Multi-species Planting and Other Practices to Restore Forest Diversity in Northeastern Minnesota

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ABSTRACT

Forest stand diversification in terms of plant species and spacing of plantings is critical to restoring components of native forests, reducing risks of insect and disease outbreaks, and providing a variety of habitats for native birds and other forest animals. We share the results of experimentation with reforestation practices to achieve more diverse upland forests in northeastern Minnesota. We also share the results of a study to determine the impact of site preparation (rock raking) and seedling "release" (removing competing surrounding vegetation after two years) on survival and height of 19 native trees and shrubs. After five years, seedling survival across the 19 species ranged from 31% to 94%, with mean of 72%. Survival was higher for sites receiving the preparation treatment (76%) than for those not receiving the treatment (68%). Site preparation significantly increased seedling height for eight species. In year three of the study we removed nearby competing vegetation (release treatment), which resulted in significantly greater seedling height for two species and less height growth for three species after two years. We discuss the value of increases in survival and height in the context of overall forest management objectives and other management strategies to diversify forest species and structure.

Keywords: forest restoration, Minnesota, reforestation, stand diversity

Beginning in the late 1980s, questions were raised about U.S. forest management practices that resulted in biologically simplified stands, often with a single species planted (e.g., Franklin 1989, Hansen et al. 1991). Of concern was loss of old growth, biological diversity, and ecological functions and processes (Vora 1994). In the northern U.S. Great Lakes states, red pine (*Pinus resinosa*) plantations had greatly reduced variability in structure and compositional complexity compared to conditions created by natural disturbance (Palik and Zasada 2003). In New Brunswick, Erdle and Pollard (2002) compared 15- to 30-year-old forest plantations to natural stands and found that while few plantations were monocultures they had less plant species diversity, and sometimes species not native to the area. They recommended broadening the mix of planted species at the forest and stand level, and taking ecological zones and biogeophysical site conditions into consideration in planting decisions. In addition, stand diversification through mixed species planting and wider spacing has been shown to increase habitat for native birds (Green 1995), and reduce the risk of insect outbreaks (Wilson 1977) and spread of root disease (Gerlach et al. 1997). For bird habitat in northern Minnesota, Green (1995) suggested maintaining a variety of habitats and diverse forests within those habitats.

Forest health has emerged as a central objective in U.S. forest management (USDA Forest Service 1993), and agency policy has changed to favor an ecosystems approach (Overbay 1992). Producing commodity resources while sustaining diverse, healthy, and productive ecosystems requires consideration of ecosystem elements (e.g., biodiversity) and the dynamic nature of landscape patterns and processes within a framework for adaptive management (Jensen 1994).

Between 1991 and 1996, forest management in Minnesota moved toward more intensively managed, but also diverse, forests across types of ownerships, with an increase in residual timber left in clear-cuts and more natural regeneration (Puettmann and Ek 1999, David et al. 2001). Besides concern over loss of biological diversity, issues emerged over "below-cost timber sales" (e.g., Cortner and Schweitzer 1993) and the use of herbicides, which eliminated their use as a routine plantation management tool in national forests in the Great Lakes region. There also emerged a greater willingness on the part of managers and the public to take some risks with potential future losses to white pine blister rust (*Cronartium ribicola*) to maintain white pine (*Pinus strobes*), given it may be 60 or more years before

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we really know if planted seedlings are truly resistant to blister rust (Stine and Baughman 1992, Rajala 1998).

Diversifying Forests

These changes in national policy and public opinion created opportunities for us to experiment with alternative approaches to forest management in the 250,000-hectare Laurentian Ranger District in the Superior National Forest north of Duluth, Minnesota (Figure 1). In most areas of the Great Lakes states, local reference plant communities do not exist, given the extensive cutover 100 years ago and subsequent logging and fire suppression up until the present. A net result of logging is a homogenization of stand ages and disturbance intervals (Mladenoff and Pastor 1993). Current forests are marked by lower species diversity, functional diversity, and structural complexity, and contain more aspen and less conifer in comparison to the pre-Euro-American period (Schulte et al. 2007). A shift to aspen (*Populus deltoides*) may enhance stand-scale diversity, nutrient cycling, and productivity but may reduce landscape-scale diversity and natural stand age structure (Reich et al. 2001). Near-boreal forests with more frequent natural disturbances and shorter-lived species such as jack pine (*Pinus banksiana*) have been less altered ecologically by logging (Mladenoff and Pastor 1993). They are also inherently unstable over time, making prediction of successional patterns difficult and dependent on the sequence of disturbance received (Frelich and Reich 1995, 1998).

