Minnesota Tree Improvement Cooperative

2013

Annual Report

Carrie Pike, Research Associate
Jim Warren, Research Fellow
Andy David, Associate Professor and Director

Department of Forest Resources

FULL MEMBERS

Beltrami County

Cass County

Crow Wing County

Iron Range Resources, Mineland Reclamation

Koochiching County

Minnesota Department of Natural Resources

Red Lake Nation

St. Louis County

University of Minnesota Department of Forest Resources

UPM-Blandin

SUPPORTING MEMBERS

BIA

Carlton County

Clearwater County

Hedstrom Lumber Company

Hubbard County

Itasca Greenhouse, Inc.

Lake County

EXECUTIVE SUMMARY

The Minnesota Tree Improvement Cooperative completed its 32nd year in 2013 with ten full members and seven supporting members. Dues payments in the amount of $54,248 were collected, which included the contract with the Minnesota Department of Natural Resources. Dr. Andrew David directed the Co-op, while Carrie Pike managed day to day operations. Pike began a split 50% appointment as Interim Director of Operations at the Cloquet Forestry Center in January 2012, which ended August 29 2013 with the arrival of Dr. Linda Nagel. Pike defended her dissertation on August 29, and her appointment as Research Associate in the Department of Forest Resources started January 1 2014.

Jim Warren provided field and technological assistance, and Egon Humenburger provided field assistance on other projects as needed. Julie Hendrickson assisted with field work in summer and fall 2013 on a part-time basis. Two business meetings were held: January 24 at the North Central Research and Outreach Center in Grand Rapids and April 4 at the Cloquet Forestry Center.

Ten and 20-year measurements were completed on a subset of sites included in the white spruce comparison trials planted in 1993 and 2003, respectively. Tree heights (year 5) were measured on the tamarack seed collection area at MN DNR's Split Rock site (reported in the Appendix). In 2013, cones were collected from 2012 controlled pollinations on red pine trees at St Louis County. Cones were collected from jack pine, white- and black spruce orchards. Controlled crosses were made among white pine selected for increased white pine blister rust resistance.

Field grafting will be attempted on red pine in 2014 at St Louis County, and controlled crosses will be made on red pine and/or white pine as nature permits. The MN DNR continues to work towards re-purposing the site at the former General Andrews Nursery into a tree improvement center. This site will likely host future grafting and serve as a progeny test-site.

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A LETTER FROM THE DIRECTOR

Dear Cooperative Members,

This year has been a little different than most so I would like to offer three personal reflections on the past twelve months. The first is thinking to myself, "It sure is a long, long way down" while at the top of a 16 foot orchard ladder at St Louis County's white pine seed orchard during breeding season. The white pine cone crop was not exceptional but the information on individual tree performance we have gained from working with the USFS Oconto River Seed Orchard is paying off. Specifically, survival measurements from field and greenhouse trials after exposure to white pine blister rust have been helpful in identifying genotypes with better than average rust resistance. Our breeding work will cross these better genotypes for use in future progeny trials and, eventually, new seed orchards.

My second recollection is the small reception we had at Dr. Rebecca Montgomery's house after Carrie's successful dissertation defense. Carrie's mom and dad from New York, Jim and Jake and the four committee members all toasted her degree. If you get a chance congratulate her on this accomplishment - we can all call her Dr. Pike now!

And finally, while reading and editing the reinvestment plan for the state's nursery and tree improvement programs, I was struck by how much had changed in the two years since the DNR was asked by the legislature to plan for a closure of its nurseries. Nothing is ever certain when sausage is being made at the state capitol but I am heartened by the fact that the new legislature asked for a reinvestment plan for the DNR's nursery and tree improvement programs. Let's all keep our fingers crossed.

Sincerely,

Andy David

Andrew David
Associate Professor
Director MTIC

INTRODUCTION

The Minnesota Tree Improvement Cooperative (MTIC) completed its 32nd year of operation in 2013. Dr. Andy David served as Director and Carrie Pike, Research Fellow (Research Associate as of January 1 2014), managed day to day operations. From January 1 through August 2013, Carrie served as 50%-time Interim Director of Operations of the Cloquet Forestry Center. Jim Warren, Egon Humenburger and Julie Hendrickson provided technical and field assistance. Dr Linda Nagel began her role as Director of Cloquet Forestry Center and Professor in the Forest Resources Department on August 26. The staff at Cloquet was also enriched with the arrival of Dr. Mike Falkowski, Research Associate and specialist in remote sensing and geospatial analysis. In addition, Mike Reinikainen (Research Fellow) joined the staff at Cloquet as the new full-time Forest Manager. Dr Vince Fritz, Department of Horticulture, began work as the new Director of Operations at the North Central Research and Outreach Center in Grand Rapids in 2013 as well.

The forest products industry in Minnesota was negatively impacted by the closure of two of four paper machines at Boise Paper in International Falls. On a brighter note, SAPPI completed conversion of its pulp mill to specialized cellulose for the textile industry. This is the largest investment in the pulp mill since its inception, and received well by the Cloquet community. Insects and diseases dominated forestry news, notably the identification of emerald ash borer in Superior, WI and climbing counts of gypsy moth caterpillars along the north shore.

Pike defended her dissertation, "Evaluation of phenotypic and physiologic characteristics of selected sources of white spruce, *Picea glauca* (Moench) on August 29, 2013. Her PhD is in the Natural Resources Science and Management graduate program in the Biology, Ecology and Conservation Management track major through the Forest Resources Department at the University of Minnesota.

This report summarizes activities and accomplishments from January 1 to December 31, 2013. 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 Dr. Andy David (Director and Associate Professor), Carrie Pike (now Research Associate) 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. Julie Hendrickson, Research Fellow, was hired in 2012 with separate funds to assist Carrie with research and MTIC work through December, 2013. Julie completed her M.S. in Natural Resources Science and Management at the U of M in fall 2012, studying genetic variation in ash seed collections advised by Dr. Andy David.

