and usually has a high humidity. It is likely that it is only a matter of time before appropriate fungal isolates to control Sexava are found and further investigations can be initiated.

The surveys demonstrated that there are several options for application of entomopathogenic fungus, depending on the age of the palm and the available resources. These methods include: incorporation of the pathogen into the soil around the trees to infect ovipositing females and newly hatched nymphs, crown application of a spray formulation, and a banding system. Thus there is potential for mycopesticide development to control Sexava in the oil palm agroecosystem as part of an integrated pest management system, but it is dependent on obtaining effective isolates

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Fine structure of *Segestidea novaeguineae* (Branscik) and its Strepsipteran parasitoid, *Stichotrema dallatorreanum* (Hofender)

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Materials and methods

Specimens for this study were collected in Popondetta, Papua New Guinea. The larvae and adult stages of *Stichotrema* were dissected from the host *Segestidea* in fixative (2.5% glutaraldehyde and 4% paraformaldehyde in 0.1M cacodylate buffer, pH 7.2), and female Strepsiptera were suitably cut to enable the penetration of the fixative, and placed the fixative overnight, then rinsed in cacodylate buffer and brought back to Oxford. The specimens were then placed in 1% osmium tetroxide, dehydrated with graded series of ethanol and embedded in Araldite. Specimens that were sent to live in Oxford were fixed as above, rinsed the next day in cacodylate buffer, placed in 1% osmium tetroxide, dehydrated, and embedded in Araldite. Sections were cut with a Richert Jung Ultracut, stained with toluidine blue (1 µm sections) and uranyl acetate and lead citrate (ultra-thin sections) and observed under a Philips EM 400T transmission electron microscope.

For the scanning electron microscope, the specimens were stained in 75% alcohol, dehydrated in a graded series of alcohol, then placed in acetone, critical point dried, sputter coated with gold, and examined in a Philips SEM 600.

Reproduction of *Segestidea novaeguineae*

Strepsiptera are different from other insect parasitoids in that the 1st instar host-seeking larvae parasitize the host by direct entry. In other parasitoids, the mother oviposits in the host. After entry in the host, the female *Stichotrema* spends her entire life (including nurturing her young) in a living *Segestidea*. All other insect parasitoids kill their hosts either during, or after, larval development, and therefore pupate in, or near, a dead host. The fitness of the host parasitised by Strepsiptera is thus often drastically affected. Strepsipterans can therefore be excellent biocontrol agents. Knowledge and greater understanding of the reproductive physiology of *Segestidea* such as how and why the Strepsipteran parasitoid *Stichotrema* may interfere with the reproduction of its host *Segestidea*, may enable us to find ways of reducing the damage done by the pest.

Fifty percent of stylopised *Segestidea* had eggs with a large bubble like structure (Solulu, MSc thesis, unpublished) (Fig A, B). After egg maturation, the eggshell is responsible for sperm entry, providing mechanical protection for the embryo, allowing gas exchange without permitting desiccation, and finally facilitating hatching. To understand these processes it was crucial to study in every possible detail the fine structural architecture of the layers and the regions of the eggshell (chorion and vitellin membrane) of unstylopised Segestidea (as this has not been previously studied), and compare it with those *Segestidea* that were stylopised by female *Stichotrema*.

Eggshell formation in insects (vitellogenesis and choriogenesis) is dependent on the physiochemical state of the insect, and the present study was to investigate (by light-, scanning-, and transmission-electron microscopy) whether the eggshell and other components parts of the bubble-shaped eggs in stylopised *Segestidea* are deformed.

Both normal and abnormal eggs of *Segestidea* have putatative hatching lines on the dorsal and ventral surfaces. The size of the bubble varied from egg to egg, and architectural structure of the chorion in the deformed eggs was also different from that of normal egg.

A morphological study of the fine structural architecture of the layers of the eggshell (chorion and vitellin membrane) revealed:

1) The structure of a normal egg of Segestidea (11.4-12.5 um) has an elaborate chorion structure (Fig. 6.2A-D; 6.3A). The upper, outer endochorion has a series of open areas and closed cavities, which holds a film of air around the egg and functions as a 'plastron'. The eggs of *Segestidea* are buried in the soil, and the embryos diapause before hatching. During this period the egg may experience both dry conditions, and wet conditions (when the egg maybe surrounded by water in the rainy season). A film of air held in the upper endochorion thus creates an air / water interface for gaseous exchange, if required.

   The surface of the egg has follicular cell imprints of the slightly convex hexagons (Fig 6.6A), and along the hatching lines the convex hexagons gradually display central single or double protrusions (Fig 6.6B,C). The convex hexagons and the hexagons with protrusions are separated by cavities, and all these areas have aeropyles of various sizes, ranging from 1.2um to 0.2um (Fig. 6.6C). Aeropyles contribute to plastron respiration and gas exchange during embryogenesis.

2) The structure of an abnormal egg from stylopised *Segestidea* (8.7 um to 11.4um) is smaller and darker in colour than a normal egg. There are no pillars connecting to the inner and outer endochorion (Fig 6.3B; 6.4A, C; 6.5A, B), and the thickness of the inner and outer endochorion is different at the region of the bubble, and in the region anterior and posterior to the bubble (Fig 6.3B; 4A-D).

   The follicular cell imprints in the abnormal eggs are also different to those in normal egg. The slightly convex hexagons (with aeropyles of various sizes) are present at the base of the bubble, and on the egg to the front and back of the bubble (Fig.6.4A-D; 6.6B). But hexagons are absent from the top of the bubble (Fig.6.4B, D), because the outer endochorion tapers and disappear at the sided of the bubble (Fig.6.4C). The hexagons with protrusions are present at the hatching line, but are not general prominent, since the abnormal egg is covered with layers of follicular epithelium (Fig 6.4A-D; 6.5A,B). Normal, unstylopised, unovulated eggs have a thin layer of follicular epithelium (Fig.6.2), which is shred at ovulation. The abnormal eggs are not ovulated but remain in the ovarioles.

   The outer endochorion in the abnormal eggs has no pillars, fine network, or cavities but is a thickened dense area (Fig.6.3B; a, C). The endochorion cannot therefore function as a plastron. Certain areas, such as the stem of the egg, have follicular cell imprints (Fig. 6.6D), but the aeropyles do not open internally.

   The architectural structure of the abnormal egg is therefore slightly altered, i.e. deformed due to stylopisation. As a result of this, the eggs of stylopised *Segestidea* are no ovulated or laid. Stylopisation therefore hinders normal egg production in *Segestidea*.

   Altered components (probably both qualitative and quantitative) in *Segestidea* that are inflicted by stylopisation, produce abnormal eggs with disruption in the eggshell layers.

   Material has now been collected to study the histochemistry of the abnormal eggshell layers.

Life cycle in female *Stichotrema dallatorreanum*

Metamorphosis

As virtually nothing is known about the general biology and life history of the neotenic, female, endoparasitic Strepsipteran *Stichotrema*, the first step was to investigate the number of larval instars in this species. The first, free-living instar leaves the mother to seek new hosts. On entering the new host it goes through a series of larval instars before it extrudes the cephalothorax through the adult

host cuticle. Metamorphosis in Strepsiptera have been found to be unique, the exuviae ensheathing the larvae are retained and not shred (as in other insects) as each apolysis is accomplished.

Larvae of various sizes were sectioned and the number of exuviae counted so as to give an indication of the number of instars in *Stichotrema* (Fig.6.7A). *Stichotrema* was found to have 4 larval instar; the first free-living host seeking stage, and the three endoparasitic stages. At the final 4th instar, the female extrudes the cephalothorax and becomes a mature, neotenic adult. This information is vital for breeding programmes.

