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CHARACTERIZATION OF SOIL ORGANIC MATTER IN PARTICLE SIZE FRACTIONS OBTAINED FROM DIFFERENT TYPES OF SOILS.

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INTRODUCTION

Soil organic matter is a heterogeneous mixture of plant debris, microbial body and metabolites, and humic substances derived from them (Kumada, 1987). These substances are not distributed uniformly in soil. Though separation into humic acid, fulvic acid and humin helps investigate soil organic matter, these humic fractions are still complex mixture of organic substances from various origins. Physical fractionation of soils according to particle size or specific gravity, however, has been used successfully by many researchers in order to characterize soil organic matter (Oades, 1984). In this study, a combination of physical and chemical fractionation of soil organic matter was carried out to investigate the process of decomposition and humification of soil organic matter in various types of soils. Humin fraction, whose chemical composition and structure have not been investigated well, was also characterized particle-size-wise using saccharide composition as an indicator for the origin of soil organic matter.

MATERIALS AND METHODS

Soils from two mollisol profiles, experiment plots of long term application of organic matter in the tropics and in the temperate zone, surface and buried volcanic ash layers, and a mineral paddy field were fractionated according to particle size. Method of fractionation is given elsewhere (Tsutsuki et al., 1988). Humic fractions were extracted from these fractions and analyzed for their compositions. Degrees of humification (*RF* and $\Delta logK$) defined by Kumada(1987) were determined for humic acids. For a humic volcanic ash soil and a mineral paddy soil, saccharide composition in the acid hydrolysate was also determined to characterize the humin fraction contained in each particle size fraction. Non-cellulosic saccharides in soils were hydrolyzed by 2 hr reflux in 2*M* trifluoroacetic acid, and cellulosic saccharides were obtained by soaking the residue with 13*M* H_2SO_4 for 16 hr followed by reflux in 0.5*M* H_2SO_4 for 5 hr (Oades, 1970).

RESULTS AND DISCUSSION

1) Mollisol

Two Hapludoll profiles (field and forest) collected in the Federal Republic of Germany were used. In these soils, medium and coarse clay size fractions contained largest amounts of organic matter (Fig.1 a, b), and the radio-carbon ages of these fractions were also oldest (Scharpenseel et al., 1986). Soil organic matter were stabilized and accumulated in medium and coarse clay size fractions in these soils. On the other hand, organic matter contained in silt and sand fractions had younger ages and decreased significantly with depth. Easily decomposable plant debris accordingly was considered to be dominant in these fractions. Degree of humification of humic acids was also highest in medium and coarse clay fractions (Tsutsuki et al., 1987).

2) Upland field soils (Ochrept) from experiment plots of long term application of farm yard manure(FYM).

These soils were collected from the Nagoya University experiment farm. These soils received 0, 2, 5, 10t of FYM / 10a every 6 months for the last 10 years. With increase in applied amounts of FYM, soil organic matter contained in silt

