79 Extension Note

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Assessing the Effects of Sitka Alder on the Growth and Foliar Nutrition of Young Lodgepole Pine in Central British Columbia (SBSdw3): 9-year Results

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Abstract

The 9-year post-treatment effects of different levels of Sitka alder (*Alnus viridis* ssp. *sinuata* [Regel] Á. Löve & D. Löve) retention (0, 500, 1000, 2000 clumps per hectare) on the development of retained alder and on the growth and foliar nutrition of young, naturally regenerated lodgepole pine (*Pinus contorta* Dougl. var. *latifolia* Engelm.) were evaluated in the Sub-Boreal Spruce biogeoclimatic zone in central British Columbia. Alder development was inversely related to alder retention density, with the largest height and crown width increments occurring at the lowest alder densities. Low to moderate levels of alder cover (<35%) did not significantly inhibit the diameter at breast height (dbh) or height growth of lodgepole pine. Over the 9-year response period, pine dbh and height increments in the high alder retention treatment were both reduced by 11% (9 mm and 42 cm, respectively) relative to the no alder retention treatment. However, the average height of lodgepole pine, and the average height difference between the pine and alder, exceeded free-growing guidelines for the SBSdw3 in all of the alder retention densities 6 years following treatment. Our results indicate that brushing on submesic to mesic sites in the SBSdw3 is likely unnecessary unless Sitka alder is taller than regenerating lodgepole pine and alder percent cover is uniformly very high (>40–50%) at early stages of pine development. The presence of Sitka alder improved the foliar nitrogen (N) concentration of young lodgepole pine growing on this site. However, the facilitative effects of alder retention on pine foliar N status were partially offset by an imbalance of foliar N relative to other nutrients (especially sulphur, S). Deficiencies of S (and possibly phosphorus, P, and potassium, K) induced by high foliar N levels may partially explain the smaller dbh and height growth of lodgepole pine in the alder retention treatments at this site.

Introduction

Sitka alder (*Alnus viridis* ssp. *sinuata* [Regel] Á. Löve & D. Löve) is a moderately shade-tolerant shrub that frequently occurs in the understorey of mature lodgepole pine (*Pinus contorta* Doug. var. *latifolia* Engelm.) forests in the interior of British Columbia (Haeussler et al. 1990). Established

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alder clumps often respond vigorously following harvest and can reach 3–4 m in height and 30–50% in cover at full maturity (Boateng and Comeau 1997).

Brushing treatments are often undertaken on mesic and wetter sites to reduce competition for light and soil resources and to minimize physical damage caused by whipping and snowpress. However, as an N-fixing species, Sitka alder's potentially important facilitative effects on long-term site productivity through N accretion, litterfall, and litter decomposition need to be considered when evaluating the significance of short-term competitive interactions with pine. The competitive effects of Sitka alder on crop trees may often be counterbalanced by the benefits of N accretion and other facilitative effects of broadleaved species (e.g., microclimate amelioration, protection from herbivores and pathogens) on conifer regeneration (Simard et al. 2006). Increased N availability due to fixation of atmospheric N may be particularly beneficial in interior lodgepole forests, where widespread N deficiencies and improved growth following fertilization with N and other nutrients have been well documented (Brockley 1996, 2005).

For the extensive Sub-Boreal Spruce (SBS) biogeoclimatic zone (DeLong et al. 1993), clear guidance is lacking on where the balance of advantage lies: at what Sitka alder density are the likely facilitative effects of N addition offset by competition with crop trees for light and soil resources? Also, does the balance between competition and facilitation change over time?

Selectively removing or retaining established alder clumps in young plantations or naturally regenerated stands is one approach to the study of lodgepole pine–Sitka alder interactions. Most Sitka alder cover in young lodgepole pine stands in the SBS zone appears to originate from resprouted clumps inherited from the previous mature stands. Therefore, using this approach should produce stand conditions that are similar to those in managed forests throughout the region.

A long-term field experiment was established in 1995 to study the effects of differing levels of Sitka alder retention (0, 500, 1000, 2000 clumps per hectare) on the growth and foliar nutrition of young (~ 7-year-old), naturally regenerated lodgepole pine. The 6-year post-treatment results of this study were reported by Brockley and Sanborn (2003). This Extension Note presents the 9-year results.

