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SHORT COMMUNICATION

The Role of Microsite Conditions in Restoring Trembling Aspen (*Populus tremuloides* Michx) from Seed

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Abstract

Encouraging natural regeneration of *Populus tremuloides* Michx (trembling aspen) from seed is a largely unexplored means for reintroducing the species into reclamation areas. We evaluated the effects of microsite (surface contour and substrate type) on aspen seedling establishment and growth on a reclaimed coal mine. The 4.6 ha study site was divided into six 48 m-wide strips that had 15 or 40 cm capping material salvaged from a nearby forest floor added to the mine surface. We surveyed 126 m long transects located in the center of each strip for microsite conditions, and the presence and height of aspen seedlings. We found that aspen seedlings generally preferred mineral-organic substrates and concave microsites. To facilitate the regeneration of aspen by seed, we suggest that land managers increase small-scale roughness and microtopographic diversity on reclaimed sites.

Key words: **microtopography, natural regeneration, organic material, seedling establishment, substrate.**

Introduction

Current land-use practices require resource managers to restore areas with locally available sources of plant material, such as seed banks and vegetation that naturally regenerates. Facilitating natural regeneration of aspen (*Populus tremuloides* Michx.) from seed is a largely unexplored means for reintroducing this widely distributed tree species into areas where disturbance has prevented its vegetative regeneration through root suckering. The paucity of information on natural aspen regeneration is critical for two reasons. First, silvicultural and restoration practices have likely neglected strategies to regenerate aspen from seed because of the assumption that asexual reproduction accounts for nearly all aspen establishment (Long & Mock 2012). In fact, sexual reproduction plays an important role in the establishment of aspen stands, especially after severe surface disturbance (Elliott & Baker 2004; Romme et al. 2005; Landhäusser et al. 2010; Long & Mock 2012). Second, global disturbances from mining affect an estimated 400,000 km^2 of which a significant area falls on landscapes occupied by *P. tremuloides* in North America and *Populus tremula* L in Eurasia (Hooke & Martín-Duque 2012). The overlap between such extensive disturbance and the range of widespread species such as *P. tremuloides* and *P. tremula* necessitates tree regeneration procedures outside the scope of traditional forestry including a focus on the role of sexual reproduction in regenerating species of *Populus*. While aspen seedlings are increasingly planted on disturbed sites, direct seeding of aspen is not a common practice (McDonough 1979; Shepperd 2001).

Bare mineral soil has traditionally been considered a necessity for aspen establishment from seed but newer research indicates that organic matter can be an equally effective substrate for germination and establishment. The presence of organic matter, either in a mixture with mineral soil or as a shallow layer of organic soil, has been found to promote growth of aspen seedlings established by seed in both field and greenhouse experiments (Romme et al. 2005; Landhäusser et al. 2010; Wolken et al. 2010; Pinno et al. 2012). Therefore, by better understanding microsite preferences of aspen, land managers can manipulate conditions to increase the probability of establishing a new, genetically diverse cohort of aspen. The objective of our study is to evaluate the effects of microsite (surface contour and substrate) on aspen seedling establishment and growth.

Methods

Our study site is a 4.6 ha reclamation area located within the Dry Mixedwood Natural Subregion of the boreal forest, about 60 km west-southwest (WSW) of Edmonton, Alberta, Canada

