



Restoration and Management of Eastern White Pine Within High Blister Rust Hazard Zones in the Lake States

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Abstract—In areas considered high hazard for blister rust in the northern Lake States, six white pine plantings were established between 1989 and 1999 to: (1) evaluate the impacts of blister rust, white pine weevil, browsing, and competition stress on tree growth and survival, and (2) evaluate the effectiveness of genetic and silvicultural strategies to minimize damage. The effectiveness of a genetic approach is being examined by evaluating seedlings from selected rust-free source trees (seed orchard collected seed) vs. non-selected nursery seedlings (field collected seed). The silvicultural approach is being examined by comparing pruned vs. unpruned trees, and shelterwood vs. clearcut treatments. Early results based on data collected through 2003 are summarized in this paper. Deer and hare browsing have caused widespread mortality at two sites. Competition has been intense on many of the sites, especially in the open-grown (clearcut) treatments, severely affecting growth and survival. The incidence of tree mortality caused by blister rust has been relatively minor, with *Armillaria* root disease killing more trees than blister rust. Results are too preliminary to fully evaluate the long-term effectiveness of pruning, shelterwood treatment, or planting selected stock in reducing blister rust incidence.

Introduction

Prior to the mid-1800s, eastern white pine, *Pinus strobus* L., played a dominant role in many of the forest ecosystems in the Lake States of Michigan, Minnesota and Wisconsin. Gevorkiantz (1930) estimated that Wisconsin alone had over 7.3 million ha that included a significant white pine component. Logging of the Lake States pinery occurred throughout the mid and late 1800s, almost eliminating the mature white pine resource. Between 1850 and 1930, over 104 billion board feet of white pine lumber was removed from northern Wisconsin (Gevorkiantz 1930). Widespread harvesting created conditions conducive to destructive fires that killed white pine regeneration and many of the remaining large white pines. Thus, future seed sources were removed from many areas. By the early 1900s the white pine resource was significantly reduced from its status 100 years earlier. Recovery has been very slow. Forest Inventory and Analysis (FIA) survey data from Michigan (1980), Minnesota (1990) and Wisconsin (1983) revealed the area of timberland in the white pine type to be only 203,564 ha (Spencer and others 1992).

Damaging Agents

There are a number of reasons why there has been limited success in efforts to restore eastern white pine. These include the introduction of the blister rust fungus *Cronartium ribicola* J.C. Fischer ex. Rabenh., a lack of

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seed trees in many locations, outbreaks of white pine weevil *Pissodes strobi* Peck, and high white-tailed deer *Odocoileus virginianus* Zimmermann populations. These limitations have given white pine a reputation as a difficult species to manage with some forest managers (Marty 1986, Jones 1992), resulting in reduced planting and decreasing the likelihood of a significant recovery of the species.

Blister Rust Hazard Zones

White pine blister rust was first detected in Wisconsin in 1913, Minnesota in 1914, and Michigan in 1917 (Benedict 1981). The fungus produces spore stages on white pine and its alternate host, species of *Ribes*. The Lake States region's cool moist weather patterns in the late summer and fall, prevalence of many lakes and wetlands, and abundant *Ribes* populations created ideal conditions for blister rust.

Climatic blister rust hazard zone maps for the region were developed in the 1960s (Van Arsdel 1961a, 1964). Much of the northern Lake States region was in zones 3 and 4, indicating moderate to high hazard of blister rust incidence (figure 1).

