Competitive Effects on Plantation White Spruce Saplings from Shrubs That Are Important Browse for Moose

Scott D. Posner and Peter A. Jordan

ABSTRACT. Conifer planting is often accompanied by herbicide control of surrounding broadleaf, woody plants that may interfere with conifer growth, a process that releases conifers from competitive suppression. Because potential competitors often provide browse for wildlife, their removal may conflict with objectives in multiple-resource management. While some agencies, such as the USDA Forest Service (USFS), have greatly reduced herbicide use, many other timber producers still rely on chemicals to release conifers from competing vegetation. In northeastern Minnesota, where moose (Alces alces) are a highly valued resource, we studied impacts of broadleaf shrubs on 4- to 16-yr-old white spruce (Picea glauca) along with the extent of browsing by moose on these shrubs. Height, diameter, and current vertical growth increment of spruce were compared among four levels of presence (density strata) of shrubs immediately surrounding each sapling. Spruce grew as well or better in the low and medium density strata as in the no-shrub stratum. In the high density stratum, height and growth increment, particularly in 10- to 16-yr-old spruce, appeared reduced. Presence of shrubs seemed to reduce frost damage in young spruce. Moose browsing reduced height of most shrub species, suggesting that these animals provide a release effect on adjacent spruce. We recommend a release strategy that avoids reduction of shrubs beyond the level that assures normal growth in young spruce, so as both to minimize loss of browse for wildlife and avoid unnecessary silvicultural costs. For. Sci. 48(2):283–289.

Key Words: Conifer-release, browsing impacts, frost damage, multiple-resource management, silvicultural costs.

FOREST MANAGERS are often required to accommodate strategies for optimizing efficiency of timber production with those for meeting habitat needs of wildlife. A case in point is the control of broadleaf, woody shrubs and saplings—collectively referred to here as shrubs—in conifer plantations. These shrubs can suppress growth in small conifers; however, at the same time, they provide potential forage or browse for large herbivores such as moose and deer as well as producing fruits and nuts for a variety of other wildlife (Lautenschlager 1993a, 1993b). Shrubs are commonly reduced or eliminated with herbicides or hand-cutting, a process referred to as “release” or “release treatment” when the intent is to reduce competitive effects on nearby young conifers. If one can determine the minimum amount of shrub reduction necessary to promote normal growth in young conifers, then release treatments can be designed to enhance timber production while at the same time minimizing loss of food resources for wildlife. This strategy also offers the economic advantage of expending no more on release treat-
ments than is needed to realize the potential timber productivity of a site.

Moose are associated with northern forests, their forage comprising primarily woody plants. Closed-canopy forests provide relatively little browse for these animals, while recently disturbed clearings generally offer an abundance of readily available forage (Telfer 1967, Peek et al. 1976, Peek 1998). In eastern North America, browse is also a major dietary component for white-tailed deer (Odocoileus virginianus), although not to the same extent as in moose. In northern hardwood and boreal forests, the majority of shrub species targeted for release treatments in conifer plantations are important forages for moose and deer, in both summer and winter. Moose, through their browsing, can serve as a silvicultural aid by suppressing potentially competitive hardwood shrubs in conifer plantations, while seldom browsing the young conifers, particularly spruce (Bedard et al. 1978). In some regions, however, high densities of moose in winter can threaten saplings of some conifers, e.g., balsam fir (Abies balsamea) in eastern North America (Brandner et al. 1990) or Scots pine (Pinus silvestris) in Scandinavia (Lavlund 1987).

Competition from surrounding vegetation can reduce growth in conifers, the impact of which varies with the species, growth form, and density of competitors, and with the age of the young conifers (Eis 1981, Lautenschlager 1995). At the same time, it is recognized that, in some cases, shrubs at moderate densities and heights actually serve to increase growth and survival in young spruce (Shirley 1945, Rudolf 1950, Logan 1969). Also, Nienstaedt and Jeffers (1976) showed that frost damage to new leaders of spruce was greater in the absence of surrounding shrubs than with some shrubs present.

When release is judged necessary for young white spruce, shrubs are killed or suppressed by mechanical or chemical treatments. Our study was on the Superior National Forest in Minnesota, where aerial spraying of pesticides has not been practiced since 1981; however, within that state and adjacent northwestern Ontario, limited use of herbicides continues on state, provincial, county, and private lands and on some state-managed portions of national forests. Release treatments on national forests are now more commonly accomplished by hand-clipping shrubs. Otherwise, the primary use of chemicals within the Superior and Chippewa National Forests of Minnesota is for control of noxious, exotic herbs.

