Characterization of the Humus of Ando Soils in Japan

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Distribution of Ando soils in Japan

Ando soils are widely distributed on terraces hills and mountain in Japan and they possess the major part of cultivated land. The area of Ando soils measured on the basis of the soil map on the scale of 1 : 500,000[2] is 60,641 km² as shown in Table 1, and it corresponds to 16.4% of the total area of Japan. And they distribute mainly in the districts of Hokkaido, Tohoku, Kanto, Chubu and Kyushu.

Ando soils are classified into four subgroups* in the soil map on the scale of 1 : 500,000. Among these subgroups, Ando soils is the largest with the area of 83% of whole Ando soils area, and Ando soil (coarse textured) is possessed of the area of 8% which distributes principally in Kyushu district, and light colored Ando soils, Gleyed Ando soils possess 6.8% and 2.2% of the areas respectively and both of them distribute in Kanto district.

That is, practically all the Ando soils which distribute from Hokkaido to Kyushu district (from the north end to the south end of Japan) are composed of the soils with the surface horizon of about 25–50 cm in thickness.

Climatic condition

The climatic character of Japan can be summarized as follows[7]: As Japan is situated at the east coast of the Asian continent, cold seasonal wind comes from the continent in winter and hot and humid seasonal wind comes from the Pacific Ocean in summer.

Consequently, the winter in Japan is colder than that in the south coast countries of the continent situated on the same latitude as Japan, and the summer in Japan is rather hotter. The heavy rainy season in early summer and autumn and the typhoon bring over with the seasonal wind plenty of rain or snow all the year round. Therefore, Japan is one of the prominent rainy and humid countries in the world.

Table 2 shows the annual mean temperature and annual precipitation of the major districts where Ando soils distribute. The annual mean temperature varies in all districts. That is, at Sapporo of Hokkaido in the northern part

* The morphological features of the subgroups of Ando soils are described in the legend of the soil map on the scale of 1 : 500,000 as follows:

Ando soils (coarse textured): Mainly composed of thick sedimentory soil of volcanic sandy gravel. A horizon well developed in many cases.

Ando soils: Derived from volcanic ejected materials or from the parent materials which contain valcanic ejected materials with high rate. This is the soil covered with black surface horizon developed more than 25 cm in thickness. Both color value and chroma of the surface horizon are less than 2.

Light colored Ando soils: Ando soils covered with pale black surface horizon of which thickness is less than 25 cm or of which humus content is law.

Gleyed Ando soils: The depth of black soil is more than 50 cm. Subsoil is grayish and spotted or possessed of gleyed horizon.

Table 1. Area of Ando soils in Japan

(km²)

District	Ando soil (coarse textured)	Ando soils	Light colored Ando soils	Gleyed Ando soils	Total
Hokkaido	—	13,864	—	—	13,864
Tohoku	941	13,785	292	335	15,353
Kanto	752	7,464	3,274	866	12,356
Chubu	305	5,776	353	11	6,445
Kinki	—	1,019	22	—	1,041
Chugoku	98	2,123	15	24	2,260
Shikoku	11	488	12	—	511
Kyushu	2,745	5,811	131	124	8,811
Sum	4,852	50,330	4,099	1,360	60,641
	(8.0*)	(83.0*)	(6.8*)	(2.2*)	(100)

*: % of total area of Ando soils

Table 2. Annual mean temperature and annual precipitation (from scientific calendar (1970))

Locality	Lat. (N)	Long. (E)	Above sea level (m)	Temperature (C)			Precipitation (mm)		
				Oct. ~Mar.	Apr. ~Sept.	Annual	Oct. ~Mar.	Apr. ~Sept.	Annual
Sapporo (Hokkaido)	44°22′	141°42′	8.7	0	15.2	7.6	590	544	1,136
Akita (Japan Sea side)	39°43′	140°06′	10.0	3.7	17.6	10.7	845	950	1,789
Kanazawa (Japan Sea side)	36°33′	136°39′	27.6	7.0	19.9	13.5	1,468	1,091	2,559
Morioka (Pacific side)	39°42′	141°10′	156.4	2.3	16.9	9.5	466	809	1,275
Tokyo (Pacific side)	35°41′	139°46′	35.8	8.3	21.0	14.7	604	958	1,563
Miyazaki (Kyushu dist.)	31°55′	131°25′	7.3	11.2	22.1	16.7	754	1,817	2,571
Karuisawa (Chubu dist.)	36°20′	138°33′	1000	0.5	14.7	7.6	369	882	1,251

of Japan, it is 7.6°C, while at Miyazaki, in south Japan, it is 16.7°C.

