Compositional Differences in Organic Matter among Cultivated and Uncultivated Argiudolls and Hapludalfs Derived from Loess

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ABSTRACT

Twelve paired pedons were sampled to investigate the effects of vegetation and ~120 yr of cultivation on Iowa soils. The study focused on organic matter in unfractionated and fractionated soil materials. Climate, parent material, time, and slope were held as constant as possible. Prairie-derived mollic epipedons had higher organic C and total N contents than did forest-derived ochric epipedons. Cultivated epipedons generally had lower organic C and total N contents than their uncultivated counterparts, but the C/N ratio was lowered markedly by cultivation only in the mollic epipedons. Although most of the organic C and total N was associated with the fine silt and coarse clay fractions of the uncultivated pedons, cultivation was associated with a relative shift of organic matter from the sand and silt fractions toward the fine clay fractions. Humic acid/fulvic acid ratios of organic matter in particle-size fractions were always lower in the cultivated horizons than in the uncultivated horizons. The E4/E6 ratios of humic materials in the particle-size fractions suggested that humic acids in mollic epipedons consisted of larger organic particles than those in ochric epipedons. Interpretations of the effects of cultivation on the soil organic matter must be made cautiously because of other agricultural influences on the uncultivated sites.

Additional Index Words: **humic acid/fulvic acid ratios, C/N ratios, organo-mineral complexes, mollic epipedons, ochric epipedons.**

MOLLIC EPIPEDONS in most of the midwestern USA reflect the additions of organic matter under native prairie vegetation. Under deciduous forest vegetation, midwestern soils usually developed ochric epipedons. This study was developed to establish baseline data on the nature of soil organic matter in mollic and ochric epipedons in Iowa. Changes in the quantity and characteristics of the organic matter after >100 years of cultivation were explored to better understand the effects of long-term cultivation on soil properties.

Numerous previous investigations have shown that cultivation of many native soils results in a decline of organic matter that is initially rapid, followed by a progressive tapering off to a lower, steady-state condition (Stevenson, 1982). A previous study of virgin and cultivated prairie-derived soils in Iowa reported that the cultivated soils had about one-third less total N in the surface 15 cm than did the uncultivated soils (Anderson and Browning, 1950). Cultivation was found to increase bulk density of most of the surface horizons studied, but there were no consistent changes in pH or available P. Changes in organic C were not determined.

A useful approach in studying soil organo-mineral relationships is to investigate organic matter associated with various particle-size fractions. In recent years, a technique of separation by ultrasonic dispersion, sedimentation, and centrifugation has been frequently used (Genrich and Bremner, 1974; Watson and Parsons, 1974; Tiessen and Stewart, 1983; Christensen and Sørensen, 1985). A few studies (Genrich, 1972, Tiessen and Stewart, 1983) have examined changes of organic C and total N distributions in particle-size fractions of cultivated soils, but a similar comparison of soils developed under different kinds of vegetation has not yet been made.

The significance of organic materials associated with silt and sand fractions is not clear. They are usually attributed to incomplete dispersion of exceptionally stable microaggregates of colloidal particles. There are also likely to be free organic particles recovered with silt and sand fractions. Finally, in soils that contain phyllosilicate minerals in silt fractions (e.g., mica or vermiculite), organic material may be adsorbed to the mineral particles in the same way that they are in colloidal fractions. In any case, organic materials in different size fractions may behave differently. For example, Tiessen and Stewart (1983) showed that organic matter in fine silt and coarse clay fractions underwent only slow changes during cultivation, whereas reductions in organic matter after 60 yr of cultivation were greatest in the sand-plus-floatable-organic matter fraction and the fine clay fraction. Similarly, Anderson and Paul (1984) and Christensen and Sørensen (1985) concluded from radiocarbon studies that silt-bound organic matter was probably more resistant to decomposition than that associated with fine clay fractions.

Several studies have suggested that humic acid/fulvic acid ratios of soils are affected by native vegetation (Kononova, 1966; Hobson, 1983), but the effects of cultivation on humic acids (HA) and fulvic acids (FA) are not well documented. The distribution of HA and FA in particle-size fractions was studied by Anderson et al. (1981) by using an alkaline pyrophosphate-ultrasonification technique. Maximum HA/FA ratios were found to be associated with the fine silt fraction, with minimum values in the fine clay fraction. On the other hand, ratios of absorbance at 465 and 665 nm (E4/E6), which are related to the size and molecular weight of organic particles (Chen et al., 1977), were not significantly different in the humic acids extracted by Anderson et al. from various size fractions.

