Market Evaluation of Phosphate Fertilizers from Various Sources for Matured Oil Palm in Malaysia

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ABSTRACT

Fertilizers are one of the most important inputs in the production of palm oil. Their use is dependent on the price of palm oil (PO), the higher the price the more the fertilizers used. P fertilizers significantly increased fresh fruit bunches (FFB) yield and the rates to be used will depend on the costs and benefits afforded by them. This study determines the costs and benefits of utilizing various sources of phosphate fertilizers through partial budgeting and dominance analysis for gross return (GR), total variable cost (TVC), marginal rate of net return (MRNR), net return (NR) and return on investment (ROI).

INTRODUCTION

Fertilizers account for about 24% of the production costs of palm oil. With their increasing cost, the aim should be to optimize fertilizer use for sustained high yields and profits per unit area through balanced fertilization and improved fertilizer efficiency (Teo *et al.*, 1998). Tarmizi *et al.* (1998) studied the effects of N, P and K fertilizers on oil palm bunch components. N fertilizers showed significant effects on bunch number, bunch weight and total oil/bunch. High N decrease F/B but the effect on oil to bunch (O/B) was minimal. They also reported that P significantly increased bunch weight without affecting the other bunch parameters. K significantly increased nut weight but reduced the mesocarp to fruit (M/F) ratio.

There are many sources of phosphate rock currently available in the market. Their P contents and solubilities vary. Five of the fertilizers, CIRP (Christmas Island Rock Phosphate), Tunisia or Gafsa (TPR), Jordan (JPR), North Carolina (NCPR), China (CPR) and the more concentrated and soluble triple super phosphate (TSP) were studied to determine their effects on the yield of oil palm. Zin *et al*. (2001) applied three rates of phosphate including a control (without P), *i.e*. 1.5, 3.0 and 4.5 kg equivalent of CIRP per palm per year. The field trials were conducted on (sedentary) Rengam series and coastal alluvial soil. The experimental design used was a randomized complete block design (RCBD) with four replicate.

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Zin *et al*. (2001) recorded data over a six-year period of full response (third to eighth year) and showed that FFB yields from the P treatments were higher on both the soil types over the control plots. Zin *et al*. (1998) also found that phosphate fertilizer improved the leaf N, P and Ca levels although there were no significant differences between the rates and the different sources of P. However, at high rates of P, leaf K tended to be depressed probably due to the antagonistic effect of Ca. In addition, it increased the soil pH, available P, total P, exchangeable Ca and Mg but depressed the soil exchangeable Al. There were significant differences in the FFB yield response to the P treatments on the inland soil, but not on the coastal alluvial soil. There were however, no significant differences in FFB yield between P from CIRP, Gafsa, JPR, NCR and TSP. From the FFB yield response, the various P sources were ranked as follows in performance: JPR=NCPR= Gafsa=CIRP=TSP>CPR. Considering that CPR had the lowest performance, while the others had the same performance, economic analysis was conducted on the various phosphate fertilizers to determine the source of P that can provide the maximum gains to the palm oil industry.

OBJECTIVES

The objectives of this paper were to determine the costs and benefits of utilizing phosphate fertilizers from various sources, as well as to indicate the market demand for the fertilizers.

METHODOLOGY

To meet the objectives of the study, economic analysis using partial budgeting and dominance analysis for GR, TVC and interest rate incurred to buy the phosphate fertilizers was carried out.

Dominance analysis for treatments was carried out on the basis of MRNR, variable cost (VC), NR and ROI. The total area under oil palm on inland as well as coastal soils was then used to determine the market demand for P fertilizer.

The data of FFB yield were taken from Zin *et al*. (1998) in their evaluation of various phosphate fertilizers for mature oil palm in Malaysia. The mean annual FFB yields for the various treatments in the trials at three different locations over a six-year period were utilized. The data are shown in *Tables 3* and *4*.

RESULTS AND DISCUSSION

Productivity of Phosphate Fertilizers in Coastal Soils

On the coastal soil, at 1.5 kg phosphate fertilizer per palm, the fertilizer producing the highest yield was NCPR. CPR was second. The ranking was NCPR > CPR > JPR > CIRP > TSP > TPR. Thus, TPR was the most inefficient at this low rate of application. At 3 kg/palm, TPR became the most productive fertilizer followed by TSP although there was little difference between them. At this rate, TPR = TSP > JPR > NCPR > CPR > CIRP. Finally, at 4.5 kg/palm, the ranking became CIRP > JPR > TSP > CPR > NCPR. However, increasing CIRP from 1.5 kg/palm to 3.0 kg/palm decreased yield while 4.5 kg resulted in a tremendous increase in output. Increasing the other phosphate fertilizers from 1.5 kg/palm to 3.0 kg/palm resulted in higher yields which declined on further increase to 4.5 kg. This, is illustrated in *Figure 1*. Thus, for coastal soils, the recommended maximum P application is 3.0 kg phosphate rock.

