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Comparison of the Effects of Different Types of P Fertiliser Applied to Oil Palm in Sumatra

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ABSTRACT

Application of P fertiliser is essential to achieve optimal oil palm yield production throughout Sumatra. Two trials were carried out in Sumatra, one in the north on a typical acid volcanic soil dominated by rhyolite and the other in the south on a representative acid volcanic/sedimentary soil dominated by dacite, to determine the most suitable P fertiliser type in these locations. The trials compared the effects of triple super phosphate (TSP), Egyptian rock phosphate (ERP), Christmas Island rock phosphate (CIRP) and China rock phosphate (CRP), which have soluble P contents in that order, in conjunction with two rates of muriate of potash (MOP).

As expected from its highly soluble P content, TSP increased leaf and rachis P more effectively than all the other rock phosphates tested in both trials. Thus, in the trial in the north, rock phosphate is required at a higher P_2O_5 rate to achieve the same yield. A similar optimal yield and rachis P level in this trial was obtained at 1.9 kg TSP (0.9 kg P_2O_5), 4.5 kg CIRP (1.4 kg P_2O_5) and 3.4 kg CRP (1.0 kg P_2O_5) per palm per year. However, because TSP generally costs more than twice the costs of rock phosphates, it is usually more economic to use the latter.

In the trial in the south, both CIRP and ERP were surprisingly found to be as effective as TSP in increasing yield when applied at the same P_2O_5 rate, despite having less effect on leaf and rachis P levels. The optimal yields in this trial were obtained with 2.7 kg TSP (1.2 kg P_2O_5), 6 kg CIRP (1.8 kg P_2O_5) and 3.6 kg ERP (1.0 kg P_2O_5) per palm per year. At typical fertiliser prices, ERP was the most economic and TSP the least economic. The reason for the poorer performance of TSP in this trial is explained by its depressive effect on leaf K, due to its higher soluble Ca content (although it has a lower total Ca content). ERP, in contrast to CIRP, did not depress leaf K and increased rachis P more due to its higher soluble P content, so was the more effective rock phosphate fertiliser.

Although TSP is always more effective in increasing tissue P levels of oil palm, it is usually the poor choice as a P fertiliser due to its high cost and depressive effect on palm K status on soils low in reserve K (as in the south of Sumatra but not in the north). Any rock phosphate is usually a better choice than TSP and in these trials, ERP, which had a higher soluble P content, was the most effective and economic.

ABSTRAK

Aplikasi baja P penting untuk mencapai hasil pengeluaran sawit yang optimum di seluruh Sumatra. Dua kajian telah dijalankan di Sumatra, di bahagian utara di tanah asid gunung berapi biasa yang didominasi oleh riyolik (rhyolite) *dan di tanah asid gunung berapi/tanah sedimentari di bahagian selatan yang didominasi oleh dasik* (dacite), *untuk menentukan jenis baja P yang paling sesuai di lokasi tersebut. Kajian ini membandingkan kesan penggunaan* triple super phosphate *(TSP),* Egyptian rock phosphate *(ERP),* Christmas Island rock phosphate *(CIRP) dan China rock phosphate (CRP), yang mempunyai kandungan P larut mengikut susunan dan kombinasi dengan dua kadar peletakan muriate of potash (MOP).*

Seperti yang dijangka daripada kandungan P larut yang tinggi, TSP lebih berkesan meningkatkan kandungan P di daun dan rakis berbanding dengan rawatan batuan fosfat dalam dua kajian tersebut. Oleh itu, kajian di bahagian utara memerlukan batuan fosfat pada kadar P_2O_5 yang lebih tinggi untuk mencapai hasil yang sama. Hasil optimum dan tahap P rakis yang sama dalam kajian ini boleh diperoleh melalui penggunaan 1.9 kg TSP (0.9 kg P_2O_5), 4.5 kg CIRP (1.4 kg P_2O_5) dan 3.4 kg CRP (1.0 kg P_2O_5) per pokok setahun. Walau bagaimanapun, memandangkan kos TSP adalah lebih dua kali ganda daripada kos batuan fos-

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fat, maka penggunaan batuan fosfat menjadi lebih ekonomik.

