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CHAPTER 11

Plant Reintroduction on a Harvested Peat Bog

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CONTENTS

INTRODUCTION

Peat harvesting for horticultural and other purposes is an important industry affecting peat bogs in southern Canada. The methods being used to extract the peat greatly affect the environment, leaving bare peat surfaces that can scarcely

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be recolonized by bog plants (Elling and Knighton, 1984). These abandoned fields rarely return through secondary succession to the original moss-dominated ecosystem. Birches or ericaceous shrubs have often been the only species found, even 10 years after harvesting stopped, and the moss layer typical of bogs has usually been absent on abandoned surfaces (Spencer et al., 1993). In order to restore those peatlands, efforts must focus on the reintroduction of *Sphagnum* species that are responsible for specific conditions found in bogs, such as acidity and peat accumulation (Clymo, 1984). The general objective of our research program is to find methods to reintroduce peatland vegetation, in order to initiate a process that will eventually lead abandoned fields back to functional peatland ecosystems.

Small-scale greenhouse experiments (Campeau and Rochefort, in press) have shown that the spreading of *Sphagnum* fragments (diaspores) on bare peat surfaces can lead to the reestablishment of a moss layer within a few months. Thus, collecting living plants on the surface layer of a natural bog (often referred to as the top spit layer), chipping this material, and spreading it on a harvested field seems to be a promising approach to restoring vegetation on abandoned sites. Greenhouse and field conditions, however, are different, and any plant material spread on bare peat surfaces faces adverse environmental conditions. As peatland restoration research is a new field in North America, it is assumed, based on the Dutch literature, that the most important problem that *Sphagna* and other plant diaspores face in colonizing bare peat surfaces is a water deficit (Schouwenaars, 1988a). The drainage necessary for harvesting purposes results in a drop of the water table generally far below 40 cm, which is considered a minimum for *Sphagnum* regeneration (Schouwenaars, 1988b). Moreover, it has been observed that dry conditions at the ground surface can lead to the formation of a crust and thus isolate plant diaspores from soil moisture (Spencer et al., 1993). Thus, rewetting harvested peat bogs by blocking drainage ditches is the first step before reintroducing plant diaspores. But even then, field observations show that dry conditions persist at the soil surface and that other interventions are needed to provide plant diaspores with favorable conditions.

In this study, one objective was to reduce evaporation from bare peat surfaces to encourage *Sphagnum* establishment, and currently the importance of reduced evaporation in the hydrological budget of harvested peatlands is being assessed (Ingram, 1983). As evaporation is closely related to wind and soil surface temperature (Enz et al., 1988), we tested two different treatments aiming to reduce this drying effect: windbreaks and ground cover (mulching). Windbreaks reduce evaporation by decreasing air flow (Rosenberg, 1976). Their efficiency is related to the porosity of the barrier in such a way that solid and very loose windbreaks are less effective than intermediate ones (Heisler and DeWalle, 1988). The horizontal extent of wind protection is a function of windbreak height, and it is accepted that the area of influence is ten times its height (Dickey, 1988). Mulching reduces evaporation by decreasing wind speed and soil surface temperature (Enz et al., 1988). Though crop residues such as straw are widely used, paper and

plastic cover are among other types of ground cover that proved to be efficient in the matter (Rosenberg et al., 1983). Microtopography also helps plant diaspores establishment. Tillage of harvested peat bogs to loosen the soil surface can provide better aeration for vascular plants and more sheltered microsites for *Sphagnum* and moss diaspores (Salonen and Laaksonen, 1994).

Small-scale experiments successfully used material collected by hand in the natural bog (Campeau and Rochefort, in press). But to scale up those experiments, methods to collect large amounts of living plant material in the natural bog and to spread it on the harvested site by mechanical means must be found. Thus, the specific objective of this study is to estimate the potential of the reintroduced plant material to survive, grow, and multiply when evaporation is reduced by windbreaks, mulching, and the creation of a microtopogaphy. A second goal is to test the ability of machinery commonly available to do some of the work involved in the restoration process.