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(53°19′N, 114°18′W). The site is part of an operational coal mining lease that actively implements progressive reclamation practices. Prior to mining, the area was a mosaic of aspen forests and agricultural land. The selected reclamation site was capped in February 2010 with a directly placed, salvaged Dark Gray Luvisol, which included the organic forest floor material (L, F, and H horizons 7 cm deep). For this study, forest soil was salvaged and placed at the same two depths, and leveled to site specification with D-10 Caterpillar bulldozers. In April 2010, physical site preparation had been completed resulting in a severely disturbed reclamation site devoid of any vegetation. The site was divided into three replicate blocks, each containing two 48 m-wide × 126 m-long strips: one capped with 15 cm capping material (SHALLOW) and the other capped with 40 cm of capping material (DEEP). We studied the establishment and growth of wind-dispersed aspen seeds that germinated on the site. A mature aspen forest (10 ha) from which dispersal was presumed to occur was located 500 m southeast of the study site. In 2010, the region received 132 mm of rain during May, the seed germination period (10-year average: 72 mm) and the 10 year average growing season (April to September) temperature was 11.9°C (Environment Canada 2013). In late August, 2010, we surveyed each block along transects centered in each strip. Along each transect, we evaluated microsite characteristics every 20 cm for a total of 630 point observations per transect. To characterize microsites where aspen seedlings were present, we used a 2.5 m wide belt transect centered on each strip. We measured all seedling heights and described the conditions of each microsite for aspen seedlings that occurred within the 2.5 m belt transect. Microsite characteristics were evaluated at a scale of 10 cm^2 surrounding each sampling point or aspen seedling and classified according to surface contour (flat, sloped, concave, or convex) and substrate type (mineral, mixed mineral and organic, or organic).

For both surface contour and substrate, we tested whether the distribution of occupied microsites was equivalent to the availability of microsites with separate chi-square tests for each soil placement depth, SHALLOW (15 cm) and DEEP (40 cm) treatment. We used an analysis of variance (ANOVA) to test for differences in seedling height by microsite for each placement depth ($\alpha = 0.05$). All analyses were performed in IBM SPSS Statistics version 20 (IBM Corp., Released 2011, IBM SPSS Statistics for Windows, Version 20.0, Armonk, NY, U.S.A.).

Results

Flat surfaces were the most common available microsites (72%) followed by sloped, concave, and convex (13, 10, and 5%, respectively) in the SHALLOW treatment (15 cm). A similar ranking of microsites occurred in the DEEP treatment (40 cm). The proportion of microsites occupied by aspen seedlings differed from their availability for both depth treatments (Table 1). In the SHALLOW treatment, aspen seedlings were overrepresented in concave and sloped microsites ($\chi^2 = 89.25$, degrees of freedom [df] = 3, $p = <0.001$). In the DEEP treatment, aspen were not only overrepresented in concave and convex microsites ($\chi^2 = 7.086$, $df = 3$, $p = <0.001$) but also occupied many flat microsites. Across both depth treatments, mean aspen height was 2.57 ± 2.33 cm (SD). Aspen height was the same across microsites in the SHALLOW treatment ($p = 0.342$), but differed for the DEEP treatment ($p < 0.001$; Fig. 1). Although aspen seedlings preferentially established on both concave and convex microsites in the DEEP treatment, trends in height did not parallel presence; aspen were significantly taller in convex than concave microsites.

Table 1. Observed and expected (based on χ^2 test) proportion of aspen seedlings across microsites characterized by surface contour at SHALLOW (15 cm) and DEEP (40 cm) depth treatments.

	SHALLOW		*DEEP*	
Topography	*Observed*	*Expected*	*Observed*	*Expected*
Flat	156	215	521	557
Sloped	64	38	44	75
Concave	70	31	97	51
Convex	10	16	52	31

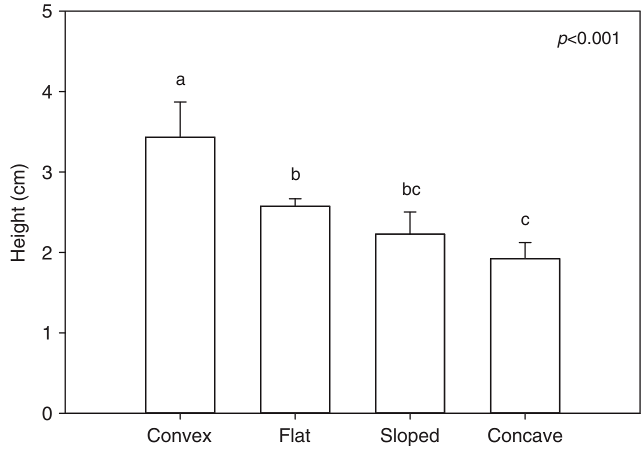

Figure 1. Mean height (±1 SE) of aspen growing in concave, flat, convex, and sloped microsites on DEEP (40 cm) depth treatments. Letters above bars denote significantly different means ($\alpha = 0.05$, $n = 3$).