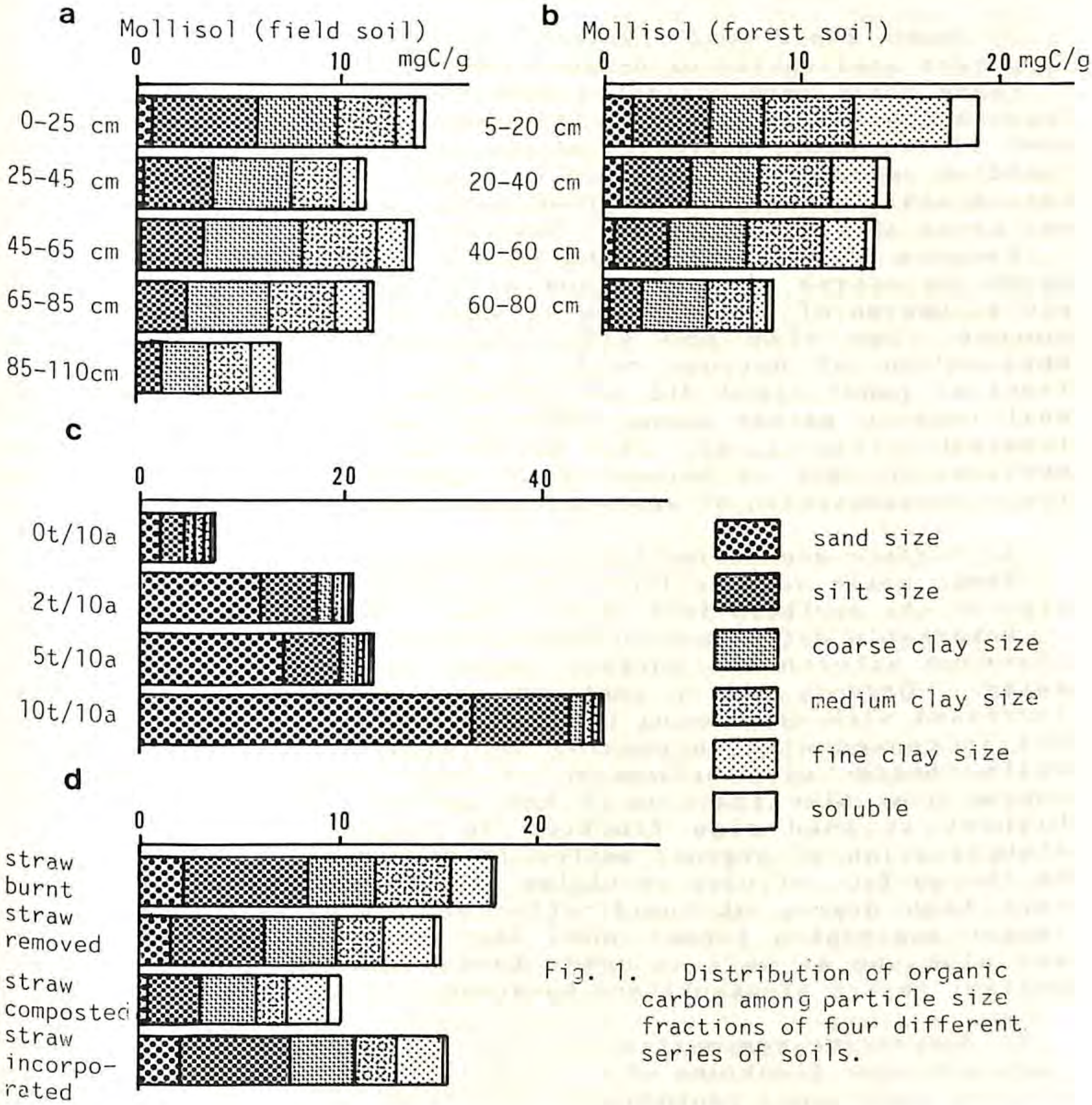

Fig. 1. Distribution of organic carbon among particle size fractions of four different series of soils.

and sand size fractions increased remarkably, while those in clay fractions increased little (Fig. 1, c). It was assumed from this that application of FYM for 10 years did not enhance the formation of clay-humus complex significantly. Humin contents in particle size fractions of no FYM application plots increased with decreasing particle size and attained maximum in the fine clay size fraction, which suggested that humin was stabilized by binding with clay. Contrarily, humin contents in particle size fractions of FYM applied plots increased with increasing particle size and attained maximum in the sand fraction, which suggested that humin in FYM applied plots were mainly decomposing plant residues. Degree of humification of humic acid was highest in silt size fraction in the no FYM plot, while it increased with decreasing particle size in FYM applied plots.

3) Paddy field soil (Fluvent) from experiment plots of long term application of harvest rest of rice.

These soils were collected from the experiment farm of the International Rice Research Institute in the Philippines. In used plots, whole harvest rest of rice was removed from the field or returned to the field in forms of straw, compost, and burned ash. Two crops were grown every year, and the 21st crop was grown at the time of soil sampling.

Amounts of humic acids and fulvic acids were especially large in coarse clay size and silt size fractions in all plots. Degree of humification of humic acids was also high in coarse clay size and silt size fractions. However, application of harvest rest in any form in the soil of tropical paddy field did not influence the distribution of soil organic matter among different particle size fractions remarkably (Fig. 1, d). This may be due to the relatively low application rate of harvest rest (0.6t/10a/year) and to the rapid decomposition of applied organic matter in the tropics.

4) Surface and buried humic volcanic ash soil (Andisol)

These soils were collected at an archaeological excavation site on the southern foot of Mt. Fuji in Numazu city.

