

Pine Resources and Treatment of Annosum Root Rot in North America

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Introduction:

Annosum root rot is the disease caused by the fungus *Heterobasidion* sp. It is one of the most destructive diseases in temperate coniferous forests throughout the world. In North America, mortality caused by the disease has been observed in the eastern states from southern Ontario to Florida and in western states from British Columbia to southern California. In the eastern United States the causal fungus has been identified as *H. irregulare*, and pines are the primary hosts of the fungus. Although the disease was confirmed earlier in the neighboring states and detection efforts by the WI DNR Forest Health Protection Program dates back as early as 1963, the disease was first confirmed in Wisconsin in 1993. As of December, 2012, annosum root rot has been confirmed in twenty-three Wisconsin counties including Adams, Buffalo, Columbia, Dunn, Green, Iowa, Jefferson, Juneau, LaCrosse, Marinette, Marquette, Oconto, Portage, Richland, Sauk, Shawano, Taylor, Trempealeau, Walworth, Waukesha, Waupaca, Waushara, and Wood counties.

Trees grown in plantations where thinning operations occur are more susceptible to this disease. Thinning operations produce freshly cut stumps which are key infection points for the fungus. *H. irregulare* can also spread from an infected tree to its neighbors by moving through root contacts. It is a basidiomycete fungus with conk-like fruiting bodies that produce large amounts of wind-dispersed spores. Infected trees exhibit thin crowns, reduced growth and eventual mortality. Immediate application of borate-based fungicides (Trade names: Sporax®, Cellu-Treat) to freshly cut stumps is the best method of preventing annosum root rot infection in a stand. The treatment is most effectively performed through a spray attachment to a processor at the time of harvesting by using water-soluble fungicide, Cellu-Treat. Currently there are more than a dozen loggers who are equipped with a spray attachment and offer the treatment in Wisconsin. The Wisconsin DNR is in the process of developing a risk-based treatment guide on state-owned land.

One of the questions that has been asked frequently is how other states have been dealing with the disease. In Maine, the disease was reported on pitch pine in a natural stand in 1909 and found in a red pine plantation in 1957. Mortality of southern pines by the disease was reported in South Carolina and Georgia in 1954. The disease has been found in the neighboring states, such as Illinois, Indiana, Iowa, Michigan, and Missouri prior to the find in Wisconsin in 1993. Despite the widespread distribution of the pathogen that is documented in the United States, mechanized applications of fungicides through a spray attachment at the time of harvesting have been performed only in Wisconsin. If annosum root rot is a serious disease, why have fungicide treatments been performed only at a limited scale or not at all in other states? The purpose of this report is to answer the abovementioned questions.

This document summarizes the current recommendations/status of annosum root rot management and the analysis of current pine resources in other states. Comparisons of pine resources by state demonstrate the high value of pine resources in Wisconsin offers and emphasize the need to take prompt action to reasonably protect these economically, socially and biologically important resources.

Materials & Method:

Fungicide treatment status in other states

Information regarding the recommendations of fungicide applications to prevent annosum root rot in other states was compiled in October, 2012, by searching on-line. Forest Health Protection program professionals in eastern US were contacted individually to obtain the current status of the fungicide application in their state/area.

Pine resource data analysis

Information regarding pine resources in each state was summarized using the data from Forest Inventory and Analysis National Program by the USDA Forest Service. The area of pine resources in each state was recovered from the U.S. Forest Service's FIDO database at <http://apps.fs.fed.us/fido/customrpt.html>. Acreage of red pine, jack pine, and state-owned artificially regenerated stands in each state was obtained from the U.S. Forest Service's EVALIDator database at <http://apps.fs.fed.us/Evalidator/tmattribute.jsp>. Surveys were conducted over multiple year periods and data from the most recent survey years was used. According to the database, artificially regenerated stands are those established by planting or artificial seeding.

Curvilinear regression analysis

Based on the 20 years of data, regarding the number of confirmed stands for each year since 1993, 2nd degree and 3rd degree curvilinear regression models were fitted. The number of stands infected with annosum root rot in 10, 20, and 30 years without the implementation of preventive treatment was estimated based on the models.

