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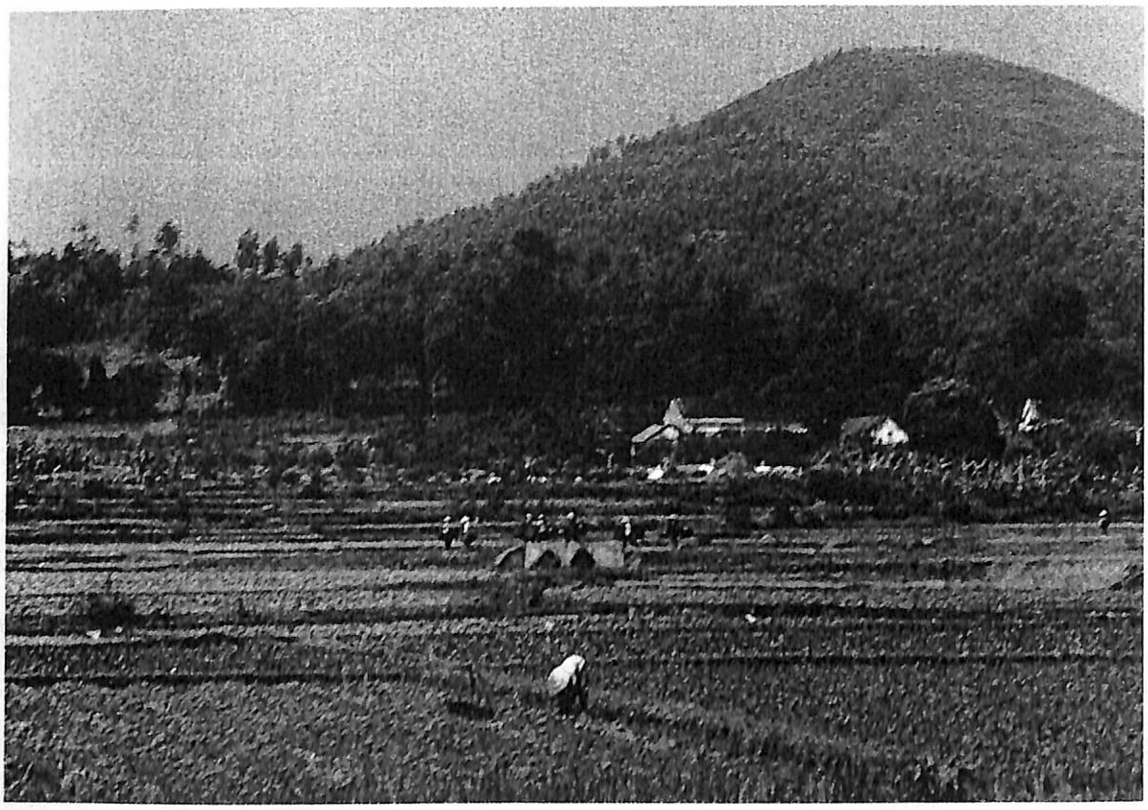

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Creative Basic Research Group for "The Development of Sustainable Biological Production Technologies Harmonized with Regional Environmental Conditions in East Asia"

THE ORGANIC MATTER COMPOSITION OF THE RED ACID SOILS UNDER DIFFERENT LAND USES IN THE MIDDLE TERRACE AREA OF WEST LAMPUNG, SOUTH SUMATRA, INDONESIA

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Composition of humic fractions, saccharides and phenolic compounds were compared between several soils under different land uses in a middle terrace area of South Sumatra, Indonesia. Though contents of humus were slightly larger in the soil under forest vegetation and lower in the cassava field, differences in the composition of humus, saccharide and phenolic compounds were not remarkable among the soils under different land uses. However, the composition of soil organic matter, as reflected by several characteristic indices, showed remarkable tendencies when soil organic matter was decomposed exhaustively. Tendencies in the proportion of humic acid extractable with NaOH in the total extractable humus (PQ_1), the absorbance of free form humic acid at 600 nm per unit concentration (RF_1), the ratio of mannose / xylose in the non-cellulosic fraction, and the composition of phenolic compounds were described in this paper.

