Effects of mineral nutrients with biowaste compost as soil conditioner for farmland

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Abstract

Bio-waste, separately collected from municipal solid waste, can be reused as soil conditioner after composting. In this study, a series of field investigations was conducted on the essential minerals (Ca, Fe, Mg, Mn, Zn, Cu) and toxic heavy metals such as Pb, Cr, Cd contained in soil which have been amended with biowaste composts and/or amended with chemical fertilizer plus lower composts. The results show that the biowaste compost applications likely led to increase mineral elements in soils for Ca, Mg, Mn and Zn. It was also found that biowaste compost showed the tendency of the increases of bio-available forms of Fe, Mn and the reverse situation for Mg. Comparison of supply ratios (SR = bio-available content/total content×100%) of all elements in compost-amended and no amended soils showed that the leachability of Fe, Mn, Zn, Pb was slightly increased by biowaste compost application, and gave a less change for other elements.

Keywords: mineral nutrients, compost, recycling, heavy metals, farmland

Introduction

Recently, large amounts of composting products derived from various solid wastes are increasingly applied in farmland amendment. Two objectives are recognized, firstly, as the soil conditioner, supplying plant nutrients, improving the physical and chemical characteristics of soils (Gallards-Lara and Nogales, 1989; Pinamonti et al., 1997; Anikwe and Nwobado 2002) and thus increasing crop yields (Roe et al., 1993; Wong et al., 1999); another one as a beneficial means of solid waste disposal, saving landfill space

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(Tisdell and Breslin, 1995; Giusquiani et al., 1998). Yet it is noticeable that the farmland amendment shouldn't be a random action but a carefully managed practice.

In this study, we intended to examine the farmland uses of composts by field investigations, for addressing the benefits of recycling composts. As the essential plant micronutrients, Ca, Fe, Mg, Mn, Cu and Zn were of particular concerns in this study. Moreover, some toxic heavy metal elements cadmium (Cd), chromium (Cr) and lead (Pb) are also observed. We expected to find out more evidences for clarifying that compost application may improve the nutrient situation of farmlands.

Materials and Methods

1. *Sample collection and Preparation*

Fifteen pairs of soil samples were separately collected from 15 sites in Yamaguchi and Miyazaki Prefecture, Japan during Oct. 2003 to Nov. 2006. The samples collected including a compost-amended soil sample and a chemical fertilizer/compost co-amended soil. Farmland amendments have been conducted in these 15 sites for different periods of time. Soil sampling was restricted in the upper soil (0-15cm) by a free selection technology, and inert materials (such as stone and straw) were removed. All samples collected in plastics bags were sent to the laboratory within 24h. Then, each sample was dried at 105°C, and then particle size reduction was achieved using an agate mortar and pestle to pass a 2 mm sieve, finally stored at 4°C until elemental analyses. Sample pretreatment were all conducted in duplicate.

2. *Total metal content*

Duplicate samples (soil, 1-2 g) were digested using HNO_3 and H_2O_2 following standard procedures (USEPA, 1996). The digests were filtered through 0.45-μm filter membranes and then filled to 50 mL with ultra-pure water for elemental analysis.

3. *Bio-available metal content*

Duplicate samples (5g) were extracted using EDTA following standard procedures (Lustenhouwer and Hin, 1993). The extractions were filtered through 0.45-μm filter membranes and then filled to 50 mL with ultra-pure water for elemental analyses.

4. *Chemical Analysis*

Measurements of Ca, Fe, Mg, Mn, Zn, Cu, Pb, Cr and Cd after digestion and also in leachate solutions were measured Inductively Coupled Plasma – Atomic Emission Spectrometry (ICP-AES, PerkinElmer, optima 3300 DV).

Results and Discussion

1. *Total Contents of minerals in soils*

Total contents of mineral elements in composts-amended soils are shown respectively in Table 1(a). Total contents of essential plant micronutrients such as Ca, Fe, Mg, Mn, Zn and Cu were all in wide ranges. As toxic heavy metals, Pb and Cr contents were in the wider range than Cd. Total contents of elements in chemical fertilizer-amended soils are shown in Table 1(b). The ranges of all element contents were similar with that of compost-amended soils. As essential minerals, total contents of Ca, Fe, Mg, Mn, Zn and Cu were all in the wide range and the total contents of toxic heavy metals also fell into the wider range.

