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Short Communication

Chromium uptake by rice and accumulation in soil amended with municipal solid waste compost

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Abstract

Effect of addition of municipal solid waste compost (MSWC) on chromium (Cr) content of submerged rice paddies was studied. Experiments were conducted during the three consecutive wet seasons from 1997 to 1999 on rice grown under submergence, at the Experimental Farm of Calcutta University, India. A sequential extraction method was used to determine the various chromium fractions in MSWC and cow dung manure (CDM). Chromium was significantly bound to the organic matter and Fe and Mn oxides in MSWC and CDM. Chromium content in rice straw was higher than in rice grain. Chromium bound with organic matter in MSWC best correlated with straw Cr ($r = 0.99^{**}$) followed by Fe and Mn oxides ($r = 0.97^{*}$) and water soluble as well as exchangeable fractions ($r = 0.96^{*}$). The water soluble and the exchangeable fractions in MSWC best correlated with grain Cr ($r = 0.98^{*}$). The Cr content of rice grain had the highest correlation with water soluble and exchangeable Cr ($r = 0.99^{**}$) while the straw Cr best correlated with the Fe and Mn oxides ($r = 0.98^{*}$). Both the carbonate bound and residual fractions in MSWC and CDM did not significantly correlate with rice straw and grain Cr. MSWC would be a valuable resource for agriculture if it can be used safely, but long-term use may require the cessation of the dumping by the leather tanneries and other major contributors of pollutants.

Keywords: Chromium; Municipal solid waste compost; Rice; Submergence

1. Introduction

In the face of a global decline of organic resources, municipal solid waste compost (MSWC) is gaining familiarity as an organic and plant nutritional soil supplement (Stratton et al., 1995). Indian cities generate about 14 million tonnes of solid waste annually. These wastes are being composted at different facilities located in metropolitan cities. Despite its potential as compost, widespread acceptability has suffered due to the presence of heavy metals including Cr and possible contamination to the food chain (Stratton et al., 1995). MSWC

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application has shown promising results for a wide variety of field crops (Epstein, 1997) but no report is available for rice, which is the principal crop in the tropics. According to Ponnamperuma (1972) waterlogged soil environment in rice ecosystems is complex and reducing conditions enhance the mobility of trace metals, initially by dissolution of Mn and Fe oxides. In reduced soil environment of rice crop, more heavy metals present in MSWC may go into soil solution, risking their uptake by the rice crop. Moreover, the organic matter decomposition in tropical climates is faster which may result in the heavy metals becoming more available to plants.

A profile of different heavy metals present in the MSWC is reported earlier (Bhattacharyya et al., 2003a,b). We report the data pertaining to the Cr element in this study. Wastes and affluent from leather tanneries are dumped in the Calcutta landfill site, which contributes to the amount of Cr in MSWC. Usually, chromium occurs in two forms; Cr(III) and Cr(VI), and plants take up both forms. Cr(III) is sparingly soluble and less toxic, while Cr(VI) being more soluble in water, is highly toxic to biota (Adriano, 1986). Chromium interferes with several metabolic processes, causing toxicity to the plants as exhibited by reduced root growth and phytomass, chlorosis, photosynthetic impairing, stunting and finally plant death (McGrath, 1982; Gardea-Torresdey et al., 2004). Studies on the dynamics of Cr in the soil–plant systems under field condition that assess plant uptake of Cr are scanty. Chromium deposited through organic amendments in the soil may accumulate rapidly since it is only slowly depleted through plant uptake, or erosion. Chromium being a potential contaminant in MSWC may limit the use of these waste materials as organic matter supplements (Epstein, 1997). It is desirable that MSWC be low in potentially toxic contaminants both organic and inorganic and high in nutrients and humus. Accumulation of heavy metals including Cr in soil increases with repeated application of MSWC thereby increasing the risk of crop uptake and food chain contamination (Stratton et al., 1995).

