ANNUAL REPORT

Minnesota Tree Improvement Cooperative

January 1-December 31

2011

C. Pike, Coordinator
J. Warren, Research Fellow
A. David, Director

FULL MEMBERS

Beltrami County
Cass County
Crow Wing County
Iron Range Resources & Rehabilitation Board
Koochiching County
Minnesota Department of Natural Resources
Plum Creek Timber Company
Red Lake Nation
St. Louis County
University of Minnesota Department of Forest Resources
UPM-Blandin

SUPPORTING MEMBERS

Carlton County
Clearwater County
Hedstrom Lumber Company
Hubbard County
Itasca Greenhouse, Inc.
Lake County

Department of Forest Resources
College of Food, Agricultural and Natural Resource Sciences
University of Minnesota

Cover photo credits:
Top left: Red pine graft at the MN DNR General Andrews Tree Nursery in Willow River Minnesota. Photo by C. Pike

Lower right: Roguing work at second-generation jack pine population managed by Crow Wing County / MN DNR south of Brainerd. Blue paint marks trees selected to "keep." Photo by C. Pike

EXECUTIVE SUMMARY

The Minnesota Tree Improvement Cooperative completed its 30th year in 2011 with eleven full members and six supporting members. Dues payments in the amount of $55,361 were collected, which included the contract with the Minnesota Department of Natural Resources. During 2011, Andrew David directed the Co-op while Carrie Pike managed day to day activities. Jim Warren provided field and technological assistance, and Egon Humenburger provided field assistance on projects related to white pine. A jack pine symposium was held in partnership with the Sustainable Forests Education Cooperative at the Cloquet Forestry Center on January 18, with over 100 people attending. Two business meetings were held: January 13 at the Cloquet Forestry Center and March 24th at the North Central Research and Outreach Center in Grand Rapids. A grafting 'party' was held at General Andrews Nursery in Willow River to graft jack pine and red pine on March 16th.

In 2011, priorities included planting new grafted orchards, collecting full-sib red pine cones, and continued work in Tofte on white pine. Cone collections from jack pine, white spruce and white pine orchards were made. Jack pine and red pine were grafted at Willow River, and slow rusting white pine phenotypes were grafted at the Forest Genetics lab in Grand Rapids. Site preparation on two sites for the white pine disease garden trial began.

Pike's PhD research continued with a second winter warming treatment applied in winter 2011, and a third sampling from a biomass study to investigate root:shoot ratios on improved and woods run white spruce. Completion date for Pike's PhD is anticipated for 2012.

Additional controlled pollinations of red pine are planned. Thinning will commence at the 2nd generation jack pine populations in St Louis County / IRRRB to facilitate cone collections. Site preparations for a white pine disease garden, progeny test, collection of Tofte slow rusting phenotypes and Ahlgren materials are underway. Site preparation towards the establishment of new red and jack pine orchards for MN DNR, Beltrami County, and Crow Wing County is ongoing. In early spring 2012, prior to budbreak, five-year tree heights should be measured on the 2008 red pine comparison trial at four sites. A new white pine disease garden will be established. Extra seedlings from Pike's white spruce research will be planted as a demo site at CFC. Field measurements for 2012 include: 20-year heights and diameters on four white spruce comparison trials established in 1993, 10-year heights and diameters on four white spruce comparison trials established in 2003, and 10-year tree heights on three 2nd generation white spruce sites. Sites for a future white pine progeny test will be finalized, and seed will be sent to a grower. Staff will assist the USDA Forest Service with their ongoing white pine blister rust screening as needed. A 30th year anniversary celebration is being planned for 2012.

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A LETTER FROM THE DIRECTOR

Dear Cooperative Members,

In 2011 the Minnesota Tree Improvement Cooperative marked the 30th year of service to its member organizations. I would like to thank all the cooperators past and present for their support throughout the years, and remind you that we will celebrate our 30th anniversary later this summer. Look for details in an upcoming monthly report.

In the past year the MTIC, like other forestry cooperatives throughout North America, experienced changes in membership that negatively impacted income. Additionally, the Minnesota legislature effectively limited the Department of Natural Resource nursery program's seedling sales. Although the long-term impact of these changes for the MTIC and forest productivity in Minnesota is yet to be determined, in the short-term we have been exploring ways to minimize the potential impacts.

On a positive note the Minnesota DNR was able to renew its dues contract at a slight increase, although not enough to offset other losses in membership dues. In the field this year we finished the analysis of the 2nd generation jack pine populations and began thinning them for genetic gain and genetic diversity. We established three new red pine seed orchards and one new white pine seed orchard using selected parents from our improved orchards. Plus we have experienced a breakthrough in our red pine grafting program that in the future will allow us to move from selections to seed orchards faster with greater survival.

Next year promises to be an extremely busy field season. Highlights include collecting jack pine pollen to breed our 3rd generation jack pine populations, and red pine pollen to create an advanced generation red pine population and an inbreeding trial. The white pine disease garden trial will be established on two sites and the white pine slow-rusting phenotype selections from Tofte will be planted at the Cloquet Forestry Center. In late summer, early fall we will be measuring various red pine and white spruce comparison trials throughout the state to get an estimate of realized genetic gain in these two important species.

Thank you for your continued support of the MTIC and forest productivity in the state of Minnesota.

Sincerely,

Andy David

Andrew David
Associate Professor
Director MTIC

INTRODUCTION

In 2011, the Minnesota Tree Improvement Cooperative (MTIC) completed its 30th year of operation! Congratulations to all the members, past and present, for their tenacity and support. Unfortunately, 2011 was not a great year for the MTIC because of a decline in membership, due primarily to the loss of one major industry member, Potlatch Forest Holdings, Inc. In addition, the future operations of the state nursery program were reduced considerably in the State legislative session. This occurred in the same year as a state government shutdown over a budgetary stalemate that lasted approximately three weeks in July. On a good note, the DNR slightly increased their membership dues to the MTIC for FY12. In spite of the lackluster economy, members of the Cooperative made significant steps in advancing their tree improvement programs. The first grafted red pine orchards were established at three sites; the first full-sib seed from a red pine breeding program were collected; thinning of the second-generation jack pine population at Crow Wing county was completed. Cone crops were generally below average across all species in 2011, but cones were collected for jack pine and white spruce. The development of new orchards and improvement of established orchards ensures an increase in seed production for the future.

Pike continued her PhD research toward a Natural Resources Science major through the Forest Resources Department at the University of Minnesota with completion anticipated sometime in 2012. A second warming treatment was applied in winter 2011, replicating the same experiment that was done in 2010. A third sample of a biomass trial comparing improved and woods run sources of white spruce was conducted, with results presented at two separate professional meetings in 2011. See the Appendix for a summary of progress to date.

This report summarizes activities and accomplishments from January 1 to December 31, 2011. It is organized into five major sections: Administration, Finances, Seed Orchards, Species Reports, and Outlook. An Appendix, containing progress reports from current and future projects that involve MTIC staff or resources, follows the Outlook section. The summaries provided have not been peer-reviewed or published, and thus the results are subject to change upon final analysis.

