Nutritional Factors Limiting Crop Growth in Tropical Peat Soils

Toshiaki Tadano*, **Kamarudin B. Ambak***2,
Koyo Yonebayashi*3, **Tetsuo Hara***4,
Pissot Vijarnsorn*5, **Chairatna Nilnond***6
and Sadao Kawaguchi*7

ABSTRACT

Soil culture experiments and field experiments on the tropical peat soils distributed in Thailand and Malaysia as well as water culture experiments were conducted in order to analyze the nutritional factors limiting crop growth. The following results were obtained.

1) Low pH and low K level of the soil were the most important factors limiting crop growth, followed by low P and low N levels.
2) Low levels of micronutrients such as Cu, B and Zn sometimes became an important factor. Cu deficiency was the most important among the micronutrient deficiencies, followed by B deficiency and eventually Zn deficiency.
3) Phenolic acids such as p-hydroxybenzoic acid, vanillic acid, syringic acid, p-coumaric acid and ferulic acid which were contained in peat soils as monomers had a toxic effect on crop growth at concentrations as low as 0.05 to 0.2mM. Total concentration of phenolic acid monomers in the peat soils ranged from 4 to 134μg/g soil which was equivalent to 0.005-0.19mM/l soil.
4) Without micronutrient application, sterility occurred in tomato and maize in a Malaysian peat soil and in rice in a Thailand peat soil. It was suggested that the sterility was not caused by the toxicity of the phenolic compounds, but by Cu deficiency.

Introduction

Peat soils formed from an adapted vegetation of mangroves, grasses, or swamp forest under waterlogged condiitions are widely distributed in the southern coastal region of Thailand and in Peninsular Malaysia.

It is well-documented that drainage and liming are indispensable in order to cultivate crop plants on these soils. It is, however, possible that the deficiency of essential elements such as phosphorus, potassium, magnesium, copper, zinc, manganese and boron may become factors limiting crop growth on these soils after the reclamation of the soils. Copper deficiency of maize (Kanapathy, 1972), cassava (Kanapathy, 1974 ; Chew *et al.*, 1978), sorghum (Chew *et al.*, 1979) and groundnuts (Chew *et al.*, 1979), boron deficiency of tomatoes (Joseph *et al.*, 1970), and deficiencies of copper, zinc and manganese in oil palm (Ng and Tan, 1974) have been reported on Malaysian Peat soils.

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*Faculty of Agriculture, Hokkaido University, Professor, Japan. *2Malaysian Agricultural Research and Development Institute, Senior Research Officer, Malaysia. *3Faculty of Agriculture, Kyoto Prefectural University, Professor, Japan. *4Faculty of Agriculture, Gifu University, Professor, Japan. *5Department of Land Development, National Soil Correlator, Thailand. *6 Faculty of Natural Resources, Prince of Songkhla University, Lecturer, Thailand. *7Faculty of Agriculture, Kyushu University, Associate Professor, Japan.

On the other hand, phenolic compounds may be contained at a toxic level in the soil solutions of peat soils. Driessen (1978) suggested that the toxicity of the phenolic compounds might occur for lowland rice grown on Indonesian peat soils, although confirmative evidence was lacking. Apart from peat soil, Wang *et al.* (1967) indicated that phenolic compounds such as p-hydroxybenzoic acid inhibited the growth of wheat, maize and sorghum under water culture conditions. Furthermore, it is well known that phenolic compounds become chelating agents for copper and make copper unavailable for absorption by plants.

Sterility becomes a serious problem in peat soils when rice plants are cultivated. Copper deficiency, toxicity of phenolic compounds or combined effect of copper deficiency and toxicity of phenolic compounds were cited as the cause of the sterility (Driessen, 1978).

The objectives of the present investigation are (1) to analyze the nutritional factors limiting crop growth in peat soils before and after liming and (2) to determine the cause of the sterility.

1 Chemical properties and bulk densities of peat soils distributed in southern Peninsular Malaysia

1) Materials and methods:

Surface soils, 15cm in depth, were collected from eleven sites of peat area in southern Peninsular Malaysia. Of these soils, four soils were collected from recently or formerly opened areas without crop cultivation, one from a natural forest, four from abandoned fields after cultivation of rice or tobacco and two from fields where oil palm and coco yam were cultivated.

The soils were air-dried and analyzed for the chemical properties.

2) Results and discussion:

Total content of C and N was comparatively high (Table 1) whereas that of P, K, Ca and Mg was very low while that of S and Fe was rather high. Levels of micronutrients were very low. Of these, the contents of Cu and Mn were similar to those reported by Driessen (1978) for the peat soils distributed in Sumatra and Kalimantan while the content of Zn was somewhat higher.

