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Chemical and Physical Properties of Andosols in Aomori Prefecture Described in a Soil Survey Report on Reclaimed Land

[1]Nobuhiko Matsuyama, [2]Saiful Karim, [1]Choichi Sasaki, [1]Masakazu Aoyama, [3]Fumihito Seito, [3]Haruki Fujisawa and [4]Masahiko Saigusa
[1]Faculty of Agriculture and Life Science, Hirosaki University, Hirosaki, 036-8561, Japan
[2]The United Graduate School of Agricultural Sciences, Iwate University, Morioka 020-8550, Japan
[3]Aomori Prefectural Industrial Technology Research Center, Kuroishi, 036-0522, Japan
[4]Department of Ecological Engineering, Toyohashi University of Technology, Toyohashi, 441-8580, Japan

Abstract: The chemical and physical properties of allophanic and non-allophanic Andosols in Aomori prefecture described in a Soil Survey Report on Reclaimed Land (SSRRL) are discussed. Volcanic ash soil and non-volcanic ash soil having more than 15 g P_2O_5 kg^{-1} of phosphate absorption coefficient are regarded as Andosols. In this study, 251 soil profiles and 657 soil horizons were classified into two groups based on exchange acidity y_1; into allophanic Andosols (y_1<6) and non-allophanic Andosols ($y_1 \geq 6$). The physical properties (soil color, texture, gravel, stickiness, consistence (dry), tilth and wetness) in SSRRL were scored into 6 classes from 0 to 5. The mean humus contents of non-allophanic Andosols was 13.1% at a depth of 0-15 cm, 11.0% at 15-30 cm and 7.7 % at 30-50 cm and were slightly higher than those of allophanic Andosols. Non-allophanic Andosols have a relatively high texture score compared with allophanic Andosols. Moreover, non-allophanic Andosols are relatively sticky. As compared with allophanic Andosols, non-allophanic Andosols have higher clay content and are sticky and hard. Thus, the differences of chemical and physical properties of allophanic Andosols and non-allophanic Andosols described in SSRRL were evaluated.

Key words: Allophanic, exchange acidity y_1, non-allophanic, top soil, subsoil

INTRODUCTION

Andosols are divided into allophanic and non-allophanic Andosols according to colloidal composition. Both types of Andosols have the characteristic properties of high phosphate retention, low bulk density and high humus content. However, there are significant agronomical differences between them in soil acidity, active aluminium that absorbs phosphate and variable charge characteristics (Shoji, 1985). There are many reports concerning the soil classification of Andosols, soil profile morphology and some chemical and physical properties (Shoji *et al*., 1985, 1993; Saigusa *et al*., 1991b; Nanzyo and Shoji, 1992, 1993). The clay fraction of typical allophanic Andosols is dominated by allophane/imogolite and has a weakly acidic character (Yoshida, 1971). On the other hand, in the typical non-allophanic Andosols, the clay fraction is dominated by 2:1-2:1:1 mineral and shows a strongly acidic character (Yoshida, 1970). Judging from the acidic character of both Andosols, the exchange acidity y_1 is a suitable criterion for classifying uncultivated Andosols into allophanic and non-allophanic Andosols; namely the exchange acidity y_1 was <6 in allophanic Andosols and ≥6 in non-allophanic Andosols (Saigusa *et al*., 1992c). Non-allophanic Andosols with the exchange acidity $y_1 \geq 6$ correspond to Non-allophanic Kuroboku horizon, as defined by the Unified Soil Classification System of Japan (JSP, 2003). Previously (Saigusa and Matsuyama, 1998; Saigusa *et al*., 1992a), it was reported the distribution of allophanic and non-allophanic Andosols and also the soil management of these Andosols with special reference to soil acidity. Subsoil plays an important role in supplying nutrients to crops. If subsoil acidity is severe, as in non-allophanic Andosols, the availability of subsoil nutrients is severely limited, resulting in poor rooting toward the subsoil. In non-allophanic Andosols, the active Al which reacts with phosphate is mainly Al-humus and the availability of phosphate to crops is lower than that in allophanic Andosols (Matsuyama *et al*., 1994). Non-allophanic Andosols easily becomes muddy when wet and compacted when dry because of a relatively low plastic limit and a weak aggregate structure (Inahara, 1989;

