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Fertility of Andosols Formed from Basaltic and Dacitic Volcanic Ashes

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Summary

Fertility of the two Andosols formed from dacitic (Kawatabi) and basaltic (Sagamihara) ashes was studied by a greenhouse experiment using dent corn. Eight experimental plots which were full fertilizer (F), no-nitrogen (-N), no-phosphate (-P), no-potassium (-K), no-calcium (-Ca), no-magnesium (-Mg), no-minor element (-M) and no-fertilizer (-F) were established. The pH (H_2O) values of these soils were adjusted to 6.5 by applying $CaCO_3$ or Na_2CO_3. The results obtained from this experiment were as follows.

The total C and N contents of two soils were high, but the C/N ratios were lower in Sagamihara soil than Kawatabi soil. The amounts of the exchangeable Ca and Mg were considerably high in Sagamihara soil and the amounts of the exchangeable K and Na were high in Kawatabi soil.

The plant growth in the -N and -Ca plots was better in Sagamihara soil than Kawatabi soil and that in the -K plot was better in Kawatabi soil than Sagamihara soil.

The amounts of N, Ca, Mg and minor elements absorbed by plants in the experiment plots without these elements were greater in Sagamihara soil than Kawatabi soil and only K uptake in the -K plot was greater in Kawatabi soil than Sagamihara soil.

It is obvious that the nutrients' supplying power of elements discussed above reflected the rock types of the parent ashes. It can be concluded that Sagamihara soil derived from the basaltic parent ash is more fertile than Kawatabi soil derived from the dacitic parent ash.

Most Andosols are excellent for the growth of upland crops due to their physical properties: remarkable friability and free drainage, but high available water. However, it is common knowledge in Japan that Andosols possess the lowest productivity among Japanese upland soils, because of their low base saturation and plentiful existence of active aluminum relating to high phosphate absorption. Therefore, liming and heavy application of phosphate fertilizers are a common practice to obtain high crop yield.

Since most Andosols used for upland crops in Japan are relatively young, it seems likely that the properties of the parent ashes are closely related to the soil fertility. The silica content of the volcanic ashes closely correlates with the various contents of Al_2O_3, Fe_2O_3, MgO, CaO, Na_2O, K_2O, TiO_2 and MnO (1). However, relationships between the fertility of Andosols and the properties of the parent ashes has scarcely been investigated.

The purpose of the present paper is to investigate the growth of dent corn planted on the soils formed from the basaltic and dacitic parent ashes and to discuss the relationships between the soil fertility and the rock types of the parent ashes.

Materials and Methods

The modern Al horizons of Kawatabi and Sagamihara soils were used for the present study. The rock types of the parent ashes of Kawatabi and Sagamihara soils are dacitic and basaltic, respectively (2, 3). Some important properties and major clay mineral compositions of the soil samples are shown in Table 1.

The chemical methods used were: pH, potentiometrically in water (1:2.5); exchange acidity (Y_1), by the titration of 125 ml of N KCl soil extract (100:250) with 0.1 N NaOH; CEC by the procedure of Wada and Harada (4); exchangeable bases with N NH_4OAC; phosphate absorption with 2.5% $(NH_4)PO_4$ (1:2): total C and N, by the dry combusion method.

The greenhouse experiments of yellow dent corn (Zea mays L.) were carried out from June 11, 1975 to July 8, 1975. Eight experimental plots which were full

TABLE 1 *Properties*

Soils	Clay content (%)	T-C (%)	T-N (%)	C/N ratio	pH (H_2O)	Y_1	CEC (me/100 g)
Kawatabi	22	13.7	0.78	17.6	3.95	21.9	27.2
Sagamihara	35	11.2	0.88	12.7	4.65	4.3	42.7

TABLE 2 *The Amounts of the Applied Nutrients*

Nutrients	Kawatabi soil	Sagamihara soil
N g/pot	0.6	0.6
P_2O_5 〃	2.0	4.2
K_2O 〃	0.6	0.6
CaO* 〃	5.6	6.5
MgO 〃	0.2	0.2
Cu mg/pot	10	10
Zn 〃	10	10
Mn 〃	16	16
Mo 〃	6	6
B 〃	1	1

*; The soils of all the plots except no-calcium plot, were adjusted to pH 6.5 by liming. The no-calcium plot was adjusted to the same pH (H_2O) by adding Na_2CO_3.