Dalam kajian di bahagian selatan, kesan CIRP dan ERP dalam meningkatkan hasil didapati sama seperti TSP apabila diaplikasi dengan kadar P_2O_5 yang sama, walaupun menunjukkan tahap kandungan P daun dan rakis adalah rendah. Hasil optimum dalam kajian ini diperoleh dengan penggunaan 2.7 kg TSP (1.2 kg P_2O_5), 6 kg CIRP (1.8 kg P_2O_5) dan 3.6 kg ERP (1.0 kg P_2O_5) per pokok setahun. Berdasarkan harga baja secara umum, penggunaan ERP adalah paling ekonomik manakala penggunaan TSP adalah sebaliknya. Punca kurang keberkesanan TSP dalam kajian ini dapat dijelaskan dengan kesan tekanan pada K daun, akibat kandungan Ca larut yang tinggi (walaupun mempunyai jumlah kandungan Ca yang rendah). Berbeza dengan CIRP, ERP tidak menimbulkan tekanan pada K daun tetapi lebih meningkatkan P rakis kerana kandungan P larut yang lebih tinggi, maka bertindak sebagai baja batuan fosfat yang lebih berkesan.

Walaupun TSP sentiasa didapati lebih berkesan dalam meningkatkan tahap P tisu sawit, namum ia tidak merupakan pilihan yang tepat sebagai baja P berikutan kos yang tinggi dan kesan tekanan pada K daun di tanah di mana kandungan K adalah rendah (seperti di selatan Sumatra tetapi tidak di kawasan utara). Sebarang batuan fosfat biasanya lebih berkesan berbanding dengan TSP dan dalam kajian ini, ERP yang mengandungi kandungan P larut yang paling tinggi, merupakan pilihan yang lebih berkesan dan ekonomik.

Keywords: rock phosphate, superphosphate, comparison, antagonistic, profitability.

INTRODUCTION

P is one of the macro-nutrients needed in large amounts for oil palm yield and P has a close relationship with other nutrients such as N. Therefore the response to P fertiliser can be maximised by applying N fertiliser in a balanced ratio (Tampubolon *et al.*, 1989). A close relationship with N and K was also observed (Tan, 1976; Foster *et al.*, 1988) who reported that a full response to fertiliser N and K can only be achieved with a balanced application of P fertiliser, and trials in Malaysia have indicated that such application of up to the equivalent of 2-3 and 3-4 kg CIRP per palm per year on coastal alluvial and inland sedentary soils respectively is profitable for mature oil palm production. The response of yield to P treatment is high and these trials also showed no reduction in optimal P fertiliser rate with time.

EXPERIMENTAL

Two P fertiliser types trials had been carried out, one in north and one in south Sumatra and they were located in Bah Lias and Sei Lakitan estates as in *Table 1*.

The trials compared triple super phosphate (TSP), Christmas Island rock phosphate (CIRP), China rock phosphate (CRP) and Egyptian rock phosphate (ERP) applied at two levels of P and at two rates of K fertiliser in a 2x2x3 factorial design with: 2 rates muriate of potash (MOP) x 2 rates P fertiliser x 3 types P fertiliser, plus 2 zero P control plots (with and without MOP). Details of the two trials and fertiliser type's properties are shown in *Tables 2* and *3*.

RESULTS AND DISCUSSIONS

Table 4 shows that in north Sumatra the highest yields were achieved with TSP fertiliser at the low rate of 0.7 kg P_2O_5 per palm per year and CIRP fertiliser at a higher rate of 1.4 kg P_2O_5 per palm per year in combination with 2 kg MOP per palm per year. Furthermore, there were no significant differences between P fertiliser types both at low rate and high rate in combination with 2 kg MOP per palm per year in Bah Lias central region north Sumatra. *Table 4* also shows that the highest yield in south Sumatra was achieved with ERP at low rate of 0.9 kg P_2O_5 per palm per year and with both TSP and CIRP at the high rate of 1.8 kg P_2O_5 per palm per year in combination with the high rate of K fertiliser. Furthermore, there were no significant differences between P fertilisers tested in terms of yield both at the low and high rate in Sei Lakitan south Sumatra.

Table 5 shows that application of all P fertilisers significantly increased leaf and rachis P from deficient to satisfactory levels, which confirms the important role of these P fertilisers in both Bah Lias and Sei Lakitan estates. Furthermore, TSP fertiliser gave the higher tissue P levels both at low and high rates, presumably because it is more soluble. Thus, TSP fertiliser may be the better choice to overcome severe P deficiency. The effects of P fertilisers on rachis P levels are also shown in *Table 5*. All P fertilisers significantly increased rachis P levels at both sites. TSP had significantly the greatest effect on rachis P in trial 1423 Sei Lakitan, but there were no significant differences between the different fertilisers in trial 282 Bah Lias.

