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YIELD RESPONSE OF OIL PALM TO FERTILIZERS IN WEST MALAYSIA

IV. SOIL NUTRIENT LEVELS

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RINGKASAN

Lapuran dibuat berkenaan kesan-kesan pembajaan N, P, K, dan Mg keatas zat-zat tanah didalam 14 percubaan kelapa sawit. Ditanah daratan pertalian pengeluaran F.F.B. tanpa pembajaan N dan K dengan tiap-tiap zat tanah N dan K didapati sangat penting. Tetapi kandongan zat tanah yang genting, bersamaan dengan pengeluaran F.F.B. yang tertinggi, didapati terlalu berubah-ubah untuk dipraktikkan.

Anggaran kehendak pembajaan kelapa sawit daripada analisa tanah cuma dapat dibuat diatas tanah-tanah yang tidak pernah menerima pembajaan.

INTRODUCTION

In a preceding paper (FOSTER and CHANG, 1977) the effect of fertilizers on oil palm leaf nutrient levels, and relationships between oil palm yield production and leaf nutrient levels, were considered in 20 selected oil palm fertilizer trials carried out by different organizations in West Malaysia. In this paper similar consideration is given to soil nutrient levels determined in the 14 trials which are still continuing, and which could therefore be soil sampled. Firstly the effect of fertilizers on some basic soil properties, which were determined in all plots, are considered. Secondly relationships between a variety of soil chemical tests carried out on unfertilized soils and yields without fertilizers are investigated, and lastly soil test critical levels corresponding to optimal yields are examined.

MATERIALS AND METHODS

Full details of the trials, which were all of single replicate 3^4 NPKMg design, have been previously given (FOSTER, 1976; FOSTER and GOH, 1977).

Composite soil samples, consisting of 0–30cm cores taken from the weeded circle of 8 palms, were collected from each plot of each trial about one year after the yield period earlier selected (FOSTER, 1976) for study. These soil samples were individually analysed for pH and extractable cations. Soil pH was determined by glass electrode in a 1:2.5 soil/water suspension. Soil bases were extracted by shaking 2g soil with 100 ml neutral normal ammonium acetate overnight. Aluminium and hydrogen were extracted by rapid leaching of 2g soil with 100 ml normal sodium chloride.

For additional analyses, soils from plots having the same level of an individual fertilizer were bulked. Thus for example three bulked samples, representing K0, K1 and K2 levels of potash fertilizer (at average levels of all other fertilizers) were obtained for each trial from the 81 individual plot samples. These bulked samples were analysed for total nitrogen by the Kjeldahl procedure, and for extractable phosphate by shaking 2g soil with 20 ml of 0.1N HCL plus 0.03N NH_4F for 1 minute (SINGH and RATNASINGAM, 1971). Potassium was extracted by five different methods. In methods 1 and 2, 2g soil was extracted with 100 ml of 0.01N and 0.1N ammonium acetate respectively, shaking overnight. Method 3 was the conventional normal ammonium acetate method described above. In method 4, 10 ml of conc. sulphuric acid was added rapidly to a mixture of 2g soil and 25 ml of water. After standing for exactly 30 minutes the mixture was diluted with water (HUNTER and PRATT, 1957). In method 5, 2g of soil was boiled with 20 ml of 1:1 HCL for one hour (SINGH and RATNASINGAM, 1971).

For each trial, response functions of the same form as those fitted to the yield and leaf nutrient data (FOSTER, 1976, FOSTER and CHANG, 1977) were fitted to the soil results obtained from analysis of individual plot samples.

RESULTS AND DISCUSSION

The fitted response functions for soil pH and extractable cations

The results of regressing soil plot data on average annual fertilizer rates (actual or equivalent amounts of sulphate of ammonia, Christmas Island rock phosphate, muriate of potash and kieserite) are shown for each trial in *Tables 1 6*. In *Table 1*, coefficients of determination and variation are tabulated. It can be seen that coefficients of determination are almost all over 60 per cent, and quite frequently exceed 80 per cent, indicating that the fitted polynomials account for most of the variation in the soil data.

Coefficients of variation are quite small for soil pH, but for soil extractable cations they mostly lie between 30 and 50 per cent. (The results for trial 3, where some of the coefficients of variation approach 100 per cent, are exceptional, and indicate extreme plot variability in this trial). These high coefficients of variation mean that predictions of soil properties at extreme fertilizer combinations have a high error. Unfortunately the fertilizer combinations of most interest are mostly extreme, as they generally include fertilizers either at zero or at their highest level. Thus the approach in earlier papers (FOSTER, 1976, FOSTER and CHANG, 1977), where most of the arguments and discussion were based on predictions from fitted response functions of yield and leaf nutrient levels at specific fertilizer combinations, is not followed in this paper.