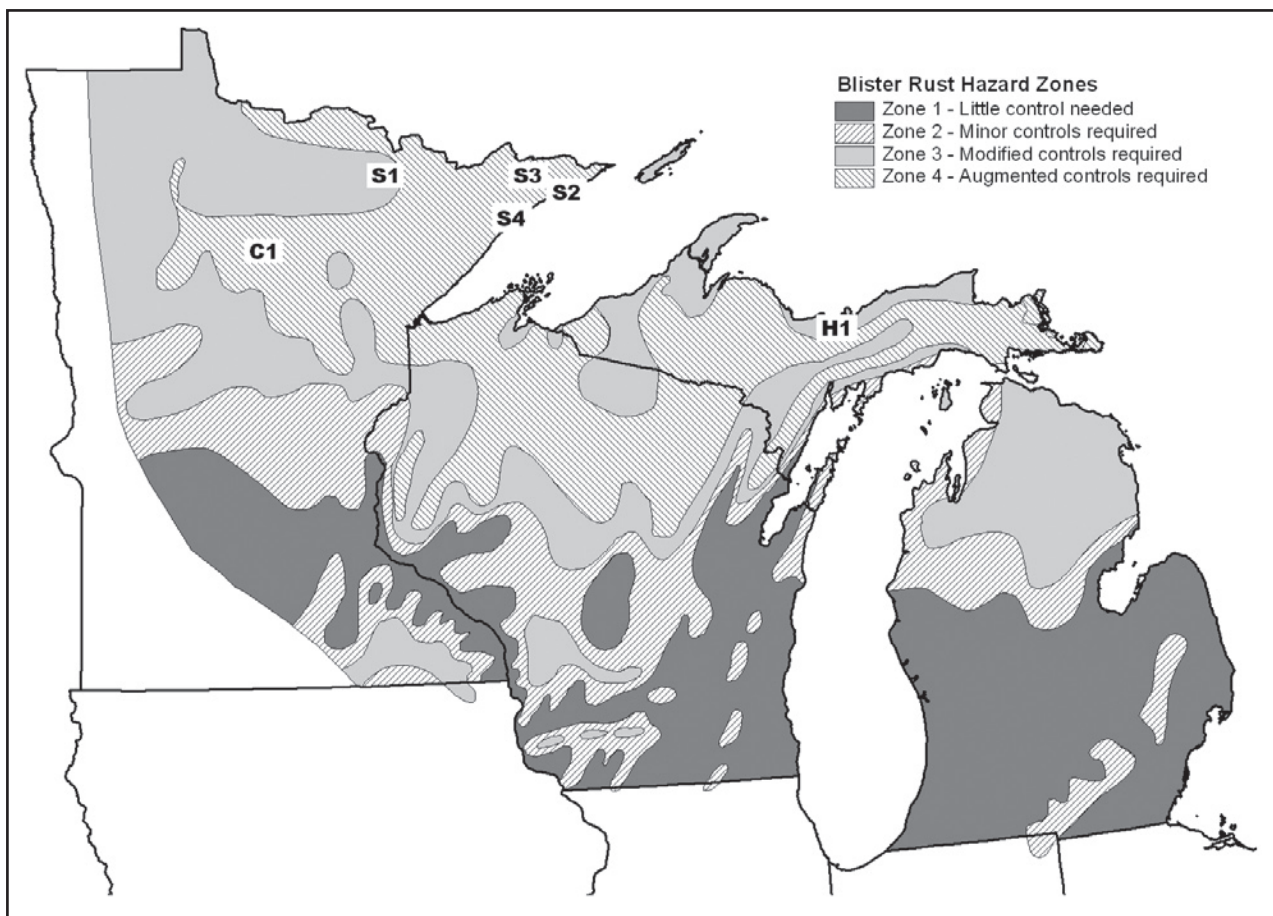


Figure 1—Climatic hazard zones of blister rust infection potential. Van Arsdel (1964) described the zones as follows: Zones 1 and 2—enough pines survive to give a commercial stand without controls. Zones 3 and 4—recommended controls included maintaining an overstory of thin-crowned species over young trees, pruning, avoiding small openings, and maintaining a closed white pine canopy when white pine is open-grown. In addition, in blister rust hazard zone 4, Van Arsdel recommended planting rust-resistant seedlings. Research/demonstration sites are H1 on the Hiawatha National Forest, C1 on the Chippewa National Forest, and S1-S4 on the Superior National Forest.