Typically, for amended soils are not only composts but also chemical fertilizer, the content ranges of essential minerals were wider than that of heavy metals. We understood that total contents of essential minerals in soils will be affected by various unpredictable factors, including rainfall, irrigation and other sources besides fertilizer. Comparison of average total contents of compost-amended soils and chemical fertilizer-amended soils shows that solid waste composts application led to the Ca, Mg, Mn, Zn and Pb increases in soils, but the changes of total contents of Fe, Cu, Cr and Cd were less evident.

2. Contents of bio-available forms of minerals in soils

Contents of the bio-available forms of elements in soils are listed in Table 1(a) and (b), respectively. The contents of bio-available forms of elements in soils, whether composts-amended or not, were all in wide ranges. This means that the contents of bio-available forms of elements were affected by soils characteristics. Comparison of average contents of bio-available forms of elements in the composts-amended soils and chemical fertilizer-amended soils shown that solid waste compost applications have led to the significant increases of Ca, Fe and Mn in soils, but Mg, Zn, Cu, Pb, Cr and Cd were less changed.

3. Effect on the mineral contents of soils

From the results of total content and bio-available content of mineral elements, we saw that solid waste composts application improved the essential plant micronutrients in amended soils. But we could not say that was true, because it was also possible that several special samples led to such results. So it is necessary to further confirm the situation of each pair of soils.

Table 1. Total contents and bio-available forms of minerals in soils.

mg/kg (dry wt.)

