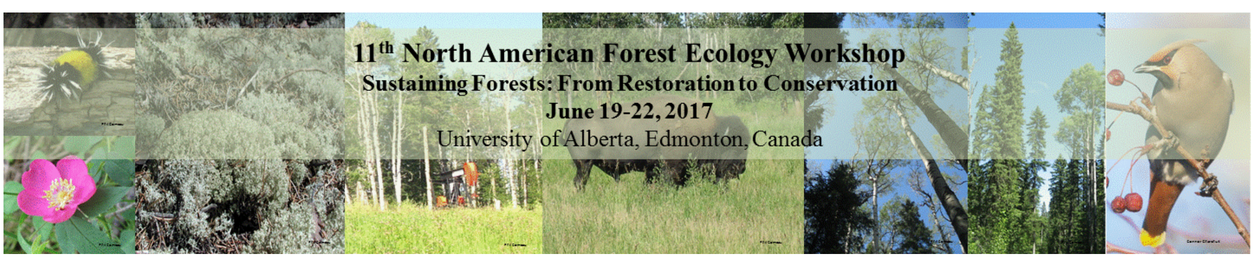
ALBERTA PACIFIC FOREST INDUSTRIES INC

Poplar Farm Research Tour

NAFEW Tour E: Poplar Genetics and Management

Updated: June 10, 2017



FOCUS ON EXCELLENCE

NAFEW Field Trip E

Tour Guides: Barb Thomas, 780-974-2564 & Bobby Hu
Al-Pac Host: Dave Kamelchuk

MAKE SURE YOU HAVE YOUR LUNCH BEFORE DEPARTING

7:45am Leave from the Lister Conference Center

8:45-9:00am Break at Clyde

9:30-9:45am Walker plantation (near Rochester. pull off highway to the east.)

- Walker was field planted on June 4, 2008 with OWD stock, at a 3x3m spacing. North half of field was native bush prior to planting while the south end was agricultural land. Trees performing much better on the south end of the plantation.

10:45am Arrive at Derko's

10:45-11:00am Break

11:00-12:00pm Al-Pac trials (Field 7)

- 2005 hybrid poplar clonal trial (view original ODETTE & ODILE)
- Look at the *P. davidiana* and *P. tremula*
- Balsam trial

12:00-12:30pm Lunch

12:30-2:00 Al-Pac trials (Field 23)

- Hybrid poplar, hybrid aspen, native aspen, birch, Quebec balsam and hybrid poplar trials

2:05-2:15pm Break at Derko's before departing to final plantation stop and return to UofA

3:30-3:45pm Okanese plantation (Range Rd 243 and Highway 2) Pull off Hwy to the west.

- Okanese field planted June 11, 2011 with OWD stock, 2.8x2.8m spacing.

5:30 Return to Lister Hall

OVERVIEW

Alberta-Pacific Forest Industries Inc. (Al-Pac) is a single-line kraft pulp mill located on a Forest Management Agreement (FMA) Area land-base of 66,000 square kilometers in northeastern Alberta, Canada. Merchantable mixed wood forest comprises 36 percent of this area and supplies the required fibre for the mill (approximately 2,600,000 m^3/yr). Al-Pac harvests less than 0.25 percent of this area each year. Ninety-three percent of Al-Pac's pulp is produced from hardwood species, primarily aspen. Al-Pac uses the "triad approach" to forest management. The three parts of the triad are extensively managed forest (harvested areas), unmanaged forest (protected areas used to benchmark against Al-Pac's harvested areas) and intensively managed areas (poplar farms). The company's harvesting is based on a natural disturbance model, in which cut-blocks are not 'clearcut'; rather they are structured to approximate the effects that a forest fire might have and are referred to as 'structured cut-blocks'. Al-Pac cut-blocks have irregular shapes, with single live trees, clumps of trees, and snags (dead standing trees that provide valuable habitat) scattered throughout them.

Al-Pac's tree improvement program is based on selecting fast-growing, high-quality fibre trees which are both insect and disease resistant. Adaptability is the number one abiotic criteria due to our relatively short growing season, variable moisture availability and harsh winters, where temperatures can dip below –40 ^{o}C. Resistance to Septoria canker is our number one biotic selection criteria.

The species, and associated hybrids, that Al-Pac focuses on for its material include two groups: poplars (*Populus balsamifera, P. deltoides, P. nigra, P. maximowiczii, and P. simonii*); and aspens (*Populus tremuloides, P. tremula, and P. davidiana*). Although the mill utilizes approximately 80 percent trembling aspen from our land base, and only 20 percent balsam poplar, material used to initiate this program has come primarily from the poplar group. Poplars have been used widely for windbreaks around farm fields for close to 100 years, and many selections have been made and released for use in the prairies through the Agroforestry Development Centre in Indian Head, Saskatchewan, Canada. There is also a long history of poplar use in phytoremediation and energy production, particularly in Europe, but increasingly in North America.

In addition to the genetics program, Al-Pac has conducted a substantial amount of silvicultural, disease, sociology, and carbon research. Over the last 20+years, this work has primarily focused on early growth and establishment of the poplars and aspens. In order to maximize the growth potential of the selected trees, the company must determine the best combination of stock type, storage method, rooting protocols, site preparation, weed control methods and fertilizer regimes. Planting design, stocking densities and the development of new growth and yield models are also helping us to refine our projected yields from this program. Other research has focussed on understanding carbon dynamics in plantations and considerable effort has been put towards research on *Septoria musiva*, a terminal canker forming fungus.

