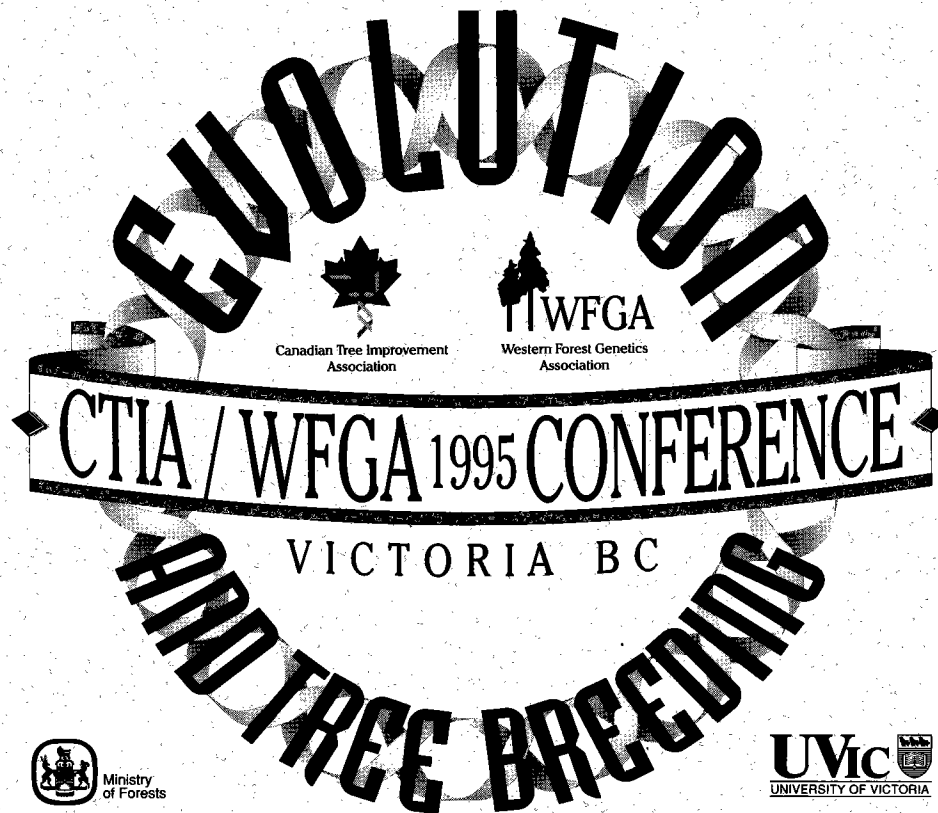


**PROCEEDINGS OF THE TWENTY-FIFTH MEETING  
OF THE  
CANADIAN TREE IMPROVEMENT ASSOCIATION**

**PART 1** Minutes and members' reports  
**PART 2** Symposium



**COMPTES RENDUS DE LA VINGT- CINQUIÈME CONFÉRENCE**

**DE**

**L'ASSOCIATION CANADIENNE POUR**

**L'AMÉLIORATION DES ARBRES**

**1<sup>re</sup> PARTIE** Procès-verbaux et rapports des membres  
**2<sup>e</sup> PARTIE** Colloque



---

PROCEEDINGS  
OF THE  
TWENTY-FIFTH MEETING  
OF THE  
**CANADIAN TREE IMPROVEMENT  
ASSOCIATION**

**PART 1**

*Minutes and members' reports*

EVOLUTION  
AND  
TREE BREEDING

Victoria, British Columbia  
August 28 - September 1, 1995

Editor:  
J. Lavereau

---

---

*Additional copies of this  
publication may be available  
(After March 31, 1996)  
from:*

Dale Simpson  
Editor, C.T.I.A./A.C.A.A.  
Natural Resources Canada  
Hugh John Flemming Forestry Centre  
P. O. Box 4000  
Fredericton, New Brunswick, Canada  
E3B 5P7

