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Establishment, survivorship, and growth of yellow birch seedlings after site preparation treatments in large gaps

François Lorenzetti [a,b,*], Sylvain Delagrange [a,b,1], Daniel Bouffard [b,1], Philippe Nolet [b,1]

[a] Université du Québec en Outaouais (UQO), Département d'informatique et d'ingénierie, Pavillon Lucien-Brault, 101, rue Saint-Jean-Bosco, pièce B-2018, C.P. 1250, Succursale Hull, Gatineau, QC, Canada J8X 3X7

[b] Institut Québécois d'Aménagement de la Forêt Feuillue (IQAFF), 58 Principale, Ripon, QC, Canada J0V 1V0

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Abstract

The occurrence of yellow birch (YB) in the northeastern forests of North America is a source of concern. Several guidelines suggest ways to favor the regeneration of this species, including creating openings from small gaps to large clearcuts, coupled or not with a variety of soil preparation treatments. However, it is not clear if soil preparation treatment favors YB establishment by simply increasing the availability of good seedbed types, or by also altering competition pressure exerted by interfering species during the period of seedling establishment. For this study, large gaps (900 m^2) were created in a 70-year old YB dominated forest, to which three treatments differing in soil disturbance intensities were applied (i.e., soil scarification (i) using a rake [raking]; or (ii) by dragging slash out to the edges of the gap [slash drag]; and (iii) limited to the passage of the harvesting equipment [control]). The proportion of seedbed types reportedly most favorable for YB establishment (i.e., mineral-dominated) increased as the severity of the site preparation increased. The opposite was observed for organic-dominated seedbeds. As a result, the stocking of YB seedlings increased with the severity of site preparation. However, YB stocking was deemed sufficient in all gaps to ensure future canopy dominance, even in the control treatment. Although YB seedlings generally achieved greater heights as site preparation intensity increased, it was clear that this did not reflect vigorous growth as, on average, greater heights coincided with greater seedling height–diameter ratios. At the seedbed level, height–diameter ratio was associated with an increase in surrounding competition pressure and an increase in the incidence of stem apical death (SAD), which in turn decreased height differences among seedbed types by the end of the study. At the gap level, this blurred the advantages of site preparation over a *laisser-faire* strategy. The incidence of SAD was greatest in the slash drag and the rake treatments. Consequently, we cannot say that intense soil scarification is worth the expenses, especially in stands where YB seed sources are abundant.

Keywords: Yellow birch; Seedlings; Regeneration; Gaps; Site preparation; Growth; Competition; Height–diameter ratio; Shoot apical death

1. Introduction

Yellow birch (*Betula alleghaniensis* Britton) is one of the most valuable hardwood species of the northeastern deciduous forests of North America (Lowe et al., 1994). However, its abundance has been reported to decrease during the last century while more shade tolerant species have increased (Woods, 2000; Nolet et al., 2001). This decrease is presumably linked to silvicultural practices limited to partial cuts and high grading since they do not provide suitable conditions, such as found in natural or created gaps, for adequate levels of yellow birch establishment and survivorship (McClure et al., 2000; Woods, 2000). Yellow birch (YB) survivorship and growth is clearly related to light availability near the ground, especially at the seedling and sapling stages (Bellefleur and Larocque, 1983a; Perala and Alm, 1990b; McClure and Lee, 1993; Beaudet and Messier, 1998; Delagrange et al., 2004). In addition, the regeneration of this mid-shade tolerant species (Forcier, 1975; Erdmann, 1990) has been associated with the availability of specific microsites (Perala and Alm, 1990b; Erdmann, 1990;

* Corresponding author at: Université du Québec en Outaouais (UQO), Département d'informatique et d'ingénierie, Pavillon Lucien-Brault, 101, rue Saint-Jean-Bosco, pièce B-2018, C.P. 1250, Succursale Hull, Gatineau, QC, Canada J8X 3X7. Tel.: +1 819 595 3900x1612/983 6589; fax: +1 819 773 1638/983 6588.

E-mail addresses: francois.lorenzetti@uqo.ca (F. Lorenzetti), sdelagrange@iqaff.qc.ca (S. Delagrange), dbouffard@iqaff.qc.ca (D. Bouffard), pnolet@iqaff.qc.ca (P. Nolet).

[1] Tel.: +1 819 983 6589; fax: +1 819 983 6588.

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Houle, 1998) that are temporally and spatially dependent on disturbance events (McClure et al., 2000; Houle, 1998). Further, YB development is generally reported to be better on disturbed or mineral soils or on very specific microsites such as decayed snags or stumps, and on mounds (Tubbs and Oberg, 1966; Houle and Payette, 1990; Perala and Alm, 1990a; McGee and Birmingham, 1997). On the other hand, Kelty and Nyland (1981) observed abundant and well-distributed YB following shelterwood seed cutting preceded by herbicide mistblowing to control understory beech, but without deliberate surface disturbance.