The Advisory committee formally met twice in 2013: January 24 at the North Central Research and Outreach Center in Grand Rapids and April 4 at the Cloquet Forestry Center. This committee consists of representatives from each member organization and meets twice annually to facilitate feedback and communication between members and staff. Pike was invited to present at the SFEC's Research Review on January 16, the MNSAF on March 27, and at the annual meeting of the Superior-Woods Tree Improvement Association in Thunder Bay on October 18. Carrie and Mike Reichenbach, Extension Educator, organized a meeting of private nurseries at the MNLA's office in Roseville on Feb 21. Carrie, Jim Warren, and Mike Reichenbach, along with Dr Gary Johnson, Extension Professor, constructed a gravel bed at Cloquet forestry center, and installed a study to test the effects of soil media (gravel vs sand) on root mass of oak and spruce. Carrie participated in a committee charged with developing a plan for the state nursery and tree improvement programs. This committee met eight times in St Paul from late July through November, 2013 and prepared a reinvestment plan to be submitted to the legislature. Pike also attended the annual workshop of the Superior-Woods Tree Improvement Association in October, the North Central Forest Pest workshop at Frontenac Minnesota in September, the state SAF meeting in Coon Rapids in February, and the SFEC annual research review in January.

Andy was invited and attended a USDA listening session on the Future of Plant Breeding in Washington, DC August 15th. He also was an invited speaker at the annual Minnesota Christmas Tree Association meeting at Black Bear Casino where he spoke about white pine blister rust research, the talk resulted in an article in the MNCTA newsletter. Andy was also invited to review the National Resource Conservation Service's standards and specifications for tree seedlings, site preparation and timber stand improvement in Minnesota.

Presentations

Pike, C. February 26, 2013. How will climate change affect seed sources and species we plant? Annual meeting of the Minnesota State Society of American Foresters, Coon Rapids, MN.

Pike, C. January 16, 2013. Seed sources for a warmer climate in Minnesota. Annual research review, Sustainable Forest Education Cooperative, and panel participant.

Pike, C. October 24, 2013. Going "topless" in Minnesota's conifer seed orchards: a primer for top-pruning trees for seed production. Annual meeting of the Superior-Woods Tree Improvement Association, Thunder Bay Ontario.

David, A. March 15, 2013. White pine blister rust research in Minnesota. Annual meeting of the Minnesota Christmas Tree Association, Black Bear Casino, Carlton, MN.

Publications

David, A. 2014. White pine blister rust research in Minnesota. MNCTA News. Summer 2014. 1pp.

Seed Orchards

The acres of MTIC orchards are shown in Table 5. 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.

The MN DNR is actively converting the facility at General Andrews Nursery into a tree improvement center. Towards this effort, a new white spruce grafted orchard was planted in 2012, and a jack pine seed collection area (St Croix area) was established. Other seed beds are being reserved for future improved jack pine, improved red pine, and white pine improved for rust resistance. New grafted red pine orchards established by MTIC cooperators in 2012 are growing well. Many grafts at St Louis County failed, so that remaining rootstock was left in place for field-grafting in 2014. The DNR will likely field-graft a red pine orchard in the future as well. Finally, Carlton County is planning to establish a hemlock seed collection area at the Gillogly Rd complex. Their objective is to graft selections from the hemlock ravine in Jay Cooke onto rootstock. The rootstock, currently at the shadehouse at General Andrews Nursery, will be planted in 2014. Field grafting may take place as early as 2015.

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	---	35
First Generation Seedling Seed	5	4	24	26	---	4	63
Improved First Generation Clonal	---	15	---	3	---	---	13
Second Generation Full Sib	4	11	6	---	---	---	21
Total acreage by species	***17***	***46***	***30***	***29***	***11***	***4***	***132***

Table 2. *Picea* spp. 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	5/17/1978	2.7	487
		UPM-Blandin	Blackberry	5/22/1978	2.5	596
		U of M CFC	Plantation "U"	5/22/1978	2.5	3168
	1st Gen. Clonal	U of M CFC	Airport 40	5/1/1995	1.1	238
	Improved 1st Gen. Clonal	Koochiching County	Big Falls	5/19/1989	2.3	79
		Koochiching County	Larsaybow	5/27/1998	4	59
		Minnesota DNR	Sturgeon Lake	5/1/1979	1.3	812
		Minnesota DNR	Split Rock	5/27/1992	2.4	262
			Totals:	**8 Orchards**	**16.4**	**5439**
White spruce	1st Gen. Clonal	Lake County	Two Harbors	9/2/1987	1	183
		Minnesota DNR	Cotton	5/1/1977	12	206
		Minnesota DNR	E3	5/12/2012	2.5	175
		Minnesota DNR	E4	5/12/2012	2.8	192
		St. Louis County	Ellsburg Rd.	5/11/1988	1.5	191
		UPM-Blandin	Arbo	5/1/1976	1.5	121
	1-1/2 Gen. Clonal	Carlton County	Gillogly Road	4/1/2003	2.1	122
		Minnesota DNR	Split Rock	9/2/2001	3.7	209
		Red Lake	Redby	4/1/2004	0.9	157
		UPM-Blandin	College	9/5/2000	2.9	762
	2nd Gen. Seedling	Lake County	Ostman Pit Road	6/6/2005	1.3	824
		Itasca County	Wabana Lake	5/20/2003	1.8	693
		Minnesota DNR	Eaglehead	6/3/2003	1.8	401
		Minnesota DNR	Eaglehead	5/1/2005	1.3	409
		St. Louis County	Ellsburg Rd. East	6/6/2003	2.1	393
		UPM-Blandin	Feeley	5/1/2005	2.4	1535
			Totals:	***16 Orchards***	***41.6***	***6,573***

