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Deficiencies and Toxicities of Some Nutrient Elements in Acid Sulfate Soils of Thailand

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ABSTRACT

This paper reviews the works on nitrogen, and phosphorus deficiencies and kinetics of Fe and Al in acid sulfate soils of Thailand. The research revealed that rice plants response to nitrogen fertilizer due to the low N mineralization rate especially soils with high acidity. Addition of organic waste materials resulted in lower mineralizable N in acid sulfate soils compared to non acid sulfate soils. Response to phosphorus fertilizer was due to low total P content and high P - fixation capacity. P - sorption studies of the soils confirmed this results. In the very acidic acid sulfate soils, no grain yield was obtained without phosphate application. Iron and aluminum are the two important toxic elements in acid sulfate soils. However, the soluble content was less in acid sulfate soils in Thailand compared to acid sulfate soils in Vietnam. Thus, no toxicity of these two elements has been reported. The toxicity symptoms of the two elements could be found when oxidized potential acid sulfate soil was leached and limed.

Key words : nitrogen and phosphorus deficiencies, Fe and Al toxicities, acid sulfate soils of Thailand.

INTRODUCTION

Acid sulfate soils of Thailand have been known and recognized about 50 years ago. The characterization and extensive studies have been done since 1969. The classical soil survey reports revealed that 1.5 million hectares of acid sulfate soils were found in Thailand and 0.8 million hectares were located in the Southern Central Plain while the remaining scattered along the Southeast coast and the Peninsula. Detailed chemical analyses of the soils were done by Kawaguchi and Kyuma (1969). It revealed that deficiencies of nutrients, especially nitrogen and phosphorus due to the high acidity of the soils were among of the adverse properties of acid sulfate soils. The available P was also low in acid sulfate soils, phosphate fertilization alone could raise the rice yield to a certain extent, but phosphate fertilization in combination with liming produced higher yields (Uwaniyom and Chareoncham-ratcheep, 1984). Toxicities of Fe and Al are also the serious problems limiting the growth and yield of rice in most of acid sulfate soils. The high concentration of Fe resulted in high percentage of unfilled grain. In the case of acid sulfate soils of Thailand, no toxicity symptoms have been found since the concentrations of water soluble Fe and Al in the soil were very low. The concentration of Mn has also been found low in acid sulfate soils of Thailand. Addition of manganese resulted in higher grain yield. The Fe toxicity could be found only when potential acid sulfate soils was oxidized and planted with lowland rice. The Al toxicity symptoms of rice have been reported in Bangkok plain during the dry stage of broadcast rice growing on acid sulfate soil (Moormann and van Breemen, 1978).

Nitrogen and phosphorus deficiencies

Responses of rice to nitrogen and phosphorus are always observed in acid sulfate soils. These are due to low mineralization rate of nitrogen and high P fixation of the soils. Attanandana and Vacharotayan (1986) reported that ammonification in acid sulfate soils especially those with high acidity was low as compared to that in non acid sulfate soils (Table 1). Application of organic waste materials resulted in lower mineralization of nitrogen in acid sulfate soils as compared to non acid sulfate soils (Table 2). Results of an experiment on rice response to nitrogen fertilizer in acid and non acid sulfate soils was shown in Table 3. The maximum dry matter yield (84 g/pot) obtained from Rangsit very acid soil was far below those of

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Table 1 pH, organic matter content and ammonification percentage of acid and non acid sulfate soils.

Soil series		pH	% O.M.	Total N	Ammonification percentage
Non acid	Ratchaburi	6.0	1.7	0.08	3.5
sulfate	Bangkok	4.5	3.4	0.17	1.7
Acid	Sena	4.5	3.7	0.19	2.2
sulfate	Rangsit	4.1	2.0	0.10	1.5
	Rangsit very acid	4.0	6.4	0.30	0.5

Source : Attanandana and Vacharotayan, 1986.

Table 2 Mineralizable N in Rangsit and Roi Et soils with organic waste amendment.