In the northern Great Lakes region, mixed hardwood (aspen)-conifer (balsam fir, *Abies balsamea*-spruce, *Picea* spp.) forests can be achieved by simply retaining sufficient advanced regeneration of conifers during logging (Greene et al. 2002). Structural complexity and species diversity in red pine plantations can be enhanced by overstory retention and planting to achieve mixed species, multi-cohort stands (Palik and Zasada 2003).

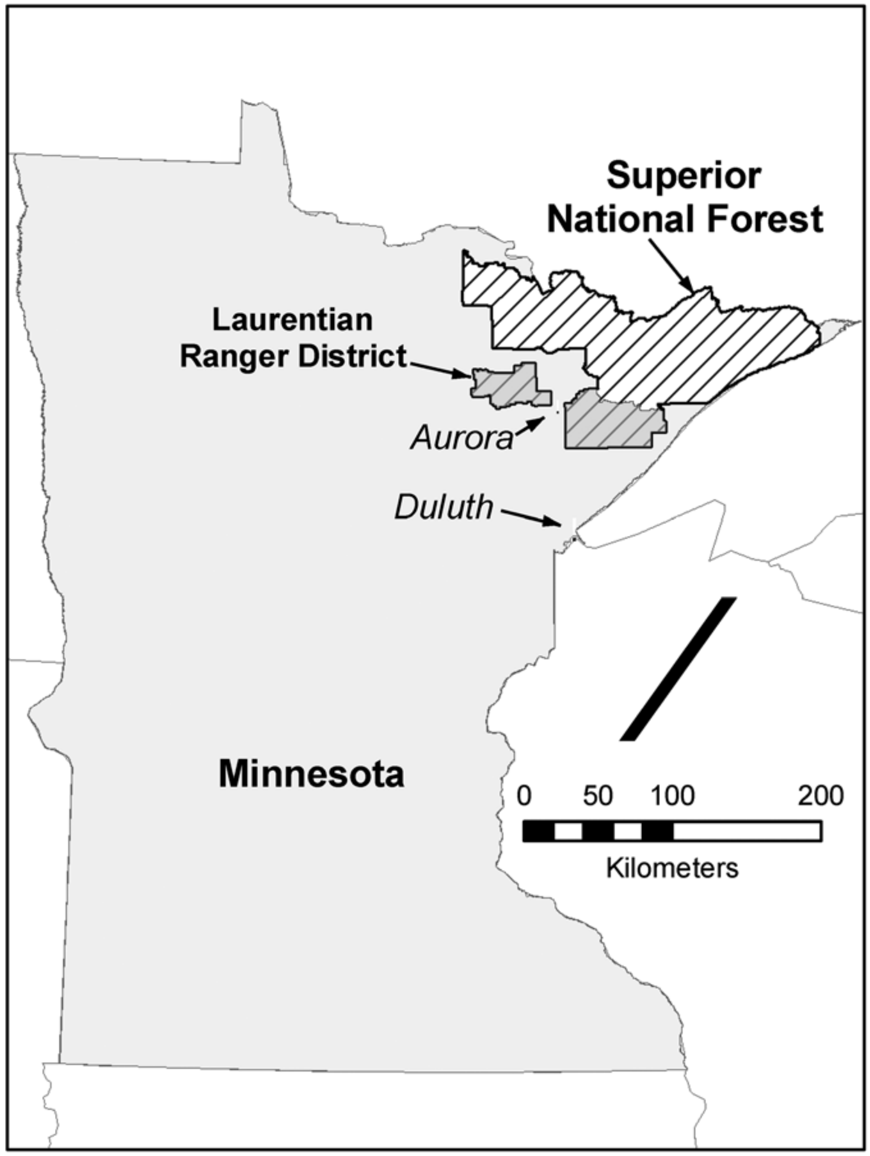

Figure 1. Location of the Laurentian Ranger District in Minnesota.