Al-Pac currently has over 10,000 ha of operational private land plantations of hybrid poplar and while new installations are not currently planned, we have acquired and developed over 25,000 new genotypes. Our current focus is on deployment of native balsam poplar on our FMA area through a recently (2011) government approved Controlled Parentage Program (PB1). This program allows for clonal material to be deployed over an area of nearly 900,000 ha with constraints associated with seed zone deployment lifted through testing of the parent material.

For more information on the Poplar Research Program please contact:

Mr. David Kamelchuk – david.kamelchuk@alpac.ca

or visit us at: www.alpac.ca

Research Highlights

FIELD 7 MILL-SITE

STOP 1 (FIELD 7): HYBRID POPLAR PLANTING - APHP1-96-05-I

First trial planted with material resulting from the first year of breeding (2001) in our joint poplar breeding program with what was the Prairie Farm Rehabilitation Administration. Tree cross types were split into 3 groups and planted in 3 separate sub-trials as follows:

(1) One parent from the Al-Pac FMA area (58 clones).
(2) Crosses with *P. nigra* (43 clones).
(3) All remaining crosses primarily comprised of *P. maximowiczii*, Hill and Walker parents (822 clones).

Each sub-trial consists of 5 blocks with a single tree replicate for each clone within each block except for clones that did not have 5 trees. In such cases what was available was planted. In sub-trial 3 an additional 3 trees of both Walker and Green Giant were planted per block as controls. Material was planted as over winter dormant plugs from July 4-15, 2005. Trial spacing is 2.5m x 2.5 m.

AP#s: 3201-4130 (with some exclusions)

Selected clones Odile (3224) & Odette (3360) have been propagated and moved to the next stage of testing in block plantings. Both Odette and Odile are Walker *x P. nigra* crosses. See flagged trees.

STOP 2: COMPARING THE DIFFERENCES IN FORM BETWEEN *P. DAVIDIANA* AND *P. TREMULA*

STOP 3: ALBERTA-QUEBEC BALSAM BREEDING PROGRAM TRIAL - APBP1B-110-09-I/II

Quebec bred material with *Populus balsamifera* parents from both Alberta and Quebec. Trees were planted as 4 tree family plots, replicated 10 times on 3 sites, 2 in Alberta, 1 in Quebec. Trial was planted in September of 2009 following budset. Spacing 2.5m x 2.5m.

Three time-lapse cameras (8MP Resolution, WingsScapes) were installed in late April 2017 in the two Alberta sites and one Quebec site to observe budburst and budset process in the best progeny (progeny no. 180081, family: 5402, crosstype:♀ABX♂QC).

Sample video is available at youtube: https://www.youtube.com/watch?v=bNT2Zlk1PYI

See attached 'Highlight' sheet (1) for more details. (B. Hu)

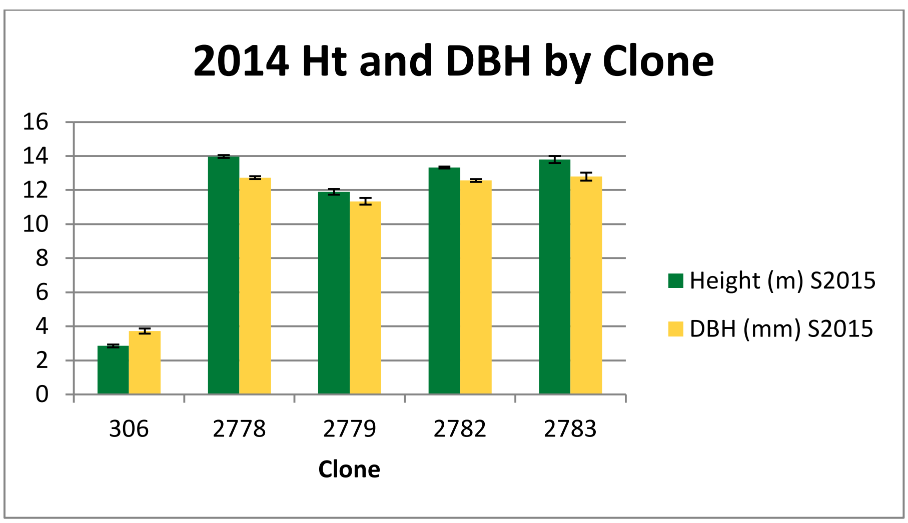
FIELD 23 MILL-SITE

STOP 1 (FIELD 23): DEMO PLANTING OF COMMON CLONES - DEMO2-85-03-D

CLONE NAME	CLONE NUMBER
Walker	24
Assiniboine	25
Northwest	27
P38P38	33
Brooks#1	36
Berlin	42
Green Giant	794
Hill	2400
Okanese	2403
Hybrid aspen (TxTa)	2782

STOP 2: HYBRID ASPEN BLOCK PLANTING TRIAL – HYBAS4-94-05-III

Block planting trial to look at attainable volumes for hybrid aspen clones. Remaining material at the BCRI lab was sent to Bonnyville Forest Nursery where it was grown in styroblocks and then transplanted into bareroot beds at Smoky Lake Forest Nursery in 2004. The resulting bareroot trees were lifted and stored over winter and planted on June 27, 2005. The trees were planted in 49 tree blocks (7x7) by clone. Trial spacing 3m x 3m. Five years after planting, clone 2779 die back to ½ the height of the trees. This dieback has not occurred again since 2010.



STOP 3: PURE SPECIES ASPEN PROVENANCE TRIAL – PROV2-34-98-I

Planted May 22, 1998 with 43 open pollinated seedlots from average selections made throughout AB, NE BC and Minnesota. Stock received on May 21, 1998 in reasonable condition, dormant, the majority of the trees were hedged, some with intact leaders. Site had sufficient rain after planting. Trees were singled twice between 98 & 2000 to establish a single leader. Photosynthesis measurements were taken in July 2000 and 2001 and Ht, Cp and DBH recorded intermittently including 2007 & 2008 (Schreiber PhD project).
AP#s: 751-793. Spacing 3m x 2m.