INTRODUCTION

In the tropics, decomposition of soil organic matter proceeds very quickly (Detwiler 1986). On the other hand, soil organic matter has the key role in the maintenance of soil fertility. Therefore, it is important to elaborate a land use system, by which the decomposition of soil organic matter can be minimized. We have investigated the effect of deforestation and land use as cultivated lands on the composition of soil organic matter in the hilly region of South Sumatra (Tsutsuki et al. 1999, Watanabe et al. 1999). To the east of Barisan range in South Sumatra, very wide and flat middle terrace area is extended and cropped mainly to cassava, sugar cane, rubber, cacao, and various upland crops. Because these areas have been cleared much earlier than the hilly area and the temperature is higher, decomposition of soil organic matter is assumed more drastic. Therefore, we have investigated the status of soil organic matter in the soils under various land uses in the middle terrace area.

MATERIALS AND METHODS

Soils were collected from several sites under different land uses within two neibouring villages, Gunung Batin and Menggala, in the northern plain of Lampung Province, South Sumatra, Indonesia. The land was almost flat and the elevation of the sampling sites ranged from 135 to 145 m. Soils were classified as ultisols (Tropohumults) by USDA Soil Taxonomy. Soils were air-dried, passed through a 2 mm sieve, and ground further using a tungsten carbide mill (Heiko TI-100) for C, N, humus, saccharide, and phenolic analysis. Carbon and nitrogen were determined with a CN analyzer (Yanaco MT 500). Humus composition was determined according to the successive extraction method by Kumada (1987). Non-cellulosic and cellulosic saccharide contents were released by successive hydrolysis with sulfuric acid, converting to alditol acetate (Oades et al 1970), then determined with capillary GC (Spiteller 1980). Phenolic compounds were released by CuO-NaOH oxidation in a sealed tube at 150 C for 6 h, then determined by capillary GC (Tsutsuki et al. 1994).

RESULTS AND DISCUSSION

Fundamental properties of soils. Several fundamental properties of soils were shown in Table 1. Total carbon contents of the soils showed a steep decrease in the lower soil layers. When the values for A layers were compared, it was largest in the secondary forest (53 g kg^{-1}), and lowest in the cassava fields (18 g kg^{-1}). Soils in shrubs, rubber and cacao plantations, and mixed gardens showed intermediate carbon contents. The C/N ratios of secondary forest soils were slightly lower (12.1-13.0) than the other soils (14.3 - 21.0), which differed little among different land uses. The soil of secondary forest was strongly acidic as shown by the very low pH(KCl), 3.7 - 3.8. The pH was slightly higher in soils of other land uses, but it was still strongly acidic.

Table 1. Fundamental characteristics and humus composition of the soils under different land uses in the middle terrace area, South Sumatra..

