The nature of organic matter in high organic matter soils of the hill country wet zone of Ceylon

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SUMMARY

Humus substances were extracted from soil and their carbon and nitrogen contents determined. Soils studied are rich in organic matter and humus substances. Humification of organic matter decreases with increasing elevation. Forest soils contain more fulvic acid than grassland soils.

INTRODUCTION

Organic matter plays a significant role in soil genesis and soil fertility and considerable work has been done to elucidate its complex nature. Little work has however been reported on organic matter in Ceylon soils.

The most striking feature of the soils of montane grasslands and adjacent areas in the hill country wet zone of Ceylon is the thick organic surface layer (4). The present investigation refers to a study of the nature of organic matter in the surface soils of three major high altitude regions in the centre of Ceylon viz., Bopatalawa (5000 ft.), Ambawela (6000 ft.) and Horton Plains (7000 ft.). Ecological and climatic data of the sites and chemical and physico-chemical properties of these soils have been discussed elsewhere (2).

Organic matter mineralisation is retarded at low temperatures and under acid conditions (1). Therefore, under low temperature and low pH conditions prevalent at high altitudes the unusually high organic matter contents of the soils studied cannot be considered a reliable index of soil fertility without further data on the nature of organic matter and rates of mineralisation.

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MATERIALS AND METHODS

At each location single samples were taken from the crest of the hill under foreset vegetation, upper slope of *patana* (montane grassland) below the forest, lower slope of *patana* and *deniya* (water logged valley bottom) in the depression. Organic carbon was determined by Walkley and Black's rapid titration method and total nitrogen by the standard macro-Kjeldhal method. Methods described by Kononova (3) were used to determine the composition of humus substances and humic acids. Fulvic acid carbon and fulvic acid nitrogen were determined by subtracting humic acid carbon and humic acid nitrogen from the humus carbon and humus nitrogen respectively. The amounts of organic carbon and total nitrogen left in the soil residue after humus substances had been extracted were estimated by subtracting the humus carbon and humus nitrogn contents from the organic carbon and total nitrogen respectively in the original soil.

RESULTS AND DISCUSSION

Brief description of the sites, depth of A_1 horizon, pH, total organic carbon, total nitrogen, total organic matter and C/N ratio are given in Table 1.

TABLE 1

Description of the soils and organic matter

Soil No. and site	*depth cm.*	*pH*	*Organic C%*	*Total N%*	*Organic matter%*	*C/N*
		BOPATALAWA				
1. Forest on hill crest	0 –8	4·5	8·92	0·86	15·37	10·37
2. Upper slope *patana*	0–15	4·5	7·42	0·55	12·79	13·49
3. Lower slope *patana*	0–18	4·6	6·76	0·55	11·65	12·16
4. *Deniya* valley— bottom	0–35	4·4	8·70	0·67	15·00	12·99
Average		4·5	7·95	0·66	13·70	12·25
		AMBAWELA				
1. Forest on hill crest	0–15	5·4	4·27	0·58	7·36	7·27
2. Upper slope *patana*	0–18	4·8	4·37	0·37	7·53	11·81
3. Lower slope *patana*	0–20	4·9	6·29	0·48	10·84	12·86
4. *Deniya* valley— bottom	0–25	4·8	5·33	0·43	9·19	12·48
Average		5·0	5·07	0·47	8·73	11·08
		HORTON PLAINS				
1. Forest on hill crest	0 –5	6·0	8·75	0·82	15·09	10·67
2. Upper slope *patana*	0–15	5·6	11·43	0·79	19·71	14·39
3. Lower slope *patana*	0–25	5·1	15·12	1·15	26·07	13·15
4. *Deniya* valley— bottom	0–25	5·1	18·63	1·29	32.12	14·44
Average		5·5	13·48	1·01	23·25	14·62

Humus Substances :

Varios interpretations have been attached to the term humus (3, 5, 7, 8). In the present investigation the term *humus* has been used to describe those humus substances extrated by o.1M sodium pyrophosphate/O.1N sodium hydroxide mixture (pH 13).

The contents of humus substances in these soils were high, average percentages being : Bopatalawa 7.32, Ambawela 3.80 and Horton Plains 9.10 (Table 2). In Horton Plains the variation in percentage of humus in soil between different sites was wide and regular : forest 3.95, upper *patana* 7.72, lower *patana* 11.10 and *deniya* 13.62. In Bopatalawa and Ambawela the variations were slight, forest soils containing more humus than upper *patana* soils, the quantity increasing thereafter down the slope to *deniya*.