In the Lake States, rust incidence varies greatly across each zone, dependent upon local topography and vegetation. It is not uncommon for trees in areas within the highest hazard zones to have a low rust incidence. Substantial local variation was recognized at the time of the development of the broad climatic hazard zone maps (Van Arsdell 1961b, 1972). Several surveys have confirmed that the incidence of rust varies in the high hazard zones. Robbins and others (1988) surveyed stands in the Upper Peninsula of Michigan and reported that only 1.5 percent of the sampled trees were diseased. In northern Wisconsin rust incidence in pole-sized stands was only 7.2 percent, and varied from 0 to 28.6 percent (Dahir and Cummings Carlson 2001).

Refinement of the climatic hazard maps to identify areas of low rust incidence may provide more opportunities for successful white pine restoration. White and others (2002) created a high-resolution map for a portion of northern Minnesota using geographical information system (GIS) techniques. Their map illustrated that there were significant acreages of “low hazard” in areas previously identified as zone 4, the area of highest risk for blister rust.

Despite the constraints in managing white pine mentioned earlier, there is growing interest in the restoration of white pine in the Lake States (Stine and Baughman 1992). However, refinements of existing management recommendations for establishing white pine across a regional landscape are needed to identify areas where restoration is likely to be successful.

To address this need, we established six white pine plantings between 1989 and 1999 in the northern Lake States to evaluate the impacts of blister rust, white pine weevil, browsing, and competition on tree survival and growth and to compare silvicultural and genetic strategies to minimize damage. These plantings are managed by USDA Forest Service Ranger Districts, following local management guidelines. In this paper, we present and discuss early results on survival and growth of selected and non-selected seedling stock in relation to browsing, blister rust, competition and other mortality agents.

Material and Methods

Seedling Stock

Seedlings of the “selected” source trees were grown at the USDA Forest Service Toumey Nursery in Michigan. Seed for these trees was collected at the USDA Forest Service Oconto River Seed Orchard (ORSO) in Wisconsin. ORSO trees originated from source trees selected in the 1960s for good tree form and freedom from blister rust in stands with a high rust incidence. At one site, Superior 1, trees were derived from an additional selected seed source originally obtained by the Minnesota Quetico-Superior Wilderness Research Center (WRC) and grown by a private greenhouse to provide containerized planting stock. The non-selected seedlings were obtained from a variety of field collected seed sources, most of unknown parentage.

Treatments

Various treatments were imposed on replicated, randomized 25-tree plots. Trees were planted at 3 x 3 m spacing. Treatments were: (1) nursery grown seedlings from selected rust-free source trees vs. nursery grown non-selected

seedlings, (2) pruned vs. unpruned trees, and (3) trees planted under a shelterwood vs. trees planted in clearcuts. All of the study sites included selected vs. non-selected seedlings. Not all of the sites included the shelterwood vs. clearcut treatments and trees have not yet been pruned at some of the locations. Pruning was planned to be initiated five years after planting, depending upon growth rates.

Data Collection and Analyses

Tree survival, tree size, incidence of browse, blister rust, white pine weevil, and other damaging agents were recorded annually through 2003. Tree size was measured using tree height for the initial 10 years and diameter at breast height thereafter. Tree size was analyzed using ANOVA and pair wise comparisons were made using Tukey's HSD comparisons. Logistic regression was used to compare tree survival, the prevalence of blister rust, Armillaria root rot, and white pine weevil attacks among planting stock types. Backward stepwise regression and the software Arc (Cook and Weisberg 1999) were used to test variables in the analyses.

Study Site Descriptions

All of the plantings are within blister rust hazard zones 3 and 4, the two highest climatic hazard zones proposed by Van Arsdel (1964). Sites are located on USDA Forest Service National Forest lands and are all within the Laurentian mixed forest. Each site is described in detail below and study locations are shown in figure 1. Sites are placed into Sections as defined by the National Hierarchical Framework of Ecological Units (McNab and Avers 1994).