Table 6 shows that leaf and rachis K were depressed at the higher P rates particularly when applied as TSP at Sei Lakitan. The more depressive effect of the TSP fertiliser on leaf and rachis K levels

TABLE 1. SITE CHARACTERISTICS AND RAINFALL DATA OF THE TRIALS

Trial	Estate	Region	Plt. year	Started	Data period	Rainfall (mm yr^{-1})	Soil moisture
282	Bah Lias	Central (NS*)	1986	1993	1997-2000	1735	36.32 %
1423	Sei Lakitan	Muara Rupit (SS*)	1997	2004	2007-2009	3260	89.88 %

Note: NS* - north Sumatra. SS** - south Sumatra.

TABLE 2. TREATMENT RATES AND TRIAL DETAILS

Trial	Levels (kg P_2O_5 palm^{-1} yr^{-1})	Fertiliser (kg palm^{-1} yr^{-1})					Plot size/ recorded (palms)	Replicate	Urea / kieserite (kg palm^{-1} yr^{-1})
		TSP	CIRP	CRP	ERP	MOP			
282	P1 (0.7)	1.5	2.1	2.1	-	0	7x7 / 5x5	2	4 / 2 *
	P2 (1.4)	3	4.2	4.2	-	2	-	-	-
1423	P1 (0.9)	2	3	-	3	1	8x8 / 4x4	4	4 / 0 *
	P2 (1.8)	4	6	-	6	3	-	-	-

Note: The plots were surrounded by a 1 m deep trench, regularly maintained; * N and Mg fertilisers were applied to all plots including the control.
TSP – triple super phosphate. CIRP – Christmas Island rock phosphate. CRP – China rock phosphate.
MOP – muriate of potash. ERP – Egyptian rock phosphate.

TABLE 3. PROPERTIES OF FERTILISERS

Fertiliser	Total P_2O_5 (%)	Soluble P_2O_5 (%)*	Total CaO (%)	Soluble CaO (%)*
TSP	46	45	20	16
CIRP	31	7.5	40	6
CRP	32	6.7		5
ERP	28	10	40	8

Note: * In 2% citric acid. TSP – triple super phosphate. CIRP – Christmas Island rock phosphate. CRP – China rock phosphate. MOP – muriate of potash. ERP – Egyptian rock phosphate.

at Sei Lakitan is presumed due to its higher soluble Ca content of 16% which increased leaf and rachis Ca at higher rates as shown in *Table 7*. The depression of leaf and rachis K levels due to higher rates of TSP is presumably an antagonistic effect of Ca. The greater negative effect of TSP on tissue K levels in south Sumatra compared with north Sumatra is probably because the soils in north Sumatra are dominated by rhyolite which is rich in K, whilst the soils in south Sumatra are dominated by dacite which is rich in Mg. Thus, in north Sumatra a high level of soil reserve K (as shown in *Table 8*) largely prevents the depressive antagonistic effect of Ca.

To determine the most profitable rate of each P fertiliser in each trial, the response equations shown in *Table 9* were derived from the yield data at the optimal high rate of K fertiliser. The point on each response curve at which the yield increment exactly equalled the cost of the fertiliser in 2011 was then determined as the most profitable P fertiliser rate and the results including the corresponding optimal yields are shown in *Table 10*. The most profitable rates of TSP and CIRP are lower in north Sumatra compared to south Sumatra.

Table 10 shows that the most profitable yields in the north Sumatra trial were obtained at 1.9 kg TSP (0.9 kg P_2O_5), 4.5 kg CIRP (1.4 kg P_2O_5) and 3.4 kg CRP (1.0 kg P_2O_5) per palm per year. However, because TSP costs much more than the rock phosphates, the latter rock phosphates are more profitable and CIRP gave the highest profit. In south Sumatra, the most profitable yields were obtained with 2.7 kg TSP (1.2 kg P_2O_5), 6 kg CIRP (1.8 kg P_2O_5) and 3.6 kg ERP (1.0 kg P_2O_5) per palm per year. At 2011 fertiliser prices, ERP was most profitable and TSP the least profitable.

CONCLUSION AND RECOMMENDATION

P fertiliser plays an important role in increasing oil palm yields in the central region of north Sumatra and the Muara Rupit region of south Sumatra. The optimal P fertiliser rates in the trial areas were 1.9 kg TSP, 4.5 kg CIRP and 3.4 kg CRP per palm per year in north Sumatra and 2.7 kg TSP, 6 kg CIRP and 3.6 kg ERP per palm per year in south Sumatra.