Results:

Fungicide treatment status in other states

Fungicide recommendations that appeared on state government official websites and current status of fungicide applications by state are summarized in Appendix A. The information about the current status in southeastern US was obtained by the USDA Forest Service Region 8 Forest Pathologist, Michelle Cram. In Region 8 (Southern Region), fungicide treatments are performed in high hazard areas. Region 8 includes Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, South Carolina, Oklahoma, Tennessee, Texas, and Virginia. Well-drained sandy soils are classified as high hazard (Cram, 1998). High hazard sites also include soils with sandy loam textures to a depth of 12 inches (30 cm) or more without poor internal drainage or high seasonal water table (Robbins, 1984). Based on the comments received from the Forest Health staff in other states, all of the fungicide treatments outside of Wisconsin were conducted manually by using primarily Sporax. Although there was awareness and interest in the disease, fungicide treatments were not recommended in other neighboring lake states.

In Canada, the disease has been confirmed in southern Ontario and Quebec. Since borate-based fungicides are not registered in Canada, forest pathologists in Ontario and Quebec are working with a pesticide manufacturing company to develop a biological fungicide based on the fungus, *Phlebiopsis gigantea*.

Pine resource data analysis

Based on the FIA data, Wisconsin was ranked 21st in total acreage of pine resources in the U.S. (Figure 1). The majority of the states with large acreage of pine resources were the states in the south (Appendix B).

Total acreage of pine resources

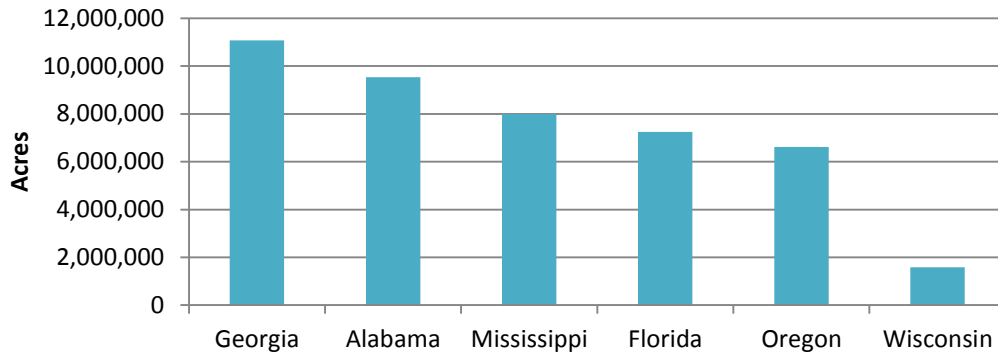


Figure 1: Total area of pine resources (acres)

However, when the acreage of two susceptible pine species groups (red/white/jack pine type and longleaf/slash pine type) was compared, Wisconsin was ranked fourth (Figure 2) (Appendix C). Although the total acreage of pine resources was large, pine resources in many southern states, such as Mississippi, South Carolina, North Carolina, Arkansas, and Texas consisted of species less susceptible to annosum root rot.