Soils	Ca		Fe		Mg		Mn		Zn		Cu		Pb		Cr		Cd	
	Available	*Total*	*Available*	*Total*	*Available*	*Total*	*Available*	*Total*	*Available*	*Total*	*Available*	*Total*	*Available*	*Total*	*Available*	*Total*	*Available*	*Total*
(a)																		
A1	1,136	2,116	1,339	15,946	65	2,417	115	284	3	12	4	11	12	21	0.7	37	0.2	0.9
A2	646	1,656	859	6,600	16	802	127	238	22	32	28	32	40	55	5.1	34	0.7	2.4
A3	921	2,420	1,497	9,620	32	1,174	101	154	11	23	22	30	20	23	2.7	33	0.5	1.2
A4	994	3,700	8,049	16,480	44	2,160	1,130	1,404	9	36	28	47	17	23	2.1	51	0.6	1.5
B1	2,471	3,678	1,637	26,512	212	4,141	189	402	14	95	11	27	5	21	0.4	43	0.1	2.4
B2	868	2,758	750	30,112	66	2,811	111	383	22	183	4	27	3	28	0.6	88	0.1	2.1
B3	5,087	9,967	414	24,898	226	2,133	93	732	45	104	17	64	4	132	0.3	48	0.2	2.6
B4a	1,855	4,700	347	24,001	91	2,919	83	603	9	88	8	32	4	17	0.1	23	—	—
B4b	6,850	11,560	799	23,200	197	2,320	653	912	50	112	17	23	26	33	0.4	28	0.4	2.4
B5a	1,921	5,828	1,173	9,225	73	1,959	149	280	8	47	3	6	7	10	1.1	43	0.2	0.3
B5b	696	2,500	1,362	9,620	47	1,972	62	158	14	58	9	16	9	23	1.4	25	0.2	2.6
B5c	1,411	2,920	2,859	9,560	71	1,170	491	944	31	50	13	19	18	24	0.4	29	1.0	1.3
B6	1,711	2,705	1,133	7,741	124	1,267	160	263	7	43	3	8	7	26	0.9	30	—	—
B7	2,270	5,320	1,969	7,840	74	912	376	554	52	57	16	23	14	21	3.8	35	0.3	2.6
B8	2,370	16,800	1,582	5,600	101	3,460	860	1,018	59	78	15	30	18	22	6.0	45	0.5	2.5
average	*2,080*	*5,242*	*1,718*	*15,130*	*96*	*2,108*	*313*	*555*	*24*	*68*	*13*	*26*	*13*	*32*	*1.7*	*40*	*0.4*	*1.9*
(b)																		
A1	1,070	1,791	1,327	21,046	45	2,562	114	281	1.7	1.9	3	7	13	17	0.5	35	0.2	1.1
A2	846	1,028	1,442	6,280	25	870	138	172	3	43	9	11	10	23	1.0	27	1.2	2.6
A3	473	1,088	1,634	11,900	37	1,308	20	86	6	26	19	28	20	36	2.6	34	0.5	2.4
A4	1,741	3,560	2,049	14,340	97	1,608	496	511	24	29	55	72	26	37	1.3	45	1.5	2.4
B1	7,408	17,469	1,225	24,697	632	3,138	445	869	124	225	24	101	6	28	1.3	89	—	—
B2	6,574	12,125	847	37,896	309	3,442	258	1,134	132	256	19	62	8	12	0.8	56	—	—
B3	2,301	4,535	423	26,851	261	1,799	64	733	8	52	4	22	3	9	0.04	14	—	—
B4a	1,646	3,756	339	26,487	171	1,705	49	714	7	38	4	24	2	12	0.1	14	—	—
B4b	865	2,240	2,029	14,660	62	1,520	396	636	9	30	9	13	14	20	0.7	46	0.4	2.6
B5a	957	1,533	1,024	10,049	73	1,274	96	198	3	34	2	2	6	13	0.8	25	—	—
B5b	362	946	819	7,500	11	814	169	284	23	30	31	34	60	86	6.4	31	1.2	2.4
B5c	294	1,312	919	5,820	22	1,056	38	92	3	21	5	7	8	19	3.2	27	0.1	1.2
B6	2,715	5,361	1,988	11,999	148	1,633	451	869	8	61	3	7	8	19	4.5	77	0.3	0.6
B7	544	1,964	1,084	8,940	10	614	255	412	10	51	5	10	8	30	0.5	28	0.1	1.3
B8	1,697	5,260	1,544	11,640	90	1,604	293	528	12	51	8	10	10	21	2.9	49	0.3	1.6
average	*1,966*	*4,265*	*1,246*	*16,007*	*133*	*1,663*	*219*	*501*	*25*	*63*	*13*	*27*	*13*	*25*	*1.8*	*40*	*0.6*	*1.8*

Note: (a), composts-amended soils; (b), chemical fertilizer-amended soils.

In 15 pairs of soil samples, two cases can be found, that is, contents of compost-amended soils higher than that of no amended soils, or in reverse. Total contents and bio-available mineral elements in soils were compared as in Figure. 1 (a) and (b), respectively.