Release management in plantations on the Superior National Forest had entailed making semiquantitative, visual estimates of vegetation surrounding young conifers, then relating these estimates to a specified threshold level of such vegetation, above which release was prescribed (USFS 1980). However, there has been little quantitative study of the relationship between growth in young spruce and the combined density, height, and nearness of surrounding shrubs.

Also, there is a need for continuing study to determine the type of treatment and the exact circumstances under which treatments must be applied in order to ensure appropriate growth in young conifers while protecting browse resources for wildlife. Our study was part of an analysis of timber-moose interactions, conducted cooperatively between the University of Minnesota and the Superior National Forest (Posner 1984, Jordan et al. 1988). The work reported here was designed to identify the point at which increasing levels of surrounding shrubs lead to decreased growth in young spruce. In addition, we measured browse removals by moose on potentially competitive shrubs to test whether this effect might be reducing shrub competition for young conifers.

Study Area

The study was conducted during summer 1983 on three spruce plantations in the Tofte Ranger District of the Superior National Forest, Cook County, Minnesota (47° N lat., 450–500 m elev.). Soils at the three sites were classified as Typic Dystrochrepts (USFS unpubl.), with textures ranging from fine sandy loam to silt loam at the surface and consistently more coarse below.

Vegetation is detailed for this region by Peek et al. (1976) in a study of moose-plant relationships. Dominant upland trees included quaking aspen (Populus tremuloides), balsam fir, paper birch (Betula papyrifera), and white spruce. Aspen and birch are used by deer and moose year round, fir is moderately preferred by moose in winter, and spruce is not used by moose and only occasionally by deer in winter. Less common deciduous trees included pin-cherry (Prunus pensylvanica), balsam poplar (Populus balsamifera), mountain ash (Sorbus spp.), and red maple (Acer rubrum) all of which, in the seedling-sapling stage, are preferred browse. Preferred browse understory shrubs included beaked hazelnut (Corylus cornuta), chokecherry (Prunus virginiana), willows (Salix spp.), red-osier dogwood (Cornus sericea), juneberry (Amelanchier spp.), and mountain maple (Acer spicatum). Two common shrubs in the plantations that are little used by moose were speckled alder (Alnus incana) and American red raspberry (Rubus idaeus).

Moose were moderately abundant in both summer and winter. Winter aerial-counts by the Minnesota Department of Natural Resources showed densities of 0.36–0.46/km² for the study region. A local aerial survey of moose tracks in snow during the winter before this study indicated that animals were somewhat more abundant in our three study stands than for the region as a whole (G. Weil, Univ. of Minn., pers. comm.).

The study stands were 10–14 km inland from Lake Superior, and were all within 20 km of each other. One stand was on a 5–10% south-facing slope, one was on a 0–5% northeast slope, and the third was essentially flat. After having been clearcut, each stand had been prepared for planting by mechanical scarification. Stand 1 was rock-raked in 1971 and planted the following year; Stand 2 was barrel-scarified in 1973 and planted the following year; and Stand 3 was brush-chopped and planted in 1969, then treated with an aerial application of 2,4-D in 1976.

A few widely spaced mature spruce and hardwoods were left in each stand. Also, naturally regenerated conifers were common in these plantations, leading to a diversity of ages among young white spruce. Height and density of shrubs were also quite variable.
Methods

We examined the influence of surrounding shrubs on the growth and size of young spruce in an analysis designed to control for other potential influences. Field measurements started on August 25, after spruce buds had set, and ran to September 17. In each of the three study plantations, we established a grid with intersections 20 to 40 m apart, depending on stand size. Within 6 m of each grid point, we selected the nearest white spruce sapling that was ≥46 cm tall, ≥4 yr old, and <4 yr older than the plantation itself. If a point lay in an uncleared inclusion or windrow or in standing water, or if the surface was dominated by rocks, no sapling was selected. From the three stands, 519 saplings were selected and flagged for revisiting, which was about 1% of all spruce saplings present.