Remarkable difference in distribution of organic matter was observed between the surface layer soil and buried layer soils. Organic matter contents in particle size fractions increased with decreasing particle size in the surface soil, but increased with increasing particle size in the buried soils. Degree of humification of humic acid was highest in coarse clay size fraction in the surface soil, while it was highest in sand size fraction in buried soils. Though stabilization of organic matter is considered to occur first on the surface of clay particles also in andisols, humus with very high degree of humification was stabilized further in larger aggregates formed under the existence of active iron and aluminum as well as under large compression in buried andisol layers (Tsutsuki and Kuwatsuka, 1990).

5) Saccharide composition of humin fraction associated with particle size fractions of a volcanic ash soil (Andisol) and a mineral paddy soil (Anthraquic Udifluvent).

Two extremely different types of soils were used; a humic volcanic ash soil (Inogashira soil) and a brown lowland soil used for paddy (Anjo soil). In Inogashira soil the largest proportions of soil and soil carbon were distributed in the coarse clay size fraction, while in Anjo soil they were in the silt and fine sand fractions. In Inogashira soil, degree of humification (*RF* and $\Delta logK$) of humic acids were almost the same among different particle size fractions except the fine clay fraction, whose humic acid showed a lower *RF* value. In Anjo soil, degree of humification of humic acid was much lower than Inogashira soil but inclined to increase slightly with increasing particle size. As discussed above, the organic matter in the humic volcanic ash soil may exist mainly in a complex form with allophane, while organic matter was not bound strongly to kaolin clay mineral and existed mainly as free fragment of decaying plant debris in the lowland soil. From particle size fractions of these soils, humin fractions were prepared and their saccharide compositions were compared from the viewpoint that saccharide is an important organic component of soil humin and that saccharide compositions reflect the origin of soil organic matter.

In Anjo humin, the amount of non-cellulosic saccharides was largest in the coarse sand size fraction and occupied mainly by xylose and arabinose, dominant components of hemicellulose (Fig. 2, a). Therefore, it was suggested that polysaccharides of plant origin were relatively unaltered in the coarse sand size fraction. With decrease in particle size, the amount of non-cellulosic saccharides decreased remarkably and attained the minimum value in the silt size fraction and increased again slightly from silt to clay size fraction. This slight increase of non-cellulosic saccharides was due to the increase in galactose and glucose, which were assumed to be mainly microbial origin. The same trends were also demonstrated by the remarkable decrease in the ratios of pentoses/hexoses and xylose/mannose.

On the other hand, cellulosic saccharides of Anjo humin were almost exclusively composed of glucose but their amounts also decreased remarkably with decrease in particle size (Fig. 2, b). The amounts of xylose and arabinose which co-existed with cellulose, however, were larger in fine sand than in coarse sand size fractions. This may be because plant tissue with larger amount of hemicellulose is more fragile.

Non-cellulosic saccharides in Inogashira humin, quite differently from Anjo humin, contained larger amounts of glucose, galactose, and mannose than xylose and arabinose (Fig. 2, c). The amounts of non-cellulosic cellulose were largest in the coarse clay size fraction in Inogashira humin. The ratio of pentoses/hexoses ranged from 0.4 to 0.8 and that of xylose/mannose from 0.9 to 1.2: these values were extremely lower than those in Anjo humin. These results suggested that the non-cellulosic saccharides in Inogashira humin were dominated by the saccharides of microbial origin.

The amounts of cellulosic saccharides in Inogashira humin were ca. 8% and largest in the coarse sand size fraction like Anjo humin (Fig. 2,d). In other size fractions, they ranged from 1.5 to 2.5% and did not show significant variation.