Productivity of Phosphate Fertilizers on Inland Soils

The productivity of the various phosphate fertilizers on inland soil is shown in *Figure 2*. Even though TSP was the most costly of the phosphate fertilizers, it produced the highest yield and thus, provided the highest return at 1.5 kg/palm. From *Figure 1*, it can be seen that at 1.5 kg/palm, TSP > NCPR > TPR > CIRP > JPR > CPR. However, at 3 kg/palm, the ability of TSP to increase yield was very

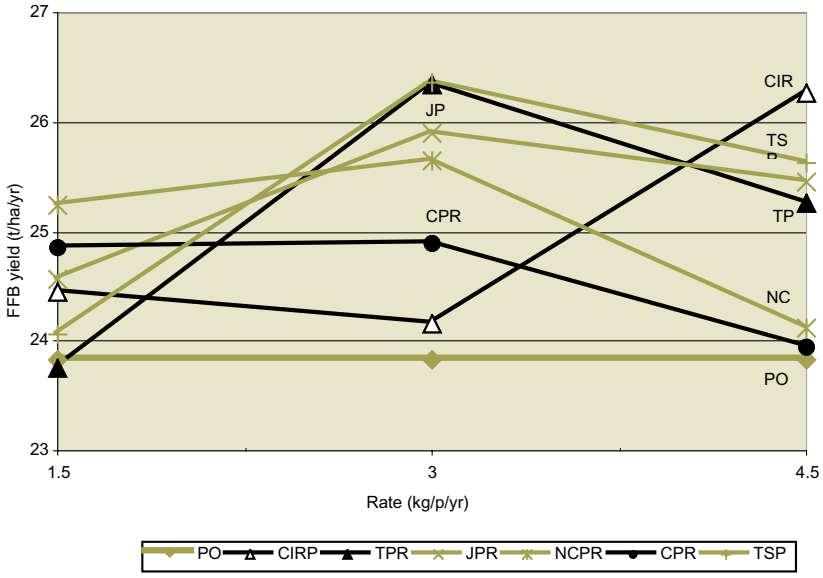

Figure 1. Dominance analysis for different rates of phosphate fertilizers on coastal soils.

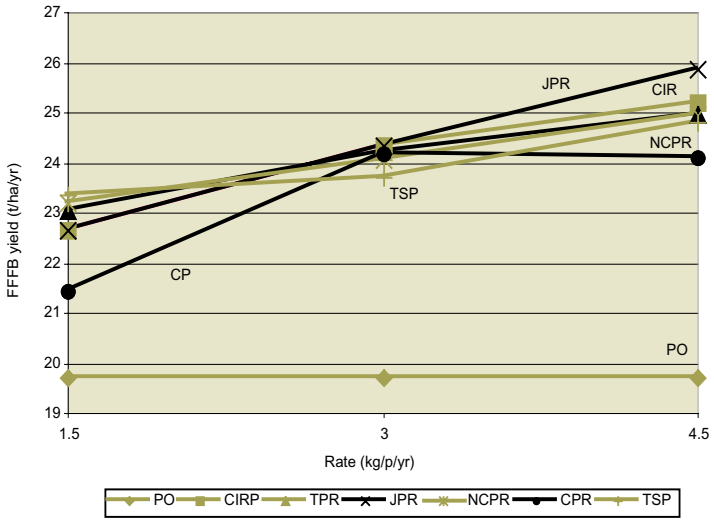

Figure 2. Dominance analysis for different rate of phosphate fertilizers on inland soils.

low compared to the other phosphate fertilizers. At this rate, CIRP produced the highest yield. In summary, at 3 kg/palm, CIRP > JPR > CPR > TPR > NCPR > TSP. Finally, at 4.5 kg/palm, the most efficient fertilizer was JPR, followed by CIRP > NCPR > TPR > TSP > CPR. These results were obtained from partial budgeting on palms cultivated on coastal soils. It can be seen that on inland soils FFB increased with the phosphate application rate.

Imports of Phosphate Fertilizers

Malaysia imports various types of phosphate fertilizers, and among which are super phosphate, ammonium phosphate and rock phosphate (ground and unground). The quantum of phosphatic fertilizers imported has increased over the years from 590 315 t in 1995 to 717 363 t in 2000 at an average annual growth rate of 3.9%. However, imports declined after 2000 to 528 023 t in 2003. Imports of rock phosphate have been quite constant at more than half a million tonnes yearly from 1995 to 2000 before declining to 332 000 t in 2001 and 379 000 t in 2003. The irregular imports is due to the fertilizer use being inversely related to the price of palm oil lagged one year as illustrated in *Table 1*.

