Seed source selection and deployment to address adaptation to future climates for interior spruce in western Canada

Project A644

Final report to the
Climate Change Impacts and Adaptation Directorate

December 2005

1.0 Principal Investigators

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2.0 Summary

Climate change is already signficantly affecting the health and productivity of Canada's forests. Planted forests that are adapted to today's climate will be maladapted when they are harvested in 60-80 years. However, if seedlots for reforestation are selected so as to maximize their adaptation over the duration of their rotation, productivity of Canada's forests could be enhanced by capitalizing on increased future temperatures.

To ensure that the most economically important tree crop planted in Canada - interior spruce (white and engelmann spruce and their hybrids) - is adapted to future climates, forest scientists from western North America have initiated a long-term project that will act as a cornerstone to the genetic resource management of interior spruce in western North America, and as a model for other species and regions.

Wild and domesticated interior spruce seedlots from 128 locations encompassing the climatic and latitudinal range of interior spruce in western North America have been carefully selected, grown, and planted in genetic tests in 18 disparate environments in BC, Alberta and the Yukon. The identity of each of the 73 728 trees planted in the tests has been mapped and recorded, and the test sites will be carefully maintained each year. Researchers will return to gather data on the growth, health and form of the trees, beginning at age 5. The data will be used to describe geographic and climatic tolerances of each seedlot, and to develop a seed deployment strategy that will maximize the health and economic value of interior spruce plantations in future climates.

'Key' funding to initiate this critical project, among the largest in North America, was provided by the Climate Change Impacts and Adaptation Directorate. The project brought together for the first time, four agencies (Research Branch of the British Columbia Ministry of Forests, Alberta Forest Service, Yukon Department of Energy, Mines and Resources, and the USDA Forest Service) in an innovative project that will capitalize on advances in climate modelling, geographic information systems and ecological modelling to provide tools that will help maintain the health and productivity of Canada's forests in a changing climate.

3.0 Background

Interior spruce (white and Engelmann spruce and their hybrids) is widely distributed as the dominant conifer species in western North America. It has significant ecological value and is the most important commercial species of any conifer in Canada. Its growth, form and health, however, are dependent on each seed source (= provenance or population) being planted only in those climates where it is adapted. Climate change is already signficantly affecting the health and productivity of Canada's forests (Logan and Powell2001; Woods et al. 2005; Filmon 2004). Forest productivity modeling predicts large economic losses due to climate change unless changes are made to current seed deployment schemes (Rehfeldt et al. 1999; Rehfeldt et al. 2001).

In genetic tests, seed from various environments (sources) are grown in disparate new environments (test sites) to understand the extent of genetic-by-environment interaction. Such tests serve as *de facto* climate change studies (Carter 1996). Despite extensive genetic testing of interior spruce, the limited environmental range of both seed sources and test sites in current genetic tests unfortunately precludes their use in climate change studies. In addition, few US seed sources have been tested in Canada, although Canadian forest managers will likely become increasingly dependent upon US seed sources as Canada's climate becomes more like that of the northern US.

4.0 Objectives

The main purpose of this project, therefore, is to ensure that western Canada's planted spruce forests are adapted to future climates. Specifically, this project seeks to: 1) understand the distribution of natural genetic variation in interior spruce and 2) to assess the performance of genetically improved spruce populations in disparate environments. This information will help us refine seed transfer guidelines for reforestation and improve conservation strategies for both natural and improved populations for the present climate, and will help us develop seed deployment strategies to maximize productivity and health of forest plantations in future climates.

5.0 Activities

5.1 Seedlots procured

The objective of the seedlot procurement step was to obtain both wild and genetically improved spruce seed from a climatically-diverse a range in western North America. Seed was therefore requested from a wide range of sources, including the BC, AB, YK, and ON governments, private seed owners in BC, and the USDA Forest Service. Of the seed received, a total of 128 seedlots were selected in the following categories:

Elite (A class) seedlots	
BC A class lots	14 seedlots
BC A+ (elite families) lots	13 seedlots
ON A+ (elite families) lots	1 seedlot
AB A class lots	8 seedlots
Wildstand (B class) seedlots	
BC lots	34 seedlots
AB lots	23 seedlots
NWT lots	2 seedlots
YK lots	8 seedlots
Western USA lots	25 seedlots

5.2 Seedlings produced

770 seedlings of each of the 128 seedlots (i.e., 98 560 seedlings) were grown at a commercial seedling nursery in Vernon using standard conifer seedling production techniques. Seed was sown in February 2004 into 415B styroblocks and placed in greenhouses. Seedlots with poor germination (< 95%) were double sown and thinned. All seedlots received identical black-out treatment in August/September. Seedlings were lifted (moved from the greenhouse to cold

storage freezers) in December 2004. The sowing process required approximately 30 person-days of labour, and the lifting process, involving labelling, sorting, bagging and boxing the seedlings for cold storage, required approximately 70 person-days of labour. Use of an incomplete block design considerably increased the labour required for lifting the seedlings, but will improve statistical resolution among the seedlots.

