MEMBERS

Beltrami County
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Crow Wing County
Iron Range Resources, Mineland Reclamation
Itasca Greenhouse, Inc.
Koochiching County
Lake County
Minnesota Department of Natural Resources
Plum Creek Timber Company
Potlatch Corporation
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
Minnesota Nursery & Landscape Association
Pine County

ANNUAL REPORT
Minnesota Tree Improvement Cooperative
January 1-December 31
2009

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College of Food, Agricultural and Natural Resource Sciences
University of Minnesota

EXECUTIVE SUMMARY

The Minnesota Tree Improvement Cooperative (MTIC) completed its twenty-eighth year in 2009 with fourteen full members and six supporting members. Dues payments in the amount of $62,816 were collected, which included the contract with the MN DNR. Two business meetings were held, one on January 15th at the Cloquet Forestry Center, and another on March 19th at the North Central Research & Outreach Center (NCROC) in Grand Rapids. The next workshop is slated for January 12, 2010 at the Cloquet Forestry Center. During 2009, Carrie Pike served as Coordinator, Dr. Andrew David was Director, Jim Warren provided field and technological assistance, and Egon Humenburger provided field assistance.

In 2009, priorities included completing measurements at the 1999 white pine progeny test in Grand Marais, Ahlgren Mukluk trial in Winton, and planting white pine grafts into the breeding arboretum in Cloquet. Three white spruce seedling experiments were established for Pike's graduate research. Five-year measurements on three installments of the 2nd generation white spruce will be postponed until April 2010. Cones were collected from 11 different seed orchards. Grafting in 2009 was completed at Willow River (white spruce and jack pine) and Grand Rapids (white pine).

Pike presented to the Bemidji State University Center for Research and Innovation (CRI), the annual meeting of the BIA in Shakopee, and published an article in Better Forests magazine.

In 2010 grafting is slated to take place for white pine at the Forest Genetics lab in Grand Rapids, and for red pine at the State Nursery in Willow River. Controlled pollinations of red pine are planned. Thinning will begin at both 2nd generation jack pine populations commencing cone collections. All actively managed MTIC orchards will be visited, and mortality and monumentation updated. Grafts will be planted into jack pine and white pine seed orchards.

Table of Contents

A Letter from the Director

Dear Cooperative Members,

From a business standpoint it was a relief to see that the new invoicing system that was instituted last year went rather smoothly and worked as intended. We also succeeded in bringing in two new grants; a three year funding commitment from the Wilderness Research Foundation and a smaller grant from the U.S. Forest Service. Both of these grants are assisting us with our white pine research.

With the shortage of jack pine seedlings the need for seed is at an all time high. Among seed orchards the cone production in our first generation jack pine orchards has been low but the second generation material has produced some cones. These cones will be collected this fall after the plantings are marked and rogued. Hopefully the existing orchards and the newly reclaimed jack pine orchards can help alleviate the shortage with a good cone year soon. The white spruce College Orchard had a banner year for cone production – 28 bushels. Way to go Jake! Kudos also to the DNR for collecting cones in several species this year.

Carrie's research on the growth characteristics of improved white spruce continues to draw interest from other researchers. Although results are still a few years in the future the scientific community is intrigued by her use of family structure to help explain a species' response to increased mid-winter temperatures. As a speaker she is an advocate for the MTIC, extolling the virtues of improved seed and reminding all that conventional tree improvement retains the genetic variation that will be required to respond to any environmental challenge.

Finally, in today's economic times we are told that the outlook for the University's finances is dark, and I know that you have heard similar news in your own organizations. As a cooperative we have been fiscally responsible, timely in finding grant monies, and efficient at getting that "bang for the buck". As a member-funded cooperative we strive to keep annual dues reasonable and if you look across the state, and the nation, you will see that we have accomplished that goal while still bringing the benefits of tree improvement to our members.

Sincerely,

Andrew David
Associate Professor Forest Genetics

Introduction

In 2009, the Minnesota Tree Improvement Cooperative (MTIC) entered its 28th year with 14 full members and six supporting members. This year was characterized by a sour economy, and a dismal outlook for the forest products industry. In addition, invasive species hit the headlines when Emerald Ash Borer was discovered in St Paul. The Cooperative is working closely with the Department of Forest Resources on projects related to the Interagency Information Cooperative led by Alan Ek. Department collaborators include Professors Tony D'Amato, Tom Burke, Andy David and Research Fellows Grant Domke and Carrie Pike.

Accomplishments during the 2009 field season included measurements on the "Mukluk" white pine trial, established by Cliff and Isabel Ahlgren in 1986. Grafting in March resulted in over 580 white pine and 800 white spruce grafts. Cones were collected from 11 different seed orchards resulting in over 200 bushels of improved cones. White pine grafts were planted into the Cloquet breeding arboretum (267 trees) in the fall of 2009.

Pike's graduate work towards her PhD in Natural Resource Science and Management (NRSM) proceeded full-speed in 2009 beginning with a meeting of her thesis Committee at the Cloquet Forestry Center in early January. Pike completed coursework requirements in St Paul and Duluth, and set up three experiments at the Cloquet Forestry Center.