TABLE 4. FRESH FRUIT BUNCHES (FFB) YIELD RESPONSE ($t\ ha^{-1}\ yr^{-1}$) TO DIFFERENT P FERTILISERS AT OPTIMAL K FERTILISER RATE AT BAH LIAS, NORTH SUMATRA AND SEI LAKITAN, SOUTH SUMATRA

Treatment	Expt. 282, Bah Lias (1997-2000)			Expt. 1423, Sei Lakitan (2007-2009)		
	TSP	CIRP	CRP	TSP	CIRP	ERP
P0	25.15	25.15	25.15	20.79	20.79	20.79
P1	30.32	29.28	29.90	24.16	23.43	25.29
P2	29.70	30.82	29.80	25.22	25.27	23.64
Lsd 1 (5%)	-	5.29	-	-	2.68	-
Lsd 2 (5%)	-	4.58	-	-	2.32	-
CV (%)	-	9.0	-	-	8.2	-

Note: Lsd1: for comparing effect of P1-P2 at different types; Lsd2: for comparing nil P (P0) with P1-P2 at different types.
TSP – triple super phosphate. CIRP – Christmas Island rock phosphate. CRP – China rock phosphate. ERP – Egyptian rock phosphate.

TABLE 5. LEAF AND RACHIS P RESPONSE TO DIFFERENT P FERTILISERS AT OPTIMAL K FERTILISER RATE AT BAH LIAS, NORTH SUMATRA AND SEI LAKITAN, SOUTH SUMATRA

Treatment	Expt. 282, Bah Lias (1997-2000)						Expt. 1423, Sei Lakitan (2007-2009)					
	Leaf P (%)			Rachis P (%)			Leaf P (%)			Rachis P (%)		
	TSP	CIRP	CRP	TSP	CIRP	CRP	TSP	CIRP	ERP	TSP	CIRP	ERP
P0	0.156	0.156	0.156	0.046	0.046	0.046	0.138	0.138	0.138	0.043	0.043	0.043
P1	0.168	0.164	0.164	0.085	0.079	0.086	0.166	0.156	0.156	0.104	0.064	0.075
P2	0.171	0.168	0.165	0.089	0.085	0.085	0.163	0.161	0.158	0.120	0.077	0.077
Lsd 1 (5%)	-	0.007	-	-	0.022	-	-	0.007	-	-	0.012	-
Lsd 2 (5%)	-	0.006	-	-	0.019	-	-	0.006	-	-	0.010	-
CV (%)	-	2	-	-	14.4	-	-	3.1	-	-	11.5	-

Note: Lsd1: for comparing effect of P1-P2 at different types; Lsd2: for comparing nil P (P0) with P1-P2 at different types.
TSP – triple super phosphate. CIRP – Christmas Island rock phosphate. CRP – China rock phosphate. ERP – Egyptian rock phosphate.

TABLE 6. LEAF AND RACHIS K RESPONSE TO DIFFERENT P FERTILISERS AT OPTIMAL K FERTILISER RATE AT BAH LIAS, NORTH SUMATRA AND SEI LAKITAN, SOUTH SUMATRA

Treatment	Expt. 282, Bah Lias (1997-2000)						Expt. 1423, Sei Lakitan (2007-2009)					
	Leaf K (%)			Rachis K (%)			Leaf K (%)			Rachis K (%)		
	TSP	CIRP	CRP	TSP	CIRP	CRP	TSP	CIRP	ERP	TSP	CIRP	ERP
P0	1.00	1.00	1.00	1.83	1.83	1.83	0.84	0.84	0.84	1.10	1.10	1.10
P1	0.90	0.86	0.93	1.52	1.44	1.61	0.82	0.83	0.84	0.96	0.97	0.89
P2	0.93	0.84	0.93	1.63	1.54	1.52	0.76	0.80	0.84	0.82	0.94	0.90
Lsd 1 (5%)	-	0.13	-	-	0.47	-	-	0.10	-	-	0.18	-
Lsd 2 (5%)	-	0.12	-	-	0.41	-	-	0.09	-	-	0.16	-
CV (%)	-	7.3	-	-	16.5	-	-	9.2	-	-	16.7	-

Note: Lsd1: for comparing effect of P1-P2 at different types; Lsd2: for comparing nil P (P0) with P1-P2 at different types.
TSP – triple super phosphate. CIRP – Christmas Island rock phosphate. CRP – China rock phosphate.
ERP – Egyptian rock phosphate.