*Produced by*  
Natural Resources Canada  
for the  
Canadian Tree Improvement Association  
Victoria, 1995

*Financial Contributions*  
British Columbia Ministry of Forests  
Centre for Forestry Biology, University of Victoria  
Western Forest Products  
Pacific Forest Products  
MacMillan Bloedel

---

---

COMPTES RENDUS  
DE LA  
VINGT-CINQUIÈME CONFÉRENCE  
DE  
**L'ASSOCIATION CANADIENNE POUR  
L'AMÉLIORATION DES ARBRES**  
**1<sup>re</sup> PARTIE**

*Procès-verbaux et rapports des membres*

DÉVELOPPEMENT ET  
L'AMÉLIORATION DES ARBRES

Victoria en Colombie-Britannique  
du 28 août au 1 septembre 1995

Rédactrice:  
J. Lavereau

---

---

*Le public aussi peut avoir des  
exemplaires sur demande en communiquant avec:*  
(Nouvelle adresse après le 31 mars 1996)

Dale Simpson, rédacteur, A.C.A.A./C.T.I.A.  
Ressources naturelles Canada-Région des Maritimes  
Centre de foresterie Hugh John Flemming  
B.P. 4000  
Fredericton (Nouveau-Brunswick)  
Canada  
E3B 5P7

*Préparé par:*  
Ressources naturelles Canada  
pour  
l'Association canadienne pour l'amélioration des arbres  
Victoria, 1995

*Sous le patronage du*  
Ministère des forêts de la Colombie-Britannique  
Centre de biologie forestière, Université de Victoria  
Produits forestiers de l'ouest  
Produits forestier du Pacifique  
MacMillan Bloedel

---

PROCEEDINGS OF THE TWENTY-FIFTH MEETING OF THE CANADIAN TREE  
IMPROVEMENT ASSOCIATION

Enquiries may be addressed to the authors or to Mr. Dale Simpson, Editor CTIA c/o  
Natural Resources Canada, Hugh John Flemming Forestry Centre, P.O. Box 4000, Fredericton,  
New Brunswick E3B 5P7.

IF YOUR ADDRESS ON THE LABEL IS INCORRECT OR INCOMPLETE,  
PLEASE RETURN CORRECTION SLIP BELOW

Others interested in receiving Proceedings, notice of meetings, etc. may return the slip to be listed  
as Corresponding Members (Canadian) or be placed on the mailing list for the Proceedings only  
(libraries, institutions, foreign addresses). If you no longer wish to receive the Proceedings,  
please check "delete" and return the completed slip to the Editor.

-----  
To: Dale Simpson, Editor, C.T.I.A./A.C.A.A.  
Natural Resources Canada-Maritimes Region  
Hugh John Flemming Forestry Centre  
P. O. Box 4000  
Fredericton, New Brunswick, Canada  
E3B 5P7

PLEASE PRINT

Name: Prof. Ms.  
Dr. Mr. \_\_\_\_\_

Address: \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_ Postal Code \_\_\_\_\_

Please check one:

- Correction
- New addressee
- Delete from C.T.I.A. mailing list

**COMPTES RENDUS DE LA VINGT-CINQUIÈME CONFÉRENCE DE L'ASSOCIATION  
CANADIENNE POUR L'AMÉLIORATION DES ARBRES**

Les demandes de renseignements peuvent être adressées aux auteurs ou à D. Simpson, rédacteur, A.C.A.A., Ressources naturelles Canada, Centre de foresterie Hugh John Flemming, B. P. 4000, Fredericton (Nouveau-Brunswick), E3B 5P7, Canada.

**SI VOTRE ADRESSE EST INEXACTE OU INCOMPLÈTE SUR L'ÉTIQUETTE, VEUILLEZ  
RETOURNER LA FICHE DE CORRECTION CI-DESSOUS**

Les personnes qui aimeraient recevoir les comptes rendus, les avis de réunions, etc., sont priées de retourner la formule pour que leurs noms soient ajoutés à la liste des membres correspondants (canadiens), ou à la liste d'envoi pour les comptes rendus seulement (bibliothèques, institutions, destinataires à l'étranger). Si vous ne désirez plus recevoir ces comptes rendus, veuillez cocher "rayer" et retourner la formule remplie à la rédactrice.