Soil	Mineralizable N (ppm)
Rangsit (Ra)	15
Ra + rice straw compost	41
Ra + activated sludge[1]	276
Ra + castor meal[1]	553
Roi Et (Re)	14
Re + rice straw compost[1]	60
Re + activated sludge[1]	363
Re + castor meal[1]	605

1 = 0.1 gm N/100 gm soil
Source : Chanchareonsook *et al.*, 1984.

Bangkok (195 g/pot), Ratchaburi (243 g/pot), Sena (191 g/pot) and Rangsit soils (191 g/pot). At the same rates of nitrogen fertilizer, Bangkok and Ratchaburi soils showed much higher dry matter yield, indicating an inherent higher soil fertility of these two non acid sulfate soils.

Results of an experiment (Figure 1) on P fertilization in acid sulfate and non acid sulfate soils revealed that available P increased with higher rate of application. However, available P was higher in non acid sulfate soils at all of the rates of P application. P sorption study of the soils revealed that the non acid sulfate soil had lowest P adsorption capacity. (Figure 2) Among the acid sulfate soils, Rangsit very acid (class P IV a) had the highest P-fixation capacity.

It has been found that Fe-P is the main P fraction in acid sulfate soils, Al-P the second most species and Ca-P the third (Table 4). All of these fractions are highly correlated with P uptake of rice (Sangtong *et al.*, 1987). Rock phosphate is a promising phosphate fertilizer in acid sulfate soils. Availability of rock phosphate would increase with soil acidity. Figure 3 and 4 showed Bray II extractable P in Ongkharak soil applied with rock phosphate which was higher than the extractable P in the same soil applied with triple superphosphate.

Three annual applications with rock phosphate have been reported to increase in soil pH, available

Table 3 Dry matter responses (g/pot) of rice plant to application of nitrogen on acid and non acid sulfate soils.

Level of Nutrient[1]		Acid sulfate soils			Non acid sulfate soils	
ppm N/pot		Sena	Rangsit	Rangsit very acid	Ratchaburi	Bangkok
No	(0)	33	23	25	26	32
N_1	(250)	156	147	65	160	141
N_2	(500)	191	191	84	243	195
N_3	(750)	188	180	78	212	175
LSD.	05	29	30	18	35	23
	01	38	40	24	47	31

1 N_1, N_2, N_3 for Rangsit very acid = 150, 300 and 450 ppm respectively.
Source : Attanandana, 1982.

Table 4 Phosphate fractions in acid sulfate soils of Thailand.

	pH	Phosphate fractions (ppm) Total P	Al-P	Fe-P	Ca-P
Non acid sulfate soils					
Bangkok	4.9	460	10.0	152.6	31.6
Acid sulfate soils					
Rangsit very acid	3.6	338	17.2	106.0	5.7
Rangsit	4.1	383	21.4	146.0	14.0
Sena	4.2	314	2.3	64.0	9.3
Acid sulfate soils*	4.9	420	26.3	137.5	13.8

Source : Sumongkayothin, 1989.
Sangtong *et al.*, 1987

P and total P contents of the acid sulfate soils (Chermsiri *et al.*, 1986). Total acidity and exchangeable Al were also decreased for all locations studied, except at Prachin Buri of which exchangeable Al was more or less unchanged (Table 5).

Fe and Al toxicities

Iron, aluminum and manganese are readily soluble under acidic condition. The pH of acid sulfate soils are always lower than 4. Therefore, Fe and Al toxicities could be expected in lowland rice. Nhung and Ponnamperuma (1966) reported a Vietnamese soil contained 800 ppm of water soluble Fe which was toxic to the rice plant. Water soluble Al of 68 ppm was also found harmful to the rice plant in acid sulfate soil from Vietnam. The study of Al in acid sulfate soils of

Table 5 Some chemical properties of paddy soils before and after 3 annual application with rock phosphate.

