Effect of long-term compost application on humus composition of whole soils and their particle size fractions in a field subjected mainly to double cropping

Thu Ha Nguyen, Maiko Tanaka and **Haruo Shindo**

Faculty of Agriculture, Yamaguchi University, Yamaguchi, Japan, Email shindo@yamaguchi-u.ac.jp

Abstract
The effect of long-term compost application (ca. 32 years) on humus composition of whole soils and their particle size fractions in a field subjected mainly to double cropping (upland and paddy crops) was investigated. Soil samples were collected from two plots of different types of management: (a) F plot, only fertilizer containing N, P, and K; (b) F + C plot, fertilizers plus compost. Each soil sample was divided into sand-sized aggregate, silt-sized aggregate, and clay-sized aggregate fractions by wet-sieving and sedimentation. In addition, coarse and medium sand-sized fractions were subdivided into "mineral particles" and "decayed plants" by a density fractionation. Compost application increased the amounts of total humus, humic acid, and fulvic acid in the whole soil and many size fractions, particularly, the silt-sized aggregate fraction. Their amounts of "decayed plants" were much larger than those of "mineral particles". On the other hand, the degree of humification of humic acids in the whole soils as well as many size fractions was decreased markedly by compost application. The findings indicate that in the continuous compost application field under study, the silt-sized aggregate fraction merits close attention as an important reservoir of soil organic carbon, including humic and fulvic acids.

Key Words
Paddy and upland fields, straw-cow dung compost, humic substances, humification

Introduction
A variety of organic amendments such as compost, farmyard manure, plant residues, food processing wastes, and sewage sludge is applied to various agriculture soils. Many investigators have observed the effects of these amendments on the physical, chemical, and biological properties, and fertility of soils in upland and paddy fields. However, the role of the amendments in the soils of double cropped (upland and paddy crops) fields needs to be further studied. Humus, which is composed of organic matter with differing origins and degrees of transformation, is one of the most important constituents of soils, and it affects various soil properties and the global carbon cycle. Particle size fractionation of soil makes it possible to separate organic matter. The objective of the present study was to gain a better understanding of the effect of continuous compost application on the quality and quantity of humus, using whole soils and their particle size fractions in a field subjected to long-term double cropping (paddy rice and barley).

Methods
Field experiment
The field experiments with different types of management were established in 1975 at Yamaguchi Prefecture Agricultural Experimental Station, Yamaguchi, Japan. The soil at this site was classified as gray lowland soil (FAO-UNESCO: Eutric Fluvisol). From the field experiments, we selected two plots (200 m^2 each): (a) F plot, only fertilizers containing N, P, and K were applied; (b) F + C plot, fertilizers plus compost were applied. The same plots were used as paddy fields for rice in summer and as upland fields for barley in winter until June 2001. The application rate of N, P_2O_5, and K_2O for each crop was 100 kg/ha. After harvest (June and November), rice straw-cow dung compost was applied at the level of 15 Mg/ha. However, since June 2001, these plots were used only as paddy fields, and the amounts of fertilizer and compost applied were reduced by half. In April 2007, to obtain an average soil sample in each plot, soils were taken from the plow layer (0-15 cm) of five sites across each of the two plots and mixed well. The soils were air-dried, gently crushed, and then passed through a 2-mm mesh sieve. These sieved samples were used for analytical determinations and physical fractionation.

Particle size fractionation
The particle size fractionation of the soil samples was carried out as described elsewhere (Tanaka and Shindo 2009). Firstly, the samples were divided into five particle size fractions, namely coarse sand-sized aggregate (212-2,000μm, CSA), medium sand-sized aggregate (53-212μm, MSA), fine sand-sized aggregate (20-53μm, FSA), silt-sized aggregate (2-20μm, SIA), and clay-sized aggregate (< 2μm, CLA) fractions, by wet-sieving

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and sedimentation. Secondly, the CSA and MSA fractions were subdivided into “mineral particles” and “decayed plants” by a density fractionation (decantation) in water.

Humus composition

Humus composition was analyzed according to the method described in Kumada (1987). Humus was extracted with a mixture of 0.1mol/L NaOH + 0.1mol/L $Na_4P_2O_7$ (1:1). Then, the extracts were separated into humic and fulvic acids by addition of H_2SO_4. The contents of humic acid (HA), fulvic acid (FA), and total humus (HT) were determined by the $KMnO_4$ oxidation method. In the present study, 1 ml of 0.02 mol/L $KMnO_4$ consumed was calculated as corresponding to 0.48 mg carbon (Ikeya and Watanabe 2003). The degree of humification (darkening) of humic acid was determined using color coefficient (Δ log K) and relative color intensity (RF) values, where the Δ log K is the logarithm of the ratio of the absorbance of humic acid at 400 nm to that at 600 nm; the RF represents the absorbance of humic acid at 600 nm multiplied by 1,000, and then divided by the number of milliliters of 0.02 mol/L $KMnO_4$ consumed by 30 ml of humic acid solution.

