CROP UPTAKE OF CADMIUM FROM PHOSPHORUS FERTILIZERS: 
I. YIELD AND CADMIUM CONTENT

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Abstract. We investigated the effects of different P fertilizers on the yields and Cd contents of oat (Avena sativa L.), ryegrass (Lolium multiflorum L.), carrot (Daucus carota L.), and spinach (Spinacia oleracea L.). These crops were grown in the greenhouse using soils treated with lime to achieve three pHs ranging from 4.77 to 5.94 for a sandy soil and 4.97 to 6.80 for a loam soil. The crop yields were generally not affected by liming or application of different kinds of P fertilizers, with a few exceptions. Application of Cd-containing NPK fertilizers in all cases tended to increase the Cd concentrations in crops, and the highest Cd concentrations in crops were obtained when the high-Cd NPK fertilizer was applied (adding 12.5 μg Cd kg⁻¹ soil). Cadmium concentrations in crops in most cases decreased with increasing soil pH. The highest percent recovery of the added Cd by plant species in the sandy soil was found for inorganic Cd-salt and in the loam soil for low-Cd NPK fertilizer. Phosphate rock resulted in the lowest recovery of the added Cd by all the plant species in both soils, but was also an insufficient P-source of its low solubility.

1. Introduction

Previous results have shown that long-term use of phosphate fertilizers increased Cd contents of soils, though the increased Cd levels in soils did not necessarily result in increased Cd concentrations in plants (He and Singh, 1993a; Bærug and Singh, 1990), as the uptake of Cd by plants was affected by a number of factors such as soil pH, exchangeable cations and Mn-oxides other than the total Cd content in soils (He and Singh, 1993b). In both greenhouse and field experiments, it has been found that application of Cd-containing fertilizers increased Cd uptake by plants, depending on the rates of application (Andersson and Siman, 1991; Eriksson, 1990; Mulla et al., 1980). Some investigators (Mortvedt, 1987; Jaakkola, 1977), on the other hand, did not find such effects. In a pot experiment, even addition of Cd as high as 49 g ha⁻¹ through NPK fertilizer did not cause any significant change in the Cd contents of wheat grain or straw (Jaakkola, 1977). Singh (1990) found that the application of a Cd-containing NPK fertilizer (40 mg Cd kg⁻¹) at the rate of 30 mg P kg⁻¹ soil did not increase Cd concentrations in oat or rape, but application of the same fertilizer at a higher rate (90 mg P kg⁻¹) increased the Cd concentrations in both crops, and that the effect of fertilizer application on Cd uptake by the two crops varied with soil types. Evidently, these contradictory

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results were caused by a variety of factors, such as soil properties, Cd concentrations and type of fertilizers, rates of fertilization, and plant species. Eriksson (1990) found that, when applied at a low dose, Cd addition through a NPK fertilizer in granular form was more effective than that in its solution form in increasing plant uptake of Cd in the loamy sand and clay soils, and that the plant uptake of Cd from soils receiving granular NPK fertilizer having a high Cd-content was greater than that from soils receiving the same form of fertilizer having a low Cd-content. But no significant differences in plant Cd between the low-Cd and high-Cd NPK fertilizer treatments were observed when the fertilizers were applied as solutions.

Soil pH is one of the important factors influencing plant uptake of Cd from soils. Investigations of pH effect on Cd uptake by plants are usually conducted by liming the soil to desired pH levels. In most cases, liming increased the Cd adsorption and reduced the Cd availability to plants in soils (Eriksson, 1989; Låg, 1987; Street et al., 1978). It was reported that soil pH exerted an effect on the availability of Cd present in soil solutions. However, increasing soil pH does not always reduce plant of Cd (Eriksson, 1989). This pH-Cd uptake relationship is dependent on soil types and plant species. Little or no effect of liming on Cd uptake by plants was observed in several experiments (Sims and Kline, 1991; Pepper et al., 1983; Jaakkola, 1977).

Plant species vary greatly both in their response to the changes in soil pH and in their ability to absorb Cd from soils. These genetic differences between plant species may be as important as soil properties in determining the effect of pH on Cd uptake. When grown in the same soil, accumulations of Cd by different plant species decreased in the order: leafy vegetables > root vegetables > grain crops (Page et al., 1987; Bingham, 1979; John, 1973). Soil type (texture) may also play an important role in affecting Cd uptake by plants. It was found that, for soils with the same total Cd content, Cd was more soluble and more plant-available in a sandy soil than in a clay soil (Eriksson, 1989). If the soils vary widely in Cd content and in other physico-chemical properties, it may be difficult to predict which of these factors has greater effect on Cd uptake by plants.

This study was planned to investigate the effects of Cd-containing NPK fertilizers on Cd uptake by different plant species grown at different pH levels in soils of varying texture. The relative uptake of Cd added as Cd-salt or NPK fertilizers was also investigated. The plant species were selected on the basis of their inherent capacity for Cd uptake and their use for food or fodder purposes.

2. Materials and Methods

Two soils, a loam and a sand collected from Aas and Elverum located in southeastern Norway were used for this study. The soil from Aas is classified as Fluventic Humaquept and that from Elverum as Typic Udipsamment (Soil survey staff, 1975). The soils were air-dried, ground and passed through a 2 mm sieve prior to mixing with the required amounts of lime and fertilizers. Some properties of these soils