---

À: Dale Simpson, rédacteur, A.C.A.A./C.T.I.A.  
Ressources naturelles Canada-Région des Maritimes  
Centre de foresterie Hugh John Flemming  
B. P. 4000  
Fredericton (Nouveau-Brunswick)  
E3B 5P7 Canada

**LETTRES MOULÉES S.V.P.**

Nom: Prof. Mme.  
Dr. M. \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_ Code postal \_\_\_\_\_

Veillez cocher une seule case:

- Correction
- Nouveau destinataire
- Rayer le destinataire de la liste d'envoi de l'A.C.A.A.



## British Columbia -- B.C. Ministry of Forests

- J.H. Russell                      *Yellow-Cedar, Western Redcedar and  
Pacific Yew Genetic Research, Conservation  
and Improvement*..... 42

## British Columbia -- B.C. Research Inc.

- B.C.S. Sutton                      *Progress Report for Canadian Tree Improvement  
Association*..... 43

## British Columbia -- B.C. Ministry of Forests

- J. Webber                      *Seed Production Research -- B.C. Ministry  
of Forests*..... 48

## British Columbia -- B.C. Ministry of Forests

- J.H. Woods                      *Coastal Douglas-Fir Breeding and  
Genetic Research*..... 52

## British Columbia -- B.C. Ministry of Forests

- C.C. Ying                      *Provenance Research*..... 54

## Alberta -- University of Alberta

- B.P. Dancik                      *Genetics and Tree Improvement Research at  
the University of Alberta*..... 55  
O.P. Rajora  
P.D. Khasa  
& Associates

## Alberta -- Forest Management Division - Land and Forest Service

- C.R. Hansen                      *Tree Improvement Programme, Alberta  
Land and Forest Service*..... 59  
N.K. Dhir  
K. Yakimchuk  
J.M. Schilf  
L. Barnhardt  
C. Andriuk  
N.W. Antoniuk  
S. Hoberg  
M.A. Mochulski

## Alberta -- University of Alberta

- F.C. Yeh                      *Quantitative and Population Genetics,  
Applied Tree Breeding and Improvement  
at the University of Alberta*..... 65  
R. Yang  
& Associates

## Saskatchewan -- Shelterbelt Centre, PFRA

W.R. Schroeder	<i>PFRA Shelterbelt Centre - Tree Improvement Summary</i> .....	69
----------------	---	----

## Manitoba -- AAFC-Morden Research Centre

C.G. Davidson	<i>Agriculture and Agri-Food Canada, Morden</i>	
R.D. Browne	<i>Research Station Tree Improvement Report</i> .....	72
S. Gobin		
R.J. Enns		
L. Dyck		

## Manitoba -- Manitoba Forestry Branch

J. Dojack	<i>Manitoba's Tree Improvement Programme</i> .....	75
G. Falk		

## Manitoba -- Canadian Forest Service

J.I. Klein	<i>Tree Improvement Under the Canada-Manitoba Partnership Agreement in Forestry</i> .....	77
------------	---	----

## Ontario -- Canadian Forest Service

P. de Groot	<i>Cone and Seed Pest Management</i> .....	80
-------------	--	----

## Ontario --

F. Di-Giovanni	<i>Pollen Contamination Reduction Software</i> .....	82
----------------	--	----

## Ontario -- Canadian Forest Service

A. Mosseler	<i>Genetic Diversity and Reproductive</i>	
L. DeVerno	<i>Success</i> .....	84
J. Lavereau		

## Ontario -- Canadian Forest Service

K. Johnsen	<i>Physiological Genetics and Plasticity</i> .....	87
J. Major		

## Ontario – Ontario Tree Improvement Board

C. Nielsen	<i>Ontario's Genetic Resources Management</i>	
J. Wild	<i>Program.....</i>	91
R. Ford		
P. Charrette		
B. White		
D. Joyce		
F. Schnekenburger		
P. Nitschke		