This report summarizes activities and accomplishments from January 1 to December 31, 2009. 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

Carrie Pike remains Coordinator of the MTIC, based at the College for Food, Agriculture, and Natural Resource Sciences (CFANS) Cloquet Forestry Center. Jim Warren continues a full-time appointment providing technological and field assistance on projects for the MTIC, the white pine blister rust program, and the Cloquet Forestry Center. Pike coordinates day-to-day operations of the Co-op's finances, communications, reports, data collection and analysis. Warren maintains the Co-op's tree databases, GIS software, and other technical and field assistance.

Dr. Andy David, Director, continues to assist with long-term directives and consultation. His time is divided between research interests in Grand Rapids, the MTIC in

Cloquet, and teaching duties in St Paul. Egon Humenburger, also based in Grand Rapids, assists on a variety of MTIC and non-MTIC related projects.

The Advisory Committee consists of representatives from each member of the MTIC. It met twice during 2009: January 15 at the Cloquet Forestry Center and again on March 19th at the North Central Research & Outreach Center (NCROC) in Grand Rapids. Norm Moody, long-time Land Commissioner for Cass County retired in early 2009. French Wynne, based in Warren Arkansas, is the primary representative for Potlatch Land Holdings, inc., with local assistance from Brian Smith in Bemidji and Lew Castle in Cloquet.

On-site visits were made to over 40 different MTIC plantings in 2009 by Pike and Warren. Pike presented her research plans on April 13th for the Forest Resources seminar series in St. Paul. This satisfies a degree requirement for the NRSM program. Pike and Warren assisted with the Cloquet Forestry Center's centennial celebration during the week of July 20th. Pike gave a one-hour presentation on tree improvement to Vermilion College students at the Cloquet Forestry Center on September 17th. On September 21, Pike was invited to speak for the CRI group in Bemidji entitled "Can our Forests Adapt to Invasive Pests?" Pike submitted an article to the Fall, 2009 edition of Better Forests entitled "Eastern white pine: the quest for resistance to blister rust disease." Pike also spoke informally with students from the Audubon Center, the Minnesota Forest Resource Partnership, and conducted tours of the Cloquet Forestry Center throughout the year.

SEED ORCHARDS

Seed orchards are the means by which genetically improved seed is produced for tree planting. Each full member is charged with site preparation and management of at least one orchard. Orchards are in place for six conifer species. The MN DNR manages the largest number of orchards, with eight orchards actively managed for seed production. All first-generation jack pine orchards have been rogued. Five of seven red pine orchards have been rogued and a sixth (Cass-Beltrami-Hubbard County's Blind Lake orchard) was marked in 2008 for roguing which is approximately 1/3 complete as of this writing. A summary of the types and sizes of orchards is shown in Table 4. Tables 5 & 6 list all orchards by species and owner for *Picea*, and *Pinus* and *Larix* respectively. All "research" trials are listed in Table 7. A research trial is intended for data collection but is not designed to be used for seed collection. Second-generation jack pine populations are listed as a "research" trial until they are thinned and are then managed for seed collection and tree breeding. Cone collections made in 2009 are shown in Table 8.

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	20	---	---	14	---	42
First Generation Seedling Seed	8	4	27	37	---	4	80
Improved First Generation Clonal	---	10	---	---	---	---	10
Second Generation Full Sib	4	11	6	---	---	---	21
Total acreage by species	***19***	***45***	***33***	***37***	***14***	***4***	***152***

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. Clonal	Koochiching County	Big Falls	19-May-89	2.3	61
		Koochiching County	Larsaybow	27-May-98	4.0	59
		Minnesota DNR	Sturgeon Lake	01-May-79	1.3	812
	1st Gen. Seedling	Minnesota DNR	Eaglehead	17-May-78	2.7	582
		Potlatch Forest Holdings, Inc.	Cloquet	01-May-78	3.0	580
		Blandin Paper Company	Blackberry	22-May-78	2.5	596
	2nd Gen. Seedling	Minnesota DNR	Split Rock	27-May-92	2.4	262
		U of M CFC	Airport 40	01-May-95	1.1	238
			Totals:	***8 Orchards***	***19.3***	***3,190***
White spruce	1st Gen. Clonal	Itasca County	Fig. Eight Lake	02-Sep-87	1.1	175
		Lake County	Two Harbors	02-Sep-87	1.0	198
		Minnesota DNR	Cotton	01-May-77	12.0	206
		Potlatch Forest Holdings, Inc.	Cloquet	01-May-77	3.3	140
		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
		Potlatch Forest Holdings, Inc.	Gillogly Road	01-Apr-03	2.1	187
		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:	***17 Orchards***	***44.8***	***6,601***

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
		Potlatch Forest Holdings, Inc.	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
		Wausau-Mosinee Paper Corp.	Barnes	27-May-88	4.1	549
	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:	***11 Orchards***	***33.0***	***6,666***
White pine	1st Gen. Clonal	Itasca County	Bass Lake	19-May-98	5.7	498
		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:	***6 Orchards***	***14.1***	***1,776***
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
		Plum Creek Timber Company	Petenwell	24-Apr-90	5.5	464
		Potlatch Forest Holdings, Inc.	Gillogly Rd.	10-Jul-81	6.6	461
		St. Louis County	Ellsburg Rd.	09-May-88	5.5	531
		Wausau-Mosinee Paper Corp.	Mosinee	23-May-90	5.7	1174
			Totals:	***7 Orchards***	***36.7***	***3,620***
Tamarack	1st Gen. Seedling	Minnesota DNR	Split Rock	12-May-08	4.3	2,005
			Totals:	***1 Orchard***	***4.3***	***2,005***

Table 4. Research trials planted by the MTIC.