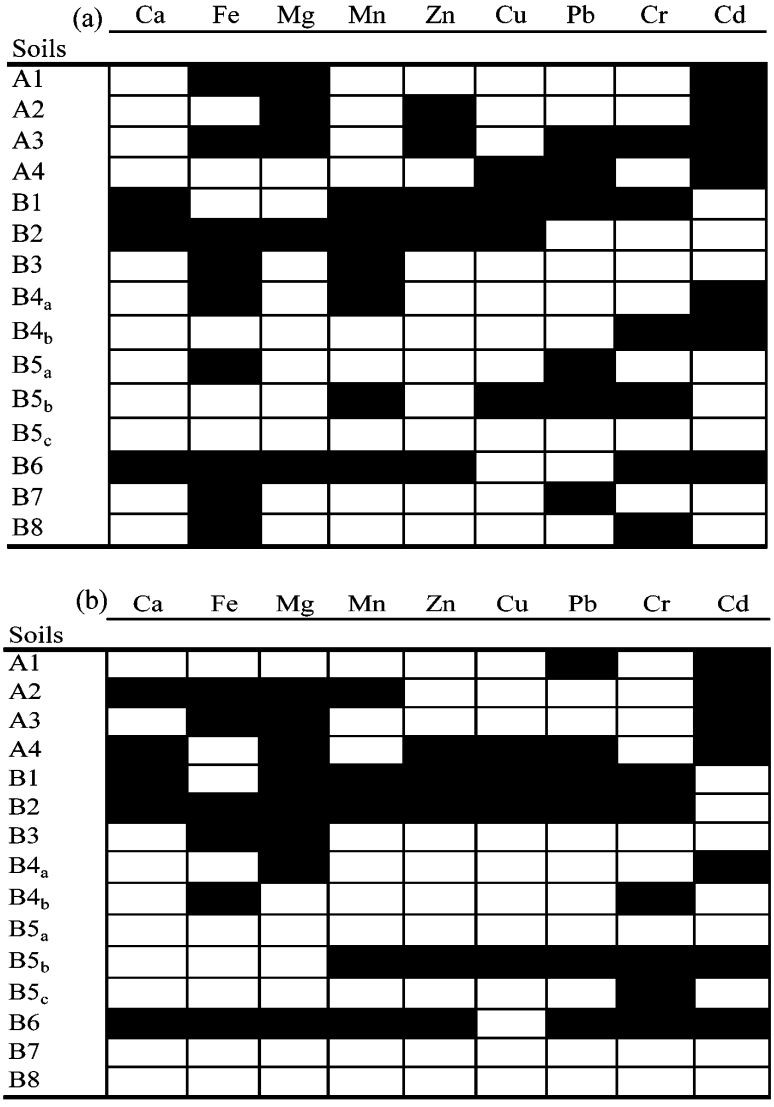

Figure 1. Comparison of total contents (a) and contents of bio-available forms (b) of element in compost-amended soils and no amended soils, white: composts›chemical fertilizer; black: composts‹chemical fertilizer

For total contents, the "amended higher than no amended" cases of Ca, Mg, Mn, Zn, Cu, Pb and Cr in 15 pair samples were much more than the reverse. But as for Fe and Cd, such difference is less significant. Generally speaking, the results indicate that the compost application led to total mineral element content increases, and that the decrease of total Fe content in compost-amended soil may also happen.

About bio-available forms of elements, the "amended higher than no amended" cases of all elements were quite more than the reverse except for Mg. So it can be understood that the solid waste compost application can amend soils regarding bio-available forms of essential minerals. Solid waste composts application led to increases of total content of Mg, but bio-available Mg didn't be improved. That means the leachability of Mg was limited in compost-amended soils. The leachability of heavy metals had been increased too with the solid waste composts application, and therefore it should be controlled.

4. Effect on the minerals supply of compost-amended soils

Table 2 shows the minerals element supply ratio (SR = bio-available content/total content×100%) of various soils. Comparing other elements in compost-amended soils and no amended soils, SR of Fe, Mg and Cr were low. It was understood that the leachability of Fe and Mg was lower than essential minerals else. SR of Ca fell into a narrow range, but that of other elements, especially Fe, Mg and Cr, showed in wide ranges. The leachability of almost all elements would be affected by different soil characteristics.

About the average supply ratio of various soils, solid waste composts led to mineral supply ratio increases except for Mg and Ca. It is proved that the leachability of Mg was limited in compost amended soils again. On the other hand, through the total content of Fe in composts-amended soils was less than no amended soils, supply ratio improvement led to bio-available content increase in composts-amended soils.

To confirm the result of Table 2, SR of each pair of soils was discussed. Figure. 2 shows SR comparison between compost-amended soils and no amended soils. About SR, the "amended higher than no amended" cases of all elements were much more than the reverse case except for Mg and Ca. Though the leachability of Ca was limited at some degree in compost-amended soils, large increase of total content of Ca ensured bio-available content improved. Solid waste compost application can improve the minerals supply situation, but continually using solid waste composts to amended soil would lead to heavy metal accumulation in soils. The controlled use of solid waste composts was advocated.