TABLE 2

Content and composition of human substances extracted by $Na_2P_2O_7$/NaOH

Soil No.	*Humus* % *Soil wt.*	*Carbon*		*Nitrogen*	
		% *of soil wt.*	% *of organic C*	% *of soil wt.*	% *of total N*
BOPATALAWA					
1	7·69	4·46	50·00	0·42	48·84
2	5·57	3·23	43·53	0·41	74·54
3	6·09	3·53	52·22	0·43	78·18
4	9·93	5·76	66·21	0·58	86·57
Average	7·32	4·25	52·99	0·46	72·03
AMBAWELA					
1	3·55	2·06	48·24	0·29	50·00
2	3·07	1·78	40·73	0·23	62·16
3	4·14	2·40	38·16	0·28	58·33
4	4·43	2·57	48·22	0·28	65·12
Average	3·80	2·20	43·84	0·27	58·90
HORTON PLAINS					
1	3·95	2·29	26·17	0·25	30·49
2	7·72	4·48	39·20	0·32	40·51
3	11·10	6·44	42·59	0·48	41·74
4	13·62	7·90	42·40	0·54	41·86
Average	9·10	5·28	37·59	0·40	38·65

Humus accumulation in soil depends on (*a*) vegetation (*b*) activity of micro-organisms (*c*) hydrothermal regime and (*d*) physical and physico-chemical characteristics of soil (9).

Addition of large amounts of organic residues to soil and poor mineralisation under the low temperature and low pH conditions prevailing are the main factors that favour accumulation of large amounts of humus substances in these soils. The relative amounts of humus substances (and organic matter) between different sites at each locality indicate that the importance of forest vegetation as a supplier of humus substances (and organic matter) diminishes with increasing elevation. The largest accumulations of humus substances at each locality were in *deniya* soils. This is probably due to vegetation and poor microbial activity resulting in slow mineralisation.

Percentage of humus carbon in organic carbon decreases markedly with rise in elevation from Bopatalawa (average 52.99) to Ambawela (average 43.84) and Horton Plains (average 37.59). Percentage of humus nitrogen in total nitrogen also decreases with increasing elevation. These observations indicate less humification at higher altitudes. According to Kononova (3), nitrogen present in humus substances is of microbial origin. The decrease in the percentage of humus nitrogen in total nitrogen with increasing elevation will therefore mean that transformation of nitrogen in organic residues to humus nitrogen through microbial plasma is less effective at higher altitudes. In all three localities the percentage of humus nitrogen in forest soils is much less than that in *patana* and *deniya* soils indicating that forest organic residue contain less humifiable nitrogen.

Humic acids and fulvic acids

The terms *humic acids* and *fulvic acids* are the same as those used by Kononova (3). Composition of humic acid and fulvic acid fractions is reported in Table 3. Average percentage of humic acid carbon in soil increases from Ambawela soils (0.74) to Bopatalawa soils (1.62) and Horton Plains soils (3.51). Percentage of humic acid carbon in organic carbon and in humus carbon also increases from Ambawela soils to Bopatalawa soils and Horton Plains soils.

These observations indicate that the conditions for humic acid formation are most favourable in Horton Plains. Humic acid nitrogen content also increases from Ambawela soils to Bopatalawa soils and Horton Plains soils, average percentages being 0.18, 0.19, and 0.32 respectively. Humic acid carbon and humic acid nitrogen are highest in *deniya* soils for every locality indicating that conditions for humic acid accumulation are most favourable in *deniya* soils.

Humic acids contain more carbon and less nitrogen than fulvic acids. Moreover, with increasing complexity humic acids become richer in carbon and poorer in nitrogen (3). Relative contents of humic acid carbon to humic acid nitrogen increase from Ambawela soils (0.74 : 0.18) to Bopatalawa soils (1.62 : 0.19) and Horton Plains soils (3.51 : 0.32). This may be due to lesser decomposition and alteration of plant materials and/or greater complexity and maturity of humic acids in Horton Plains than in Bopatawala and Ambawela.

Bopatalawa and Ambawela soils contain more fulvic acid carbon than humic acid carbon while the reverse is true of Horton Plains soils. The percentage of fulvic acid carbon in organic carbon and in humus carbon are least in Horton Plains soils indicating that conditions for fulvic acid accumulation are least favourable in Horton Plains. Percentages of fulvic acid nitrogen in soil, in total nitrogen and in humus nitrogen decreased with increasing elevation indicating that with increasing elevation conditions become less favourable for the formation of fulvic acid nitrogen.

Ratios of humic acid carbon fulvic acid carbon are generally low, average values for the three locations being, Bopatalawa 0.72, Ambawela 0.51, and Horton Plains 1.89. The ratios are lower than for ordinary chernozem (2.85). In Ambawela the average ratio is even lower than the figure of 0.56 reported for strongly podsolised soils (3). These data confirm the earlier observation that humus substances of Horton Plains soils are characterised by a greater proportion of humic acids while fulvic acids predominate in Bopatalawa and Ambawela soils. Stevenson (6) reported that the proportion of fulvic acids is higher for forest soils than for grassland soils. A similar result is evident in the present investigation from the lower ratios of humic acid carbon to fulvic acid carbon for forest soils than for *patana* and *deniya* soils.

Organic matter in soil residue :

Organic matter in the soil residue (Table 4) represents organic substances insoluble in the alkali pyrophosphate extracting mixture. Organic carbon and total nitrogen in soil residue, expressed as percentages of organic carbon and total nitrogen respectively of the original soil, increases with increasing elevation indicating that humication decreases with altitude. This probably is due to decreasing microbiol activity altering soil organic matter with increasing elevation.