Methods

The study site is located on a submesic site approximately 55 km southwest of Prince George within the Stuart Dry Warm variant of the SBS zone (SBSdw3/04) (DeLong et al. 1993). The site was harvested in 1987 and subsequently naturally regenerated to a mixture of lodgepole pine and Sitka alder. Virtually all of the alder at this site had regenerated from clumps held over from the previous mature stand. At the time of trial establishment, the heights of pine trees and Sitka alder clumps averaged about 1.5 m and 1.8 m, respectively. The density of lodgepole pine was about 10 500 stems per hectare, while the alder density averaged 4100 clumps per hectare, representing a mean alder cover of 51% (Sanborn et al. 2001).

Four treatments were tested: (1) pine + no alder (i.e., complete eradication of alder clumps); (2) pine + low alder (500 clumps per hectare retained); (3) pine + moderate alder (1000 clumps per hectare retained); (4) pine + high alder (2000 clumps per hectare retained). A total of twelve 0.08-ha rectangular treatment plots were established in May 1995. Each of the four treatments was randomly assigned to three of the treatment plots.

The lodgepole pine in each treatment plot was manually thinned to a uniform density of 1000 stems per hectare. This post-thinning density is considerably lower than most operational prescriptions for young lodgepole pine. However, the objective was to delay crown closure so that a vigorous Sitka alder understorey would be maintained for a prolonged period.

The 500, 1000, and 2000 clumps per hectare alder retention regimes were created by selecting alder "leave" clumps based on a grid pattern dictated by the alder retention density. All other clumps within each treatment plot were cut near ground level, followed immediately with an application of glyphosate (trade name Vision®) to the cut stumps (1 part herbicide : 2 parts water). A follow-up glyphosate treatment was carried out in 1996 to control resprouting of alder stumps. These treatments achieved at least 95% mortality of the cut alder clumps. In subsequent years, manual clipping was undertaken as needed to ensure complete control of the target alder clumps.

A square, 0.036-ha assessment plot was established within each rectangular treatment plot to monitor the growth and development of retained pine and alder clumps. Each assessment plot had 36 tagged lodgepole pine trees and a number of alder clumps proportional to the specified alder retention density (i.e., 18, 36, and 78 clumps for the 500, 1000, and 2000 alders per hectare densities, respectively). The total height of tagged pine and alder, the diameter at breast height (dbh) of pine, and the crown width of alder clumps were measured in October 1995. These measurements were repeated in the fall of 1998 (3rd year), 2001 (6th year), and 2004 (9th year). The straightened length of the tallest stem within each clump was used as the height measurement for Sitka alder. The initial, 3-, 6-, and 9-year dbh and height measurements were used to calculate dbh and height increments for each of the three measurement periods.

Pre-treatment alder percent cover was assessed using the line-intercept method, for which transects were located along the four sides and two diagonals of each assessment plot. Alder percent cover was based on the tally of points, at 1-m intervals along each transect, which fell beneath alder canopies. The same transects were used to re-assess alder cover in years 1, 3, 6, and 9.

Using standardized foliar sampling guidelines (Brockley 2001), replicated samples of current-year foliage were collected from 10 lodgepole pine trees in each treatment plot in the fall of 1995 (year 0) and after years 3, 6, and 9. For each sampling date, one composite sample per treatment plot, consisting of equal amounts of oven-dried foliage from each of the 10 sample trees, was prepared for nutrient analysis.

The effects of Sitka alder retention density on the 1- to 9-year height increment of alder, and on the 9-year height and dbh increments of lodgepole pine, were subjected to analysis of covariance (ANCOVA), using initial height and dbh as the covariates. The Bonferroni correction was used to adjust the *p* values of the least-square means for multiple comparisons of height and dbh treatment means.

Foliar nutrient data for individual nutrients and nutrient concentration ratios were subjected to analysis of variance (ANOVA). Unadjusted treatment means were compared using Duncan's multiple range test.

Orthogonal polynomial contrasts were used to test the linear and quadratic trends among the various growth and nutrient treatment means. A level of significance of $\alpha = 0.05$ is used for inferring statistical significance.