Planting, both in the open and under a canopy, is often needed to diversify a stand with other species. This may replicate re-invasion from local fire refuges that may have occurred prior to large-scale logging and European settlement (Frelich and Reich 1995).

In this paper we report on our work with several reforestation practices, their traditional use in the northern Great Lakes, and opportunities we explored to diversify forests. Plants naturally often grow in clumps (Frelich et al. 1998, Frelich and Puettmann 1999), for example, and so we attempted to replicate that with extensive "clump planting" to diversify aspen and jack pine stands. Neighbors within clumps or groups can buffer competition with other species, allowing a few individuals of slower growing species to survive and reach canopy status (Frelich and Puettmann 1999). Biodiversity will likely be maximized by organizing a diversity of structures over a large area, not by creating the same structure over many hectares (O'Hara 1998).

We also provide the results of a study implemented in 1997 to characterize seedling survival and height growth for 19 species of trees and shrubs. The study was designed to determine 1) the influence of site preparation and soil type on seedling survival and height growth, and 2) the subsequent

Table 1. Effects on survival and height of 19 native tree and shrub species: 1) five years after initial planting in 1997, with and without site preparation, or "rock raking," in which vegetation and some topsoil is scraped into piles to facilitate planting and seedling survival; and 2) effects on height of planted species two years after "release" in 2000, which involved clearing of competing vegetation 1 m around each seedling in first half of each row in each subplot. Numbers represent 95% confidence interval; * indicates $p < 0.05$.

Species	5 years after planting						2 years after release	
	Survival (%)			Height (cm)			Height (cm)	
	No site prep	Site prep		No site prep	Site prep		No release	Release
American plum (*Prunus americana*)	70–83	75–87		30–46	32–51		33–49	33–49
Black ash (*Fraxinus nigra*)	62–100	60–99		34–45	32–42		30–45	29–44
Black spruce (*Picea mariana*)	67–86	74–94		45–60	67–93	*	54–71	64–80
Burr oak (*Quercus macrocarpa*)	89–99	85–96		41–53	45–58		39–55	39–55
Choke cherry (*Prunus virginiana*)	64–86	71–93		30–49	31–47		33–51	34–52
Highbush cranberry (*Viburnum opulus* v. *americana*)	54–72	64–81	*	26–47	35–63		28–64	9–45
Jack pine (*Pinus banksiana*)	44–67	62–85	*	33–50	52–77	*	38–70	61–93
Juneberry (*Amelanchier* sp.)	82–95	79–92		55–77	48–66	*	52–69	43–60
Mountain ash (*Sorbus americana*)	73–84	73–84		30–46	37–57		38–52	32–46
N. red oak (*Quercus rubra*)	75–88	79–92		42–58	57–80	*	50–62	38–50
Paper birch (*Betula papyrifera*)	45–82	60–96		59–92	80–123		71–95	72–93
Redosier dogwood (*Cornus stolonifera*)	57–80	71–94	*	44–63	56–80	*	52–71	49–68
Red pine (*Pinus resinosa*)	20–42	26–48	*	39–61	49–73	*	44–68	47–72
Sugar maple (*Acer saccharum*)	65–84	59–79		30–47	37–56		36–54	21–38
Tamarack (*Larix laricina*)	29–59	44–73	*	78–122	97–150		92–119	101–128
Northern white cedar (*Thuja occidentalis*)	58–81	57–80		34–41	40–48	*	37–42	36–41
White pine (*Pinus strobus*)	53–74	64–86		23–36	30–47	*	29–41	28–40
White spruce (*Picea glauca*)	35–62	53–81	*	63–80	71–94	*	66–83	69–85
Yellow birch (*Betula alleghaniensis*)	35–100	61–100		49–92	40–71		49–68	46–64

influence of release on seedling survival and height growth. We discuss the results of this study in the larger context of our reforestation management strategies for the Laurentian Ranger District.