Sampling site	pH (1:1H_2O)	Total acidity me/100 g	Exch. Al me/100 g	O.M. %	Total P ppm	Bray II-P ppm
Pathum Thani-Province						
Before fertilization	4.0-4.5	5.80	3.75	3.22	333	8.5
After fertilization	4.5-6.5	2.22	1.55	3.25	528	67.2
Nakorn Nayok Province						
Before fertilization	3.7-4.5	9.89	8.11	3.14	287	7.4
After fertilization	4.3-5.1	10.06	7.44	3.94	482	56.5
Prachin Buri Province						
Before fertilization	4.0-4.6	8.24	5.02	2.47	242	6.3
After fertilization	4.5-4.9	6.30	5.15	2.83	515	68.5

Source : Chermsiri *et al.*, 1986.

Table 6 Concentration of water soluble Fe and Al at various growth stages and the grain yields of rice in Rangsit very acid and Ongkharak soils.

	Water soluble Fe (ppm)			Water soluble Al (ppm)			Grain yield
	TP	FW	HV	TP	FW	HV	gm/pot
Rangsit very acid							
Rock phosphate	3.0	60.0	52.0	2.5	1.2	1.3	7.3
Triple superphosphate	5.4	58.0	80.0	3.5	1.5	0.9	11.7
Ongkharak							
Rock phosphate	0.5	70.0	9.0	0.7	1.5	2.5	23.3
Triple superphosphate	4.5	48.0	9.0	11.0	57.5	60.0	4.6

TP = Transplanting, FW = Flowering, HV = Harvesting
Source : Woraanuwattanakul, 1986.,
Sawudyotin, 1987.

Table 7 Concentration of water soluble Fe and Al at transplanting and harvesting stages and the grain yield of rice in acid and non acid sulfate soils.

	Water soluble Fe at harvesting (ppm)	Water soluble Al at transplanting (ppm)	Grain yield (gm/pot)
Rangsit very acid	28	8.0	6.3
Rangsit	4	0.9	66.0
Sena	22	1.0	2.6
Bangkok	16	0.9	69.0

Source : Sumongkayothin, 1989.

Table 8 Extractable Fe and Al and survival of the rice plant in oxidized Bang Pakong soil.

soil series	NaOAc-extractable Fe (ppm)	NaOAc-extractable Al (ppm)	Survival of rice plant (days)
Bang Pakong (Bg)	1175	493	3
Bg (leached + limed)	1688	163	25

Source : Petchayapisit, 1985.

Thailand by Sangtong *et al.* (1981) revealed that Rangsit very acid soil from various locations contained KCl extractable Al contents of 3.0 - 8.5 me/100 g while Ongkharak soil contained 2.0 - 5.5 me/100 g. Other acid sulfate soils, i.e. Sena and Rangsit soils, contained KCl extractable Al of as high as 1.2 and 5.3 me/100 g, respectively. Kinetics of Fe and Al in the most acidic acid sulfate soils of Thailand (Rangsit very acid and Ongkharak soils) have been studied. The results showed that the highest contents of water soluble Fe and water soluble Al for unlimed Ongkharak soils were 70 and 60 ppm, respectively. In the case of Rangsit very acid soil, the highest water soluble Fe of 80 ppm and the highest water-soluble Al of 3.5 ppm were found. Rock phosphate application in Ongkharak soil lessened the water soluble Al, resulted in higher grain yield. An experiment comparing other acid sulfate soils to non acid sulfate soils revealed that water-soluble Fe were 28, 4, 22 and 16 ppm at harvesting stage for Rangsit very acid, Rangsit, Sena and Bangkok soils, respectively.

In the case of water -soluble Al, there were 8.0, 0.9, 1.0 and 0.9 ppm at transplanting stage for Rangsit very acid, Rangsit, Sena and Bangkok soils, respectively (Table 7). There is no possibility of Fe and Al toxicities in these soils. Water soluble Al and Fe of 68 ppm and 800 ppm was reported to be toxic to the rice plants (Nhung and Ponnamperuma 1966). When an oxidized potential acid sulfate soils, (Bang Pakong soil series) was submerged and planted with rice, iron toxicity symptoms developed after 11 days and the plants survived only 3 days. It can be stayed for 25 days when the soil was leached and limed. The NaOAc -extractable Fe

Table 9 Water soluble and extractable Fe and Al at transplanting stage on straw yield in Rangsit soil.

