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Effects of Sources of Phosphorus Fertilizer on Crop Yields in Rice-Soybean Double Cropping

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ABSTRACT

An effect of rock phosphate applied to rice on soybean seed yield in typical rice-soybean cropping system of the north was investigated on Low Humic Gley Soils (Typic Tropaqualfs) in a farmer's field in Tambon Chomphu, Amphoe Muang, Changwat Lampang during July, 1983 – April, 1984. Three randomized complete blocks with 4 treatments of 0, 37.5 kg P_2O_5/ha of triple superphosphate (TSP), 1250 and 2500 kg/ha of 3% P_2O_5 citrate soluble (30% total P_2O_5) rock phosphate were utilized to study the effect of fertilizer sources and rates on a local indica rice cultivar Sanpatong. A split plot design was subsequently superimposed on this phosphate-rice experiment with 4 sub-plot treatments consisting of 0, 18.75, 37.5, 75 kg P_2O_5/ha of TSP fertilizer applications, to determine the residual effect of these different phosphate fertilizers on soybean cultivar SJ. 4.

The results indicated no rice yield response to either form of phosphate fertilizer but showed a significant increase ($P > 0.01$) in the plant P-uptake levels and in the soil Bray II-P availability levels when applied with both forms of phosphated fertilizer.

Significant increase ($P > 0.01$) in soybean seed yield with the application of superphosphate fertilizer was obtained in the main check treatment and the residual TSP treatment. No response was observed from those newly TSP application to either rate of those residual rock phosphate. These results thus indicate that rock phosphate can be an effective source of phosphorus fertilizer in the rice-soybean double cropping system under some conditions of lowland soils.

INTRODUCTION

Paddy rice field in irrigated areas of some northern provinces like Chiangmai, Chiangrai, Lamphun, Lampang, Phrae and Phayao was used after paddy rice harvesting season for growing some other crops such as soybean, groundnut, tobacco, garlic, and vegetables. These areas have different soil fertility status. Problem often found in relation to plant nutrients was an insufficiency of available phosphorus for plant growth, especially in growing soybean and groundnut. According to a study on Thai paddy soil fertility undertaken by Chantanaparb, *et al.* (1976), it was stated that 141 out of 197 paddy soil samples in the North contained available phosphorus ranging from 1 – 10 ppm P which were considerably low. Tiaranan, *et al.* (1977) discovered that response to phosphatic fertilizers of soybean cultivar S.J. 2 had some relationship with an analytical result of available phosphorus in soil, i.e., soybean did not respond to phosphatic fertilizer application when soil contained more than 12 ppm available phosphorus and if soil contained an available phosphorus value of 3 – 4 ppm P, an application of 56.25

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kg P_2O_5/ha phosphatic fertilizer would double soybean yield. Most of the soil in Maewang Irrigation Project area in Lampang province had low value of available phosphorus. Farmers in the area grow paddy rice as their main crop in the wet season and soybean as their subsidiary crop in the dry season. A 16-20-0 fertilizer was generally applied to paddy rice. Most growers did not use fertilizer for soybean or, if applied, the amount has been minimal. This was because the fertilizers are comparatively expensive and farmers believed that soybean can use the left over fertilizers applied to paddy rice. There was a possibility for easily or rapidly soluble forms of the applied phosphatic fertilizer (16-20-0 fertilizer) to be fixed in the soil, therefore, phosphorus was not in the form usable to paddy rice. Degree of the phosphorus fixation would depend on chemical and physical conditions in the soil. Phosphate in fertilizers applied to paddy rice might not have residual effect or might remain only in a small quantity for subsequent soybean. Thus it could be concluded that low available phosphorus in the above soil condition was not sufficient for plant growth and therefore soybean yield per unit area remained low.

As indicated that problems would arise if the easily soluble phosphatic fertilizers was used and if the soil contains low available phosphorus, therefore, it was recommended that slowly soluble phosphatic fertilizers should be used in the rice-soybean cropping system. Slowly soluble characteristic of rock phosphate could be useful as it gradually released available phosphorus during the plant growth period. In addition, rock phosphate applied to rice might have a residual effect in the form of available phosphorus on soybean in the subsequent crop.

In general, most experiments in Thailand on rock phosphate were undertaken in acid sulfate soil where paddy rice is grown. There were also studies of the rock phosphate residual effect on next season crop which is again paddy rice. The current research would therefore provide data information for comparing efficiency between the rapidly and the slowly soluble phosphatic fertilizers in term of available phosphorus in the rice-soybean cropping system. The experiment was conducted in paddy Lampang Soil Series in one location. Field was flooded during paddy rice was grown. Soybean was grown subsequent to paddy rice harvest.

