ANNUAL REPORT

OF

THE PAPUA NEW GUINEA
OIL PALM RESEARCH ASSOCIATION

1987

SEVENTH ANNUAL REPORT

of the

PAPUA NEW GUINEA

OIL PALM

RESEARCH ASSOCIATION

1987

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AGRONOMY

MANAGEMENT BOARD

CHAIRMAN	F.E. McGuire
NEW BRITAIN PALM OIL DEVELOP. LTD.	J.R. Gilbert
DEPARTMENT OF PRIMARY INDUSTRY	J. Christensen (alternate to Secretary,D.A.L.)
HARGY OIL PALMS PTY. LTD.	N.Van der Lann(to September) J. Wynand (from October)
HIGATURU OIL PALMS PTY. LTD.	F.E. McGuire
MILNE BAY ESTATES	J.N. Hansen
DIRECTOR OF RESEARCH	T. Menendez

In attendance

MANAGING AGENTS REPRESENTATIVE AND SECRETARY
J.F.W. Benn (to June)
A.R. McMaster (from July)

SCIENTIFIC ADVISORY BOARD
as at 9th October, 1987

F.E. McGuire	Chairman, PNGOPRA
W. Hadfield	Department of Primary Industry
J. Piggott	Higaturu Oil Palms Pty. Ltd.
J. Wynand	Hargy Oil Palms Pty. Ltd.
E.A. Rosenquist	New Britain Palm Oil Development Ltd.
T. Menendez	Director of Research

In attendance

A.R. McMaster	Secretary, PNGOPRA

By invitation

J.R. Gilbert	Harrisons and Crosfield (PNG) Ltd.
A. Benton	Higaturu Oil Palms Pty. Ltd.
M. Hoogeweegan	Milne Bay Estates Pty. Ltd.
H.C. Harries	New Britain Palm Oil Development Ltd.
R.N.B. Prior	Senior Entomologist, PNGOPRA
A.S. Wilkie	Agronomist, PNGOPRA
I. Orrell	Soils Agronomist, PNGOPRA

EXECUTIVE STAFF

DIRECTOR OF RESEARCH	T. Menendez, B.Sc., DPB., M.I. Biol.
AGRONOMIST	Ir. M. Vugts-Hovers. (to May)
AGRONOMIST (Higaturu)	A.R. Wilkie, B.Sc., M.Sc., (from Aug.)
SOILS AGRONOMIST(Higaturu)	R.L. Atherton, B.Sc., (to July)
ASSISTANT AGRONOMIST	P. Navus, B.Ag.,Sc., (on study leave in U.K. from September)
ASSISTANT AGRONOMIST	A. Oliver, B.Sc. (from February)
SOILS AGRONOMIST	I. Orrell , B.Sc., (from September)
RESEARCH ASSISTANT	P. Sereva, B.Ag., Sc., (to October)
ENTOMOLOGIST[1]	R.N.B. Prior, M.Sc.

NON-EXECUTIVE STAFF

SECRETARY	M. Mape
TYPIST/CLERK	L. Likky (from August)
SENIOR TECHN. ASSISTANT	S. Embupa
SUPERVISORS	B. Rimandai
	D. Yapasi (Higaturu)
FIELD ASSISTANT	P. Sokip
	D. Stanley (Milne Bay from March)
SENIOR FIELD ASSISTANT	J. Nagi (Hargy)
TECH. ASSISTANT	D. Tomare (Higaturu)
RECORDS CLERK	C. Golu
SENIOR RES. RECORDER	B. Lukara
RESEARCH RECORDER	P. Sio
RECORDERS	J. Dapo
	S. Makai
	B. Bubu
	A. Poka
	P. Lus
	J. Yalikua
	T. Enock (Higaturu)
	W. Kanama (Higaturu)
	G. Betari (Higaturu)
	G. Bonga (Higaturu)
	D. Leonard (Higaturu)
	M. Yaura (Higaturu)
DRIVERS/HANDYMEN	K. Duke
	E. Luscombe (Higaturu)

([1] On attachment from Department of Agriculture and Livestock)

CHAIRMAN'S STATEMENT

The volatility of the palm product market experienced in 1986, continued into 1987 with greatly depressed prices being experienced in the early part of the year. A marked recovery however took place in the latter half of the period which saw sales prices rise by almost 150%.

Let us hope this trend continues, and the palm oil industry, of which our Association is an integral and most important part, returns to a more even 'keel'.

Work on all areas of research as per the 1986 programme continued and expanded. Nutrition has remained and will remain the focal part of our programme where firm recommendations for all areas are being made.

It proved impossible to gain meaningful results from research trials directly placed on smallholder blocks, and while this sector's needs are seen to be vitally important to the industry, emphasis has now shifted to on-farm demonstrations, particularly fertiliser applications, using results from properly conducted trials in the nucleus estate area. I am convinced this is the correct methodology and one which will prove of immediate benefit to the smallholder sector. It is essential that these are combined with an extension effort, and close liaison, both on site and in preparation of extension literature with Department of Agriculture and Livestock personnel will be required.

The combined exercise of the introduction of *E. plagiatus* into Indonesia and Papua New Guinea failed due to importation difficulties into the former country. This effectively would have doubled the cost to our Association had we 'gone it alone' and following promising population studies of *E. kamerunicus* particularly in Oro Province, combined with improved pollination, it was decided to await further news from Indonesia before taking the matter further. An additional pollinator may well be required in the future and this line of research should not be shelved.

I am pleased to report on-going financial support from the Government of Papua New Guinea to our Association, very much needed over the difficult years of 1986/87, and their promise of continued funding will assist greatly in ensuring not only a sound financial base but also the high quality of research which we expect from our Association.

Thanks again goes to Mr. Menendez, the Director of Research, and his staff for all their efforts and support during the year. Last year we welcomed two new agronomists - Simon Wilkie to Popondetta (also covering MBEPL) and Ian Orrell to Kimbe. Both have settled in well and their arrival adds much needed strength to our 'team'.

Sadly John Benn, Secretary of PNGOPRA for several years departed to the U.K. to embark on further full time studies. We wish him and his family success in the future. Ross McMaster takes over the role of Secretary to the Association - he is most welcome and I hope will find the position novel and rewarding.

Finally my thanks to my fellow members of the Management and Scientific Advisory Boards for their support and advice during 1987.

F.E. McGuire

PART 1. ADMINISTRATION AND DEVELOPMENT

MANAGEMENT BOARD AND SCIENTIFIC ADVISORY BOARD

The Management Board met thrice, at Lae on 11th February and 27th March and at Higaturu Oil Palms Pty Ltd on 9th October. The Sixth Annual General Meeting of the Association was held in Lae on 27th March at which Mr. F.E.McGuire was re-elected as Chairman. Messrs. Harrisons and Crosfield (PNG) Ltd were re-appointed as Managing Agents for the coming year.

The Scientific Advisory Board met at Higaturu Oil Pty Ltd on 9th October. This was preceded by an informal meeting between Scientific Advisors and PNGOPRA staff on 7th October and a field trip to trials on surrounding estates, attended by most Board members, on 8th October.It was agreed that the Board would meet at Dami Research Station next year.

FINANCE

The income from the research levy was reduced to 65 toae per tonne of fresh fruit bunches with effect from 1st April 1987 and the Government grant for the year was reduced to K93,300.00, resulting in annual expenditure slightly exceeding income. Accumulated funds at the end of the year were thus reduced to K159,332.00. Full details of the Association's Accounts for 1987 and the Auditor's Report are presented in Appendix II.

Messrs. Price Waterhouse were re-elected as auditors.

STAFF

There were considerable changes in executive staff during the year. The Agronomist at Dami and the Soils Agronomist at Higaturu both resigned, with effect from May and July respectively. Furthermore the Assistant Agronomist at Dami proceeded on study leave to attend a course in Agricultural Extension at the University of Reading in September and the appointment of the Research Assistant at Dami was terminated in October. However a new Agronomist to take charge of the Higaturu substation was appointed in August and a new Soils Agronomist arrived at Dami in September. The staff at Higaturu was strengthened by the creation of a new post of Assistant Agronomist which was filled in February. The D.P.I. Senior Entomologist continued his attachment to PNGOPRA at Dami.

At the Junior Staff level there were few changes. A field assistant was posted to Milne Bay to supervise newly established trials in the area.

TOURS

In the course of work the Senior Entomologist was based at Higaturu for extended periods to study pollination. Both he and the Director of Research attended the International Oil Palm Conference held in Kuala Lumpur in June. Other off-station duty visits of staff were to Bialla and Navo in West New Britain, to Milne Bay Estates in Milne Bay Province and to Lae on management matters. The Director of Research also attended Research Committee meetings of the Coffee Research Institute, the Department of Agriculture, University of Technology and the Oil Palm Research Station, New Britain Palm Oil Development Ltd.

DEVELOPMENT

Buildings

Modifications were completed at the PNGOPRA Higaturu station and additional housing was provided to accommodate the increased executive staff. Similarly, additional housing for increased executive staff was provided at Dami.The allocation of buildings rented from New Britain Palm Oil Development, Higaturu Oil Palms and Hargy Oil Palms is shown in Appendix III

Vehicles

During the year, three vehicles were kept beyond the 3-year write-off period resulting in frequent repairs and break-downs. The Agronomist's vehicle was eventually replaced in September and the Entomologist's vehicle is due to be replaced early next year. Details of vehicles at the end of the year is shown in Appendix IV.

Equipment

At Dami an IBM XT micro-computer and peripherals were installed in the Records Section and a new drying oven in the Sample Preparation room. It is planned to install similar facilities at Higaturu next year.

VISITORS

Adams M., Harcros Trading (PNG) Ltd.,Lae.
Anthony G., University of New England, Armdale, N.S.W.,Australia.
Bai B., Dept. of Prime Minister and Nat. Exec. Committee,Waigani.
Baker D., Monsanto, Melbourne, Australia.
Banka, R., Forestry Department, University of Technology, Lae.
Barnes, A.J., Department of Agriculture and Livestock, Kimbe.
Beangke, N., Agricultural University, Wageningen, Netherlands.
Bisa, Jaru, Water Resources Division, Boroko.
Breure K., Harrisons Fleming Advisory Services, London, U.K.
Bruce-Smith G., Harcros Trading (PNG) Ltd.,Lae.
Cundall, N and J., Cocoa and Coconut Research Institute, Kerevat.
Christensen J., Department of Agriculture & Livestocks, Konedobu.

Dogra A., PNG Coffee Research Institute, Kainantu.
Ellman A., Commonwealth Development Corporation, London, U.K.
Eri V.S., Harrisons and Crosifield (PNG) Ltd., Lae.
Foli C., Twifo Oil Palm Plantations Ltd., Accra, Ghana.
Fujishima M., Ebara Corporation, Tokyo, Japan.
Gilbert J., Harrisons and Crosfield (PNG) Ltd, Lae.
Gillbanks R.A., New Guinea Plantations, Kieta.
Grant P., Macdonald Wagner, Brisbane.
Grealy T., Australian High Commission, Port Moresby.
Greasley W.A., Harrisons Fleming Advisory Services, London, U.K.
Green A., World Bank, Washington, U.S.A.
Greenwood J.M.F., World Bank, Washington, U.S.A.
Greer H., Harcros Trading, Pty Ltd., Kimbe.
Harding P., Coffee Research Institute, Kainantu.
Holmes J., Monsanto Ag. Co., Cairns, Australia.
Hoponoa T., Forestry Department, University of Technology, Lae.
Howlett D., Land use Section, DAL, Konedobu.
Hunt B., Australian High Commission, Port Moresby.
Kamzi G., Dept. Agriculture & Livestock,Economics Branch,Konedobu
Kargbo C.S., Depart. of Agriculture,University of Technology,Lae.
Kiap B., Forestry Department, University of Technology, Lae.
Kiara J.M., PNG Coffee Research Institute, Kainantu.
King D., Analytical Services Ltd., Cambridge, New Zealand.
King K.C., Morobe Pharmacies Pty. Ltd., Lae.
Kemp M.H., Harrisons Malaysian Plantations Berhad, Kuala Lumpur.
Maheswaran A., World Health Organisation, Water Res. Div.,Boroko.
Manus P.A., Depart. of Agriculture, University of Technology,Lae.
McGregor J., PNG Analytical Laboratories, Lae.
Mills L., Rabaul.
Miles J.C., Farmset Pacific Islands, Rabaul.
Mongi G., Provincial Foreign Aid Co-ordinator,Dept. of WNB,Kimbe.
Prentice T., Harrisons and Crosfield, London.
Rahman M.J. Asian Development Bank, Manila, Philippines.
Rankine I., Solomon Islands Plantations Ltd., Solomon Islands.
Sherrington J., Department of Primary Industry, Konedubu.
Shimomura H., Jakarta, Indonesia.
Suwetja J.M., Harrisons Fleming Advisory Services, London, U.K.
Taylor J.G., Harrisons Fleming Advisory Services, London, U.K.
Tupe L., Forestry Department, University of Technology, Lae.
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Verdooren R.L., Harrisons Fleming Advisory Services, London, U.K.
Watt W., Forestry Department, University of Technology, Lae.
Weber E., Farmset Ltd., Goroka.
Zimmer-Vorhaus E., World Bank, Washington D.C., U.S.A.
Zia J., PNG Coffee Research Institute, Kainantu.

PART II RESEARCH

REVIEW OF RESEARCH

(H.L.F.)

Pollination

Prior to the introduction of the pollinating weevil, *Elaedobius kamerunicus*, oil palm yields in Papua New Guinea were limited by poor fruitset due to inadequate pollination.

In **Investigation 603** the weevil pollination force is being regularly monitored throughout the country to ensure it remains adequate. Results in 1987 indicated that in all areas it remained high throughout almost the entire year. However fruitset has been found to vary considerably from one bunch to another within an individual palm and still shows a low average in certain areas of the country. The cause of this occasional poor fruitset is being studied in **Investigation 603** and results so far have indicated no correlation with the pollination force or environmental factors. It has been noted that poor fruitset tends to be associated with high yield and that sometimes an anthesising bunch does not attract pollinating weevils.. Studies will be carried out in the future to determine if poor fruitset is a physiological reaction of the palm to the stress of heavy fruiting.

Nutrition

Before the introduction of *E.kamerunicus*, few yield responses of oil palm to fertilizer had been recorded and minimal fertilizer was being used on oil palm in the country. However now that sink strength has been considerably increased due to improved pollination, large responses to fertilizer are being recorded in trials. The most frequent and largest responses recorded have been to N fertilizer (**Experiment 305** and **306** at Higaturu, **Experiment 107** and **108** at Mosa, **Experiment 201** at Hargy). **Experiments 305** and **108** have shown that high yields of the order of 30/t/ha FFB can sometimes be sustained with the application of N fertilizer alone, but without this fertilizer yield may drop to half within a few years. Very consistent responses to single applications of organic material, including empty bunches (**Experiment 109a**, **109b** and **110** at Mosa, **Experiment 309** at Higaturu) and Palm Oil Mill Effluent (**Experiment 109a**, **109b** at Mosa and **Experiment 308** at Higaturu) have been recorded and at least in the Mosa experiment, the responses seem to have been largely due to increased N uptake. It is therefore strongly recommended that growers give particular attention to N nutrition, and apply sufficient N fertilizer or organic materials to maintain leaf N at an optimum level, which the above trials have identified as approximately 2.5% in frond 17.

Due to the dominating importance of N nutrition, it is proposed that the dynamics of N in the soil be studied in the future, giving particular attention to the maintenance of organic matter and the recovery of applied N fertilizer. **Experiment 115**, in which cut fronds are placed in different ways, would be included in these studies.

Oil Palm in Papua New Guinea is largely grown in high rainfall areas on soil derived from volcanic materials and there are unique nutritional problems associated with this environment. Thus high requirement for nitrogen can be attributed to the high rainfall and to the limited development of organic matter at any depth in these soils. Howeve· oil palm on these soils is distinguished not only by low ιptake of N in the absence of fertilizer, but also by a marked cation/anion imbalance. In particular Ca uptake on these high base soils is exceptionally high and leaf levels of chlorine and sulphur are usually very poor.

Responses to fertilizer prior to the introduction of the pollinating weevil were obtained only with materials containing chlorine (**Experiments 101, 102** and 103). Thus in **Experiment 102**, yield was increased by KCl fertilizer, but not by K_2SO_4 or bunch ash. These experiments suggest a limiting influence of chlorine which is further substantiated by the results of current **Experiment 306**, in which chlorine in frond 17 in unfertilized plots is below 0.15%. In the latter trial, leaf N levels can be increased only in the presence of KCl, which also markedly improves leaf Cl but depresses the leaf K level. In this trial yield is most significantly correlated with leaf chlorine and is negatively correlated with leaf potassium, suggesting that the effect is due to the former and not the latter.

However the role of chlorine in oil palm nutrition is still controversial. For example some plots in Experiment 305 with very low leaf Cl levels give high yields. **Experiment 110** at Mosa and **310** at Higaturu are designed to investigate anion nutrition. The former has so far given confusing results, although the highest yield in the absence of mulch in 1987 was given by the chlorine treatment, whilst the latter is too new to given any results.

Further research is clearly needed to resolve the chlorine controversy. Additional trials are needed to determine whether ammonium chloride can be used instead of the more expensive combination of ammonium sulphate and potassium chloride. It is also intended to monitor the uptake and distribution of both K and Cl in different palm tissues in existing experiments, since leaf nutrient levels may not reflect total palm uptake. Until more data is available, if fertilizer input is limited (for example in the case of typical smallholders) ammonium chloride is strongly recommended, but if maximum yields are aimed for, it would be safest to use a combination of NH_4SO_4 and KCl in areas where the latter has given a response.

Leaf levels of Mg are generally low. Furthermore Mg deficiency symptoms are frequently observed, particularly in the Mosa area where **Experiments 106** and 107 have both indicated a need for this nutrient. Unfortunately the high soil Ca levels make the alleviation of both K and Mg deficiency difficult, since Ca competes with these two cations. In the long term, the continuous application of N fertilizer should acidify the soil and reduce competition from the calcium - in the short term it is recommended to apply kieserite if leaf Mg levels are particularly low and deficiency symptoms are acute.

Only on the alluvial soils in the Milne Bay area, has K fertilizer been shown to be unequivocally essential for satisfactory palm performance in Papua New Guinea. As found along much of the southern coast of Central Province, there is an extreme imbalance of K to Mg in the soils around Milne Bay, and as found with coconuts in Central Province, **Experiment 501** indicates an absolute necessity for appreciable fertilizer K from planting. It is strongly advised that oil palm should not be planted in this area without regular K fertilizer applications.

The requirement for phosphate fertilizer on the volcanic soils of Papua New Guinea remains an enigma. Severe phosphate deficiencies are generally found on soils derived from volcanic materials and the low soil extractable P levels and high soil P retention values generally observed on volcanic soils in this country, strongly suggest a need for additional P. However oil palm leaf P levels are generally reasonable and neither yield nor leaf P levels have been increased by P fertilizer in **Experiments 106** and **107** at Mosa or **305** at Higaturu, all of which are on soil, formed from alluvially redeposited pyroclastic material. In **Experiment 306** there is a response to superphosphate fertilizer in the absence, but not in the presence of N, so in practice P is not needed. It seems possible that mycorrhizal activity may be promoting the uptake of P by oil palm on these soils.

In the smallholder demonstrations around Popondetta and Mosa (**Experiments 307** and **112**), phosphate fertilizers tend to give a response, but from these simple trials it cannot be determined if P is still required in the presence of N. Only on the volcanic soils at Hargy and Navo, which have been directly formed on airfall pyroclastic material, has a real need for P been demonstrated in **Experiments 201** and **203**.

Physiology

In the Progeny trial at Arehe, **Experiment 709**, limited observations have indicated that the Dami material has better fruitset characteristics than material from Cameroon, including some "long stalked" material. Several new seed testing trials are in preparation, including two fertilizer trials which will both include 16 known DxP crosses from Dami, a Dami commercial seed trial which will compare crosses from 5 selected *pisifera* and 30 selected *dura* parents and an International seed trial designed to compare elite commercial mixtures from different International sources under Papua New Guinea conditions. The clonal density trial, **Experiment 705**, has now been reduced to a small observation block due to the abnormal performance of several of the clones.

Recording in the continuous leaf nutrient study will be concluded next year when the data will be intensively analysed to identify seasonal and long term effects relevant to foliar diagnosis. Comparison of the growth characteristics of the palm in the different environments will be carried out at the same time.

Smallholder demonstrations

In both West New Britain and Oro Province a series of small fertilizer trials was continued during the year on selected smallholder blocks (**Experiments 112, 113 and 307**), to demonstrate and publicise the benefits of fertilizer application. In both series on mature palms (**Expts.112 and 307**) an overall yield response to fertilizer was recorded - although the effects were not visually obvious, discussions with the smallholders indicated that the regular visits of OPRA staff had impressed them with the importance of fertilizer application. In **Experiment 113** involving several blocks of immature palms, the visual effect of N fertilizer was a striking confirmation of OPRA's official fertilizer recommendation for smallholders in the Mosa area.

Experiments 113 and 307 will be replaced next year by a new series of demonstrations covering more extensive areas in West New Britain and Oro Provinces. The priority of these trials will be to publicise PNG OPRA's official fertilizer recommendations, emphasising the yield decline which occurs in the absence of fertilizer and demonstrating methods and rates of fertilizer application. The results from **Experiment 112** have shown that yield recording once a quarter is adequate to demonstrate effects and estimate annual yield. However the sites will be well characterised, including collection of soil and leaf samples, so despite minimal recording it is expected that valuable research data on variation between sites will be simultaneously acquired.

Crop protection

During 1987 there was minimal damage by oil palm pests, inluding Sexava, *Scapanes* and bagworms, in the Mosa and Popondetta areas. This indicates the success of the management policy advocated by PNGOPRA (**Investigations 601 and 606**), in which pesticides are applied only by trunk injection, so that natural parasites are not weakened or eliminated by spraying.

Sexava remains the major threat and caused serious damage in the Bialla area during the year, where the terrain makes control difficult. In **Investigation 607**, mass rearing and release of the Sexava egg parasites, *Leefmansia bicolor* and *D. leefmansi* continued throughout the year, in an attempt to control this pest by biological means. Although attempts to recover either parasite after release in the field have been negative, it may be noted that pest outbreaks in the release areas were minimal during the year.

Pathogenic species of *Ganoderma* have been identified in isolated palms in West New Britain in the past and infection by this fungus in replants is a potential hazard. However in the fifth year of two field investigations (**Experiments 801 and 803**) in the Hoskins area, in which oil palm seedlings had been planted in close proximity to material infected with *Ganoderma*, no sign of any infection was detected, indicating no cause for concern over this disease. These observations will be continued for one more final year, after which it should be safe to conclude that the risk of infection by this fungus in replants is minimal.

WEST NEW BRITAIN PROVINCE

Fertilizer Trials

(I.O.)

EXPERIMENT 106: Factorial fertilizer experiment on young, replanted palms at Bebere Plantation.

Site Details: This area was planted in August 1982 at a planting density of 135 palms ha^{-1}. 1152 palms are used in the experiment covering an area of approximately 8.5 ha. The site had previously been under oil palm for 14 years.

Design: Two replicates of a $3^2 \times 2^2$ factorial (N, K+Mg, P and age of planting material). The 72 plots are arranged in 6 blocks of 12 plots. Each plot consists of 16 recorded palms without guard rows between plots.

Treatments: Fertilizers, the last application of which was in June 1985, were applied twice yearly, at rates increasing with age. The rates of the fertilizers applied (in kg/palm) were as follows:

	N			P		K			Mg		
LEVEL	0	1	2	0	1	0	1	2	0	1	2
Months from planting											
6	0.25	0.25	0.4	0	0	0	0	0	0	0	0
10	0	0.3	0.6	0	0.2	0	0.5	1.0	0	0.2	0.4
16	0	0.6	1.2	0	0.2	0	1.0	2.0	0	0.4	0.8
22	0	0.6	1.2	0	0	0	1.5	3.0	0	0.6	1.2
28	0	1.2	2.4	0	0	0	1.25	2.5	0	1.0	2.0
34	0	1.2	2.4	0	0	0	1.25	2.5	0	1.0	2.0

Nitrogen was applied as sulphate of ammonia, phosphate as triple super phosphate, potassium as bunch ash or muriate of potash and magnesium as kieserite. Phosphate was applied during the first year only. Bunch ash was applied 3 months after the nitrogenous fertilizer to avoid ammonia volatilization. The ratio of potassium to magnesium was kept constant in plots fertilized with the combination of potassium and magnesium. Seedlings were planted at either 16 or 24 months of age.

An atypically long drought immediately after planting checked growth.

Results and Discussion: The plot data means of the treatment main effects on FFB yield, yield components and petiole WxT measurements for Jan-Dec 1987 are presented in Table 1. Cumulative data from Jan 85 to Dec 87 are presented in Table 2.

Table 1: Experiment 106, Production per hectare, Jan-Dec 1987

	s.b.w. (kg)	No. of bunches	Wt. of bunches (t)	WxT Aug 87 (cm^2)
No	11.0	2277	24.9	19.81
N1	11.2	2226	24.6	19.88
N2	11.2	2186	24.3	19.85
K/Mg0	**10.8**	2252	24.0	18.92
K/Mg1	**11.3**	2210	24.7	20.23
K/Mg2	**11.4**	2227	25.0	20.39
P0	11.1	2241	24.5	19.93
P1	11.2	2219	24.6	19.76
16 Mnth old planting	**10.2**	**2445**	24.8	19.86
24 Mnth old planting	**12.2**	**2015**	24.4	19.83
$LSD_{.05}$ (N+K/Mg)	0.34	87.3	0.85	1.29
$LSD_{.05}$ (P+Age)	0.42	106.9	1.05	1.59
C.V.(%)	6.5	8.2	7.3	13.7

(N.B. Treatments showing statistically significant effects are shown in bold type.)

Table 2: Experiment 106, Production per hectare per year, Jan 85-Dec 87

	s.b.w. (kg)	No. of bunches	Wt. of bunches(t)
N0	8.2	2533	20.5
N1	8.2	2553	20.8
N2	8.2	2537	20.7
K/Mg	**7.9**	2544	**20.1**
K/Mg	**8.3**	2545	**20.9**
K/Mg	**8.4**	2534	**21.0**
P0	8.2	2546	20.6
P1	8.2	2536	20.7
16 Mnth old planting	**7.6**	**2801**	**21.3**
24 Mnth old planting	**8.8**	**2280**	**20.0**
$LSD_{.05}$ (N+K/Mg)	0.23	95.0	0.81
$LSD_{.05}$ (P+Age)	0.19	27.6	0.66
C.V.(%)	4.8	6.4	6.8

Analysis of the 1987 data shows nitrogen application to have had no significant effect on FFB yield, single bunch weight or petiole WxT measurements. The reduction in number of bunches due to nitrogen application is only significant at p=0.09 for the dominant linear component of this response. This apparent reduction in number of bunches may in part be due to compensation for the earlier increase in single bunch weight due to nitrogen application. The cumulative data from Jan 85 to Dec 87 shows no significant effect of nitrogen applications on FFB yield, or yield components.

Both 1987 data and cumulative data, show phosphate application to have had no significant effect on FFB yield or yield components. The soil on which experiment 106 is placed has a mean phosphate retention (Saunders method) over the site of 57% and a mean Olsen extractable phosphorus level over the site of 6.0 $\mu g\ ml^{-1}$. Bearing in mind the very small amounts of fertilizer phosphorus applied, a lack of phosphorus response is not surprising.

The combined muriate of potash (bunch ash in earlier applications)/kieserite application, in 1987, produced an increase in single bunch weight, the linear regression component of this response being significant at p=0.007. There was no effect of potassium/magnesium application on number of bunches. The increase in single bunch weight is therefore responsible for the increase in FFB yield, which is significant at p=0.06 (linear regression component). It is probable that the potassium/magnesium application has increased vegetative growth as indicated by the increase in petiole WxT measurements, the linear regression component of which is significant at p=0.07. The cumulative data shows a significant (linear regression component p=0.0005) increase in single bunch weight, no response in number of bunches and a significant (linear regression component p=0.02) increase in FFB yield.

The potassium/magnesium response is probably due to the effect of magnesium. In the adjacent experiment 107, magnesium application has produced a significant increase in FFB yield. The mean exchangeable magnesium over the site is low at 0.89 me/100g, while the mean exchangeable potassium over the site is normal at 0.65 me/100g. The magnesium base saturation is relatively low at 6.4% while potassium base saturation is normal at 4.7%. Estimation of reserve magnesium by extraction with boiling 1N HCl, gives a very low value of 1.6 me/100g.

Production data for 1987, shows that using 16 month old planting material rather than 24 month old planting material, produced a significant ($p<0.001$) increase in number of bunches and a significant ($p<0.001$) decrease in single bunch weight, resulting in no significant effect on FFB yield. The age of planting material had no significant effect on petiole WxT measurements. The cumulative data shows 16 month old planting material to have a significantly ($p<0.001$) higher number of bunches than 24 month old planting material. The 16 month old planting material also had a significantly ($p<0.001$) lower single bunch weight than 24 month old planting material.

The cumulative data does show a significant ($p<0.001$) increase in FFB yield when comparing 16 month old to 24 month old planting material.

Analysis of frond 17 leaflet samples taken in October 1986, show that only the potassium/magnesium and age of planting treatments have had a significant effect on leaflet nutrient levels. Table 3, illustrates the effect of potassium/magnesium application and age of planting material on the predicted values for frond 17 leaflet tissue levels of magnesium, potassium and calcium.

Table 3: Experiment 106, Effect of potassium/magnesium application and age of planting material on leaflet Mg, K and Ca levels (predicted values).

Treatment	16 Month old planting material			24 Month old planting material		
	K/Mg0	K/Mg1	K/Mg2	K/Mg0	K/Mg1	K/Mg2
Magnesium (% D.M.)	0.187	0.191	0.207	0.197	0.213	0.218
Potassium (% D.M.)	1.171	1.097	1.061	1.090	1.038	1.026
Calcium (% D.M.)	0.899	0.850	0.845	0.943	0.894	0.889

The potassium/magnesium application and age of planting material both have significant ($p<0.001$) effects on the frond 17 leaflet levels of magnesium, potassium and calcium. The 24 month old planting material generally has higher levels of calcium and magnesium and lower levels of potassium than the 16 month old planting material. The potassium/magnesium application increases leaflet magnesium levels but decreases leaflet potassium and calcium levels.

Analysis of the frond 17 leaflet chloride levels shows that only the potassium/magnesium treatment and block differences affect the leaflet chloride levels; the K/Mg effect being significant ($p<0.001$) and the block effect being significant at $p=0.01$. Table 4, shows the effect of the muriate of potash/kieserite application on the frond 17 leaflet chloride levels (predicted values), on block 1 (with the lowest chloride levels) and block 6 (with the highest chloride levels).

Table 4: Experiment 106, Effect of muriate of potash/kieserite treatment on frond 17 leaflet chloride levels (predicted values).

Treatments	**K/Mg0**	**K/Mg1**	**K/Mg2**
	Frond 17 leaflet chloride level (% D.M.)		
Block 1	0.23	0.41	0.48
Block 6	0.26	0.45	0.51

Although the leaflet chloride levels are raised by the potassium/magnesium treatment from a fairly low level, and the rise in leaflet chloride level corresponds to the increase in yield, it is not possible to determine whether chloride is playing a significant part in the fertilizer response.

To summarize: The 16 month old planting material has yielded better than the 24 month old planting material. The combined muriate of potash/kieserite application is the only fertilizer treatment to cause a yield response. Evidence from the adjacent experiment 107 and results of soil and leaflet tissue analysis indicate that magnesium, is most likely to be the limiting element. Analysis of leaflet tissue analysis data shows that the combined potassium/magnesium application increased the magnesium and chloride leaflet levels. The fertilizer response in experiment 106 is probably due to addition of magnesium.

EXPERIMENT 107: Fertilizer experiment on mature, replanted palms, Bebere.

Site Details: The palms were planted in December 1982 and January 1983 at a planting density of 135 palms ha^{-1}. The experiment uses 2592 palms in total, 1152 palms being recorded. The experiment area is approximately 19.2ha. The site had previously been under oil palm for 14 years.

Design: This experiment consists of a mixed series $3^2 \times 2^3$ factorial design (N,P,K,Mg and establishment N). The 72 plots are arranged in 6 blocks of 12 plots each. Each plot consists of 36 palms of which the central 16 are recorded. The recorded palms are of 16 different progenies arranged in the same spacial configuration in each plot. Five of these progenies were selected from high bunch number (HBN) families and eleven from families with medium sex ratio (MSR).

Treatments: Except for nitrogen, no fertilizers were applied during the first two years following planting. At three months, all plots received 0.25kg sulphate of ammonia per palm and an additional 1kg sulphate of ammonia per palm was applied at 12 months as the treatment "establishment nitrogen". The other treatment applications commenced in February 1985. Fertilizers are applied as two equal split doses per year. Annual fertilizer application rates are as follows:-

	Kg $palm^{-1}$ $year^{-1}$		
LEVEL	0	1	2
Sulphate of ammonia	0.0	1.0	2.0
Triple superphosphate	0.0	0.5	1.0
Sulphate of potash	0.0	1.8	-
Kieserite	0.0	2.0	-

Results: Table 5, illustrates the adjusted FFB yield, yield components and petiole WxT data for the treatment main effects for the period January to December 1987.

There is a strong correlation between pre-treatment petiole WxT measurement data and yield, yield component and post-treatment petiole WxT measurement data. Adjustment of the experimental data by the pretreatment petiole WxT measurements using analysis of covariance (ANCOVA) greatly reduces the experimental error. For example the error mean squares are reduced by 40%, 20.6%, 27% and 25% for FFB yield, s.b.w., number of bunches and petiole WxT data respectively. Adjusted data is presented where ANCOVA has been used.

