Growing *Sphagnum*

FOREWORD

S. Glatzel[1] and L. Rochefort[2]

[1]University of Vienna, Austria and [2]Université Laval, Québec, Canada

In many places, especially in Europe, the collection of *Sphagnum* moss and the extraction of low-humification (fibric) *Sphagnum* peat from peatlands is no longer possible because these materials have become too scarce. Moreover, the favoured land uses for peatlands in both good and degraded condition nowadays include their protection and restoration for biodiversity conservation as well as rewetting to preserve the terrestrial carbon store. In restoring *Sphagnum* peatlands for nature conservation and other ecosystem services, an important goal is the recovery of their natural vegetation. This may not happen spontaneously for a variety of reasons (e.g. Poulin *et al*. 2005) so that intervention is often required, especially to establish growing *Sphagnum* (Figure 1) on bare peat surfaces.

Sphagnum fibre is an indispensable raw material for numerous valuable products, and demand continues to grow worldwide despite the increasing availability and industry uptake of peat alternatives (Caron & Rochefort 2013). For an in-depth explanation of what makes *Sphagnum* so good as a constituent of horticultural growing media and an account of where the market is expanding, see the review by Caron *et al*. (2015). However, concerned consumers and environmental groups campaign for more sustainable production methods because the material for this application is mostly obtained by extraction of so-called 'white' or 'blond' peat (also marketed as 'peat moss' by some suppliers). Undecomposed *Sphagnum* is used as 'floral moss' for orchid propagation, as packaging material (e.g. for fish and orchids), for specialised products like biodegradable flowerpots, for green walls or roof gardening, and as 'seed' material for peatland restoration. To meet all of these demands, we need to develop new techniques for producing *Sphagnum* fibre. Considering the fact that *Sphagnum* moss will have lost 90 % of its biomass by the time it eventually becomes peat (Clymo 1984), *Sphagnum* fibre is obtained more efficiently by harvesting moss than by peat extraction. Recently, the practice of growing *Sphagnum*, known as '*Sphagnum* paludiculture' or '*Sphagnum* farming', has been tested in several locations. *Sphagnum* farming is defined as the sustainable production of non-decomposed *Sphagnum* biomass on a cyclic and renewable basis.

The challenges of growing *Sphagnum* are manifold. The propagation of diaspores is especially important because, in many cases, the protected status of *Sphagnum* is an obstacle to finding propagule material in sufficient quantities. Then, horticultural and agronomic aspects of producing a crop are not straightforward (Gaudig *et al*. 2014, Pouliot *et al*. 2015) because we are dealing with a plant that lacks roots and whose leaves respond directly to the environment on account of their single-layered cell structure. *Sphagnum* tends to be out-competed by other plants in regions with abundant nitrogen supply (Limpens *et al*. 2011), such as parts of central Europe that are heavily affected by atmospheric nitrogen deposition. Difficult legal issues arise and traditional conservationist views are challenged when grassland is converted to 'cropland' to produce *Sphagnum*, and when Red List species are to be harvested. Consequently, research is needed on topics ranging from the biology, propagation and cultivation of *Sphagnum* to irrigation engineering, economics and the revision of land tenure law before a full-scale *Sphagnum*-based agro-industry can be developed.

The 'Growing *Sphagnum*' Special Volume of *Mires and Peat* brings together research spanning the whole of the spectrum outlined above, in 13 articles.

Silvan *et al*. (2017) describe a method tested in Finland by which *Sphagnum* biomass is harvested directly from mires. Early results indicate that there is potential for sustainable operation of the approach in a manner that is largely comparable with sustainable forestry management. Another sustainable production approach is proposed by **Gaudig *et al*.** (2017) for Germany, whereby formerly extracted bogs can be converted to the climate-friendly land use of *Sphagnum* farming. During the first large-scale trial in Europe, they measured a production of 19.5 tonnes *per* hectare of accumulated dry biomass after nine years.

When harvesting *Sphagnum* from semi-natural or natural peatlands, its regrowth needs to be ensured. **Krebs *et al*.** (2018) compare *Sphagnum* regrowth on sites in (cool) temperate Germany and warm temperate Georgia, and find no pronounced difference between these two climatic zones.

Figure 1. Some example species of growing *Sphagnum* moss. Top left: a mixture of *Sphagnum balticum* (the more-slender species, reddish colour) and *Sphagnum papillosum* (more robust, ochre colour); top right: *Sphagnum fimbriatum* - note the insectivorous sundew (*Drosera* sp.) plant rooted in the moss carpet; bottom left: *Sphagnum majus*; bottom right: *Sphagnum lindbergii*. In the two right-hand images, the spherical objects are spore capsules. Photos: Gilles Ayotte.

