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INTERNATIONAL SOCIETY OF SOIL SCIENCE CONFERENCE

15TH - 20TH AUGUST 1977

KUALA LUMPUR

PLANTATION CROPS AND SOIL MANAGEMENT

UNITED PLANTATIONS BERHAD
(Incorporated in the States of Malaya)

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Teluk Anson, 24th May 1977
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Mr. Chan Heun Yin,
The Secretary,
CLAMATROPS,
c/o Soils and Crop Management Division,
Rubber Research Institute of Malaysia,
P.O. Box 150,
KUALA LUMPUR.

Dear Sir,

Conference on 'Classification and Management of Tropical Soils' Kuala Lumpur

We have pleasure in submitting our paper titled 'Response of Cocoa under Coconuts to Fertilisers on Coastal Clays in Peninsular Malaysia' by Ng Siew Kee and Edward Chan for the above conference.

Regards.

Yours faithfully,
UNITED PLANTATIONS BERHAD
RESEARCH DEPT.,

Edward Chan
SENIOR RESEARCH OFFICER

Cag - 565/77.

INTRODUCTION

Cocoa is fast becoming the third-most important export orientated crop after rubber and oil palms in Malaysia. The majority of the plantings so far, in Peninsular Malaysia has been under existing coconut stands on the coastal clays along the west coast. With over 180,000 hectares of coconuts in West and East Malaysia suitable for underplanting cocoa (Hassan, 1976), the expansion of cocoa acreage in this country will continue to be concentrated in this area.

This intensification of land utilisation will lead to a more rapid removal of soil nutrients, which unless replenished adequately, would limit productivity of the dual cropping system.

Being a relatively new commercial crop, little information on cocoa manuring is available in Malaysia, and much less of it in combination with coconuts. Ng (1968) has mentioned the problem of manuring such a mixed planting due to the differential requirements for nutrients of the two crops. This aspect of nutrition will assume increasing importance with the widespread planting of the high yielding MAWA hybrid coconut in place of the local tall variety. More information is clearly needed to ensure an efficient use of fertilisers and maximum returns from a mixed cocoa-coconut planting.

This paper presents the results from three trials sited on coastal clays on an estate in the Lower Perak district.

EXPERIMENTAL

The 2^4 NPKCa trial (Experiment 1) was initiated in July 1971, on 3-year old cocoa under 40-year old tall coconuts growing on Kangkong series soil. The cocoa was planted at 741 trees/ha. A basal application of N equal to 25% of the N1 level was given to the N0 plots in early 1975 to alleviate the miserable condition of the trees. In the year prior to the trial's commencement, 37 kg. ammonium sulphate, 22 kg. C.I.R.P., 15 kg. muriate of potash and 225 kg. limestone per ha. were applied to the cocoa. The tall coconuts have received no fertilisers for the past 30 years.

The 3^2x 2 NKP trial (Experiment 2) commenced in April 1973 on 7-year old cocoa under 35-year old dwarf coconuts grown on Selangor series soil. The original cocoa density was 840 trees/ha. but was thinned to 630 trees/ha. prior to treatment. Fertilisers applied in 1972 to the cocoa were 193 kg. ammonium nitrate, 86 kg. C.I.R.P., 150 kg. muriate of potash and 225 kg. limestone per ha. The dwarf palms received 1 kg. muriate of potash and 0.5 kg. limestone per palm.

The sources of N trial (Experiment 3) commenced in April 1973 on 5-year old cocoa under 50 year old tall coconuts on Kangkong series soil.

The planting material used in all three trials consisted of locally selected open pollinated (F2) crosses of Upper Amazon origin.

The fertiliser rates in each of the trial are summarised in Table 1. The nitrogenous fertilisers were split into two applications per annum i.e. in March/April and in September/October, while the other fertilisers were applied in a single application in March/April. In the case of urea in Experiment 3, the leaf litter was vigorously disturbed immediately after application to ensure that the fertiliser came into contact with the moist soil surface. The other fertilisers were applied onto the leaf litter.

Pod production of individual trees was recorded and analyses of the pod components were carried out twice a year. Stem diameter measurements were carried out annually. Leaf samples (4th leaf) were collected from recently matured flushes for chemical analysis once a year prior to the application of fertilisers in March/April.

RESULTS

Canopy Growth

Nitrogen deficiency symptoms appeared in the trees ot receiving N within a year of the last application. A eneral yellowing of the foliage is followed by a decrease in he size as well as numbers of leaves on the trees, resulting n sparse canopies. Dieback of twigs was common. Under the avier shade found in Experiment 3, the symptoms are less arked.

Yield and Leaf Analysis

Experiment 1

N significantly increased the pod yield of individual trees by an average of 42% over a 5-year period. The response was significant in the first year itself (Table 2). The difference between the N1 and NO treatments narrowed to only 25% in 1975/76 and this can be attributed to the basal N applied in early 1975. A smaller but significant response was recorded for two years only in 1972/73 and 1973/74, to limestone applied in 1971 and 1972. Leaf Ca, however, remained significantly higher in the limed plots (Table 3). Liming also improved the girthing of the trees.

None of the treatments had any effect on the pod size, bean size or the pod value.

Applications of ammonium nitrate, C.I.R.P. and muriate of potash have resulted in higher leaf levels of N, P and K respectively (Table 3). Leaf P was significantly depressed by N application and this could be a dilution effect, as apart from yield, the vegetative growth was also much greater as a result of N application. In fact, leaf K was also significantly lower in the presence of N. Leaf Mg was depressed by ammonium nitrate and muriate of potash applications in 1975 and 1976. Leaf Ca was raised by C.I.R.P. in 1975 but depressed by muriate of potash in 1974, 1975 and 1976.

Experiment 2:

A significant increase in pod yield per tree was recorded, again, only to N applications. Over a 4-year period, the mean advantage with N was 24% and 34% for the N_1 and N_2 treatments, respectively (Table 4). The quadratic component of the response was highly significant, indicating a falling off in response at the higher level of N.

Ammonium nitrate and C.I.R.P. applications have resulted in higher N and P status respectively, in the leaves. Ammonium nitrate also depressed the leaf Mg and P levels, but not that of K. The detailed leaf analysis results are given in Table 5.

Experiment 3:

All three sources of N tested significantly increased the pod yield per tree over control by an average of 37%. The differences between the three sources were not significant (Table 6). The N status of the leaves was generally improved by the treatments (Table 7). As expected leaf P was significantly lower compared to the control.

Soil Analysis

The analysis results are given in Appendix 1. The treatment effects on the soil are summarised thus:

Liming raised the soil pH (Appendix 1a). Two years after the treatment was effected, the pH was 6.2 in the top 7.5 cm. of soil and 5.3 in the 7.5-30 cm. layer. The corresponding pH for the unlimed soil was 5.4 and 4.8 respectively.

Of the N fertilisers in Experiment 3, ammonium sulphate had the greatest acidifying effect on the soil pH, lowering it to 4.5 in the 0-15 cm. layer (Appendix 1b). The pH was only slightly affected by the other two N sources. All three N sources, however, decreased the exchangeable Ca and Mg with ammonium sulphate having the largest effect. In addition, ammonium sulphate increased the available P. In Experiment 2, exchangeable Mg was decreased by the treatments (Appendix 1c). Weir (1974) in Jamaica, found similar effects of ammonium sulphate on the soil pH and exchangeable Ca and Mg.

Pretreatment P status of the soils are generally high with available P values above 40 ppm. C.I.R.P. applications increased both the total and available forms of P in Experiments 1 and 2. Muriate of potash increased the already high levels of total and exchangeable K (Appendix 1a and 1c).

DISCUSSION

The results obtained so far on the two major coastal soils indicate nitrogen to be the main nutrient necessary to sustain the high yields of cocoa. The importance of N can be gauged by the fact that a yield response was obvious at the end of the first year of treatment. In all cases, yellowing of the foliage and reduction in leaf area were the first indications of nitrogen hunger. The shade regime, however, affects the magnitude of response to N (Murray, 1954). Dwarfs, generally, provide more topshade than tall coconuts, and this may be partly responsible for the smaller response recorded in Experiment 2.

The beneficial effects of liming is in accordance with the early observation on calcium requirement of cocoa on coastal clays (Ng, 1968). The better girthing of the cocoa in the early mature years also points to the importance of liming in soil amelioration during the immaturity period. Mainstone et al (1973) reported similar beneficial effects on immature cocoa on an inland soil.

The absence of a response to K application even after 5 years reflects the inherently high K status of these soils (Ng, 1965). The lower limit of exchangeable K necessary to support normal growth of cocoa has been reported as 0.2 me/100 g. soil (Hardy, 1958; Smyth, 1966). The exchangeable K in the topsoil here is still well above 0.5 me. but it is interesting to note that in Experiment 3, the exchangeable K in the control plot was 0.72 me. - down from a pretreatment level of 1.1 me/100 g. soil. This would indicate a gradual decline in available K supply and the need for potash application in due course.

The available P levels of these soils are above 30 ppm. - well above the 10 ppm. level below which a high response to applied P can be expected (Egbe & Omotoso, 1972). Mainstone et al (1973) obtained growth responses to applied P on an inland soil where the available P was between 5-9 ppm.

The result with urea in comparison with ammonium nitrate and sulphate on coastal clays is in agreement with findings of Pusparajah (1964) for rubber. It is however necessary to disturb the leaf litter following urea application in order to reduce volatilisation losses as Watson et al (1962) had shown that up to 18% of N can be lost as ammonia when urea is applied to rubber leaf litter. In view of its being the cheapest source of N on the one hand and its high N content on the other, use of urea would incur savings both in material as well as labour costs.

It is interesting to compare the leaf analysis data obtained in these experiments with the limits given by Murray (1968). Where significant responses to N were obtained, the leaf N levels of controls ranged from 1.60-1.80% which agrees well with the deficient value of 1.80% set by Murray. However, with calcium, our data points to a higher critical value of 0.5%

which is appreciably higher than Murray's limit of 0.3%, whereas for P, most of the values recorded in these experiments fall into his 'low' range of 0.13-0.20. As for K and Mg, our values are well above his deficient limits.

ACKNOWLEDGEMENTS

The authors wish to thank the Manager, Kuala Bernam Estate on whose estate the trials are sited, and Messrs. United Plantations Berhad for permission to present this paper.

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Title : Response of Cocoa under Coconuts to Fertilisers on Coastal Clays in Peninsular Malaysia.

Running Title : Response of Cocoa to Fertilisers on Coastal Clays.

Table 3 : Expt. 1. Leaf (No. 4) Analysis Results (% dm.)

Treatment	February 1973					April 1974					January 1975					March 1976				
	N	P	K	Mg	Ca	N	P	K	Mg	Ca	N	P	K	Mg	Ca	N	P	K	Mg	Ca
N_0	1.56	0.164	1.249	0.542	0.606	1.81	0.182	1.620	0.676	0.746	1.65	0.203	1.722	0.571	0.692	1.88	0.169	1.675	0.608	0.496
N_1	1.58	0.140	1.161	0.547	0.638	1.85	0.154	1.557	0.674	0.761	1.79	0.163	1.641	0.529	0.705	2.02	0.142	1.608	0.586	0.509
Var. Test	ns	22.31**	ns	ns	ns	ns	57.83**	4.90*	ns	ns	32.9**	176.7**	10.22**	14.80**	ns	27.4**	106.2**	6.30*	5.15*	ns
P_0	1.56	0.141	1.195	0.546	0.605	1.83	0.153	1.577	0.677	0.731	1.71	0.168	1.687	0.555	0.691	1.97	0.147	1.677	0.587	0.476
P_1	1.58	0.163	1.215	0.543	0.638	1.83	0.182	1.600	0.673	0.776	1.73	0.198	1.675	0.545	0.706	1.93	0.163	1.607	0.606	0.529
Var. Test	ns	18.16**	ns	ns	ns	ns	65.34**	ns	ns	ns	ns	93.71**	ns	ns	ns	ns	39.86**	6.95*	4.06*	9.70**
K_0	1.56	0.154	1.177	0.546	0.643	1.83	0.173	1.502	0.700	0.794	1.71	0.183	1.557	0.575	0.748	1.95	0.157	1.560	0.609	0.519
K_1	1.58	0.151	1.233	0.543	0.601	1.82	0.162	1.674	0.650	0.719	1.73	0.183	1.805	0.525	0.649	1.95	0.153	1.724	0.585	0.486
Var. Test	ns	ns	ns	ns	4.56*	ns	9.36**	36.03**	ns	9.34**	ns	ns	96.51**	21.10**	19.25**	ns	ns	38.12**	6.39*	ns
CaO	1.54	0.147	1.205	0.559	0.543	1.84	0.167	1.579	0.668	0.670	1.73	0.187	1.699	0.556	0.605	1.96	0.156	1.639	0.610	0.448
Ca1	1.60	0.158	1.205	0.531	0.702	1.82	0.169	1.598	0.661	0.837	1.71	0.179	1.663	0.544	0.792	1.94	0.154	1.644	0.584	0.558
Var. Test	ns	4.72*	ns	ns	67.40**	ns	ns	ns	ns	39.64**	ns	6.59*	ns	ns	67.75**	ns	ns	ns	7.51**	41.91**

* Significant at 5%
** Significant at 1%.

Table 5 : Expt. 2. Leaf (No. 4) Analysis Results (% d.m.)

Treatment	March 1973 (Pretreatment) N	P	K	Mg	Ca	March 1974 N	P	K	Mg	Ca	January 1975 N	P	K	Mg	Ca	March 1976 N	P	K	Mg	Ca
N_0	1.78	0.177	1.969	0.537	0.524	1.81	0.191	2.046	0.557	0.451	1.84	0.200	2.148	0.566	0.542	1.94	0.187	2.085	0.534	0.392
N_1	1.78	0.171	1.952	0.536	0.537	1.86	0.173	2.091	0.519	0.449	1.91	0.159	2.066	0.525	0.556	1.99	0.148	2.027	0.503	0.420
N_2	1.80	0.171	1.903	0.536	0.517	1.93	0.159	2.063	0.479	0.399	2.04	0.147	2.105	0.497	0.531	2.21	0.142	2.011	0.466	0.367
Var. Test	ns	ns	ns	ns	ns	** 10.98	** 52.38	ns	** 13.70	** 6.71	** 12.74	** 77.53	ns	** 10.02	ns	** 59.68	** 67.23	ns	** 11.12	ns
K_0	1.78	0.169	1.954	0.520	0.512	1.86	0.173	2.652	0.519	0.443	1.95	0.167	2.033	0.530	0.549	2.04	0.153	1.978	0.509	0.411
K_1	1.79	0.175	1.989	0.536	0.527	1.84	0.174	2.055	0.512	0.447	1.91	0.173	2.167	0.536	0.552	2.05	0.157	2.075	0.501	0.373
K_2	1.79	0.175	1.881	0.554	0.539	1.90	0.175	2.093	0.524	0.409	1.93	0.167	2.119	0.522	0.528	2.05	0.161	2.071	0.494	0.397
Var. Test	ns	ns	ns	ns	ns	ns	ns	ns	ns	* 3.50	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
P_0	1.78	0.172	1.920	0.541	0.537	1.86	0.170	2.063	0.524	0.437	1.91	0.166	2.114	0.534	0.529	2.05	0.154	2.046	0.493	0.387
P_1	1.80	0.174	1.963	0.532	0.515	1.87	0.178	2.070	0.513	0.429	1.95	0.172	2.099	0.524	0.557	2.04	0.164	2.036	0.509	0.399
Var. Test	ns	ns	ns	ns	ns	ns	** 9.53	ns	ns	ns	ns	ns	ns	ns	ns	ns	** 8.74	ns	ns	ns

* Significant at 5%
** Significant at 1%.

Table 7 : Expt. 3. Leaf (No. 4) Analysis Results (% d.m.)

Treatment	1973 (Pretreatment)					1974					1975					1976				
	N	P	K	Mg	Ca	N	P	K	Mg	Ca	N	P	K	Mg	Ca	N	P	K	Mg	Ca
CONTROL	1.64	0.158	1.390	0.635	0.762	1.62	0.193	1.739	0.628	0.686	1.68	0.207	1.720	0.558	0.658	1.85	0.192	1.763	0.605	0.562
A.N.	1.68	0.158	1.464	0.599	0.712	1.71	0.163	1.667	0.599	0.683	1.85	0.167	1.555	0.548	0.671	2.00	0.150	1.639	0.579	0.567
A.S.	1.59	0.151	1.434	0.595	0.725	1.80	0.160	1.626	0.598	0.670	1.91	0.170	1.623	0.528	0.633	2.06	0.156	1.679	0.564	0.506
UREA	1.71	0.159	1.482	0.593	0.695	1.74	0.176	1.691	0.615	0.696	1.87	0.171	1.623	0.553	0.667	1.94	0.159	1.614	0.598	0.648
LSD.(P=0.05)	-	-	-	-	-	0.089	0.015	ns	ns	ns	0.089	0.016	ns	ns	ns	0.112	0.018	ns	ns	ns
LSD.(P=0.01)	-	-	-	-	-	0.124	0.021	-	-	-	0.125	0.022	-	-	-	0.158	0.025	-	-	-

C.A.N. = Calcium ammonium nitrate
A.N. = Ammonium nitrate
A.S. = Ammonium sulphate.

RESPONSE OF COCOA TO FERTILISERS ON COASTAL CLAYS

LIST OF TABLES

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PAPER No.48 RESPONSE OF COCOA UNDER COCONUTS TO FERTILISERS ON COASTAL CLAYS IN PENINSULAR MALAYSIA

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Table 1 : Nutrient Rates Used (Kg/Ha.)

Nutrient	Source	Level of Application	Trial		
			Expt.1	Expt.2	Expt.3
N	Ammonium Nitrate (26% N) in Expt. 1 & 2.	0	0	0	0
		1	145	82	156
		2	-	164	-
P_2O_5	Christmas Island Rock Phosphate (C.I.R.P.) (≏ 36% P_2O_5)	0	0	0	-
		1	56*	96	-
K_2O	Muriate of Potash (60% K_2O)	0	0	0	-
		1	333	151	-
		2	-	302	-
CaO	Limestone Dust (≏ 45% CaO)	0	0	-	-
		1	80+	-	-

* 2.75 tonnes/ha. applied in 1971. Subsequently, 56 kg. per ha. P_2O_5 was applied annually.

