Activity Report 2003-2008

Experimental Sphagnum Farming Station
Shippagan, New-Brunswick

April 2009

NSERC's Industrial Research Chair in Peatland Management

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Groupe de recherche en écologie des tourbières

Peatland Ecology Research Group

NSERC'S INDUSTRIAL RESEARCH CHAIR IN PEATLAND MANAGEMENT

Experimental *Sphagnum* Farming Station Shipaggan, New Brunswick

Activity Report 2003-2008

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Canadian Sphagnum Peat Moss
Tourbe de Sphaigne Canadienne

CRSNG
NSERC

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1. General description

Peatland Ecology Research Group (PERG) and its partners from the peat industry agreed in putting forward a project to promote *Sphagnum* biomass production under NSERC's Industrial Research Chair in Peatland Management. More specifically, the goal of the *Sphagnum* farming project is to rapidly produce a renewable source of *Sphagnum* fibre biomass for: 1) potentially contribute to the production of new high quality growing substrates, 2) production of floral moss, 3) fabrication of products composed mainly of *Sphagnum* fibre and 4) serve as a supply site of *Sphagnum* diasporas for peatland restoration after peat harvest.

In this perspective, the Shippagan peatland, abandoned after block-cut peat harvesting, offers a baulk and trench topography ideal for rapid *Sphagnum* growth without having to make intensive modifications to the field (Figure 1; Price et al., 2002; Campeau et al., 2004). Residual trenches (old trenches made by block-cutting) have been selected for their accessibility, their vegetative cover dominated by *Sphagnum* and also their hydrological conditions favourable to rewetting. Actually, trenches create humid microclimatic conditions propitious to *Sphagnum* growth.

Figure 1. Welcome sign located at *Sphagnum* farming station and an example of a spontaneously revegetated trench by *Sphagnum* and ericaceous shrubs after abandonment of peat harvesting activities in 1970.

This project's main goal is to create an experimental station dedicated to research on the production of a renewable source of *Sphagnum* fibre biomass in an abandoned peatland after block-cut peat harvesting. *Sphagnum* farming was an objective of the NSERC's Industrial Research Chair in Peatland Management in its first mandate (2003-2008) and the renewal of its second mandate (2008-2013) allows the continuance of research activities.

2. Experimental station

The Shippagan peatland is located in the Acadian Peninsula in North-East New Brunswick (47°40’ N; 64°43’ W, Figure 2). In the database of the New Brunswick Department of Natural Resources, the Shippagan peatland’s reference number is 527.

Figure 2. Arial view of the Shippagan peatland, showing the entire studied area.

3. Peatland preparation for *Sphagnum* farming

The private sector of the Shippagan peatland, property of Sun Gro Horticulture, (also known as sector 3 in previous reports) and the governmental sector, Crown land property, (also known as sector 1 in previous reports) have been selected because they offer the best growing conditions for *Sphagnum* (Figure 3). Data is compiled in a report called *«Caractérisation du site expérimental de Shippagan et techniques suggérées dans un but de recherche sur la production de fibre de sphaigne»*. This report is available on the Peatland Ecology Research Group Website (http://www.gret-perg.ulaval.ca/). Moreover, a summary of research activities and a description of the work realized by peat companies involved in the project are presented respectively in annexes 1 and 2.

In the private sector, a first production cycle began in 2004. In that sector, eight basins of 15 m X 15 m were installed, including six basins with *Sphagnum* introduction and two control basins without any vegetation (to evaluate the spontaneous colonization of *Sphagnum* in the basins). In the governmental sector, a second production cycle was completed in 2006. It consists of six 15 m X 90 m basins, all with introduced *Sphagnum*. The most recent production cycle, which started in 2008 in the governmental sector, consists of a 15 m X 100 m basin.

3.1. Field preparation method

Development allowing station access

Ensuring accessibility to the farming station was an important first step. In May 2004, using a modified track-mounted excavator, an access path was built and culverts were installed to reach the peatland. This same general purpose excavator equipped with a blade shaped shovel allowed us to dig drainage channels (Figure 4a) to lower the water table and provide a more stable work surface for the machinery. From September to December 2005, the portion of the access path between the private and governmental sector was developed and solidified by spreading a large quantity of root residues using a tractor equipped with a shovel and a cultivator. During this same period, in order to allow heavy vehicles to go through the governmental sector, culverts were installed (Figure 4b), the channels along the road were cleaned and the road itself was widened.

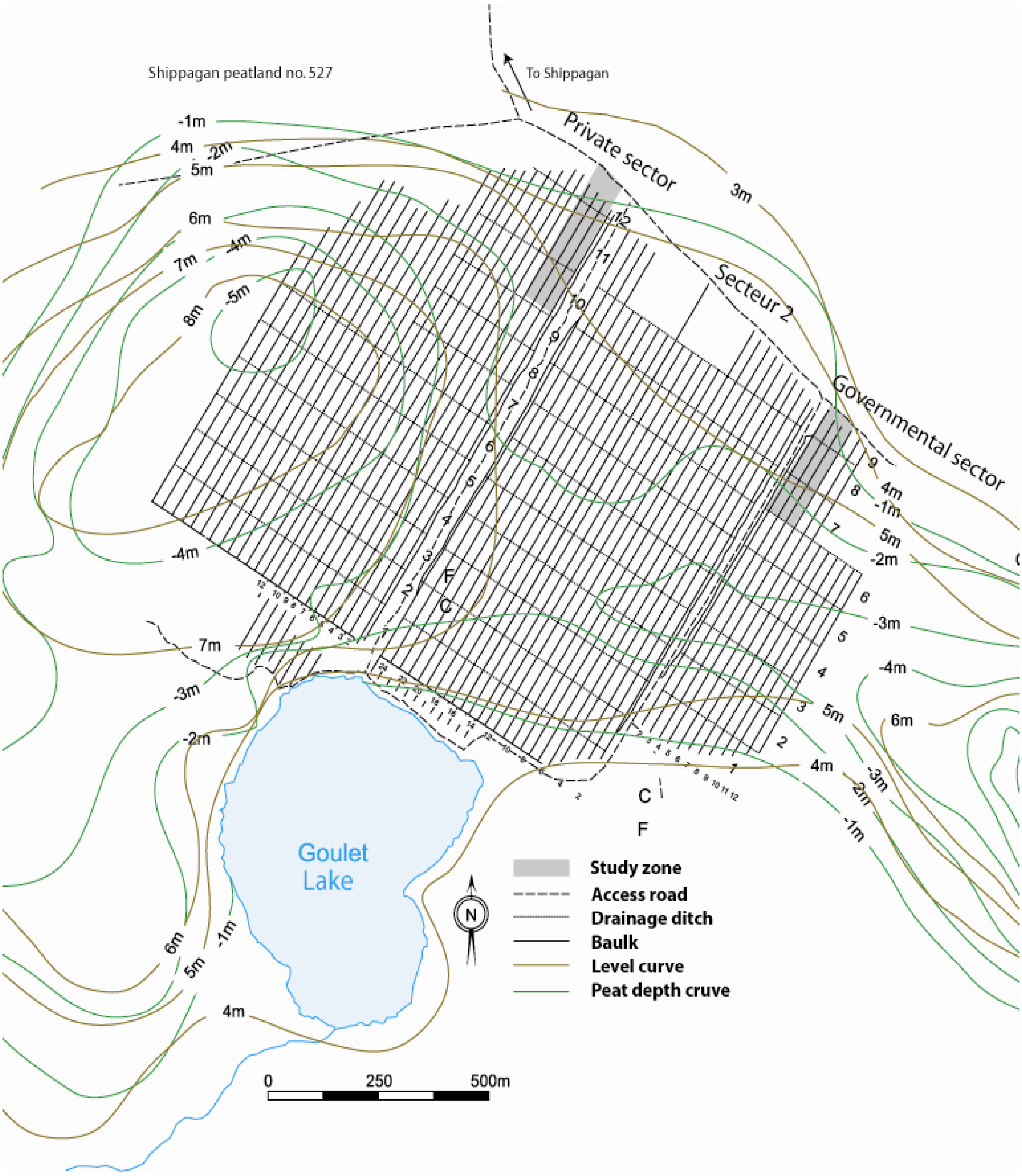

Figure 3. Location of *Sphagnum* farming zones

Brush cutting

The peatland area used for *Sphagnum* farming, including trenches and baulks, then had to be cleared of undergrowth to allow better on-site circulation. Undergrowth clearing was done manually, using a brush cutter or a chain saw for all production cycles (2004, 2006, and 2008).

Basin preparation

In order to introduce *Sphagnum* for its culture, it was necessary to completely remove the pre-established basin vegetation. For the 2004 production cycle, the removed vegetation (see following section for removal techniques) was preserved partly on the baulks and reintroduced in the basins at the end of their preparation. For the 2006 production cycle, the surface vegetation was removed from the basins between September and November 2005, using an excavator (Figure 4c). In December 2005, this plant material was transported to the No. 530 peatland in Shippagan to be used as restoration reintroduction material.

Following the complete removal of the basin vegetation (Figure 4d), the residual surface was leveled to allow good contact of *Sphagnum* diasporas with the ground. For the 2004 production cycle, surface leveling was done manually using a roller (Figure 4e). For the 2006 production cycle (spring 2006), basin preparation involved using a cultivator to homogenize the bare peat surface. The peat was thawed out at a 30cm depth, which allowed heavy vehicles to go through. Then, the basins' topography was leveled using a wooden pole pulled by two tractors (Figure 4f), moving on baulks along the basins. As for the 2008 production cycle, leveling was not deemed to be necessary.

4a. Cleaning drainage ditches.

4b. Culvert installation.

4c. Removal of surface vegetation.

4d. Basin in which vegetation has been completely removed.

4e. Manual basin leveling.

4f. Basin leveling using a wooden pole pulled by two tractors.

Figure 4. Station planning before *Sphagnum* introduction for farming.

Vegetation harvest

In order to harvest *Sphagnum* at a 30cm depth, various management approaches and harvesting techniques have been experienced. The goal was to find well adapted options to that type of abandoned peatland (after block-cut). In the 2004 production cycle, it was important to find an adequate technique guarantying: 1) *Sphagnum* fragments of a convenient size and 2) as less damage as possible to soil structure, since basins where *Sphagnum* was harvested were also future production cycles. We concluded that the most efficient technique was with the help of an excavator on tracks equipped with a mechanical fork (Figure 5a), as it was best adapted for working in trenches and less damaging. That type of machinery requires only one passage through the station and can easily harvest newly formed *Sphagnum*. Moreover, fibre stays intact and is ideal for manipulation and transformation. Contrarily, the rotovator requires two passages on the same harvesting zone, which weakens the field structure. Also, with the rotovator, it is hard to adjust harvesting depth in order to obtain a uniform surface of exposed peat. Another technique, manual harvest with shovels and forks, takes too much time and is not appropriate for large scale projects (Miousse 2005).