Results

Sitka alder growth

The pre-treatment percent cover of Sitka alder was similar in all alder retention treatments (49–53%). One year after treatment, alder percent cover was reduced to 10, 20, and 38% for the low (500 clumps per hectare), moderate (1000 clumps per hectare), and high (2000 clumps per hectare) alder retention treatments, respectively. Thereafter, the percent cover increased steadily and consistently in all treatments through year 6, and then declined slightly in year 9 (Figure 1a). The crown width development of retained alder clumps was inversely related to alder retention density, with the largest crown width, and 9-year crown width increment, measured at the lowest alder retention density (Figure 1b). Crown width declined slightly in the 7- to 9-year measurement period.

Alder retention density had a significant effect on 1- to 9-year alder height increment ($p < 0.001$), which was inversely related to alder retention density. The significant linear effect ($p < 0.001$) is clearly illustrated in Figure 2. The height growth pattern of alder was similar in all treatments, with slow growth in the first measurement period and faster growth in the next two periods (Figure 2).

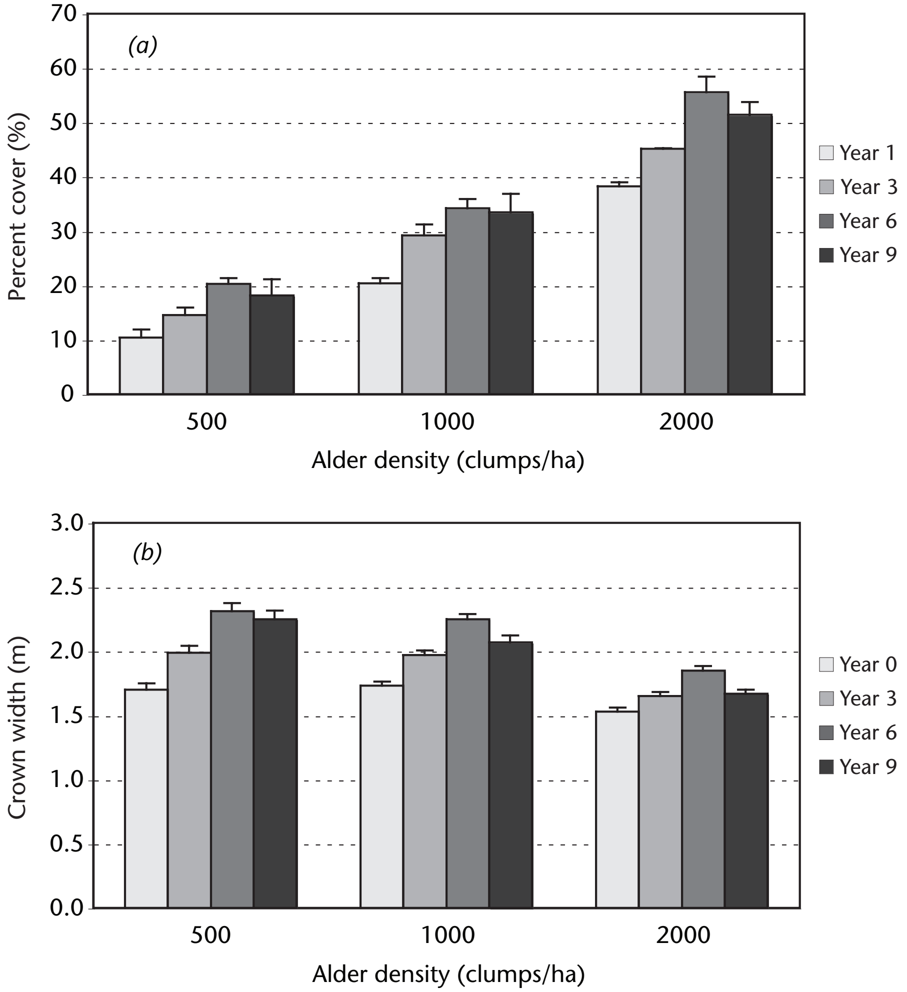

FIGURE 1 *(a) Percent cover and (b) crown width of Sitka alder by year and alder retention treatment. Error bars represent standard error.*

Lodgepole pine growth

When the treatments were applied in 1995, the lodgepole pine trees were shorter than the retained alder clumps in all alder density treatments (Figure 3). Three years later, however, pine had overtopped the retained alder in all treatments. By year 9, the height differential between pine and alder ranged from 2.2 m in the low alder retention treatment to 2.8 m in the high alder retention treatment.