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	Carlton County	Gillogly Rd.	28-Jun-83	5.5	183
		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
		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	601
		St. Louis / Iron Range Resources	Ellsburg Rd. East	12-May-99	3.78	2064
			Totals:	***8 Orchards***	***20.0***	***4,779***
White pine	1st Gen. Clonal	Itasca Greenhouse	Sayward	16-Jun-05	0.8	404
		Minnesota DNR	Split Rock	25-May-93	1.0	88
		Minnesota DNR	St. Francis	15-May-85	3.0	319
		Red Lake Nation	Cooks Rd.	05-May-11	2.2	207
		St. Louis County	Ellsburg Rd.	02-May-90	1.1	233
		St. Louis County	Ellsburg Rd. East	21-Jun-99	2.5	184
			Totals:	***6 Orchards***	***10.6***	***1,435***
Red pine	1st Gen. Seedling	Carlton County	Gillogly Rd.	10-Jul-81	6.6	472
		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
		St. Louis County	Ellsburg Rd.	09-May-88	5.5	531
	1st Gen. Clonal	Carlton County	Gillogly Rd.	01-May-11	0.5	51
		Red Lake Nation	Cooks Rd.	05-May-11	1.3	50
		St. Louis County	Ellsburg Rd. West	01-Jun-11	1.5	62
			Totals:	***7 Orchards***	***22.2***	***1,684***
Tamarack	1st Gen. Seedling	Minnesota DNR	Split Rock	12-May-08	4.3	1,795
			Totals:	***1 Orchard***	***4.3***	***1,795***

Table 4. 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	2012	2017
White spruce	Comparison trial	1993	Minnesota DNR	Dago Lake Rd	2012	2022
		1993	Potlatch Forest Holdings, Inc.	Orr	2012	2022
		1993	Plum Creek Timber Company	Gordon	2012	2022
		1993	Blandin Paper Company	Hwy 61	2012	2022
		1995	U of M	CFC-Airport 40	2005	2015
		2003	Koochiching County	Little Fork	2012	2022
		2003	Minnesota DNR	Side Lake *	2012	2022
		2003	Potlatch Forest Holdings, Inc.	Brookston	2012	2022
		2003	St Louis County	Jean Duluth Rd	2012	2022
		2003	UPM-Blandin	Wilson Lake *	2012	2022
	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	2012	2016
		2003	St. Louis County	Ellsburg East	2012	2016
		2003	Minnesota DNR	Eaglehead	2012	2016
		2005	Lake County	Ostman Pit	2009	2014
		2005	Minnesota DNR	Eaglehead	2009	2014
		2005	UPM-Blandin	Feeley	2009	2014
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	2016
		2007	Potlatch Forest Holdings, Inc.	Lake George	2011	2016
		2007	U of M	CFC	2011	2016
		2007	St Louis County	NE Grade	2011	2016
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 2013, white spruce experienced a higher-than average seed year across the state. The DNR collected their first cones from the Split Rock white spruce orchard, an orchard that they reclaimed as the surviving grafts emerged from thick grass. Mutch's Forestry, contracted to manage Blandin's orchards, procured 27 bushels from the College orchard in Grand Rapids, the most of any cooperator this year. In addition, cones were collected from jack pine and black spruce orchards (Table 9).

Table 5. Cones collected by MTIC members in 2012

Species	*Agency / Industry*	*Orchard*	*# bushels*
Jack pine	Carlton Co.	Gillogly Rd	10.0
	MN DNR	Nickerson	6.0
White spruce	MN DNR	Split Rock	1.0
	Blandin	College	27.0
	Red Lake	Redby	1.0
Black spruce	Blandin	Blackberry	9.5
Total number of bushels collected			54.5

SPECIES REPORTS

Black spruce

Black spruce cone crops were generally small across the region, although Mutch's Forestry managed to procure almost 10 bushels from Blandin's **Blackberry** orchard. Koochiching County's **Big Falls** and **Larsaybow** orchards are well-maintained, with Big Falls producing seed crops every few years. The Minnesota DNR's **Eaglehead** will require additional thinning and topping, and veg management to facilitate work in the orchard. The black spruce orchard at MN DNR **Split Rock** is well maintained and produces bumper cone crops periodically that are collected. Aerial seeding remains the predominant method of artificial regeneration in the state. Demand for seed fluctuates wildly from year to year, but supplies of improved seed are generally suitable for the amount of hand- or machine-planting that occurs each year.

White spruce

Improved first-generation seed orchards are starting to reach maturation. Blandin's **College** orchard is leading the MTIC with white spruce seed production. Red Lake's **Redby** is starting to produce regular crops. Sanitation (removal of all cones) efforts at both orchards appear to be helping to prevent establishment of cone/seed insects. Carlton County's **Gillogly Rd** orchard has suffered damage from porcupine whose palate favors the most vigorous grafts!!! About a dozen white spruce grafts were planted in the Koochiching County's **Big Falls** orchard complex to provide the county with their own seed source. The grafts were planted behind the existing black spruce orchard.

The DNR's **Split Rock** orchard, which had been abandoned due to low survival, was mowed carefully by the staff and General Andrews Nursery, revealing 209 trees out of 255 trees planted (82% survival). This orchard was built using the top 25 genotypes from the 1986 progeny test and represents an elite source of white spruce with some of the highest gains for volume growth in the MTIC. An additional new grafted white spruce orchard was established at the General Andrews Nursery in Willow River to supplement the DNR's need for improved white spruce seed. These grafts were made from the existing A and B blocks at Willow River that had been slated for removal. This new orchard will contain a wide range of selected genotypes from our program representing a diverse seed source with lower genetic gains than the Split Rock orchard.

In spring 2013, staff completed data collection on two white spruce comparison trials planted in 1993 (**Orr MN** – Potlatch land, and **Gordan** WI – Plum Creek land). Measurements at **Dago Lake Rd**, adjacent to the General Andrews nursery was started but not completed due to poor survival. Tree measurements were also completed on three sites for the white spruce comparison trial planted in 2003: **Potlatch Brookston** just north of Cloquet, **Kooch County Devereaux Rd** near Littlefork, and **St Louis County Jean Duluth Rd** north of Duluth. Measurements at Blandin's – **Wilson Lake** site were started but not completed in spring 2013. The MN DNR – **Side Lake** site will be visited from a different entrance (the original entrance was flooded by a beaver dam) in early 2014.