Hiawatha 1 (H1), established in 1989, was located on the Munising Ranger District, Hiawatha National Forest, within Section 212H, Northern Great Lakes. Northern hardwoods occupied the site prior to plot establishment. Treatments included planting trees under a shelterwood vs. planting in a clearcut, selected vs. non-selected seedlings, and pruned trees vs. unpruned trees. Non-selected trees came from seed collected locally on the Hiawatha National Forest. A total of 1,200 trees were planted in 48 plots across six treatment blocks. Pruning was initiated in 1994.

Chippewa 1 (C1) was located on the Cass Lake Ranger District, Chippewa National Forest, within Section 212N, Northern Minnesota Drift and Lake Plains. Plots were established in 1998 within a series of small (0.04 to 0.27 ha) harvest units resulting in a series of small clearcuts. The local forest type was a mix of aspen *Populus tremuloides* Michx., paper birch *Betula papyrifera* Marsh., red pine *P. resinosa* Ait., jack pine *P. banksiana* Lamb. and a few scattered large white pine. Treatments included selected vs. non-selected seedlings, and pruned vs. unpruned trees. There was no shelterwood treatment on this site. Non-selected seedlings came from the State of Minnesota, Willow River Nursery. A total of 600 trees were planted in six replicated blocks that included the four treatments. Pruning was initiated in 2001.

Superior 1 (S1) was located on the LaCroix Ranger District, Superior National Forest, within Section 212L, Northern Superior Uplands. The clearcut site was occupied by a two-year-old aspen stand when planted in spring 1997. Treatments included two selected seedling sources (ORSO and WRC) vs. non-selected seedlings, and pruned vs. unpruned trees. Non-selected trees came from the State of Minnesota, Willow River Nursery. There was no shelterwood treatment on this site. A total of 900 trees were planted in six replicated blocks that included the six treatments. Pruning has not been initiated.

Superior 2 (S2) was located on the Gunflint Ranger District, Superior National Forest, within Section 212L, Northern Superior Uplands. This site was occupied by a mature paper birch stand with harvest treatments completed in 1996 and planting in the spring of 1997. Treatments included planting trees under a shelterwood vs. planting in a clearcut, and selected vs. non-selected seedlings. The shelterwood was established as narrow strips (15.2 m) cut through a mature paper birch stand that was adjacent to the clearcut unit. Non-selected trees came from the State of Minnesota, Willow River Nursery. A total of 1,200 trees were planted in 12 replicated blocks that included the four treatments. This site was replanted in 1998 because of heavy browse damage. Pruning has not been initiated.

Superior 3 (S3) was located on the Gunflint Ranger District, Superior National Forest, within Section 212L, Northern Superior Uplands. The stand was mature red and white pine. A seed tree harvest was completed in 1998 and the site was planted in 1999. Treatments included selected vs. non-selected seedlings, and pruned vs. unpruned trees. No shelterwood or clearcut treatments were applied. Non-selected trees came from the State of Minnesota, Willow River Nursery. A total of 600 trees were planted in six replicated blocks that included the four treatments. Pruning was initiated in 2003.

Superior 4 (S4) was located on the Tofte Ranger District, Superior National Forest, within Section 212L, Northern Superior Uplands. The stand was mature red and white pine. A seed tree harvest was completed in 1998 and the site was planted in 1999. Treatments included selected vs. non-selected seedlings, and pruned vs. unpruned trees. No shelterwood or clearcut treatments were applied. Non-selected trees came from the State of Minnesota, Willow River Nursery. A total of 600 trees were planted in six replicated blocks that included the four treatments. Pruning has not been initiated.

Mechanical release of seedlings from competing vegetation has been done on the plots on an as-needed basis. Control of animal browsing was done on sites C1 and S2 using paper terminal bud caps. The chemical animal deterrent (Plantskydd®) was used at C1.