Acreage of pine resources

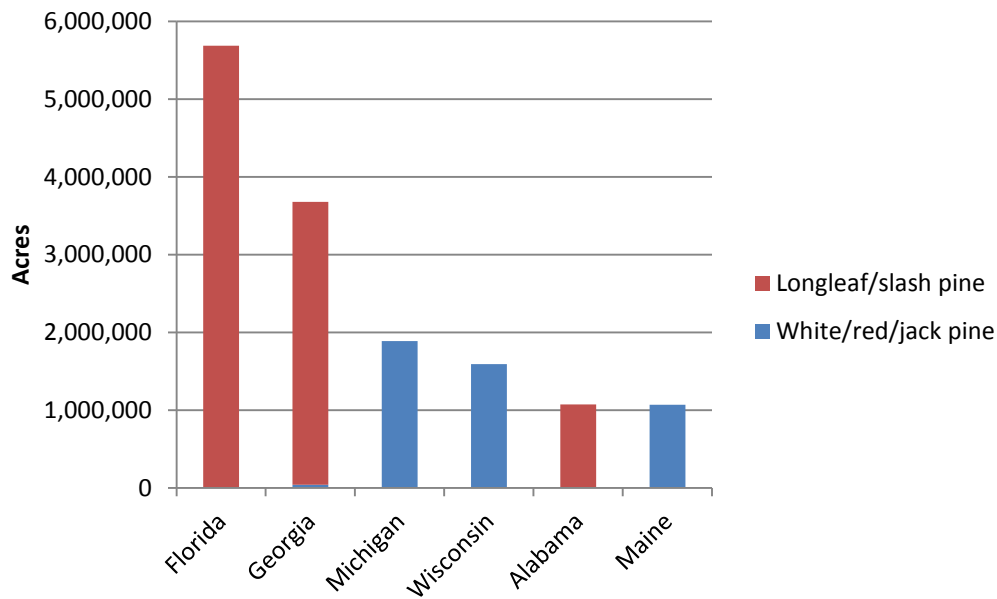


Figure 2: Area of white/red/jack pine and longleaf/slash pine (acres)

In Wisconsin, mortality of overstory mature red, white, and jack pines has been observed. Acreage of white/red/jack pine forest type was approximately 1.6 million acres in Wisconsin and ranked 2nd to Michigan (Figure 3) (Appendix D). According to the FIA data, approximately 2/3 of the red, white, and jack pine timberland in Wisconsin is privately owned. The second largest portion of red, white, and jack pine timberland is owned by counties and municipalities, which accounts for 19% of the ownership. Only 8% is owned by the state government and 9% is found in National Forests.

Acreege of red/white/jack pine

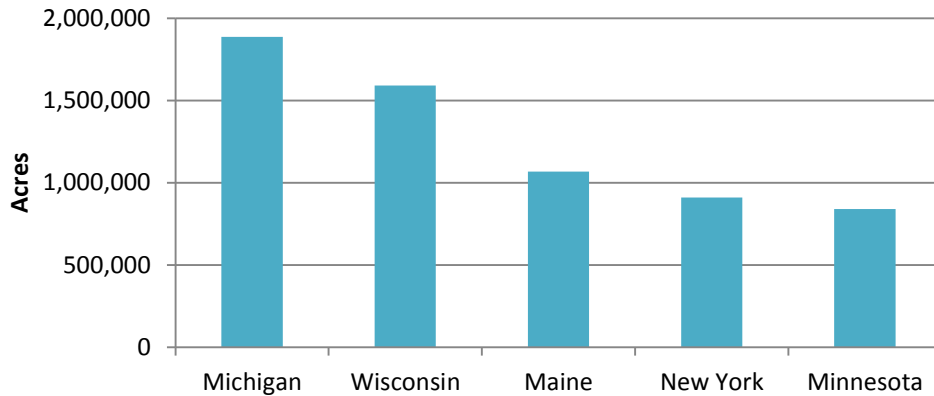


Figure 3: States with large white/red/jack pine resource

In the northeastern U.S., red pine is considered the most susceptible commercially valuable pine species. Wisconsin, Michigan, and Minnesota contain approximately 88% of the red pine resource in the United States (Figure 4) (Appendix E). States such as Maine and New York have a large amount of pine resource that is classified as red, white, and jack pine forest group type, but a very small portion of it is red pine. Wisconsin has approximately three-quarters of a million acres of red pine stands and more than three-quarters of them are considered to have a plantation origin. The majority of red pine acreage in most states is comprised of artificially regenerated stands.