The pH ranged from 3.3 to 4.8 with a mean value of 4.05 (Table 2). Bray-II P was rather

Table 1 Mean total content of elements in the surface horizon of peat soils distributed in southern Peninsular Malaysia (Number of sites: 11)

Element		Mean content	±	SD
C	(% of dry soil)	33.8	±	7.8
N	(%)	1.38	±	0.30
P	(ppm)	450	±	280
K	(ppm)	250	±	300
Ca	(ppm)	1,190	±	620
Mg	(ppm)	360	±	290
S	(ppm)	3,550	±	1,440
Fe	(ppm)	3,620	±	1,160
Mn	(ppm)	11.0	±	8.9
Cu	(ppm)	6.3	±	3.7
Zn	(ppm)	21.1	±	14.4
B	(ppm)	14.4	±	5.9
Ash	(%)	20.2	±	7.2

Table 2 Mean chemical properties of the surface horizons of peat soils distributed in southern Peninsular Malaysia (Number of sites : 11)

	Mean	±	SD
PH (H_2O)	4.05	±	0.41
Bulk density (g/ml)	0.21	±	0.09
Bray II-P (mg P_2O_5/100g)	3.48	±	2.10
CEC (meq/100g)	89	±	19
Exchangeable (meq/100g)			
K	0.32	±	0.18
Na	1.15	±	0.67
Ca	3.32	±	2.02
Mg	2.69	±	2.15
Al	15.1	±	9.1
Base saturation (%)	8.5	±	4.7
0.1 N HCl soluble (ppm)			
Fe	322	±	232
Mn	6.9	±	6.2
Cu	0.53	±	0.24
Zn	6.3	±	2.9
B	2.8	±	2.1

low and CEC was comparatively high. Values of exchangeable K, base saturation and 0.1N HCl soluble Cu were extremely low. When the amounts of available elements of the soils are evaluated, it is important, especially in peat soils, to consider the bulk density. Since the mean bulk density of the peat soils was 0.21, the amounts of available elements per unit weight soil were calculated as being five times larger than the actual available amounts.

2 Effect of appplication of lime, N, P, K, Mg, Cu, Zn, Mn, B and Mo on the growth of maize and lowland rice cultivated in a peat soil in Narathiwat, Thailand

1) Materials and methods :

Surface soil, 15cm in depth, was collected from a peat soil area in Narathiwat, Thailand. After the soil was air-dried lightly, pot experiments were conducted in the greenhouse of Prince of Songkhla University. A quantity of 9.00 kg of the soil with a moisture content of 80% was added to the pots and the thirteen treatments indicated in Fig. 1 were applied. The experiments were conducted both under lowland and upland conditions. Two plants of lowland rice, variety RD-25, and one plant of maize, variety hybrid Suwan Fl 2301 were grown until maturity.

The original pH of the soil was 4.0, the value of Bray II-P was 3.7 mg P_2O_5/100 g, the contents of exchangeable K, Ca and Mg were 0.37, 9.6 and 2.4 meq/100 g, respectively and of DTPA extractable Cu, Zn and Mn 0.29, 1.86 and 0.61 ppm, respectively.

2) Results and discussion :

Growth of maize which was extremely poor in the -NPK-L treatment (Fig. 1), was improved to some extent by the application of N, P and K without liming while with liming, it was further improved. However, sterility occurred in the +NPK+L+Mg treatment where no micronutrients were applied. Among the treatments with liming and Mg application, growth was poorest and grain yield lowest in the −K treatment, followed by the −P, −Cu, −B and −N treatments. Shoot growth was limited to some extent and grain yield was decreased considerably under the −Cu treatment while shoot growth was normal but grain yield was decreased considerably under the −B treatment.