Alternative Management Strategies

Beginning in the 1992, we explored numerous alternative management strategies to promote species diversity, functional diversity, and structural complexity in the Laurentian Ranger District. Our management practices complied with Minnesota Forest Resources Council (1999) guidelines for site preparation: regenerate the site as soon as possible after logging, scarify or trench only the area necessary, avoid linear straight rows and follow the contours of the land, protect existing conifer regeneration (especially clumps), avoid operations during saturated soil conditions, and monitor and manage the site. Sites planned for logging and reforestation should be logged in late spring–early summer to the extent feasible and be planted as soon as possible after harvest.

Tree and shrub planting may be necessary to re-establish or restore native species following logging (e.g., Scheiner et al. 1988). The Minnesota Forest Resources Council (1999) also suggests that species selection be based on site capabilities, existing natural regeneration, historical vegetation, variation in growth rates and seed production, mixing of deciduous and coniferous species, and sunlight requirements. The best regeneration of preferred species occurs when site preparation is timed with good seed years (e.g., Godman and Mattson 1976), although from a practical standpoint this is not possible with a large reforestation program.

We worked with 19 tree and shrub species (Table 1), 14 of which were not routinely planted or studied for reforestation success in northern Minnesota. We inspected existing vegetation of potential planting sites and developed a recommendation for species composition. An ecological classification system under development was used to identify which of the 19 species were naturally associated with potential planting sites' soils or ecological landtypes (ELT). These recommendations typically had to be adjusted before planting based on the actual numbers of each species available from the agency nursery and other local nurseries in a particular year. All seedlings were propagated from local seed sources.

Site Preparation

The goal of site preparation is to alter site conditions to favor establishment, growth, and survival of desired vegetation and may be accomplished using mechanical means, fire, or herbicides. It is common practice to brush or "rock rake" an entire site creating large piles of cut vegetation with some top soil also scraped into the pile. In management application we reduced use of rock-raking because of soil displacement and expense ($350–$500 per hectare). We avoided site preparation in some areas where logging left the site fairly clear of slash and brush. We found this more effective on drier, sandier, less productive sites that had been logged in the summer. Summer logging accomplishes some site preparation, because much of the nutrient resources of competing vegetation such as aspen are above ground (Alban 1985, Bates et al. 1989, Perala 1991). We were less successful in finding the ideal low-impact soil preparation method for more productive soils with strong vegetation competition, especially if they were logged in the winter, which encourages re-sprouting of aspen and deciduous shrubs (Prettyman 1987). We used a Brakee-scarifier or plow (Alm et al. 1988) that created 0.3 m × 0.3 m bare patches for planting, or disk trenching in rows of ditches 0.15–0.3 m deep and planting trees mid-slope in the ditches. These methods left more of the soil, forest floor, and understory plant communities less disturbed than brush (rock) raking.

Stand Diversification

Forest management needs to produce a diversity of habitats to meet the needs of a variety of animals and plants, and more attention needs to be paid to establishment of mixed hardwood-conifer forests, as well as diverse stands rather than just primarily aspen or red pine monocultures. We observed that a large number of avian species used mixed conifer-deciduous forests, although some bird species were primarily in deciduous forests and some mostly in coniferous forests. This has been documented by Green (1995) and others. It has been suggested that trees and shrubs with large seed (e.g., oaks) should be planted where appropriate but not present because such species may have a more difficult time adjusting to climate change.

We modified our upland planting program so that about one third of the sites (about 40 ha total within 200–300 ha cumulative area) were planted with clumps, another third with wide spacing (4.6 m), and the remaining third using 3 m × 3 m spacing that would eventually result in the stand being dominated by the species planted. The second two approaches typically covered about 80–120 ha each year. The majority of clear-cuts (600–800 ha total/year) were not planted because of poor access, limited budgets, and Superior National Forest Plan emphasis on aspen for fiber production and on white-tailed deer (*Odocoileus virginianus*) and ruffed grouse (*Bonasa umbellus*) habitat. We used a different approach in upland jack pine clear-cuts because of a regional reduction in jack pine forest.