For the 2006 and 2008 production cycles, vegetation needed for reintroduction was harvested with the help of a rotovator and an excavator (Figure 5b) to a depth of 10cm. Harvesting was done nearby and introduced *Sphagnum* species were similar to the ones initially found in the targeted basin, well adapted to humid conditions found in trenches. Vegetation was mainly composed of *Sphagnum* with a small amount of vascular plants (less than 15% of the cover).

Introduction of *Sphagnum* in basins

Sphagnum species introduced in all the production cycles are mainly: *Sphagnum rubellum, Sphagnum magellanicum, Sphagnum fuscum and Sphagnum flavicomans*. Introduction of *Sphagnum* for the 2004 production cycle was done manually (Figure 5c) in a 1:10 ratio. For the 2006 and 2008 production cycles, which are at much larger scale, vegetation was spread in basins with a lateral manure spreader (Figure 5d) pulled by a tractor circulating on baulks. Since the use of that type of machinery is not very common in peatland restoration, we had to try different adjustments. The main problems we encountered were related to the shredding of vegetation in order to obtain optimal fragment size and the constant spreader jams caused by roots. To make efficient spreading possible, vegetation had to be almost exclusively composed of *Sphagnum* and had to contain a very small amount of roots. When roots were abundant, they blocked the spreader, modifying the fragment size and the distance they could be thrown. Therefore, it was hard to spread *Sphagnum* fragments uniformly on plots. We also had to make sure not to fill the spreader to its full capacity in order to avoid vegetation compaction and obstruction of the spreader. Despite a few problems, *Sphagnum* spreading was a success (St-Arnaud, 2006a, 2006b).

***Sphagnum* protection**

In order to protect *Sphagnum* fragments against desiccation, they were covered with straw mulch following Quinty and Rochefort (2003) recommendations (3,000 kg/ha). In the 2004 production cycle, straw was spread manually. In the 2006 and 2008 production cycles, straw was spread with a <u>lateral straw spreader</u> pulled by a tractor circulating on baulks. (Figure 5e).

Hydrological control

Barriers were installed in the two sectors to control water level (Figure 6a). A water level control system was installed in the private sector and six others were installed in the governmental sector. These devices enabled the evacuation of spring and autumn water surplus and minimized water losses during drought periods.

5a. Vegetation harvest with the help of an excavator equipped with a mechanical fork.

5b. Vegetation harvest with the help of a cultivator.

5c. Manual *Sphagnum* introduction in trenches.

5d. *Sphagnum* introduction with a lateral manure spreader.

5e. Straw spreading with a lateral straw spreader.

5f. Example of a basin three years after *Sphagnum* introduction.

Figure 5. *Sphagnum* introduction and protection.

Hydrological follow-up

Following the creation of new production cycles, wells were installed in the basins in order to measure water table depth. These measurements enable us to more efficiently characterize the *Sphagnum* growth conditions. In the summer of 2007, 24 wells were installed in the private sector (2004 production cycle) and 30 in the governmental sector (2006 production cycle). In the spring of 2008, four wells were added in the governmental sector and two in the private sector. The wells (Figure 6b) are spread in the *Sphagnum* farming basins and old harvest trenches surrounding the basins. When the field team is in Shippagan, the height of the water table is measured once a week. In 2007 and 2008, water level in zones presenting good *Sphagnum* growth was 10 ± 8 cm under the peat surface. In general, *Sphagnum* farming basins have a higher water table than old surrounding trenches (approximately 13 cm higher in the farming basins).

6a. Water level control (barrier).

6b. Water level follow-up (wells).

Figure 6. Hydrological control and follow-up.

3.2. Predictions for the expansion of the Sphagnum farming station

In order to better define the stages and resources necessary for *Sphagnum* farming and to improve the techniques and series of mechanized operations used until now, we plan on developing one or two new *Sphagnum* farming basins every year from 2009 to 2012. Work will take place in the governmental sector within the limits defined by the occupation license granted by the New Brunswick government. If possible, the removed surface material will be used for other restoration projects. The processes and machinery used will be similar to those described in section 3.1 (Field preparation method). Annual implementation of new production cycles will also enable us to define the influence of abiotic factors such as climate on the success of the biomass production cycles.

4. Assessment of the *Sphagnum* biomass production cycle's periodicity

The annual follow-up of the *Sphagnum* biomass production cycles is an important stage aimed at determining the optimal cultivation period allowing to obtain *Sphagnum* biomass on a renewable basis. Evaluation of the vegetation establishment (see section 4.1) allows us to estimate the required time before a complete basin *Sphagnum* cover can be achieved. That measurement also enables us to follow vascular plant and other bryophytes evolution in the basins. Harvest and sorting of biomass samples (section 4.2) from the farming basins make it possible to know the exact contribution of each plant type (*Sphagnum*, others bryophytes, *Ericaceae*, other vascular plants) to biomass accumulation. By measuring the *Sphagnum* productivity (section 4.3) and decomposition (section 4.4) in the basins, we should find the number of years after introduction where the decomposition rate remains low and the productivity rate is high, signs of optimal biomass accumulation. Follow-up of these parameters (Table 1) is carried out in the 2004 (Figure 7) and 2006 (Figure 8) production cycles. Follow-up of the 2008 production cycle will begin in June 2009.

Table 1. Follow-up parameters for the determination of *Sphagnum* biomass production cycle periodicity. (The 2004 production cycle is located in the private sector and the 2006 production cycle is located in the governmental sector.)

Follow-up parameters	Measurements	Location	Measurements dates	Experiment duration	Samples taken	Sample distribution
4.1. Vegetation establishment	Vegetation cover (%)	2004 cycle	Sept. 2005 Oct. 2006 August 2007	2005 to 2007	144[1] (25 cm X 25 cm)	Systematic (5 bassins)
4.2. Biomass accumulation	Dried biomass (g/m^2)	2006 cycle	August 2007 June 2008	2007 to 2012	336 (25 cm X 25 cm)	Systematic (6 bassins)
		2004 cycle	June 2007 June 2008	2007 to 2012	20 (25 cm x 25 cm)	Random (5 bassins)
4.3. *Sphagnum* carpet productivity	*Sphagnum* elongation[2] (cm/year)	2006 cycle	June 2007 June 2008	2007 to 2012	24 (25 cm X 25 cm)	Systematic (6 bassins)
		2004 cycle	June 2007 June 2008	2007 to 2012	30 nests (1 nid ~ 30 *Sphagnum* stems)	Random (5 bassins)
	Dried biomass (g/stem cm)	2004 cycle	June 2008	2007 to 2012	30 (15 cm^2)	Random (5 bassins)
4.4. Decomposition rate	*Sphagnum* carpet density (capitules/m^2)	2004 cycle	June 2008	2007 to 2012	30 (15 cm^2)	Random (5 bassins)
	Decomposition percentage[3] (%)	2004 cycle	June 2007 June 2008	2007 to 2009	30 nests (1 nid = 11 decomposition bags)	Random (5 bassins)

[1] Number of quadrates (quadrate size).
[2] Elongation measurements are done with a marking technique. Inside the nest, about thirty stems from various *Sphagnum* species are marked in June with permanent paint. In June of next year, the stems marked in the previous year are removed and measured to evaluate elongation.
[3] Decomposition is evaluated with the decomposition bag technique, which uses small mesh bags contains a small pre-weighed quantity of targeted plants (i.e. *Sphagnum*). Each nest contains 11 bags: 2 containing *S. rubellum*, two *S. fuscum*, two *S. magellanicum*, two *S. flavicomans*, two cellulose disks and one *S. rubellum* from *Sphagnum* farming. The cellulose disks allow the elimination of intrinsic properties related to *Sphagnum* species choice.

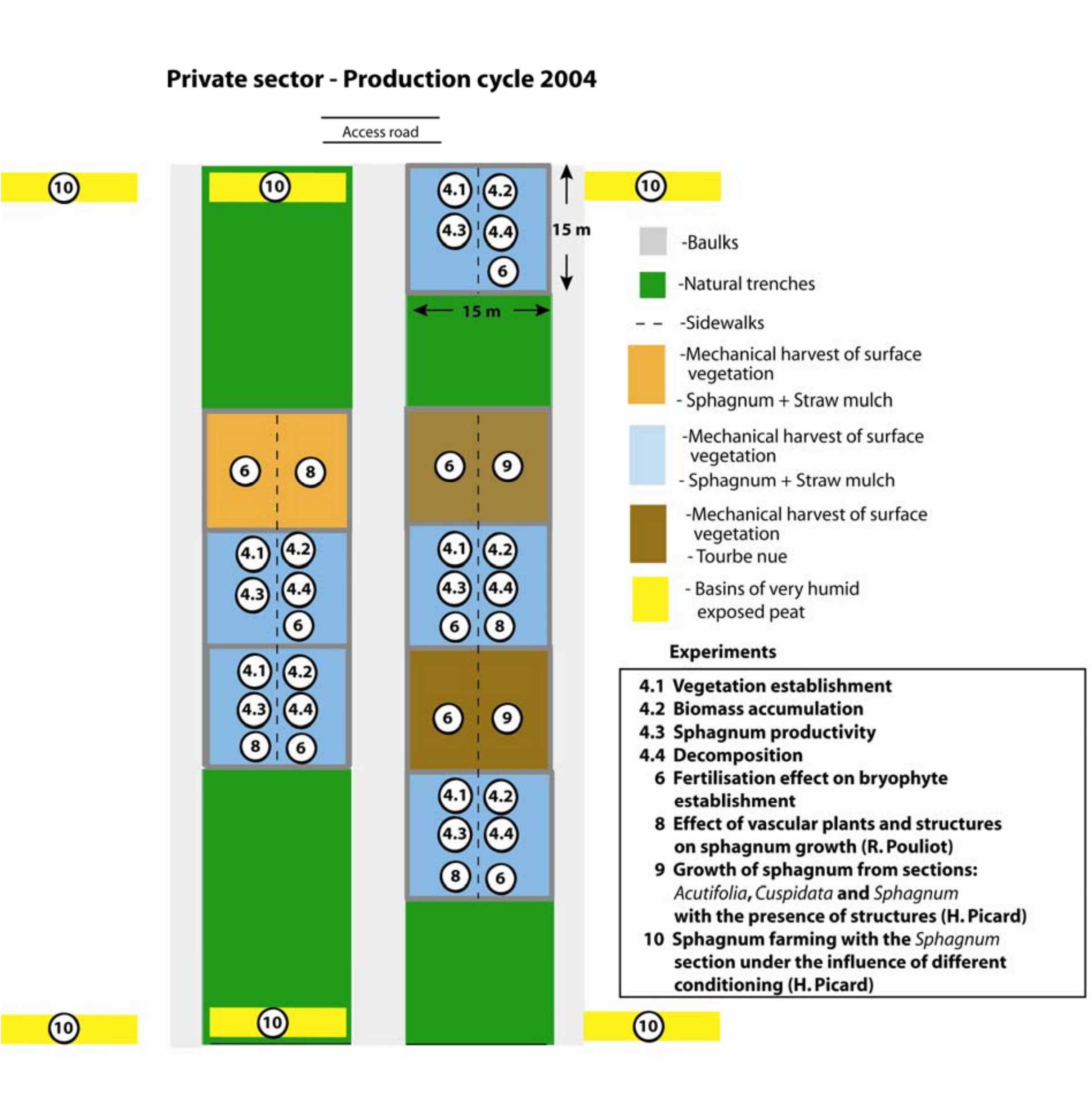

Figure 7. *Sphagnum* farming station's private sector experiments.

