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ORGANIC CONSTITUENTS OF FOREST HUMUS LAYERS IN THE COASTAL WESTERN HEMLOCK BIOGEOCLIMATIC ZONE OF BRITISH COLUMBIA IN RELATION TO FOREST ECOSYSTEMS

2. HUMUS FRACTION DISTRIBUTION

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K. Klinka and L. E. Lowe

BRITISH COLUMBIA FOREST SERVICE
Research Division
Victoria, B.C.

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K. Klinka[1] and L. E. Lowe[2]

1 British Columbia Forest Service, Research Division, Victoria, B.C.

2 University of British Columbia, Department of Soil Science, Vancouver, B.C.

ABSTRACT

Humus fraction distribution of humus layers was assessed on six forest ecosystems, representing soils of xeric, mesic and hygric hygrotopes in both wet and dry subzones of the Coastal western hemlock biogeoclimatic zone. Humic acid (HA) levels increased with increasing moisture for both subzones, and in the wetter (CWHb) subzone on average reached higher levels for each hygrotope than in the corresponding hygrotope of the dry subzone. The fulvic acid (FA) fraction showed little variation between four of the ecosystems but was significantly lower for the mesic and hygric sites of the CWHb subzone. The latter was attributed to greater downward translocation of these acid soluble constituents. Ratios of HA to FA tended to increase with increasing moisture for both subzones, in contrast to reports in the Russian literature. HA:FA ratio also appeared to be related to humus form.

Changes in fraction distribution are discussed in relation to moisture regime and biological activity and to rates of humus synthesis and decomposition.

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INTRODUCTION

Many workers have investigated the distribution and nature of humus fractions in soils, although the information on agricultural soils is much more abundant than for forest soils. In particular Russian workers have conducted extensive studies on the humus fractions of a wide range of soils in relation to both soil genesis and, more especially, to humus formation (e.g. Tyurin 1951, Kononova 1966, Sukachev and Dyllis 1964). These workers have reported relationships between zonal soils and the composition of humic acids (HA) and fulvic acids (FA), and also between soil zone and the HA:FA ratio (Ch:Cf, based on carbon content). Major soil groups have been reported to exhibit distinctive Ch:Cf levels, and also characteristic ranges for elemental analysis of HA as well as susceptibility to coagulation and optical properties. Little comparable data are available on North American soils, although a recent study by Anderson *et al*. (1974) indicated systematic changes in humic fractions on moving from arid Brown, through Dark Brown and Black Chernozemic, to more humid Gray Luvisolic soil zones. Methods of examining the distribution of organic fractions in forest humus layers in British Columbia have been discussed by Lowe (1974).

The present study is part of a program investigating relationships between forest ecosystems established by synecological methods and the composition of forest humus layers. A previous report (Klinka and Lowe, B.C.F.S. Research Note No. 74 in print) discussed proximate analysis results, whereas the present report deals with the distribution of humus fractions. A subsequent report will discuss optical properties of humic acid fractions.

MATERIALS AND METHODS

Samples and sampling sites

Samples of forest humus layers were collected from forest ecoystems in the U.B.C. Research Forest, which lies in the Coastal western hemlock (CWH) biogeoclimatic zone of British Columbia. Details of the forest ecosystems investigated, and of the humus forms and selected chemical properties of the samples, have been reported in Research Note No. 74. Three ecosystem units were selected in both dry (CWHa) and wet (CWHb) subzones, on soils with xeric, mesic and hygric hygrotopes. Forest productivity was generally higher in the CWHa subzone, and for each subzone increased from xeric to mesic to hygric ecosystems.

Extraction Methods

The methods of extraction selected were based on the classical alkaline extraction methods developed for use on mineral soils, but adapted for use on samples containing substantial amounts of unhumified material in addition to the humus fractions.