Treatment			Al (ppm)		Fe (ppm)		Straw
			H_2O soluble	KCl-extract.	H_2O soluble	KCl-extract.	(g/tiller)
Check			6	3	71	435	41
Al	5	me/100g	48	15	465	1,154	35
	10	me/100g	168	165	601	1,484	16
	15	me/100g	224	268	572	2,021	9
Fe	0.5	%	32	11	1,506	4,352	4
	1.0	%	49	14	2,933	7,875	0
	2.0	%	97	26	2,962	14,928	0
Mn	750	ppm	8	3	176	364	53
	1500	ppm	8	3	246	375	60
	3000	ppm	13	3	307	365	38

Source : Pienpermpat, 1985.

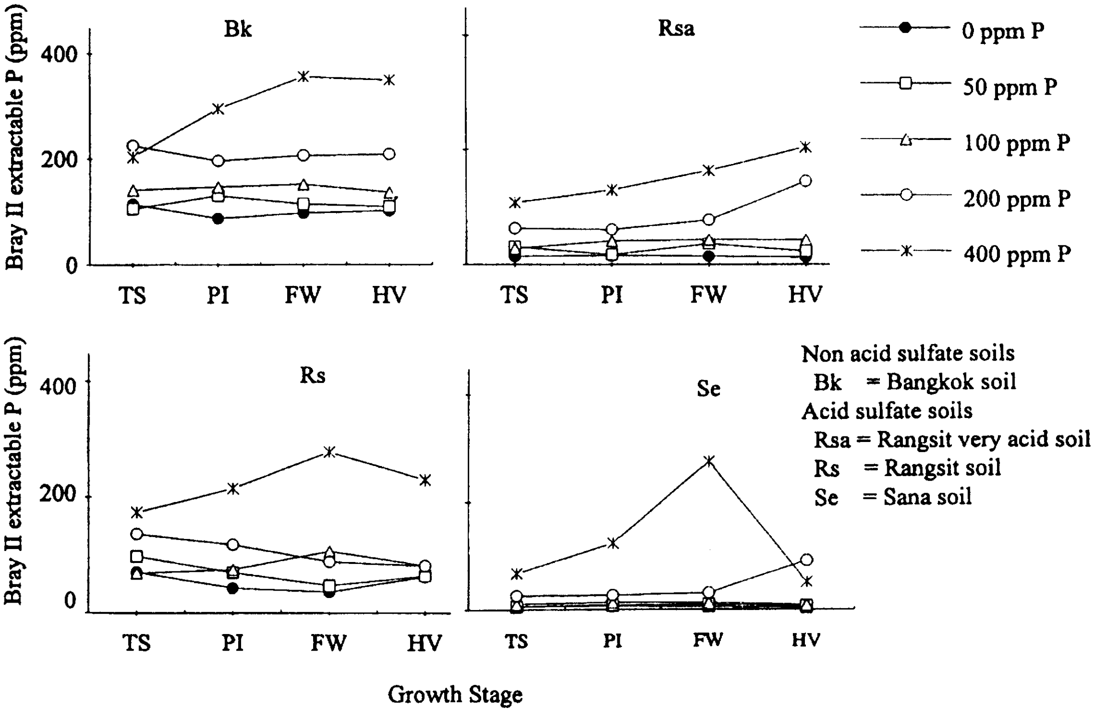

Figure 1 Available P at various stages of rice plants grown with different rates of monoammonium phosphate application in acid and non acid sulfate soils (Sumongkayothin, 1989).