\+ tonnes/ha. $CaCO_3$ applied over the first 2 years (1971-72) only. None applied subsequently.

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Table 2 : Expt. 1. Yield and Girth Response to N and Ca Applications

	No. of Pods/Tree/Year						Stem Diameter++ (cm)
Treatment	1971-72+	1972-73	1973-74	1974-75	1975-76	Total	July 1976
N_0	7	23	33	25	39	127	8.8
N_1	11**	30**	50**	40**	49**	180	8.8
$\frac{N_1}{N_0}$ x 100	157	130	152	160	125	142	-
Ca0	9	24	37	31	43	144	8.6
Ca1	9	28**	42**	34	45	158	8.9**
$\frac{Ca1}{Ca0}$ x 100	ns	117	114	ns	ns	110	-

* Significant at 5%
** Significant at 1%
\+ July-June.
++ Measured 30 cm. above ground level.

RESPONSE OF COCOA UNDER COCONUTS TO FERTILISERS ON COASTAL CLAYS IN PENINSULAR MALAYSIA

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Table 4 : Expt. 2. Yield Response to N Application

Treatment	No. of Pods/Tree/Year+				
	1973-74	1974-75	1975-76	1976-77	Total
N_0	51	39	43	41	174
N_1	59	49	55	53	215
N_2	65	52	58	58	233
Var. Test	ns	21.50**	28.54**	17.18**	27.71**
N_L	-	**	**	**	**
N_Q	-	**	**	**	**

\+ April-March.
* Significant at 5%
** Significant at 1%.

Table 6 : Expt. 3. Yield Response to Various Nitrogenous Fertilisers

Treatment (Source of N)	No. of Pods/Tree/Year+				
	1973-74	1974-75	1975-76	1976-77	Total
Control	34	23	20	39	116
A.N.	38	29	31	63	162
A.S.	41	29	35	56	161
Urea	39	27	36	53	154
LSD.(P=0.05)	ns	6	9	12	20
LSD.(P=0.01)	ns	8	12	16	29

\+ April-March.
A.N. - Ammonium nitrate
A.S. - Ammonium sulphate.

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RESPONSE OF COCOA UNDER COCONUTS TO FERTILISERS ON COASTAL CLAYS IN PENINSULAR MALAYSIA

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Appendix 1a : Expt. 1. Soil Analysis Results

Treatment	Depth (cm)	pH (H2O)	%C	%N	P ppm. 6N HCl	Exch. (me/100 g. Soil) K	Mg	Ca
Control	0-7.5	5.3	1.90	0.12	281	0.54	15.42	5.56
	7.5-30	4.8	0.56	0.04	182	0.65	19.33	5.24
N	0-7.5	5.6	2.35	0.16	314	0.76	13.38	5.37
	7.5-30	5.0	0.62	0.04	191	0.68	19.30	4.97
P	0-7.5	5.4	2.22	0.13	842	0.59	13.57	5.73
	7.5-30	4.9	0.54	0.05	220	0.76	17.97	5.17
K	0-7.5	5.2	1.93	0.14	233	0.65	11.72	5.66
	7.5-30	4.7	0.58	0.04	158	0.81	17.97	5.08
Ca	0-7.5	6.2	1.68	0.11	274	0.51	13.12	5.72
	7.5-30	5.3	0.60	0.04	186	0.62	18.09	4.89

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Appendix 1b : Expt. 3. Soil Analysis Results (0-15 cm)

Pretreatment (1973)

Source of N	pH (H2O)	%C	%N	P ppm. 6N HCl	Exch. (me/100 g soil) K	Mg	Ca	6N HCl K (me.)
CONTROL	5.2	1.57	0.12	264	0.74	15.38	4.50	2.54
A.N.	5.0	1.53	0.11	323	0.79	14.58	4.34	2.90
A.S.	5.0	1.88	0.14	300	0.75	15.50	4.36	3.10
Urea	5.0	1.75	0.12	228	0.70	15.16	4.37	2.40

Post-treatment (1977)

Source of N	pH (H2O)	%C	%N	P ppm. Total+	Av.*	Exch. (me/100 g Soil) K	Mg	Ca	6N HCl K(me.)
CONTROL	5.2	0.70	0.13	349	162	0.71	23.78	8.03	3.07
A.N.	4.9	1.09	0.18	321	162	0.69	15.18	7.58	3.10
A.S.	4.5	1.20	0.18	465	202	0.70	12.13	6.99	2.88
Urea	4.9	1.13	0.20	285	156	0.71	15.18	7.55	3.08

+ Perchloric-sulphuric.
* Acid Fluoride.
A.N. - Ammonium nitrate
A.S. - Ammonium sulphate.

RESPONSE OF COCOA UNDER COCONUTS TO FERTILISERS ON COASTAL CLAYS IN PENINSULAR MALAYSIA

S.K. Ng and Chan

ppendix 1c : Expt. 2. Soil Analysis Results (0-15 cm.)

etreatment (1973)

reatment	pH (H2O)	%C	%N	P ppm. 6N HCl	Exch. (me/100 g Soil) K	Mg	Ca	6N HCl K me.
000	5.4	2.68	0.18	545	1.11	7.48	4.46	3.38
111	5.4	2.67	0.20	500	0.96	7.92	4.51	2.81
221	5.2	2.23	0.14	233	1.15	8.21	3.84	3.23

st-treatment (1977)

reatment	pH (H2O)	%C	%N	P ppm.		Exch. (me/100 g Soil)			6N HCl
				Total+	Av.*	K	Mg	Ca	K me.
000	4.7	1.7	0.24	451	40	0.72	6.11	6.27	3.21
111	4.6	2.0	0.25	599	85	1.65	5.04	9.30	3.94
221	4.3	2.0	0.26	636	98	2.56	3.48	6.26	5.16

\+ Perchloric-sulphuric.
* Acid Fluoride.

Received 31/5/77

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NUTRIENT RESPONSES OF PERENNIAL TREE CROPS ON A COASTAL CLAY SOIL IN PENINSULAR MALAYSIA

by

Chew Poh Soon and Khoo Kay Thye*

INTRODUCTION

The main tree crops grown on the coastal clay soils in Peninsular Malaysia are oil palms, coconuts, rubber and cocoa. Rubber does not perform as well as oil palms in these soils (Chan and Pushparajah, 1972) and many areas have been replanted with oil palms.

The coastal clay soils occur mainly on the west coast of the country and cover approximately 963,000 acres (Wong, 1972). Their nutrient content is usually high and the main limitation to satisfactory growth is drainage. An important pre-requisite in the management of these soils for perennial tree crops is therefore adequate drainage.

In view of the importance of these soils, considerable research into the agronomy and nutrition of the crops grown has been carried out, particularly for oil palms (eg. Gray and Hew, 1968; Hew and Poon, 1973; Tan and Ng, 1973). However, most of the trials have been on Selangor and Briah series soils and relatively less information is available on performance and growth of crops grown on Kangkong series soils, the third important soil series among the coastal clays.

This soil series (Typic Tropaquept) is clay textured, plastic in consistency and differs from the Selangor and Briah series by its

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more coarse, angular blocky structures in the sub-soil and consequent imperfect to poor natural drainage and aeration (Law and Tan, 1975). Management of this soil for satisfactory performance is therefore more demanding (Cheong and Ng, 1973) than on the other coastal clay soils. It occurs in large tracts in the Sabak Bernam and Bagan Datoh areas which are the most important coconut growing areas in the country and now also the most important cocoa area.

Torkington Estate in Sabak Bernam grows the three principal tree crops in the district i.e. coconuts (4,463 acres), cocoa underplanted under the coconuts (3,425 acres) and oil palms (1,784 acres). The soil on the estate is mainly Kangkong series and fertiliser trials were sited to test nutrient responses of the three crops grown.

The nutrient responses of the three crops are discussed in this paper.

Experimental details

The trials were laid out in factorial arrangements as given below:-

Trial I : 2^3 NPK trial on mature Malayan Dwarf Red coconuts

Trial II : 3^4 NPKCa trial on young cocoa underplanted under Tall coconuts.

Trial III : 4 x 3 NK trial on mature oil palms.

Fertiliser rates in the trials are shown in Table 1.

In Trial I, the fertilisers are applied once a year but in Trials II and III, nitrogen is split into two applications a year. The other fertilisers are applied once a year.

Further details of the trials are given in Appendix I. Pre-treatment soil analysis results are shown in Appendix II.

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RESULTS

The yields of the palms and cocoa bushes were recorded at every harvest as nuts (coconuts), pods (cocoa) and fresh fruit bunches or FFB (oil palms). Total pod yields in the cocoa including that diseased or damaged by pests were counted. Conversions into economic products for coconuts and cocoa were checked periodically.

Leaf analysis and tree and leaf measurements were also carried out.

Vegetative growth

In the coconut trial, nitrogen had the greatest effect on frond growth and increased size of fronds (Table 2).

Consistent detrimental effect on girthing in cocoa was noted to high applications of nitrogen. Both potassium and calcium appeared to increase girth at the first level of application but response was poorer at the highest level of application (Table 3). Girthing rate in 1974/75 appeared to be very poor.

Nitrogen appeared to increase size of the fronds in oil palms.(Table 4) Potassium appeared to increase leaf area in the absence of nitrogen in 1975. This effect was not noted in 1976.

Frond production was increased by nitrogen.

Leaf nutrient levels

Nitrogen, phosphate and potassium increased leaf levels of their respective nutrients in coconuts (Table 5). In addition, nitrogen and potassium depressed magnesium levels in each year.

Nitrogen decreased leaf P and K levels in cocoa in both 1974 and 1975. Leaf N levels were increased only in 1975 (Table 6).

Phosphate increased leaf P levels in both 1974 and 1975. However, leaf Ca level was depressed. Potassium tended to increase K leaf levels and in 1975, it depressed leaf N levels.

In oil palms, nitrogen increased leaf N levels in 1975. At the highest N level, there was a decline in leaf P. The 1976 results showed the same trend. In 1976, nitrogen appeared to increase leaf K levels but at the highest rate, decreased leaf K level (Table 7). Potassium applications did not appear to affect leaf nutrient levels.

Yields

The main yield responses are to nitrogen and potassium. The largest responses seen are in the coconuts to nut and copra yield to nitrogen. However the highest rates of nitrogen depressed yields in the cocoa and oil palms.

Potassium increased yields in cocoa and possibly in oil palms although in the latter, high rates appeared to depress yields (Table 8).

The conversion rates of coconuts and cocoa were reduced by nitrogen. Copra conversion was increased by potassium while dry/cocoa bean conversion appeared to be reduced in fertilised plots.

A significant NK interaction effect was detected in the cocoa trial. Application of nitrogen or potassium alone reduced yields. Yields were increased when the two nutrients were applied together (Table 9).

Calcium limestone application increased yields in cocoa (Table 10).

DISCUSSIONS

In the three trials, the oil palms (Trial II) was the only area which received significant fertiliser applications prior to the trials. The coconut areas were not fertilised at all.

An estimate of nutrient removal in the trial areas over the period of the trials described is shown in Table 11.

The respective nutrient removal by the three crops in the non-fertilised plots may reflect their ability to take up nutrients and the nutrient supplying power of the soil under the management systems prevailing. Although this presumption may not be totally correct as plant composition is expected to differ with different levels of soil fertility, the oil palm appears best able to exploit the soil. However the higher productivity of the oil palms and management including previous fertiliser applications may also influence the differences noted.

Nutrient requirements in the oil palm exceed that of coconuts and cocoa by about 2.5:1 for N, 2:1 for P, 1.5:1 for K, 2.5:1 for Mg and 6:1 for Ca. When at their highest yields, the relative differences between the crops are reduced especially for potassium and the removal of nutrients in cocoa and coconuts are increased.

The increased nutrient removal in the coconuts despite no potassium application is indicative of the potassium supplying powers of the soil as responses have been maintained in the trial to 1975 (Khoo et. al. 1976). The nutrient removal in cocoa is least although in combination with the Tall coconuts, the nutrient removal exceeds that of coconuts.

Cocoa and coconuts may not be able to exploit the soil as well possibly due to relatively less extensive roots and lower root activity. Oil palm roots have numerous large air spaces and produce pneumathodes which appear more common in moist conditions (Purvis, 1956) and may be better adapted to poorly aerated conditions and coconut roots less so (Geisler, 1971, cited in Kanapathy, 1973). Dwarf coconut palms have been observed to be

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more sensitive to poor drainage conditions. Unlike the fibrous root systems of the palms, cocoa has a tap root system as in rubber (Hevea). Reduced rooting volume due to high water-tables on the coastal soils causes the poorer performance of Hevea (Chan and Pushparajah, 1972). Soong (1976) reported poorer feeder root growth in rubber in Selangor series compared to lighter inland soils. Cocoa does not have a vigorous rooting system (Smyth, 1975), so that they may be expected to be less efficient in absorbing nutrients from the soil.

The pre-treatment soil analysis results confirm the high nutrient content of Kangkong series but in Trial I (coconuts), the soil nitrogen level below 0-6" is low and probably contributed to the good response to nitrogen seen in the trial.

Cheong and Ng (1973) have observed that oil palms on soils, including Kangkong series, with high clay or silt content, low humus content and poor permeability have very low leaf N levels. These soil factors are probably inhibitory to good root growth and nitrogen uptake. Responses to nitrogen may therefore be expected on Kangkong series.

Nitrogen is the main limiting nutrient in Trial I (coconuts) and its application increased leaf N, frond size and probably leaf area index and yield. Beneficial effects to nitrogen were also seen in cocoa and oil palms but to a lesser extent probably because of the higher soil nitrogen and less competitive inter-row covers. Heavy grass, which is regularly slashed 7-8 times a year, are present in the coconuts. The grass immobilises nitrogen while slashing the grass increases the competition effect. Spraying out the inter-row weeds improved nitrogen nutrition and increased yield (Hew, 1972). In the cocoa, the grasses are largely sprayed out and only relatively light grass grows between the oil palms where shade is

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heavy.

An interesting feature in the results has been the detrimental effects of high nitrogen applications in cocoa and oil palms. Leaf N levels were increased but phosphorus and potassium levels were depressed in cocoa and this appeared in oil palms too. The girth of cocoa also appeared to be depressed but this effect on vegetative growth was not apparent in the oil palms.

The highest nitrogen rates appear to have caused an imbalance in cocoa and oil palms. Viets (1965) has suggested that excessive nitrogen can absolutely and relatively decrease root production. This effect will possibly result in poorer uptake of phosphorus and potassium thereby causing an imbalance and reduction in yield. No studies on root cation exchange capacities of cocoa and oil palms are known but high nitrogen applications have been reported to increase cation exchange capacity of the roots which will result in a greater tendency for divalent cations to be taken up at the expense of potassium (Munson, 1970). This has not been observed in the trials reported. Where potassium is limiting, application of nitrogen can cause reduction of yield in oil palms (Ollagnier and Ochs, 1973).

The positive NK interaction in the cocoa is probably the effect of high nitrogen and the low rates of potassium applied in relation to the plants' requirements and competition by the coconuts (Tam, 1968).

In coconuts and cocoa, potassium applications raised leaf K levels but not in oil palms. Only nitrogen raised leaf K levels. This has also been observed in other trials on the coastal soils (Hew et al. 1973) possibly due to antagonism by the high calcium and magnesium contents in the soil.

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orster and Chang (1976) have suggested that this may also be due to balance ith the lower calcium uptake of the plants. It may be noted that in elation to critical or optimum potassium levels normally roposed for the crops, the levels of leaf K in all trials are low.

The response of cocoa to calcium limestone applications is otable as it is the only crop of the three which is known to respond to his nutrient on coastal clay soils which are not acid. The pH in the imed plots were raised 0.3 units to pH 4.70 in 1976. Ng et al. (1970) uggests that cocoa roots may be rather sensitive to aluminium ions hich are in greater abundance under more acid conditions.

CONCLUSION

The main nutrient requirement of perennial tree crops grown on Kangkong series soil is nitrogen. If the crop removes large amounts of potassium, uptake of which is poor on this soil, it is probably advisable to apply this nutrient as well. Excessive nitrogen should not be applied and care taken to avoid nutrient imbalances as reductions in yield may result.

Management practices should be geared to reduce competition for nitrogen and increase uptake of this nutrient by the crops planted.

Needs of crops with special requirements such as cocoa which requires higher pH for better yields should be checked.

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Penyelidek.n Pertanian Barlow Boustead Sdn. Bhd.

We thank Messrs. Syarikat / . and Barlow Boustead Estate gency Sdn Bhd for permission to publish this paper and Messrs. I.C.I. griculture), Malaya for co-operation in Trials I and II. The help of e Managers at Torkington Estate and our staff in the maintenance, ecording and computation of the trials is also much appreciated.

Table 2. Effect of nitrogen on Frond 14 size in coconuts (Trial 1)

	1971		1972	
	Weight (kg)	Length (cm)	Weight (kg)	Length (cm)
N_0	2.24	304	2.16	297
N_1	2.39	315	2.43	312
S.E. ±	0.10	4.3	.06	3.5

e 3. Responses in girth size of cocoa to fertiliser application

(Trial II)

	Nitrogen			Potassium			Calcium			
r	no	n1	n2	ko	k1	k2	Ca0	Ca1	Ca2	SE ±
3	7.77	7.72	7.48	7.57	7.72	7.68	7.59	7.72	7.67	.12
4	8.01	8.06	7.76	7.85	8.03	7.96	7.87	8.05	7.91	.10
5	8.11	8.09	7.68	7.87	8.06	7.95	7.87	8.08	7.93	.12

Table 4. Frond 17 measurements and frond production in oil palms (Trial III)

	1975		1976		Frond production	
	Leaf area (m^2)	Estimated dry weight (kg)	Leaf area (m^2)	Estimated dry weight (kg)	1975	1976
no	14.3	3.11	15.8	3.32	22.4	21.0
n1	14.5	3.04	16.3	3.44	23.6	20.9
n2	14.5	2.98	16.1	3.49	24.6	21.5
n3	14.6	3.10	16.4	3.43	23.6	21.8
S.E.±	.37	.11	.6	.10	.5	.4

Table 9 . NK interaction effect on cocoa yield, Oct. 1972-75 in Trial II

	Pods/acre ($x10^2$)				Dry beans kg/acre		
	No	N1	N2		No	N1	N2
Ko	352	346	365	Ko	1537	1408	1434
K1	349	397	378	K1	1486	1680	1537
K2	342	410	407	K2	1447	1783	1576

Table 10. Yield response to calcium in cocoa (Trial II)

	Pods/acre ($x10^2$)	dry beans kg/acre
Cao	359	1447
Ca1	381	1602
Ca2	378	1576
S.E.±	13	65

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LE : Nutrient responses of perennial tree crops on a coastal clay soil in Peninsular Malaysia

rtened title : Nutrient responses of tree crops

A B S T R A C T

Nutrient responses of cocoa underplanted under coconuts, coconuts oil palms on a heavy clay soil with coarse structures and imperfect to r drainage are described. The results of fertiliser applications on f nutrient levels, growth and yield are presented.