Total acreage of red pine

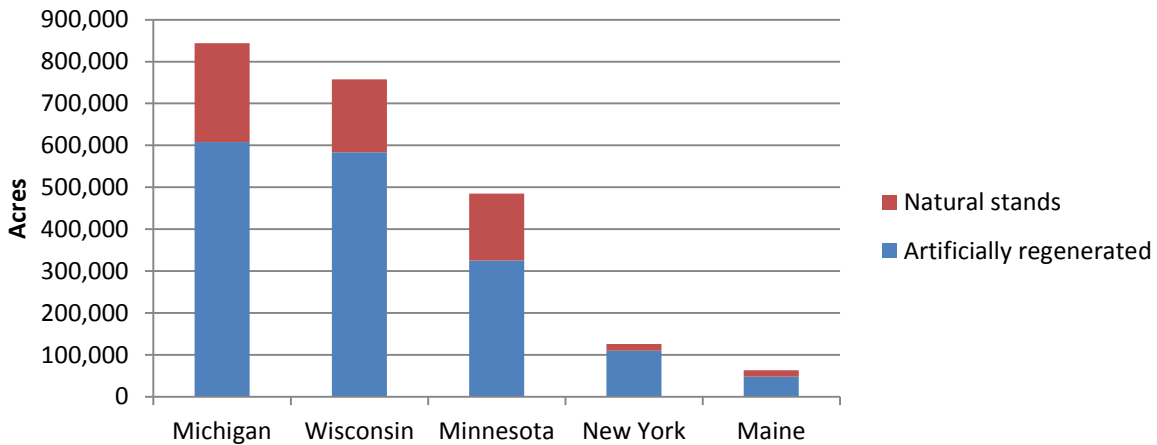


Figure 4: Area of red pine showing percentage of artificially regenerated stands

More than half of the red pine stands in Maine and Pennsylvania were 30 years of age or younger, whereas more than 2/3 of the red pine stands in other states, including Michigan, Minnesota, and Wisconsin, were older than 30 years (Figure 5) (Appendix F). In Wisconsin, 83% of the red pine is between 16 and 70 years old.

Percentage of red pine by age class

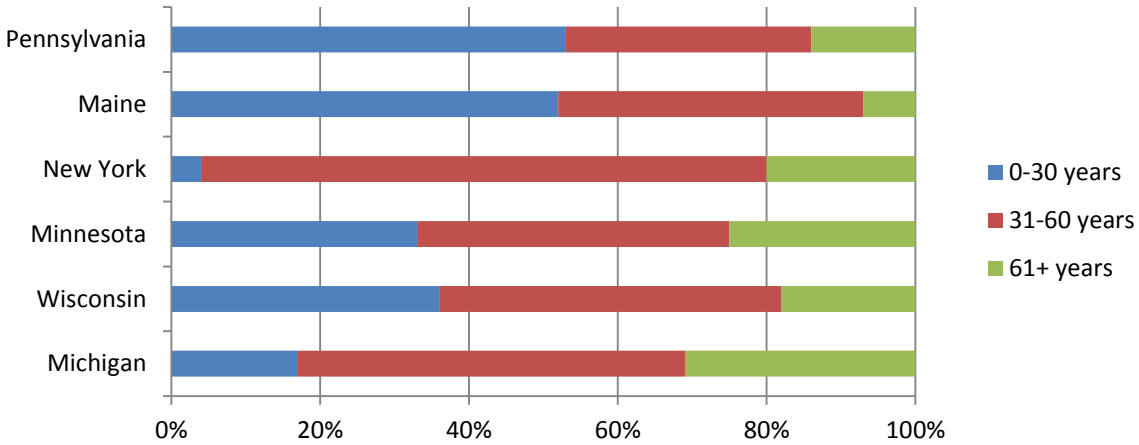


Figure 5: Percentage of red pine acreage by stand age class

Currently annosum root rot is found in 60 stands in 23 counties. Every year, more stands are found with the disease within the counties where the disease has been confirmed (Figure 6). Almost every year, the disease is found in a new county as well. Since the first find in 1993, only 10 stands were confirmed with the disease for the first 10 years. However, from 2003 to 2012, additional 50 stands have been confirmed with the disease.