5.3 Test sites identified

Test sites were carefully chosen to uniformly sample the mean annual temperature (MAT), mean annual precipitation (MAP), and latitudinal space occupied by spruce in BC, AB and YK. Candidate regions were identified by filtering an Excel database of 450 Environment Canada meteorological stations on latitude, MAT and MAP. Once 18 regions were finalized, staff worked with industrial and government contacts to identify several candidate sites within each region. Each candidate site was visited to assess its adequacy in meeting the strict test site criteria, and one final site was selected for each region.

Final test sites are located from central Yukon (Mayo) to southern BC (Cranbrook). Geographic coordinates and values of current climate parameters of the 18 test sites are shown in Appendix 2.

5.4 Seedlings planted

Where necessary, test sites were site-prepped and brushed prior to planting. All 18 sites were planted between February and June 2005. The experimental design consists of an incomplete block design containing 8 reps and 16 blocks within each rep. Families were assigned to blocks using the Alphagen software. Seedlots are planted in 4-tree row plots. Spacing is 2 x 1 m to facilitate systematic thinning upon crown closure, and a single row of buffer trees is planted around the perimeter of each test.

5.5 Seed and site climate data obtained

Geographic coordinates and elevation of the 128 seedlots and 18 sites were obtained and entered into the recently released climate interpolation software “ClimateBC” to obtain values of current and future climate variables relevant to seedling growth and health. (See Appendices 1 and 2)

5.6 Information archived

In order to ensure that staff and contractors are able to re-locate the test sites, access notes, GPS coordinates and a series of maps, including aerial photographs, have been prepared for each test site and are stored in hardcopy and electronically. In addition, to facilitate measurement of each tree, layout maps indicating the seedlot to which each planted seedling belongs has been prepared (hardcopy and electronic versions) and the data entered into a hand-held datalogger.

6.0 Activities planned

6.1 Test site maintenance

Each of the 18 test sites will be visited (annually for the first 3 years and every 3 years thereafter) to assess the need for road maintenance, re-labelling of trees, fencing, and vegetation control, and these activities will be performed where needed. Letters will be written to each of the licensees, excluding test sites from their management responsibilities.

6.2 Data collection and analysis

Data related to growth, insect and disease damage, and stem form will be collected every five years, beginning at age 5. A log grade algorithm will be developed utilizing the collected data, and the dollar value of each tree at rotation will be estimated. Average tree dollar values for each seedlot will be calculated at each site and related to test site climate. Relationships of each seedlot’s dollar value with test site climate will enable the most economically productive seedlot to be identified for any planting site considering its projected climate.

6.3 Extension

A fine scale adaptive map of interior spruce in western North America will be developed and distributed to websites frequented by silviculturalists in western North America to help provide an understanding of the patterns of adaptive variation in the species. This map will form the foundation of a review of interior spruce breeding and conservation plans and the development of software that will calculate the impacts of interior spruce seed transfer.

A site-specific, climate-based strategy for deployment of wild and domesticated interior spruce seed will be developed.

The climatic and geographic tolerances of each seedlot will be described in extension notes for foresters and in referreed international publications

7.0 Scientific attention

Although the project is in the early stages, it has gained considerable attention, having been the subject of discussion at various events, including:

- BC Forest Genetics Council's Interior Tree Advisory Committee meeting (Vernon, November 2004)
- Climate change workshops co-hosted by CCAIRN and the McGregor Model Forest (Prince George, November 2004)
- Climate change workshop co-hosted by CCAIRN and UBC (UBC, December 2004)
- International conference on Climate Change and Forest Genetics (http://www.for.gov.bc.ca/hti/ctia/index.htm) (Kelowna, July 2004).
- Alberta Forest Genetics special climate change meeting (Edmonton, April 2005)
- BC MoF – Future Forests Conference (Prince George, December 2005)

8.0 In-kind contributions

128 seedlots were obtained from a range of sources. The cost of field collection of a seedlot varies greatly with geography and proximity to helicopter facilities, ranging from $1000 to $4000 per seedlot.

Sowing and lifting of the seedlings (not included in the seedling production cost) involved approximately 30 and 70 person-days of labour, respectively, and were paid for by the BC Ministry of Forests.

