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Heavy Metal Concentration in Plant Leaves from Three Sites in Mie Prefecture

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Abstract

To identify heavy metal accumulator plants suitable for phytoremediation, concentration of heavy metals was analyzed in leaves of woody and herbaceous plants obtained from three sites in Mie Prefecture. The elemental concentrations varied considerably among the different plant species. A large intraspecific variation was also observed in the elemental concentrations at the different sites, corresponding with the concentration of each element in the soil of the sites. *Chengiopanax sciadophylloides* was identified as a strong and specific Mn accumulator. In contrast, *Clethra barbinervis* seems to absorb many kinds of heavy metals from soil, but its ability to transfer a heavy metal from soil to plant was found to be lower than that of *C. sciadophylloides*.

Key Words: heavy metal concentration, hyperaccumulator, *Chengiopanax sciadophylloides*, *Clethra barbinervis*

Introduction

Application of heavy metal-accumulating plants is a promising method for remediation of soils polluted with heavy metals. About 450 hyperaccumulator plant species for seven heavy metals (Cd, Co, Cu, Mn, Ni, Tl, and Zn) are known[1].

Little research has been conducted in Japan on heavy metal-accumulating plants. The concentrations of various elements in wild plants grown at an area artificially polluted by industrialization were determined by Yamada et al.[2]. Tatekawa et al.[3] reported high levels of Cd in few species of Asteraceae, Polygonaceae, Cyperaceae, and Liliaceae families. Memon et al.[4-6] analyzed heavy metal concentration in plants distributed in the temperate forest of central Japan. Furthermore, Harada and Hatanaka[7] analyzed natural background levels of trace elements in wild plants, whereas Takada et al.[8,9] examined heavy metal concentrations in a number of plants collected from many places in Japan, including polluted and non-polluted areas. Regarding Japanese heavy metal hyperaccumulators, Mizuno et al.[10] reported Ni accumulation by *Thlaspi japonicum* and Kubota and Takenaka[11] identified *Arabis gemmifera* as a Cd hyperaccumulator.

In the present study, in order to locate and identify suitable plants for heavy metal accumulation, we analyzed concentration of heavy metals in leaves of woody and herbaceous plants obtained from three sites in Mie prefecture. In general, heavy metal hyperaccumulator plants grow in zones with high concentrations of heavy metals. Since serpentine soils and mineral belt areas are known to have high concentrations of some heavy metals, we also analyzed plants growing in areas with such soils in Mie prefecture.

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Materials and Methods

Leaves of numerous woody and herbaceous plants that are common at the sampling site were collected from Site A (a forest at Shiraki-cho, Toba city, a serpentine soil area), Site B (Mt. Fujiwara, at Fujiwara-cho, Inabe city, a mineral belt zone), and Site C (Hirakura Experiment forest, Mie University at Misugi-cho, Tsu city). Mature intact leaves were collected from healthy branches or twigs of the plant. Soil samples (5-10 cm in depth) near each sampled plant in each site were collected.

The plant samples were washed with distilled and deionized water, dried at 70℃ in an oven for 72 h, and then ground using mortar and pestle. The soil samples were air-dried for 1 to 2 weeks and then dried at 100℃ for 2 days. The dried soil samples were passed through a 2 mm mesh sieve. Powdered plant leaves (0.1-1 g) were placed in plastic tubes with a plastic stopper. Twenty times (vol/wt) of 1 M HCl was added to the tubes, shaken reciprocally for 5 h, and filtered[12]. One gram of each soil sample was placed in a tall beaker and digested with HNO_3 and $HClO_4$, then filtered and diluted with water to make the final volume 50 mL. The concentration of metals in the extracts and digested solutions was measured using an atomic absorption spectrometer (Shimadzu AA-6500).

