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Metal Accumulation Capacity of Five Species of Sphagnum Moss

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Biological monitoring of airborne metals has proven to be superior to the traditional physico-chemical and technical methods especially in remote areas and in large-scale investigations (e.g. Glooschenko *et al.* 1981). The peat mosses (*Sphagnum* spp.) have been successfully used as accumulators of heavy metals. The applicability of the *Sphagna* depends principally on their exceptionally high cation exchange capacity (Clymo 1963).

Well-developed interspecific differences were found in the mineral element composition of mosses occupying uniform habitats depending on atmospheric sources of nutrient inputs (Aulio 1980), and in accordance with the trophic status of the sites studied (Aulio 1982). The conclusion drawn from those comparisons was that the moss species itself was the most important factor in determining the specific metal accumulation phenomena. Other studies have emphasized the role of environmental factors in directing the variability in the elemental composition of the *Sphagna* (Pakarinen 1978).

The present paper describes the first experimental evidence of the species-specific differences in the cation accumulation properties in *Sphagnum* mosses. Manganese was chosen for the object of the experiments because this element appears to show the greatest variability under natural conditions.

MATERIALS AND METHODS

The accumulation of manganese was studied in five species of peat mosses (*Sphagnum* spp.). Of these, three species belonging to the Sect. Acutifolia, viz. *S. nemoreum*, *S. fuscum* and *S. russowii*, occupy dry hummocky microhabitats, whereas *S. majus* (Sect. Cuspidata) grows in wet hollows, and *S. papillosum* occupies intermediate moist lawn microhabitats. The nomenclature of the *Sphagnum* mosses follows Isoviita (1966).

The plant material was collected from the ombrotrophic raised bog Kurjenrahka in SW Finland (cf. Aulio 1980). For each species, the current years' growth increments were used. These capitula (20-30 individuals were used for each species and each treatment) were

submerged in dishes containing 150 ml of Mn-free nutrient medium (MS-solution of Waris 1953). Inorganic manganese was added to the medium as $MnSO_4.4H_2O$ to produce final concentrations of 1, 10 and 100 µg/l manganese in the nutrient solution. Before experiments, the acidity of the medium was adjusted to pH 5.0. The mosses were incubated for 60 hours at 18 °C under continuous light (intensity of 120 $\mu E/m^2/s$). The accumulation as a function of time was studied in the hollow species *S. cuspidatum* (Sect. Cuspidata). Capitulum segments were incubated in medium containing 10 µg/l of manganese. The treatments lasting from 30 minutes to 128 hours were carried out in triplicate. The experimental conditions were as described above. After treatments, the levels of manganese accumulated in moss tissues were determined by conventional methods of flame atomic absorption spectrophotometry (for details, see Aulio 1980). Three replicates were analysed for each species and for each treatment. All the results are presented as µg/g of dry weight.

RESULTS AND DISCUSSION

The accumulation as a function of time revealed that the enrichment of manganese took place rapidly. Over 90 % of the manganese accumulated in the equilibrium state was taken up during the first 30 minutes of the experiment (Fig. 1). Thereafter the accumulation resulted in negligible increases in the total manganese content of the moss tissues (Fig. 1). This pattern suggests that the accumulation of manganese in *S. cuspidatum* was achieved through passive cation exchange processes in the cell walls.

Similarly, the direct relationship between the metal levels in the moss tissues and in the growing medium closely resembles features of passive enrichment in each of the five species (Fig. 2). The hypothesis of passive uptake is strongly supported by the morphological characteristics of the *Sphagna*, i.e. the great proportion of dead hyaline cells, as well as the well-developed cation exchange capacity of the cell walls (Clymo 1963). Such a passive accumulation of metals in cell walls, without any enrichment in cytoplasm, has been reported e.g. in *Grimmia doniana* (Brown & Bates 1972). In contrast, based on the vertical distribution of elements, Pakarinen (1978) suggested that *Sphagnum* mosses apparently can take up manganese through active processes.

The duration of the experiment was based on the assumption that at the end of the period the accumulation had reached the equilibrium level in each of the species (cf. Fig. 1). The enrichment of manganese at the highest Mn-application would thus demonstrate the actual accumulation capacity of the species studied. Hence the capacity reflects the total levels of metals taken up by the moss tissues, not only the fraction bound into the exchange sites of cell walls.

The accumulation profiles (Fig. 2) clearly demonstrated that the interspecific differences, previously reported in field materials (Aulio 1980), maintained even in uniform experimental conditions.