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	n/a
	Comparison trial	2008	Koochiching County	Franz Jevne	n/a	2010
White spruce	Comparison trial	1993	Minnesota DNR	Dago Lake Rd	2002	2012
		1993	Plum Creek Timber Company	Gordon	2002	2012
		1993	Potlatch Forest Holdings, Inc.	Orr	2002	2012
		1993	Blandin Paper Company	Hwy 61	2002	2012
		1995	Potlatch Forest Holdings, Inc.	Hill City	2000	n/a
		1995	U of M	CFC-Airport 40	2005	2010
		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
		2005	Minnesota DNR	Eaglehead	---	2010
		2005	UPM-Blandin	Feeley	---	2010
Jack pine	2nd generation population	1999	St Louis / Iron Range Resources	Ellsburg E.	2008	--
		1999	Crow Wing / Minnesota 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	1999	St Louis County	Ellsburg Rd	2008	2012
		1999	USFS	Grand Marais	2008	2012
		1999	ORSO	ORSO	2008	2012

Table 5. Cones collected by MTIC members in 2009.

Species	*Agency / Industry*	*Orchard*	*# bushels*
Black spruce	Koochiching Co.	Larsaybow	1
		Big Falls	1
	MN DNR	Split rock	28
White spruce	UPM - Blandin Paper	College	75.5
	Lake County	Two Harbors	2.0
	MN DNR	Cotton	29.4
Jack pine	MN DNR	Longprairie	5.0
	St Louis County	Ellsburg Rd	16.0
Red pine	MN DNR	Eaglehead	9.0
	St Louis County	Ellsburg Rd	16.0
White pine	St Louis County	Ellsburg Rd	18.0

SPECIES REPORTS

Black spruce

Status

In 2009, black spruce crops were variable across the state. **Koochiching County** secured two bushels from a collection made at both the **Big Falls** and **Larsaybow orchards.** Given the small amount of black spruce planted in northern Minnesota, these cones will meet seed needs for the next few years. In January, 2009 the **MN DNR** collected 28 bushels of improved black spruce from their **Split Rock** orchard complex near Moose Lake. This is the largest crop ever collected from that site. Trees were severely topped with that collection but the trees are recovering well and future cones will be easily accessible from the ground. **Blandin's Blackberry** orchard remains in excellent condition, and had a modest crop in 2009 which to date, wasn't slated for collection.

Short and long-term planning

Orchards remain in good condition and will be maintained for seed in the near future. No new orchards or progeny tests are planned for black spruce unless demand for the seed increases. Survival at the comparison trial planted in 2008 in Koochiching county, near the Franz Jevre State Park was, unfortunately, lower than expected. This site, like many of its kind, experiences a widely-fluctuating water table that dropped severely in 2009 during a drought in early summer. The planting will continue to be monitored for growth and survival.

White spruce

Status

White spruce cones were highly variable across MTIC orchards in 2009. Some orchards posted a large cone crop (**DNR -Cotton**, **Blandin -College**), where others had only small crops (**St Louis Co. –Ellsburg Rd**, **Blandin – Latimer, Blandin – Arbo**). The **St Louis County Ellsburg Rd** orchard is recovering nicely from the topping it received in fall of 2007. The DNR topped all trees at their **Cotton** orchard by hiring a private lift/operator. Cones were also collected at **Lake County's Two Harbors** orchard, and trees there were topped from a ladder with a pole pruner. **UPM-Blandin** harvested cones at their highly productive **College orchard.** Grafts at the **Red Lake's Redby** orchard are now well-established thanks to the regular maintenance it has received. Cones were produced on the more vigorous grafts. **MN DNR's** improved-first generation orchard at the **Split Rock orchard complex** was abandoned this year due to poor survival. A new site will be located in 2010 to replace this orchard. Survival at **Potlatch's** new improved-first generation orchard at **Gillogly Rd** complex was modest.

Short and long-term planning

The last state-wide bumper crop for white spruce occurred in 2006. Blandin's College orchard continues to shine with a huge crop picked in 2009 by Jake Mutchler of Mutchler Forestry, contracted to manage Blandin's orchards. This orchard is intensively managed with regular fertilization, irrigation, top pruning and vegetation control. The consistent and large cone crops are a reflection of this management effort. In older orchards, cone and seed insects are omnipresent. Given the costs and limitations of applying insecticides, routine maintenance such as cone removal, mowing, brush removal, and even scarification under trees is necessary to reduce the incidence of pests. The MN DNR is currently housing a large number of white spruce grafts produced to replace the current breeding arboretum at Willow River. In 2010, plans for outplanting these grafts will be made. A new site that encompasses both gene conservation and seed production may be produced.