Results and Discussion

Heavy metal concentrations in the soil samples from the three sites are shown in Table 1. Considerable variation was observed in the metal profiles in the soils from the three sites. The soil at Site A is a serpentine soil; high concentrations of Cr, Mn, Co, and Ni were detected in this soil. The soil at Site B is mineral belt soil; high concentrations of Cu, Zn, Cd, and Pb were detected in this soil. The soil at Site C has no special properties of heavy metal concentration.

Heavy metal concentrations in the plant samples are shown in Table 2. Because the elemental concentrations varied considerably among the plant species, we speculated that the mineral elemental status of each species might be a hereditary character under genetic control. Some intraspecific variations in elemental concentrations were observed at each site and a large intraspecific variation was observed among the different sites, depending on the concentration of elements in the soil of each site.

As shown in Tables 1 and 2, Mn concentration in *C. sciadophylloides* (range, 4,870-1,600 mg kg^{-1}; average, 3,106 mg kg^{-1}) at Site C was about 9 times that in soil (average 341 mg kg^{-1}); however, Mn concentration in other plants collected from site C did not demonstrate higher concentrations of heavy metals than that in soil except for *C. barbinervis* (range, 1,230-98 mg kg^{-1}; average 564 mg kg^{-1}) and *Wisteria floribunda* (408 mg kg^{-1}). Manganese concentration in *C. sciadophylloides* was the highest of all plants collected from Site C. Manganese concentration in *C. sciadophylloides* grown in a forest at Uresino-cho, Matsusaka city was over 10 g kg^{-1} [13]. Because of its ability to selectively accumulate Mn, and the concentration of other heavy metals is not high, *C. sciadophylloides* is useful for phytomining of Mn.

Table 1 Heavy metal concentration of soils at three sites in Mie prefecture

mg kg^{-1}

Sites	Cr	Mn	Fe	Co	Ni	Cu	Zn	Cd	Pb
Site A	1990±750	1300±420	82600±13500	118±23	1310±200	10.6±5.7	78.4±21.2	0.00±0.00	6.6±3.7
Site B	39.4±10.4	513±261	47100±6000	6.54±3.40	24.5±7.21	70.6±21.9	222±45	0.62±0.56	121±38
Site C	10.8±3.1	341±235	34800±3400	5.22±2.61	7.3±0.9	10.7±1.0	102±76	0.00±0.00	23.4±7.0