Structure of the cuticle in *Stichotrema*

The ultrastructure of the cuticle in *Stichotrema* is not uniform throughout. Studies with light-scanning-, and transmission-electron microscopy has revealed that certain areas of the cuticle might have what might be interpreted as a 'porous' cuticle. Further work is to be done to investigate whether these areas are parts of the cuticle that are in close contact with the host. Takis Solulu found that many female *Stichotrema* wrapped themselves round the gut of the host, and above mentioned areas of cuticle might be the area which are in direct contact with the gut of *Segestidea*. Most other insect parasitoids have mouthparts and feed directly on the host tissues, but *Stichotrema* has no mouthparts, and food is presumably absorbed via the host's haemocoel.

Embryology in *Stichotrema*

The neotenic female *Stichotrema* remains totally endoparasitic in the host *Segestidea*. The first instar larvae develop viviparously in the mother (within the host).

a) The developing embryo in *Stichotrema* has two regions of base lamina: 1) an inner, thin dense layer; 2) an outer loose, sponge-like lamina (Fig. 6.7B) both of which are probably tropic in function for the absorption of nutrients from the mother haemocoel.

b) The embryonic development is as follows:

1) Each developing embryonic rudiment is a vesicle and connects to the other by putative nutritive chords. The presence of the nutritive chords illustrates the true nature of haemocoelic viviparity, in which the nutrients are derived directly from the mother *Segestidea*, almost like parasitism.

2) The late embryos of *Stichotrema* develop in the haemocoel, totally dispensing with an egg, or embryonic membranes, or amnion. This is a unique feature in *Stichotrema* since most insects have embryonic membranes; the amnion, or the serosa, which protects the yolk from contact with the follicular epithelium; or the chorion of the egg.

3) The development of the 1st instar takes place within the embryo. The 1st instar cuticle is formed within the embryo, and the cuticle of the embryo is persistent around the developing 1st instar. Just before emergence, the outer dorsal envelope disintegrates; the embryo lies free in the haemocoel of the mother, absorbing the nutrients; and the 1st instar in turn develops within the exposed embryo. When the 1st instar is fully developed it emerges from the cuticle of the embryo, tans and then emerges to the exterior via the brood canal opening of the mother to find a new host.

Microorganisms

Rickettsia like microorganisms have been found in *Stichotrema*, and at present, with PCR amplification and bacterial 16s rDNA sequence data the nature and type of organisms are being determined. In other insects these microorganisms have been found to have a profound effect on sex

determination and host fitness. This study of the microorganisms is particularly important in *Stichotrema* due to its peculiar mode of reproduction.

Conclusion and further studies

A study of the oogenesis and vitellogenesis together with the histochemistry of the eggs of unstylopised *Segestidea* and those of *Segestidea* stylopised by *Stichotrema* is required to understand the whether the nutritional levels of the host affects its egg production. Fecundity of Segestidea is directly related to their control, and this study will access whether feeding of *Stichotrema* in *Segestidea* is affecting its egg production and also if the egg produced by *Segestidea* are viable. These studies on the aspects of the fecundity of *Segestidea* are to establish whether *Stichotrema* negatively affects the performance of its host. Fecundity of a pest is central to any biocontrol programme.

Electron microscopy has revealed that the reproduction in *Stichotrema* is unique and now cytogenic studies are carried out. These are crucial to the understanding of the nature of this unique form of reproduction in *Stichotrema*. A study of the embryology, cytogenetics and the sex determination mechanism in *Stichotrema*, will give an understanding of the mode of reproduction in *Stichotrema*.

Finally, morphologically *Stichotrema* found in mainland PNG is similar to that found in West New Britain and therefore genetic studies are to be carried out to verify whether these are genetically similar, or different populations.

Figures

Figs. 6.1 a, B.A – SEM of mature egg of unstylopised *Segestidea novaeguineae*. h = hatching line. Bar = 10mm. B- SEM of egg of stylopised *S. Novaeguineae* with bulbous protrusion (arrow). Bar = 1mm.

Figs 6.2 A-D. SEMs of mature eggs of unstylopised *Segestidea novaeguineae*. A- Cross-section of egg with inner endochorion (ie), outer endochorion (oe), hatching line (h). Bar = 1mm. B - eggshell outside the hatching line with inner endochorion (ie), outer endochorion with pillars (arrow) and cavities (c), and follicular cell imprints of slightly concave hexagons (arrow head). Bar =0.1mm. C- Eggshell at hatching line with inner endochorion (ie), outer endochorion (oe) and follicular cell imprints with central protrusions (arrow head). Bar =01.mm. D - unovulated egg with a porous floor (f), inner endochorion (ie), outer endochorion (oe) and follicular epithelium (arrow head). Bar =0.1mm

Figs 6.3A-B. A - thin section of mature eggs of unstylopised *Segestidea novaeguineae* outside hatching line with inner endochorion (ie), outer endochorion (oe) with pillar (arrow) and cavities (c), and follicular imprints of slightly concave hexagons (fc) with aeropyles (arrow head) x 128. B - 5 um section of the abnormal egg outside hatching line with thick inner endochorion (ie) and continuous dense outer endochorion (oe) at base of bulbous protrusion (arrow head), both of which taper to top of bulbous protrusion (arrow), (Fe) follicular epithelium x32.

Figs 6.4 A-D. SEMs of abnormal eggs of *Segestidea novaeguineae*. A - cross section of abnormal eggs in the region of the bulbous protrusion (b) with inner endochorion (ie) and outer endochorion (oe) both of which taper to the top of bulbous protrusion (arrow), (Fe) follicular epithelium. Bar = 1mm. B - top of bulbous protrusion with very thin inner endochorion (arrow heads). Bar = 1mm. C - one side of bulbous protrusion (b) with tapering endochorion (ie) and outer endochorion (oe) which narrows and disappears, (*) follicular epithelium. Arrowhead points towards top of bulbous protrusion. Bar = 1mm. D - top of bulbous protrusion (b) showing perforated inner endochorion (arrow head). Bar = 0.1mm

Figs 6.5 A-B. A - SEM of cross section through stem of abnormal egg showing greatly concave hatching lines (arrows) with broad inner endochorion (ie) to the dorsal and ventral side of the hatching line. Bar = 1mm. B - high magnification of area at hatching line showing the concave endochorion (ie) meeting back to back. Bar line = 0.1mm

Figs 6.6 A-D. A - SEM of surface of normal egg outside the hatching line with follicular cell imprints of slightly convex hexagons and aeropyles of varying sizes (arrow head). Bar = 10um. B - SEM of hexagons (at hatching line) with single and double central protrusions. Bar = 0.1mm. C – ultra-thin section of a raised follicular cell imprint with aeropyles (arrow head) of various sizes on outer surface, x 4,940. [Inset] SEM of a single follicular cell imprint with aeropyles all around the protrusions. Bar line = 10um. D - SEM of surface of abnormal egg with torn follicular epithelium revealing follicular cell imprints of slightly convex hexagons (arrow head). Bar = 1mm.

Figs. 6.7 A-B. A - Thin section of late 3rd instar female of *Stichotrema dallatorreanum*. The cuticle of this instar is at an early stage of secretion; the overlying 3rd instar cuticle (3) is at a stage of resorption and the epicuticle of the 2nd instar cuticle (2) forms the outermost layer. X64. B - ultra-thin section of the basal lamina of the egg of *Stichotrema dallatorreanum* with inner dense outer (1) and outer sponge-like lamina (2). X 35,800.