MATERIALS AND METHODS

An effect of rock phosphate applied to rice on seed yield of a subsequent soybean crop was investigated in a typical rice-soybean cropping system of the North during July, 1983 - April, 1984. The experiment was conducted in a farmer's field in Tambon Chomphu, Amphoe Muang, Lampang Province where "Low Humic Gley Soils (Typic Tropaqualfs)" was identified. Three randomized complete blocks with 4 treatments of 0(A1), 37.5(A2) kg P_2O_5/ha of triple superphosphate and of 1250 (A3) and 2500(A4) kg/ha of 3% P_2O_5 citrate soluble (30% total P_2O_5) rock phosphate were utilized to study the effect of fertilizer sources and rates on yield of local indica rice cultivar Sanpatong. A split plot design was subsequently superimposed on this phosphatic-rice experimant, with 4 sub-plot treatments consisting of 0(B1), 18.75(B2), 37.50(B3), 75.00(B4) kg P_2O_5/ha of triple superphosphate fertilizer applications, to determine the residual effect of these different phosphatic fertilizers on soybean cultivar S.J.4.

In the first phase of the experiment, phosphatic fertilizers were applied to paddy rice according to the mentioned treatments together with basal fertilizers, i.e., 50 kg N/ha of Urea and 37.5 kg K_2O/ha of KCl in each treatment. Fertilizers were broadcasted evenly and well mixed with the soil one day prior to transplanting period. At the panicle initial stage, top dressing with Urea of 25 kg N/ha was undertaken. Samples of plant as well as soil were collected in order to determine plant-P uptake and phosphorus availability through chemical checkings at different stages.

In the second phase of the experiment, triple superphosphate was applied to each subplot according to the above treatment arrangement. In addition, 18.75 kg N/ha of Urea and 37.5 kg K_2O/ha of KCl were also applied to each subplot as basal fertilizers. Banding method was used for all the three kinds of fertilizers. During this phase, the soybean field was irrigated. Samples of plant as well as soil were collected in order to determine plant-P uptake and phosphorus availability through chemical checkings at some stages.

RESULTS AND DISCUSSION

First Crop Experiment (Paddy Rice) :

A study on effect of types of phosphatic fertilizers on phosphorus availability in soil and on yield of local indica paddy rice cultivar "Sanpatong" in Lampang Soil Series was aimed to compare effects between two types of phosphatic fertilizers viz., triple superphosphate and rock phosphate. The results indicated that paddy rice did not respond to any phosphatic fertilizers. There was no significant difference in dry weight of paddy rice and straw with or without phosphatic fertilizers plot treatments (Table 1). This result corresponded well with experimental results reported by Srisomboon (1970, 1971), Vachhani and Abichandani (1956). Although, soil in the experimental area prior to the application of phosphatic fertilizers contained an average available phosphorus of 3 ppm P (Bray II) which was considerably low and common to most Thai paddy soil in the North. This soil also contained an extracted iron of 40 ppm Fe. It was possible then that phosphorus might be fixed in the form of iron phosphate (total phosphorus in Lampang Soil Series was 120 ppm P) as phosphorus in most Thai paddy soils were in ferrous phosphate compound form (Cholitkul and Tyner, 1971; Kawakuchi and Kyuma, 1969 and Sangtong *et al.*, 1984). Under the submergence condition, iron would be changed to phosphate which was formerly in the form of ferric phosphate, more easily soluble form of ferrous-phosphate (Chiang, 1963 a and Patrick and Mahapatra, 1968). Besides, the hydrolysis of aluminum phosphate (Valencia, 1962) and an increase in pH of soil under submerged condition (Ponnamperuma, 1965) helped fix phosphorus. Then it was released in the more useful form to paddy rice and was sufficient for its growth and high production, especially for local indica paddy rice cultivar "Sanpatong" grown in Lampang Soil Series. Moreover, local-paddy rice varieties did not respond to phosphatic fertilizers.