ADMINISTRATION

The MTIC operates under the leadership of Andy David (Director / Associate Professor), Carrie Pike (Research Fellow / Coordinator) and Jim Warren (Research Fellow). Egon Humenburger (Assistant Scientist) assists on projects as needed. Andy and Egon are based at the North Central Research and Outreach Center (NCROC) in Grand Rapids.

The Advisory committee formally met twice in 2011. This committee consists of representatives from each member organization and meets to facilitate feedback and communication between members and staff. Each summer, staff attempt to visit all operating seed orchards and periodically visit trials and tests. In January 2011, MTIC co-hosted a jack pine symposium with the Sustainable Forests Education Cooperative (SFEC) at the Cloquet Forestry Center. Pike developed the agenda, contacted speakers, moderated the meeting, and presented a paper titled "Jack pine: proposed seed zones in a brave new world." Pike presented a research paper at the SFEC annual research review at Cloquet on Feb 22. Pike attended a five-day workshop entitled "Genetic Analysis in Tree Breeding" in Raleigh, North Carolina May 16 – 20. Tuition and lodging for the training were covered with a scholarship provided to select graduate students by the Conifer Translational Genomics Network Project. Pike attended the annual meeting of the Canadian Forest Genetics Association in Thunder Bay, August 15-19. Pike assisted USDA Forest Service's Oconto River Seed Orchard (ORSO) Manager Carrie Sweeney with scoring white pine seedlings at (ORSO) from September 6-9. The seedlings that were surveyed had been inoculated with rust in 2010 and out-planted outside at ORSO for study. Over 40 different genotypes from the USDA Forest Service orchard were included in this trial. Some of these genotypes have been grafted into MTIC orchards. Nearly all of the Forest Service genotypes that occur in MTIC orchards will be screened in the next few years.

In 2011, seven articles were submitted to "My Minnesota Woods" with the intention of educating private landowners about the value of seed source control and the tree improvement program. Hopefully in the future, cooperative membership can be increased

through the addition of private greenhouses that serve the public's seedling needs, or by other organizations that work directly with private landowners (i.e. Extension, MFA, etc.). The following articles were submitted towards that effort and are online at http://www.myminnesotawoods.umn.edu/

May 2011: **C. Pike**. *What is an improved tree?*
June 2011: **A. David.** *Comparing and contrasting plant hardiness and seed zones.*
July 2011: **C. Pike.** *Do conifers flower?*
September 2011: **A. David.** *Four keys to successful seed collection.*
October 2011: **C. Pike.** *A guide for landowners to improve growth and survival of eastern white pine, Minnesota's "favorite" tree.*
November 2011: **A. Obenchain**. *Can introducing genetic resistance help manage blister rust in eastern white pine?* Ontario Ministry of Natural Resources' Ontario Forest Research Institute.
December 2011: **C. Pike.** *Trees can run?! Ensuring healthy, productive future forests in Minnesota*.

Other article submissions in 2011:
Pike, C. *Seed matters: tree seed, tree improvement and you*. Tree Farming for Better Forests, spring edition.
Pike, C. *Your genetics program: a tool to increase reforestation success in a future climate*. DNR Roots publication.

Presentations in 2011:
Pike, C. August 16. POSTER: *Proposed seed zones for jack pine in a brave new world*. Canadian Forest Genetics Association, Lakehead University, Thunder Bay Ontario. (Currently on display at the Cloquet Forestry Center.)
Pike, C. August 16**.** *Do selected families of white spruce partition biomass differently from unselected local sources?* Canadian Forest Genetics Association, Lakehead University, Thunder Bay Ontario.
Pike, C. February 22**.** *Do selected families of white spruce partition biomass differently from unselected local sources?* SFEC / SAF sponsored Research Review at the University of Minnesota's Cloquet Forestry Center.
Pike, C. January 25**.** *Genetics, climate change and implications for reforestation in the future.* Invited speaker at MN DNR, 500 Lafayette Pl., St Paul MN.
Pike, C. January 18. *Jack pine – Proposed Seed Zones in a Brave New World.* SFEC / MTIC sponsored Jack pine symposium at the University of Minnesota's Cloquet Forestry Center.

FINANCES

Funding for the MTIC comes from several sources. Membership dues (renewed annually) and the two-year contract with the Minnesota Department of Natural Resources account for just over 50% of all funding (Figure 1). A full seventy-five percent of dues payments were collected from public agencies, including state and county.

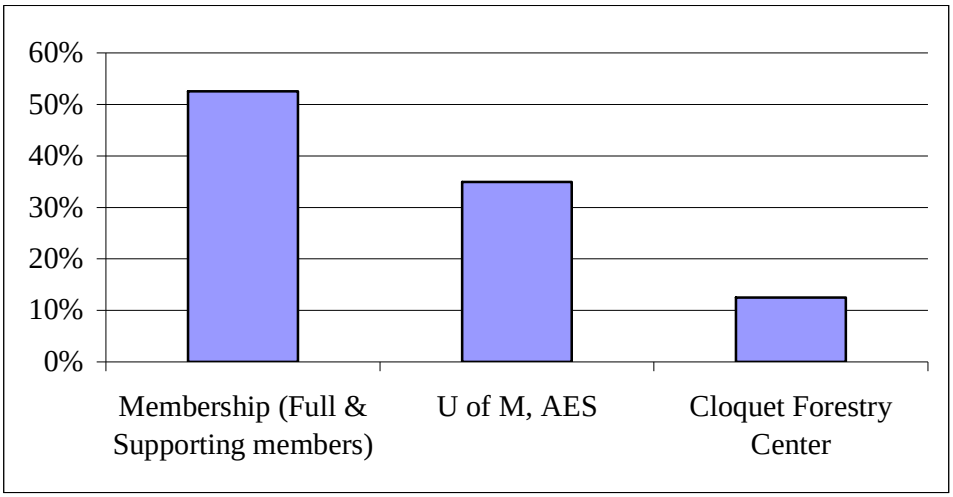

Figure 1. Income sources as a percentage of total income received for Minnesota Tree Improvement Cooperative during FY11 (July 1, 2010 through June 30, 2011).

Seed orchards

Seed collections from orchards in 2011 were down from the past years for three main reasons: cone and seed insects are over-populating orchards, orchards are overcrowded, and 2011 was a lackluster cone year. In addition, cones on older orchards are not easily reached from the ground and require outside equipment for picking. Overcrowding decreases light and results in lower cone production. Thinning would help alleviate this problem. New orchards established in the last few years are not yet up to production. Our techniques for grafting red and jack pine have improved, and three new grafted red pine orchards, one new white pine orchard, and one new jack pine orchard were established in 2011. Seed production from all orchards will need to increase to meet future demand.