STUDY SITE

The study site is located at Rivière-Ouelle (47°27′N, 69°58′W), 140 km east of Québec City, on the south shore of the St. Lawrence River (Figure 1). Mean annual temperature is 4.2°C (Environnement Canada, 1993). The coldest month is January, with a mean of −11.3°C and the warmest is July with 18.8°C. The annual precipitation is 930 mm, of which 645 mm falls as rain. Mean annual evapotranspiration is estimated to be 525 mm (Wilson, 1971). Nevertheless, there is a water deficit during the summer months (June, July, and August). Westerly winds are dominant over the year, but easterly winds are more frequent from February to April and during snowfalls. The bog covers an area of 15 km^2; about half of it is used for peat harvesting.

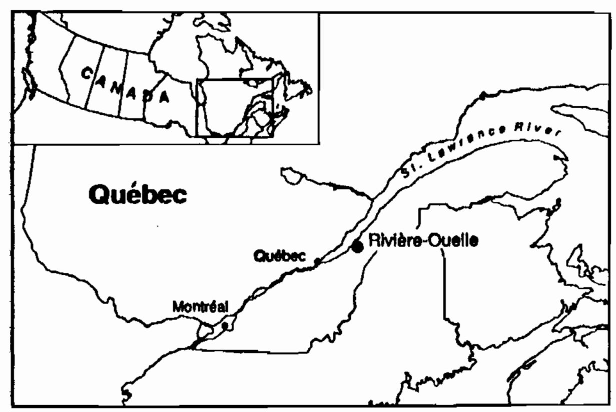

Figure 1 Location of study site.

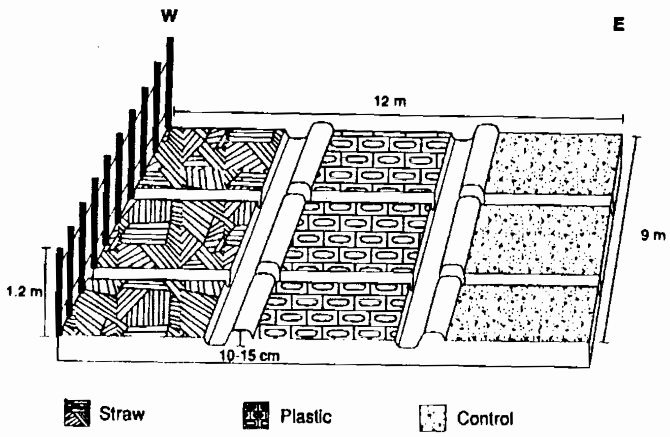

Figure 2 Schematic view of a main plot showing the arrangement of windbreaks, ground covers, and microtopography. On this plot, the windbreak is effective in summer while westerly winds are dominant. Depressions and mounds created with the machinery are parallel to the subplots, while tracks left by the manure spreader are perpendicular. For the effect of snow trapping, the windbreak would be on the right side, and for both effects there would be windbreaks at each end.

METHODS

Preparation of the Experimental Site

The experiment was conducted on two bays that had been abandoned for 10 years. Bays are the areas between two drainage ditches; in this case they are 40 m wide. The drainage ditches along the bays were blocked in May 1993. Microtopography was created using an excavator that pushed the soil across the bay before spreading any living material. Flat areas were bordered by a depression and a mound, the depressions being about 10 to 15 cm deep (Figure 2).

Collecting and Spreading Living Plant Material

Living plant material was collected in the nearby natural bog with a shredder used by the producers to prepare the peatland surface before harvesting. The shredder went over an area of about 500 m^2 (15 × 35 m), and the top spit layer was chipped on a thickness of 10 to 15 cm. This provided a material containing pieces from 1 to a few centimeters long with some bigger chunks. A manure spreader was used to distribute the living plant material on the experimental site to a surface eight times larger than the natural site (ratio collected-surface/surface-covered, 1:8). Because some difficulty occurred when adjusting the manure spreader, the plant material was unevenly spread on the ground. The spreader also left tracks, which added some microtopography at the site.