The primary objective of the present study was to simultaneously document the effects of vegetation and cultivation on the soil organic matter of mollic and ochric epipedons in Iowa. Variations in related physical and chemical parameters were also determined.

MATERIALS AND METHODS

The study area was located in Hardin County, IA. The mean annual precipitation is 833 mm and the mean annual temperature is 8 °C (Fig. 1). Sites were selected to allow comparison of cultivated and non-

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cultivated soils originally developed under tall-grass prairie and deciduous forest while keeping all other variables constant. The prairie- and forest-derived pedons selected belonged to mapping units of the Tama (fine-silty, mixed, mesic Typic Argiudolls) and Fayette (fine-silty, mixed, mesic Typic Hapludalfs) series, respectively (Voy, 1985).

Samples of epipedon horizons from three replicate pedons ($\sim$25 m apart) on summit landscape positions were collected from uncultivated Tama (UT), cultivated Tama (CT), uncultivated Fayette (UF), and cultivated Fayette (CF) soils. The UT sites were chosen along a railroad right-of-way. Although native vegetation at the sites was probably dominated by big bluestem (*Andropogon gerardi*) (Smith et al., 1950), contemporary vegetation was dominated by Kentucky bluegrass (*Poa pratensis* L.), smooth brome (*Bromus inermis* Leysser), and goldenrod (*Solidago* spp.). The UF sites were in a deciduous forest that had been used as pasture but not cultivated. Contemporary vegetation at the UF sites consisted of white oak (*Quercus alba*) and shagbark hickory (*Carya ovata*), with an understory of hawthorn (*Crataegus* spp.), multiflora rose (*Rosa multiflora*), and black locust (*Robinia pseudoacacia*) and ground vegetation of Kentucky bluegrass and common dandelion (*Taraxacum officinale*). Although the vegetation at the uncultivated sites did not represent virgin conditions, such conditions (i.e., where native forest and prairie sites are close enough that other soil-forming factors can be held constant) are extremely rare in Iowa. The cultivated sites were across field boundaries and 20 m from their respective uncultivated counterparts. Because Hardin County was settled in the 1860s, cultivation is believed to have begun about 120 yr ago. In recent years, the cultivated sites have been in a corn-soybean rotation (*Zea mays* and *Glycine max*, respectively) with annual P and K additions and biannual N additions of 250 kg ha^{-1}. All the pedons developed in Peoria Loess, the deposition of which ended about 14 000 yr ago (Ruhe, 1969).

Pedon descriptions verified the morphological uniformity of the pedons. Thickness of the loess over coarser glacial sediment ranged from 70 to 120 cm, so some pedons would be classified as Fayette Variant (50–100 cm to till) or as Dinsdale soils (fine-silty, mixed, mesic Typic Argiudolls). Ap horizon samples were collected at each of the six cultivated sites. At all uncultivated sites, A horizons were sampled, as well as E and BE horizons where present in the ochric epipedons.

Samples were air-dried and ground to pass a 2-mm sieve. Subsamples were further ground to pass a 150μm sieve (100-mesh) for organic C and total N analyses of unfractionated soil materials. Particle-size distribution was determined by the pipette method (dispersion by Na metaphosphate) of Kilmer and Alexander (1949), with modifications by Walter et al. (1978). Bulk density was determined on triplicate air-dried clods (100–200 cm^3) by the paraffin-coating technique (Blake, 1965).

Particle-size fractionation was accomplished by ultrasonically dispersing 100 g of A horizon sample in distilled water at a soil-to-water ratio of 1:4, sonifying for 15 min at 140 W in a cup horn vibrator cooled with water. Preliminary investigations established the vibration intensity, time of exposure, soil-to-water ratio, and sample weight that would result in clay percentages similar to those obtained with chemical dispersion as used in the standard pipette method. The particle-size classes used in this study were sand plus organic matter floatable in water ($>$ 50 μm), coarse silt (50–20 μm), fine silt (20–2 μm), coarse clay (2–0.2 μm), and fine clay ($<$0.2 μm). The separation at 50 μm was by wet sieving, at 20 and 2 μm by repeated sedimentation and siphoning, and at 0.2 μm by centrifugation (Jackson, 1975). Clay was concentrated by adding MgCl$_2$. Both coarse and fine clays were first dialyzed to remove excess MgCl$_2$ and then freeze-dried.