The fitted response functions are too lengthy to report in full in this paper but all significant partial regression coefficients for single and two-factor variables are shown in *Tables 2–6* for soil pH and extractable K, Mg, Ca and Al + H respectively. These results show that the application of N fertilizer significantly depresses soil pH and increases the extractable (Al + H) level in almost all trials including those on coastal soils where the N source was generally ammonium nitrate or calcium ammonium nitrate. The biggest changes in pH were observed in trials 23 and 61 where the regular application of sulphate of ammonia depressed soil pH by over 0.2 units for every kilogram of fertilizer applied per palm. On all soils the level of soil extractable K and Mg was generally significantly depressed by N fertilizer, but extractable Ca was depressed at only a few sites (mostly inland). It must be emphasised that any N fertilizer can depress soil pH, since every nitrate ion lost by leaching carries away one cation equivalent. In less acid soils, rock phosphate generally has no effect on soil pH levels, but the results presented here show that the application of rock phosphate significantly increases pH and soil extractable Ca (and concomitantly depresses exchangeable Al + H) in almost all trials. However the increase in soil pH due to the application of 1 kg rock phosphate per palm is generally much less than the decrease due to the application of 1 kg sulphate of ammonia per palm. This effect of rock phosphate counteracting soil acidity has also been reported for soils in West

TABLE 1. REGRESSION OF SOIL ANALYSIS RESULTS (0–30 cm) ON FERTILIZER RATES (KG/PALM/YEAR). MEAN TRIAL VALUES AND COEFFICIENTS OF DETERMINATION AND VARIATION

Trial No.	Mean extr. cations (m.e/100g)					Coefficients of determination (R^2 %)					Coefficients of variation (%)				
	pH	K	Mg	Ca	A1+H	pH	K	Mg	Ca	A1+H	pH	K	Mg	Ca	A1+H
3	3.98	1.86	2.29	1.97	5.50	67.5	62.8	51.8	46.3	63.0	5.6	74.0	101.8	94.9	42.2
4	4.11	0.85	1.03	1.10	3.67	77.9	92.8	85.5	77.7	64.0	5.1	27.2	33.0	25.5	29.7
5	3.84	1.59	3.17	1.88	5.59	73.6	92.4	62.0	71.4	58.0	5.0	25.5	37.8	30.0	33.0
61	3.92	1.06	0.94	1.44	11.54	70.2	83.3	77.7	73.3	68.8	5.2	32.3	38.1	29.5	9.6
10	4.76	1.14	4.07	3.48	2.07	25.5	88.6	69.0	71.2	89.0	21.4	36.8	50.9	33.6	41.5
2	3.72	3.81	2.29	1.52	10.29	78.6	93.5	68.7	68.9	56.4	5.2	24.7	59.7	31.7	19.9
6	4.17	2.42	5.35	2.90	5.20	76.8	91.4	66.2	64.8	69.7	8.6	28.2	41.9	37.0	42.0
9	3.70	3.94	6.85	9.66	3.55	68.6	80.2	91.0	73.1	73.2	5.5	46.4	21.5	33.4	26.8
27	4.47	0.13	0.18	0.45	1.60	81.1	57.9	61.6	76.9	65.1	3.8	68.7	67.4	28.1	35.0
26	4.43	0.19	0.45	0.77	1.95	59.9	61.4	48.2	52.5	54.2	5.1	50.5	49.8	44.3	34.2
28	4.29	0.33	0.51	1.05	2.21	76.0	88.3	85.3	74.1	75.0	5.3	32.0	39.8	30.8	29.6
23	4.23	0.29	0.33	0.89	2.49	87.0	87.8	89.6	58.0	68.1	2.6	37.9	27.0	37.4	25.7
41	4.38	0.32	0.47	1.25	2.57	41.2	67.1	63.6	45.0	37.4	11.4	49.5	45.6	68.9	47.6
8	4.19	0.73	0.66	0.85	5.61	59.2	79.1	71.7	76.9	40.4	4.6	48.6	70.9	31.2	28.9

TABLE 2. REGRESSION OF SOIL pH (0–30 cm) ON FERTILIZER RATES (KG/PALM/YEAR)