Site A, Toba city Site B, Mt. Fujiwara Site C, University forest

Table 2 Heavy metal concentrations in the leaves of each plant species

mg kg^{-1}

plant species	sampling site	Cr	Mn	Fe	Co	Ni	Cu	Zn	Cd	Pb	Mg	Ca
Abelia spathlata	Site A	tr	31	115	tr	17.6	4.83	10.6	tr		9520	6230
Abies firma	Site C	tr	141	45	tr	1.31	1.76	15	tr	tr	1700	3030
Acer carpinifolium	Site C	tr	197	121	tr	1.3	13.6	73.9	tr	tr	5670	13400
Acer palmatum	Site B	tr	411	87	tr	2.43	6.18	44.3	0.54	1.61		
Acer sieboldianum	Site C	1.56	94		tr	0.59	3.51	36.1	tr	2.2		
Acorus gramineus	Site A	tr	67		tr	8.43						
Aesculus turbinata	Site C	tr	78		tr	0.83	5.59	11.8	tr	3.47		
Albizzia Julibrissin	Site A	tr	29	59.9	tr	14.2	1.95	7.83	tr		7800	2390
Alnus firma	Site A	tr	59	99.4	tr	8.47	3.63	14.6	tr		5260	10100
Alnus japonica	Site C	2.23	156		tr	1.29	7.16	27.9	0.13	3.64		
Angelica Miqueliana	Site A	tr	123		tr	10.3						
Aquilegia Buergerina	Site A	tr	59		tr	33.9						
Aralia elata	Site A	tr	225	86.4	tr	28.6	6.55	28.9	tr		14700	5040
Artemisia vulgaris	Site A	tr	256		tr	13.9						
Aucuba japonica	Site B		216				5.87	30.6	0.58	6.32		
Aucuba japonica	Site B		346				4.44	22.1	0.51	3.03		
Aucuba japonica	Site B		1157				4.04	21.9	tr	tr		
Benzoin umbellatum	Site C	tr	335	52.3	tr	2.69	7.81	49.3	tr	tr	3580	4500
Benzoin umbellatum	Site A	tr	164	172	1.44	12	3.85	33.7	tr		8940	5670
Buxus microphylla	Site B		120				3.21	74.2	tr	tr		
Callicarpa mollis	Site A	tr	423	89.9	tr	4.97	7.09	23.4	tr		2860	5510
Camellia japonica	Site C	tr	226	40.9	tr	0.44	5.22	8.39	tr	tr	1150	8910
Camellia japonica	Site A	tr	1460		tr	10.1						
Camellia japonica	Site A	tr	1050		tr	10.7						
Cardamine flexuosa	Site A	tr	94		tr	39.9						
Carpinus japonica	Site C	tr	163	39.8	tr	0.85	5.9	13	tr	tr	2780	5620
Carpinus japonica	Site C	0.26	115		tr	0.75	0.77	11.3	tr	tr		
Carpinus laxiflora	Site C	1.72	198		tr	1.12	8.21	20	tr	2.64		
Carpinus Tschonoskii	Site C		93		tr	0.88	9.69	55.7	tr	1.78		
Celtis sinensis	Site A	tr	59	91.9	tr	7.11	7.47	11	tr		13400	24300
Cephalotaxus drupacea	Site A		231		tr	19.72						
Cephalotaxus drupacea	Site A		170		tr	25.7						
Chengiopanax sciadophylloides	Site C	1.08	4870		tr	1.53	5.68	15	0.05	2.79		
Chengiopanax sciadophylloides	Site C	1.69	4380		tr	2.66	6.4	27.3	0.09	2.61		
Chengiopanax sciadophylloides	Site C	3.51	2390		tr	2.22	4.84	34.5	0.13	3.45		
Chengiopanax sciadophylloides	Site C	2.9	2290		tr	3.16	7.53	80.3	0.18	3.1		
Chengiopanax sciadophylloides	Site C	tr	1600	63.1	tr	3.72	14.4	27.6	tr	tr	8880	4590
Cinnamomum Camphora	Site A	tr	223	42.4	tr	3.57	9.71	13.2	tr		4930	3050
Cinnamomum japonicum	Site C	tr	43	92.6	tr	tr	3.22	7.03	tr	tr	780	5540
Cinnamomum japonicum	Site A	tr	212		tr	60.1						
Cinnamomum japonicum	Site A	tr	109	73.3	tr	24.5	3	8.75	tr		3620	4570
Cinnamomum japonicum	Site A	tr	58		tr	39.4						
Cinnamomum japonicum	Site A	tr	101		tr	54.7						
Cinnamomum japonicum	Site A	tr	118		tr	88.2						
Cinnamomum japonicum	Site B		57				5.32	9.22	tr	tr		
Cinnamomum japonicum	Site A	tr	221		tr	84						
Cirsium japonicum	Site A		156		tr	88.03						