The increase in FFB yield due to nitrogen application is only significant at p= 0.058. No other treatment had a significant effect on bunch yield. The nitrogen yield response is due to non - significant trends in both single bunch weight and number of bunches. The kieserite treatment produced an increase in single bunch weight but this effect was only significant at p= 0.074. The kieserite effect on FFB yield was not significant.

The petiole WxT measurements were taken in September 1987 and show a significant (p= 0.029) increase due to nitrogen application.

Table 5: Experiment 107, Adjusted production data per hectare, Jan-Dec 1987.

	Wt. of bunches (t)	**s.b.w.** (kg)	**No. of bunches**	**Petiole WxT Sept. 87** (cm^2)
N0	24.2	9.41	2577	**26.2**
N1	25.4	9.60	2647	**27.8**
N2	25.3	9.56	2645	**27.2**
P0	25.1	9.6	2612	27.0
P1	24.9	9.38	2654	27.1
P2	25.0	9.59	2602	27.0
K0	24.9	9.45	2633	27.1
K1	25.1	9.60	2613	27.0
Mg0	24.7	9.43	2619	27.0
Mg1	25.3	9.62	2627	27.1
-est. N	25.1	9.46	2655	27.1
+est. N	24.8	9.58	2591	27.0
C.V.(%)	7.2	4.5	6.1	7.5
$LSD_{.05}$ (N+P)	1.05	0.25	93.6	1.19
$LSD_{.05}$ (K+Mg)	0.86	0.20	76.4	0.97

Table 6, illustrates the adjusted FFB yield and yield component data for the treatment main effects for the period January 1986 to December 1987.

The cumulative 1986-7 data shows a significant (p= 0.04) increase in FFB yield due to kieserite application of 4%. This yield increase is due to a non-significant increase in number of bunches and a significant (p= 0.018) increase in single bunch weight. Analysis of the 1986 tissue analysis data presented in the Sixth Annual Report shows that kieserite application produced a highly significant (p= 0.005) increase in frond 17 leaflet magnesium content from 0.181% D.M. without kieserite to 0.197% D.M. with kieserite application. Regression analysis of the yield and tissue analysis data shows a significant (p=0.0015) relationship between Frond 17 leaflet magnesium level and yield. Figure 1 illustrates the data points and regression model for this relationship. From the regression model, a rise in frond 17 leaflet magnesium content of 0.1% D.M. is equivalent to an increase in FFB yield of 3.31 t/ha/yr in this experiment.

Table 6: Experiment 107, Adjusted production data per hectare, Jan 86 - Dec 87

	Wt. of bunches t	s.b.w. kg	No. of bunches
No	41.4	8.00	5172
N1	42.4	8.05	5271
N2	43.2	8.10	5328
Po	42.5	8.11	5241
P1	42.4	7.97	5313
P2	42.1	8.07	5216
Ko	42.3	8.02	5279
K1	42.3	8.09	5234
Mgo	**41.5**	**7.94**	5221
Mg1	**43.2**	**8.16**	5293
-Est. N	42.6	8.01	5315
+Est. N	42.1	8.09	5199
C.V.(%)	8.2	4.6	7.9
LSD.05 (N+P)	2.04	0.22	242.4
LSD.05 (K+Mg)	1.66	0.18	197.9

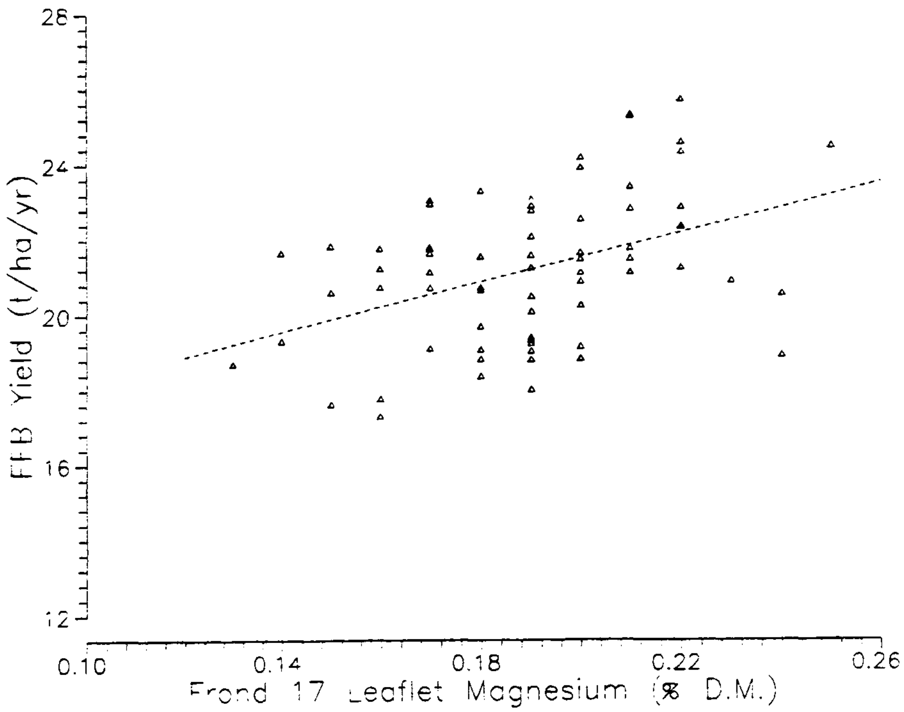


Fig.1. Experiment 107, Relationship between FFB Yield and Frond 17 Leaflet Magnesium Content.

The increase in yield due to nitrogen application is only significant at p=0.08 (linear response component).

This experiment is indicating biological responses to both nitrogen and magnesium applications. The treatment application rates are rather low; an increase in application rates should increase the magnitude of the nitrogen and magnesium responses, enabling clearer conclusions to be drawn from this experiment.

This is an agrogenetic experiment, that is each plot consists of the same mixture of identified DxP crosses. Yield, yield component and petiole WxT measurement data for these progenies are presented in Table 7.

Table 7: Experiment 107, Production per progeny per hectare, Jan-Dec 1987.

Progeny	**Wt. of bunches** (t)	**s.b.w.** (kg)	**No. of bunches**	**Petiole WxT Sept 87** (cm^2)
HBN				
1	21.2	8.0	2659	23.8
	27.4	9.8	2790	30.2
3	24.8	9.5	2599	27.7
4	23.7	9.2	2578	22.4
5	23.8	8.9	2691	29.8
Mean	24.2	9.1	2663	26.8
MSR				
6	27.3	9.4	2888	31.1
7	25.7	10.0	2565	25.8
8	21.3	8.3	2576	25.7
9	24.0	10.9	2209	27.3
10	28.1	10.7	2629	27.6
11	24.5	9.6	2569	28.7
12	24.1	7.9	3056	21.6
13	26.7	11.0	2426	29.4
14	26.9	10.3	2606	30.7
15	26.8	9.7	2771	23.7
16	23.9	9.9	2408	27.1
Mean	25.4	9.8	2609	27.2
C.V.(%)	25.4	18.6	25.3	20.4
$LSD_{.05}$	2.08	0.59	217.3	1.80

MSR (medium sex ratio) progenies produced a significantly (p <0.001) greater single bunch weight than HBN (high bunch number) progenies. There is no significant difference between bunch numbers of MSR and HBN progenies. Due to their higher bunch weights, the MSR progenies have produced a significant (p= 0.003) higher FFB yield over HBN progenies. Petiole WxT measurements show no significant difference between MSR and HBN.

EXPERIMENT 108: Systematic Nitrogen Fertilizer Trial, Kumbango.

Site Details: This area was planted in 1972 at a planting density 120 palms ha^{-1}. 2134 palms are used in the experiment covering an area of approximately 18 ha. This experiment was initiated in 1985 in an area of Kumbango plantation which was felt to be suffering a decline in soil organic matter level.

Design: Two sources of nitrogen are compared in systematically increasing levels of 8 equal steps, replicated four times. A set of levels of each source abutts a second set but with the direction of increase of dose in one set being opposite to the other. Two replicates of this arrangement were placed in a block mulched with 30 t ha^{-1} empty bunches in March 1985 and two replicates placed in an unmulched one. There is a total of 64 plots, each plot consisting of the two rows on either side of a harvesting path (twin row) and on average consisting of 33 palms. There are no guard rows between levels but the two sources are guarded from each other and the end rows are guarded.

Treatments: The annual fertilizer applications to this experiment are as follows;

	Kg $palm^{-1}$ $year^{-1}$							
LEVEL	0	1	2	3	4	5	6	7
Ammonium chloride	0	0.9	1.8	2.7	3.6	4.5	5.4	6.3
Diammonium phosphate	0	1.2	2.4	3.6	4.8	6.0	7.2	8.4

The fertilizer is applied as two split doses per year. Application commenced in July 1985.

For each level of application, both ammonium chloride and diammonium phosphate supply the same quantity of nitrogen.

Results: The FFB yield data calculated on a per hectare per annum basis, for the period January 1986 to December 1987, is presented in Table 8. The single bunch weight and number of bunches data are presented in Tables 9 and 10 respectively.

Table 8: Experiment 108, FFB yield per hectare per annum, January 1986 to December 1987.

	FFB Yield ($t\ ha^{-1}\ yr^{-1}$)			
	Ammonium chloride		**Diammonium phosphate**	
LEVEL	**-Mulch**	**+Mulch**	**- Mulch**	**+ Mulch**
0	19.2	22.8	16.6	19.3
1	22.7	23.1	21.4	21.8
2	25.2	25.3	22.3	24.5
3	27.3	26.2	25.6	27.0
4	25.4	29.9	24.5	29.7
5	28.7	28.7	28.0	28.6
6	29.8	29.5	29.15	29.9
7	28.7	29.2	29.2	28.0
C.V.(%)	7.4			
$LSD_{.05}$	7.6			

Table 9: Experiment 108, Single bunch weights, January 1986 to December 1987.

	Single bunch weight (kg)			
	Ammonium chloride		**Diammonium phosphate**	
LEVEL	**-Mulch**	**+Mulch**	**-Mulch**	**+Mulch**
0	20.2	21.9	20.1	19.5
1	21.2	21.6	20.0	20.5
2	21.9	22.7	19.9	21.3
3	22.2	23.7	21.2	21.6
4	22.3	24.8	21.9	22.7
5	22.9	23.9	21.3	22.8
6	22.6	23.6	21.3	23.1
7	23.8	23.6	22.8	23.3
C.V.(%)	4.0			
$LSD_{.05}$	1.8			

Table 10: Experiment 108, Number of bunches per hectare per annum, January 1986 to December 1987.

	Number of bunches			
	Ammonium chloride		**Diammonium phosphate**	
LEVEL	**-Mulch**	**+Mulch**	**-Mulch**	**+Mulch**
0	1901	2060	1655	1976
1	2130	2136	2136	2119
2	2303	2233	2247	2302
3	2461	2206	2406	2499
4	2277	2414	2245	2611
5	2507	2395	2635	2504
6	2628	2500	2737	2598
7	2411	2471	2567	2407
C.V.(%)	6.6			
$LSD_{.05}$	309			

A problem of this design of experiment, is the lack of control of the inherent spacial fertility trending within the experimental site. A manifestation of this problem is a downward biasing of the D.A.P. treatment results. It is estimated that the D.A.P. treatment is yielding approximately 3t ha^{-1} yr^{-1} FFB lower than the ammonium chloride treatments irrespective of the treatment effect.

Overall, mulching has produced a significant ($p= 0.013$) 1.2t ha^{-1} yr^{-1} increase in FFB yield, there is no significant interactions between type of fertilizer applied or rate of fertilizer applied and the presence or absence of mulch. Mulching had no significant effect on number of bunches but produced a significant ($p= 0.0001$) increase in single bunch weight of 0.94kg.

Figure 2. illustrates the data and response curves of FFB yield to fertilizers applied. The effect of mulch has not been separated out.

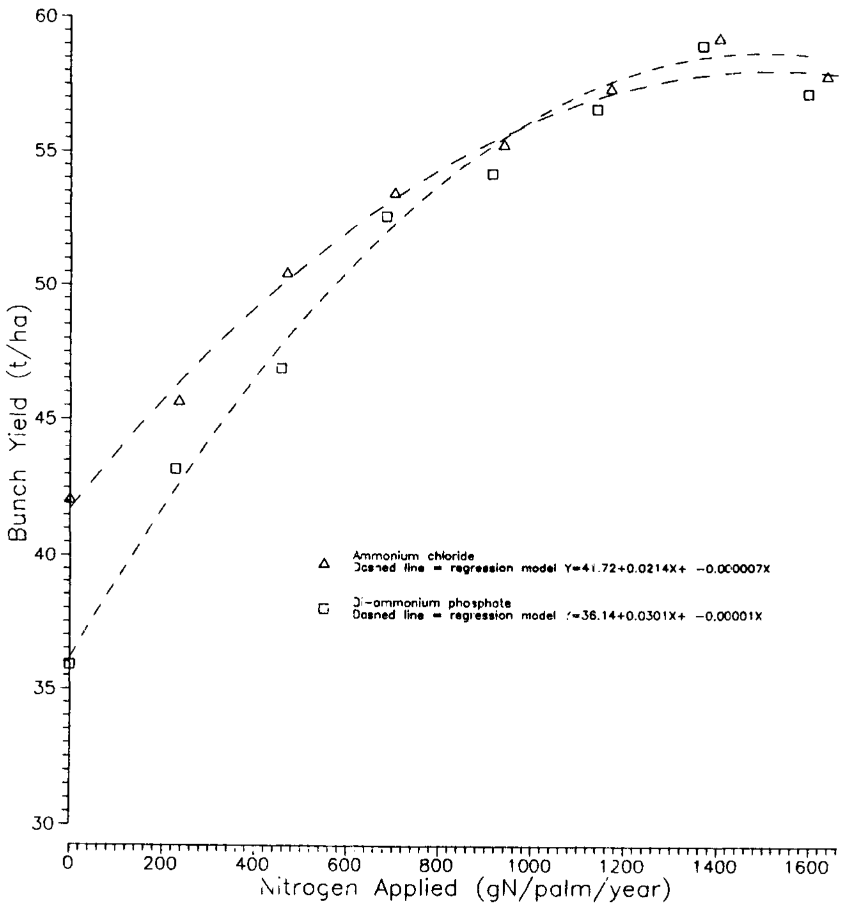


Fig.2. Experiment 108, Yield per hectare, Jan.86-Dec.87.

Bearing in mind the downward biasing of the D.A.P. treatment as described above, the curves are very similar. This indicates the FFB yield response is due to the influence of nitrogen only. It can be concluded that phosphate and chloride have not effected FFB yield.

Figs. 3, 4 and 5 illustrate the best fit parabolic regression models for the data in Tables 8, 9 and 10 respectively.

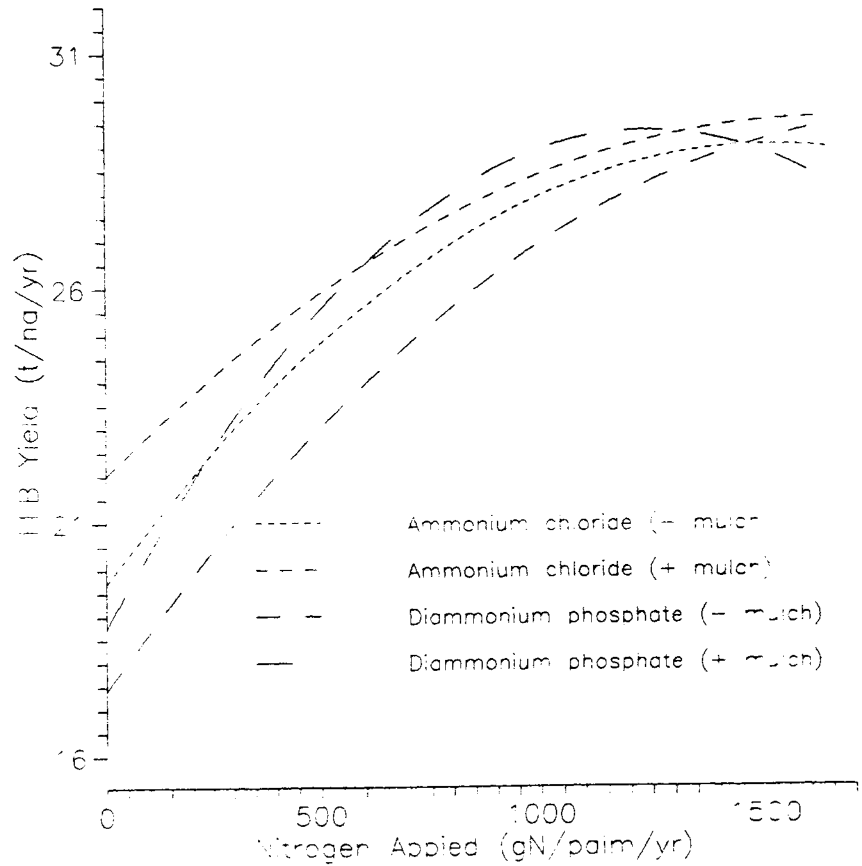


Fig: 3 Experiment 108, Effect of Fertilizer (quantified as N applied) and Mulching on FFB Yield.

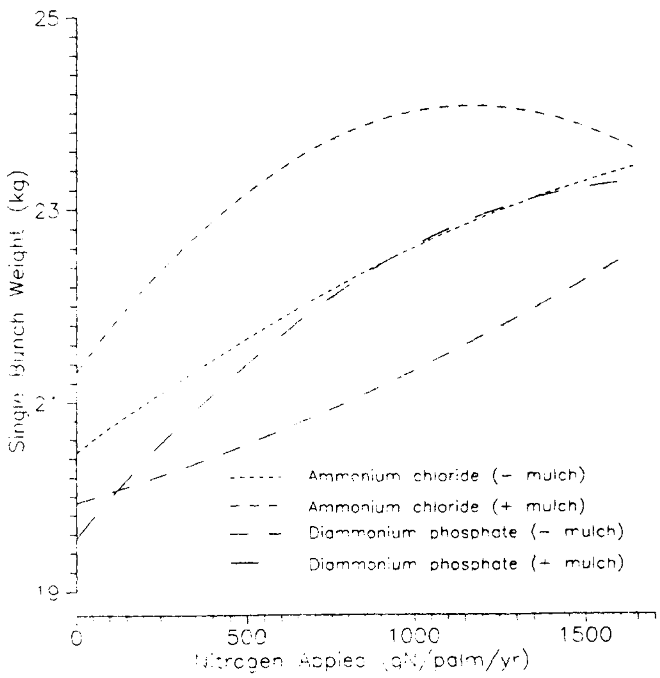


Fig: 4 Experiment 108, Effect of Fertilizer (quantified as N applied) and Mulching on Single Bunch Weight.

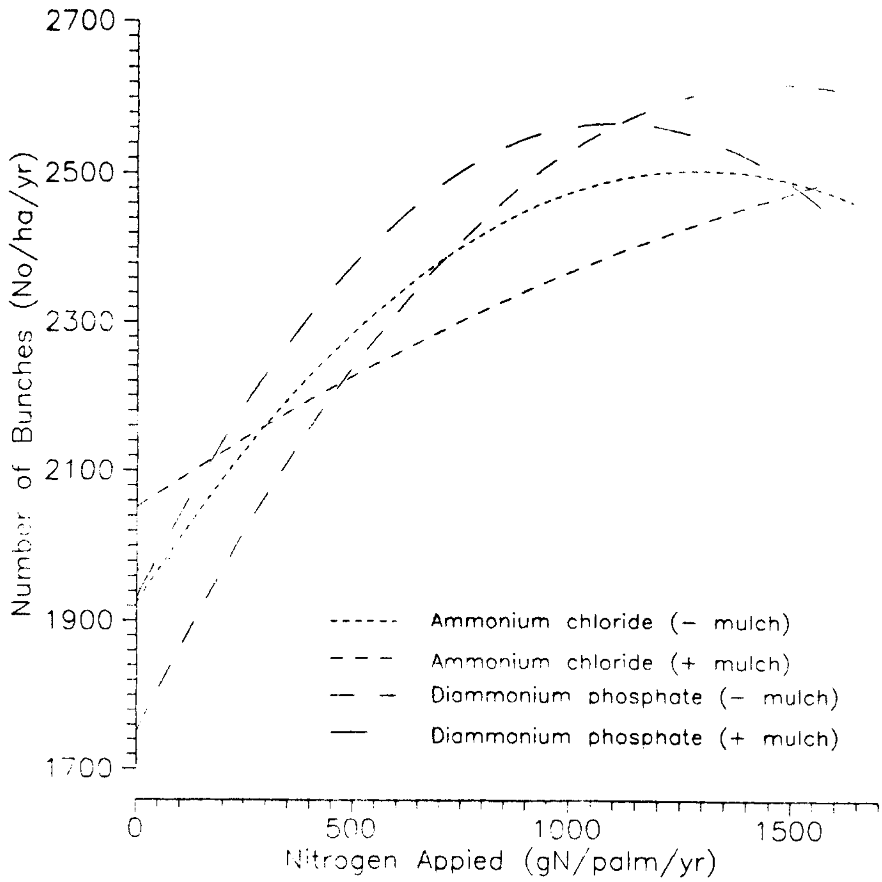


Fig: 5. Experiment 108, Effect of fertilizer (quantified as N applied) and Mulching on Number of Bunches.

The mulch effect on FFB yield is clear but does not influence the shape or slope of the response curve. All curves appear to reach a peak yield at about 29t ha^{-1} yr^{-1}, at this point a factor other than nitrogen, phosphorus or chlorine shortage is limiting yield. The presence of mulch does appear to influence the nitrogen response in single bunch weights. Up to a nitrogen application rate of 1000 gN $palm^{-1}$ yr^{-1}, the diammonium phosphate and ammonium chloride s.b.w. response curves in the presence of mulch have steeper slopes (3.1 and 2.7 kg s.b.w. to kg N) respectively than in the absence of mulch (1.4 and 2.2 kg s.b.w. to kg N respectively). FFB yield is very closely correlated with the number of bunches, consequently the response curves for number of bunches is very similar to that for FFB yield.

The frond 17 leaflet tissue analysis data for August 1987 is presented in Table 11.

The effect of mulching on frond 17 elemental contents, has been a significant ($p= 0.007$) increase in nitrogen content of about 0.12% D.M., a significant ($p= 0.007$) increase in potassium content of about 0.05% , a significant ($p= 0.0006$) decrease in sulphur content of about 0.01% , a significant ($p= 0.02$) decrease in manganese content of about 5ppm, a signific 0.0002) decrease in boron content of about 1.2 ppm and a

Table 11: Experiment 108. Frond 17 Leaflet Nutrient Levels, August 1987.

	Rate (kg/Palm/yr)	N (% D.M.)		P (% D.M.)		K (% D.M.)		Mg (% D.M.)		Ca (% D.M.)		S (% D.M.)		Cl (% D.M.)		Fe (ppm D.M.)		Mn (ppm D.M.)		Zn (ppm D.M.)		Cu (ppm D.M.)		B (ppm D.M.)	
		-Mch	+Mch	-Mch	+Mch	-Mch	+Mch	-Mch	+Mch	-Mch	+Mch	-Mch	+Mch	-Mch	+Mch	-Mch	+Mch	-Mch	+Mch	-Mch	+Mch	-Mch	+Mch	-Mch	+Mch
Ammonium chloride	0 0	2.20	2.30	0.140	0.140	0.930	0.965	0.230	0.215	0.870	0.895	0.150	0.135	0.285	0.335	66.5	75.0	66.0	63.0	19.5	(32.5	4.5	5.0	12.5	11.0
	0.9 1	2.15	2.30	0.140	0.135	0.870	0.960	0.215	0.210	0.895	0.870	0.155	0.140	0.315	0.460	66.5	73.0	73.5	64.0	18.5	19.0	4.0	4.5	13.5	11.0
	1.8 2	2.30	2.50	0.145	0.145	0.855	0.895	0.195	0.200	0.910	0.905	0.150	0.140	0.400	0.475	73.0	70.5	70.0	65.0	18.5	19.0	5.0	4.5	13.0	10.0
	2.7 3	2.35	2.50	0.145	0.145	0.810	0.900	0.170	0.195	0.960	0.880	0.145	0.150	0.420	0.535	89.0	80.5	84.5	68.0	20.0	18.5	4.5	5.0	12.0	11.0
	3.6 4	2.35	2.65	0.145	0.145	0.825	0.815	0.165	0.165	0.960	0.985	0.150	0.140	0.460	0.540	82.0	69.0	80.5	74.0	18.0	19.0	5.0	4.5	12.5	11.5
	4.5 5	2.45	2.65	0.155	0.150	0.805	0.935	0.155	0.185	0.955	0.965	0.160	0.150	0.485	0.605	72.5	80.5	89.0	77.0	18.5	19.5	4.5	5.5	12.5	10.5
	5.4 6	2.60	2.50	0.155	0.150	0.825	0.895	0.160	0.180	1.025	1.030	0.160	0.140	0.545	0.660	79.5	83.0	90.5	82.5	19.0	19.0	5.0	4.5	12.0	11.0
	6.4 7	2.40	2.65	0.150	0.150	0.865	0.920	0.155	0.205	0.935	1.000	0.155	0.140	0.565	0.630	88.0	80.0	94.5	82.5	15.5	18.0	5.0	6.5	12.5	9.0
Diammonium phosphate	0	2.00	2.10	0.140	0.130	0.885	0.910	0.265	0.265	0.890	0.980	0.135	0.135	0.240	0.290	76.0	70.5	74.5	68.5	20.0	22.0	4.0	4.5	12.0	12.5
	1.2	2.20	2.25	0.140	0.140	0.885	0.885	0.240	0.240	0.915	0.940	0.140	0.140	0.220	0.275	63.0	62.5	71.0	66.5	20.0	22.0	4.5	5.5	12.0	11.0
	2.4	2.35	2.25	0.145	0.145	0.925	0.975	0.205	0.250	0.900	0.955	0.145	0.150	0.200	0.330	70.0	66.5	70.5	69.0	21.5	20.5	4.5	5.5	11.0	11.0
	3.6	2.25	2.35	0.145	0.155	0.980	0.955	0.215	0.215	0.880	0.935	0.145	0.145	0.220	0.305	73.0	63.0	67.0	67.0	22.5	21.0	5.0	5.0	14.0	12.0
	4.8	2.45	2.30	0.150	0.155	0.960	0.950	0.200	0.225	0.860	0.945	0.150	0.150	0.235	0.315	79.5	67.0	69.0	66.0	23.0	20.5	5.0	5.0	11.5	12.5
	6.0	2.30	2.40	0.155	0.150	0.920	0.970	0.190	0.220	0.915	0.950	0.155	0.140	0.225	0.345	86.0	75.0	68.0	70.5	20.5	21.0	5.0	5.5	13.0	11.5
	7.2	2.25	2.55	0.160	0.150	0.905	0.950	0.195	0.190	0.900	0.890	0.155	0.140	0.240	0.295	78.0	82.0	74.0	79.0	23.0	20.0	6.0	4.5	12.0	12.5
	8.4	2.30	2.6	0.160	0.155	0.940	1.020	0.180	0.200	0.855	0.870	0.160	0.150	0.210	0.325	76.0	75.5	80.0	79.5	18.0	21.5	5.0	5.0	11.0	10.5

significant (p= 0.008) increase in chlorine content of about 0.1% D.M. Both calcium and magnesium frond 17 leaflet levels were increased by mulching, by 0.02 and 0.01% D.M. respectively, but these increases only reached significance at the 10% level. The effects of mulching on leaflet nutrient contents were more pronounced in the areas receiving ammonium chloride fertilizer than in those receiving diammonium phosphate. This is probably due to a difference in the soil characteristics between these areas rather than an effect of the fertilizer applied. There is no significant interaction between mulching and level of fertilizer applied.

Figures 6 to 11 illustrate the effects of application of ammonium chloride and diammonium phosphate on frond 17 leaflet nutrient levels. Only the elements that are significantly ($p<0.05$) affected by fertilizer application are included. Data from mulched and unmulched areas have been combined in order to gain sufficient replication to produce reliable regression models.

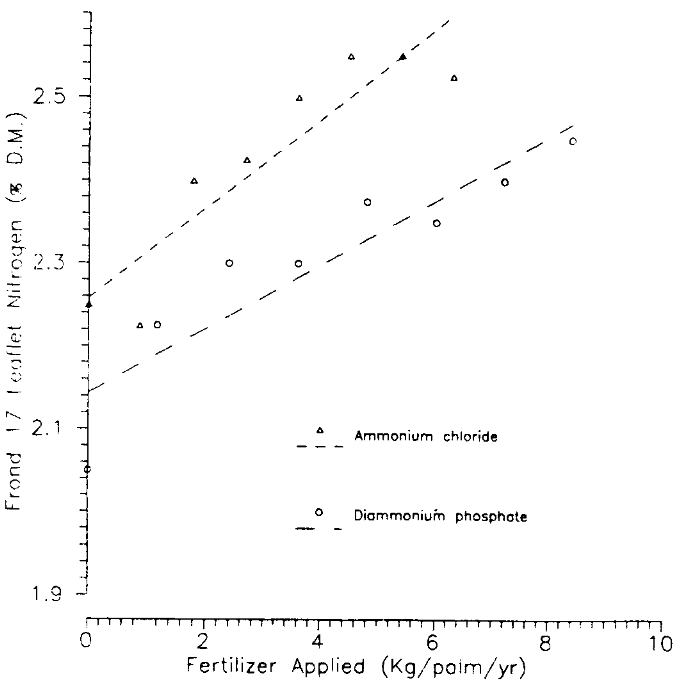


Fig.6. Experiment 108, Effect of Fertilizer Application on Frond 17 Leaflet N Level.

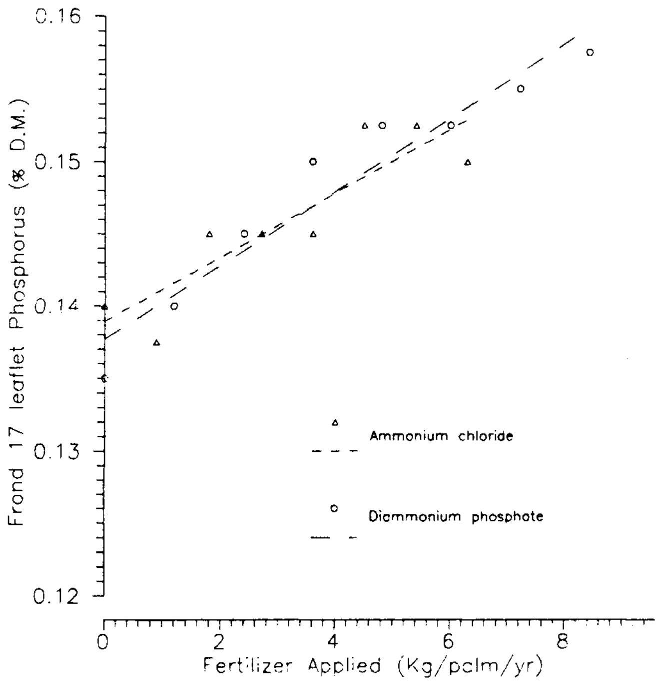


Fig.7. Experiment 108, Effect of Fertilizer Application on Frond 17 Leaflet P Level.

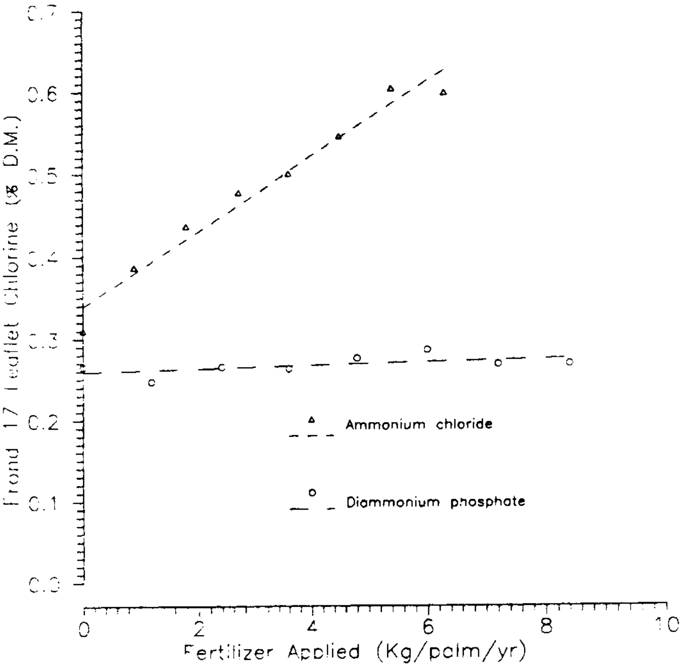


Fig.8. Experiment 108, Effect of Fertilizer Application on Frond 17 Leaflet Cl Level.

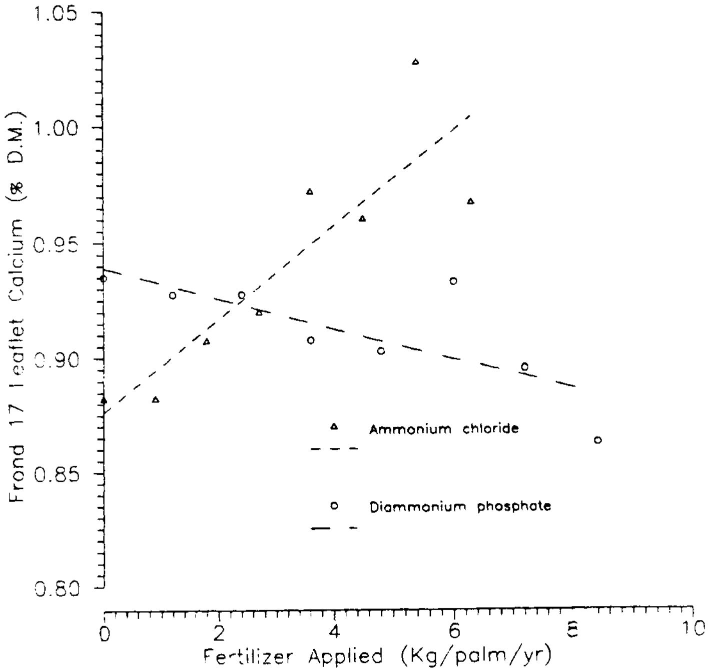


Fig.9. Experiment 108, Effect of Fertilizer Application on Frond 17 Leaflet Ca Level.