Trial No.	Level at middle fertilizer rates	Significant partial regression coefficients								
		N	N^2	P	P^2	K	K^2	Mg	Mg^2	2 factor
3	3.948	–.075***		.066***		037***	.013*			PK = –.014*
4	4.200	–.124***		.106***		.043***				KMg = –.020**
5	3.783	–.127***	.022*	.052***						
61	3.963	–.238***		.084***						
10	4.537			.114***		.094***				PK = –.025***
2	3.569	–.149***	.032**			–.053***	.024**			NK = .025***
6	4.263	–.161***		.138***				.057*		NP = –.041**, NK = .021* NMg = .027*, PK = –.028*
9	3.720	–.040***		.118***	–.030*	.023**				
27	4.476	–.082***		.032***		.014*				
26	4.520	–.056***		.023***	–.003**					
28	4.139	–.159***		.073***			.009*		.034*	
23	4.187	–.213***		.058***		–.079***			–.053*	NK = .148***, KMg = .137***
41	4.460					.123*				
8	4.146	–.037***								

TABLE 3. REGRESSION OF 0–30cm SOIL EXTR. K (m.e./100g) ON FERTILIZER RATES (KG/PALM/YEAR)

Trial No.	Level at middle fertilizer rates	Significant partial regression coefficients								
		N	N^2	P	P^2	K	K^2	Mg	Mg^2	2 factor
3	2.182					0.455***	–0.107**			
4	0.612	–0.061***				0.280***		–0.078***		NK = –0.023***, NMg = 0.021* PMg = –0.040**, KMg = –0.019*
5	1.654	–0.120***				0.485***		–0.144***		NK = –0.035**, KMg = –0.051***
61	1.160	–0.200***				0.505***				NK = –0.130**
10	0.812	–0.070***		.024*		0.183***	0.012***	–0.058***		KMg = –0.011***
2	3.184	–0.208**		.200*	.248**	1.400***				NK = –0.074*
6	2.251			.126*		.793***				PK = 0.066**
9	4.970					.880***		–0.635***		KMg = –0.144**
27	0.103	–0.011**				0.021***				NK = –0.002*
26	0.187					0.032***				NK = 0.004**
28	0.246	–0.050***				0.070***	0.006**			NK = –0.012***
23	0.222	–0.075***				0.357***	0.114*			NK = –0.106***
41	0.292					0.094***				
8	0.499					0.264***				PK = 0.031*

TABLE 4. REGRESSION OF 0–30cm SOIL EXTR. Mg (m.e./100g) ON FERTILIZER RATES (KG/PALM/YEAR)

Trial No.	Level at middle fertilizer rates	Significant partial regression coefficients								
		N	N^2	P	P^2	K	K^2	Mg	Mg^2	2 factor
3	2.022							0.836***		PMg = 0.260**
4	1.110	-0.145***				0.036*		0.360***	0.087***	NK = 0.030**, NMg = –0.051***
5	2.810	–0.308***						0.389***		PK = –0.086*
61	0.908	-0.265***	0.158*					0.679***		NMg = –0.358***, PMg = 0.133*
10	3.274		0.120**			0.409***		0.264***		
2	1.918	0.457***				-0.403***		0.497***		NK = 0.139**, KMg = –0.137*
6	5.635	-0.460***				0.257*		0.640***		NP = -0.162*, NK = 0.117*
9	7.184	0.445***				-0.308***	0.069*	2.143***	0.378***	NK = 0.049*, NMg = –0.213*** KMg = -0.093*
27	0.133	0.020***						0.057***		NMg = –0.012***
26	0.502	0.032***		0.009*				0.055***		NMg = –0.009*
28	0.409	0.127***	0.025***	0.028*		0.023**		0.168***		NK = 0.013**, NMg = 0.062*** KMg = 0.015**
23	0.333	0.086***		0.019**				0.355***		NK = 0.043*, NMg = 0.084*** PK = 0.033**, PMg = 0.029*
41	0.461							0.267***		
8	0.399	0.047**				–0.113***		0.312***		PK = 0.041*, KMg = 0.078***

TABLE 5. REGRESSION OF 0–30cm SOIL EXTR. Ca (m.e./100g) ON FERTILIZER RATES (KG/PALM/YEAR)