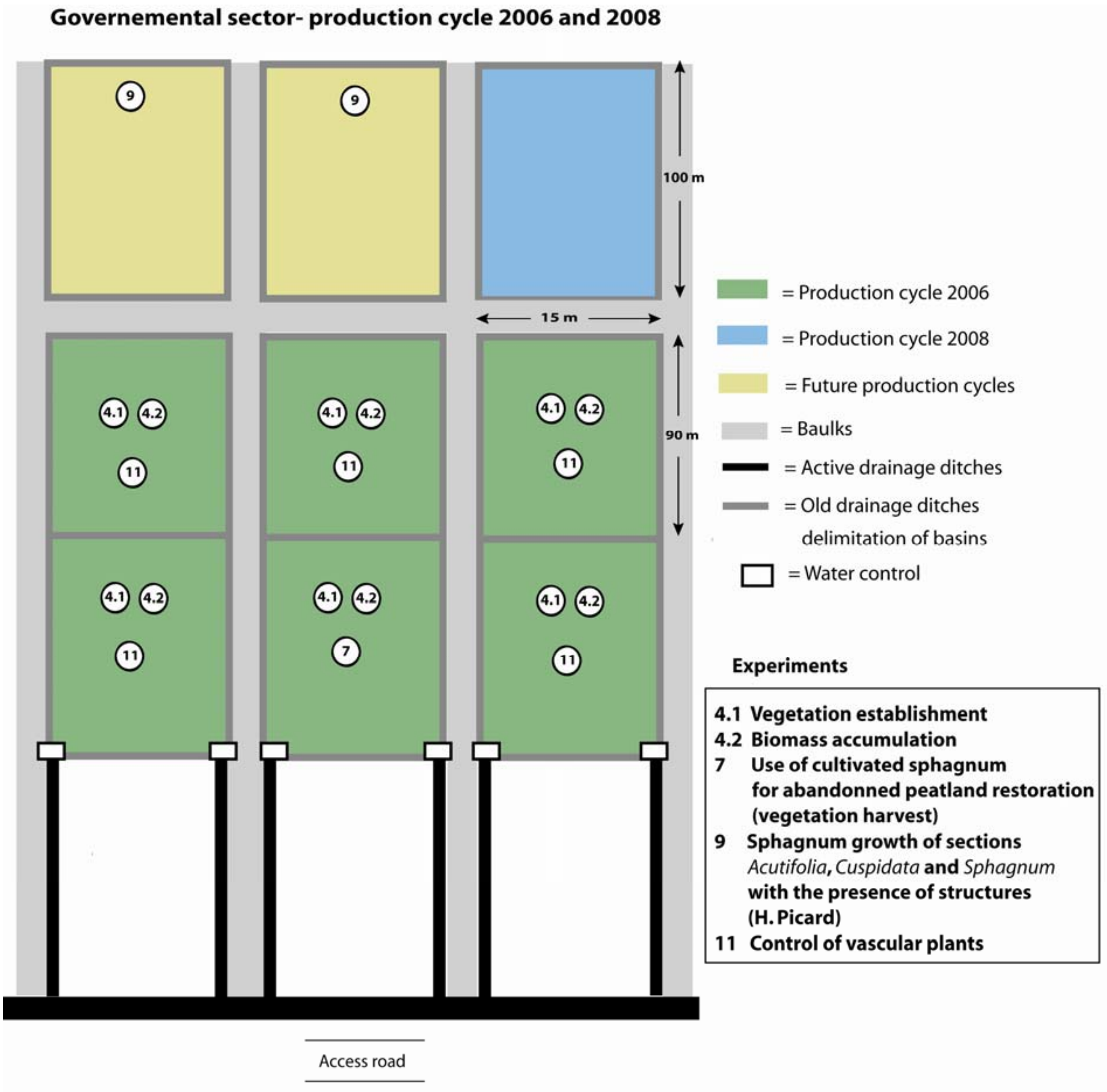

Figure 8. ***Sphagnum*** **farming station's governmental sector experiments.**

4.1. Vegetation establishment (vegetation cover)

For the 2004 production cycle, three years after introduction, the carpet mainly composed of *Sphagnum* reaches a cover of almost 100% (Figure 9). Approximately 53% of the *Sphagnum* carpet is composed of *Sphagnum* of the *Acutifolia* section (mainly *Sphagnum rubellum*), 30% of the *Sphagnum* section (*Sphagnum magellanicum*) and 5% of the *Cuspidata* section.

However, the development of the *Sphagnum* carpet is slower in the 2006 production cycle, since two years after the introduction, the *Sphagnum* cover was 25 ± 3% whereas in the 2004 production cycle, the cover after two years already reached 75 ± 2 % (Figure 9). This slower evolution of the *Sphagnum* carpet establishment evolution in the 2006 production cycle can be partly due to the difficult climate shortly after the *Sphagnum* introduction in the basins. During the first establishment year, periods of intense rain caused water accumulation in the wettest basin zones (up to 2 feet of water) which displaced the reintroduced material that was not yet anchored to the ground, and accentuated the sedimentation processes of small peat particles on regenerating moss fragments. The technique used for *Sphagnum* introduction in the basins surely also has an influence. Indeed, for the 2004 production cycle, the plant material was introduced manually; thus distributed very uniformly in the basins and the *Sphagnum* fragments underwent little stress compared to an introduction on a large scale with a manure spreader (2006 production cycle) which tears the fragments in smaller pieces. The 2006 production cycle should therefore take a little more time than the 2004 production cycle before reaching a complete *Sphagnum* cover.

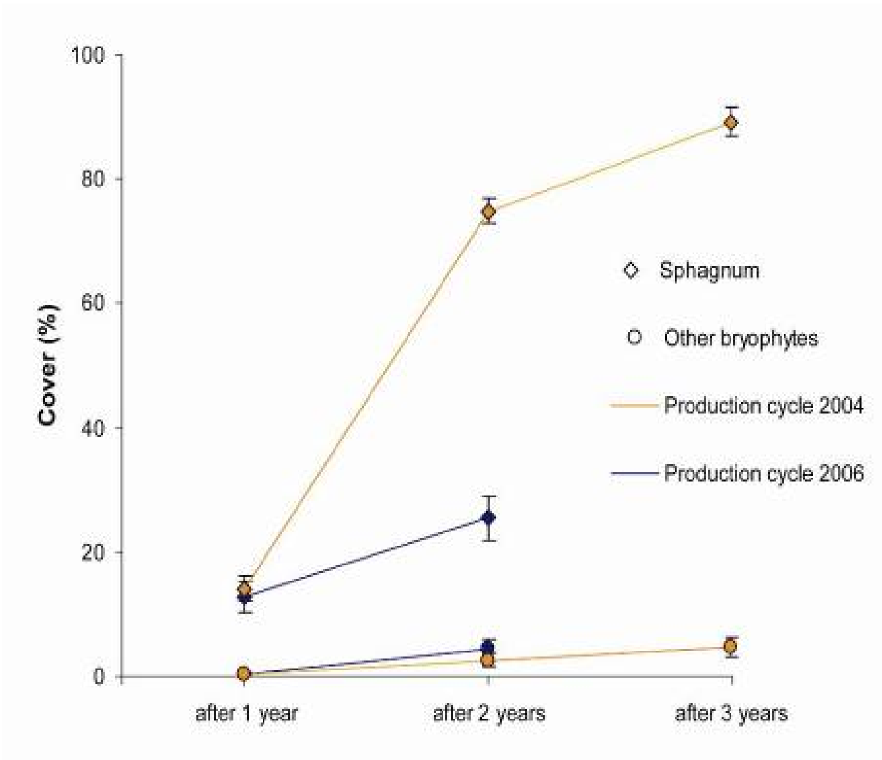

Figure 9. Bryophyte carpet establishment speed for 2004 and 2006 production cycles (average ± standard error).

4.2. Biomass accumulation

Sphagnum biomass accumulation (Figure 10) is much greater than the biomass accumulation of other plant types (Table 2), and this, for the two production cycles (2004 and 2006). Biomass accumulation evolves quickly in the 2004 production cycle and should, in the next few years, show the same evolution in the 2006 production cycle (Figure 10).

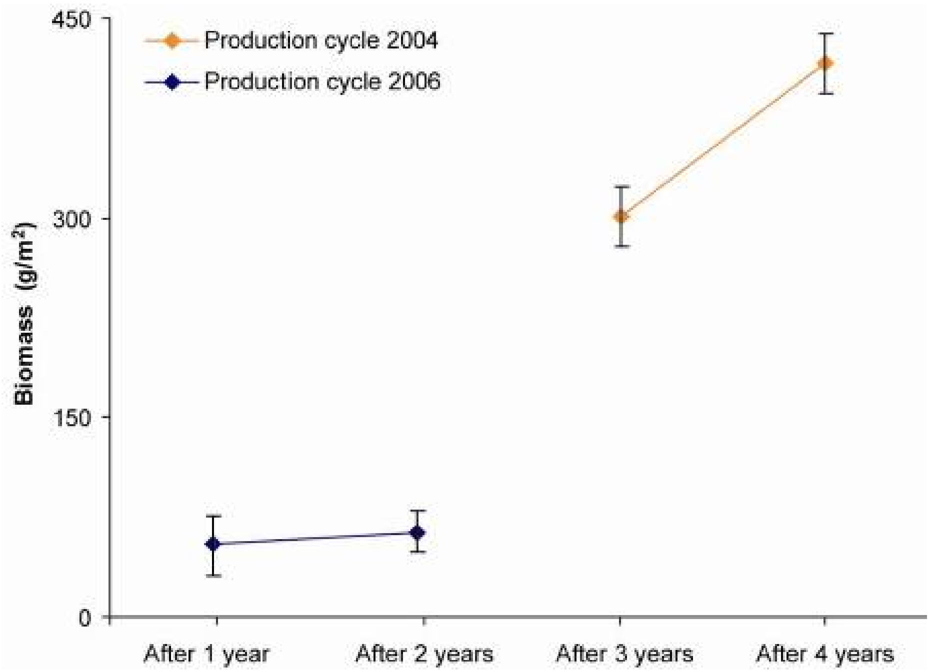

Figure 10. ***Sphagnum*** **biomass production (dry weight in g/ $m^{2)}$ for the 2004 and 2006 production (average ± standard error).**

Table 2. Biomass accumulation (dry weight in g/m^2) of plant groups other than *Sphagnum* for the 2004 and 2006 production cycle (average ± standard error).

	Biomass accumulation (g/m^2)			
	After 1 year Cycle 2006	After 2 years Cycle 2006	After 3 years Cycle 2004	After 4 years Cycle 2004
Other bryophytes	1 (0)	3 (1)	13 (9)	97 (46)
Ericaceous shrubs	12 (4)	3 (1)	23 (7)	38 (16)
Other vascular plants	3 (1)	7 (4)	7 (3)	97 (43)

4.3. Sphagnum carpet productivity

The average productivity of the 3rd growth year's *Sphagnum* carpet in the 2004 production cycle is estimated at 262.6 g/m^2 per year. *Sphagnum rubellum* and *Sphagnum magellanicum* contribute to more than 85% of this annual average productivity (Figure 11).