When phosphatic fertilizers were applied to paddy soil, phosphorus from rapidly soluble fertilizers (which was triple superphosphate) would be released and then fixed promptly by soil mass and available phosphorus was, as a result, left minimum (Chang, 1976 and Chiang, 1963 b). In the case of rock phosphate (which was a slowly soluble fertilizer), available phosphorus usable for plants would be released gradually and continuously (Van Raij, 1981). The plants were therefore able to absorb the released available phosphorus sufficiently during their growth period. Table 1 shows the supportive analytical results. Surplus available phosphorus would be kept accumulatively in the soil. Although phosphorus was fixed in submerged soil condition similar to the case of well drained upland soil, however, the effect was not substantial, as various chemical reactions indicated above helped increase the amount of available phosphorus and rock phosphate also gradually released phosphorus. Available phosphorus was, as a result, kept accumulatively. In conclusion, available phosphorus in soil at different stages of paddy rice growth and total plant P uptake obtained from the plots treated by both high and low rock phosphate application rates (A3, A4) were higher than those obtained from the plots treated by triple superphosphate (A2) and from the plot with no phosphatic fertilizer (A1) (Table 1).

No increase in dry weight of yield (seed and straw) indicated that paddy rice did not respond to any phosphatic fertilizers. However, according to an analysis of the available phosphorus, there was an increase in total phosphorus in paddy rice. This characteristic of nutrient absorbtion was known as luxury consumption.

Second Crop Experiment (Soybean) :

A study on the residual effect of phosphatic fertilizers on yield of soybean cultivar S.J.4 grown after paddy rice harvest was aimed to compare the effects of triple superphosphate (A2) and rock phosphate of 2 rates i.e. 1250 (A3) and 2500 (A4) kg/ha, previously applied to paddy rice measured in term of available phosphorus. In growing soybean, four rates of triple superphosphate, i.e., 0(B1), 18.75(B2), 37.50(B3) and 75.00(B4) kg P_2O_5/ha were additionally applied to respective plots. The results indicated that there was residual effect of rock phosphate for both rates. As a result, dry weight of stover, grain and phosphorus concentration and uptake in soybean obtained from the plots treated with rock phosphate were higher than those obtained from the plots treated previously with triple superphosphate which had lower residual effect and from the plots with no phosphatic fertilizer (A1). The difference was significant. The above results were supported by the analytical values of phosphorus in soil sample collected at preplanting period and at 44 days old of soybean peroid. The plots previously applied with two rates of rock phosphate to paddy rice gave the higher analytical values than the plots previously applied with triple superphosphate and than the plots with no phosphatic fertilizers (Table 2). This corresponds well with the experimental results reported by Kuramarohita and Ratanarat (1982).

With respect to the newly applied triple superphate of 4 rates, soybean, in case of the plots not previously applied with phosphatic fertilizer and of the plots previously applied with triple superphosphate to paddy rice having relatively low analytical value of available phosphorus, responded to the newly applied phosphatic fertilizers. Dry weight of yield and total phosphorus uptake of soybean obtained from the plots previously treated with triple superphosphate tends to have higher value than those obtained from the plots not previously treated with phosphatic fertilizer for paddy rice. The reason is that soybean received high quantity of phosphorus from the residual effect of triple superphosphate and from the newly applied phosphatic fertilizers. As regards to both rates of rock phosphate applied, residual effects were obvious, and analytical values of available phosphorus in the soil at pre-planting period of soybean were relatively high. Soybean did not respond to the newly applied phosphatic fertilizer, i.e., no difference in dry weight of soybean yield between the plots treated and not treated with phosphatic fertilizers was observed. However, if rock

Table 1 Effect of phosphatic fertilizers on dry weight (kg/ha), phosphorus concentration (%) and phosphorus uptake (kg/ha) of rice, and available phosphorus in soil (ppm P) at different growth stages.

Treatment	Dry weight		P-concentration		Total P-uptake	Available P-Bray II in soil			
	Grain	Straw	Grain	Straw		Pre-planting	Tillering	Flowering	After harvest
1. No fertilizer (A_1)	4062	3412	0.327	0.100	16.63	3.0	2.6	3.0	3.3
2. Triple superphosphate (37.5 kg P_2O_5/ha) (A_2)	3787	3131	0.400	0.124	18.98	3.0	4.0	7.3	6.7
3. Rock phosphate (1250 kg/ha) (A_3)	3937	3381	0.669	0.116	30.31	2.7	26.7	60.3	23.7
4. Rock phosphate (2500 kg/ha) (A_4)	4081	3425	0.717	0.137	34.04	3.6	55.0	114.0	19.7
CV (%)	5.2	9.2	6.1	5.1	9.2	–	–	–	–
LSD.05	NS	NS	0.065	0.012	4.60	–	–	–	–

NS : Non significant

Table 2 Residual effect of phosphatic fertilizer, applied for rice grown before soybean, on available phosphorus in soil (ppm P), and dry weight (kg/ha), phosphorus concentration (%) and phosphorus uptake (kg/ha) of soybean.

