Amelioration of Tropical Peat/Acid Sulfate Soils and Its Effect on Sulfate Reduction Under Waterlogging

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Tropical swampy peat forests are widely distributed on the coastal area of South-East Asia. Recently, land reclamation has been started in the area to meet the increasing demand for cultivable land. However, the reclamation has rarely been successful due to the following causes: Serious land subsidence due to both the slash and burning of forests and dehydration, contraction and decomposition of peat taking place after drainage. Nutrient deficiencies hinder crop growth. After the peat layer becomes shallow, the underlying marine deposit /containing pyrite minerals/ may cause a strong surface acidification. Although lowland rice is the most adequate crop for peat land, its sterility /that is the failure of grain formation/, may occur in the paddy field. After applying lime to the peat/acid sulfate soils, the evolution of hydrogen sulfide is frequently observed under waterlogging.

Since 1983, experiments aiming the improvement of tropical peat/acid sulfate soils have been conducted in the Narathiwat Province, located in the southern peninsula of Thailand, in the framework of the cooperation between Japanese and Thai scientists. These studies comprise 1/ field experiments to treat acidification, 2/ the elucidation of soil and water characteristics in peat land area, 3/ plant nutritional approach to poor soil fertility and 4/ the clarification of the cause of rice sterility.

This paper introduces a field experiment set up to treat both the surface acidification of peat/acid sulfate soils and the sulfate reduction process under waterlogging followed by lime application.

Field experiment to treat surface acidification

The Kab Daeng series /peat soil/ and the Munoh series muck acid sulfate soil/ were selected as the experimental sites.

Tests were carried out not only with the correction of the acidity of the top soils by applying lime dust equivalent to the total acidity but also by inserting a buffering layer of lime gravel /diameter of 3/8 inch/ at the depth of 5 cm between the top soil and the acidic subsoil for protection against surface acidification due to the upward movement of acidic groundwater. Lime dust application was designated LD, the underlaying of lime gravel: LG and fertilizer application was designated F.

The treatment of each experimental plot for paddy rice was as follows: P1 and P5: control plots without any treatment; P2 and P6: plots treated with fertilizer and lime dust; P3 and P7: plots treated with fertilizer and underlaid with lime gravel; P4 and P7: plots treated with fertilizer, lime dust and underlaid with lime gravel.

Table 1 shows paddy rice yields in the P1, P2, P3 and P4 plots in the Munoh soil series between 1983 and 1989. Without liming /P1/ paddy rice could not be grown on the young acid sulfate soil. Lime dust application on the surface /P2/ decreased soil acidity quickly and resulted comparatively higher rice yields at an earlier period, but its residual effect is not permanent. The underlaying of lime gravel /P3 and P4/ gave rise to a long-lasting residual effect. At plot P3 /in which lime gravel was underlaid and lime dust was not applied/ the rice yield had increased with time.

Table 1

The rice yield and the ratio of sterilized grain in the Munoh series from 1983 to 1989

Plot	Paddy rice, kg/ha						
	1st crop 8-12/83 RD25	2nd crop 8-12/84 RD25	3rd crop 10-3/85 Hom Mali	4th crop 7-11/85 RD23	5th crop 10-2/86 Hom Mali	6th crop 9-1/88 KooMuang	7th crop 10-2/89 RD23
P1 Control	2 /70/*	0	63 /7/	0	8 /11/	0	51 /16/
P2 F.LD	783 /37/	765 /39/	769 /6/	2,113 /10/	2,336 /11/	37 /48/	286 /20/
P3 F.LG	10 /20/	541 /58/	850 /5/	3,519 /12/	2,078 /16/	298 /37/	1,071 /31/
P4 F.LD.LG	1,162 /24/	256 /68/	470 /6/	2,638 /10/	3,150 /9/	33 /84/	2,009 /18/

Table 2

The rice yield and the ratio of sterilized grain in the Kab Daeng series from 1983 to 1989

Plot	Paddy rice, kg/ha						
	1st crop 8-12/83 RD25	2nd crop 1-4/84 RD25	3rd crop 8-12/84 RD25	4th crop 11-4/85 Hom Mali	5th crop 7-11/85 RD23	6th crop 9-4/87 RD13	7th crop 7-11/88 RD23
P5 Control	1,061 /26/*	16 /20/	418 /20/	44 /25/	469 /11/	0	0
P6 F.LD	802 /27/	437 /18/	541 /53/	1,288 /11/	2,606 /5/	357 /19/	735 /10/
P7 F.LG	861 /40/	224 /21/	408 /53/	525 /11/	2,600 /8/	1,112 /12/	1,551 /11/
P8 F.LD.LG	603 /40/	916 /14/	367 /50/	1,444 /8/	3,981 /5/	1,049 /21/	1,429 /5/