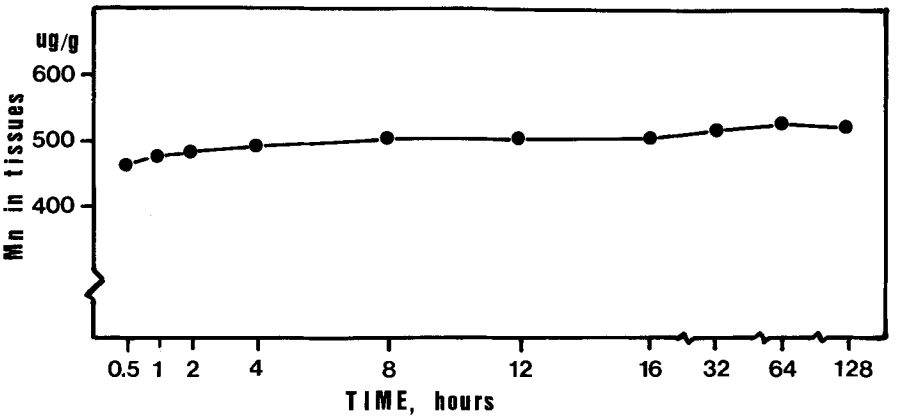

Figure 1. Manganese uptake in *Sphagnum cuspidatum* as a function of time. Mean values for three replicates grown in medium of 10 µg/l of manganese.

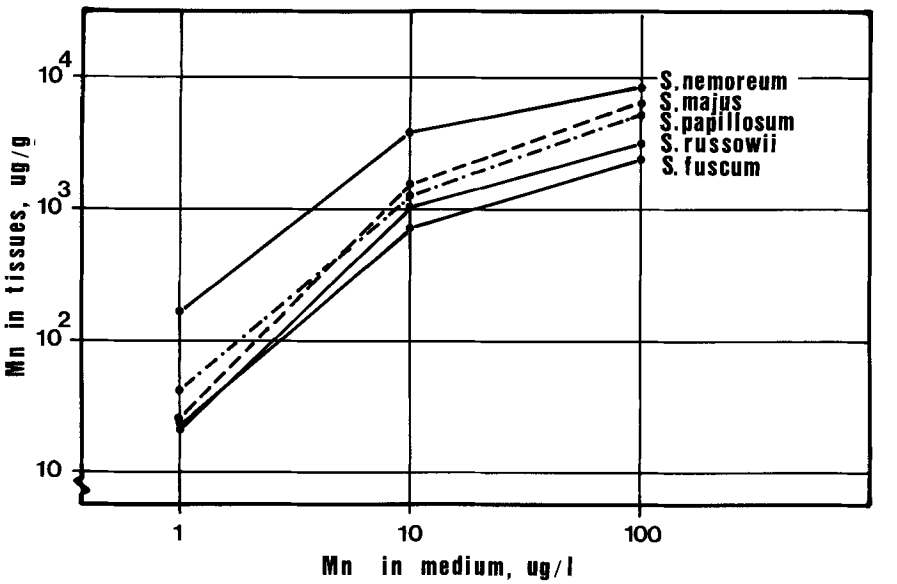

Figure 2. Manganese contents (µg/g dry weight) in five species of *Sphagnum* mosses grown for 60 hours at varying concentrations of manganese in the growing medium. Each point represents arithmetic mean for three replicate samples.

The differences in the manganese accumulation capacity were considerable (Fig. 2, note the logarithmic scale on the ordinate). Thus, at the highest concentration (100 µg/l), the values recorded for *S. nemoreum* were twofold the levels measured in *S. fuscum* (9400 µg/g and 4950 µg/g, respectively).

The order of the taxa in respect to their accumulation capacity coincided well with the results obtained in the previous investigation of field-collected materials (Aulio 1980), where it was assumed that the taxa accumulated metals specifically under uniform availability of airborne nutrients. In spite of the marked interspecific variations the present study could not verify any patterns in the cation accumulation capacity either according to the systematic relationships of the genus (cf. Puustjärvi 1955) or according to the species' natural habitats (cf. Clymo 1963, Spearing 1972). Thus, both the species having the highest and the lowest values (*S. nemoreum* and *S. fuscum*, respectively) are members of the Sect. Acutifolia. Furthermore both species occupy same kinds of dry microhabitats.

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