We used a two-tiered sampling design. From the 519 total saplings, a subset of 180 was selected for intensive sampling. We wanted about five trees in each of four shrub-density strata (see below) for each of three age classes in each of the three stands (36 cells). Due to field irregularities and the imprecision of the initial visual estimates, distribution of the intensive subset was uneven among the stand-stratum-age cells, ranging from 3 to 8 per cell. This subset was then used for measuring soil characteristics, quantifying the extent of surrounding shrubs, and counting annuli to test the reliability of aging by whorl counts. These trees, when classified into shrub strata, served as standards for workers learning to make visual estimates of strata in the extensive subset (519 – 180 = 339).

At each spruce in the intensive subset, a 15-cm-deep soil core was taken to sample the stratum within which most of the fine-root biomass of spruce is confined (Safford and Bell 1972). Soil texture was determined for each sample according to USDA (1975) procedures. Distribution of the four shrub-density strata among soil-texture types was analyzed by a Chi-square goodness-of-fit test in a two-way table.

A system was devised for classifying into four levels or strata the relative extent of shrub-presence immediately adjacent to each spruce. The criteria defining these density strata combined two dimensions of competition by shrubs: one for soil moisture and nutrients (shrub density), and one for incident light (degree to which the spruce was over-topped by shrubs).

For evaluating shrub density, a stem was counted only if it exceeded a specified minimum basal diameter (at 15 cm above-ground level), the specification differing among each of four surrounding zones: a center circle and three concentric annular circular plots centered on the spruce. Within 50 cm of the spruce, all stems were counted; at 51–80 cm, only stems ≥6 mm diameter were counted; at 81–113 cm, only those >10 mm; and at 114–183 cm only those >15 mm. Thus only increasingly larger diameter shrubs were counted as distance from the spruce increased, with none recorded beyond 183 cm. In addition, every stem within 183 cm that overtopped the spruce was counted; height of these of course varied according to the height of the sapling.

Shrub-density strata were derived by combining the number of specified stems within the concentric plots with the number of stems that overtopped the spruce. Criteria for the four strata were as follows: the no-shrub stratum had neither any shrub of qualifying diameter nor any overtopping the spruce; the low-density stratum had 1–10 shrubs, of which <6 overtopped the spruce; the medium-density stratum had 11–20 shrubs, of which <11 were overtopping; and the high-density stratum had either or both >20 shrubs or >10 shrubs overtopping the spruce. Field personnel, after a day of practice on the intensively measured subset, developed consistent ability in visually classifying strata, thus assuring acceptable accuracy in the assignment of shrub strata for the extensive subset.

For all sampled spruce, height of the tree plus height of the three upper-most whors were measured (1 cm) and from these we reconstructed vertical-growth increments for the past four growing seasons. Basal diameter (1 mm) was determined from the average of two perpendicular caliper measurements just above the basal flare. Age was estimated for the extensive sample from a count of terminal bud scars or whors and verified from annuli counts on basal cross-sections collected from each intensively sampled spruce.

To account for other environmental factors potentially affecting size and growth rate in the study spruce, we recorded the following qualitative data: forks (four levels), frost damage (two levels), mechanical damage (on terminal or laterals), damage by either snowshoe hares (Lepus americanus) or red squirrels (Tamiasciurus hudsonicus), density of surrounding grass, and density of a common forb, big-leaf aster (Aster macrophyllus), a common species reported to have allelopathic effects (Fisher 1980).

All shrub stems counted around the intensively sampled spruce were characterized by species, height, basal-diameter, quadrant centered on the spruce (N,E,S,W), and hedging by moose. “Hedging” is defined here as the removal of a terminal stem during the past winter and/or an earlier winter, causing an apparent suppression of vertical growth. Hedged shrubs typically had a growth form of multiple terminal stems, indicating that normal vertical growth had been interrupted, hence slowing or stopping their normal rate of escape from the reach of moose. The shrub’s crown class was qualitatively rated as dominant (receiving light from above and from three sides), codominant (light from above plus from one or two sides), intermediate (partial light from above only), or understory (no direct light from above). The relative degree to which the shrub shaded the spruce sapling was rated as high, medium, low, or none.