Treatment	Available P-Bray II in soil		Dry weight		P-concentration		P-uptake	
	Pre-planting	44 days of soybean age	Grain	Stover	Grain	Stover	Grain	Stover
A_1	3.3	3.7	487	387	0.263	0.021	1.300	0.081
A_2	6.7	6.0	1043	768	0.288	0.025	3.037	0.193
A_3	23.7	81.0	2743	1643	0.494	0.040	13.575	0.650
A_4	19.7	135.7	2737	1725	0.548	0.053	15.006	0.912

Table 3 Dry weight of grain, stover, grain phosphorus uptake and stover phosphorus uptake (kg/ha) as affected by different combinations of residual phosphatic fertilizer (A) and fresh phosphatic fertilizer (B).

Factor A	Factor B	Treatment combination	Dry weight		P-uptake	
			Grain	Stover	Grain	Stover
A_1	B_1	A_1B_1	487	387	1.300	0.081
	B_2	A_1B_2	1418	1093	4.256	0.239
	B_3	A_1B_3	1731	1237	5.825	0.275
	B_4	A_1B_4	2250	1556	9.950	0.480
	(average)		(1475)	(1068)	(5.331)	(0.268)
A_2	B_1	A_2B_1	1043	768	3.037	0.193
	B_2	A_2B_2	1587	1143	5.275	0.248
	B_3	A_2B_3	1962	1381	7.125	0.297
	B_4	A_2B_4	2325	1493	10.475	0.448
	(average)		(1731)	(1181)	(6.481)	(0.296)
A_3	B_1	A_3B_1	2743	1643	13.575	0.650
	B_2	A_3B_2	2775	1718	14.468	0.741
	B_3	A_3B_3	2806	1725	14.762	0.867
	B_4	A_3B_4	2825	1725	15.412	0.882
	(average)		(2787)	(1700)	(14.556)	(0.785)
A_4	B_1	A_4B_1	2737	1725	15.006	0.912
	B_2	A_4B_2	2893	1768	15.243	0.818
	B_3	A_4B_3	2793	1725	15.531	0.817
	B_4	A_4B_4	2818	1768	14.106	0.874
	(average)		(2812)	(1750)	(14.975)	(0.856)
CV (%) (A)			5.0	6.4	14.7	23.7
$LSD_{.05}$ (A)			225	156	1.918	0.128
CV (%) (B, AB)			6.1	6.6	11.0	13.9
$LSD_{.05}$ (B, AB)			225	162	2.243	0.171

