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<https://doi.org/10.5109/23732>

出版情報：九州大学大学院農学研究院紀要. 25 (4), pp.241-249, 1981-04. Kyushu University
バージョン：
権利関係：

Chemical Properties of Paddy Soils in Thailand and Malaysia

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(Received January 29, 1981)

As a part of International Cooperative Studies on the Increasing Productivity of Soils in Tropical Area (1976-1978), chemical properties of paddy soils in Thailand and Malaysia were studied for the purpose of elucidation of the fundamental characteristics of the soils so as to evaluate soil fertility and to implement advanced technical practices for higher production of rice. Each several soil samples were collected from the central, northern, northeastern and southern regions of Thailand and the western Malaysia. Research in soil chemical analysis has led to findings which are of great significance to soil fertility. On the basis of analytical data fertility of the soils were evaluated, and soil series were classified into the three categories of low, moderate and high fertility according to the inherent fertility of their surface soils. Soils from the soil series of low and moderate fertility have many defective characters which should be ameliorated, such as low pH, low contents of available nitrogen, phosphorus and/or potassium and high salinity. However, it might be not so troublesome problems to ameliorate these soils, when the problems of water are resolved.

INTRODUCTION

Rice production in Thailand exceeds the domestic demand. However, there is a possibility of a deficit of food due to the increase of population at a high rate of 3.0 percent per year. Rice production for the last decade increased 20 percent, but the increase of yield per unit area is only 2.4 percent which is the least in tropical Asian countries. The increased production of outputs for the last decade was largely due to the expansion of cultivated land, but it should be increased in terms of yield per unit area in the future. For instance, the 1.8 ton rice yield per hectare is still relatively low as com-

pared to that of developed countries. This is due to less diffusion of modern agricultural techniques using fertilizers, and due to the extension of the relatively unproductive lands. It is necessary to increase the soil fertility and to improve the less productive soils distributed in Thailand.

West Malaysia still imports rice to feed her population. Rice production for the last decade in this country increased 50 percent, but the increase was also mainly due to the expansion of cultivated land. Here, the increase of yield per unit area is also necessary.

To get the basic data to improve the soil fertility in both countries, we initiated a project to conduct field survey and laboratory work in 1977 and 1978. Clay mineralogy study is presented by Wada *et al.* (1981). Here we would like to present a chemical properties study.

MATERIALS AND METHODS

Soil samples

Field studies and soil sampling were carried out in December 1977 and 1978. These details are described by Wada *et al.* (1981) in a separate paper and description of soil samples are also listed in their paper.

Chemical analyses

Chemical analyses were carried out by the following methods (Black *et al.*, 1965):

1. pH

pH was measured in 1 : 2.5 soil-water suspension and 1 : 2.5 soil-N KCl suspension with a glass electrode pH-meter.

2. Organic carbon

Organic carbon was determined by a dry-combustion method using CN Corder (Model MT-500 W, Yanagimoto Mfg. Co., Ltd., Japan).

3. Total nitrogen

Total nitrogen was also analyzed by a dry-combustion method using the CN Corder.

4. Available nitrogen

Mineralized nitrogen was determined after incubation of air-dried soil samples under submerged condition for 4 weeks at 30°C.

5. Available phosphorus

Available phosphorus was determined by Bray-II method.

6. Cation exchange capacity

Cation exchange capacity was measured by the improved Schollenberger method.

7. Exchangeable bases

Exchangeable bases were determined in leached solution obtained from the procedure of measuring CEC by atomic absorption spectrometry.

RESULTS AND DISCUSSION

The results of chemical properties of surface soils are given in Table 1. Although the number of samples is not so diverse, classification of soil series on the basis of the some chemical properties was tentatively carried out to know the tendency of the properties. Debate was done referring to the works of Kawaguchi and Kyuma (1969 a, b, 1977) and Motomura *et al.* (1979).

pH

Table 2 shows the classification of soil series on the basis of pH of the surface soils listed in Table 1. Soils from Ongkharak and Thanyaburi series in Bangkok Plain and from Kundor and Guar series in Peninsula region show the pH less than 4.5. These soils are derived from marine and brackish water deposits and are acid sulfate soils. The acidity of the above soils is followed by the soils from Ayutthaya and Bangkok series in Bangkok Plain. Soils from Sansai series in Northern Valleys and Roi Et series in Khon Kaen region show more or less low pH due to their coarse texture and severe weathering and leaching.