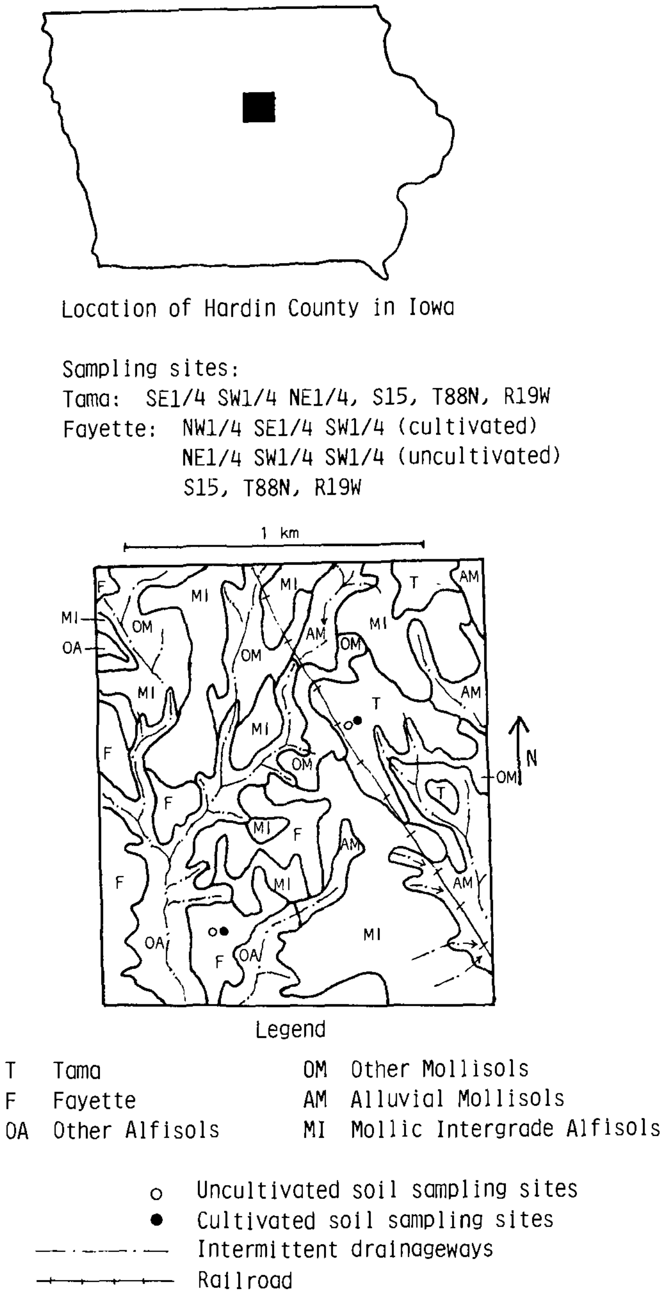

Fig. 1. Location of sampling sites in Iowa and with respect to associated soils (map modified from Voy, 1985).

Organic C contents of unfractioned soil materials, size fractions, and extracts of humic materials were determined by a modified Mebius procedure or, in a few instances, with a high-temperature induction furnace (Nelson and Sommers, 1982). Nitrogen was measured by the "regular" semimicro-Kjeldahl method (Bremner and Mulvaney, 1982) and referred to as total N, although fixed NH_4 may account for 4 to 6% of the "true" total N (Genrich, 1972). Total P was determined by the alkaline oxidation method of Dick and Tabatabai (1977). Exchangeable bases were determined by an ammonium acetate-atomic absorption method (Thomas, 1982). Cation exchange capacity was determined by the ammonium acetate–semimicro-Kjeldahl method (Soil Survey Staff, 1972). Soil pH was measured by using a 1:1 water-to-soil ratio.

