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Metal stress and decreased tree growth in response to biosolids application in greenhouse seedlings and *in situ* Douglas-fir stands

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ABSTRACT

To assess physiological impacts of biosolids on trees, metal contaminants and phytochelatins were measured in Douglas-fir stands amended with biosolids in 1982. A subsequent greenhouse study compared these same soils to soils amended with fresh wastewater treatment plant biosolids. Biosolids-amended field soils had significantly higher organic matter, lower pH, and elevated metals even after 25 years. In the field study, no beneficial growth effects were detected in biosolids-amended stands and in the greenhouse study both fresh and historic biosolids amendments resulted in lower seedling growth rates. Phytochelatins – bioindicators of intracellular metal stress – were elevated in foliage of biosolids-amended stands, and significantly higher in roots of seedlings grown with fresh biosolids. These results demonstrate that biosolids amendments have short- and long-term negative effects that may counteract the expected tree growth benefits.

1. Introduction

In 2010, it is estimated the United States produced 8.2 million dry tons of biosolids from municipal wastewater plants (US Environmental Protection Agency, 1999). Biosolids are the nutrient-rich solid, semisolid, or liquid organic materials that result from the treatment of domestic wastewater by municipal wastewater treatment plants. Disposal of biosolids in landfills is viewed as a waste of valuable space with diminishing capacities threatening many municipal landfills. Moreover, disposal of biosolids in landfills is also viewed as an unsustainable use of resources as biosolids represent a ready supply of nutrient-rich organic-based soil amendments that may be used to restore the productivity of depleted soils.

It was estimated that approximately 48% of the biosolids produced in 2010 were used for land applications (US Environmental Protection Agency, 1999), and biosolids application to managed forest lands has been an important method of non-landfill disposal in the Puget Sound region (Cole et al., 1986). Because biosolids are rich in the macronutrients nitrogen and phosphorus, and since they are composed primarily of organic matter that can help retain soil moisture and decrease the bulk density of soils (similar to compost), the assumption has been that biosolids application promotes tree growth (He et al., 1992; Perez et al., 2007). However, study results vary widely depending on the source of the biosolids, the length of the study conducted, the original site productivity, the method of biosolids application, the age of the trees treated and more (Zasoski et al., 1983; Berry, 1985; Harrison et al., 1994; Henry and Cole, 1997; Bulmer et al., 2007). One question prompted by this variable growth response is the possible impact of pollutant chemicals, including metals, present in mixed municipal biosolids, and how these may work to counteract the benefits of fertilization and increased soil organic matter.

Municipal biosolids often contain elevated concentrations of some heavy metals, including Cd, Cu and Pb, resulting from domestic, commercial and industrial sources of wastewater (Bose et al., 2008). Fertilizing trees with biosolids often results in increased heavy metal concentrations in soil (Wei and Liu, 2005; Yuan, 2009; Achiba et al., 2010). Trees then take up metals from biosolids-amended soils resulting in elevated cellular metal concentrations (Zasoski et al., 1984; Berry, 1985; Harrison et al., 1994).

Several studies have related metal contamination to negative impacts on forests, including decreased forest productivity (Chernenkova and Kuperman, 1999; Pukacki and Kaminska-Rozek, 2002; Koptsik et al., 2004). In 4-year experiments on simulated young forest ecosystems Menon et al. (2007) found significantly decreased fine root and above ground biomass, decreased leaf area and decreased water use efficiency in *Picea abies* grown in metal contaminated (3000 ppm Zn, 640 ppm Cu, 90 ppm Pb and 10 ppm Cd) soils. Specific to biosolids, several studies have observed decreased growth in Douglas-fir seedlings (Zasoski et al., 1983) and pine seedlings (Berry, 1985) resulting from sewage sludge amendments.

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