In early spring 2010, three second-generation plantings (planted in 2005 at MN DNR's **Eaglehead**, Lake County's **Ostman Pit Rd**, and Blandin's **Feeley** site) will be measured for five-year survival and height growth. This work was postponed until early spring to take advantage of low levels of competing vegetation. These sites won't likely produce cones for at least another ten years. Maintaining production in existing grafted orchards is critical to safeguard seed supplies in the interim period.

Jack pine

Status

Cone crops in jack pine orchards were generally low for the second straight year. In early 2009 approximately five bushels of cones were collected at **MN DNR's Longprairie orchard**. In August 2009 a modest cone crop was present at **Iron Range Resources Calumet** but a collection is not expected for this year. At **Cass, Beltrami and Hubbard**

County's joint **Deep Portage** orchard, efforts to remove competing vegetation and release orchard trees were begun in 2007, and are ongoing. The two second-generation jack pine plantings, **Crow Wing Co/MN DNR County Line Rd**, and **St Louis Co/Iron Range Resources Ellsburg Rd East**, remain in excellent condition and will be marked in 2010 to commence thinning and cone collections.

Short and long term planning

In recent years, deer browse has become a serious hindrance to artificial jack pine regeneration. This is particularly alarming since many older stands are being regenerated after years of damage from jack pine budworm. To prevent whole-sale losses of plantations, budcapping has become an annual ritual in many parts of the state on jack pine. Plans for expanding orchards and seed collections are ongoing to meet an emerging demands for seed.

Second-generation orchards have reached spacing constraints at both locations. This will be eased in 2010 when a light, systematic thin will be applied to remove the lowest-performing trees from the lowest-performing families. Jack pine grafts produced at the DNR's General Andrews Nursery will be planted alongside the second-generation trees (within the fenced area) at Crow Wing/MN DNR's County Line Rd site. These grafts were made from top-performing families targeted for tree breeding for producing the second-generation populations. Site prep began in fall 2009 and grafts may be outplanted in spring 2010. In addition, 300 jack pine rootstock were potted in spring 2009 for grafting in 2010. The purpose of these grafts is to increase cone/seed production to reach future seed demands for state and county lands. Seed and/or scion may be used from these sites to build additional orchards for other cooperative members.

Red pine

Status

Cone crops were highly variable across the state. The **MN DNR Eaglehead** orchard, which up until now has produced few cones, fashioned a bumper crop with cones observed on nearly every tree. The DNR hired a logger to remove approximately 100 trees to ease crowding in the orchard and facilitate cone collections. This followed a thinning in 2008 in which approximately 50 trees were removed. A large crop was also found at **St Louis – Ellsburg Rd** but ironically (and inconveniently) the cone crop was sparse at the nearby **MN DNR Cotton** red pine orchard where loppers were busy topping the adjoining white spruce orchard. St Louis topped several trees in the orchard (number to be determined), and secured a modest cone crop. The cone crop was sparse at **Potlatch – Gillogly Rd** and no cones were collected. We were informed this year that **Plum Creek** rescinded ownership of the **Petenwell** orchard located south of Wisconsin Rapids in south-central Wisconsin.

Roguing at the **Cass-Beltrami-Hubbard County's Blind Lake** orchard began in early 2008 and is on hold temporarily. Completion is anticipated in 2010-2011.

Short and long-term planning

Tree breeding is planned for the St Louis County red pine orchard as soon as a sizeable cone crop is available. Unfortunately for this effort, second-year cones were abundant in 2009 at Ellsburg Rd but first-year cones were scarce. Trees will continue to be monitored in early spring so that crosses can be made using stored pollen.

The MN DNR prepared 500 rootstock for grafting in 2010. A new grafted orchard is proposed alongside the existing MN DNR Eaglehead red pine orchard. Cooperators who wish to participate in the production of a new grafted orchard will be determined in 2010. Help is being requested with grafting at General Andrews in 2010 to ease workload of nursery staff. First-generation orchards will continue to be thinned to ease spacing constraints so that trees don't self prune above the reach of a ladder. The MN DNR's efforts at thinning Eaglehead red pine in the last two years are commendable, and will enhance cone crops of all remaining trees in the future. Remaining trees should be topped with the next sizeable cone crop.

White pine

Status

Cones at white pine orchards were relatively low in 2009 with one exception. Cones were picked at the **St Louis County's Ellsburg Rd – East** orchard. Few were found at the CFC breeding arboretum or at MN DNR **St Francis orchard**. Some mortality was observed at the **Saywards'** orchard, and some grafts were replaced.

The site chosen in Clearwater County for Red Lake's new grafted white pine orchard was abandoned after soil tests revealed a profile that is not conducive to white pine growth. A site adjacent to the white spruce orchard in Redby is being prepped for planting in late 2010.

In fall 2009, 267 grafts were planted into the CFC breeding arboretum from grafting efforts at the forest genetics lab in Grand Rapids (2008-2009), and those stored at the Iron Range Resources shadehouse, that were produced in 2006-2007. This nearly filled the available space in the arboretum.