Trial No.	Level at middle fertilizer rates	Significant partial regression coefficients								
		N	N^2	P	P^2	K	K^2	Mg	Mg^2	2 factor
3	2.177			0.525***						
4	1.052	–0.043*		0.231***		0.054***		–0.095***		PMg = –0.041**
5	1.709			0.379***	–0.091*	–0.065*			0.103*	
61	1.516			0.474***		0.089*				
10	3.131			0.236***		0.216***		–0.100**		NK = 0.027*, NMg = –0.034** PK = –0.032***
2	1.677			0.322***		–0.081**				PK = –0.051*, PMg = –0.063*
6	3.476			0.608***	–0.196*	–0.117*		–0.257***		
9	10.87			2.465***	–0.748**					
27	0.426	–0.032***		0.052***						NP = –0.004*, NK = 0.004**
26	0.949	–0.047***		0.039***	–0.003*					NP = –0.005*
28	1.064	–0.122***		0.191***	–0.039*					
23	1.137			0.158***						
41	1.446					0.168*				
8	0.893			0.233***	–0.064**	–0.065***	0.026*			PK = –0.031**

TABLE 4. REGRESSION OF 0–30cm SOIL EXTR. Mg (m.e./100g) ON FERTILIZER RATES (KG/PALM/YEAR)

Trial No.	Level at middle fertilizer rates	Significant partial regression coefficients								
		N	N^2	P	P^2	K	K^2	Mg	Mg^2	2 factor
3	2.022							0.836***		PMg = 0.260**
4	1.110	-0.145***				-0.036*		0.360***	-0.087***	NK = 0.030**, NMg = –0.051***
5	2.810	–0.308***						0.389***		PK = -0.086*
61	0.908	0.265***	0.158*					0.679***		NMg = –0.358***, PMg = 0.133*
10	3.274		0.120**			0.409***		0.264***		
2	1.918	0.457***				0.403***		0.497***		NK = 0.139**, KMg = 0.137*
6	5.635	0.460***				0.257*		0.640***		NP = -0.162*, NK = 0.117*
9	7.184	0.445***				0.308***	0.069*	2.143***	0.378***	NK = 0.049*, NMg = –0.213*** KMg = –0.093*
27	0.133	0.020***						0.057***		NMg = 0.012***
26	0.502	-0.032***		0.009*				0.055***		NMg = 0.009*
28	0.409	-0.127***	0.025***	0.028*		0.023**		0.168***		NK = 0.013**, NMg = 0.062*** KMg = 0.015**
23	0.333	-0.086***		0.019**				0.355***		NK = 0.043*, NMg = 0.084*** PK = 0.033**, PMg = 0.029*
41	0.461							0.267***		
8	0.399	0.047**				-0.113***		0.312***		PK = 0.041*, KMg = 0.078***

TABLE 6. REGRESSION OF 0–30cm SOIL EXTR. Al+H (m.e./100g) ON FERTILIZER RATES (KG/PALM/YEAR)

Trial No.	Level at middle fertilizer rates	Significant partial regression coefficients								
		N	N^2	P	P^2	K	K^2	Mg	Mg^2	2 factor
3	5.027	0.437**		–0.393*		–0.350**	0.140*			NMg = 0.160*, PMg = 0.267**
4	3.168	0.244***		–0.395***		–0.111*		–0.355***		KMg = 0.078*
5	5.332	0.656***		–0.427**		–0.194*				
61	10.770	0.826***		0.730***	0.408**	–0.411***				
10	1.067			–0.122***	0.035***	–0.402***	0.035***			NP = –0.020*, PK = 0.020**
2	11.49	0.675***		–0.408*		–0.399***				
6	5.209	0.625***		–0.969***		–0.280*				NK = –0.116*, PK = 0.156*
9	3.211	0.105*		–0.666***	0.243***			0.268***		PMg = 0.139**
27	1.310	0.126***		–0.091***						
26	1.896	0.134***		–0.073***						
28	2.310	0.439***		–0.241***	0.062*					
29	2.301	0.458***		–0.174***						
41	2.428					–0.492**				
8	5.660	0.134*								

Malaysia under Hevea (PUSHPARAJAH, SOONG, YEW and ZAINOL, 1975). The application of rock phosphate increased the level of soil extractable K in three coastal trials and the level of soil extractable Mg in three inland trials, presumably by increasing the cation exchange capacity of the soils. Potash fertilizer showed the expected effect of markedly increasing soil extractable K in all trials, and also significantly decreased extractable (Al + H) in all coastal trials, and extractable Mg in about half the total number of trials. Mg fertilizer significantly increased soil extractable Mg in all trials, but significantly depressed the level of other extractable cation in only a few cases (all on coastal soils).

Relationships between F.F.B. yields obtained without individual fertilizers and soil test levels

To assess the requirement of an individual fertilizers by oil palm at a specific site it is necessary to know both the shape of the response curve and the position on the curve in the absence of fertilizer. The amount of fertilizer required to raise yield up to the level at which response just covers the cost of a fertilizer increment can then be determined. In an earlier paper (FOSTER and GOH, 1977) it has been shown that the slope of response curves can be predicted from soil and climatic properties. Here we consider whether yield in the absence of fertilizer, which identifies the starting point on the response curve, can be predicted from soil chemical tests designed to assess nutrient availability.