The aim of the study was to ascertain the forms of Cr in the MSWC and cow dung manure (CDM) and how the forms are linked to the uptake by rice plants. This was envisaged to throw light on the Cr contamination in the soil–plant system by the application of MSWC.

2. Materials and methods

Field experiments were conducted for three consecutive years in the monsoon seasons (June to September) of 1997–1999 on rice (*Oryza sativa* L.) at the Agriculture Experimental Farm of Calcutta University, Baruipur (22°2′N and 88°26′E), West Bengal, India. The site of the experiment represented Gangetic alluvial soil (*Typic Fluvaquent*), characteristics of which including Cr content are given in Table 1. In the field experiments, MSWC derived from Calcutta city wastes, well rotten CDM and fertilizer (F) (urea, single superphosphate and muriate of potash to supply N, P and K respectively) were used. The characteristics of MSWC and CDM are given in Table 1. The distribution of different forms of Cr in MSWC and CDM are listed in Table 2.

The experimental detail and the treatments are cited in the article by Bhattacharyya et al. (in press). Soil samples were collected from surface (0–0.2 m depth) at random from each plot, once prior to setting up of the experiment in 1997 and the other two after rice harvest in 1998 and 1999. Samples were air dried, ground and sieved through 2 mm sieve. Characteristics of the air-dried MSWC and CDM samples were carried out in

Table 1
Characteristics of soil, municipal solid waste compost (MSWC) and cow dung manure (CDM)

Parameter	Soil ± SE	MSWC ± SE			CDM ± SE		
		1997	1998	1999	1997	1998	1999
pH	5.5 ± 0.01	7.3 ± 0.01	7.4 ± 0.01	7.4 ± 0.01	6.1 ± 0.01	6.2 ± 0.06	6.2 ± 0.05
EC (dS m^{-1})	0.29 ± 0.01	2.7 ± 0.02	2.8 ± 0.01	2.7 ± 0.02	2.2 ± 0.02	2.2 ± 0.03	2.2 ± 0.06
Sand (%)	26 ± 0.06	40 ± 0.02	42 ± 0.02	42 ± 0.01	–	–	–
Silt (%)	29 ± 0.11	30 ± 0.02	28 ± 0.01	28 ± 0.03	–	–	–
Clay (%)	45 ± 0.35	30 ± 0.01	30 ± 0.01	30 ± 0.02	–	–	–
Organic C (g kg^{-1})	14 ± 0.11	114 ± 0.58	111 ± 2.31	113 ± 1.73	110 ± 1.73	126 ± 2.89	127 ± 2.31
Total N (g kg^{-1})	1.7 ± 0.01	10.1 ± 0.17	9.9 ± 0.115	10 ± 0.58	11.8 ± 0.058	11.4 ± 0.29	11.6 ± 0.58
C/N	8.2 ± 0.03	11.29 ± 0.01	11.21 ± 0.02	11.3 ± 0.17	9.32 ± 0.05	11.05 ± 0.02	10.95 ± 0.58
Humus-C (g kg^{-1})	–	29 ± 0.40	32 ± 0.29	30 ± 1.15	–	–	–
Total S (g kg^{-1})	0.1 ± 0.01	6.7 ± 0.11	7.3 ± 0.06	7.2 ± 0.17	1.4 ± 0.02	1.6 ± 0.01	1.3 ± 0.06
CEC (cmol kg^{-1})	19 ± 0.17	105 ± 2.89	105 ± 2.89	100 ± 2.31	68.6 ± 0.23	66.7 ± 1.73	72.8 ± 1.73
Total Cr (mg kg^{-1})	48 ± 1.7	653 ± 6.93	662 ± 2.31	678 ± 2.89	52.5 ± 1.15	51.8 ± 1.73	54.5 ± 1.15
DTPA Cr (mg kg^{-1})	8 ± 0.11	55 ± 1.53	58 ± 1.73	71 ± 1.15	14 ± 0.63	18 ± 0.58	20 ± 0.58

SE = standard error.