Results

Hiawatha 1

In 2003 survival of non-selected and selected trees was similar, 55 and 56 percent respectively ($p = 0.91$). Survival was lower in the clearcut treatment compared with trees in the shelterwood, 51 vs. 63 percent ($p < 0.01$). Much of the early mortality was caused by *Armillaria* root disease and unknown causes.

Blister rust incidence was less on the selected trees (3 percent) compared with non-selected trees (7 percent) ($p = 0.03$). Blister rust incidence on all trees was greater in the shelterwood treatment (7 percent) compared with the clearcut treatment (2 percent) ($p < 0.01$).

The incidence of white pine weevil attack on surviving trees was greater in the clearcut treatment (56 percent) than in the shelterwood treatment (41 percent) ($p < 0.01$).

Tree diameter was greater in the clearcut than in the shelterwood, 7.7 cm (SE 0.144) vs. 4.2 cm (SE 0.134) ($p < 0.01$). In the clearcut plots, competition from sprouting hardwood stumps has affected growth of some trees.

Deer or hare browse has not occurred on this site. Diameter of selected trees (6.5 cm) (SE 0.163) was greater than non-selected trees (5.2 cm) (SE 0.165) ($p < 0.01$). The diameter of pruned trees (5.6 cm) (SE 0.170) was less than unpruned trees (6.1 cm) (SE 0.164) ($p = 0.03$).

Chippewa 1

In 2003 there was no significant difference in tree survival between non-selected (66 percent) and selected trees (69 percent) ($p = 0.43$). Selected trees were taller (1.3 m) (SE 0.035) than non-selected trees (1.2 m) (SE 0.034) ($p = 0.01$).

Damaging agents have had minor impacts thus far. Armillaria root disease killed 27 trees between 2000 and 2003. This disease has probably killed additional trees, but this could not be confirmed. In 2003, blister rust incidence was still low: three trees were killed and nine additional trees were diseased. Blister rust incidence was similar on selected trees (three diseased, two killed) and on non-selected trees (six diseased, one killed). Browse damage on trees at this site has been minor. Competition from woody and herbaceous vegetation, overtopping the young pine, has been severe.

Superior 1

Browse damage and competition were major contributing factors to tree mortality on this site. In 2003, overall survival was 56 percent. Survival was greater in non-selected trees (66 percent) than in selected ORSO (53 percent) and selected WRC (49 percent) trees ($p < 0.01$). Deer and snowshoe hares have caused extensive browse damage. In 2002 more than 85 percent of the trees had been browsed to near ground level. Competition stress from aspen suckers along with other woody and herbaceous growth has been heavy.

After six growing seasons, mean tree height was less than 1.0 m, largely due to browsing and competition. The non-selected trees were taller (0.7 m) (SE 0.021) than either the selected WRC (0.5 m) (SE 0.025) or selected ORSO (0.5 m) (SE 0.024) trees ($p < 0.01$). There have been no weevil attacks.

There were no significant differences in blister rust incidence among selected and non-selected trees ($p = 0.91$). A total of 21 trees (six killed) have blister rust cankers: eight non-selected trees, six selected ORSO trees, and seven selected WRC trees.

Superior 2

In 2002, tree survival of the non-selected and selected seedlings was 29 and 24 percent respectively. This site was replanted in 1998 after the original 1997 planting failed because of extensive browsing and competition stress. In 2002, over 97 percent of the surviving trees were browsed. This was despite the use of paper bud caps used as browse protection. Further, the use of paper bud caps on the small trees caused trees to bend and become deformed under snow.

Superior 3

In 2003, overall tree survival was 80 percent. Survival between non-selected and selected trees was 78 percent and 83 percent, respectively ($p = 0.22$). In 2003, non-selected trees (1.1 m) (SE 0.023) were taller than selected trees (1.0 m) (SE 0.023) ($p < 0.01$).

