Sphagnum farming in progress – experiences and perspectives

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Summary
As white peat would otherwise remain in the mire for thousands of years, its extraction for horticultural use mobilizes 'fossil' CO_2 and destroys unique mire biodiversity unrecoverably. Furthermore peat is a finite resource and its extraction is continually relocated to new areas. This polluting and non sustainable extraction continues because an appropriate alternative for peat in horticulture is still lacking. Wet cultivation ('paludiculture') of peat moss biomass on rewetted degraded bogs (*Sphagnum* farming) may provide such alternative. Results of a first research project illustrate the possible implementation of *Sphagnum* farming in Germany.

Key index words: peat, casing for mushroom production, physical and chemical parameters.

Introduction
White peat (slightly humified *Sphagnum* peat) offers optimal quality for horticultural substrates (Schmilewski 2008). About 30 Mio m³ of this moss peat are globally used for this purpose annually. This peat would normally remain for thousands of years in the mire as an important carbon store. By using it as a substrate it is converted after a short period of use to almost 6 Mio t of CO_2.

The stocks of white peat in Western and Central Europe are nearly depleted. As peat accumulates so slowly that it is practically a non-renewable resource, the extraction is continually relocated to new areas. Peat extraction is thus non sustainable and harmful to the climate and to biodiversity. Therefore alternatives have urgently to be found. White peat consists of incompletely decomposed *Sphagnum* plants. In the process of peat formation more and more plant material disappears by decomposition until eventually only 10-15% of the net primary production is durably stored as peat. To maximise yields the primary production can thus be much more efficiently utilised by using as fresh *Sphagnum* biomass as possible. Fresh *Sphagnum* biomass appears to have similar physical and chemical properties as white peat, has an additional bactericide and fungicide effect and enables plant cultivation without loss of quality (Emmel in press). Fresh *Sphagnum* biomass is already being used as a growing medium for special cultures e.g. orchids. It is currently being collected from natural peatlands in a non sustainable way (Orchard 1994, Whinam et al. 2003). Such wild harvesting cannot provide enough *Sphagnum* biomass to substitute white peat as the scarcity of undisturbed bogs requires their strict protection in most parts of the world. In contrast, degraded bogs provide a big potential for *Sphagnum* cultivation. By rewetting the bogs and stimulating *Sphagnum* establishment, degraded landscapes are converted into green *Sphagnum* lawns. Such wet cultivation ('paludiculture') provides habitats for rare species, inhibits CO_2 emission, supplies an important raw material and may ensure continual employment in rural areas.

As *Sphagnum* growth is largely determined by abiotic conditions (Lütt 1992), primary production may be enhanced by managed cultivation. Studies in *Sphagnum* ecology under natural conditions and for bog restoration indicate that *Sphagnum* productivity can be increased by high water tables (Clymo and Reddaway 1974, Lütt 1992, Rydin 1993), phosphate and potassium fertilisation (under conditions with high atmospheric nitrogen deposition - such as in Western Europe - peat moss growth is not nitrogen-limited, Malmer 1990, Aerts et al. 1992, Verhoeven et al. 1996, Limpens & Berendse 2000), some shading (Pedersen 1975, Clymo & Hayward 1982, Lütt 1992) and increased CO_2 availability (Silvola 1990, Paffen & Roelofs 1991, Smolders et al. 2001). Until recently, however, no research has focused on growing *Sphagnum* for commercial purposes. This paper reports on a three year research project on the feasibility of *Sphagnum* farming in Germany focussing on identifying optimal conditions for *Sphagnum* growth using greenhouse and field experiments.

Materials and Methods
Samples of different *Sphagnum* species were cut out from natural peat moss lawns and placed in pots (12x12x12 cm) maintaining their natural configuration. Cultivation took place under controlled conditions in a greenhouse using a nutrient solution after Rudolph et al. (1988). Different water levels (*stable* at 2 cm below the capitula, *fluctuating* between 2 cm (1 week) and 8 cm (3 weeks) below the capitula or starting with 2 cm below the capitula and relatively *sinking* with moss growth) were maintained by irrigating with demineralised water (several times a day) and by adjusting the position of the pots in a water basin. Every third week the plants were provided (with a dispensette)

with a nutrient solution proportional to the annual deposition in Lower Saxony (= control), with variants of different concentrations of phosphorus and potassium. All treatments comprised six replicates.