The acres of orchards listed in Table 5 were reduced to reflect current membership. New grafted red pine orchards were added. The grafted jack pine orchard in Crow Wing was not included because of the low survival of grafts.

Table 6 shows the current status of all *Picea* orchards, and Table 7 shows all *Pinus* and *Larix* orchards. All 'active' research trials related directly to the MTIC are shown in Table 8. All trials that will require measurements in 2012 field season are highlighted.

Table 1. Acres of seed orchard by species and orchard type.

Orchard Type	*Black spruce*	*White spruce*	*Jack pine*	*Red pine*	*White pine*	*Tamarack*	*Total acreage*
First Generation Clonal	8	16	---	---	11	---	34
First Generation Seedling Seed	5	4	24	26	---	4	63
Improved First Generation Clonal	---	10	---	3	---	---	13
Second Generation Full Sib	4	11	6	---	---	---	21
Total acreage by species	***16***	***40***	***30***	***29***	***11***	***4***	***130***

Table 2. *Picea* spp seed orchards actively managed by the MTIC.

Species	*Orchard Type*	*Organization*	*Planting*	*Date Planted*	*Size (ac)*	*Live Trees*
Black spruce	1st Gen. Seedling	Minnesota DNR	Eaglehead	17-May-78	2.7	487
		Blandin Paper Company	Blackberry	22-May-78	2.5	596
		U of M CFC	Plantation "U"	22-May-78	2.5	
	1st Gen. Clonal	U of M CFC	Airport 40	01-May-95	1.1	238
	Improved 1st Gen. Clonal	Koochiching	Big Falls	19-May-89	2.3	61
		Koochiching	Larsaybow	27-May-98	4.0	59
		Minnesota DNR	Sturgeon Lake	01-May-79	1.3	812
		Minnesota DNR	Split Rock	27-May-92	2.4	262
			Totals:	***8 Orchards***	***16.4***	***2,253***
White spruce	1st Gen. Clonal	Lake County	Two Harbors	02-Sep-87	1.0	182
		Minnesota DNR	Cotton	01-May-77	12.0	206
		St. Louis County	Ellsburg Rd.	11-May-88	1.5	189
		UPM-Blandin	Arbo	01-May-76	1.5	121
	1st Gen. Seedling	UPM-Blandin	Latimer	15-May-67	4.1	224
	1-1/2 Gen. Clonal	Minnesota DNR	Split Rock	02-Sep-01	3.7	255
		Carlton County	Gillogly Road	01-Apr-03	2.1	78
		Red Lake	Redby	01-Apr-04	0.9	157
		UPM-Blandin	College	05-Sep-00	2.9	780
	2nd Gen. Seedling	Lake County	Ostman Pit Road	06-Jun-05	1.3	818
		Itasca County	Wabana Lake	20-May-03	1.8	693
		Minnesota DNR	Eaglehead	03-Jun-03	1.8	401
		Minnesota DNR	Eaglehead	01-May-05	1.3	764
		St. Louis County	Ellsburg Rd. East	06-Jun-03	2.1	393
		UPM-Blandin	Feeley	01-May-05	2.4	900
			Totals:	***15 Orchards***	***40.4***	***6,161***

Table 3. *Pinus* spp and *Larix laricina* orchards actively managed by the MTIC.

Species	Orchard Type	Organization	Planting	Date Planted	Size (ac)	Live Trees
Jack pine	1st Gen. Seedling	Cass / Beltrami/ Hubbard Counties	Deep Portage	08-Oct-82	3.4	492
		Crow Wing County	Crow Wing	04-Jun-85	2.1	247
		Iron Range Resources	Calumet	16-Sep-82	1.7	220
		Minnesota DNR	Longprairie	18-May-84	4	465
		Minnesota DNR	Nickerson	15-May-84	2.4	387
		Carlton County	Gillogly Rd.	28-Jun-83	5.5	183
		Red Lake Nation	Redby	29-Apr-87	1.8	516
		St. Louis County	Ellsburg Rd.	10-May-88	1.6	279
	2nd Gen. Seedling	Crow Wing Co. / MN DNR	County Line	01-May-99	2.6	1264
		St. Louis / Iron Range Resources	Ellsburg Rd. East	12-May-99	3.78	2064
			Totals:	***10 Orchards***	***28.9***	***6,117***
White pine	1st Gen. Clonal	Itasca Greenhouse	Sayward	16-Jun-05	0.8	401
		Minnesota DNR	Split Rock	25-May-93	1.0	88
		Minnesota DNR	St. Francis	15-May-85	3.0	319
		St. Louis County	Ellsburg Rd.	02-May-90	1.1	233
		St. Louis County	Ellsburg Rd. East	21-Jun-99	2.5	237
			Totals:	***5 Orchards***	***8.4***	***1,278***
Red pine	1st Gen. Seedling	Cass / Beltrami/ Hubbard Counties	Blind Lake	10-Sep-91	5.3	400
		Minnesota DNR	Cotton	29-Jul-81	4.5	462
		Minnesota DNR	Eaglehead	25-Jun-81	3.6	128
		Carlton County	Gillogly Rd.	10-Jul-81	6.6	461
		St. Louis County	Ellsburg Rd.	09-May-88	5.5	531
	1st Gen. Clonal	Carlton County	Gillogly Rd.	01-May-11	0.5	65
		Red Lake Nation	Cooks Rd.	05-May-11	1.3	141
		St. Louis County	Ellsburg Rd. West	01-Jun-11	1.5	153
			Totals:	***8 Orchards***	***28.8***	***2,341***
Tamarack	1st Gen. Seedling	Minnesota DNR	Split Rock	12-May-08	4.3	2,005
			Totals:	***1 Orchard***	***4.3***	***2,005***

Table 8. Active MTIC research trials.

Species	*Planting Type*	*Year planted*	*Organization*	*Planting Name*	*Last measured*	*Next Scheduled*
Black spruce	Full-sib progeny test	1995	U of M	CFC-Airport 40	1995	--
	Comparison trial	2008	Koochiching County	Manitou	2011	2015
White spruce	Comparison trial	1993	Minnesota DNR	Dago Lake Rd	2002	2012
		1993	Plum Creek Timber Company	Gordon	2002	2012
		1993	Blandin Paper Company	Hwy 61	2002	2012
		1995	U of M	CFC-Airport 40	2005	2015
		2003	Koochiching County	Little Fork	2007	2012
		2003	Minnesota DNR	Side Lake	2007	2012
		2003	Potlatch Forest Holdings, Inc.	Brookston	2007	2012
		2003	St Louis County	Jean Duluth Rd	2007	2012
		2003	UPM-Blandin	Wilson Lake	2007	2012
	Progeny test	1986	Lake County	Finland	2005	2015
		1986	Minnesota DNR	Nickerson	2005	2015
		1986	Minnesota DNR	Ross Lake	2008	2015
		1986	St Louis County	Rabbit Lake	2005	2015
		1986	UPM-Blandin	Nine-mile	2005	2015
	2nd generation population	2003	Itasca County	Wabana Lake	2007	2012
		2003	St. Louis County	Ellsburg East	2007	2012
		2003	Minnesota DNR	Eaglehead	2007	2012
		2005	Lake County	Ostman Pit	2010	2015
		2005	Minnesota DNR	Eaglehead	2010	2015
		2005	UPM-Blandin	Feeley	2010	2015
Jack pine	2nd generation population	1999	St Louis / IRRRB	Ellsburg East	2008	--
		1999	Crow Wing / MN DNR	County Line Rd	2008	--
Red pine	Comparison trial	2007	Beltrami County	Lake Bemidji	---	2011
		2007	Potlatch Forest Holdings, Inc.	Lake George	---	2011
		2007	U of M	CFC	---	2011
		2007	St Louis County	NE Grade	---	2011
White pine	Progeny test for blister rust resistance	1999	St Louis County	Ellsburg Rd	2008	--
		1999	USFS	Grand Marais	2008	--
		1999	ORSO	ORSO	2008	--