Jack pine

The second-generation population at St Louis County/IRRRB **Ellsburg Rd East** was rogued in fall 2013. Our attempts to visit and take pictures were sidetracked with the snow-dumping that we received in early December. Before the roguing was started, Jim and Julie placed metal identification tags on the remaining trees that will be used for scion collection in the future. Crow Wing County / MN DNR population south of Fort Ripley was rogued last year. All trees remaining after roguing need to be permanently tagged.

IRRRB-**Calumet** is being abandoned as an orchard, to be replaced by the new second-generation orchard at **Ellsburg Rd** in collaboration with St Louis County. Carlton County-**Gillogly Rd**, MN DNR**-Long Prairie,** and MN DNR**-Nickerson** are all actively managed for cone production. St. Louis County's first-generation orchard at **Ellsburg Rd** may be thinned for cone collection in the near future, as the orchard is burly and overgrown. Both Cass-Beltrami-Hubbard's-**Deep Portage**, and MN DNR**-Bemidji** are in rough shape and not used for cone collections anymore. Organizations that have need of jack pine seed should consider revisiting these orchards even if it is a one-time collection based on harvest.

At the General Andrews facility, we propose to establish two new improved second-generation orchards. One orchard would be composed of top trees from the Crow Wing/MN DNR population and the second orchard would consist of top trees from St Louis County / IRRRB population in Ellsburg Rd. We also plan to fill the space adjacent to the second-generation trees in Crow Wing County with grafts to enhance seed production at that site.

Red pine

Grafted orchards are slated to replace aging seedling-seed orchards. At Carlton County – **Gillogly Rd,** survival was 78% in 2012, but most grafts were thriving. At St. Louis County - **Ellsburg Rd West**, survival was only about 40%. The remaining rootstock trees were vigorous with enough leaders to permit field-grafting in the future, so we anticipate field grafting in spring 2014 if the weather permits. Survival is lower at Red Lake-

Cooks Rd, but the remaining grafts were transplanted into one section of the orchard to reduce the amount of area to mow and manage. These will be re-surveyed in 2014.

Tree breeding in red pine was started in 2010 to develop a second-generation population and simultaneously to test inbreeding effects in red pine. We used PAM (Positive Assortative Mating) to develop mates for the second-generation population. We developed an index to rank trees using a combination of tree data from St Louis County, and family means from six other MTIC orchards (Ashwabay, Cass County, Cotton, Eaglehead, Petenwell, Potlatch), adjusted for rep-effects. Tables 8 and 9 below detail the crosses made from 2010 and 2012 controlled pollinations, and the total number of seeds in storage. In fall 2013 we collected cones from 17 controlled crosses at the St Louis County Ellsburg Road orchard.

Table 6. Controlled pollinations completed and/or planned at St Louis County's red pine orchard. "Type" refers to the PAM rank (Positive Assortative Mating) where Type= 1 was composed of the top two ranks, 1 and 2. (Rank 1 represents the genotype with the highest potential for volume growth). Cross 2 composed of ranks 3 and 4, etc. Underlined trees were slated for the cross. Genotypes not underlined were bred when the female parent or pollen was not available.

Female	Male	Type	# Seed (2010 x)	# Seed (2012 x)	Total # Seeds
518.1122	101.1135	1	91		91
102.1057	452.1120	2			0
452.1128	102.1057	2	68		68
271.1202	209.1186	3			0
209.1186	271.1202	3	201		201
234.1087	265.1145	4	17		17
430.1144	234.1087	4	25		25
245.1177	109.1137	5	0		0
107.1147	245.1177	5		147	147
448.1159	288.1209	6	44		44
452.1118	448.1159	6	57		57
471.1133	412.1186	7			0

412.1187	471.1133	7	125		125
103.1131	430.1140	8		36	36
430.1140	103.1123	8	88		88
225.1138	226.1158	9			0
226.1158	225.1143	9	37		37
234.1081	226.1158	9		104	104
104.1131	494.1170	10	66		66
494.1170	104.1131	10		136	136
105.1103	210.1131	11	122		122
228.1037	106.1125	12			0
106.1131	228.1037	12	150		150
226.1153	106.1125	12	45		45
502.1212	268.1153	13	106		106
238.1026	512.1279	14	31		31
457.1067	215.1141	15	64		64
518.1125	457.1067	15	5		5
232.1194	267.1153	16			0
267.1136	232.1194	16	64		64
108.1091	244.1145	17	203		203
486.1074	212.1193	18			0
271.1187	486.1074	18	45		45
211.1101	446.1135	19		80	80
446.1136	211.1101	19	43		43
207.1084	403.1064	20		73	73

Table 7. Controlled crosses (red pine) made for inbreeding trial. Type refers to half-sib relatedness, where parents share a common mother tree. Inbred crosses were crossed using either stored pollen or pollen collected the same season.

Female	Male	Type	#Seed 2010 x	#Seed 2012 x	Total # Seeds
104.1140	104.1131	Half sib			0
105.1097	105.1103	Half sib	53		53
106.1129	106.1125	Half sib			0
106.1131	106.1125	Half sib			0
226.1153	226.1158	Half sib	49		49
234.1081	234.1087	Half sib	68		68
430.1144	430.1140	Half sib	23		23
448.1171	448.1159	Half sib			0
452.1118	452.1120	Half sib	13		13
452.1128	452.1120	Half sib			0
457.1070	457.1067	Half sib			0
502.1200	502.1212	Half sib		22	22
518.1125	518.1122	Half sib		103	103
104.1131	104.1131	Inbred		191	191
105.1103	105.1103	Inbred	252		252
106.1131	106.1131	Inbred			0
108.1091	108.1091	Inbred		66	66
234.1081	234.1081	Inbred		101	101
234.1087	234.1087	Inbred	65	39	104
238.1026	238.1026	Inbred		70	70
430.1140	430.1140	Inbred	159	118	277
430.1144	430.1144	Inbred		99	99
448.1159	448.1159	Inbred	36		36
457.1067	457.1067	Inbred	80	198	278
518.1122	518.1122	Inbred		46	46
518.1125	518.1125	Inbred	4		4

White pine

Most white pine orchards were devoid of cones in 2013. Early survival at Red Lake's new grafted orchard, **Cooks Rd**, is excellent. The arboretum at Cloquet was further maintained: Jim and Julie brushed, staked and tagged the new part of the breeding arboretum. Research and breeding related to white pine blister rust continued on several fronts in 2013.