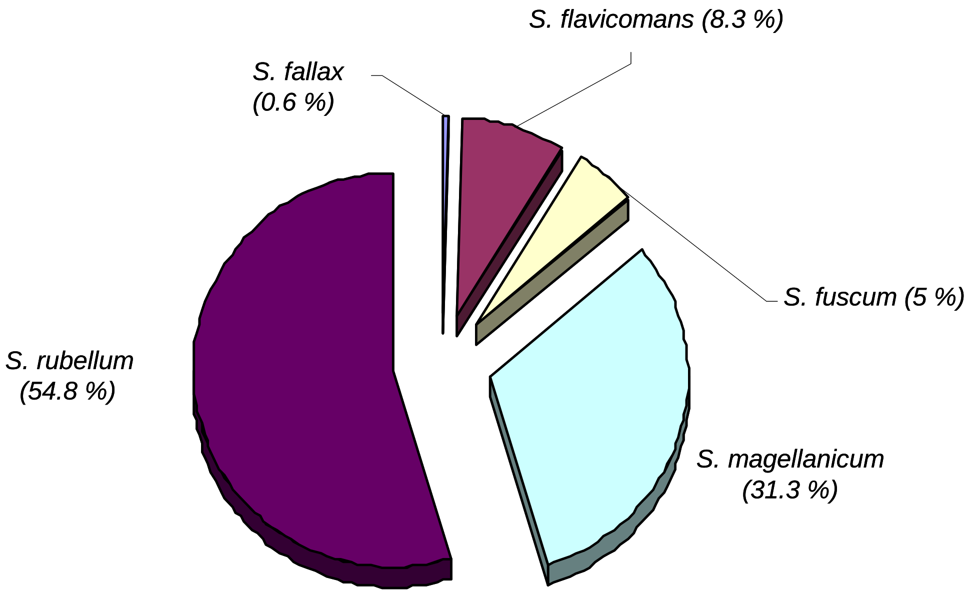

Figure 11. Contribution of each *Sphagnum* species to the average annual production (262.6 g/m2 per year) for the 3rd growth year of the 2004 production cycle.

4.4. Decomposition rate

Half the bags which were inserted in the *Sphagnum* carpet in June 2007 (a bag of each *Sphagnum* species) in addition to the bag of *Sphagnum rubellum* coming from the *Sphagnum* farming experimental station were withdrawn in June 2008, after one year of decomposition. The remaining bags will be withdrawn in June 2009 after two years of decomposition. Results will be compiled in 2009.

5. Use of *Sphagnum* fiber in growing substrates

Objectives

1) Evaluate if the addition of *Sphagnum* fibre can increase the potential of low quality peat (brown *Sphagnum* peat, H5 on von Post scale).

2) Determine if *Sphagnum* fiber could replace perlite in commercial growing substrates.

Location

Université Laval greenhouses.

Experiment duration

From 2004 to 2005.

Method

The experiment's set-up was done in January 2004. The experiment tested nine substrate levels (von Post H3 in H5 with *Sphagnum* addition at various levels). Treatments were repeated six times and were laid out in a completely random way.

Results

The most promising results were observed in a mixture where fine peat particles were subtracted and where 30% of *Sphagnum* fibre was added. Moreover, our results show that *Sphagnum* fibre can partly or completely replace perlite in growing substrates. All results of this experiment are presented in appendix 3.

6. Effects of fertilization on bryophyte establishment

Objective

Determine if adding fertilizer improves the *Sphagnum* carpet's establishment speed.

Location

Private sector of the Shippagan peatland (Figure 7).

Experiment duration

From 2005 to 2007.

Method

In September 2005, half of the six *Sphagnum* farming basins (15 m X 15 m) as well as two basins (15 m X 15 m) without vegetation were fertilized. The fertilizer used, rock phosphate 0-13-0[1], was applied at a rate of 15 kg/ha.

Results

Adding fertilizer does not support *Sphagnum* establishment. However, fertilization seems to slightly increase establishment of the other bryophytes, such as *Polytricum strictum* and *Dicranella cerviculata* (Figure 12). Moreover, we noted that certain vascular plants, naturally present around the studied zone, such as *Eriophorum vaginatum* and *Chamaedaphne calyculata,* gradually repopulate the basins. Their cover is however relatively weak (5%) and not influenced by fertilization.

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[1] N-P-K

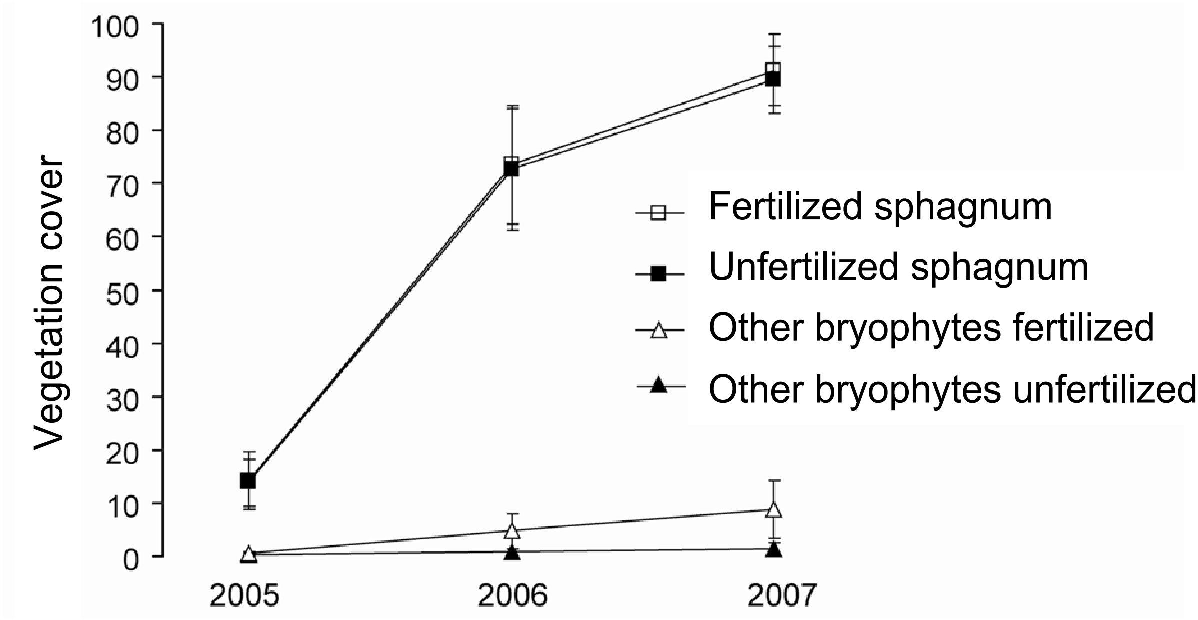

Figure 12. Cover percentage of *Sphagnum* and other bryophytes, three years after their reintroduction for the 2004 production cycle (average ± standard error).

7. Assessment of the production cycle of *Sphagnum* cultivated for reintroduction material in abandoned peatland restoration

One of the objectives of *Sphagnum* farming being to provide material for the restoration of abandoned peatlands after vacuum peat harvest, an experiment trying to evaluate the potential of *Sphagnum* cultivated for restoration is in progress. This experiment began in 2007 and will be repeated annually until 2012. It includes a phase on the field in a sector given up following peat harvest by aspiration in the No. 580 peatland located at Lamèque-Portage and a phase in the Université Laval greenhouses. This experiment compares two *Sphagnum* sources: *Sphagnum* from a natural zone and *Sphagnum* cultivated at the experimental station and taken in a governmental sector basin (Figure 8). This experiment will enable us to evaluate the necessary number of years for cultivated *Sphagnum* to reach or exceed the restoration potential of the *Sphagnum* found in natural peatlands *.

***Detailed results of this experiment are presented in the activity report of the Peatland Ecology Research Group (Boudreau and Rochefort, 2009).**

8. Structure and vascular plant effect on *Sphagnum* vertical growth

Here is a description of part of the project carried out by **Rémy Pouliot**, doctorate student under the supervision of Line Rochefort, linked with the *Sphagnum* farming station.

Problematic

Several hypotheses were made to explain the formation of peatland microtopography. It seems that the small scale surface models, like the hummock and depression gradient, could initiate itself from the intrinsic properties of the species present, and this, in only a few years or decades. However, there were very few studies made about this gradient's formation even if several ideas were proposed to explain the formation of the *Sphagnum* hummocks. For example, the interactions between vascular plants and *Sphagnum* are perhaps essential to hummock formation. Because of their physical structures or exchanges with the environment, vascular plants could encourage the appearance and vertical growth of the hummocks' typical *Sphagnum* species. In fact, it is possible that the vascular plants' stems provide a physical support for *Sphagnum* growth, thus supporting the muscinal carpet development. Within the framework of the *Sphagnum* farming project, this study will make it possible to determine if the presence of vascular plants trigger a faster accumulation of *Sphagnum* biomass.

Objectives

1) Determine the effect of living vascular plants on *Sphagnum* vertical growth.

2) Determine the effect of inert structures imitating vascular plants on *Sphagnum* vertical growth.

Location

Université Laval greenhouses and a Shippagan peatland private sector (Figure 7).

Experiment duration

From May 2006 to May 2010.

Material and method

Three experiments were put in place. In the private sector of the Shippagan peatland, a field experiment was done, (July 2006 to July 2008) and two experiments were done in the Université Laval greenhouses (July 2007 to April 2008 and May 2008 to February 2009).

For the greenhouse and field experiments (July 2007 to April 2008), there were six blocks and six treatments. They were applied to a *Sphagnum* carpet without any topography. To recreate a *Sphagnum* carpet in our greenhouse, we collected the first three centimeters of plant material from the surface of a natural peatland. The plant material was sorted to remove vascular plants and keep only *Sphagnum rubellum*. The material was then introduced into culture vats following a 1:3 ratio. The vats were filled beforehand more or less decomposed blonde peat. The treatments selected for these two experiments are as follows: 1) *Chamaedaphne calyculata* living, 2) *Eriophorum vaginatum var. spissum* living, 3) *Eriophorum angustifolium* living, 4) dead ericaceous structures 5) vertical wood stakes (trunk imitations of ½ inch diameter) and 6) control. These six treatments were randomly distributed in culture vats (0,52 m X 0,34 m = 0,177m^2) and repeated in four greenhouse blocks. In the field, treatments were randomly distributed in 1,5 m X 1,5 m plots and repeated in six blocks on the Shippagan peatland private sector (Figure 7).