Corresponding Author: Nobuhiko Matsuyama, Faculty of Agriculture and Life Science, Hirosaki University, Hirosaki, 036-8561, Japan

Maeda *et al*., 1978). From these agronomic viewpoints, soil managements of the two groups of Andosols are big differences. The large-scale soil survey on reclaimed land was held from 1948 to 1963. It was to investigate the actual condition of soil fertility around Japan. The soil survey was done at a point per 1 ha of reclaimed land (virgin soil). The coverage of soil survey was about 500,000 ha in Japan. Then, a Soil Survey Report on Reclaimed Land (SSRRL) (MAFFJ, 1965) was published in the 1960s. These reports provide useful information (physical and chemical properties of the soil) on the virgin soil before cultivation. It is highly possible that the cultivation changes some soil properties. The virgin soil data is very important to estimate the effect of the cultivation on soil degradation. The objective of the present study is to compare the chemical and physical properties of allophanic Andosols with those of non-allophanic Andosols in Aomori prefecture using the virgin soil data in SSRRL.

MATERIALS AND METHODS

Grouping of allophanic and non-allophanic Andosols described in SSRRL: It was examined the data on the soil properties for each soil horizon, investigation point, soil profile number, soil depth, soil color, physical properties, chemical properties and soil classification in SSRRL. There were four soil groups in SSRRL: volcanic ash soil, non-volcanic ash soil, bog soil and half-bog soil. Volcanic ash soil is defined as the soil originating from tephra. Non-volcanic ash soil is defined as the soil which does not originate from tephra. However, Kato (1970) reported that "non-volcanic Andosols" is widely distributed in Tokai district of Japan. Volcanic ash soil and "non-volcanic Andosols" were regarded as Andosols (Saigusa *et al*., 1992b; Matsuyama *et al*., 2005). From the viewpoint of soil management, these soils were collected from three layers; topsoil (0-15 cm), subsoil (15-30 cm) and subsoil (30-50 cm) which are referred to as I, II and III layers, respectively. The soil horizons which include the border at 15 and 30 cm on the profile belonged to both the upper and lower layers, respectively. The soil horizons were divided into two groups by the exchange acidity y_1; <6 for allophanic Andosols and ≥ 6 for non-allophanic Andosols.

Evaluation of soil properties of Andosols in SSRRL: The chemical and physical properties of each horizon in SSRRL were examined by the routine methods. We used the data of humus content, pH(H_2O), pH(KCl), exchange acidity y_1, exchangeable Ca and phosphate absorption coefficient. Some physical properties (soil color, texture, gravel, stickiness, consistence (dry), tilth and wetness) were also reported in SSRRL. These properties were evaluated by the simple score as described in Table 1. The physical properties were examined according to the methods described in Aomori Prefecture (1958), MAFFJ (1961) and Yokoi (1987). Soil color: the gradation of black, brown, yellow and red, texture: the clay content (the method defined by the Japanese Agricultural Scientific Societies), gravel: the ratio of area occupied by gravel through the soil profile, stickiness: the adhesion of wet soil when pressed with fingers, consistence (dry): the crushing strength of air-dried soil, tilth: the hardness of tillage (sticky in a wet condition and lumpy in a dry condition), wetness: the moisture condition when pressed with fingers.