Several factors, in addition to competing vegetation, appeared associated with height growth in spruce saplings, so a set of covariates was introduced to reduce the variance in our design. To detect covariation, log-linear models were fit to multiway frequency tables for the recorded variables and the size and growth increment of the spruce. Aster, frost damage, and shading from the west showed significant interactions with growth increment, so they were used as covariates in an analysis of covariance (ANCOVA) of the effects of shrub stratum on growth increment. Stand was also used as a
covariate to adjust for possible site differences. Separate ANCOVAs with height and diameter as dependent variables were generated to reveal possible differences in biomass. We grouped trees into three age classes (4–6, 7–9, and 10–16 yr.) and used one-way ANCOVAs, with each age-class analyzed separately.

We used Bonferroni’s Z-statistic (Neu et al. 1974) to determine if frost damage to spruce occurred more than expected in the various shrub strata. We used analysis of covariance to test if hedging resulted in reduced shrub heights. Each stand was analyzed separately because of site differences in growth and hedging rates.

Results

Soils from the intensively sampled plots included sandy loams, loams, and clay loams. We found little or no association ($X^2 = 11.645, df = 6, P = 0.074$) between shrub strata and soil texture.

Age of sampled spruce ranged from 4 to 16 yr. The mean, current-season height increment (terminal growth) for all trees was 34 cm (SE = 0.79, range = 2–90). Among all age classes, none of the three, individual spruce that were either of greatest height, of greatest basal diameter, or of greatest current growth-increment were found in the no-shrub stratum (Table 1). Spruce in the no-shrub stratum were consistently less than or equal in the three aforementioned measures than were those in the low-density stratum. Among spruce ≥ 7 yr old, the only set showing less growth than the average in the no-shrub stratum were a few in the high density stratum.

In the low-density stratum, 4–6 yr spruce had greater mean height and diameter than those in the medium-density ($P = 0.022$ and $P = 0.041$, respectively) and high-density strata ($P = 0.027$ and $P = 0.004$, respectively). Also, mean growth increment in the low density ($P = 0.001$) and medium density ($P = 0.046$) strata was greater than in the high density stratum. Spruce saplings of 7–9 yr in both medium and high density strata showed a greater mean growth increment ($P = 0.019$ and $P = 0.031$, respectively) and height ($P = 0.004$ and $P = 0.019$, respectively) than those in the no-shrub stratum.

Spruce saplings 7–9 yr old in the low density stratum also had greater mean height than those in the no-shrub stratum ($P = 0.045$). Data suggest that for 10–16 yr spruce saplings, those in the medium density stratum had greater mean growth increment and height than those in any other stratum, but statistical significance was shown only between the high density and medium density strata ($P = 0.043$ and $P = 0.042$, respectively).

Frost damage occurred more than expected in the low density shrub stratum ($P = 0.007$), and it appeared even greater in the no-shrub stratum, but sample size there was inadequate for statistical analysis. Spruce with frost damage were 10% shorter ($P < 0.001$) than undamaged trees.

For all shrubs sampled, the frequency of hedging by moose averaged 75% in Stand 1, 65% in Stand 2, and 74% in Stand 3. Browsing frequency was highest on dominant and codominant shrubs. There were no significant differences in frequency of hedging among shrub strata ($P > 0.25$). Despite possible selection by moose for taller shrubs, hedged stems of beaked hazel, chokecherry, quaking aspen, and paper birch were shorter than unhedged stems of the same species. Willow, balsam poplar, and pin-cherry appeared to have a similar relation, though not statistically significant. Some species, such as quaking aspen in Stand 1 and pin-cherry in Stand 2, had such a high frequency of hedging that there were not enough unhedged stems for comparison.

Discussion

Broadcast application of herbicides, particularly on public lands, has drawn extensive public criticism (Lemon 1980). Before 1984, the most common method of plantation release was by aerial spraying. From 1984–1986, all aerial applications were suspended on U.S. national forests, and in 1990, the Eastern Region of the USFS instituted a temporary ban on all pesticide use. Restriction of broadcast application of herbicides increases the need for effective alternative techniques for releasing young conifers. In a study of release methods in northeastern Minnesota, Benzie (1984) reported that mean heights of chemically released white spruce were not

Table 1. Adjusted means for growth increment, height, and basal diameter in a total of 519 white spruce saplings, each of which was assigned to 1 of 4 shrub-density strata and 1 of 3 age classes. Means were adjusted for site, aster, density of graminoids, frost damage, and specific age of each spruce. Density strata are defined in the text.