## Ontario – University of Toronto

L. Zsuffa	<i>Forest Genetics Research at the Faculty</i>	
R.L. Gambles	<i>of Forestry, University of Toronto.....</i>	97
W.A. Kenney		
D. Lin		
B.J. Vanstone		

## Quebec – Ministère des Ressources naturelles

R. Beaudoin	<i>Amélioration des Arbres Forestiers à la Direction</i>	
S. Mercier	<i>de la Recherche Forestière du Ministère</i>	
M.-J. Mottet	<i>des Ressources Naturelles.....</i>	102
A. Rainville		
A. Stipanovic		
G. Vallée		
M. Villeneuve		

## Quebec -- Université Laval

J. Bousquet	<i>Current Research in Forest Genetics and Tree</i>	
F.M. Tremblay	<i>Biotechnology at Laval University.....</i>	112
N. Isabel		

## Quebec – Service canadien des forêts

G. Daoust	<i>Génétique et Amélioration des Arbres au</i>	
J. Beaulieu	<i>Service canadien des forêts.....</i>	119
M. Deslauriers		
R.C. Hamelin		
P. Li		
A. Plourde		

## Quebec – Forintek Canada Corp.

S.Y. Zhang	<i>Forintek's Wood Quality and End-Use</i>	
	<i>Studies Related to Tree Improvement</i>	
	<i>Programs.....</i>	129

## New Brunswick -- J.D. Irving Ltd.

G. Adams	<i>J.D. Irving Limited - Tree Improvement Summary</i> .....	133
----------	---	-----

## New Brunswick -- Université de Moncton

G.-É. Caron	<i>Seed, Cone, and Pollen Studies at the Université de Moncton</i> .....	135
-------------	--	-----

## New Brunswick -- Canadian Forest Service

Y.S. Park J.M. Bonga S.I. Cameron R.D. Hallett C.H.A. Little J.A. Loo R.F. Smith	<i>Forest Genetics Research at Canadian Forest Service - Maritimes Region</i> .....	138
--	---	-----

## New Brunswick -- University of New Brunswick

G.R. Powell R.A. Savidge E.K. Morgenstern	<i>Tree Improvement and Related Studies at the University of New Brunswick</i> .....	145
---	--	-----

## New Brunswick -- Fraser Inc.

P. Roussel	<i>Fraser Inc. - Tree Improvement Programme</i> .....	149
------------	---	-----

## New Brunswick -- Canadian Forest Service

J.D. Simpson V.C. Steel	<i>New Brunswick Tree Improvement Council Update</i> .....	151
----------------------------	--	-----

## New Brunswick -- Department of Natural Resources &amp; Energy

K.J. Tosh M.S. Fullarton	<i>Tree Improvement Progress in New Brunswick</i> .....	154
-----------------------------	---	-----

## Nova Scotia -- Department of Natural Resources

H. Frame D. Steeves	<i>Cooperative Tree Breeding in Nova Scotia</i> .....	156
------------------------	---	-----

## Nova Scotia -- Genesis Forest Science Canada Inc.

T.J. Mullin	<i>Tree Improvement Consulting Services Provided by Genesis Forest Science Canada Inc.</i> .....	158
-------------	--	-----

Prince Edward Island – Department of Agriculture, Fisheries and Forestry

W.M. Glen	<i>Tree Improvement Progress in PEI.....</i>	162
W.J. MacKinnon		
M.N. Myers		

Newfoundland – Department of Natural Resources

C.M. Harrison	<i>The Current Status and Future Direction of Tree Improvement in Newfoundland and Labrador.....</i>	165
---------------	--	-----

