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ECOLOGICAL RESTORATION OF LAGG-SWAMP SPECIES ON CUTOVER PEATLANDS

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SUMMARY

A relatively more recent challenge in restoration of cutover peatlands is the restoration of the lagg-swamp. That is, the minerotrophic band surrounding the dome in natural raised bogs. In our study, we follow three objectives: 1) to characterize the effects of shade on the regeneration of two typical moss species of natural lagg-swamps when reintroduced in cutover peatlands; 2) to characterize the effects of shade and presence of a moss carpet on the germination of one sedge species and one shrub species; 3) to characterize the effects of shade, presence of a moss carpet and fertilization on the growth and survival of shrub seedlings.

KEYWORDS : *Dicranum polysetum*, *Sphagnum fallax*, *Carex trisperma*, *Nemopanthus mucronatus*, biological interactions

INTRODUCTION

In eastern Canada, a method has been developed for the ecological restoration of cutover peatlands (Rochefort and Lode, 2006). As most ecological restoration methods, this *Sphagnum*-layer transfer method is essentially based on the restoration of historical abiotic conditions (i.e. peatland rewetting, introduction of nurse species, and mulching) and the reintroduction of key ecosystem engineer species (i.e. *Sphagnum* spp.).
One new challenge is the development of a restoration method adapted to sectors of cutover peatlands with shallow residual peat upon peat extraction activities. These sectors were occupied by *Sphagnum*-dominated vegetation prior to peat harvesting, but they cannot be restored using the *Sphagnum*-layer transfer approach because rewetting will inevitably result in peat enrichment by minerals, an inappropriate abiotic chemical condition for bog *Sphagnum* species establishment.

In the last decades, afforestation has been used extensively to revegetate cutover sectors with thin residual peat as several coniferous tree species (mainly *Larix laricina*, *Picea mariana*, and *Pinus banksiana*) thrive well when they can have access to mineral substrates (Bussières *et al*,. 2008; Caisse *et al*., 2008). Nevertheless, we believe that other good candidates for rehabilitation on these sectors are understory species found inside natural lagg-swamps. Lagg-swamps are the ecotonal habitats found at the margins of raised bogs, where peat is naturally thinner (Howie and Meerveld, 2011).

Very little is known on the autecology of lagg-swamp species; most peatland studies in North-America have focused on the ombrotrophic sectors of raised bogs. The present study aimed at characterizing the effects of different factors on the establishment of lagg-swamp species reintroduced in cutover peatlands with shallow residual peat. In particular, we tried to answer the following questions:

1. Is shade beneficial for the establishment of lagg-swamp mosses in cutover peatlands?
2. How does shade, presence of a moss carpet and fertilization influence the establishment of lagg-swamp vascular plant species in cutover peatlands?

MATERIALS AND METHODS

Study species

Two reasons have driven the choice of the species for the experiments. Firstly, the four selected species are frequent and abundant inside natural lagg-swamps (personal observations). *Dicranum polysetum* is a dominant moss species on hummocks, while *Sphagnum fallax* is a dominant moss species in hollows. *Carex trisperma*, a sedge, is one of the most frequent species in the herbaceous layer. *Nemopanthus mucronatus* is always one of the dominant shrub species. Secondly, the species are easily harvested and can be collected in large quantities (personal observations). *C. trisperma* produces only three seeds per shoot, but the species is dominant in many wet coniferous forests and harvesting of large seed lots is thus rapidly achieved. For the shrub layer, we chose to focus on *N. mucronatus* because seeds are abundant: each mature shrub produces a large amount of berries that each contains 4 to 7 seeds, and ripe berries stay on the shrub during most of the fall season.

Study sites

All the experiments were replicated on five experimental sites of cutover peatlands in New-Brunswick, Canada. One experimental site is located at the harvested peatland of Lamèque-Portage (47° 49' 26.1042" N, 64° 38' 13.977" W), two experimental sites at the harvested peatland of St-Raphaël (47° 47' 37.701" N, 64° 35' 17.1162" W) and two experimental sites at the harvested peatland of Pointe-Sapin (46° 57' 45.6552" N, 64° 51' 45.4968" W). The five experimental sites share many similar characteristics: low electrical conductivity (between 93 and 174 μS), low pH (between 3.4 and 4.1), high peat bulk density (between 0.12 and 0.33 g/mL), low water table level (average of -48 cm based on two measurements in each site during summer 2011). In addition, the selected peatland sectors had been abandoned for over 10 years, had a relatively low cover of spontaneous vegetation, and had between 15 cm and 30 cm of residual peat.

Description of experiments

Experiment 1: Effect of shade on mosses

The first experiment has studied the effect of shade on the mosses *Dicranum polysetum* and *Sphanum fallax*. First, mosses were harvested in nearby natural lagg-swamps and transferred on four 2.5m x 2.5m plots (ground cover of 100%: 50% *D. polysetum* and 50% *S. fallax*) in each experimental site for a total of 20 experimental units. Mosses were mulched with hay for the first growth season and the first winter. Each plot was then randomly assigned to one of two shade treatments: full-light or artificial shade (neutral shade-cloth 70% shade). Shade treatment was applied during the second and the third growth seasons. Finally, ground cover of each species was evaluated in each plot after three entire growth seasons.