Cone Collections

In 2011, seed collections for jack pine outnumbered other species. Blandin's College orchard continues to lead production among white spruce orchards. Thinning operations at the Crow Wing / MN DNR 2nd generation population resulted in a large number of cones harvested. Cone crops for red pine, black spruce, white pine and white spruce were low statewide and in Co-op orchards.

Table 9. Cones collected by MTIC members in 2011

Species	*Agency / Industry*	*Orchard*	*# bushels*
Jack pine	Carlton County	Gillogly Rd	18.0
	Crow Wing / MN DNR	County Line Rd	14.0
White spruce	Carlton County	Gillogly Rd	0.3
	Red Lake	Redby	0.3
	UPM Blandin	College	19.6
White pine	St Louis Co.	Ellsburg Rd A & B	12.0
Total number of bushels collected			64.1

SPECIES REPORTS

Picea spp.

Black spruce

Nearly all orchards were visited and cone crops were generally low statewide. A small crop at Blandin's **Blackerry** was not harvested, and few cones were found at Koochiching County's **Big Falls** and **Larsaybow** orchards. The DNR **Eaglehead** site was not visited in 2010. A seedling trial planted in northern Koochiching County on a lowland site was measured but the analysis was not completed by this writing. The black spruce orchards are in good shape even though cones on some orchards are rarely picked. Demand for seed in the future is not likely to wane, so future seed collection areas or seedling-seed orchards should be established to supplement supplies of seed for aerial seeding.

White spruce

This year was a low-cone year, with sparse crops produced on most orchards, except for Blandin's **College** orchard. Young orchards (Red Lake **Redby**, and Carlton County **Gillogly Rd)** are developing well, and a small number of cones were removed from trees for sanitation. Six white spruce grafts, of improved sources, were planted in Koochiching county's Big Falls black spruce orchard to provide a new seed source for the county. The new grafts are planted in an area of the orchard where mortality of the black spruce grafts was high. If the white spruce grafts survive and grow well, then additional grafts may be added in the future. Cone and seed insects are becoming problematic at several orchards, such as DNR **Cotton** and St Louis **Ellsburg Rd**. Management efforts that include sanitation (by removing cones during off-peak years), scarification, and herbicide under the drop zone should be attempted in addition to pesticides.

In summer and fall of 2012, several key trials will need to be measured. MTIC staff will prepare datasheets and arrange for the work to get done, with assistance from each cooperating agency or industry. These include 20th year measurements at four white spruce comparison trials (Potlatch - **Orr**, DNR - **Dago Lake Rd**, Blandin Paper - **Hwy 61**, Plum Creek - **Gordon WI**). Also, 10th year measurements are due at four comparison trials planted in 2003 (Potlatch – **Brookston**, Kooch County – **Little Fork**, St Louis Co - **Island Lake**, Blandin Paper – **Wilson Lake**, MN DNR – **Side Lake**). Finally, ten year measurements are due at three second generation white spruce sites (Itasca – **Wabana Lake**, MN DNR - **Eaglehead**, St Louis – **Ellsburg Rd East**). This list will be prioritized at the March business meeting. We may have some free hands to help this summer thanks to a student-program based at Cloquet, so measurements will likely begin in early August, earlier than previous years.

Pinus* spp. and *Larix laricina

Jack pine

The second generation population at **Crow-Wing County / DNR** is rogued! Next year **St Louis County/IRRRB** will need to start roguing their site. Scion from select trees was collected at MN DNR **Longprairie** orchard in winter 2011. The grafts were planted

alongside the site in Crow Wing County / MN DNR's **County Line** orchard in May to enhance seed production. Unfortunately, many of the grafts failed, probably due to the prevalence of cones that were present on the scion material. In the future, additional grafts should be made and that site filled.

Several first generation seedling orchards are used sporadically for cone collections: IRRRB-**Calumet**, Carlton County-**Gillogly Rd,** and MN DNR**-Long prairie** but should be used more intensively to meet high seed needs in this species**.** Carlton County collected their first ever cone crop at the **Gillogly Rd orchard**. Several first-generation orchards are senescing and may be replaced in the future with advanced second-generation material. These include **St Louis-Ellsburg Rd, Crow Wing County,** Cass-Beltrami-Hubbard's-**Deep Portage**, and MN DNR**-Bemidji.**

In spring 2012, pollen will be collected and stored from the best tree from each family at each second-generation planting for future tree breeding. In the future we will establish grafted orchards (improved second generation orchards), and a third generation population. Finally, open-pollinated seed for a future seed source trial of second-generation sources should be secured in fall 2012.

Red pine

A new slate of red pine grafted orchards was established in 2012 using scion collected from the top trees at the MN DNR-**Eaglehead** red pine orchard. The new clonal orchards are located at St Louis County - **Ellsburg Rd West**, Red Lake-**Cooks Rd**, and Carlton County – **Gillogly Rd**. Red pine grafting had failed in previous years largely due to the failure of grafts to thrive in culture. Through some trial and error we learned that grafts that appeared in-active in the greenhouse respond by leafing out after planting. To improve survival, the rootstock was potted in April, 2010, grafted in March, 2011, and planted in May of that year. These grafts will be monitored closely for survival in 2012.

Seed from controlled crosses that were made in 2010 was picked and stored for a future second-generation population, and for a study to measure the effects of inbreeding on the phenotype of red pine. The cones were largely safe-guarded from cone/seed insects by

mesh bags that were placed on each branch in early spring 2011. In a few cases, angry squirrels were hungry enough to chew holes in the mesh bags to access the cones. The seed will be extracted and stored during winter 2012. Note that these controlled crosses will serve two purposes, 1) creation of a second-generation population using a positive assortative mating design and 2) test the effects of inbreeding on red pine growth. Since the majority of crosses contained fewer than five cones, most crosses will need to be repeated to increase seed numbers. Pollen was collected in 2011 to replicate this effort in the future.