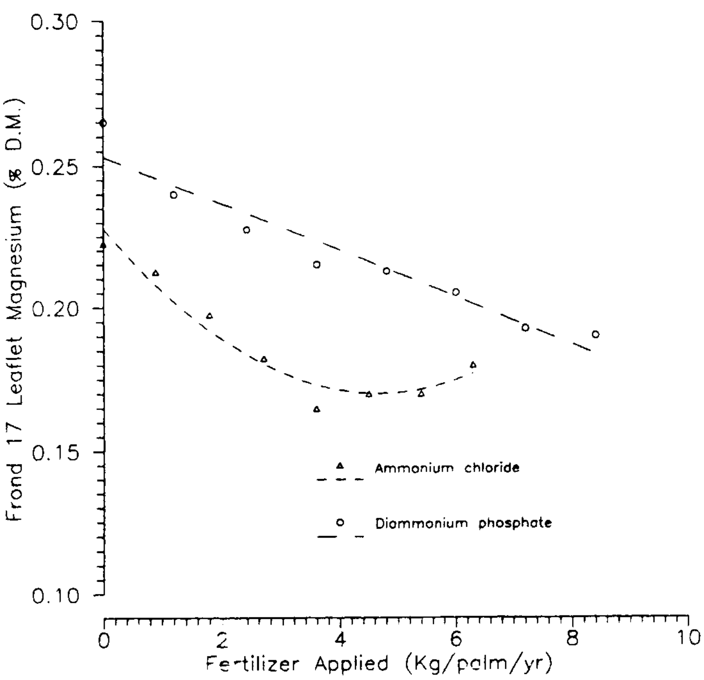


Fig.10 Experiment 108, Effect of Fertilizer Application on Frond 17 Leaflet Mg Level.

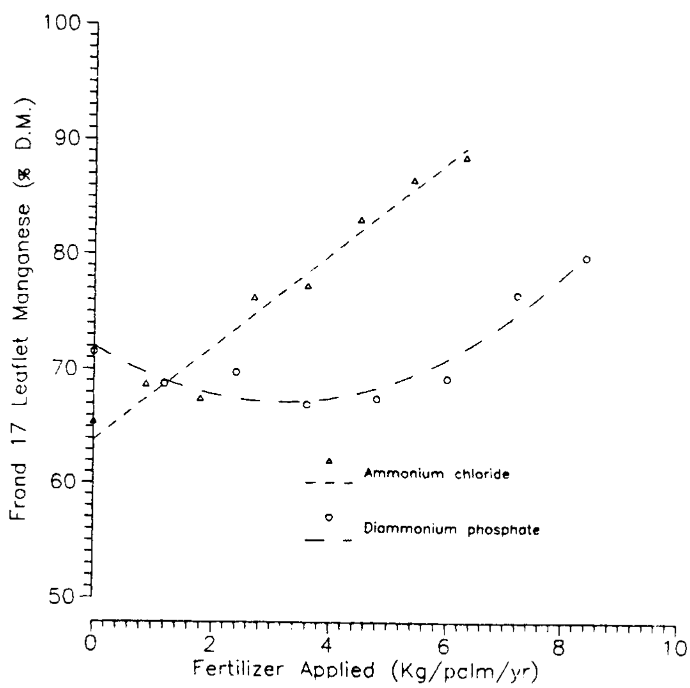


Fig.11 Experiment 108, Effect of Fertilizer Application on Frond 17 Leaflet Mn Level.

There is a linear increase in leaflet nitrogen levels with application of both ammonium chloride and diammonium phosphate. On a per unit of nitrogen applied basis, there is no difference between the ability of ammonium chloride and diammonium phosphate to increase leaflet nitrogen levels. Both fertilizers produce an increase in frond 17 leaflet nitrogen content of 0.21% D.M. for every kg of nitrogen applied per palm per year.

Both ammonium chloride and diammonium phosphate produce a linear increase in frond 17 leaflet phosphorus content with increase in application rate. The magnitude and slope of these response curves are the same. A number of workers, EMMERT (1971), FOSTER (1977) and OLLAGNIER et al (1970), have shown nitrogenous fertilizer to increase leaf phosphorus levels, phosphorus uptake by plants may be specifically enhanced by ammonium ions. Bearing this in mind, it is not surprising that ammonium chloride increases leaflet phosphorus content; it is surprising though that it does so to the same degree as diammonium phosphate application.

Frond 17 leaflet chlorine level shows a linear increase with application of ammonium chloride. The increase in leaflet chloride levels is equivalent to 0.074% Cl (on a dry matter basis) for every kg of chlorine applied per palm per year. Diammonium phosphate application has no effect on leaflet chlorine content.

Frond 17 leaflet calcium and magnesium levels are reduced by application of diammonium phosphate, leaflet magnesium levels are also reduced by ammonium chloride application. Leaflet calcium levels on the other hand are increased by ammonium chloride application. The drop in leaflet magnesium due to ammonium chloride application may be in part due to the marked increase in calcium uptake due to the same treatment.

A commonly observed consequence of ammonium chloride application, is a dramatic increase in leaflet manganese content; this effect is clearly demonstrated in this experiment. The effect of diammonium phosphate on leaflet manganese content is less distinct.

By using the parabolic regression models for effect of fertilizer type and rate on FFB yield (see Fig.2), an optimum fertilizer application rate can be calculated for given input costs and output values. Figures 12 and 13 illustrate the relationship between calculated optimum fertilizer application rate and the ratio of fertilizer cost to FFB value. The X axis for each fertilizer covers a maximum realistic ratio range for each fertilizer for as long as the calculated optimum fertilizer application is positive.

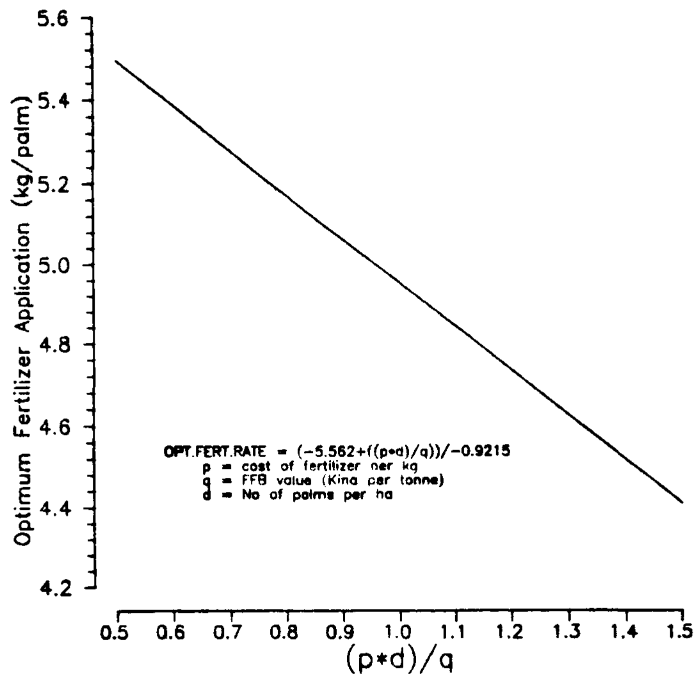


Fig: 12. Experiment 108, Ammonium Chloride Application Rate to Optimize Profit.

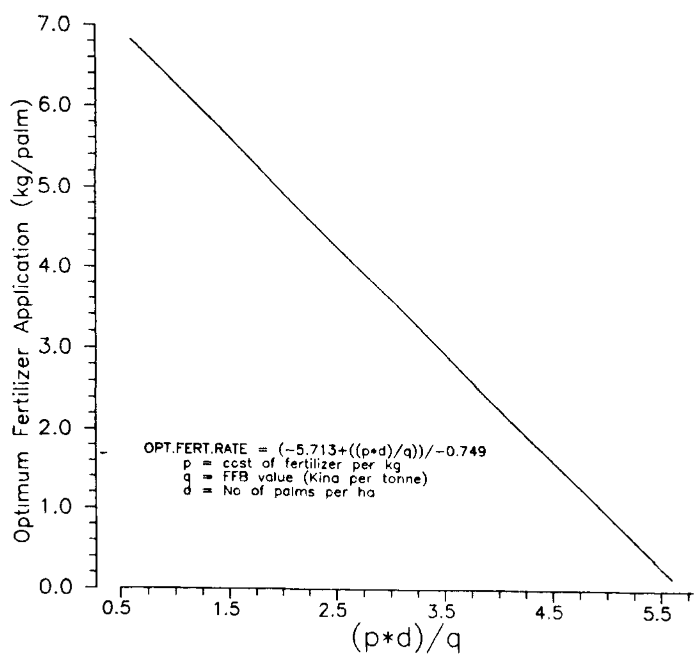


Fig:13. Experiment 108, Di-ammonium Phosphate Application Rate to Optimize Profit.

The models in Figs. 12 and 13 are simplistic and contain a number of crude assumptions, but bearing in mind the many uncontrollable variables involved in such models on perennial crops that are yielding constantly and have a lag between application and response of over a year, such models should prove useful indicators for producing recommended fertilizer application rates in the long term.

Both ammonium chloride and diammonium phosphate are equally effective nitrogen sources, no specific response to phosphate has been observed and so bearing in mind the relative costs of ammonium chloride and diammonium phosphate, ammonium chloride must be the prefered nitrogen source of the two.

EXPERIMENT 110 : Nitrogen/anion experiment on young, replanted palms, Bebere.

Site details: The experimental site was planted in February 1985 at a density of 135 palms/ha. The experiment uses 1152 palms, covering an area of 8.8 hectares. Plots consist of 16 palms with no guard rows.

Design: The experiment consists of 24 treatments, in 3 replicates of completely randomised blocks. Blocking was based on petiole WxT measurements.

Treatments: Fertilizer treatment application rates are as follows:

Treatment	**Non-N Anion and Level**		**Non-N anion Source**	**Additional Ammonium Nitrate**
			Kg $Palm^{-1}$	$Year^{-1}$
1	Chloride	0	0.0	1.6
2	Chloride	1	0.5	1.2
3	Chloride	2	1.0	0.8
4	Sulphate	0	0	1.6
5	Sulphate	1	1.25	0.8
6	Sulphate	2	2.50	0.0
7	Phosphate	0	0.0	1.6
8	Phosphate	1	1.4	0.8
9	Phosphate	2	2.8	0.0
10	Nil	0	0.0	0.0
11	Nil	0	0.0	0.0
12	Nil	0	0.0	0.0

(N.B. Treatments 13 to 24, as above, but mulched.)

Apart from the 'Nil' treatments, all treatments and levels receive the same amount of nitrogen, the only difference between them being the type and level of accompanying non-nitrogenous anion (either chloride, sulphate or phosphate). Plots receiving treatments 1 to 12 are unmulched, plots receiving treatments 13-24 were mulched with about 100 kg of empty bunches per palm in April and May 1984. Application of fertilizer started in June 1985 and was continued at half yearly intervals. The above rates are those used since June 1986, the two applications prior to this time were at half these rates.

Results: FFB yield and yield component data for 1987 are illustrated in table 12.

Table 12. Experiment 110, Production per hectare, Jan-Dec 1987.

Total N applied (g $palm^{-1}$)		Non-N anion & level	s.b.w (Kg) mulched	s.b.w (Kg) unmulched	No of bunches mulched	No of bunches unmulched	FFB yield (t ha^{-1} yr^{-1}) mulched	FFB yield (t ha^{-1} yr^{-1}) unmulched
550		0	6.2	5.9	3550	**3001**	21.9	**17.8**
550	Chloride	1	6.2	6.2	3645	**3153**	22.6	**19.5**
550		2	6.5	6.2	3322	**3499**	21.5	**21.7**
550		0	6.2	5.9	3550	3001	21.9	17.8
550	Sulphate	1	5.0	6.5	3493	3063	20.8	19.9
550		2	6.4	6.1	3338	3235	21.4	19.7
550		0	6.2	5.9	3550	**3001**	21.9	**17.8**
550	Phosphate	1	6.3	5.9	3289	**3184**	20.6	**18.8**
550		2	6.3	5.9	3321	**3378**	20.1	**20.0**
0.0	No Fert.		6.1	6.2	**3494**	**3145**	**21.2**	**19.5**
	Mean		6.2	6.1	**3462**	**3162**	**21.5**	**19.2**
C.V.(%)			4.3		5.9		6.7	
$LSD_{.05}$			0.44		323		2.2	

Mulching overall has produced no significant effect on single bunch weight, but has produced a significant ($p<0.0001$) increase in number of bunches. This increase in number of bunches has produced a significant ($p<0.0001$) increase in FFB yield of 2.3 t ha^{-1} yr^{-1}.

Chloride application produced a significant ($p=0.003$) increase in number of bunches in the absence of mulching. This increase in number of bunches produced a significant ($p=0.0009$) increase in FFB yield of 3.95 t ha^{-1} yr^{-1}. Unfortunately these responses to chloride only raise the FFB yield and number of bunches from below to just above those experienced in the absence of fertilizer application.

Phosphate application has produced a significant ($p=0.02$) increase in number of bunches in the absence of mulching. This increase in number of bunches has led to an increase in the FFB yield of 2.2 t ha^{-1} yr^{-1}, which was significant at $p=0.056$. As with the chloride responses, phosphate addition has only brought the yields up to the level of those attained in the absence of fertilizer.

In the absence of fertilizer application mulching produces a significant ($p<0.0001$) increase in number of bunches and a significant ($p=0.0008$) increase in FFB yield of 2.3 t ha^{-1} yr^{-1}.

Figures 14 and 15 illustrate the effect of treatments on unmulched and mulched palms respectively, using parabolic regression through the data points.

The means of the petiole WxT measurements carried out in experiment 110 during 1987 (Jan, April, July and Oct) are presented in Table 13.

Table 13. Experiment 110. Petiole WxT measurements, 1987.

Total N applied (g $palm^{-1}$)	Non-N anion & level		Petiole WxT measurements (cm^2) Mulched	Unmulched
550		0	18.66	17.29
550	Chloride	1	18.86	17.10
550		2	19.20	17.90
550		0	18.66	17.29
550	Sulphate	1	17.77	17.59
550		2	18.33	17.96
550		0	18.66	17.29
550	Phosphate	1	17.15	17.76
550		2	18.78	18.16
0.0			**18.61**	**17.72**
	Mean		**18.47**	**17.61**
C.V. (%)			4.8	
$LSD_{.05}$			1.42	

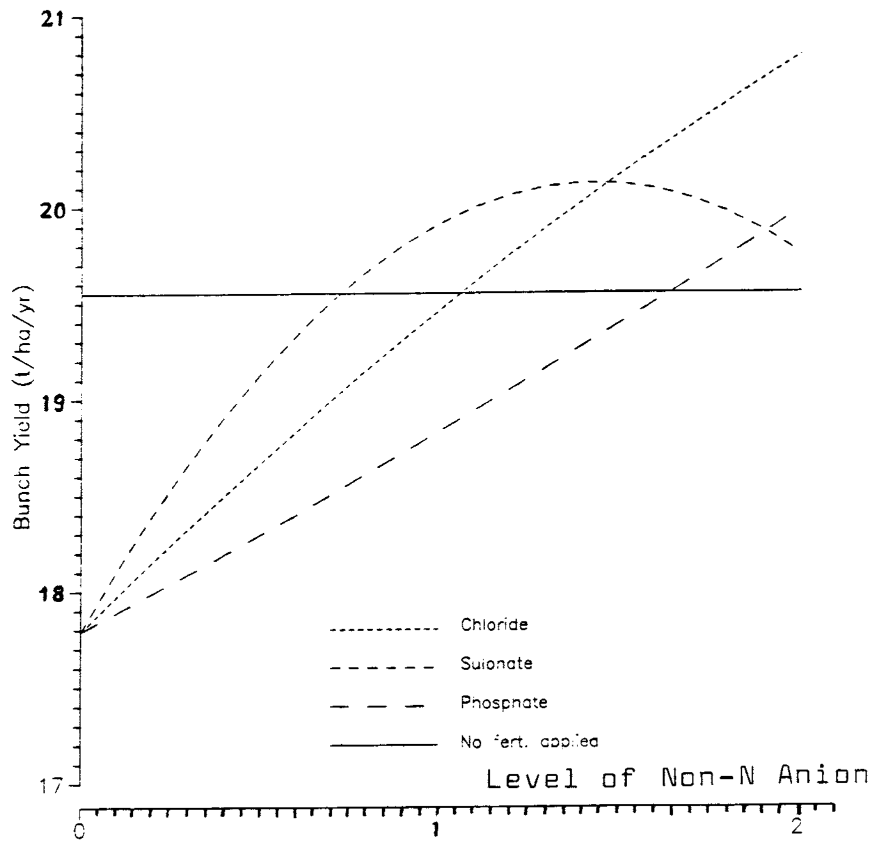


Fig:14. Experiment 110, Effect of non-nitrogenous anion on bunch yield of unmulched Oil Palm

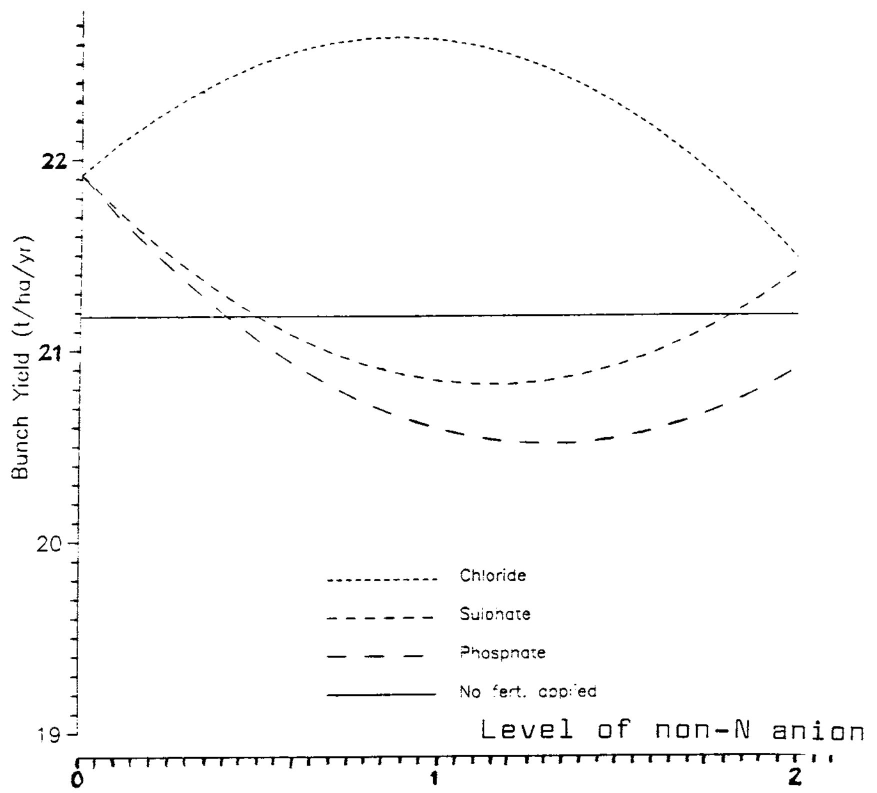


Fig:15. Experiment 110, Effect of non-nitrogenous anion on bunch yield of mulched Oil Palm

Mulching has produced a very highly significant (p=0.001) increase in petiole WxT measurement.

None of the non-nitrogenous anion treatment effects are statistically significant, though there is a trend of increasing petiole WxT with all non nitrogenous anion treatments in the absence of mulch.

Figure 16. illustrates the effect of non-nitrogenous anion on petiole WxT measurements on unmulched oil palm, using parabolic regression curves through the data points.

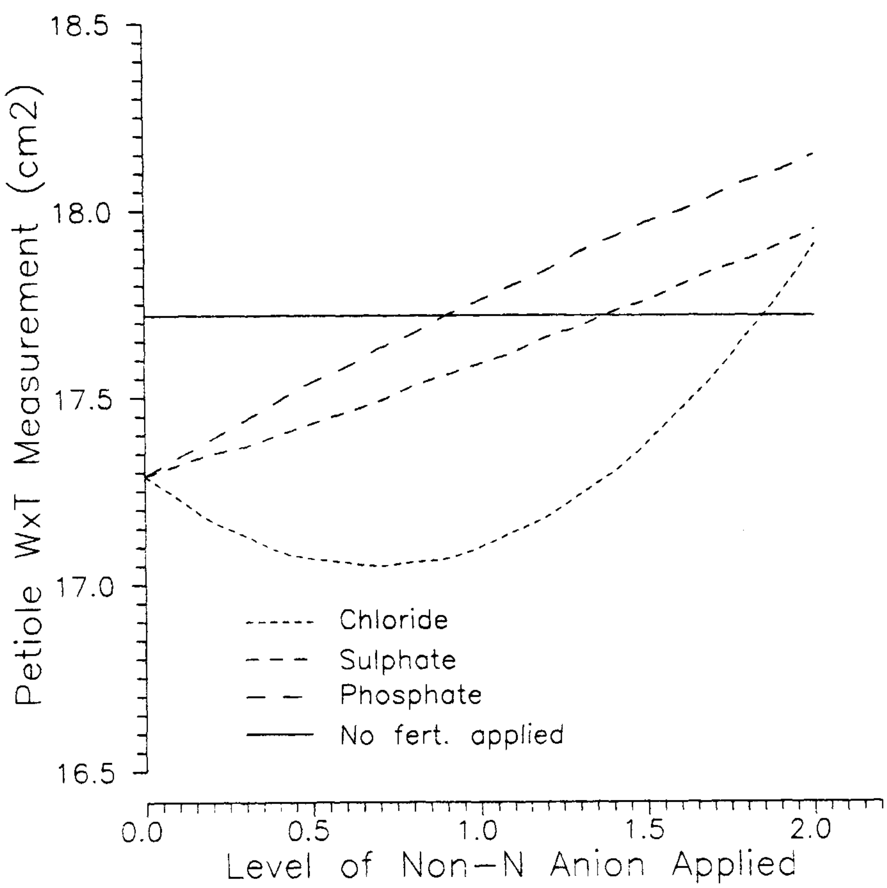


Fig:16. Experiment 110, Effect of non-nitrogenous anion on petiole WxT measurements of unmulched Oil Palm.

As was observed with the yield data, the responses due to application of non-nitrogenous anion have raised the petiole WxT measurements from below to just above the level attained without any fertilizer addition.

Results of the frond 17 leaflet tissue analyses carried out in June 1987 are presented in Table 14.

TABLE 14. EXPERIMENT 110, Effects of treatment on tissue analysis of frond 17 leaflets.

Total N applied (g palm)	Non-N anion &	level	N %DM		P %DM		K %DM		Mg %DM		Ca %DM		S %DM		Cl %DM		Fe ppmDM		Mn ppmDM		Zn ppmDM		Cu ppmDM		B ppmDM	
			+Mlch	-Mlch	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-
550		0	2.61	2.54	.17	.17	**1.07**	**1.00**	.22	.20	1.15	1.20	.17	.17	**.26**	**.22**	60.0	61.1	**62.1**	**61.4**	22.4	19.1	7.1	6.3	11.4	12.3
550	Chloride	1	2.53	2.60	.16	.17	**.95**	**.86**	.21	.20	1.17	1.19	.17	.17	**.50**	**.49**	55.3	66.3	**80.7**	**88.3**	20.3	26.7	7.0	5.3	12.0	11.3
550		2	2.60	2.50	.16	.16	**.85**	**.85**	.19	.21	1.24	1.20	.17	.16	**.55**	**.56**	61.7	62.3	**84.0**	**100.3**	19.0	18.3	6.0	5.7	9.3	9.3
550		0	2.61	2.54	.17	.17	1.07	1.00	.20	.20	1.15	1.20	.17	.17	.26	.22	60.0	61.1	62.1	**61.4**	22.4	19.1	7.1	6.3	11.4	12.3
550	Sulphate	1	2.73	2.67	.16	.16	.98	1.03	.20	.21	1.15	1.22	.17	.18	.27	.24	55.0	65.0	72.7	**82.7**	18.0	22.3	5.0	6.3	9.0	10.7
550		2	2.70	2.47	.16	.16	1.04	1.08	.20	.20	1.13	1.17	.18	.17	.29	.22	61.0	56.3	72.3	**78.7**	21.7	20.0	6.0	7.0	10.0	12.3
550		0	2.61	2.54	.17	.17	1.07	1.00	.22	.20	1.15	1.20	.17	.17	.26	**.22**	60.0	61.1	**68.1**	**61.4**	22.4	19.1	7.1	6.3	11.4	12.3
550	Phosphate	1	2.67	2.53	.16	.17	.99	.94	.19	.20	1.14	1.27	.17	.18	.27	**.24**	61.0	54.3	**72.0**	**72.7**	18.3	17.7	5.3	5.3	10.3	12.7
550		2	2.63	2.70	.16	.16	.96	.94	.22	.19	1.15	1.18	.17	.17	.29	**.31**	59.3	62.3	**76.7**	**78.3**	19.3	19.7	5.7	5.7	11.3	10.3
0.0	No. Fert.		2.59	2.49	.17	.17	1.06	1.07	.20	.21	1.179	1.18	.18	.17	.27	.26	59.7	56.89	47.9	51.9	20.4	18.4	6.4	7.4	11.4	11.5
Mean			2.61	2.52	.16	.16	1.013	.992	.205	.204	1.163	1.198	.175	.175	.313	.291	59.4	60.1	65.7	70.1	20.4	19.8	6.3	6.4	10.9	11.5
CV			5.9%		4.8%		8.6%		10.7%		5.5%		7.0%		9.8%		12.9%		10.6%		21.4%		21.9%		22.5%	
$LSD_{0.05}$			0.25		0.013		0.14		0.04		0.11		0.02		0.05		12.68		11.85		7.12		2.29		4.16	

Only the frond 17 leaflet chlorine levels were significantly affected by the experimental treatments. As expected, the addition of fertilizer chloride, increased the leaflet chlorine levels dramatically, from 0.26 %D.M mulched and 0.22 %D.M unmulched to 0.55 and 0.56 %D.M at the high chloride rates, respectively. The phosphate application has also significantly increased the frond 17 leaflet chlorine levels, though the increase is only statistically significant in the absence of mulch. This effect of phosphate on leaflet chlorine levels, is also observed in Experiment 108.

Chloride application has caused a significant reduction in frond 17 leaflet potassium level, both in the presence and absence of mulch, of about 0.19 %D.M.

All non-nitrogenous anion applications, particularly chloride application, have significantly increased frond 17 leaflet manganese levels. Addition of nitrogen has also significantly increased leaflet manganese levels. In the absence of mulch, nitrogen application has increased the frond 17 leaflet manganese levels from 51.9 ppm D.M. to 76.1 ppm D.M. In the presence of mulch, nitrogen application has increased leaflet manganese levels from 47.9 ppm D.M. to 71.6 ppm D.M.

EXPERIMENT 111: Fertilizer Experiment on Young Palms, Malilimi.

Site Details: Three pilot sites were planted at Malilimi in September 1983 at a planting density of 135 palms per hectare. The opportunity was taken to superimpose a simple experiment to detect the differences expected from chemical analysis of the soils. The soils at Malilimi are extremely heterogeneous in composition and have been recorded as containing compacted or firm layers.

Design: Four replicates of completely randomised blocks, each of two sites containing 2 replicates. Two plots at another site were treated at a later date for comparison.

Treatments: The objective of this experiment is to investigate if soil characteristics permit normal growth of palms, with or without fertilizers (N and P).

	Fertilizer (Kg $palm^{-1}$ $year^{-1}$)	
Treatment	**Ammonium chloride**	**TSP**
1	0.0	0.0
2	0.0	0.5
3	1.0	0.5

Results: The FFB yield and yield component data for 1987 are presented in Table 15.

Table 15. Experiment 111, FFB yield and yield components per hectare, Jan-Dec 1987.

	Treatment	No of bunches	s.b.w (kg)	FFB Yield (t)
Block 1	No Fert.	2814	6.3	17.6
	P	2498	6.3	15.7
	N+P	2342	7.6	17.8
Block 2	No Fert.	2801	6.2	17.3
	P	2852	6.1	17.5
	N+P	2751	6.4	17.5
Block 3	No Fert.	2298	5.7	13.1

Block 3 clearly has lower yield potential than blocks 1 and 2, probably due to the unfavorable soil physical properties associated with block 3.

The effects of fertilizer applications are not clear. In block 1 it appears that nitrogen application increases s.b.w. but also reduces the number of bunches resulting in no effect on FFB yield. Fertilizer application in block 2 shows no effect on FFB yield.

Cumulative FFB yield and yield component data from Nov 85 to Dec 87 are presented in Table 16.

Table 16. Experiment 111, FFB yield and yield components per hectare per year, Nov 1985 - Dec 1987.

	Treatment	No of bunches	s.b.w (Kg)	FFB Yield (t)
Block 1	No Fert.	2873	5.2	15.0
	P	2660	5.3	13.9
	N+P	2554	6.0	15.1
Block 2	No Fert.	2565	5.2	13.5
	P	2411	5.2	12.9
	N+P	2335	5.3	12.9
Block 3	No Fert.	2196	4.7	10.5

Clearly Block 1 produces the highest yield and Block 3 the poorest yield. The effect of fertilizer application is unclear. As with the 1987 data, in block 1, nitrogen application appears to increase s.b.w and decrease number of bunches, with no effect on FFB yield.

EXPERIMENT 116: Systematic Nitrogen fertilizer trial, Bebere.

Site Details: This trial is situated on sections E3 and E4 of Bebere Plantation. The area was planted in 1971 at a planting density of 120 palms per hectare. The trial covers an area of approximately 15 ha.

Design: This experiment comprises a systematic design of 8 replicates of 7 treatments (5 treatment rates). 4 replicates receive 1 year's ammonium chloride application and 4 replicates receive 2 year's ammonium chloride application. Each replicate contains 5 treatment rates of ammonium chloride increasing systematically in one direction. This dose rate gradient in one replicate abutts a second replicate with the dose rate gradient in the opposite direction. There is a total of 56 plots, each plot consisting of the two rows of palms on either side of a harvesting path (twin row) and containing about 30 palms. There are no guard rows between different treatment application rates.

Treatments : Fertilizer application rates are as follows;

	Kg $palm^{-1}$ $year^{-1}$						
LEVEL	**0**	**0**	**0**	**1**	**2**	**3**	**4**
Ammonium chloride, one year application only	0.0	0.0	0.0	1.5	3.0	4.5	6.0
Ammonium chloride, two years application only	0.0	0.0	0.0	1.5	3.0	4.5	6.0

Annual fertilizer application rates are split into 2 applications per year.

Fertilizer applications commenced in April 1987.

Results: Yield recording began in July 1987. No treatment effects on yield or yield components were observed or expected during 1987.

EXPERIMENT 117. Systematic Nitrogen Fertilizer Trial, Kumbango.

Site Details: This trial is situated in sections D8 and D9 of Kumbango Plantation. The area was planted in 1975 at a planting density of 120 palms per hectare. The trial covers an area of approximately 15 ha.

Design: Two sources of nitrogen are compared in a systematically increasing level of application rate. Treatments are replicated four times. A systematic set of application rates for a nitrogen source abutts a second set with it rates increasing in the opposite direction. There is a total of 56 plots, each plot consisting of the two rows of palms on either side of a harvesting path (twin row) and containing about 35 palms. There are no guard rows between different treatment application rates.

Treatments : Fertilizer application rates are as follows;

Kg palm^{-1} year^{-1}

LEVEL	0	0	0	1	2	3	4
Ammonium chloride	0.0	0.0	0.0	1.5	3.0	4.5	6.0
Urea	0.0	0.0	0.0	0.85	1.7	2.55	3.40

For a given application level, both sources supply the same quantity of nitrogen.

Annual fertilizer application rates are split into 2 applications per year.

Fertilizer application commenced in April 1987.

Results: Yield recording began in July 1987. No treatment effects on yield or yield components were observed or expected in 1987.

EXPERIMENT 118 : Systematic Nitrogen Fertilizer Trial, Kumbango.

Site Details: This trial is situated in section B9 of Kumbango plantation. The area was planted in 1977 at a planting density of 120 palms per hectare. The trial covers an area of approximately 7.5 ha.

Design: This experiment comprises a systematic design of 4 replicates of 7 treatments (5 treatment rates). Each replicate contains 5 treatment rates of ammonium chloride increasing systematically in one direction. This dose rate gradient in one replicate abutts a second replicate with the dose rate gradient in the opposite direction. There is a total of 28 plots, each plot consisting of the two rows of palms on either side of a harvesting path (twin row) and containing about 33 palms. There are no guard rows between different treatment application rates.

Treatments : Fertilizer application rates are as follows;

	Kg palm^{-1} year^{-1}						
LEVEL	**0**	**0**	**0**	**1**	**2**	**3**	**4**
Ammonium chloride	0.0	0.0	0.0	1.5	3.0	4.5	6.0

Annual fertilizer application rates are split into 2 applications per year.

Fertilizer applications commenced in April 1987.

Results : Yield recording began in July 1987. No treatment effects as yield or yield components were observed or expected during 1987.