Short and long-term planning

In fall 2008, Egon, Jim, Andy, Carrie Sweeney and Paul Berrang made a commendable effort to collect open-pollinated seeds from 100 mother trees at white pine "moose fence" property near Tofte. This effort resulted in seed from 91 mother trees that will be used for testing in the lab and potentially for progeny testing in the future. The seed was extracted and processed by Carrie Sweeney and her staff at the Oconto River Seed Orchard (ORSO). In November, 2009, Carrie and her staff inoculated seedlings from 36 seedlots with blister rust. These seedlings were obtained from crosses made at ORSO.

Grafts remain at the General Andrews nursery in Willow River, Cloquet Forestry Center temporary storage, and at Red Lake for planting in 2010. Additional grafting is on hold until screening efforts via SEM (Standard Electron Microscopy) commences.

White pine research update

A. David

The past year has seen quite a bit of activity in white pine from grafting scion material to laying the ground work for future studies and trials. In late winter the MTIC and USDA Forest Service personnel from ORSO collected scion from over 70 rust free trees at the Moose Fence site near Tofte. We targeted the same trees that we collected seed from in fall 2008. In this manner we have both seed and scion for testing and breeding from rust free trees in one of the highest rust risk areas in Minnesota. These scions were then grafted at the greenhouse in Grand Rapids and the Oconto River Seed Orchard facility in Langlade, Wisconsin and tended over the summer. Due to the exceptional survival rates among families (Table 9) and overall health of the grafts, a portion of the CFC arboretum was site prepped and the MTIC portion of the grafts was planted in early fall. Additional grafts went to ORSO, as their understock suffered winter injury and made for poor rootstock, and to MTIC cooperators. Portions of this research were supported by a gene conservation grant from the USDA Forest Service to A. David and P. Berrang (USDA Forest Service, ORSO) and a grant from the Wilderness Research Foundation (WRF) to A. David, C. Pike and J. Warren.

Another source of breeding and testing material from the Tofte, Moose Fence site are trees that exhibit a slow rusting phenotype. These are trees that, although infected, appear to be coexisting with the blister rust fungus. A white pine that can coexist with the fungus without affecting the tree's structural integrity would allow for the long term presence of white pine on the landscape. In western five needled pines such as western white pine and sugar pine this slow rusting phenotype is characterized by a vertically elongated canker, indicating either that the tree is growing faster than the fungus or that the tree has impeded the lateral growth of the fungus. This slow rusting phenotype also appears among the Tofte trees and may be a source of additional breeding and testing material. Recognizing the importance of the Moose Fence site to future white pine breeding and conservation efforts the USDA Forest Service has awarded an additional gene conservation grant to A. David and P. Berrang to preserve the genetic variation in these slow rusting phenotypes. In the coming year we expect to be surveying the Tofte planting for slow rusting phenotypes, monumenting them, and collecting scion and/or seed as appropriate.

In the past year the WRF awarded a three year grant to A. David, C. Pike and J. Warren to a) test if the occluded stomates trait is a likely mechanism of rust resistance in progeny of 327, b) recreate the better Ahlgren crosses for greenhouse screening trials and field testing and c) graft slow rusting phenotypes from the Tofte planting and select Ahlgren parents into the CFC breeding arboretum. The rationale for the first objective was the research done by J. Smith at the University of Minnesota where he hypothesized that the higher survival rate among progeny of 327 was due to needle waxes that occlude the stomates and act as a physical barrier excluding rust hyphae from entering the needles. This fall, as part of the first objective, needles were collected from progeny of 327 at white pine trials near Isabella and at CFC and subjected to environmental scanning electron microscopy (eSEM). Although the results have not been finalized, the incidence of occluded stomates in the progeny were low suggesting that either the occluded stomate trait

is not transferred to progeny or that the needle waxes found on needles grown in a greenhouse setting are not sustainable in a field setting.

This past spring we took almost daily photos of developing white pine terminal and lateral buds to have a photographic history of vegetative bud development. We will use this history to delineate different stages of bud development and then use this information to assess bud development in the field. This information will come in handy when we assess phenotypic plasticity in our white pine regional provenance test (Pike Bay, MN, Eveleth, MN and Langlade, WI) that was established in 2000 by P. Anderson in cooperation with the MTIC. One of the goals of this study is to assess phenological similarity among seed sources at different geographical distances and use this information to create seed transfer guidelines for white pine in Minnesota.

As a final note the MTIC would like to establish a white pine progeny trial in the near future. This trial would be used initially to assess growth potential among our seed orchard selections and eventually to help assess field resistance to white pine blister rust. As this is currently in the planning stages the MTIC is open to suggestions on host sites and host organizations.

Table 6. Results of white pine grafting at Grand Rapids, Spring 2009.

# Families	Total Grafted	Total Surviving	Survival %
77	620	583*	94.0

* Of the 37 grafts that died, two were related to understock failure and 35 to scion failure, including eight from one family.

Publications and Presentations

Publications

Jacobs, J. J., T. A. Burnes, A. J. David and R. A. Blanchette. 2009. Histopathology of primary needles and mortality associated with white pine blister rust in resistant and susceptible *Pinus strobus*. Forest Pathology 39:361-376.