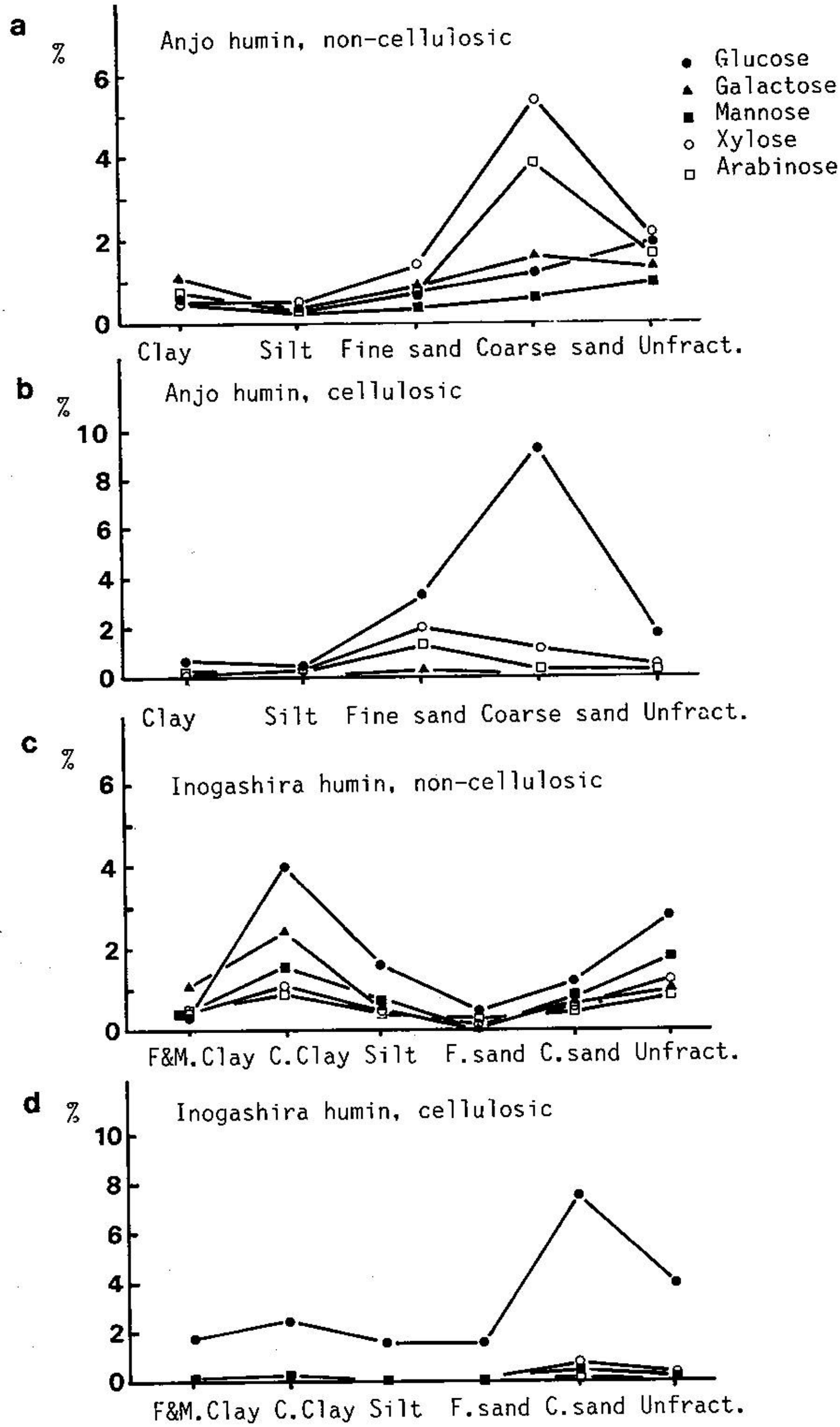

Fig. 2. Saccharide composition of non-cellulosic and cellulosic hydrolysates of Anjo and Inogashira soil humin.
Unit: saccharide-C/humin-C x 100

Glucose occupied most part of this saccharide fraction and other saccharides were very low. It was suggested from these results that saccharides of plant origin existed almost solely in the coarse sand size fraction in Inogashira humin, and they underwent rapid degradation and transformation with decrease in particle size, so that the saccharides of microbial origin dominated in finer particle size fractions.

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ABSTRACTS

In most soils, highly humified humic substances were associated with silt size, coarse clay size and medium clay size fractions. Organic matter in the sand size fraction were dominated by decomposing plant debris. Application of organic matter (farm yard manure, straw and compost) in fields increased the organic matter content in sand size fraction. The formation of clay-humus complex was not enhanced by the application of organic matter in fields even in large amounts. High decomposition rate of organic matter in the tropics also minimized the formation of stable humus in soil. Besides the protection by clay particle, larger sand size aggregates protected organic matter from further decomposition and enhanced humification in buried volcanic ash soils. Humin in different particle size fractions showed also extremely different saccharide composition with respect to particle size. In a mineral paddy soil non-cellulosic saccharides were largest in the coarse sand size fraction and assumed to come from hemicellulose, while in a humic volcanic ash soil they were largest in the coarse clay size fraction and assumed to be mostly microbial origin. Cellulosic saccharides were occupied almost solely by glucose and largest in the coarse sand size fraction in both soils. The amounts of cellulosic saccharides decreased remarkably with decrease in particle size.