Trees and shrub species not common to the stand, but native and found on the same soils (or ELTs) elsewhere in our area, were planted at 3 m × 3 m spacing in clumps. We limited clumps to a maximum size of 1.6 ha so that they would be managed as part of the larger stand rather than as a separate small stand. Clumps were typically located in open portions of clear-cuts, and near roads to facilitate logistics of tree planting and stand maintenance. Clumps were more difficult and expensive to plant and maintain given travel time, logistics, and communication problems (i.e., it is more efficient to plant a fixed number of available seedlings in a fewer number of larger sites than in more numerous scattered sites, and more difficult to relocate planted seedlings amidst dense regrowth). We found it difficult to plant more than 20 to 30 clumps (0.4–1.6-ha each) in a year. We planted native shrubs to enhance wildlife habitat (e.g., berries). The shrubs usually came from the nurseries in bunches of 25 and so we typically planted shrub species (listed in Table 1) in groups of 25 as a wildlife attractant.

We successfully used direct seeding to regenerate jack pine (Benzie 1977a) and black spruce (*Picea mariana*) (Johnston 1977). Jack pine would typically regenerate to a mixed hardwood forest without burning and seeding, and we wanted to maintain some "purer" stands of jack pine as were once more common with more frequent natural fire (Scheller et al. 2005).

Release

Stand maintenance, or "release" from competing vegetation (also known as timber stand improvement or TSI), is often needed to manipulate stand composition to maintain survival and growth of planted seedlings or naturally occurring desired species. This is because within one to three years of logging, along with growth of herbaceous species, woody species such as aspen, hazel (*Corylus* spp.), and alder (*Alnus* spp.) often resprout profusely and compete with planted seedlings for moisture, nutrients, sunlight, and growing space.

To maintain stand diversity, we modified the previous standard practice of cutting all competing vegetation or use of herbicides (no longer an option for use on broad scale in Lakes States National Forests). Some plantations had excellent individual seedling survival, or abundant unanticipated natural regeneration, with 1,000 to 2,000 or more seedlings/ha of desirable seedlings. Starting around 1993 we required contractors to "release" only 700 seedlings/ha of desired species (planted or natural). Aspen need only be cut within 1.8 m of the 700/ha targeted seedlings. Competing species besides aspen need only be cut within 1 m of each of the 700/ha targeted seedlings. Posner and Jordan (2002) advocated a similar release strategy for white spruce seedlings in moose habitat to minimize loss of browse for wildlife.

White Pine

We increased the proportion of planted white pine to roughly 20–40% of the overall species mix. Bearing tree records suggest white pine made up to 16%–24% of tree basal area of pre-European settlement forests (Friedman et al. 2001). Natural regeneration of white pine after logging may require an abundance of seed trees (Weyenberg et al. 2004). Dovčiak et al. (2003) found that vegetative competition may cause white pine recruitment into the canopy to be lower on deeper soils unless overstory cover and understory shrubs are reduced once seedlings exceed one meter in height. Open-grown white pine is susceptible to injury by white pine weevil (*Pissodes strobe*), however (Katovich 1992). A light overstory may reduce defoliation of white spruce (*Picea glauca*) seedlings by sawfly (*Pikonema alaskensis*) (Morse and Kulman 1984). Rajala (1998) recommended 50% crown cover and a minimum of 50% sunlight for white pine seedlings, and outlined several scenarios where underplanting white pine may work. Canopy openings as small as 200 m² may be sufficient to perpetuate some shade-tolerant species if they are not competing with existing understory plants (Webster and Lorimer 2005). Delaying release until four to five years after planting, and thereby maintaining some cover, may reduce weevil injury. This presented a challenge in finding the ideal release time in a mixed species plantation because species such as jack pine and red pine may growth better with an earlier release. TSI was typically done three to five years after planting or logging. Maintaining seedlings of shade intolerant species such as jack pine or red pine sometimes required two TSI treatments. As mentioned, site impacts might be lower without site preparation and an additional release treatment the year after planting. This would need testing.