Organic matter associated with particle-size fractions was extracted once with 0.1 *M* NaOH–0.1 *M* $Na_4P_2O_7 \cdot 7H_2O$ at a pH of about 13 (Schnitzer et al., 1981). The alkaline pyrophosphate extract was acidified to pH 2 with 1 *M* H_2SO_4 or 2 *M* HCl and centrifuged to separate HA and FA. The HA fraction was purified by treatment with a dilute HCl–HF solution. Fulvic acids were purified by passing the aqueous solution three times in succession over Amberlite IR-120 (Aldrich Chemical Co., Inc., Milwaukee, WI) exchange resin in the H form. Both fractions were then freeze-dried (Schnitzer, 1982). E4/E6 ratios were determined from absorbance of aqueous solutions made by dissolving 2–4 mg of humic material in 10 ml of 0.05 *M* $NaHCO_3$ solution. The absorbance was measured at 465 and 665 nm.

RESULTS AND DISCUSSION

Properties of Unfractionated Soil Materials

General properties of the soil horizons sampled are given in Table 1. The A horizons varied in thickness, with the cultivated Tama horizons being thinner than the uncultivated Tama horizons. In contrast, the cultivated Fayette Ap horizons were thicker than the uncultivated Fayette A horizons. Bulk densities of the Tama (prairie) horizons were greater than those of the Fayette (forest) horizons. The cultivated Ap horizons had higher bulk densities than the uncultivated A horizons of both soils. Thus, cultivation seemed to have both reduced original differences in A horizon thickness due to native vegetation and to have increased bulk density of the A horizons.

Clay contents of surface horizons of the Fayette pedons were lower than those of Tama surface horizons. Field observations suggested that the B/A clay ratios of the Fayette pedons were greater than those of the Tama pedons. There probably has been more net translocation of clay from A to B horizons in the forest-derived soil than in the prairie-derived soil (White and Riecken, 1955). The clay contents of the CF Ap horizons were less than those of the UF A horizons, probably because the cultivated horizons were a mixture of the original A and E horizons, the latter typically being lower in clay.

Distinct differences in pH and exchangeable bases occurred among the horizons. In general, the pH values of UF horizons were greater than those of UT horizons. Similarly, the base saturation values of UF horizons were somewhat higher than those of UT horizons. Other workers (e.g., White and Riecken, 1955) have noted similar patterns and have argued that the deeper penetration of tree roots to less weathered parent material allows more basic cations to be returned to the soil surface compared with prairie vegetation. The cultivated horizons had lower cation exchange capacities than their uncultivated counterparts, probably because they had less organic matter.

The amounts of organic C, total N, and total P in the soil surface horizons may be considered from three points of view. First, the contents may be compared on the basis of mass per unit mass of soil (g kg^{-1})

Table 1. General physical and chemical properties of the sampled soil materials.

Pedon and horizon	Depth	Texture†				Bulk density, air-dried	pH	Exchangeable bases			Cation exchange capacity	Base saturation‡
		Sand	csi	fsi	Clay			Ca	Mg	K		
	cm	%				Mg m^{-3}		cmol kg^{-1}				%
UT1-A1§	0–14	10	34	30	26	1.11	6.0	25.7	4.6	1.3	36.4	87
UT1-A2	14–28	6	34	33	30	1.13	6.0	22.3	3.9	0.8	32.0	84
UT1-A3	28–46	4	35	30	30	1.27	5.8	15.4	2.9	0.4	29.9	63
UT2-A1	0–14	8	35	28	29	1.15	6.1	19.1	3.4	1.0	29.6	79
UT2-A2	14–31	6	36	29	29	1.34	5.6	19.2	3.3	0.4	28.5	80
UT2-A3	31–48	5	36	28	31	1.41	5.3	13.9	3.1	0.3	29.2	59
UT3-A1	0–12	9	36	28	27	1.01	6.4	26.8	4.9	1.3	37.8	87
UT3-A2	12–27	7	38	29	26	1.25¶	6.0	19.9	3.8	0.5	32.4	75
UT3-A3	27–40	5	37	29	30	1.49	5.6	12.0	2.9	0.3	26.9	57
CT1-Ap	0–27	5	41	27	26	1.55	5.3	14.5	3.6	0.7	25.2	75
CT2-Ap	0–23	5	40	28	27	1.52	5.1	14.1	3.4	0.5	24.5	73
CT3-Ap	0–25	5	38	29	29	1.47	5.0	12.7	3.1	0.6	21.4	77
UF1-A	0–10	8	39	34	19	1.14	6.4	17.7	2.7	0.7	23.1	91
UF2-A	0–10	7	36	38	19	1.09	6.2	18.3	3.1	0.5	25.7	85
UF3-A	0–10	8	38	36	18	0.99	6.3	19.0	3.4	0.8	25.4	91
CF1-Ap	0–16	9	46	31	15	1.42	5.5	9.2	1.4	1.2	13.7	86
CF2-Ap	0–20	7	43	34	16	1.43	5.4	9.1	1.3	0.9	12.0	94
CF3-Ap	0–20	8	41	34	17	1.36	5.2	9.2	1.4	1.2	17.9	66