Reports: Genetic variation of hydraulic and wood anatomical traits in hybrid poplar and trembling aspen. S.G. Schreiber, U.G. Hacke, A. Hamann, B.R. Thomas. 2010.
See attached sheet (2) for more details.

STOP 4: NATIVE PAPER BIRCH AND FINNISH *P. PENDULA* TRIAL - BIRCH1-54-01-I (F-23)

Phase 1 screening trial of selected birch from Finland and Al-Pac's forest management area. Fifteen seedlots x 6 trees/seedlot/rep x 8 reps for a total of 48 trees per family. Trial area was seeded down to fescue, therefore, all maintenance was be done by mowing. Two border rows of excess material was planted. Spacing 3x1.5m.
AP#s: 2198-2207, 2259, 2260, 2262-2264, borders – 2198, 2200, 2201
Early results were promising with the trial however, one can now see signs of disease and sap sucker damage.

SILVA FENNICA

Silva Fennica 46(3) research articles
www.metla.fi/silvafennica · ISSN 0037-5330
The Finnish Society of Forest Science · The Finnish Forest Research Institute

From the Arctic Circle to the Canadian Prairies – a Case Study of Silver Birch Acclimation Capacity

Matti Rousi, Boy J.H.M. Possen, Risto Hagqvist and Barb R. Thomas

Rousi, M., Possen, B.J.H.M., Hagqvist, R. & Thomas, B.R. 2012. From the Arctic Circle to the Canadian prairies – a case study of silver birch acclimation capacity. Silva Fennica 46(3): 355–364.

Earlier provenance research has indicated poor success even in short distance transfers (> 2–3° latitude) of silver birch (*Betula pendula* Roth) southward from their origin. These results may indicate poor adaptability of silver birch to a warming climate. Some of the scenarios for a warming climate in Finland suggest effective heat sums are likely to double in the north and increase 1.5 fold in the south for the period of 2070–2099. Consequently, the outlook for silver birch appears bleak. To study the acclimation of birch to this projected change we established a provenance trial in northeastern Alberta, Canada, at the temperature area currently predicted for Central Finland (lat. 64–66°N) at the turn of this century (1400 dd). Our 10-year experiment showed that all the Finnish provenances (origins 61–67°N) have acclimated well to the warmer growth conditions experienced in Alberta at 54°N. These results suggest that silver birch has the potential to acclimate to thermal conditions predicted for Finland at the end of the 21st century. Our results also indicate that silver birch has the potential as a plantation species in Canada, where the Finnish birch grew faster in the boreal forest region of Canada than local paper birch (*Betula papyrifera* Marsh.) provenances.

Keywords acclimation, *Betula papyrifera*, *Betula pendula*, birch adaptability, critical night length, provenance transfers
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E-mail matti.rousi@metla.fi
Received 1 March 2012 **Revised** 19 June 2012 **Accepted** 2 July 2012
Available at http://www.metla.fi/silvafennica/full/sf46/sf463355.pdf

STOP 5: PHASE II/III TESTING OF SELECTED CLONES FROM 2005 HYBRID POPLAR TRIAL - APHP10A-114-09-II/III

Twenty seven top clones from early selections from APHP1-96-05-I + Walker, Northwest and Okanese as controls. Planted in 3x3 tree blocks and replicated 3 times/field. Excess trees were used to plant 1 row of border trees around the trial. Spacing 3 x 3m.
AP#s: 24, 27, 2403, 3224, 3311, 3360, 3372, 3374, 3474, 3486, 3494, 3505, 3509, 3550, 3560, 3587, 3603, 3633, 3739, 3746, 3780, 3958, 3961, 3966, 3969, 3975, 3976, 4007, 4061, 4072 – including: ODILE (3224) & ODETTE (3360)

STOP 6: QUEBEC HYBRID POPLAR TRIAL – APHP5-106-08-I

This trial represents hybrid poplars bred in Quebec with AB and QB parent clones. This trial was measured for height and diameter in the fall of 2015 as well as assessed for *Septoria* damage. Walker and Okanese clones were used as control clones. Trial spacing is 2.5m x 2.5m.
AP#s: 4459-4521, 24, 2403

Height and DBH after seven years of growth is shown below. Control trees used in the trial were 2403 = Okanese and 24 = Walker.

Key families:

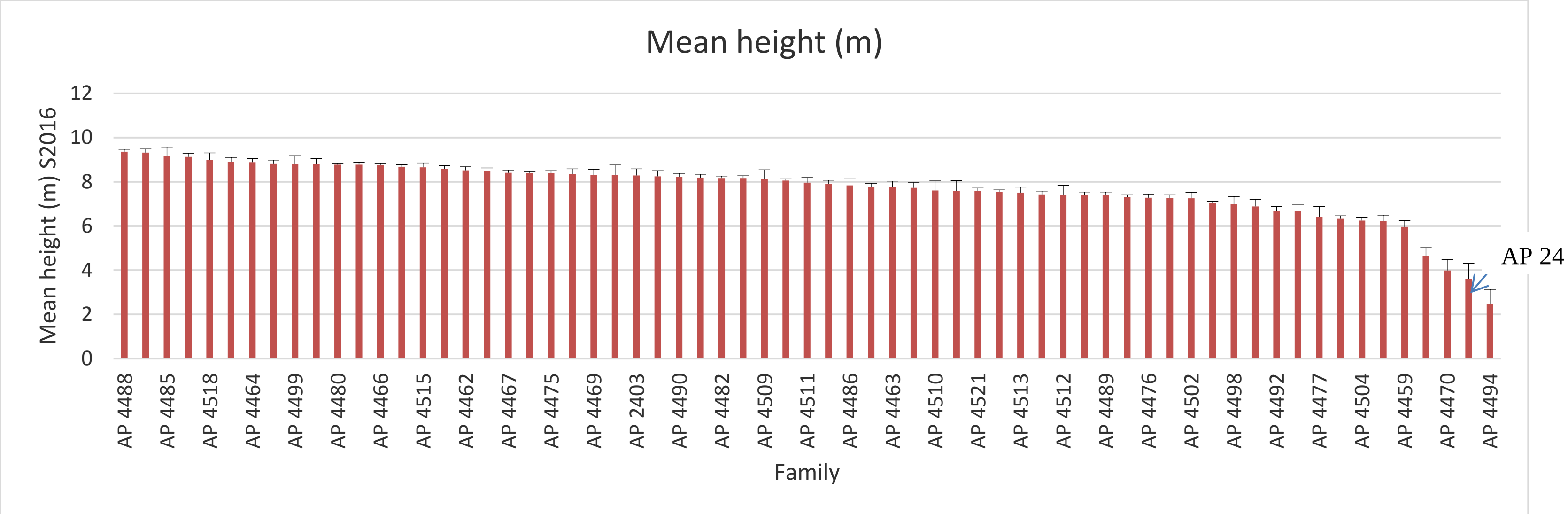
AP 4488 = *P. maximowiczii* x *P. balsamifera* (tallest)

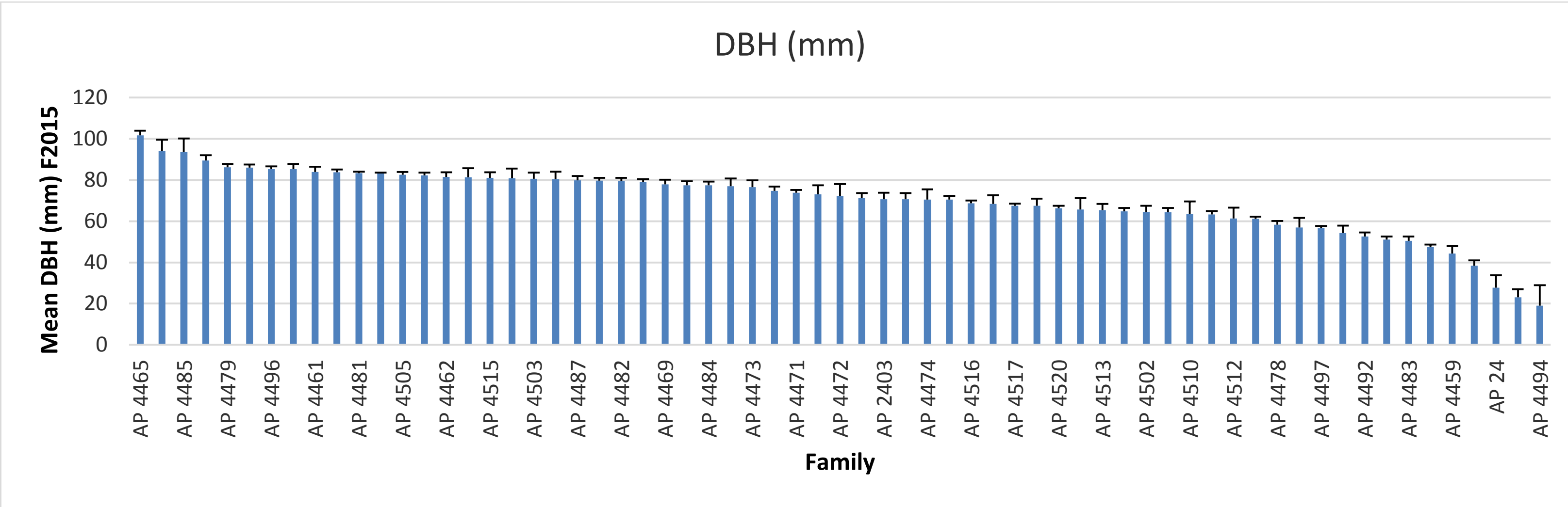
AP 4465 = *P. balsamifera* x *P. maximowiczii* (largest DBH)

AP 4474 = *P. balsamifera* x *P. maximowiczii* (lowest *Septoria* score)

AP 4494 = *P. maximowiczii* x *P. balsamifera* (smallest & highest *Septoria* score)