Nitrogen is the main limiting nutrient but depressed yield in oa and coconuts when applied at the highest rates. Responses were ed to potassium in oil palms and cocoa. The highest yields in these crops were obtained when both nitrogen and potassium were applied. ever, no yield response to potassium was obtained in coconuts.

Calcium limestone applications increased yield in cocoa.

The soil nutrient contents and nutrient supplying power, nutrient oval by the crops and management practices are discussed in relation the results seen.

	TrialI(coconuts)	Trial II (cocoa under tall coconuts)	Trial III (oil palms)
a) Year planted	1951/52	Cocoa : Oct. 1970 (seed at stake) Coconuts: 1925/26	1967
b) Varieties	Malayan Dwarf Red	Cocoa : Mixed U. Amazon hybrid (Sabah) Coconuts: Malayan Talls	DxP Chemara
c) Planting pattern and density	22 ft. x 22 ft.△ 104 palms/acre	Cocoa : Double rows in coconut inter-rows 323 bushes/acre Coconuts: 30 ft. square	29 ft. x 29 ft.△ 60 palms/acre
d) Design	2^3 NPK factorial. Randomised blocks with 4 replicates	3^4 NPKCa factorial in single replicate	4 x 3 NK factorial with 3 replicates
e) Plot size	16 palms with isolation trenches	30 trees with border rows and drain	9 palms with border palms.
f) Pre-treatment records	November 1968	August 1971	April 1973
g) Treatments commenced	January 1969	August 1971	March 1974.

Trial	Depth (in)	pH	Org.C	N%	C/N	P (ppm) total	P (ppm) avail.	Exch. cations (m.e.%) K	Exch. cations (m.e.%) Ca	Exch. cations (m.e.%) Mg	C.E.C. (m.e.%)	Notes
I	0- 6	5.0	1.98	.20	9.9	-	95[1]	.66	3.85	10.4	28.2	Inter-rows.
	6-12	4.4	.81	.10	8.1	-	46[1]	.44	3.10	13.7	29.2	Analysed by Dept. of
	12-24	4.3	.84	.09	9.3	-	44[1]	.56	2.75	15.3	28.7	Agriculture
II	0- 6	4.9	2.23	.21	10.6	-	9.0	.62	3.94	18.5	32.2	Inter-rows.
	6-12	4.6	1.95	.18	10.8	-	10.1	.64	3.69	18.3	32.5	Analysed by O.P.R.S.
	12-24	4.3	1.50	.14	10.7	-	11.2	.60	3.00	16.6	33.9	Banting
III	0- 6	4.9	1.38	.22	6.9	436	18.7	1.06	2.7	17.0	n.a.	Palm circle.
	6-18	4.5	.76	.13	6.3	312	10.8	.47	2.4	28.1	n.a.	Analysed by H.R.U. Lab.
	18-30	4.3	.74	.11	7.4	345	16.6	.69	2.1	29.3	n.a.	

[1] Sol. P in 0.1N NaOH

n.a. - no analysis

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PAPER No.49 NUTRIENT RESPONSES OF PERENNIAL TREE CROPS ON COASTAL CLAY SOIL IN PENINSULAR MALAYSIA

P.S. Chew and K.T. Khoo

Table 1. Treatment rates in fertiliser trials at Torkington Estate

Trial I (Coconuts)	Trial III (Oil Palms)
N : 0, 1.8 kg N26/palm/year	N : 0, 0.7, 1.4, 2.7 kg Urea/palm/year
P : 0, 1.4 kg CIRP/palm/year	K : 0, 1.8, 3.6 kg M.pot/palm/year
K : 0, 1.8 kg M.pot/palm/year	

Trial II (Cocoa)

	Yr. 1 (1971)	Yr. 2 (1972)	Yr. 3-5 (1973-5)
N :	0, 57, 113	0, 170, 340	0, 284, 567 gm N26/bush/year
P :	0, 43, 85	0, 43, 85	0, 57, 113 gm Double Super phosphate/bush/year
K :	0, 43, 85	0, 43, 85	0, 85, 170 gm M.pot/bush/year
Ca:	0, 170, 340	0, 227, 454	0, 227, 454 gm Ca. lime-stone/bush/year

N26 - Nitro 26 (26% N) Urea - 46% N

CIRP - Christmas Island Rock Phosphate (36% P205)

M. Pot. - Muriate of potash (60% K20)

Double superphosphate - 40% P205

Calcium limestone - 56% CaO

P.S. Chew and K.T.Khoo

Table 5 : N, P and K leaf analysis results in Frond 14, Coconuts

(Trial I)

	% N				% P				% K		
	1970	1971	1972		1970	1971	1972		1970	1971	1972
No	1.80	2.04	1.66	Po	.136	.139	.133	Ko	.69	.62	.61
N1	1.93	2.11	1.76	P1	.138	.142	.137	K1	.81	.76	.77
SE ±	.02	.04	.04		.001	.004	.002		.02	.03	.03

Table 6. Effect of nitrogen on leaf nutrient levels in Leaf 4, Cocoa (Trial II)

	1975				
	%N	%P	%K	%Mg	%Ca
No	1.84	.198	1.66	.89	.61
N1	1.94	.189	1.81	.83	.59
N2	2.06	.174	1.57	.88	.63
S.E.±	0.04	.008	0.12	.03	.04

Table 7. Effect of nitrogen application on leaf nutrient levels in Frond 17, oil palms (Trial III)

	% N		% P		% K	
	1975	1976	1975	1976	1975	1976
No	2.76	2.71	.164	.160	.91	.88
N1	2.81	2.72	.168	.162	.91	.94
N2	2.87	2.77	.170	.166	.90	.96
N3	2.85	2.74	.167	.160	.90	.89
S.E.±	.06	.05	.002	.004	.03	.05

P.S. Chew and K.T. Khoo

Table 8. Yield responses to nitrogen and potassium in Torkington Estate trials.

	Coconuts			Cocoa			Oil Palm
	Trial I. Yield/acre 1969-72			Trial II. Yield/acre Oct. 1972-75			Trial III. Yield/acre Apr. 1974-76
	nuts($x10^2$)	copra(kg)		pods($x10^2$)	dry bean wt.(kg)		FFB (m.ton)
No	202	3033	No	349	1486	No	26.5
N1	266	3893	N1	384	1628	N1	28.1
		175	N2	383	1512	N2	28.7
						N3	26.9
Ko	237	3437	Ko	354	1460	Ko	27.0
K1	231	3489	K1	375	1563	K1	28.6
			K2	387	1602	K2	27.1
S.E.±	11.5	175		13	65		1.3

ble 11. Estimated nutrient removal in trials at Torkington Estate

ial	Crop	Yield/ac.	N	P	K	Mg	Ca	Notes
			Estim ed n trient removal kg/acre/year					
I	Coconuts (Copra/year 1969-72)	1.19 m.ton[1]	16.3	2.76	40.6	3.38	1.48	based on estimate for Dwarf Yellows (Chan, 1976)
		0.76 " [2]	10.4	1.76	25.9	2.16	.94	
II	Cocoa (dry beans/ year 1973-75)	.57 m.ton[1]	12.8	2.51	25.1	3.27	1.63	based on Ng and Thamboo (1967)
		.49 " [2]	11.0	2.16	21.6	2.81	1.40	
	Coconuts (Copra/year 1973-75)	.46 " [3]	5.6	2.43	11.6	.76	.48	based on estimate for Malayan Talls (Chan, 1976)
II	Oil palms (FFB/year Apr.'74-76)	10.8 m.ton[1]	31.2	4.68	39.4	8.19	8.61	based on Ng and Thamboo (1967)
		9.5 " [2]	27.5	4.11	34.7	7.20	7.59	

1) highest yield, Trial I (NP), Trial II (N_1K_2), Trial III (N_2K_2)

2) control yield (nil fertiliser in Trials I and III, NoKo in Trial II)

3) estimated yield in whole trial area

ABSTRACT

NUTRIENT LEVEL CHANGES DURING A 20 YEAR SHIFTING CULTIVATION CYCLE IN SARAWAK (MALAYSIA)

by J.P. Andriesse x)

The study was carried out on a XANTHIC FERRALSOL. The shifting cultivation method employed is felling and burning primary or secondary forest, the growing of one upland rice crop followed by one cassave relay crop, whereafter the land is abandoned for forest regeneration of up to 20 years of bush/fallow, a new cycle starting with renewed felling and burning.

Soil sampling procedures involved careful selection of fields based on homogeneity of soil and bush/fallow stage with as far as possible one replicate for each stage. Each field delivered 3 sampling sites, upperslope, middle slope and lower slope; each site 5 individual topsamples. One field was sampled prior and subsequent to burning and after harvesting. Soils were analyzed on %C, %N, available P, Ca, Mg and K.

The results of the replicates indicate that the natural variability within one specific soil series may be greater than differences in nutrient level caused by the bush/fallow stage. Slope situation may cause a larger variability than stage in forest regeneration. Large increases in major nutrients are only found after the burn, the levels reverting to former values after one cropping season. It is concluded that as far as chemical fertility is concerned, 20 years of bush/fallow serves mainly to accumulate sufficient plant nutrients in the living vegetation

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to sustain one crop. The study further indicates that extreme caution must be exercised in establishing causal relationships between soil analytical data and shifting cultivation practices, particularly when indirect study methods are used, the natural nutrient level of the soil is low, and the coefficients of variation are unknown. Many of such studies suffer from this limitation which may have been partly responsible for their strongly conflicting results.

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INTRODUCTION

Large societies throughout the tropics are for their subsistence still mainly dependent on so-called shifting cultivation or bush/fallow systems. These vary in technique and level of management depending upon local conditions but all have in common that use is made of the natural restoration power of the soil to replenish lost fertility during a relatively short cropping period by a prolonged period of bush/fallow.

Due to an increasing population in many areas the bush/fallow period has become too short for allowing a sufficient build-up of plant nutrients in the soil for a subsequent cropping period. The mechanism responsible for soil fertility restoration is very complex. Kellogg (1956) expressed the urgency for studying such systems, thus: 'no research is more badly needed than to establish the precise action of bush/fallow ......millions of people depend on it! I should rather know the answer to this question than that of any other unanswered question in soil science'.

Nye and Greenland (1960) and Conklin (1963) evaluated the problem and reviewed much of existing knowledge on the subject. Since then a number of studies were carried out in tropical areas of which the results appear to be conflicting. The present author tried his hand on this problem by conducting some observational studies since 1961 in Sarawak also with variable results and he had to conclude that the employment of indirect methods had strong

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limitations under the local conditions. In order to investigate this contention fully a more elaborate study was set up in 1974, involving detailed sampling procedures and the introduction of replicates and the variable site factor 'slope'. This paper presents and discusses the preliminary results of this study.

METHODS

Basic requirements for selecting the study area were: (i) a relatively newly farmed area having fields with secondary forest regrowth of 1 to 20 years of age and which had experienced not more than 2 or 3 cropping periods, (ii) comparable farming technique and level of management, (iii) comparable topography, (iv) homogeneity of soils.

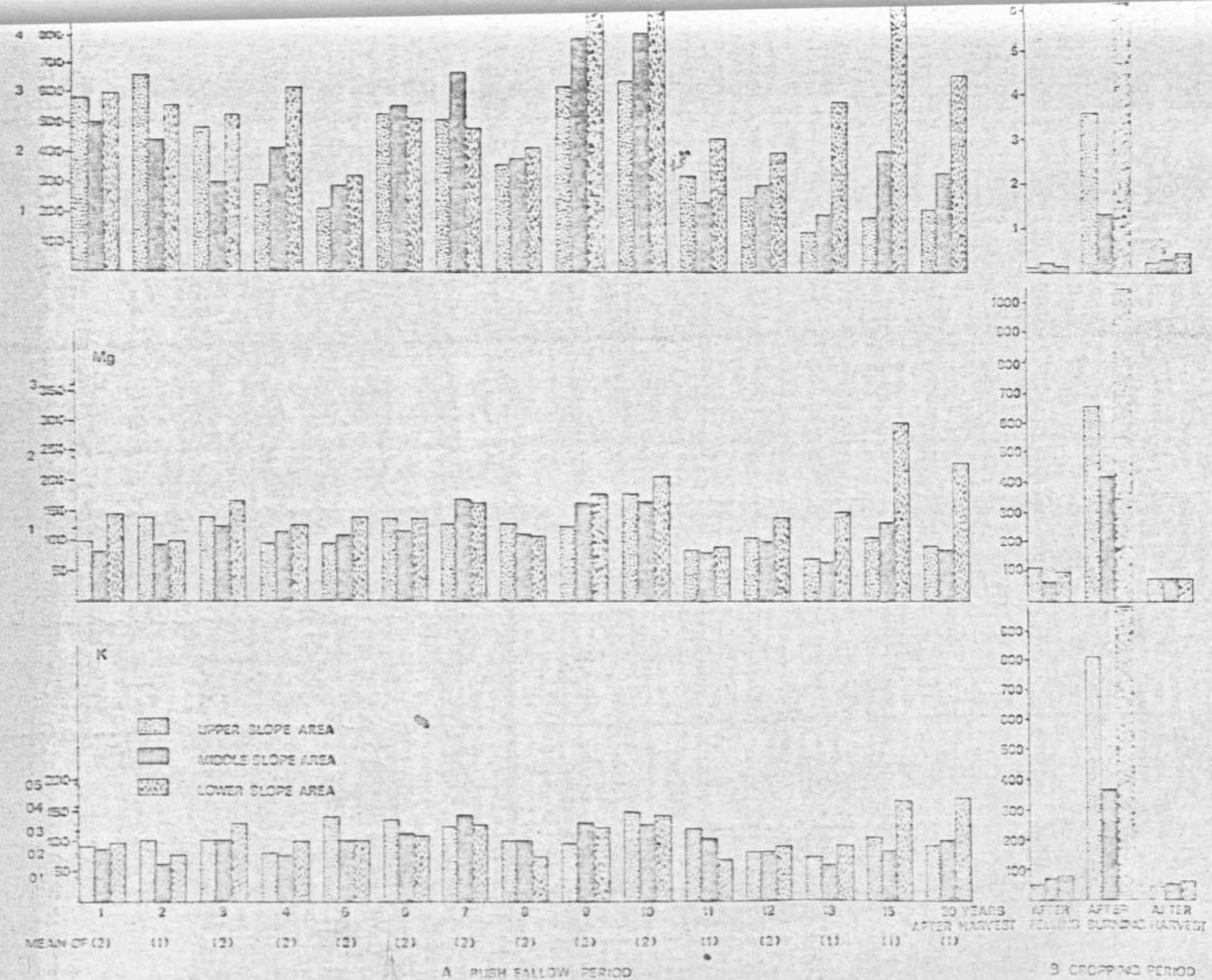
An area along the Bau-Lundu road in West Sarawak which had been soil surveyed at a semi-detailed level (Andriesse, 1967) appeared to be suitable and the field study commenced during June 1974 when felling for the new cropping year had just started.
Fields representing bush/fallow stages from 1 to 20 years in duration, with one replicate for each stage were selected. All fields were in a 2nd or 3rd cycle of forest regrowth with the exception of those in the 9th, 10th, 15th and 20th year having had only one previous cropping period. No representative replicates for the 2nd and 11th year could be found because of soil difference, whereas fields in their 13th, 15th and 20th year of regrowth had no replicates because areas with such a long regeneration period are exceptional and mainly found in more hilly terrain. Slopes generally varied from 8-10°, exceptions being fields for the 13th, 15th and 20th years which for mentioned reasons had slopes ranging from 12 to 20°.

Each field delivered three sampling sites, upper slope, middle slope and lower slope situations. At each site individual samples of the 2 cm deep surface soil were collected at five points situated as the dots indicating the number 5 on a dice, the distance from the central dot being 5 m in all directions.