EXPERIMENT 201 : Fertilizer Trial, Hargy.

Site Details: The palms (IRHO DxP) in the trial site were planted in 1973 at a planting density of 115 palms ha^{-1}. The trial contains 2916 palms in total, 1296 of these being recorded. The trial covers an area of approximately 25.4 ha.

Design: The trial consists of one replicate of a 3^4 factorial design. The 81 plots are divided into 3 blocks of 27 plots each. Each plot consists of 36 palms, the central 16 of which are recorded.

Treatments: Treatment application was initiated in June 1982, the rates are as follows;

		LEVEL	
Fertilizer	**0**	**1**	**2**
		Kg palm^{-1} year^{-1}	
Sulphate of ammonia	0.0	1.0	2.0
Triple superphosphate	0.0	0.8	1.6
Muriate of potash	0.0	1.0	2.0
Kieserite	0.0	1.0	2.0

Fertilizers are applied twice yearly. Previous to October 1986, potassium was applied as bunch ash at rates of 0.0, 1.5 and 3.0 kg palm^{-1} year^{-1}.

Results: The FFB yield, yield components and petiole WxT measurement data for 1987 are presented in Table 17.

Table 17. Experiment 201, FFB yield, yield components and petiole WxT measurement, Jan-Dec. 1987.

	FFB Yield (t ha^{-1})	s.b.w (Kg)	No of bunches (ha^{-1})	Petiole WxT (cm^2)
N0	**22.2**	21.4	**1044**	37.3
N1	**23.7**	21.4	**1110**	37.9
N2	**23.2**	20.8	**1122**	38.1
P0	**21.9**	**20.8**	**1051**	37.2
P1	**23.1**	**21.0**	**1105**	38.0
P2	**24.1**	**21.7**	**1120**	37.9
K0	23.2	20.8	1117	37.7
K1	22.7	21.5	1064	37.9
K2	23.2	21.3	1095	37.6
Mg0	23.5	21.6	1092	38.4
Mg1	22.7	21.2	1072	37.3
Mg2	22.9	20.8	1112	37.6
C.V.(%)	9.3	6.6	10.8	5.2
$LSD_{.05}$	1.2	0.8	65	1.1

From the 1987 data, it appears that the phosphate response identified in previous years is increasing in significance. The linear response component of the phosphate FFB yield response is very highly significant (p=0.001). Figure 17 illustrates the effect of Triple superphosphate application of FFB yield. Triple superphosphate application has significantly increased both numbers of bunches produced (p=0.05) and the single bunch weight (p=0.04).

The triple superphosphate FFB yield response data for 1987 has been used to approximately estimate the effect of triple superphosphate application on plantation profitability. Figure 18. illustrates the relationship between crop value, fertilizer costs and planting density on the estimated optimum economic fertilizer application rate.

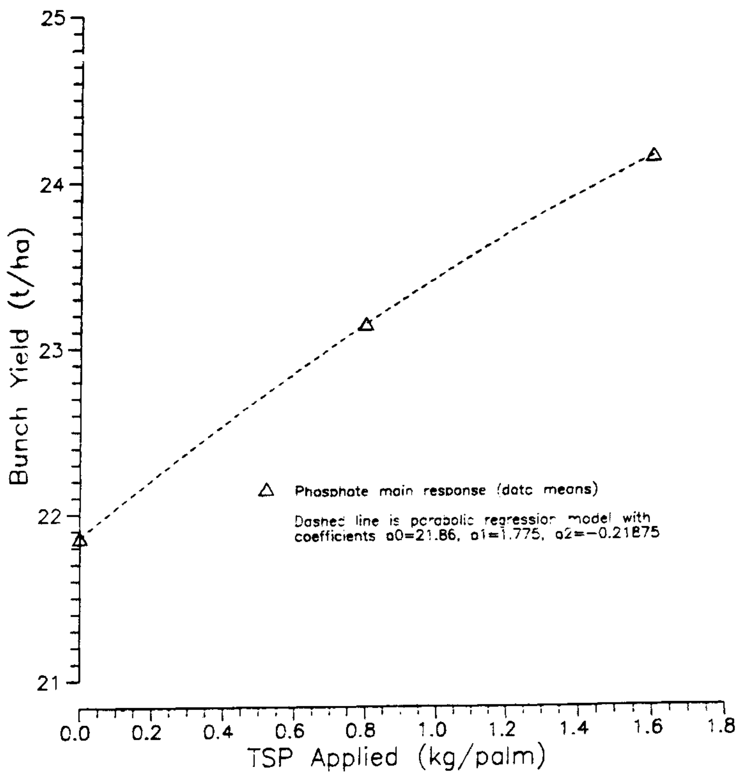


Fig:17. Experiment 201, Bunch Yield Response to Triple Superphosphate Application (Jan-Dec87).

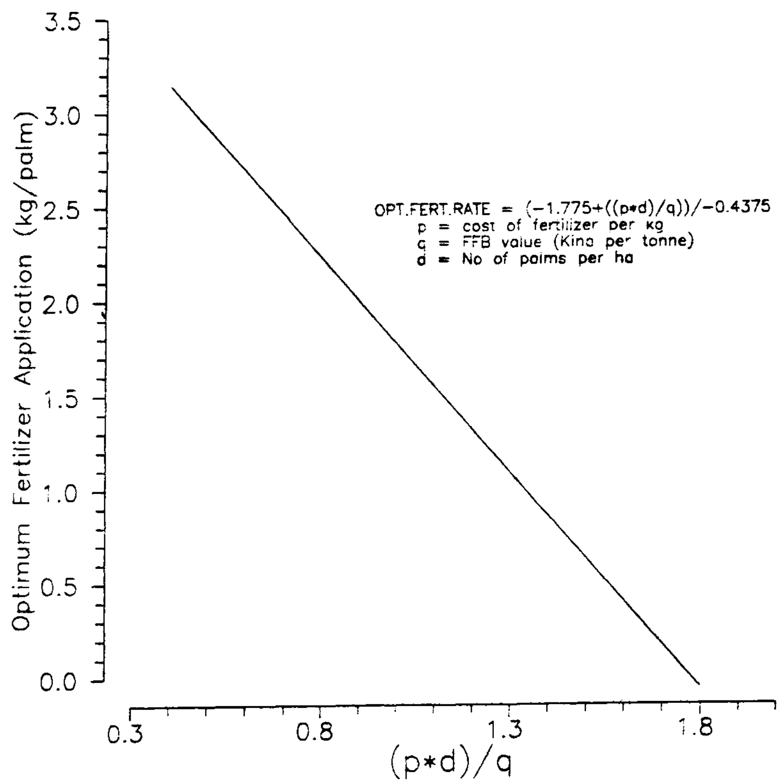


Fig: 18. Experiment 201, TSP Application Rate to Optimize Profit.

Nitrogen application has produced a significant ($p=0.028$) increase in the number of bunches produced, but the higher nitrogen rate has reduced the single bunch weight and as a consequence, the significant ($p=0.05$) FFB yield response to nitrogen follows a parabolic surface, the coefficients of which are; $a_0=22.19$, $a_1=0.925$ and $a_2=0.025$.

Fertilizer treatments have produced no significant effects on petiole WxT measurements, but nitrogen application produces a non significant upward trend in petiole WxT measurement.

The cumulative FFB yield and yield components data from January 1985 to December 1987, are presented in Table 18.

Table 18. Experiment 201, FFB yield and yield components per hectare per annum, Jan.85-Dec.87.

	FFB Yield (t)	s.b.w (Kg)	No. of bunches
N0	24.0	21.8	1100
N1	24.6	21.9	1119
N2	24.8	21.4	1150
P0	**23.4**	**21.4**	**1084**
P1	**24.6**	**21.6**	**1132**
P2	**25.5**	**22.1**	**1152**
K0	24.7	21.4	1147
K1	24.5	22.0	1106
K2	24.3	21.7	1115
Mg0	24.4	**22.1**	**1097**
Mg1	24.1	**21.6**	**1111**
Mg2	25.0	**21.4**	**1160**
C.V.(%)	6.4	5.3	8.0
$LSD_{.05}$	0.9	0.6	49.6

The 3 years cumulative data, shows no significant (at 95% level) nitrogen responses, though nitrogen does produce an increase in number of bunches that is significant at $p=0.07$ (linear response component). Nitrogen produces a non-significant reduction in single bunch weight. The net result is an increase in FFB yield due to nitrogen application that is only significant at $p=0.09$ (linear response component).

Triple superphosphate application, results in a significant ($p=0.004$) increase in number of bunches produced, and a significant ($p=0.04$) increase in single bunch weight, resulting in a very significant ($p=0.001$) 9% increase in FFB yield amounting to 1.6 kg $palm^{-1}$ $year^{-1}$.

From the analyses carried out in 1987, the mean leaflet magnesium level was found to be 0.14% D.M., which is very low. Interestingly kieserite application has produced a significant (p=0.05) increase in number of bunches produced, though a significant (p=0.04) reduction in single bunch weight has prevented a significant yield response to kieserite application.

During 1987, tissue sampling of selected plots was carried out in experiment 201 as part of Investigation 706. The means of the samplings carried out in January, March, June and November are presented in Table 19.

Table 19, Experiment 201, Frond 17 leaflet nutrient contents on a dry matter basis from selected plots (means of several samplings carried out during 1987).

Treatment Level				N	P	K	Mg	Ca	S	Cl	Fe	Mn	Zn	Cu	B
N	P	K	Mg	%	%	%	%	%	%	%	ppm	ppm	ppm	ppm	ppm
0	0	0	0	2.52	0.163	1.020	0.142	0.990	0.183	0.250	60.0	77.2	27.2	7.0	20.7
2	2	2	2	2.20	0.153	0.945	0.138	0.930	0.165	0.235	59.2	64.5	23.7	6.2	17.0
2	2	0	0	2.32	0.165	1.002	0.155	0.895	0.178	0.223	68.0	70.7	26.2	6.2	20.2
2	1	2	2	2.32	0.155	0.985	0.153	1.007	0.173	0.310	52.5	72.7	24.5	5.7	18.7
0	2	0	0	2.25	0.158	1.040	0.140	0.925	0.170	0.177	56.7	67.5	27.7	6.7	18.5
C.V.(%)				5.1	3.7	4.9	11.7	6.7	4.2	18.8	13.8	8.3	7.9	11.2	24.1
$LSD_{.05}$				0.18	0.009	0.075	0.026	0.099	0.011	0.069	12.6	9.0	3.1	1.1	7.1

It is difficult to draw any conclusions as to the treatment effects on frond 17 leaflet tissue nutrient levels. Neither the nitrogen, phosphorus or magnesium leaflet levels seem to be affected by application of these elements. The leaflet potassium level appears to be depressed by the application of potassium (plus magnesium).

EXPERIMENT 203: Phosphate Establishment Trial, Navo.

Site Details: The trial palms were planted in May 1986 at a planting density of 120 palms per hectare. The trial comprises 200 palms, all are recorded.

Design: 50 replicates of selected pairs of equally sized seedlings.

Treatments: Three months after planting (August 1986), one of each pair of seedlings received 300g sulphate of ammonia, and the other received 300g sulphate of ammonia plus 400g triple superphosphate.

Results: Petiole WxT measurements were carried out in February, May, August and November 1987. The means of the 4 measurements are shown below;

	Sulphate of ammonia only	**Sulphate of ammonia plus triple superphosphate**
Petiole WxT measurement	347.7 mm^2	377.0 mm^2

The increased petiole WxT measurements observed in the phosphate treated palms, are significant at $p = 0.03$

Soil analysis from a site approximately $^1/_2$ mile from this experiment on very similar soil, indicates that phosphate is the major limiting plant nutrient. Olsen extractable phosphate was in the range 2 to 5 $\mu g\ ml^{-1}$ with a mean of 3 $\mu g\ ml^{-1}$ in the 0-30 cm "top soil" and in the range 1 to 2 ug ml^{-1} with a mean of 1 $\mu g\ ml^{-1}$ in the 30-60 cm "sub soil". Olsen extractable phosphate would be regarded as low to very low in this soil. Phosphate retention in the "top soil" is in the range 34-62% with a mean of 50%. In the "sub soil" phosphate retention is in the range 49-89% with a mean of 73%. The phosphate retention is not generally very high, particularly in the "top soil". This fact probably explains why the oil palm can respond vegetatively to the low amount of phosphate applied in this trial. Oil palm growing on a more mature soil formed on airfall volcanic ash and lapilli would probably not respond as in this trial, due to much higher phosphate retention in the soil preventing plant uptake of applied phosphate.

WEST NEW BRITAIN PROVINCE

Mill Waste Trials

(I.O.)

EXPERIMENT 109a:Mill Waste Manurial Trial on Young palms,Bebere

Site Details: The palms in the trial site were planted in 1978 at a planting density of 135 palms per hectare. The trial area contains 1080 palms in total, 480 of these being recorded. The trial covers an area of approximately 8 ha.

Design: The trial consists of a randomised block design, with 5 replicates and 6 treatments. Each plot consists of 36 palms, the central 16 palms being recorded.

Treatments: Treatments include the use of raw palm oil with effluent (POME) and munched (chopped) bunches at the following rates:

	Treatments	**Date of Application**
1.	Nil	-
2.	Nil	-
3.	POME 500 l/palm	Oct.84, Sept.85, Nov.86
4.	POME 1000 l/palm	Oct.84, Sept.85, Nov.86
5.	Munched bunches and POME 100 t/ha	April '86
6.	Munched bunches 100 t/ha	May-July '85

POME was applied annually, the other treatments being applied once only.

Results: Yield and yield component means are summarized in Table 20:

Table 20: Experiment 109a, Yield per hectare 1987.

	Jan'87-Dec'87			Jan'86-Dec'87		
	No. of bunches	Wt. of bunches t	s.b.w. kg	No. of bunches	Wt. of bunches t	s.b.w. kg
Nil	1085	22.2	20.6	**2307**	43.4	**18.9**
500 l POME/palm	1117	23.2	20.9	**2476**	48.3	**19.6**
1000 l POME/palm	1166	24.2	21.0	**2545**	49.0	**19.4**
100t MB/POME/ha	1152	25.2	21.9	**2584**	51.1	**19.8**
100t MB/ha	1137	24.2	21.3	**2591**	49.6	**19.2**
Mean	1131	23.8	21.1	2501	48.3	19.4

Cumulative data from January 1986 to December 1987 show a very highly significant (p=0.0004) increase in yield due to mill waste application compared with none. There are no statistically significant differences in yield response between different types and rates of mill waste application however. There is a significant (p=0.017) increase in number of bunches due to application of mill waste, but no significant difference between type or rate of mill waste applied.

Yield and yield component data for 1987 show an increase (p=0.068) in bunch yield due to mill waste application compared with none. No other significant differences were observed.

EXPERIMENT 109b: Mill Waste Manurial Trial on older palms, Bebere.

Site Details: The palms in this trial were planted in 1970 at a planting density of 143 palms ha. The palms were later thinned to 123 palms ha. The trial is located in an area were, after 15 years of oil palm cultivation, yields were declining markedly and organic matter depletion appeared to be a problem.

Design: The trial consists of 4 replicates of 6 treatments in completely randomised blocks. Each plot consists of a row of palms either side of a harvest path (twin row) containing approximately 60 palms. One twin row was left between plots as guard rows.

Treatments:

	Treatment	**Dates of Application**
1.	Nil	-
2.	Nil	-
3.	POME 500 l/palm	June - Sept.85, July 86
4.	POME 1000 l/palm	June - Sept.85, July 86
5.	Empty bunches 50 t/ha	Sept - Oct.85
6.	Munched bunches 50 t/ha	Oct - Nov.85

Results: FFB yield and yield components data are summarized in Table 21.

Table 21: Experiment 109b, Yield per hectare 1987.

	Jan-Dec 1987			Jan'86-Dec 1987		
	No. of bunches	Wt. of bunches t	s.b.w. kg	No. of bunches	Wt. of bunches t	s.b.w. kg
Nil	607	11.9	21.3	**1372**	27.9	**20.7**
500 l POME/palm	745	15.2	21.2	**1616**	33.5	**22.4**
1000 l POME/palm	630	13.1	23.4	**1448**	30.6	**22.1**
50t EM/ha	670	13.7	27.1	**1486**	31.5	**24.7**
50t MB/ha	671	14.0	16.8	**1556**	33.1	**18.6**
Mean	665	13.6	22.0	1496	31.3	21.7

Cumulative yield data from January 1986 to December 1987 show a highly significant ($p=0.007$) increase in yield due to mill waste application with no significant differences between types and rates of mill waste applied. Application of mill waste has produced a significant ($p=0.033$) increase in number of bunches, but again no significant difference between type and rate of mill waste applications was observed for this effect. Apart from the low single bunch weight attributed to the munched bunch application, no other treatment had a significant effect on single bunch weight.

Data for January to December 1987 show a significant ($p=0.074$) increase in single bunch weight due to mill waste application compared with no mill waste application, but no other differences are statistically significant. The coefficient of variation for cumulative yield data is 9.8% compared with 21.6% for the first three quarters of 1987.

EXPERIMENT 202: Hargy Bunch Refuse Manurial Trial.

Site Details: The palms (IRHO DxP) in this trial were planted in 1973 at a planting density of 115 palms/ha. The trial area comprises 1080 palms in total, 480 palms being recorded. The trial covers an area of approximately 9.4 ha.

Design: 5 replicates of 6 treatments in a randomised complete block design. Each plot consists of 36 palms in total, the central 16 being recorded.

Treatment: The treatments which were applied once only, are as follows:

	Treatment	Date Applied
1.	Nil	-
2.	Nil	-
3.	Empty bunches 50 t/ha	Aug - Dec. 84
4.	Empty bunches 100 t/ha	Aug - Dec. 84
5.	Empty bunches 100 t/ha + 1kg S.A./palm)	Aug 84 - Jan 85
6.	Empty bunches 25 t/ha	Jan - Feb 85

Results: Yield and yield component data are summarized in Table 22.

Table 22: Experiment 202, Hargy bunch refuse manurial trial, Yield Ha^{-1}

	Jan-Dec 1987			Jan'86-Dec 1987		
	No. of bunches	Wt. of bunches (t)	s.b.w. (kg)	No. of bunches	Wt. of bunches (t)	s.b.w. (kg)
Nil	**1072**	21.52	**20.1**	**1955**	39.8	**20.4**
25t EFB/ha	**1016**	21.5	**21.2**	**1863**	40.6	**21.8**
50t EFB/ha	**990**	22.3	**22.6**	**1893**	44.0	**23.3**
100t EFB/ha	**851**	19.3	**22.5**	**1721**	40.4	**23.4**
100t EFB/ha + 1kg SOA/palm	**953**	21.6	**22.8**	**1742**	40.4	**23.3**
Mean	993	21.3	21.6	1835	41.0	22.4

The cumulative data from January 1986 to September 1987 show a significant (p=0.028) reduction in number of bunches and a significant (p<0.001) increase in single bunch weight due to application of empty bunches over no empty bunch application. There is no significant effect on yield. There is no significant rate response or response due to addition of sulphate of ammonia to date.

The yield and yield component data from January to September 1987 also show the significant (p=0.021) reduction in number of bunches due to empty bunch application and a significant (p=0.001) increase in single bunch weight. Again there is no significant effect on bunch yield or significant responses due to rate or to addition of sulphate of ammonia to date.

WEST NEW BRITAIN PROVINCE

Smallholder Trials

(P.N., H.L.F.)

EXPERIMENT 112, Nitrogen and Phosphate Trials, Buvussi.

Planted:	1980
Design:	8 replicates of 3 treatments (-, P, NP)
Treatments:	1. Nil
	2. 1 kg/palm/year TSP
	3. 1 kg/palm/year TSP + 1 kg/palm/year NH_4Cl
Treatments commenced:	April/May 1986

This series of demonstration trials is located on the 1980 smallholder plantings at Buvussi. Investigations were initially carried out to determine why oil palm growth was so poor in this area. A soil survey indicated that a compact concretionary layer generally found below 30cm and overall poor soil fertility were the two most likely main causes. These trials were undertaken to demonstrate that poor fertility can be alleviated by fertilizer application. Since soil available P was found to be particularly poor, P fertilizer both with and without N fertilizer was the main treatment tested.

Of the eight smallholder blocks chosen, six adjacent to the lower slopes of Mt.Otto showed particularly poor palm growth, whilst the two others showed better performance although they are also on compacted soils.

Yields recorded in 1987, which was the second year after initial treatments were applied, showed considerable variation between sites as shown in Table 23:

Table 23: Experiment 112, Yield performance (Jan-Dec 1987) and petiole cross-section (WxT) in May 1987 in different replicates.

Replicate No.	FFB t/ha	Bunch No. /ha	Bunch Wt. kg	WxT cm^2
5	21.57	1477	14.67	21.80
8	18.41	1355	13.58	20.13
4	17.76	1567	11.42	23.40
7	17.46	1560	11.20	20.50
6	14.01	1014	13.77	21.10
2	12.71	944	13.49	22.77
3	12.28	1115	10.99	20.90
1	12.07	1015	11.88	20.97
$LSD_{.05}$	2.15	196	1.48	2.00

The FFB yields, which differ mainly due to differences in bunch number, clearly fall into two groups. These groups do not correspond very well with the original assessment of palm vigour, nor with the vegetative measurements. Due to the marked differences in yield it was decided to analyse the data from the two groups separately. Mean treatment results for yield performance, petiole cross-section and leaf nutrient levels measured in 1987 for these two groups are shown in Table 24:

Table 24. Experiment 112, Mean treatment results for yield (Jan-Dec.1987), petiole cross-section(May 1987) and leaf 17 nutrient levels (April 1987).

	LOWER YIELDING BLOCKS				HIGHER YIELDING BLOCKS			
Treatment:	(-)	P	P+N	$LSD_{.05}$	(-)	P	P+N	$LSD_{.05}$
FFB(t/ha)	11.79	12.22	14.29	1.95	17.23	19.70	19.46	1.64
Bch.No.(ha)	982	1016	1069	166	1449	1576	1444	208
Bch.Wt.(kg)	12.07	12.07	13.46	0.92	11.88	12.74	13.53	1.93
WxT (cm^2)	21.2	20.6	22.5	2.0	20.8	21.4	22.3	2.0
LEAF 17								
% N	2.30	2.33	2.25	0.40	2.23	2.20	2.25	0.21
% P	.153	.153	.153	.008	.150	.155	.155	.010
% K	0.94	0.98	0.91	0.11	1.01	0.98	0.88	0.09
% Mg	0.22	0.22	0.22	0.05	0.21	0.22	0.22	0.02
% Ca	1.19	1.15	1.17	0.13	1.15	1.15	1.16	0.11
% Cl	0.08	0.07	0.28	0.02	0.07	0.06	0.32	0.03
ppm Mn	51	52	47	7.6	44	41	54	6.4

The results in Table 24 show a significant yield increase due to P fertilizer alone in the case of the higher yielding blocks, but the lower yielding blocks show a significant response to only the combined P + N application. In both cases the yield improvement is largely due to an increase in bunch weight.

Although the P fertilizer treatment has had no significant effects on leaf nutrient levels, the modest increase in leaf P in the higher yielding blocks suggests that the yield improvement is due to increased uptake of this nutrient. The addition of ammonium chloride has markedly increased leaf Cl levels in all blocks, but has had no effect on leaf N levels, suggesting the yield improvement in the lower yielding plots could be due to chlorine, which is exceptionally low in the control plots. Chlorine is also probably the reason for the significant depression of K, due to ammonium chloride application, in the higher yielding plots.

The leaf nutrient data reveal no marked differences between the two groups and both soil and management will be evaluated in the future to determine if they are the cause of the yield differential.

When all the replicates are combined,the increase in petiole cross section due to the P+N treatment becomes significant and with time this treatment may become optimum for both groups. Considering the low rates of fertilizer applied, the yield increases of several tonnes FFB per hectare would be very profitable if continued in the future. The results give hope that the low yields generally recorded in the Buvussi area can be substantially improved with appropriate fertilizer applications.

Yield Assessment

A limitation to the number of demonstration trials which can be carried out in Smallholder areas is the time taken to record yields. Furthermore it is difficult to keep track of harvesting in numerous small plots over a wide area. If a simpler alternative method of yield assessment, compared with the traditional method of weighing all bunches, could be established - then the number of demonstrations could be increased.

FFB yield consists of two main components - bunch number and average bunch weight - the former generally showing the most response to agronomic treatments. A black bunch count is an obvious method of estimating bunch number and the accuracy of this method was investigated in the Buvussi trials. Every month throughout late 1986 and 1987, on approximately the same date, the number of black bunches on all palms in every plot was counted. Correlations were then carried out with true bunch number per plot in 1987 with the results shown in Table 25:

Table 25. Experiment 112, Simple correlation of average black bunch counts (Sept 86-Aug 87) with true annual bunch number (Jan 87-Dec 87).

Black bunch count frequency	Correlation (r) with true annual bunch no.
1. 12 times per year	0.760***
2. 6 times per year	0.791***
3. 3 times per year	0.775***

There is clearly no advantage in carrying out a black bunch count more frequently than three times per year. The current data gives the following prediction equation based on the average given by three counts in the year:

Predicted annual bunch no. per palm =
2.564 x (Average Black bunch count per palm) - 1.832

The average residual error was 9.3%. The practical usefulness and limitation of the black count method (based on three counts per year) is illustrated by the average results for the different replicates shown in Table 26.

Table 26. Experiment 112, Actual and predicted bunch numbers in Buvussi trials in 1987

Replicate No.	True Bunch no./palm	Predicted Bunch no./palm	Black Bunch no./palm	FFB t/ha
4	13.06	11.60	5.24	17.76
7	13.00	12.39	5.55	17.46
5	12.31	10.35	4.75	21.57
8	11.29	13.92	5.43	18.41
3	9.29	9.07	4.25	12.28
1	8.46	10.50	4.81	12.07
6	8.45	8.81	4.15	14.01
2	7.87	8.94	4.20	12.71
L.S.D.$_{.05}$	1.63		0.83	2.15
C.V.(%)	8.93		9.84	8.84

Whilst all the trials in one yield group can be significantly distinguished from all the trials in the other group based on bunch number, the black bunch method would misplace one trial and another trial cannot be significantly distinguished.

Annual bunch production can also be estimated from limited harvest records. Correlations were calculated between annual production and production recorded in individual months and the results are shown in Table 27.

Table 27. Experiment 112, Simple correlation of annual bunch production in 1987 with bunch production in individual months

Individual months	Corr.(r) with ann.bunch no.
Jan + Jul	0.682***
Feb + Aug	0.778***
Mar + Sep	0.545**
Apr + Oct	0.601**
May + Nov	0.736***
Jun + Dec	0.802***
Feb + Jun + Oct	0.824***
Mar + Jul + Nov	0.852***
Feb + May + Aug + Nov	0.879***

The results show that the correlation of annual bunch production with average black bunch count (r=0.775) is generally better than the correlation with the number of bunches harvested in any two months. However the correlation with bunches harvested in either three or four months is superior. Since it is relatively easy to also weigh the bunches when they are counted, it would seem that limited harvest recording (i.e. in at least three months) is a better method for yield assessment compared with black bunch counts. Correlation of annual FFB yield production in 1987 with various measurements is shown in Table 28.

Table 28. Experiment 112, Simple correlation of various measurements with annual FFB yield in 1987

Measurement	Corr. (r) with annual yield
Black bunch count(in 3 months)	0.560**
Bunch harvest number(in 3 months)	0.667***
Bunch harvest number(in 4 months)	0.709***
Total Bunch weight(in 3 months)	0.834**
Total Bunch weight(in 4 months)	0.845**

Based on this very limited data obtained in one year of this experiment, it would seem that carrying out a full harvest recording every four months would be the most satisfactory short-cut method of yield assessment.

EXPERIMENT 113, Fertilizer trial on replanted palms.

Planted	:	1985
Design	:	Two demonstration plots and one central control at each centre.
Treatments commenced	:	At Kapore and Sarakolok,Nov.85. At Buvussi, Dec.85.
Recording commenced	:	At Kapore and Sarakolok,Oct.87.

In three different smallholder areas, a block was partinioned into three plots. The middle plot was designated the control and the outer plots were used to demonstrate the current N fertilizer recommendation for replanted oil palm:

	Ammonium chloride (g/palm)	
Month	Control plot	Demonstration plots
3	200	200
6	-	240
12	-	480
18	-	480
24	-	960

During 1987, the appearance of the palms and petiole cross-section measurements indicated to smallholders that the recommended fertilizer applications were having a beneficial effect. This was further demonstrated to them by yield recording for the first three months of yield production (October-December 1987) at Kapore and Buvussi. The results shown in Table 29 indicate the considerably higher early yield obtained in the demonstration plots.

Table 29: WNBP Fertilizer Demonstration Plots Production per palm (Oct-Dec 1987)

Site	Treatment	Plot	No. of Bunches	Weight of Bunches (kg)
KAPORE	Full N	1	1.45	2.93
	Control	2	0.29	0.61
	Full N	3	2.21	4.37
SARAKOLOK	Full N	1	1.64	3.66
	Control	2	1.08	2.03
	Full N	3	1.64	3.11
MEAN	Full N		1.74	3.52
	Control		0.68	1.32

Yield recording during early production is scheduled to be carried out at Buvussi in early 1988.

ORO PROVINCE

Fertilizer Trials

(S.W., A.O.)

EXPERIMENT 305, Fertilizer factorial experiment, Arehe

Planted:	1978
Design:	3x2x3x2 N,P,K,Mg confounded factorial
Treatments commenced:	September 1981
Original details:	3rd Annual Report
Soil type:	Higaturu family - deep sandy clay loam, good drainage and physical properties.

Treatment rates in kg/palm/year:

	0	1	2
Ammonium sulphate	0	2.0	4.0
Triple superphosphate	0	2.0	-
Muriate of potash	0	2.0	4.0
Kieserite	0	1.0	-

Note: Until 1984, sulphate of ammonia was applied at 1.0 and 2.0 kg,and triple superphosphate at 0.5kg per palm per annum.

The yield data presented in Table 30, indicates substantial responses to SOA and MOP ($p<0.001$). Both fertilizers have a significant quadratic component, indicating that the most suitable application rate is likely to be close to the N1 and K1 rates.

Consideration of the single year's data for 1987 requires caution, but is a useful indication of trends.

During 1987 the response to SOA was increased. Fertilized plots maintained good yield levels above 30 t/ha, whilst yield on the unfertilized plots showed a marked decrease (to an overall mean of 25.5 t/ha for N0 plots). Soil reserves of N now appear insufficient to maintain yields, without additional inputs.

The 1987 figures indicate a continued response to MOP, in the order of 2 t/ha. For 1987 the statistical significance was reduced ($p<0.05$) possibly due to fluctuation in the yield cycle. Since soil reserves of both K and Cl are low, and bearing in mind the demand for K by the oil palm, it would be surprising if response to MOP continued to decline at this stage.

Table 30, Experiment 305 yield data

	1987 No of bunches	1987 Wt of bunches t/ha	1987 s.b.w. kg	Wt t/ha 1984-87
N 0	**1351**	**25.5**	19.0	**30.2**
N 1	**1580**	**30.8**	19.7	**33.7**
N 2	**1661**	**32.1**	19.4	**34.0**
P 0	1555	29.7	19.2	32.6
P 1	1507	29.3	19.5	32.6
K 0	1556	**28.1**	**18.1**	**31.2**
K 1	1525	**30.3**	**19.9**	**33.2**
K 2	1512	**30.0**	**20.0**	**33.5**
Mg 0	1541	29.8	19.4	32.8
Mg 1	1521	29.2	19.3	32.4
LSD (N&K)	96	1.6	0.77	0.98
LSD (P&Mg)	79	1.3	0.63	0.80
C.V.(%)	11	9	7	5

(N.B. Treatments showing statistically significant effects are shown in bold type)

Splitting up the yield into its components, bunch number can be seen to be largely a nitrogen effect ($p<0.001$). For bunch weight, the major factor is K. There is a significant quadratic component to the response, and K2 gives virtually the same bunch weights as K1.

P appears to increase s.b.w. on its own, but the effect is masked in the presence of K (see table 31): a similar interaction also occurs with rachis cross-section measurements.

Table 31: Experiment 305, Effect of P and K treatments on single bunch weight.

s.b.w. (kg) - 1987

	K0	K1	K2
P0	17.45	19.87	20.18
P1	18.83	19.97	19.81

The mean plot yields, summarised in Table 32, indicate the extent of actual yield gains through fertilizer use, which might be under-estimated on an initial consideration of Table 30. Yield without any fertilizer has fallen markedly, to only 20 t/ha during 1987, resulting in an increased response to fertilizer, now greater than 10t/ha. This confirms observations from smallholdings where fertilizer has not been applied.

Table 32: Ordered mean plot yields

1987				1984-87			
Treatment	t/ha	%	No of Plots	Treatment	t/ha	%	No of Plots
NPK	32.71	164	8	NPK	34.69	133	8
N	32.34	162	4	N K	34.42	132	8
N K	31.56	158	8	NPKMg	34.40	132	8
N KMg	30.88	155	8	N KMg	34.29	132	8
NPKMg	30.87	155	8	NP Mg	33.31	128	4
NP Mg	30.57	153	4	NP	33.3	128	4
NP	30.44	153	4	K	33.29	128	4
N Mg	29.67	149	4	N	32.47	125	4
K	28.31	142	4	KMg	32.07	123	4
KMg	27.31	137	4	N Mg	31.70	122	4
PK	26.50	133	4	PK	30.11	116	4
PKMg	25.11	126	4	PKMg	29.49	113	4
P Mg	24.01	120	2	P	29.48	113	2
Mg	23.75	119	2	P Mg	28.83	111	2
P	23.42	117	2	Mg	27.98	108	2
0	19.96	100	2	0	25.99	100	2

(Note: For N and K, levels 1 and 2 are averaged.)