To investigate the effects of possibly increased CO_2-supply from decomposing peat, *S. papillosum* was cultivated in an open greenhouse (only protected from rainfall) in pots with different substrates (sterilised highly-decomposed *Sphagnum* peat [pH 3,2], sod of bog grassland [pH ca. 4,5], or highly-decomposed *Sphagnum* peat [pH 3,2] limed up to pH 8,1 with 10 g CaO l^{-1} peat). The substrates were covered with 10 cm of sterilised highly-decomposed *Sphagnum* peat over which *S. papillosum* fragments were spread and subsequently covered with a layer of straw mulch to provide a suitable microclimate (Quinty and Rochefort 2003). Water levels in all variants were kept on 0 and 5 cm below the capitula by irrigating with demineralised water two times a day. Fertiliser solution was applied every third week with a dispensette. All treatments comprised three replicates.

After one or three years the length and biomass growth of the mosses was measured and its increase tested against the various parameters using a three way factorial ANOVA (R Development Core Team 2004).

Results

Our pot experiments conclusively show that a high and stable water level (2 cm below the capitula) is the most decisive factor for *Sphagnum* growth whereas fertilisation has only a minor effect (fig. 1). Differences in productivity between the different *Sphagnum* species are significant, but small. Most values range between 3 and 6 t dry mass ha^{-1} y^{-1}. Differences in length increase are clearer: *S. fallax* grows faster in length than the other species, *S. papillosum* shows the lowest values. *Sphagnum* growth on black peat and bog grassland sods is much better than on limed black peat (which was limed to stimulate CO_2 production).

Discussion

Even if *S. fallax* shows the highest growth values (max. 48 cm y^{-1} and 9 t dry mass ha^{-1} y^{-1}) its cultivation is risky because it collapses more often than the other species and it is unsuitable for growing media (Emmel and Kennet 2007). Because yields are similar the selection of *Sphagnum* species for cultivation is determined by their structure (compact or elongated) and horticultural suitability. Species of the section Cymbifolia (*S. papillosum*, *S. palustre*) grow more compact than *S. fallax* or *S. fimbriatum.*

Fertilisation is not necessary for stimulating growth as the nutrient input by atmospheric deposition in Lower Saxony is sufficient. A high and stable water level is decisive for maximizing yields of every tested species. A good irrigation system is therefore the base of successful *Sphagnum* farming.

The assumed higher decomposition rate of bog grassland and limed substrates could not be confirmed by CO_2 measurements, indeed the lower biological activity in the substrate points to less CO_2-release after liming.

Conclusion/Outlook

The results of the first project are promising and point to the feasibility of *Sphagnum* farming on cut-over bog and bog grassland in Germany. With water level regulation the