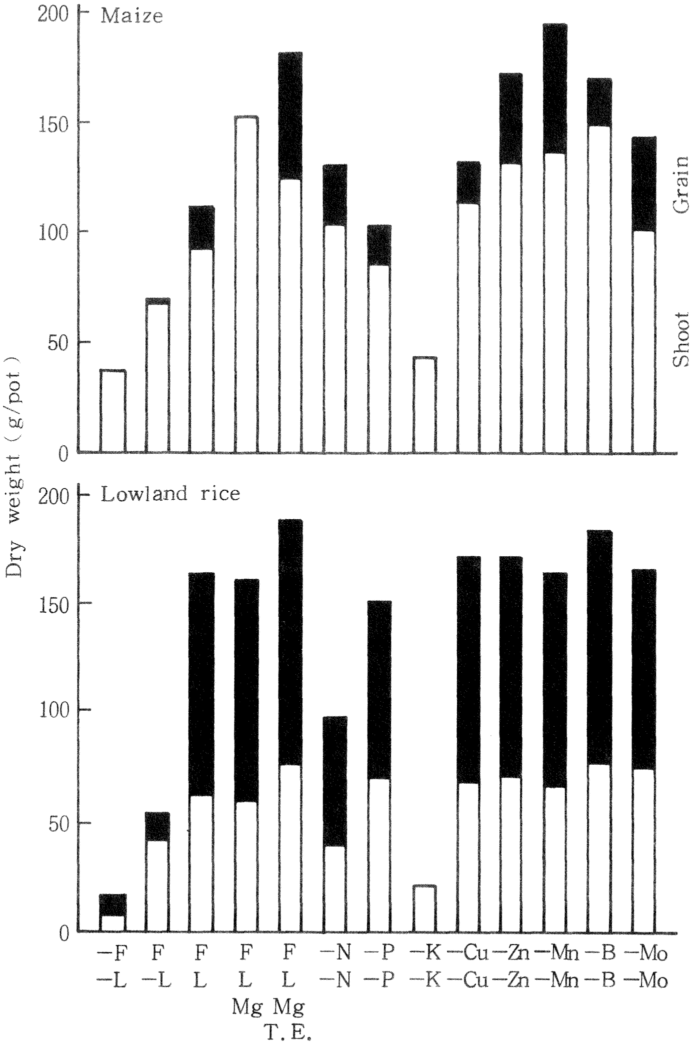

Fig. 1 **Effect of application of lime, N, P, K, Mg and trace elements on the growth of maize and lowland rice cultivated in the Narathiwat peat soil.**

(F : N+P+K, L : Liming, T.E. : Trace element).

Growth of lowland rice was very poor in the absence of liming (Fig. 1). The difference in the dry weight between the +NPK−lime and the +NPK+lime treatments was larger in lowland rice than in maize. Tolerance of lowland rice to acid soils is usually higher than that of maize mainly because the tolerance to high Al is higher in the former than the latter (Tanaka and Hayakawa, 1975). On the other hand, since lowland rice was grown under flooded conditions and the peat soil contained a large amount of organic matter, Fe toxicity might have occurred. However, since the Fe content of the shoot under the +NPK−lime treatment was 330 ppm (data not indicated), which was lower than the critical content for Fe toxicity (Tadano, 1974) and almost the same as that under the control treatment, the occurrence of Fe toxicity under the +NPK−lime treatment was therefore unlikely. It is, thus, assumed that the extremely poor growth of lowland rice under the +NPK−lime treatment was caused by different factors and was not related to Al and Fe toxicities.

Growth of lowland rice in the treatments with liming was poorest under the −K treatment (Fig. 1). Dry weights of grain and shoot under the −N and the −P treatments were lower to some extent than those in the control and no effect of the micronutrient application was detected. The absence of effect of the micronutrient application on the growth of lowland rice appeared to be due to the high tolerance of this crop to low levels of micronutrients.

3 Content of phenolic compound monomers in peat soils

1) Materials and methods:

Eighteen surface soils, 8 to 25 cm in depth, were collected from peat areas. Of these, ten soils were collected from Thailand and eight from Malaysia. Immediately after the soils were collected, phenolic compound monomers were extracted by an acetonitrile: water (3: 1) solution (Katase, 1981) at 80°C for 24 hr.

2) Results and discussion:

p-Hydroxybenzoic acid, vanillic acid, vanillin, syringic acid, protocatechuic acid, p-coumaric acid, p-hydroxybenzaldehyde and ferulic acid were detected as monomers (Table 3). Mean content was the highest for p-hydroxybenzoic acid and the lowest for ferulic acid. The highest concentration of 148 μM/1 soil was obtained for p-hydroxybenzoic acid, followed by protocatechuic acid (45 μM), vanillin (36 μM), vanillic acid (32μM), syringic acid (23μM), p-coumaric acid (13μM), p-hydroxybenzaldehyde (9μM) and ferulic acid (2μM). Total concentration of the phenolic compound monomers ranged from 5 to 188μM/1. Generally, the concentration of the phenolic compound monomers in peat soils tends to increase for several years after soil drainage and to decrease thereafter.