Lodgepole pine dbh increment was significantly affected by Sitka alder retention density (p = 0.013). The effect of alder on 1- to 9-year dbh increment was significantly linear (p = 0.002), with less radial growth measured in the moderate and high alder retention densities than in the low alder and no alder treatments (Figure 4a). Over 9 years, the dbh increment in the high alder retention density was 11% (9 mm) less than in the no alder treatment. Differences in 9-year dbh increment between the low and moderate alder retention densities and the no alder retention treatment were not statistically significant (Figure 4a).

Lodgepole pine height increment was significantly affected by Sitka alder retention density (p = 0.029). The effect of alder on 1- to 9-year height increment of pine was significantly linear (p = 0.005), with progressively less height growth with increasing alder retention density (Figure 4b). Height increment of pine under high-density alder cover was 11% (42 cm) less than in the no alder retention treatment over 9 years. The negative effects of low and moderate alder retention densities on the 9-year height increment of lodgepole pine were smaller (9–24 cm) and were not statistically significant (Figure 4b).

The negative effect of high alder retention density on lodgepole pine dbh and height development was less pronounced in the 7- to 9-year measurement period than in the 4- to 6-year period (Figures 4a, b).

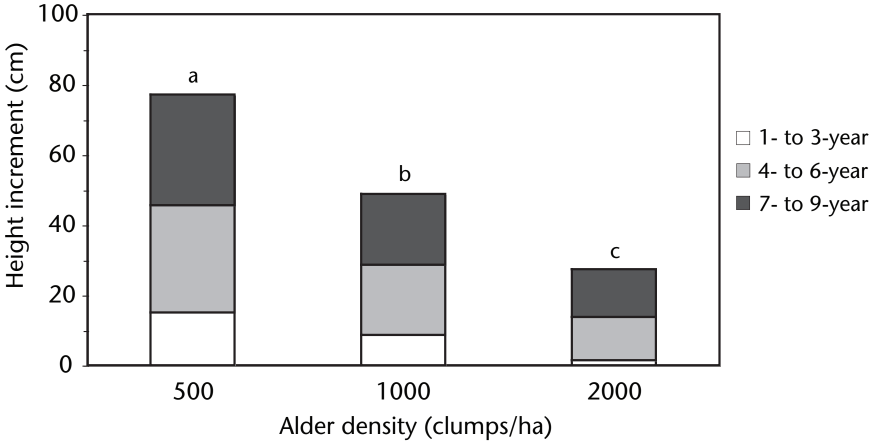

FIGURE 2 *Height increment of Sitka alder by year and alder retention treatment. Bars topped by different letters are significantly different (p < 0.05).*

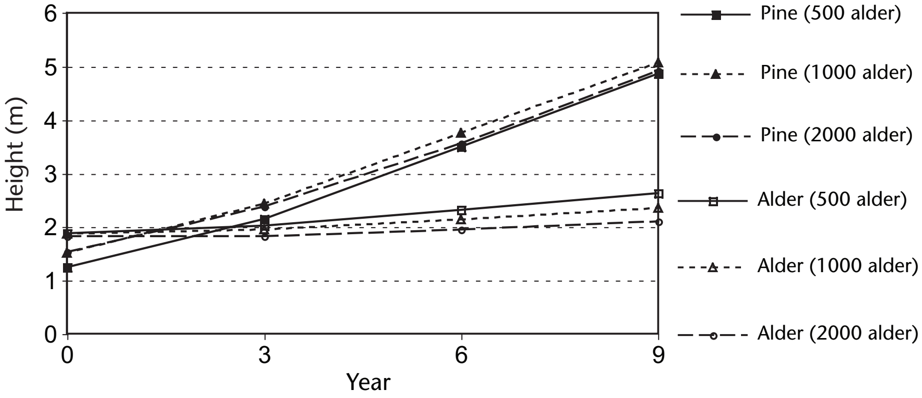

FIGURE 3 *Height development of lodgepole pine and Sitka alder at different alder retention densities (500, 1000, and 2000 alder clumps per hectare). For each year, plotted values are means of all measurements combined.*