All treatments without SOA or MOP averaged 24 t/ha or less during 1987. The best yielding fertilizer combinations during 1987 are very similar to those overall from 1984-1987, except that the response to SOA was increased during 1987. Generally, combinations including both SOA and MOP have provided the highest yields, all averaging at least 34.3 t/ha for 1984-1987 (32% above control), and 30.9 t/ha during 1987 (55% above control).

The overall highest yielding fertilizer combination is the NPK combination. During 1987 this yielded particularly well, giving 64% more than the control, and 1 t/ha higher yield than the closest NK fertilizer combination. This may indicate a developing requirement for P.

TSP is involved in contrasting interactions with SOA and MOP. With SOA, TSP improves yield only at N1. With MOP, there is a yield response to TSP only at K0, which is lost in the presence of MOP, with TSP possibly even reducing yield at K1 and K2.

The analysed data from a factorial trial represents responses to certain nutrients, averaged over all levels of other nutrients. There will be various interactions and other responses occurring, even if they do not appear at a statistically significant level. Thus the effect of applications of K and N alone (rather than with P and/or Mg) may well be different from the overall effect indicated by the trial. Table 33 indicates yields with various rates of SOA and MOP, both in the absence and presence of P and Mg fertilizers.

Table 33: Plot yields per hectare with N and K fertilizers

A. In absence of P and Mg fertilizers(t/ha F.F.B.)

	1987				84-87		
	N0	N1	N2		N0	N1	N2
K0	20.4	31.9	32.1	K0	26.5	32.3	32.1
K1	25.5	33.4	30.4	K1	31.2	35.8	34.2
K2	30.5	28.6	34.9	K2	34.8	33.3	35.1

(N.B. Above yields have been adjusted for blocks)

B. At average levels of P and Mg fertilizers(t/ha F.F.B.)

	1987				84-87		
	N0	N1	N2		N0	N1	N2
K0	22.8	30.7	30.9	K0	28.1	31.2	31.3
K1	26.6	30.6	33.6	K1	32.9	33.5	34.6
K2	27.1	31.2	31.8	K2	32.5	34.9	34.6

Overall the N1K1 fertilizer combination in the absence of P and Mg appears to be optimum, although a substantial yield improvement was found with application of either SOA or MOP alone.

In the absence of P and Mg, the N0K0 yield is appreciably lower and the N1K1 yield is substantially higher. Thus the response to SOA and MOP application at the N1K1 level, is 4 to 5 t/ha greater when P and Mg are omitted.

Table 34 indicates vegetative measurement results. The vegetative index measurement in particular corresponds remarkably closely to the yield data in Table 30.

Table 35, with plot vegetative measurement values, also confirms the yield data, indicating all combinations of SOA and MOP as the treatments producing the greatest response. The PK combinations have a poorer response than K alone.

For height, the only significant effect has been SOA, producing overall about 4% greater annual increase at the N1 rate. However, Table 35 indicates that overall the N treatments have had 4-10% faster growth than the controls, with the highest yielding plots generally having the fastest vertical growth. Combinations with phosphate appear to have a slightly reduced height increment, but the variations in height are relatively small compared to the variations in yield. The control plots have grown at 73 cm per annum, with combinations of N and K increased to 77 - 80 cm per annum.

Table 34: Vegetative Measurement Results in 1987

	V.I.[1]	WxT cm^2	Frond prodn./yr	Height m
N 0	**790**	**36.1**	**21.9**	**4.185**
N 1	**937**	**39.6**	**23.6**	**4.326**
N 2	**954**	**39.7**	**24.1**	**4.370**
P 0	903	38.7	23.3	4.325
P 1	884	38.2	23.1	4.262
K 0	**851**	**36.4**	23.3	4.258
K 1	**908**	**39.1**	23.2	4.328
K 2	**921**	**39.9**	23.1	4.295
Mg 0	884	38.0	23.2	4.285
Mg 1	903	38.9	23.2	4.302
LSD (N&K)	38	1.2	0.42	0.14
LSD (P&Mg)	31	1	0.34	0.11
C.V.(%)	7	5	3	6

((1) Note: The "Vegetative Index" is produced by multiplying the mean rachis cross-section by the annual frond production.)

Table 35: Ranked mean plot yields for Vegetative Index and Annual Height Increment (from 1983)

Treatment	1987 Vegetative Index	%	No.of Plots	Treatment	1983-87 Ht Inc cm/yr	%	No.of Plots
N K	990	143	8	N K	80.5	110	8
N KMg	975	141	8	N KMg	80.4	110	8
NPKMg	967	139	8	N Mg	79.6	109	4
NPK	940	136	8	NPKMg	79.3	108	8
NP Mg	910	131	4	NP Mg	78.7	108	4
N	897	129	4	K	78.3	107	4
N Mg	894	129	4	N	77.7	106	4
NP	879	127	4	NPK	77.2	106	8
KMg	825	119	4	PK	76.2	104	4
K	814	117	4	P Mg	76.2	104	2
PKMg	809	117	4	NP	76.1	104	4
P	793	114	2	KMg	76.0	104	4
Mg	793	114	2	0	73.1	100	2
P Mg	777	112	2	Mg	72.5	99	2
PK	761	110	4	P	72.4	99	2
0	694	100	2	PKMg	71.8	98	4

Table 36 summarises the annual leaf analysis data. Care is necessary in interpreting the changes in nutrient levels. They arise as a result of complex interactions in the soil and within the plant, and do not necessarily all affect yield.

Table 36, Leaf analysis related to fertilizer treatments in 1987

	N0	N1	N2	P0	P1	K0	K1	K2	Mg0	Mg1	LSD.05 N/K	LSD.05 P/MG	C.V.(%)
N%	**2.33**	**2.51**	**2.58**	2.48	2.47	2.46	2.47	2.50	2.48	2.47	.09	.07	6.1
	100	**108**	**111**	100	100	100	100	102	100	100			
P%	**.149**	**.155**	**.154**	.153	.153	.153	.153	.152	**.154**	**.151**	.003	.0025	3.4
	100	**104**	**104**	100	100	100	101	100	**100**	**98**			
K%	.855	.875	.888	.869	.877	**.935**	**.860**	**.824**	.877	.869	.044	.036	8.7
	100	102	104	100	101	**100**	**92**	**88**	100	99			
Cl%	.419	.403	.368	.410	.383	**.203**	**.459**	**.528**	.394	.400	.072	.059	31.5
	100	96	88	100	93	**100**	**226**	**260**	100	102			
S%	**.152**	**.163**	**.163**	.160	.159	.159	.160	.160	.160	.159	.004	.003	4.6
	100	**107**	**107**	100	99	100	100	101	100	99			
Ca%	**.922**	**.859**	**.846**	**.889**	**.863**	**.830**	**.888**	**.910**	.883	.868	.034	.028	6.7
	100	**93**	**92**	**100**	**97**	**100**	**107**	**110**	100	98			
Mg%	**.218**	**.202**	**.195**	.206	.204	.209	.204	.202	.203	.207	.012	.009	9.6
	100	**93**	**90**	100	99	100	98	97	100	102			
Mn ppm	**110**	**132**	**156**	133	133	**121**	**135**	**142**	136	130	17.5	14.2	22.8
	100	**120**	**141**	100	100	**100**	**112**	**118**	100	95			
Zn ppm	**18.8**	**15.8**	**15.0**	16.7	16.4	16.8	16.3	16.6	16.5	16.6	1.41	1.15	14.7
	100	**84**	**80**	100	98	100	97	99	100	100			

SOA application has a major effect in increasing the N and S levels over the critical ranges. SOA is also associated with an increase in P content, which was not achieved by TSP application.

Calcium and Magnesium contents are lowered and the Mn content raised. This would be expected, due to the acidifying effect of the fertilizer, but is unlikely to affect yield. The Zn level is reduced.

The only identified effect of TSP application was a marginal reduction in calcium content.

Application of MOP substantially reduced K levels, from the already low percentage at K0. Calcium content was raised, approximately balancing the reduced K content. Chloride levels were greatly increased.

This does not necessarily rule out a potassium response. It should be borne in mind that soils at Higaturu have very low K reserves, and the palms have a major K requirement. Good yield responses have also been obtained from empty bunches: presumably a K effect, since their chloride level is very low.

The only significant effect of kieserite application was a marginal reduction in phosphate content.

Table 37 indicates the long term yield and leaf analysis data for selected plots. This particularly indicates a fall in yield during 1986 and 1987 for plots not receiving N, associated with a decline in leaf N% over the range 2.3 - 2.5%.

Table 37: Progressive changes in yield and nutrient status

		82	83	84	85	86	87	AVG
N0K0	Yield	28.3	28.27	30.44	30.22	23.34	19.96	26.76
	N%	2.8	-	2.45	2.6	2.4	2.2	2.49
	K%	1.2	-	0.97	1.02	0.95	0.91	1.01
	P%	0.18	-	0.17	0.17	0.16	0.15	0.17
	Cl%	0.21	-	-	0.19	0.16	0.13	0.13
N1K0		82	83	84	85	86	87	AVG
	Yield	28.9	33.22	34.02	34.68	29.7	32.22	32.14
	N%	2.9	-	2.55	2.65	2.5	2.65	2.65
	K%	1.05	-	0.94	0.94	0.89	0.96	0.96
	P%	0.16	-	0.15	0.17	0.16	0.16	0.16
	Cl%	0.17	-	-	0.14	0.11	0.07	0.10
N0K1		82	83	84	85	86	87	AVG
	Yield	26.95	32.24	36.91	34.68	28.36	25.81	30.83
	N%	2.95	-	2.6	2.6	2.45	2.2	2.56
	K%	1.05	-	0.86	0.93	0.9	0.85	0.92
	P%	0.16	-	0.16	0.18	0.16	0.15	0.16
	Cl%	0.27	-	-	0.46	0.48	0.44	0.24
N1K1		82	83	84	85	86	87	AVG
	Yield	28.25	31.94	36.51	38.02	33.7	32.61	33.51
	N%	2.7	-	2.65	2.70	2.55	2.55	2.63
	K%	1	-	0.86	0.94	0.86	0.81	0.89
	P%	0.16	-	0.16	0.17	0.16	0.15	0.16
	Cl%	0.37	-	-	0.50	0.47	0.45	0.29

EXPERIMENT 306, Fertilizer factorial experiment, Ambogo

Planted:	1980
Design:	3^4 confounded factorial in 1 replicate.
Treatments commenced:	1982
Original details:	3rd Annual Report
Soil type:	Ambogo and Penderetta families - recent alluvial origin, having silty loam top soil and sandy loam subsoil, with mottling due to seasonally high water tables

Treatments in kg/palm/year:

	0	1	2
Ammonium sulphate	0	1.5	3.0
Triple superphosphate	0	0.5	1.0
Murate of potash	0	2.5	5.0
Kieserite	0	0.75	1.5

Long term yield data presented in Table 38, indicates substantial responses to both N and K fertilizers ($p<0.01\%$). In both cases level 1 provides the major improvement: 3.2 tonnes/ha for SOA, and 4.0 t/ha for MOP. At level 2, SOA provided a total gain of 4.1 t/ha, but the quadratic component of the response to MOP was negative and significant and the yield at level 2 was only 3.0 t/ha (less than at level 1).

Table 38: Experiment 306, Yield per hectare

	1987 No. of bunches	1987 Wt. of bunches t/ha	1987 s.b.w. kg	1984-87 Wt t/ha
N 0	**1811**	**24.7**	13.7	**28.1**
N 1	**2014**	**27.9**	13.9	**29.8**
N 2	**2013**	**28.8**	**14.4**	**30.3**
P 0	**1920**	**26.6**	**13.9**	**29.2**
P 1	**1951**	**26.7**	**13.7**	**29.4**
P 2	**1968**	**28.1**	**14.4**	**29.7**
K 0	**1924**	**24.8**	**13.0**	**27.5**
K 1	**1950**	**28.8**	**14.9**	**30.8**
K 2	**1964**	**27.8**	**14.2**	**29.9**
Mg 0	1960	**26.2**	**13.4**	29.0
Mg 1	1941	**28.2**	**14.7**	30.0
Mg 2	1937	**27.0**	**13.9**	29.3
$LSD_{.05}$	132	1.8	1.1	1.1
C.V.(%)	12	12	15	7

With time fertilizer responses have increased considerably, with unfertilized yields falling sharply.

Table 39 summarises the plot yields for the major treatment combinations in more detail. This indicates that in 1987 N alone provided a yield 67% above the no fertilizer control, and K alone produced an average yield 60% greater than the zero fertilizer yield of only 14.4 t/ha (down from 30.3 in 1985, and 23.2 in 1986). These control yields are similar to those from smallholdings where fertilizer has not been applied.

Table 39: Ordered mean plot yields

1987	t/ha	%	No.of Plots	1984-87	t/ha	%	No.of Plots
N K	31.21	216	4	N KMg	32.01	136	8
N KMg	30.52	211	8	N K	30.73	131	4
NPKMg	29.36	203	16	NPK	30.73	131	8
NP Mg	28.42	197	8	NPKMg	30.51	130	16
NPK	27.84	193	8	PKMg	29.96	127	8
PKMg	27.65	191	8	NP Mg	29.85	127	8
P	27.14	188	2	KMg	29.56	126	4
KMg	25.74	178	4	PK	28.58	122	4
N Mg	25.47	176	4	NP	28.15	120	4
NP	25.30	175	4	N	28.03	119	2
P Mg	24.35	169	4	K	27.69	118	2
N	24.17	167	2	P Mg	27.56	117	4
PK	24.11	167	4	N Mg	27.50	117	4
K	23.01	160	2	P	25.90	110	2
Mg	17.34	120	2	0	23.50	100	1
0	14.44	100	1	Mg	23.43	100	2

Overall the best yields have been obtained by all the treatments which combine SOA and MOP (93% or more above the control in 1987).

Kieserite and TSP have not depressed yields. Kieserite recorded a statistically significant quadratic response during 1987. This is somewhat surprising, since soil analyses indicate that magnesium is the one nutrient in plentiful supply in the soil.

Applications of SOA and MOP alone (no TSP or kieserite) recorded the highest plot yields in 1987 (31.2 t/ha), and second highest yields for the period 1984-1987 (30.7 t/ha). For good results the combination of both fertilizers is now required, since yield from plots receiving only SOA or only MOP declined to 24.2 and 23.1 t/ha ectively during 1987.

Table 40 indicates yields with different combinations of SOA and MOP. The effect of these fertilizers is somewhat different in the present and absence of P and Mg fertilizers.

Table 40: Yields with N and K fertilizers

A. In absence of P and Mg fertilizers (t/ha F.F.B.)

	1987 N0	1987 N1	1987 N2		84-87 N0	84-87 N1	84-87 N2
K0	14.7	28.1	21.0	K0	23.9	31.0	25.9
K1	23.3	32.5	28.6	K1	28.3	33.2	30.8
K2	22.6	31.3	31.4	K2	26.7	29.3	29.0

B. At average levels of P and Mg fertilizers (t/ha F.F.B.)

	1987 N0	1987 N1	1987 N2		84-87 N0	84-87 N1	84-87 N2
K0	22.3	26.7	25.4	K0	25.8	28.8	28.0
K1	26.7	28.1	31.5	K1	30.2	30.0	32.2
K2	25.1	29.0	29.4	K2	28.4	30.6	30.8

In the presence of P and Mg fertilizers, higher yields are obtained with N0K0 but lower yields are obtained at N1K1. This trend appears to have increased, so that in the presence of P and Mg the response to N1K1 is only 5.8t/ha, whilst in the absence of P and Mg the response is 17.8 t/ha.

Whilst the yields in the absence of P and Mg are not replicated, they are consistent (between years, with trial 305, and with smallholder performance) and provide confirmation of the detail of this important response.

Various interactions have also been observed (see Table 41). A P response is observed in the presence but not in the absence of N, with P reducing response to N. There appears to be a similar interaction between K and P. Interactions such as these contribute to an under-estimation of the N and K responses.

Table 41: Fertilizer interaction tables

Yield t/ha	1987 P0	1987 P1	1987 P2	Yield t/ha	84-87 P0	84-87 P1	84-87 P2
N0	22.0	24.4	27.8	N0	27.1	28.6	28.7
N1	29.0	27.0	27.7	N1	30.7	29.1	29.7
N2	28.6	28.8	28.8	N2	29.9	30.5	30.5

Yield t/ha	1987 K0	1987 K1	1987 K2	Yield t/ha	84-87 K0	84-87 K1	84-87 K2
P0	22.1	29.0	28.6	P0	26.3	31.0	30.4
P1	25.2	28.1	28.0	P1	27.3	31.2	29.8
P2	27.0	29.3	28.0	P2	29.0	30.3	29.6

Yield t/ha	1987 K0	1987 K1	1987 K2	Yield t/ha	84-87 K0	84-87 K1	84-87 K2
N0	22.3	26.7	25.1	N0	25.8	30.2	28.4
N1	26.7	28.1	29.0	N1	28.8	30.0	30.6
N2	25.4	31.5	29.4	N2	28.0	32.2	30.8

N and K on their own tend to have a quadratic form of response (maximum response at level 1). In combination there is an interaction which improves yields at the higher application rates (K1N2 giving the maximum yield).

Bunch number is mainly a nitrogen effect (P<1%). Two interactions have proved significant. P and K in combination give poorer results than alone, and P and Mg together give better results than alone.

Single bunch weight was increased by K and Mg. The quadratic component of these responses was significant (P<5%), indicating that the level 1 application was close to the optimum.

Tables 42 and 43 indicate vegetative measurement results. Most of the data is remarkably similar to trial 305. Response of vegetative index to fertilizer is almost identical. Frond production is similar and wxt measurements only slightly lower. However vertical growth recorded during 1987 was substantially higher in trial 306, being increased by SOA, particularly at the higher rate.

The overall height figures also indicate a small height response to MOP. However, the increase of about 15% in growth rate at N1K1, is compensated for by an approximate doubling in yield compared to the control plot. The control plot has recorded a relatively high vertical growth rate, but low wxt values. The dry matter allocation appears to have been increased for vertical growth, and reduced for fruit.

Table 42: Experiment 306, Vegetative measurement data(1987)

	V.I.[1]	WxT cm^2	Frond prodn./yr	Height m
N 0	**741**	**33.0**	**22.4**	**3.082**
N 1	**809**	**34.9**	**23.2**	**3.169**
N 2	**861**	**36.3**	**23.7**	**3.378**
P 0	814	34.8	23.3	3.214
P 1	796	34.7	22.9	3.217
P 2	800	34.7	23.0	3.198
K 0	**772**	**33.1**	**23.3**	**3.127**
K 1	**810**	**35.3**	**22.9**	**3.293**
K 2	**829**	**35.8**	**23.1**	**3.209**
Mg 0	**786**	**34.0**	23.1	3.168
Mg 1	**826**	**35.7**	23.1	3.271
Mg 2	**798**	**34.6**	23.1	3.190
LSD.05	34	1.2	0.41	0.109
C.V.(%)	8	6	3	6

(1) Veg.index is product of WxT and frond production

Table 43: Ordered mean plot yields for vegetative data

	1987 V.I.	%	No of Plots		1984-87 Veg.grth m	%	No of Plots
N K	886.4	144	4	N	1.25	108	2
NPKMg	855.2	139	16	NPKMg	1.2	103	16
N KMg	845.3	137	8	N KMg	1.19	103	8
NPK	837.6	136	8	0	1.16	100	1
N Mg	833.9	135	4	NPK	1.15	99	8
N	806.4	131	2	NP	1.11	96	4
KMg	802.7	130	4	N Mg	1.1	95	4
NP Mg	800.0	130	8	NP Mg	1.1	95	8
NP	759.3	123	4	K	1.09	94	2
PKMg	758.6	123	8	PKMg	1.08	93	8
Mg	736.5	120	2	KMg	1.07	92	4
P Mg	729.8	119	4	N K	1.05	91	4
P	721.3	117	2	PK	1.04	90	4
K	715.3	116	2	Mg	0.99	85	2
PK	711.8	116	4	P Mg	0.92	79	4
0	615.4	100	1	P	0.76	66	2

Frond production was increased by SOA, and WxT by SOA, MOP, and kieserite, resulting in a significant quadratic component effect of kieserite upon leaf index. The vegetative index data is extremely similar to yield data in terms of response to fertilizer.

There are few significant interactions, and the form of these interactions is not clear. Study of the raw data suggests that TSP may have some effect in reducing vertical growth. Since other data indicates an antagonism between TSP and SOA, such an effect would be likely.

Table 44 indicates leaf nutrient data, related to fertilizer applications. Care is necessary in interpreting the data, since they arise as a result of complex interactions in the soil and within the plant. Thus in certain circumstances changes in leaf nutrient levels may not affect yields, and it is also possible for yield to be affected without necessarily observing a related change in leaf nutrient levels.

Application of SOA increased leaf N, which is relatively low throughout the trial, and also leaf S.

SOA was also associated with an increase in P content which was not achieved by TSP application. The calcium level was unaffected (in contrast to a reduction in expt.305) but magnesium levels were reduced, and manganese levels increased from very low initial levels. These effects are likely to be due to the acidifying effect of the SOA.

The Zn level was reduced by SOA, as in expt.305, but in this case the reduction was not significant.

Table 44: Leaf analysis related to fertilizer treatments - 1987

	N0	N1	N2	P0	P1	P2	K0	K1	K2	Mg0	Mg1	Mg2	LSD.05	C.V.(%)
N%	**2.22**	**2.32**	**2.33**	2.32	2.25	2.30	**2.23**	**2.29**	**2.35**	2.29	2.28	2.3	0.089	7.1
	100	105	105	100	97	99	100	103	105	100	100	100		
P%	**0.146**	**0.15**	**0.15**	0.149	0.148	0.15	0.149	0.148	0.15	0.15	0.149	0.148	0.003	4.2
	100	103	103	100	99	101	100	99	101	100	99	99		
K%	0.823	0.846	0.823	0.83	0.831	0.829	**0.879**	**0.805**	**0.806**	0.831	0.828	0.831	0.036	8.0
	100	103	100	100	100	100	100	92	92	100	100	100		
Cl%	0.339	0.34	0.357	0.334	0.342	0.35	**0.115**	**0.439**	**0.481**	**0.313**	**0.366**	**0.357**	0.044	23
	100	100	105	100	102	105	100	382	418	100	117	114		
S%	**0.167**	**0.173**	**0.177**	0.171	0.173	0.172	0.173	0.171	0.172	0.173	0.173	0.17	0.005	6.1
	100	104	106	100	101	101	100	99	99	100	100	98		
Ca%	0.754	0.763	0.755	0.749	0.762	0.761	0.753	0.762	0.757	0.746	0.767	0.759	0.033	8.0
	100	101	100	100	102	102	100	101	101	100	103	102		
Mg%	**0.275**	**0.256**	**0.259**	0.262	0.269	0.26	**0.289**	**0.254**	**0.247**	**0.259**	**0.258**	**0.274**	0.014	10
	100	93	94	100	103	99	100	88	85	100	100	106		
Mn%	**37**	**53**	**98**	60	63	65	**53**	**66**	**69**	62	60	66	13.1	38
	100	143	265	100	105	108	100	125	130	100	97	106		
Zn%	17.3	16.8	16.4	17.2	16	17.3	17.6	15.8	17.2	16.2	17	17.4	2.2	24
	100	97	95	100	93	101	100	90	98	100	105	107		

TSP application did not have any significant effects upon the leaf nutrients measured, nor upon yield.

Application of MOP in combination with other fertilizers substantially reduced K levels, from the already low percentage at K0. However, even in the absence of any fertilizer, in the control plot, the K% has declined to an exceptionally low 0.77%.

Magnesium levels also fell, and the nitrogen level rose, balancing the reduction in K and Mg. Manganese was increased, but calcium was not affected (in contrast to the reduction in expt.305).

Chloride levels were increased by about 400% on plots receiving MOP.

Kieserite application increased magnesium levels , but the only observed effect was at rate 2 (1.5 kg/year) whilst rate 1 had the major effect upon yield. Sulphur levels were unaffected, but chloride levels were increased by about 15%. The interactions differed from those identified in trial 305.

EXPERIMENT 310, Anion and fertilizer frequency trial, Ambogo

Planted:	1980
Design:	Randomised blocks, with 5 replicates of 7 plots of 7 treatments.
Treatments commenced:	November 1986.
Original details:	6th Annual Report (for 1986)
Soil type:	Ambogo/Penderetta families.

Treatments:

Treatment code	Fertilizer	Kg/palm/yr	Applications/yr
1	None	0.0	0
2	$MgSO_4$	2.0	2
3	$MgCl_2$	1.5	2
4	K_2SO_4	3.0	2
5	KCl	2.5	2
6	K_2SO_4	3.0	1
7	KCl	2.5	1

Yield data for 1987 is presented in Table 45 and growth data in Table 46. At this stage, with the trial only in operation for 1 year, no significant effects have been observed, nor would they be expected. Higher yield values are generally matched by higher initial rachis measurements, confirming that treatment effects cannot yet be observed. The general yield levels at this site are currently good, although in the longer term, if no N applications are made, they may be expected to decline.

Table 45: Yield data for trial 310: 1987

Treatment	S.Bunch wt	Bunches/ha	Yield tonnes/ha
Control	13.4	2317	31.08
$MgSO_4$	13.9	2320	32.04
$MgCl_2$	13.7	2220	30.49
$K2SO_4$	13.5	2274	30.61
KCl	14.0	2183	30.63
K_2SO_4 x1	14.5	2217	32.12
KCl x1	13.3	2286	30.40
$LSD_{.05}$	0.88	288	3.31
C.V.(%)	5	10	8

Table 46: Vegetative measurement data for trial 310: 1987

Treatment	Vegetative index	Petiole cross section cm^2 April	Frond prodn. /year Oct
Control	603	25.44	23.7
$MgSO_4$	597	24.96	24.0
$MgCl_2$	596	25.32	23.5
K_2SO_4	648	27.36	23.8
KCl	623	25.98	24.0
K_2SO_4 x1	637	26.52	24.0
KCl x1	571	24.32	23.5
$LSD_{.05}$	72	2.97	1.4
C.V.(%)	9	9	4

ORO PROVINCE

Mill Waste Trials

(S.W., A.O.)

EXPERIMENT 308, Mill effluent trial, Arehe

Planted:	1978
Design:	Randomised blocks, with 5 replicates of 3 treatments.
Treatment commenced:	A single application of effluent was made in June 1986.
Original details:	5th Annual Report
Soil type:	Ohita family- a very dark loam and humic topsoil, overlying a sandy subsoil. These soils are derived from recent volcanic ash falls, and have very rapid permeabilities.

Treatment (June 1986):

Treatment code:	1	2	3
Kg effluent per palm	0	625	1250

Initial soil leaf and yield data summarised in Table 17 indicates the inherently high level of variability over the area of this trial, which has hindered experimental precision.

Table 47: Expt.308, 1984 data indicating site variability.

Leaf analysis and ffb yield in tonnes/ha:

	N%	P%	K%	S%	Ca%	Mg%	Cl%	FFB 1986
MAX	2.5	0.16	1.04	0.18	1.01	0.33	0.36	24.02
MIN	2.3	0.14	0.63	0.16	0.75	0.17	0.21	13.73
VARn % (1)	109	114	165	113	135	194	171	175
AVG	2.373	0.1506	0.854	0.171	0.890	0.234	0.254	19.07
S.D.	0.079	0.0059	0.116	0.005	0.076	0.053	0.042	3.074
C.V.(%)	3	4	14	3	9	23	17	16

Soil analysis data:

		ppm	Extractable cations me/100g			Percentage saturation					O.M.	P reten.
	pH	P	K	Ca	Mg	CEC	K	Ca	Mg	Na	%	%
MAX	5.7	7	0.14	6.9	2.32	19	0.9	39	14.7	0.6	15.2	94
MIN	5.3	3	0.07	2.7	0.43	12	0.4	16	2.7	0.2	4.6	35
VARn %	108	233	200	256	540	158	225	244	544	300	330	269
AVG	5.52	4.6	0.107	4.68	1.416	16.26	0.666	28.86	8.74	0.446	9.49	67.26
S.D.	.108	.98	0.019	1.46	0.654	1.907	0.154	8.35	3.88	0.106	3.83	24.38
C.V.(%)	2	21	18	31	46	12	23	29	44	24	40	36

(1) The percentage variation is the maximum figure divided by the minimum expressed as a percentage.

The chemical analysis and approximate equivalent fertilizer value of the POME is summarised in Tables 49 and 50. It can be seen that the nutrient content of 1250 l POME per palm per annum approximates to the palm's full fertilizer requirement.

The actual benefit of the effluent may differ in practice. Many of the nutrients are in organic forms, from which they are released slowly (which may be a considerable advantage in the long term, but leads to a slower initial response). Additionally, nitrogen is taken up in the breakdown of the organic matter, and there may be other losses by run off or leaching, so that the chemical analysis of the effluent may over-estimate its value, particularly for nitrogen. If application were to damage the soil structure, this would also counter-balance the nutritional benefits.

Table 48: Analysis of POME applied to trial 308

	Percentage Analysis of d.m. Sample 1	Sample 2	Average	(1) gms/Palm at 1250 l	(2) Content % fresh POME
N%	1.7	1.6	1.65	887	0.071
C%	55	53	54	29025	2.322
C/N	32	33	32.5		
P%	0.32	0.37	0.345	185	0.015
K%	2.7	2.6	2.65	1424	0.114
S%	0.24	0.24	0.24	129	0.01
Ca%	1	1.1	1.05	564	0.045
Mg%	0.53	0.62	0.575	309	0.025
Na%	0.03	0.02	0.025	13	0.001
Cl%	0.69	1.3	0.995	535	0.043
				mg/palm	ppm
Feppm	920	1000	960	516	41.3
Mnppm	27	29	28	15	1.2
Zn ppm	41	36	38.5	21	1.66
Cu ppm	36	29	32.5	17	1.4
Co ppm	0.05	0.06	0.055	0.03	0.0024

Note: (1) Grams of each nutrient in 1250 l of fresh POME.
(2) Estimated dm content 4.3%.

Table 49: Fertilizer equivalent of POME [1]

Nutrient	Fertilizer Equivalent: Kg	Type of fertilizer
N	4.22	Sulphate of Ammonia
S	0.54	Sulphate of Ammonia
P	0.93	Triple Superphosphate
K	2.85	Muriate of Potash
Cl	1.19	Muriate of Potash

Note: [1] Kg of fertilizer required to supply the same amount of nutrient as 1250 l of POME.

Yield data for 1987 is summarised in Table 51. The first annual application was applied in 1986. It was subsequently decided that the application would not be repeated, and that the trial should be completed in 1988. However, in view of the deteriorating state of the palms without fertilizer application, it was decided that the area should revert to estate fertilizer practice in 1988, and 1987 was accordingly the last year of yield recording. Thus the time for observation of possible treatment effects was inadequate. Never-the-less, yield data for 1987, in Table 50, is of interest.

Table 50: Experiment 308, Yield data : 1987

Treatment	Single bunch wt Mean	Single bunch wt Since [1] treatment	Bunches/ha Mean	Bunches/ha Since [1] treatment	Yield tonnes/ha Mean	Yield tonnes/ha Since [1] treatment
Control	14.71	-2.07	1112	-167	16.13	-5.17
625 l	14.68	-1.9	1003	-135	14.77	-4.07
1250 l	14.76	-1.54	956	-92	14.08	-2.99
$LSD_{.05}$	2.25	1.84	189	289	4.01	4.66
S.D.(%)	1.54	1.12	130	198	2.74	3.19

Note:[1] 1987 yields less the equivalent 1986 yields.

Overall the decline in yield occasioned by the absence of fertilizer was not arrested during 1987. This emphasises the requirement for adequate fertilizer applications before yield is seriously affected, since the decline is difficult to arrest at a later stage.

However, the fall in yield was considerably less on palms receiving effluent than on untreated palms, and the yield advantage was proportionate to the amount of effluent applied. In comparison to the control palms, the decline in F.F.B. yield by palms receiving the maximum effluent application was on average 2.2 t/ha less. It is probable that had the trial continued longer, this difference would have further increased.

The vegetative measurement data in table 51 do not show any treatment effect 1 year after the application.

Table 51: Experiment 308, Vegetative measurement data : 1987

Treatment	Vegetative index Mean	Vegetative index Since [1] treatment	Petiole cross section cm^2 Mean	Petiole cross section cm^2 Since [1] treatment	Frond production /year Mean	Frond production /year Since [1] treatment
Control	568	-202	32.4	-0.73	17.6	-5.74
625 l	588	-188	33.2	-0.71	17.6	-5.22
1250 l	572	-211	34	-0.63	16.9	-5.76
$LSD_{.05}$	81	80	4.3	2.4	1	1.15
S.D.	56	55	3	1.6	0.7	0.79

Note: [1] 1987 yields less the equivalent 1986 yields.

Leaf analysis data is presented in Table 52. Apart from a slight increase in calcium levels in treated palms, there are no clear treatment effects in the samples taken one year subsequent to the initial effluent application.