Family/ Clone # /name	Alternative code/name	Family #	Sex	Genus	Female parent (species/hybrid)	Clone#/ Name of Female Parent	Male parent (species/hybrid)	Clone#/ Name of Male Parent
AP 4459		23132		*Populus*	*balsamifera*	A 135	*deltoides x nigr*	1-2004
AP 4460		23137		*Populus*	*balsamifera*	A 135	*maximowiczii*	PxM3
AP 4461		23149		*Populus*	*balsamifera*	A 135	*maximowiczii*	f7760-3
AP 4462		23156		*Populus*	*balsamifera*	A 135	*maximowiczii*	f7758-2
AP 4463		23169		*Populus*	*balsamifera*	A 135	*maximowiczii*	f7758-1
AP 4464		23173		*Populus*	*balsamifera*	A 135	*maximowiczii*	f7756-1
AP 4465		23177		*Populus*	*balsamifera*	A 151	*maximowiczii*	f7758-1
AP 4466		23181		*Populus*	*balsamifera*	A 109	*maximowiczii*	f7758-2
AP 4467		23187		*Populus*	*balsamifera*	A 177	*maximowiczii*	f7756-1
AP 4468		23192		*Populus*	*balsamifera*	A 109	*maximowiczii*	PxM1
AP 4469		23200		*Populus*	*maximowiczii*	f7759-2	*balsamifera*	A 172
AP 4470		23211		*Populus*	*maximowiczii*	f7759-2	*balsamifera*	A 141
AP 4471		23217		*Populus*	*balsamifera*	A 177	*maximowiczii*	f7759-4
AP 4472		23218		*Populus*	*balsamifera*	A 171	*maximowiczii*	f7759-6
AP 4473		23221		*Populus*	*balsamifera*	A 151	*maximowiczii*	f7758-2
AP 4474		23233		*Populus*	*balsamifera*	A 109	*maximowiczii*	PxM3
AP 4475		23238		*Populus*	*balsamifera*	A 171	*maximowiczii*	f7758-2
AP 4476		23239		*Populus*	*balsamifera*	A 109	*maximowiczii*	PxM2
AP 4477		23247		*Populus*	*maximowiczii*	f7754-2	*balsamifera*	A 172
AP 4478		23253		*Populus*	*balsamifera*	A 177	*deltoides x nigr*	7-2004
AP 4479		23259		*Populus*	*maximowiczii*	f7750-1	*balsamifera*	A 174
AP 4480		23274		*Populus*	*balsamifera*	A 177	*maximowiczii*	f7757-1
AP 4481		23280		*Populus*	*maximowiczii*	f7735-1	*balsamifera*	A 149
AP 4482		23283		*Populus*	*maximowiczii*	f7750-1	*balsamifera*	A 141
AP 4483		23286		*Populus*	*(deltoides x nigra) x*	4950	*balsamifera*	A 172
AP 4484		23291		*Populus*	*balsamifera*	A 171	*maximowiczii*	f7758-1
AP 4485		23297		*Populus*	*balsamifera*	A 151	*maximowiczii*	f7753-2
AP 4486		23300		*Populus*	*balsamifera*	A 177	*maximowiczii*	f7758-1
AP 4487		23303		*Populus*	*maximowiczii*	f7751-1	*balsamifera*	A 149
AP 4488		23304		*Populus*	*maximowiczii*	f7734-1	*balsamifera*	A 172
AP 4489		23305		*Populus*	*maximowiczii x trich*	5-2004	*balsamifera*	A 172
AP 4490		23306		*Populus*	*maximowiczii*	f7758-3	*balsamifera*	A 149
AP 4491		23308		*Populus*	*maximowiczii*	f7750-1	*balsamifera*	A 172
AP 4492		23320		*Populus*	*maximowiczii x trich*	5-2004	*balsamifera*	A 149
AP 4493		23325		*Populus*	*balsamiferaM*	915004	*balsamifera*	A 149
AP 4494		23330		*Populus*	*maximowiczii*	f7751-1	*balsamifera*	A-141
AP 4495		23334		*Populus*	*maximowiczii*	f7758-3	*balsamifera*	A-172
AP 4496		23336		*Populus*	*maximowiczii*	f7751-1	*balsamifera*	A-174
AP 4497		23359		*Populus*	*balsamiferaM*	915004	*balsamifera*	A-172
AP 4498		23366		*Populus*	*maximowiczii*	f7754-2	*balsamifera*	A-141
AP 4499		23371		*Populus*	*balsamifera*	A-171	*maximowiczii*	f7757-1
AP 4500		23375		*Populus*	*maximowiczii*	f7750-1	*balsamifera*	A-168
AP 4501		23398		*Populus*	*maximowiczii x ((nig*	3-2004	*balsamifera*	A-172
AP 4502		23401		*Populus*	*maximowiczii*	f7754-2	*balsamifera*	A-168
AP 4503		23402		*Populus*	*maximowiczii*	f7759-7	*balsamifera*	A-172
AP 4504		23405		*Populus*	*maximowiczii x ((nig*	3-2004	*balsamifera*	A-149
AP 4505		23419		*Populus*	*?*	?	*balsamifera*	A-141
AP 4506		23420		*Populus*	*maximowiczii x bals*	915302	*balsamifera*	A-141
AP 4507		23422		*Populus*	*deltoides x?*	22603	*balsamifera*	A-149
AP 4508		23424		*Populus*	*maximowiczii*	f7734-1	*balsamifera*	A-149
AP 4509		23437		*Populus*	*maximowiczii*	f7754-1	*balsamifera*	A-149
AP 4510		23458		*Populus*	*deltoides*	4938	*balsamifera*	A-172
AP 4511		23463		*Populus*	*maximowiczii*	f7759-7	*balsamifera*	A-149
AP 4512		23466		*Populus*	*maximowiczii x bals*	915319	*balsamifera*	A-149
AP 4513		23472		*Populus*	*maximowiczii x bals*	915302	*balsamifera*	A-174
AP 4514		23474		*Populus*	*maximowiczii x bals*	915302	*balsamifera*	A-168
AP 4515		23479		*Populus*	*maximowiczii*	f7751-1	*balsamifera*	A-168
AP 4516		23484		*Populus*	*maximowiczii x trich*	4-2004	*balsamifera*	A-168
AP 4517		23488		*Populus*	*maximowiczii x trich*	4-2004	*balsamifera*	A-174
AP 4518		23502		*Populus*	*maximowiczii*	f7759-7	*balsamifera*	A-168
AP 4519		23509		*Populus*	*deltoides*	4942	*balsamifera*	a-172
AP 4520		23511		*Populus*	*maximowiczii x trich*	4-2004	*balsamifera*	A-141
AP 4521		23526		*Populus*	*maximowiczii x trich*	4-2004	*balsamifera*	A-172