In relation to optimising *Sphagnum* growth conditions on extracted bogs, **Guêné-Nanchen *et al*.** (2017) question the expected importance of vascular plants competing with the developing moss carpet. When the dominant vascular plant invading the *Sphagnum* farming system has a graminoid form (e.g. a sedge) it appears that no ‘weed’ control is needed because the plant produces minimal amounts of litter.

It is important to assess the greenhouse gas release and carbon sequestration potential of *Sphagnum* farming as a new land use strategy for peatlands, because the drained and fertilised peatlands that are used for traditional farming have been identified as hotspots of agricultural GHG emissions. **Günther *et al*.** (2017) report that establishing a *Sphagnum* farm on bog that was formerly under grassland utilised for low-intensity agriculture reduced its GHG emissions, and suggest that the fields could be designed for even higher C sequestration efficiency by minimising the area occupied by irrigation ditches. Interestingly, this idea has been tested on the other side of the Atlantic by **Brown *et al.*** (2017), who showed that CO_2 uptake was indeed maximised when the irrigation system consisted of perforated sub-surface drainage tiles. These authors recommend that, to maximise CO_2 uptake, the irrigation system design should confine the range of water table fluctuations to ± 7.5 cm of the seasonal mean.

From another management viewpoint, the mechanical harvesting of farmed *Sphagnum* biomass in a wetland environment is challenging. **Kumar** (2017) discusses the results of various trials that continue through the post-harvest processing of *Sphagnum* material to produce professional growing media constituents, and concludes that mechanical treatments do not impact negatively on the quality of the eventual product.

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When producing *Sphagnum* biomass, economic aspects are critical. Is *Sphagnum* farming lucrative? What needs to be done to make it economically viable in different legislative contexts, with and without agricultural and environmentally motivated subsidies? **Wichmann *et al*.** (2017) present a first assessment of the economics of establishing commercial *Sphagnum* cultures on areas belonging to different land use categories.

The collection and propagation of suitable *Sphagnum* species is a challenging prerequisite when setting up sites for cultivation. Due to the widely varying environmental settings of *Sphagnum* cultivation sites, many different approaches are being tested. **Hugron & Rochefort** (2018) compare the regeneration capacity on outdoor experimental plots of cultivated *Sphagnum* and *Sphagnum* harvested from natural peatland. When donor plants are very rare, *Sphagnum* propagated from sterile tissue cultures may be a viable alternative. **Caporn *et al*.** (2018) describe this ‘micropropagation’ process and the introduction of juvenile mosses into field sites on degraded raised and blanket bogs in northern England.

An adequate water supply is a key requirement for the successful cultivation of *Sphagnum*. **Brust *et al*.** (2018) outline the importance of understanding all components of the water balance of *Sphagnum* farming sites and emphasise the benefits of large sites in terms of lower seepage losses and a reduced oasis effect. Problems of low, high or fluctuating water table can be overcome by establishing *Sphagnum* in floating cultures. **Hoshi** (2017) compares the growth of *Sphagnum* capitula established in colonies of different sizes on floating rafts at mountain and urban sites in south-west Japan.

In their closing contribution, **Gaudig *et al*.** (2018) provide a comprehensive review of current knowledge relating to the entire sequence of *Sphagnum* farming operations, from the selection of suitable seed material and the cultivation process to post-harvesting applications of *Sphagnum* biomass in horticultural growing media.

The contents of this Special Volume show that some progress towards *Sphagnum*-based agriculture has been made since 2004, but several questions still need answers. Ecological considerations that will be important when producing a crop on peat bog soil include the export of dissolved organic carbon (DOC) and phosphorus (P) to downstream water bodies, as well as biodiversity. To obtain a complete picture of all economic and ecological aspects, it is important to conduct life cycle analyses as well as local case studies. The results may help to disentangle the complex relationships between the multiple facets of *Sphagnum* biomass production mentioned above, and to balance the inevitable trade-offs.

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Volume Editors' contact information:

[1]Professor Stephan Glatzel, Department of Geography and Regional Research, University of Vienna, Austria.
Email: stephan.glatzel@univie.ac.at

[2]Professor Line Rochefort, Department of Plant Sciences, Université Laval, Québec, Canada.
Email: Line.Rochefort@fsaa.ulaval.ca