Windbreaks and Ground Covers

The experiment testing the effect of windbreaks and ground covers on the recolonization success of *Sphagnum* species, other mosses, and vascular plants was designed as a split-plot experiment in a completely randomized design. For windbreaks, wooden snow fences were set perpendicular to the prevailing winds (Figure 2). The fences were 1.2 m high, with a porosity of 50 percent. Windbreaks were expected to work as snow traps in winter. Consequently, there were four possibilities regarding the position of the windbreaks: (1) the effect of windbreaks in summer, (2) the action of fences as snow traps in winter, (3) the combination of both, (4) a control with no windbreak. The experimental site was divided into 12 main plot units (15 × 9 m), to which the four levels of the windbreak factors were randomized (three replicates for each windbreak condition).

Each main plot unit was subdivided into three subplots units, to which the three cover types (no cover, plastic cover, and straw) were randomized. The plastic cover consisted of plastic snow fences (porosity 66 percent) that were unrolled on the ground, while straw was spread by hand at a density of approximately 1500 kg/ha. As 3600 to 4000 kg/ha are needed to achieve 100 percent ground covering (Greb, 1966; Unger, 1976), both the straw cover and the plastic cover were estimated to have approximately the same porosity.

Data Collection

The effects of treatments (windbreaks and cover types) toward the establishment of a vegetation cover were assessed by counting the number of plant individuals present at the end of the growing season. For the purpose of this experiment, three groups of plants were considered: (1) *Sphagnum* species, (2) other mosses (only the *Dicranum* and *Polytricum* genera), (3) vascular plants. Plants were counted in several sampling units (generally three) in each replicate. Sampling units consisted of four quadrants of 25 × 25 cm, systematically positioned in a 1-m square frame placed on flat surfaces. Mean numbers obtained for each sampling unit were averaged to give the values used for the analysis of variance for each subplot.

Counts were also made in depressions. Because they account for a small amount in terms of surface, sampling units in depressions consisted of only two quadrats. Those data were not included in the analysis of variance comparing windbreaks and cover types but were used to compare plant reestablishment between depressions and flat surfaces.

As mentioned earlier, the use of a manure spreader resulted in an uneven thickness of material. Thus, when counting plant individuals, each sampling unit was attributed a rating for material thickness as follows: (1) scant (material covering less than 50 percent of the ground), (2) thin layer (material covering over 50 percent of the ground), and (3) thick layer (100 percent of the ground covered by a layer more than 2 cm thick). These data were used to evaluate the effect of spread material thickness on plant reestablishment.

Finally, a vegetation survey was also conducted at the nursery borrow site at the end of the growing season, in order to estimate the damage caused by the machinery when chipping and collecting the living plant material.

Statistical Analysis

The effects of the two factors tested (windbreaks and cover types) on the number of *Sphagnum* individuals, other mosses, and vascular plants were compared using the GLM procedure of SAS (SAS Institute, 1988). Once the overall effect of a factor was shown significant with no interaction with the other factor, differences between the levels of a factor were located using a Tukey test (Sokal and Rohlf, 1981). Data were square-root transformed to meet the assumptions of normality and to reduce heterogeneity of variance $[y = \sqrt{(x + 0.5)}]$. The significance level for the ANOVA and the Tukey test was set at 0.05.

RESULTS AND DISCUSSION

Windbreaks

As no direct measurements of physical parameters (near ground temperature, evaporation, wind reduction) were done, we cannot assess the effect of windbreaks on the microclimate at the ground surface. However, our results show that windbreaks did not affect significantly the number of plants on the bare peat surface after the first growing season (Table 1). On the other hand, the presence of windbreaks substantially increased snow depth as expected. The site was visited at the end of March 1994, when there was little snow left on the harvested area. On the lee side of snow fences snow depth was still up to 1 m.