---

***C.T.I.A. ACTIVE MEMBERS***

---

CTIA ACTIVE MEMBERS<sup>1</sup>

Greg Adams  
 J.D. IRVING  
 Sussex Tree Nursery  
 R.R. # 4  
 Sussex, New Brunswick  
 E0E 1P0

W. D. Baker  
 N.W. Ont. Forest Tech. Dev. Unit  
 Thunder Bay Nursery  
 R.R. # 1  
 Thunder Bay, Ontario  
 P7C 4T9

Brian Barber  
 B. C. Ministry of Forests  
 Research Branch  
 31 Bastion Square  
 Victoria, British Columbia  
 V8W 3E7

R. Beaudoin  
 Min. des Ressources naturelle  
 Service de L'Amelioration des Arbes  
 2700 Rue Einstein  
 Ste. Foy, Quebec  
 G1P 3W8

Henry Benskin  
 B. C. Ministry of Forests  
 Forest Renewal Sect. Res. Branch  
 31 Bastion Square  
 Victoria, British Columbia  
 V8W 3E7

J. M. Bonga  
 Natural Resources Canada-Maritimes  
 Hugh John Flemming Forestry Centre  
 P. O. Box 4000  
 Fredericton, New Brunswick  
 E3P 5P7

Dr. Robin Browne  
 AAFC - Morden Research Centre  
 Unit 100-101-Route 100  
 Morden  
 Manitoba  
 R6M 1Y5

Chris Atack  
 Ministry of Natural Resources  
 896 Riverside Drive  
 Timmins  
 Ontario  
 P4N 3W2

Dr. J. Balatinecz  
 Faculty of Forestry  
 University of Toronto  
 33 Willcocks Street  
 Toronto, Ontario  
 M5S 3B3

Leonard K. Barnhardt  
 Alberta Forest Service  
 Reforestation & Reclamation Branch  
 Pine Ridge Nursery Box 750  
 Smoky Lake, Alberta  
 T0A 3C0

Jean Beaulieu  
 Ressources naturelles Canada  
 Service canadien des forets-Quebec  
 1055 Rue du PEPS C.P. 3800  
 Ste. Foy, Quebec  
 G1V 4C7

Robert D. Bettle  
 Dept. of Natural Resources  
 Timber Management Branch  
 P. O. Box 6000  
 Fredericton, New Brunswick  
 E3B 5H1

Jean Bousquet  
 C. R. B. F.  
 Fac. de foresterie et de geomatique  
 Universite Laval  
 Ste. Foy, Quebec  
 G1K 7P4

Stewart E. Cameron  
 Natural Resources Canada-Maritimes  
 Hugh John Flemming Forestry Centre  
 P. O. Box 4000  
 Fredericton, New Brunswick  
 E3B 5P7

---

<sup>1</sup> An active member will be expected to submit a written report on their work prior to each meeting of the Association.

Dr. M. Carlson  
 B. C. Ministry of Forests  
 Kalamalka Res. Stn. & Seed Orchard  
 3401 Reservoir Road  
 Vernon, British Columbia  
 V1B 2C7

Guy E. Caron  
 Ecole de sciences forestieres  
 Univ. de Moncton Edmundston Campus  
 165 Boulevard Hebert  
 Edmundston, New Brunswick  
 E3V 2S8

Gaetan Daoust  
 Ressources naturelles Canada  
 Service canadien des forets-Quebec  
 1055 Rue du PEPS C.P. 3800  
 Ste. Foy, Quebec  
 G1V 4C7

Linda DeVerno  
 Natural Resources Canada-Maritimes  
 Hugh John Flemming Forestry Centre  
 P. O. Box 4000  
 Fredericton, New Brunswick  
 E3B 5P7

Dr K. Narinder Dhir  
 Alberta Forest Service  
 9920-108 Street  
 Edmonton  
 Alberta  
 T5K 2M4