Using the results of USFS blister rust field screening trials (912, 922, 924 and 989A) plus USFS greenhouse screening trials (2009-2010) and results from the Moose Fence trial at Tofte we have begun to accumulate pollen from select trees to cross onto select grafted genotypes at the St. Louis County orchards and at the CFC breeding arboretum. This summer we made 31 crosses at the St. Louis County orchards and eight additional crosses at the CFC arboretum (Tables 8 and 9). Additional crosses would have been made at CFC but there was a shortage of female cones on select genotypes. In following years we will make additional crosses and add selections out of the USFS greenhouse screening process to MTIC orchards so that they can be crossed and evaluated.

Table 8. White pine crosses made at the St. Louis County seed orchard.

		Females					
		C 101	**MI 25**	**MI 27**	**P 30**	**P 343**	**Totals**
Males	**MI 69**	x	x	x	x	x	5
	MI x55	x	x	x	x	x	5
	ON 466	x	x	x	x		4
	ON 49x	x	x	x	x		4
	ON 504	x	x	x	x		4
	ON 469	x	x	x	x	x	5
	ON 646	x		x	x	x	4
	Totals	7	6	7	7	4	31

Table 9. White pine crosses made at the CFC breeding arboretum.

		Females		
		502	**116**	**Totals**
	111	x	x	2
	412	x	x	2
Males	**416**	x	x	2
	502		x	1
	MI 69	x		1
	Totals	4	4	8

Tamarack

The MN DNR established a tamarack seed collection area in 2008. Mother trees were not selected for any particular trait, so the planting is technically a seed production area, not an "improved" orchard. However, this site represents a diverse seed collection area with added statistical value: we maintained the origin of each tree in the planting, and set up a randomized complete block design with single-tree plots. The seed sources originated across four different DNR seed zones. The planting was designed for seed production, but also to learn more about the effects of seed transfer on tamarack growth. A short summary is included in the appendix of this report.

OUTLOOK

The economy is steadily improving, but forest managers continue to face other obstacles such as insects and diseases and changing patterns of temperature and precipitation that challenge forest regeneration. Battling "mother nature" will require creativity, experimentation and novel silvicultural tools. It may be heartening to hear that the skills, concepts and data generated by decades of tree improvement, progeny and provenance testing in Minnesota can assist. Perhaps the moniker of "Tree Improvement" is too narrow to describe the full range of services that cooperative genetics research implies. Even so, the DNR's ongoing efforts to convert the former General Andrews nursery into a new "tree improvement center" represent a positive shift in priorities that may translate into novel funding. This would invigorate the DNR's seed and seedling program, as well as inject new energy and leadership to the sector of applied forest genetics in the state.

The completion of Carrie's PhD was a significant milestone both for Carrie and the MTIC. Publications that are generated from that work will increase exposure of Minnesota's tree improvement efforts nationally and internationally. Carrie's workload as a Research Associate will likely entail a combination of grant writing, teaching and research on top of outreach and engagement with the MTIC.

The MTIC has starting integrating silviculture into the program by helping to establish demonstration areas with and without a genetic component. These collaborative projects between the Department of Forest Resources and stakeholders help promote smart forestry practices, which simultaneously improve forest productivity and increase exposure to forest genetics. The value of these demonstration areas for practicing foresters and politicians should not be underestimated.

COOPERATIVE WORK PLAN: FIELD SEASON 2014

White spruce

- Measure tree heights (10th year) on second-generation populations: Lake County (Ostman Pit Rd), MN DNR (Eaglehead), and Blandin (Feeley property).
- Determine genotypes to remove from Blandin College orchard
- Work on Blandin white spruce demonstration areas.
- Assess survival at the white spruce comparison trial on String of Pearls (Blandin).
- Visit 2003 white spruce comparison trial site at Side Lake area (Tim Russ)
- Continue orchard management (MN DNR, St Louis, Red Lake, Blandin, Carlton County, Koochiching County)
- Collect all cones from orchards!

Jack pine

- Collect pollen from second-generation orchards for future tree breeding.
- Make plans for field grafting at General Andrews facility.
- Tag all trees at the two second-generation jack pine populations.

Red pine

- Field grafting in April 2014 at St Louis County Ellsburg Rd.
- Survey graft survival at Red Lake, Ellsburg Rd, Carlton County
- Plant rootstock at General Andrews for field grafting in 2015.

White pine

- Collect seed from 2013 controlled crosses
- Make new crosses if possible.

Hemlock (Carlton County)

- Plant rootstock into Gillogly Rd orchard.
- Identify trees for grafting in 2015 or later.

Black spruce

- Monitor orchards for cone/seed crops.

MTIC FIVE- TO TEN-YEAR PROJECT GOALS

White spruce:

- Continue monitoring white spruce second-generation populations.
    - Identify top genotypes.
    - Graft top genotypes into new improved second-generation orchards.

Jack pine

- MTIC – make new controlled crosses at second-generation populations
- Crow wing/ DNR – add new grafts to the fenced area
- Develop new grafted populations for MTIC cooperators: DNR (General Andrews), Beltrami County, Cass County, Red Lake.