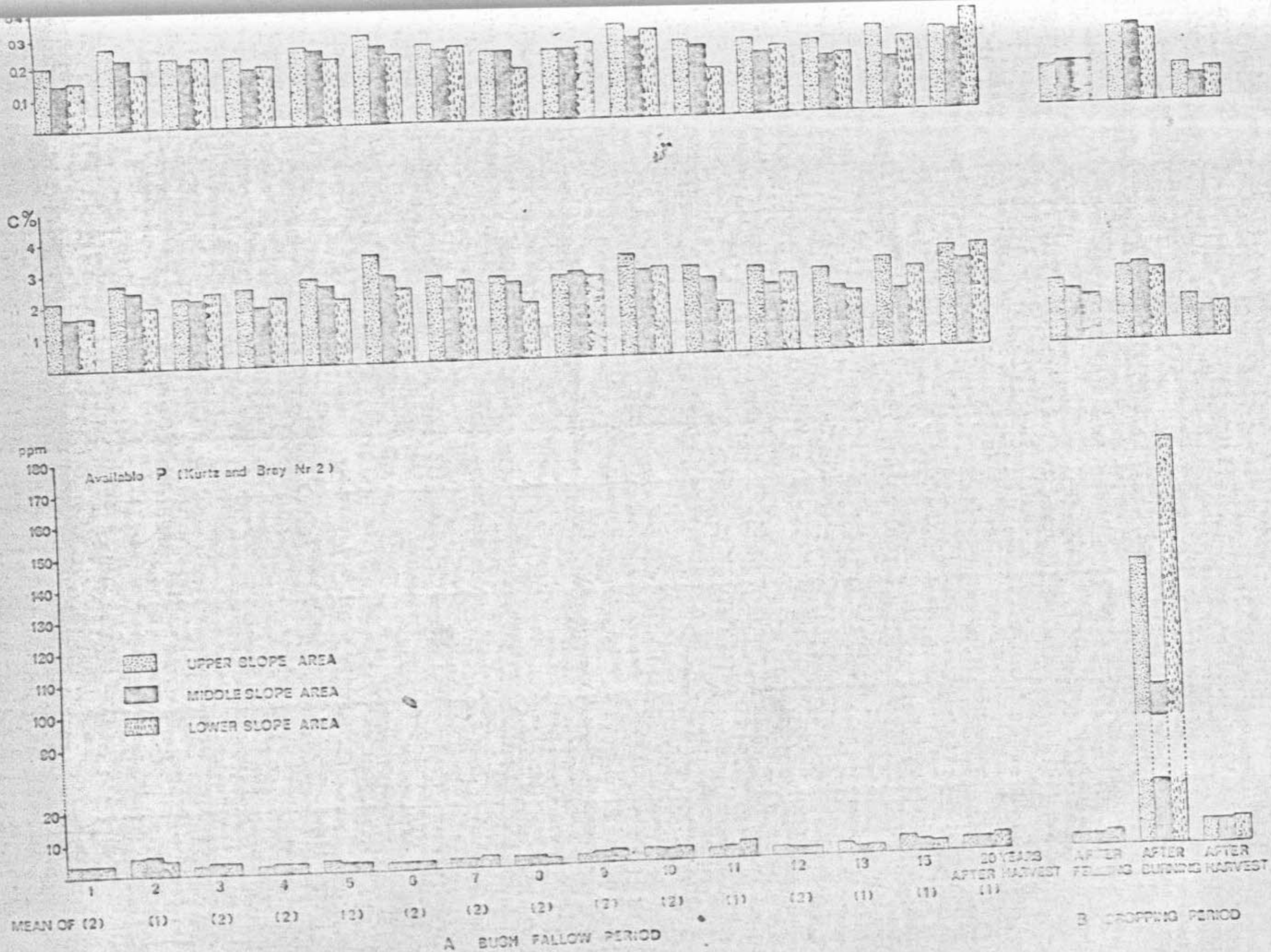
In addition one shallow pit was dug at midslope for sampling the subsoil to test the soil type.
For studying changes occurring during the cropping period, one field used for upland rice in the 1974/75 season was sampled thrice in the manner as indicated, once after felling, once after burning and once after harvesting.
All individual samples were dried at 40°C in the laboratory and thereafter split in half. One half was used to make up a bulksample for each site, the remaining half kept for investigating the variability per site.
The fine earth fraction (< 2 mm) of bulked site samples were analysed for available Ca, Mg and K using the Morgan-Venema extraction (NH_4-acetate/acetic acid extraction, pH 4.8).
Total nitrogen was determined by micro-Kjeldahl and carbon using the Walkley-Black method. Phosphorus was determined by Kurtz and Bray, no. 2.
Subsoil samples were only analysed for texture since within the local soil series texture is the most variable factor. The series involved is locally defined as the Stom series characterised by a sandy loam surface horizon overlying a clay loam to clay subsoil. The series is derived from poorly consolidated Tertiary mudstones and belongs to the local group of Red-Yellow Podzolic soils. There is however no argillic horizon and the soil is best classified in the FAO/UNESCO world soil legend (1974) as a XANTHIC FERRALSOL.

RESULTS

Figs. 1 and 2 show in a diagrammatic form the mean results of the chemical analyses on the surface soil bulksamples. Separate diagrams were drawn for the bush/fallow (A) and cropping periods (B) since the field samples for the cropping period had a slightly different soil



Mg
K
UPPER SLOPE AREA
MIDDLE SLOPE AREA
LOWER SLOPE AREA
1
2
3
4
5
6
7
8
9
10
11
12
13
15
20 YEARS AFTER HARVEST
MEAN OF (2) (1) (2) (2) (2) (2) (2) (2) (2) (2) (1) (2) (1) (1) (1)
AFTER FELLING
AFTER BURNING
AFTER HARVEST
A BUSH FALLOW PERIOD
B CROPPING PERIOD


0.3
0.2
0.1
C%
4
3
2
1
ppm
180
170
160
150
140
130
120
110
100
80
20
10
Available P (Kurtz and Bray Nr 2)
UPPER SLOPE AREA
MIDDLE SLOPE AREA
LOWER SLOPE AREA
1
2
3
4
5
6
7
8
9
10
11
12
13
15
20 YEARS AFTER HARVEST
AFTER FELLING
AFTER BURNING
AFTER HARVEST
MEAN OF (2)
(1)
(2)
(2)
(2)
(2)
(2)
(2)
(2)
(2)
(1)
(2)
(1)
(1)
(1)
A BUSH FALLOW PERIOD
B CROPPING PERIOD

type and direct comparison between the analyses from both periods is therefore not permissible. The values for Ca, Mg and K are expressed both in ppm and meq. to enable comparison with results of studies elsewhere. It should be noted that because of the analytical method employed meq. values do also include water soluble cations, but because of their extreme low values a direct comparison with meq. values obtained by convential methods is for practical purposes justified. The complete results of the chemical analyses are given in Appendix 1.

(i) Ca-Mg-K

According to standards given by Bailey (1964) for Sarawak soils, values for Ca, Mg and K are for most sites of medium level. Only after burning exceptionally high levels are found. These drop to almost their initial medium levels after only one cropping season. For all three elements, but particularly for Ca and Mg, high levels are only reached in fields 9, 10, 15 and 20 years. It is probably significant that this coincides with the fact that fields 15 and 20 and one replicate of both fields 9 and 10 had only experienced one previous cropping period and that for this reason the recuperation power of the soil may be greater. The number of cropping cycles a field has been put through is likely to have a strong bearing on variability of soil properties between fields. In general there appears to be little relation between nutrient level and duration of bush/fallow period. Slope situation appears to be more important than length of bush/fallow period in causing variability in Ca, Mg and K levels. Of significance may be the tendency for lower slope sites to have higher nutrient levels than middle or upper slope sites. This may become more apparent with the length of the bush/fallow period and might be caused by erosion. It is likely that this variability

APPENDIX I

TICAL DATA ON MAJOR NUTRIENTS OF BULK SAMPLES FROM SOILS
20 YEARS UPLAND RICE/BUSH FALLOW CYCLE IN SARAWAK

FIELD	POSITION			in ppm				in %	
	Upper slope	middle slope	lower slope	Ca	Mg	K	av P	C	N
r felling	x			100	100	45	3.5	2.07	0.13
		x		153	65	20	3.3	1.74	0.13
			x	146	97	76	4.5	1.62	0.13
r burning	x			3585	656	812	140	2.20	0.25
		x		1335	4.0	369	100	2.57	0.25
			x	6116	1073	981	170	2.15	0.23
r harvest	x			245	75	33	7.3	1.41	0.11
		x		258	75	45	7.3	0.99	0.09
			x	620	75	54	8.0	1.08	0.10
ar (a)	x			175	78	77	3.4	2.22	0.20
		x		275	81	95	3.9	1.95	0.16
			x	341	94	92	3.2	1.74	0.15
ar (b)	x			997	119	107	2.9	2.19	0.19
		x		729	82	77	2.7	1.90	0.12
			x	860	121	98	3.4	1.71	0.16
ear	x			657	143	92	5.7	2.76	0.27
		x		441	93	60	5.9	2.46	0.23
			x	554	100	76	4.5	1.98	0.17
ear (a)	x			244	69	51	3.7	2.25	0.21
		x		154	70	65	3.7	1.90	0.17
			x	375	115	90	2.7	2.46	0.21
ear (b)	x			725	216	145	1.9	2.61	0.25
		x		653	101	132	3.2	2.55	0.23
			x	675	222	170	3.7	2.37	0.24
4 year (a)	x			360	116	82	2.5	2.73	0.25
		x		454	112	56	2.7	2.04	0.18
			x	620	152	98	2.1	2.25	0.21
4 year (b)	x			213	79	76	1.9	2.22	0.21
		x		373	123	97	3.0	1.86	0.19
			x	613	103	97	3.5	2.19	0.20
5 year (a)	x			122	63	99	4.7	2.82	0.28
		x		215	101	103	4.1	2.91	0.29
			x	299	159	116	2.9	2.31	0.22
5 year (b)	x			311	125	186	2.7	2.73	0.24
		x		368	114	103	2.4	2.22	0.21
			x	343	123	89	3.6	1.92	0.19
6 year (a)	x			195	139	163	3.2	4.50	0.28
		x		336	140	127	2.9	3.30	0.31
			x	503	164	125	2.9	2.73	0.26
6 year (b)	x			859	135	125	1.9	2.55	0.21
		x		771	97	98	3.1	2.55	0.22
			x	534	116	94	2.5	2.07	0.19
7 year (a)	x			501	121	120	2.5	2.22	0.19
		x		565	132	136	2.7	2.13	0.19
			x	603	163	125	3.7	2.92	0.25
7 year (b)	x			640	139	126	3.1	3.60	0.37
		x		771	214	150	2.9	2.91	0.29
			x	359	173	129	3.1	2.67	0.25

FIELD	POSITION			in ppm				in %	
	Upper slope	middle slope	lower slope	Ca	Mg	K	av P	C	N
8 year (a)	x			527	145	90	3.1	2.70	0.20
		x		624	101	89	3.8	2.70	0.25
			x	346	94	66	1.8	2.04	0.16
8 year (b)	x			190	102	115	3.1	2.30	0.23
		x		320	126	116	3.1	2.34	0.22
			x	684	124	76	2.5	1.59	0.16
9 year (a)	x			206	99	92	3.3	[illegible]	0.21
		x		396	176	148	3.4	2.73	0.22
			x	509	230	151	4.3	2.79	0.26
9 year (b)	x			1034	152	98	2.2	2.65	0.24
		x		1122	154	108	2.2	2.76	0.24
			x	1577	133	97	2.5	2.43	0.22
10 year (a)	x			580	208	145	3.1	2.76	0.27
		x		921	190	172	4.1	2.85	0.28
			x	1028	239	164	5.1	2.83	0.31
10 year (b)	x			699	155	150	4.5	3.66	0.35
		x		699	145	83	2.7	2.58	0.23
			x	827	188	110	2.7	2.79	0.28
11 year	x			321	85	121	3.4	2.73	0.25
		x		234	80	104	3.7	2.37	0.23
			x	450	99	67	5.1	1.59	0.14
12 year (a)	x			150	68	[illegible]	3.1	2.58	0.23
		x		115	69	59	2.5	1.92	0.12
			x	302	131	88	3.1	2.55	0.18
12 year (b)	x			352	145	99	2.7	2.65	0.24
		x		460	131	104	2.3	2.66	0.19
			x	502	145	65	2.1	2.52	0.22
13 year	x			134	70	71	1.6	2.58	0.22
		x		194	65	56	2.3	1.98	0.18
			x	571	150	91	2.9	1.89	0.17
15 year	x			184	103	104	5.1	2.88	0.27
		x		409	133	83	4.1	1.83	0.16
			x	1073	300	163	3.7	2.52	0.24
20 year	x			209	93	93	4.1	3.24	0.27
		x		332	83	97	4.1	2.82	0.26
			x	666	430	167	5.1	3.30	0.33

was already initially present under primary forest condition.

(ii) C and N

According to Bailey (op cit) an N level of less than 0.25 % is low for Sarawak soils. During the bush/fallow period this level is only surpassed in fields 2, 6, 10, 15 and 20. For the latter three fields this may again be caused by the fact that these fields were only used once for cropping; for fields 2 and 6 no apparent reason can be given. Even after burning in the cropping period this level of 0.25 % is barely reached although a significant increase of 75 % as compared with the 'after felling' stage had occurred. Differences due to length of bush/fallow period, if existing, are very small. Of significance may be the fact that the total N content of lower slope sites is generally less than that for upper slope sites. This is the reverse situation as found for the Ca, Mg and K levels. The carbon values show very much the same tendencies as observed for the nitrogen, although after burning in the cropping period the increase is relatively less. The slope component is probably more significant for causing variability than duration of the fallow period.

(iii) available P

Available P values are all within the medium range for Sarawak soils (Bailey, op cit). The levels change little throughout the bush/fallow period. A very significant increase of 30 to 40 times the initial value is found after burning, these values after harvesting dropping to almost their initial levels.

Table 1 - Available nutrients in kg/ha before and after harvest related to nutrients removed by 1 rice crop (1 ton/ha)

Element	present in surface soil		removed by panicle
	after burn	after harvest	(de Geus, 1973)
N	264	132	10
P	23	0.7	2.7
Ca	792	66	2.6
Mg	127	12.7	1.9
K	106	12	2.3

(iv) nutrient balance

Table 1 supplies information on the amounts of available nutrients, calculated in kg/ha present in the surface 2 cm of soils after burning and after the harvest, together with those required for one rice crop. The latter value is based on nutrients removed by the panicle with a yield of 1 ton/ha of unbusked rice. In practice such yields are rarely reached in the studied area and the stated nutrient requirements are therefore maximal. Table 1 clearly illustrates that most of the available nutrients must have been removed from the surface soil either through leaching or erosion and that after the rice harvest particularly P has become deficient. This element may therefore play a crucial role in the system.

DISCUSSION

Studies into nutritional changes of soils under shifting cultivation were made by Popenoe (1960) in Guatemala, by Reynders (1961) in New Guinea, by Zinke et al (1970) in North Thailand and recently by Driessen et al in Indonesia (1976). A comparison is made of results of these studies with those presently obtained.

(i) Ca, Mg and K levels

Popenoe reported a decline in exchangeable Ca and Mg after burning but total Ca showed an increase. A further decline was found to occur during the fallow (sampled in the 2nd year). Reynders, on the contrary found a rapid decrease in Ca, Mg and K levels during the cropping period after initially high levels upon burning; this was followed by a considerable, gradual but rapid, increase during the fallow period ranging from 3 to 10 years. Zinke et al state that the sum of the basic cations is higher at the beginning of the cycle at the time of cutting and burning and less in the forest fallow regrowth. During the fallow period there is a gradual discharge of calcium in the soil due to uptake by the forest; magnesium and potassium do not show as pronounced a variation as calcium, the magnesium content in the fallow period tending to be higher than in the unburned control plot, whereas potassium content is higher 1 year after burning but during the fallow it drops to a low amount, the burned field having the lowest level. Driessen et al conclude that after an occupation period of 2 to 3 years the surface soil is even richer in plant available nutrients than at the beginning of cultivation. The influence of the fallow was not studied by them. The results of the present study indicate that during the fallow nutrient levels in the topsoils remain fairly constant probably due to the fact that uptake and leaching is balanced by addition through litter fall and rain-wash of leaves. The fluctuations in the analytical data are probably more due to natural variability than to length of the bush/fallow period. Nye and Greenland (1960) state that during the fallow increases of exchangeable Ca, Mg and K are generally small compared with the amounts of these elements accumulated in the living forest. Present data tend to confirm this viewpoint as may also be evidenced by the tremendous increase in available nutrients after burning the cut-down forest. There appears to be no long term after-effect of the burn, the nutrient levels dropping to almost their initial values of before the burn after one cropping season (8 months). Other workers (op cit) report that in instances increases may occur.

(ii) Available P

Concerning the P-cycle, differences between the various study results are even greater than those reported for Ca, Mg and K. The results reported by Popenoe (op cit) may be directly comparable to those presented in this study since the same extraction method was used. He found an increase in some soils after burning, a decrease in others but a general large decrease after 2 years of second growth. Zinke et al (op cit) using bicarbonate soluble phosphorus report that in all phases of the forest fallow cycle (3 stages of 1, 4 and 7 years) P was higher than in the corresponding unburned forest control. Therefore a residual effect of burning persist during the fallow. They however, found higher levels in the deep subsoil of the forest control plot than under fallow. Driessen et al (op cit) found a marked increase in total P after 2 years of cultivation and even more so after 7 years. Available phosphorus (acetic-acid extraction) decreased but comparatively much less. Most workers agree that for a proper study of the P-cycle attention must be given to the form in which phosphorus is present and to the extraction method. This is also borne out by the present study. Large additions in available P are only found upon burning. This is rapidly lost either through leaching and uptake but a possible transformation into non-extracted other forms of P is highly likely. Soils high in Ca and Al may show rapid P-fixation after burning while also the pH is drastically changed which also has an effect on the Al-chemistry. During the fallow no significant effect can be seen in the available P values as analyzed but a possible accumulation may be in the organic form which upon mineralization is fixed as Al-phosphate. Such a mechanism may be partly responsible for the high P values upon burning, the Kurtz and Bray extraction being specific for aluminium phosphates. Phosphate fractionation studies therefore appear to be a necessity for elucidating the role of P in the shifting cultivation cycle. These are presently undertaken, the results not being available yet at this time of reporting.

(iii) Organic matter

The build-up and decomposition of organic matter during the fallow and cropping periods are important factors related to the organic P content and the ability of the soil to keep exchangeable nutrients in the cycle. Nye and Greenland (1960) state that it is generally agreed that soil humus (in this context all organic matter not containing recognizable plant remains) increases in amounts under the fallow.

The determination of organic C as an indirect measure for quantity of organic matter is still the most practical method whereas % N may give indications to its quality and N supplying power. Zinke et al (op cit) report highest amounts of C upon burning and 1 year thereafter followed by a decrease towards the middle of a 10 year cycle, the C content at the end of the fallow approaching that of the old unburned forest control field. The N content follows more or less the same trend but total N in surface and subsoil is highest in the period immediately after the burn.

Popenoe found a general decrease in organic matter after burning and a slow build-up in the fallow, already noticeable after 2 years. Reynders states that the organic matter content of the A1 horizon shows little variation during the cultivation and regeneration periods. The present study also provides little evidence for a build-up of organic matter during the fallow although some increase in C and N is observable after the 4th year. Whether this is significant can only be assessed if a full statistical analysis is made of all analytical evidence from the individual samples. The mean values for the fields having replicates already indicate that a large variation can be expected (see Appendix 1). Coulter (1950) observes that with limitation the N content of the soils in Malaysia could be utilized as one criterion for following regeneration of a degraded soil. Our results do not indicate such a simple relationship and it is unlikely that % N will signify progression in regeneration during the cycle. The above made comparisons illustrate how conflicting the results obtained in the various studies can be. Discrepancies between results appear to be more severe for the bush/fallow period than for the cropping period. This may be a pointer to the likely causes. When studying in detail the methodology employed in the referred to studies it become apparent that all have two factors in common. Firstly, sampling in the cropping period is done in the same field whereas sampling for the bush/fallow stages is done in different fields and the assessment of changes in nutrients during the cycle is done indirectly. Secondly, none of the studies gives attention to the natural variability of soil properties which may be present.