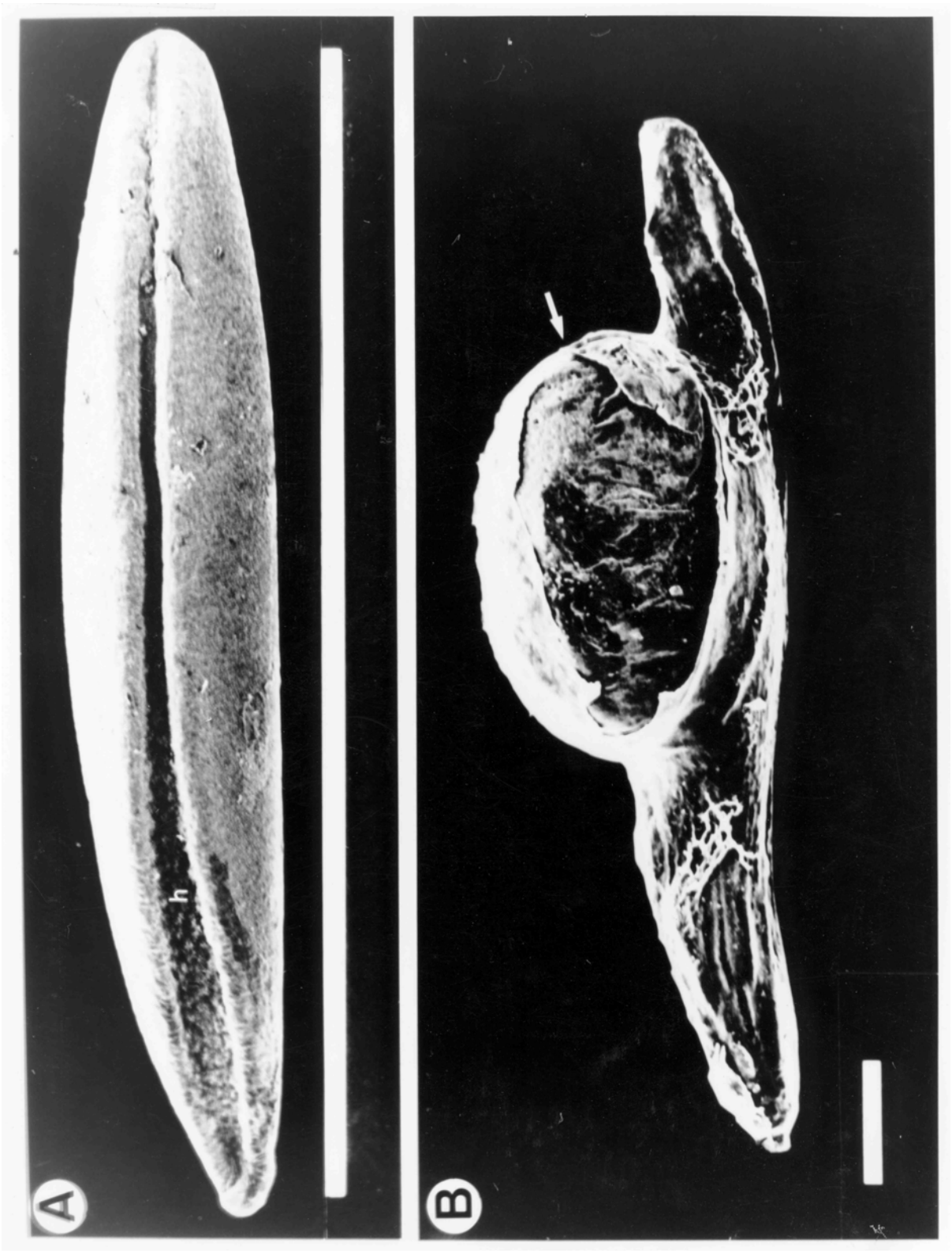


Figure 6.1

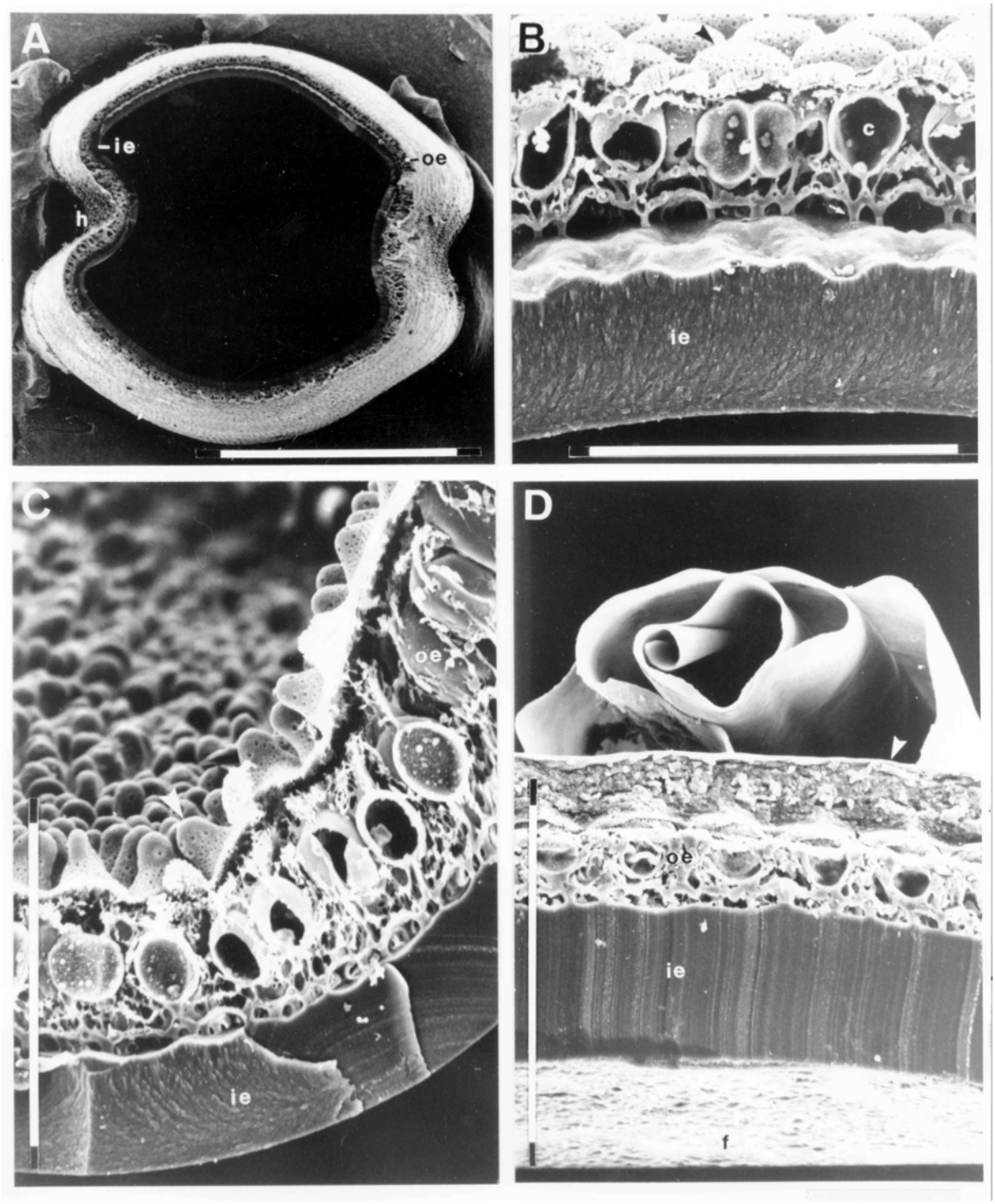


Figure 6.2

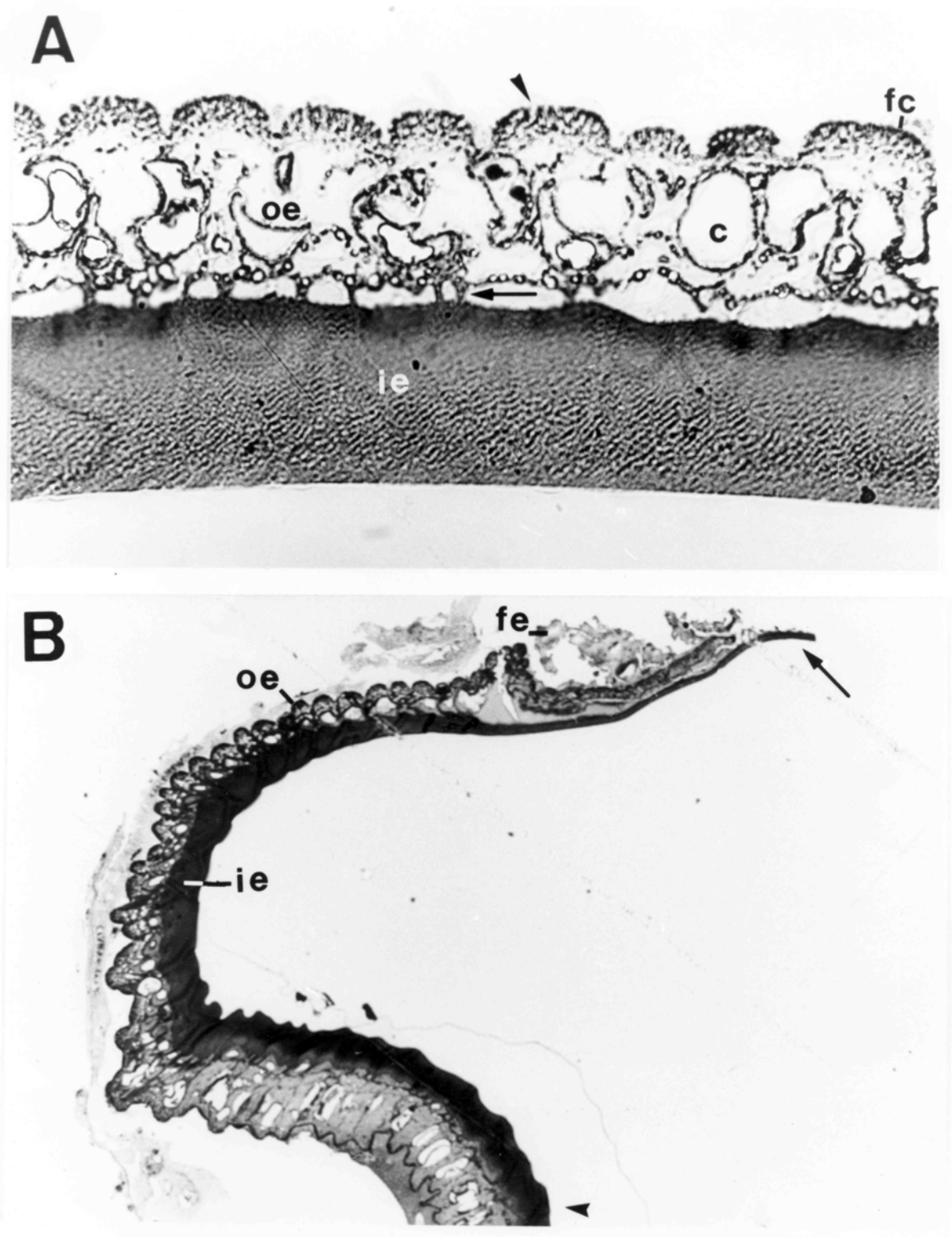


Figure 6.3

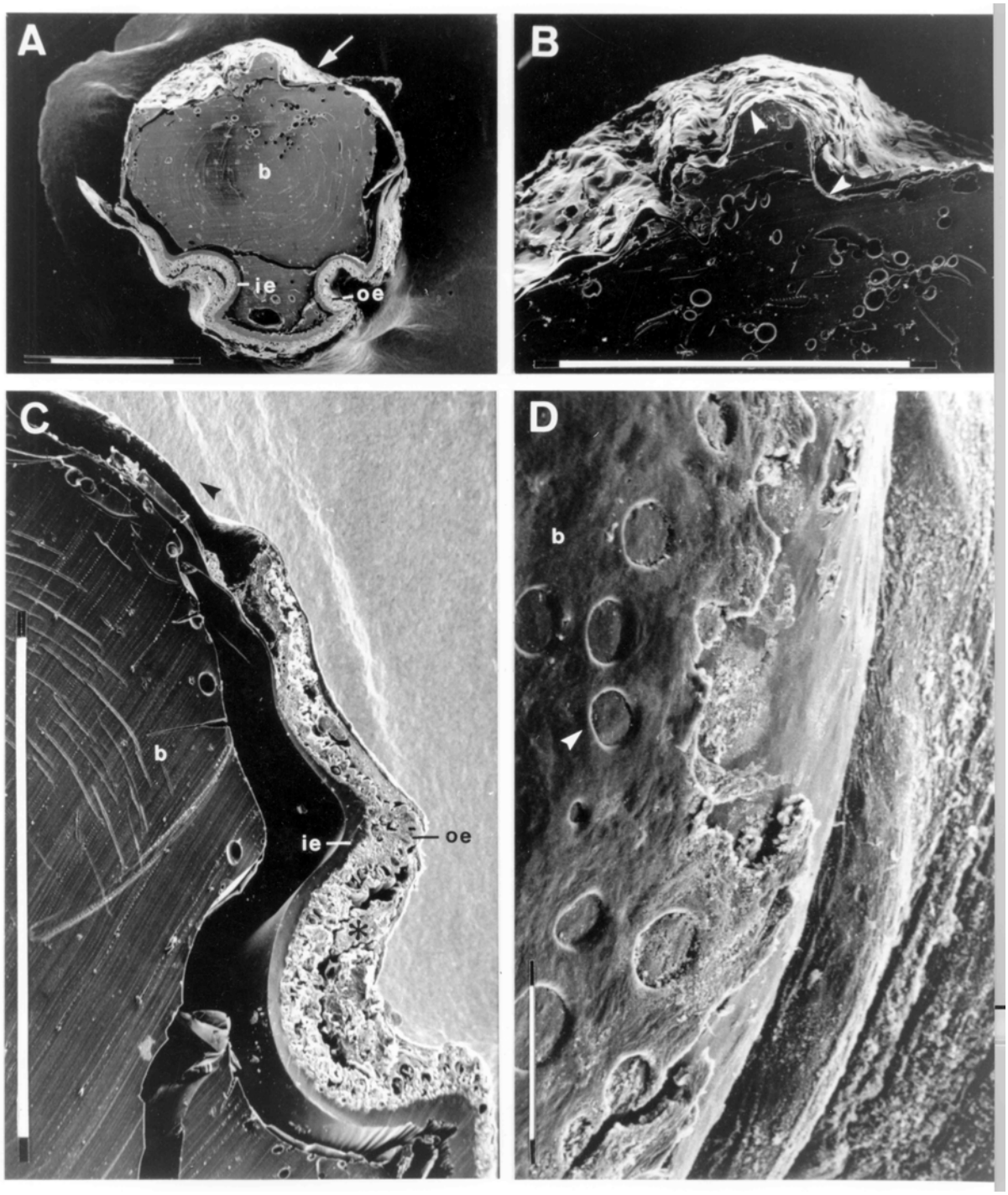


Figure 6.4

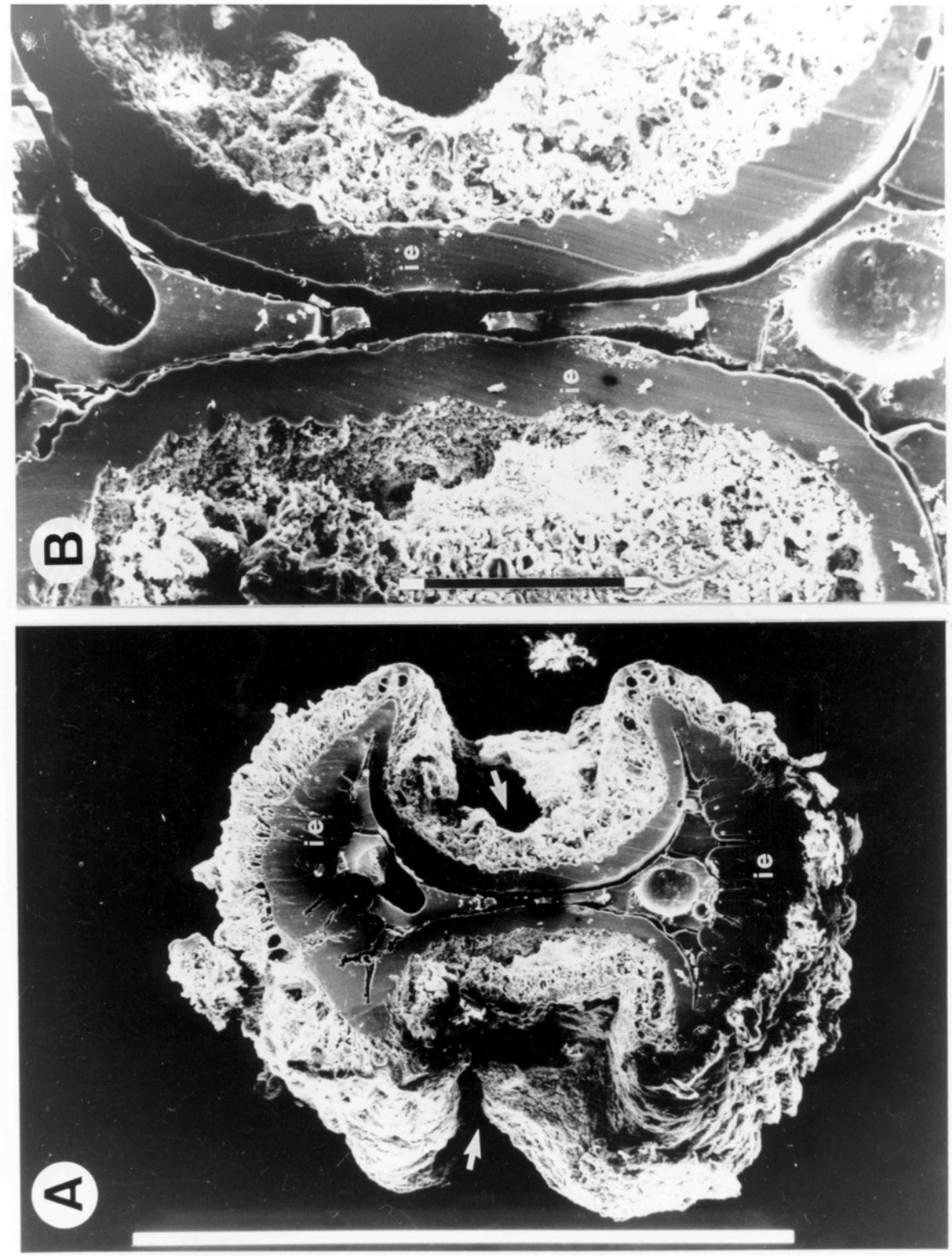


Figure 6.5

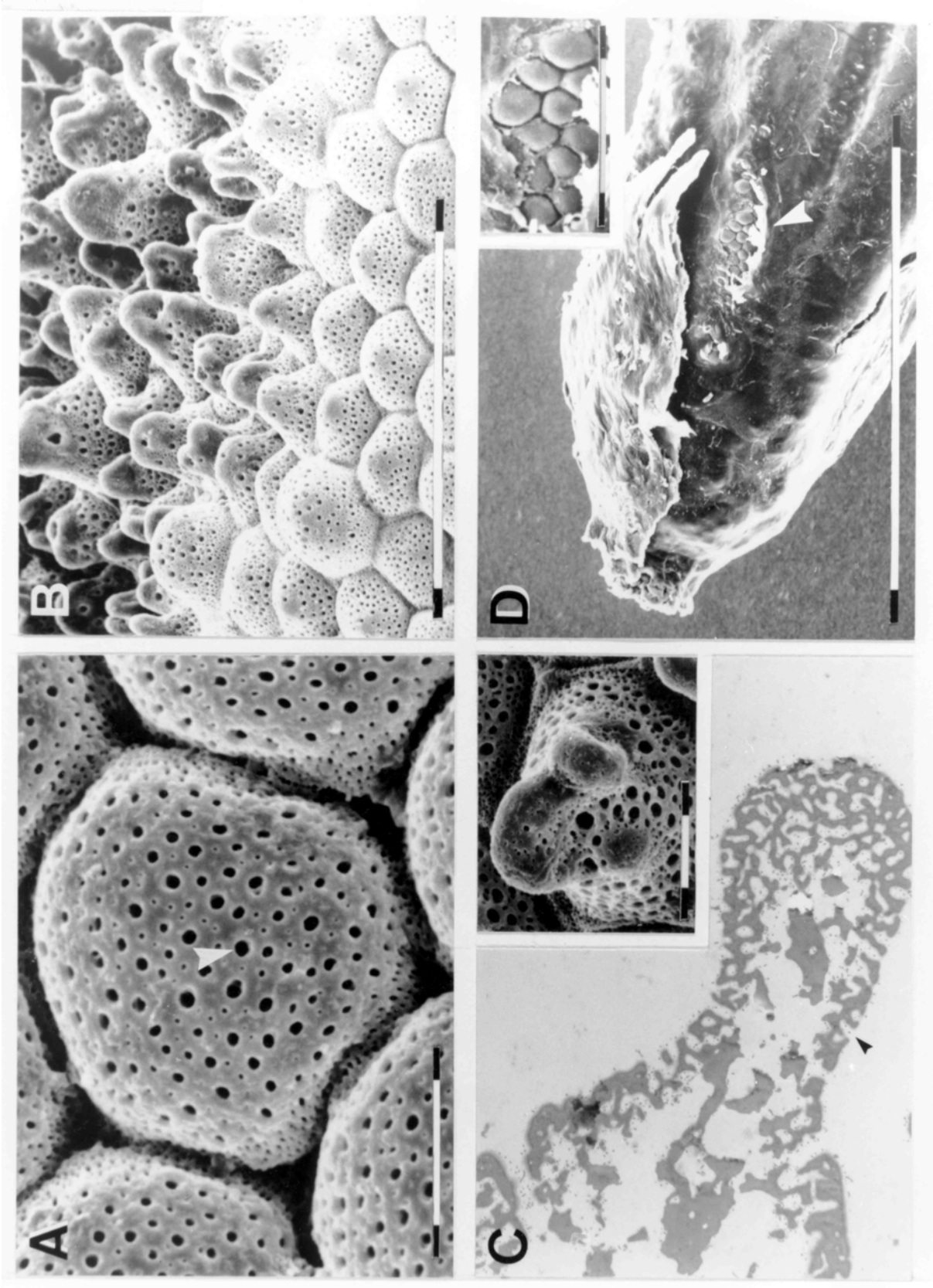


Figure 6.6

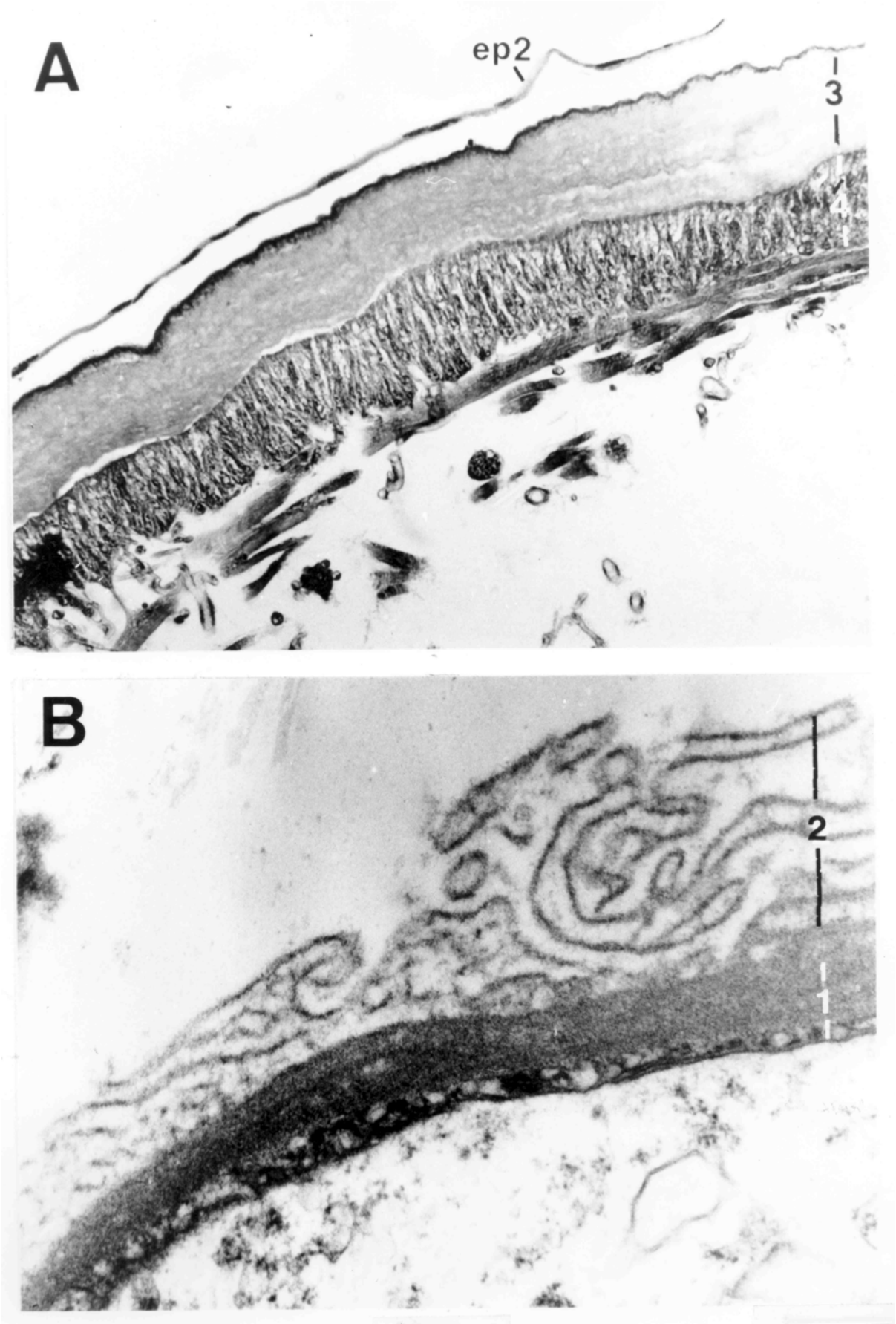


Figure 6.7

4. PLANT PATHOLOGY

4.1 *Ganoderma* Project (PNG Stabex Project No 4.2).

A number of species of *Ganoderma* have been reported to produce a basal stem rot of oil palm with severe losses occurring in some of the older planting within Malaysia and the Solomon Islands. Most research on *Ganoderma* has been based on the premise of root to root spread of the disease and has concentrated on the field control of the disease by such methods as removing infected palms and digging up the stumps and shredding to speed decay. Current research both at PORIM and at IMI has not supported this, rather it suggests that spores have a role in the spread of the disease. If this is the case then a completely new approach is required.