Table 52: Experiment 308, Summary of leaf analysis results, 1987 (percentage nutrient contents in leaf dm)

	Treatment: litres of POME			Statistical result	
	0	625	1250	$LSD_{.05}$	S.D.
Nutrient					
N	1.78	1.74	1.78	0.2	0.14
86 to 87	-0.4	-0.34	-0.32	0.2	0.14
84 to 87	-0.6	-0.66	-0.56	0.23	0.16
P	0.14	0.14	0.14	0.01	0.008
86 to 87	-	-0.01	-	0.01	0.007
84 to 87	-0.01	-0.01	-0.01	0.01	0.009
K	0.81	0.85	0.83	0.16	0.11
86 to 87	0.07	0.05	0.07	0.16	0.11
84 to 87	-0.01	-0.04	-0.03	0.18	0.12
S	0.15	0.14	0.15	0.02	0.012
86 to 87	-0.01	-0.02	-	0.02	0.014
84 to 87	-0.12	-0.03	-0.02	0.02	0.012
Ca	0.93	0.94	0.96	0.15	0.1
86 to 87	-	0.07	0.05	0.15	0.1
84 to 87	0.02	0.06	0.07	0.16	0.1
Mg	0.28	0.28	0.28	0.04	0.026
86 to 87	0.04	0.04	0.03	0.03	0.022
84 to 87	0.05	0.04	0.04	0.04	0.03
Cl	0.23	0.18	0.16	0.06	0.037
86 to 87	-0.02	-	-	0.05	0.035
84 to 87	-0.05	-0.07	-0.07	0.04	

A possible reason for the lack of significant effects is that they could have been lost over the year, particularly in view of the initial low fertility levels, at which applied nutrients can readily be "diluted" through improved yield or growth.

The generally low leaf nutrient levels confirm the requirement for fertilizers in order to maintain production on this soil.

Conclusions

The inherent variability of the site, and the short period of recording subsequent to treatment application have reduced the experimental precision.

There is evidence of a yield benefit (2.2 t/ha) during 1987 from the 1986 application of POME, the benefit being greatest at the maximum application rate.

Since the major effect is upon bunch weight, this corresponds to the effect of MOP in other trials at Higaturu. There is no clear evidence of a nitrogen benefit. There is no evidence of any adverse effect at the rates of application used within this trial.

These findings generally confirm those of the POME application trials carried out in West New Britain (Expts.109a & b).

POME application at up to 1250 l/palm can therefore be recommended on an agronomic basis as a result of this trial and there is no evidence of any likelihood of problems.

EXPERIMENT 309, Empty bunch application trial, Ambogo

Planted:	1980
Design:	Randomised blocks, with 5 replicates of 5 plots (3 treated plots and 2 controls per block).
Treatment commenced:	A single application of empty bunches was made between September and December 1984.
Original details:	4th Annual Report (1984)
Soil type:	Penderetta family- with a thin dark sandy clay loam topsoil, overlying a sandy loam subsoil.

Treatments:	1 & 2	3	4	5
Empty bunch t/ha 11/84	0	50	100	100
SOA kg/palm 11/84	0	0	0	1

The analysis of the EFB applied in 1984 is given in Table 53. The main nutrient supplied was potassium, with about 2% K in the DM, (30% DM in the fresh EFB). Application at 50t/ha would therefore provide approximately 2kg of K nutrient per palm, equivalent to 4 kg of MOP.

Table 54 indicates the exact straight fertilizer equivalents to the nutrient content of the EFB. However, the EFB is not directly equivalent to standard fertilizers, as it contains a greater range of nutrients, which are held in various organic forms, resulting in gradual release of nutrients over an extended period, as a result of decomposition of the EFB.

For potassium this is beneficial: use of standard K fertilizer at such rates could be harmful, and would also be more subject to loss from the soil.

The supply of N from EFB is more complex. Nitrogen is used up in the decomposition of the organic matter, so that EFB would not necessarily be an effective source of N. In this trial the leaf analysis results indicate that EFB has improved N nutrition to a highly significant extent (Table 57). This benefit may also have been influenced by the vigorous growth which was noted of leguminous cover crop over the applied EFB. The *Calopogonium* would have contributed nitrogen required during the decomposition of the EFB, and recycled nutrients from the EFB to the palms through leaf litter.

Table 53: Analysis of empty bunches applied to trial 309

	Percentage Analysis of d.m. Sample 1	Sample 2	Sample 3	Average	(1) gm/Palm at 100 t/h
N%	0.72	0.95	0.69	0.79	1768
C%	43	46	42	43.7	97790
C/N	60	48	61	56.3	
P%	0.09	0.09	0.07	0.08	179
K%	2.1	2.1	1.7	1.97	4408
S%	0.07	0.08	0.08	0.08	179
Ca%	0.29	0.25	0.22	0.25	559
Mg%	0.11	0.12	0.11	0.11	246
Na%	0.01	0.01	0.01	0.01	22
Cl%	0.18	0.21	0.25	0.21	470
					mg/palm
Feppm	130	94	98	107	239
Mnppm	10	13	7	10	22
Zn ppm	22	19	15	19	43
Cu ppm	7	11	13	10	22
Co ppm	0.02	0.11	0.04	0.06	0.13

Note:
(1) Grams of each nutrient in 100/143 tonnes of fresh EB.
(2) Note: estimated dm content 32%.

Table 54: Fertilizer equivalent of empty bunches (1)

Nutrient	Fertilizer Equivalent: Kg	Type of fertilizer
N	8.33	Sulphate of Ammonia
S	.75	Sulphate of Ammonia
P	.91	Triple Superphosphate
K	8.82	Muriate of Potash
Cl	1.04	Muriate of Potash

Note: (1) Kg of fertilizer required to supply the same amount of each nutrient as 700 kg of EB (the amount per palm at the 100 t/ha rate).

Yield data for 1987 is presented in Table 55. General yield levels have declined by around 10 t/ha from 1986 to 1987. Since no fertilizer applications have been made subsequent to the initial empty bunch application in 1984, depletion of soil nutrients is now taking its toll on all treatments.

The main nutrient deficiency responsible for the decline in yield during 1987 appears to be N. The results in this experiment therefore confirm the results from Expt.306 data indicating the requirement for N on Ambogo soils during 1987.

Table 55: Yield data for trial 309

Treatment	S.Bunch wt	Bunches/ha	F.F.B Yield tonnes/ha 1987	1986	1985	85-87
Control	**8.93**	**1788**	**16.00**	**25.45**	**27.02**	**22.82**
50 t/ha	**10.26**	**1884**	**19.37**	**29.53**	**31.30**	**26.73**
100 t/ha	**10.12**	**2059**	**20.83**	**30.11**	**30.02**	**26.99**
100 + SOA	**10.82**	**2174**	**23.42**	**32.25**	**31.92**	**29.20**
$LSD_{.05}$(1)	1.15	252	3.42	3.85	4.41	3.09
$LSD_{.05}$(2)	1.01	232	3.01	3.39	3.88	2.72
C.V.(%)	8.6	9.5	12.8	9.8	10.9	8.7

($LSD_{.05}$ (1) & (2) for comparison of trt.v trt. and trt.v.ctrl respectively)

Although overall yields have declined, the response to empty bunch application increased during 1987, with significant benefits in terms of yield, bunch numbers and s.b.w.. The yield in the control plots (16 t/ha) is very similar to that in the control plot in Expt.306 (14.4 t/ha) and the yields with empty bunch application (19.4 - 23.4 t/ha) are similar to those in Expt.306 where only MOP was applied (23.1 t/ha).

All EFB treatments have given significantly higher yields than the controls, with the difference between treated and untreated plots increasing each year betwwen 1985 and 1987. On average they have provided 13.8 t/ha greater yield than the control over the 3 years since treatment.

The differences between the individual EFB treatments are less, and have not proved statistically significant. It appears that there are only minor differences between the 50 t/ha and the 100 t/ha applications of EFB. The 100 t/ha treatment, with addition of SOA on the original mulch appears superior: in comparison with the 50 t/ha EFB treatment, for the 3 years 1985 to 1987 the 100 t/ha treatment yielded 0.78 tonnes more and the 100t/ha plus SOA yielded 7.41 tonnes more.

The trial palms have never received N fertilizer, and are showing visible deficiency symptoms. In view of the long period (3 years) since the initial N application, which was only of 1 kg of SOA, the increased yield is most unlikely to be a direct result of the fertilizer N. This is confirmed by the leaf analysis results: the leaf level of K is highest for the treatment with additional SOA, but the levels of N, Cl and Mg for this treatment have fallen slightly below those for the other EFB treatments.

The benefit of application of SOA onto the EFB mulch appears therefore not to be a direct N effect, but due to improved mobilisation and uptake of nutrients from the EFB, as a result of the accelerated breakdown of the EFB encouraged by the initial application of SOA. Application of SOA onto the EFB mulch has been definitely beneficial, and should be a recommended practice, if EFB is applied.

Vegetative measurements on the palms (Table 56) closely confirms the yield data, with the vegetative index (product of frond production and rachis cross-section) corresponding particularly closely to yield variation between the treatments. Height differences between the treatments are minor, and not statistically significant.

Table 56: Experiment 309, Vegetative measurement data : 1987

Treatment	Vegetative index	Petiole cross section cm^2	Frond prodn. /year	Height m
Control	**381**	**21.18**	**17.95**	1.87
50 t/ha	**443**	**22.22**	**19.90**	1.95
100 t/ha	**471**	**22.95**	**20.50**	2.06
100 + SOA	**500**	**23.77**	**20.98**	2.01
L.S.D.(trt.v trt.)	87	2.34	3.01	0.29
L.S.D.(trt.v ctrl)	77	2.06	2.65	0.26
C.V.(%)	15	7.8	11.3	11.2

Leaf analysis in this trial (Table 57) has identified a highly significant rise in K levels following EFB application, accompanied by higher N and Cl levels and lowered Mg levels in comparison to the control. However, between 1984 and 1987, all N and Cl levels had fallen substantially. EFB has therefore mainly improved K nutrition, with a corresponding reduction in Mg levels. This confirms that the nutritional benefits of the EFB application are primarily due to the K supplied.

The raised K leaf content is of particular note, since on the other trials at Higaturu application of MOP has always resulted in reduced K levels in the leaf (but similar raised yields). Uptake of K from organic matter is therefore apparently different, and avoids a problem which occurs with mineral K uptake from the Higaturu soils, which results in a fall in leaf K in spite of rises in yield. This effect makes it difficult to understand the response to MOP: possibly the K is available to other parts of the palm, despite lowered levels in frond 17.

Table 57: Summary of leaf analysis results for trial 309 (percentage nutrient content in leaf dm)

Nutrient	Treatment: t/ha of empty bunches 0	50	100	100 + SOA	Statistical result LSD.05	S.D.
N(1987)	**1.93**	**2.18**	**2.24**	**2.12**	0.22	0.16
(84 to 87)	-0.63	-0.4	-0.36	-0.48	0.32	0.24
(1984)	2.56	2.58	2.6	2.6		
P(1987)	0.15	0.15	0.15	0.15	0.01	0.009
(84 to 87)	-0.027	-0.022	-0.03	-0.026	0.01	0.009
(1984)	0.177	0.172	0.18	0.176		
K(1987)	**0.855**	**0.964**	**0.938**	**1.008**	0.087	0.065
(84 to 87)	-0.027	0.070	0.034	0.118	0.116	0.087
(1984)	0.882	0.894	0.904	0.89		
S(1987)	0.131	0.132	0.130	0.138	0.023	0.017
(84 to 87)	-0.034	-0.036	-0.036	-0.028	0.027	0.02
(1984)	0.165	0.168	0.166	0.166		
Ca(1987)	0.904	0.896	0.866	0.868	0.061	0.046
(84 to 87)	-0.02	-0.016	-0.048	-0.05	0.085	0.064
(1984)	0.924	0.912	0.914	0.918		
Mg(1987)	**0.36**	**0.332**	**0.326**	**0.298**	0.045	0.034
(84 to 87)	0.027	0.006	-0.006	-0.024	0.046	0.035
(1984)	0.333	0.326	0.332	0.322		
Cl(1987)	0.191	0.232	0.22	0.218	0.045	0.034
(84 to 87)	-0.151	-0.108	-0.146	-0.114	0.049	0.037
(1984)	0.342	0.34	0.366	0.332		

Since the benefit of EFB application has now been clearly established, and in view of the declining yields, it has been decided to superimpose new treatments during 1988.

The benefit of EFB application is apparently largely due to the K content of the empty bunches, so that it is intended to assess bunch ash and MOP as sources of K, with and without additional N. A control treatment will be retained for comparison.

Conclusions

EFB application has been highly beneficial. Over the 3 years following the initial application, the total yield advantage has ranged from a minimum of 11.73 t/ha for the 50 t/ha EFB treatment to 19.84 t/ha for the 100t/ha EFB plus 1 kg SOA treatment.

Only minor differences were detected between the benefit from the 50t/ha treatment and the 100t/ha treatment.

Distribution of SOA over the fresh EFB appears beneficial. The addition of 1kg of SOA per palm to the fresh EFB provided a yield advantage of 6.63 t/ha during the trial, in comparison to the same treatment without SOA.

Leaf analysis indicated the main nutritional benefit of the EFB to be K, with N and Cl also supplied in smaller amounts. Uptake of K from organic matter differs from that from MOP: EFB application raised leaf K levels, whilst MOP applications at Higaturu have always lowered leaf K levels.

SMALLHOLDER TRIALS

Oro Province

(S.W., A.O.)

EXPERIMENT 307, Smallholder fertilizer trial.

Planted:	1978-81
Design:	Randomised blocks, with 3 treatments. Replicates now reduced from 7 to 3.
Treatments commenced:	1984: TSP in October, and SOA in December Original details: 4th Annual Report
Soil types:	Detailed in the 6th Annual Report, but broadly similar to Higaturu and Ambogo

Treatments in Kg/palm/year:

Treatment code:	0	1	2
Ammonium sulphate	0	2	2
Triple superphosphate	0	0	0.5

Ammonium sulphate is applied twice a year, and TSP once.

Yield data for 1987 is presented in Table 58. A significant treatment effect has been identified, with fertilized plots providing a significantly ($p<0.05$) higher yield than the controls, during 1987. This confirmed the previous suggestion that fertilizers had improved yields, albeit not to the point of statistical significance at that stage.

N only plots averaged 10% greater yield than the control, and N+P plots 24% greater than the control, but the difference between the 2 fertilizer treatments was not significant. Yields on the control plots in the range of 10-20 t/ha, are in line with those found on control plots in the trials at Higaturu.

During 1987 yield levels have generally fallen, particularly on the unfertilized plots. The effective increase in fertilizer response, even at the reduced yields, has resulted in the significant treatment effect developing.

Table 58: Trial 307, Yield per hectare

Treatment	s.b.w. kg	1987: No of bunches	1987: Wt of bunches t/ha	Average 86 & 87 Wt of bunches t/ha
Control	12.42	1299	**15.67**	18.05
N	12.89	1364	**17.26**	19.72
N + P	12.97	1513	**19.47**	22.41
$LSD_{.05}$	2.57	234	3.37	5.28

Table 15 indicates vegetative measurements. The responses were very similar to those for yield, but none were statistically significant.

Table 59: Trial 307, Vegetative Measurement Data

Treatment	1987 V.I.	1987 WxT	1987 Frond prodn./yr	84 to 87 WxT increase
Control	585	23.2	25.1	6.0
N	656	24.7	26.6	6.4
N + P	690	25.3	27.1	7.9
$LSD_{.05}$	129	3.7	3.2	3.0

Table 60 indicates the leaf analysis results

Table 60: Trial 307, Leaf Analysis Data, 1987

Treatment:	Control	N	N+P	$LSD_{.05}$
N%	1.97	2.17	2.13	0.26
P%	0.15	0.15	0.15	0.02
S%	0.14	0.13	0.14	0.01
K%	0.97	0.98	0.97	0.16
Cl%	0.13	0.09	0.06	0.08
Ca%	0.88	0.88	0.82	0.17
Mg%	0.23	0.21	0.22	0.07

Leaf levels of P, K, Ca and Mg are all broadly in line with values at Higaturu. The P level appears generally adequate, but there are considerable variations between sites. The N and S levels are, surprisingly, lower than those at Higaturu, even on the fertilized plots. This is in spite of equivalent applications of SOA. The levels of both N and S are fairly low. There is evidence for an increase in leaf N levels as a result of the SOA applications, but without any corresponding increase in S levels. The increased leaf N level is the only clear change corresponding with the increased yield from the fertilized plots.

Chloride is very low, around 0.1%, which is typical of areas which have never received chloride containing fertilizers. At Higaturu, where MOP has been applied, typical values have risen to around 0.4%.

Conclusions

This trial has run for only 3 years, with a constant reduction in the number of replicates involved. For a fertilizer trial, this is a relatively short period. Overall, the yield levels within the trial have shown great variation between sites and years. However, a response to nitrogen has developed, but it has not been identified nearly as clearly as in all the major trials at Higaturu.

It is unfortunately likely that the fertilizers applied have not been ideal, in view of the major responses also obtained to KCl in the experiments at Higaturu, and it is possible that different results would have been obtained, had it been included in this trial.

Problems with the organisation and running of the experiment, and the unfortunate reduction of the number of replicates led to the decision late in 1987 to discontinue the experiment. However, a new series of Smallholder Demonstration sites will commence in 1988, aiming to demonstrate and assess the benefits of appropriate fertilizer practices. N, P and K fertilizers will be included.

MILNE BAY PROVINCE

Fertilizer Trials

(S.W., A.O.)

EXPERIMENT 501, Establishment fertilizer experiment, Hagita.

Planted:	1986
Design:	Randomised blocks, with 3 replicates of 3x2x3 N,P,K treatments.
Treatments commenced:	July 1986.
Original details:	6th Annual Report (for 1986)
Soil type:	Plantation series - clay loam topsoil, over a fine sandy clay loam subsoil.

Treatments: See Table 61.

A particular growth problem has been experienced in the Milne Bay area, which has also been evident within this trial. Palms have been stunted, with restricted growth of basal leaves, deep green colouration, drying up of leaf perimeters, and, in more serious cases, restricted growth of young leaves, and browning of spear leaves.

In view of these effects and the initial observations of fertilizer responses, the opportunity was taken to revise the application rates for the second year, as shown in Table 61. Borate was introduced on split plots throughout the trial, and the K0 treatment converted to a low application, in view of the severe effects observed on K0 plots. Separate zero fertilizer observation plots were set up to maintain a comparison of performance without fertilizer.

Table 61: Experiment 501, Amended fertilizer schedule in kg/palm, 11/87

Age (months)	Date	SOA 0	SOA 1	SOA 2	TSP 0	TSP 1	MOP 0	MOP 1	MOP 2	B 0	B 1
3	7/86	0.3	0.3	0.4							
6	10/86		0.3	0.6		0.5		0.3	0.5		
12	4/87		0.6	1.2		0.5		0.5	1.0		
18	10/87		0.6	1.2		0.5	0.5	1.5	2.5		0.05
24	4/88		0.9	1.8		0.5	0.5	1.5	2.5		

Applications of N, P, and K fertilizers were made to the trial in May and November 1987. Petiole cross-section measurements taken in May 1987 did not show any significant treatment effects, but since treatment effects are not immediately evident in the petiole, this was not surprising. In order to assess developments more rapidly, two additional measurements were undertaken in September 1987, one involving maximum palm height measurement, and the other using a health index to score palm condition.

Subsequent rachis cross-section measurements taken in November provided strong support for the other measurements: see Tables 62, 63 and 64. Statistical analysis of the results into the main fertilizer effects gave similar results for all three assessments.

Table 62: Experiment 501, Establishment fertilizer trial, mean maximum height (cm per palm), September 1987

	Level 0	Level 1	Level 2
N	225	224	223
P	223	224	-
K	**194**	**235**	**243**

Table 63: Experiment 501, Establishment fertilizer trial, percentage health indices.

	Level 0	Level 1	Level 2
N	73	73	74
P	73	74	
K	**57**	**79**	**85**

Table 64: Experiment 501, Petiole cross-section November 1987

TREATMENT	W x T cm^2	%
N0	4.54	100
N1	4.65	102
N2	4.73	104
P0	4.63	100
P1	4.65	100
K0	**4.26**	**100**
K1	**4.82**	**113**
K2	**4.85**	**114**
$LSD_{.05}$	0.57	
C.V.(%)	7	

No relationship between N or P and growth was identified, but K had an extremely strong effect on health and development ($P < 0.001$). The intermediate level of K application was adequate to provide for the majority of the improvement. The requirement for K was confirmed by soil and leaf analyses indicating very low K levels (Tables 65 and 66).

Table 65: Soil chemical analysis, Hagita

Depth cm	pH	Exchangeable Cations m.e. per 100g Na	K	Mg	Ca	CEC	Base sat. %	Extr.P ppm
0-10	6.2	0.5	0.3	9.2	22.5	31.8	100	16
50-70	6.5	0.6	0.1	8.1	31.7	39.3	100	7

Table 66: Leaf nutrient analysis, Hagita

Palm appearance	N %	P %	K %	S %	Ca %	Mg %	Na %	Cl %	Fe ppm	Mn ppm	Zn ppm	Cu ppm	B ppm
Deficient	2.5	0.13	0.32	0.17	0.87	0.69	0.01	0.62	147	196	13	7	16
Healthy	3.0	0.16	0.48	0.18	0.91	0.58	0.01	0.66	176	134	17	8	14

There is a possible interaction between K and N, which has not yet reached a statistically significant level. Response to high levels of K is increased in the presence of N, so that the highest rachis measurements in the trial were obtained in the NK plots,as shown in Tables 67 and 68. The best treatment is N1K2, which is similar to the estate fertilizer practice.

Table 67: Experiment 501, Mean petiole cross-section (cm^2)

	K0	K1	K2
N0	4.09	4.82	4.71
N1	4.20	4.66	5.09
N2	4.49	4.97	4.74

Table 68:Experiment 501,Example plot petiole cross-sections(cm^2)

TREATMENT	W x T	%
NPK	4.88	117
NK	4.85	116
K	4.78	114
PK	4.75	114
NP	4.40	105
N	4.29	103
O	4.18	100
P	4.00	96

Whilst it appears that the poor growth is very largely related to K deficiency, further research will be pursued to assess whether other nutrients may be involved.

There is no evidence of any benefit to application of P, except,possibly, in combination with other nutrients.

EXPERIMENT 503, Nursery fertilizer trial, Hagita, MBE, Alotau

Planted: May 1987
Design: A single Latin Square, with 7 nutrient treatments, in plots of 4 polybags.
Treatments commenced: August 1987.

Treatment allocation:

Treatment code	N (SOA)	P (TSP)	K (MOP)	Trace-elements
1	0	0	0	0
2	1	1	1	0
3	1	1	0	1
4	1	0	1	1
5	0	1	1	1
6	1	1	1	1
7	0.5	0.5	0.5	0.5

Total weight applied in each treatment in gm/month/seedling:

Trt code: Month	1	2	3	4	5	6	7
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	6.0	4.0	4.0	4.0	6.0	3.0
3	0.0	6.0	4.0	4.0	4.0	6.0	3.0
4	0.0	12.0	8.0	8.0	8.0	12.0	6.0
5	0.0	18.0	12.0	12.0	12.0	18.0	9.0
6	0.0	30.0	20.0	20.0	20.0	30.0	15.0
7	0.0	30.0	20.0	20.0	20.0	30.0	15.0
8	0.0	30.0	20.0	20.0	20.0	30.0	15.0
9	0.0	30.0	20.0	20.0	20.0	30.0	15.0
10	0.0	30.0	20.0	20.0	20.0	30.0	15.0
11	0.0	30.0	20.0	20.0	20.0	30.0	15.0
12	0.0	30.0	20.0	20.0	20.0	30.0	15.0

Initial performance data in Table 69 have not indicated any significant treatment effects, but performance within the experiment has been variable, obscuring treatment effects.

Table 69: **Experiment 503, Seedling growth data, November 1987**

TREATMENT	Mean Leaf number	%
A: Control	6.87	100
B: NPK	6.99	102
C: NP +TE	6.94	101
D: NK +TE	7.21	105
E: PK +TE	6.84	100
F: NPK +TE	6.89	100
G: 1/2NPK+TE	7.03	102

PHYSIOLOGY

EXPERIMENT 102, Density and N Fertilizer Trial, Dami (T.M)

Planted:	1970
Design:	Randomised blocks with plots split for fertilizer
Treatments commenced:	Density - at planting Fertilizers: 1970 - 1971 N 1971 - 1973 N K Mg 1974 - 1981 K Mg 1986 Re-randomised for 4 levels NH_4Cl
Recording commenced:	1973
Details at:	5th Annual Report, page 25 and 3rd QPR 1986, page 16.

Production from these palms was very low throughout the year. This featured a swing back to an optimum response at lower densities than in the previous four years. The calculated optimum density for yield per hectare was 118 palms/ha for the current year and 136 palms per hectare for the period since planting 15 years ago.

In Table 70 results for 1987 are presented. The effects of density previously reported continued but were more irregular, yield per palm for example showing a more distinct quadratic response than previously. Yield differences were almost entirely dictated by differences between the number of bunches produced. Yield per hectare did not differ significantly between treatments.

The sub-plots, to which fertilizer treatments had been applied from the start of the experiment until 1981, were replaced in March 1986 with 4 levels of ammonium chloride arranged to cancel out any residual effects of the earlier treatments. As would be expected so soon after the first application of ammonium chloride, there was no significant effect on yield over the period Jan-December 1987.

Table 70: Experiment 102, 1987 and Cumulative Production

TREATMENT	PER PALM			PER HECTARE		
	1987			1987		1973-87
palms/ha	No. of bunches	Wt. of bunches kg	s.b.w. kg	No. of bunches	Wt. of bunches	Wt. of bunches t
56	8.2	203.8	25.1	457	11.4	205.8
110	5.1	125.0	24.6	563	13.8	321.5
148	3.9	86.5	22.3	576	12.8	307.0
186	3.0	64.5	21.9	560	12.0	279.8
lsd	1.2	22.4	2.0	130	2.7	
c.v.	13.8	11.7	5.0	15	14	

Optimum density for current yield = 118 palms/ha
Optimum density for cumulative yield = 136 palms/ha

Ammonium[1] Chloride 11/86 Kg/palm.yr	PER PALM JAN-DEC 87 No. of bunches	Wt. of bunches kg	s.b.w.[2] kg
0	4.3	98.0	22.8
2	4.6	106.9	23.2
4	4.4	105.2	23.4
6	4.7	112.8	24.3
lsd	1.1	23.5	2.3
c.v.	22.9	21.1	9.2

[1] at 110 and 148 palms/ha only
[2] adjusted means (pre-treatment sbw was co-variable)

EXPERIMENT 115, Kumbango frond placement(T.M.)

Continuing the treatments consistently has been carried out by the plantation. PNGOPRA has monitored single bunch weight each month with the idea of detecting any change and if an effect on s.b.w. is found, introducing twin row recording of yield.

A year has now elapsed since frond placement commenced. Black bunch counts in 1988 should indicate whether or not the treatments affected abortion. Entering into full-scale twin row recording will be considered when this additional data is available.

EXPERIMENT 705, Clonal density trial, Arehe (S.W.)

Planted:	December 1985
Design:	Split-plot, randomised blocks, with 3 replicates of 4 densities and 4 clones.
Original details:	5th Annual Report (for 1985)
Soil type:	Generally Higaturu family, but affected through previous use as a nursery.

Current data is presented in Table 71. Progress of this trial has been upset through the variable performance of the clones involved. The original intention that this trial should provide a guide to spacing and varietal characteristics of commercial clones has obviously been frustrated. However, observation of the current performance appears to identify 3 principle categories of clones:

1. Clones with apparently normal performance (UF12, UF15 and UF4 in the guard rows).
2. Clones with serious and ongoing abnormal growth (UF6).
3. Clones reverting to normal from abnormal (UF18).

On this basis, ongoing observation of a proportion of the palms will be of interest. The remainder will be removed.

Table 71: Clonal growth and flowering data

Variety	W x T	Flowering Normal	16/12/87 Abnormal	Comments:
UF6	6.7	11	61	
UF12	7.25	72	0	
UF15	7.61	72	0	
UF18	8.92	60	12	Many palms male only

INVESTIGATION 708: Continuous variation of leaf nutrient levels

The main objective of this investigation is to obtain information which will assist in the interpretation of the results of foliar analysis. Leaf nutrient levels can show quite marked seasonal fluctuations and unless these are taken into account, erroneous conclusions may be drawn. In addition the general trends with time are of considerable practical interest as they indicate changes in soil fertility.

Leaf nutrient levels are being monitored monthly at two sites in Oro Province (Experiments 305 and 306) and bi-monthly at two sites in West New Britain (Experiments 109a and 201). This investigation started in 1984/85 and is due to end in 1988, when data over three years will have been collected from all the sites.

Results in 1987

1) Oro Province: Monthly fluctuations in rainfall, FFB yield and leaf nutrient levels in the two experiments at Higaturu during 1987 are shown in Figs. 19 and 20. Since the fluctuations at different fertilizer levels were similar, the results shown have been averaged over high and low treatments.

Of particular note is the marked trough in leaf P level in August, which corresponded with a period of low rainfall and FFB yield in both areas. The similarily of the leaf nutrient fluctuations at the two sites, which although in the same region are some distance apart, is extraordinary and suggests the dominating influence of a common climatic factor.

The trend of FFB yield and leaf N changes over three years in the two experiments is shown in Fig. 21, where 3 month moving averages have been plotted. In the absence of fertilizer it can be seen that leaf N declines much faster and monthly yields fail to rise in peak periods.

2) West New Britain Province: The trend of leaf nutrient changes over three years in Trials 109a and 201 is shown in Figs. 22-25. In both cases there is a marked decline in leaf N level as observed in the Oro Province trials. However from a nutritional viewpoint, what matters is the balance of N with the bases, particularly Ca. As can be seen, the latter also declines with palm age, and it is only a matter of concern if the N decline is greater. The status of Mg also depends on its ratio with Ca, and due to the decline in the latter, it apparently increases with palm age.

Conclusion

When complete data over three years has been accumulated next year, multiple correlation studies will be carried out to investigate the influence of rainfall, sunshine, yield level and fertilizer applications on seasonal leaf nutrient fluctuations in the different areas. Long term fertility trends with time will also be evaluated.

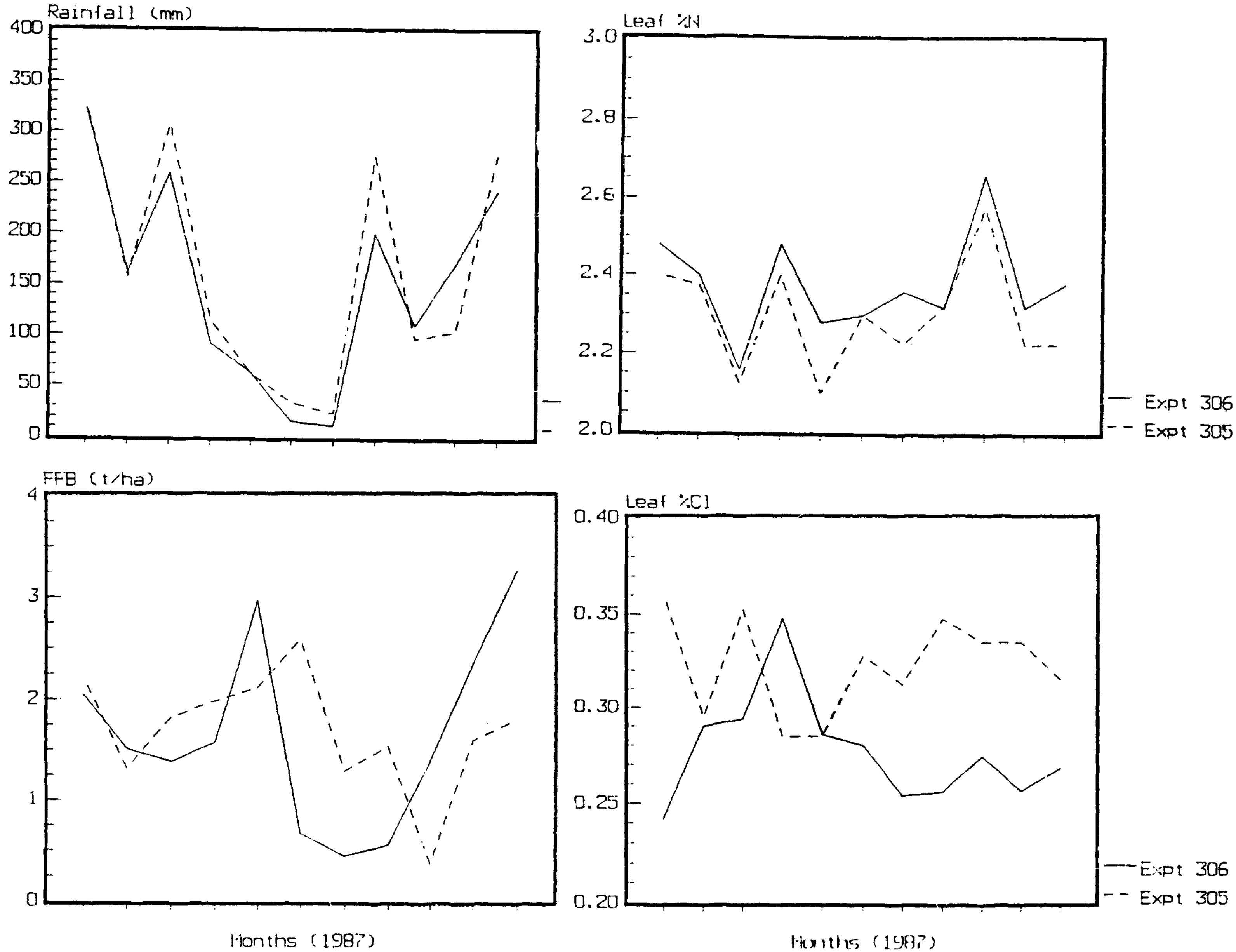


Fig. 19 Monthly fluctuations in rainfall, FFB yield and leaf nutrient levels at Higaturu during 1987.