As discussed above, soil chemical test values cannot be reliably predicted for individual fertilizer combinations in these trials because of high coefficients of variation. We are therefore obliged to consider the mean yields and soil chemical properties of all the plots in each trial which did not receive individual fertilizers. In *Table 7* are presented mean F.F.B. yields and soil test levels obtained in each trial in the absence of P and Mg fertilizers. There is no significant relationship between the mean yields obtained without P fertilizer and soil extr. P values, and the mean yields obtained without Mg fertilizer and soil extr. Mg values, whether coastal trials (the first 6) and inland trials (the first 5) are considered separately or all together. This does not necessarily mean that the soil test methods are useless, as the mean F.F.B. yields obtained in the absence of P and Mg fertilizer may have been limited by inadequate average levels of N and K fertilizers.

In *Tables 7 and 8* are presented mean F.F.B. yields and soil test levels obtained in the absence of N and K fertilizers respectively. The mean yields obtained without N fertilizer in the coastal trials are not related to soil per cent nitrogen, and yields without K fertilizer in the coastal trials are significantly related at the 10 per cent level ($r = 0.732$) only to soil K extracted from the soil by method 3 when expressed as a percentage of total cations extracted (aluminium being the dominant cation). The fitted regression equation for the latter relationship is shown in *Figure 1*. In the case of the inland trials, mean yields obtained without N fertilizer are highly significantly correlated with soil percent nitrogen ($r = 0.967^{**}$) as illustrated in *Figure 2* where the fitted regression equation is shown. Mean yields obtained without K fertilizer in the inland trials are also significantly related to soil K extracted by 1:1 boiling hydrochloric acid (method 5) at the 5% level ($r = 0.884^{*}$) and to soil K extracted by 1N ammonium acetate (method 3) at the 10% level ($r = 0.825$), but not to soil K extracted by the other 3 methods nor to soil K extracted by method 3 when expressed as a percentage of total bases or cations extracted. Yields without K fertilizer predicted on inland soils by the two successful soil K tests are shown by the fitted regression equations in *Figure 3*.

It is concluded that on inland soils, total soil nitrogen may be a useful test for predicting yield in the absence of N fertilizer and soil potassium extracted by methods 3 and 5 may be

TABLE 7. MEAN F.F.B. YIELDS AND SOIL TEST LEVELS IN THE ABSENCE OF N, P & Mg FERTILIZERS

Trial No.	Mean F.F.B. yield (t/ha) without N fertilizer	Soil % N	Mean F.F.B. yield (t/ha) without P fertilizer	Soil extr. P p.p.m.	Mean F.F.B. yield (t/ha) without Mg fertilizer	Soil extr. Mg	
						m.e./100g	% of total extr. cations
4	25.92	0.076	26.57	48	26.29	0.28	4.0
5	26.20	0.106	26.18	50	26.48	2.42	19.6
61	25.12	0.204	25.05	175	25.22	0.47	3.2
10	25.20	0.266	24.75	171	25.47	2.87	26.9
2	24.56	0.170	25.29	75	25.25	1.38	7.6
6	20.63	0.175	23.50	41	23.15	3.96	26.5
27	17.85	0.074	21.25	132	22.00	0.08	3.6
26	19.20	0.070	21.86	61	22.32	0.28	8.9
28	22.00	0.189	21.40	30	22.41	0.22	5.7
23	31.00	0.155	20.22	25	20.81	0.10	2.7
8	23.14	0.214	21.68	27	25.58	0.14	1.9

TABLE 8. MEAN F.F.B. YIELDS AND SOIL K TEST LEVELS IN THE ABSENCE OF K FERTILIZER

Trial No.	Mean F.F.B. yield (t/ha) without K fertilizer	Soil K (m.e./100g) removed by different extractants					Soil extr. K (3)	
		(1)	(2)	(3)	(4)	(5)	% of total extr. bases	% of total extr. cations*
4	25.24	0.10	0.12	0.12	0.15	1.62	5.3	1.9
5	25.48	0.22	0.26	0.27	0.28	2.75	4.6	2.2
61	25.08	0.35	0.36	0.37	0.59	2.28	14.1	2.5
10	24.59	0.15	0.17	0.19	0.19	1.28	4.9	2.3
2	24.15	0.26	0.33	0.33	0.53	2.50	5.9	1.9
6	23.06	0.17	0.23	0.23	0.29	3.62	2.4	1.5
27	18.83	0.04	0.04	0.04	0.14	0.57	6.0	1.6
26	18.32	0.08	0.08	0.08	0.09	0.32	6.1	2.4
28	21.21	0.10	0.10	0.10	0.14	0.59	5.5	2.5
23	20.61	0.03	0.03	0.05	0.06	0.37	3.8	1.3
8	24.53	0.14	0.14	0.15	0.27	3.62	7.4	1.9