Soil properties of the representative cultivated Andosols in Aomori prefecture: We used the data of soil colloidal composition in the representative cultivated Andosols in Aomori prefecture (30 points and 60 samples; Saigusa *et al*., 1991a) described in the environment assessment at the Aomori Prefectural Industrial Technology Research Center (APITR center) for comparison with the data in SSRRL. These were used the data of acid oxalate-extractable Si, Al and Fe (Blakemore *et al*., 1981), pyrophosphate-extractable Al and Fe (Blakemore *et al*., 1981), pH(H_2O), pH(KCl), exchange acidity y_1, humus content, phosphate absorption coefficient, available phosphate, exchangeable Ca, bulk density, three phases ratio and particle size distribution. These physical and chemical data except for the amorphous materials (Si_o, Al_o, Fe_o, Al_p and Fe_p) were

Table 1: Soil properties of Andosols

	Score					
Soil property	0	1	2	3	4	5
Soil color	-	black	brownish black/dark brown	brown/bright brown	yellowish brown/yellow	red/reddish brown
Texture	-	<12.5%	12.5-25%	25-37.5%	37.5-50%	>50%
Gravel	0	2-5%	5-10%	10-20%	>20%	-
Stickiness	0	slight sticky	sticky	very sticky	strong sticky	-
Consistence (dry)	0	soft	hard	very hard	-	-
Tilth	-	friable	firm	very firm	-	-
Wetness	-	dry	moderate	moist	wet	very wet

Values are Mean±SD

analyzed at the APITR center. The methods of analysis were the standard soil analysis (JSSSPN, 1997). Since the original data were not published, we used the data with permission from the APITR center.

RESULTS AND DISCUSSION

Soil properties of allophanic and non-allophanic Andosols described in SSRRL: In SSRRL, 251 soil profiles and 657 soil horizons in Aomori prefecture are described. The soil horizons were divided into three layers; topsoil (0-15 cm), subsoil (15-30 cm) and subsoil (30-50 cm) which are referred to as I, II and III layers, respectively. In the present study, there were 300 soil horizons, 361 soil horizons and 337 soil horizons of I, II and III layers, respectively. Table 2 shows the chemical properties of Andosols in SSRRL. The mean humus contents of I, II and III layers were 12.3, 10.0 and 7.3%, respectively, in allophanic Andosols and 13.1, 11.0 and 7.7%, respectively, in non-allophanic Andosols. The mean humus content of non-allophanic Andosols was slightly higher than that of allophanic Andosols. Non-allophanic Andosols were strongly acidic judging from exchange acidity y_1. The mean phosphate absorption coefficients of non-allophanic Andosols in the subsoil were relatively low.

Table 3 shows the scores of physical properties of Andosols in SSRRL. The mean scores of texture in I, II and III layers were 4.15, 4.13 and 4.04, respectively, in allophanic Andosols and 4.35, 4.36 and 4.40, respectively, in non-allophanic Andosols. Non-allophanic Andosols were suggested to relatively high clay content. The clay fraction (<0.01 mm) defined by the Japanese Agricultural Scientific Societies, includes the humic substances (Yokoi, 1987). Therefore, the texture may be overestimated by the humic substances in humic Andosols. However, the method of texture is useful for agriculture because of the simple evaluation. Actually, the mean score of texture at each soil layer was considered to correlate with the clay content because both Andosols had similar humus contents. The mean score of gravel in allophanic Andosols in the III layer was relatively high. This may be related to the pumice in the subsoil. Oike (1972) reported that pumice (commonly called "Awazuna") was distributed widely in the eastern part of Aomori prefecture. The mean score of stickiness in non-allophanic Andosols was 1.31, 1.36 and 1.78, respectively. Those in non-allophanic Andosols were relatively high. The mean score of consistence (dry) in non-allophanic Andosols was 1.43, 1.57 and 1.97, in I, II and III layers, respectively which were relatively high. These results reflect the difference in main clay minerals between allophanic and non-allophanic Andosols; allophane/imogolite in allophanic Andosols and 2:1-2:1:1 minerals in non-allophanic Andosols. The difference in the mean score of tilth between allophanic and non-allophanic Andosols layers was only from 0.04 to 0.1. These results suggested that non-allophanic Andosols had a relatively high clay content, stickiness and hardness as compared with allophanic Andosols.