Experiment 2: Effects of shade and presence of a moss carpet on seed germination

The second experiment focused on the effect of shade (full light vs neutral shade-cloth 70% shade) and the presence of a moss carpet (bare peat vs moss carpet of *Dicranum polysetum* and *Sphagnum fallax*) on the germination rates of two vascular plants. It was set up as a factorial experiment in a randomized complete block design: each of the four treatments was repeated in the five experimental sites for a total of 20 experimental units. First, seeds from *Carex trisperma* and *Nemopanthus mucronatus* were harvested in nearby natural lagg-swamps during fall, cleaned and kept in humid clothes during a cold stratification (4°C) of eight months (from October to May). After the stratification, seeds were packed in small lots containing 50 seeds of both species and each lot was randomly assigned to one of the four treatments. Seeding was done on 50cm x 50cm plots of the four treatments. Seedlings of the two species were counted inside each plot after two growth seasons.

Experiment 3: Effects of shade, presence of a moss carpet and fertilization on transplanted shrubs

The third experiment aimed at characterizing the effects of shade (full light vs neutral shade-cloth 70% shade), presence of a moss carpet (bare peat vs moss carpet of *Dicranum polysetum* and *Sphagnum fallax*) and fertilization (unfertilized plots vs fertilized plots) on the growth and survival of transplanted shrubs. It was set up as a factorial experiment in a randomized complete block design: each of the eight treatments was repeated in the five experimental sites for a total of 40 experimental units. Seeds of *Nemopanthus mucronatus* were harvested in nearby natural lagg-swamps during fall, cleaned and kept in humid clothes for three cycles of stratification (4°C for eight months, 20°C for six months, 4°C for four months). Seeds were then sown in cells in a greenhouse in a germination substrate (peat-vermiculite mix). Seedlings were fertilized weekly with a 10-20-30 solution. After one month of growth in greenhouse (in early summer), six *N. mucronatus* seedlings were transplanted inside each experimental plot. For the plots with the fertilization treatment, the transplanted shrubs were fertilized at plantation time using a granular slow-releasing fertilizer (4-16-28; 60 g applied at the base of each shrub). After one entire growing season, survival was evaluated and *N. mucronatus* seedlings still alive were carefully dug up to take different measurements: shoot length, leaf area, above-ground biomass, and below-ground biomass.

Data analysis

For each experiment, ANOVAs were conducted to test for significant effects using R version 2.2.1 (The R Foundation for Statistical Computing). The five experimental sites were used as the blocking factor. In the two factorial experiments (Experiment 2 and Experiment 3), interactions between factors were also included inside the models.

RESULTS

Experiment 1: Effect of shade on mosses

Our results showed that 1) the conditions under shade cloth were more favorable than the conditions in full-light for the regeneration of *Dicranum polysetum* and *Sphagnum fallax* in cutover peatlands, and 2) *D. polysetum* regeneration potential is higher than *S. fallax* in all our experimental conditions (Fig. 1). *S. fallax* cover decreased over time (from 50 % initial cover). *D. polysetum* showed a different response: cover decreased in full light, but cover increased under shade.

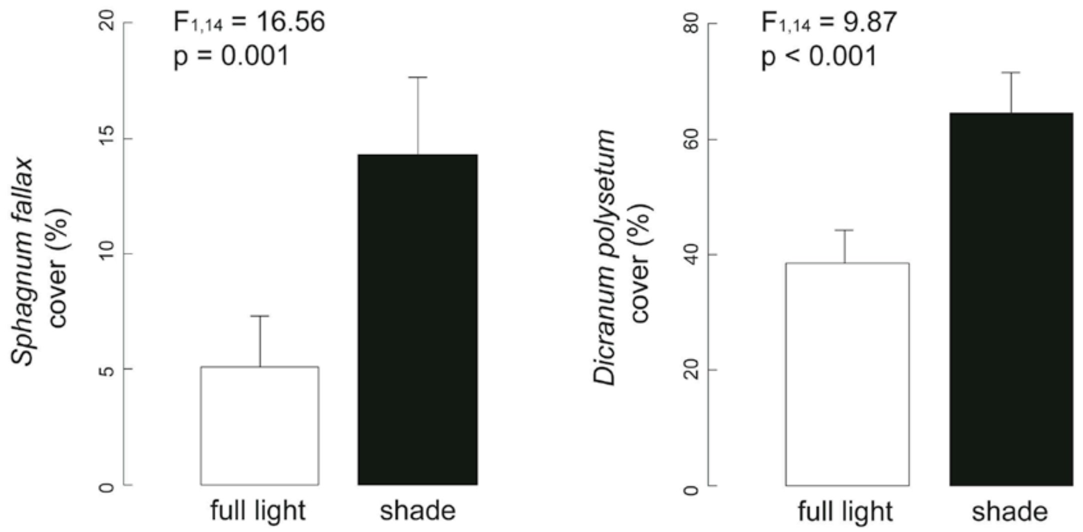

Fig. 1. Ground cover of two mosses in full light and under shade in cutover peatlands three years after their reintroduction from natural lagg-swamps. Initial covers were 50 % for both species. Note that the vertical axis is scaled differently in each graph.