Soil Extractants:
(1) 0.01 N ammonium acetate
(2) 0.1 N " "
(3) 1 N " "
(4) Hot conc. sulphuric acid
(5) Boiling 1:1 hydrochloric acid
* Al and H extracted by 1 N NaCl

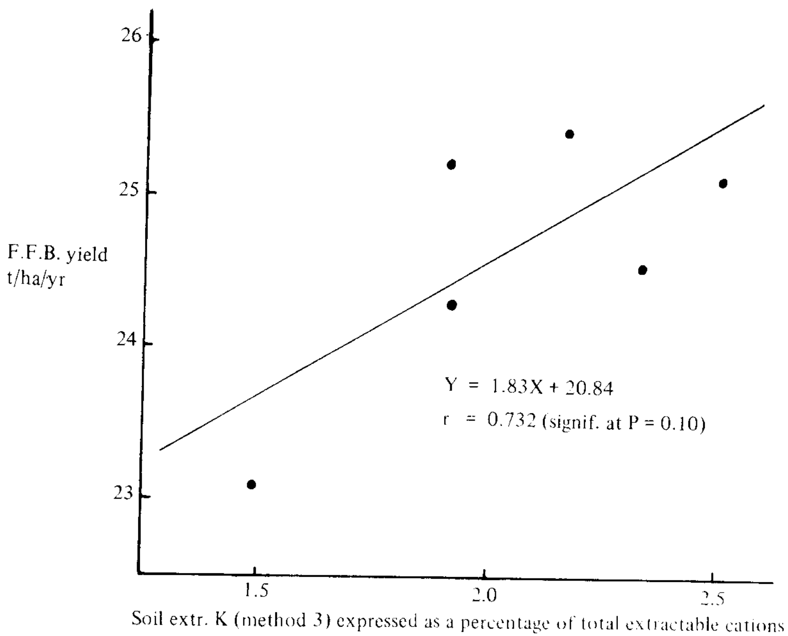

Figure 1. Mean F.F.B. yields and soil extr. K levels (method 3) recorded in individual coastal trials in the absence of K fertilizer.

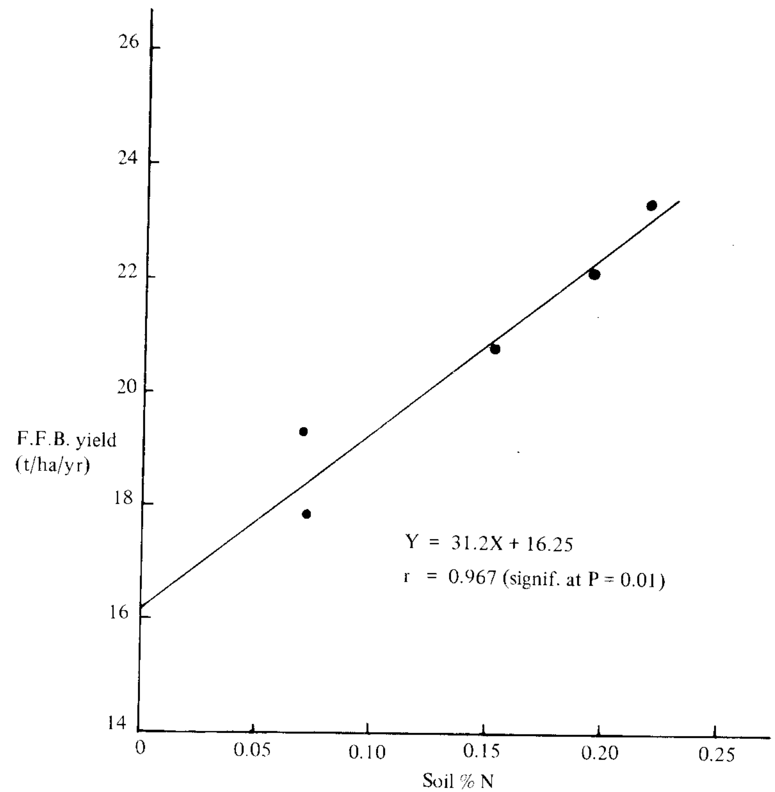

Figure 2. Mean F.F.B. yields and soil nitrogen levels recorded in individual inland trials in the absence of N fertilizer.