*The numbers in parenthesis show % of sterilized grain

Table 2 gives data on paddy rice yields in the P5, P6, P7 and P8 plots in the Kab Daeng soil series from 1983 to 1989. Without liming /P5/, paddy rice yield was highest in the first year, however the yield declined significantly in later periods. Lime dust application on the surface /P6/ was not effective at a later period. The residual effect of the underlaid lime gravel /P7 and P8/ occurred with time.

The improvement of pH values of the topsoils by lime dust application and the underlaying of lime gravel coincided with rice yields grown on these plots. Table 3 demonstrates that lime dust application increased the soil pH to 5.0-6.0 in 1984, however by 1986 the soil pH returned to values below 3.5. On the contrary, the soil pH in the plots underlaid with lime gravel ranged between 4-5 in the later period.

Sulfate reduction process under waterlogging followed by lime application

In August 1986, surface soil samples were collected at Munoh series and Kab Daeng series from plots with different treatments. These air-dried soil samples were used for the incubation experiment.

The soil samples were put in truncated syringes of 50 ml volume and submerged with water at a 1:4 soil:water ratio.

The incubation was conducted at 30 ^{o}C. Periodically Eh, pH, sulfide, water soluble sulfuric acid and the number of sulfate reducing bacteria were determined for the incubated soils.

Eh and pH. - Fig. 1 shows the changes in Eh and pH values in the Munoh series during incubation. The Eh dropped in the decreasing order of: P4 > P3 > P2 > P1, a higher initial soil pH stimulated the Eh decline. The pH increases parallel with the Eh decline.

The same tendency was found in the Kab Daeng for Eh and pH, the correlation coefficient between Eh and pH was -0.841 in the Munoh series and -0.911 in the Kab Daeng series.

Sulfide and water-soluble sulfuric acid. - Fig. 2 illustrates the increase of sulfide in the Munoh series with time during incubation. In the plots P4 and P3 sulfide formation started 7 to 14 days after waterlogging. The amount of sulfide at a later period was in the decreasing order of: P4 = P3 > P2 > P1. Water-soluble sulfuric acid in the Munoh soil decreased in correspondence with the sulfide formation. It was clear that sulfate reduction was followed by the significant decline of Eh and the increase of pH. The same tendency was found for sulfide and water soluble sulfuric acid in the Kab Daeng series.

Abundance of sulfate reducing bacteria - As shown in Fig. 3, sulfate reducing bacteria in the Munoh series increased in the P4 plot from 14 days after waterlogging. The abundance of sulfate reducing bacteria was most highest in the P4 plot and corresponded to the amount of formed sulfide on the 60th day after waterlogging. A similar tendency in the abudance of sulfate reducing bacteria was found in the Kab Daeng series.

Relationship between Eh, pH and sulfide formation. - As shown in Fig. 4, in the Munoh series a critical Eh for sulfide formation was +100 mV, and the critical pH for sulfide formation was 5.0. In the Kab Daeng series, the same figures were obtained for the critical Eh and pH.

Table 3

Changes in the pH values of the topsoils /0-10 cm depth/ in the experimental plots in the Munoh series and Kab Daeng series from 1984 to 1986

Plot	Munoh series		Plot	Kab Daeng series	
	1984	1986		1984	1986
P1, Control	3.68	3.15	P5, Control	4.15	3.37
P2, F.LD	5.50	3.60	P6, F.LD	5.00	4.16
P3, F.LG	4.65	4.58	P7, F.LG	5.08	4.22
P4, F.LD.LG	5.33	5.64	P8, F.LD.LG	5.79	4.78