4 Effect of phenolic acids on the growth of several crop plants and occurrence of sterility in rice plants

1) Materials and methods:

Table 3 Content of phenolic compound monomers extracted by acetonitrile: water (3: 1) solution and calculated concentrations* in peat soils (Number of sites: 18)

Species of phenolic compounds	Content (μg/g soil)	Calculated concentration (μM/l soil)		
	mean ± SD	mean ± SD	lowest	highest
p-Hydroxybenzoic acid	9.2 ± 22.6	15.5 ± 32.6	1	148
Vanillic acid	3.9 ± 3.6	6.1 ± 6.7	1	32
Vanillin	3.0 ± 3.2	5.5 ± 7.6	1	36
Syringic acid	2.3 ± 2.9	3.1 ± 5.1	trace	23
Protocatechuic acid	1.5 ± 4.4	3.1 ± 10.3	trace	45
p-Coumaric acid	1.4 ± 1.6	2.2 ± 2.9	trace	13
p-Hydroxybenzaldehyde	1.1 ± 1.2	2.3 ± 2.2	trace	9
Ferulic acid	0.4 ± 0.7	0.4 ± 0.5	trace	2
Total	22.5 ± 30.9	38.7 ± 49.8	5	188

* Concentrations (μM/l soil) were calculated based on the bulk densities of the soil which were 0.28±0.11.

Experiment 1: Young seedlings of rice, maize, wheat, soybean and tomato were transferred to 56 liter plastic vessels containing a standard nutrient solution and treatments with 0, 0.05, 0.25, 0.5 and 1μM p-hydroxybenzoic acid were applied. The pH of the solution was adjusted to 4.2 and the treatment solutions were changed every six days. Twenty days after the initiation of the treatments, the plants were harvested.

Experiment 2 : Young seedlings of rice, tomato and lettuce were transferred to 56 liter plastic vessels containing a standard nutrient solution. After transfer, 0.2mM p-hydroxybenzoic acid, vanillic acid, p-coumaric acid, ferulic acid or syringic acid was added to the solutions. The pH of the solution was adjusted to 4.2 and the plants were harvested at 20 days after treatment.

Experiment 3 : Young seedlings of rice plants were transferred to 12 liter plastic pots containing a nutrient solution with 0.05ppm Cu and treatments with 0, 0.10, 0.25 and 0.50mM p-hydroxybenzoic acid (p-HBA) were applied. The treatments were continued until harvest.

2) Results and discussion :

Effect of graded concentrations of p-hydroxybenzoic acid on the growth of the crop plants is shown in Fig. 2. The pH of the nutrient solution was 4.2 because the growth inhibitory effect of the phenolic compounds is larger at a lower pH than at a higher pH (Tadarcetal, 1991). Growth of all the crop plants was inhibited with the increase of the concentration of p-hydroxybenzoic acid. The inhibitory effect, however, differed with the species of crop plants. The inhibitory effect of this phenolic acid was in the order of tomato> maize≒soybean>wheat>rice. The critical concentration for the inhibition was lower than 0.05 mM in tomato, 0.25 mM in maize and soybean and 0.5 mM in wheat and rice.

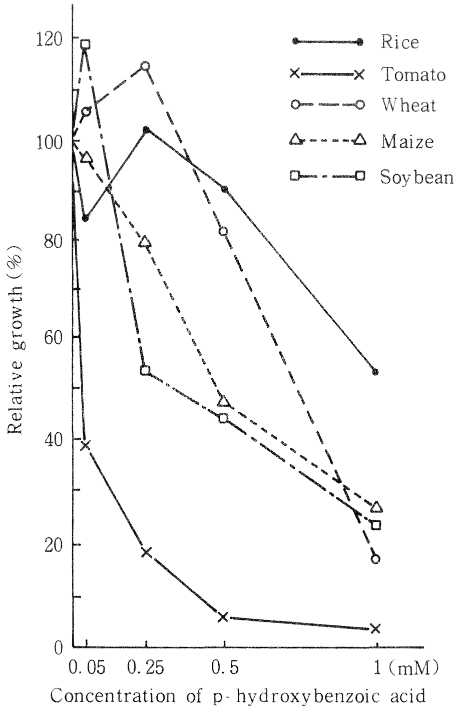

Fig. 2 Effect of graded concentration of p-hydroxybenzoic acid on the growth of five crop species.

In Experiment 2, the toxic effect of five species of phenolic acids was compared at the concentration of 0.2 mM (Fig. 3). The toxic effect of ferulic acid was largest, followed by that of p-coumaric>vanillic≒syringic>p-hydroxybenzoic acid. In every phenolic acid treatment, the root color turned brownish and root formation was inhibited in the same manner although the degree of the color change and inhibition of root formation differed with the species of phenolic acids. Thus, it is assumed that the mechanism of growth inhibition by these phenolic acids was similar.