plant species	sampling site	Cr	Mn	Fe	Co	Ni	Cu	Zn	Cd	Pb	Mg	Ca
Cirsium japonicum	Site A		89		tr	9.3						
Cirsium japonicum	Site A		59		tr	62.7						
Citrus Unshiu	Site B	1.7	11		0.2	0.42	5.37	13.5	0.01	2.3		
Clethra barbinervis	Site C	1.72	689		12.3	11	5.05	238	0.99	3.28		
Clethra barbinervis	Site C	2.05	1230		42.8	12.9	5.48	421	2.36	4.11		
Clethra barbinervis	Site C	1.56	736		17.7	8.33	5.38	301	1.16	3.83		
Clethra barbinervis	Site C	1.81	500		12.9	8.81	5.28	295	1.1	3.05		
Clethra barbinervis	Site C	2.32	338		1.51	3.89	6.98	11.6	0.67	3.2		
Clethra barbinervis	Site C	tr	98	50.2	4.76	8.02	13.8	132	tr	tr	4150	1210
Clethra barbinervis	Site C	2.2	619		2.6	4.95	5.52	79.6	0.47	3.16		
Clethra barbinervis	Site C	1.22	304		2.23	3.1	5.51	61	0.46	3.13		
Clethra barbinervis	Site A	tr	1220	190	295	110	6.22	116	0.99		14600	1790
Clethra barbinervis	Site A	2.9	1200		25.4	223	6.35	96.9	0.56	3.21		
Clethra barbinervis	Site A	8.28	1140		25.1	230	3.97	186	0.92	3.26		
Clethra barbinervis	Site A	tr	1100	60.5	21	104	4.01	15.6	tr		13800	6790
Clethra barbinervis	Site A	1.98	677		122	97.5	6.78	93.4	0.8	2.71		
Clethra barbinervis	Site A	1.5	1070		279	211	4.32	87	0.68	2.71		
Clethra barbinervis	Site A	tr	560	203	39.4	150	4.99	67.8	0.47		14000	6490
Clethra barbinervis	Site A	2.48	1490		140	332	6.27	90.9	0.75	3.06		
Clethra barbinervis	Site A	1.68	1050		158	278	6.6	89.5	0.58	2.56		
Clethra barbinervis	Site A	2.26	470		43.3	407	4.08	66.9	0.72	3.1		
Clethra barbinervis	Site A	2.36	1210		174	290	4.73	136	1.24	2.58		
Clethra barbinervis	Site A	2.11	496		19.3	158	7.59	95.6	0.5	3.23		
Clethra barbinervis	Site A	1.26	725		60.9	167	4.6	110	0.45	2.72		
Clethra barbinervis	Site B	tr	1530	110	58.7	33.1	5.43	246	10.9	1.43		
Clethra barbinervis	Site B	0.14	1590		69.3	43.3	6.87	288	10	1.62		
Clethra barbinervis	Site B	tr	1050		23.8	17.3	7.49	323	18.6	2.3		
Clethra barbinervis	Site B	tr	1030	103	15.2	13	7.73	275	14.6	16.3		
Clethra barbinervis	Site B	0.35	604		28.5	13.8	9.14	354	8.23	1.65		
Clethra barbinervis	Site B	tr	1130	80.4	31.8	25.3	6.58	227	6.98	2.64		
Clethra barbinervis	Site B	0.48	1220		34.3	25	10.8	278	7.28	1.8		
Clethra barbinervis	Site B	1.13	1360		59.8	23	8.29	196	6.29	1.8		
Clethra barbinervis	Site B	tr	1090	81.2	24.5	31	5.3	179	5.42	1.43		
Clethra barbinervis	Site B	0.3	1230		108	13	8.32	74.4	2.09	1.65		
Clethra barbinervis	Site B	0.61	2010		45.2	50.1	8.47	383	5.48	1.02		
Clethra barbinervis	Site B	0.42	459		12.6	15.3	5.79	187	3.35	1.05		
Clethra barbinervis	Site B	tr	2230	110	35.5	21.9	5.81	294	6.84	tr		
Clethra barbinervis	Site B	0.1	1690		37	42.5	5.15	196	6.46	1.7		
Clethra barbinervis	Site B	tr	928	82.8	56.7	13.2	8.79	97.4	22.3	tr		
Clethra barbinervis	Site B	tr	1170	79.7	14.6	16.8	5.82	269	4.57	tr		
Cleyera ochnacea	Site C	tr	54	35.9	tr	7.81	3.77	8.71	tr	tr	2280	7870
Cleyera ochnacea	Site A	tr	206	154	tr	14.2	1.52	6.1	tr		13900	13900
Cleyera ochnacea	Site A	tr	345		tr	17.3						
Cleyera ochnacea	Site A	tr	243		tr	16						
Cornus controversa	Site C	tr	111	50.6	tr	0.45	6.57	74.3	0.31	tr	2510	4690
Cryptomeria japonica	Site A	tr			tr	7.47						
Cryptomeria japonica	Site A	tr			tr	3.81						
Damanacanthus indicus	Site A		42		tr	49.19						
Daphniphyllum macropodum	Site B		19				3.91	17.4	tr	tr		