As for the annual precipitation, it is abundant in the coastal regions of the Sea of Japan in Honshu (the main land of Japan) and also in the south of Kyushu. For example, at Tokyo, one of the cities located at the coastal regions of the Pacific, it is 1563 mm, while at Kanazawa city in the coastal region of Sea of Japan, it is 2559 mm, and at Miyazaki, it is 2571 mm. But normal distribution of annual precipitation is somewhat different between the coastal regions of the Sea of Japan and the south regions of Kyushu: namely, rainfall is abundant in the former at the colder half-year, while in the latter, it is plentiful in the warm half-year.

Humus content of Ando soils

Ando soils contain more humus than Podzol soil, Brown forest soils and Red-yellow soils in Japan. As the result of many studies on the humus in the Ando soils in Japan, it is considered that the source of this humus is herbs, and Allophane has an important role on the accumulation of the humus.

Table 3. Humus content of Ando soils (subgroup)

Region	Plowed layer of crop field Humus (%)	Surface horizon of uncultivated soil Humus (%)
Hokkaido	7~18	11~30
Japan Sea side of Tohoku	7~24	21~31
Pacific side of Tohoku	4~20	15~23
Kanto	3~21	16~23
Kyushu	3~11	19~33
High altitude area*	12~25	28~46

*: The area's altitude ranges 1,000~1,500 m, in Kanto and Chubu districts

Table 3 shows the humus contents of the surface horizon of uncultivated Ando soils (subgroup) and the plow layer of upland soils. The humus content of upland soil (3–25%) is less than that of the uncultivated soil (11–30%).

As to the regional difference of the humus contents of soils, the contents in the regions of high altitude and in the coastal regions of the Sea of Japan of Tohoku district are high both in uncultivated and upland soils, and those in the Pacific coast rigion and in the Kanto district are rather low in any soils.

In Kyushu district, the humus content of upland soils is low while that of uncultivated soils is high.

In Hokkaido, the humus content of uncultivated soils is high next to the north-east coastal regions of the Sea of Japan and even the minimum content of upland soils is higher than the humus contents of north-east Pacific coastal, Kanto and Kyushu districts. From these results, the regional variety of humus accumulation in the Ando soils may be concluded as follows:

That is, much humus is accumulated in the Ando soils especially in the high altitude regions of Kanto and Chubu districts. In the coastal regions of the Sea of Japan of Tohoku district, the humus contents are high both in uncultivated and upland soils. Therefore, there may be some favorable conditions for the accumulation of humus in these regions.

In Hokkaido, the decomposition of humus progresses slowly because of low temperature, consequently the minimum humus content of upland soils may be high in spite of the rather small production of herbs, the source of humus.

In Kyushu district, humus is accumulated abundantly in uncultivated soils because of the big production of herbs under the condition of high temperature and plenty of precipitation.

But the temperature of this district is rather high all throughout the year and the decomposition of humus is very active, therefore, the humus in upland soils decreases rapidly.

Such regional difference of the accumulation and decomposition of humus may affect the composition of humus and on the characteristics of humic acid which shall be described later.

Humus composition and the optical properties of humic acid

Table 4 shows the outline of the humus composition of various soil types in Japan[1] obtained by means of the Ponomareva method[4].

The principal part of the humus of Ando soils consists of fraction–1* of humic acid and fluvic acid, and they exist in the combination with mobile aluminum. Next to these two components are fraction–1a* and fraction–4* of the fluvic acid. Fraction–2 can scarcely be detected in many Ando soils and fraction–3* amounts to less than a few per cent.

The humus of Ando soils, which mainly

* **Prescription of fraction by Phonomareva method**
Fraction-1a: This combines with mobile R_2O_3 and can be dissolved directly by 0.1n H_2SO_4.
Fraction-1: This combines mobile R_2O_3 and can be dissolved dirctly by 0.1n NaOH.
Fraction-2: This combines with Ca and can be dissolved by 0.1n NaOH after treament with 0.1n H_2SO_4
Fraction-3: This combines stable R_2O_3 and clay, and can be dissolved by 0.1n NaOH after treatment with 1.0n H_2SO.
Fraction-4: This combines with stable R_2O_3 and clay, and can be dissolved by hydrolysis with hot 1.0n H_2SO_4.