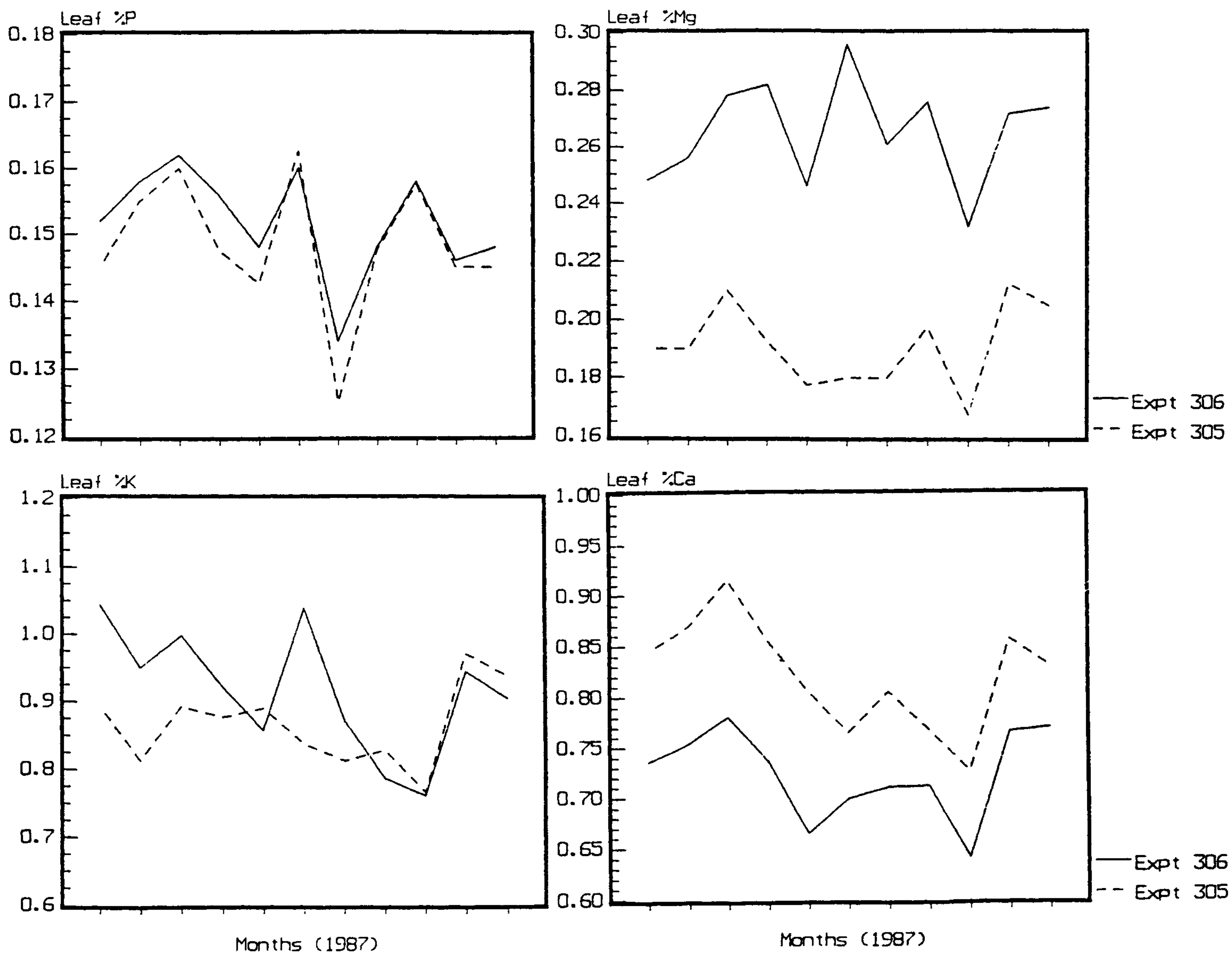


Fig. 20 Monthly fluctuations in leaf nutrient level at Higaturu during 1987

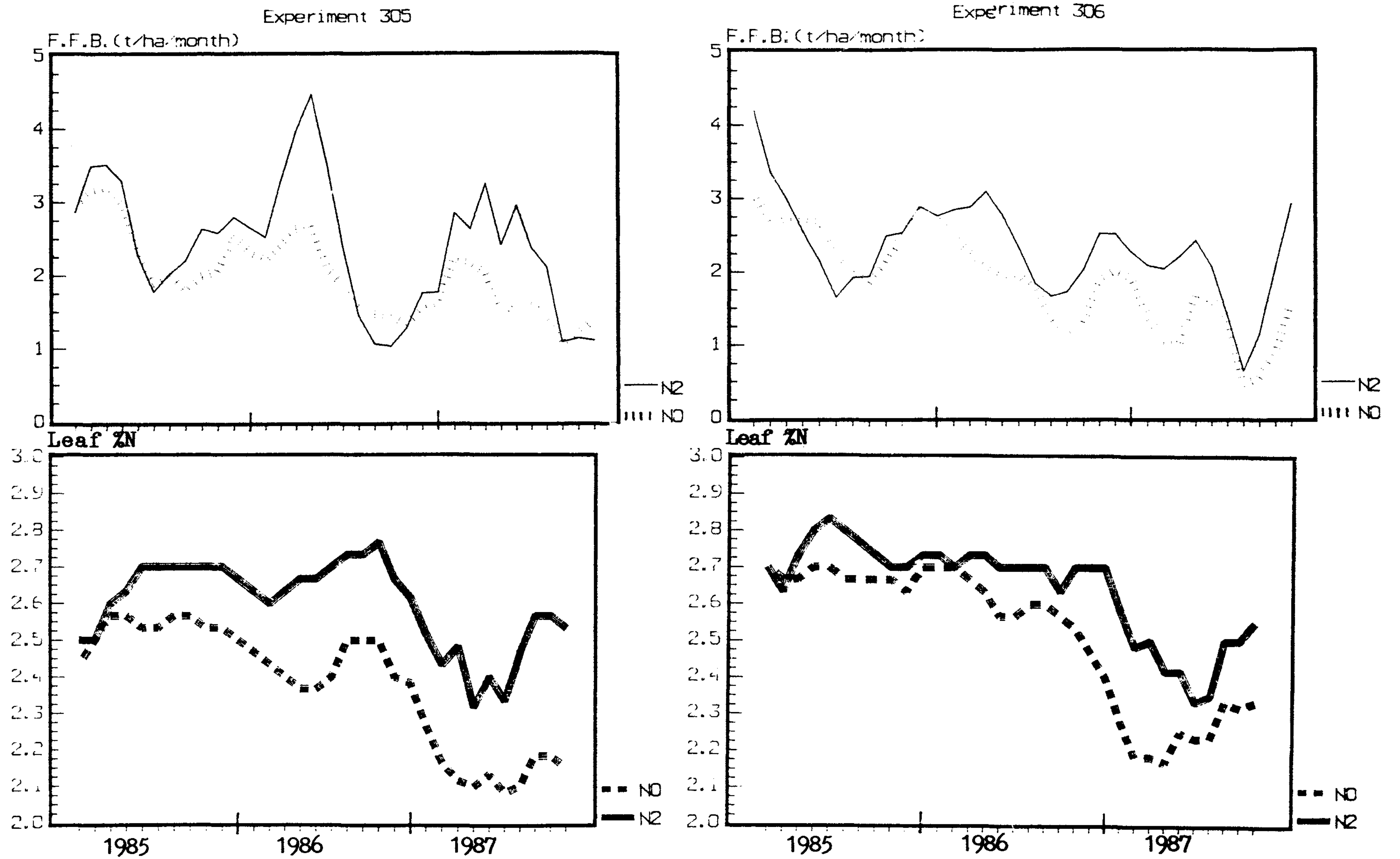
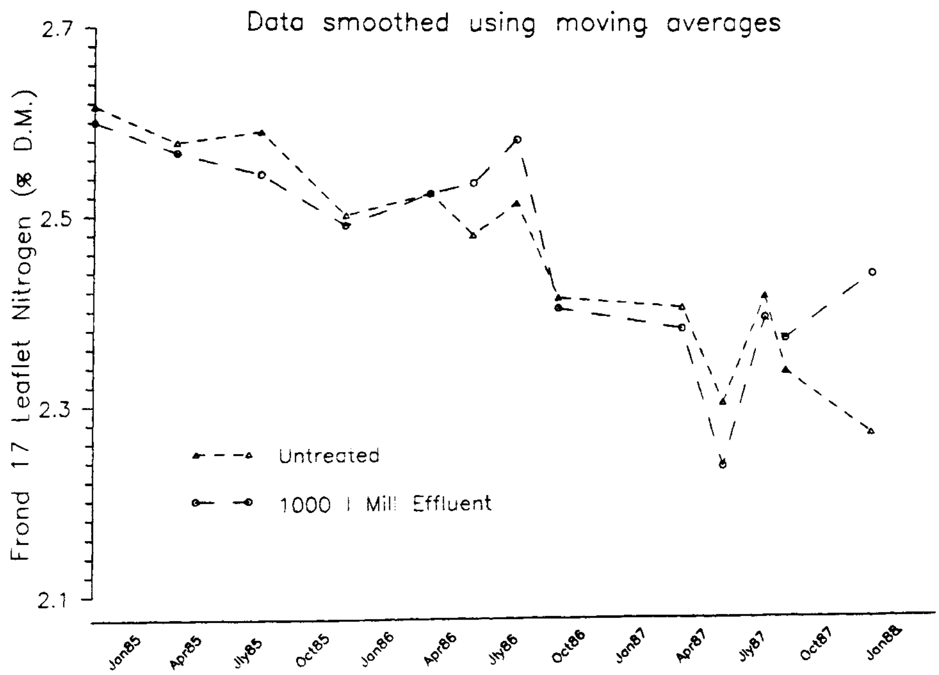


Fig. 21 Monthly variation in FFB yield and leaf N levels over three years in the absence (N0) and presence (N2) of N fertilizer.



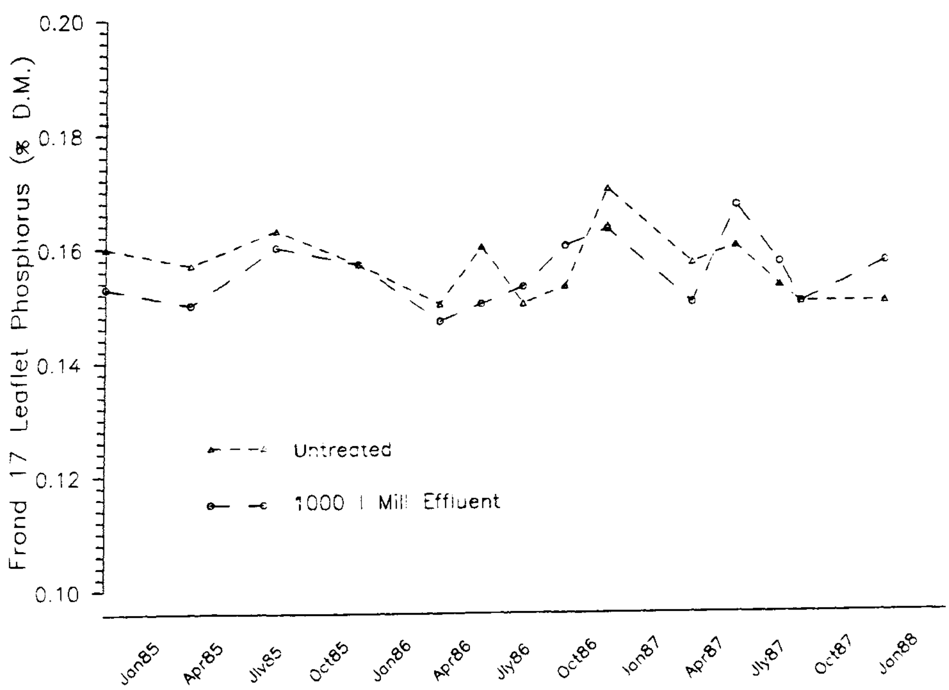


Fig.22 Experiment 109a, Frond 17 leaflet N and P levels,1985-87.

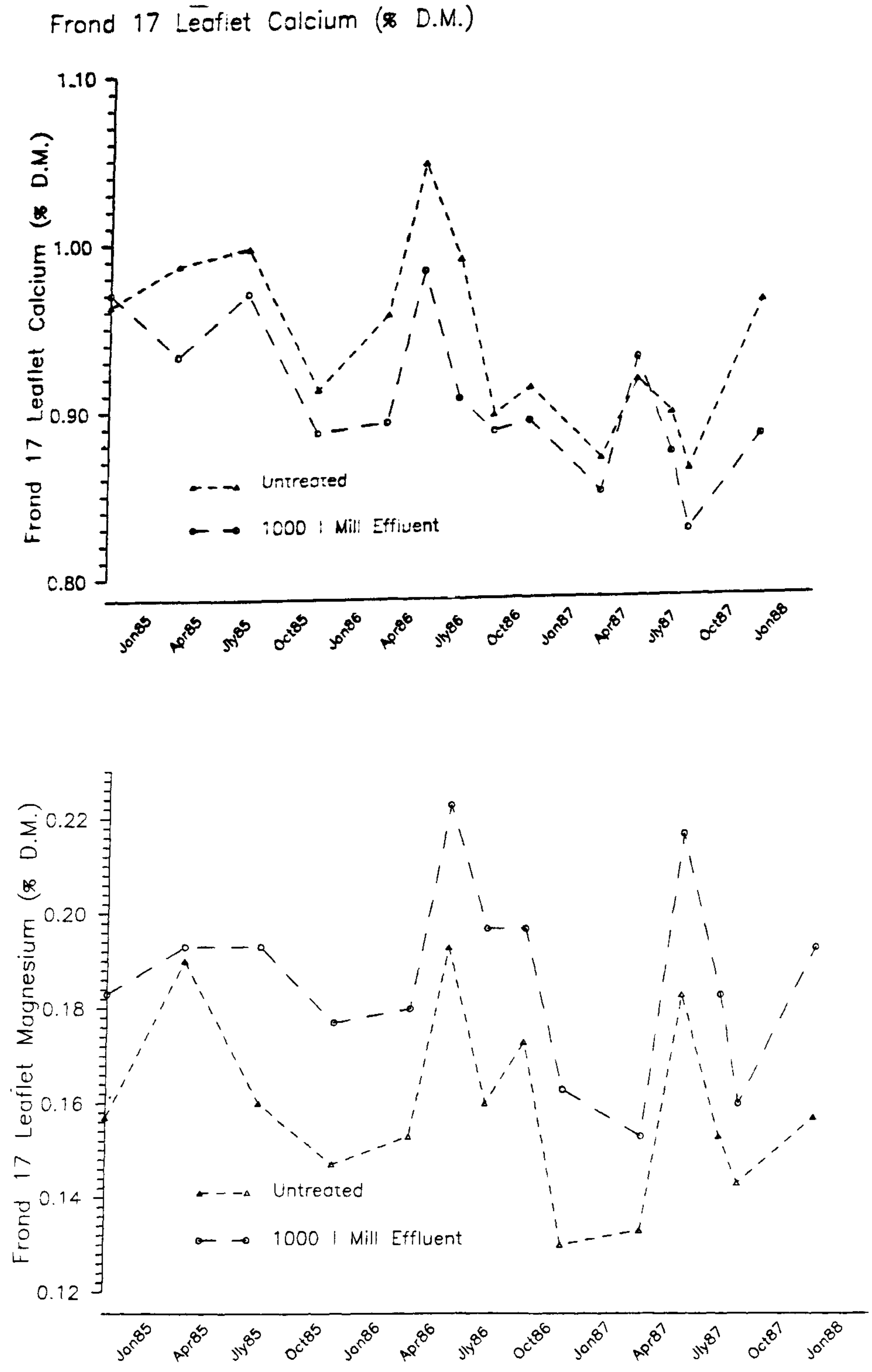
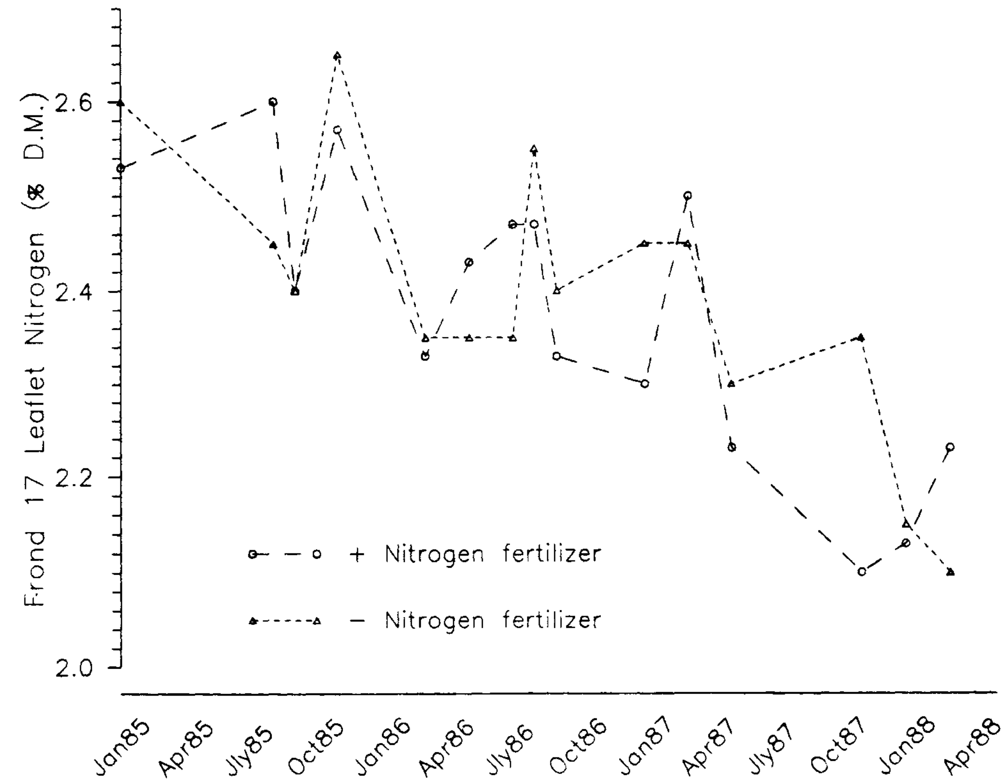


Fig. 23 Experiment 109a, Frond 17 leaflet base levels 1985-87.



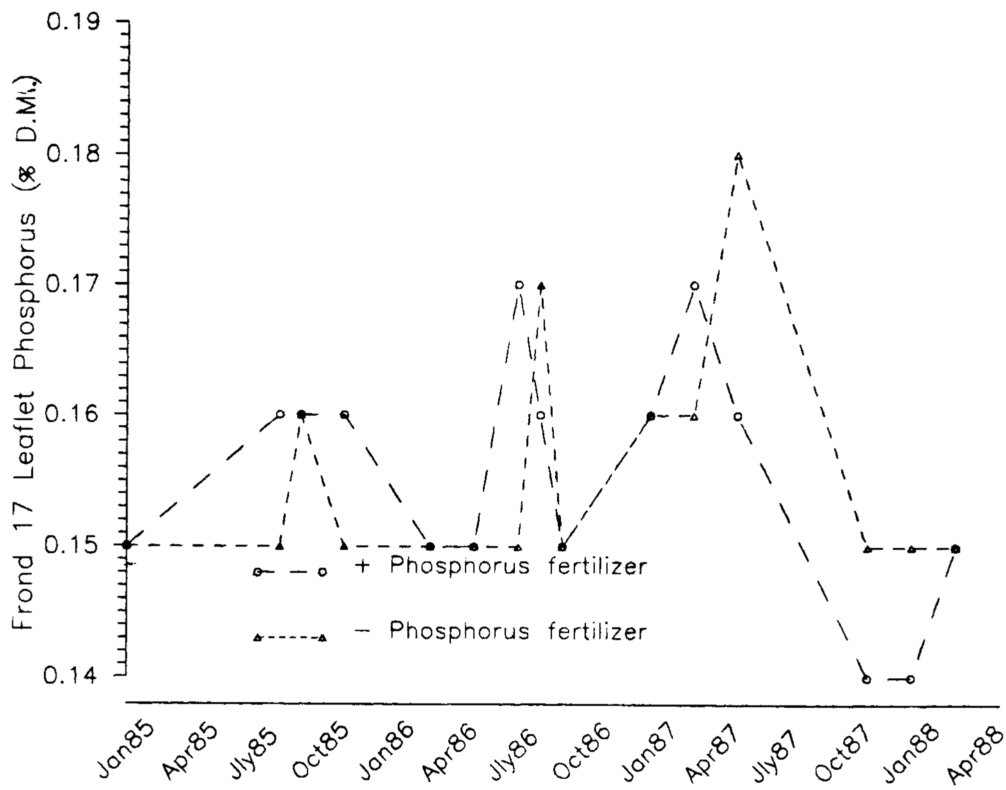
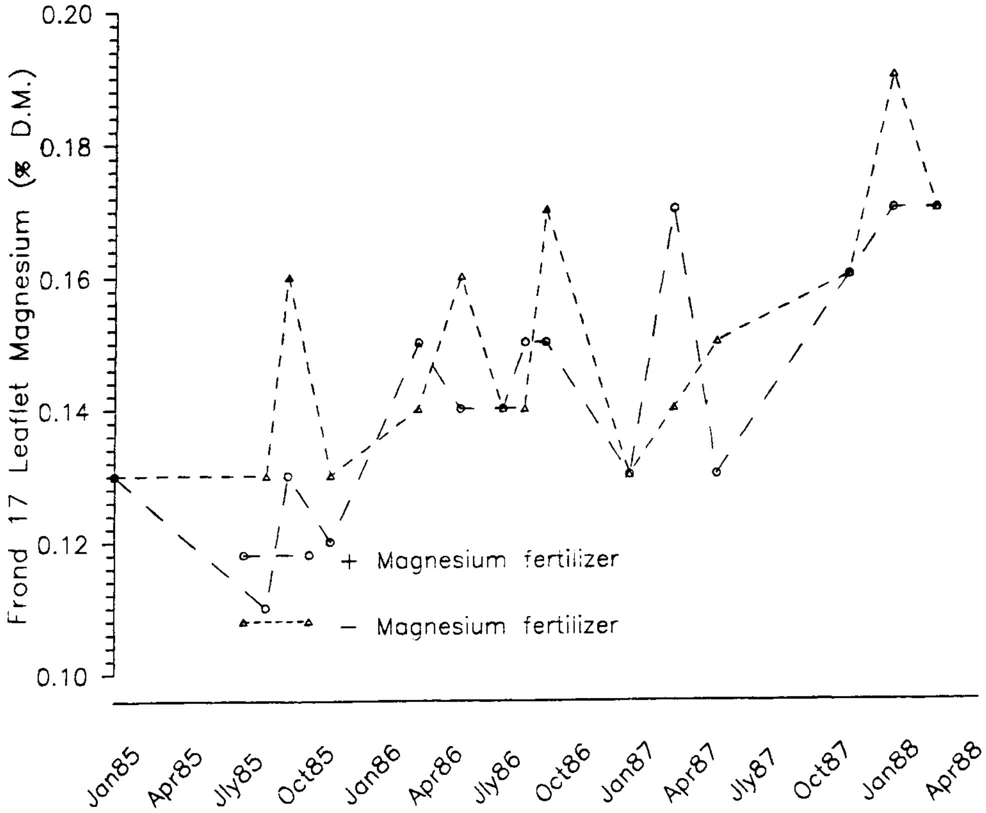


Fig.24 Experiment 201, Frond 17 leaflet N and P levels, 1985-87.



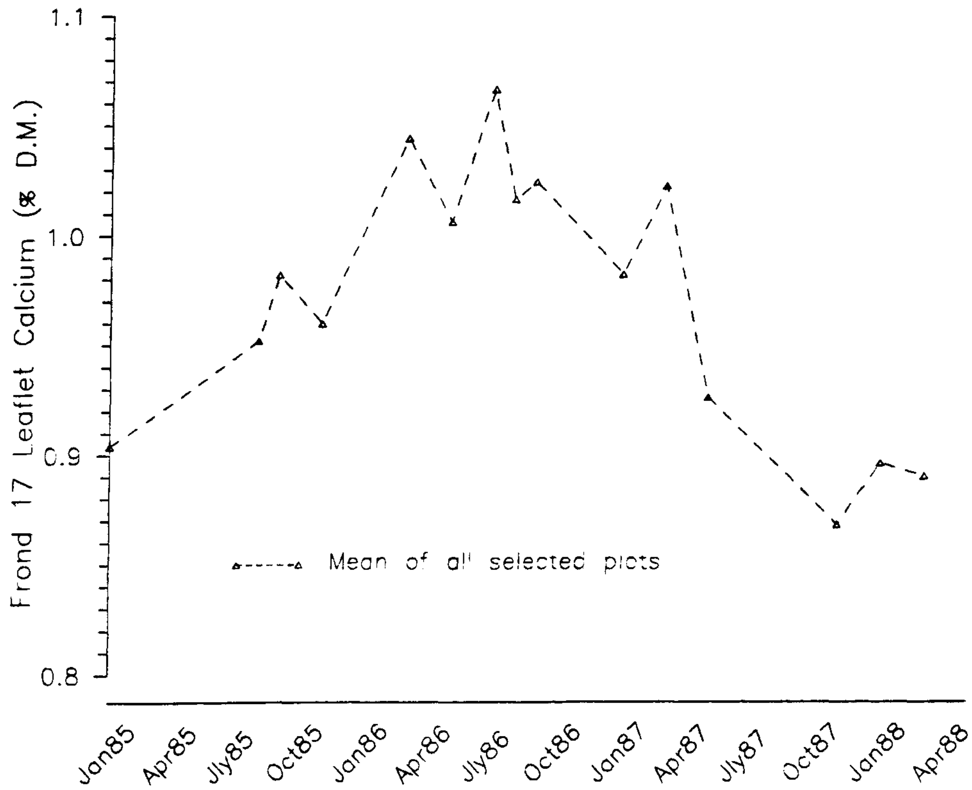


Fig.25 Experiment 201, Frond 17 leaflet base levels, 1985-87.

EXPERIMENT 709, Progeny Trial, Arehe

Planted:	1980
Design:	2 replicates of a 4x4 latin square, with 4 progenies.
Original details:	HOPPL Annual Agronomy Report for 1981
Soil type:	Mainly Higaturu family.

Yield recording of this trial commenced in January 1987, and fruitset studies in November.

Thus only 2 month's data has accumulated so far, and the work has been restricted to a detailed study of every bunch on 10 palms per variety, and also from an additional selection of 7 palms having particularly exposed ("long stalked") bunches. All the long stalked palms are from the Cameroon material.

From the initial results the MSR variety has been identified as having excellent fruitset characteristics, and the long stalked and HBN palms have had significantly poorer fruitset, with the normal African palms having the worst fruitset, at only 63% of the MSR value.

The fruitset varies greatly according to the position of the fruits on the bunch. In the top third, fruitset is good for all varieties, although even here the fruitset on the normal African material is poorer (see Table 72). In all bunches as described in other studies, fruitset diminished from top to base, with the steepest gradient where the fruitset was poorest.

Table 72: Fruitset and palm characteristics, 1987

Treatment	Percentage Fruitset Base	Centre	Top	Overall	Stalk length cm
MSR	74 a	88 a	84 a	81 a	22.1 a
"LONG"	40 bc	74 b	89 a	64 b	24.0 a
HBN	43 b	81 ab	82 a	63 b	17.7 b
CO1	34 cd	59 c	73 b	53 c	23.7 a
CF1	27 d	61 c	75 b	49 c	19.3 b

Note:
Means with different letters differ significantly (P<5%).

In the central area fruitset on the African (but not the Dami) material becomes distinctly poorer. The poorest fruitset is at the base, and variation is the greatest. Basal fruitset is thus the major factor affecting overall fruitset. The Dami material, and particularly the HBN has maintained a significantly superior basal fruitset to the African material.

In order to investigate factors which may be responsible for variations in fruitset, stalk length and sheath weight have been recorded because they could affect accessibility of receptive flowers to pollinating insects.

The palms with the best fruitset: MSR and "long-stalked", both had significantly longer stalks and lower sheath weights. However, the HBN material had a relatively short stalk length, and high sheath weight, but still maintained a better fruitset than African material which had similar or superior sheath and stalk values.

The reason for the poor fruitset of the two Cameroon progenies is not understood. Because apical fruitset was also poor in these bunches, physiological differences in anthesis of scent production are suggested.

These initial results will provide a basis for further study of fruitset throughout this experiment.

As regard to yield by the 4 varieties, there has not been any significant difference (at p=0.05) between the HBN, MSR, and CF1 varieties during 1987. These 3 varieties have all significantly outperformed the CO1 variety, which yielded only 79% as much as the HBN palms. In practice, the yield of MSR at 93% of HBN and CF1 at 91% indicated a yield loss around 2 t/ha.

The Cameroon material is more variable than the Dami material, with a substantial proportion of non-bearing palms, but some excellent material.

For the yield components, CF1 is very similar to MSR for bunch numbers and s.b.w.. HBN also has a similar bunch weight, but a significantly higher bunch production. CO1 has an even higher bunch production, but very low bunch weights, resulting in a poor overall yield.

In regard to growth, Table 73 shows that the HBN palms are the tallest, whilst CF1 and particularly CO1 are shorter.

Table 73: Experiment 709,Yield and vegetative data : 1987

Treatment	No of bunches /ha	Wt of bunches t/ha	s.b.w. kg	Rachis cross sn cm^2	Palm height m
HBN	2329	27.75	11.9	22.9	1.88
MSR	2156	25.89	12.0	23.6	1.78
CF1	2087	25.14	12.0	21.7	1.69
CO1	2596	21.79	8.4	24.3	1.42
$LSD_{.05}$	147	2.62	0.9	2.9	0.14
CV(%)	6	10	8	12	8

ENTOMOLOGY

(R.N.B.P)

Investigation 602 : Pollinators

The entomologist attended the 1987 International Oil Palm Conference in Kuala Lumpur, Malaysia in June where papers were presented on the effects of *Elaeidobius kamerunicus*, other species of *Elaeidobius* and *Mystrops costaricencis* (in Malaysia and South America).

The problem of poor fruit set in parts of P.N.G. was discussed with Dr. R.A. Syed during a post conference session. He is aware of similar situations in Indonesia and from our data he concludes that there should not be a fruit set problem with the density of weevils recorded in P.N.G. Dr. Syed suggested that other factors, such as poor scent production and accessibility to the basal region of the inflorescence could be contributing causes. The situation regarding the introduction of a second pollinator for P.N.G. will be reviewed again next year.

Investigation 603 : *Elaeidobius kamerunicus* : Field studies.

Fruitset

Figs. 26 (i)&(iv) and 27 (i)-(v) contain graphs of average fruitset data collected on a monthly basis from two sites in West New Britain and five sites in Oro Province. Following assessment of last year's recording of fruitset and after carrying out some special weevil studies in February this year, it was decided to revise the recording system. Random fruitset studies were continued at Popondetta at all sites until September and in addition 20 palms were studied intensively in two areas, one at Arehe (1983 planting) and the other a plot adjacent to Ambogo Fertilizer Trial 306. For these palms every bunch is analysed and flower production, or lack of it, in every frond (which are numbered sequentially) is recorded. Bunches were harvested every two weeks in an under-ripe condition, as black bunches, to avoid being harvested accidentally during normal estate harvesting rounds.

Most of the data from these new studies will be presented at a later date. However it is recorded here that very high fruit set fluctuations are occurring from one bunch to the next, differences as high as 200 percent being observed. Typical results from West New Britain Province are shown for Buluma and Hargy 1979 Dami material in Fig. 28 and for Hargy 1973 I.R.H.O. material in Fig. 29. Results from a high yielding block exhibiting below average fruit set, recorded in Ambogo 1979 Dami material in Oro Province, are shown in Fig. 29. Average fluctuations for fruitset in series of bunches from all sites are in the 10-50% range, which if translated into oil yield per bunch represents considerable variation over a very short period of time.

These fluctuations appear to have no direct link with population fluctuations of *E. kamerunicus* (Fig. 26(iii)). The weevil pollination force remained high all year except for January and this did not correlate with an overall depression of fruit set at Buluma in July and August (Fig.26 (i)).