The price of crude palm oil (CPO) was high in 1998 and declined from 1999 till 2001. This resulted in a decline in imports of fertilizers from 605 123 t to 331 928 t. Considering that the CPO price was lower in 2001 than in 2000, the effect is further seen in the quantum of fertilizers imported in 2002 which further declined to 305 935 t. However, when the price of CPO increased to RM 1364/t in 2002, fertilizer imports increased to 379 470 t in 2003.

Correlations between the price of CPO, *vs*. the average price of phosphate fertilizers and import of phosphate fertilizers for 1994 to 2003 produced a strong and positive relationship between the CPO price and imports. The imports of P fertilizers fluctuate in tandem with implies that the price of CPO. The relationship between the CPO price and average fertilizer price, though positive, was not strong. On the other hand, the correlation between the average fertilizer price and imports of fertilizers was negative, meaning there is an inverse relationship between the price of fertilizers, and their imports. This is illustrated in *Table 2*.

Rock phosphate fertilizers are the most commonly applied phosphate fertilizers for oil palm. They are imported from various countries such as China, Christmas Island, Jordan, Tunisia and North Carolina. CIRP is the most important although its share has declined from a high of 48% in 1998 to 25% in 2003. CPR in 2003 was 13% of total imports while TPR and JPR accounted for 8% and 3% respectively. There were no imports of NCPR in 2002 and 2003 possibly due to its high price and also the after effects from the 11 September bombing of the World Trade Centre causing ships to fear to ferry American products. Rock phosphate from other sources accounted for 51% of the total imports in 2003. Prior to 2003, the other sources of imports were at least 25 countries, but in 2003 they had been whittled down to seven. These are Australia, Egypt, Algeria, India, Hong Kong, Japan and Thailand. The fertilizers included natural calcium phosphate, natural

TABLE 1. RELATIONSHIP BETWEEN PRICES OF CRUDE PALM OIL (CPO), FERTILIZERS AND IMPORTS OF FERTILIZERS

Year	CPO price	Average fertilizers price	Fertilizers imports
1998	2 377	248	605 123
1999	1 450	241	577 929
2000	997	224	520 119
2001	895	219	331 928
2002	1 364	214	305 935
2003	1 544	240	379 470

TABLE 2. CORRELATION BETWEEN THE PRICES OF CRUDE PALM OIL (CPO), FERTILIZERS AND IMPORTS OF FERTILIZERS

Correlation				
		CPO	Avg. price	Fertilizer import
CPO	Pearson	1	0.261	0.606
	Sig. (2-tailed)	-	0.498	0.083
	N	9	9	9
Avg. fertilizer	Pearson	0.261	1	-0.406
	Sig. (2-tailed)	0.498	-	0.278
	N	9	9	9
Fertilizer	Pearson	0.606	-0.406	1
	Sig. (2-tailed)	0.083	0.278	-
	N	9	9	9

Note: lagged one year.

aluminium calcium phosphate and phosphatic chalk (ground and ungrounded).

Partial Budget Analysis

Partial Budget analysis of the different rates of phosphate fertilizers to oil palm was performed assuming the other factors remaining constant. The price of RM 230/t FFB (the average for 1988-2003) was used to derive the gross returns from sale of FFB (The average price January-August 2004 was RM 340/t). If the average price were to prove profitable than a sensitivity analysis on the price would not be necessary. The total variable cost for a hectare of oil palm with no phosphate application was estimated to be RM 2078. The prices of the various P fertilizers were computed based on the quantity and weighted average value of each imported by Malaysia during 1995-2003. They are in *Table 3*.

For 1995-2000, the most expensive fertilizer was TSP, followed by TPR, NCPR, JPR, CIRP and CPR. However, after the 11 September, Malaysia did not import any NCPR. The prices of rock phosphate fertilizers went on an upward spiral but TSP declined. Nevertheless, TSP remained the most expensive fertilizer, followed by TPR, JPR, CPR and CIRP.

The results of the partial budget analysis are illustrated in *Tables 4* and *5* with the former showing the dominance analysis for coastal soils and the latter for inland soils.

Returns on Investment in Coastal Areas

ROI is used widely to evaluate the performance of an operating division within a firm. Quite simply, it measures the profitability of a division relative to its investment base and is analogous to the similar concept used in project planning. M N Paudel and S H Upasena computed ROI as the ratio of gross return to total variable cost and this procedure is adopted in this analysis.