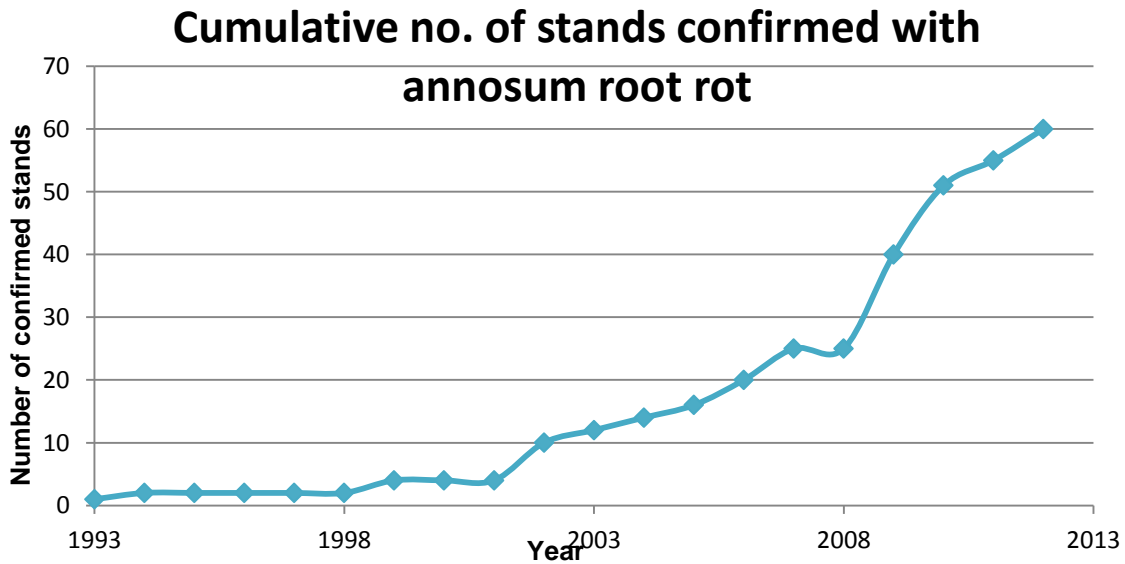


Figure 6. Cumulative number of confirmed stands of annosum root rot

Based on the actual data of the number of confirmed stands each year for 20 years (1993-2012), 2nd degree and 3rd degree curvilinear regression models were fitted (Figure 7). The number of stands infected with annosum root rot in 10, 20, and 30 years without the implementation of preventive treatment was estimated based on the models was shown in

Table 1. Rsquare of both 2nd degree and 3rd degree polynomial fit models was 0.93 and P value was less than 0.0001.

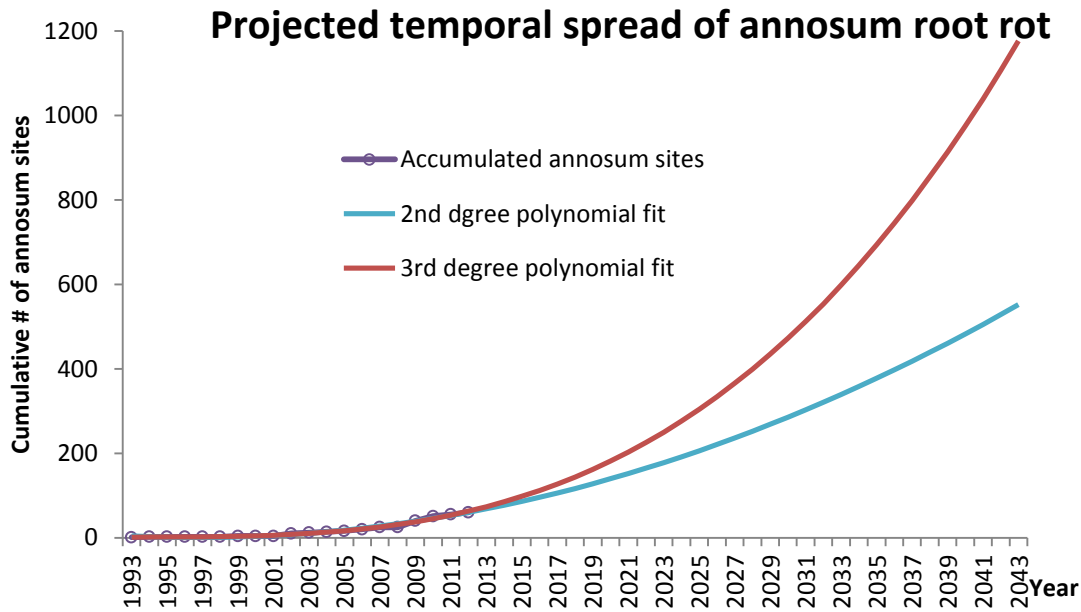


Figure 7. Projected increase in the number of the stands with annosum root rot

	2 nd degree polynomial projected no of confirmed stands	3 rd degree polynomial projected no of confirmed stands
Projected 2022	165	226
Projected 2032	321	554
Projected 2042	552	1177

Table 1. Projected number of stands confirmed with annosum root rot in 10, 20, 30 years

Conclusion: Although Wisconsin was ranked 21st in total acreage of pine resources in the U.S., Wisconsin was ranked fourth in the acreage of susceptible pine species. It was interesting to hear that fungicide treatment is seldom recommended in Texas because they plant loblolly and shortleaf pines instead of slash pine, which is highly susceptible to the disease. Planting less susceptible pine species can be one of the management options if there are more resistant species that could suit the site and economic needs. However, in Wisconsin, all of the native pine species (red, jack, white) are considered susceptible to annosum root rot.