Samples were extracted with ethanol:benzene (1:1) to remove the lipid fraction (fats, waxes, resins, etc.), and with 0.1 N H_2SO_4 to remove basic cations and enhance extraction efficiency with alkali. Soluble humus fractions (HA and FA) were then extracted with 0.1 N NaOH. The residue from the alkaline extraction was hydrolysed with 1 N H_2SO_4 under reflux after pretreatment with cold 72% H_2SO_4. Organic matter solubilized by this treatment was designated 'hydrolysable residue', whereas the solid residue was termed 'non-hydrolysable residue'. The hydrolysable residue is considered to consist essentially of unhumified plant materials, mainly polysaccharides including cellulose. The non-hydrolysable residue will include the most stable plant residues components like lignin, as well as the humin fraction. The extraction procedures were essentially those described previously (Lowe 1974) except for the use of smaller sample weights and extraction volumes, and the omission of a hot NaOH extraction. Yields of each fraction were determined gravimetrically and corrected for ash content.

RESULTS AND DISCUSSION

The distribution of HA, FA, hydrolysable residue and non-hydrolysable residue fractions is reported in Table 1. While some variation in distribution of fractions was noted, HA, FA and non-hydrolysable residue fractions were in all cases major components, while the hydrolysable residue accounted on average for only 3.1% of the total organic matter. Based on mean values for four plots, HA was more abundant than FA in all units, and for each subzone, HA levels increased from xeric to mesic to hygric habitats. Levels of FA were very similar in four of the units (22.5% to 24.5%) but were substantially lower (13.5% - 14.2%) for the units on the mesic and hygric habitats of the CWHb subzone. The lower levels of FA in organic horizons of some sites in the moister CWHb subzone, may well be due to greater downward movement of mobile FA components, since soils profiles of the CWHb zone have been reported to exhibit more marked eluviation than those of the CWHa zone (Krajina 1965, 1969; Lesko 1961; Orloci 1964 and Kojima 1971.)

HA levels increased within each subzone with increasing moisture (from xeric to mesic and to hygric), indicating that HA accumulation is favoured by moister conditions, whereas the more extended periods of soil desiccation in xeric ecosystems tends to inhibit HA accumulation. However, this effect could be due either to decreased inputs of HA-precursors at drier sites, to a slower rate of HA synthesis (perhaps as a result of lower microbiological activity), or to a slower rate of degradation of HA at the moister sites, as a result of excessive moisture levels. Probably all three factors are involved. It is suggested that in the cooler, more humid subzone (CWHb), excess moisture retards HA degradation at the hygric ecosystems (BLECHNUM - AF - WH), whereas in the CWHa subzone, lack of moisture retards HA synthesis in the xeric ecosystems.

The relative proportions of HA and FA as indicated by the Ch:Cf ratio has been considered by a number of Russian workers (Kononova 1966, Sukachev and Dyllis 1964) to be the most important humus characteristics reflecting the processes of humus formation. Sukachev and Dyllis have suggested a classification of soil organic layers based on this property. The Russian workers have indicated that Ch:Cf values decrease on passing from chernozem soils to podzolic soils, and concluded that the more humid conditions under which podzols are formed are less favourable to the production of HA, but rather favour the formation of the more mobile FA materials. Kononova (1966), for example, reports typical podzol Ch:Cf values in the 0.5-0.8 range, which is substantially lower than most of the values found in the present study in a region where podzolic soils predominate. Two important factors probably account for this apparent discrepancy. Many workers have suspected, and Gascho and Stevenson (1968), Petruzzelli et al. (1974) have clearly demonstrated that Ch:Cf values are highly dependent both on methods of extraction and on conditions for separating the HA and FA fractions. Hence values reported by different workers are frequently not comparable. Furthermore, much of the data reported for podzolic soils by Kononova (1966) and freely quoted by others, appears to be based largely on mineral horizons, either virgin or cultivated, and is not necessarily relevant to organic horizons of such soils. Indeed, Ch:Cf values reported by Czerney and Fiedler (1968) for an extensive study of spruce humus in Europe were mainly greater than 1.0, with mean values for L, F, H and Ah horizons of 1.0, 1.3, 1.9 and 1.3 respectively. A similar increase in Ch:Cf with decomposition was reported by Lowe (1972) for a western hemlock-western redcedar stand in British Columbia. Thus, the common assumption that humid conditions favoring podzol formation give rise to low Ch:Cf values, i.e a predominance of FA over HA, appears unacceptable, as far as organic horizons are concerned, as is the suggestion that increasing moisture causes decreasing Ch:Cf values. For organic soil horizons under coniferous forest cover, the reverse appears to be the case, at least in the CWH zone.