Table 2. Mineral element SR (%) of various soils

Soils	Ca		Fe		Mg		Mn		Zn		Cu		Pb		Cr		Cd	
	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)
A1	54	60	8	6	3	2	41	41	24	89	40	38	58	75	1.9	1.4	21	16
A2	39	82	13	23	2	3	53	80	68	8	88	76	73	46	15.1	3.8	29	46
A3	38	43	16	14	3	3	65	23	46	23	73	68	88	55	8.2	7.7	42	21
A4	27	49	49	14	2	6	80	97	26	82	58	76	74	70	4.1	2.9	40	63
B1	67	42	6	5	5	20	47	51	14	55	42	24	22	20	0.9	1.4	6	–
B2	31	54	2	2	2	9	29	23	12	52	16	31	9	64	0.7	1.5	5	–
B3	51	51	2	2	11	15	13	9	43	16	26	18	3	38	0.5	0.3	7	–
$B4_a$	39	44	1	1	3	10	14	7	11	19	25	17	24	20	0.6	0.4	–	–
$B4_b$	59	39	3	14	8	4	72	62	45	30	76	70	78	68	1.4	1.5	17	15
$B5_a$	33	62	13	10	4	6	53	48	16	9	52	91	67	46	2.5	3.2	87	–
$B5_b$	28	38	14	11	2	1	39	60	24	75	57	90	38	70	5.5	20.8	8	50
$B5_c$	48	22	30	16	6	2	52	41	61	13	69	70	76	42	1.4	11.7	77	8
B6	63	51	15	17	10	9	61	52	16	13	41	46	25	43	2.9	5.9	–	54
B7	43	28	25	12	8	2	68	62	91	20	69	49	65	25	10.7	1.8	12	8
B8	14	32	28	13	3	6	84	55	75	24	50	79	82	45	13.2	5.9	20	19
average	42	47	15	11	5	6	51	47	38	35	52	56	52	49	4.7	4.7	28	30

Note: (a), composts-amended soils; (b), chemical fertilizer-amended soils.

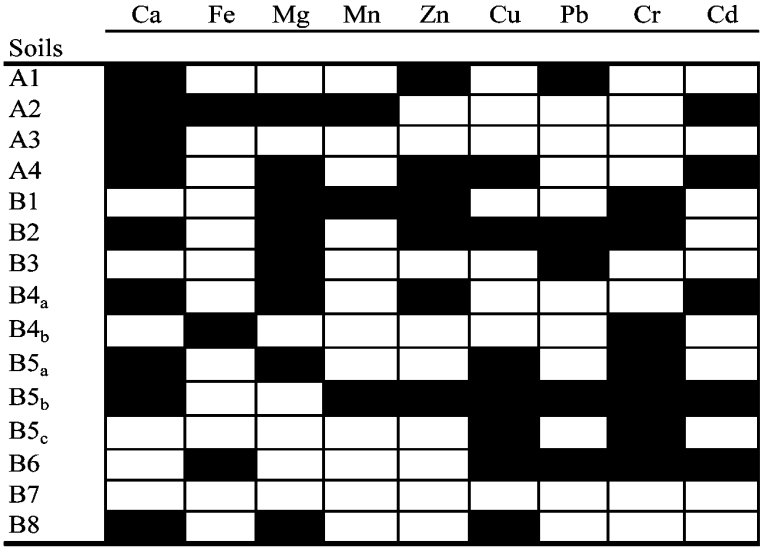

Figure 2. Supply ratio comparison between compost-amended soils and no amended soils, white: composts›chemical fertilizer; black: composts‹chemical fertilizer.

Conclusions

Solid waste composts led to increase of mineral elements in soils except in case of Fe. Toxic heavy metals of Pb, Cr and Cd in soils were also increased in different extents. It is also found that soil applications of solid waste composts has become increased bio-available forms of useful mineral elements except for Mg and Ca, but less for heavy metals. Based on SR investigation, mineral elements

in various soils, leachability of almost all mineral elements was improved except for Mg and Ca, but large increase of total content of Ca ensured bio-available content improvement. Potential use of solid waste composts to amended soil would possibly lead to heavy metals accumulation in soils. Therefore, the rational and controlled application of solid waste composts is helpful for not only safe solid waste disposal but also the soil amendment.

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