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Influence of compost amendment on pyrene availability from artificially spiked soil to two subspecies of *Cucurbita pepo*

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ABSTRACT

The dissolved organic matter (DOM) fraction of soil organic matter (SOM) may positively contribute to polycyclic aromatic hydrocarbons (PAHs) bioavailability. This work investigated the effects of DOM-rich and PAHs-free compost amendment on the plant uptake of pyrene. Two subspecies of *Cucurbita pepo* (ssp. *pepo* cv. Raven and ssp. *texana* cv. Sunray) were grown for three weeks in a spiked soil containing 83.9 mg kg^{-1} pyrene under four different treatments; inorganic fertilizer (IF) alone, 15% (v/v) mixed gardening compost with IF (MX15%+IF), MX30% alone, and no fertilization (NF). Equilibrium pyrene desorptions from a spiked soil (104 mg kg^{-1}) under different concentrations (35–590 mg-C L^{-1}) of DOM extracts derived from two types of composts including MX and cow manure were also conducted. After harvest, the decrease in the pyrene concentration of the soil ranged from 46–65% for the different treatments. The total dry biomass for both plants was highest under MX15%+IF. The bioconcentration factors of pyrene for both also tended to decrease with increasing MX dose from 15% to 30%. However, the total uptakes of pyrene with IF and MX15%+IF were not statistically different (36.7 and 33.7 μg for Raven, and 5.20 and 7.90 μg for Sunray, respectively). These values were around 100% higher than that with NF (17.4 μg for Raven and 2.0 μg for Sunray). The pyrene desorption data confirmed the ability of DOM to associate with pyrene as indicated by its increase in apparent water solubility. On the basis of these results, MX application at 15% (v/v) does not significantly reduce the phytoextraction of pyrene due to the enhancement of plant growth as well as the possible contribution of DOM fractions to pyrene bioavailability. The application of compost may not pose serious concerns regarding the efficiency of phytoremediation of PAHs-polluted soil.
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1. Introduction

Polycyclic aromatic hydrocarbons (PAHs), a class of persistent organic pollutants (POPs), are ubiquitous environmental contaminants that are mainly derived from anthropogenic sources, such as incomplete combustion of organic materials (Sims and Overcash, 1983; Freeman and Cattell, 1990). They consist of two or more fused benzene rings and some including benzo[*a*]pyrene, are known or suspected carcinogens and/or mutagens (USEPA, 1985). Because PAHs are lipophilic and recalcitrant (Latimer and Zheng, 2003), the contaminants may accumulate in organic geosorbents such as soil and sediment (Simonich and Hites, 1994; Ockenden et al., 2003).

Phytoremediation is the in-situ use of plants to remediate organic and/or inorganic contaminated natural solids. It is an effective, inexpensive and environmentally-friendly approach, particularly for the large scale rehabilitation of soil, which is contaminated with a wide range of toxic chemicals such as heavy metals, organics, and radionuclides (Pradhan et al., 1998). Recently, numerous studies investigating the application of phytoremediation to treat PAHs-contaminated soil using a variety of plant species have been carried out (Liste and

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Alexander, 2000; Fismes et al., 2002; Maila and Cloete, 2002; Gao and Zhu, 2004; Parrish et al., 2006). Two major strategies have been forwarded for this purpose: phytodegradation and phytoextraction (Cunningham et al., 1995). The former is based on the secretion of plant photosynthates in root exudates, which then stimulate the metabolic activities of microbial communities in the rhizosphere (Anderson et al., 1994). Several plants enhance the activity of rhizospheric microorganisms and thus accelerate the biodegradation of PAHs (Aprill and Sims, 1990; Liste and Alexander, 2000). However, the biodegradability of PAHs beyond the 4-ring structure has been limited by the low aqueous solubility and strong association with soil organic matter (SOM) of PAHs (Potter et al., 1999; Antizar-Ladislao et al., 2004).