White pine seedlings required additional special treatments. Pruning of lower branches (bottom 2 m) reduces the chances of infection by white pine blister rust (French 1992, Rajala 1998, Hummer 2000). We used tree tubes to protect seedlings from deer browsing but did not try budcaps recommended by Rajala (1998) except for one stand in 2005. The Menominee Indian Reservation in Wisconsin demonstrates regeneration practices that may be used in future restored forests with white pine. Relying heavily on natural regeneration, managers planted seedlings only if sites had fewer than 200 trees per ha of featured species over more than 75% of the area after one to two years (Beilfuss 2001).

Seedling Survival and Growth Study

In 1997 we initiated a study in order to characterize seedling survival and height under different management practices for the 19 species of trees and shrubs. The study was designed to determine 1) the influence of site preparation and soil type on seedling survival and height, and 2) the influence of a release treatment on seedling survival and height.

The study used a split-plot design. Nine study sites (whole plots) were selected in 1997 that had reasonable access and were spatially distributed across the Laurentian Ranger District. Although we selected sites based on access, we expected them to be representative of the population of sites in the District. Sites were chosen on two of the most common soil or ecological landtypes (ELT) in our region, ELT 13 (deep loamy over dry sand) and ELT 14 (deep coarse loamy dry) (1986 Superior National Forest Plan Appendix C on file). Six sites were selected on ELT 13 and three sites on ELT 14. Timber site indices (Carmean 1975) were typically 55–60 (local descriptor using English units, dominant trees are 17–18 m tall after 50 years) for both ELTs, although ELT 14 was more productive than ELT 13 with trees 1–3 m taller after 50 years and larger in diameter. The shrub layer on ELT 14 was denser and taller than on 13, and often characterized by mountain maple (*Acer spicatum*), while hazel (*Corylus americana*, *C. cornuta*) were more characteristic of ELT 13. Annual precipitation was 680 to 740 mm.

Each site was divided into two paired sub-plots approximately 60 m × 150 m, part of the same logged stand, and on the same soil type. Within each pair of sub-plots, one plot was site-prepped with rock raking and the other plot was not rock raked. Rock raking is a means of creating favorable microsites for tree seedling establishment using rakes attached to crawler tractors to pile slash, remove brush and shallow roots, and scarify the ground.

In each sub-plot, 19 species were planted in staked rows with 50 seedlings of one species per row (19 rows, Table 1). Rows were planted 3 m apart and individual seedlings within rows were planted 3 m apart in 1997. The planting contractor selected the species for each row by reaching into a bag and grabbing a bundle of 50 seedlings. This simulated random allocation of species to each row and the sequence of seedlings was different for each site. Species planted were native to our soils and ecosystems, and a mixture of USDA Forest Service stock and private stock was used. The seed source was northern Minnesota. Black spruce, jack pine, paper birch (*Betula papyrifera*), tamarack (*Larix laricina*), white pine, and yellow birch (*Betula alleghaniensis*) were one-year-old container stock. Other species were three-year-old bare-root stock.

We made repeated measures of seedling survival and height in each site in fall 1997, summer 1999, summer 2000, summer 2001, and summer 2002. During the course of the study it was apparent that competing vegetation was influencing the growth of seedlings of some species. As a second step, in the summer of 2000 we released half of the surviving seedlings of each species (first half of each row) in each sub-plot by removing competing vegetation within 1 m of each seedling.

Statistical analyses were carried out separately for three independent variables individually for the 19 species: 1) seedling survival excluding "released" seedlings, 2) seedling height excluding released seedlings, and 3) seedling height for released seedlings. For survival and height excluding release, we used two-way repeated measures mixed model Analysis of Variance (ANOVA) for each species (SAS, Version 8, SAS Institute) to investigate differences between the design factors (ELT and site preparation) and their interactions. Site was treated as a random effect, ELT and site preparation were fixed effects, and years were treated as repeated measures. For released seedlings, we used a similar mixed-model ANOVA that also tested for height differences between released and non-released seedlings. For all tests, height data were subject to ln transformation to improve normality and homoscedasticity. Statistical significance was judged using $\alpha \leq 0.05$. Only results for year five are presented in Table 1.