Damage to trees by disease and herbivory has been minimal thus far. Armillaria root disease was confirmed on 15 trees that died between 2001

and 2003. Blister rust incidence has been relatively low; 14 trees have been killed (eight selected, six non-selected) by blister rust through 2003 with 20 additional diseased trees seven selected, 13 non-selected). Competition from woody and herbaceous vegetation has been minimal.

Superior 4

In 2003, overall tree survival was 56 percent. Recent tree mortality was caused by equipment used for salvage logging in the area in spring 2003. Because tree injury was extensive in four plots, these plots were removed from the data analyses. In the remaining plots survival was 67 percent. Differences in survival between non-selected and selected trees were minimal, 66 percent and 69 percent respectively ($p = 0.42$). Mean tree heights for non-selected trees were (1.1 m) (SE 0.027) and selected trees (1.0 m) (SE 0.014) ($p = 0.13$).

Pest incidence and severity has been low. Armillaria root disease was confirmed on 14 trees that died between 2001 and 2003. Blister rust has affected only six selected trees (two dead) and one non-selected tree. The incidence of browse damage has been low; however, competition from woody and herbaceous vegetation overtopping the young pine has been severe.

Combined Results Across Sites

Overall, tree survival of the non-selected trees (67 percent) was greater than the ORSO selected trees (62 percent) ($p = 0.01$). More non-selected trees (4.1 percent) were infected by *C. ribicola* than ORSO trees (2.6 percent) ($p = 0.04$). However, there was no significant difference in the number of non-selected selected trees (1.1 percent) killed by blister rust compared to the ORSO trees (1.4 percent) ($p = 0.50$).

Discussion

Deer and hare browsing and competition stress have been strong contributors to tree mortality on several of the sites, especially Superior 1 and 2. Many trees were browsed to the ground line. Trees on other sites, e.g., Superior 3 and 4, had little browsing damage. In a recent Minnesota study, Krueger and Puettmann (in press) concluded that herbivory was more likely to cause plantation failure than insect or disease incidence. White pine is a winter food source (January through March) for white-tailed deer (Rogers and others 1981). The intensity of browse on white pine occurring at the local level can be influenced by over-wintering deer populations and the local availability of more preferred food sources (Hamerstrom and Blake 1939). High incidence of feeding damage can occur in one area while in other areas little damage may occur. In addition to deer and snowshoe hares, moose also browse white pine (Pastor 1992).

The use of paper bud caps for protection against deer browsing has been widely recommended in Minnesota. However, in our experience, the bud caps themselves may be an impediment to the growth of young trees. The paper bud caps restricted terminal growth on many of the smaller seedlings (<10 cm tall) and often distorted the terminals while under snow cover. Bud caps should probably not be used until trees reach a height of 50 cm.

Though woody and herbaceous competition has not been quantitatively measured, it is evident that growth and survival of pine on several sites has

been severely affected by heavy cover. This has been especially evident in the clearcut treatments at the Superior 1 and 2 and Chippewa 1 sites and on the nutrient rich, mesic sites.

Mechanical removal of competing woody vegetation was done at the Superior 1, Chippewa 1, and Hiawatha 1 sites. However, within a year resprouting, young pine was again overwhelmed by woody vegetation. Grass and other herbaceous vegetation often smothered young pines after heavy snowfalls.

Van Arsdel (1964) recommended planting rust resistant seedlings in hazard zone 4 as the most effective control measure for that zone. Early data from Hiawatha 1 (Ostry 2000) indicated that the ORSO selected stock had significantly lower blister rust incidence than non-selected stock. Although these data reported here are preliminary, this trend has continued on the Hiawatha 1 site; but across all sites no significant difference was detected in the number of trees killed among selected and non-selected trees.

Most fatal blister rust cankers occur in the lower portions of trees, thus pruning of lower branches can significantly reduce the likelihood of lethal cankers (Weber 1964; Lehrer 1982; Hunt 1991). Van Arsdel (1964) recommended that pruning be initiated as early as two years after planting. At that time it also may be advisable to remove needles on the main stem because we have documented that stem cankers on the lower stem can originate from these infected needles.