In 2012, all new grafted orchards should be monitored and survival assessed. Sites for new orchards should be located and plans for grafting in 2013 need to be in place. Cooperators who will host future grafted orchards include MN DNR, Cass and Beltrami counties, in partnership with Hubbard County.

As breeding efforts approach completion, sites for these second generation populations will be identified. In the meantime, first-generation orchards should be thinned to alleviate spacing constraints, and cone collections should continue. Efforts to control burgeoning cone and seed insects should continue.

White pine

Progress was made on several fronts in eastern white pine. Red Lake established a new white pine grafted orchard with 241 trees on a well-prepared site. Approximately 45 different genotypes were planted, which included seven plus-trees selected from the Red Lake Reservation. Additional grafts of this material were planted into the CFC breeding arboretum.

Staff at the USDA Forest Service Oconto River Seed Orchard continues to screen approximately 40 open pollinated seedlots annually for resistance to white pine blister rust. Pike assisted Carrie Sweeney (USFS) with scoring trees for rust incidence in fall 2011. Data is being compiled by the Forest Service and will eventually be available to members of the MTIC.

Tofte trial was revisited and many trees re-assessed for the presence of 'slow-rusting' cankers that may be used to develop a separate population of genotypes. Approximately 50

different clones were grafted and will be planted at a site prepared at the Cloquet Forestry Center in spring 2012.

Site preparations will be completed in spring 2012 at two locations for the disease garden. A time-line of events appears in the Appendix. A proposal was provided in the 2010 Annual Report.

Open-pollinated seed for future progeny testing will be sent to a grower in 2012. This progeny test will prioritize the identification of genotypes with superior growth rates instead of rust resistance. One site at St Louis County has been located, and two others are being sought. A grower has not yet been identified.

Mortality survey is also planned for the "lost" progeny test in St Louis County, 989-A, planted in 1990 in collaboration with the USDA Forest Service and St Louis County. In the fall 2011, Jim Warren visited the site with Mark Pannkuk (St Louis County), and Brad Jones (now with Itasca Community College). Monumentation at the site is excellent, and the site will be visited and surveyed again, ideally in early 2012. The seedlings planted in this study had been previously inoculated with rust at Oconto River Seed Orchard. Surviving "canker-free" trees identified after inoculation are planted at this site. Mortality survey will also include presence of rust, and signs of corked-over infections.

Tamarack

The MN DNR established a seed collection area-orchard at the **Split Rock** property near Moose Lake in 2008. Survival is excellent, and tree heights could be measured after five or ten years to measure differences among the 30 sources. Entire blocks may be removed for destructive seed collection in the future, or a lift may be driven down the wide rows for picking. A mortality survey should be conducted in 2012, so that survival can be reported in next year's Annual Report.

OUTLOOK

The economy in 2011 remained sluggish, and the drop in membership rolls forced the MTIC to tap into reserve funds. Carrie's position as Interim Coordinator in early 2012 will help offset salary and fringes, so carry-forward funds are not expected to be tapped in FY12.

In spite of the economic hardship, a series of new grafted orchards reflects optimism for the future reforestation in the state. New red pine, jack pine and white spruce orchards will further enhance seed production. Efforts to reduce cone and seed pests through increased sanitation (removing cones on off-peak years) and scarifying the soil under the drip-line are crucial steps to reduce the build-up of cone and seed pests in orchards.

New laws established in 2011 restrict tree seedling sales at the DNR nurseries to public agencies and designated conservation easements. A new business plan for the state nurseries, to be unveiled in early 2012, will serve as a roadmap for the MN DNR's future tree improvement program. MTIC should reach out to private nurseries to expand membership, and provide new channels to make improved seedlings available to purchase by private landowners.

The MTIC reached a significant benchmark in 2011 thanks to the ongoing support of all members past and present. A celebration is planned for 2012 to commemorate this event.

2012 COOPERATIVE WORK PLAN

White spruce

- Check for current cone crop, pick cones!
- Add more grafts to Big Falls orchard in Koochiching County
- Measure tree heights and diameters on: four comparison trials established in 1993 (20th year measurements), four comparison trials planted in 2003 (10th year measurements), and four second generation white spruce sites planted in 2003.
- Plant grafts residing at General Andrews Nursery (grafted from A and B blocks)

Jack pine

- Collect pollen for breeding in the future.
- Pot-up rootstock for grafting in 2013
- Thinning at St Louis county / IRRRB 2nd generation jack pine orchard.
- Thin out old orchards!

Red pine

- Early spring: five year heights and survival at 2008 comparison trials (CFC, St Louis, Beltrami, Potlatch – Bemidji).
- Pot up rootstock for grafting in 2013
- Check for female cones and make more crosses as needed.
- Thin out old orchards and collect cones!!!!
- Monitor and manage new grafted orchards.

White pine

- Complete eSEM project from 2011.
- Survey survival at white pine progeny test "989-A" at St Louis County
- Establish new disease garden.
- Plant grafts at CFC.
- Finalize plans for progeny test (acquire seed, ship to grower, find other sites).
- Assist ORSO with tree scoring for blister rust.
- Continue Tofte work

APPENDIX

White pine research update

A. David

Since Jason Smith (2005) hypothesized in his dissertation that our most resistant white pine genotype P327 owed its increased resistance to occluded stomates we have been interested in using this morphological trait as a screening tool to quickly identify other white pine genotypes for inclusion into our white pine blister rust breeding program. Currently we are working with Todd Burnes of the R. Blanchette laboratory (Plant Pathology, University of Minnesota, St. Paul campus) to assess stomatal occlusion in 123 ramets of 34 different genotypes collected from MTIC seed orchards, USFS ORSO gene banks and the Tofte trial. These genotypes represent four different categories in white pine blister rust resistance screening including: resistant, likely resistant, likely susceptible and susceptible. Burnes has been using environmental scanning electron microscopy (eSEM) to picture the stomates. Over the winter we will devise a quantitative method to evaluate the amount stomatal occlusion and perform the analysis. If increased stomatal occlusion is closely correlated with increased levels of resistance to blister rust then we may have a quick method for screening white pine and selecting those that have above average resistance to blister rust.

Last year (2010), with the assistance of USFS ORSO personnel, we revisited and rescored all the living white pine in the Tofte, Moose Fence planting for vigor, rust, number of cankers, percent bole alive and presence or absence of callus. We identified 114 slow-rusting phenotypes, i.e. trees that have coexisted with white pine blister rust for at least 20 years and have small, oval cankers with callus formation. This past spring, again with help from USFS ORSO personnel, we collected scion from the top 50 slow-rusters and grafted them at Grand Rapids. This spring they will be out-planted and fenced as a separate population at the Cloquet Forestry Center.