54 boxes of surround (buffer) seedlings were donated by the MoF, at a cost of approximately $50/box.

Project collaborators are listed below. Contributions are described in terms of annual full-time equivalents (FTE) each individual worked on the project between April 2003 and March 2006:

Barry Jaquish (BC MoF scientist)	0.15 FTE
Greg O'Neill (BC MoF scientist)	0.15 FTE
Alvin Yanchuk (BC MoF scientist)	0.05 FTE
Bonnie Hooge (BC MoF technician)	0.40 FTE
Gisele Phillips (BC MoF technician)	0.10 FTE
Val Ashley (BC MoF technician)	0.10 FTE
Jill Peterson (BC MoF administrator)	0.025 FTE
Don White (YK EMR forester)	0.025 FTE
Leonard Bernhardt (AB FS scientist)	0.025 FTE
Jerry Rehfeldt (USDA FS scientist)	0.025 FTE

Maintenance costs of the test sites over the next 10 years are estimated at $90 000. Tree measurement and assessments will be made at ages 5 and 10, and will cost approximately $72 000 on each occasion. These costs will be paid by BC MoF, Alberta Forest Service, and the Yukon Department of Energy Mines and Resources.

9.0 Appendices

Appendix 1 – List of test sites
Appendix 2 – Selected project photographs

10.0 References

Carter, K.K. 1996. Provenance tests as indicators of growth response to climate change in 10 north temperate tree species. Can. J. For. Res. **26**: 1089-1095.

Filmon, G. 2004. Firestorm 2003. Provincial review of the 2003 fire season [online]. Available from http://www.2003firestorm.gov.bc.ca/.

Logan, J. and J.A. Powell. 2001. Ghost forests, global warming and the mountain pine beetle. American Entomologist 47: 160-173.

Rehfeldt, G.E., Wykoff, W.R., and Ying, C.C. 2001. Physiological plasticity, evolution, and impacts of a changing climate on *Pinus contorta*. Climatic Change **50**: 355-376.

Rehfeldt, G.E., Ying, C.C., Spittlehouse, D.L., and Hamilton, D.A., Jr. 1999. Genetic responses to climate in *Pinus contorta*: niche breadth, climate change, and reforestation. Ecological Monographs **69**: 375-407.

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Appendix 1. Geographic coordinates and climate values of test sites in "Seed source selection and deployment to address adaptation to future climates for interior spruce in western Canada"

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Site number	**Site name**	**latitude**	**longitude**	**elevation**	MAT	MAP	MWMT	MCMT	TD
1	Wells	53.1550	121.5556	1230	1.7	947	12.2	-9.2	21.5
2	Duncan_Lake	50.3818	116.9219	640	5.3	888	17.2	-7.6	24.9
3	Kalamalka	50.2434	119.2768	440	7.3	391	18.9	-4.8	23.7
4	Nakusp	49.8870	117.8896	1107	3.6	939	15.3	-7.9	23.2
5	Cranbrook	49.2450	115.5750	1370	3.3	867	15.2	-9	24.2
6	Mayo	63.5425	137.3424	456	-3.7	395	15.4	-26	41.4
7	Whitecourt	54.5333	115.7833	816	2.5	629	15.6	-11.4	27
8	Skimikin	50.7000	119.2500	506	6.7	561	18.2	-5.4	23.6
9	Pine Pass	55.1474	122.7764	811	2	1197	14.3	-11	25.3
10	Fort Nelson	58.7300	123.7103	640	-0.8	570	14.5	-16.4	30.9
11	Parsnip	54.5372	122.0281	805	2.5	900	14.4	-10.2	24.5
12	Jordan River	48.4262	124.0229	141	9.1	2448	15.7	3.1	12.6
13	Terrace	54.4700	128.5800	217	6	1281	15.9	-4.5	20.4
14	High Level	59.1333	117.5667	370	-1.8	419	15.6	-22.2	37.8
15	Harrison Hotsprings	49.3416	121.99558	166	8.3	2070	16.8	0.2	16.5
16	Revelstoke	50.7500	117.9500	910	4	1160	15.6	-7.9	23.5
17	Alexis Creek	52.0291	123.5260	1040	2.5	340	13.8	-9.6	23.4
18	Tete Jaune Cache	52.9642	119.4169	780	3.1	670	15	-10.1	25.1

MAT	Mean Annual Temperature
MAP	Mean Annual Precipitation
MWMT	Mean Warm Month Temperature
MCMT	Mean Cold Month Temperature
TD	Temperature Difference (MWMT-MCMT)
MSP	Mean Summer Precipitation
AHM	Annual Heat to Moisture ratio
SHM	Summer Heat to Moisture ratio