Lodgepole pine foliar nutrition

Initial lodgepole pine foliar N levels were high in all treatments, averaging 16.5 g/kg for the fall 1995 sampling (Figure 5a). A significant treatment effect was evident by year 3 (p = 0.024), with pine in the no alder retention treatment having significantly lower foliar N levels than trees in the alder retention treatments (Figure 5a). The treatment effect persisted in year 6 (p = 0.004) and was clearly linear (p < 0.001), with the lowest N level occurring in the no alder retention treatment and the highest N level in the high alder retention treatment. Treatment effects were not statistically significant in year 9 (p = 0.413), due to improved foliar N status of trees in the no alder retention treatment (Figure 5a).

Beginning in year 3, and extending through year 9, pine foliar S levels in retained alder treatments were often lower than in the no alder treatment (Figure 5b). Foliar levels of other nutrients were relatively unaffected by treatment throughout the 9-year study period (data not shown).

Treatment effects were clearly evident in the balance of foliar N relative to several other nutrients. In years 3 and 6, there were statistically significant treatment effects on foliar N/P, N/K, and N/S, with lodgepole pine in all alder retention treatments having

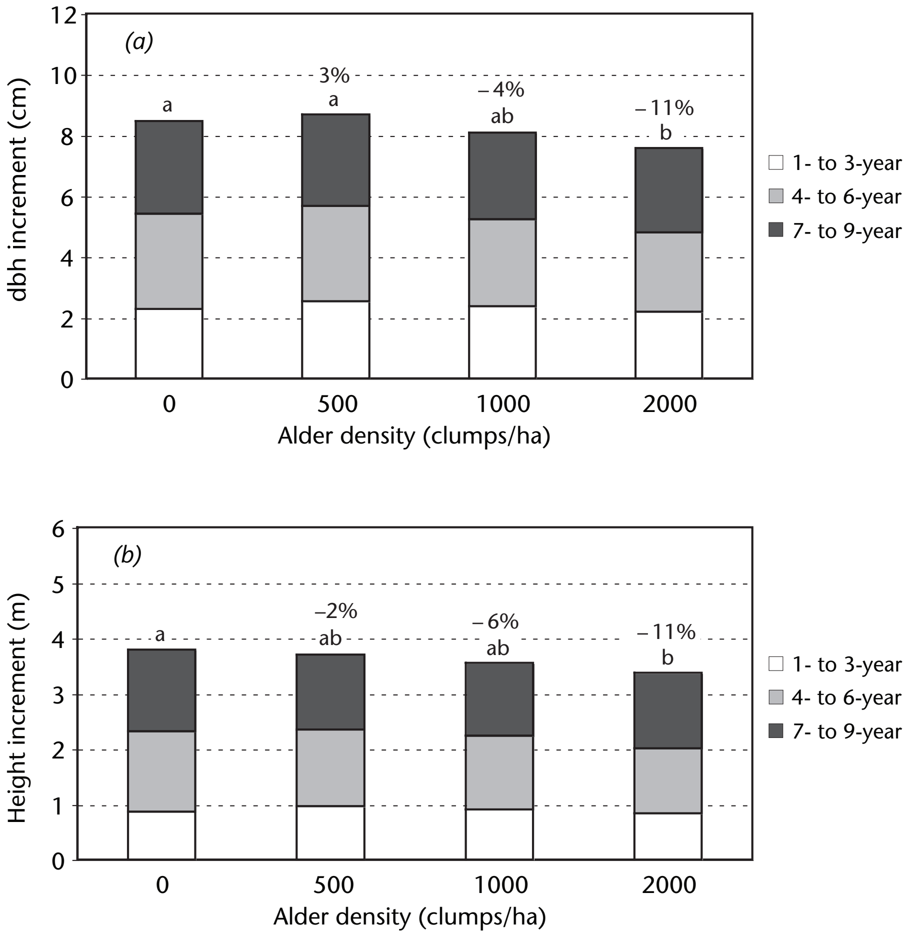

FIGURE 4 *(a) Diameter at breast height (dbh) increment and (b) height increment of lodgepole pine by measurement period and alder retention treatment. Numbers above bars indicate change relative to the no-alder treatment for the 1- to 9-year measurement period. Bars topped by different letters are significantly different (p < 0.05).*