This past spring we also took the opportunity to collect scion and graft all the remaining white pine genotypes at the Fall Lake seed orchard on the Wilderness Research Foundation property near Ely, Minnesota. These were genotypes that Cliff and Isabelle Ahlgren had identified as having the best potential rust resistance characteristics among the many genotypes they had worked with over their careers. Initially we had hoped to make controlled crosses among these trees however, the spacing, height and physical condition of some of the them required that they be grafted before some genotypes were lost to mortality.

Smith, J. 2005. Host-pathogen interactions in rust disease pathosystems. Ph.D. dissertation, University of Minnesota, 170p.

White Pine Germplasm Trial – Disease Gardens

Proposed Timeline

2010

- Rootstock for grafts was potted at Forest Genetics Lab
- Seed was obtained and germinated at Forest Genetics Lab
- Trial sites were located on University of Minnesota property at Cloquet and Ely.

2011

- Site preparation will be completed at both sites
- Pin flags will be placed at each planting location.
- Secure a source of *Ribes* to plant within rows.

2012

- Trees will be planted in May
- Local *Ribes* populations will be surveyed within 500 ft of the plantings on all sides.
- *Ribes* will be planted within planted rows.
- Sites will be monitored at least twice before winter 2012.
- Trees will be budcapped or caged.

Update on MTIC Jack Pine Breeding Program

Summary
Second generation orchards were marked in fall 2011 to maintain trees with the best volume and stem straightness. Genotype by environment interactions were significant, indicating the need for at least two separate populations in the state. Open-pollinated seed from Crow Wing / MN DNR is recommended for deployment in the Central Seed Zone, zone 105. Seed from St Louis County / IRRRB is recommended for deployment in the north central or northeast seed zones, 104 and 102 respectively. Gains in volume that are possible by using seed collected from the thinned 2nd generation populations are approximately 10% for volume. However, this gain is highly conservative, and real gains are likely to approach of 15-20% in volume compared to wild sources. Genetic gains for grafted orchards constructed from the top genotypes are likely to exceed 20% for tree volume.

Background

- Open-pollinated seed was collected from superior wild trees across Minnesota and Wisconsin in the early 1980s.
- Seed was germinated, grown and planted into seedling-seed orchards at eight different locations. Several sites have been abandoned due to root collar weevil damage (Bemidji), change of ownership (Kallstrom) or other problems (Link Lake). Sites still used for production include Crow Wing County, Carlton County Gillogly Rd, DNR Nickerson, DNR Eaglehead, DNR Longprairie, and IRRRB Calumet.
- Many selections (families) were planted into the nearest orchards and are not replicated at other sites (so they are unique to one site). Other families were replicated across two or more sites.
- At first-generation orchards, families were ranked using 10-12 year tree heights (age varied by orchard). The orchards were rogued to leave the top 12-15% trees, using combined index selection in which the best individuals from the best families were retained in the orchard, all others were rogued out.
- For breeding purposes, the best individual from each of the best families was chosen. A positive assortative mating scheme was devised so that no family was crossed more than once either within or among sites. The goal was to make 25 crosses per site at each of six sites.
- After the breeding was completed and seeds were germinated, the new population consisted of 143 new full sib families generated from 286 different parent genotypes. The full-sib seedlings were planted in 1999 into the existing 2nd generation jack pine populations at Crow Wing County and St Louis County. (Sites on Potlatch land in Cloquet and Cass County land near Leech Lake failed after the first season).
- After ten years of growth, genotype by environment interactions were significant for volume growth, indicating the need for two separate populations in the state (MTIC Annual report for 2010).

Methods for selecting "keep" trees at 2nd generation populations

This information pertains to the MTIC's two (remaining) second-generation populations, Crow Wing County / MN DNR "County Line" and St Louis county / IRRRB "Ellsburg Rd East." Breeding values were calculated in ASReml (VSN International, Ltd., UK). This data was previously analyzed and reported in the 2001, 2003, 2008 and 2010 MTIC Annual Reports. To summarize, highly significant g x e interaction for tree volumes occurred, requiring a minimum of at least two separate seed zones for this population. The objective was to keep the best individuals from the best families with a minimum of two trees remaining from each family at each site to maintain sufficient diversity for future generations.

Variables

Ht 2008 m: Tree heights measured with a Haglof® hypsometer to the nearest 0.1 meters in fall 2008 after the tenth growing season.

DBH 2008 mm: Tree diameters measured with a Haglof® caliper (one measurement per tree) to the nearest mm in fall 2008, at the same time as tree heights.

Stem form: Straightness of the bole using a 6-point scale (Fullarton, 2001).

Vol08m3: Volume was generated with this formula:

$$\text{Volume in cubic meters} = 0.48 * (\pi *(1/2\text{dbh})^2 * \text{tree height}$$

The 0.48 factor was from **Gevorkiantz and Olsen (1955).** Best Linear Unbiased Predictors (BLUP) were determined using ASReml software (VSN International) with the model below, with 'tree' as the only 'random' variable. The μ (site mean), site, and rep were all listed as 'fixed' variables:

$$\text{Volume or Stem Form} = \mu + \text{Site} + \text{Rep} + \text{Tree}$$

Breeding values were calculated by adding the mean (μ) to the BLUP. The final breeding value for each tree was calculated with the following equation:

$$\text{Composite breeding value} = 0.8 * BV_{volume} + 0.2 * BV_{stem\text{-}form}$$

Each living tree in the orchard received a composite breeding value generated with this formula. Individual trees were ranked in each orchard. All trees with the top 1/3 breeding values were maintained in the orchards. For families with no representatives in the top 1/3, the two trees with the highest breeding value from each family were maintained in each orchard. Note that for the 43 families at St Louis that were not replicated at Crow Wing, four trees were retained at the St Louis orchard. At Crow Wing, gall rust was not considered in breeding value calculations mainly because trees with excellent growth and stem form were generally free of gall rust, so its addition as a separate trait seemed redundant. All trees were visited and assessed for gall rust incidence to compare family means and make recommendations for constructing future orchards with better than average resistance to gall rust. Pine-oak gall rust is the local gall rust species in Crow Wing County, so families that appear to foster resistance are not likely to possess resistance to the pine-pine gall rust that is local to the St Louis County site.

All "keep" trees were painted in summer 2011 with blue paint in Crow Wing County and orange paint in St Louis County. By December 2011 thinning was completed in Crow Wing County. St Louis County will be thinned in 2012.

Development of future orchards for seed production and gene conservation

The MTIC's two primary objectives are maximizing seed production and maintaining a genetically diverse breeding population. Toward that goal, grafted orchards, and/or orchards from mass-controlled pollinations, should be constructed to bolster seed production state-wide. For reforestation efforts in the central seed zone, selections and ortets will be made from Crow Wing/DNR site. For reforestation in the north-central and north-eastern seed zones, future orchards will be composed of genotypes originating from St Louis County / IRRRB site. Open-pollinated seed from either second-generation population can also be used for reforestation, but genetic gains were sacrificed slightly in order to conserve individuals from all families in the orchard. We will attempt to designate separate trees for advanced-generation breeding to avoid conflicts with topping that occurs when scion is collected.