Red pine

- MTIC - Complete all red pine crosses.
    - DNR, St Louis, other cooperators: locate sites on which to establish new second-generation populations.
- DNR, Beltrami, new improved first-generation grafted orchards

White pine

- Continue to support USFS screening at ORSO
- Develop new improved first-generation orchards with increased resistance to blister rust disease.
- Establish progeny test using data from field trials and USFS screening at ORSO.

Hemlock

- Graft onto rootstock at Gillogly Rd

APPENDIX

Tamarack: an investigation of seed sources for Minnesota

Abstract

Tamarack is a common covertype across northern Minnesota but seed is difficult to acquire in high quantities for artificial reforestation. The objective of this trial was to measure differences in growth among a variety of seed sources in Minnesota. Open-pollinated seed from 30 mother trees was obtained, and the location (seed zone and county) was recorded. Seed was germinated and planted into one site in Pine County Minnesota. Tree heights were measured after five growing seasons. Saplings from the local seed zone (Central) were significantly taller than all others, exceeding the North West and North East by 4% in height. The adjacent North Central seed zone was statistically smaller, but only resulted in 1% loss in height. Tamarack seed sources for planting in the central seed zone should be limited to seed from the local (Central) or adjacent (North Central) seed zones.

Introduction

Tamarack (*Larix laricina*) grows throughout the northern two thirds of Minnesota, primarily on low-land areas such as the Forested-Rich Peatland systems (MN DNR, 2003). Once a dominant covertype in Minnesota, tamarack has been reduced following intense logging, conversion of land for agriculture, and fire suppression, all of which favored aspen regeneration (Hanberry, Palik, & He, 2013). The species is typical of other boreal conifers in that it inhabits a large geographic range, spanning North America, and is grown commercially across the lake states (Rudolf, 1966). In recent years, the species has significantly declined from insect outbreaks, primarily the eastern larch beetle (Seybold, Albers, & Katovich, 2002) and larch sawfly (Hanberry et al., 2013).

Natural regeneration of tamarack is commonly seen along the margins of a clear cut, and alongside black spruce in bogs. It often exceeds growth of spruce early in the rotation, but is usually surpassed by mid-late rotation (Fayle, 1979). Artificial reforestation is usually restricted because of a lack of seed, owing to challenges in procuring cones and the propensity for hollow seeds (MN DNR, 2013). Seed from wild trees represent the primary seed source for artificial reforestation in Minnesota. Genetic improvements are possible (MacGillivray, 1969; Reimenschneider & Nienstaedt, 1983), but are a low priority in Minnesota. Instead, the development of seed collection areas is proposed as a low-cost option for seed procurement. Costs for establishing seed collection areas may be offset by decreasing the costs to procure seed.

Genetic diversity in tamarack is high, similar to other wind-pollinated conifers. Tamarack may possess greater population structure than other conifers in the lake states (Cheliak, Wang, & Pitel, 1988), which will require attention to the seed source used for

reforestation. Provenances differ mainly in their late season phenology: northern sources set buds earlier than southern sources (Farmer, O'Reilly, & Shaotang, 1993; Rehfeldt, 1995), a process that is governed strongly by photoperiod and not temperature. Date of bud-set also correlated strongly with number of frost-free days in Wisconsin, a result attributed to a cline that follows geographic divisions as well as latitudinal gradients (Rehfeldt, 1995). In spite of a low population structure, differences in seed sources between northern and southern provenances are present and latitudinal seed transfer may result in mal-adaptation.

The Minnesota Department of Natural Resources instituted seed zones for the state nurseries in the mid-1990s to safeguard nursery stock from maladaptation that might occur from hyper-extended seed transfer. The DNR delineated six seed zones based on temperature and precipitation gradients (Rudolf, 1956). The map and seed zones may be found at this hyperlink: http://www.dnr.state.mn.us/forestry/ecs_silv/fieldpractices/seedcollection.html. These zones set a benchmark standard, guiding seed transfer in the state, but have not been tested quantitatively. The current study was designed to test seed from mother trees occurring across a geographic gradient and seed zones to observe the effects of seed transfer of tamarack in the state. Only one site located in the southern range edge was planted, so we cannot assess the effects of northward movement of seed. Even so, we can infer the effect of transfer distances from more commonly used northerly seed sources to a location further south.

Methods

Seed for this study was obtained from thirty different mother trees after felling. Mother trees were representations of native wild stock with no selection imposed. The trees were collected from seven different counties (hereby referred to as provenances) in the state of Minnesota.

The site was a former hay-field with coarse-textured soils, pH 6.5 and 2.8% organic matter. The field was disked and sprayed the year prior to planting. The site was planted as a randomized complete blocks with single-tree row plots. The site was planted into two adjacent blocks, A and B. Block A contained 62 reps and Block B contained 21 reps. Reps were spaced 16 feet (4.9 m) apart; trees in the rep were spaced 8 feet 2.4 (m) apart. The wide spacing was designed to promote crown development for seed collection. Trees were hand-planted in spring 2008, and tree heights were measured to the nearest centimeters in fall 2012 after the fifth growing season.

Data was checked and found to be normally distributed with stable variances with no outliers. All analyses were done in SAS version 9.3 (SAS Institute Inc, Cary NC). A mixed models ANOVA (SAS/STAT proc mixed) was used to compare seed zones. Block, rep and family were set as random variables with seed zone and family nested within seed zone as fixed variables.

$$\text{Tree height} = Block_i + Rep_j + Seed\ zone_k + Family\ (Seed\ zone)_{jk} + e_{ijkl} \quad \text{Equation 1.}$$

Tukey's test was used to compare seed zones, adjusted for multiple comparisons. Variance components were calculated in SAS/Stat (Proc varcomp) using the REML procedure. Narrow-sense heritabilities were calculated with Equation 2:

$$h^2 = \frac{4 * \sigma^2_{family}}{\sigma^2_{error} + \sigma^2_{family}} \quad \text{Equation 2.}$$

Standard errors for the heritability were calculated with Equation 3, where N=the number of trees per family, R = the number reps, and F=the number of half-sib families:

$$SE = \frac{\frac{(1-h^2)}{4} * [1 + NR - 1) * \frac{h2}{4}]}{\sqrt{[\frac{NR}{2} * (NR-1) * (F-1)]}} \quad \text{Equation 3.}$$

Results

Average tree height was 179 cm (Table 12) across 1795 surviving trees. Overall survival was 90%, ranging from 85-94% per provenance (Table 12). The confidence interval for tree heights was narrow so that 95% of all tree heights occurred within 3% of the site mean.

