Recruitment of boreal forest trees in poplar plantations on mine waste rock slopes

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Ecological facilitation: plants helping plants

The facilitation model (Connell & Slatyer 1977) suggests that the presence of certain species may benefit the establishment of other species. For example, seed germination and survival in harsh environments may be favoured under so-called nurse plants compared to open ground.

Can hybrid poplar act as a nurse plant in a boreal mining context?
Revegetation in a landscape of slopes

Waste rock piles are a major component of mining landscapes. Critical goals of site revegetation include: erosion control and returning the site to a functional ecosystem.

From waste rocks to a forest ecosystem?

- Plantation of boreal tree species on a respread topsoil? Erosion can be a serious problem for slow growing trees in slopes...
- Hydroseeding? An herbaceous ground cover can have an important competitive effect on tree recruitment...
Fast-growing plantations as an alternative revegetation technique on waste rock slopes

1) The rapid development of an extensive root system could help to stabilize the topsoil layer.

2) The rapid development of a tree cover could improve the understory micro-environmental conditions.
Objective and hypothesis

Can hybrid poplar act as a nurse plant?

-&gt; This research project aims to assess whether fast-growing plantations can accelerate the reestablishment of boreal tree species on waste rock slopes.

Hypothesis: A partial tree cover provides the most favourable conditions for boreal tree recruitment on waste rock slopes.
Material and method

Canadian Malartic mine site

Hybrid poplar plantation of 3 years of age:
- P. maximowiczii × P. balsamifera, 915319
- on a 50-cm overburden topsoil layer
- on a waste rock slope of 3H:1V

Randomized complete block design

3 blocks x hybrid poplar spacing treatments

control  4 x 4 m  2 x 2 m  1 x 1 m

Sampling units
- Seeding experiments/microenvironment monitoring
- Natural colonization

Experimental surveys
1) Seeding experiments (mid and late successional tree species)
2) Naturally established tree seedlings (mostly pioneer species)
3) Microenvironment (soil moisture, light, temperature, herbaceous biomass and leaf litter cover)
Preliminary results
More than twice as many seedlings were observed under the 2x2 m spacing treatment compared to the control.

### Relative abundance of colonizing tree and shrub species found in the hybrid poplar plantation during summer 2014

<table>
<thead>
<tr>
<th>Species</th>
<th>relative abundance (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Populus sp. (P. tremuloides &amp; P. balsamifera)</em></td>
<td>73</td>
</tr>
<tr>
<td><em>Salix sp.</em></td>
<td>13</td>
</tr>
<tr>
<td><em>Picea mariana</em></td>
<td>5</td>
</tr>
<tr>
<td><em>Prunus pensylvanica</em></td>
<td>4</td>
</tr>
<tr>
<td><em>Abies balsamea</em></td>
<td>2</td>
</tr>
<tr>
<td><em>Sorbus americana</em></td>
<td>2</td>
</tr>
<tr>
<td><em>Betula populifolia</em></td>
<td>0.5</td>
</tr>
<tr>
<td><em>Cornus stolonifera</em></td>
<td>0.5</td>
</tr>
</tbody>
</table>

The large majority of the seedlings observed are aspens, balsam poplars and willows.

*Fitted values and 95% confidence intervals estimated by Monte Carlo simulations from a Poisson glmer*
Why do we observe more young seedlings of aspen, balsam poplar and willows under the intermediate spacing treatment?
A look at the influence of the spacing treatment on the microenvironment might provide clues!
The relation between soil moisture contents in July and hybrid poplar spacing follows a quadratic pattern.

Soil moisture is known to be the main limiting factor for germination and early survival of boreal forest trees (Greene et al. 1999).

**Mean volumetric soil moisture content in July 2014 in relation to hybrid poplar spacing with a 95% CI *:**

<table>
<thead>
<tr>
<th>Hybrid poplar spacing (log of tree density(/10m²)+1)</th>
<th>Volumetric soil moisture content (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>control</td>
<td>-1.03</td>
</tr>
<tr>
<td>(4x4m)</td>
<td>-0.54</td>
</tr>
<tr>
<td>(2x2m)</td>
<td>0.21</td>
</tr>
<tr>
<td>(1x1m)</td>
<td>1.36</td>
</tr>
</tbody>
</table>

Marginal R² = 0.23
Conditional R² = 0.63

*Fitted values and 95% confidence intervals estimated by Monte Carlo simulations from a Gaussian lmer

**Seedling abundance of colonizing species in relation to volumetric soil moisture content in July 2014 with a 95% CI *:**

<table>
<thead>
<tr>
<th>Volumetric soil moisture content (%)</th>
<th>Seeding abundance (/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>3</td>
</tr>
</tbody>
</table>

Marginal R² = 0.16
Conditional R² = 0.81

*Fitted values and 95% confidence intervals estimated by Monte Carlo simulations from a Poisson glmer

- Part of the variability of the seedling abundance might be explained by the soil moisture contents during the germination period of the main pioneer species.

- Greater moisture content in the intermediate spacing treatment during the germination period may subsequently contribute to greater abundances.
Soil moisture contents generally decrease as canopy density decreases, because of higher evaporation on open ground.

However, if a cover species has transpiration rates that exceed evaporation rates from bare soil, then instead a dense, fast-growing canopy can reduce water availability at the soil surface (Burton & Bazzaz 1991).

Why do we find greater soil moisture contents under the intermediate spacing treatment?

- Soil moisture contents generally decrease as canopy density decreases, because of higher evaporation on open ground.
- However, if a cover species has transpiration rates that exceed evaporation rates from bare soil, then instead a dense, fast-growing canopy can reduce water availability at the soil surface (Burton & Bazzaz 1991).
Seedling abundance is negatively correlated with leaf litter cover: leaf litter is generally considered as a poor seedbed, which dries out quickly. It can also constitute a physical barrier for germinating seedlings trying to reach the soil underneath (Greene & Johnson 1998; Hesketh et al. 2009).
Quadratic effect of the hybrid poplar spacing on leaf litter cover: tree cover and understorey vegetation cover contribute differently to the leaf litter accumulation along the spacing gradient.

- Herbaceous biomass is negatively correlated with hybrid poplar density.

**Leaf litter cover in relation to hybrid poplar spacing with a 95% CI (mid-July 2014) *

**Herbaceous biomass in relation to hybrid poplar spacing with a 95% CI (mid-July 2014) *

*Fitted values and 95% confidence intervals estimated by Monte Carlo simulations from a binomial glmer

*Fitted values and 95% confidence intervals estimated by Monte Carlo simulations from a Gaussian lmer
Fast-growing plantations as an ecoengineering tool to improve revegetation on waste rock slopes

First sampling season results:
- Abundance values of pioneer species after two growing seasons were greater in the 2x2 m spacing treatment compared to the control and the other spacing treatments.
- Better microenvironmental (esp. soil moisture and leaf litter cover) conditions were found in the 2x2 m spacing treatment during the germination period of the main pioneer species.

Upcoming works:
- Further analysis of the data collected during the second sampling season (esp. seeding experiments with later-successional tree species).
- Joint examination of data related to the nursing effect and top soil stabilizing effect of hybrid poplar plantations.

→ Our findings will have practical implications for the development of innovative revegetation techniques on waste rock slopes in forested regions. But the project is only at its beginning, and many aspects are yet to be studied!

Thank you!