								Fraction extracted with 0.1 *M* NaOH						Fraction extracted with 0.1 *M* $Na_4P_2O_7$					
	Layer	Depth (cm)	T-C (g kg^{-1})	T-N (g kg^{-1})	C/N	pH (H_2O)	pH (KCl)	Ch_1 (gC kg^{-1})	Cf_1 (gC kg^{-1})	PQ_1 (%)	RF_1	$\Delta logK_1$	$Type_1$	Ch_2 (gC kg^{-1})	Cf_2 (gC kg^{-1})	PQ_2 (%)	RF_2	$\Delta logK_2$	$Type_2$
Gunung Batin village																			
Secondary forest	A1	0-5	53.1	4.4	12.1	4.60	3.81	17.7	13.7	56	48	0.633	P±	0.8	0.6	57	55	0.579	P
	A2	5-12	18.3	1.5	12.2	4.62	3.74	2.2	6.1	27	25	0.653	P++	0.2	0.6	25	44	0.567	P++
	B	12-15	9.1	0.7	13.0	4.77	3.74												
Shrub	A1	0-8	21.8	1.1	19.8	4.84	4.23	7.5	4.8	61	57	0.666	B±	0.2	0.1	67	89	0.552	A±
	A2	8-15	19.0	1.0	19.0	4.72	4.21	7.5	4.8	61	56	0.658	B±	0.1	0.1	50	113	0.536	A+
	A3	15-24	15.3	1.0	15.3	4.97	4.25	4.6	4.6	50	54	0.654	B+	0.1	0.1	50	106	0.527	A+
	B	24-40	8.5	0.6	14.2	5.01	4.28												
Rubber plantation	A1	0-5	35.2	2.2	16.0	4.46	3.83	7.3	9.0	45	42	0.725	B+	0.4	0.2	67	61	0.638	B
	A2	5-18	18.4	1.1	16.7	4.60	4.01	2.9	5.8	33	49	0.672	B+	0.2	0.4	33	85	0.582	A+
	B	18-40	8.6	0.6	14.3	4.69	4.06												
Mixed garden	Ap	0-15	37.7	2.6	14.5	4.58	3.83	8.5	9.4	47	49	0.745	B±	0.4	0.5	44	59	0.640	B
	B	15-40	13.4	0.8	16.8	4.65	3.95												
Cassava field	Ap	0-10	18.4	1.0	18.4	4.69	4.33	3.6	5.0	42	75	0.643	B±	0.2	0.2	50	96	0.547	A+
Menggala village																			
Shrub	A1	0-7	25.9	1.6	16.2	5.00	4.15	11.3	6.6	63	46	0.789	B±	0.2	0.1	67	86	0.564	A±
	A2	7-18	21.4	1.3	16.5	4.75	4.07	8.0	5.9	58	47	0.740	B±	0.1	0.2	33	91	0.555	A+
Rubber plantation	A1	0-3	43.2	2.7	16.0	4.77	4.09	13.5	8.3	62	55	0.714	B±	0.7	0.3	70	40	0.628	P
	A2	3-19	22.5	1.2	18.8	4.86	4.22	6.0	4.7	56	76	0.653	B±	0.3	0.2	60	75	0.552	B±
	B	19-30	4.2	0.2	21.0	4.93	4.27												
Cacao planation	A1	0-3	28.7	1.8	15.9	4.97	4.08	10.4	7.8	57	49	0.692	B±	0.2	0.4	33	115	0.545	A+
	A2	3-21	37.5	2.5	15.0	5.16	4.31	11.9	8.4	59	47	0.734	B±	0.5	0.3	63	80	0.599	A+
Mixed garden	Ap	0-20	28.3	1.5	18.9	5.79	4.65	8.1	5.5	60	61	0.718	B	0.5	0.3	63	76	0.601	B±
	B	20-40	11.0	0.5	22.0	4.99	4.23												
Cassava field	Ap	0-20	18.1	1.0	18.1	4.91	4.12	5.2	4.1	56	68	0.615	B+	0.2	0.2	50	110	0.538	A+
	B	20-36	6.2	0.4	15.5	5.02	4.18												

Notes: Ch: humic acid carbon, Cf: fulvic acid carbon, PQ=Chx100/(Ch+Cf)
Subscript 1 denotes the fraction extracted with 0.1 *M* NaOH, while subscript 2 with 0.1 *M* $Na_4P_2O_7$.
RF=(Absorbance at 600 nm of humic acid solution x 1000)/ (carbon mg in 2 ml of humic acid solution x 33.3)
Δ logK=log (K_{400}/K_{600}) of humic acid solution, where K denotes the absorbance at 400 or 600 nm..

Humus composition. When humic fractions were extracted stepwisely with 0.1 *M* NaOH and 0.1 *M* $Na_4P_2O_7$, 91 - 98 % of the soluble humus was extracted with 0.1 *M* NaOH, which is considered to have existed in free form (Table 1). The fraction extracted with 0.1 *M* $Na_4P_2O_7$, combined form, was very low. On the carbon basis, total soluble humus occupied 50- 70 % of total soil carbon (Table 2). The color intensity at 600 nm (RF_1) of humic acid was lower in the secondary forest soil than those in the other soils. From RF_1 and $\Delta logK_1$, free form humic acid of the secondary forest soil was grouped into P type, which exhibited a remarkable feature of Pg absorption in A_2 layer. On the other hand, free form humic acids extracted from the soils of shrubs, plantations, mixed gardens and cassava fields showed slightly higher RF and they all belonged to B type. Very slight to slight contribution of Pg absorption was also observed in these B type humic acids. The combined form humic acid in the secondary forest also belonged to P type which exhibited a remarkable feature of Pg in the A_2 layer. In the other soils, RF_2 were considerably larger than RF_1 and they were grouped into A, B and P types, in which A type was dominant (Table 1). Predominance of B type in the free form humic acids and A type in the combined form humic acids was surprising, when the very fast mineralization of soil organic matter in the tropical soils is considered.