The ROI for the various phosphate fertilizers in coastal areas are shown in *Table 4* and illustrated in *Figure 3*. All the ROI's were positive. Using 1.5 kg/palm phosphate fertilizer, especially TSP and TPR, produced ROI below that of the control. At this rate, NCPR provided the highest return of RM 3665/ha or ROI of 2.71. CPR gave the second highest return of RM 3599, or ROI of 2.70. This was followed by JPR and CIRP. When the phosphate fertilizer was increased to 3 kg/palm, TPR provided the highest return of RM 3846/ha. The ROI was 2.74. TSP provided the next highest return of RM 3831 with ROI of 2.72. This was followed by JPR, NCPR and CPR. However, the return from CIRP of RM 3396 at ROI of 2.57 was lower than the control which returned RM 3405 at a ROI of 2.64. Increasing the phosphate application to 4.5 kg/palm completely changed the situation. The net return from CIRP increased from RM 3396 (at 3.0 kg/palm) to RM 3840/ha at a ROI of 2.74. CIRP was the only fertilizer that increased net return and ROI. The returns from JPR, TSP and TPR decreased but remained higher than that of the control. Not with standing this, their ROI were below that for the control. The other fertilizers gave negative returns with CPR and NCPR giving returns and ROI's below those of the control.

TABLE 3. WEIGHTED AVERAGE PRICES OF PHOSPHATE FERTILIZERS, 1995-2000 AND 1995-2003 (RM/t)

	1995/2000	1995/2003
CIRP (P_1)	170	186
TPR (P_2)	263	276
JPR (P_3)	193	206
NCPR (P_4)	293	272
CPR (P_5)	178	201
TSP (P_6)	536	499

TABLE 4. DOMINANCE ANALYSIS FOR DIFFERENT P RATES ON COASTAL SOILS

Treatment	FFB yield (t/ha/yr)	Gross return (RM)	Input cost (RM)	TVC	(GR - TVC) Net return	(^NR/^TVC) MRNR	(GR/TVC) ROI
P_0	23.8	5 483.2	0	2 078.0	3 405.2	0	2.64
$P_1R_{1\ (CIRP)}$	24.4	5 623.5	41.2	2 119.2	3 504.2	2.40	2.65
P_1R_2	24.1	5 556.8	82.5	2 160.5	3 396.2	-	2.57
P_1R_3	26.2	6 042.1	123.8	2 201.8	3 840.2	3.51	2.74
$P_2R_{1\ (TPR)}$	23.7	5 464.8	66.9	2 144.9	3 319.8	-	2.55
P_2R_2	26.3	6 058.2	133.8	2 211.8	3 846.3	3.30	2.74
P_2R_3	25.2	5 812.1	200.7	2 278.7	3 533.3	0.64	2.55
$P_3R_{1\ (JPR)}$	24.5	5 648.8	49.9	2 127.9	3 520.8	2.32	2.65
P_3R_2	25.9	5 957.0	99.9	2 177.9	3 779.0	3.74	2.74
P_3R_3	25.4	5 855.8	149.8	2 227.8	3 627.9	1.49	2.63
$P_4R_{1\ (NCPR)}$	25.2	5 807.5	64.4	2 142.4	3 665.0	4.03	2.71
P_4R_2	25.6	5 899.5	128.9	2 206.9	3 692.5	2.23	2.67
P_4R_3	24.1	5 547.6	193.4	2 271.4	3 276.1	-	2.44
$P_5R_{1\ (CPR)}$	24.8	5 717.8	40.8	2 118.8	3 598.9	4.74	2.70
P_5R_2	24.9	5 727.0	81.7	2 159.7	3 567.2	1.98	2.65
P_5R_3	23.9	5 506.2	122.6	2 200.6	3 305.5	-	2.50
$P_6R_{1\ (TSP)}$	24.0	5 533.8	77.1	2 155.1	3 378.7	-	2.57
P_6R_2	26.3	6 062.8	154.2	2 232.2	3 830.6	2.76	2.72
P_6R_3	25.6	5 894.9	231.3	2 309.3	3 585.6	0.78	2.55

Notes: Based on an FFB price of RM 230/t

CIRP - $_1$ NCPR - $_4$ = 1.5 kg CIRP@213 g P_1.
TPR - $_2$ CPR - $_5$ = 3.0 kg CIRP@426 g P_2.
JPR - $_3$ TSP - $_6$ = 4.5 kg CIRP@639 g P_3.

Returns on Investment on Inland Soils

The results from the different rates of phosphate fertilizers on inland soils are shown in *Table 4* and *Figure 4*. From *Figure 4*, at 1.5 kg all the phosphate fertilizers gave net returns higher than that of the control of RM 2451 and ROI of 2.18. TSP provided the highest net return of RM 3213 and a ROI of 2.49, followed by NCPR with RM 3196 and a ROI of 2.49. TPR provided the third highest net return and ROI, followed by CIRP, JPR and CPR. Increasing the rate to 3.0 kg/palm, only TSP showed a decreased net return and ROI. The net return was RM 3217 while the ROI decreased to 2.42, thus producing the lowest net return and ROI. The highest net return and ROI was from CIRP with RM 3433 and 2.59 respectively. The net return from JPR was RM 3418 and the ROI 2.57, making it the second most economically viable fertilizer. CPR provided the third highest return, followed by TPR and NCPR. When the rate was increased further to 4.5 kg/palm, JPR produced the highest net return of RM 3722 and a ROI of 2.67. The net return from CIRP of RM 3594 was the second highest while its ROI was 2.63. The net returns and ROI's from NCPR, TPR, and TSP were third, fourth and fifth, respectively. However, CPR produced a lower net return and ROI than from 3.0 kg/palm.