The research programme at the Milne Bay Laboratory is based on three assumptions:

I. The oil palm plantation is sown with plants derived from the cross between two types of oil palm - (*dura* x *pisifera*, or x *tenera*). It is therefore a population of individuals that is likely to be segregating for resistance to *Ganoderma*.

II. The *Ganoderma* population has a highly developed mating system containing a large number of genes for aggressiveness. The selection pressures during the infection cycle results in the accumulation of these aggressiveness genes. Consequently there is erosion of the oil palm resistance. The main reason for the difference between PNG - at the beginning of the cycle and Malaysia where is suggested that high levels of aggressiveness have already developed.

III. Spread and infection is by wind borne spores and infection is during the first few years after transplanting.

The project has two objectives:

I. To study the epidemiology of the *Ganoderma* fungus, the origin of the primary inoculum and the infection process, and to use this knowledge to implement new control strategies.

II. To look at the variability of aggressiveness in the pathogen in relation to resistance of the host. This will enable us to monitor seed production programme at DAMI to ensure the maintenance of high levels of resistance to *Ganoderma* within the oil palm plantings.

4.2 *Ganoderma* Survey Report 1995-1996, Milne Bay and Poliamba Estates

Introduction

This report covers *Ganoderma* disease surveys for Milne Bay and Poliamba Estates carried out by OPRA and MBE staff up to September 1996. Three surveys have been carried out to date. The first in 1994 covered only 1986 plantings in Milne Bay and was carried out by staff of Milne Bay estates. The second survey in September 1995 covered all three estates Waigani, Hagita and Giligili at Milne Bay and selected estates at Poliamba in New Ireland. The third survey for Milne Bay that included Sagarai commenced in July 1996 and has been completed. Surveys will be done at six-monthly intervals.

Disease Survey Results

Disease Incidence In Each Province; Tables 4.1 and 4.2 show disease levels in each estate by age group in Milne Bay and New Ireland Provinces.

Mean disease incidence is higher in New Ireland (0.64%, range 0.17-1.17) than in Milne Bay (0.15%, range 0.01-0.53). The highest occurrence of the disease in Milne Bay was observed in 1986 ex-coconut plantings in Waigani (0.5-3%). There was no difference in the disease incidence between ex-coconut and ex-forest areas for 1987 plantings at Waigani. Incidence in 1987 ex-coconut plantings at Giligili is twice that of ex-forest areas.

Maramakas and Medina 1989 plantings had the highest levels of disease in New Ireland.

Block Comparisons In Milne Bay: Figures 4.1, 4.2 and 4.3 show the incidence of infection in surveyed blocks at Waigani, Hagita and Giligili at Milne Bay. P indicates blocks receiving palm oil mill effluent (POME). Over 50% of blocks in Waigani showed an increase in numbers of palms infected in the second survey (1996). The number of diseased palms in all POME blocks increased markedly.