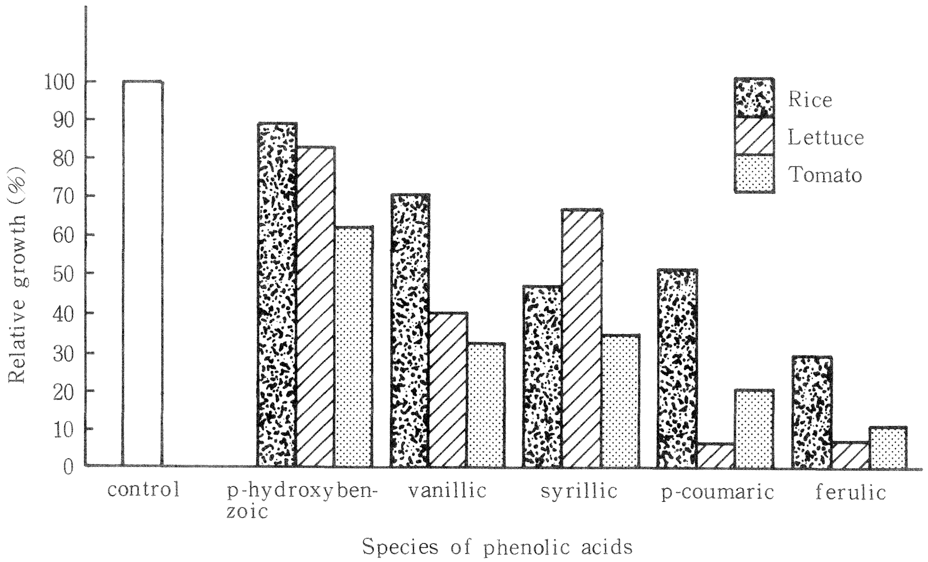

Fig. 3 Effect of five species of phenolic acids on the growth of rice, lettuce and tomato (Concentration of phenolic acids : 0.2mM).

In Experiment 3, the dry weight of rice plant was largest under the 0.10 mM p-HBA treatment (Table 4) and it decreased with a further increase of p-HBA concentration. The decrease was much more severe in the shoot than in the panicle. Cu content of the shoot in all the treatments was far higher than the critical value for the deficiency (Tanaka *et al.*, 1978).

The number of panicles per plant at harvest increased in the 0.10 mM p-HBA treatment compared with the treatment without p-HBA. However, it decreased strongly with an increase of p-HBA concentration at higher levels above 0.10 mM. Changes in the number of ripened grains, sterile grains and total grains per plant, respectively, with the increase of the p-HBA concentration also showed the same tendency as that of the number of ears per plant. The sterility percentage was not different between the treatment with 0.10 mM p-HBA and that without p-HBA, but it decreased with the increase of the p-HBA concentration at levels above 0.10 mM. The decrease of the sterility percentage in the 0.25 and 0.50 mM p-HBA treatments was ascribed to the marked decrease of the number of ears per plant which was more severe than the decrease of the shoot dry weight. Thus, it is considered that phenolic acid such as p-HBA does not induce sterility directly if Cu is applied adequately. It remains

Table 4 Effect of p-hydroxybenzoic acid (p-HBA) concentration on the growth and the occurrence of Sterility in rice plants

Concentration of p-HBA (mM)	Dry weight (g/plant)			Panicle no/plant	No. of grains per plant			Sterility percentage	1,000 grain weight (g)	Cu content in shoot (ppm)
	Shoot	Panicle	Total		Ripened	Sterile	Total			
0	28.2	22.6	50.8	44	1,001	200	1,201	16.7	24.2	36.6
0.1	37.7	24.7	62.4	62	1,415	272	1,598	17.0	23.5	45.0
0.25	23.4	20.9	44.3	33	990	121	1,111	10.9	24.2	38.6
0.5	19.3	17.0	36.3	22	704	65	769	8.5	23.7	24.0

to be determined whether other species of phenolic acids such as ferulic acid and p-coumaric acid, etc., which had a strong inhibitory effect on rice growth could induce sterility directly. However, since the mode and mechanism of growth inhibition by these phenolic acids were assumed to be similar to that by p-HBA, it is suggested that other species of phenolic acids are not able to induce the sterility directly either.

5 Effect of liming and micronutrient application on the growth and the occurrence of sterility in rice plants cultivated in peat soils distributed in southern Thailand

1) Materials and methods:

Two peat soils with different degrees of decomposition of organic matter, i.e. Bacho soil with a lesser degree which contained a higher concentration of phenolic compounds and Kab Daeng soil with a higher degree which contained a lower concentration, were used for the pot experiment.

Seven kg of each soil was added to 10 ℓ pot, and four treatments indicated in Table 5 were applied to each soil. Magnesium calcium carbonate was added into these pots at low (10g/pot) and high (40g/pot) levels. Rice plants, variety RD 23, were grown under submerged conditions up to harvest time.