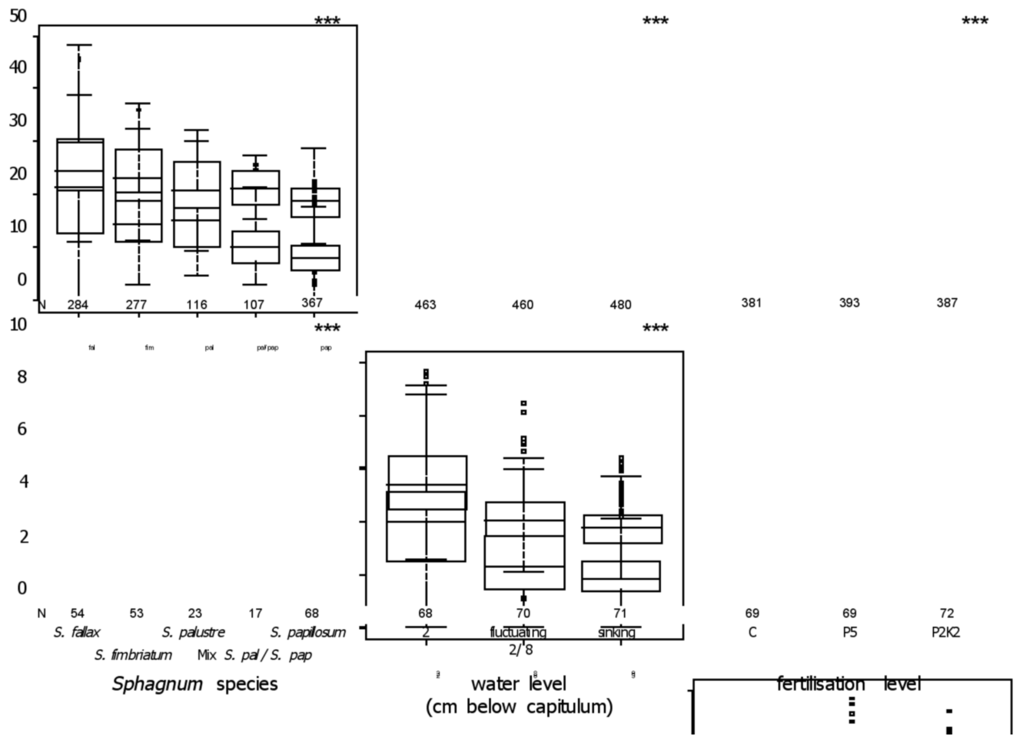

Figure 1. Length increase (cm y^{-1}) and dry mass productivity (t ha^{-1} y^{-1}) for different Sphagnum species, water level regimes and fertilisation levels of peat mosses in a nutrient solution under controlled conditions. *** level of significance (p < 0,001).

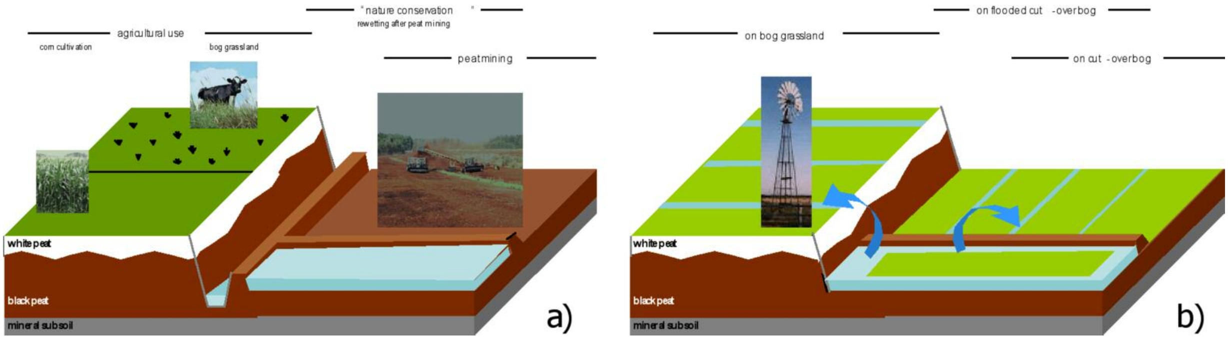

Figure 2. Mosaic of degraded bogs a) with current use types and b) with possible Sphagnum farming.

productivity of peat mosses can be increased. The production rates determined in the greenhouse experiment (fig. 1) can, however, only be applied to field conditions to a limited degree. The mean growth rate for *S. papillosum* after the first 3 years amounted to 1 to 3 t dry mass ha^{-1} y^{-1}. In contrast to the greenhouse experiment, where from the beginning moss plants in their natural configuration were used, a dense moss lawn first had to establish from fragments spread on a rewetted cut-over bog. Additionally in the field the vegetation period is much shorter and competition with vascular plants may reduce *Sphagnum* growth (Kamermann 2006).

With a conservative yield of 65 m^3 of *Sphagnum* biomass per ha per year (corresponding to 2 t dry mass ha^{-1} y^{-1}), the area for *Sphagnum* farming required to cover the demands for white peat in Germany (3 Mio m^3 a^{-1}) is ca. 45.000 ha (provided that *Sphagnum* biomass replaces white peat 1:1). The most promising region to realize this area is Lower Saxony where ca. 165.000 ha of bog grassland ('Deutsche Hochmoorkultur') do not have other perspectives for economic use. In addition to degraded bogs, open water areas are currently surveyed as potential areas for *Sphagnum* farming using specially constructed floating mats. That would allow bog waters not only to function as water reservoirs to supply the cultivation area in dry periods (cf. Quinty & Rochefort 2003) but additionally as *Sphagnum* farming areas. As the *Sphagnum* covered mats would have less evapotranspiration than open water, a mosaic of rewetted peat areas (with on-the-ground cultivation) and deeper waters (with floating mat cultivation) could provide optimal conditions for *Sphagnum* farming (fig. 2). Difficulties (e.g. weeds, irrigation) and risks (e.g. parasites) of upscaling *Sphagnum* farming (Gaudig and Joosten 2007) have to be tested in further large scale field experiments.

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