Summary:
White pine blister rust caused by *Cronartium ribicola* is a damaging non-native disease of five-needled pines in North America. Efforts to control the disease and mitigate damage to date have been only somewhat effective. Recent efforts to improve the health of eastern white pine and reestablish the tree as a dominant species in the North Central United States have focused on identification and propagation of disease-free eastern white pine (*Pinus strobus)* growing in areas with a high incidence of blister rust. Many of these selections have been shown to resist infection following artificial inoculation with *C. ribicola*. In this study, 13 eastern white pine families derived from controlled pollination of selections previously determined to possess putative resistance as well as susceptible selections were inoculated with *C. ribicola*. Mortality data from inoculation studies show superior survivability in three families with over 60% of seedlings able to survive the 52 week post-inoculation monitoring period compared to 0–10% survival of the most susceptible families. Primary needles were collected for histological analysis from all inoculated families 4 weeks after inoculation and from selected families 6.5 weeks and 38 weeks after inoculation. Histological observations of infection sites show distinct resistance reactions in the families more likely to survive infection based on mortality data. Analysis of the reactions in susceptible families revealed extensive hyphal colonization of the vascular bundle and adjacent mesophyll cells that appear uninhibited by tree responses. In resistant families, collapsed cells adjacent to infection sites, heavy deposition of phenolic compounds and abnormal cell growth were documented more frequently and appear to play an integral role in the ability of these eastern white pine families to impede growth of C. ribicola in primary needle tissue.

C. Pike. 2009. Eastern white pine and the quest for resistance to blister rust disease. *Tree Farming for Better Forests.* Fall 2009 edition.

Summary
Eastern white pine is revered in Minnesota both for its majestic stature and its timber value. An iconic symbol of the wilderness, white pine also plays an important role in the ecology of Minnesota forests, both as favorite perch for bald eagles and a food source. White pine, like many other native trees, is challenged by an exotic pest brought inadvertently to our shores. The fungus, white pine blister rust, threatened all five-needle pines in North America when it arrived in early 20th century. Almost 100 years later, resistant families have been identified in western white pine and sugar pine, but attempts to locate resistance in eastern white pine have met with only

marginal success. This article will update progress in the 100-year search for resistance, and will describe current research aimed at improving regeneration of this species across Minnesota.

Presentations

C. Pike. "Can our forests adapt to invasive pests?" Invited speaker at Bemidji State University's Center for Research and Innovation, September 21, 2009, Bemidji MN.

C. Pike. Using improved seed for reforestation in a changing climate. Invited speaker at the Annual meeting of the Bureau of Indian Affairs. January 28th 2009, Shakopee, MN.

C. Pike. Characterization of variation for functional and phenological traits in *Picea glauca*: does selection for fast-growth impose an ecological cost? Forest Resources 8107 seminar series. April 13, 2009, St Paul, MN.

Abstract
White spruce possesses a high degree of genetic variation. Tree improvement programs have increased heights and diameters of commercial tree plantings through artificial selection. The mechanisms used by improved seedlings to attain this added growth are not well understood. White spruce is prone to damage from early spring frost, leading to concerns that artificial selection might amplify the propensity for frost damage of improved seedlings. Early bud-break is one potential mechanism associated with improved growth. If bud-break or other functional plant traits possess low levels of heritability, or correlate weakly with growth, then the ecological "fitness" of improved seedlings should not be compromised. However, few studies have calculated heritabilities for plant traits that affect function or phenology exclusive of wood properties. I will measure a variety of plant traits associated with tree growth, using a 25-year old progeny test established by members of the Minnesota Tree Improvement Cooperative. These traits will be correlated to existing datasets of tree heights and diameters to identify ecological tradeoffs that may occur as a consequence of selection for improved growth. A seedling trial will be used to measure the differential response of improved and unimproved seedlings to early-season warming in a greenhouse. Additionally, differences in relative timing of bud-break will be observed between families, and root: shoot ratios will be measured destructively over time to reveal possible below-ground tradeoffs. Results from these experiments will be used to select families that combine fast growth without sacrificing other traits important to the "fitness" of white spruce on the landscape in Minnesota. These results could be used to model the potential of white spruce to evolve in the presence of climate change, the mother of all selectors.

OUTLOOK

The Minnesota Tree Improvement Cooperative weathered a difficult economic year in good standing, a significant achievement. The contract with the MN DNR was renewed in 2009 for another biennium. State-appropriated white pine funds were renewed in 2009, and Warren's appointment with the Cloquet Forestry Center continues. MTIC staff continue to work collaboratively with the USDA Forest Service Regional Geneticist and Manager of Oconto River Seed Orchard to advance improvements in resistance to white pine blister rust. Electron Microscopy work on white pine needles will continue in 2010 with assistance from staff at the Blanchette Pathology lab in St. Paul. In January 2010 a white pine symposium organized by the MTIC and the Sustainable Forest Education Cooperative (SFEC) is planned and attendance has exceeded 100 people by this writing. This workshop will be reported in the 2010 MTIC annual report, and digital proceedings will be made available on the SFEC website.