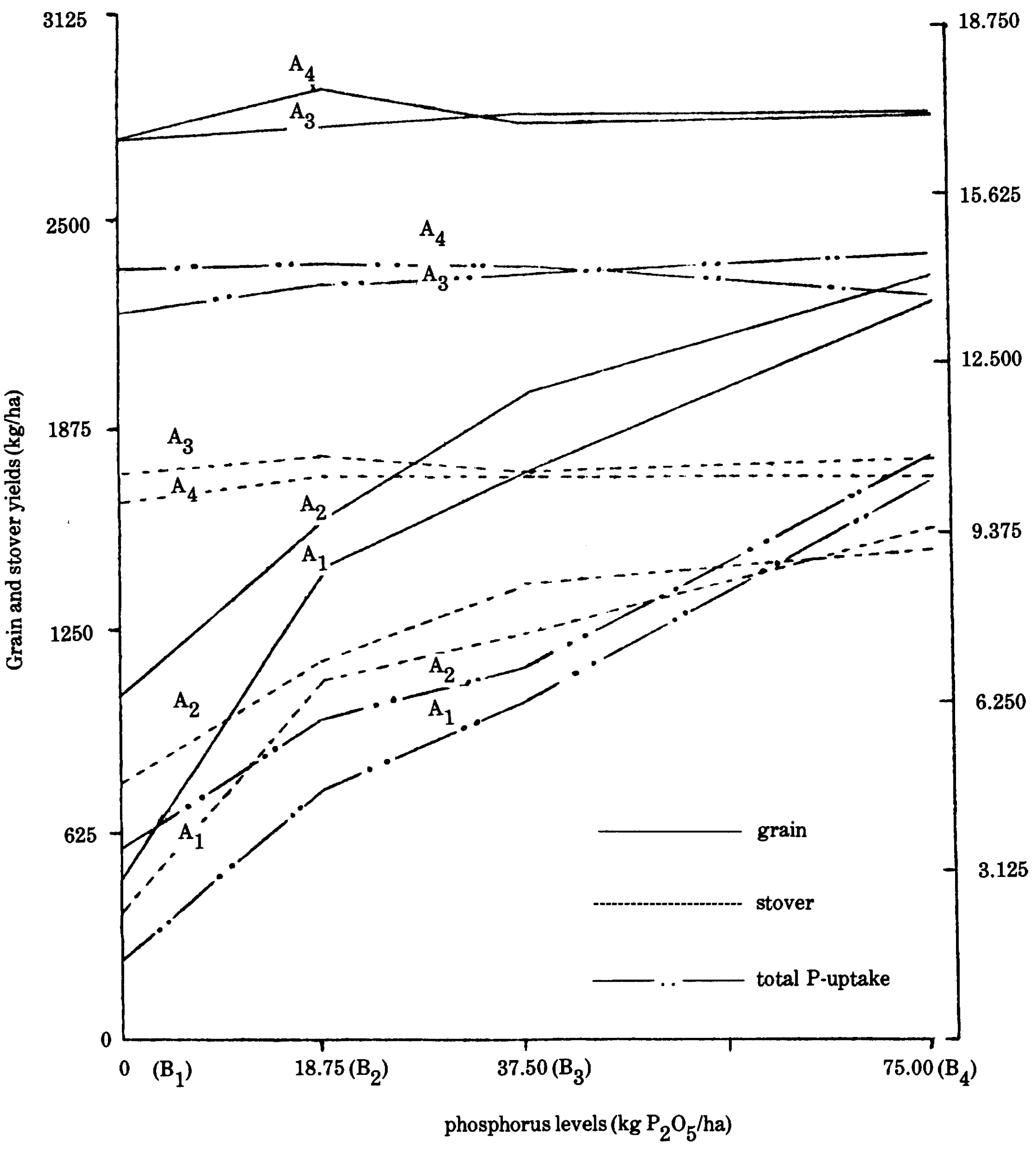

Figure 1 Residual and accumulative effects of phosphatic fertilizers on yields and total phosphorus uptake of soybean in rice-soybean double cropping system.

phosphate had low residual effects, newly applied phosphatic fertilizer helped increase total phosphorus in plant according to the increased rates of fertilizer applied (Table 3 and Figure 1). This corresponds well with the experimental results reported by Tiaranan, *et. al.* (1977, 1981 and 1982).

CONCLUSIONS

First Crop Experiment (Paddy Rice) :

The results indicated the following conditions;

1) The local indica rice cultivar "Sanpatong" did not respond to phosphatic fertilizers when used in Lampang Soil Series, i.e., there was no significant difference in dry weight of paddy rice and straw between with and without phosphatic fertilizer applications;

2) Phosphorus concentration and plant P-uptake in paddy rice when applied with both forms of phosphatic fertilizers in 3 treatments higher than that of the remaining treatment with no phosphatic fertilizer application, i.e., the analytical result of the 2,500 kg/ha rock phosphate treatment was the highest followed by the 1,250 kg/ha rock phosphate treatment and the triple superphosphate treatment gave the lowest value;

3) Phosphorus availability in soil at various stages of sampling when applied with both forms of phosphatic fertilizers was higher than that of the remaining plots treated with no phosphatic fertilizer. However, at the tillering stage and flowering stage of paddy rice, the result of the 2,500 kg/ha rock phosphate treatment was the highest followed by the 1,250 kg/ha rock phosphate treatment and the triple superphosphate treatment gave the lowest, value.

Second Crop Experiment (Soybean) :

1) There was residual effect of the phosphatic fertilizers applied to paddy rice in the form of available phosphorus for the subsequent soybean cultivar S.J.4. The residual effect was best obtained from both rates of rock phosphate fertilizers applied, with no difference between each other. As a result, dry weight of soybean yield, phosphorus concentration and plant P-uptake in soybean in the rock phosphate treatments was of the highest value. Only a mild residual effect was observed from triple superphosphate treatment. They was a trend showing that yield and plant-P-uptake of soybean from the triple superphosphate treatment was higher than that of the treatment with no phosphatic fertilizer application to previous paddy crop. However, the difference was not obvious;

2) Either in the case with no fertilizer residual effect or with residual effect of triple superphosphate, soybean would respond to the newly applied-triple superphosphate at different rates as evidenced that dry weight of yield and plant P uptake showed increasing values in accordance with the increased rates of fertilizers applied. On the contrary, soybean would not respond to the newly applied phosphatic fertilizers where rock phosphate was previously applied and residual effects were observed, particularly if measured in term of yield.

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