Table 4.1 Summary for Milne Bay Province. [1] 1994,1995 & 1996 surveys

ESTATE	YEAR OF PLANTING	HECTARES SURVEYED	TOTAL TO DATE [1]	PREVIOUS CROP/VEG	% INCIDENCE [2]
WAIGANI	1986	799.9	540	coconut	.53
	1987	277.1	60	coconut	.17
	1987	147.5	34	forest	.18
	1988	521	92	forest	.14
HAGITA	1986	502.1	154	coconut	.24
	1987	256.5	67	forest	.21
	1988	104.1	17	forest	.13
GILIGILI	1987	414.7	81	coconut	.15
	1987	132.1	11	forest	.07
SAGARAI	1989	431	6	forest	.011
	1990	401	7	forest	.014
	1993	558	9	forest	.013

Table 4.2 Summary for New Ireland Province

ESTATE	YEAR OF PLANTING	HECTARES SURVEYED	TOTAL INFECTED	PREVIOUS CROP/VEG.	% INCIDENCE
BAIA	1989	14	3	coconut	0.17
LUGAGON	1990	14	6	coconut	0.33
MARAMAKS	1989	54	70	coconut	1.01
MEDINA	1989	36	54	coconut	1.17
BOLEGILA	1988	71.4	77	coconut	0.85
LIBBA	1990	59.1	24	coconut	0.32

Fig. 4.1. Disease Incidence By Block In Waigani

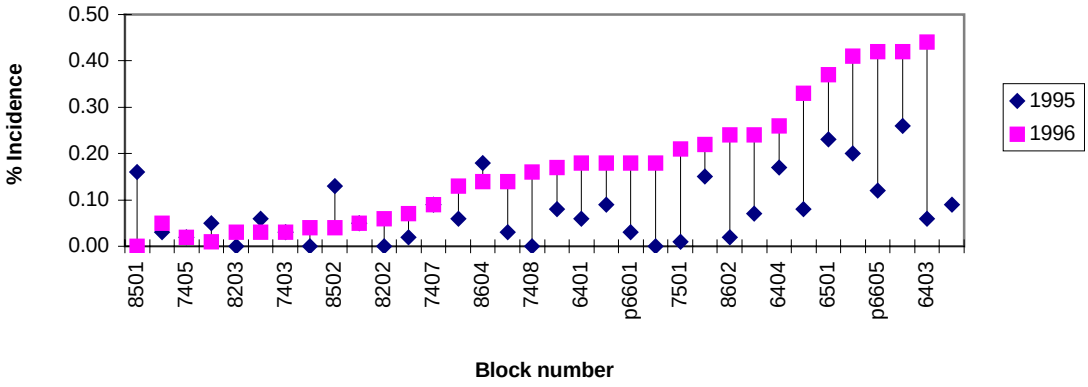


Fig 4.2. Disease incidence by block in Hagita

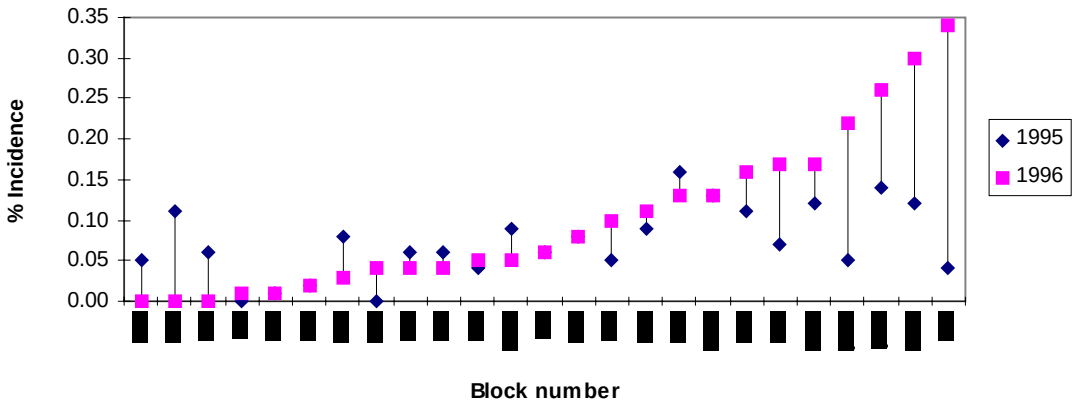
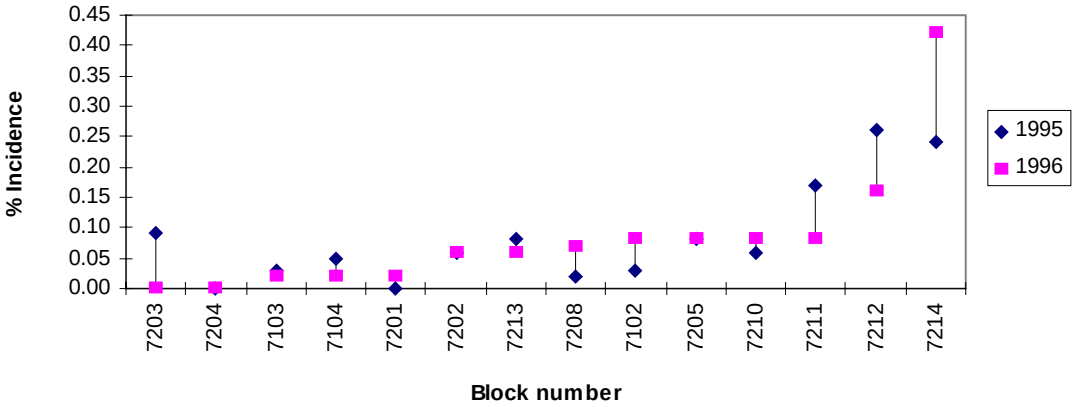
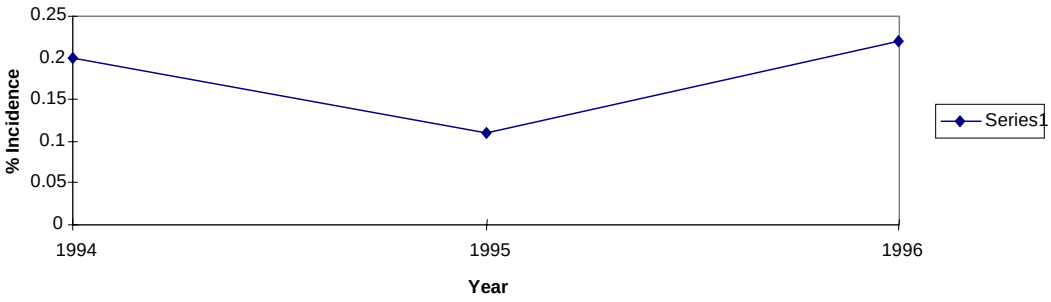


Fig 4.3 Disease incidence by block in Giligili



Just fewer than 50% of the blocks in Hagita and Giligili estates had a higher disease incidence in 1996 than the previous year. Sixty percent of POME blocks in Hagita showed increased disease levels. The remaining blocks had the same or decreased incidence of basal stem rot.

Fig 4.4. Average disease incidence in 1986 plantings over three-years



Disease Data Collection and Analysis

Survey Form; A survey form was prepared to collect information on disease symptoms and other variables in the field. This form will be used for future follow-up surveys by OPRA staff.

All palms identified in the survey by MBE staff were inspected by OPRA staff and data recorded according to the survey form. Selected palms were marked with yellow tape for future study. All other palms were removed according to current control practices.