2) Results and discussion:

The original pHs of the Bacho and Kab Daeng soils were 3.4 and 3.7. The pHs of these soils one day after the addition of magnesium calcium carbonate rose to 3.8 and 4.6 at the low and the high lime levels in the Bacho soil and to 4.1 and 4.7 in the Kab Daeng soil, respectively.

Table 5 Effect of application of lime and micronutrients on the yield, yield components and micronutrient content of rice grown on Bacho and Kab Daeng peat soils

Soil	Lime (g/pot)	Micro-nutrients	pH (H_2O)	Dry weight (g/pot)			Panicle no/pot	Spikelet no/panicle	Filled grain (%)	Wt. of 1,000 grains (g)	Micronutrient content (ppm)*				
				Shoot	Grain	Total					Fe	Mn	Zn	Cu	B
Bacho	10	−	3.8	—	—	—	—	—	—	—	—	—	—	—	—
	10	+	3.8	9.0	4.4	13.4	4.0	97	51	22.1	56	66	139	3.8	21
	40	−	4.6	26.8	7.8	34.6	5.3	98	66	22.8	53	71	68	1.0	8
	40	+	4.6	58.8	40.1	98.9	21.0	95	82	24.5	43	71	138	3.0	19
Kab Daeng	10	−	4.1	82.1	70.5	152.6	33.7	95	92	23.9	74	107	124	2.2	9
	10	+	4.1	92.3	83.2	175.5	43.3	86	92	24.2	65	107	169	4.9	18
	40	−	4.7	72.4	57.7	130.1	30.3	84	94	24.2	58	168	152	2.2	13
	40	+	4.7	90.5	88.4	178.9	43.3	90	95	24.0	45	145	174	5.1	26

* Content in shoot on a dry weight basis.

The growth was very poor at the low lime level in the Bacho soil and all the plants died before harvest time with the exception of those in the treatment with micronutrients (Table 5). The growth was improved at the high lime level in the Bacho soil, and the plants which received micronutrients had a larger straw and grain weight than those without micronutrient application. The growth was much better in the Kab Daeng soil than in the Bacho soil. The large difference in growth between the Bacho soil and Kab Daeng soil was partly attributed to the low pH of the Bacho soil. However, the difference in growth was also found at the high lime level between the Bacho soil at pH 4.6 and Kab Daeng soil at pH 4.7. This result suggests that the higher concentration of phenolic compounds contained in the Bacho soil may account for the inhibition of rice growth.

The panicle number per pot and the filled grain percentage decreased at the high lime level without micronutrient addition in the Bacho soil. The panicle number per pot decreased in the absence of application of micronutrients in the Kab Daeng soil, but the spikelet number per panicle, filled grain percentage and 1000 grain weight did not change appreciably.

In the treatment without micronutrient application, the value of the Cu content was critically low for the deficiency (Tanaka *et al.*, 1978), in particular in the Bacho soil. The B content was slightly higher than the critical value (Yamanouchi, 1976) in both soils. The contents of Fe, Mn and Zn were higher than the critical values for the deficiency. It is therefore considered that Cu deficiency was also responsible for the poor growth in the treatments without micronutrient application in both soils and that the sterility occurring in the absence of micronutrient application at a high level of lime application in the Bacho soil may be due to Cu deficiency.

6 Effect of liming and micronutrient application on the growth and the occurrence of sterility in tomato and maize cultivated in a peat soil distributed in southern Peninsular Malaysia

1) Materials and methods:

Field experiments were conducted with tomato, variety MT11, and maize, variety Suwani, in a peat soil located in the Peat Experiment Station of the Malaysian Agricultural Research and Development Institute in Pontian, Malaysia. The experimental field was set up immediately after a secondary forest was cleared. In the experiment, the treatments consisted of the application of 0, 4, 8, 12, 18, 28 and 40tons/ha of $CaCO_3$ with and without supply of micronutrients such as Fe, Mn, Zn, Cu, B and Mo. Plant samples were taken at 30