In the field, two series of measurements were taken, in July 2007 and July 2008. The *Sphagnum* height since their reintroduction was measured (40 *Sphagnum* per plot). The same measurements were taken for the greenhouse experiment, but at shorter intervals (once a month between September 2007 and April 2008). In this case, height measurements were taken between fixed points above the *Sphagnum* carpet and carpet surface (five tensed wires under which ten height measurements were periodically taken). The difference in height measurements between two time periods corresponded to the vertical growth during this period. Biomass measurements were also taken at the end of the experiments. To proceed, the *Sphagnum* biomass formed since the beginning of the experiment was collected, vascular plants were removed and the biomass was dried and weighed.

The greenhouse experiment (May 2008 to February 2009) also included four blocks, but this time, nine treatments were tested. In addition to treatments found in the two other experiments, three new treatments were applied to more thoroughly study the effect of inert vertical structures, which are as follows: 7) vertical wood stakes (1 inch diameter), 8) vertical wood stakes (¼ inch diameter) and 9) plastic straws (¼ inch diameter). .

The same growth measurements than in the first greenhouse experiment were taken once a month between August 2008 and February 2009, in addition to the final biomass measurement.

Preliminary results

The field study results show that treatments with living vascular plants allowed a better *Sphagnum* vertical growth (Figure 13). Indeed, the *Sphagnum* growth was stimulated, in descending order by importance, by the presence of *Eriophorum vaginatum, Eriophorum angustifolium* and *Chamaedaphne calyculata.*

The situation was somewhat different during the greenhouse experiment between July 2007 and April 2008 (Figure 14). In this case*, Eriophorum angustifolium* did not stimulate *Sphagnum* vertical elongation. This time, *Sphagnum* growth was initially supported by the presence of *Chamaedaphne calyculata,* then by vertical wood stakes and *Eriophorum vaginatum.*

One of the reasons that could explain such a great difference between the treatments involving *Eriophorum angustifolium* is their abundance both in the greenhouse and on the field. Indeed, in the greenhouse, Eriophorum presented a very dense 100% cover, whereas on the ground, its cover was approximately 90% and not very dense. In the greenhouse, the competition for light exposure between *Sphagnum* and vascular plants of the *Eriophorum* type was probably too high to allow good growth.

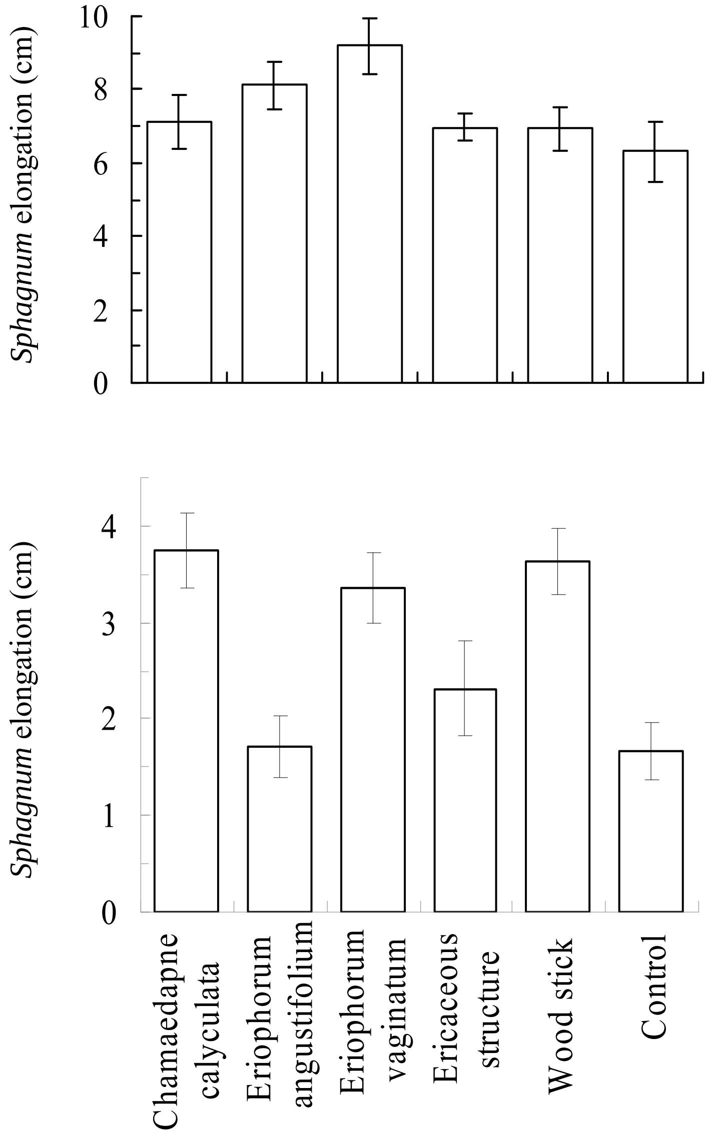

Figure 13. A) *Sphagnum* vertical growth (mean ± standard deviation) for experience 1 (in the field). Growth corresponds to elongation since *Sphagnum* reintroduction done in 2004 (thus after four years). Treatments were applied in July 2006. B) *Sphagnum* vertical growth (mean ± standard deviation) for experience 2 (in greenhouse). Growth corresponds to elongation since the first measurement period, which is the starting point of the experiment.

On the other hand, treatments with living *Ericaceae (Chamaedaphne calyculata)* allowed good *Sphagnum* growth in the greenhouse, probably because there were more structures available for their development. Moreover, they could benefit from a wetter and more constant microclimate over time. *Ericaceae* also have a three-dimensional structure, which offered more support for *Sphagnum* vertical growth than the two-dimensional structure of the herbaceous species. Moreover, when the *Sphagnum* succeeded in having sufficient access to light, the *Eriophorum vaginatum* tussocks offered a better growth structure than the *Eriophorum angustifolium* cylindrical stems. Finally, the presence of vertical wood stakes allowed astonishing *Sphagnum* growth in the greenhouse. Indeed, the stake's roughness provided anchoring points, and this, in spite of a non-existent three-dimensional structure.

About the biomass at the end of the greenhouse experiment between July 2007 and April 2008, treatments with the inert structures (vertical stakes and ericaceous structures) and control allowed better *Sphagnum* accumulation (Figure 14). The control's *Sphagnum* biomass was 81% larger than under the *Eriophorum vaginatum* treatment, which does not support the accumulation of *Sphagnum* biomass. The most effective treatment to support good growth and good biomass accumulation was therefore the one with vertical wood stakes.

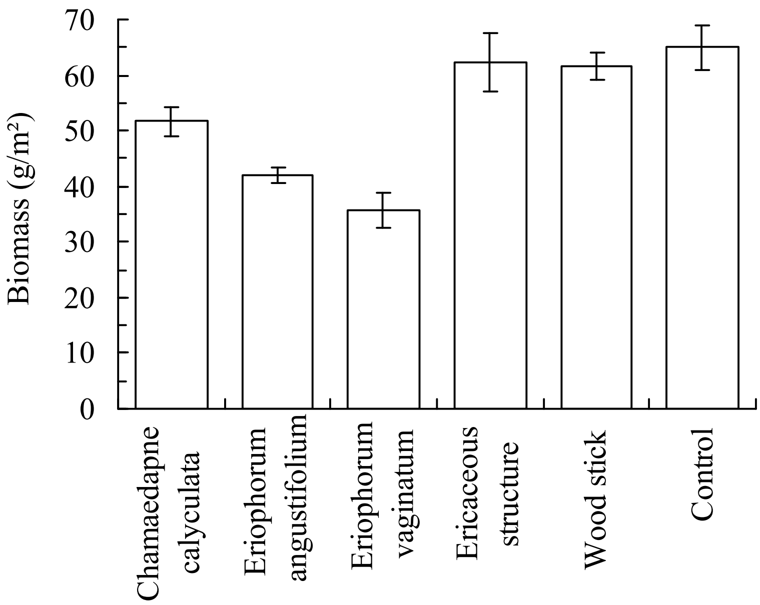

Figure 14. Accumulated *Sphagnum* biomass (mean ± standard deviation) over nine growth months in the greenhouse experiment.

Since the results with vertical wood stakes seem very promising, three new treatments were applied for the other experiment undertaken in the greenhouse from May 2008 to February 2009, all with vertical structures. The results of this experiment will be processed in the next months.

It seems that vascular plants support *Sphagnum* growth. However, in a *Sphagnum* farming context, it is perhaps undesirable to have roots or other vascular plant parts in *Sphagnum* fibers. In this case, it would be interesting to include certain inert structures imitating vascular plants in the *Sphagnum* carpets, such as vertical wood stakes. Nevertheless, if vascular plant presence matters a little, for example if *Sphagnum* farming is used to produce restoration material, the presence of living vascular plants (mainly *Ericaceae*) would be an asset to support vertical growth and thickening of the muscinal carpet, in addition to providing a seed bank.

9. Growth of *Sphagnum* of the *Acutifolia* and *Sphagnum* sections, introduced with natural and artificial structures in a biomass production context

Here is a project carried out by **Hélène Picard**, master student under the supervision of Line Rochefort, linked with the *Sphagnum* farming station.

Problematic

According to Rémy Pouliot's preliminary results (see Section 8 : The effect of vascular plants and structures on *Sphagnum* growth), *Sphagnum* growth of the *Acutifolia* section would be supported by the presence of vascular plants (living and dead *ericaceae*) or artificial structures imitating small shrubs' trunk. Is it the same trend for *Sphagnum* of the other taxonomic sections?

Objectives

1. Compare establishment rates and *Sphagnum* growth of the *Sphagnum* section (introduced with *S. fallax)* and *Acutifolia* section in the presence or absence of natural or artificial structures.

2. To determine which type of treatment (with or without structure) facilitates the establishment and growth of *Sphagnum* of the *Sphagnum* section (introduced with *S. fallax)* and *Acutifolia* section.

3. To determine the *Sphagnum* species to promote in large-scale *Sphagnum* farming in order to obtain high establishment and production rates.

Location

Private sector (Figure 7) and governmental sector (Figure 8) of the Shippagan peatland.

Experiment duration

From May 2008 to ...

Materials and method

The establishment success and growth of four *Sphagnum* species on four structuring types of growing substrates (factorial experiment with two factors) were tested according to a plan in complete blocks experimental device. The five blocks each contain sixteen 0.75 m X 1 m plots in which the treatments resulting from factor combination are randomly distributed (Figure 15a).

The four structures tested are: 1) wood stake, 2) *Chamaedaphne calyculata* living, 3) dead *Chamaedaphne calyculata* structure (Figure 15b) and 4) no structure (control). The *Sphagnum* species tested are: 1) *Sphagnum fuscum,* 2) *S. rubellum,* 3) *S. magellanicum + S. fallax* (50:50 mixture) and 4) *S. papillosum + S. fallax* (50:50 mixture).

The material harvest and introduction (vascular plants and *Sphagnum*) was carried out in May 2008. The sowing ratio was 1:10. The material was collected in the natural sectors of the Shippagan peatland, and in a natural part of the No. 580 peatland located in Lamèque-Portage.

In each plot, eighteen structures were planted before the introduction of *Sphagnum* fragments. The fragments were then covered with straw mulch in order to improve the moisture conditions. Thereafter, a net was added in order to avoid dispersion by wind and water

For each species, the vegetation cover percentage was estimated using three 25 cm X 25 cm quadrates laid out systematically in the plots. This measurement was taken at the end of the first growth season (October 2008) and a second series of measurements will be taken in October 2009. Various data were also taken to characterize the peat, water table height, substrates' moisture and the microclimate.

