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CHARACTERISTICS OF HUMIC SUBSTANCES IN HUMID SUBALPINE FOREST SOILS IN CENTRAL TAIWAN

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A b s t r a c t. The study site, 2700 m a.s.l., is located in the central Taiwan. A globally rare combination of the mean temperature (ca. 9.5 ^{o}C) and total annual precipitation (ca. 4100 mm) makes studies on pedogenic and edaphic processes of the moist soils in this area worthwhile. The study was undertaken to investigate distribution and characteristics of humic substances in this subalpine forest ecosystem. Fulvic acids comprised a higher total organic carbon fraction (1.8 to 25%) than humic acids (1.1 to 13.4%). Fulvic acids were more mobile and migrated downwards to deeper horizons. Comparatively, humic acids were distributed more in the surface horizons. The humification index, based on E_4/E_6, showed that humification varied in different horizons even in the same profile. The $\Delta logK$ and *RF* values indicate that the types of humic acids extracted from *Tsuga* forest soil are grouped as P or A types, whereas Rp or B types are in *Picea* forest soil, suggesting a high degree of humification of humic acids in such soils. Features of the absorption spectra were consistent with the classification of humic acids with $\Delta logK$ and *RF* values. Humification indices and humic acid types in these subalpine soils indicate that they are similar to acidic soils elsewhere with abundant rainfall and cold climate.

K e y w o r d s: fulvic acids, humic acids, humification, subalpine forest ecosystem, Central Taiwan.

INTRODUCTION

Parent material, vegetation and prevailing climate exerts a predominant influence on the distribution and properties of humic substances [3,5]. Degree of humification and migration of humic substances from the O layer to deeper horizons may differ from site to site with different relief of landscape. Humic acids develop into a series of a certain type, namely A, B, Rp and P, according to the classification system proposed by Kumada *et al.* [6]. Several studies postulate that humic substances are effective agents of mineral degradation and that they play important roles in many geological processes [4,13]. The purpose of the present study was to evaluate distribution and characteristics of humus in the humid subalpine soils in the subtropical region, where pedogenesis and edophological information is limited.

MATERIALS AND METHODS

Study sites and sampling

The major part of this study was conducted at Tatajai (23°28'N, 120°54'E) with the elevation of 2700 m a.s.l. in the Central Taiwan. The climate of this locality is similar to a temperate one, with the mean annual precipitation and temperature of about 4100 mm and 9.5 °C, respectively. This area has been selected as a representative long-term ecological study site for subalpine forest ecosystems in Taiwan. Vegetation at Tatajai is similar to temperate areas. Mountainous forests are mainly coniferous, and predominantly made up of *Tsuga chinensis.* By comparison, a *Picea morrisonicola* forest is distributed strictly on the slope to the north. Soil profiles of *Tsuga* and *Picea* forests were investigated, based on the international soil classification system [11]. Visible material, such as roots and litter were manually removed prior to sieving while the remaining soil was air-dried, crushed and sieved through a 2-mm sieve.

Extraction and separation of humic substances

Separation of fulvic and humic acids was performed following the method of Tan [12]. The air-dried soil was extracted with 0.1 M $Na_4P_2O_7$ under N_2. The alkaline supernatant was separated from the residue by centrifugation, then acidified with 6 M HCl to pH=1 and allowed to stand at room temperature for 24 h. The supernatant (fulvic acids) was separated from the coagulation (humic acids) by centrifugation. The humic acid fraction was then purified by HCl-HF mixture and air-dried. Each extracted fraction was analyzed for carbon content with a total organic carbon analyzer using the heat-persulfate oxidation method. Organic C in the soil was determined with Fison NA1500 CHN analyzer. The content of each element in soil was converted to an oven-dried basis.

Humification index

The E_4/E_6 ratio of humic acids in the present investigation was determined by a spectrometric measurement based on Kononova [5]. The above-mentioned purified humic acids were dissolved in a 0.05 N $NaHCO_3$ solution, then measured with a spectrophotometer (Hitach U-2000) at 400 and 600 nm against the reagent blank.

Determination of absorption spectra and classification of humic acids

Subsamples of humic acids were dissolved in 0.1% NaOH for optical density measurement. The absorption spectra were drawn in the 220 to 700 nm range [8]. These curves were expressed as λ with log$K$ values of the humic acids, where λ and log$K$ were wavelength and optical density, respectively.