Soil properties of representative cultivated Andosols in Aomori prefecture: Reclaimed land in Japan is often located at a relatively high altitude. It compared the results obtained from the data in SSRRL with the soil properties of the representative cultivated Andosols in Aomori prefecture. Table 4 shows the contents of amorphous materials and some chemical properties in the representative cultivated Andosols in Aomori prefecture with special reference to their colloidal compositions. The mean content of acid oxalate-extractable Si (Si_o) in topsoil and subsoil of allophanic Andosols was 9.4 and 12.0 g kg^{-1}, respectively. The mean Al_p/Al_o ratio (pyrophosphate-extractable Al/acid oxalate-extractable Al) in topsoil and subsoil of allophanic Andosols was 0.29 and 0.22, respectively. On the other hand, the mean Si_o content of topsoil and subsoil in non-allophanic Andosols was 3.5 and 4.4 g kg^{-1}, respectively. The Al_p/Al_o ratio in topsoil and subsoil of non-allophanic Andosols was 0.48 and 0.43, respectively. In typical non-

Table 2: Chemical properties of Andosols in a soil survey report on reclaimed land

Soil group	humus (%)	pH H_2O	pH KCl	Exchange acidity y_1	Exchangeable Ca (g kg^{-1})	Phosphate adsorption coefficient
Allophanic Andosols						
I (0-15 cm)	12.3±4.2	5.7±0.5	5.0±0.6	2.5±1.5	0.98±0.54	17.1±4.9
II (15-30 cm)	10.0±4.8	5.7±0.4	5.1±0.6	2.2±1.5	0.76±0.51	18.1±5.4
III (30-50 cm)	7.3±4.6	5.8±0.4	5.2±0.6	1.8±1.4	0.64±0.58	18.2±6.2
Non-allophanic Andosols						
I (0-15 cm)	13.1±4.3	5.3±0.5	4.5±0.4	9.6±4.5	0.64±0.48	17.3±6.0
II (15-30 cm)	11.0±4.8	5.3±0.4	4.6±0.4	9.3±5.1	0.60±0.46	16.2±5.0
III (30-50 cm)	7.7±5.3	5.4±0.4	4.6±0.4	10.1±5.5	0.55±0.45	14.9±6.1

Values are Mean±SD

Table 3: Scores of physical properties of Andosols in a soil survey report on reclaimed land

Soil group	Soil color	Texture	Gravel	Strickness	Consistence (dry)	Tilth	Wetness
Allophanic Andosols							
I (0-15 cm)	1.82±0.96	4.15±0.67	0.10±0.38	1.09±0.70	1.25±0.52	1.68±0.48	1.54±0.59
II (15-30 cm)	2.34±1.18	4.13±0.85	0.16±0.50	1.26±0.76	1.45±0.65	1.84±0.38	1.72±0.57
III (30-50 cm)	2.92±1.16	4.04±1.01	0.31±0.69	1.42±0.84	1.73±0.74	1.95±0.22	1.96±0.46
Non-allophanic Andosols							
I (0-15 cm)	2.01±0.88	4.35±0.67	0.17±0.48	1.31±0.71	1.43±0.64	1.78±0.47	1.64±0.61
II (15-30 cm)	2.49±1.13	4.36±0.79	0.14±0.39	1.36±0.68	1.57±0.71	1.88±0.33	1.70±0.54
III (30-50 cm	3.04±1.11	4.40±0.89	0.21±0.54	1.78±0.85	1.97±0.84	1.90±0.31	1.95±0.44

Values are Mean±SD

Table 4: Amorphous materials contents and chemical properties of cultivated Andosols