† Sand = >50 μm, csi = 50–20 μm, fsi = 20–2 μm, clay = <2 μm.

‡ Percentage of cation exchange capacity satisfied by exchangeable Ca, Mg, and K. Exchangeable Na in these soils is normally <0.1 cmol kg^{-1}.

§ UT = uncultivated Tama, CT = cultivated Tama, UF = uncultivated Fayette, CF = cultivated Fayette.

¶ No data available. Value is interpolated from A1 and A3 values.

(Table 2). From this perspective, cultivated horizons had less organic C and total N than uncultivated horizons. Total P contents were similar to one another. Second, organic C, total N, and total P that occur in the tillage zone may be taken into account by calculating the thickness and bulk density of horizons to a 20-cm depth (Table 3). On this basis (mass per unit area, i.e., g m^{-2}), the prairie-derived surface materials had higher levels of organic C and total N than did the forest-derived surface materials. Cultivated surface horizons had lower organic C levels than did uncultivated surface horizons, but total N and total P levels were not greatly different. Finally, changes in organic C, total N, and total P due to cultivation may be calculated on the basis of the epipedon by taking into account the thickness and bulk density of all horizons in the epipedons (Table 3). From this standpoint, cultivation resulted in a loss of organic C, total N, and total P from the mollic epipedon (Tama pedons). At the Fayette sites, the ochric epipedon, which usually included the E and BE horizons, had lost organic C. Total N and total P levels, on the other hand, were about the same as in the uncultivated state. In summary, cultivated surface horizons generally had lower levels of organic C and total N than uncultivated surface horizons, even though fertilizer N had been added during the period of cultivation. Cultivation seemed not to significantly affect the pool of total P, possibly because there had been regular additions of P fertilizers to the soils. In addition, P is not volatilized and is not as readily leached as is N.

The depletion of organic C and total N with cultivation can be attributed to changes in the magnitude of biological and physical processes in soils (Stevenson, 1982). Increased microbial activity under periodically better aerated conditions caused by tillage might increase the decomposition rate of soil organic matter (Rovira and Greacan, 1957); so would the exposure of tillage-inverted horizons to growing-season temperatures that are considerably higher near the soil surface than at depth. Reduced rates of C input to the soil, particularly root residues and exudates, are also likely related to rates of C depletion. Soil erosion has also been reported as a factor of organic matter loss in some soils (Barrows and Kilmer, 1963).

Table 2. Average organic C, total N, total P, and C/N ratios of the sampled horizons.

Soil and horizon	C $\bar{x}$	C SD	N $\bar{x}$	N SD	P $\bar{x}$	P SD	C/N ratio
	g kg^{-1}						
Uncultivated Tama							
A1	65.3	17.3	3.39	0.53	0.65	0.09	19
A2	36.1	6.5	2.29	0.36	0.54	0.03	15
A3	23.9	3.1	1.81	0.30	0.52	0.04	13
Cultivated Tama							
Ap	21.8	0.7	1.92	0.08	0.58	0.02	11
Uncultivated Fayette							
A	35.1	8.9	3.26	0.57	0.65	0.05	11
E	9.4	3.0	1.0	0.3	0.36	0.08	10
BE	6.4	0.9	0.7	0.1	0.32	0.01	9
Cultivated Fayette							
Ap	15.1	3.2	1.52	0.34	0.55	0.13	10
BE	5.3	2.1	0.9	0.3	0.41	0.11	6

The C/N ratios of the Ap horizons were lower than those of the uncultivated A horizons, suggesting that cultivation enhanced the process of C oxidation just described (Table 2). The C/N ratio decreased with depth for UT horizons. Moreover, the C/N ratios of UT horizons were higher than those of UF horizons in this study. This result is not consistent with textbook generalizations that the C/N ratios of virgin soils formed under grass vegetation are usually lower than those of soils formed under forest vegetation (Stevenson, 1982). Although horizon types and thicknesses closely reflected the present forest vegetation, it is possible that introduced grasses and animal manure associated with pasturing at the forest sites confounded the expected C/N relationships. It is also conceivable that the Fayette site was not "always" wooded, but was a product of forest encroachment in a previously prairie environment. Still, there were no macromorphological features, such as organic coatings in the B horizons, to indicate that the Fayette sites had once been under prairie vegetation.