fertilizer (F), no-nitrogen (-N), no-phosphate (-P), no-potassium (-K), no-calcium (-Ca), no-magnesium (-Mg), no-minor element (-M) and no-fertilizer (-F) were established. The weight of soils placed in Wagnel pots (a/5000) were 2.5 kg/pot for Kawatabi soil and 2.9 kg/pot for Sagamihara soil. The amounts of the fertilizers applied are shown in Table 2. Because the phosphate absorption and the pH (H_2O) values of the two soils were different, the amounts of applied phosphate and calcium varied. The soil moisture was maintained at 60% of maximum water holding capacity. Four seeds of dent corn were planted in each pot and were thinned to two after emergence. The plant height, leaf number and nutrient deficiency symptons were observed during the growing cycle and the plants were harvested at the 8 to 9 leaf stage.

Results and Discussion

1) *Properties of the Soils*

As shown in Table 1, the clay contents of the soil samples indicate that the weathering of the soils has considerably advanced.

The total C and N contents of two soils were high. However, the C/N ratios were observed to be greater in Kawatabi soil than Sagamihara soil. The C/N ratios suggest that nitrogen fertility of the soils is higher in Sagamihara soil than in Kawatabi soil.

of the Soils

Exchangeable cations (me/100 g)				Base saturation degree(%)	Phosphate absorption (P_2O_5mg/100 g)	Major clay mineral
Ca	Mg	K	Na			
0.59	0.42	0.69	0.18	7	2710	Chloritized 2:1 mineral
3.7	1.22	0.28	0.09	13	3250	Allophone, Imogolite

The exchangeable cations reflected the rock types of the parent ashes. Namely, the amounts of the exchangeable Ca and Mg were considerably higher in the Sagamihara soil and the amounts of the exchangeable K and Na were higher in the Kawatabi soil.

The clay fractions are dominated by chloritized 2:1 mineral in Kawatabi soil and by allophane and imogolite in Sagamihara soil. Since the base saturation of both samples is low, the soil acidity of these samples reflected the clay mineral compositions. Allophane and imogolite are weaker in acid property than chloritized 2:1 mineral (5, 6). Therefore, the soil acidity was weaker in Sagamihara soil than in Kawatabi soil.

2) *Growth and Nutrient Uptake of Dent Corn*

The growth of dent corn in the two soils is shown in Fig. 1 and 2. The nutrient concentrations of dent corn is shown in Table 3 and the total amounts of nutrients absorbed by dent corn is shown in Table 4.

The growth of dent corn planted in the F plots was observed to be normal in both soils.