Grafting for 2010 will take place at MN DNR General Andrews Nursery on jack and red pine, and at the U of M Forest Genetics lab in Grand Rapids on white pine. In April 2010, five-year tree heights will be measured on the 2nd-generation white spruce located in Eaglehead (MN DNR), Warba (Blandin), and Two Harbors (Lake County). Tree breeding in red pine will take place pending availability of first-year conelets at the red pine orchard in St Louis county. The 2nd generation jack pine populations will be marked for an early thinning in 2010, after which cone collections can begin. Sites for new orchards (MN DNR, Cass/Beltrami/Hubbard Counties, Red Lake) will be selected in the next few years to ensure that seed supplies can be maintained without interruption. All orchards will be visited to monitor cone crops and management needs.

2010 Cooperative Work Plan

Black spruce

- Visit all orchards, assess management needs.
- Assess third year growth and mortality at Kooch County's black spruce comparison trial

White spruce

- Locate site for new clone bank to replace breeding arboretum at General Andrews Nursery, and new orchard to replace the Split Rock orchard.
- Prune rootstock, re-tag, and update survival of young, improved first-generation orchards (Potlatch – Gillogly Rd, Red Lake – Redby, new grafts at St Louis County – Ellsburg Rd, Lake County – Two Harbors).
- Measure five year heights at second-generation white spruce populations at MN DNR Eaglehead, Lake County – Ostman Pit Rd, UPM Blandin– Feeley Unit. (early spring 2010)
- Pike's graduate research

Jack pine

- Grafting at Willow River.
- Out-plant potted grafts at General Andrews Nursery to new orchard adjacent to 2nd generation population in Crow Wing County.
- Manage first-generation orchards.
- Continue reclamation of Cass-Beltrami-Hubbard Deep Portage orchard.
- Mark 2nd generation jack pine for thinning.
- Begin roguing 2nd-generation populations.
- Collect cones!!!!

Red pine

- Grafting at Willow River.
- Site prep alongside Eaglehead orchard to plant new grafts.
- Tree breeding if available (June 2010).
- Roguing Cass-Beltrami-Hubbard County red pine orchard.
- Thin orchards and harvest cones.

White pine

- Grafting winter 2010.
- Care for newly planted grafts in the breeding arboretum.
- SEM analysis of inheritance of occluded stomates

APPENDIX

Research proposal: Testing the efficacy of occluded stomates as a mechanism for increasing white pine blister rust resistance

A. David

Rationale:

Greenhouse screening trials by different research groups spanning several decades have routinely placed P327 at, or near, the top of white pine families most resistant to blister rust. In limited field trials of open pollinated progeny P327 again ranks near the top of families with low levels of rust infection. Jason Smith's dissertation research identified wax occluded stomates as one of several possible mechanisms by which P327 experiences lower levels of blister rust infection. Occluded stomates provide an obvious morphological barrier to rust infection and could, if highly heritable, serve as a screenable trait.

Questions to be Answered:

Are occluded stomates inherited? We know that P327 has occluded stomates but we don't know if this condition is passed on to progeny of P327. If this trait is heritable it may help explain the increased rust resistance of P327 progeny in greenhouse and field trials.

Is the presence of occluded stomates correlated with increased survival in the field? We should be able to tell if a higher percentage of progeny with occluded stomates exist in survivors of P327 families compared to non-P327 families.

Materials and Methods:

There are two white pine genetic trials that we can use to compare survivability of families with and without P327 as a parent. The first is the Ahlgren's north shore planting where P327 is used as a male parent. The second is Dick Meier's USFS planting along the north shore where P327 is used as a female parent. There are also additional families that do not have P327 as a parent at these sites.

Since blister rust infection typically happens in late summer early fall we should be able to collect needles from late summer onward. There are two objectives here. First, test for the presence or absence of the trait in the parents of the crosses. Second, test for the presence or absence of the trait in individuals from different families in the field.

First, we need to demonstrate that we can find occluded stomates and know where to look for them. Sample the following 5 parent trees:

P327 and parent of family with high survival at WRF Ahlgren site. (2 trees)
Parents of a cross with low survival at WRF Ahlgren site. (2 trees)
Parent of a cross with low survival at USFS Meier site. (1 tree)

Test first, second and third year needles (if present) at low and middle crown positions on 2 sides. (12 samples per tree x 5 trees = 60 samples)

Hopefully, the presence or absence of occluded stomates is consistent throughout a tree. Assuming there are no unexpected differences (we should find occluded stomates on P327 not on the other parents) proceed to collecting and analyzing needles from individual trees of designated families in the field.

We want to sample individual trees in families where P327 is the male parent and the female parent and in families where P327 is not involved as a parent

Expected Results:

With the survival data we already have collected we can determine if the percentage of survivors is different between P327 and non-P327 families in the field.

The environmental SEM data collected on the parents should tell us if the presence or absence of occluded stomates is consistent throughout the entire tree, and whether or not the occluding waxes break down over time. It will also tell us how many samples per tree we need to collect and from where in the crown.

The environmental SEM data collected on field progeny will tell us if occluded stomates occur in individuals of any families tested. We could then test to see if there is a correlation between presence of occluded stomates and family survival percentage.