Properties of Fractionated Soil Materials

Weights of five size fractions (fine and coarse clay, fine and coarse silt, and sand-plus-floatable-organic matter) were recorded after fractionation of each soil material. Recovery of the originally fractionated 100 g ranged from 94.0 to 98.7%, with an average recovery of 96.9%. Clay recovered ranged from 60 to 84% of that predicted by chemical dispersion and sampling of clay by the pipette method. Other investigators have judged that similar results are caused by the presence of stable aggregates in coarser fractions (Anderson et al., 1981) or by resistant coatings on large mineral particles (Healy and Claridge, 1974). In these high-base-status soil materials, it is possible that clay particles recoagulated after sonification and during the sedimentation/decantation cycles. There were also slight losses of material during fractionation. It seems most

Table 3. Organic C, total N, and total P contents calculated for the surface 20 cm and for the epipedons.

	In the surface 20 cm						In the epipedon					
	C		N		P		C		N		P	
Soil and horizon	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD
	g m^{-2}											
Tama												
Uncultivated	12.51	2.95	0.68	0.09	0.14	0.01	21.57	3.77	1.33	0.18	0.31	0.04
Cultivated	6.59	0.25	0.59	0.03	0.17	0.01	8.23	0.56	0.73	0.10	0.22	0.02
Fayette												
Uncultivated	5.30	1.29	0.49	0.07	0.12	0.01	6.51	1.06	0.65	0.08	0.19	0.01
Cultivated	3.88	0.60	0.41	0.07	0.15	0.03	4.86	0.60	0.56	0.10	0.22	0.06

Table 4. Average organic C (OC), total N, and C/N ratio of particle-size fractions.

Soil and	Floatable OM			Sand			Coarse silt			Fine silt			Coarse clay			Fine clay			Recovery†	
horizon	OC	N	C/N	OC	N	C/N	OC	N	C/N	OC	N	C/N	OC	N	C/N	OC	N	C/N	OC	N
	g kg⁻¹			g kg⁻¹			g kg⁻¹			g kg⁻¹			g kg⁻¹			g kg⁻¹			%	
UT-A1	182.7	7.50	24.4	112.8	1.20	94.0	13.3	1.13	11.8	43.6	3.75	11.6	78.0	7.57	10.3	64.7	7.37	8.8	80	102
UT-A2	198.3	5.70	34.8	97.9	0.84	116.5	7.9	0.70	11.3	30.4	2.75	11.1	59.0	6.05	9.8	57.5	6.53	8.8	92	109
UT-A3	140.1	3.87	36.2	44.8	0.34	131.8	5.6	0.54	10.4	23.5	2.33	10.1	48.1	5.30	9.1	49.6	5.67	8.7	95	114
CT-Ap	191.7	8.37	22.9	39.6	0.37	107.0	4.5	0.33	13.6	23.4	2.41	9.7	48.2	5.65	8.5	50.9	6.20	8.2	101	108
UF-A	200.3	12.53	16.0	4.3	0.14	30.7	10.9	0.99	11.0	38.7	3.82	10.1	66.4	8.36	7.9	86.1	11.83	7.3	93	97
CF-Ap	186.6	11.23	16.6	2.6	0.05	52.0	3.5	0.25	14.0	19.1	1.91	10.0	42.7	5.33	8.0	57.1	7.57	7.5	104	107

† Recovery in particle-size fractions as a percentage of the organic C and total N determined on unfractionated soil samples.

likely that those losses occurred in clay fractions rather than in other fractions because large volumes were involved in clay collection (Watson and Parsons, 1974).