Ground Covers

Ground covers promoted plant reestablishment for the three groups of plants measured (Table 1; Figure 3). Straw tended to give a higher number of individuals per m^2 than the plastic cover. In all situations, vascular plants were far less numerous than mosses and *Sphagna*, but they were more abundant under the straw than in the control plots ($p < 0.05$). Our observations, however, force us to qualify those results. At the end of the growing season in October 1993, we noted a clear difference in the shape or health of *Sphagnum* capitula between both types of cover, despite comparable numbers. Under the plastic cover, *Sphagna* capitula were small and barely visible. Since summer growth was minimal, the plastic cover only allowed *Sphagna*, and to some extent other plant diaspores, to survive but not flourish. However, under the straw we found big and healthy *Sphagna* capitula and mosses. Their growth even led to the formation of small clusters of capitula. Straw not only increases the chance of survival but also promotes the growth of plant fragments, which is an important point to consider regarding the reestablishment of a moss carpet. It is not known yet what is the real effect of straw. It probably decreases evaporation by lowering ground surface temperature and wind effect, but it may also help plant reestablishment by introducing some nutrients by leaching. Other studies already pointed out such beneficial effect of straw on plant reintroduction (Bradshaw, 1987).

Table 1 Anova Tables for the Experiment on the Effect of Windbreaks and Ground Covers on Plant Reestablishment

Source	df	Type III SS	Mean square	F value	p > F
Number of *Sphagnum* individuals					
Windbreaks	3	68	22.8	0.66	0.6012
Error a	8	278	34.7	—	—
Cover	2	114	56.8	9.47	0.0019
Interaction	6	22	3.7	0.62	0.7137
Error b	16	96	6.0	—	—
Number of moss individuals					
Windbreaks	3	107	35.8	1.07	0.4139
Error a	8	267	33.4	—	—
Cover	2	60	30.0	9.21	0.0022
Interaction	6	26	4.3	1.31	0.3101
Error b	16	52	3.3	—	—
Number of vascular plant individuals					
Windbreaks	3	9	3.0	1.46	0.2969
Error a	8	17	2.1	—	—
Cover	2	38	18.8	7.91	0.0041
Interaction	6	14	2.3	0.95	0.4885
Error b	16	38	2.4	—	—

Note: The experiment was designed as a split-plot experiment in a completely randomized design.

Microtopography

Microtopography had a positive effect on diaspore establishment. Whatever the ground cover, the number of plant individuals for the three groups of plants more than doubled in depressions, compared to flat areas (Figure 4). The presence of depressions reduced the positive effect of ground covers, as we obtained a comparable success with and without any cover. However, the best overall results were found in depressions with the application of straw. Wetter conditions found in the depressions and the fact that in those microsites wind and solar radiation are less important help explain the positive effect of microtopography. Depres-

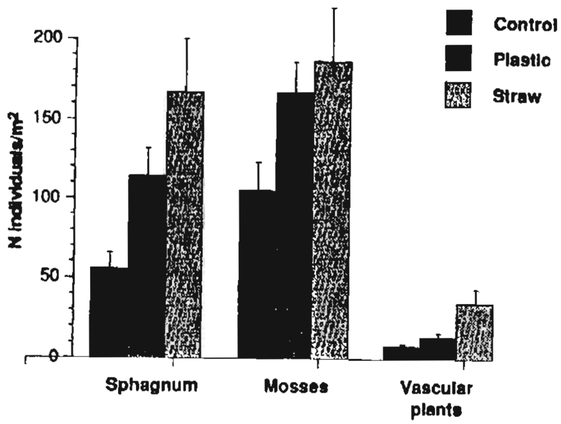

Figure 3 Effect of ground cover types on the establishment of the three groups of plants. Mean number of individuals per m² (± standard deviation). Both ground covers, plastic and straw, have a significant positive effect ($p < 0.05$) on the number of *Sphagnum* and mosses when compared to the number of plants observed in the control plots according to the Tukey test. More vascular plants ($p < 0.05$) were found under the straw ground cover than in the control plots.

