Ecological Engineering 74 (2015) 135–147

Contents lists available at ScienceDirect

Ecological Engineering

journal homepage: www.elsevier.com/locate/ecoleng

Sphagnum farming: A long-term study on producing peat moss biomass sustainably

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ARTICLE INFO

Article history:
Received 9 April 2014
Received in revised form 25 September 2014
Accepted 6 October 2014
Available online 29 October 2014

Keywords:
Cutover bog
Horticultural substrate
Hydrology
Paludiculture
Peatland
Reclamation

ABSTRACT

Sphagnum farming refers to the cultivation of *Sphagnum* mosses to produce *Sphagnum* biomass sustainably. Some possible uses of these fibers are as ingredients in growing substrates, as floral moss, as plant packaging during transport, or as moss reintroduction material for peatland restoration projects. Because this biomass production is sustainable, *Sphagnum* farming should reduce human impacts on natural peatlands. Despite its various benefits, research on *Sphagnum* farming is limited. To determine if *Sphagnum* farming is feasible on a large-scale basis (on the order of 900–1500 m^2 size basin), 6 yearly production cycles were implemented in trenches of former block-cut peatland in eastern Canada. These sites were monitored over seven growing seasons. *Sphagnum* cover (67%) and accumulated biomass (787 $g\,m^{-2}$) from the culture basins were similar or superior to surveys from restored peatlands. However, cover and biomass values differed greatly among production cycles when comparing the time elapsed since the creation of the basins. Differences in productivity during different cycles were largely coupled with variations of water table levels compared to intrinsic properties of plant interactions. We believe that the optimization of water access (for example through automated of irrigation systems) for *Sphagnum* mosses would greatly improve the productivity of *Sphagnum* farming.

1. General introduction

Peat will continue to be a major component of growing substrates over the next decades because of its unique qualities, low cost, and availability (Caron and Rochefort, 2013). *Sphagnum* farming is the cultivation of *Sphagnum* mosses to produce biomass of non-decomposed *Sphagnum* fibers on a cyclic and renewable basis. If a certain quantity of these *Sphagnum* fibers is used in conventional peat products, it would reduce the impact of peat extraction or of simple harvesting in the wild, while having the potential to maintain the quality of growing substrate mixes. *Sphagnum* can be farmed on various degraded and drained peatlands of former lands used for agriculture, forestry, roads, oil pad, energy, or horticultural substrates. Non-decomposed *Sphagnum* fibers thus produced would have the advantage to be harvested on a cyclic and renewable basis in comparison to peat moss conventionally harvested from natural peatlands. The establishment of a *Sphagnum* moss paludiculture (production under wet conditions) would reduce the negative environmental impacts of drainage such as peat oxidation, soil subsidence and CO_2 emissions (Joosten, 1998; Joosten et al., 2012).

Sphagnum fibers have multiple end uses that are environmentally sound. These fibers are currently sold as floral moss used in orchid propagation (largely for *Phalaenopsis* species), for roof greening (popular in South Asia), in miniature models, for urban yard landscaping, to top dress containers and flower beds, for lining wire framed hanging baskets, on lawn wire sculpture or for making wreath. These fibers could also successfully substitute peat in growing substrates (Emmel, 2008; Reinikainen et al., 2012), consequently lengthening the life time of a given peat deposit and reducing the expansion of peat harvesting, and can replace perlite or vermiculite in horticultural growing mixes (Jobin et al. submitted). In addition, *Sphagnum* fibers could be used to manufacture compostable plant pots, thus contributing to a substantial reduction of plastic. Further uses of these fibers include packaging seedling plants for transport and for cellar storing of root vegetables, protecting them against spoiling, mice, insects and other potential invaders. Finally, the *Sphagnum* fibers could be reintroduction material for ecological restoration of

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http://dx.doi.org/10.1016/j.ecoleng.2014.10.007
0925-8574/

cutover bog when using the moss layer transfer technique (Graf et al., 2012 or Rochefort and Lode, 2006 for the method description), especially in regions where natural peatlands are scarce and should be preserved.

Despite the multiple environmental benefits of *Sphagnum* farming, research, literature and ongoing projects are limited. Small scale trials have been conducted in many countries, such as Canada, Germany, Chile, Ireland, Finland, Korea, New Zealand and Japan in the last 10 years. With the exception of Gaudig et al. (2014), results from these trials were mostly presented in reports, which were not in English (see for example: Blievernicht et al., 2011; Joosten, 2010; Pouliot et al., 2012; Silvan, 2008), in conferences proceedings (see for example: Campeau and Rochefort, 2002; Gaudig et al., 2012; Krebs, 2008; Pouliot et al., 2013) or in journals without peer review (as Peatlands International, see for example: Joosten et al., 2013 or Landry et al., 2011b).

The general aim of this article is to review the main drivers favoring *Sphagnum* growth in cultivation and to present the results from a field experiment where 6 production cycles (on the order of 900–1500 m^2 size basin) were installed over 7 years in trenches of a block-cut peatland after cessation of peat harvest activities. In this experiment we wanted to determine if *Sphagnum* farming is feasible (logistically and for *Sphagnum* growth) on a large scale basis. More specifically, our goals were to determine (1) if large-scale mechanized *Sphagnum* farming will allow dense moss carpet to establish and develop quickly (within 5 years) and (2) whether an optimal hydrology for *Sphagnum* species could be maintained in the basins through an open ditch and overflow controls.

