Net Mineralization Rate of Selenium from Plant Material and Inorganic Salts

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Introduction

Selenium (Se) is an essential nutrient for animals, humans and microorganisms. The importance of Se in the prevention, as well as the treatment, of chronic and degenerative diseases in humans has been established (Rayman 2000). In large parts of the world Se availability in soils is very low. Thus, crops produced in these areas may have very low Se concentrations (Oldfield 2002). In order to increase the average Se intake, Se-enriched mineral fertilizers have been used in crop production (White and Broadley, 2009). However, only a limited amount of added Se is absorbed by crops (Hambuckers 2008). Most of the published studies on Se transformations in soil have been carried out at high concentrations. It is still not fully understood if changes in soil environmental factors may cause mobilization of previously applied Se. Therefore, it may be safer to find an alternative Se source that is more bioavailable than Se in inorganic fertilizers.

Catch crops have been used successfully in agriculture to improve soil fertility, increase nitrogen and sulfur content in the soil and avoid nutrient leaching. Several forage plant species (wild mustard, canola, alfalfa, birds foot trefoil, tall fescue) absorb Se when grown in soil where Se enriched plant tissues are incorporated (Bañuelos et al. 1991; Bañuelos et al. 1992; Dhillon et al. 2007). The efficiency with which Se in plant residues is utilized depends on the rate at which they are mineralized and thus on the timing of Se release relative to crop requirements. Otherwise, nutrients are susceptible to leaching from the root zone before they can be taken up by the crop (Bañuelos and Lin 2005). The mineralization of selenium from seleniferous organic material is slow and a large proportion of Se (>80%) remains unutilized by the following crops (Ajwa et al. 1998; Dhillon et al. 2007). The intention of the present study was to estimate the net Se mineralization rate from plant material, relative to inorganic salts, and to evaluate the risk of Se leaching after their application.

Materials and Methods

A laboratory incubation experiment under aerobic conditions was established using a randomised complete block design with three replicates of three types of plant material and two inorganic treatments.

Plant material of fodder radish (FR), Italian ryegrass (IR) and hairy vetch (HV) was collected from catch crop field experiments at Aarslev (Denmark) in November 2008. The plant material was chopped and stored at -20°C. Soil was air-dried and sieved (< 4 mm).

Leaching columns were constructed from 25 cm long Perspex glass tubes with an inner diameter of 7 cm. The bottom of the tubes was covered with glass wool. A thin layer of glass wool was placed on top of the soil in each tube to restrict evaporation but allow aeration. The tubes were filled with a mixture of sieved soil and sand in a ratio of 2:1 (900 g dry weight). Fodder radish, hairy vetch and Italian ryegrass were added to provide the equivalent of 3500 kg DM ha⁻¹. Sodium selenate was applied corresponding to 10 g Se ha⁻¹ in two treatments. In one of them (Se+C) 1470 g C ha⁻¹ was added as sucrose. An unamended soil treatment was included as a control (C). All the treatments were mixed thoroughly with the soil-sand mixture and placed over the soil in the tube (10 cm depth), with a 3 cm layer of unamended soil placed above the mixture. The moisture content of the soil-sand mixture was brought to approximately 85% of the
water holding capacity. The tubes were incubated in the dark at room temperature.

Four weeks after incubation, tubes were stepwise leached with 200 ml of de-ionized water in 100 ml aliquots. The leaching was repeated approximately every 4-5 weeks. The leachate was collected and the total amount was recorded. Samples of the leachate were stored at 4°C in glass bottles with 2% HNO₃ prior to analysis by ICP-MS.

Results and Discussion

The addition of plant material was found to reduce the Se concentration in leachate significantly during the first leaching. In sandy soils, where organic matter is applied it has been shown that Se is effectively bound to soil organic matter and a small fraction of the added Se is utilized by plants (Johnsson 1991; Ajwa et al. 1998). In the first leaching, Se concentration in leachate was lower when inorganic Se was applied than in the control treatment (not significant). The addition of sucrose reduced Se leaching, which is consistent with other studies (Ajwa et al. 1998), however the reduction was not significant. The differences in Se concentration in the leachate between the treatments in the second leaching were not significant.

Figure 1. Se concentration (µg L⁻¹) in leachate. Vertical bars indicate SE.

Statistically significant interactions were found between the first and the second leaching. After one month incubation since the first leaching, Se concentration in leachate was significantly increased wherever organic C sources were added. The opposite trend was found for the control and the Se inorganic treatment, where the Se concentration was reduced from the first to the second leaching. The effect of organic mater and C application on the timing of availability of soil Se added as organic or inorganic Se will be clarified further when the results of all four leachings will be available.

References