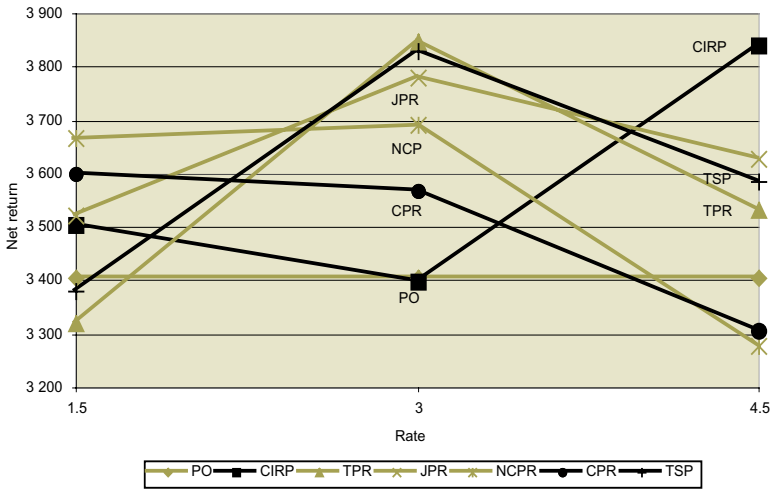

Figure 3. Net returns for different rates of phosphate fertilizers on coastal soils.

TABLE 5. DOMINANCE ANALYSIS FOR DIFFERENT RATES ON INLAND SOILS

Treatment	FFB yield (t/ha/yr)	Gross return (RM)	Input cost (RM)	TVC	(GR - TVC) Net return	(^NR/^TVC) MRNR	(GR/TVC) ROI
P_0	19.69	4 528.7	0	2 078.00	2 450.70	0	2.18
$P_1R_{1\ (CIRP)}$	22.63	5 204.9	41.29	2 119.29	3 085.61	15.38	2.46
P_1R_2	24.32	5 593.6	82.58	2 160.58	3 433.02	11.89	2.59
P_1R_3	25.20	5 796.0	123.88	2 201.88	3 594.12	9.23	2.63
$P_2R_{1\ (TPR)}$	23.04	5 299.2	66.91	2 144.91	3 154.29	10.52	2.47
P_2R_2	24.21	5 568.3	133.86	2 211.86	3 356.44	6.77	2.52
P_2R_3	24.97	5 743.1	200.77	2 278.77	3 464.33	5.05	2.52
$P_3R_{1\ (JPR)}$	22.63	5 204.9	49.94	2 127.94	3 076.96	12.54	2.45
P_3R_2	24.33	5 595.9	99.91	2 177.91	3 417.99	9.68	2.57
P_3R_3	25.87	5 950.1	149.85	2 227.85	3 722.25	8.49	2.67
$P_4R_{1\ (NCPR)}$	23.21	5 338.3	64.49	2 142.49	3 195.81	11.55	2.49
P_4R_2	24.07	5 536.1	128.94	2 206.94	3 329.16	6.81	2.51
P_4R_3	24.97	5 743.1	193.43	2 271.43	3 471.67	5.28	2.53
$P_5R_{1\ (CPR)}$	21.45	4 933.5	40.87	2 118.87	2 814.63	8.90	2.33
P_5R_2	24.18	5 561.4	81.75	2 159.75	3 401.65	11.63	2.58
P_5R_3	24.11	5 545.3	122.65	2 200.65	3 344.65	7.29	2.52
$P_6R_{1\ (TSP)}$	23.34	5 368.2	77.10	2 155.10	3 213.10	9.89	2.49
P_6R_2	23.69	5 448.7	154.20	2 232.20	3 216.50	4.97	2.44
P_6R_3	24.81	5 706.3	231.30	2 309.30	3 397.00	4.09	2.47

Marginal Rates of Net Return on Coastal Soils

Total, average and marginal relationships are very useful in optimization analysis. The definitions of totals and averages are too well known to warrant restating, but it is perhaps appropriate to define *marginal*. A marginal relationship is defined as the change in the dependent variable of a function associated with a unitary change in one of the independent variables. In a total revenue function, marginal revenue is the change in total revenue associated with a one unit change in output. The MRNR for this purpose is thus defined as the change in NR due to a one unit change in the TVC. Thus, an entrepreneur would continue to produce a product until the marginal revenue equals the marginal cost.

Considering that we are now bringing the concept of MRNR into the discussion, the important parameters are summarized in *Table 6* for ease in comparison.