Average contents of organic C and total N and C/N ratios in particle-size fractions are presented in Table 4. Coarse, nonhumified organic fragments were recovered with the sand fractions. To limit analysis of organic materials to those chemically bound to sand grains, separation of floatable organic matter from the sands was attempted by repeated ultrasonic dispersion and water decantation. Visual inspection, however, revealed that separation was not complete. Still, C/N ratios suggested that floatable organic matter was compositionally distinct from organic matter associated with sand fractions. The analysis of organic C and total N that remained associated with sand fractions indicated that the mollic A horizons contained much more organic C associated with sand fractions than did the ochric A horizons. Moreover, uncultivated horizons had more organic matter associated with sand fractions than did cultivated horizons.

Except for the sand and floatable organic matter fractions, contents of organic C and total N generally increased as particle size decreased (Table 4). Two exceptions were horizons UT-A1 and UT-A2, in which the coarse clay fraction had the greatest organic C contents. In addition, the coarse clay fraction of UT-A1 had the greatest total N content of the >50-μm fractions. The contents of organic C and total N in the size fractions seemed to vary with those of the corresponding unfractionated soil materials; i.e., if the unfractionated material had a high organic C content, all the fractions had relatively high organic C contents.

Table 5. Average distribution of recovered organic C and total N among particle-size fractions.

Soil and horizon	Floatable organic matter	Sand	Coarse silt	Fine silt	Coarse clay	Fine clay
	%					
			Organic C			
UT-A†	13	14	9	31	26	8
CT-Ap	8	9	8	33	25	17
UF-A	19	1	14	41	17	8
CF-Ap	11	1	10	37	26	15
			Total N			
UT-A†	6	2	11	36	34	12
CT-Ap	5	1	6	35	31	21
UF-A	12	0	13	41	22	11
CF-Ap	7	0	7	36	31	19

† Average of all UT horizons, weighted by horizon thickness.

The average contents of organic C and total N in the fine silt fractions were almost the same as in the unfractionated soil materials. However, the organic C and total N contents of clay fractions were approximately two to three times those of fine silt and unfractionated materials and nearly 10 times those of coarse silt fractions. The C/N ratios decreased as particle size decreased, suggesting that the organic materials in coarse fractions were less humified than those of finer fractions (Turchenek and Oades, 1979). Organic materials associated with coarser fractions may disintegrate relatively rapidly to enter finer, mineral-associated organic matter pools as a result of cultivation (Tiessen and Stewart, 1983).

Another way to consider the data is to determine the distribution of organic C and total N among the various size fractions. The amount of organic C in each fraction was weighted according to the percentage of that fraction in the unfractionated soil material (Table 5). Fine silt and coarse clay fractions of all soil materials studied contained most of the organic C and total N. In Fayette soil materials, more organic C and total N were in the clay fractions of the cultivated horizons than were in the clay fractions of the uncultivated horizons. The same was true for the fine clay fractions of Tama soil materials. Generally, less of the organic C and total N occurred in coarse silt, sand, and floatable organic matter fractions of cultivated horizons when compared with uncultivated horizons. The data suggest that, associated with cultivation, there was a relative shift of organic matter from coarser to finer fractions, a finding consistent with the previous work of Tiessen and Stewart (1983).

Properties of Extracted Organic Matter

The HA/FA ratios of the soil materials studied are presented in Table 6. Because of limited quantities of samples, the UT-A2 horizons were chosen to represent the uncultivated Tama soil materials. The maximum HA/FA ratio occurred in fine silt fractions, consistent with the work of Anderson et al. (1981). For all fractions and for unfractionated soil materials, HA/FA ratios were seemingly reduced by cultivation, although the absolute differences were not great for the silt fractions. This observation is consistent with the work of Dormaar (1979), who found that HA C as a percentage of total C decreased after cultivation, whereas FA C increased.

It has been previously reported that cultivated Tama Ap horizons have higher HA/FA ratios than do cultivated Fayette Ap horizons (Hobson, 1983). Konon-

Table 6. Properties of extracted humic materials.