Differences among seed zones and families nested within seed zones were highly significant (ANOVA $p<0.001$). Seed sources from all other seed zones were significantly shorter than the local (Central) seed zone (Figure 1). Trees from the North Central seed zone, just north of Central zone, were also significantly shorter by approximately 1% than those from the Central zone.

Heritabilities were modest at 10% with a standard error of 0.006. Roughly 28% of the variation was attributed to site factors (block and rep) while 67% of the variation was attributed to random error (Table 13).

Table 1. Survival, least-squared means for ten year tree height, and standard errors for the seven provenances tested in this trial.

Provenance	Survival	Mean	Std Error	No. Mothers	No. trees planted	No. trees alive
Baudette	85%	175	3.17	5	430	366
Blackduck	87%	174	4.72	3	198	172
Littlefork	89%	174	2.83	7	441	391
Bemidji	92%	176	7.17	1	71	65
Nimrod	92%	193	4.48	4	237	217
Cloquet	92%	175	3.10	5	398	365
DeerRiver	94%	194	4.52	5	224	210
Site Total	90%	179	1.44	30	1,999	1,786

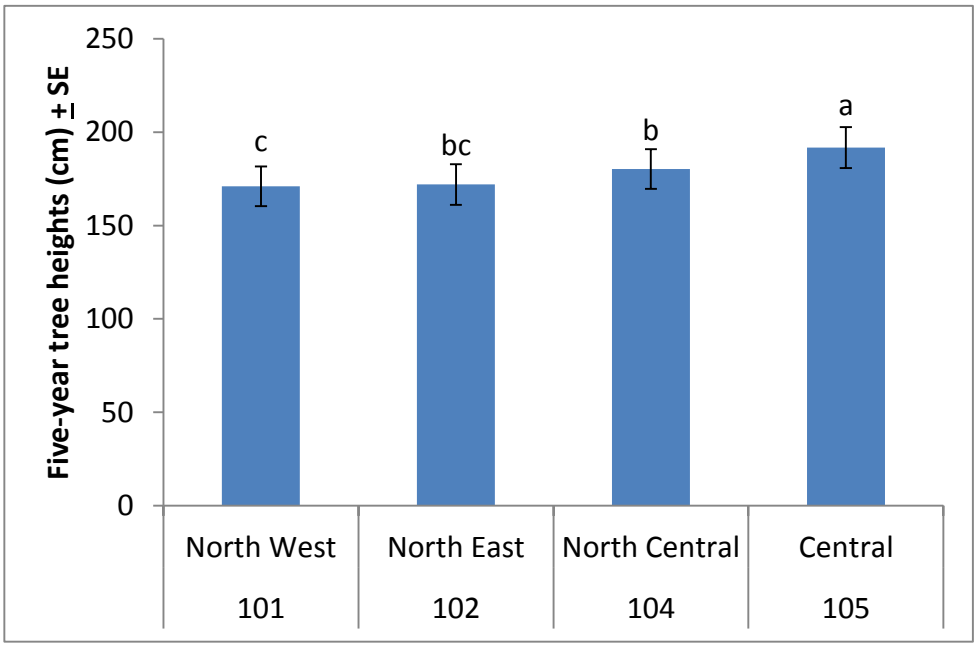

Figure 1. Average tree height (cm) after five growing seasons for four seed zones represented in this population. Differences using Tukey's test (p<0.05) are shown with different letters. Number of trees per seed zone=603 (North West), 441 (North East), 622 (North Central) and 237 (Central).

Table 2. Variance components for tree heights at Split Rock tamarack planting.

Component	Variance	%
Var(Block)	172.8	4%
Var(Rep)	914.3	24%
Var(Family)	113.5	3%
Var(Seed zone)	57.94	2%
Var(Error)	2588	67%
Total	3847	100%

Discussion

Conditions at the Split rock site were highly favorable for tamarack survival, which was exceptionally high (90%), and no insect populations were observed damaging the trees. Tree heights from the Central seed zone were significantly taller than trees from all other seed zones, supporting the use of local seed as defined by current seed zones. Tree heights from the North West and North Central seed zones were approximately 4% shorter than the local (Central) zone. These differences occurred with no selection imposed, and in spite of high tree-tree variation observed on the site. Differences in tree volume are likely to be much higher, and will be assessed after all trees reach diameter at breast height.

Differences between northern and southern seed zones have been observed in past studies: at a site in north central Wisconsin, trees from northern seed sources were smaller than those from local, more southerly latitudes (Riemenschneider & Jeffers, 1980). In range-wide provenance trials, steep phenotypic differences between Alaskan/Yukon population and other populations was observed (Parker & Dickinson, 1990). Provenance trials are useful for detecting populations on a large scale but often fail to represent variations on a much finer regional scale. For example, populations along ecological margins within close proximity produced significant differences with no selection imposed (Rehfeldt, 1995). The planting site at Split Rock is located on a southern range edge where tamarack tends to occur in isolated pockets along the southern range-edge of the boreal forest. Transfer distances to this southerly location may be more conservative than transfer distances in the northern part of the state, but additional studies are necessary to confirm this. Transfer from North West and North Central seed zones to the Central seed zone resulted in clear losses in height growth. No family by site interactions could be studied because trees were planted only at one location. Additional sites should be used to investigate site by family interactions in case they are unstable, especially for isolated southern populations (Reimenschneider & Nienstaedt, 1983).