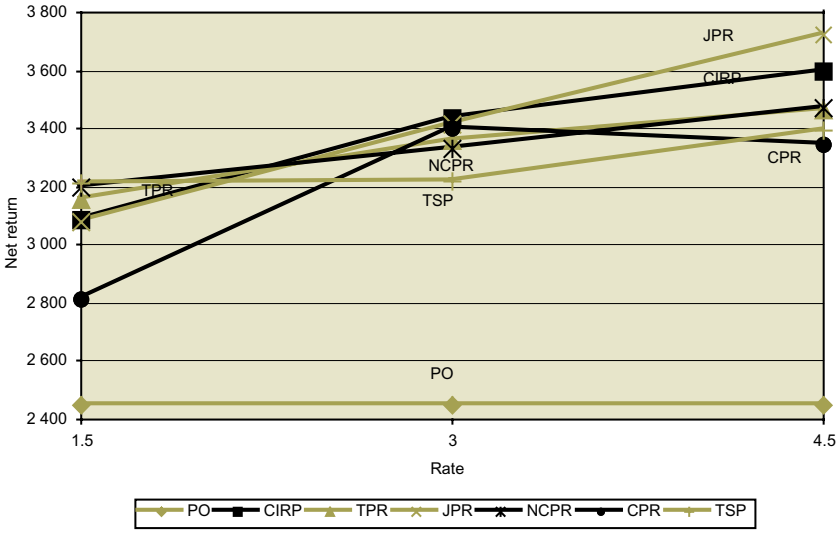

Figure 4. Net returns for different rates of phosphate fertilizers on inland soils.

There were differences in the types of phosphate fertilizer to apply to obtain the highest return from the crop than on inland soils. At 1.5 kg/palm, NCPR provided the highest NR followed by CPR and JPR. However, MRNR for CPR was the highest followed by those for NCPR and CIRP. At this level, CIRP also provided a high net return, a MRNR greater than 1 and a ROI in excess of 2. However, the MRNR's for TSP and TPR were negative. Thus, if growers were to apply phosphate fertilizer at 1.5 kg/palm, the top choice would be NCPR. In case of difficulty in obtaining the fertilizer, the alternatives in order of maximizing profits are CPR, by JPR and CIRP. TSP and TPR should not be applied.

If the rate of application were to be increased to 3.0 kg/palm, the

TABLE 6. RANKING OF NET RETURNS (NR), MARGINAL RATE OF NET RETURN (MRNRs) AND RETURN ON INVESTMENT (ROIs) OF VARIOUS PHOSPHATE FERTILIZERS ON COASTAL SOILS

Ranking	1.5 kg	3.0 kg	4.5 kg
1	NCPR	TPR	CIRP
NR	3 665 (3 659)	3 846 (3 833)	3 840 (3 828)
MRNR	4.03 (3.57)	3.30 (2.91)	3.51 (3.10)
ROI	2.71 (2.70)	2.74 (2.72)	2.74 (2.73)
2	CPR	TSP	JPR
NR	3 599 (3 595)	3 831 (3 815)	3 628 (3 613)
MRNR	4.74 (4.21)	2.76 (2.42)	1.49 (1.26)
ROI	2.70 (2.69)	2.72 (2.70)	2.63 (2.61)
3	JPR	JPR	TSP
NR	3 521 (3 516)	3 779 (3 769)	3 586 (3 562)
MRNR	2.32 (2.02)	3.74 (3.32)	0.78 (0.62)
ROI	2.65 (2.65)	2.74 (2.72)	2.55 (2.53)
4	CIRP	NCPR	TPR
NR	3 504 (3 500)	3 693 (3 680)	3 533 (3 513)
MRNR	2.40 (2.09)	2.23 (1.94)	0.64 (0.49)
ROI	2.65 (2.65)	2.67 (2.66)	2.55 (2.53)
5	TSP	CPR	CPR
NR	3 379 (3 371)	3 567 (3 527)	3 306 (3 246)
MRNR	-0.34 (-0.40)	1.98 (1.00)	-0.81 (-0.87)
ROI	2.57 (2.56)	2.65 (2.60)	2.50 (2.44)
6	TPR	CIRP	NCPR
NR	3 320 (3 313)	3 396 (3 388)	3 276 (3 257)
MRNR	-1.28 (-1.25)	-0.11 (-0.19)	-0.67 (-0.70)
ROI	2.55 (2.54)	2.57 (2.60)	2.44 (2.42)

fertilizer that provided the highest net revenue was TPR with RM 3846; its ROI was 2.74 and MRNR 3.30. This is followed by TSP, JPR and NCPR with net returns of RM 3831, RM 3779 and RM 3693, respectively. With marginal analysis, one would expect that further increases in CPR application would further increase profits. However, this did not materialize because its usage at 3.0 kg/palm decrease in net revenue to RM 3567 from RM 3599 while the ROI declined from 2.70 to 2.65. Similarly, the MRNR declined from 4.74 to 1.98. Thus, at 3.0 kg/palm, one should apply TPR followed by TSP, JPR and NCPR. Increased application of CPR and CIRP should not be done because it would result in losses.