Classification of humic acids followed the criteria proposed by Kumada [6]. The value of ΔlogK was obtained as follows: $\Delta \log K = \log K_{400} - \log K_{600}$, where K is the absorbance at 400 or 600 nm. On the other hand, RF value (relative color intensity) is defined as $RF = K_{600} \times 1000/c$, where K_{600} means optical density at 600 nm and c is the amount of 0.1 M $KMnO_4$ consumed by 30 mL of the humic acid solution.

RESULTS AND DISCUSSION

Distribution of humic substances

The content of fulvic acids in both of the forest soils was higher than that of humic acids (Table 1). The ratio of fulvic acids to humic acids (FA/HA), which indicates degree of humus polymerization in the soil horizon, was used to evaluate humification of humic acids [2]. Results in Table 1 coincided with those generally found, i.e. the ratio of FA/HA ordinarily increases with the increasing depth in the soil horizons [11]. In addition, the values of FA/HA of all horizons in Table 1 were generally higher than 1.0, which indicates dominance of the fulvic acid fraction in both soils. The above was attributed to a prominent downward migration of fulvic acids through soil horizons. Similar results were found in another perhumid mountain forest soils in northeastern Taiwan [1], and the argillic Bh horizons in German Mollisols [14]. On the other hand, the results are different to those reported for Andosols in Mexico [3], and both forest and grassland soils in Canada [9]. Less humic acids and more fulvic acids were present in deep horizons suggesting an increasing mobility of the latter due to the acidic and humid environment in such subalpine region.

Humification index and humic acid types

The ratio of absorbancy of humic substances at 400 to 600 nm, referred to as the E_4/E_6 ratio, as proposed by Kononova [5], has been widely used as a parameter of the humification index for characterizing humic and fulvic acids. Kumada [8] has equated the increase of E_{600} and the consequence of decreasing E_4/E_6 with

T a b l e 1. Physical and chemical properties of subalpine *Tsuga* and *Picea* forest soils in Central Taiwan

Site	Horizon	Depth (cm)	pH (H_2O)	CEC (cml kg^{-1})	Org.C (g kg^{-1})	C content (g kg^{-1})		FA/HA	E_4/E_6	ΔlogK	*RF*	HA type
						FA	HA		(HA)			
Tsuga forest	O	13-0	3.6	75.2	464	11.8	10.4	1.14	2.94	0.47	47	P
	A	0-8	4.0	14.5	90	17.3	8.2	2.11	4.16	0.62	49	P
	B	8-30	4.4	10.7	41	11.4	3.5	3.26	2.12	0.47	102	A
	2A	30-48	4.5	12.1	49	11.8	6.6	1.79	3.12	0.31	97	P
	2B1	48-65	4.4	10.1	40	10.0	3.9	2.59	3.86	0.59	43	P
	2B2	65-109	4.5	10.4	39	9.7	3.7	2.65	2.03	0.31	142	A
Picea forest	O	13-0	4.6	54.7	503	9.3	5.9	1.59	3.56	0.55	55	P
	A	0-6	4.8	19.1	67	8.7	6.6	1.33	2.72	0.76	50	B
	E	6-17	5.4	19.1	39	3.1	2.5	1.23	2.62	0.88	51	B
	2A	17-32	6.8	8.2	11	1.6	1.0	1.65	9.48	0.98	26	Rp
	2B	32-46	7.2	6.8	9	1.0	0.6	1.56	9.89	1.00	21	Rp

FA - fulvic acids; HA - humic acids.

increasing "degree of humification". The ratio changes with different vegetation types and sites [3]. In the present study, E_4/E_6 values differed among the two soil profiles. For *Tsuga* forest, the E_4/E_6 ratio ranged from 2.03 to 4.16, and was in the threshold of Stevenson [11]. On the other hand, the E_4/E_6 value in 2A to 2B horizons of *Picea* forest were higher (2.62~9.89) than the others. This suggests that the humic acids in such buried horizons were less mature.