In the northeastern U.S. red pine is considered the most susceptible commercially valuable pine species. Wisconsin has approximately three-quarters of a million acres of red pine stands and more than three-quarters of them are considered to have a plantation origin. Based on the analysis of pine resources, the disease could have a significant impact in the states with a large acreage of red pine, such as Michigan, Minnesota, and Wisconsin.

More than half of Maine and Pennsylvania’s red pine resource is younger than 30 years of age. States such as Wisconsin with a higher percentage of red pine that has reached thinning age are more susceptible to annosum root rot infection. It is noteworthy that the Forest Health staff in Maine are concerned about the potential for the disease to substantially increase in the very

near future because many plantations of red pine in Maine were established on industry lands during the 1970's and 80's and they have reached the necessary size for commercial thinning.

The number of stands found with the disease has increased 5 times for the recent 10 years (2003-2012) compared to the first 10 years (1993-2002) since the first confirmation in Wisconsin in 1993. This increase is partly due to increased awareness by foresters, loggers, and landowners. However, considering that detection efforts for annosum root rot by the WI DNR Forest Health Protection date back to 1963, it is hard to believe that all infested stands were overlooked previous to the first find in 1993. Based on the recent phylogeographic study (Linzer et al. 2008), the pathogen moved from Eurasia into North America via the Beringian land bridge. The fungus may have existed in low population for a long time in natural stands in Wisconsin. It is possible that pine management in plantations with multiple thinnings has played a major role in the increased susceptibility to the disease in Wisconsin in recent decades. The projections for the spread of this disease based on the regression models are alarming. Since the disease is often found three to eight years after thinning, it may take up to 10 years or more before the effect of treatment becomes noticeable at the landscape level.

In conclusion, annosum root rot could pose a serious impact if 1) a state possesses a large acreage of susceptible pine resources, such as red, white, and jack pines, but especially red pines, 2) susceptible pine resources are in high demand economically, 3) pine resources are maintained high density without non-susceptible species mixed in (such as plantation setting), 4) stand management includes multiple thinning to produce high quality timber and 5) pines are grown in sandier soils. States with a large acreage of red pine plantations that have entered thinning such as Wisconsin, Michigan, and Minnesota are in need of assessing potential risk and incorporating proactive management regime plans to reduce the risk of loss of pine resources to this disease.

Wisconsin's forest products industry is an important part of the state economy. There are more than 1,300 forest products related companies in Wisconsin with more than 52,000 workers employed. The majority of the Wisconsin forest products industry's needs are supplied by Wisconsin forests: over 90% of the wood harvested in Wisconsin is used by Wisconsin manufacturers. Wisconsin is the number one papermaking state in the nation. More than 5.3 million tons of paper and over 1.1 million tons of paperboard are produced annually. The papermaking industry provides more than 40,000 jobs in Wisconsin.

Pines are in high demand for quality paper production as well as utility poles, posts and lumber. It is estimated that approximately 20% of the species harvested in Wisconsin are pines. Based on the latest FIA data, there are 610 MMCF (1,000,000 cubic feet) of pole size and 2,128 MMCF of sawlog size pine resources (jack, red, and white pines) in Wisconsin. In 2008, approximately 15,000 MCF of red pine sawlogs and similar volume of red pine pulpwood were produced in Wisconsin. In addition, approximately 520,868 cords of pine is annually harvested in Wisconsin. About 408,503 of those cords are red pine. Pine plantations generate revenues for public and private entities.

The data presented in this document emphasizes the importance of protecting our pine resources in Wisconsin from annosum root rot. Situations in other states should not be used as an excuse not to take a proactive approach to minimize the damage to our pine resources by annosum root rot in Wisconsin. Our state offers the unique assets of pine resources that the state economy and the citizens of Wisconsin rely on. Prompt development and implementation of a scientifically-sound and operationally-practical treatment guide should be sought to protect our pine resources.

