3 Alkali Earth Metals Ca and Sr

Calcium (Ca) is the most common natural alkaline earth metal. In plants, calcium is a nutrient element; however, unlike in animals, its functions in plants are limited: it is mobile and necessary for cell division, cell wall, and membrane functions. The calcium content of the earth crust (2.96%) exceeds that of strontium (Sr) by several orders of magnitude (3.4×10^{-2}%), and may discriminate strontium uptake by plants, including its radioactive isotopes. Plant roots take up Ca as divalent ions, uptake is passive, and Ca^{2+} is taken up by facilitated diffusion via a specific Ca channel. Calcium is restricted to the apoplast and an efflux mechanism is important, as Ca easily forms complexes with phosphate, which may affect the energy mechanism (Greger, 2004). Uptake of Sr appears to occur equally by either metabolic or passive processes. Strontium is considered an approximate chemical and physiological analogue of Ca and is often associated with Ca. This chemical analogy implies competition between these two ions. Due to discrimination by the chemical analogue of calcium, the transfer coefficient for Sr is low. The sorption of ^{90}Sr in soils is enhanced by the increased concentration of CO_3^{2-}, PO_4^{3-} and SO_4^{2-} anions and the by the co-precipitation of Sr compounds with low solubility and low assimilability. Therefore, Sr has low bioavailability in soils with a high content of exchangeable forms of phosphorus and sulfur.

Concentrations of Ca and Sr in soil fractions: bulk soil, rhizosphere, soil-root interface, fungal mycelium and fruit bodies of fungi are relatively high (Table 3.1).

The concentration of Ca is found to be slightly higher in the rhizosphere fraction and mycelium than in the bulk soil and soil-root interface fractions. Strontium concentration is higher in the rhizosphere. Fungal sporocarps

contained noticeably less calcium and strontium than mycelium. Despite a very high level of Ca in bulk soil, the mechanism of Ca exclusion appears efficient.

Table 3.1 *Concentrations of alkaline earth metals (mg kg^{-1} DW) and bioconcentration ratios (BCR: defined as concentration of the element (mg kg^{-1} DW) in the specific fraction divided by concentration of the element (mg kg^{-1} DW) in bulk soil), in soil fractions and fungi, mean values ± standard deviation (Vinichuk et al. 2010b)[1].*

Element	Bulk soil	Rhizo-sphere	Soil-root-interface	Fungal mycelium	Fruit bodies
			Concentrations		
Ca	11785 ±11 335[a]	16042±9 513[b]	10514±7 122[a]	15 780 ±9 992[b]	377.2 ±293.2
Sr	17.14 ±10.6[a]	22.5±7.77[b]	18.7±7.85[a]	17.9±6.77[a]	0.873±0.749
			Bioconcentration ratios		
Ca	-	1.27±0.51	0. 80±0.24	2.03±1.56	0.06±0.06
Sr	-	1.32±0.53	1.18±0.56	1.31±0.66	0.10±0.18

[1]Means within rows with different letters (a or b) are significantly different ($p < 0.01$).

Table 3.2 *Element bioconcentration ratios (BCR: mg kg^{-1} DW in fungi) / (mg kg^{-1} DW in bulk soil) for fungal sporocarps.*

Sampling plots according to Vinichuk et al. (2010b)	Species	Ca	Sr
4	*Boletus edulis*	0.02	0.01
6	*Cantharellus tubaeformis*	0.04	0.03
10	*Collybia peronata*[a]	0.09	0.05
7	*Cortinarius armeniacus*	0.13	0.04
5	*C. odorifer*	0.01	0.04
8	*C.* spp.	0.21	0.14
8-10	*Hypholoma capnoides*[a]	0.05	0.66
1	*Lactarius deterrimus*	-	0.03
3	*L. scrobiculatus*	0.01	0.03
6	*L. trivialis*	0.05	0.03
5-7	*Sarcodon imbricatus*	0.04	0.02
2	*Suillus granulatus*	0.03	0.01
8-10	*Tricholoma equestre*	0.02	0.09

[a]Saprophyte.

Fungal sporocarps varied in their ability to accumulate alkaline earth metals, although the concentration of calcium within fruit bodies of different species was several orders of magnitude higher than the concentration of strontium (Table 3.2).

Although the alkaline earth metal radium (Ra) was also included in this study, the concentrations were below the detection limit (0.005 mg kg^{-1} d.w.) and were excluded.

Calcium uptake correlates fairly well with Sr uptake in fungi: the Pearson correlation of Sr and Ca in fruit bodies of fungi is 0.904 (P-value = 0.000).