higher ratios (nearing, or exceeding, P, K, and S deficiency thresholds) than trees in the no alder treatment (Figures 6a, b, c). The relationship between alder density and foliar N/S was strongly linear in years 3 and 6 (p < 0.001), with progressively higher ratios with increasing alder density (Figure 6c). Significant linear relationships between alder density and foliar N/P and N/K were also evident in years 3 and 6. Treatment effects on foliar N/S concentration ratio persisted in year 9, with significantly higher ratios in all alder retention treatments than in the no alder treatment (Figure 6c).

Summary and Management Implications

The Sitka alder at this site has exhibited vigorous growth during the 9-year study period. After 9 years, mean alder height across all alder retention densities was 2.24 m, with the tallest clumps, and largest absolute and relative height and crown width increments, being associated with the lowest alder density. Seventeen years after harvest, the retained clumps in all of the alder retention treatments continue to exhibit modest height growth. However, alder percent cover and crown width declined in all alder retention treatments during the 7- to 9-year measurement period, with the largest declines occurring in the highest alder retention density treatment. The decline may be associated with very dry soil conditions and the observed crown dieback of alder clumps in year 9. The vigour of alder crowns was visibly improved the next year. Nevertheless, the widening height differential between overtopping lodgepole pine and Sitka alder, and the reduced ability of alder to compete with pine for soil and light resources, will likely result in a gradual decline in Sitka alder vigour over time.

The 9-year results from this study indicate that low to moderate levels of alder cover (<35%) do not significantly inhibit the dbh or height growth of young lodgepole pine growing on submesic to mesic sites in the SBSdw3 subzone. Even at the highest alder retention density, dbh and height growth of pine trees were not significantly reduced until alder percent cover reached 45% (Brockley and Sanborn 2003). Over 9 years, the dbh and height growth of pine in the high alder retention treatment were reduced by 9 mm and 42 cm, respectively, compared with the growth of pine in the no alder treatment. However, the average height of lodgepole pine, and the average height difference between the pine and alder, exceeded free-growing guidelines for the SBSdw3 in all of the alder retention densities 6 years following treatment (B.C. Ministry of Forests 2000). Because we did not measure the growth of lodgepole pine in the untreated stand, where alder percent cover averaged about 50% at the beginning of the study, we are not certain that alder control was not needed at this SBS site. However, our results indicate that Sitka alder brushing on submesic to mesic sites in the SBSdw3 is likely unnecessary unless Sitka alder is taller than regenerating lodgepole pine and alder percent cover is uniformly very high (>40–50%) at early stages of pine development.