plant species	sampling site	Cr	Mn	Fe	Co	Ni	Cu	Zn	Cd	Pb	Mg	Ca
Daphniphyllum macropodum	Site B		17				2.72	24.7	tr	3.35		
Deutzia Maximowicziana	Site C	tr	54	58.7	tr	2.09	3.29	14.6	tr	tr	8040	36600
Diospyros Kaki	Site A	tr	295	85.8	tr	9.47	1.58	69.2	0.82		11400	2660
Elaeagnus glabra	Site A	tr	49		tr	10.2						
Elaeagnus pungens	Site B	tr	187	57.8	tr	7.39	14.7	19.6	tr	tr		
Elaeagnus pungens	Site B		1340				11.7	29.6	tr	3.41		
Elaeagnus pungens	Site B		251				13.7	26.8	tr	3.08		
Elaeagnus pungens	Site B		2090				5.64	44.5	tr	7.45		
Eriobotr ya japonica	Site A	tr	265		tr	3.92						
Eurya japonica	Site C	tr	299	46	tr	3.81	5.07	8.6	tr	tr	1370	1180
Eurya japonica	Site A	tr	575		tr	5.37						
Eurya japonica	Site A	tr	811		tr	8.43						
Eurya japonica	Site A	tr	502	54.4	tr	5.59	1.56	9.36	tr		7180	11700
Eurya japonica	Site B		786				3.56	8.35	tr	tr		
Eurya japonica	Site B		730				3.82	10.3	tr	tr		
Evodiopanax innovans	Site B	tr	1150	80.5	tr	2.07	5.73	277	6.55	0.69		
Evodiopanax innovans	Site B	tr	214	77	tr	1.37	6.19	173	5.66	0.44		
Evodiopanax innovans	Site B	tr	577	75.5	tr	2.48	3.84	331	14	0.46		
Evodiopanax innovans	Site B	tr	154	73.9	tr	2.6	5.27	219	4.89	1.03		
Fagara mantchurica	Site A		78	21.7	tr	1.69	2.2	7.8	tr		18800	3300
Ficus erecta	Site A	tr	197	151	tr	6.96	5.67	29.8	tr		20200	44200
Gardenia jasminoidesw	Site A	tr	37	48.9	tr	10.7	3.86	10.7	tr		12800	10300
Gleichenia dichotoma	Site A	tr	1420		tr	6.1						
Gleichenia dichotoma	Site A	tr	1790		tr	2.07						
Gleichenia dichotoma	Site A	tr	600	87.3	tr	3.17	4.83	26.8	tr		1170	
Gleichenia glauca	Site A	tr	1280		tr	21.1						
Hamamelis obtusata	Site C	1.69	128		tr	0.98	7.59	14.8	tr	2.85		
Hamamelis japonica	Site B	tr	443	72.4	tr	4.92	5.57	13.1	0.24	1.88		
Hydrangea hirta	Site C	tr	53	98.1	tr	5.24	9.2	57.5	tr	tr	2660	
Hydrangea hirta	Site B	tr	121	380	tr	11	6.31	30.1	tr	3.94		
Ilex crenata	Site C		295	60.4	tr	3.58	4.37	258	0.86	tr	3600	5800
Ilex crenata	Site B	0.78	1037				2.43	931	14.77	tr		
Ilex crenata	Site B	tr	3080	98.8	tr	5.11	5.33	1580	29.3	0.47		
Ilex crenata	Site B	tr	2780	83	tr	11.4	5.04	459	16.2	1.49		
Ilex crenata	Site B		955				4.65	656	7.42	tr		
Ilex crenata	Site B	tr	1270	74.4	tr	6.13	3.6	908	23.5	1.32		
Ilex crenata	Site B		3340				5.79	828	10.4	tr		
Illicium relicium	Site C	tr	93	34.9	tr	4.43	1.73	9.19	tr	tr	2250	1060
Illicium relicium	Site B		192				3.5	13.7	tr	tr		
Illicium relicium	Site B		312				1.96	9.45	tr	tr		
Illicium relicium	Site B		236				3.14	14.2	tr	tr		
Lespedeza bicolor	Site A	tr	45	69	tr	11.9	6.28	11.7	tr		5750	3030
Ligularia tussilaginea	Site A	tr	50		tr	24.6						
Ligularia tussilaginea	Site A	tr	76		tr	18.5						
Ligustrum japonicum	Site A	tr	42		tr	11.7						
Ligustrum japonicum	Site A	tr	38	31.3	tr	5.53	2.95	25.8	tr		5310	3000
Ligustrum japonicum	Site A	tr	102			1.05						
Ligustrum japonicum	Site B		145				5.17	74.2	tr	tr		
Litsea glauca	Site C	tr	278	76.5	tr	1.51	4.91	29.5	tr	tr	856	3530