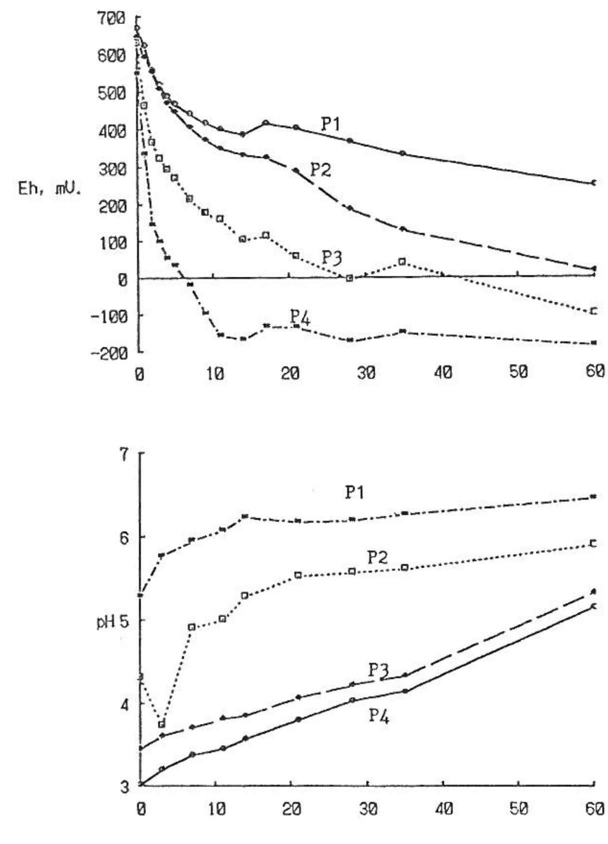

Fig. 1

Eh and pH values in the Munoh soil series in plots P1, P2, P3 and P4. P1: Check; P2: LD.F; P3: LG.F; P4: LD.LG.F

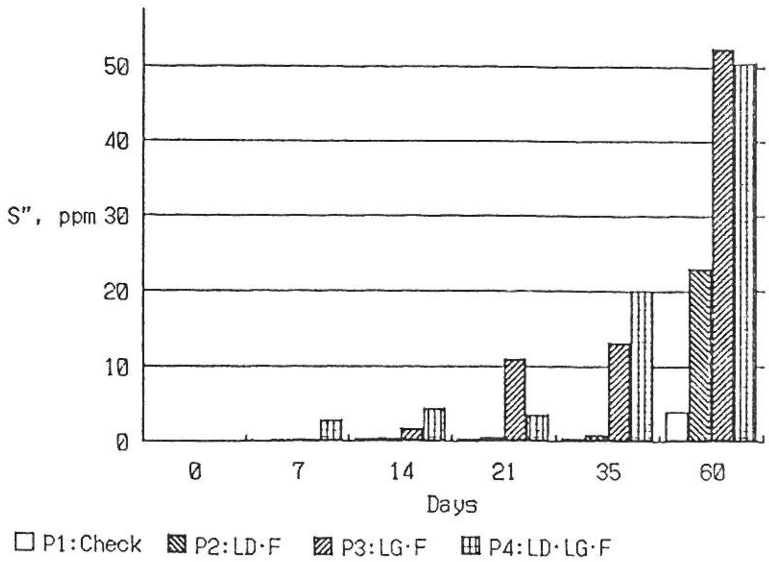

Fig. 2
Sulfide in the Munoh soil series. P1: Check; P2: LD.F; P3: LG.F; P4: LD.LG.F