Mean height (m)
Mean height (m) S2016
12
10
8
6
4
2
0
AP 4488
AP 4485
AP 4518
AP 4464
AP 4499
AP 4480
AP 4466
AP 4515
AP 4462
AP 4467
AP 4475
AP 4469
AP 2403
AP 4490
AP 4482
AP 4509
AP 4511
AP 4486
AP 4463
AP 4510
AP 4521
AP 4513
AP 4512
AP 4489
AP 4476
AP 4502
AP 4498
AP 4492
AP 4477
AP 4504
AP 4459
AP 4470
AP 4494
Family
AP 24


DBH (mm)
Mean DBH (mm) F2015
120
100
80
60
40
20
0
AP 4465
AP 4485
AP 4479
AP 4496
AP 4461
AP 4481
AP 4505
AP 4462
AP 4515
AP 4503
AP 4487
AP 4482
AP 4469
AP 4484
AP 4473
AP 4471
AP 4472
AP 2403
AP 4474
AP 4516
AP 4517
AP 4520
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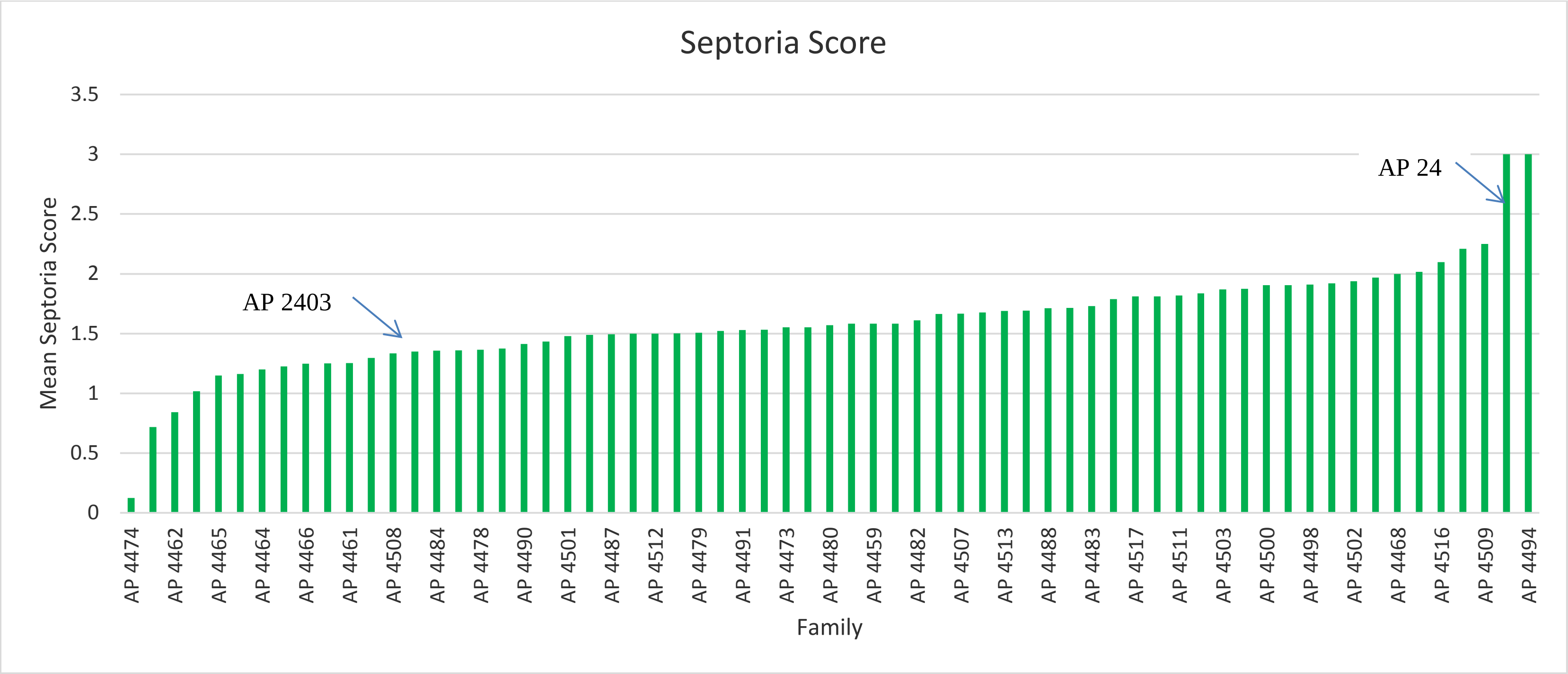
AP 4478
AP 4497
AP 4492
AP 4483
AP 4459
AP 24
AP 4494
Family



Septoria Scoring S2016 (May) 0=none evident; 1 = canker on branch; 2 = canker on main stem but healed or healing; 3 = canker on main stem that looks like top could break off

(1) Is hybrid vigour possible in native balsam poplar breeding?

Background

Poplars (*Populus* L.) are the most widespread deciduous trees in Canada's boreal forest, covering a total of 13.1% of the boreal region, and are second only to spruce (47.3%) in total area covered. Hybrid poplars occur both naturally and artificially and result from crossing two (or more) distinct species or two individuals within one species with desirable characteristics. Hybrid vigour, typically achieved through controlled crossing of two species, or pure genetic lines of the same species, has long been exploited in agriculture and in some tree species including *Populus*. When two or more species are crossed to produce hybrid progeny, some of them can be expected to yield growth performance far superior than either parent (ie: hybrid vigour/heterosis).