<table>
<thead>
<tr>
<th>Age (yr)</th>
<th>Shrub stratum</th>
<th>N</th>
<th>Growth increment</th>
<th>Height</th>
<th>Basal diameter</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>(cm) SE</td>
<td>(cm) SE</td>
<td>(mm) SE</td>
</tr>
<tr>
<td>4–6</td>
<td>No shrub</td>
<td>16</td>
<td>18 ± 2.2</td>
<td>112 ± 10.6</td>
<td>22 ± 2.4</td>
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<tr>
<td></td>
<td>Low density</td>
<td>37</td>
<td>23 ± 1.4</td>
<td>133 ± 6.8</td>
<td>26 ± 1.6</td>
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<tr>
<td></td>
<td>Medium density</td>
<td>23</td>
<td>20 ± 1.8</td>
<td>107 ± 8.6</td>
<td>21 ± 2.0</td>
</tr>
<tr>
<td></td>
<td>High density</td>
<td>25</td>
<td>15 ± 1.8</td>
<td>108 ± 8.4</td>
<td>19 ± 1.9</td>
</tr>
<tr>
<td>7–9</td>
<td>No shrub</td>
<td>26</td>
<td>27 ± 3.0</td>
<td>156 ± 15.3</td>
<td>35 ± 3.9</td>
</tr>
<tr>
<td></td>
<td>Low density</td>
<td>62</td>
<td>32 ± 1.9</td>
<td>193 ± 9.6</td>
<td>43 ± 2.4</td>
</tr>
<tr>
<td></td>
<td>Medium density</td>
<td>44</td>
<td>36 ± 2.2</td>
<td>213 ± 11.4</td>
<td>43 ± 2.9</td>
</tr>
<tr>
<td></td>
<td>High density</td>
<td>51</td>
<td>35 ± 2.1</td>
<td>202 ± 10.6</td>
<td>39 ± 2.7</td>
</tr>
<tr>
<td>10–16</td>
<td>No shrub</td>
<td>34</td>
<td>42 ± 3.1</td>
<td>247 ± 13.8</td>
<td>61 ± 7.0</td>
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<tr>
<td></td>
<td>Low density</td>
<td>87</td>
<td>42 ± 1.9</td>
<td>256 ± 8.4</td>
<td>63 ± 4.3</td>
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<tr>
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<td>Medium density</td>
<td>60</td>
<td>43 ± 2.3</td>
<td>260 ± 10.0</td>
<td>71 ± 5.1</td>
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<tr>
<td></td>
<td>High density</td>
<td>54</td>
<td>36 ± 2.5</td>
<td>230 ± 10.9</td>
<td>64 ± 5.5</td>
</tr>
</tbody>
</table>

NOTE: * indicates a significantly greater mean ($P < 0.05$) than b, SE = Standard Error.
Our results agree with Gustafson’s (1943) finding that height of spruce increased with shading until the saplings were 8–10 yr old, after which shading caused height–growth increment to decrease slightly. Shirley (1945) and Logan (1969) also reported positive height–growth response in white spruce with shading. However, they reported a decrease in total biomass for shaded trees. In this study, a reduction in mean diameter or height, hence presumably in growth, was observed for treated conifers. In another study, Perala (1982) also reported positive height–growth response in hand-released conifers.

In our study, the occurrence of frost damage in spruce was higher where shrub density was low or lacking compared to where density was medium. This effect may have resulted in a 10% increase in height growth. Other studies also report serious impacts of frost on white spruce (Russell 1963, Stiell 1976). Vulnerability to frost damage varies with location and topography. While stands in this study were not located in frost-prone areas, they did sustain some damage. In stands where spring frost is more severe, there may well be a major benefit from a moderate density of shrubs.

Moose hedged 65–86% of the shrubs in the three study plantations and did so within each shrub density stratum from low to high. Bergerud and Manuel (1968) also reported an evenly distributed hedging of shrubs in white spruce stands in Newfoundland; >30% of their study area showed reduced shrub growth from moose hedging. Hjeljord and Grnvold (1988), studying effects of various release techniques in Norway, concluded that moose browsing provided considerable release from competition for young Norway spruce (P. abies). Krefting (1974) reported that 14 yr after a widespread wildfire in 1936 at Isle Royale, Michigan, moose were still hedging many birch and aspen, serving to keep these shrubs within their reach, and on shallow-soil sites, this suppression by moose still persists >50 yr after the fire (P. Jordan, pers. observation). Krefting’s (1974) enclosures at Isle Royale demonstrated that, under full protection, these trees outgrew the reach of moose within a few years, as was also found there in a more recent enclosure (P. Jordan, S. Sell, and J. Campbell, Univ. of Minn., pers. comm.).