An existing overstory can reduce blister rust incidence by promoting dew formation in the upper canopy (Van Arsdel 1961b) rather than on the seedlings growing in the understory. Microclimatic conditions are crucial in the movement of fungal spores and infection of pines (Van Arsdel 1967). However, at the Hiawatha 1 site, infection of trees has occurred despite the shelterwood treatment. These trees were closest to a local population of *Ribes*. This supports the recommendation to eliminate *Ribes* in proximity to pine. On this site the presence of *Ribes* adjacent to trees in the shelterwood treatment is apparently making the overstory protection ineffective.

There was an intensive effort to eradicate *Ribes* plants in many forested areas beginning in the early 1900s. This effort lasted over 50 years and represented the largest tree disease control program ever undertaken in the United States (Benedict 1981). The program was eventually largely abandoned and viewed as not effective in many parts of the country. However, it was deemed partially effective in the East (Benedict 1981, Maloy 1997) and has been shown to be effective in local areas (Van Arsdel 1972, Stewart 1957). Ostrofsky and others (1988) reported that in Maine, where *Ribes* eradication efforts had been ongoing for over 70 years, incidence of blister rust was reduced by over 50 percent in treated areas.

White pine weevil attacks do not kill trees but can lead to stem deformity and significant value loss in wood products (Brace 1971). To date, trees have been damaged by white pine weevil only at the Hiawatha 1 site, the oldest planting. The weevil attacks were more prevalent on trees in the clearcut treatment. Weevil populations are expected to increase at all sites as the trees reach 10-20 years of age. White pine weevil preferentially attacks the largest, most vigorous trees in a stand (Kreibel 1954), and open-grown white pine are more heavily attacked by this weevil than trees grown in shade (Graham 1918). Management recommendations for reducing weevil impacts have largely been based on growing trees under an existing canopy. However, shade reduces growth rates, especially diameter growth (Borman 1965). Pubanz and others (1999) observed that in 30-80 year-old open-grown plantations of white pine in Wisconsin, sufficient numbers of "crop-trees" did develop even though weevil attacks were prevalent. They concluded that

weevil impacts were often over-stated and recommended that management strategies stress pruning, maintaining unsuppressed crown position (open-grown), and full stocking. Our study should allow further evaluation of the differences in the incidence of weevil attacks on trees growing in the clearcuts vs. shelterwood and pruned vs. unpruned treatments.

Management Implications

While white pine blister rust is a serious disease, it is only one of several damaging agents affecting early tree survival and growth. Factors such as woody and herbaceous competition, browsing, and *Armillaria* root disease may be more significant threats to the survival of young white pine.

Local variation in rust incidence within the northern Lake States is recognized. Potential planting sites should be evaluated based on local microclimatic and topography risk factors previously described by Van Arsdel (1961b). Rust incidence is influenced by proximity of *Ribes* to white pine. Therefore, managers should avoid planting in areas that harbor abundant *Ribes* populations. Local eradication of *Ribes* in blister rust hazard zones 3 and 4 has been shown to be effective in reducing the incidence of blister rust and may be a viable management strategy.

Although pruning has been shown to be effective in reducing the incidence of blister rust (Hunt 1991; Lehrer 1982; Weber 1964), early results from this study cannot yet validate those results.

Prior to planting, managers should evaluate local herbivore populations, especially in the winter and early spring. Potential planting sites with high deer or hare populations should be avoided unless effective browse protection is provided. Slow growth rates and browse damage to trees on many of our sites have delayed tree pruning and may eventually increase their risk to infection by blister rust.

Krueger and Puettmann (in press) concluded that competition, especially from woody plants, can severely impact white pine establishment. Our results support those conclusions. Without adequate weed control, planting failures are likely, especially in clearcut areas and on mesic, nutrient rich sites.

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