plant species	sampling site	Cr	Mn	Fe	Co	Ni	Cu	Zn	Cd	Pb	Mg	Ca
Litsea glauca	Site A	tr	166		tr	20.3						
Litsea glauca	Site B		145				4.87	44.2	0.92	tr		
Litsea glauca	Site B		220				5.69	47.6	0.88	2.95		
Litsea glauca	Site B		185				7.62	30.8	1.79	tr		
Lycopodium serratum	Site A	2.28	47		tr	26.5						
Machilus Thunbergii	Site A	tr	159	70.3	tr	15.5	9.84	36.8	tr		2880	1730
Maesa japonica	Site A		19		tr	12.66						
Mallotus japonicus	Site C	2.42	234		tr	0.91	7.26	40.1	tr	2.79		
Mallotus japonicus	Site A		137	77.8	tr	8.76	5.81	23	tr		11200	9600
Meliosma myriantha	Site C	2.18	116		tr	0.39	6.03	13.3	tr	4.11		
Miscanthus sinensis	Site A	tr	225		tr	2.08						
Myrica rubra	Site A	tr	706		tr	5.07						
Myrica rubra	Site A	tr	601		tr	14.5						
Oenanthe Stolonifera	Site A	tr	419		tr	18.9						
Ophiopogon japonicus	Site A	tr	46		tr	14.7						
Orixa japonica	Site C	tr	38	48.5	tr	3.06	10.6	26.9	tr	tr	3450	9390
Orixa japonica	Site B	tr	64	92	tr	1.99	6.5	26	0.15	1.49		
Osmanthus ilicifolius	Site C	tr	42	31.5	tr	0.59	2.58	26.3	tr	tr	479	10200
Osmanthus ilicifolius	Site A	tr	197		tr	34.4						
Osmanthus ilicifolius	Site A	tr	79		tr	23.8						
Osmanthus ilicifolius	Site A	tr	257	169	tr	26.1	4.1	32.1	tr		8510	7280
Ostrya japonica	Site C	2.35	328		tr	2.71	7.61	12.4	tr	3.31		
Parabenzoin trilobum	Site B	tr	835	99.2	tr	2.89	11.6	105	6.22	1.27		
Pieris japonica	Site C		219	71.8	tr	2.17	4.48	13.7	tr	tr	730	7700
Pieris japonica	Site A	3.55	2491		tr	22.41						
Pieris japonica	Site A		1208		tr	15.18						
Pieris japonica	Site A		153	84.4	tr	12.15	3.2	13.8	0.99		6010	8500
Pieris japonica	Site B		962				6.84	33.4	1.71	tr		
Pieris japonica	Site B		608				4.83	33.8	0.78	tr		
Pieris japonica	Site B		1475				4.05	15.5	tr	tr		
Phalaris arundinacea	Site A	tr	87		tr	3.17						
Rhododendron macrosepalum	Site A	4.16	947		tr	6.51						
Phyllostachys bambusoides	Site A	tr	13		tr	5.13						
Pinus Thunbergii	Site A	tr	66		tr	22.9						
Pleioblastus Simonii	Site A	tr	71		tr	2.82						
Podocarpus macrophylla	Site A	tr	26		tr	6.46						
Podocarpus macrophylla	Site A	tr			tr	2.32						
Populus Sieboldi	Site C	tr	73	38.8	tr	0.52	5.9	69.3	tr	tr	2680	4710
Quercus acutissima	Site A	tr	768	55.3	tr	6.07	3.95	11	tr		4420	5270
Quercus crispula	Site C	0.82	159		tr	1.3	2.9	16.6	tr	1.62		
Quercus phillyraeoides	Site A	tr	1110		tr	10.1						
Quercus phillyraeoides	Site A	tr	751		tr	17.2						
Quercus phillyraeoides	Site A	tr	777		tr	14.7						
Quercus phillyraeoides	Site A	tr	381	140	tr	10.8	3.06	10.5	tr		6130	8350
Quercus serrata	Site A	tr	386	79.4	tr	7.25	3.31	13.1	tr		6930	6530
Quercus serrata	Site B	tr	309	59.4	tr	6.61	8.97	21.7	tr	1.38		
Rapanaea neriifolia	Site A	tr	46		tr	6.25						
Rapanaea neriifolia	Site A	tr	66		tr	14.5						
Rhododendron Kaempferi	Site B	tr	181	127	tr	5.7	5.99	35.4	3.26	4.69		