All Malaysian soils show the low pH. The following reasons have been suggested (Kawaguchi and Kyuma, 1969 b) : (1) acidic parent rocks, (2) severe leaching by heavy rain, and (3) peaty and/or swampy with sediments of brackish environment. Soils from Lop Buri series which is derived from weathered calcareous materials, shows nearly neutral pH. The pH of the paddy soil usually increases in submerged conditions and rice plant is tolerant to a relatively low pH. Thus, as far as our investigations of pH values of paddy soils under cultivation in general of Thailand and Malaysia are concerned, a low pH value does not seem to be a severe problem.

Organic carbon

It is well known that organic matter becomes decomposable after being exposed to dry conditions. As the dry season in Thailand is quite remarkable and the temperature is very high after flooding, organic matter is decomposed easily. That is one of the reasons why the carbon content in Thai soils is generally lower than that of Japanese soils. The organic carbon content in soils from Khon Kaen region is the lowest. This seems to be due to their coarse texture. Carbon content in soils of Bangkok Plain is rather high, particularly in acid sulfate soils due to the low decomposition rate of organic matter under such low pH condition. In Northern Valleys, the carbon content in soils of Sansai series is lower than that of Phimai series. It also seems to be due to the difference of their texture. West Malaysian soils show rather higher content of carbon. One reason is the wet climate throughout the year and the other is the low decomposition rate of organic matter in acid soil.

Total nitrogen and C/N ratio

Total nitrogen content in soils in each region shows the same tendency as organic carbon. Accordingly, C/N ratio changes in a narrow range. The

Table 1. Chemical properties

Region	Soil series	Site No.	Texture	pH		Org. C (%)	
				(H ₂ O)	(KCl)		
I. Northern Valleys	Sansai	TL-1	S L	4.50	3.95	0.60	
		TL-2	S L	5.35	4.30	0.73	
		TL-4	L	5.20	4.43	0.46	
	Hangdong-Phimai Phimai	TL-3	S C L	5.22	3.77	0.94	
		TL-5	LiC	5.88	4.82	1.61	
		TL-6	H C	5.35	4.13	1.47	
II. Khon Kaen	Roi Et	TL-8	S L	5.53	3.82	0.44	
		TL-9	L S	4.80	3.90	0.28	
	Ratchaburi	T L-7	LiC	5.50	4.00	0.78	
III. Bangkok Plain	Klaeng	T L-25	S L	4.56	3.93	0.78	
		T L-12	LiC	5.77	4.60	0.97	
	Saraburi	T L-29	H C	4.27	3.61	3.01	
		T L-10	H C	4.00	3.28	1.68	
	Thanyaburi	TL-13	SiC	4.84	4.05	1.06	
		T L-21	H C	5.02	4.21	1.68	
	Bangkhen	T L-22	H C	5.12	4.48	2.39	
	Bangkok	TL-23	H C	5.08	4.19	1.45	
		T L-24	H C	5.70	4.98	2.37	
	Lop Buri ¹⁾	T L-27	H C	6.84	5.65	1.49	
IV. Peninsula	a. Southeast Coast (Thailand)	Klaeng	TL-31	LiC	4.89	4.12	0.89
			TL-32	C L	4.32	3.88	0.72
b. Middle West (Malaysia)	Samut Prakan	T L-30	H C	5.80	4.80	2.27	
		Hutan	ML-13	H C	4.42	3.51	2.71
		Tualang-Kundor	ML-11	H C	4.45	3.75	2.07
		Kundor	ML-14	H C	4.28	3.59	3.28
		Guar	ML-15	LiC	3.89	3.44	4.06

¹⁾ Soil sample description of TL-27 is not shown in separate paper written by Wada Lop Buri series ; and Farmer's field.

Table 2. Soil series classified according to the pH value of surface soils.

pH(H ₂ O)	Soil series (Region)
<4.5	Ongkharak, Thanyaburi (III), Hutan, Tualang-Kundor, Kundor, Guar (IV)
4.5-5.5	Sansai, Hangdong-Phimai (I), Roi Et (II), Klaeng, Ayutthaya, Bangkhen, Bangkok (III), Klaeng (IV)
>5.5	Phimai (I), Ratchaburi (II), Saraburi, Lop Buri (III), Samut Prakan (IV)

nitrogen content in soils of Bangkok Plain and West Malaysia is rather higher than that of other regions. This tendency is attributable to the same reasons previously explained for the case of organic carbon in both regions.