At 4.5 kg/palm, CIRP gave the highest net return of RM 3840, the highest MRNR of 3.51 as well as the highest ROI of 2.74. Nevertheless, this net return was lower than that from TPR at 3.0 kg/palm. The net return from JPR was the second highest with a MRNR of slightly in excess of 1 and ROI of 2.63. Compared to the rate of 3.0 kg/palm, the higher level of 4.5 kg/palm resulted in further deterioration of the NR and ROI as well as MRNR. Application of the other phosphate fertilizers at 4.5 kg/palm decreased the NR, ROI as well as the MRNR. This means that the maximum application should not exceed 3.0 kg/palm. Application of CPR should not be more than 1.5 kg/palm as losses would be incurred.

Marginal Rate of Net Return on Inland Soils

Table 7 summarizes the marginal rates of return and other relevant parameters for comparing the amounts of phosphate fertilizer to be apply on inland soils. *Table 5* shows that there are differences in the types of phosphate fertilizer to apply to provide the highest return from the crop than on coastal soil. At 1.5 kg/palm, TSP provided the highest NR followed by NCPR and TPR. The MRNR for CIRP at 15.38 was the highest followed by JPR with 12.54. The MRNR for TSP was, however, low at 9.89 while that of NCPR higher at 11.55. Application of phosphate fertilizers is highly recommended considering that revenue can be further increased through their application. At 1.5 kg/palm, the preferred fertilizer to apply for the highest return obtainable would be TSP. The next would be NCPR followed by TPR, CIRP, JPR and CPR.

When the rate of phosphate fertilizer application was raised to 3.0 kg/palm, the net revenue increased except that from TSP which declined. CIRP provided the highest NR of RM 3433 and also the highest MRNR of 11.89. JPR provided the second highest return followed by CPR, TPR and NCPR. Considering that CIRP provided the best return, it should be the preferred fertilizer to apply. However, if it is not available, then the next best alternative is CPR. This is followed by TPR and NCPR. However, application of TSP at 3 kg/palm would only slightly increase net revenue from RM 3213 at 1.5 kg to RM 3217.

Further increasing the phosphate fertilizers to 4.5 kg/palm resulted in further increases in net revenue except from CPR where revenue plummeted to RM 3345

TABLE 7. RANKING OF NET RETURNS (NR), MARGINAL RATE OF NET RETURN (MRNRs) AND RETURN ON INVESTMENTS (ROIs) FROM VARIOUS PHOSPHATE FERTILIZERS ON INLAND SOILS

Ranking	1.5 kg	3.0 kg	4.5 kg
1	TSP	CIRP	JPR
NR	3 213 (3 205)	3 433 (3 425)	3 722 (3 708)
MRNR	9.89 (8.90)	11.89 (10.72)	8.49 (7.64)
ROI	2.49 (2.48)	2.59 (2.58)	2.67 (2.65)
2	NCPR	JPR	CIRP
NR	3 196 (3 189)	3 418 (3 408)	3 594 (3 582)
MRNR	11.55 (10.42)	9.68 (8.73)	9.23 (8.30)
ROI	2.49 (2.48)	2.57 (2.56)	2.63 (2.62)
3	TPR	CPR	NCPR
NR	3 154 (3 148)	3 402 (3 362)	3 472 (3 452)
MRNR	10.52 (9.48)	11.63 (7.49)	5.28 (4.71)
ROI	2.47 (2.46)	2.58 (2.53)	2.53 (2.51)
4	CIRP	TPR	TPR
NR	3 086 (3 081)	3 356 (3 343)	3 464 (3 444)
MRNR	15.38 (13.89)	6.77 (6.07)	5.05 (4.50)
ROI	2.46 (2.45)	2.52 (2.50)	2.52 (2.50)
5	JPR	NCPR	TSP
NR	3 077 (3 072)	3 329 (3316)	3 397 (3 374)
MRNR	12.54 (11.33)	6.81 (6.11)	4.09 (3.63)
ROI	2.45 (2.44)	2.51 (2.49)	2.47 (2.45)
6	CPR	TSP	CPR
NR	2 815 (2 810)	3 217 (3 201)	3 345 (3 285)
MRNR	8.90 (7.98)	4.97 (4.42)	7.29 (4.57)
ROI	2.33 (2.32)	2.44 (2.42)	2.52 (2.45)

from RM 3402 at the 3.0 kg. This was surprising considering that the MRNR of CPR was the second highest and exceeded that of JPR. At 4.5 kg, JPR ranked first in providing the highest NR while its MRNR was lower than that of CIRP even though its net return was the second highest. The third highest net return was from NCPR, followed by TPR and TSP. Thus, applying 4.5 kg/palm phosphate fertilizer can further increase profits. JPR would be the most preferred choice, followed by CIRP, NCPR, TPR and TSP. Application of CPR is not recommended at 4.5 kg/palm since the net return is lower than that at 3.0 kg/palm.