In this project, we are testing the hypothesis that within species breeding of widely spaced populations of balsam poplar will lead to the expression of hybrid vigour. We are exploring the potential underlying mechanisms through both field and greenhouse assessments. In September 2009, three field trials (two in Alberta (AB) (Field 7 and 23) and one in Quebec (QC) (Field QC)) were established in conjunction with Alberta-Pacific Forest Industries Inc. (Al-Pac) and Mr. Pierre Périnet (Ministry of Forestry, Quebec). Five male parents from each province with five female parents from Quebec, and four female parents from Alberta were used for breeding, both for within region and between region crosses. Preliminary analysis on 6-year height and diameter from the Alberta field sites only, indicate differences in family performance among the different cross-types. The preliminary results showed that AB x QC crosses ranked first for height and DBH and exhibited a later bud-burst.

Clones were selected, based on growth performance in the field trials, for a greenhouse trial carried out in summer 2016. Trees were grown in a randomized complete block design under near-optimal greenhouse conditions from May 2016 to August 2016. Diameter and height growth was measured biweekly and photosynthesis three times during the growing season. In late June internode tissue samples were collected from 2-3 trees from each cross and each parent for hormone analysis (gibberellic acids (GAs), indole-3-acetic acid (IAA) and abscisic acid (ABA)).These hormones will tell us if hybrid vigour is due to hormone levels and linked to photosynthetic performance.

Overall, the above approaches will determine the potential of using disparate, native populations of balsam poplar to produce superior progeny with enhanced stem growth traits. Future use of this material on crown land for reforestation or reclamation may require additional field testing to meet policy regulations.

Objectives

Determine if hybrid vigour:

- Is due to specific gene interactions;
- Is due to hormone levels and linked to physiological performance;
- Is due to phenology (bud-burst & bud-set) resulting in a longer growing season.

Preliminary results:

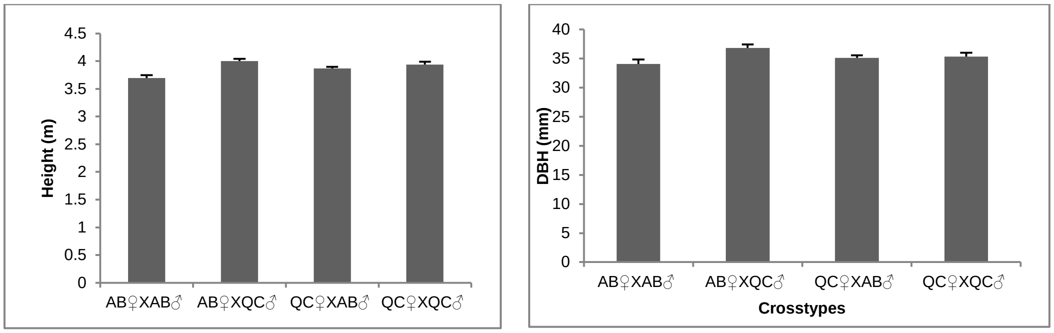
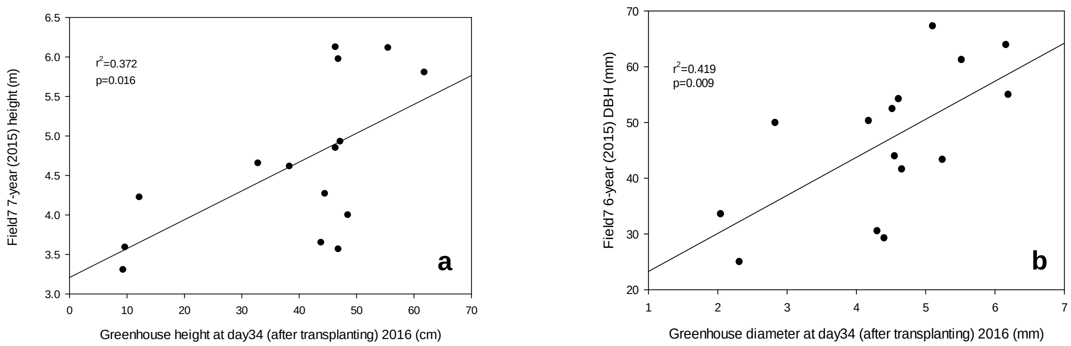
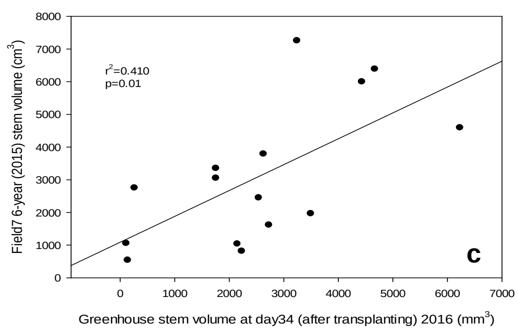


Figure 1. Mean height (+se) (left) and DBH (+se) (right) at year-6 for two Alberta sites with different cross-types in 2015.





- AB♀ x QC♂ crosses ranked first for height and DBH
- Field growth (height, DBH, and stem volume) at Year-6 (2015) and greenhouse growth were significantly correlated for 15 selected progenies

Figure 2. Correlation between field growth data and greenhouse growth data for 15 selected progenies in 2016 for a) height; b) diameter; c) stem volume.