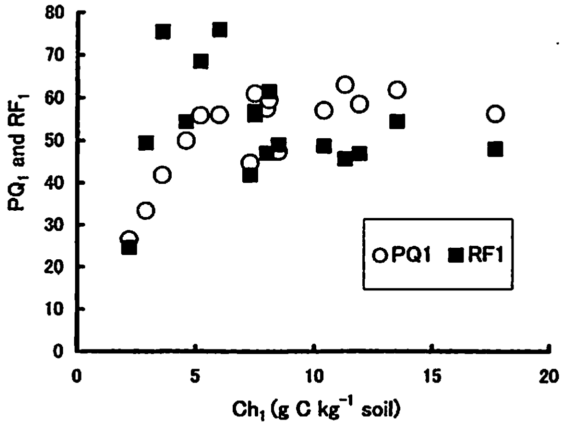

Fig. 1. Relationship between PQ_1, RF_1 and Ch_1.

The proportion of free form humic acid in total free form humus (PQ_1) showed an interesting tendency with the amount of free form humic acid extracted (Ch_1). The PQ_1 changed little while the Ch_1 was above 5 g kg^{-1}, but PQ1 decreased proportionally with Ch_1 when the Ch_1 was below 5 g kg^{-1} (Fig.1). This implies that humic acid is degraded preferentially when soil organic matter is mineralized exhaustively. The absorbance at 600 nm of humic acid per unit concentration (RF_1) showed a tendency to increase when the Ch_1 decreased to 5 g kg^{-1}. But RF_1 decreased again when Ch_1 decreased further (Fig. 1). This implies that humic acid with high degree of humification was relatively stable until soil organic matter attain a certain level, but it was decomposed finally.

Saccharide composition. Non-cellulosic saccharide carbon occupied 6.7- 14.8 % of total soil carbon, while cellulosic saccharide carbon occupied 1.1- 3.0 % (Table 2). The effect of land use was not remarkable in the soils of middle terrace area. We do not have enough information to explain the difference in saccharide contents among the sites. However, as far as the composition of saccharides is concerned, an interesting tendency was found between the ratio of mannose / xylose and the content of non-cellulosic saccharides. Mannose in soil is considered to be microbial origin while xylose in soil is derived from hemi-cellulose and, therefore, is plant origin.

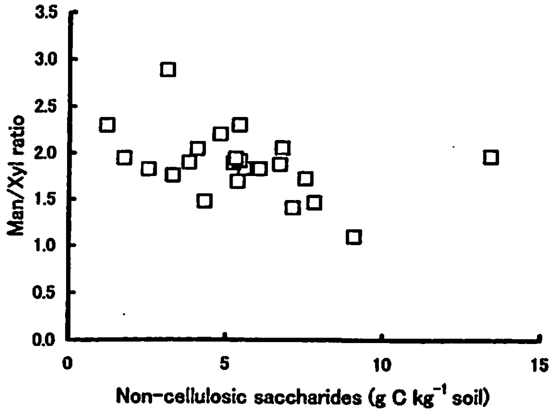

Fig. 2. Relationship between Mannose/Xylose ratio and total non-cellulosic saccharide content.

The ratio of mannose / xylose increased as the content of non-cellulosic saccharide decreased (Fig. 2). This implies that as saccharide component is decomposed, microbial saccharide increases its proportion in the soil.