sions represent sheltered sites where plant fragments can survive and grow and from where a moss carpet could establish and expand to adjacent flat areas and mounds. On the other hand, we did not expect plant fragments to reestablish readily on raised parts, and no data were collected on mounds. Indeed, visual observations showed that very few diaspores survived on those sites. Mounds are made of loose, lower density peat, and, though no measurements were made, its bigger pore size favors rapid drainage and impedes the presence of capillary water (Armson, 1977). Such dry conditions make the mounds unsuitable sites for diaspores survival. The efficiency of plant reestablishment in depressions, when compared with flat areas, compensates for the lack of regeneration on the mounds. Depressions can act as starting points for the establishment of a moss carpet that will spread to mounds, provided they are not too high.

Thickness of Living Material

The uneven thickness of living plant material spread on the experimental site appeared as an unexpected factor that may have influenced our results. However, for each ground cover type (control, plastic, and straw), about the same proportion of quadrats were measured under the different thicknesses of living plant material. Therefore, the sampling method does not interfere with the results on ground covers (Table 2). The numbers of living individuals after one growing season varied with the thickness of the spread material. With no ground cover (control), the number of individuals for the three groups of plants rose with the greater thickness of spread material (Figure 5). In the presence of ground covers, plastic

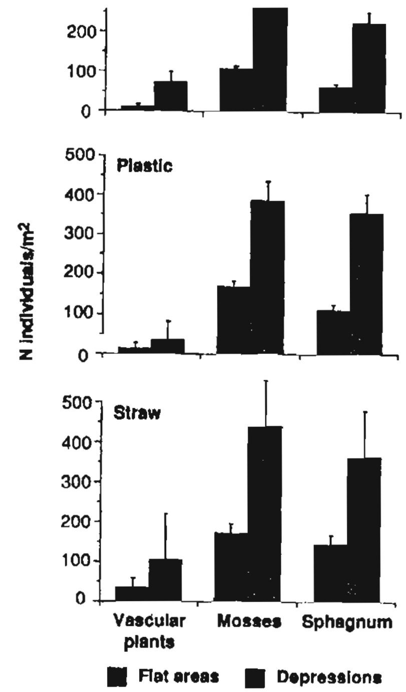

Figure 4 Effect of microtopography on the establishment of the three groups of plants. Mean number of individuals per m² (± standard deviation). N varies from 4 to 46 sampling units. The highest numbers of individuals per m² are found in depressions with straw where they reach over 105, 364, and 439 for vascular plants, *Sphagnum* species, and other mosses, respectively.

Table 2 Distribution of Quadrats, in Percentage, According to the Thickness of Living Plant Material Spread

	Scant %	Thin layer %	Thick layer %
Control	15	72	13
Plastic	17.5	72.5	10
Straw	14	67	19

Note: The almost equal distribution of quadrats under the different thicknesses of plant material does not influence the results for the ground cover types, except for a small underestimation of the positive effect of straw, as the thin layer had a better success (Figure 3).