Experiment 2: Effects of shade and presence of a moss carpet on seed germination

Seeds germinated in all seeded plots. Absence or presence of a moss carpet did not significantly influence the germination of *Carex trisperma* and *Nemopanthus mucronatus*. Presence of shade significantly improved germination rates of both species (Fig. 2).

Experiment 3: Effects of shade, presence of a moss carpet and fertilization on transplanted shrubs

Both shade and fertilization influenced *Nemopanthus mucronatus* seedlings. Shade significantly increased seedling survival (74 % in full light; 92 % under shade). Fertilization increased fitness of the seedlings that survived: seedling biomass was increased by 68 % and seedling height was increased by 54 %.

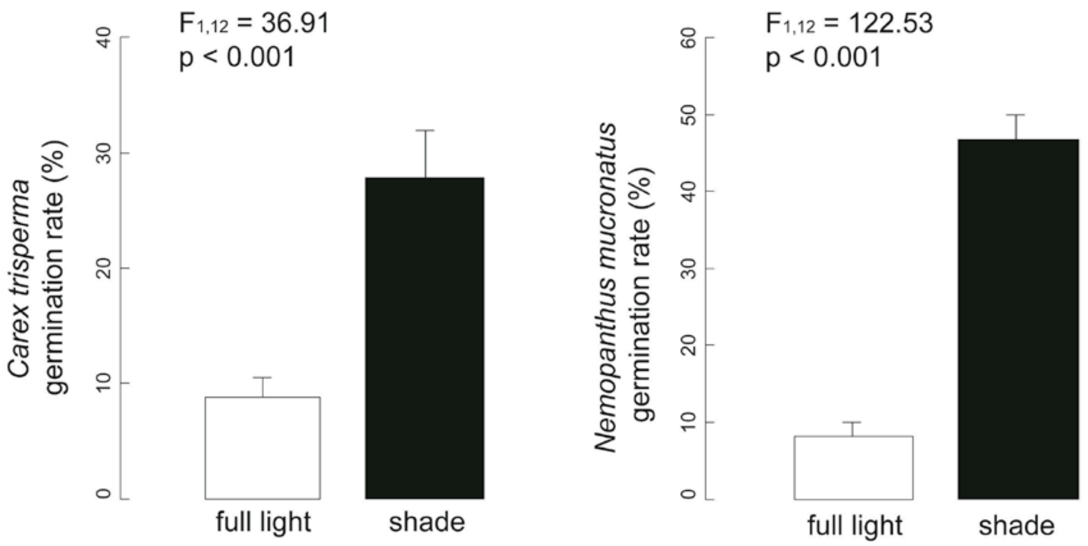

Fig. 2. Germination rates of two vascular plants in full light and under shade in cutover peatlands. Note that the vertical axis is scaled differently in each graph.

CONCLUSION

In this study, we have shown that understory lagg-swamp species can be successfully reintroduced in cutover peatlands. From the two moss species, *Dicranum polysetum* seems better adapted to the abiotic conditions of cutover peatlands than *Sphagnum fallax*; its ground cover was higher in all sites after three growing seasons. *Carex trisperma* seems a good candidate species for the herbaceous layer: seeds germinated well and seedlings survived to their first summer. The shrub *Nemopanthus mucronatus* also seems a good candidate species: seeds are abundant, germination rates are relatively high, and transplanted shrubs survive relatively well in cutover peatlands. Because shrubs form the dominant layer in natural lagg-swamps, we think that it is important to include at least one shrub species in the restoration of cutover bogs with thin residual peat layer. Also, other studies have shown that shrubs have good potential in ecological restoration (Hovick and Reinartz, 2007; Gómez-Aparicio *et al.*, 2004).

Overall, the results from our three experiments showed that shade generally increases restoration success, at least during the early establishment of plants. Firstly, our moss-transfer experiment shows that it is possible to reintroduce lagg-swamp mosses in cutover peatlands; but shade significantly increases the cover occupied by mosses. Secondly, for the restoration of vascular plants, the two species we sown germinated well in full-light, but germination rates were significantly higher under shade. Thirdly, for the transplanted *Nemopanthus mucronatus* shrubs, fertilization was the main limiting factor influencing growth, but shade significantly increased survival rates.

In general, mosses did not influence seed germination, shrub growth and shrub survival. From a management perspective, it means that the restoration of the moss layer may be done at any step during the restoration of the understory.

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