The natural variability in soil properties within one field, or between fields of one soil series is a serious limitation in studying the effect of one or more external factors upon such properties. This point is frequently made by Nye and Greenland (1960) and has been recently emphasized again by Ahn (1974). Bailey (1964) made a detailed study on the variation of chemical properties of a range of soils used for shifting cultivation in Sarawak and the results of this study indicate the futility of comparing analytical data from one observation point in a particular field with those of another field obtained by similar means. The coefficient of within site variation (C.V.) he arrived at for upland soils of similar nature as used in this study are given in Table 2. Beckett and Webster (1972) reviewed from a multitude of sources the variability of some soil properties and give some indicative C.V.'s which can generally be expected (see Table 2). Gillman (1976) investigated the C.V.'s of chemical properties of red basaltic soils under rainforest in North Queensland, Australia, and the values shown in Table 2

Table 2 - Coefficients of within site variation (C.V.) in % of some chemical properties of soils

Element	Bailey (1964) (Sarawak, upland soils)	Beckett and Webster (1971) (in general)	Gillman (1976) (Queensland, Aus. basalt soils)
Ca	20 - 50	10 - 40	12 - 48
Mg	10 - 20	-	14 - 52
K	20 - 50	35	5 - 34
av.P	5 - 50	40 (20.natural condition)	5 -146
% N	5 - 40	10 - 20 (10.natural condition)	4 - 16
% C	2 - 30	-	7 - 18.

Note
According to Beckett and Webster C.V. in between field generally is 25% for C and N, 35 - 50% for K, P, Mg and Ca.

may be representative for the variability which can also be expected under natural conditions in Sarawak. From this table it is quite apparent that homogeneity in particular of P, Ca, Mg and K values is a far cry from reality.

In natural forest with soils having low to very low levels of plant nutrients the quantity and quality of biological activity varies greatly over that distances. Burning causes a similar effect as can normally be observed by the very irregular stand of the crops in fields under shifting cultivation. Beckett and Webster (op cit) point out that for natural forest as much as half the C.V. is present within a few m^2, while for cultivated fiels this is even more. They also refer to studies indicating that the variation in P, Ca, Mg and K within series has a median value of 58 % C.V.

The present study was set up to circumpass as much as possible natural variability by distinguishing slope situation as a major factor in causing variability and by introducing replicates. The complete analytical work on the individual surface samples for each site still awaits completion but the tentative conclusions based on the analyses of the bulk samples per site already indicate that the variability between fields having the same slope situation and the same length of fallow period is too great to allow making reliable detailed conclusions on the effect of the fallow period on the nutrient cycle. Comparing e.g. field 1 with the replicate 1a and field 3 with the replicate 3a (Appendix 1) learns that particularly Ca shows a great variability. This confirms the observations made by Bailey (1964) and Gillman (1976) who came to the conclusions that Ca always has the greatest C.V.

The results sofar also indicate that one important factor, namely the number of cultivation cycles a particular field has been put through must be introduced in studies of this nature in order to get statistically reliable results.

The noted discrepancies in the results of studies on shifting cultivation could therefore be easily caused by the variability of chemical soil properties present between the sampled fields. The use of indirect methods to study the effect of shifting cultivation on soil properties would only give reliable results if a statistical analysis of the C.V.'s is incorporated in the study, the C.V.'s becoming more important with lower levels of available plant nutrients. In comparing results obtained by independent studies in tropical areas an added difficulty is the variability in ecology of which in particular soil type and climate are important factors.

It should be noted that the studies by Popenoe and Reynders were made on relatively fertile soils with high Ca levels. Altitude and climate play a role in the accumulation and decomposition of organic matter which in its turn has a direct effect on exchangeable nutrients, phosphate status and leaching regime. Therefore, even if the results obtained by the various studies would be reliable, care must be excercised in extrapolating results beyond the site specific ecology.

Despite the many shortcomings and the incompleteness of the study sofar it may be tentatively concluded that for the local situation in Sarawak the effect of the bush/fallow cycle as far as available nutrients is concerned is to balance mainly losses due to leaching and accelerated erosion and to accumulate in the living vegetation sufficient nutrients to support one crop of rice upon the burn of the felled forest. The level of nutrients increases greatly upon the burn but they virtually drop to the initial pre-burn levels in about 8 months. Leaching and erosion may account for most of these losses. For P, transformation into other, non-available forms may be possible and should be further investigated. There is

little evidence for a build-up of organic matter during the fallow period. These results confirm practical field experience that a good burn is a prerequisite for a good harvest.
A direct relationship between quantity and quality of vegetation and the nutrients supplied for the cropping season can therefore be expected and shortcutting the fallow period will have a direct negative effect on crop productivity. This is also borne out by the facts. The very low levels of nutrients commonly found in Sarawak subsoils would make it very difficult to restore original fertility through a new cycle of vegetation within a reasonable time and the effect of every cropping period, even as short-lived as it may be, is rapid degeneration.

CONCLUSION

Since the time the call was made for more detailed information on the role of the fallow on shifting cultivation little headway has been made due to errors in methodology as indicated. It is suggested that the only possible way to remedy the apparent lack in our knowledge is to set up studies in specific sites selected on the overall ecology. Prestudies should be made to assess the C.V.'s of properties to be investigated. Changes should be carefully monitored, covering a full cycle at each specific site. Sampling procedures and analytical methods should be standardized.

ACKNOWLEDGEMENT

The logistic support given by the Soils Division, Department of Agriculture in Sarawak during the field stage of this study is greatly appreciated. Financial support was received from the Executive Board, Royal Tropical Institute, Amsterdam, while the analytical work was carried out by the laboratories of this Institute.

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MAJOR NUTRIENT REQUIREMENTS OF OIL PALMS ON DEEP ACID PEAT IN MALAYSIA.

by

S.P. CHEONG and S.K. NG

INTRODUCTION

Deep peat i.e. > 2 metres in depth, is generally considered unsuitable for the cultivation of most tree crops, being highly acidic ∠ low in available nutrients including ∠and micro-nutrients. In Peninsular Malaysia, peat which is composed of mainly partially decomposed plant residues has been reported to cover about 2 million acres and is commonly found overlying alluvial clay (Coulter 1957). Many experiments have been carried out on peat to study the nutritional requirements of a wide range of short term crops such as pineapples (Tay et al 1968), sweet potatoes (Chew 1970), tomatoes (Joseph et al 1970), maize (Lim et al, Kanapathy 1972) and tapioca (Lim et al 1973, Chan and Tan 1973) whereas investigations on perennial tree crops are relatively limited.

Oil palms planted on deep acid peat are known to suffer from many nutritional disorders, such as Peat Yellows which has been attributed mainly to potassium shortage (Ng and Tan 1974) and Mid-Crown Chlorosis which has been shown to be caused by copper deficiency (Ng et al 1974, Cheong and Ng 1976). Boron deficiency has also been observed on oil palms planted on deep peat. However, with regards to the major nutrient needs of oil palms on deep peat, little published information is available although response to potash has been reported (Hew, pers. comm.). In view of the considerably large area of peat which has been planted with oil palms, particularly in the Lower Perak District in Peninsular Malaysia as well as in the Labuk Valley in Sabah, amounting to more than 10,000 ha., it is equally important to ascertain the major nutrient requirements of oil palms on deep peat so that proper nutrient balance can be provided. Towards this end, the experimental findings of a 2^5 NPKMgCa factorial fertiliser trial on a 1961 oil palm planting on deep acid peat are presented.

EXPERIMENTAL

A 2^5 NPKMgCa factorial experiment was established in May 1968 on a mature oil palm planting on forest peat of about 2.5 metres depth. The palms were of Dura x Tenera origin planted on ex-pineapple land in October 1961 at 136 palms/ha. (55/acre). The experiment was replicated once, with a total of 32 treatment plots and in each plot there were 24 recording palms which were demarcated by guard trenches about 1 metre deep. Two levels of N, P, K, Mg and Ca manuring were tested and the rates of fertiliser application are given in Table 1.

Manuring of sulphate of ammonia was split into 2 equal applications a year in February/March and August/September whereas C.I.R.P., muriate of potash, kieserite and limestone dust were applied once a year in February/March. The fertilisers were broadcasted around the palms within the weeded circle of about 2 metre radius.

RESULTS AND DISCUSSIONS

1. Effects on Vegetative Growth

The treatments produced notable effects on frond size and colour but unfortunately, no vegetative measurements were recorded till 1975. As shown in Table 2, N markedly reduced the frond length, frond area and frond dry weight but significantly increased the frond production. The main effects of P were similar to that of N except that the reduction in frond dry weight was not significant. The Ca treatment however, showed better frond development with evidently greater frond length, frond area and frond dry weight although frond production was significantly lowered. Applications of K and Mg apparently did not affect the vegetative growth characters significantly, except for an increase in frond dry weight with K.

Marked NPCa interactions on frond development were noted as indicated in Table 3. The N_1P_1 treatments were more depressive on frond length, frond area and frond dry weight than N_1 or P_1 alone but the frond production was significantly higher. Apparently N showed greater depressive effects on frond length, area and dry weight than P. The presence of Ca apparently counteracted against the adverse effects of N and P in terms of frond characters only.

A striking if not spectacular influence of certain treatments in the experiment was on frond chlorosis and senescence. Census carried out in 1970 and 1974, as shown in Table 4, strongly indicated that applications of N and P induced marked chlorosis and enhanced frond senescence with the combination of N and P having the greatest effects.

2. Effects on Leaf Nutrient Status

Leaf analysis was started in 1970 and the main effects of treatments on mean leaf nutrient status of 1970-1974 are presented in Table 5, while the annual leaf analysis results are given in Appendix 1.

N, P and K markedly raised the leaf N, P and K levels respectively, whereas only moderate increases in leaf Mg and Ca level were obtained in the Mg and Ca treatments respectively. The response in leaf N status to N manuring was more evident in the earlier years as shown in

Appendix I. From the leaf nutrient levels only K was found to be deficient as indicated in the Ko treatment.

The N and P treatments produced excessively high leaf P levels whereas Ca application showed evident depressive effects on P. Apparently the Mg and Ca treatments lowered the leaf K status as might have been expected but not significantly. Conversely a marked decline in leaf Mg status was obtained in the K treatment, whereas an increase was caused by N application. The leaf Ca status was significantly raised in the P treatment but lowered in the N and K treatments, although the N effect was less marked in the later years. A notable decrease in leaf N status was also recorded in the K treatment.

Very significant NP, NCa and PCa interactions on leaf P levels were obtained as shown in Table 6. The NP interaction revealed that the response in leaf P status to N application was small in the absence of P but a synergistic effect between N and P in raising the leaf P status to an excessively high level was observed. In the absence of Ca, the manuring of N and P also produced very high leaf P status but these effects were mitigated with Ca application.

3. Effects on Soil Nutrient Status

The chemical analysis of peat samples collected within the palm manuring circle of the control, N, P, K, Mg and Ca plots are presented in Table 7. The control showed that the peat was highly acidic, has a high organic matter (N, C and P) status with a wide C/N ratio but low in potassium and moderately high in magnesium and calcium reserves.

Application of sulphate of ammonia narrowed the C/N ratio and limestone dust apparently produced a similar but less marked effect. However the C/N ratios were still considerably high. The C.I.R.P. treatment increased the soil P status to extremely high levels and the NH_4F fraction was significantly higher than the 0.1N NaOH fraction.

The soil Ca status was also raised and the soil pH slightly improved with C.I.R.P. application. Muriate of potash, kieserite and limestone dust significantly raised the soil K, Mg and Ca levels respectively, with a large proportion of the K and Mg in the exchangeable fraction, which particularly reflects the low reserve and buffering capacity of potassium in peat. The soil acidity was considerably reduced with limestone dust and a marked increase of 1 pH unit was obtained as compared to the control.

4. Effects on Yield

The N and P treatments, as shown in Table 8, significantly decreased the cumulative yield of fresh fruit bunches with markedly lower bunch weight as well as bunch number. The K treatment, however produced evident improvements in cumulative yield, bunch weight and bunch number. A similar notable yield increase was obtained in the Ca treatment but the response in bunch weight was less marked. The favourable yield response is probably attributed to the liming effect as the leaf and soil Ca levels did not indicate Ca to be deficient. Application of Mg showed no significant effects on yield.

The yearly yield responses to the N, P, K, Mg, Ca, NP and KCa treatments are presented in Graph 1. Application of N showed more severe yield depression than P and this difference was significant in the 3rd year and maintained consistently up to the 6th year. In the K treatment, an initial large yield increase was achieved but the response markedly declined after the 4th year and was only marginal in the 6th year. The effect of Ca on yield was initially small but the response increased gradually and was significantly higher than that of K in the 6th year. The Mg treatment showed a small yield increase in all the years.

Marked NP and KCa interactions on the fresh fruit bunch yield were obtained as indicated in Table 9 and Graph 1. The NP combination produced significantly greater depression on yield than N (-20%) or P (-27%) alone. The bunch weight and bunch number were both adversely affected. On the other hand, a higher yield response was obtained in the KCa treatment as compared to the K (+9%) or Ca (+13%) treatment which was attributed mainly to a significant increase in bunch number.

DISCUSSION

The experiment has produced anticipated responses but some were rather unexpected. Thus, the positive effects of potassium on acid peat which is known to be low in potassium status on leaf development and yield of fresh fruit bunches are not really surprising as prior to treatment, available potash supply was already low. The effects of potassium on reducing pinnae chlorosis and frond senescence can be ascribed to the better utilisation of amines and free a acids in protein sythesis (Amberger 1975) and organic acids in carbohydrate metabolism (Morard 1974). Additionally promotion of stomatal efficiency leading to less transpiratio losses (Morard 1974) may explain the delay in frond senescenc in the K treatment. More effective carbohydrate and protein formation and translocation is likely to be responsible for the greater yield of fruit bunches.

The response to limestone is unlikely to be due to a direct effect of calcium as even in the control, calcium level in the leaf was not deficient. Most probably, improvement in overall nutrient mineralisation and availability due to a rise in soil pH and a better cationic-anionic balance in the plant system are the main mechanisms of calcium action. In this regard, the lack of any significant negative influence of limestone on potassium nutrition as indicated by frond colour and leaf K status is somewhat surprising as Ca/K antagonism is well known. Presumably, greater mineralisation of the organic matter by limestone also released organically bound potassium as Chew (1973) found that liming not only increased available nitrogen but also the uptake of potassium. Thus, it appears that liming is a cheap method of releasing inherent nitrogen as well as potassium in the peat and accordingly the KCa treatment gave the largest yield response.

In contrast, the negative effects of both N and P are highly interesting as such results for oil palm have not been reported before. The striking influence of N and P, especially in combination, in aggravating leaf chlorosis and senescence is likely to be due to an accentuated anionic-cationic imbalance due to the accumulation of free amino-acids, amines and organic acids (Epstein 1972). These conditions lead to a marked loss of photosynthetic tissue, resulting in lower yields. It appears, therefore, that unless the peat medium is adequately supplied with exchangeable bases, marked nutrient imbalances would result with heavy application of N or P.

CONCLUSION

The experiment has indicated that oil palm nutrition on deep acid peat is highly complex with proper nutrient balances holding the key to successful palm growth and productivity. A sound basic understanding of the influence of different fertilisers on nutrient mineralisation and availability is necessary in order to attain optimum palm nutrition. At this juncture, it appears that a combination of limestone and potash gives satisfactory growth and yield responses. However, further research is necessary to elucidate the inter-relationship between major and micro-nutrients since both have such critical effects on the oil palm on deep peat.

ACKNOWLEDGEMENT

We thank United Plantations Berhad for permission to publish this paper and Messrs. H. Mollegaard and Tan Yap Pau for conducting the initial phase of the experimentation.

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Mal. Agr. J. 46, No. 4, 458-468.

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Titl : Major Nutrient Requirements of Oil Palms on Deep Acid Peat in Malaysia.

Running Title : Major Nutrient Needs of Oil Palms on Peat.