Ch:Cf of forest humus layers does however appear to be related to the degree of decomposition, (Czerney and Fiedler 1968) and in the present study this was reflected in a relationship to humus forms, which differ in proportions of F, H and Ah material. Mean Ch:Cf values for F-mor, H-mor, moder and mull were 1.23, 1.84, 2.33 and 1.25 respectively.

The hydrolysable residue fraction, which includes cellulose and cellulose from undecomposed plant residues, was relatively insignificant for all the humus samples. Only in the case of decayed wood samples were appreciable amounts found. For these samples, and especially in the case of decayed wood of Douglas-fir, the hydrolysable residue was substantially more abundant than the HA or FA fractions.

The materials remaining at the end of the extraction sequence (non-hydrolysable residue) were observed to contain considerable amounts of plant debris, particularly those derived from F-mor and decayed wood samples. The residues from H-mor and mull samples appeared amorphous and presumably consist essentially of humin, together with mineral materials. All residues will also likely contain materials comparable to the immature HA fraction extractable with hot NaOH solution, which were described in a previous paper (Lowe and Godkin 1975). The variation in composition of the non-hydrolysable residue fraction clearly make it difficult to interpret differences in the abundance of this fraction. The high levels in the TIARELLA - POLYSTICHUM - WESTERN REDCEDAR alliance are presumably due mainly to accumulation of humin, whereas the high levels in decayed wood samples can be largely attributed to lignin that has undergone little or no modification.

Some indication of the degree of humification is given by the sum of HA plus FA fractions (Table 1). Some differences between ecosystems were apparent, with HA+FA increasing from xeric to mesic to hygric ecosystems in the CWHa subzone. In the more humid CWHb subzone, the *Vaccinium* - moss - western hemlock association appeared to show less accumulation of extractable humus fraction than the other ecosystems. However, this may be misleading if signficicant downward translocation occurs of FA components produced within the organic layers. On the other hand these sites had higher levels of both lipid fraction and hydrolysable residue fraction than other sites in this subzone, suggesting less active decomposition processes.

SUMMARY AND CONCLUSIONS

Analysis of organic fraction distribution in forest humus layers, by methods that recover the major classical humus fractions, yield information not obtainable by proximate analysis alone. On application of such methods to six ecosystem units from the Coastal western hemlock biogeoclimatic zone of British Columbia, differences between ecosystems within the CWHa and CWHb subzones were found, particularly with respect to levels of the humic acid fraction and Ch: Cf ratio. Both properties appeared to be related to moisture regime. Increasing moisture was associated with increasing humic acid formation, and contrary to what might be expected from Russian literature, with increasing Ch:Cf ratio. Mesic and hygric habitats in the CWHb subzone were characterized by much lower levels of fulvic acid fraction than the other habitats studied.