TABLE 7. LEAF AND RACHIS CA RESPONSE TO DIFFERENT P FERTILISERS AT OPTIMAL K FERTILISER RATE AT BAH LIAS, NORTH SUMATRA AND SEI LAKITAN, SOUTH SUMATRA

Treatment	Expt. 282, Bah Lias (1997-2000)						Expt. 1423, Sei Lakitan (2007-2009)					
	Leaf Ca (%)			Rachis Ca (%)			Leaf Ca (%)			Rachis Ca (%)		
	TSP	CIRP	CRP	TSP	CIRP	CRP	TSP	CIRP	ERP	TSP	CIRP	ERP
P0	0.60	0.60	0.60	0.31	0.31	0.31	0.56	0.56	0.56	0.28	0.28	0.28
P1	0.66	0.71	0.63	0.42	0.39	0.34	0.62	0.61	0.63	0.33	0.30	0.35
P2	0.66	0.71	0.67	0.43	0.40	0.42	0.69	0.61	0.64	0.37	0.33	0.34
Lsd 1 (5%)	-	0.11	-	-	0.08	-	-	0.11	-	-	0.05	-
LSd 2 (5%)	-	0.10	-	-	0.07	-	-	0.09	-	-	0.05	-
CV (%)	-	8.1	-	-	10.9	-	-	12.2	-	-	11.2	-

Note: Lsd1: for comparing effect of P1-P2 at different types; Lsd2: for comparing nil P (P0) with P1-P2 at different types.
TSP – triple super phosphate. CIRP – Christmas Island rock phosphate. CRP – China rock phosphate.
ERP – Egyptian rock phosphate.

TABLE 8. INHERENT SOIL PROPERTIES (at depth 0-40 cm of top soil)

Region	Trial	Dominant soil parent	Exchangeable cations (me/100 g)			Hot extr. acid K (me/100 g)
			K	Mg	Ca	
North Sumatra	282	Rhyolite	0.15	0.12	0.71	3.65
South Sumatra	1423	Dacite, clay stone	0.12	0.24	1.39	0.73

TABLE 9. YIELD RESPONSE EQUATIONS FOR DIFFERENT P FERTILISERS

Trial No.	P type	P response equation
282, Bah Lias	TSP	$y= -5.9082x^2 + 11.521x + 25.15$
North Sumatra	CIRP	$y= -2.6429x^2 + 7.75x + 25.15$
	CRP	$y= -4.949x^2 + 10.25x + 25.15$
1423-Sei Lakitan	TSP	$y = -1.4259x^2 + 5.0278x + 20.79$
South Sumatra	CIRP	$y = -0.4938x^2 + 3.3778x + 20.79$
	ERP	$y = -3.7963x^2 + 8.4167x + 20.79$

Note: y = predicted FFB yield ($t\ ha^{-1}\ yr^{-1}$) ; x = fertilizer P_2O_5 ($kg\ palm^{-1}\ yr^{-1}$).
TSP – triple super phosphate. CIRP – Christmas Island rock phosphate.
CRP – China rock phosphate. ERP – Egyptian rock phosphate.

TABLE 10. MOST PROFITABLE RATES OF DIFFERENT P FERTILISERS IN NORTH AND SOUTH SUMATRA

Trial	Type	Fert. rate (kg)	P_2O_5 (kg)	FFB ($t\ ha^{-1}\ yr^{-1}$)	Yield increase ($t\ ha^{-1}\ yr^{-1}$)	Fert. cost (Rp. million)	FFB value (Rp. million)	Profit (Rp. million)
282	TSP	1.9	0.9	30.7	5.5	1.6	6.4	4.8
NS	CIRP	4.5	1.4	30.8	5.6	1.1	6.6	5.5
	CRP	3.4	1.0	30.4	5.3	0.8	6.1	5.3
1423	TSP	2.7	1.2	24.8	4.0	2.2	4.6	2.4
SS	CIRP	6.0	1.8	25.3	4.5	1.4	5.2	3.8
	ERP	3.6	1.0	25.4	4.6	0.7	5.4	4.7

Note: P fertilisers price based on north and south Sumatra budget 2011, PT.PP.LondonSumatra,Tbk. [Assuming prices of each kg of triple super phosphate (TSP) = Rp 5761, Christmas Island rock phosphate (CIRP) and China rock phosphate (CRP) = Rp. 1632, Egyptian rock phosphate (ERP) = Rp. 1863, muriate of potash (MOP) = Rp. 4244 and fresh fruit bunches (FFB) = Rp. 1161.]

In both trials, TSP gave the highest P status both in the leaf and rachis compared with the rock phosphates and consequently in north Sumatra higher P_2O_5 rates of rock phosphate were required to achieve the same yield as TSP. However, in south Sumatra, the FFB yield obtained from TSP was not significantly better than from the rock phosphates because TSP significantly depressed K uptake due to its higher soluble Ca content.

In both north and south Sumatra, it is recommended to use ERP or another rock phosphate fertiliser of similar P solubility, since it is more profitable than TSP due to its lower price and more profitable than CIRP due to its greater effectiveness.

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