The ability of plantation managers to affect moose populations in order to influence the extent and degree of browsing will vary with local environmental, regulatory, and jurisdictional conditions. While many factors besides forage affect local presence of moose, if other factors are favorable, the animals will frequent stands where browse is most abundant. However, they will not come if browse has already been removed, i.e., by intensive release treatments (Lautenschlager et al. 1999), or if herbicide treatments lead to a replacement of high preference species (e.g., Sorbus spp.) by lower preference ones (e.g., Betula spp.) as found in Norway by Hjeljord and Grnvold (1988).

Raymond et al. (1996) found that available biomass of deciduous browse decreased 70% on clearcuts 2 yr after treatment with glyphosate, but browse was not affected 7–11 yr posttreatment. During the later time periods, browse species had regenerated in the treated clearcuts, while browse in the untreated stands had grown beyond the reach of moose, thus becoming unavailable. In Maine, Eschholz et al. (1996) found less winter presence of moose 1–2 yr following glyphosate aerial applications, but at 7–11 yr, moose presence was greater in the treated sites than in untreated controls. While changes in available forage were not measured, the authors speculated that the relatively greater moose presence in treated sites might have been due to there being more conifer cover in those stands.

In our study, moose tended to browse and reduce heights of dominant and codominant shrubs overtopping spruce saplings. These are the same shrubs that in USFS competition-release surveys would be taken as clear indicators of competition (USFS 1980). Thus, where moose are at medium-to-high density in winter, browsing may suppress shrubs, even to the point at which their impact on young conifers becomes negligible. In such cases, major savings for timber managers can be realized by omitting release treatments, and the benefits to wildlife are obvious. In our study area, with winter moose densities of 0.36–0.46/km², browsing suppressed shrubs. Ongoing studies at Isle Royale National Park, Michigan (Jordan et al. 2000) have shown that, where long-term density of moose is well above average for the species, i.e., 1.5–3.5/km², these animals can clearly suppress vertical growth of shrub-form hardwoods through their persistent cropping of both leaves in summer and twigs in winter. Repeated measurements at fixed plots over several decades have shown that chronic browsing of deciduous shrubs and young trees not only has suppressed height growth but has been severe enough to cause decreased height of living tissue and increased mortality among individual shoots and seedlings (P. Jordan, unpubl. data).

A primary objective of this study was to estimate competitive impacts of surrounding broadleaf shrubs on spruce saplings in plantations when those shrubs also comprise browse for wildlife, and from this to make management recommendations. Caution must be used, however, in extrapolating from this study. Sampling was from a narrow set of circumstances: all study stands had similar treatment histories, they were all within the same USFS ecological land type, and spruce saplings growing under conditions atypical within these stands were omitted. At the same time, our findings tend to parallel those of Shirley (1945) and Logan (1969), who studied white spruce responses to surrounding shrubs in a range of sites where soils and treatment histories differed markedly from ours.

One may question whether the linkage we found between better growth in spruce and moderate presence of shrubs was a function of microsite differences: i.e., where soil fertility is above average, both sets of plants might have been favored so as to override competitive suppression. This would suggest that a fine-grain mosaic of soil quality existed within each stand, with gradients among patches being quite sharp. Such seems unlikely based on there having been no association found between density of surrounding shrubs and soil tex-
ture. That local soil differences did not account for a positive linkage between shrubs and spruce is further suggested from experiments of others in which microsite was controlled, and a similar positive response to shading was found (Gustafson 1943, Shirley 1945, Logan 1969). In a study of competitive effects of surrounding vegetation on small, white spruce seedlings in Maine, Lautenschlager (1995) found that competitive vegetation was much more abundant on a well-drained site and that it reduced spruce growth more than on a somewhat poorly drained site.