Preliminary results

The preliminary analysis of the first growth year's results showed few differences between treatments. Differences should be observed after the 2^{nd} growth season. The results obtained following this experiment will make it possible to learn about plant associations (vascular-*Sphagnum*) to promote for fast *Sphagnum* carpet establishment and to obtain a higher production afterwards.

15a. Experimental bloc showing *Sphagnum* species scattering under natural and artificial structures (Shippagan experimental station).

15b. *Sphagnum magellanicum* and *Sphagnum fallax* introduction under dead *Chamaedaphne calyculata* stems (Shippagan experimental station).

Figure 15. Experiment studying *Sphagnum* growth under structure influence.

10. Farming of *Sphagnum* of the *Sphagnum* taxonomic section under different growing substrate conditionings

Here is a project carried out by **Hélène Picard**, master student under the supervision of Line Rochefort, linked with the *Sphagnum* farming station.

Problematic

Sphagnum of the *Sphagnum* taxonomic section has interesting porosity and liquid absorption/retention characteristics and constitutes a type of fiber sought by the horticultural industry. However, these species do not easily establish themselves when directly reintroduced on a bare peat substrate.

On the contrary, *Sphagnum* of the *Cuspidata* section, like *Sphagnum fallax*, grow and regenerate themselves quickly on bare peat under very wet conditions. The introduction of *Sphagnum* of this section would make it possible to condition the substrate, which would make it more favorable for the *Sphagnum* section.

In Chile, a current practice is to sow *Sphagnum magellanicum* (*Sphagnum* section) on *Sphagnum* carpets of the *Cuspidata* section. Thus, re-sowing *Sphagnum* of the *Sphagnum* section on well established *Cuspidata* carpets could also be done in North America to increase establishment speed of the *Sphagnum* section species.

Objectives

1. To compare the establishment and *Sphagnum* biomass production rates of the *Sphagnum* section on various substrate conditionings and according to monospecific or plurispecific introductions.

2. To determine the conditioning types that facilitates the establishment of *Sphagnum* of the *Sphagnum* section.

3. To determine the *Sphagnum* species to promote in large-scale *Sphagnum* farming in order to obtain high establishment and biomass rates.

Location

Private sector (Figure 7) of the Shippagan peatland and Université Laval greenhouses.

Experiment duration

From January 2008 to ...

Material and method

Greenhouse experiment

A factorial experiment was put in place to evaluate the establishment and growth success of two *Sphagnum* species of the *Sphagnum* section (first factor), particularly *S. magellanicum* and *S. papillosum*. The study also sought to know the effect of a second factor: the introduction of *Sphagnum* of the *Sphagnum* section on four types of substrate conditioning: 1) *S. fallax* already established to strong density, 2) *S. fallax* already established to low density, 3) simultaneous introduction of *Sphagnum* of the *Sphagnum* section and *S. fallax* on bare peat and 4) no conditioning (introduction of the *Sphagnum* of the *Sphagnum* section on bare peat). Treatments resulting from these combinations were distributed in 0.71 m X 1.11 m culture vats, filled with peat (von Post H3) and divided in two according to a split plot experimental device repeated six times.

Sphagnum used for the experiment were collected at the Saint-Charles-de-Bellechasse peatland (November 6, 2007) and cooled at a temperature of 4 °C for two months. They were frozen thereafter (- 4 °C) up to one week before sowing.

In March 2008, we introduced *S. fallax* with 1:4 (weak) and 1:2 (strong) densities. Water level was maintained to 5 cm under the peat surface.

When *S. fallax* carpets were well established (after three months growth), *S. magellanicum and S. papillosum* were introduced (approximately 1:2 density). It should be noted that simultaneous introduction of low density *S. fallax* with one or the other of the two *Sphagnum* section was done at the same time. Water level was then maintained to 10 cm under the peat surface.

Various data was taken within the course or at the end of the experiment:

- Estimation of the vegetation cover percentage and enumeration of capitula of each species was done with two 15 cm X 15 cm quadrates per sub-plot (half of vat). Measurements were taken once every three weeks at the beginning of the experiment then once a month from July 2008. The density was measured until June 2008 only.

- In order to determine the final biomass for each *Sphagnum* species, all the plant material was collected at the end of the experiment and a sample of each sub-plot was sorted, dried and weighed.

- The elongation of the *Sphagnum* stems was evaluated from three samples of about ten *Sphagnum* stems per sub-plot.

- Measures were also taken to characterize the peat, climate and substrates' moisture.

Field experiment

Establishment success and *Sphagnum* growth were evaluated according to two factors. The first factor verifies the effect of the substrate conditioning type and includes: 1) bare peat, 2) *Sphagnum* carpets of the *Cuspidata* section established for one year with an initial ratio of 1:10 and 3) *S. fallax (Cuspidata* section) introduced (1:10 ratio) at the same time as *Sphagnum* of the *Sphagnum* section (1:10 ratio). The second factor evaluates the various performances of two *Sphagnum* species of the *Sphagnum* section: 1) *S. magellanicum* and 2) *S. papillosum.* The treatments were distributed in 1 m X 1 m plots according to a split plot experimental device repeated in six blocks dispersed in the private sector of the Shippagan peatland (Figure 2).

Sphagnum harvest and introduction were carried out in May 2008. The sowing ratio was 1:10. The material was collected in the natural zones of the Shippagan peatland, as well as in a natural part of the No. 580 peat bog located in Lamèque-Portage. The freshly introduced *Sphagnum* was covered with straw mulch to improve the moisture conditions and a net to avoid dispersion by wind and water.

Various measurements were taken within the course and at the end of the experiment:

- Estimation vegetation cover percentage of each species using three 25 cm X 25 cm quadrates in each sub-plot. Measurements were taken at the end of the first growth season (October 2008) and a second series of measurements will be carried out in July 2009.

- In order to determine the final biomass for each *Sphagnum* species, biomass samples in each treatment will be taken in the summer of 2009.

- Various measurements were also taken to characterize the peat, the height of the water table and the substrates' moisture.

Preliminary results

The first analysis of the data obtained in the greenhouse suggests that during the first two months following the introduction, *S. magellanicum* shows the highest establishment rates when introduced on a *S. fallax* carpet with low density or simultaneously with *S. fallax*. At the end of the experiment, *S. magellanicum*, introduced only or simultaneously with *S. fallax,* shows the highest covering rates (Figure 16). Throughout the experiment, we noticed that *S. magellanicum* has a certain advantage on *S. papillosum* in establishment speed and growth, no matter the type of conditioning.

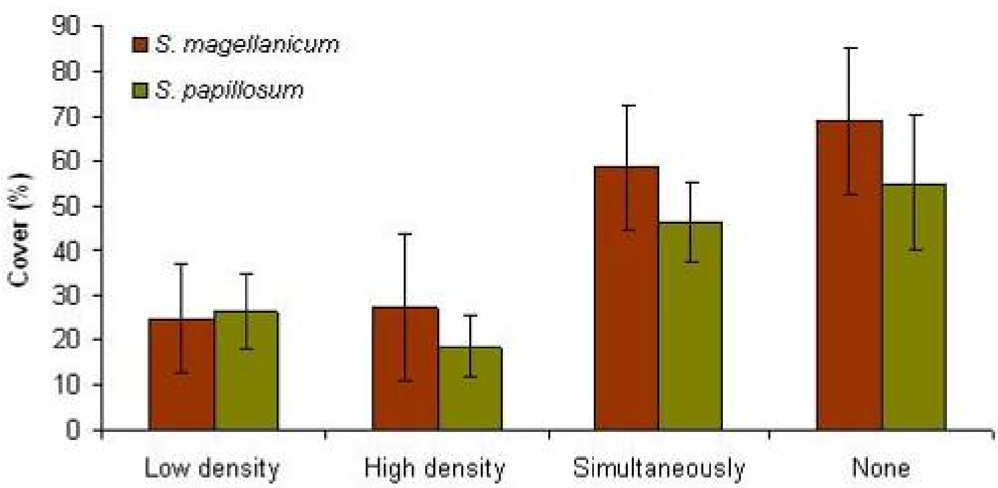

Figure 16. *Sphagnum magellanicum* and *S. papillosum* vegetation cover (%) according to different growing substrate conditioning with *S. fallax* after six greenhouse growth months (mean ± standard deviation).

However, the preliminary field results are different from those obtained in the greenhouse. The highest covering percentages at the end of the first growth season are observed for *S. magellanicum* and *S. papillosum* without growth substrate conditioning (Figure 17).

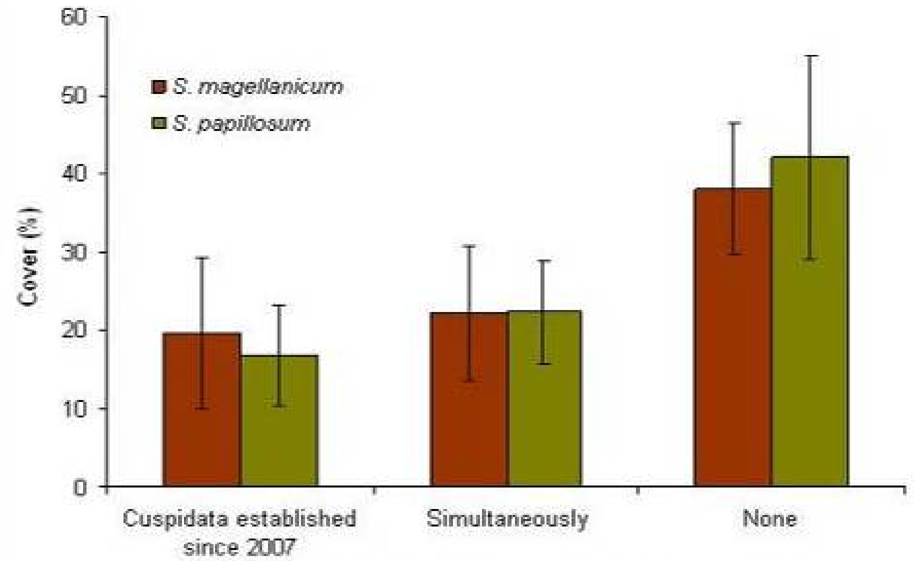

Figure 17. *Sphagnum magellanicum* and *S. papillosum* vegetation cover (%) according to different growing substrate conditioning with *S. fallax* after one growth year on the field (mean ± standard deviation).

Variance analyses (ANOVA) which will be carried out in the next weeks will make it possible to determine if there are significant differences between the treatments. The results will allow new knowledge on associations (*Sphagnum*-*Sphagnum*; Figure 18) to promote for a fast establishment of *Sphagnum* carpets of the *Sphagnum* section and a great biomass.

18a. *Sphagnum papillosum* simultaneously introduced with *S. fallax*, after one growth season on the field

18b. *Sphagnum magellanicum* introduced on low density *S. fallax carpet*, after five growth months in a greenhouse.