Phenolic compounds. Phenolic compounds released by CuO-NaOH oxidation are derived from lignin structure in soil organic matter as well as in plant residue. Composition of p-hydroxy-phenyl, vanillyl, syringyl and cinnamyl compounds also differ according to the classification of plants. The proportion of the phenolic compounds carbon in the total carbon was very low and ranged between 2.7- 10.2 g C kg^{-1} (Table 2). This does not necessarily mean that lignin structure is not important in soil organic matter, because only the surface of lignin molecule is decomposed by CuO-NaOH oxidation. The proportion of phenolic compounds in the total soil carbon tended to be larger in the surface soil layer and decreased in the lower soil layer. This is contrasting to the yield of humic fraction or saccharides because they did not differ significantly between the upper and lower soil layers (Table 2). This means that lignin structure is kept in relatively fresh plant residue and, therefore, is more readily decomposable than humic fractions or saccharide fractions.

Table 2. Distribution of carbon in the soils under different land uses in the middle terrace area. in South Sumatra, Indonesia. (unit: g C kg^{-1} total C)

		Extractable humus					Saccharides			Phenolic compounds				
		Ch_1	Cf_1	Ch_2	Cf_2	total	Non-cel	Cel	total	H	V	S	C	total
Gunung Batin village														
Secondary	A_1	333	258	15.1	11.3	618	102	17	119	1.4	2.0	1.0	3.1	7.4
forest	A_2	120	333	10.9	32.8	497	148	20	168	0.5	0.6	0.0	1.0	2.1
Shrub	A_1	341	218	9.1	4.5	573	97	30	127	1.0	1.4	0.7	1.4	4.4
	A_2	395	253	5.3	5.3	658	115	28	144	1.3	1.3	0.0	1.1	3.6
	A_3	307	307	6.7	6.7	627	127	26	153	1.3	1.1	0.0	0.8	3.1
Rubber	A_1	209	257	11.4	5.7	483	104	13	118	1.8	2.9	2.1	3.4	10.2
plantation	A_2	161	322	11.1	22.2	517	120	15	135	1.2	1.4	0.7	1.8	5.0
Mixed garden	Ap	224	247	10.5	13.2	495	84	11	94	3.1	1.8	1.1	1.8	7.8
Cassava field	Ap	200	278	11.1	11.1	500	118	29	147	2.0	1.6	0.7	2.5	6.8
Menggala village														
Shrub	A_1	435	254	7.7	3.8	700	95	18	113	1.7	1.3	1.0	1.8	5.7
	A_2	381	281	4.8	9.5	676	100	17	117	1.1	1.0	0.5	1.2	3.8
Rubber	A_1	314	193	16.3	7.0	530	67	11	78	1.1	1.8	1.3	1.6	5.7
plantation	A_2	261	204	13.0	8.7	487	73	13	87	0.7	0.9	0.4	0.7	2.7
Cacao	A_1	359	269	6.9	13.8	648	96	11	107	1.2	1.1	0.5	0.8	3.6
plantation	A_2	313	221	13.2	7.9	555	81	12	93	1.3	1.5	1.0	1.1	4.9
Mixed garden	Ap	286	194	17.7	10.6	509	62	13	75	1.4	1.1	0.8	1.5	4.7
Cassava field	Ap	289	228	11.1	11.1	539	85	23	109	1.1	1.2	0.5	1.7	4.4

Notes: See the footnote of Table 1 for Ch and Cf.
Non-cel: Non-cellulosic saccharides, Cel: cellulosic saccharides.
H: p-hydroxyphenyl, V: vanillyl, S: syringyl, C: cinnamyl compounds, respectively.

Among phenlic compounds, syringic compounds were abundant only in the thin surface layer. Even in an A layer, proportion of syringic compounds decreased steeply with depth. Syringic compounds are characteristic to Angiosperm woods and leaves, and the litter of these materials is decomposed easily under tropical condition. Cinnamyl compounds were also abundant in the uppermost layer, but they still existed in considerable proportion in the lower layers. Cinnamyl compounds are contained in large amounts in gramineous plants. Because gramineous plants are ubiquitous and have a extended root system, cinnamyl compounds were observed abundantly in most of the soil profiles.

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