2. Drivers favoring *Sphagnum* growth in cultivation

Among drivers influencing *Sphagnum* growth, the more important are the intrinsic properties of *Sphagnum* species, plant interactions (among *Sphagnum* species and between *Sphagnum* and other moss or vascular plant species), and water level. All these factors can modify the yield rates in *Sphagnum* farming basins.

The intrinsic properties of *Sphagnum* species are generally similar within a main subgenus (*Acutifolia*,*Cuspidata* or *Sphagnum*) (Clymo and Hayward, 1982; Coulson and Butterfield, 1978; Johnson and Damman, 1993; Rochefort et al., 1990; Rydin, 1993; Rydin et al., 2006). These properties will affect the accumulation rate and the quality of biomass accumulating in *Sphagnum* farming basins. Species within the *Acutifolia* subgenus generally have higher stem densities and greater abilities to transport water by capillarity, enabling them to form carpet and cushion well above the water table. They have the lowest growth rates among all subgenera, but also the lowest decomposition rates (Johnson and Damman, 1993; Rochefort et al., 1990), with a result they can be interesting in *Sphagnum* farming. As a result, they often form the bulk of peat deposits in North America. Intrinsic properties of species from the *Sphagnum* subgenus can confer great porous and structuring quality to growing media due to their large hyaline cells and pores (Malcolm, 1996). Due to their size, these species generally have lower stem densities than species for the *Acutifolia* subgenus, but biomass per surface unit is still high. They also have low decomposition rates, but they do not have a great ability to transport water which can hamper their growing time during a field season (McCarter and Price, 2012). The generally wet species of the *Cuspidata* subgenus have the highest growth rates, but are also associated with low stem densities and high decomposition rates, quickly leaving only bundle of stem with poor porous quality. They also have the worst abilities to transport water. For all these reasons, the *Sphagnum* species from *Acutifolia* and *Sphagnum* subgenus should be targeted in the context of *Sphagnum* farming.

Competition or facilitation events in peatlands have a significant effect on *Sphagnum* growth and interactions between species are closely related to the distance from the water table. In fact, competition between *Sphagnum* species will be the limiting factor in the wetter part, closer to the water table level, while physiological tolerance to water stress will be more important in the driest part, farther of the water table level (see for example: Andrus et al., 1983; Rydin, 1993; Rydin and McDonald, 1985). In the context of large-scale reintroduction of *Sphagnum* diaspores in culture basins, donor material contains diaspores of species from all subgenera with a dominance of *Acutifolia*and *Sphagnum* subgenera. As competitive abilities of *Sphagnum* species will differ according to their position along the water table gradient, the control of the water table level in the basins can help to increase the growth of targeted species, while preventing the establishment of others. *Sphagnum* species can also interact positively with others. Experimentation in the field upon an earlier idea which pioneer species from *Cuspidata* subgenus (as *Sphagnum fallax* (Klinggr.) Klinggr.) can rapidly colonize humid areas and then prepare the substrate for the targeted species and facilitate their implantation speed (Grosvernier et al., 1997), was proved wrong. Indeed, under controlled water table level, no gain of biomass was observed for *Sphagnum magellanicum* Brid. or *Sphagnum papillosum* Lindb. when grown with *S. fallax* (Picard, 2010). On the other hand, the establishment and growth of species from the *Sphagnum* subgenus improve when mixed with species from the *Acutifolia* subgenus (Chirino et al., 2006). These species allow a better transport of water by capillarity to surrounding stems of *Sphagnum* subgenus when the water stress increases, reinforcing the choice of species from these subgenera for the *Sphagnum* farming. In addition, the presence of vascular plants can increase *Sphagnum* growth by creating adequate microclimates, by providing physical supports and by stabilizing the water table and the soil surface (Malmer et al., 1994, 2003). These effects are more important when the relative humidity is low, such as under continental temperate climate than under hyperoceanic climate where high rates of relative humidity prevails (Andrus, 1986; Kleinebecker et al., 2007; Pouliot et al., 2011). Moreover, the climate during the year when *Sphagnum* species were reintroduced affects the plant establishment speed, whereas the climate during subsequent years does not influence the development of *Sphagnum* carpet (Chirino et al., 2006). A better control of water table near the surface via irrigation, at least during the first year after basin creation, could overcome the limitation of the climatic effect, making the presence of vascular plants unnecessary. Finally, in greenhouse experiments, it was possible to control fungi infection in *Sphagnum* carpets by a fungicide application without any effects on *Sphagnum* growth (Landry et al., 2011a), giving us an option if this problem appears in *Sphagnum* farming basins. The control of algal proliferation should be also easier under a controlled water table level. Controlling the water table level is thus essential In *Sphagnum* farming because the right water level will positively affect the growth of target *Sphagnum* species and reduce the competition effects of undesirable ones.

Farming *Sphagnum* mosses in flat topography into basins helps to retain more water during dry summers as basins are lower than the surrounding lands and the presence overflow wooden devices avoids prolonged periods of flooding. Indeed, cultivating *Sphagnum* mosses in formerly peat block-cut trenches allows for a better development of the moss carpet during dry years, while having no effect during wet years (Campeau et al., 2004). While blocking drainage ditches can be enough to promote *Sphagnum* growth in old block-cut cutover peatlands (González et al., 2013), such trenches require an overflow outlet to prevent flooding. Flooding can harm *Sphagnum* establishment because newly introduced material can be displaced, peat erosion can bury the established material (Rochefort and Lode, 2006), and prolonged floods cause elongation of *Sphagnum* stems without any gain of biomass (Campeau et al., 2004).