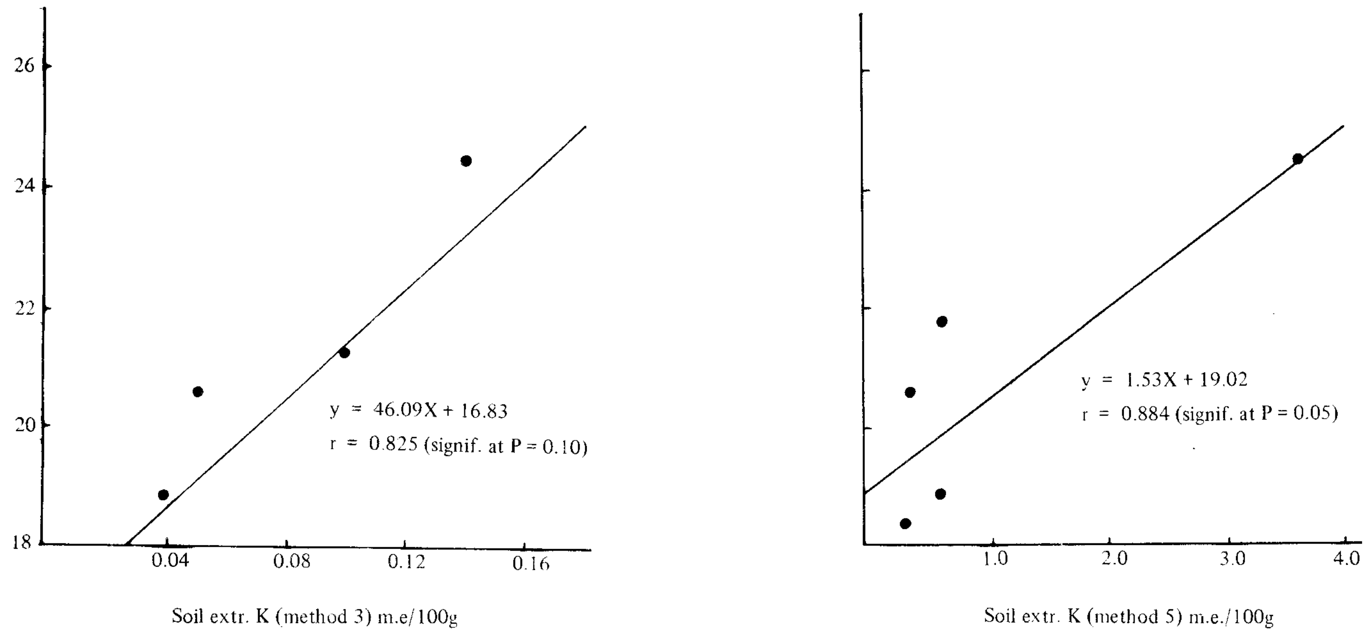

Figure 3. Mean F.F.B. yields and soil extr. K levels (methods 3 and 5) recorded in individual inland trials in the absence of K fertilizer.

useful tests for predicting yield in the absence of K fertilizer. All the coastal soils had high levels of soil K extracted by methods 3 and 5, compared with most of the inland soils, which explains why the coastal trials mostly gave much higher yields in the absence of fertilizer. Yield differences between the coastal trials in the absence of K fertilizer appear to be influenced more by the ratio of extractable K to other extractable cations (particularly aluminium) rather than by the absolute amount of soil extractable K.

Unfortunately the use of a single replicate design in these trials and the high coefficients of variation for the soil results allows us to consider yields without individual fertilizers only in the presence of **average** rather than **optimal** levels of other fertilizers. It is therefore possible that some of the poor correlations found with soil tests were due to yields being restricted by nutrients other than the one being investigated – thus for example the lack of correlation with soil P tests may have been due to inadequate average levels of K fertilizer. For a more conclusive evaluation of the use of soil tests for predicting oil palm yields without fertilizer, well replicated results are required obtained at optimal levels of all fertilizers except the one under investigation.

Soil test levels at optimal fertilizer rates

Soil nutrient availability tests are also very useful if "target" or "critical" levels can be established which correspond to optimal yields. Fertilizer rates can then be adjusted to maintain these critical soil nutrient levels. This is not possible with nitrogen since the natural soil source is organic whilst the fertilizer source is inorganic, but it is possible for P, K and Mg since the natural inorganic source of these nutrients and that applied as fertilizer can be considered together.