Figure 18. Examples of growing substrate conditioning treatments for *Sphagnum* taxonomic section *Sphagnum* growth.

11. Vascular plant control

Objective

In the event of a major vascular plan invasion in a *Sphagnum* farming station, we are trying to find simple and effective techniques to counter this problem.

Location

Governmental sector of the Shippagan peatland (Figure 8).

Experiment duration

From 2008 to 2012.

Method

This experiment was put in place in June 2008. Four treatments are applied to vascular plants: 1) cut using an edge cutter, 2) covered with a second layer of straw, 3) controlled by means of a domestic herbicide and 4) no treatment. These treatments are repeated in five blocks located in the governmental sector basins and randomly distributed in 8 m X 3 m pieces. The domestic herbicide used for treatment 3 is Roundup. Application was done on the vascular plants only, making sure not to touch the *Sphagnum*. All recommendations related to the use of this product were respected.

The treatments will be applied every year but covering percentages will be evaluated every two years to limit trampling. The vascular and non-vascular plant covering percentage was measured before the treatment (June 2008) and after the treatment (August 2008).

Results

With high quality floral moss or high quality growing substrate production in perspective, a simple and effective vascular plant control method would be a profitable tool not to harm mono specific *Sphagnum* production. After the first year trial, no treatment really stood out as being more effective. A few years of measurements will be necessary to classify the treatments in terms of effectiveness.

12. Planning of new research activities for 2009

The following activities will be carried out between May 1st and November 1st 2009. A summary of the overall research initiatives for year 2009 is presented in Appendix 1.

12.1. Sphagnum productivity compare to a reference ecosystem

To better appreciate the experimental station's performance, we foresee adding a reference ecosystem. This reference ecosystem, a natural peatland located in the Acadian Peninsula (location to be determined), will enable us to have a basic value to compare the productivity of the *Sphagnum* farming experimental station.

12.2. Access path development

Since the portion of the access path between the governmental sector and the private sector is more and more deteriorating, repair work will start in spring 2009. We may add root and gravel residues on the path. If necessary, new culverts and wooden walkways could also be built in 2009.

12.3. Automatic and continuous water table measurement

In spring 2009, we will install a water table reader in the two sectors of the *Sphagnum* farming station (private and governmental sectors). Those installations will enable us to have better uninterrupted hydrological follow-ups in the two sectors and during periods when we are not present in the field. We will still continue to manually measure the water table depths during each visit since wells cover the two sectors and allow us to evaluate the differences between the basins.

12.4. Large scale farming of Sphagnum taxonomic section Sphagnum

In 2009, if time and labor allow it, we will carry out a *Sphagnum* farming trial of the *Sphagnum* taxonomic section on a medium or large scale. To realize that, we would like to arrange a quarter or a third of a trench and sow *Sphagnum* of the *Sphagnum* section in there.

13. General conclusion

Currently, *Sphagnum* farming in peatlands abandoned after harvest is an option more and more sought-after. Rapid development of a renewable *Sphagnum* biomass would allow a new after-use of abandoned peatlands, while providing high quality material for peatland restoration and production of horticultural substrates. In European countries, where most of the natural peatlands have disappeared, access to *Sphagnum* biomass would greatly facilitate restoration of peatlands after peat harvesting.

There is still very few researches' focusing on *Sphagnum* farming and the *Sphagnum* farming station in Shippagan presents a remarkable opportunity to develop expertise in this field. In the last few years, studies made by the Peatland Ecology Research Group (PERG) and its partners from the peat industries will allow development of new *Sphagnum* farming techniques and will enable a better understanding of environmental factors capable of accelerating its production cycle. Comprehension and determination of an optimal *Sphagnum* production cycle on a renewable basis will allow us to propose *Sphagnum* farming options to the different stakeholders of the peat industry.

Results collected in the last four years have been very encouraging; *Sphagnum* carpets are productive and develop quickly. It is by identifying the biotic (i.e.: *Sphagnum* fragments handling) and abiotic factors (i.e.: moisture) with most impact on *Sphagnum* biomass production that research will contribute to optimize production cycles. Ultimately, this will allow us to obtain better quality *Sphagnum* biomass within an acceptable time table and allow management of renewable *Sphagnum* biomass production.

14. Publications

Publications and other documents stemming from the *Sphagnum* farming project:

Boudreau, S. & L. Rochefort. 2009. Chaire de recherche industrielle du CRSNG en aménagement des tourbières. Rapport des activités 2008. Groupe de recherche en écologie des tourbières, Université Laval, Québec, Québec.

Campeau, S., L. Miousse & F. Quinty. 2004. Caractérisation du site expérimental de Shippagan et techniques suggérées dans un but de recherche sur la production de fibre de sphaigne. Bryophyta Technologie inc., Saint-Charles-de-Bellechasse, Québec.

Jobin, P., J. Caron, L. Rochefort & B. Dansereau. 2005. Developing new substrates with *Sphagnum* fibres. Affiche présentée dans le cadre de l'International Symposium on Growing Media. Angers, France, 4 au 10 septembre 2005.

Miousse, L. 2005. Site expérimental dédié à la culture de la sphaigne à Shippagan, Nouveau-Brunswick. Rapport d'activités 2003-2004. Groupe de recherche de écologie des tourbières, Université Laval, Québec, Québec.

St-Arnaud, C. 2006a. Volet 3 - Site expérimental dédié à la culture de la sphaigne à Shippagan, Nouveau-Brunswick. Rapport d'activités 2003-2006. Groupe de recherche en écologie des tourbières, Université Laval, Québec, Québec.

St-Arnaud, C. 2006b. L'utilisation adéquate de l'épandeur à fumier latéral dans le cadre du projet de culture de sphaigne. Rapport interne. Groupe de recherche en écologie des tourbières, Université Laval, Québec, Québec.

St-Arnaud, C. & L. Rochefort. 2007. Chaire de recherche industrielle du CRSNG en aménagement des tourbières. Volet 3 - Site expérimental dédié à la culture de la sphaigne à Shippagan, Nouveau-Brunswick. Rapport d'activités 2003-2007. Groupe de recherche en écologie des tourbières, Université Laval, Québec, Québec. 26 pp.

St-Arnaud, C. & L. Rochefort. 2008. Chaire de recherche industrielle du CRSNG en aménagement des tourbières. Site expérimental dédié à la culture de la sphaigne à Shippagan, Nouveau-Brunswick. Rapport d'activités 2003-2008. Groupe de recherche en écologie des tourbières, Université Laval, Québec, Québec. 28 pp.

Publications linked to *Sphagnum* farming in general:

Campeau, S. & L. Rochefort. 1996. *Sphagnum* regeneration on bare peat surfaces: field and greenhouse experiments. Journal of Applied Ecology 33: 599-608.

Campeau, S. & L. Rochefort. 2002. Possibilities and limits to *Sphagnum* farming. Pp. 264-269 in G. Schmilewski and L. Rochefort, eds. Peat in horticulture – quality and environmental challenges. Proceeding of the 2002 International Peat Society Symposium, Pärnu, Estonia. International Peat Society, Jyväskylä, Finland.

Campeau, S., L. Rochefort & J. S. Price. 2004. On the use of shallow basins to restore cutover peatlands: Plant establishment. Restoration Ecology 12(4): 471-482.

Chirino, C., S. Campeau & L. Rochefort. 2006. *Sphagnum* establishment on bare peat: The importance of climatic variability and *Sphagnum* species richness. Applied Vegetation Science 9: 285-294.

Gaudig, G. 2005. *Sphagnum* farming - an international workshop in Germany. Peatlands International 1/2005: 15.

Gaudig, G. & H. Joosten. 2002. Peat moss (*Sphagnum*) as a renewable resource – an alternative to *Sphagnum* peat in horticulture? Pp. 117-125 in G. Schmilewski and L. Rochefort, eds. Peat in horticulture – quality and environmental challenges. Proceeding of the 2002 International Peat Society Symposium, Pärnu, Estonia. International Peat Society, Jyväskylä, Finland.

Joosten, H. 1998. Peat as a renewable resource: the road to paludiculture. Pp. 56-63 in T. Malterer, K. Johnson and J. Stewart, eds. Peatland restoration and reclamation, techniques and regulatory considerations. Proceeding of the 1998 International Peat Symposium, Duluth, Minessota. International Peat Society, Jyväskylä, Finlande

Joosten, H. 2000. Peat farming: The ultimate challenge for the peat “producers”. Peatlands International 1/2000: 35-36.

Payette, S. & L. Rochefort (eds.). 2001. Écologie des tourbières du Québec-Labrador. Presses de l'Université Laval, Québec, Québec.

Poulin, M., L. Rochefort, F. Quinty & C. Lavoie. 2005. Spontaneous revegetation of mined peatlands in eastern Canada. Canadian Journal of Botany 83: 539-557.

Price, J. S., L. Rochefort & S. Campeau. 2002. Use of shallow basins to restore cutover peatlands: Hydrology. Restoration Ecology 10: 259-266.

Quinty, F. & L. Rochefort. 2003. Guide de restauration des tourbières, 2e édition. Association canadienne de mousse de sphaigne et Ministère des Ressources naturelles du Nouveau-Brunswick. Québec, Québec.

Reinikainen, O. & M. Haukioja. 2005. *Sphagnum* cultivation - looking into the future. Peatlands International 1/2005: 16-19.

Robert, É. C. 1997. Régénération spontanée de deux tourbières ombrotrophes anciennement exploitées. M.Sc. Thesis, Université Laval, Sainte-Foy, Québec.

Robert, É. C. 2000. Régénération spontanée de deux tourbières ombrotrophes anciennement exploitées. Ministère des Ressources naturelles et de l'Énergie du Nouveau-Brunswick, Division des ressources minières et de l'énergie, Dossier public 2000-11. (#ISSN: 1205-7436; #ISBN: 1-55137-750-9). 83 pp.

Robert, É. C., L. Rochefort & M. Garneau. 1999. Natural revegetation of two block-cutting post-mined peatlands in eastern Canada. Canadien Journal of Botany 77: 447-459.

Rochefort, L., S. Campeau & J.-L. Bugnon. 2002. Does prolonged flooding prevent or enhance regeneration and growth of *Sphagnum*? Aquatic Botany 74: 327-341.

Appendix 1: Summary of work done at the Shippagan experimental station

	2003	2004	2005	2006	2007	2008	2009
Bryophyta report							
Station caracterization and study zone reccomandation	X						
Method and station preparation							
Development allowing station access		X	X	X			X
Brush cutting		X	X			X	X
Basin preparation / material harvest / introduction of *Sphagnum* in basins/ *Sphagnum* protection		X	X	X		X	X
Hydrological controls installation		X		X			
Hydrological follow-up					X	X	X
Expansion of the *Sphagnum* farming station		X		X		X	X
Assessment of the *Sphagnum* biomass production cycle's periodicity							
Vegetation establishment			X	X	X	X	X
Biomass accumulation					X	X	X
Sphagnum carpet productivity					X	X	X
Decomposition rate					X	X	X
Related experiments							
Use of *Sphagnum* fiber in growing substrates		X	X				
Effects of fertilization on bryophyte establishment			X	X	X		
Assessment of the production cycle of *Sphagnum* cultivated for reintroduction material in abandoned peatland					X	X	X
Effects of structures on *Sphagnum* growth (R. Pouliot)					X	X	X
Effects of structures on *Sphagnum* and *Acutifolia* sections growth (H. Picard)						X	X
Sphagnum section growth according to different conditioning (H. Picard)						X	X
Vascular plant control						X	X

Appendix 2: Company and *Sphagnum* farming project collaborator contributions

FPM Peat Company ltd.