TABLE 3.—Composition of Humic Acid and Fulvic Acid Fractions

Soil No.	Humic Acid						Fulvic Acid						Humic Acid C / Fulvic Acid C
	Carbon			Nitrogen			Carbon			Nitrogen			
	% of Soil wt.	% of Oranic C	% of Hums C	% of Soil wt.	% of Total N	% of Hums N	% of Soil wt.	% of Oranic C	% of Hums C	% of Soil wt.	% of Total N	% of Hums N	
						Bopatalawa							
1	0·90	10·09	20·18	0·10	11·63	23·81	3 56	39·91	79·82	0·32	37·21	76·16	0·25
2	0·70	9·43	21·67	0·13	23·64	31·71	2·53	34·10	78·33	0·28	50·91	62·29	0·28
3	1·10	16·27	31·16	0·17	30·91	39·53	2·43	35·95	68·84	0·26	47·27	60·47	0·45
4	3·78	43·45	65·62	0·35	52·24	60·34	1·98	22·76	34·38	0·23	34·33	39·6(	1·91
Ave.	1·62	19·81	34·66	0·19	29·60	38·85	2·63	33·18	65·34	0·27	42·43	61·1(	0·72

TABLE 3—Composition of humic Acid and fulvic Acid Fractions

Soil No.	Humic Acid						Fulvic Acid						Humic Acid 'C' / Fulvic Acid C
	Carbon			Nitrogen			Carbon			Nitrogen			
	,%of Soil wt.	,%of oragnic C	,%of Humus C	,%of Soil wt.	%of Total N	,%of Humus N	,%of Soil wt.	,%of Organic C	,%of Humus C	,%of Soil wt.	,%of Total N	,%of Humus N	
						Ambawela							
1	0·40	9·37	19·42	0·10	17·24	34·48	1·66	38·88	80·58	0·19	32·76	65·52	0·24
2	0·56	12·81	31·46	0·19	51·35	82·61	1·22	27·92	68·54	0·04	10·81	17·39	0·46
3	0·84	13·35	35·00	0·20	41·67	71·43	1·56	24·80	65·00	0·08	16·67	28·57	0·54
4	1·14	21·39	44·36	0·24	55·81	85·71	1·43	26·83	55·64	0·04	9·30	14·29	0·80
Ave.	0·74	14·23	32·56	0·18	41·51	68·56	1·47	29·61	67·44	0·09	17·38	31·44	0·51
						Horton Plains							
1	0·85	9·71	37·12	0·16	19·51	64·00	1·44	16·46	62·88	0·09	10·98	36·00	0·59
2	2·83	24·76	63·17	0·28	35·44	87·50	1·65	14·44	36·83	0·04	5·06	12·50	1·72
3	4·34	28·70	67·39	0·39	33·91	81·25	2·10	13·89	32·61	0·09	7·83	18·75	2·07
4	6·01	32·26	76·08	0·45	34·88	83·33	1·89	10·14	23·92	0·09	6·98	16·67	3·18
Ave.	3·51	23·86	60·94	0·32	30·94	79·02	1·77	13·73	39·06	0·08	7·71	21·98	1·89

TABLE — 4 Composition of Organic matter in Soil residue

Soil No.	Organic matter %of Soil wt.	Carbon %of Soil wt.	Carbon %of Organic C	Nitrogen %of Soil wt.	Nitrogen %of Total N	C/N
Bopatalawa						
1	7·69	4·46	50·00	0·44	51·16	10·14
2	7·22	4·19	56·47	0·14	25·45	29·93
3	5·57	3·23	47·78	0·12	21·82	26·92
4	5·07	2·94	33·79	0·09	13·43	32·67
Ave.	6·39	3·71	47.01	0.20	27.96	24.92
Ambewela						
1	3·81	2·21	51·76	0·58	50·00	7·62
2	4·47	2·59	59·27	0·14	37·84	18·50
3	6·71	3·89	61·84	0·20	40·67	19·45
4	4·76	2·76	51·78	0·15	34·88	18·40
Ave.	4·94	2·86	56·16	0:20	41·10	15·99
Horton Plains						
1	11·14	6·46	73·83	0·57	69·51	11·33
2	11·98	6·95	60·80	0·47	59·49	14·79
3	14·96	8·68	57·41	0·67	58·26	12·96
4	18·50	10·73	57·60	0·75	58·14	14·31
Ave.	14·15	8·21	62·41	0·62	61·35	13·35

Organic matter in forest soils differs from that in grassland soils in that the C/N ration of organic matter in soil residue and also in original soil is lower for forest soils than for grassland soils. This is possibly due to differences in composition between organic matter from mainly dicotyledonous forest flora and that from grassland vegetation.

The observation that C/N ratio of organic matter in soil residue in grassland soil decreases with elevation from Bopatalawa to Ambawela and Horton Plains is not in agreement with the earlier observation that humification decreases with elevation. However it must be understood that organic substances not extracted by extracting mixture includes humin (humic acids in strong combination with mineral matter) in addition to unhumified organic matter. Therefore, it must be investigated whether differences in humin content between the three localities contribute to this discrepancy.

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