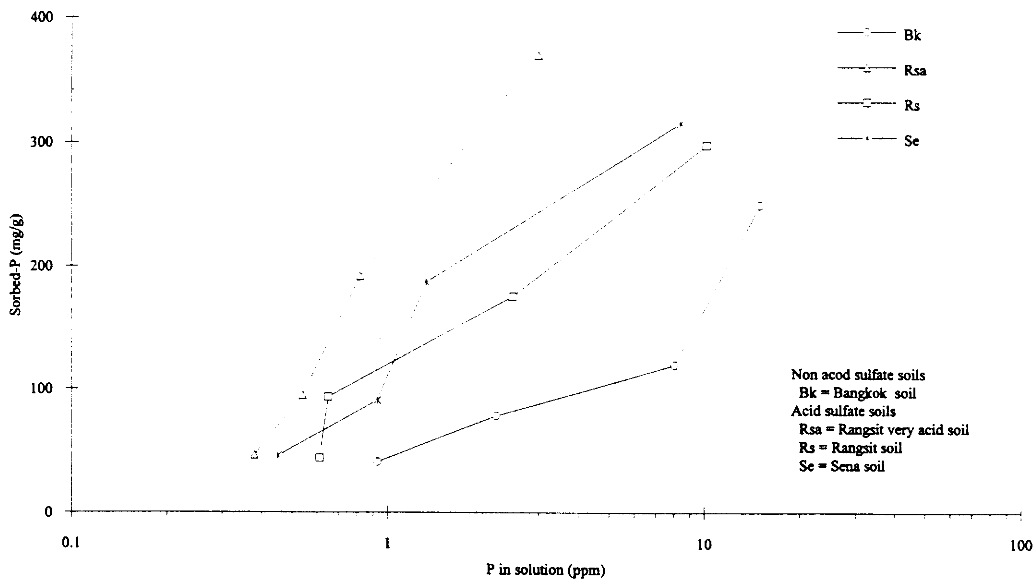

Figure 2 P-sorption of acid and non acid sulfate soils (sumongkayothin, 1989).

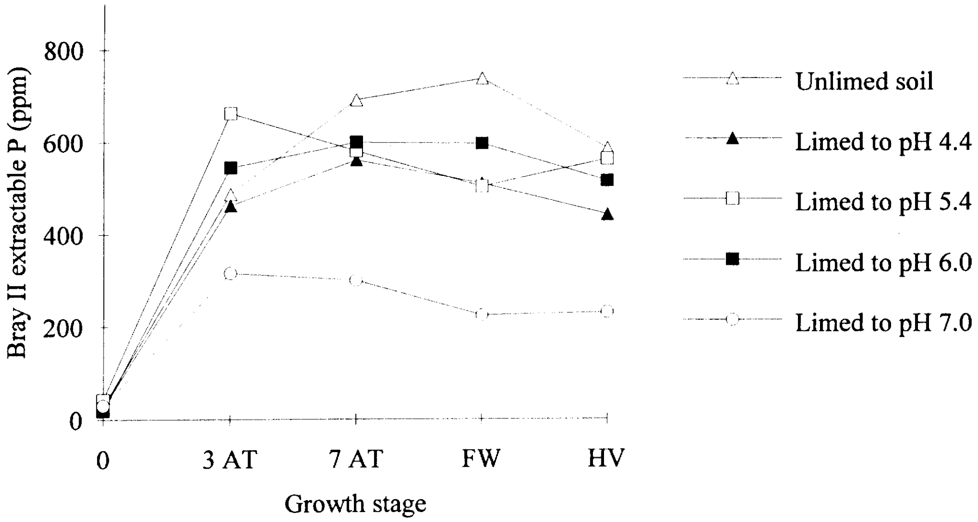

Figure 3 Bray II extratable P at various stages of rice growth in Ongkharak soil with rock phosphate application (Sawudyothin, 1987).