Sensitivity Analysis

Closely associated with the weather and other natural hazards that affect risk are price fluctuation and the increasing costs of inputs by oil palm growers. In this analysis, the price of FFB utilized was RM 230/t and was the average price during 1998-2003. The costs of the phosphate fertilizers used were their average landed prices also for the same period. During the period, the imported prices increased only very slowly at 0.43% per year. However, in this analysis, the prices were set to increase by 10% a year to determine the sensitivity of returns to increasing prices. On the other hand, the price per tonne of FFB was fixed at RM 230. The results of the sensitivity analysis are shown by figures in brackets in *Table 6* for coastal areas while those for inland areas are illustrated in *Table 7*.

Sensitivity Analysis for Coastal Soils

With a 10% increase in the prices of phosphate fertilizers, application at 1.5 kg/palm decreased NR, MRNR and ROI. The fertilizers in order of giving the highest returns were NCPR, CPR, JPR and CIRP. As the returns from TSP and TPR were low, they should not be applied. At 3 kg/palm, the increase in fertilizer cost NR, MRNR and ROI for all the fertilizers. However, the NRs were positive and exceeded that of the control. The highest returns produced were in the order TPR > TSP > JPR > NCPR > CPR. The returns from CIRP was however, lower than that obtained with 1.5 kg. At 4.5 kg/palm, the increase in price decreased net revenue for all the phosphate fertilizers. However, only the net return from CIRP exceeded TSP at 3 kg/palm. Thus, at 4.5 kg CIRP is the only fertilizer to apply for a better net return.

Sensitivity Analysis for Inland Soils

On inland areas, the increase in price at application of 1.5 kg/palm still allowed all the fertilizers to produce NR and ROI higher than those for the control. The ranking of fertilizers for the highest returns remained the same as that before the price increase. At 3 kg TSP should not be applied because net revenue would have declined to RM 3201 from RM 3205 at 1.5 kg. The fertilizers to apply for the highest returns were in the order CIRP > JPR > CPR > TPR > NCPR. Applying 4.5 kg/palm and assuming a 10% hike in price, the return produced by CPR was lower than that from 3.0 kg. Thus, CPR should not be applied at the 4.5 kg/palm. The fertilizers to apply at 4.5 kg/palm for the highest returns were JPR followed by CIRP, NCPR, CPR and TSP.

CONCLUSION

An economic evaluation of phosphate fertilizers on oil palm on coastal and inland soils was done through partial budgeting and dominance analysis. It was found that to apply fertilizer depended on the NR obtained at the different levels of fertilizer.

On coastal soils, apply NCPR, CPR, JPR or CIRP in order of priority at 1.5 kg/palm to maximize returns. TSP and TPR should not be applied. Profits can be further increased by applying at 3.0 kg/palm with the highest returns from TPR followed by TSP, JPR and NCPR. CPR and CIRP should not be applied at 3.0 kg/palm as losses would be incurred. Application at 4.5 kg/palm further decreased NR and ROI as well as MRNR. This means that the application of phosphate fertilizers on coastal soils should not exceed 3.0 kg/palm. Application of CPR should not be more than 1.5 kg/palm, as losses would be incurred.

The types of phosphate fertilizer to apply on inland soils differed form those on coastal soils. At 1.5 kg/palm, the preferred fertilizers for the highest return were TSP > NCPR > TPR > CIRP > JPR > CPR. Increasing the application to 3.0 kg/palm, increased the net revenue except with TSP which net revenue decline. CIRP provide the highest NR. Followed by JPR, then CPR, TPR and NCPR. TSP should not be applied at this rate because it decrease NR. The return is further increased if the rate is increased to 4.5 kg/palm. At this rate, JPR was the best followed by CIRP, NCPR, TPR and TSP. CPR is not recommended at 4.5 kg/palm since the NR was lower than 3.0 kg/palm.

A sensitivity analysis was also conducted with the cost of phosphate fertilizers raised by 10% a year while the price of FFB was unchanged. Under this condition, application of most of the phosphate fertilizers continued to be economically viable for both inland and coastal soils.

The total area under oil palm in the country in 2003 was 3 802 040 ha of which 3 303 133 ha or 87% of the area were mature. Based on the country's import of phosphate fertilizers of 279 470 t all of which were applied for oil palm, the average application per palm was 0.57 kg. This quantum is far below the amount for maximum net revenue. Thus, oil palm growers should increase their application of phosphate fertilizers.

ACKNOWLEDGEMENT

The authors wish to thank the Director-General of MPOB for approval to present this paper. Thanks are also recorded to the Director of Economics and Industry Development Division for his useful comments.

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