Available nitrogen

Available nitrogen is particularly important in Southeast Asia, where the amount of fertilizer applied is rather low. However, the amount of NH₄-N mineralized during 4 weeks in the soils of this area is remarkably lower than that of Japan. This is due to the low content of organic matter in these soils.

of surface soils.

Total N (%)	C/N	NH ₄ -N mineralized (mg/100 g) (%)		Avail. P ₂ O ₅ (mg/100 g)	CEC (me /100 g)	Na	Exchangeable (me/100 g soil)		Mg
							K	Ca	
0.038	15.8	1.66	4.37	28.80	2.03	0.04	0.03	0.96	0.10
0.056	13.0	4.88	8.71	0.64	3.98	0.12	0.05	2.56	0.61
0.041	11.2	1.93	4.71	0.34	1.78	0.08	0.04	1.88	0.32
0.082	11.5	5.18	6.32	2.24	12.95	0.08	0.13	6.07	1.24
0.143	11.3	9.29	6.50	0.21	10.27	0.21	0.28	10.66	2.22
0.150	9.8	5.29	3.53	1.28	18.62	0.13	0.51	10.60	1.61
0.043	10.2	3.00	6.98	0.96	5.18	0.14	0.04	1.53	0.44
0.025	11.2	2.18	8.72	0.30	3.05	1.10	0.08	7.84	1.30
0.070	11.1	2. a4	4.06	1. 12	15.54	0.26	0.30	7.66	2.48
0.060	13.0	3.44	5.73	2.27	9. 77	1. 47	0.41	5.68	4.69
0.092	10.5	3.68	4.00	0.88	19.62	0.34	0.23	10.75	3.14
0.223	13.5	1. 79	0. 57	2.80	19.42	1.21	0.33	1. 68	3.12
0.190	8. 8	3.16	1.66	0. 72	25.50	1. 46	0.53	7.45	6.90
0.012	10. 4	3.21	3. 15	0.48	19.02	0. 94	0.53	9. 18	4.74
0.149	11. 3	7.73	5. 19	3.56	15.78	0.35	0.37	11.08	4.38
0.260	9. 4	11.23	4.40	3.90	20.86	1.21	0.77	13.73	8.90
0.139	10.5	1. 57	1. 13	1. 67	21.52	2. 15	0. 90	a. a2	12.81
0.192	12. 3	5.37	2.79	2.60	20.25	2.27	0. a3	5.11	9.95
0.058	25.8	4.52	7.79	1. 58	32.97	0.59	0.27	36.66	4.56
0.073	12.1	2. 52	3.45	1.82	4.16	0. 13	0. 05	3. 12	0.25
0.064	11.3	2.84	4.43	1.92	2.56	0.15	0.07	0.97	0.39
0.158	14.4	6.84	4.33	2.60	20.27	1.51	0.42	9.04	13.44
0.250	10.8	a. 88	3.55	1. a3	11.50	0.57	0.15	3.77	2.05
0.213	9.7	9.22	4.33	4.64	10.40	0.12	0.06	2.40	5.51
0.213	15.4	6.92	3.25	2. a3	17.22	0.55	0.21	6.86	1.53
0.313	13.0	1. 76	0.56	5. 19	13.88	0.18	0. 28	1.00	0.59

et al. (1981). Location soil series; management are Kao-sam-yod. Muang, Lop Buri;

Table 3. Soil series classified according to the available nitrogen mineralized in surface soils under anaerobic condition.

Mineralized NH ₄ -N mg/100 g	Soil series (Region)
< 5	Sansai (I), Roi Et. Ratchaburi (II), Klaeng. Saraburi, Ongkharak, Thanyaburi, Bangkok (III), Klaeng. Guar (IV)
5-10	Hangdong-Phimai. Phimai (I), Ayutthaya, Lop Buri (III), Samut Prakan, Hutun, Tualang-Kundor. Kundor (IV)
>10	Bangkhen (III)

Table 3 shows the classification of soil series on the basis of the content of available nitrogen in surface soils. Phimai series in Northern Valleys, Bangkhen series in Bangkok Plain and Hutun, Tualang-Kundor and Kundor series in Peninsula region show the relatively high available nitrogen.