Appendix A: Status of fungicide applications to prevent annosum root rot (ARR) in other states

State	Recommendations	Current status	Information source
Alabama	To prevent ARR, treat stumps with borax whenever thinning in a high hazard area	Treatment is done in high hazard areas in Region 8. Applications are done manually. (Information from USDA FS R8 Forest Pathologist, Michelle Cram)	Alabama Forestry Commission website http://www.forestry.state.al.us/annosus_root_rot.aspx?bv=3
California	Chemical treatment of the freshly cut stump surface with Sporax to prevent stump surface colonization is used in California and elsewhere.	Applications are done in federal lands (2006 publication). Unknown on other lands.	California Dept. of Forestry and Fire Protection website http://ceres.ca.gov/foreststeward/pdf/treenote6.pdf Forest Service website http://srs.fs.usda.gov/pubs/ja/ja_otrosina020.pdf
Florida	In disease-free stands on high hazard sites, the application of appropriately registered, granular or soluble borax to fresh-cut stump surfaces during thinnings or other partial cuts may be warranted to prevent in residual trees.	Treatment is done in high hazard areas in Region 8. Applications are done manually. (Information from USDA FS R8 Forest Pathologist, Michelle Cram)	Florida Dept. of Agriculture and Consumer Services http://www.freshfromflorida.com/pi/enpp/pathology/pathcirc/pp398.pdf
Georgia	The connection between thinning and subsequent infection has focused on treating stumps to prevent or control ARR	Treatment is done in high hazard areas in Region 8. Applications are done manually. (Information from USDA FS R8 Forest Pathologist, Michelle Cram)	Georgia Forestry Commission website http://www.gatrees.org/forestmanagement/annosumroot.cfm
Maine	Maine Forest Service recommends stump treatments	Actual treated acres are limited, probably under 100 acres per year. The disease is considered a moderate problem, with the potential to substantially increase in the very near future. Many plantations of red pine were established on industry lands during the 1970's and 80's. They have entered a size for commercial thinning.	Personal communication with William D. Ostrofsky, Forest Pathologist, Maine Forest Service
Michigan	No treatments are being recommended at this point.	"Annosum was confirmed in Michigan several years ago but, until last summer, it had never been found within the natural range of our red and jack pine type. At this point it's been confirmed in two red pine stands (one private, one state) in the northern Lower Peninsula. Our plan is to continue delimitation surveys this year to determine distribution of the disease in Michigan. We are keeping our	Personal communication with MI DNR forest health staff (Roger Mech)

		foresters, consultants, industry folks, etc. abreast of our findings, of the potential impacts if Annosum is determined to be widespread here, and of the treatment options”.	
Minnesota	No treatments are being recommended at this point since ARR has not been confirmed in Minnesota.	“I don’t think either Sporax or Cellu-treat is registered for use in Minnesota at this time. We haven’t developed any plans as to what we will do when we find annosum here, although Jana and I have been thinking and talking about that for a couple years now. I think we would want to have stumps treated once it shows up here. We need to talk about it and start to develop a plan”.	Personal communication with MN DNR forest health staff (Mike Albers)
Mississippi	On disease free sites, protect the host by treating stumps with products containing the active ingredients boron sodium oxide or tetrahydrate immediately after trees are cut	Unknown	Mississippi State University http://msucares.com/lawn/tree_diseases/416annosum.html
New Hampshire	Recommended on the rare occasions	Due to organic soils, the disease rarely expands larger than ¼ acre. Treatment was made on stumps around the major road and visible areas where post-harvest tree mortality would be problematic in a busy state park.	Personal communication with Kyle Lombard, Forest Health Program Coordinator, the NH Division of Forests and Lands)
North Carolina	Hazard areas have been used in management. Stump surface may be treated with several chemicals.	Treatment is done in high hazard areas in Region 8. Applications are done manually. (Information from USDA FS R8 Forest Pathologist, Michelle Cram)	North Carolina State University website http://www.cals.ncsu.edu/course/pp318/profiles_mirror/annosum/arm.htm
Rhode Island	Unknown	Annosum root rot is a lesser problem because most red pine plantations have been harvested.	Personal communication with Bruce Payton, Supervising Forester, Rhode Island Division of Forest Environment
Texas	Thinning on high ARR Hazard Soils: Always cover freshly cut stumps with at least 1/8” of borax within 24 hours of harvest	This practice is seldom recommended these days, since we stopped planting slash pine (an exotic) in East Texas, and loblolly and shortleaf are less susceptible to the disease. Personal communication with the Texas Forest Service forest health staff (Ron Billings)	Texas Forest Service website http://txforestservice.tamu.edu/uploadedFiles/Landowners/Annosus%20Root%20Rot%202.pdf
Vermont	Unknown	Rarely performed. A few consulting foresters insist on it.	Personal communication with Barbara Burns,