In the last few decades, there has been increasing information on the ability of *Cucurbita pepo* ssp. *pepo* (zucchini) to phytoextract significant amount of POPs such as PCDD/Fs (Hülster et al., 1994), *p,p*'-DDE (White, 2001), DDT (Lunney et al., 2004) and drins (Otani et al., 2007). Certain zucchinis have also been found to accumulate high molecular weight PAHs from weathered contaminated soil (Parrish et al., 2006). The accumulation of PAHs through plant roots is closely associated with the sorption/desorption reactions to PAHs from the SOM. The content and quality of SOM has been considered one of the major factors affecting the extent of plant uptake of PAHs and other related contaminants (Ryan et al., 1988; Chiou et al., 1998; Nam et al., 1998; Wilcke, 2000). The sorption of organics generally increases with the SOM content (Ryan et al., 1988; Chiou, 2002). Hence, there has been a limited application of organic amendment to phytoextract PAHs from soil. Inorganic fertilization has been favorably used (e.g. Liste and Alexander, 2000; Parrish et al., 2006). However, certain types of organic materials, particularly composts, contain easily decomposable young organic matter (e.g. plant residue and manure), which are capable of improving the physicochemical soil properties for enhanced plant growth (e.g. soil density, water holding capacity, aggregate stability and cation exchange capacity). The SOM quality of composts also differs from the natural SOM in soils. They are particularly rich in dissolved organic matter (DOM) fractions, which may act as a mobile sorbent of low solubility organics thereby improving their soil release (e.g. McCarthy et al., 1989; Chin et al., 1997; Jones and Tiller, 1999; Wilcke, 2000).

The aim of this work was to evaluate the application of DOM-rich compost for the phytoextraction of pyrene (4-ring PAHs) from an artificially spiked soil. Two subspecies of *C. pepo* (i.e. ssp. *pepo* and ssp. *texana*) having different abilities to accumulate *p,p*'-DDE via root uptake under field experiments were employed (White et al., 2003). Though plant accumulation of PAHs in the presence of sewage sludge and its composted form have been well studied (Wild et al., 1992; Petersen et al., 2003; Oleszczuk and Baran, 2005a,b; Cai et al., 2008), the extent by which such organic amendment affects PAHs root uptake has not been clearly established. This is due to the presence of PAHs in the composted material and that no efforts were made to establish the pathway for PAHs accumulation. In this study, the use of PAHs-free compost and the covering of pots with plastic silver sheet were made to specifically isolate the contribution of root to shoot translocation on pyrene build-up. It was postulated that the DOM components of compost may favorably enhance the soil desorption of pyrene for its greater root uptake.

2. Materials and methods

2.1. Plants and organic materials

The two different subspecies of *C. pepo*; ssp. *pepo* (zucchini, cv. Raven) and ssp. *texana* (summer squash, cv. Sunray), were purchased from Johnny's Selected Seeds (Albion, ME). These plants were reported to have different bioconcentration factors (BCFs, defined as the ratio of concentration of a target chemical in the vegetation to that in the soil, Fismes et al., 2002) against *p,p*'-DDE in field experiments with Raven having the relatively higher BCF than Sunray (White et al., 2003). We have also confirmed that Raven and Sunray are good and poor accumulators of pyrene, respectively, from pot experiments (data not shown).

Three types of PAHs-free organic materials were used, including mixed gardening compost (MX), cow manure compost (CM), and peat (PT). These were purchased from a local home center and were sieved through a 2.8 mm mesh prior to use. The MX is a mixture of bark and poultry/swine manure. General information about these amendments is shown in Table 1. For plant cultivation, MX was chosen over CM based on their electrical conductivity (EC) values. The lower EC of MX would permit its application even at higher dosage without concerns regarding the negative effect of high salt content to the plants. For desorption studies, activated carbon (AC, Wako pure chemical Industries, Ltd. Osaka Japan) was also used in addition to MX, CM and PT. Activated carbon is a representative of a strong PAHs-binding organic material (Zimmerman et al., 2004) and therefore may serve as the reference for the different composts regarding pyrene desorption.

Table 1 – General characteristics of three organic amendments used

Amendments	pH (H_2O) [a]	EC [a] ($dS\ m^{-1}$)	Total-C ($g\ kg^{-1}$)	Total-N ($g\ kg^{-1}$)	Total-P ($g\ kg^{-1}$)	Total-K ($g\ kg^{-1}$)	C/N	DOM [b] (g-C kg^{-1})
MX	6.09	6.03	419	26.4	66.0	33.0	15.9	5.5
CM	9.82	8.09	405	24.4	–	–	16.6	14.2
PT	4.28	0.13	474	4.6	–	–	104.0	1.0

MX: mixed compost; CM: cow manure compost; PT: peat; DOM: dissolved organic matter; –: not determined; values are dry weight basis.
[a] Measured in 1:20 sample/water ratio (w/v).
[b] Extracted in 1:10 sample/water ratio (w/v).

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