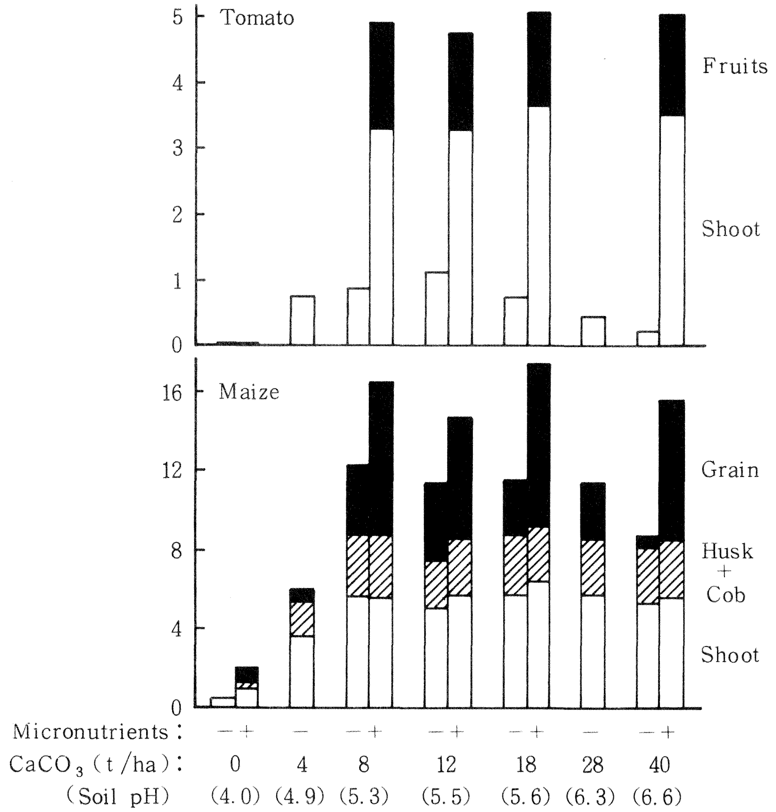

Fig. 4 Effect of liming and micronutrient application on the growth of tomato and maize at harvest in a peat soil distributed in southern Peninsular Malaysia.

Table 6 Effect of liming and micronutrient application on the yield components, sterility and micronutrient content in tomato and maize cultivated in a peat soil distributed in southern Peninsular Malaysia

Treatment		Tomato		Maize				Micronutrient content (ppm)*									
								Tomato					Maize				
CaCO$_3$ (t/ha)	micro-nutrients	No. of fruits per plant	Dry wt. per fruit	No. of ears per plant	No. of grains per ear	%	Wt. of 1,000 grains (g)	Fe	Mn	Zn	Cu	B	Fe	Mn	Zn	Cu	B
0	−	0	0	0	0	0	0	—	—	—	—	—	—	—	—	—	—
	+	0	0	0.3	54	13	93	—	—	—	—	—	—	—	—	—	—
4	−	0	0	1.4	106	26	209	91	89.3	55.1	3.0	34.4	119	65.8	19.8	1.2	13.8
8	−	0	0	1.8	124	30	299	255	62.1	65.8	2.0	20.4	124	78.4	30.2	3.0	6.2
	+	57.8	1.14	1.1	385	93	343	61	71.0	97.0	4.4	31.1	156	96.6	43.9	3.1	9.7
12	−	0	0	1.4	169	41	310	77	51.6	72.5	2.3	16.4	98	88.5	35.6	3.7	6.1
	+	52.3	1.10	1.1	306	74	343	60	58.9	77.4	3.0	25.3	128	86.8	43.7	5.8	9.8
18	−	0	0	2.1	84	20	290	70	54.5	77.4	1.7	15.1	137	80.8	32.0	3.0	6.0
	+	51.4	1.02	1.0	395	96	361	69	42.3	77.4	3.2	24.8	116	93.3	40.1	5.7	9.9
28	−	0	0	2.1	110	27	366	73	51.6	63.2	2.0	16.0	134	72.4	27.9	3.1	6.2
40	−	0	0	2.2	17	4	311	74	47.7	71.3	4.0	18.7	110	77.1	27.1	3.2	5.6
	+	49.7	1.13	1.0	412	110	324	80	37.3	66.4	4.2	20.0	125	80.4	31.4	4.1	8.6

* Content in shoot in dry weight basis at 30 days after planting.

days after sowing and at harvest for the determination of the dry weight and element content.

2) Results and discussion :

Soil pH at the planting time which was 4.0 in the treatment without liming (Fig. 4) increased with the increase of the amount of lime applied. The growth of tomato was extremely poor in the treatment without liming. However when micronutrients were applied, the growth became normal in the treatment with 8 tons/ha of lime where the soil pH of 5. 3 was attained. When the micronutrients were not applied, the growth was considerably poor even under liming. No fruits were formed in the treatments without micronutrients (Fig. 4, Table 6). In addition, shoot growth was retarded at the soil pH above 5.0 in the treatments without micronutrients.