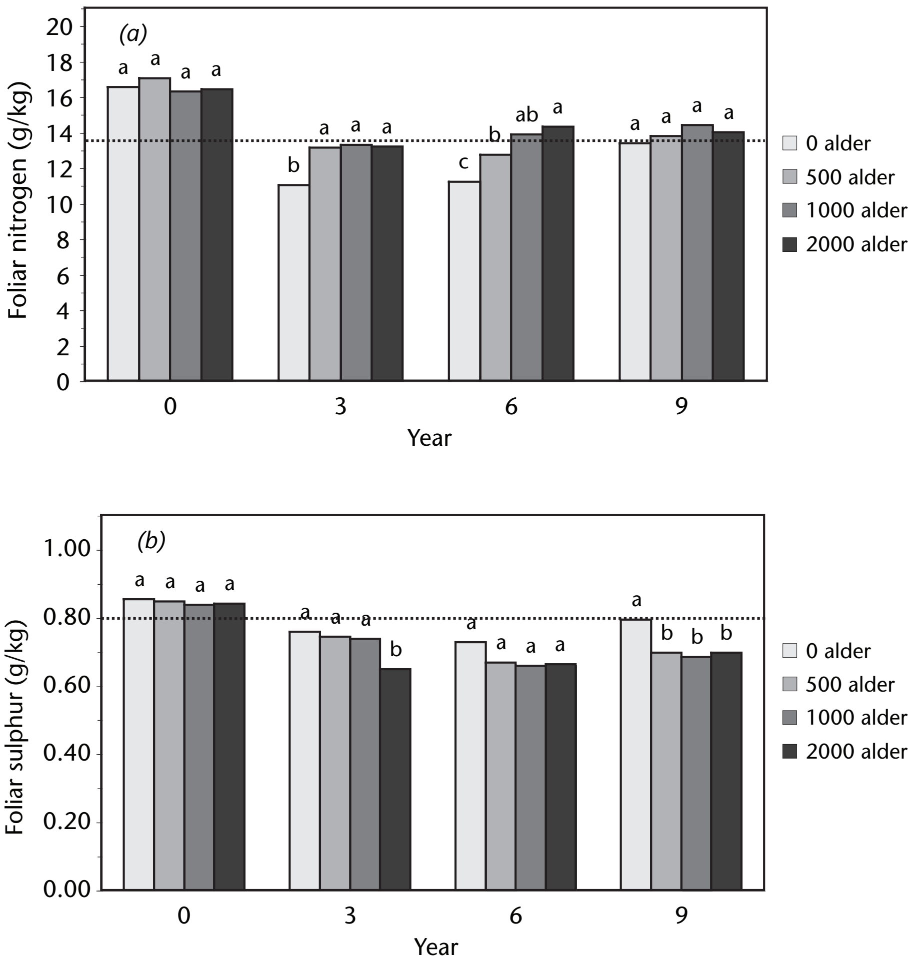

FIGURE 5 *(a) Foliar N concentration and (b) foliar S concentration in current-year foliage of lodgepole pine by alder retention treatment and year. Bars topped by different letters are significantly different ($p < 0.05$). Dotted horizontal lines represent "critical" levels below which a possible nutrient deficiency may occur (Brockley 2001).*

These results and conclusions are consistent with those reported for a pine–alder study in southern British Columbia (Simard et al. 2006).

The presence of Sitka alder has improved the foliar N status of the young lodgepole pine growing on this site. Measurements made over a 3-year period indicate that symbiotic N-fixation by alder in the 2000 clumps per hectare treatment is contributing 10–15 kg N/ha annually (Sanborn et al. 2002). Although this amount is small compared with a typical operational fertilizer application (200 kg N/ha), the cumulative N accretion over the entire period before canopy closure may largely offset typical N losses from wildfire and/or harvesting in these ecosystems. Since Sitka alder can persist as an understorey shrub throughout stand development, this N accretion will continue, though likely at a reduced rate. The dramatically lower soil N mineralization reported by Simard et al. (2006) 15 years after complete alder removal in another study further highlights the facilitative effects of Sitka alder N-fixation and nutrient cycling on soil N fertility and the potential long-term benefits of an alder understorey on tree growth and site productivity.

The facilitative effects of alder retention on lodgepole pine foliar N status in this study were partially offset by an imbalance of foliar N relative to other nutrients (especially S). Mineral horizons of soils in the interior of British Columbia have very low S concentrations (Kishchuk and Brockley 2002). Results from several interior fertilization studies indicate that N-deficient lodgepole pine may not respond favourably to N fertilization unless S is included in the fertilizer prescription (Sanborn and Brockley 2005). Induced S deficiencies (and possibly P and K deficiencies) caused by high foliar N levels may partially explain the smaller dbh and height growth of lodgepole pine in the alder retention treatments at this site.

We will continue to monitor this experiment so that the balance between competitive and facilitative effects of Sitka alder on lodgepole pine growth and foliar nutrition can be evaluated over the long term.