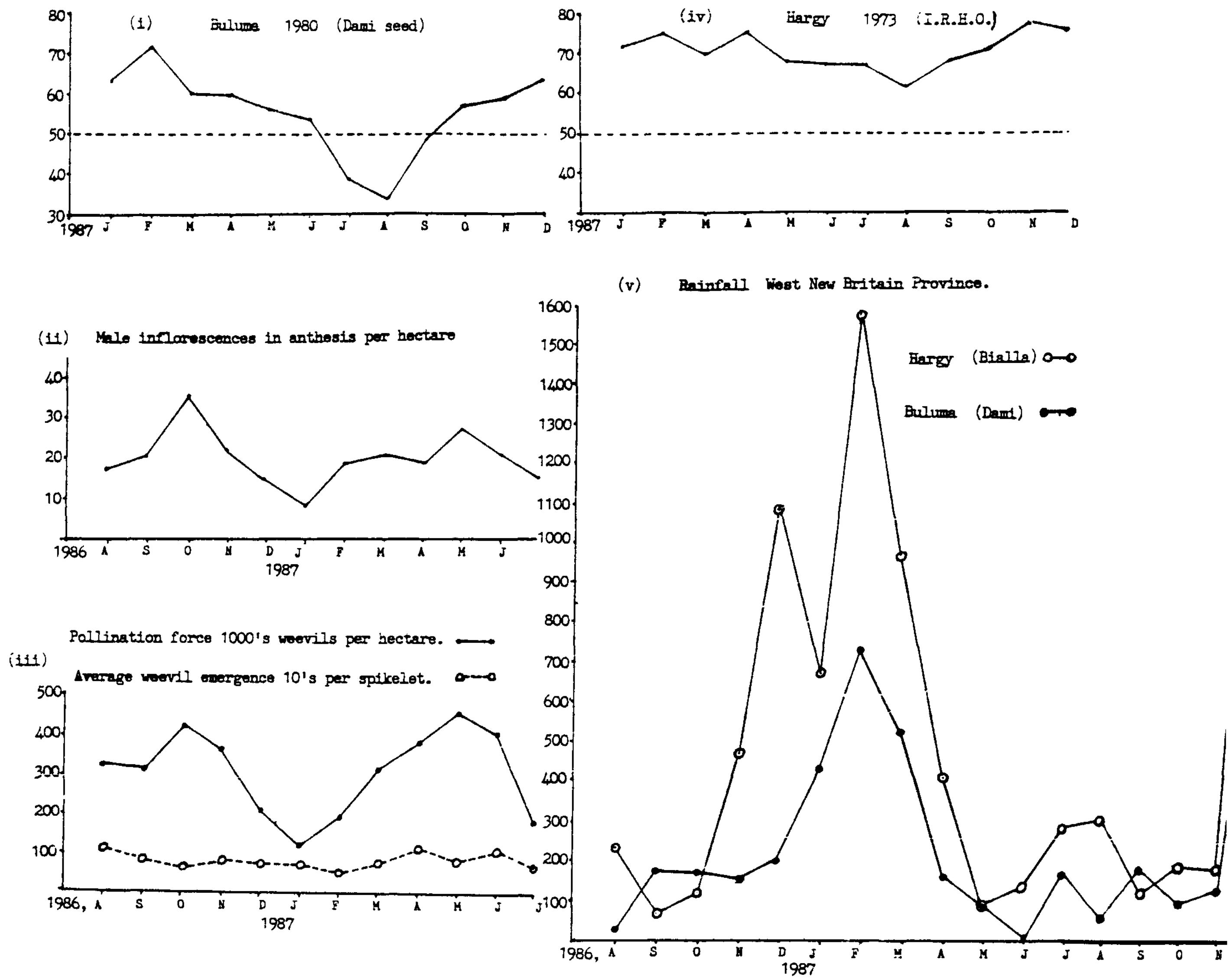


Fig 26(i) - (v) Average percentage fruit set for two sites in West New Britain Provin(male flower and pollinating weevil data and rainfall 1987

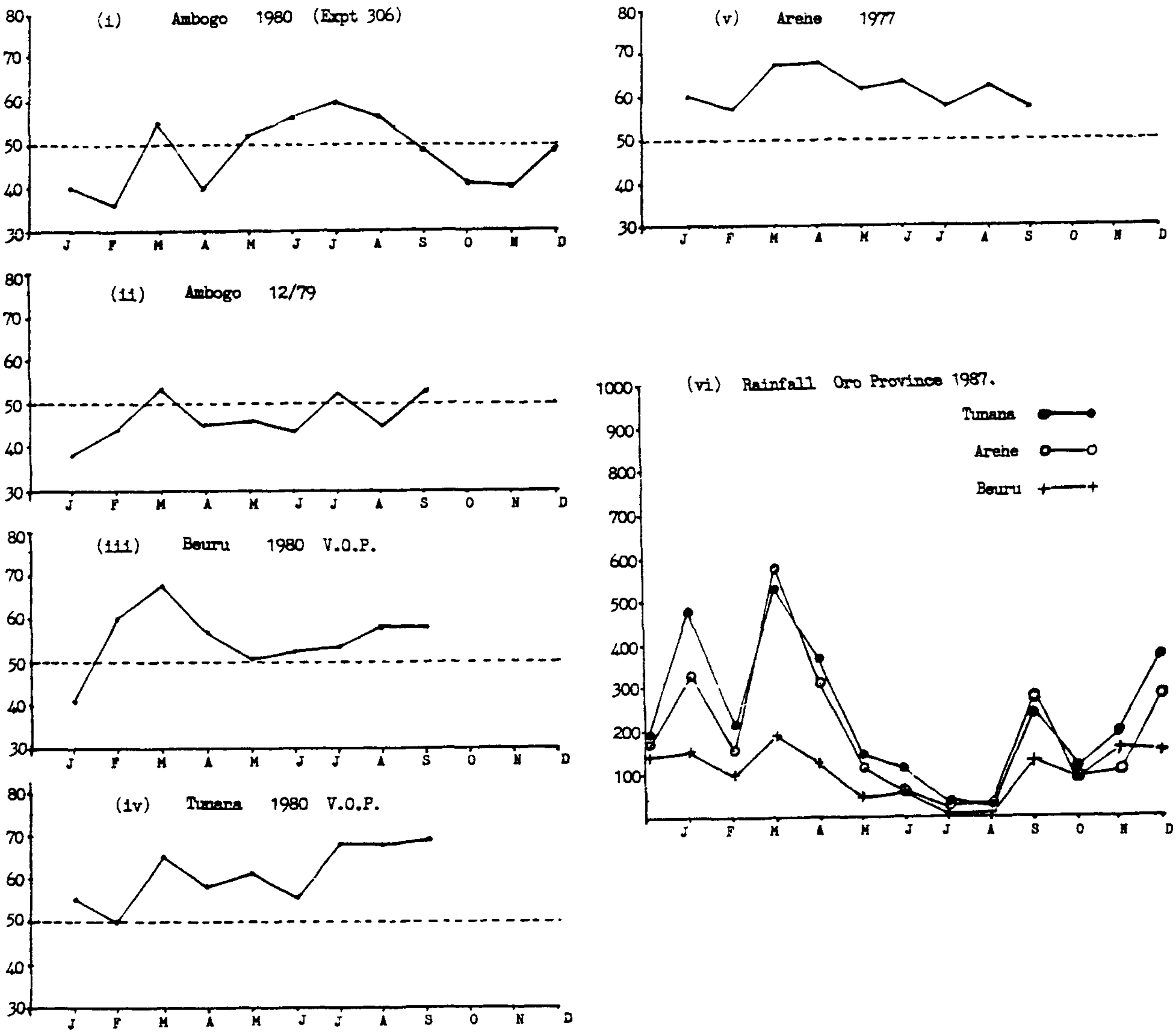


Fig 27 (i) - (vi) Average percentage fruit set for five sites in Oro Province and rainfall 1987

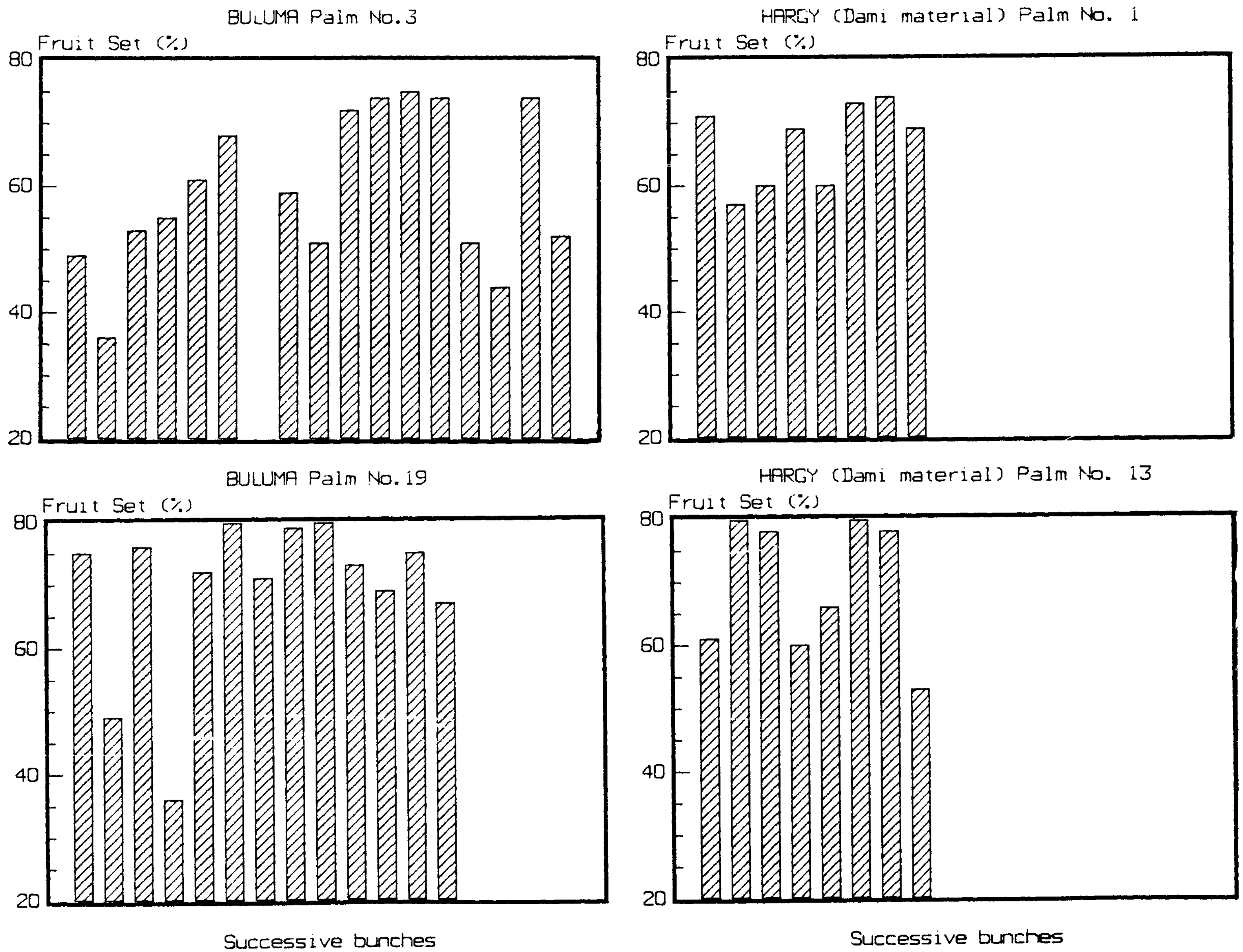


Fig. 28 Fluctuations in percentage fruit set in individual palms at Buluma and Hargy (Dami material).

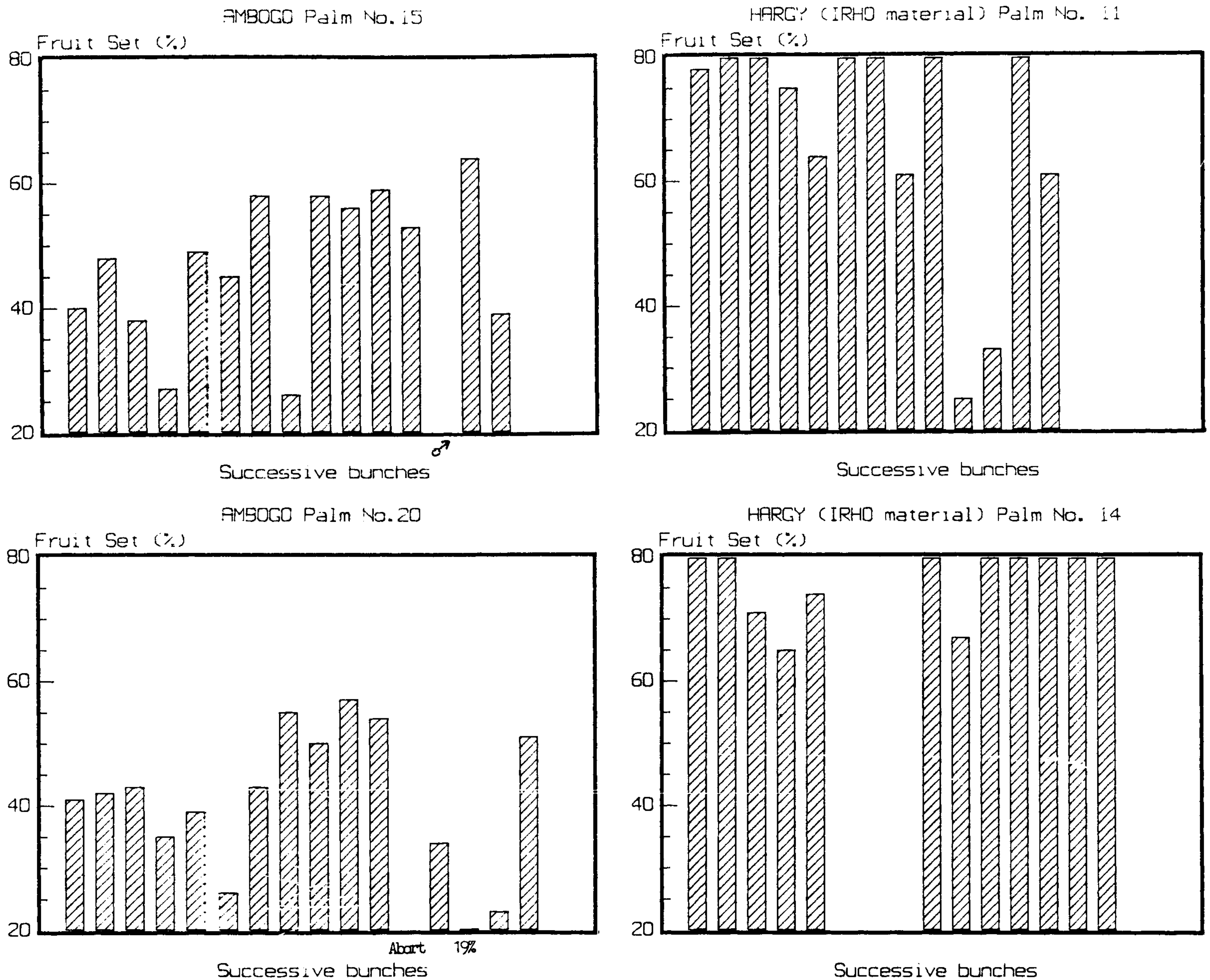


Fig. 29 Fluctuations in percentage fruit set in individual palms at Hargy (IRHO material) and Ambogo.

Trapping weevils arriving at anthesing female inflorescences is carried out by completely covering each inflorescence with a fly-wire cage sprayed with permanently tacky glue from before anthesis until anthesis is completely past. The following data represents the number of weevils trapped while attempting to visit the inflorescence during anthesis and which became stuck to the sticky fly-wire.

At Popondetta Oro Province:- In Ambogo 1979 planting (area adjacent to Expt. 306) results ranged from 752 to 14,659 weevils caught on 8 traps with an average of 9000. In Arehe 1976/77 planting results ranged from 4,250 to 13,003 weevils on 4 traps with an average of 8,750. In Arehe 1979 planting results ranged from 10,007 to 15,006 weevil on 4 traps with an average of 12,500.

In West New Britain Province 20 palm studies have been set up at Buluma (1979 planting) and at Hargy where both the 1973 I.R.H.O. material and Dami material (1979 planting) on the estate are being carefully recorded. On 24/4/87 three sticky traps were set at Buluma where two traps yielded over 30,000 weevils each and one 2278 weevils. There was no obvious reason for this big difference as all three inflorescences were in anthesis at the same time and were only a row or two apart in the block.

From these sets of trap data and the continuing lack of correlation within our other sets of data in the fruitset studies, it is becoming more likely that variation in fruitset is a function controlled by the palm itself. However it remains important to explain the consistently high fruitset at Hargy and the consistently poor fruitset at Popondetta (particularly in Ambogo estate). Until a satisfactory answer is found, yield predictions and forecasts of high yields from super clones may not be very reliable.

Rainfall (Figs 26(v) and 27(vi))

At Dami,in West New Britain Province, the annual rainfall was 3362mm which is 400mm below the average for the past 8 years. However, this was largely due to a record dry period of only 8mm in June, with April, May, August and November recording less than the average rainfall. The deficit was reversed dramatically in December with more than twice the average rainfall with 802mm for the month.

At Hargy (Bialla, West New Britain Province) some of the heaviest rain ever recorded fell during the months of February, March and December resulting in extensive damage and flooding. May was the driest month with 92mm. The total precipitation for Hargy was 6190mm for the year which is believed to be the highest ever recorded for West New Britain.

In Oro Province rainfall was average for the year with a range of 1254mm in the driest oil palm area at Sorovi near Beuru, through 2360mm for Arehe estate and reaching 3062mm in the wettest area recorded at Iseveni, near Tunana.

Investigation 601 : Sexava Chemical Control

The amount of chemical treatment required this year was the lowest since 1977 with the last significant area of smallholders being treated in February at Buvussi settlement W.N.B. Since then no Sexava outbreaks have been recorded up to the year's end in the Hoskins (W.N.B.) scheme. However, on Hargy plantation W.N.B., almost continuous Sexava damage has occurred throughout the year. After damage continued in some treated areas an inspection was carried out and recommendations were made to improve the treatment procedure.

In Oro Province Sexava damage remained low with chemical treatment confined to a few scattered smallholder blocks and a small area on Higaturu, Arehe field 77c.

Investigation 607 : Sexava biocontrol

Mass rearing and release of the two most important Sexava egg parasites *L. biocolor* and *D. leefmansi* continued throughout the year. The cultures would probably not have survived had eggs not been available from Hargy (Bialla), as elsewhere in West New Britain, Sexava was not at collectable levels.

For the twelve month period 1st Jan - 31st December 1987, 245,120 *Leefmansia bicolor*, and 837,500 *Doirania leefmansi* were liberated at the following sites.

Release sites	*L. bicolor*	*D. leefmansi*
Dami Oil Palm Research Station, W.N.B.	74,400	306,250
Kumbango Pltn., Div. I., W.N.B.	58,200	48,000
Tamba Smallholdings, W.N.B.	10,000	-
Bebere Plnt., W.N.B.	11,000	-
Walindi Pltn., W.N.B.	11,000	15,000
Hargy Pltn., Bialla. W.N.B.	173,120	296,250
Higaturu Pltns., Oro Province.	20,800	25,000

Investigation 606 : Bagworm (*Lepidoptera, Psychidae*) control.

Throughout this year no significant bagworm damage has been recorded anywhere in the oil palm developments and no parasites have been collected.

Investigation 605 : Records and observation of other pests.

Rhabdoscelis obscurus Boisd (sugarcane weevil): Damage to unripe black bunches was reported on Bebere, Kumbango and Togulo plantations W.N.B. at the beginning of the year. Confirmation was obtained on a few bunches but many others were simply over-ripe and left from a previous harvest. In the third quarter this weevil was observed damaging and pupating in the cut frond bases on seedlings still in the polybags. Whilst larval damage to cut fronds on mature palms is not new, development and pupation on seedling oil palms has not been recorded previously. As with the damage to frond bases on mature palms the larval tunnels appear to be superfical and not of economic significance. However it is noteworthy that *Rhabdoscelis* has a history as a serious pest of other crops, notably sugarcane, and its incidence on coconuts can sometimes cause serious damage. Its appearance on oil palm, as an introduced crop, is comparatively recent and its progress as a pest of oil palms should be closely followed.

In Oro Province Stick insects (*Phasmidae*), which appeared to be parasitised by a Tachinid, were reported by the entomology technician in January. On a subsequent visit this was confirmed by the entomologist but todate no adult flies have emerged from the puparia obtained. Whether this tachinid is the same species that is infecting Sexava cannot be confirmed but it would be useful to have an alternative host for the parasite.

Also in Oro Province rat damage was recorded on Arehe plantation to both black bunches and male flowers. No treatment was recommended. In W.N.B. on Kapiura plantation rat-damage to young palms continues in the new plantings and rat baits are being employed to reduce the damage.

Investigation 608 : Scapanes control.

The two areas on Bebere plantation W.N.B., selected for observation of *Scapanes* damage to young underplanted palms, were set up in December 1987. Unfortunately the control plot where the old palms were to be felled was not comparable due to a delay in planting the young palms. It was several months after felling that the palms were planted and by that time vigorous Pueraria growth had covered most of the felled palms, thereby reducing the attractiveness of this plot to *Scapanes*. Not a single case of *Scapanes* damage has been recorded to these 1170 palms in the twelve month period under investigation.

On the other observation plot of 1120 underplanted palms where the mature palms were left standing after poisoning, the results are as follows:- For the six month period 11/12/86 - 11/6/87 a total of 18 palms (1.6 percent) were killed by *Scapanes*, which is within the normally accepted range of 1-2 percent in areas susceptible to *Scapanes* damage. However the total number of palms attacked by *Scapanes* in the same period was 68 (6 percent) and of these 4.4 percent recovered from the initial attack. Additional information from these plots was that at the time of the first survey (Dec 86) - 32 palms had been recently attacked, whilst 17 were recovering from attacks prior to the survey. The next month (January) 25 new attacks were recorded. Subsequently 2 attacks in February; 8 in March; none in April; 1 in May; and none in June. No new attacks were recorded during the rest of the year. In November some palms on the underplanted plot were damaged by spear rot and recovered during December with the production of new spears. None of these spear rot affected palms had been damaged by *Scapanes*.

PATHOLOGY

Investigation 801, Incidence of *Ganoderma* disease

This experiment, designed to investigate the danger of *Ganoderma* disease after replanting, was set up in 1982 at Bebere plantation at two separate sites. At each site three replicates of six treatments, comparing different methods of felling palms, are being tested. The six felling methods were:

1. Palms poisoned and left standing
2. Palms poisoned and subsequently felled at 1 metre
3. Palms poisoned and subsequently felled at 30cm
4. Palms not poisoned and felled at 1 metre
5. Palms not poisoned and felled at 30 cm
6. Palms excavated

After the treatment plots had been thinned by one seventh by the above methods, three seedlings were planted within 1 metre of each stump. At regular intervals since 1984 the seedlings have been uprooted, split and the root and stem tissues examined for any signs of infection.

In Section 20 of Bebere, the last remaining seedlings were removed and split during 1987. As in preceding years no sign of any invasion by *Ganoderma* was observed despite the development of *Ganoderma* sporophores on the stumps. In Section 9 of Bebere, one seedling per stump remains and these will be dug up and inspected prior to replanting in 1988/89.

Investigation 803, *Ganoderma* spp. tests of pathogenicity

In this experiment various methods are being used to test the pathogenicity of *Ganoderma* species. Initially direct inoculation into the roots and stem of standing palms was carried out which produced no signs of any infection after several years. In the main experiment, established in the Dami beach area, infected palm wood was placed at the base of young field palms. After four years, no visual signs of any infection by *Ganoderma* species have been observed. These palms will continue to be monitored for several more years.

PUBLICATIONS

Van Heel, W.A., Breure, C.J. and Menendez, T. (1987). The early development of inflorescences and flowers of the oil palm (*Elais guinensis*,Jacq) seen through the scanning electron microscope. Blumea 32, 67-78.

Menendez, T. (1987). The results of thinning oil palm in West New Britain. Proc. 1987 Int. Oil Palm Conference, Kuala Lumpur.

Prior, R.N.B. (1987). Insect pests of oil palm in Papua New Guinea and their control. Proc. 1987 Int. Oil Palm Conference, Kuala Lumpur.

APPENDIX I

METEOROLOGICAL DATA

Table 74 : Rainfall (mm) all sites 1987

	Jan	Feb	March	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
W.N.B. PROVINCE													
Dami	430	725	537	159	92	8	157	53	181	96	122	803	3363
Bebere	529	1163	494	145	29	3	168	36	154	139	108	884	3852
Kumbango	552	947	538	122	84	2	210	53	120	114	132	950	3824
Hargy	671	1573	427	413	92	63	140	309	127	180	177	1252	5424
Navo	1563	1429	471	288	224	34	133	72	317	272	214	1107	6124
ORO PROVINCE													
Arehe	327	157	586	307	114	61	34	23	276	96	103	277	2361
Ambogo	323	162	503	258	91	62	16	11	200	109	170	242	2147
Isavene	517	220	445	252	88	68	53	29	266	79	188	322	2527
MILNE BAY PROVINCE													
Hagita	126	237	174	222	165	28	168	45	115	25	97	335	1737

Table: 75 Meteorological Data, Dami, 1987

	Rainfall mm		Rainy days		Sunshine (h/m)	
	1970-87	1987	1970-87	1987	1970-87	1987
January	632.2	429.6	24.5	26	116.5	124.0
February	646.8	724.8	24.0	27	112.0	39.3
March	536.6	537.0	25.3	28	122.2	129.7
April	352.3	159.0	21.2	17	150.2	156.2
May	229.7	92.0	17.8	12	168.0	177.8
June	153.2	7.6	15.9	4	162.2	176.6
July	179.5	157.0	15.5	13	152.7	125.3
August	144.5	53.0	14.8	9	179.4	190.5
September	178.3	181.4	13.8	15	181.0	175.2
October	160.0	95.6	14.9	10	181.0	139.6
November	247.1	122.4	17.6	15	177.0	192.8
December	387.8	802.6	22.6	27	129.2	84.8
Total	3848.0	3362.0	227.9	203	1831.4	1711.8

Table 76 : Meteorological Data, Higaturu 1987

	Rainfall mm			Sunshine hrs			Rainy days		
	1986	1987	1981-87	1986	1987	1981-87	1986	1987	1981-87
January	203	327	238	101	172	160	17	23	18
February	315	157	263	145	99	121	20	21	20
March	148	586	364	171	174	164	10	25	20
April	435	307	256	174	153	169	22	24	19
May	134	114	186	222	216	174	11	11	15
June	225	61	167	134	161	142	19	11	16
July	64	34	66	184	203	165	10	5	9
August	180	23	116	187	200	178	13	10	14
September	44	276	148	197	136	172	6	16	13
October	122	96	216	180	225	183	19	12	17
November	306	103	239	169	223	187	18	12	16
December	184	277	307	191	146	155	18	23	20
Total	2360	2361	2566	2055	2108	1970	183	193	197

Table 77 : Rainfall (mm), Hargy 1987

	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
1986	527	698	350	1266	620	239	323	243	60	108	474	1083	5991
1987	671	1573	427	413	92	63	140	309	127	180	177	1252	5424
1981-87	548	765	685	472	411	221	325	282	204	229	368	927	5437

APPENDIX II

THE ASSOCIATION'S ACCOUNTS FOR 1987

Auditor's Report to the members of Papua New Guinea Oil Palm Research Association Inc.

In our opinion the attached balance sheet, income and expenditure account and accompanying notes thereon as set out are drawn up so as to give a true and fair view of the state of affairs of the Association as at 31 December 1987 and of its income and expenditure for the period ended on that date.

Price Waterhouse
Chartered Accountants
Lae, 24th March 1988

Balance sheet as at 31st December, 1987

	KINA 1987	KINA 1986
Accumulated funds		
	159,322	179,533
Represented by:		
FIXED ASSETS (Note 2).....................	49,498	45,884
CURRENT ASSETS:		
Cash at bank and on hand..................	91,652	149,330
Debtors...................................	110,992	78,652
	202,644	227,982
CURRENT LIABILITIES:		
Trade Creditors..........................	78,352	39,007
Other Creditors and Accruals.............	14,458	55,326
	92,810	94,333
Net Current Assets/......................	109,834	133,649
	159,332	179,533

Statement of Income and Expenditure for the year ended 31st December 1987

	KINA	
INCOME:	1987	1986
FFB Levy................................	379,527	447,462
Profit on Disposal of Fixed Assets.......	1,499	2,700
Interest received.......................	15,895	5,458
Government grant received...............	93,300	116,000
	490,221	571,620
EXPENDITURE;		
Agency, Audit, Legal and Professional fees	14,057	17,819
Bank charges............................	1,309	1,379
Depreciation............................	13,915	21,514
Direct experiment costs.................	57,936	99,601
Electricity, water and gas..............	15,376	19,951
Insurance...............................	8,305	5,875
Laboratory..............................	504	620
Medical.................................	4,908	2,664
Motor vehicle...........................	33,705	20,271
Office expenses.........................	14,411	11,579
Rentals and other accommodation costs....	73,951	51,045
Repairs and Maintenance - buildings......	20,413	13,869
Salaries, wages and allowances...........	211,235	186,654
Staff recruitment.......................	10,440	-
Staff training..........................	6,484	3,082
Travel and entertainment................	23,473	11,192
	510,422	467,115
(DEFICIT)/SURPLUS FOR THE YEAR	(20,201)	104,505
ACCUMULATED FUNDS BROUGHT FORWARD	179,533	75,028
ACCUMULATED FUNDS CARRIED FORWARD	159,332	179,533

31 December 1987

STATEMENT OF ACCOUNTING POLICIES

Basis of Accounting: The accounts have been prepared on the basis of historical costs and do not take into account changing money values or current valuations of non-current assets.

Fixed assets and depreciation: Fixed assets are recorded at cost. Depreciation is calculated by the straight line method at rates considered adequate to write off the assets over their estimated economic lives.

Current rates of depreciation are as follows:-
Furniture & equipment 10% per annum
Motor vehicles 33.33% per annum

Direct experiment costs: Costs in relation to experiments are written off as direct experiment costs in the year they are incurred.

FIXED ASSETS

	KINA	
	1987	1986
Household, office and laboratory, furniture and equipment at cost.........	47,039	44,550
Less accumulated depreciation...........	19,955	15,455
	27,084	29,095
Motor vehicles at cost...................	59,691	54,330
Less accumulated depreciation...........	37,277	37,541
	22,414	16,789
Total written down values...............	49,498	45,884

CAPITAL COMMITMENT

Capital expenditure authorised and contracted for totalled : K Nil (1986 K8,900).

MANAGEMENT BOARD'S STATEMENT 31 DECEMBER 1987

We, F.E. McGuire and J.R. Gilbert, being two of the members of the Management Board of the Papua New Guinea Oil Palm Research Association Inc., hereby state that in our opinion the accompanying balance sheet is drawn up so as to exhibit a true and fair view of the state of affairs of the Association at 31 December 1987 and the statement of income and expenditure is drawn up so as to give a true and fair view of the results of the business of the Association for the period ended on that date.

For and on behalf of the Board

F.E. McGuire

J.R. GILBERT

Lae
24th March 1988

SECRETARY'S STATEMENT

I, Alfred Ross McMaster, Secretary of the Papua New Guinea Oil Palm Research Association Inc., do hereby state that the accompanying balance sheet and statement of income and expenditure are, to the best of my knowledge drawn up so as to exhibit a true and fair view of the state of affairs of the Association as at 31 December 1987 and of the results for the period ended on that date.

A.R. McMASTER
SECRETARY

Lae,
24th March 1988

APPENDIX III

ALLOCATION OF RENTED BUILDINGS

NEW BRITAIN PALM OIL DEVELOPMENT LTD.

Offices and laboratory (7 rooms)	1
Entomological building	1
Store (4 rooms)	1
"M"houses	1
"A" houses	3
"AR" houses	1
"IB" houses	3
"JG" houses	7
"DLQ" houses	2
"SMQ" houses	1

HARGY OIL PALMS PTY LTD.

Office	1
Bossboi quarters	1

HIGATURU OIL PALMS PTY LTD.

Agronomy and main office	1
Entomological office	1
Insectory	1
Executive duplex	1
Sirogo house	1
Supervisor's houses	2
Intermediate	1
Labour houses	3

APPENDIX IV

ALLOCATION OF VEHICLES

Vehicle	Reg.No.	User	Purchased	Km run
Toyota Hilux 4WD(twin)	AEJ 558	D.O.R.	11/83	67,880
Toyota Hilux 4WD(single)	AEQ 283	Higaturu	3/85	124,958
Toyota Hilux 4WD(single)	AFF 235	Soils Agron.	8/87	5,015
Toyota Hilux 2WD(single)	AEJ 601	Entomologist	12/83	105,696
Daihatsu Delta	AHA 967	Driver(Dami)	2/86	(N.R.)
Daihatsu Scamp 4WD	AKA 951	Asst. Agron.	1/86	44,746

(N.R. = Not recorded)

APPENDIX V
LIST OF ONGOING INVESTIGATIONS

Number	Location	Title	Initiated
AGRONOMY			
102	Dami	Density/fertilizer trial	1970
106	Bebere	Replanting establishment trial	1982
107	Bebere	Replanting fertilizer trial	1982
108	Kumbango	Mature palm nitrogen/anion systematic trial	1985
109a	Bebere	Factory-waste manurial trial	1984
109b	Bebere	Factory-waste manurial trial	1985
110	Bebere	Nitrogen/anion trial on young replanted palms	1985
111	Malilimi	Fertilizer experiment on young palms	1985
112	Buvussi	Nitrogen & phosphate fertilizer trial	1985
113	(Various)	Smallholders' nitrogen fertilizer and food cropping demonstrations on replanted palms	1985
115	Kumbango	Frond placement trial	1987
116	Bebere	Systematic nitrogen fertilizer trial	1987
117	Kumbango	Second systematic nitrogen fertilizer trial	1987
118	Kumbango	Third systematic nitrogen fertilizer trial	1987
201	Hargy	Fertilizer trial	1982
202	Hargy	Refuse manurial trial	1984
203	Navo	Effect of establishment phosphate	1986
305	Arehe	Fertilizer factorial experiment	1981
306	Ambogo	Fertilizer factorial experiment	1983
308	Arehe	Mill effluent manurial trial	1985
309	Ambogo	Bunch refuse manurial trial	1984
310	Ambogo	Fertilizer frequency and anion trial	1986
501	Hagita	Establishment fertilizer trial	1986
503	Hagita	Nursery fertilizer trial	1987
ENTOMOLOGY			
601		Sexava: chemical control	1981
602		Pollinators: introductions	1980
603		Pollinators: field studies	1981
604		Sexava: field studies	1981
605		Other pests: general studies	1981
606		Bagworms: general studies	1982
607	Bebere	Sexava: biological control	1983
608		Rhinoceros beetles	1986
PHYSIOLOGY			
705	Arehe	Clone and density trial	1986
706		Continuous flowering censuses	1981
707		Continuous vegetative growth study	1980
708		Continuous leaf nutrient study	1981
709	Arehe	Progeny experiment	1987
PATHOLOGY			
801	Bebere	Incidence of Ganoderma disease	1982
803	Dami	Ganoderma spp. tests of pathogenicity	1983