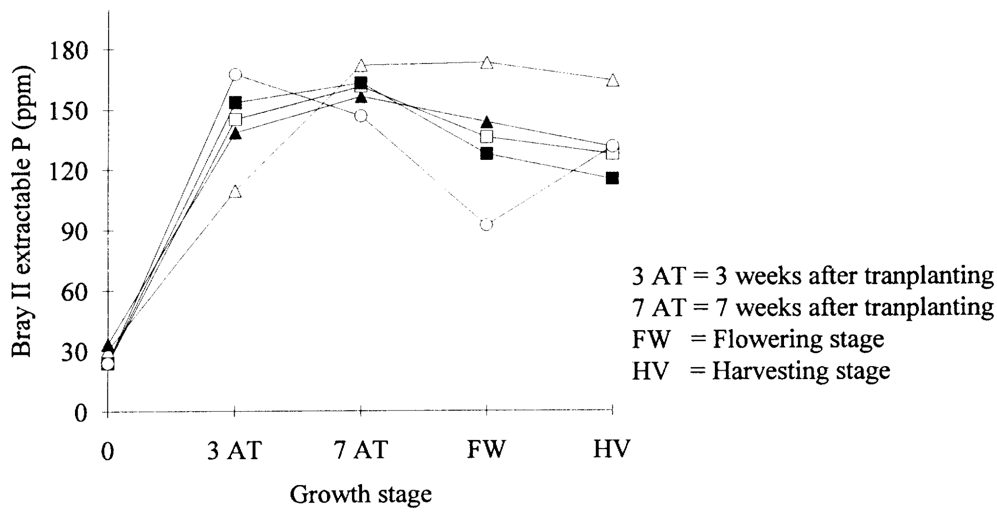

Figure 4 Bray II extratable P at various stages of rice growth in Ongkharak soil with triple superphosphate application (Sawudyothin, 1987).

Table 10 Residual effects of liming and phosphate fertilization on water soluble Fe, Al at transplanting stage and yields of rice in Rangsit very acid and Ongkharak soils.

Treatment		Al (ppm)	Fe (ppm)	Yield (gm/pot)	
				grain	straw
Rangsit very acid					
L_0	P_0	50	95	0	2.1
	P_1	49	125	39.1	45.3
L_1	P_0	25	115	0	1.7
	P_1	22	70	68.2	60.7
L_2	P_0	11	50	0	2.2
	P_1	11	32	77.2	65.5
Ongkharak soil					
L_0	P_0	55	230	0	13.5
	P_1	42	245	66.0	65.2
L_1	P_0	38	220	0	8.2
	P_1	33	170	72.3	58.9
L_2	P_0	17	230	0	10.8
	P_1	19	120	82.6	61.8

L_0 = no lime
L_1 = limed to pH 4.5
L_2 = limed to pH 5.5
P_0 = no phosphate fertilizer
P_1 = 75 ppm P
Source : Kaewprommal, 1985.

and Al were 1688 and 163 ppm respectively (Table 8). Plant analysis revealed the iron content as high as 3095 ppm and Mn content of 330 ppm.

An experiment on Rangsit soil revealed that water soluble and extractable Al and Fe increased with Al addition. This results was also true with Fe addition. Mn addition at substantial amount increased grain yield while a decrease in grain yield was obtained when Mn was over added (Table 9).

Residual effect of liming and phosphate application on water soluble Fe and Al and yield of rice in Rangsit very acid and Ongkharak soils revealed the pronounced effect of phosphorus. Without phosphate application, no grain yield was obtained from both soils. Combination of liming and phosphate application markedly increased grain yield (Table 10). Although toxic effect of Al was not found, but relatively low concentration of Al was observed on liming and phosphate application.

CONCLUSIONS

Various experiments on acid sulfate soils of Thailand showed pronounced effects of nitrogen and phosphate fertilization especially in the case of Rangsit very acid and Ongkharak soils. These were due to low N-mineralization and high phosphate fixing capacity of these soils. Phosphorus fractionation revealed that Fe-P was the main phosphate compound found in acid sulfate soils and Al-P was the second most species in these soils. Water soluble Fe and Al in acid sulfate soils were generally low, and toxicity rarely occurred accordingly. In the case of strongly acid soils, Rangsit very acid and Ongkharak soils, high Al contents though not in a toxic range, markedly depressed rice grain yield.

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