Based on the relationship between the amount of humic acids and its humification degree in the soils with different pH, humic acids can be classified into different types with the criteria of $\Delta \log K$ and *RF* [6,7]. In strongly acidic soils, Rp type is mostly replaced gradually by P type; in moderately acidic soils, Rp type is transformed into B type, and in weakly acid to alkaline soils, the transformation of humic acids proceeds from Rp type, via B type, to A type [8]. Degree of humification increases with the optical properties *RF* and decreases with the $\Delta \log K$ value of humic acids. Humic acids in each soil horizon were grouped in Fig. 1 as a diagram. Literature states that variation of humification in different horizons is noticeable, even in the same profile. The P and A types were found only in *Tsuga* forest soil horizons, while P, B and Rp types were found in those of *Picea* forest horizons. Results of Fig. 1 showed that strongly acidic or acidic soil horizons were highly humidified. The only exception was the buried horizons in *Picea* forest which were poorly humidified in neutral to weakly alkaline soils.

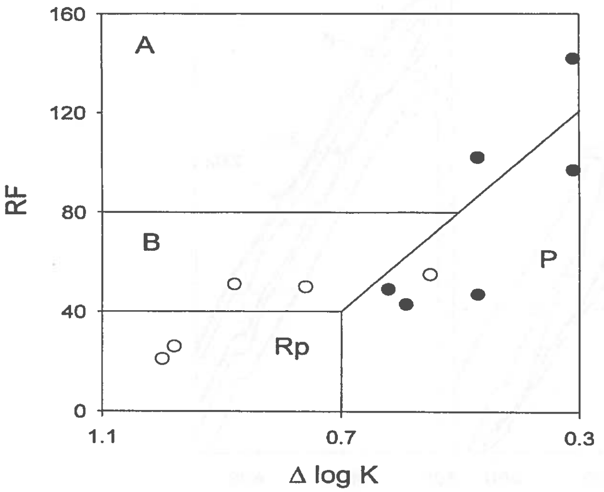

Fig. 1. Classification diagram of humic acids extracted from subalpine *Picea* (O) and *Tsuga* (●) forest soils, Central Taiwan.

The Rp and P types of HAs obtained in this study are widely distributed in other forest soils and some grassland soils around the world with similar altitudes and soil pH, such as northeastern China [15], central Japan [6,8], northeastern Scotland [6] and the mountain areas of northeastern Taiwan [1]. These results indicate that humification of humic acids terminates as P, B, or A types, according to the acidity of soil respectively, under humid and cold climate conditions.

Spectra of humic acids

The absorption spectra of humic acids are given in Fig. 2. Based on the definition of Kumada [8], humic acids in the O, A, 2A and 2B1 horizons of *Tsuga* forest were grouped as P type, which represent typical absorption spectra peak near 615 nm. On the other hand, A and B types had no convex or a shoulder-like absorption peak in the absorption spectra, as humic acids in the B and 2B2 horizons in *Tsuga* forest and A and E horizons in *Picea* forest. Features of the absorption spectra displayed in Fig. 2, were consistent with the above-mentioned humification index in Table 1.

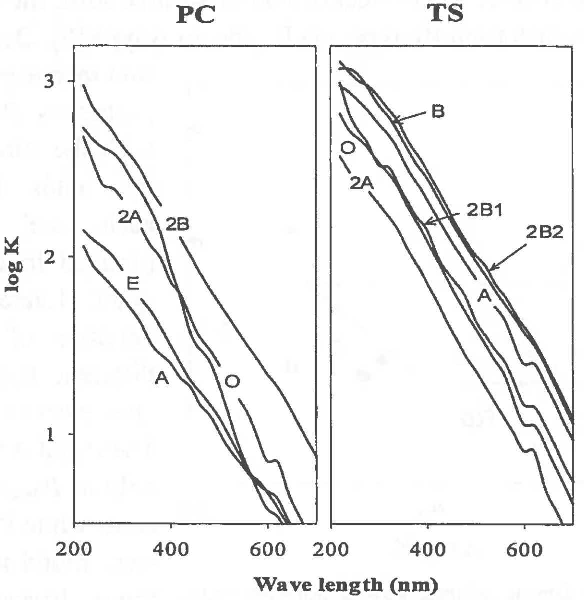

Fig. 2. Absorption spectra of humic acids in soil horizons from subalpine *Picea* forest (PC) and *Tsuga* (TS) forest soils, Central Taiwan.

CONCLUSIONS

Our results extended our knowledge on the characteristics of humic substances in forest ecosystems with high precipitation and cold climate. It showed that fulvic acids, the major composition of extractable humic substances, were more mobile than humic acids and migrated downwards to deeper horizons. The humic acids in this study showed a high degree of humification similar to the soils elsewhere which are influenced by similar cool and humid climatic conditions.

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