In a series of experiments conducted by Kai *et al.* (1979) to study nitrogen behaviour in Thai paddy soils, it was found that the mineralization of native soil nitrogen correlated very well with the absorption of nitrogen by the rice plants. This relation reflects a good index of the nitrogen supplying power

of Thai paddy soils.

Available phosphorus

All samples show the low content of available phosphorus except TL-1, which is an exceptional case, and which might have been due to the fact that the soil was heavily dressed with phosphate fertilizer in the previous seasons.

Table 4 shows the classification of soil series on the basis of the content of available phosphorus in surface soils. Less than 2 mg/100 g soil of available P_2O_5 are measured in Sansai and Phimai series in Northern Valleys, Roi Et and Ratchaburi series in Khon Kaen region, Saraburi, Thanyaburi and Lop Buri series in Bangkok Plain, and Klaeng and Hutan series in Peninsula region. Application of phosphate fertilizer is essential to increase the rice production in these areas.

Table 4. Soil series classified according to the content of available phosphorus in surface soils.

Available P_2O_5 mg/100 g	Soil series (Region)
< 2	Sansai, Phimai (I), Roi Et, Ratchaburi (II), Saraburi, Thanyaburi, Lop Buri (III), Klaeng, Hutan (IV)
2-10	Hangdong-Phimai (I), Klaeng, Ongkharak, Ayutthaya, Bangkhen, Bangkok (III), Samut Prakan, Tualang-Kundor, Kundor, Guar (IV)
>10	Sansai ¹⁾ (I)

¹⁾ Exceptional case.

Table 5. Soil series classified according to the CEC of surface soils.

CEC me/100 g	Soil series (Region)
< 6	Sansai (I), Roi Et (II), Klaeng (IV)
6-20	Hangdong-Phimai, Phimai (I), Ratchaburi (II), Klaeng, Saraburi, Ongkharak, Ayutthaya (III), Hutan, Tualang-Kundor, Kundor, Guar (IV)
>20	Thanyaburi, Bangkhen, Bangkok, Lop Buri (III), Samut Prakan (IV)

Cation exchange capacity

Cation exchange capacity (CEC) is one of the soil characters which well reflect the inherent soil fertility. Table 5 shows the classification of soil series on the basis of the magnitude of CEC of surface soils. Soils of Sansai series in Northern Valleys show the CEC less than 4 me/100 g soil and those of Hangdong-Phimai and Phimai series in the same region show the moderate CEC reflecting the soil texture. Soils of Roi Et series show lower CEC but that of Ratchaburi series shows rather high CEC, in Khon Kaen region.

Acid sulfate soils and those related soils such as Ongkharak, Thanyaburi, Ayutthaya and Bangkhen in Bangkok Plain are fine texture which show rather high CEC. The soil from Lop Buri series is calcareous Grumusol and also

shows heavy clay texture and very high CEC. In Peninsula region in Thailand, soils of Klaeng series show low CEC but those of Samut Prakan series show higher CEC reflecting the soil texture. Soils in the middle west coast of Malaysia are generally fine texture and show moderate **CEC**.

Exchangeable Ca and Mg

Table 6 shows the classification of soil series on the basis of the content of exchangeable Ca in surface soils. As TL-9 of Roi Et series is affected by salt bed, exchangeable Ca and Mg are extremely high. The soil from Lop Buri series is calcareous Grumusol and exchangeable Ca is very high in these soils. However, exchangeable Ca and Mg in other regions are generally low except for the soils in Bangkok Plain. Soils of Bangkok Plain which are marine clay origin show high exchangeable **Mg**.

Table 6. Soil series classified according to the content of exchangeable Ca in surface soils.

Exc. -Ca me/100 g	Soil series (Region)
<3.5	Sansai (I), Roi Et (II), Ongkharak (III), Klaeng, Tualang-Kundor, Guar (IV)
3.5-7	Hangdong-Phimai (I), Klaeng, Bangkok (III), Hutan, Kundor (IV)
> 7	Phimai (I), Roi Et ^v , Ratchaburi (II), Saraburi, Thanyaburi, Ayutthaya, Bangkhen, Lop Buri (III), Samut Prakan (IV)

^v Saline soil.

Table 7. Soil series classified according to the content of exchangeable K in surface soils.