Table 4. Humus composition of various soil types in Japan
(Ponomareva's method; % of total carbon)

Soil types	Horizon	Depth (cm)	Organic carbon (%)	Humic acid fraction		Fulvic acid fraction				Humin	ch : cf
				1	Sum(ch)	1a	1	4	Sum(cf)		
Podzol soils	H A	0～ 5	11.0	23	27	3	16	8	31	42	0.9
	A 2	5～10	1.7	17	9	14	12	5	35	46	0.6
Brown forest soils	A 1	0～10	8.5	19	22	12	18	6	40	38	0.6
Red soils	A 1	0～ 5	6.6	16	18	6	14	7	30	52	0.6
	A 3	5～23	2.9	18	21	10	19	8	45	34	0.5
Ando soils	A11	0～ 5	10.9	21	23	12	20	7	41	37	0.6
(Hokkaido dist.)	A12	5～13	8.8	22	24	16	19	13	50	27	0.5
	B 1	13～30	4.6	14	15	28	26	7	65	20	0.2
Ando soil	A12	3～15	7.6	17	23	14	17	6	41	36	0.6
(Kanto dist.)	A 3	35～58	6.7	15	25	6	25	10	46	29	0.6
	B 1	58～75	3.8	12	18	6	27	14	57	25	0.3
Ando soil	A11	0～ 6	12.7	22	25	9	15	6	33	42	0.8
(Tohoku dist.)	A12	15～27	8.5	29	31	16	11	3	35	34	0.9
Ando soils	A11	0～ 5	20.4	32	35	7	14	6	28	37	1.2
(Kyushu dist.)	A12	15～30	17.6	37	39	9	15	6	31	30	1.3

Data of Adachi, T. (1973)

consists of fraction–1, –1a and –4, is common to the Podzol soil, Brown forest soil and Red-yellow soils in Japan. But the humus of Ando soils can be discriminated from the humus of other soils by means of the properties of humic acid as described later.

Furthermore, specificities of the humus of Ando soil in every region of Japan can be shown by means of Ch:cf and the distribution of fraction–1 of humic acid and fraction–1a and –4 of fluvic acid in the soil profiles. For example, in the regions of high altitude, the Sea of Japan coastal regions of Tohoku and Kyushu districts which are regions of high humus content, the ratio of Ch:cf is higher than the Pacific coastal regions of Tohoku and Kanto districts, the regions of low humus content.

Though the ratio of Ch:cf in Hokkaido is similar to that of Kanto district, in the B1 horizon of the latter, the fraction–1a of fluvic acid is less and fraction–4 is greater than that of the former.

Table 5 shows the RF values and $\Delta \log\text{-}k$

Table 5. RF and Δ log-k of humic acid fraction-1

Soil types	Horizon	RF*	$\Delta \log\text{-}k$**
Brown forest soils	A1	120	0.613
Red soils	A1	50	0.756
	A3	80	0.760
Ando soils (Hokkaido dist.)	A11	146	0.542
	A12	218	0.471
Ando soils (Kanto dist.)	A12	274	0.505
	A3	273	0.505
Ando soils (Tohoku dist.)	A11	173	0.547
	A12	245	0.517
Ando soils (Kyushu dist.)	A11	264	0.500
	A13	244	0.500

Data of Adachi, T (1973)

* : $RF = \frac{k600}{ml} \times 2,247$

$k600$ is the absorption coefficient at $\lambda = 600\ m\mu$.

ml is ml of 0.1n $KMnO_4$ consumed in acid condition per 30 ml of humic acid solution used for colorimetry

** : $\Delta \log\text{-}k = \log\text{-}k\ 400 - \log\text{-}k\ 600$

Table 6. Elementary composition of humic acid

Soil types	C	H	N	O***	C : N	C : H	O : H
Aodo soils* (Hokkaido dist.)	55. 99	4. 19	4. 15	35. 67	13. 5	13. 4	8. 5
Ando soils* (Kanto dist.)	57. 03	3. 75	3. 96	35. 50	14. 4	15. 4	9. 6
Ando soils* (Kyushu dist.)	60. 08	2. 56	2. 16	35. 20	27. 9	23. 5	13. 7
Red yellow soils**	55. 13	5. 18	5. 19	34. 50	10. 6	10. 6	6. 6

* : Data of Tokudome, S. and Kanno, I. (1964)
** : Data of Kanno, I. et al. (1965)
*** Oxygen=100−(C+H+N)

of fraction-1 of humic acid. The RF value of Ando soils is higher and its $\Delta \log\text{-}k$ is lower than those of the Brown forest and Red-yellow soils. In comparison among Ando soils, in Kanto and Kyushu districts, the RF values are higher and $\log\text{-}k$ are lower than those of Hokkaido and Tohoku districts.