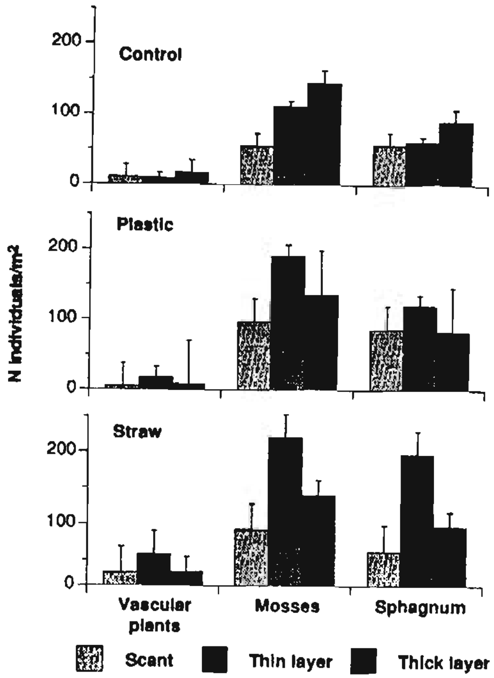

Figure 5 Effect of living plant material thickness on the establishment of the three groups of plants. Mean number of individuals per m² (± standard deviation). N varies from 4 to 33 sampling units.

or straw, the reintroduction had a better success when a thin layer (material covering more than 50 percent of the ground) of plant material was applied. When it was scanty (less than 50 percent of ground covering) or too abundant (more than 2 cm thick), ground covers had no positive influence and even had a negative effect in some cases. This suggests that when the material is too abundant, diaspores located at the bottom suffer from being buried, while those at the top lose contact with the ground and hence soil moisture. Otherwise, it is normal to have fewer plants when there is less plant material.

Plant Recovery at the Collection Site

Overall success is limited if part of a natural bog has to be destroyed to restore a harvested site. It is important that natural areas not be damaged irreversibly by collecting the top spit layer. For the purpose of this experiment, the ratio collected surface/surface covered by the living plant material was 1:8. Experiments started in 1994 have shown that this ratio could be up to 1:20, provided that diaspores are smaller and the living plant material devoid of chunks. On the other hand, results of a vegetation survey conducted after the growing

season, three months after the top spit layer was harvested, indicate that the removal of the vegetation did no irreversible damage to the bog. In fact, vascular plants recovered well. A mean of 261 shoots of vascular plants per m² was found at the borrow site, compared with 105 under the best conditions on sites under restoration (in depressions with straw). The situation is similar for *Sphagnum* species with 385 capitula and for the mosses with 468 individuals, compared to 364 and 439, respectively, in depressions with straw at the experimental site. The shoots of vascular plants came from the root system and/or rhizomes left in place. For technical reasons, we cannot pick up all the chipped material; hence, many living *Sphagna* and moss fragments are left on the ground and many of them survived. Another interesting point is that the composition of vascular plants reflects that found in natural conditions. *Chamaedaphne calyculata* (L.) D. Don and *Kalmia angustifolia* L. were well represented, while the other species were less abundant. *Ledum groenlandicum* Retzius was the only species that was under-represented.

CONCLUSION

Little is known about peat bog restoration in North America, and this experiment represents one of the first trials aiming to reintroduce plant diaspores on a large scale (1300 m²). Colonization by *Sphagnum* and other moss species is very slow, and many years of observation are needed to assess the success of this method in terms of reestablishing a moss carpet. However, the following conclusions can be drawn from this experiment after one growing season, which can guide further experiments:

1. Windbreaks showed no effect on the success of plant reestablishment at this site. Direct measurements of physical parameters should be done in order to assess the effect of windbreaks on ground surface microclimate.
2. The use of a ground cover allowed more individuals per m² to reestablish when a thin layer of plant material was spread on bare peat sufaces. Straw gave better results than plastic, as suggested by the better health of individuals and the formation of small clusters after one growing season. Straw has the double advantage of being very cheap and easily available.
3. The top spit layer of a natural bog has good potential for regeneration of the three groups of plant considered. The reestablishment of the vegetation, though, was more successful when ground covers were provided to increase water availability for plants.
4. The thickness of living plant material spread on the bare surface was an important variable. Too little or too much material inhibited the positive effect of ground covers.
5. Microtopography proved to be efficient in terms of number of individuals per m² for each group of plant by providing wetter and sheltered sites.
6. The plant recovery at the natural nursery site suggests that collecting living plant material does no irreversible damage to the environment.
7. Commonly available machinery accomplished the work involved in the restoration process.

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