	Conc. ($g\ kg^{-1}$)						pH						
Soil group	Si*	Al*	Fe*	Al**	Fe**	Al_p/Al_o	H_2O	KCl	Exchange Acidity y_1	Humus (%)	Phosphate absorption coefficient	Avaialble phosphate ($g\ kg^{-1}$)	Exchangeable Ca ($g\ kg^{-1}$)
Allophanic Andosols													
Topsoil (n = 21)	9.4±3.1	27.4±6.3	10.6±2.4	7.7±2.9	3.9±2.0	0.29±0.10	5.7±0.5	4.9±0.5	2.2±3.0	12.0±3.5	19.4±3.3	0.272±0.203	2.02±1.12
Subsoil (n = 25)	12.0±7.0	30.8±12.7	11.4±4.4	6.1±3.1	3.1±2.8	0.22±0.11	5.7±0.5	4.9±0.4	2.2±3.1	8.6±4.1	20.9±4.5	0.063±0.090	1.22±0.79
Non-allophanic Andosols													
Topsoil (n = 9)	3.5±0.9	16.3±3.9	10.2±5.0	8.0±3.2	5.3±3.7	0.48±0.12	5.5±0.5	4.6±0.4	3.5±3.7	12.9±4.0	16.0±5.0	0.516±0.404	2.09±1.14
Topsoil (n = 5)	4.4±2.4	18.7±10.4	11.9±3.0	8.9±6.6	5.6±3.2	0.43±0.16	5.5±0.4	4.5±0.2	8.6±5.4	10.1±7.5	17.9±6.5	0.088±0.159	0.76±0.51

Values are Mean±SD, *Acid oxalate-extractable, **Pyrophosphate-extractable

Table 5: Physical properties of cultivated Andosols

		Three phases ratio (%)			Particle size distribution (%)			
Soil group	Bulk density (g cm^{-1})	Solid	Water	Air	Coarse sand	Fine sand	Silt	Clay
Allophanic Andosols								
Topsoil (n = 21)	0.81±0.16	35±11	49±9	15±10	22±10	35±7	27±8	15±7
Subsoil (n = 25)	0.78±0.16	34±11	53±9	14±5	26±12	43±12	22±8	9±8
Non-allophanic Andosols								
Topsoil (n = 9)	0.78±0.15	33±12	52±10	14±9	19±12	31±6	33±10	18±7
Topsoil (n = 5)	0.81±0.19	35±16	53±13	11±5	18±6	30±5	35±7	17±3

Values are Mean±SD

allophanic Andosols, the active-Al is mainly occupied by the Al-humus complex and the Al_p/Al_o ratio is higher than 0.5 (Saigusa *et al*., 1991b). Since the humus content of non-allophanic Andosols in Aomori prefecture was relatively low, the Al_p/Al_o ratio also was relatively low. The humus content of non-allophanic Andosols was slightly higher than that of allophanic Andosols (0.9 to 1.5%). Cultivated Andosols sometimes have been subject to soil improvement such as liming. Thus, the exchange acidity y_1 of non-allophanic Andosols in the topsoil was improved. The mean phosphate absorption coefficient in topsoil and subsoil of allophanic Andosols was 19.4 and 20.9 g P_2O_5 kg^{-1}, respectively and that of non-allophanic Andosols was 16.0 and 17.9 g P_2O_5 kg^{-1}, respectively. Those of non-allophanic Andosols were lower than those of allophanic Andosols (3.0 to 3.4 g P_2O_5 kg^{-1}). Table 5 shows some physical properties of the representative cultivated Andosols in Aomori prefecture. There was no difference in either bulk density or three phases ratio between allophanic and non-allophanic Andosols. The clay content of topsoil and subsoil in allophanic Andosols was 15 and 9%, respectively and that in non-allophanic Andosols was 18 and 17%, respectively. The mean clay contents of non-allophanic Andosols were relatively high values.

Thus, the mean values of humus content, phosphate absorption coefficient and clay content in allophanic Andosols and non-allophanic Andosols in the representative cultivated Andosols tended to be similar to those in SSRRL. We considered that it useful to clarify the chemical and physical properties of Andosols described in SSRRL in relation to the colloidal compositions and it will reveal the soil properties changed by cultivation.

CONCLUSIONS

From these results, we may conclude that non-allophanic Andosols have the trends of higher clay content, more stickiness, more hardness and strongly acidity compared with allophanic Andosols in the data of SSRRL.

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