Growth of maize was also extremely poor without liming and it became normal with 8 tons/ha of lime when micronutrients were applied (Fig. 4). When micronutrients were not applied, shoot growth was normal in the treatments with liming at the rate of more than 8 tons/ha but sterility occurred. In these treatments, the number of ripened grains per ear was 32, 55 and 21% of the treatments with micronutrients at pH 5.3, 5.5 and 5.6, respectively (Table 6). The sterility in the treatment without micronutrients became more severe when the soil pH was higher (pH 6.6) as seen in the treatment with 40tons/ha of lime.

Micronutrient content in the shoot at 30 days after planting is shown in Table 6. In the treatments without micronutrients, Cu content of tomato was lower than the critical value for the deficiency. Cu content of maize and B content of both plants were near the critical values.

Conclusion

Nutritional factors limiting crop growth in tropical peat soils distributed in southern Thailand and southern Peninsular Malaysia were investigated. Low pH and low K level of the soils were the most important factors limiting crop growth, followed by low P and low N levels. Deficiencies of Cu, B and/or Zn also frequently became important nutritional factors limiting crop growth, of which Cu deficiency was the most important.

It was shown that phenolic compounds such as p-hydroxybenzoic acid, vanillic acid, vanillin, syringic acid, protocatechuic acid, p-coumaric acid, p-hydroxybenzaldehyde and ferulic acid were contained in the peat soils as monomers and that the total content ranged from 0.005 to 0.19 mM/l soil. Based on the water culture experiments, it was shown that these phenolic compounds had a toxic effect on the growth of crop plants at a concentration as low as 0.05 mM. Since the lowest concentration of 0.05 mM for the toxicity was obtained with p-hydroxybenzoic acid which had the weakest toxic effect, the lowest levels for the toxicity in the other phenolic compounds are assumed to be much lower.

It was also suggested that the sterility of the plants which occurred frequently in the peat soils was not caused by the toxicity of the phenolic compounds, but mainly by Cu deficiency. The possibility of B deficiency together with Cu deficiency should be further investigated.

References

1) Chew, W.Y., Joseph, K.T. and Ramli, K. (1978) : Influence of soil-applied micronutrients on cassava (*Manihot esculenta*) in Malaysian tropical oligotrophic peat. Exptl Agric., 14, 105-111.
2) Chew, W.Y., Joseph, K.T. and Ramli, K. (1979) : Influence of applied copper and other micronutrients on groundnuts (*Arachis hypogaea*) and sorghum (*Sorghum bicolor*) on Malaysian oligotrophic peat. Trop. Agric., 56, 25-32.
3) Driessen, P.M. (1978) : Peat soils. *In* "Soils and Rice", IRRI Publication, pp.763-779.
4) Joseph, K.T., Hussein, S. and Williams, C.N. (1970) : Assessing the nutrient status of a peat soil from the Klang area. Malay. Agric. J., 47, 338-345.
5) Kanapathy, K. (1972) : Copper requirements and residual effect with maize on a peat soil. Malay. Agric. J., 48, 249-263.
6) Kanapathy, K. (1974) : Fertilizer experiments on shallow peat under continuous cropping with tapioca. Malay. Agric. J., 49, 403-412.
7) Katase, T. (1981) : The different forms in which p-coumaric acid extracts in a peat soil. Soil Sci. 131, 271-275.
8) Ng, S.K. and Tan, Y.P. (1974) : Nutritional complexes of oil palms planted on peat in Malaysia. I. Foliar symptoms, nutrient composition and yield. Oleagineux, 29, 1-14.
9) Tadano, T. (1974) : Studies of the iron nutrition of rice plants. (5) Change of the susceptibility to iron toxicity during the growth. J. Sci. Soil Manure, Jpn., 45, 521-524. (In Japanese).
10) Tadano, T., Pantanahiran, W. and Nilnond, C. (1991) : Inhibitory effect of canal water from a tropical deep peat soil on the elongation of rice roots. Soil Sci. Plant Nutr. 37. (In press.)
11) Tanaka, A. and Hayakawa, Y. (1975) : Comparison of tolerance to soil acidity among crop plants. 2. Tolerance to high levels of aluminum and manganese. J. Sci. Soil Manure, Jpn, 46, 19-25. (In Japanese).
12) Tanaka, A., Tadano, T. and Miura, S. (1978) : Comparison of adaptability to heavy metals among crop plants. (4) Adaptability to copper. J. Sci. Soil Manure, Jpn, 49, 361-366. (In Japanese).
13) Wang, T.S.C., Yang, T.K. and Chuang, T.T. (1967) : Soil phenolic acids as plant growth inhibitors. Soil Sci., 103, 239-246.
14) Yamanouchi, M. (1976) : Comparison of adaptability to boron among crop plants. J. Sci. Soil Manure, Jpn, 47, 281-286. (In Japanese).