The optimum latitude for seed sources for planting in northern Wisconsin ranged from 43.5 to 46° Latitude in a previous study (Riemenschneider & Jeffers, 1980), corresponding to central Wisconsin, Maine and Nova Scotia. Our data verifies that seed from the southern (Central) seed zone is best for that site, but we cannot ascertain whether that seed source would be superior if transferred to other northerly seed zones in Minnesota. Our data is the first to test seed transfer of tamarack seed sources within Minnesota. Advanced studies are needed to compare the susceptibility of seed sources to the insects that pose large-scale threats to the health of tamarack forests across the state, and investigate transfer distances among seed zones in the northern two seed zones.

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White pine update
A. David

In May 2013, David, Humenberger, Gottleib, Jones and Pannkuk evaluated survival and blister rust incidence at the USDA Forest Service's white pine genetics trial 989A. The trial is located off of Fox Farm Road, near Rice Lake, MN approximately 15 miles from Lake Superior. Comprised of 122 families of open pollinated and control pollinated origin across five replications, it was designed as a field test of blister rust resistance established in 1990 by the USFS (Dick Meier) and St. Louis County Land Department (Brad Jones). The trial was extremely well monumented with rebar and aluminum tags at the head of each plot which was fortuitous because survival was so low at 2.3% (80 of 3489 seedlings) that without it the trial would have been a total loss.

Although the low survival and precludes traditional statistical analysis (all families appear non-significantly different) some information is worth noting. The trial included four families considered by USFS to be resistant and four additional families considered susceptible controls. The four resistant families produced two surviving trees both with active cankers, while the susceptible families produced one tree with an active canker. Among the surviving trees 36 had no cankers, 10 had inactive cankers and 34 had active cankers of varying sizes and shapes. Twenty-one families had at least two surviving trees. Among these families MI 95 x P327 produced three uninfected trees while six other families each produced two uninfected trees at a minimum. Open pollinated family S 280 did produce four survivors, however three of them were cankered (Table 1).

Because the parental backgrounds of the families are not well organized it is not possible to assign breeding values for male or female parents. However, because the site is located in a high rust risk area and there is a high incidence of rust in surviving trees, suggesting the seedlings likely died from blister rust, we have targeted some of the parents for inclusion into our rust resistance breeding program.

Table 3. Number of surviving trees and their canker status from families with at least two survivors at the Rice Lake, MN white pine blister rust resistance trial.

Family		Number of surviving trees with		
Female	Male	No cankers	Inactive cankers	Active cankers
C 101		1	2	
C 101	U 15	2		1
C 103		1		1
C 106	C 119	1		1
C 108		2		
C 120	C 102			2
MI 38		2		
MI 53	P18+P30	1		1
MI 53		1		1
MI 58	P18+P30			2
MI 61	P 343	2		
MI 77	X 99	1	1	
MI 87		1		1
MI 95	P 327	3		
MI 98		2		
MI 155		1	2	
ON 4	MI 35	2		
S 102		1		1
S 151				2
S 280		1	1	2
Unknown	Unknown			2

Disease Garden Trial - Namebini

The Disease Garden Trial is an evaluation of parental white pine material as grafts and their progeny planted as seedlings at the same location to evaluate the inheritance of blister rust resistance. In 2012 we established two sites at the DNR nursery in Eveleth, MN and at the HWRC near Winton, MN. This past June we established a third site north of Duluth called Namebini with leftover seedlings on private land owned by Carl and Cindy Haensel, 6614 McQuade Road, Duluth, MN. Due to size constraints this site has two plantings (an upland and a riparian/upland transition zone) each with three replications.

The seedlings were planted in late May and the sites were fenced by Ca. Haensel and volunteers throughout the summer. Survival was checked in fall and found to be excellent (>95%) at all locations.

During summer vegetation management was conducted at the HWRC site to release seedlings from aspen suckers. Survival and growth were recorded at both Eveleth and HWRC in the fall. Survival rates exceeded 90% at both locations. Now that the Disease Garden Trial has been installed on three sites we can follow the progression of blister rust over time and compare levels of blister rust infection in the parents and progeny in the same locations.

Evaluation of phenotypic and physiologic characteristics of selected sources of white spruce, *Picea glauca* (Moench) Voss

C. Pike, PhD Thesis. Natural Resource Science and Management degree. December 2013.

ABSTRACT

White spruce is highly valued for its wood pulp in commercial forestry in Minnesota. Seed orchards have been developed using genotypes selected for increased volume production. I conducted three different experiments to study the variation of ecophysiologic traits among genotypes selected from the Minnesota Tree Improvement Cooperative's program to better characterize the phenotype of selected genotypes. In chapter 1, I analyzed wood specific gravity, tree volume, and leaf traits on 25-year old trees in a white spruce progeny test. Wood specific gravity was negatively correlated with tree volume. Needle traits, primarily specific leaf area (SLA), leaf area ratio (LAR) and leaf mass ratio (LMR), were positively correlated with wood volume. In chapter 2, I planted seedlings from four genotypes selected for superior volume growth and two wild sources in a common garden. I harvested ten trees from each genotype, each year for three years. I examined biomass allocation, tree allometry and assessed genetic correlations among allocation of biomass to major organs. The largest differences in biomass were found between the two wild sources that represented two different seed zones in Minnesota. Selected sources more closely resembled the southern, than the northern, wild source. The northern wild sources had slightly higher allocation to roots but otherwise no significant differences in allometry were found. In chapter 3, I set up an outdoor experiment by planting five selected- and two wild- seed sources into 1-gallon containers to test the effects of mid-winter warming on phenology and growth of white spruce. Bud-break time was delayed in plots that were warmed in February, and advanced in those warmed in March. Overall controls had the highest height growth and intermediate bud-break time. Climatic warming that takes place during winter months may delay or advance bud-break depending on the timing. Growth of white spruce is expected to decline with increased episodes of winter warming. Selected sources should be favored in reforestation across Minnesota because of the higher productivity and adaptability to local conditions.

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2013

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