Management Recommendations

Because low-to-moderate levels of surrounding shrubs were associated with stable or increased growth of young white spruce, it would appear, at least for Minnesota, that removal of most woody, broadleaf shrubs surrounding young spruce is not necessary from the standpoint of timber-production objectives. This is particularly true in frost-prone sites. Excessive removal of broadleaf shrubs also has the potentially undesirable effect of reducing browse and other forage resources for wildlife. As high shrub densities were associated with reduced growth in all but 7- to 9-yr-old spruce, some release treatments are justified. Baskerville (1961) showed that 60–90 cm tall spruce (most of which would be 4–6 yr old) showed the greatest relative growth response to release. The effects of releasing trees of this age can last ≥6 yr (Lahela 1980). Excessive release treatments, however, may eliminate most surrounding shrubs while contributing little to better growth than had shrubs been left at high density. Excessive releases also increase the stand-management costs, which often cannot be recouped at the end of the plantation rotation.

Aerially applied herbicides in heavy concentrations affect all densities of shrubs, severely reducing the quality of habitat for large ungulates without necessarily producing superior conditions for growth of young spruce. Heavy applications of systemic toxins such as glyphosate can eliminate much of the browse resource for the duration of the rotation (Kennedy and Jordan 1985). Lighter applications of herbicides, or uneven aerial applications can leave substantial forage for moose in (Santillo 1994) without an apparent reduction in the quality of their diets (Raymond et al. 1996). Our results indicate that using a selective release technique that leaves shrubs at low to moderate densities will favor spruce growth, while at the same time reducing costs and providing more forage for wildlife. In this regard, manual techniques, mechanical or chemical, that are confined to the immediate vicinity of saplings likely to be suppressed by competing shrubs would appear most appropriate.

Given that moose can reduce competing shrubs, hence potentially benefit young conifers, to what degree can forest managers take advantage of this natural release? First, the geographical and ecological distribution of moose is limited by a wide variety of natural factors including climate, year-round food resources, predation, and parasites and diseases, as each is reviewed in Franzmann and Schwartz (1998). In general, if moose are quite sparse or absent in a region, simple management strategies are not likely to change this. However, where moose are reasonably abundant, then patterns of forest management can serve to increase or decrease their local abundance in one or more seasons (Thompson and Stewart 1998). Throughout most of North America and Scandinavia, hunting removals today are seldom great enough to prevent moose from providing a release function as long as habitat conditions are otherwise favorable.

Literature Cited


Kennedy, E.R., and P.A. Jordan. 1985. Ecological and management objectives. This is particularly true in frost-prone sites. Excessive removal of broadleaf shrubs also has the potentially undesirable effect of reducing browse and other forage resources for wildlife. As high shrub densities were associated with reduced growth in all but 7- to 9-yr-old spruce, some release treatments are justified. Baskerville (1961) showed that 60–90 cm tall spruce (most of which would be 4–6 yr old) showed the greatest relative growth response to release. The effects of releasing trees of this age can last ≥6 yr (Lahela 1980). Excessive release treatments, however, may eliminate most surrounding shrubs while contributing little to better growth than had shrubs been left at high density. Excessive releases also increase the stand-management costs, which often cannot be recouped at the end of the plantation rotation.

Aerially applied herbicides in heavy concentrations affect all densities of shrubs, severely reducing the quality of habitat for large ungulates without necessarily producing superior conditions for growth of young spruce. Heavy applications of systemic toxins such as glyphosate can eliminate much of the browse resource for the duration of the rotation (Kennedy and Jordan 1985). Lighter applications of herbicides, or uneven aerial applications can leave substantial forage for moose in (Santillo 1994) without an apparent reduction in the quality of their diets (Raymond et al. 1996). Our results indicate that using a selective release technique that leaves shrubs at low to moderate densities will favor spruce growth, while at the same time reducing costs and providing more forage for wildlife. In this regard, manual techniques, mechanical or chemical, that are confined to the immediate vicinity of saplings likely to be suppressed by competing shrubs would appear most appropriate.

Given that moose can reduce competing shrubs, hence potentially benefit young conifers, to what degree can forest managers take advantage of this natural release? First, the geographical and ecological distribution of moose is limited by a wide variety of natural factors including climate, year-round food resources, predation, and parasites and diseases, as each is reviewed in Franzmann and Schwartz (1998). In general, if moose are quite sparse or absent in a region, simple management strategies are not likely to change this. How-


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