Exc. -K me/100 g	Soil series (Region)
<0.15	Sansai, Hangdong-Phimai (I), Roi Et (II), Klaeng, Tualang-Kundor (IV)
0.15-0.3	Saraburi, Lop Buri (III), Hutan, Kundor, Guar (IV)
>0.3	Phimai (I), Ratchaburi (II), Klaeng, Ongkharak, Thanyaburi, Ayutthaya, Bangkhen, Bangkok (III), Samut Prakan (IV)

Exchangeable Na and K

Table 7 shows the classification of soil series on the basis of the content of exchangeable K in the surface soils. Soils from Sansai and Hangdong-Phimai series in Northern Valleys, Roi Et series in Khon Kaen region and Klaeng and Tualang-Kundor series in Peninsula are deficient in potassium. This can be explained by two reasons. One is their relatively coarse texture, low CEC and the other is leaching under the wet condition throughout the year in Peninsula regions.

However, soils from other series show generally higher content of potassium than Japanese soils. Especially soils derived from marine clay have a high sodium and potassium contents. High available K in Ayutthaya, Bangkhen and Bangkok series and low K in Klaeng, Tualang-Kundor series may be

explained by the content of mica in the soils as Wada *et al.* (1981) has suggested in a separate paper.

Evaluation of the fertility of soils

Table 8 shows the classification of soil series on the basis of inherent soil fertility which is tentatively proposed from the data mentioned above.

When the problems of water are excluded, soils from Phimai series in Northern Valleys, Bangkhen and Ayutthaya series in Bangkok Plain and Samut Prakan series in Peninsula are very fertile and less problem soils.

Adversely, soils from Sansai series in Northern Valleys, Roi Et series in Khon Kaen region and Tualang-Kundor, Guar and Klaeng series in Peninsula have many defective characters which should be ameliorated. However, as Takahashi *et al.* (1979) described, it is not a troublesome problem to ameliorate these soils. For instance, yields from Kuan Gut (TL-31) and Pattani (TL-32) in Klaeng series were increased from 2.0 t/ha to 3.6 t/ha and from 1.5 t/ha to 4.0 t/ha respectively, by supplying N, P, K fertilizers. Soils from Rangsit (TL-10) and Khlong Luang (TL-13) in Thanyaburi series are ameliorated by supplying 10 t/ha of lime and 25 kg P₂O₅/ha. Especially, rice yield of Rangsit Rice Experiment Station (TL-10) where soil is of less problem with the exception of pH and phosphorus condition, was increased from 2.0 t/ha to 4.9 t/ha after supplying lime and N, P, K fertilizers.

Table 8. Soil series classified according to the inherent fertility of surface soils.

Fertility	Soil series (Region)
Low	Sansai (I), Roi Et (II), Klaeng, Tualang-Kundor, Guar (IV)
Moderate	Hangdong-Phimai (I), Ratchaburi (II), Klaeng, Saraburi, Ongkharak, Thanyaburi, Bangkok, Lop Buri (III), Hutan (IV)
High	Phimai (I), Ayutthaya, Bangkhen (III), Samut Prakan (IV)

ACKNOWLEDGEMENTS

The authors wish to thank the grant given to this International Joint Research Project from the Japan Society for the Promotion of Science and the permission given to us by the National Research Council for the Regulations Governing the Promotion of Foreign Research in Thailand.

The authors also wish to thank Dr. Jisuke Takahashi, Mrs. Jaovapa Hasathon, Miss Jintana Somboondumrongkul in Rice Division and Dr. Manuwetaya Srisen, Mr. Samunao Phetchawee, Mr. Bunharn Tangcham in Division of Agricultural Chemistry, Department of Agriculture (Thailand), Dr. Takanori Igaraishi in Tropical Agricultural Research Center (Japan), Dr. Chaitat Pairintra in Faculty of Agriculture, Khon Kaen University, Dr. Niwat Hirunburana in Faculty of Agriculture, Chiang Mai University, Mr. Joseph Samy and Mr. Xavier Arulandoo in Malaysian Agricultural Research and Development Institute, and Dr. Koji Wada, Dr. Motoki Ikeda, Dr. Chitoshi Mizota, Dr. Sadao Kawaguchi

and Dr. Keizo Tsuchiya in Faculty of Agriculture, Kyushu University for their kind help to study this work.

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