plant species	sampling site	Cr	Mn	Fe	Co	Ni	Cu	Zn	Cd	Pb	Mg	Ca
Rhododendron quinquefolium	Site C	tr	33	92	tr	3.22	7.12	20.8	tr	tr	2490	1650
Rhododendron reticulatum	Site C	tr	68	79.3	tr	5.25	6.26	21.2	tr	tr	4460	5150
Rhododendron sanctum	Site A	tr	315	162	1.45	19.6	2.08	11.2	0.42		10300	6870
Rosa multiflora	Site A	tr	27		tr	16.2						
Rubus Burgeri	Site A	tr	677		tr	29.4						
Rubus Burgeri	Site A	tr	161		tr	22.5						
Rubus crataegifolius	Site A	tr	80		tr	18.8						
Salix integra	Site C	2.37	26		tr	1.52	5.51	75.2	0.28	3.34		
Sapium japonicum	Site C	tr	38	41.9	tr	0.83	7.02	23	tr	tr	2170	2070
Skimmia japonica	Site B		44				3.81	37.7	2.78	tr		
Skimmia japonica	Site B		86				3.62	59.1	1	tr		
Solidago altissima	Site A	tr	55		tr	23.3						
Sonchus oleraceus	Site A	tr	53		tr	3.96						
Sphenomeris chusana	Site A	tr	54		tr	5.09						
Sphenomeris chusana	Site A	tr	100		tr	8.12						
Stephanotis japonica	Site A	tr	214		tr	35.1						
Stephanotis japonica	Site A	tr	56		tr	13.6						
Stewartia monadelpha	Site C	2.93	315		tr	3.88	3.47	15	tr	3.39		
Torreya nucifera	Site C	tr	33	45		1.82	5.17	14.9	tr	tr	1050	5310
Torreya nucifera	Site B		681				4.93	19.7	tr	tr		
Trachycarpus excelsa	Site A	tr	32		tr	13.5						
Verbena phlogiflora	Site C	2.63	77		tr	1.59	9.08	27	tr	3.91		
Verbena phlogiflora	Site A	tr	23	133	tr	10.7	11.1	18.4	tr		6520	5640
Viburnum tomentosum	Site C	tr	57	59.4	tr	0.25	7.32	15	tr	tr	3930	6080
Wistaria floribunda	Site C	1.52	408		tr	1.56	8.15	34	tr	3.13		
Wisteria floribunda	Site A	tr	281	88.9	tr	7.08	3.6	15.1	tr		7410	9380