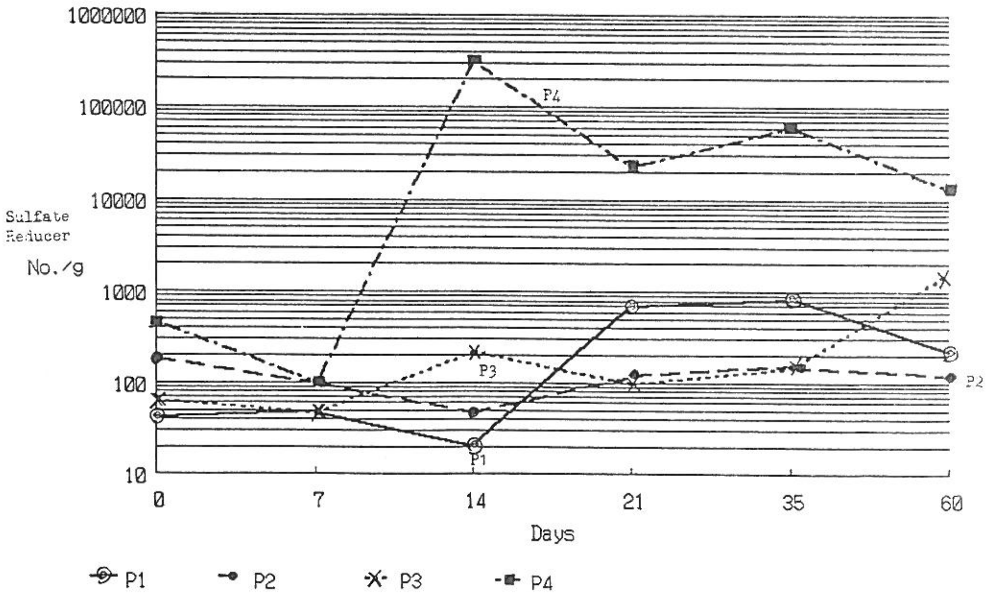

Fig. 3
Number of sulfate-reducing bacteria in the Munoh soil series

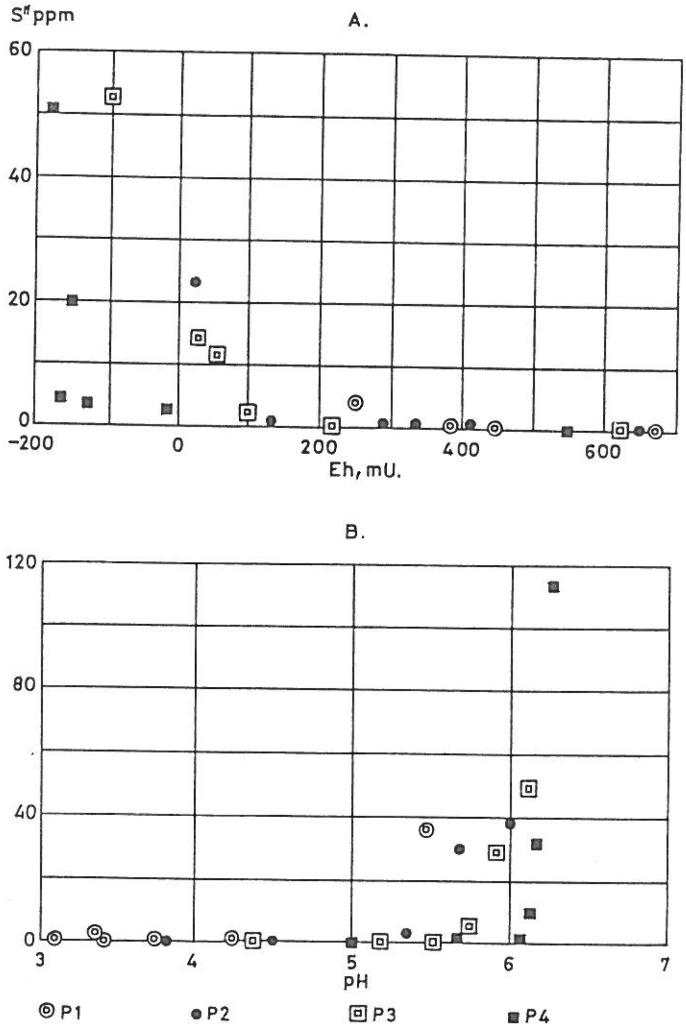

Fig. 4

Relationship between Eh and sulfide /A/ and pH and sulfide /B/ in the Munoh soil series. P1: Check; P2: F.LD; P3: F.LG; P4: F.LD.LG

Summary

Tropical swampy peat forests are wide-spread on the coastal area of South-East Asia. Their reclamation has rarely been successful due to several defects, among these is surface acidification. Authors carried out a field trial to treat both surface acidification and the sulfate reduction process under waterlogging followed by lime application.

The amelioration was conducted not only with the correction of the acidity of the surface soil by incorporating lime dust but also by underlaying a buffering layer of lime gravel between the surface and the acidic subsoil.

The combination of lime dust application and underlaying with lime gravel gave higher rice yields than the plot treated only with lime dust. The improvement of pH values of the topsoils in treated plots coincided with the results of their crop yields.

Incubating the waterlogged soils under a closed system, the authors investigated effects of the above-mentioned amelioration treatment on the sulfate reduction process, measuring Eh, pH, sulfide, water-soluble sulfuric acid and sulfate-reducing bacteria. As a result, authors elucidated that the critical pH was 5.0 and the critical Eh +100 mV for sulfate reduction.