Yellow birch is a prolific seeder (Erdmann, 1990; Houle, 1994), and the seeds are quite small. In contrast to sugar maple (*Acer saccharum*, Marsh.) or American beech (*Fagus grandifolia*, Erhr.), YB seedling roots do not readily penetrate the undecomposed leaf litter layer. Also, germination of YB seeds is highly dependent on soil temperature, humidity, and seedbed nutrient content (Godman and Krefting, 1960; Erdmann, 1990; Burton and Bazzaz, 1991; Houle, 1992,1998; Carlton and Bazzaz, 1998).

Although the regeneration ecology of YB has received considerable attention, this knowledge has not been fully integrated into a comprehensive silvicultural system. Current silvicultural practices in Quebec include soil scarification after harvest as a means to increase favorable seedbeds, and therefore enhance YB establishment and development (Linteau, 1948; Godman and Krefting, 1960; Hatcher, 1966; Erdmann, 1990; Perala and Alm, 1990a). When coupled with large openings in the canopy, this practice considerably changes the overall environment for the developing seedlings. It exposes the mineral soil, enhancing YB seed germination and establishment. Yet it also changes the abiotic conditions from that found in natural, unmanaged, stands. Soil scarification exposes increased proportions of mineral soil across the forest floor while also removing or greatly disturbing the pre-established vegetation. Yet if in direct sunlight, those mineral seedbeds will more readily dry out and become unsuitable microsites. Under such conditions, mixed organic and mineral soils have a better potential for water retention and may provide a better environment for the seedlings. Indeed, better growth has often been observed on mixed substrates than on mineral soils (Tubbs and Oberg, 1966; Houle and Payette, 1990).

Soil scarification does not create a single and homogenous kind of seedbed. Rather it leaves a combination of seedbed types, including mineral soil, mixed organic and mineral soil, mixed organic layers, and scattered decayed wood (Nolet and Poirier, 2001). Yet, this complex mosaic of microsites and its importance on treatment success have never been considered in tests of site preparation treatments. Scarification operations using rakes also remove the established understory vegetation composed of species adapted to understory conditions. Yet when intensive soil scarification is combined with heavy overstory cutting, the treatment may also enhance the establishment of opportunistic and aggressive species such as raspberry and pin cherry that may interfere with YB development and survival (Marks, 1974; Heitzman and Nyland, 1994; Donoso and Nyland, 2006; Nyland et al., 2007). Altogether, there are advantages and downsides to intensive soil scarification. By increasing favorable seedbeds, the treatment creates an environment in which conditions are qualitatively different from those found in unmanaged forests. Conversely, less intensive site preparation treatments may minimize the undesirable effects and create conditions more optimal for YB.

To compare these alternatives, we created large gaps in yellow birch-balsam fir dominated stands by removing all trees, thus increasing light availability compared to partial cutting, and then applied three site preparation treatments of varying severity. By creating a continuum of disturbance severities in the gaps, the treatments also contributed to a range of intensities of removal of established understory vegetation.

To assess and understand the effects of the site preparation treatments, we made observations at both the seedbed and the gap scales. Specifically, for each treatment we estimated the proportions of different substrates, reported favorable or not to YB establishment and we measured the initial establishment success on these seedbed types. We then followed for 3 consecutive years the establishment of YB seedlings on 5 of the most commonly occurring or the most favorable seedbeds for YB germination. We also observed the survivorship and growth of first cohort seedlings on the 3 seedbeds on which YB established best or showed better initial survivorship. We also identified and quantified the dominant interfering species in the immediate vicinity of the seedlings that we followed.

2. Material and methods

2.1. Study site and site preparation treatment

The study area is located in the southern part of the 'Lac Laverdière' landscape unit (Robitaille and Saucier, 1998), about 62 km north of the town of Saint-Michel-des-Saints (47°01′N, 74°20′W, Québec, Canada). In this landscape, stands are dominated by balsam fir (A*bies balsamea* (L.) Mill.) and/or by yellow birch. Deep till soils cover more than half of the total area (Robitaille and Saucier, 1998). Mean elevation is about 520 m. Drainage is relatively good as a result of gentle slopes, moderate rock content and the sandy loam texture of soils. Mean annual temperature is 2.5 °C and precipitation averages 1050 mm/year. The length of the growing season generally ranges between 160 and 170 days. The specific stands selected for this study were dominated by 70-year old yellow birch (YB). The study site is about 1 Km by 0.5 Km in size, and located on a gentle slope varying in aspect from southwest to southeast.

During the fall of 2000, a series of square 900 m^2 gaps (30 m of edge on a side) were created, leaving ca. 100 m of undisturbed forest between the gaps. There was an abundance of seed source around the gaps, and seed supply was not considered a limiting factor. Eighteen gaps were randomly selected for the application of three site preparation treatments, with 6 gaps per treatment. Two of the treatments involved pushing all slash to the edges of the gap with a skidder, followed by raking or not (a single one pass of a 2.75 m rake with 55 cm tines spaced 60 cm apart). These treatments are referred to as