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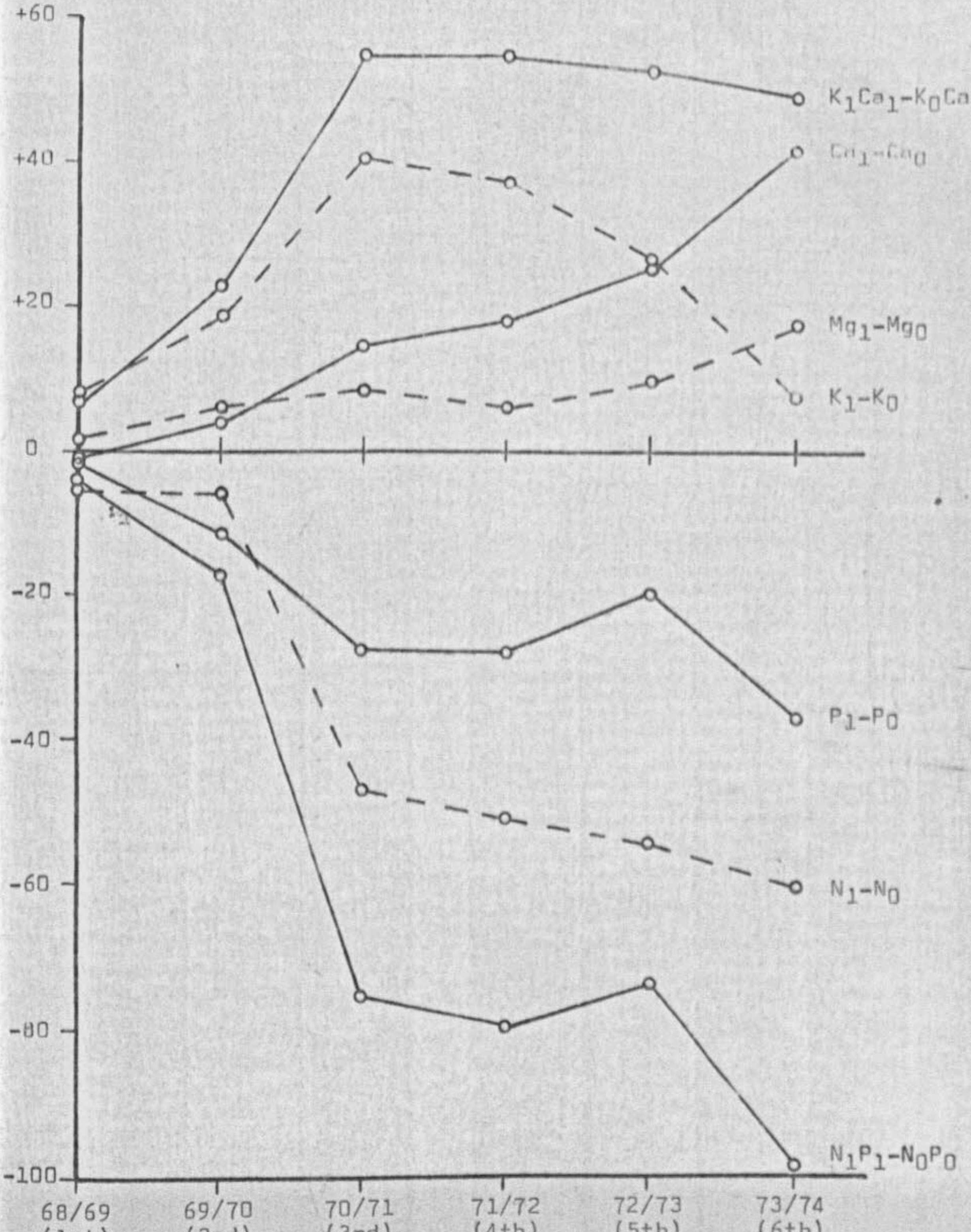
Appendix I : Effects of N, P, K, Mg and Ca Manuring on the Leaf Nutrient Status of Oil Palms on Deep Acid Peat

Treatments	1970 N	1970 P	1970 K	1970 Mg	1970 Ca	1971 N	1971 P	1971 K	1971 Mg	1971 Ca	1972 N	1972 P	1972 K	1972 Mg	1972 Ca
N0	2.66	0.176	0.856	0.428	0.512	2.54	0.164	0.801	0.449	0.589	2.50	0.165	0.751	0.447	0.617
N1	2.82	0.204	0.839	0.423	0.483	2.64	0.198	0.815	0.485	0.558	2.47	0.179	0.757	0.517	0.620
Var. Test	**	**	ns	ns	*	**	**	ns	**	*	ns	*	ns	**	ns
P0	2.74	0.167	0.859	0.437	0.478	2.61	0.154	0.805	0.465	0.539	2.48	0.156	0.739	0.478	0.596
P1	2.74	0.213	0.835	0.434	0.517	2.57	0.208	0.811	0.469	0.608	2.50	0.188	0.769	0.486	0.640
Var. Test	ns	**	ns	ns	**	ns	**	ns	ns	**	ns	**	ns	ns	ns
K0	2.78	0.195	0.692	0.471	0.514	2.62	0.187	0.594	0.532	0.597	2.54	0.177	0.581	[illegible]	0.633
K1	2.70	0.186	1.003	0.399	0.481	2.56	0.175	1.022	0.402	0.549	2.44	0.166	0.927	0.422	0.604
Var. Test	**	ns	**	**	*	ns	ns	**	**	**	**	ns	**	**	ns
MgO	2.74	0.191	0.850	0.423	0.498	2.59	0.181	0.814	0.454	0.584	2.49	0.174	0.769	0.468	0.630
Mg1	2.74	0.190	0.844	0.448	0.497	2.59	0.181	0.802	0.480	0.563	2.49	0.169	0.739	0.496	0.606
Var. Test	ns	ns	ns	ns	ns	ns	ns	ns	*	ns	ns	ns	ns	ns	ns
CaO	2.76	0.203	0.865	0.422	0.491	2.62	0.198	0.840	0.461	0.557	2.52	0.181	0.778	0.484	0.608
Ca1	2.72	0.178	0.830	0.449	0.504	2.57	0.164	0.776	0.473	0.589	2.46	0.163	0.730	0.480	0.628
Var. Test	ns	**	ns	*	ns	ns	**	*	ns	*	*	**	ns	ns	ns
LSD.(P=0.05)	0.06	0.009	0.038	0.025	0.025	0.07	0.018	0.055	0.024	0.026	0.05	0.013	0.053	0.028	0.052

Treatments	1973 N	1973 P	1973 K	1973 Mg	1973 Ca	1974 N	1974 P	1974 K	1974 Mg	1974 Ca
N0	2.49	0.166	0.879	0.456	0.500	2.29	0.165	0.809	0.413	0.529
N1	2.54	0.184	0.899	0.490	0.470	2.30	0.206	0.871	0.422	0.495
Var. Test	ns	*	ns	*	ns	ns	*	*	ns	ns
P0	2.54	0.155	0.897	0.474	0.463	2.32	0.157	0.850	0.413	0.489
P1	2.49	0.195	0.881	0.472	0.507	2.27	0.215	0.830	0.421	0.534
Var. Test	ns	**	ns	ns	**	ns	**	ns	ns	*
K0	2.57	0.181	0.651	0.525	0.520	2.36	0.195	0.744	0.439	0.518
K1	2.46	0.169	1.127	0.421	0.450	2.24	0.177	0.936	0.395	0.505
Var. Test	**	ns	**	**	**	**	ns	**	**	ns
MgO	2.52	0.176	0.905	0.457	0.489	2.28	0.190	0.864	0.405	0.526
Mg1	2.51	0.174	0.873	0.489	0.432	2.31	0.182	0.815	0.429	0.497
Var. Test	ns	ns	ns	*	ns	ns	ns	ns	*	ns
CaO	2.53	0.187	0.911	0.473	0.475	2.30	0.206	0.873	0.422	0.482
Ca1	2.51	0.163	0.867	0.473	0.435	2.29	0.166	0.807	0.412	0.542
Var. Test.	ns	**	ns	ns	ns	ns	*	*	ns	**
LSD.(P=0.05)	0.06	0.014	0.079	0.024	0.030	0.07	0.031	0.055	0.023	0.036



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-40
-60
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Ca_1-Ca_0
Mg_1-Mg_0
K_1-K_0
P_1-P_0
N_1-N_0
$N_1P_1-N_0P_0$
68/69 (1st)
69/70 (2nd)
70/71 (3rd)
71/72 (4th)
72/73 (5th)
73/74 (6th)
YEAR OF CROPPING

Table 4 Effects of NPKMg and Ca on Frond Chlorosis and Senescence

Treatment Plots NPKMgCa	September 1970 Mean No. of Fronds/Palm			April 1974 Mean No. of Fronds/Palm		
	Chlorotic	Semi-Desiccated	Total	Chlorotic	Semi-Desiccated	Total
00000	3.3	0.1	3.4	6.4	1.7	8.1
10000	6.7	4.4	11.1	6.0	6.5	12.5
01000	8.8	4.1	12.9	9.4	6.8	16.2
00100	0.7	0	0.7	4.2	0.9	5.1
00010	4.5	0.3	4.8	6.0	1.6	7.6
00001	1.4	0.1	1.5	3.0	0.5	3.5
11000	13.7	12.4	26.0	8.8	12.2	21.0

Table 6 : NP, NCa and PCa Interactions on Mean Leaf P Status (Frond 17 % d.m. : 1970-74)

NP Interaction	P_0	P_1
N_0	0.157	0.178
N_1	0.159	0.230
PCa Interaction		
Ca0	0.159	0.232
Ca1	0.157	0.176
NCa Interaction	**Ca0**	**Ca1**
N_0	0.171	0.163
N1	0.219	0.169

Mean LSD.(P=0.05) = 0.017

MAJOR NUTRIENT REQUIREMENTS OF OIL PALMS
ON DEEP ACID PEAT IN MALAYSIA

LIST OF TABLES

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MAJOR NUTRIENT REQUIREMENTS OF OIL PALMS ON DEEP ACID PEAT IN MALAYSIA

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MAJOR NUTRIENT REQUIREMENTS OF OIL PALMS ON DEEP ACID PEAT IN MALAYSIA

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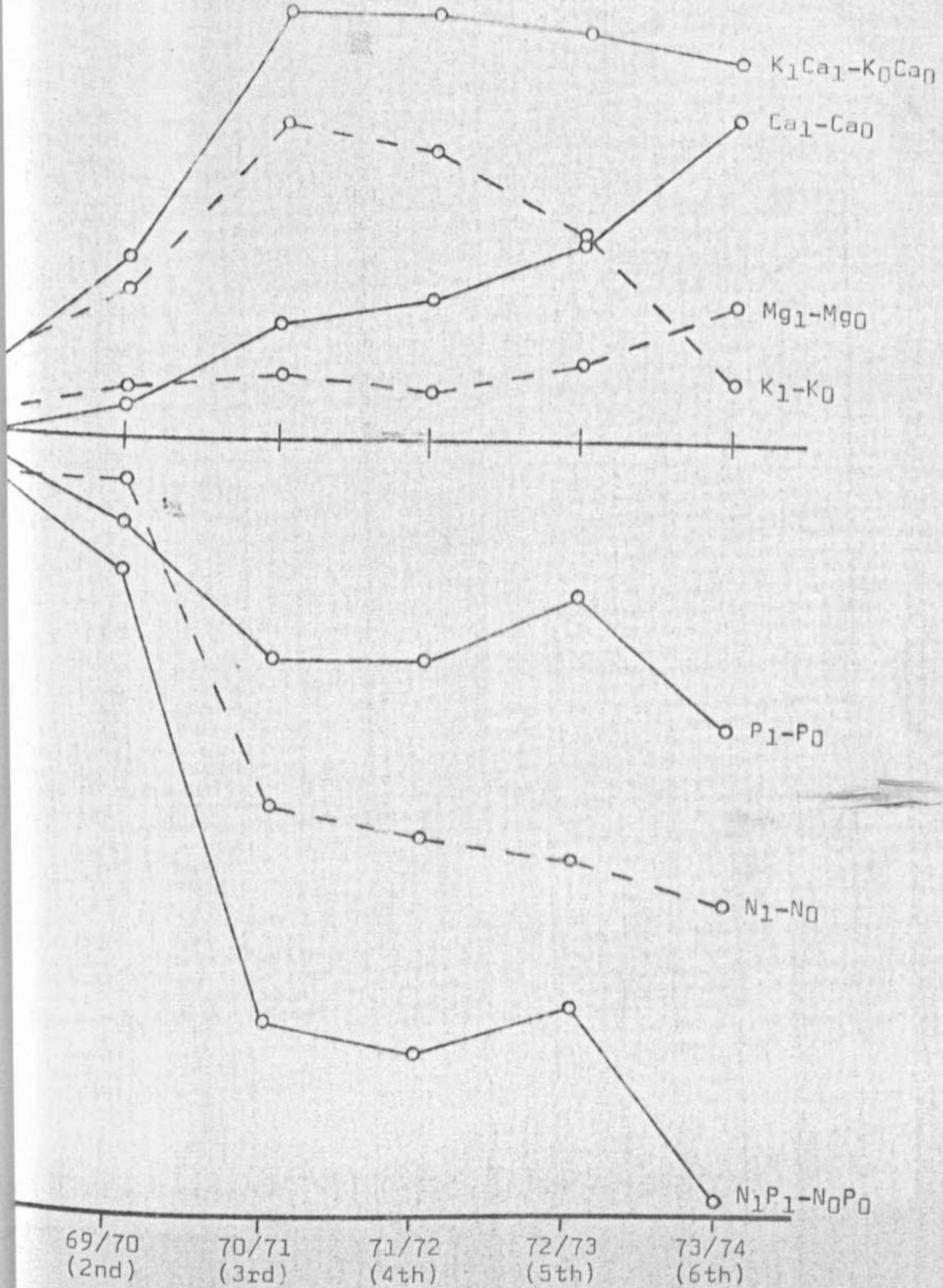

PAPER No.56 MAJOR NUTRIENT REQUIREMENTS OF OIL PALMS ON DEEP ACID PEAT IN MALAYSIA

S.P. Cheong and S.K. Ng

Table 1 : Fertiliser Application Rates (Kg/Palm/Year) 1968-73

Fertiliser		Level of Application 0	1
Sulphate of Ammonia	(21% N)	Nil	6
Christmas Island Rock Phosphate	(≏36% P_2O_5)	Nil	6
Muriate of Potash	(60% K_2O)	Nil	6
Kieserite	(26% MgO)	Nil	3
Limestone Dust	(≏45% CaO)	Nil	6

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Table 2 : Effects of NPKMg and Ca on Frond Length, Area, Dry Weight and Production

Treatments	Frond 9 (July 1975)			Frond Production
	Length (m)	Area (m^2)	Dry Wt. (kg)	Jul.'74-Jul.'75
N_0	5.28	9.61	4.24	19.7
N_1	4.57	7.84	3.80	21.7
Var. Test	**	**	**	**
P_0	5.20	9.25	4.06	19.4
P_1	4.64	8.19	3.97	22.0
Var. Test	**	**	ns	**
K_0	4.96	8.70	3.91	20.7
K_1	4.88	8.74	4.12	20.7
Var. Test	ns	ns	ns	ns
Mg_0	4.94	8.73	3.98	20.8
Mg_1	4.90	8.71	4.06	20.6
Var. Test	ns	ns	ns	ns
Ca_0	4.74	8.20	3.82	21.3
Ca_1	5.10	9.24	4.22	20.1
Var. Test	**	**	**	**
LSD.(P=0.05)	0.18	0.55	0.22	0.53

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Table 3 : NPCa Interactions on Frond Length, Area, Dry Weight and Production

Treatments	Frond 9 (July 1975) Length (m)*	Area (m^2)**	Dry Wt. (Kg)***	Frond Production Jul.'74-Jul.'75
$N_0P_0Ca_0$	5.50	9.75	4.16	18.5
$N_1P_0Ca_0$	4.67	7.85	3.61	20.3
$N_0P_1Ca_0$	4.96	9.07	4.13	21.2
$N_1P_1Ca_0$	3.83	6.14	3.37	25.2
$N_0P_0Ca_1$	5.49	10.17	4.37	19.1
$N_1P_0Ca_1$	5.15	9.24	4.11	19.8
$N_0P_1Ca_1$	5.15	9.43	4.31	20.1
$N_1P_1Ca_1$	4.62	8.13	4.09	21.5
LSD.(P=0.05)	0.26	0.77	0.31	0.75

* Length of rachis
** Measured according to Hardon et al (1969)
*** Measured according to Corley and Hardon (1970).

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Table 5 : Effects of NPKMg and Ca Manuring on Leaf Nutrient Status

Mean Nutrient Levels of Frond 17 (% d.m.) 1970-74

Treatments	N	P	K	Mg	Ca
N_0	2.50	0.167	0.819	0.439	0.549
N_1	2.56	0.194	0.836	0.467	0.525
Difference	+0.06	+0.027	+0.017	+0.028	-0.024
P_0	2.54	0.158	0.830	0.453	0.513
P_1	2.51	0.204	0.825	0.456	0.561
Difference	-0.03	+0.046	-0.005	+0.003	+0.048
K_0	2.57	0.187	0.652	0.502	0.556
K_1	2.48	0.175	1.003	0.408	0.518
Difference	-0.09	-0.012	+0.351	-0.094	-0.038
Mg_0	2.52	0.182	0.840	0.441	0.545
Mg_1	2.53	0.179	0.815	0.468	0.529
Difference	+0.01	-0.003	-0.025	+0.027	-0.016
Ca_0	2.55	0.195	0.853	0.452	0.523
Ca_1	2.51	0.167	0.802	0.457	0.552
Difference	-0.04	-0.028	-0.051	+0.005	+0.029
LSD (p=0.05)	0.06	0.017	0.056	0.025	0.034

Table 7 : *Effects of NPKMg and Ca Fertilization on the Nutrient Status of Deep Acid Peat (Sampled August 1975)*

Treatment Plots	Depth cm.	pH H_2O	Loss on Igni-tion %	Total N %	C/N	Phosphorus (ppm.) Total	0.1N NaOH	Acid Fluo-ride	Exch. Cations me/100 gm. K	Mg	Ca	6NHCl Sol. me/100 gm. K	Mg	Ca
Control	0-15	3.4	88.2	1.49	31.4	342	45	11	0.42	0.91	3.68	0.45	1.16	11.14
Control	15-30	3.6	93.1	1.27	37.5	298	32	4	0.44	0.74	4.01	0.48	0.97	10.13
+N	0-15	3.6	88.4	1.49	28.1	322	93	15	0.34	1.05	3.37	0.61	2.33	13.06
+N	15-30	3.6	90.5	1.28	36.0	270	31	2	0.44	0.76	2.97	0.46	0.99	7.34
+P	0-15	3.9	83.6	1.39	31.6	9210	946	2795	0.22	1.77	18.54	0.33	2.08	63.17
+P	15-30	3.8	88.9	1.10	38.9	3562	864	1196	0.25	1.46	12.57	0.48	2.02	53.01
+K	0-15	3.7	87.7	1.28	34.9	398	58	14	4.37	0.86	2.73	4.39	1.05	8.15
+K	15-30	3.4	93.0	1.26	37.8	301	48	20	5.17	0.75	3.32	5.20	0.89	10.36
+Mg	0-15	3.6	86.8	1.44	30.1	415	88	30	0.68	4.26	4.19	0.69	5.55	11.78
+Mg	15-30	3.4	92.7	1.11	38.1	300	115	51	0.77	4.07	5.31	0.80	6.64	12.57
+Ca	0-15	5.4	82.7	1.46	29.7	485	52	7	0.21	2.86	68.35	0.49	4.50	151.74
+Ca	15-30	4.8	86.2	1.22	35.7	649	77	18	0.31	3.11	69.38	0.37	6.11	152.08

Table 8 : Effects of NPKMg and Ca on Fresh Fruit Bunch Yield (1968-74)

Treatments	Mean FFB. Yield/Palm Per Year(Kg)	Mean Bunch Wt. (Kg.)	Mean No. of Bunches/Palm Per Year
N0	169	11.7	14.2
N1	133	10.6	12.3
Var. Test	**	**	**
P0	162	11.5	13.8
P1	140	10.8	12.6
Var. Test	**	*	**
K0	140	10.8	12.7
K1	162	11.5	13.9
Var. Test	**	*	**
Mg0	147	10.9	13.1
Mg1	155	11.4	13.4
Var. Test	ns	ns	ns
Ca0	142	10.9	12.7
Ca1	160	11.4	13.7
Var. Test	**	ns	**
LSD.(P=0.05)	10.8	0.69	0.49

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Table 9 : NP and KCa Interactions on Fresh Fruit Bunch Yield (1968-74)

Treatments	Mean FFB. Yield/Palm Per Year (kg)	Mean Bunch Weight (kg)	Mean No. of Bunches/Palm Per Year
N_0P_0	176	12.0	14.3
N_0P_1	163	11.3	14.1
N_1P_0	148	10.9	13.4
N_1P_1	119	10.4	11.3
K_0Ca_0	129	10.4	12.1
K_0Ca_1	150	11.2	13.2
K_1Ca_0	156	11.5	13.4
K_1Ca_1	170	11.6	14.4
LSD. ($P=0.05$)	15.3	0.97	0.35

ABSTRACT

EFFECTS OF SOME SOIL MANAGEMENT ON SOIL MOISTURE RETENTION AND ON THE GROWTH OF CORN AND MUNG BEAN

Effects of soil managements such as mulching of organic matter, intertillage practice and subsoiling on intake and storing of rain water into soil were evaluated on a Reddish Brown Lateritic soil, during the corn growing period and the succeeding Mung bean growing period in the rainy season, and during the fallow in the dry season. In the field experiments, the amounts and distributions of available moisture retained by 1m deep soil were surveyed periodically. The responses of the plants to the treatments were also examined.