(2) A reciprocal transplant experiment with trembling aspen in western Canada

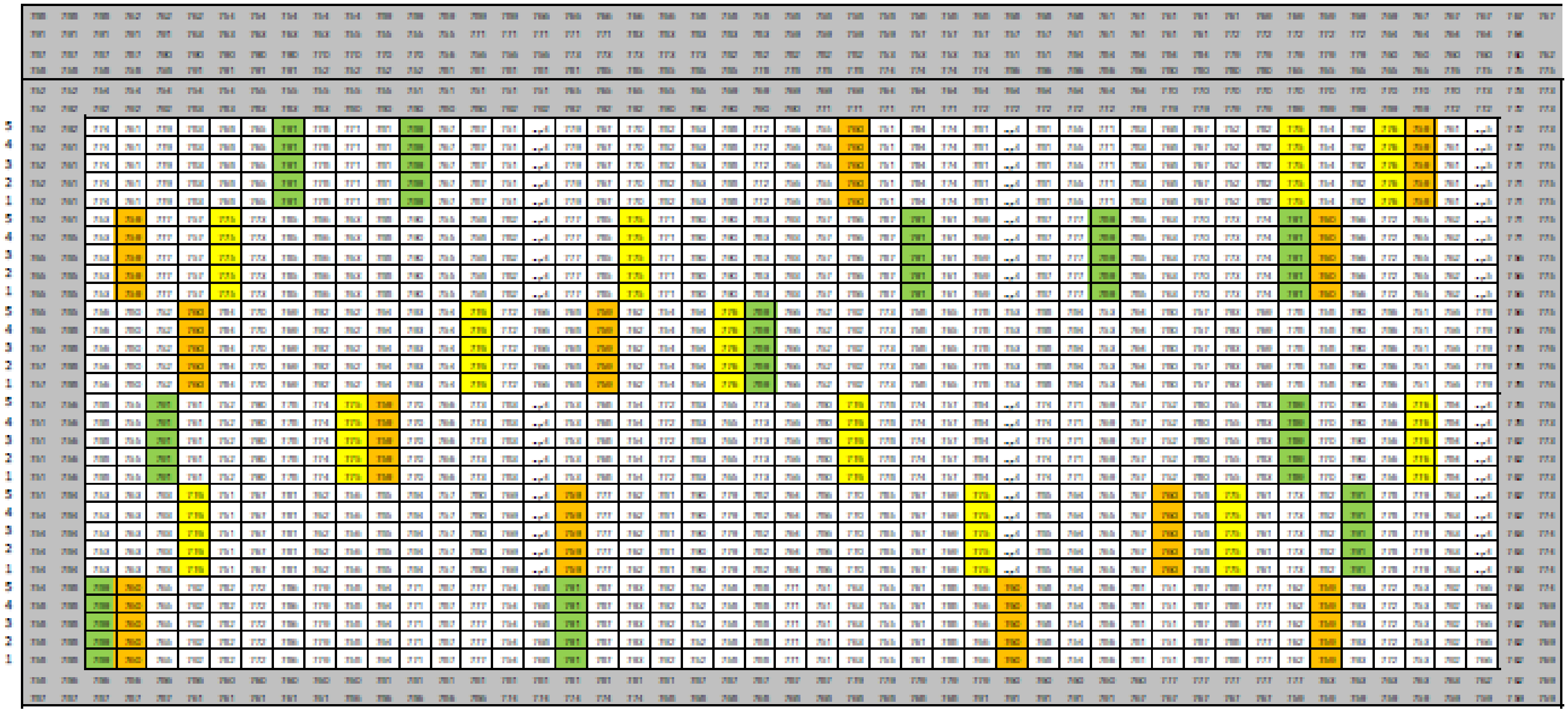
- Established by the industrial members of the Western Boreal Aspen Cooperative in 1998
- Planting sites and collection locations were chosen to represent forest management areas of the participating Canadian forestry companies. This one here represents central Alberta.
- Regions were unequally represented with three to eleven collection locations, reflecting assumptions where productive genotypes for reforestation in western Canada may be found
- Also included five seedlots from the boreal shield ecoregion in Minnesota (MN) for testing in western Canada (Fig. 1, Table 1). Note that there is no corresponding test site for this region

<u>Results from this aspen provenance trail have been published in three papers</u>:

1. Schreiber, S. G., Hacke, U. G. and Hamann, A. (2015). Variation of xylem vessel diameters across a climate gradient: insight from a reciprocal transplant experiment with a widespread boreal tree. *Functional Ecology* **29**: 1392-1401.
2. Schreiber, S. G., Ding, C., Hamann, A., Hacke, U. G., Thomas, B. R. and Brouard J. S. (2013). Frost hardiness vs. growth performance in trembling aspen: an experimental test of assisted migration. *Journal of Applied Ecology* **50**: 939-949.
3. Schreiber, S. G., Hacke, U. G., Hamann, A. and Thomas, B. R. (2011). Genetic variation of hydraulic and wood anatomical traits in hybrid poplar and trembling aspen. *New Phytologist* **190**: 150-160.

<u>Main findings:</u>

1. Vessel diameters are very plastic in their response to changing environmental conditions and are positively correlated with moisture availability.
2. Moving populations in a northwest direction, e.g. MN to central AB or northern AB, results in increased growth compared to locally adapted populations at their respective tests sites. However, moving populations in a southeast direction, e.g. BC to central AB or AB foothills, results in poor growth performance. South to north YAY, north to south NAY!
3. Vessel diameter showed a negative relationship with tree height, i.e. narrower vessels are associated with taller trees. It is known that narrower vessels (< 30 micron) are less likely to experience freezing-induced embolisms in the xylem (air bubbles in the water conducting network). Accumulating more embolisms during spring time (when freeze-thaw events occur most frequently) may result in impaired water transport to the leaves and hence negatively affect overall growth over multiple years.



Rep 6	Rep 5	Rep 4
Rep 1	Rep 2	Rep 3

9	759	BC
10	760	
25	775	cAD
26	776	
39	789	MN
41	791	

N