In *Table 9* are shown average soil P and K test levels measured in all plots which received optimal rates of P and K fertilizers respectively, in trials where significant and economic responses to P and K fertilizer were obtained. There are too few results for P to allow any firm conclusions, although it may be noted that the soil extractable P critical levels are very different for the two inland trials where fertilizer was applied to the weeded circle. In the case of K, it can be seen that for all the soil tests there is a very considerable range of apparent soil critical levels – thus soil K extracted by method 3 ranges from 0.22 to 3.53 m.e/100g at optimal fertilizer K rates in the different trials. Part of this variation is due to different methods of applying the fertilizer, the highest results of course arising where fertilizer applications was restricted to the weeded circle (where the soil samples were collected). However, even where fertilizers were applied in the same way there is still considerable variation in critical soil K test levels which probably arises from three sources: uneven application of fertilizers, variable extent to which fertilizer nutrients have reached equilibrium with the soil, and the variable effect of other soil properties on crop uptake of potsssium. It is probably other soil properties which cause the greatest variation in soil critical levels – the coastal soils for example having very much higher critical K levels than the inland soils. It is concluded that there is tremendous variation in soil K critical values from site to site which makes the use of soil critical levels an impractical tool for the assessment of fertilizer requirements.

CONCLUSION

Response functions have been satisfactorily fitted to soil nutrient test levels measured in a selection of oil palm fertilizer trials, and the results indicate that N, P, K and Mg fertilizers significantly affect the soil levels of nutrients other than the one they supply. In particular N fertilizers markedly increase soil extractable Al and decrease soil extractable K and Mg, whilst

TABLE 9. SOIL TEST LEVELS AT OPTIMAL RATES OF P AND K FERTILIZERS

Trial No.	Soil extr. P.(p.p.m.) at optimal P fertilizer levels	Soil K (m.e./100g) removed by different extractants at optimal K fertilizer levels					Soil extr. K (3) at optimal K fertilizer levels	
		(1)	(2)	(3)	(4)	(5)	% of total extr. bases	% of total extr. cations
4	–*	1.36	1.38	1.73	1.76	4.15	49.7	24.6
2	–*	3.48	3.52	3.53	3.55	4.84	20.4	7.9
27	188	0.22	0.24	0.22	0.25	0.71	25.9	9.2
26	–*	0.26	0.26	0.27	0.23	0.52	17.9	7.8
28	124	0.24	0.28	0.27	0.24	0.68	15.3	6.5
23	142	0.52	0.55	0.57	0.58	1.06	33.1	13.7
8	240	0.69	0.78	0.79	0.97	4.17	37.7	9.7

N.B.
i) Soil Extractants as in *Table 8*
ii) Fertilizers applied to weeded circle in coastal trials 4 and 2 and in inland trials 23 and 8. Fertilizers broadcast in inland trials 27, 26 and 28.
iii) * = No profitable fertilizer response.

P fertilizer (in the form of rock phosphate) markedly increases soil extractable Ca and decreases soil extractable Al.

Unfortunately coefficients of variation were generally high so that soil tests at only average and not optimal levels of fertilizer could be reliably predicted. However, despite the possibility that average yields without fertilizer in some of the trials may have been limited by inadequate levels of other fertilizers, average yields without N and K fertilizers on inland soils were found to be significantly related (at the 5% level) to the levels of total soil N and soil K extracted by boiling 1:1 hydrochloric acid respectively, whilst yields without K fertilizer on coastal soils were significantly related (at the 10% level) to soil K extracted by 1N ammonium acetate when expressed as a percentage of total cations extracted. Soil test critical levels corresponding to optimal yields were found to be very variable, partly because of different times and methods of fertilizer application and partly because of differences in other soil properties which affect crop nutrient uptake.

Oil palm fertilizer requirements may be estimated by testing soil samples either before or after fertilizer application. The results presented in this paper indicate that because of the high variation in critical soil test levels corresponding to optimal yields, only the first approach is likely to be very reliable, and unfortunately in practice, areas of unfertilized soil are often not available.

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SUMMARY

The effects of N, P K and Mg fertilizers on soil nutrient test levels in 14 oil plam fertilizer trials carried out in West Malaysia is reported. On inland soils, F.F.B. yields without N and K fertilizers were found to be significantly related to soil N and K tests respectively. However, critical soil test levels corresponding to optimal yields were found to be too variable to be of practical use. Thus only analysis of unfertilized soils is likely to aid the estimation of oil palm fertilizer requirements.

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