1) **Future orchards**

Grafted orchards would be developed from 20-30 unrelated genotypes, using top 30 unrelated trees with the highest breeding values for the 2nd generation orchards for scion material. Alternatively, mass-controlled pollination could be used to create new seedling-seed orchards. In sites where gall rust pressure is high, orchards may be constructed from families with the lowest incidence of gall rust (approximately 12 genotypes). All other orchards should be constructed from the tree in each family with the highest breeding value for volume and stem form (20-30 genotypes).

2) Breeding population

The third-generation population will be created by making controlled crosses on the trees remaining in the 2nd gen populations after thinning. Pollen will be collected in 2012 for making crosses in 2013 and beyond. The 3rd-generation breeding population will be made from a set of disconnected factorials at both the Crow Wing and St. Louis County sites. This would allow us to measure general combining ability for each new family while maintaining sufficient genetic diversity.

Breeding attempts would create a minimum of 50 new crosses at Crow Wing and 71 crosses at St Louis. Since genotype by environment interactions were significant, the top 50% of families at Crow Wing will overlap little with the top 50% at St Louis. However, it is inevitable that some families may be crossed twice, once at each site, because it performed well at both sites. A family that performs well in both populations should be maintained in both populations.

Estimates of Genetic Gains

Genetic gains are best calculated in a field trial containing one or more local checklots. The MTIC has not established such a trial yet, so we can only *estimate* genetic gains. By selecting

the top 10% of genotypes, expected gains in volume are 8% in Crow Wing and 12% in St Louis, an average of 10% gain in volume. However, this estimate is highly conservative since the estimate is based on additional volume possible within an already improved population. Gains are roughly additive from the first to the second generation, so expected gains in height from the first-generation of selection can be added to gains from the second generation. It is likely that additional wood volume would exceed 15-20% over local, wild sources if seed is used from an improved 2nd generation orchard.

References

Fullarton, M. 2001. Genetic field test handbook: New Brunswick Tree Improvement Council Guidelines. Fredericton, NB, Canada. 44 pp.

Gevorkiantz, S. R. and L.P. Olsen. 1955. Composite volume tables for timber and their application in the Lake States. U.S. Dept. Ag. Tech. Bull. No. 1104. 51 pp.

Pike, Warren, David. 2010. Annual Report of the Minnesota Tree Improvement Cooperative. Department of Forest Resources. University of Minnesota, St Paul, MN. 59 pp.

Progress report on Pike's graduate research

Evaluation of phenotypic and physiologic characteristics of genetically improved white spruce

C. Pike

Pike continued to make progress towards completion of a PhD in the Natural Resource Science and Management major, with an emphasis in ecology and genetics of forest trees. Class-work was completed in 2009 and candidacy exams were passed in 2010. In 2011, focus was to complete data collection and begin analysis and interpretation. In *Part I* data on a variety of traits are being collected from 25-year old trees at the MTIC white spruce progeny test. In *Part II*, root:shoot ratios of containerized seedlings are being measured over time. An experimental warming study was conducted for *Part III*, in which seedlings were subjected to artificial mid-winter thaws.

Part I. Data collection from white spruce progeny test

In 2008, one branch sample and one 10mm wood core was collected from each of 300 trees. Ten trees from each of 30 families were sampled, ten from each of three selection tiers: top-, mid-, and low-performing families. Family "performance" was determined from 20-year data on tree volumes. The ten trees per family were divided evenly between two sites, Nickerson and Finland. Wood specific gravity was estimated from each wood core. The foliar samples were processed to calculate leaf mass area (LMR) and leaf area ratio (LAR) on all previous years' needles from each branch sample. A sub-sample of needles was prepared and analyzed for nitrogen and carbon content. Heritabilities, phenotypic, and genetic correlations were calculated for all traits and trait combinations.

Dendrometer bands were placed on each of 24 trees at each of two sites, Finland and Nickerson, in fall 2009 and re-placed again in April 2011. Tree diameters were recorded weekly over the course of two growing seasons on the dendrobands with help from Justin Mayne, Lake County Forester based in Finland. Pike and Warren collected weekly readings at the Nickerson site. Growth curves were generated and are being compared using nonlinear regression statistics. Results were not completed in time for inclusion in this report.

Part II. Root:shoot ratios in improved and unimproved sources of white spruce

This study was installed in May 2008, with the last sampling expected in fall 2013. In fall 2011, 60 trees were destructively sampled, cleaned, dried, and weighed. The objective of the experiment is to compare the allocation of above and below ground biomass within and among different seed sources of white spruce over a five-year period. Data collected after the 1st and 2nd growing seasons was presented at the SFEC Annual Research Review in February 2011 at the Cloquet Forestry Center, and again at the CFGA meeting in Thunder Bay in August.

Part III. Effects of cumulative artificial winter warming and exposure on phenology and growth of white spruce

This study was installed in May 2008, and data collection was completed in fall 2011. The first warming treatment was applied during winter 2010, with phenological traits measured in spring and early summer of 2010 and repeated in winter 2011. Phenological traits include time of budbreak, bud elongation, and cessation of terminal growth. In fall 2009, before the warming treatment was applied, tree heights and diameters were measured. These measurements were re-taken in fall 2010 and again in fall 2011 after the warming treatments were applied. The variation in responses will be compared among treatments and among seed sources, (five improved sources and two natural, un-selected sources). Two plots of 56 trees each were subjected to each of the treatments listed below in winter 2010. The experiment was repeated in 2011 with some alterations in the treatment design (see below).

Treatment structure for warming experiment in winter 2010:

1. Control, no warming, no snow removed.
2. Snow removed and trees warmed for four days in February
3. Snow removed in February but trees not warmed. (Control for effects of snow removal in February)
4. Snow removed and trees warmed for four days in March
5. Snow removed in March but trees not warmed. (Control for effects of snow removal in March)
6. Snow removed and trees warmed for four days in April
7. Snow removed in April and trees not warmed. (Control for effects of snow removal in April)
8. Snow removed and trees warmed for four days each in February and March (Effects of sequential warming)
9. Snow removed in February and March and trees not warmed. (Control for effects of sequential warming)

Treatment structure for warming experiment in winter 2011:

1. Control, no warming, no snow removed.
2. Snow removed and trees warmed for six days in February
3. Snow removed in February but trees not warmed. (Control for effects of snow removal in February)
4. Snow removed and greenhouse plastic was placed over the bed to passively warm.
5. Snow removed and trees warmed for six days in March
6. Snow removed in March but trees not warmed. (Control for effects of snow removal in March)
7. Snow removed and greenhouse plastic was placed over the bed to passively warm.
8. Snow removed and trees warmed for six days each in February and March (Effects of sequential warming)

9. Snow removed in February and March and trees not warmed. (Control for effects of sequential warming)

Results update

Part I, Ecophysiographic assessment of selected families in a progeny test: Wood specific gravity was negatively correlated with tree height and diameter, but the correlations were not significantly different from zero. Trees from the top selection tier differed significantly from those in the lowest tier for tree heights, diameters, leaf mass ratio (LMR), and leaf area ratio (LAR) (Table 8). It is possible that selected sources possess subtle differences in needle morphology that may improve their capacity to photosynthesize, thereby increasing their capacity to grow. In global datasets across species, LAR and LMR are positively correlated with growth rate, but intra-specific correlations between growth and needle traits are not well studied.