Seedling Survival Results

Species survival five years after planting ranged from 31% for red pine to 94% for bur oak (Table 1). Red pine had the lowest survival, with rates below 40% in all treatments. Bur oak (*Quercus macrocarpa*) and juneberry (*Amelanchier* sp.) survival was greater than 80% in all cases. Overall survival for ELT 14 was marginally greater (77%) than for ELT 13 (72%), but jack pine was the only species with significantly different survival (p = 0.01) between ELT 14 (77%) and ELT 13 (51%). Overall survival was higher for prepared sites (76%) than for those not prepared (68%). Six species had significantly higher survival ($p \leq 0.05$) in areas receiving site preparation (highbush cranberry (*Viburnum opulus* var. *americana*), jack pine, redosier dogwood (*Cornus stolonifera*), red pine, tamarack, and white spruce), while no species had significantly greater survival in non-prepared sites. Paper birch and red pine were the only two species having a significant interaction effect between site preparation and ELT. For paper birch, survival was significantly different between site preparation treatments (45% without site preparation, 86% with site preparation) on ELT 13 but not on ELT 14 (81% vs. 70%, respectively). For red pine, survival was significantly lower on the non-preparation treatment in ELT 14 compared to preparation (33% vs. 47%, respectively), but there was not a significant difference in ELT 13 (28% vs. 26%, respectively). The species that had both significantly greater survival and height growth from site preparation were jack pine, redosier dogwood, red pine, and white spruce (Table 1).

Seedling Height Results

Jack pine and white cedar (*Thuja occidentalis*) were the only species to respond significantly to soil type, with both growing faster in height on ELT 14. Site preparation had a significant influence on seedling height for nine species after five years (Table 1). Eight of these species were positively influenced by site preparation, with height ranging from 16% to 56% greater on prepared sites (mean = 33%). Juneberry was the only species to have significantly lower height (–12%) with site preparation. American plum (*Prunus americana*), choke cherry (*Prunus virginiana*), and mountain ash (*Sorbus americana*) did not show a significant year effect, indicating that height growth was negligible through the course of the study for these species. Black spruce was the only species with a significant interaction between soil type and site preparation for height growth. For this species, the interaction was evidence of a difference in magnitude but not direction: site preparation had greater height in both ELTs, but the magnitude of the difference was smaller in ELT 13.

Removing nearby competing woody vegetation (release treatment) induced significantly faster seedling growth between 2000 and 2002 for black spruce (+15%) and jack pine (+43%), and declining seedling height for juneberry (–15%), northern red oak (*Quercus rubra*; –21%), and sugar maple (*Acer saccharum*; –34%) (Table 1).

Discussion of Study Results

Generally, our study showed that site preparation increased overall survival of planted species. Growth of competing vegetation was stronger on our more productive soil type (ELT 14). In greenhouse experiments, Walters and Reich (2000) showed increased seedling survival and growth with additional light; and shade intolerant species (e.g., aspen, paper birch, jack pine, yellow birch, tamarack) were less shade tolerant when soil fertility was lower. Thirteen of our nineteen species survived best on our more productive soil type (ELT 14) when planted in areas that had been site-prepped. We expected site preparation to make a larger difference on the more productive ELT 14, by reducing competitive vegetation. This did occur for red pine, but we don't have an explanation for the opposite results with paper birch, or why juneberry had lower height growth with site preparation. The general lack of significant soil type and interaction effects overall for both height growth and survival indicates that the site preparation effect can be generalized across the two soil types for most species.

Our study showed significant positive height increases from release treatment after two years for only two of six conifers and none of the deciduous species (Table 1). These results would likely change if monitored for a longer time period. Perala (1982) summarized from a literature review that conifers in the Upper Great Lakes averaged 43% greater survival, 120% greater height growth, and 814% greater weight growth when released from competing vegetation. Puettmann and Reich (1995) reported reduced height and diameter growth for red pine and quaking aspen growing under competitive conditions, although red pine had higher specific gravity offsetting the reduction in wood volume. Cornett et al. (1998) found that reducing understory vegetation enhanced early regeneration of balsam fir and white pine. Perala (1982) stated that release affected conifer survival less than conifer growth, with jack pine benefiting most from release.