Elementary composition, X-ray diffractograms and infrared absorption spectrum of humic acid

The C content of humic acid of Ando soils is higher and its contents of H and N are lower in comparison with the humic acid of Red-yellow soil in the results of studies by Tokudome and Kanno[5),6)], and Kanno et al.[3)] as shown in Table 6. And in comparison among Ando soils, the C content of Kyushu district is far higher and its content of H and N are lower than those of Hokkaido.

As shown in Fig. 1, in the X-ray diffractograms of the humic acid of Ando soils, a peak caused by the reflection of amorphous carbon-like structure can obviously be recognized at the point of the wavelength of about 3.4 Å. And this peak can be recognized remarkably with the sample soil of Kyushu district while no peak appeared in the analysis of the Hokkaido sample.

In the infrared absorption spectrum shown in Fig. 2, an absorption band caused by the existence of aromatic c=c group is recognized

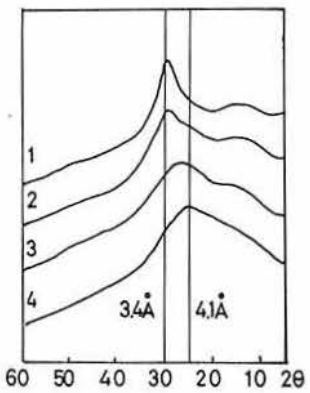

Fig. 1. X-ray diffractograms of humic acid (CoKα). Data of Tokudome, S. and Kanno, I. (1967)
1 Ando soils (Kyushu dist.)
2 Ando soils (Kanto dist.)
3 Ando soils (Hokkaido dist.)
4 Red yellow soils (Kyushu dist.)

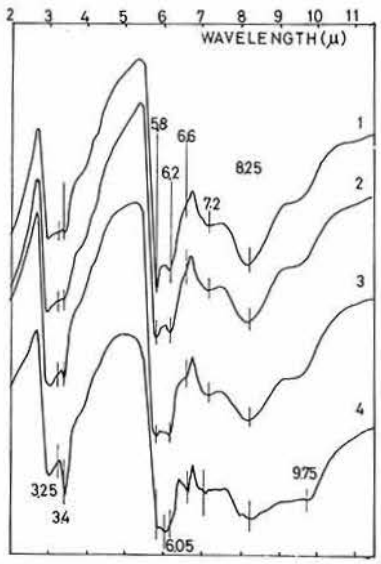

Fig. 2 Infrared absorption spectra of humic acid. Data of Tokudome, S. and Kanno, I. (1967). Sample numbers are the same as those given in Fig. 2

around 6.2μ but the absorption around 3.4μ which suggests the existence of aliphatic C–H group and that around 6.6μ which indicates the existence of the aromatic c=c with chain carbon structures are rather obscure. And the absorption around 5.8μ which shows the existence of carboxyl radical (or carbonyl radical) and the absorption caused by ether, ester and organic acid around 8.25 μ are widely recognized.

The characteristics of the humus in Ando soils are different from those in Podzol, Brown forest and Red-yellow soils as described above, and the regional differences could also be recogniezd on the humus content, humus composition and its distribution in the soil profiles and on the properties of humic acid. This latter differences might be caused by climatic conditions.

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References

1) Adachi, T.: Studies on the humus of volcanic ash soils—Regional differences of humus composition in volcanic ash soil in Japan. *Nat. Inst. Agr. Sci.* B, No. 24, 127 (1973).
2) Economic Planning Agency: Soil map of Japan 1 : 500, 000 (1969).
3) Kanno, I. et al.: Genesis and characteristics of a Red-yellow soils derived from cristalline schist, Kurogi, Kyushu, *Bull. Kyushu Agr. Exp. Sta.*, **11**, 325(1965).
4) Ponomareva, V.V.: Contribution to the study of humus composition according to the scheme of Tyurin, Pochivovedenie, No. 8, 66 (1957).
5) Tokudome, S. & Kanno, I.: Characterization of humus of humic Allophene soils in Japan, *Bull. Kyushu Agr. Exp. Sta.*, **10**, 195 (1964).
6) Tokudome, S. & Kanno, I.: Nature of humus of some Japanese soils, *Bull. Kyushu Agr. Exp. Sta.*, **13**, 187 (1967).
7) Wadachi, K. (ed.): Climate of Japan, Tokyodo, Tokyo (1958).