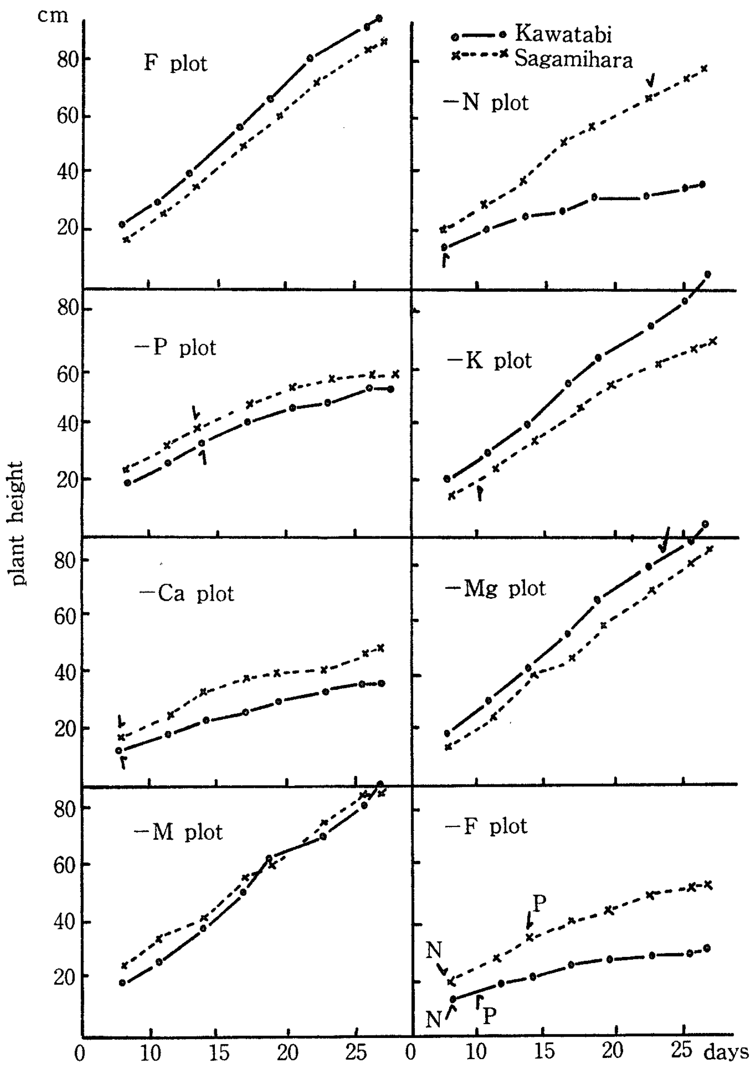

FIG. 1. Plant height of dent corn after transplanting. Arrows in the figures show the time when the deficiency symptoms appeared.

The growth of dent corn in the -N plot was inferior to that of the F plot, especially in Kawatabi soil. As expected from the C/N ratios of the soils, the plant height, dry weight and leaf numbers at harvest in the -N plot were greater in Sagamihara soil than in Kawatabi soil. The N concentrations of the plants in all the plots except the -N and -F plots were 3.7–5.1%. The similar results are obtained by Ishizuka and Kin (7). As for the N uptake of plants in -N plot, both the N concentration and amount were clearly higher in Sagamihara soil than Kawatabi soil. The C/N ratios of soil organic matter in Andosols were found to decrease

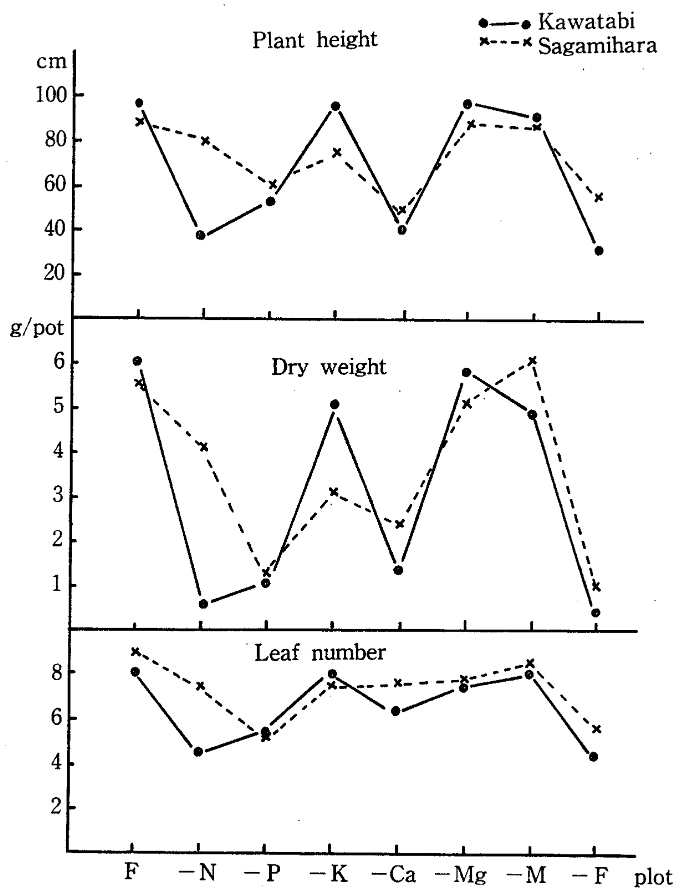

Fig. 2. Plant growth at harvest stage.

Table 3 *Nutrient Concentrations of Dent Corn*

Soil	Treatment	N (%)	P_2O_5 (%)	K_2O (%)	CaO (%)	MgO (%)	Zn (ppm)	Cu (ppm)
Kawatabi	+F	3.99	0.74	7.54	0.81	0.28	90	8.6
	−N	1.09	1.00	7.20	0.80	0.27	81	4.1
	−P	4.40	0.23	7.33	1.39	0.39	88	8.3
	−K	4.69	0.78	4.33	1.03	0.46	89	6.7
	−Ca	4.90	0.94	8.20	0.20	0.35	108	10.8
	−Mg	4.20	0.70	7.89	0.80	0.16	76	7.0
	−M	4.23	0.73	8.41	0.85	0.30	70	4.4
	−F	1.12	0.47	5.33	0.39	0.35	39	4.8
Sagamihara	+F	4.77	0.81	5.53	0.85	0.35	103	12.3
	−N	2.10	0.88	5.99	0.49	0.20	48	8.4
	−P	3.77	0.23	7.16	2.02	0.34	130	14.3
	−K	4.97	0.73	2.25	1.04	0.74	125	nd
	−Ca	5.01	1.11	4.58	0.37	0.34	114	12.5
	−Mg	4.70	0.84	5.80	0.75	0.27	105	12.6
	−M	4.60	0.77	5.34	0.81	0.34	82	11.4
	−F	3.58	0.22	4.00	2.55	0.81	nd	11.8