tr; trace no datum; not determined

Site A, Toba city Site B, Mt.Fujiwara Site C, University forest

Table 3 Differences of heavy metal concentrations in the leaves of *Clethra barbinervis* sampled from three sites

mg kg^{-1}

Sampling Site	Cr	Mn	Fe	Co	Ni	Cu	Zn	Cd	Pb	Mg	Ca
SiteA	2.06	955	151	108	212	5.42	96	0.66	2.91	14100	5020
SiteB	0.22	1270	92	41	24.9	7.24	241	8.71	2.27		
SiteC	1.84	564	50	12	7.6	6.63	192	0.9	2.97	4150	1210

Site A, Toba city Site B, Mt. Fujiwara Site C, University forest

At Site C, Mn, Co, and Zn concentrations in *C. barbinervis* were higher than those in soil (Mn: 564 mg kg^{-1} in *C. barbinervis* and 341 mg kg^{-1} in soil; Co: 12.1 mg kg^{-1} in *C. barbinervis* and 5.22 mg kg^{-1} in soil; Zn: 192 mg kg^{-1} in *C. barbinervis* and 102, Table 1 and 3). *C. barbinervis* also accumulated Cd (0.9/0.0). In contrast to *C. sciadophylloides*, *C. barbinervis* seems to absorb many kinds of heavy metals from soil but its ability to transfer Mn from soil to plant was lower than that of *C. sciadophylloides*.

As shown in Table 3, average concentrations of Co, Ni, and Mg in the leaves of *C. barbinervis* were higher in leaves collected at Site A; and Zn and Cd concentrations were higher in leaves collected in Site B than at other areas. These trends may have resulted from the concentration of each heavy metal in soil at these sites. Ni concentration in *C. barbinervis* collected at Site A was highest but did not meet or exceed the criterion of hyperaccumulation by Brooks[1] (1000 mg kg^{-1}). The concentrations of Zn and Cd are highest

in *Ilex crenata* from Site B (Table 2) but the concentrations did not meet or exceed the criteria by Brooks[1], 10,000 and 100 mg kg^{-1} respectively.

The concentration of heavy metals in wild plants varies according to plant species and further study is required to search for more hyperaccumulator plants in Japan.

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三重県下三地点における植物葉中の重金属元素濃度

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要　旨

重金属回収に用いうる植物を探索するため，三重県下三地点における木本，草本植物の葉の重金属元素濃度を測定した。その結果，重金属濃度は植物の種によって大きく変動することが明らかになった。同じ地点の同じ植物種であっても濃度は変動し，また，地点が異なる同じ植物種の場合には，その地点における土壌の当該重金属濃度に応じて葉中の濃度が大きく変動した。コシアブラ（*Changeopanax sciadophylloides*）はBrooksの定義による超集積性植物であること，マンガンのみを特異的に集積し他の重金属は集積しないことが確認された。また，リョウブ（*Clethra barbinervis*）は多種類の重金属元素を高濃度に集積するが，土壌からの移行係数はコシアブラによるマンガン吸収の場合に比べて小さかった。