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Table 1. Humus form and distribution of humus fractions in ecosystems of the Coastal western hemlock zone

(fractions expressed as % of total organic matter)

Ecosystem Unit*	Plot no.	Humus form	Organic matter %	HA %	FA %	Hydrolysable residue %	Non-hydrolysable residue %	Ch:Cf	HA+FA %
CWHa, GAULTHERIA - DOUGLAS-FIR (xeric)									
	021	F-mor	64.5	19.2	24.6	2.5	24.1	0.78	43.8
	030	H-mor	75.4	28.9	19.9	3.6	19.6	1.45	48.7
	057	moder	50.1	20.9	24.6	2.6	32.1	0.85	45.5
	083	F-mor	88.8	23.4	20.7	2.9	25.2	1.13	48.1
Mean			69.7	23.1	22.5	2.9	25.2	1.05	46.5
CWHa, MOSS - WESTERN HEMLOCK (mesic)									
	007	F-mor	86.6	23.6	26.7	3.7	17.5	0.88	50.2
	024	H-mor	93.3	31.4	21.5	2.8	19.2	1.46	52.9
	032	H-mor	82.1	30.0	25.8	3.5	19.8	1.16	55.8
	124	F-mor	90.6	25.2	24.7	5.7	19.9	1.02	49.9
Mean			88.2	27.5	24.5	3.9	19.1	1.13	52.2
CWHa, TIARELLA - POLYSTICHUM - WESTERN REDCEDAR (hygric)									
	015	mull	26.0	31.2	23.5	1.9	35.6	1.33	54.7
	098	moder	26.0	36.9	19.8	0.7	26.3	1.87	56.7
	135	mull	72.2	29.8	24.5	0.9	25.0	1.21	54.3
	148	mull	14.5	31.7	25.9	0.3	9.8	1.22	57.6
Mean			34.7	32.4	23.4	1.0	31.6	1.41	55.8
CWHb, Vaccinium - Gaultheria - Douglas-fir - western hemlock (xeric)									
	053	F-mor	91.9	25.7	25.2	3.3	24.9	1.02	50.9
	055	F-mor	91.3	29.5	20.5	4.8	22.4	1.44	49.9
	056	F-mor	85.1	26.6	24.2	3.6	21.1	1.10	50.8
	063	F-mor	92.8	24.9	27.9	4.2	21.3	0.89	52.8
Mean			90.3	26.7	24.5	4.0	22.4	1.11	51.1
CWHb, Vaccinium - moss - western hemlock (mesic)									
	044	H-mor	85.0	32.1	14.2	4.0	26.0	2.26	46.2
	087	H-mor	93.0	28.5	16.6	4.1	22.1	1.72	45.1
	089	F-mor	91.8	25.7	14.3	4.0	24.4	1.80	40.0
	125	H-mor	85.8	26.4	11.6	4.3	23.2	2.27	38.1
Mean			88.9	28.2	14.2	4.1	24.0	2.01	42.4
CWHb, BLECHNUM - AMABILIS FIR - WESTERN HEMLOCK (hygric)									
	062	F-mor	91.5	32.6	14.3	3.4	22.6	2.28	46.9
	095	H-mor	91.4	35.8	13.9	3.1	20.7	2.57	49.8
	114	moder	76.9	42.9	10.9	2.1	26.8	3.94	53.7
	149	moder	80.5	39.8	15.0	2.2	22.2	2.66	54.7
Mean			85.1	37.8	13.5	2.7	23.1	2.86	51.3
CWHa, Decayed wood samples									
	030	DF	98.5	9.3	5.6	25.1	25.5	1.65	14.9
	032	DF	99.0	15.8	4.5	27.4	15.0	3.48	20.3
	001	WRC	99.5	4.6	3.1	9.6	61.9	1.45	7.7
	023	WRC	99.5	6.2	4.0	8.8	38.2	1.57	10.2
Mean			99.1	9.0	4.3	17.7	35.1	2.03	13.3

* Categorical rank of plant alliance and plant association was designated by capital and small letters respectively.

Abbreviations used: AF - *Abies amabilis* (Dougl.) Forbes, DF - *Pseudotsuga menziesii* (Mirb.) Franco var. *menziesii*, WRC - *Thuja plicata* Donn ex D. Don in Lamb.

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