Microsites with mixed mineral and organic (mineral-organic) substrates were most commonly (67%) followed by pure mineral (33%) and pure organic (<1%) substrates in the SHALLOW treatment. Pure mineral was the most common (57%) substrate followed by mineral-organic (42%) in the DEEP treatment. The proportion of occupied microsites differed from their availability for both depth treatments (Table 2); aspen were overrepresented in mineral-organic and underrepresented in mineral substrates (SHALLOW: $\chi^2 = 171.5$, $df = 2$, $p = <0.001$; DEEP: $\chi^2 = 166.9$, $df = 1$, $p = <0.001$); however, seedling height did not differ among substrates in both depth treatments (minimum $p = 0.44$).

Table 2. Observed and expected (based on χ^2 test) proportion of aspen seedlings across microsites characterized by substrate at SHALLOW (15 cm) and DEEP (40 cm) depth treatments.

	SHALLOW		DEEP	
Substrate	*Observed*	*Expected*	*Observed*	*Expected*
Mineral	98	203	414	557
Mineral-organic	201	95	300	157
Organic	1	2	0	-

Discussion

Establishment of aspen seedlings showed pronounced microsite preference; seedlings were overrepresented in concave microsites and mineral-organic substrates across both treatment depths. Both microsite characteristics may be related to reliable soil moisture availability which is an important factor in the germination and growth of aspen (Perala 1990). Seedling establishment was underrepresented on flat and mineral microsites, although more so in SHALLOW than DEEP treatments. This difference in establishment may be due to the presence of deeper soils in DEEP treatment acting to buffer against variation in soil moisture. Although establishment was low on convex microsites in the DEEP treatment, we observed that seedlings in these sites grew tallest. Convex microsites were elevated by 2–4 cm, the average height of an aspen seedling. These elevated microsites may have experienced higher light availability than concave microsites. In addition to differences in light availability, intraspecific competition (Romme et al. 2005) may also have played a role in seedling mortality in concave microsites. Two to ten aspen seedlings were often found occupying the same 10 cm^2; such high seedling densities may have limited the growth of individual seedlings on these microsites. The same overall trends were not observed in SHALLOW treatment where the higher organic soil concentration likely provided more soil nutrients and greater vegetative competition thereby, reducing the effects of microtopography on seedling height.

Across its range, aspen regeneration faces a variety of challenges such as industrial mining and drought-induced sudden aspen dieback (Long & Mock 2012). Approximately 8% of Canada's land area was staked by prospecting claims in good standing in 2008, demonstrating the extent to which mining could shape North American forests and the need for a variety of reclamation techniques to restore disturbed areas to self-sustaining forests (Bouchard 2009). An understanding of the microsite preferences for bottomland hardwood trees has already successfully influenced reclamation practices in such ecosystems (Simmons et al. 2012) and our findings on aspen microsite preferences can be similarly applied to upland reclamation sites. Additionally, the findings of this study might also be applicable to other species with long-distance wind-dispersed seeds, especially the closely related *Populus tremula*. Microtopographic diversity and the inclusion of organic matter in restoration substrate material have the potential to facilitate the establishment of aspen and other *Populus* species on heavily disturbed areas.

Implications for Practice

- Knowing the prevailing wind direction and the distance to the nearest seed source is essential in promoting natural tree establishment of wind-dispersed tree species.
- Increased surface roughness and microtopographical diversity of the capping surface is essential in order to encourage natural regeneration of wind-dispersed tree species.
- An organic amendment to mineral capping materials should increase aspen establishment success.

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