In the corn cultivation, mulch of rice straw (4.7ton/ha) was effective in holding soil available moisture throughout the growing period, and it increased the corn yield. Appreciable effects in holding soil moisture and increase of the yield were also observed in the intertillage treatment which was given several times during the vegetative growth stage. However, subsoiling of up to ... in depth with 80cm intervals failed to increase total available moisture in soil and the yield. The different levels of soil moisture obtained by the treatments were mainly related to the conditions of soil surface, that is, the degrees of crust formation, which governed infiltration of rain water.

In the Mung bean cultivation, mulch of cornstalk (5ton/ha), intertillage and subsoiling increased the amounts of available moisture in soil on the whole, but the yield did not responded to the treatments.

In the dry season fallow, mulching of cornstalk(5ton/ha) was effective to preserve soil moisture and to collect rain water efficiently into soil, and it could provide favorable soil moisture reserves for the succeeding crops. Incorporation of cornstalk (...ton/ha) was effective in holding rain water into soil, but it also accelerated losing of soil moisture during the dry season...

THE BENCHMARK SOILS PROJECTS

An Innovative Approach to Agrotechnology Transfer

L. D. Swindale, J. A. Silva, and F. H. Beinroth

The purpose of this paper is to describe the Benchmark Soils Projects conducted by the Universities of Hawaii and Puerto Rico under two contracts with the U. S. Agency for International Development. It also indicates how, by an extension of some of the work of the projects, it should be possible to establish a network of soil research stations throughout the tropics, and how the concepts of the projects can be used for agroproduction technology transfers. The basis of the research program and of the proposed network is the soil family as defined in the U. S. Soil Taxonomy.

A. The Benchmark Soils Projects

The Projects of the Universities of Hawaii and Puerto Rico were initiated in 1974 and 1975, respectively, under contracts with the United

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States Agency for International Development. The objectives of the projects are to correlate food crop yields on a network of benchmark soils, to determine scientifically the transferability of agroproduction technology among tropical countries and to develop a methodology and create the required infrastructure for expeditious agrotechnology transfer. It is hoped that the projects will assist cooperating tropical countries in Africa, Asia and Latin America in using soil survey information for formulating agricultural development plans and to tap the potential of upland areas for intensive food production.

1. The Soil Families of the Projects

The benchmark soils of the network belong to common soil families as defined in the Soil Taxonomy (Soil Survey Staff, 1975). The soil family is the fifth lowest categoric level of the system. As stated in Soil Taxonomy, the family has been conceived with the intent "to group the soils within a subgroup having similar physical and chemical properties that affect their responses to management and manipulation for use. The responses of comparable phases of all sites of all soils in a family are nearly enough the same to meet most of our needs for practical interpretations of such responses." Soil families have restricted ranges in properties in the horizons of major biologic activity below plow depth. These properties are important to the movement and retention of water and to aeration and include particle-size distribution, mineralogy, temperature regime, and thickness of the soil penetrable by roots. In combination with the characteristics defined by the higher categories to which a family belongs, the family differentiae provide soil groupings that are relatively homogeneous in the properties important to the growth of plants. Soils of the same families should, therefore, have essentially the same management requirements and responses and should have similar potentials for crop production. Consequently, the soil family should have the inherent quality of facilitating agrotechnology transfers.

At this stage of the projects, one family each has been selected for experimentation from the subgroups of Hydric Dystrandepts and Tropeptic Eutrustox. Experiment sites were established on Dystrandepts in Hawaii, the Philippines and Indonesia, and on Eutrustox in Brazil, Hawaii and Puerto Rico. Other families including a family from the Great Group of Tropohumults or Tropudults will be added.

a. Hydric Dystrandepts. One family of soils derived from volcanic ash, the thixotropic, isothermic family of Hydric Dystrandepts is being used in the Philippines, Indonesia and Hawaii in the Benchmark Soils Project of the University of Hawaii. These are well-drained, upland soils used for both plantation crops and diversified agriculture by small farmers. Many are still forested, particularly those on steeper slopes.

The soils have dark brown to dark reddish brown surface layers that are moderately to extremely acid overlying dark brown to reddish brown subsoils that are silty clay to clay in texture, smeary, low in bulk density and slightly to moderately acid. The mineralogy is dominated by amorphous materials. Mean soil temperatures at 50 cm depth are higher than 15° C but lower than 22° C, and the mean summer and winter temperatures differ by less than 5° C. Cation exchange capacities are high and base saturations low. The soils fix phosphorus in forms that are only slowly available to plants.

The soils have good physical conditions for plant growth, but require large amounts of phosphate fertilizers to make them productive. Frequent applications of nitrogen and potassium fertilizers are required along with calcium for high production.

b. Tropeptic Eutrustox. The soils that link the Hawaii and Puerto Rico projects are members of the clayey, kaolinitic, isohyperthermic family of Tropeptic Eutrustox. These are well-drained, red upland soils occurring under savanna or deciduous forest vegetation in subhumid tropical regions. Although they are strongly weathered, they have an appreciable supply of bases and more than 50 percent base saturation in the subsoil. Eutrustox are slightly acid to neutral and are mineralogically dominated by kaolin and iron oxides. Among their adverse properties are a limited water holding capacity, a tendency to compact when cultivated with heavy equipment, and phosphorus deficiency. Their main constraint for agricultural use is the insufficiency of soil moisture for more than three months per year. Eutrustox are extensive in Brazil and tropical Africa and are preferred to immediate development over other Oxisols on account of their high base saturation status.

c. Tropohumults and Tropudults. The extensive red upland soils in the humid regions of tropical Asia are Ultisols; acid soils with red, clayey, dense subsoils. In the warmest parts of these regions the soils belong to the Great Group of Tropudults and in the cooler regions with more humus in the profile, they belong the to Great Group of Tropohumults. The soils are underutilized because problems in their management have not been solved. Several countries have asked the project to concentrate to some extent on these soils. Soil surveys in areas where these soils occur have generally not been detailed enough to provide data for soil y classification. Soil survey and characterization are being done to ify suitable benchmark sites on these soils in the Philippines, esia and Africa.

The Experimental Work of the Projects

The types of experiments being conducted in the projects were established at a workshop on "Experimental Designs for Predicting Crop Productivity with Environmental and Economic Inputs" held in Honolulu in 1974 (Silva and Beinroth, 1975). The three types of experiments being used are called transfer, variety and management experiments.

a. Transfer Experiments. Transfer experiments for testing the hypothesis of transferability are simple, with only 2 variables related to soil family characteristics. P x pH and K x P are the treatment combinations being used on the Dystrandepts and Eutrustox, respectively. The same treatment combinations may differ among families. All other controllable factors, i.e. irrigation, other nutrients, plant protection, and plant density, are maintained near optimum levels so that treatment effects will clear. Each transfer experiment is replicated three times.

The experimental design used in all transfer experiments is a 5^2 partial factorial developed by Escobar and described in the paper by Laird and Turrent of CIMMYT presented at the workshop (Silva and Beinroth, 1975). This design was chosen because it has several good characteristics in addition to the fact that its 13 treatments cover the factor space adequately. These treatments consist of the following combinations of the two variables (coded levels): +.85 +.85, 0 + .85, -.85 + .85, +.40 +.40, -.40 +.40, +.85 0, 0 0, -.85 0, +.40 -.40, -.40 -.40, +.85 -.85, 0 -.85, -.85 -.85. The middle level of the range of treatments had the coded value 0. Two control treatments are also used, the complete control which receives no fertilizer to allow assessment of the native soil fertility and the partial control which receives all added nutrients except the variables.

The primary indicator crop is maize which is grown at all sites. A secondary indicator crop, soybeans, is grown at sites where there is special interest in it and where the work load will allow it.

b. Variety Experiments. It has been decided to use the "best adapted local variety" as the test crop in the transfer experiments. Since varieties differ in their yield potential, it is necessary to evaluate all varieties used in transfer experiments throughout a soil family network under similar conditions at the primary site in each country. To prevent use of varieties that are unresponsive to the variables in the transfer experiments, a factorial combination of two levels of these two variables is superimposed on the variety experiment.

c. Management Experiments. Management experiments on maize and soybeans are installed at each primary site. The objectives of these experiments are (1) to provide information on economic and efficient practices which local farmers might utilize and (2) to provide information for subsequent soil interpretation and land classification. Particular attention will be given to costly inputs and high-energy cultural practices as well as important farmer practices.

d. Experiment Sites.

Primary Sites - A primary site is established in each country on each soil family and consists of an area of about 10 hectares to provide sufficient land for the many experiments envisaged during the life of the project. Transfer, variety and management experiments are conducted at a primary site. The site is located on an existing University or Government research station where possible. Complete weather stations and adequate storage (including water storage) and office facilities are established at each primary site, if these do not already exist.

Secondary Sites - There may be one to three secondary sites on which only transfer experiments are conducted on a soil family in a country. These additional sites are necessary to fully test the transfer hypothesis, and to account for significant, uncontrollable variables. Secondary sites are about one hectare in size, have a complete weather station and water storage facilities, where needed.

e. Climatic Variables. Climate is an uncontrolled variable in the design of agronomic experiments. Hence, it is essential that significant climatic variables be measured at each experimental site to allow a meaningful test of the transfer of agrotechnology from one site to another. Air and soil temperature, rainfall, relative humidity, solar radiation, wind direction and wind speed are monitored at all sites. Pan evaporation is measured on some sites also.

f. Land Capabilities

The soil, yield and climatological data are analyzed by methods of multivariate analysis to produce the desired land potential, capability and transferability information. Wherever available, local yield data and land capability information will be included in the data base to increase the quality of yield predictions at various levels of soil classification to cover a larger group of soils than will be represented by the benchmark soils network. The production capabilities developed for different soils can be used as a first approximation to production targets for these soils in other tropical and subtropical lands.

4. Progress to Date

a. Transfer Experiments. Levels of the phosphorus variable in the Dystrandept and Eutrustox are expressed as ppm P in the soil solution measured according to the method of Fox and Kamprath (1970) while lime levels in the Dystrandept are based on KCl extractable Al according to the method of Kamprath (1970). Potassium levels in the Eutrustox are based on the N ammonium acetate, pH 7.0 extraction method.

Although the experimental designs for the transfer experiments are not complex, strict supervision of field plot work is needed to obtain sound, scientific data. The total number of experiments must be large enough to reduce the variation to an acceptable level.

Hawaii - Four transfer experiments with maize, variety H 610, and three with soybeans, Kahala and Jupiter varieties, have been completed on each of the two secondary sites on the Hydric Dystrandepts in Hawaii. The first two maize experiments harvested have been analyzed. One was a late summer planting (August) on the Kukaiau site and the other a fall planting (October) on the Halawa site. These crops were planted as soon as the sites were prepared to gain experience with the experimental approach and crops in Hawaii. Plantings are being made in May-June for the dry season crop in December-January for the wet season crop now that the sites are fully established.

Maize grain yields for the Kukaiau site (Kukaiau series), which is at 394 meters elevation, increased markedly with the first increment of P over the partial control treatment followed by a more gradual increase with subsequent levels of P (Figure 1). Maximum yield with P was apparently approached at the highest lime rate (1110 kg/ha). The response to lime was relatively small and generally negative at the highest rate of P.

Grain yields for the Halawa site (Niulii series), which is at 485 meters elevation, also showed a marked response to N and P applications over the complete control and a smaller response to P over the partial control (Figure 2). Apparently there was sufficient residual P in the soil so that when N and K were supplied fair yields were obtained. Maximum yield with P was apparently approached with the low and high rates of lime (105 and 1295 kg/ha), but not with the middle rate of lime. Response to lime was generally negative. Both sites were former sugarcane fields which had received P and lime applications in the past. It is of interest that these two fields, which are at slightly different elevations, gave comparable yields of about 6000 kg/ha when both P and lime were applied.

Transfer experiments with soybean varieties Jupiter and Kahala had yields ranging from 2330 to 3140 kg/ha and 3230 to 3830 kg/ha, respectively. Response to P was evident in the early stages of growth, but was not as apparent later.

Philippines - One transfer experiment with maize, variety DMR Comp #1, and one with soybeans, variety TK 5, have been installed and harvested at the primary site at Philippine Union College (PUC), in the Philippines. Response of maize to P was striking in this Hydric Dystrandept. Plants in the control plots which did not receive P died (Figure 3). Response to higher levels of P was smaller. Maximum yield with P was apparently approached at the low (79 kg/ha) and medium (945 kg/ha) levels of lime, while response to P at the highest rate of lime (1748 kg/ha) was erratic. Response to lime was relatively small and was negative in some cases (Figure 3).

The transfer experiment with soybeans indicated a marked response to P over the control plots which was generally followed by continued response

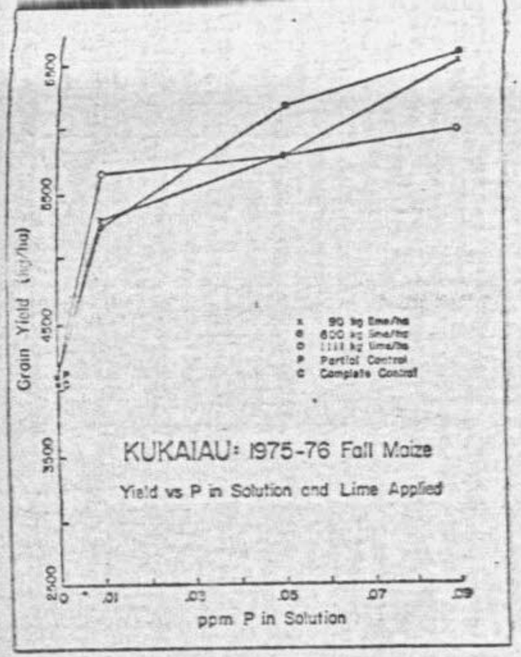

Fig 1. Grain yield versus P in solution and lime applied for secondary site at Kukaiau, Hawaii

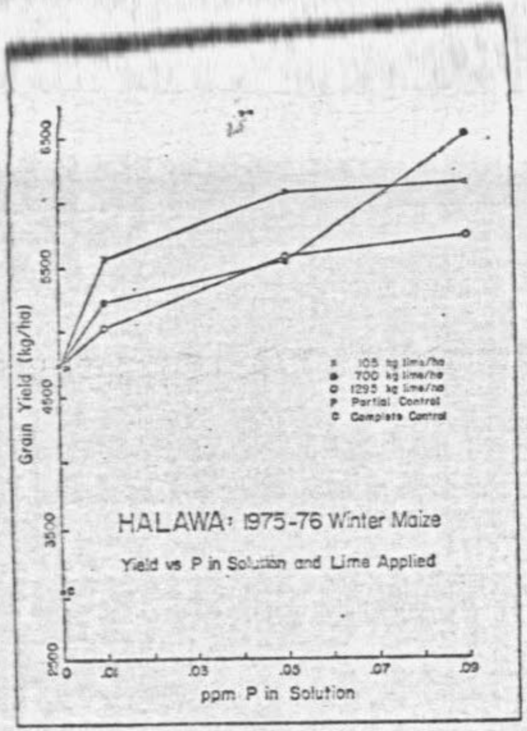

Fig 2. Grain yield versus P in solution and lime applied for secondary site at Halawa, Hawaii

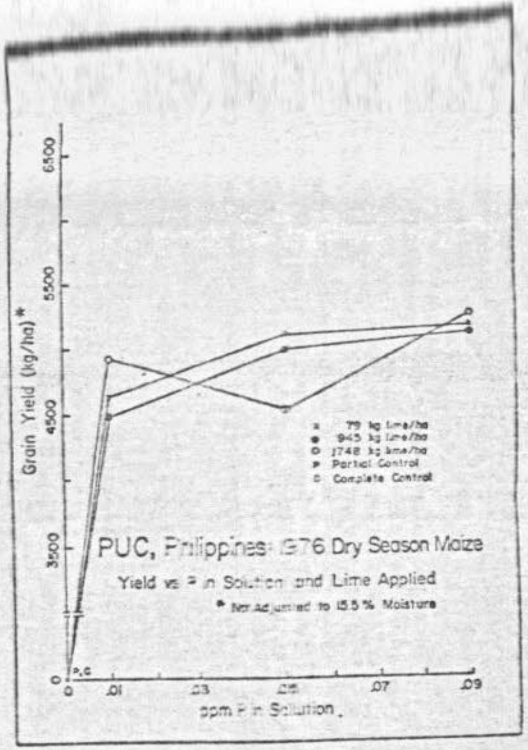

Fig 3. Grain yield versus P in solution and lime applied for primary site at Philippine Union College, Naga City, Philippines

to higher levels of P, but at a lower rate of increase. Maximum yield with P applications was apparently being approached.

Direct comparison of yield levels of maize in Hawaii and the Philippines is not appropriate because the crops were grown in different seasons and a different variety was used in the two locations. However, patterns of yield response were generally similar and indicated that the same family of Hydric Dystrandepts in Hawaii and the Philippines will not grow an acceptable crop (or any crop in the Philippines) without large applications of phosphorus. In addition, response to lime was small or negative in both locations. This tends to support the hypothesis of transferability in a general, practical way and suggests that this family of Hydric Dystrandepts requires P and little, if any, lime for acceptable maize yields.