Progress report on graduate research

Evaluation of phenotypic and physiologic characteristics of genetically improved white spruce

C. Pike

Pike's graduate research consists of four parts. For part I, trees were sampled from two sites of the MTIC white spruce progeny test. From 300 sample trees (10 trees from each of 30 families), one increment core, one wood density core, and one branch sample were obtained. Wood density was assessed, and tree rings will be measured. Estimates of specific leaf area are ongoing and needles were assayed for leaf Nitrogen and Carbon. Dendrobands were placed on 30 trees at each of two progeny test locations (Finland and Nickerson). This was done to determine the start and end dates of diameter growth on select families. Part II consists of a biomass study in which root:shoot ratios of containerized seedlings will be calculated. The first data was collected in fall, 2009. An experimental warming study is planned for Part III, with an observational study for Part IV.

As part of Pike's graduate research, supplies were purchased for setting up the biomass study and warming experiments using a grant obtained from the MN DNR. Ten nursery beds were constructed using pressure-treated dimensional lumber overlaid with cattle panels to support 2-gallon pots used for warming and phonological observations (Part IV). Beds were partially buried for insulation. Support hoops, constructed of PVC pipes, were secured to the beds and shadecloth was placed. A sprinkler was set up to water trees throughout the summer. An electricity upgrade was completed on the CFC shop. Warming lamps were borrowed from Cedar Creek, and greenhouse plastic/temperature sensors from the Montgomery lab in St Paul. All pots were filled with potting soil, and planted with greenhouse-grown seedlings.

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

Objectives:

- To quantify the relationship between above- and below-ground biomass within and among different seed sources of white spruce.

Sampling scheme:

- Each fall for five years, 10 trees per seed source will be destructively sampled (60 seedlings each year for each of five years).
- All sample tissue will be rinsed and dried. Roots, shoots, and needles will be separated and weighed. Average biomass of roots, shoots, and needles will be calculated per seed source and statistically compared among sources.

Research questions:

- If a tree produces a large amount of above-ground biomass (volume growth) is this growth at the expense of root growth? Does the amount of root growth reflect the amount of above-ground growth?
- Does the ratio of biomass between roots and shoots differ among sources in a given year? Among years?

Progress made in 2009:

- 300 13-gallon pots were filled with potting soil and placed into trenches. Seedlings were planted, monumented, and a mulch of wood shavings applied. Irrigation was set up and pots were watered in the early spring.
- Fall 2009, 60 seedlings were excavated. Tissue was separated by type (root, shoot, needles), dried, and weighed.

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

Design:

- All racks were constructed with 2 x 4 x 16 foot pressure-treated boards and cattle panels for support. Racks are underlain with landscape fabric.
- Racks were buried for better insulation against summer heat and winter cold.
- Each 1.65-gallon pot was filled with potting soil (50% peat moss, 15% perlite and 35% composted bark).
- PVC pipes are used for hoop structures. 30% shade-cloth was used to reduce watering requirements.
- Racks are watered by a sprinkler.
- A prototype for warming in the winter is being developed.
- Seven seed sources are being tested. Five were selected for fast growth and two represent "woods run" sources.
- Painted stakes distinguish different seed sources. One seed source is represented in each 7-tree row of each rack, and there are 24 rows in each rack.

Objectives:

- To quantify the variation in tree seedling response to periodic winter thaws.

Research questions:

- If white spruce seedlings experience a short period of warm temperatures mid-winter, well ahead of the time of budbreak, do they retain a memory of this warming event and begin to accumulate the degree days?
- Does a winter thaw result in early budbreak? Reduced growth? Delayed budbreak? Delayed budset? Increased mortality?

Sampling scheme:

- Tree heights and seedling diameters at the root collar were measured fall 2009.
- Each warming treatment is accompanied by a return to ambient conditions. Treatments:

1. Control, no warming
2. Warming for 4 days in February
3. Warming for 4 days in March
4. Warming for 4 days in April
5. Warming in February and March (Treatments 1 and 2)
6. Warming in February, March and April (Treatments 1, 2 and 3)

- Collection of phenological traits will take place in spring 2010-2011. Variables measured include time of budbreak, elongation, growth, and cessation of growth. In fall 2010, mortality, tree heights and diameters will be re-measured.

Part IV. Characterization of phenological traits among 21 sources of white spruce

Design:

- In each of two racks, seven seedlings from each of 21 sources of white spruce are planted. Four woods run sources (Little Fork, Baudette, Hibbing and Hill City), and 17 improved sources are represented.

Objectives:

- To determine variability within and among seed sources in terms of phenological traits such as time of budbreak, growth and budset.

Research questions:

- White spruce is notoriously susceptible to early spring frosts. Are improved sources likely to break buds earlier than woods run sources? Alternatively, do they achieve extra growth by extending growth into the fall?
- Do all improved sources behave the same, that is, do they all break bud at the same time?

Sampling scheme:

- No experimental manipulations are planned. Observational data on phenological traits will be made periodically in spring 2010 and 2011.
- This is primarily a demo planting to compare variation within and among sources of white spruce.

Minnesota Tree Improvement Cooperative

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2009

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