	Unfractionated soil†			Coarse silt			Fine silt			Coarse clay			Fine clay		
Soil and horizon	HA/FA	E4/E6 (HA)	E4/E6 (FA)	HA/FA	E4/E6 (HA)	E4/E6 (FA)	HA/FA	E4/E6 (HA)	E4/E6 (FA)	HA/FA	E4/E6 (HA)	E4/E6 (FA)	HA/FA	E4/E6 (HA)	E4/E6 (FA)
UT-A2	1.95	2.7	3.2	2.38	3.3	4.9	2.68	2.1	3.3	1.01	2.3	4.8	0.92	1.7	7.8
CT-Ap	1.68	3.3	2.4	2.29	1.5	4.5	2.64	1.3	3.5	0.85	2.4	3.9	0.54	1.4	6.8
UF-A	2.01	4.4	6.3	1.71	4.3	4.7	1.93	4.0	4.8	1.07	3.3	2.9	0.91	1.9	3.4
CF-Ap	0.73	3.9	4.9	1.38	4.5	6.5	1.92	1.6	4.5	0.84	2.4	6.3	0.67	2.0	2.7

† HA = humic acid; FA = fulvic acid; E4/E6 = ratio of absorbance at 465 and 665 nm, respectively.

ova (1966) also indicated that forest soils normally have higher contents of FAs, whereas grassland soils are higher in HAs. The present study does not confirm this relationship for the uncultivated epipedons, but HA/FA ratios of organic matter associated with silt fractions are consistent with that prediction. The lack of agreement of HA/FA ratios in unfractionated, uncultivated materials may be related to the use of the UF site as pasture. Kononova (1966) indicated that regular additions of manure tend to widen soil HA/FA ratios.

The E4/E6 ratios of HA and FA of the particle-size fractions are given in Table 6. All the E4/E6 ratios of HA were <5, and they tended to decrease as particle size of the fraction that the HA came from decreased. This suggests that HAs in the finer size fractions were larger than those in coarser fractions. In general, the E4/E6 ratios of FA were greater than those of HA (i.e., smaller particle size), but not all of them were >5 as reported by other researchers for unfractionated soil FA (Schnitzer, 1971). Humic acids of the ochric epipedons (UF-A and CF-Ap) generally had higher E4/E6 ratios (i.e., smaller particle sizes) than their mollic epipedon counterparts, but other consistent differences of E4/E6 as a function of vegetation or cultivation were not identified. McKeague (1971) also found that E4/E6 ratios of organic matter extracts were not diagnostic of different kinds of soil surface horizons.

CONCLUSIONS

In this study, A horizons of mollic epipedons generally had greater cation exchange capacities, greater levels of exchangeable bases, greater organic C contents, and greater total N contents than did their ochric-epipedon counterparts. On the other hand, ochric A horizons had higher pH and base saturation values than mollic A horizons. Cultivated soil surface horizons had lower pH values, lesser cation exchange capacities, lower levels of exchangeable bases, lesser organic C contents, and usually lesser total N contents than their uncultivated counterparts. These differences may be generally attributed to the effects of vegetation and cultivation of the soil because other soil-forming factors were relatively constant in the study area. Still, absolute generalizations are difficult to make because of recent pasturing at the forest site and the introduction of nonnative grasses at the prairie site.

In an investigation of organo-mineral complexes unaltered by chemical dispersion treatments, most of the organic C and total N was associated with the fine silt and coarse clay fractions of uncultivated horizons. Cultivation was associated with a relative shift of organic matter from sand and silt fractions toward fine clay fractions. The HA/FA ratios of organic matter in particle-size fractions were always lower in the cultivated horizons than in the uncultivated horizons, but E4/E6 ratios showed few consistent differences associated with native vegetation or cultivation in the particle size of humic materials. Again, the interpretations of organic matter dynamics due to cultivation must be made cautiously because of agricultural influences on the uncultivated sites.

Several directions for future research are suggested by this investigation. First, more information is needed to establish that organo-mineral complexes isolated by size fractionation (especially with ultrasonic dispersion) are representative of the kinds of complexes occurring in field soils. Perhaps electron microscopic examinations of undistrubed soil materials can be useful in this regard. Second, further characterizations of free, relatively coarse organic materials in soil would be useful to better understand the fates of C and N during decomposition processes. Additional investigation of organic matter in mollic and ochric epipedons may be useful for the purpose of soil classification. Hobson (1983), for example, has suggested that HA/FA ratios of extracted organic matter might be a classification criterion to distinguish eroded Mollisols from Alfisols. Finally, more complete characterization of the ecosystems, especially the microbial communities, at the study sites would help to better understand the dynamics of soil organic matter.

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