Indonesia - A primary and two secondary sites have been established in Indonesia on a Hydric Dystrandept. Transfer experiments with maize, variety Bastar Kuning, and also with soybeans, variety Orba, have been installed on each of the sites and are to be harvested shortly. These are the first plantings in Indonesia. A full complement of transfer, variety and management experiments are planned for the next planting.

Puerto Rico - Eight transfer experiments with maize and soybeans have been completed, two with each crop at both the primary and secondary sites established on a Tropeptic Eutrustox near Isabela, Puerto Rico. Maize yiel in the first experiment at the primary site ranged from 6,590 to 11,515 kg/ha. There was a marked increase in yield with the first increment of P, a further increase with the next increment, but none with higher levels of P. Maize yields with the same variety, Pioneer X 306 B, were lower at the secondary site, but the trends were similar to those found at the primary site. Soybean yields from the first two experiments ranged from

683 to 2,872 kg/ha. Plant height measurements for both crops reflect a marked early growth response to P applications, but this trend was less apparent at lower growth stages.

Brazil - Field operations in Brazil were initiated in mid 1976 near Jaiba in northern Minas Gerais. The first two transfer experiments with maize and soybeans have been completed at the primary site on Tropeptic Eutrustox. Plant growth responded strongly to P applications and it is expected that this observation will be substantiated by pending statistical analysis of the grain yield data.

An additional primary site and two secondary sites in Tropeptic Eutrustox have been located in Brazil and are being prepared and equipped for experimentation.

b. Variety and Management Experiments. A variety trial with maize comparing varieties from Hawaii and the Philippines was conducted at the primary site in the Philippines. A management experiment to study the response of maize to chicken manure, which is a recommended local practice, and various levels of N, P, K and lime was also conducted at the site.

Variety trials with maize have been conducted in Puerto Rico with varieties from Australia, Central America, Brazil, Hawaii and the Philippines. Variety trials with maize and also with soybeans have been carried out in Brazil. In addition, two management experiments with maize were conducted in Brazil to study the interactions between varieties, plant populations and levels of P.

c. Other Activities. The project will also provide training in utilization of agrotechnology transfer for professional staff and students in cooperating countries. Hawaii and Puerto Rico project staff and counterpart staff meet at annual coordination meetings to ensure uniformity of technique, discuss experimental results and plan future experiments.

Fellowships are offered to students from cooperating countries. They receive academic training at the University of Hawaii or the University of Puerto Rico and field experience on experimental sites in their home country.

Project results are disseminated through attendance and presentation of papers at various national and international meetings and the conduct of seminars such as the ICRISAT seminar (Swindale ed. 1977) held in January 1976. Project workshops are held in cooperating countries to acquaint appropriate officials with the purposes and benefits of the project and the specific and generalized results.

B. The Soil Research Network

The soil research network that AID supports can be established through formal administrative structures and arrangements, or through cooperative, technical linkages between interested institutions using the soil family as the basis. It can be implemented by expanding the network of benchmark soil locations or by classification, at the family level, of the soils of existing agricultural research stations.

1. Expanding the Benchmark Soils Network

a. Project Families in Other Countries. The three families that will be part of the existing projects undoubtedly exist in more countries than those that will be cooperating fully with the projects. Where they are located, and suitable sites established, they can be added to the network. The Benchmark Soils Projects will assist countries in extending the network to the extent that finances will allow.

b. Additional Benchmark Families. As the value of the soil family concept becomes evident, it is expected that cooperating countries will wish to extend the approach to other soils. In fact, both the Philippines and Indonesia have taken steps to set up their own Benchmark Soils Projects and the Hawaii Project will cooperate with them with this endeavor. These in-country projects will concentrate on soils important in country development plans that are not in families receiving initial emphasis.

It should be easy to add families which vary only slightly from the project families, and for which the cause of the variation has a predictable effect upon crop production. This would include, for example, isohyperthermic or isomesic families of Hydric Dystrandepts for which the effect of the variation -- in mean annual soil temperature -- on crop production can be computed. It would also include, in relation to the clayey, kaolinitic, isohyperthermic family of Tropeptic Eutrustox, the parallel family of Eutrorthox in which the variation from a seasonally dry to a usually moist climate is likely only to increase the reliability of good crop yields without irrigation.

2. Soil and Crop Data Bank

The University of Hawaii has developed and is expanding a computerized storage and retrieval system for soil taxonomic and characterization data known as the Soil Data Bank. The entries of the bank include many soils of important agricultural experiment stations of the tropics. The Projects anticipate to complement this system by a Reference Center for Crop Production Research in the Tropics by soil taxonomic units. Both data files will not only enhance the international communication among pedologists and agronomists, but will also provide suitable mechanisms for expediting transfers of agroproduction technology among tropical countries.

C. Anticipated Results

The number of experiments conducted annually will be sizeable because it is necessary to have 8 to 10 sites in each soil family network for adequate statistical interpretation. Therefore when all sites are established, 18 maize and about 10 soybean transfer experiments, 6 maize and 3 soybean variety experiments and about 8 management experiments with maize and soybeans will be conducted per year per soil family. This will be a total of about 45 experiments per year on all three families.

If the hypothesis of transferability of agrotechnology is not disproven it will enable research results obtained on a soil family in one part of the world to be transferred to the same family existing in another part of the world. This should make research results available throughout the network to countries with common soil families which should result in savings in time and resources, and in a more rapid increase in production.

Crop yields obtained by the projects have been several times local yields and are the result of impressive amounts of agricultural inputs, including irrigation. Only the more advanced farmers with profitable market outlets will be prepared to make the efforts needed to achieve comparable results. However, this does not imply that only high management level technology is transferable. The management experiments should provide information to local farmers with limited resources to indicate how they can economically increase their yields. It is fully recognized that transferred technology can only relate to production targets. Many social and economic questions will need to be answered before production targets become realities.

Land capability schemes developed for the countries of the network should indicate suitabilities of different regions for development under high, medium, or low levels of input, and the probabilities of success of information transfer from the network. This information will be available for incorporation into development plans of cooperating nations. The Soil Data Bank will serve as the link between countries with similar soil families.

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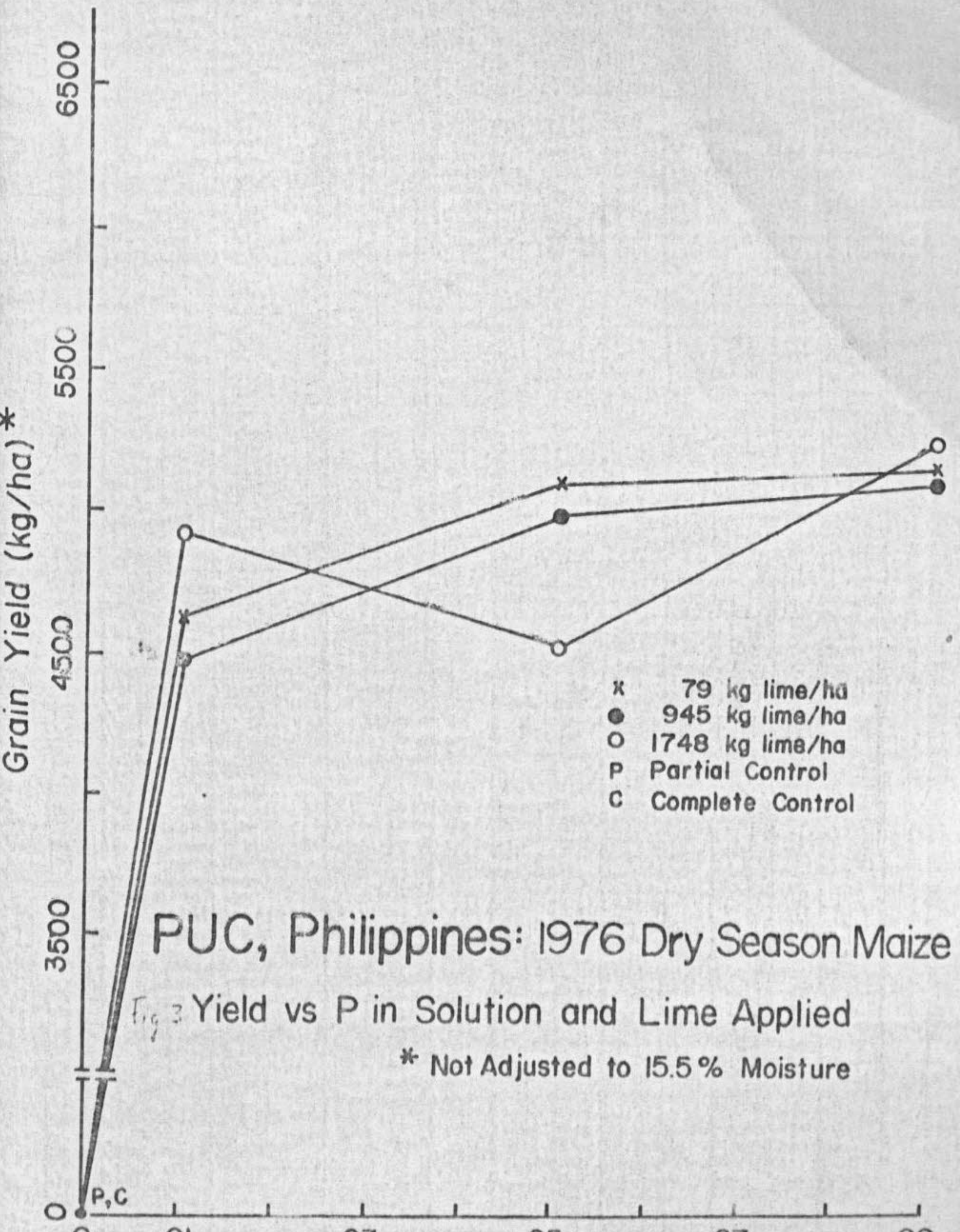
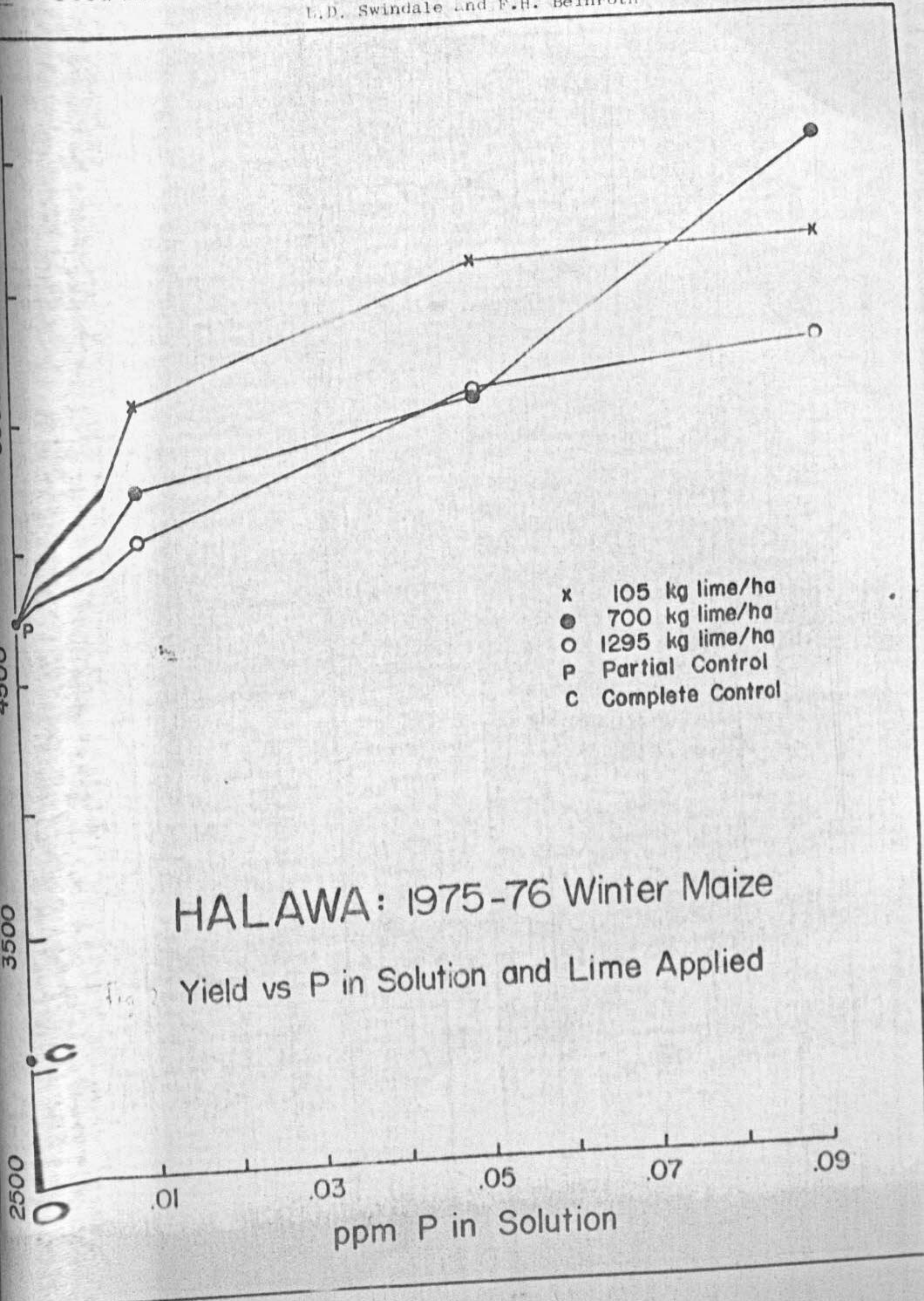
Shortened Title: Benchmark Soils Project

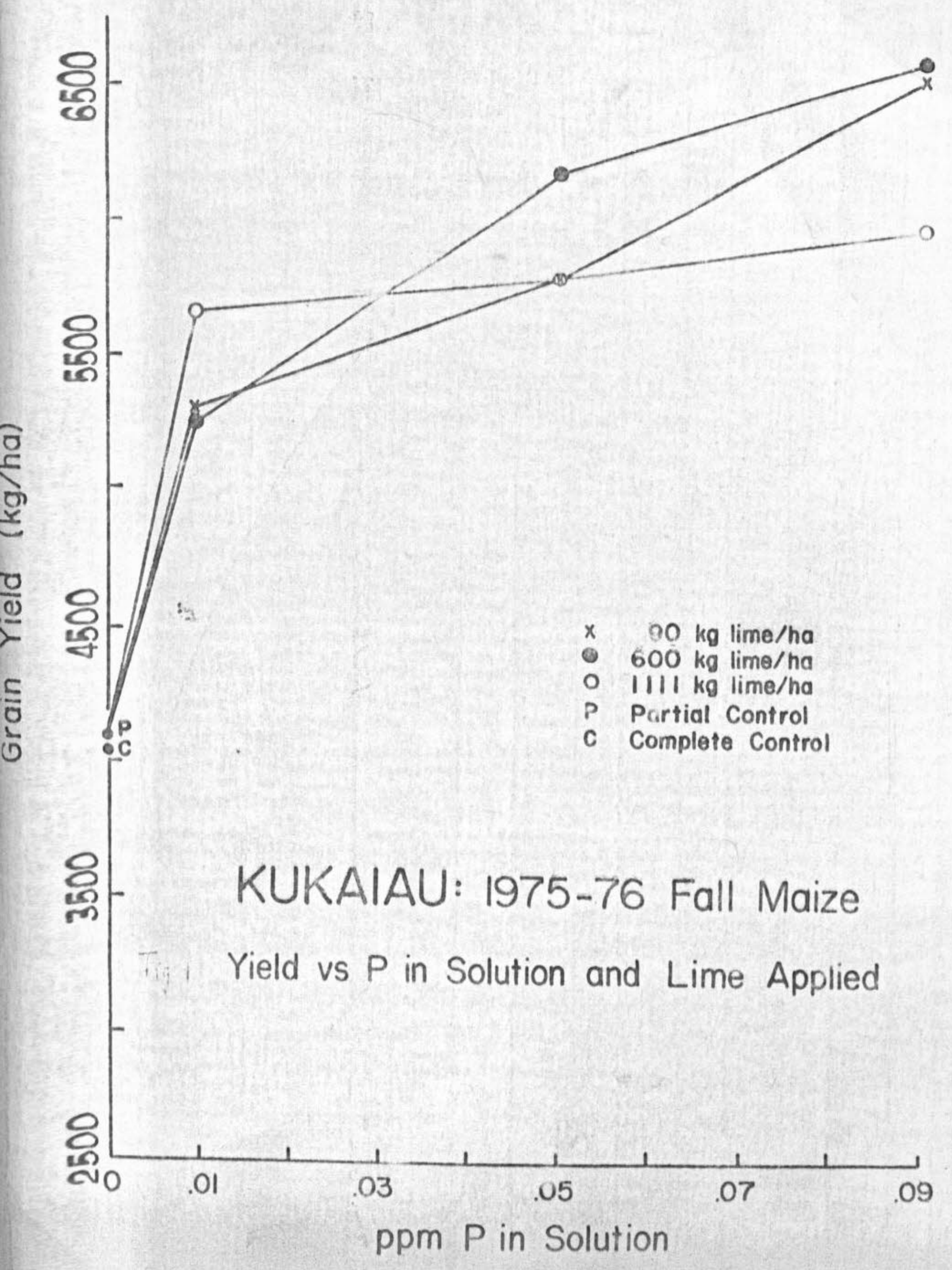


PUC, Philippines: 1976 Dry Season Maize

Fig 3 Yield vs P in Solution and Lime Applied

* Not Adjusted to 15.5 % Moisture


x 105 kg lime/ha
● 700 kg lime/ha
o 1295 kg lime/ha
P Partial Control
C Complete Control
P
C
HALAWA: 1975-76 Winter Maize
Yield vs P in Solution and Lime Applied
2500
3500
4500
0
.01
.03
.05
.07
.09
ppm P in Solution


Grain Yield (kg/ha)
6500
5500
4500
3500
2500
0
.01
.03
.05
.07
.09
ppm P in Solution
X 90 kg lime/ha
● 600 kg lime/ha
O 1111 kg lime/ha
P Partial Control
C Complete Control
P
C
KUKAIAU: 1975-76 Fall Maize
Yield vs P in Solution and Lime Applied