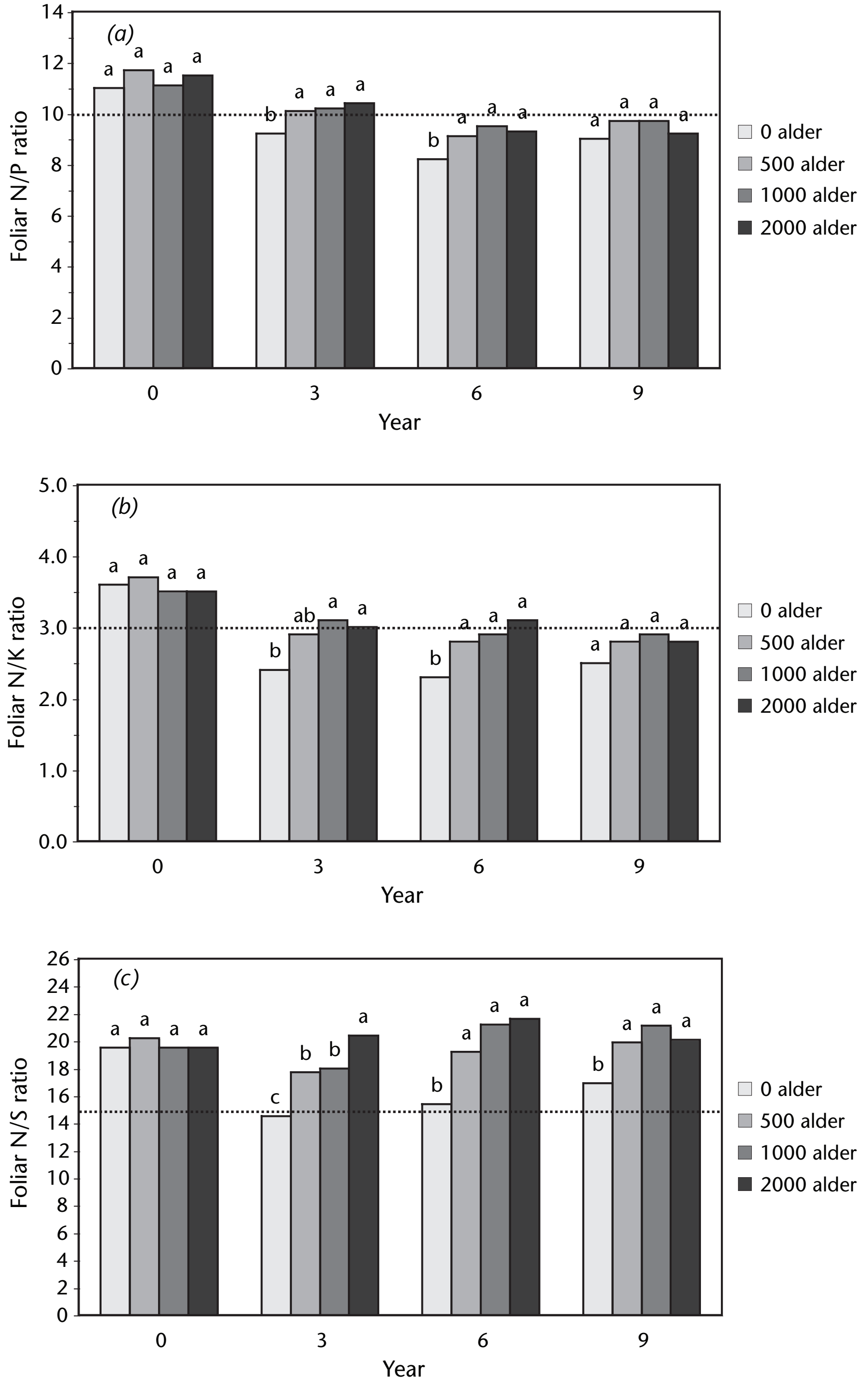

FIGURE 6 *Foliar (a) N/P ratio, (b) N/K ratio, and (c) N/S ratio in current-year foliage of lodgepole pine by alder retention treatment and year. Bars topped by different letters are significantly different ($p < 0.05$). Dotted horizontal lines represent "critical" levels above which probable nutrient imbalances (i.e., deficiency) relative to N are indicated (Brockley 2001).*

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Web Resources

Additional information on B.C. Ministry of Forests and Range stand management research, including project descriptions and links to additional publications, is available at: <http://www.for.gov.bc.ca/hre/standman/>.

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