TABLE 4 *Amounts of Nutrients Absorbed by Dent Corn (mg/pot)*

Soil	Treatment	N	P_2O_5	K_2O	CaO	MgO	Zn ($\times 10^{-3}$)	Cu ($\times 10^{-3}$)
Kawatabi	+F	240	44	453	48	17	540	52
	−N	6	6	40	4	2	45	2
	−P	46	2	76	14	4	91	9
	−K	244	41	225	54	24	465	35
	−Ca	66	13	111	3	5	146	15
	−Mg	244	41	457	47	9	440	40
	−M	250	36	413	42	15	343	21
	−F	5	2	24	2	2	17	2
Sagamihara	+F	269	47	311	48	19	582	69
	−N	89	37	254	21	9	203	35
	−P	47	3	88	25	4	161	18
	−K	160	24	73	34	24	404	12
	−Ca	122	27	112	9	8	277	30
	−Mg	238	43	294	38	13	529	64
	−M	282	47	327	50	21	504	70
	−F	35	2	39	25	8	175	12

with the decrease of the soil acidity (8). As mentioned above, the soil acidity is mainly dependent on the clay mineral composition of the soils and allophane and imogolite have weaker acid properties than chloritized 2:1 mineral. Therefore, the N fertility will be higher in Sagamihra soil than in Kawatabi soil.

The growth of dent corn in the -P plot was very inferior to that in the F plot. Phosphate deficiency disease in the -P plot of both soils was observed in the early stage of plant growth. The P concentration of the plants in the -P plot of the both soils was much lower than those in F plot and the P absorbed by the plants in the -P plot was only about 4% of those in the F plots. As the P content in volcanic ash is very small and active Al relating to high P absorption is abundant in Japanese upland soils formed from the volcanic ashes, heavy application of P fertilizer is a common practice to obtain high crop yield.

There was no notable difference in plant growth between the F plot and -K plot in Kawatabi soil. However, in the case of Sagamihara soil, the plant growth of the -K plot was inferior to that of the F plot, indicating the K deficiency. The K uptake by the plant in the -K plot was considerably lower, especially in Sagamihara soil, than that in the F plot. The K content in volcanic ash increases with the increase of Si content as described by Shoji et al (1) and the greater part of K in the volcanic ash is contained in the volcanic glass (9) which is the most abundant and the most weatherable. The results of the plant growth and the K uptake by the plants in -K plot reflected the difference in the rock types of the parent ashes. Therefore, the K fertility is higher in Kawatabi soil than in Sagamihara soil.

The plant in the -Ca plot showed very poor growth, especially in Kawatabi soil, and the Ca deficiency disease appeared in the early stage of growth in both soils. Though the plant growth of the -Mg plot was similar to that of the F plot in both soils, Mg deficiency disease was observed in only Kawatabi soil. Both the Ca uptake by dent corn in the -Ca plot and the Mg uptake by dent corn in the -Mg plot were higher in Sagamihara soil than in Kawatabi soil. The Ca and Mg contents in the parent ash decrease with the increase in the total Si content (1). Reflecting the rock types of the parent ashes of the two soils, the amounts of the exchangeable Ca and Mg in Sagamihara soil were greater than in Kawatabi soil. It is clear that the fertility of both elements is higher in Sagamihra soil than in Kawatabi soil.

The plant growth of -M plot was almost the same as that of the F plot and minor element deficiency disease didn't appear. The Zn concentrations of the plants in -M plot were 70 ppm in Kawatabi soil and 82 ppm in Sagamihara soil. These concentrations are much higher than the critical value of Zn deficiency of the higher plants. On the other hand, the Cu concentrations of the plants in -M plot were 4 ppm in Kawatabi soil and 11 ppm in Sagamihara soil. The value of Kawatabi soil is almost the same as the critical value of the Cu deficiency of the higher plants. The Cu content of the parent ash decreases as total Si content increases, but the Zn content is not correlated with total Si (10). The lower Cu uptake by dent corn in -M plot of Kawatabi soil is owing to the felsic rock types of the parent ash.

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