Results

In the whole soils, the amounts of HT, HA, FA, and extracted humus (HE, HA + FA) were much larger in the F + C plot than in the F plot. Similar results were obtained for the extraction ratio (HE/HT) and the precipitation ratio (PQ, HA/HE). In the F + C plot, the amount of HA greatly exceeded that of FA.
The recovery of mass weight by physical fractionation was 97.0 for the F plot and 101% for the F + C plot. Thus, the percentage distribution of mass weight in the particle size fractions was corrected to a total of 100% (Table 1). In both F and F + C plots, the distribution of mass weight in the particle size fractions increased in the order of CLA < FSA < MSA < SIA < CSA and it did not largely differ between these plots. As expected, in the CSA and MSA fractions of both plots, the distribution values of “mineral particles” were much larger than those of “decayed plants”.

Table 1. Percentage distribution of mass weight in particle size fractions.
F plot: only fertilizers containing N, P, and K were applied; F + C plot: fertilizers plus compost were applied; CSA: coarse sand-sized aggregate fraction; MSA: medium sand-sized aggregate fraction; FSA: fine sand-sized aggregate fraction; SIA: silt-sized aggregate fraction; CLA: clay-sized aggregate fraction; “M”: “mineral particles”; “D”: “decayed plants”.

Plot	CSA		MSA		FSA	SIA	CLA
	“M”	“D”	“M”	“D”			
F	31.1	1.1	19.7	0.9	14.1	21.3	11.9
F + C	32.7	1.3	17.1	1.7	12.6	25.3	9.3

In both plots, the HT, HA, and FA contents of particle size fractions were much higher in “decayed plants” of the CSA and MSA fractions than in the other fractions (e.g. Tables 2 and 3). However, the values (%) of quantitative distribution of the HT, HA, and FA in particle size fractions, which were calculated from the data of mass weight distribution (Table 1) and of humus content of fraction (Tables 2 and 3), were much larger in the SIA and CLA fractions than in the other fractions. In the F + C plot, the distribution values of the HT, HA, and FA were larger for the SIA fraction than the CLA fraction, and the reverse was true for the F plot. The findings indicate that continuous compost application accumulated humus into the SIA fraction.

Table 2. Quantitative distribution (%) of total humus in particle size fractions and their total humus contents. See Table 1 for the abbreviations.

Plot	Total humus content of fraction (g C/kg fraction)							Quantitative distribution (%)						
	CSA		MSA		FSA	SIA	CLA	CSA		MSA		FSA	SIA	CLA
	“M”	“D”	“M”	“D”				“M”	“D”	“M”	“D”			
F	1.28	246	1.00	187	1.52	18.3	39.9	2.88	19.4	1.43	12.2	1.55	28.2	34.4
F + C	3.17	222	1.13	185	3.72	27.9	60.3	5.09	14.0	1.19	15.4	2.30	34.6	27.4

Table 3. Quantitative distribution (%) of humic acids in particle size fractions and their humic acid contents. See Table 1 for the abbreviations. N.D: Not determined because the amount was very small.

Plot	Humic acid content of fraction (g C/kg fraction)							Quantitative distribution (%)						
	CSA		MSA		FSA	SIA	CLA	CSA		MSA		FSA	SIA	CLA
	“M”	“D”	“M”	“D”				“M”	“D”	“M”	“D”			
F	N.D	111	N.D	61.4	N.D	7.71	14.8	N.D	23.4	N.D	10.7	N.D	31.7	34.0
F + C	N.D	118	N.D	112	N.D	21.3	26.7	N.D	13.5	N.D	16.8	N.D	47.7	21.9

In the present study, the degrees of humification of the humic acids (HAs) extracted from the whole soils and several fractions were determined. According to Kumada (1987), the degrees of humification of soil HAs become higher as Δ log K value decreases and RF value increases. The degrees of humification of HAs extracted from the whole soils and the SIA and CLA fractions were much lower in the F + C plot compared to the F plot. Compost application induced a decrease of humification degree of HA. In the case of F + C plot, the degree of humification was lower in the SIA fraction than in the CLA fraction. Such a definite relationship did not occur for the F plot. In both plots, the amounts in “decayed plants” were much lower than those in the SIA and CLA fractions.

Table 4. Degrees of humification of humic acids in whole soils and their particle size fractions. See Table 1 for the abbreviations. Δ log K: the logarithm of the ratio of the absorbance of humic acid at 400 nm to that at 600 nm; RF: the absorbance of humic acid at 600 nm multiplied by 1,000, and then divided by the number of milliliters of 0.02 mol/L $KMnO_4$ consumed by 30 mL of humic acid solution.

Plot	Δ log *K* value					*RF* value				
	Whole soil	CSA “D”	MSA “D”	SIA	CLA	Whole soil	CSA “D”	MSA “D”	SIA	CLA
F	0.696	0.940	0.756	0.657	0.638	40	14	31	50	52
F + C	0.807	0.939	0.893	0.806	0.719	28	15	21	29	37

Conclusion

Continuous compost application in a field subjected to long-term double cropping increased the amounts of HT, HA, and FA in the whole soil and many particle size fractions, particularly the SIA fraction. In contrast, the degree of humification of HA was decreased by this application. The findings indicate that for long-term compost application, the SIA fraction may play an important role as a reservoir of soil organic carbon, including humic and fulvic acids.

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