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Does high cation exchange capacity of Sphagnum mosses drive fen-bog successions?

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Acidic bogs currently contain about 30% of the world's terrestrial carbon sink. The processes leading to bog formation are crucially important for Earth's carbon cycle. We challenge the widely accepted theory about the mechanism of peatland acidification, which claims that a shift from rich, alkaline fen to a poor, acidic bog is caused by alive Sphagnum peat mosses that have high cation exchange capacity (CEC), being an adaptation to nutrient acquisition in a nutrient poor environment.

We tested the hypotheses that (1) living Sphagna have extraordinarily high cation exchange capacity, compared to other bryophytes and acidify their environment by exchanging tissue-bound protons for basic cations in soil water, being therefore responsible for rich fen – poor bog succession, and (2) bryophytes CEC increases with increase of habitat water availability, measured as field cushion water content, and does not depend on habitat nutrient availability.

We screened 20 sub-arctic bryophyte species, including rich fen brown mosses and poor bog Sphagna for CEC, in situ soil water acidification capacity (AC), and field cushion water content. The first two traits were measured in lab experiments and the last one was measured through two field seasons in the field every hour. To our surprise we discovered that brown mosses and Sphagna had nearly equal CEC ranging from 155 to 185 μeq/g dry mass. However, Sphagnum AC was 5-20 times higher than AC of rich fen mosses (30-60 μeq/g dry mass vs virtually 0). For all species investigated, AC was much lower than their CEC, but for Sphagnum the difference was only 1.2-5 fold, while for rich fen mosses it was 50-200 fold. Bryophyte tissue CEC increased along with increase of field cushion water content averaged though the vegetation season.

Our first hypothesis is not confirmed. Instead, our results suggest that the CEC sites of the rich fen mosses in situ are saturated with basic cations, while those of Sphagna are not, suggesting that brown moss tissues conduct cation exchange immediately after ontogeny, while bog Sphagna are not able to do this due to the absence of basic cations in bog water. This refutes the commonly accepted paradigm of living Sphagnum CEC being responsible for peatland acidification, as Sphagnum's ecological predecessors, brown mosses, are capable of doing the same job. We conclude that CEC of living Sphagna does not play any considerable role in the fen–bog shift. Alternatively, we propose that exclusively indirect effects of Sphagnum expansion such as peat accumulation and subsequent blocking of upward alkaline soil water transport are keys to the fen–bog succession and therefore for bog-associated carbon accumulation.

Our second hypothesis is confirmed. The similarly high CEC of bryophytes growing in wetlands, both nutrient rich and poor, and much lower CEC of bryophytes associated with dryer areas, refutes the commonly accepted idea that high cation exchange capacity of (some) bryophytes is an adaptation to nutrient poor environments. We suggest that rather high cation exchange capacity is an adaptation to nutrient acquisition in extremely wet habitats irrespective to their nutrient richness.