		Treatment has been conducted on state lands.	Forest Health Program Manager, Vermont Division of Forestry
Virginia	Stump treatment to prevent ARR infections on high hazard sites	Unknown	Virginia Dept. of Forestry website http://www.dof.virginia.gov/health/intro-forest-health.htm

Appendix B: Pine resources by state (acres)
(Only the top states with pine resources are shown in the table)

State	White/Red/Jack Pine	Longleaf/Slash Pine	Loblolly/Shortleaf Pine	Ponderosa Pine	Western White Pine	Lodgepole Pine	Total
Georgia	41,104*	3,638,021	7,388,550				11,067,675
Alabama	6,015*	1,068,091	8,453,381				9,527,487
Mississippi		774,682	7,221,237				7,995,919
Florida		5,685,182	1,560,403				7,245,585
Oregon				4,897,942	16,134*	1,707,195	6,621,271
Montana				2,764,007		3,506,210	6,270,217
South Carolina	15,582*	523,246	5,531,165				6,069,993
North Carolina	127,278	310,208	5,392,499				5,829,985
Louisiana		792,280	4,942,165				5,734,445
Arkansas			5,515,751				5,515,751
Texas		150,483	5,140,585				5,291,068
Idaho				1,389,609	45,252*	1,683,418	3,118,279
Virginia	164,118		2,918,279				3,082,397
Colorado				1,574,400		1,433,564	3,007,964
Arizona				2,871,215			2,871,215
Washington				1,916,590	18,052*	564,573	2,499,215
New Mexico				2,400,391			2,400,391
California				1,965,214	47,732*	333,609	2,346,555
Wyoming				1,051,054		1,230,979	2,282,033
Michigan	1,886,347						1,886,347
Wisconsin	1,590,215						1,590,215

(* denotes sampling error greater than 25%)

Appendix C: States with large area of white/red/jack pine and longleaf/slash pine resources

State	White/Red/Jack Pine	Longleaf/Slash Pine	Total
Florida		5,685,182	5,685,182
Georgia	41,104*	3,638,021	3,679,125
Michigan	1,886,347		1,886,347

Wisconsin	1,590,215		1,590,215
Alabama	6,015*	1,068,091	1,074,106
Maine	1,068,063		1,068,063
New York	909,053		909,053
Minnesota	840,418		840,418
Louisiana		792,280	792,280
Mississippi		774,682	774,682
South Carolina	15,582*	523,246	538,828
New Hampshire	532,219		532,219
North Carolina	127,278	310,208	437,486
Massachusetts	402,320		402,320
Vermont	399,624		399,624
Pennsylvania	339,341		339,341
Virginia	164,118		164,118

(* denotes sampling error greater than 25%)

Appendix D: States with large white/red/jack pine resources

State	White/Red/Jack Pine (Acres)
Michigan	1,886,347
Wisconsin	1,590,215
Maine	1,068,063
New York	909,053
Minnesota	840,418
New Hampshire	532,219
Massachusetts	402,320
Vermont	399,624
Pennsylvania	339,341
Virginia	164,118
North Carolina	127,278

(* denotes sampling error greater than 25%)

Appendix E: Area of red pine by state (acres)

	Total Red Pine	% Artificial Regeneration
Michigan	844,254	72%
Wisconsin	757,665	77%
Minnesota	485,058	67%
New York	126,068	87%
Maine	63,399*	75%

Pennsylvania	24,454*	100%
Indiana	17,974*	82%
Maryland	10,193*	100%

(* denotes sampling error greater than 25%)

Appendix F: Percentage of red pine by age class

	0-30 years	31-60 years	61+ years
Michigan	17%	52%	31%
Wisconsin	36%	46%	18%
Minnesota	33%	42%	25%
New York	4%	76%	20%
Maine	52%	41%	7%
Pennsylvania	53%	33%	14%
Indiana	0%	61%	39%
Maryland	0%	100%	0%

Reference:

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