Wagner (2000) summarizes that maximizing tree growth requires controlling the amount of interspecific competition at a minimum response threshold. This means preventing any overtopping by surrounding vegetation at one to three years after planting for red pine, jack pine, and upland black spruce, and one to four years after for white pine. The threshold level of competition for survival is higher and not well known. It would probably occur when overtopping occurs for an extended period of time. Generally, tree seedling growth is more limited by herbaceous than woody vegetation, especially if soil moisture is limiting. Maximizing tree seedling growth generally requires that competing vegetation cover be under 20%. Ohmann (1982, 1983) reported that, in response to release, pines established successfully and understory vegetation recovered quickly to resemble that in stands that had regenerated naturally. Other studies have found significant increases in red pine height after control of competing vegetation (e.g., Benzie 1977b, Lantagne 1989).

The negative response of northern red oak, sugar maple and juneberry to release treatment in our study could be an artifact of measurement only two years after treatment or due to genetic variation, in at least northern red oak. While released oaks would be more exposed to white-tailed deer, we did not observe heavy browsing on seedlings in our experimental plots. Oak seedlings in Minnesota typically have trouble outgrowing competing vegetation (Crow 1988). DuPlissis et al. (2000) documented higher northern red oak seedling survival and diameter growth as understory competition decreased.

Summary

Our study documented that stands can be successfully diversified by planting native species absent from a site because of past logging and other factors. Diversity can be enhanced by varying spacing of seedlings, clumping some plantings, and varying composition or density of species planted. Site preparation before planting, and release from competing vegetation, can aid in seedling survival and growth, and hence plant community diversification. Differences between treatment combinations were apparent five years after seedlings were planted. Although the results are species-specific, sites receiving the site preparation treatment generally had higher survival and growth rates. For most species, the release treatment did not improve seedling survival or height growth after two years; that would likely change over a longer time period for some species. A lack of funding has prevented a repeat measurement. Scientists wishing to use the study for long-term research should contact the Superior National Forest, Laurentian Ranger District in Aurora, Minnesota (co-author Steve Lerol).

Based on our qualitative experience, and in concert with guidelines from the Minnesota Forest Resources Council (1999), we suggest the following general management recommendations for northeastern Minnesota and the northern Great Lakes region. The concepts could be applied elsewhere.

Site preparation

- In our study area the benefits of low-impact site preparation methods (e.g., Brakee-scarifier or shallow disk trenches) generally outweigh the resulting short-term soil disturbance.
- Sites left fairly clear of slash and brush from logging may not need site preparation.

Diversification

- Evaluate landscape as well as within-stand plant diversity.
- Focus on species naturally associated with a site, and use seedlings grown from local seed sources.
- To achieve spatial and species diversity, a planting program should include regular, dispersed wider spacing, and small clump plantings within larger stands that would otherwise regenerate to more simplified aspen monocultures.
- If only relatively few numbers of some species, such as shrubs, are planted, plant them in small groups rather than scattered individually. This will facilitate their maintenance and enhance native bird habitat.

Maintenance

- Control of competing vegetation may be needed to achieve desired stand composition objectives. A release treatment 3–5 years after planting will likely enhance survival and growth of a desired number of targeted individuals, about 700 seedlings/ha in our area.
- White pine seedlings may need pruning of lower branches (bottom 2 m) to reduce the risk from blister rust, and use of bud caps or other techniques to protect terminal buds from deer.

Our larger qualitative experience and our study document that stands can be successfully diversified by planting several species on prepared or unprepared sites, and in some cases survival, height, and diversity may be enhanced by stand tending. Timing and method of release treatments will need to be tailored to site conditions and desired species mix.

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Additional Reading on Reforestation in the Northern Great Lakes Region

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