In 2004, 2005, 2006, 2007 and 2008 the company participated in the experiment setup at the experimental station. It provided different machine types (tractors, trucks, manure spreaders, etc.) and did a part of the field work. It also provided straw bales and stakes. It transported the plant material that covered basins outside the peatland in fall of 2005. It constructed culverts and wooden walkways, and improved the access road's quality in 2005 and 2006. In 2008, it transported the manure spreader from Pokeshaw to the experimental station.

Coastal Zones Research Institute (CZRI)

On July 7 2005, there was a strategic meeting at the Coastal Zones Research Institute in Shippagan. Line Rochefort, Jonathan Price, Mike Waddington, Luc Miousse, Stéphanie Boudreau, Claudia St-Arnaud, Roxane Andersen and Rémy Pouliot (PREG), Jean-Yves Daigle (CZRI) as well as Markus Thormann, mycology and forestry pathology (Natural Ressources Canada) were present. In spring 2005, Line Rochefort, Luc Miousse, Claudia St-Arnaud, Jean-Yves Daigle and Markus Thormann also participated in a *Sphagnum* farming workshop in Bremen, Germany. In 2007, the CZRI was also involved in the planning the technology transfer workshop in Shippagan.

Acadian Peat Moss ltd

Each year since 2004, Acadian Peat Moss is involved in the improvement of the access road and in the setup of experiment by lending machinery (excavators, tractors, etc.) It also fabricated seven water lever control systems and culvert. It also provided wooden stakes and equipment (drills, snowshoes, etc.) to the Université Laval team.

New Brunswick ministry of natural resources

In 2003, New Brunswick ministry of natural resources (NRM) made topographical surveys in the studied zone. In 2006, it provided two information signs explaining the experimental station activities. In 2007, a NRM member joined the team to help the research work for a 10 days period.

Sun Gro Horticulture Inc.

From 2004 to 2008, Sun Gro Horticulture Inc. participated in the installation of experiments by lending machinery (excavators, tractors, all terrain vehicles, lateral manure spreaders, etc.) and by completing field work. In 2005, it did work to improve the access road and removed trees on Crown Land sectors. In 2006, it bought and replaced the pipe connecting the Sun Gro Horticulture sector to the municipal system. In 2007, it participated in the setup of the experiment studying experimental station *Sphagnum* use for abandoned peatland restoration. In 2008, it also provided materials (fertilizer, straw, etc.) for that experience.

Premier Horticulture

The Premier Horticulture Company provided and transported machinery (harrow) on the Shippagan station in 2003.

ASB Greenworld Ltd.

ASB Greenworld Ltd. bought materials during *Sphagnum* farming experiment setup.

Use of *Sphagnum* fiber in growing substrates.

Peat companies were also involved in *Sphagnum* use in horticultural substrates experiments that took place at Université Laval: **Sun Gro Horticulture Inc.** took care of the drying and handling of peat, **Premier Horticulture** donated peat and **Tourbières Berger Inc.** provided lime bags.

Appendix 3: Poster presented at the *International Symposium on Growing Media* (Anger, France) about *Sphagnum* fiber use in horticultural growing substrates.

Developing new substrates with Sphagnum fibres

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Introduction

New experiments are on going to commercially produce *Sphagnum* fibres. The fibres obtained possess very valuable properties and could be used to improve low quality peat and/or substitute mix components such as aggregates. The peat industry is seeking methods to valorise brown peat and sieving is already used by some companies. Valorisation of low quality peat would reduce the pressure on peatlands. Moreover, perlite is an expensive component that is widely used in commercial mixes. Its substitution by *Sphagnum* fibre, while maintaining the mixes quality, would participate to lower the production cost of peat companies.

Objectives

The objectives of this study were 1) to enhance the value of brown peat by adding Sphagnum fibres and/or removing fine particles and 2) to replace perlite by Sphagnum fibres in commercial mixes.

Material and methods

•Sphagnum fibre (SF) was obtained from a naturally restored bog in Shippagan, New Brunswick. The 15 cm top layer of *Sphagnum magellanicum* moss was manually collected and air-dried. The SF was then sieved to obtain particle size ranging from 1 to 5 mm of diameter.

•Brown sphagnum peat (BRSP) (H5 on the von Post scale) and blond sphagnum peat (BSP) (H3 on the von Post scale) from Premier Horticulture peatland (St-Henri de Lévis and Pointe-Lebel , Québec) were sieved to remove the particles over 5 mm. Half of that brown sphagnum peat stock was sieved (SBRSP) again to remove the fine particles below 1 mm.

•The following 9 substrates were then prepared:

1. 100% BRSP : 0% SF
2. 85% BRSP: 15% SF
3. 70% BRSP: 30% SF
4. 100% SBRSP: 0% SF
5. 85% SBRSP: 15% SF
6. 70% SBRSP: 30% SF
7. 70% BSP : 30% perlite
8. 70% BSP: 15% perlite and 15% SF
9. 70% BSP: 30% SF

•All substrates' pH were adjusted to 5.5 using limestone. A peat-light fertiliser was also added before plantation to avoid micronutrient deficiencies.

•In the spring 2004, *Pelargonium x hortorum* "Kim" and *Petunia x hybrida* "Wave" plants were grown into 15 cm pots and plug trays respectively in two separate experiments. Plants were given a constant liquid feed using a soluble fertilizer 15-15-18 (Plant-Prod Québec, Québec), providing 250 mg/L of N at each watering. At the end of the experiment, shoots and roots were harvested and dried at 70°C to determine dry biomass.

•The following substrates' properties were measured at the begening and at the end of the experiment: Air-filled porosity (**θ_a**), easily available water (**EAW**), saturated hydraulic conductivity (**K_s**), pH and electrical conductivity (**EC**).

•The experimental designs were completely randomized with 6 repetitions for a total of 54 experimental units. Treatment effects were evaluated using an analysis of variance and a multiple comparison test (LSD 0.05) using the Statistical Analysis System (SAS Institute, Raleigh, NC).

Results and discussion

Impact of sieving and SF on physical properties

•SBRSP had a higher air-filled porosity and hydraulic conductivity but had a lower water retention compared to BRSP and BSP. These differences last throughout the cultivation period.

•When SF were added to peat, it increased water retention for all peat types. It also increased hydraulic conductivity of BRSP and SBRSP but had no effect on BSP. Moreover, SF had no impact on air-filled porosity of BRSP while reducing it for SBRSP and BSP.

•The effects of SF disappeared during the cultivation period, except for water retention which remained slightly higher in BRSP and SBRSP.

Crop yield and substrates

•The growth of *Pelargonium* was unaffected by SF addition, except for the top biomass which was slightly lower with 15% SF added to BRSP.

•*Petunia* top biomass was increased with 30% SF addition into SBRSP and root biomass was also increased with 30% SF addition to BRSP and SBRSP.

•Plant growth was better correlated with initial physical properties, i.e. EAW for *Pelargonium* top dry biomass and K_s for *Pelargonium* and *Petunia* root dry biomass.

Table 1 : Initial and final physical properties of substrates.

	Initial			Final		
Treatments	θ_a ($cm^3.cm^{-3}$)	EAW ($cm^3.cm^{-3}$)	K_s ($cm.s^{-1}$)	θ_a ($cm^3.cm^{-3}$)	EAW ($cm^3.cm^{-3}$)	K_s ($cm.s^{-1}$)
1	0.198^{cd}	0.309^{e}	0.104^{f}	0.242^{cd}	0.226^{cde}	0.362^{fg}
2	0.205^{c}	0.343^{d}	0.193^{e}	0.252^{bc}	0.250^{abcd}	0.397^{efg}
3	0.211^{c}	0.358^{cd}	0.306^{cd}	0.228^{cde}	0.278^{a}	0.334^{fg}
4	0.283^{a}	0.250^{f}	0.565^{b}	0.309^{a}	0.198^{e}	0.668^{cd}
5	0.247^{b}	0.292^{e}	0.528^{b}	0.277^{ab}	0.231^{cd}	0.571^{de}
6	0.277^{a}	0.315^{e}	0.950^{a}	0.284^{ab}	0.220^{de}	0.516^{def}
7	0.194^{cde}	0.375^{c}	0.224^{de}	0.188^{f}	0.252^{abc}	0.238^{g}
8	0.174^{de}	0.408^{b}	0.192^{e}	0.208^{def}	0.265^{ab}	0.262^{g}
9	0.139^{f}	0.453^{a}	0.221^{de}	0.199^{ef}	0.276^{a}	0.226^{g}
Probability	0.001	0.001	0.001	0.001	0.001	0.001

Table 2 :Top and root dry biomass of Pelargonium x hortorum "Kim" and Petunia x hybrida "Wave".

	Pelargonium		Petunia	
Treatments	Top biomass (Grams)	Root biomass (Grams)	Top biomass (Grams)	Root biomass (Grams)
1	28.73^{ab}	2.67^{bc}	7.32^{abcd}	1.07^{d}
2	24.32^{c}	2.18^{c}	6.35^{d}	1.03^{d}
3	25.58^{bc}	2.90^{bc}	7.08^{bcd}	1.43^{bc}
4	26.29^{bc}	3.28^{ab}	6.92^{cd}	1.25^{cd}
5	26.18^{bc}	2.80^{bc}	7.20^{abcd}	1.14^{cd}
6	28.94^{ab}	3.09^{ab}	8.28^{a}	1.59^{ab}
7	30.81^{a}	2.53^{bc}	7.69^{abc}	1.09^{d}
8	28.03^{ab}	2.30^{c}	7.81^{abc}	1.01^{d}
9	28.57^{ab}	2.63^{bc}	8.18^{ab}	1.13^{cd}
Probability	0.013	0.01	0.027	0.001

Table 3 : Pearson's correlation coefficients between plant growth parameters and substrate physical properties.

	Initial properties			Final properties		
Variable	K_s	θ_a	EAW	K_s	θ_a	EAW
Pelargonium top dry biomass	-0.03	-0.21	**0.29**	-0.12	0.02	0.00
Pelargonium root dry biomass	**0.39**	0.28	-0.23	—	—	—
Petunia top dry biomass	0.15	-0.08	0.22	—	—	—
Petunia root dry biomass	**0.36**	0.11	-0.04	—	—	—

Note: The bolded values are significant to 0.05

Conclusions

•The best yields were obtained with SBRSP and 30% SF addition and with BSP with or without SF. Yields were best correlated to EAW.

•Removal of fine particles from BRSP seems very promising with 30% SF addition.

•SF can partially or completely replace perlite in BSP mixes.

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