Table 4. Differences among selection tiers for height, diameter, leaf area ratio and leaf mass ratio. Least-squared means (first line), standard errors (middle line) are shown for each trait. Tiers that differ significantly using Tukey's test ($p < 0.05$) are indicated with different letters (third line).

	Selection Tier		
	Low	**Middle**	**Top**
20-year heights, dm	74.559	75.086	81.746
	4.659	4.671	4.663
	b	b	a
20-year dbh cm	110.990	114.950	126.350
	4.992	5.036	5.007
	b	b	a
LAR, cm^2 g-1	0.057	0.058	0.072
	0.006	0.006	0.006
	b	ab	a
LMR, g g^{-1}	0.460	0.466	0.499
	0.016	0.016	0.016
	b	ab	a

Part 2, Biomass partitioning study. Tree heights did not differ significantly between selected and natural sources after the first growing season, although root mass was greater for improved sources than for unselected sources (Figure 2). After the second growing season, no differences among sources were significant for any single trait. However, selected and unselected sources did differ significantly when all traits were analyzed together in a discriminant analysis. Selected sources were generally taller, with heavier needle mass compared to woods run sources. In spite of their added height, selected sources had lighter branches / woody material than the smaller, but heavier, woods run sources. These

differences in woody mass may be attributed to differences in architecture and branching patterns, but further studies are necessary to confirm this.

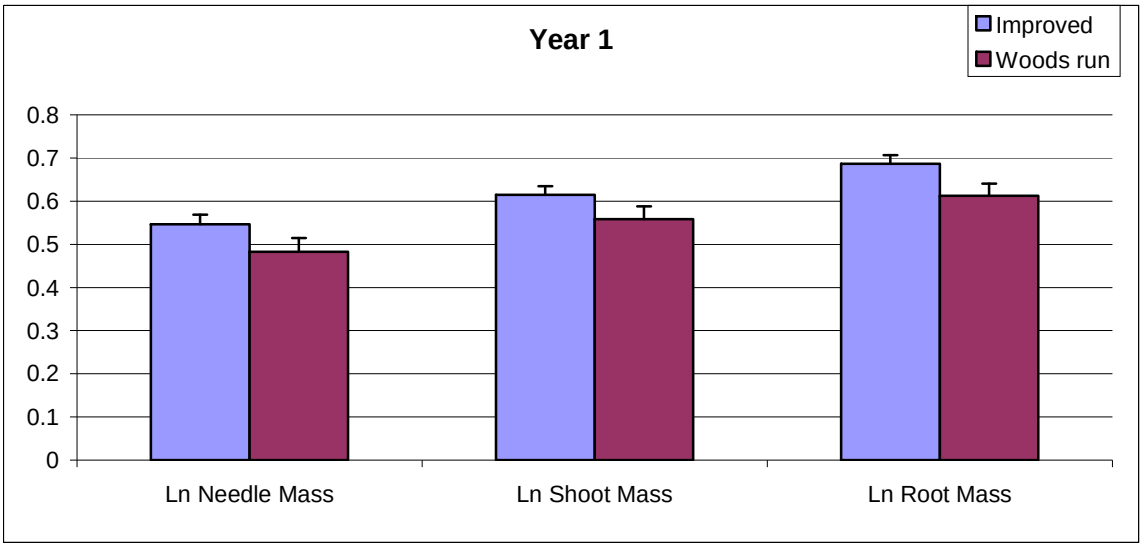

Figure 2. Least-squared means for Log needle, shoot, and root mass between woods run and improved sources. Differences were only significant between sources for Ln Root Mass at $p < 0.05$.

Part 3, Winter warming experiment. The first warming treatment was applied in winter 2010 and repeated in 2011. Survival at both seedling trials is excellent, and no seedlings were lost as a result of any treatment. No winterburn was apparent on any tree following the 2010 treatment.

Trees that were warmed three times (a total of 12 days) did not experience an obvious acceleration in the timing of budbreak, but exhibited a reduction in height growth relative to un-warmed controls (Figure 3). These effects were less apparent in 2011 (data not shown) because of natural warming that coincided with the treatments. The reduction in growth that was perceived in both years is attributed to carbon losses through increased respiration as a result of exposure and warming.

Trees from improved sources also exhibited less variation with respect to budbreak and bud-set times than wild sources, but data analysis to verify significance of these findings is not yet complete.

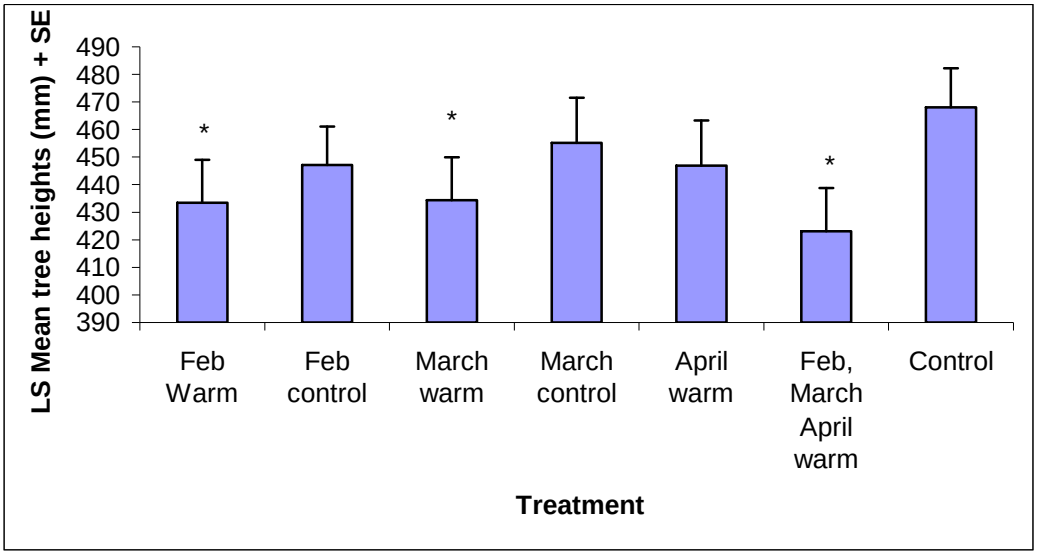

Figure 3. Effects of artificial warming in 2010 on white spruce tree heights in fall 2010. Treatments that differ from the controls are indicated with an asterisk.

Minnesota Tree Improvement Cooperative

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2011

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