Analysis Of Data; Table 4.3 shows that over half the palms examined in the 1995 survey at Milne Bay had visible basal rot. Fifty percent (50%) of 1987 plantings in ex-coconut areas had *Ganoderma* fruiting bodies while 19% of palms in ex-forest areas had fruiting bodies. The number of fruiting bodies present decreased further in the 1988 plantings (13.2%).

Table 4.3 Summary of Disease Data in Milne Bay.

	% With Basal Rot			% With Fruiting Bodies			% Next To Windrow		
Year	1986	1987	1988	1986	1987	1988	1986	1987	1988
FOREST	-	61.9	52.8	-	19.0	13.2	-	71.0	8
COCONUT	50.3	61.8	-	54.5	50.9	-	46.9	50.9	34.0

Each symptom of the disease was given a rating from one to six, beginning with the first signs of discoloration of the fronds (pale yellow = 1) to collapsed palm (collapsed = 6). Symptoms were then correlated to the number of basidiophores (fruiting bodies) found per palm. Symptoms were also correlated to the age of the palms in Milne Bay Province. Data presented is for 279 palms.

There was no relationship ($r = -0.098$ and $r = -0.184$) between the degree of disease symptoms and the number of fruiting bodies seen on each palm at both Milne Bay and New Ireland. Clearly the presence or absence of fruiting bodies is not an indication of the degree of infection. Disease expression was also not related to age of the palm.

The most pertinent observation is that there is no consistent set of symptoms. Symptoms vary from palm to palm, from severe stunting and death in 6 - 7 year old palms through those around 8 years onward with yellowing of fronds and loss of production, to palms with severe basal rot yet no top symptoms and no loss of production. Disease expression or symptoms do not necessarily increase with age of the palm, but is rather dependent on the inherent level of tolerance of the palm to infection.

All infected palms within the Milne Bay Estates were tagged during the survey and these were subsequently removed by felling the palm by and digging out the root ball, then cutting the palm into manageable pieces for removal from the plantation.

Future Work

- A further survey will be conducted during 1997.
- Surveys will be implemented in the other plantations around PNG
- A control strategy based on a zero incidence of *Ganoderma* brackets will be developed and implemented.

4.3 Field Trial

Surveys only produce information regarding the state of the epidemic in relation to plants with symptoms. They give us no indication as to the incidence of infected palms with no symptoms.

In order to obtain some insight into these early infections, two blocks of 1 ha were identified from the previous survey that had higher than average incidences of infection.

The palms to be felled were first pruned then pushed over with a front-end loader. The idea being that any infected palms would break at the base exposing the infection. Trunks were cut 50 cm above the base to expose infection moving up the trunk, then rolled onto the frond heap leaving the old row free for replanting.

All plant material was left on-site to produce the worst scenario for infection. Young palms were planted in the inter rows. These blocks are still being monitored.

In the first block 66 palms were pushed over. None of the palms had top symptoms nor did they have any basal stem rot. Twenty palms (30%) had fingers of what was interpreted as old infection of *Ganoderma*. No *Ganoderma* was isolated from these areas. Thirty one of the palms (47%) broke above the root zone exposing some part of the basal plate.

In the second block 108 palms were pushed over. Two of the palms had top symptoms similar to *Ganoderma* basal stem rot. Again 47% of the palms broke 1 cm above the root interface irrespective of any *Ganoderma* basal rot.

Of the two palms that had top symptoms only one had a basal rot typical of *Ganoderma*, although *Ganoderma* was not isolated. Two weeks after the palm was felled there was still no sign of fungal activity on the cut surface.

Four other palms which had no top symptoms had a basal rot typical of *Ganoderma*, however, the fungus was only isolated from one of these palms. Brackets formed on the trunk base left in the ground and on the cut end of the trunk, six months after felling this palm.

Twenty-six of the palms (24%) had fingers of what could conceivably be old infections of *Ganoderma* above the basal plate.

No explanation is given for the 82 palms that fractured above the root transition zone. There was certainly nothing to suggest that it was associated with infection of *Ganoderma*. Protruding form the trunk, however, were numerous vascular bundles that had ended at he base of the palms but were not associated with the root system. The tips of these bundles, corresponded to the lower surface of the basal plate, were black, suggesting an abscission layer. These vascular bundles are similar to those found in the old frond bases and it is suggested that these are the old vascular bundles to the first leaves of the palm. Vascular bundles protruding from the areas of *Ganoderma* rot had numerous lesions. The *Ganoderma* fungus was easily isolated from lesions associated with the area of active *Ganoderma*.

This observation has led us to postulate that spore borne infection may be initiated via the vascular bundles of the first leaves.

Future Work

- This block will continue to be monitored for subsequent infection of the young palms.
- The hypothesis that infection is via the leaf bases of young palms will be studied.
- Several of the removed trunks were degraded rapidly by an organism that broke-down the parenchyma tissue. A project will be initiated with the IMI to investigate the possibility of utilising this rapid trunk degradation as a form of biological control of *Ganoderma* during the re-plant cycle.

4.4 Development of Improved Screening Procedures

One of our premises is that there is a range of tolerance in the oil palm population to *Ganoderma*. To demonstrate this we require a more sensitive screening method than the one currently used. Firstly we have to develop an aeroponics growing system to produce a large number of uniform plants. Secondly we will have to develop lines of oil palm with higher levels of susceptibility to the disease. Initial trials will be conducted using seed harvested from infected palms anticipating that these populations will have a higher incidence of susceptibles than the commercial seed lines.

A test system was set up using two 2 x 1 x 1 metre fiberglass containers, which supports 50 plants per unit. Each container has two *Spraying Systems ¼ J* nozzles spraying for 30 seconds followed by 11.5 minutes at rest. Four litres of a half strength hydroponics nutrient solution is sprayed per box per 24 hours. The advantage of using misting nozzles is that there is no need to re-circulate the nutrients thus avoiding the danger of cross infection or bacterial contamination. The disadvantage is that great care is required to maintain the nozzles in good working condition. These are constantly monitored by using individual reservoirs in each growing box.

An aeroponics unit based on the trial system will be established with 20 boxes capable of growing 1,000 oil palms.

4.5 Laboratory Studies

Basic mating system studies.

It is generally accepted that the *Ganoderma* species have a tetrapolar mating system. That is, there are two sets of complimentary mating types. A will cross with B, not C or D. C will cross with D. Thus in a collection of sexually derived spores there is a 1:3 chance of mating.

This was confirmed for the *Ganoderma* responsible for the oil palm infections in Milne Bay. However, it was quickly demonstrated that this only applied for crossings from spores derived from the same oil palm, whether from the same bracket or from different brackets on the same palm. When crossings were made between spores from different palms, all crosses were successful. This indicates

that multi-alleles are involved and demonstrates that this particular *Ganoderma* has evolved a highly complex mating system that strongly favours out crossing.

4.6 Molecular Characterisation

Most equipment was received towards the end of June 1996 and molecular work began in July 1996.

Spore prints were collected from four fruiting bodies in different blocks for use in genetic studies of *Ganoderma*. Reciprocal crosses within and between families were carried out and all single spore isolates and selected dikaryons were cultured, dried and DNA was extracted.

4. Restriction digests were commenced on single spore isolates within a family for use as a possible marker in population studies. It was found that mtDNA varied between families and could possibly be used as a means of distinguishing families but not within families and therefore would not be useful in genetic studies. Mitochondrial DNA would also need to be confirmed as digests were carried out on total DNA. A mitochondrial probe prepared and labeled by IMI, U.K. was brought out by Dr. Rob Miller and tested against PNG isolates. This proved to be unsuccessful at the time.

The methodology for determining dikaryotization was established and first trial matings were completed.

The growth of generated dikaryons on waste oil palm mesocarp fibre and oil palm wood was examined.