A. Dion  
 Can. Pacific Forest Products Ltd.  
 1053 Boul Ducharme  
 La Tuque  
 Quebec  
 G9X 3P9

Dr. D. G. Edwards  
 Natural Resources Canada  
 Pacific Forestry Centre  
 506 West Burnside Road  
 Victoria, British Columbia  
 V8Z 1M5

Gordon Falk  
 Dept. of Natural Resources  
 P. O. Box 27 Group 8  
 R.R. # 2, Dugald  
 Manitoba  
 R0E 0K0

John Carlson Asst. Pr  
 Univ. of B. C. Faculty of Forestry  
 MacMillan Building  
 193-2357 Main Mall  
 Vancouver, British Columbia  
 V6T 1Z4

Dr. Bruce Dancik  
 University of Alberta  
 Dept. of Renewable Resources  
 855 General Services Bldg.  
 Edmonton, Alberta  
 T6G 2H1

Dr. Campbell G Davidson  
 AAFC - Morden Research Centre  
 Unit 100-101-Route 100  
 Morden  
 Manitoba  
 R6M 1Y5

Marie Deslauriers  
 Ressources naturelles Canada  
 Service canadien des forets-Quebec  
 1055 Rue du PEPS C.P. 3800  
 Ste. Foy, Quebec  
 G1V 4C7

Franco Di-Giovanni  
 76 Ptarmigan Drive  
 Guelph  
 Ontario  
 N1C 1B6

John Dojack  
 Manitoba Forestry Branch  
 300-530 Kenaston Blvd.  
 Winnipeg  
 Manitoba  
 R3N 1Z4

Dr. Yousry A. El-Kassaby  
 Pacific Forest Products Ltd.  
 Saanich Forestry Centre  
 8067 East Saanich Road  
 Saanichton, British Columbia  
 V8M 1K1

Dr. R. E. Farmer  
 Lakehead University  
 School of Forestry  
 Thunder Bay  
 Ontario  
 P7B 5E1

W. H. Fogal  
Ecology Products and Service  
P. O. Box 293  
Chalk River, Ontario  
K0J 1J0

Michele Fullarton  
N. B. Dept. of Natural Resources  
Tree Improvement Centre  
Kingsclear Tree Nursery R. R. # 6  
Fredericton, New Brunswick  
E3B 4X7

William M. Glen  
Dept. of Agric., Fish. & Forestry  
P. O. Box 2000  
Charlottetown  
Prince Edward Island  
C1A 7N8

Dr. Alan G. Gordon  
Ontario Ministry of Natural Res.  
Ontario Forest Research Institute  
P. O. Box 969  
Sault Ste. Marie, Ontario  
P6A 5N5

Dr. Richard Hamelin  
Ressources naturelles Canada  
Service canadien des forets-Quebec  
1055 Rue du P.E.P.S. C.P. 3800  
Ste. Foy, Quebec  
G1V 4C7

Dr. Rong H. Ho  
Ontario Ministry of Natural Res.  
Ontario Forest Research Institute  
1235 Queen Street E.  
Sault Ste. Marie, Ontario  
P6A 5N5

B. Jaquish  
B. C. Ministry of Forests  
Kalamalka Research Station  
3401 Reservoir Road  
Vernon, British Columbia  
V1B 2C7

Dr. Kurt Johnsen  
Natural Resources Canada-Maritimes  
Hugh John Flemming Forestry Centre  
P. O. Box 4000  
Fredericton, New Brunswick  
E3B 5P7

Howard M. Frame  
Dept. of Natural Resources  
Tree Breeding Centre  
P. O. Box 190  
Debert, Nova Scotia  
B0M 1G0

Dr. Robert Gambles Res. As  
University of Toronto  
Faculty of Forestry  
33 Willcocks Street  
Toronto, Ontario  
M5S 3B3

Josefina S. Gonzalez  
Forintek Canada Corporation  
2665 East Mall  
University of British Columbia  
Vancouver, British Columbia  
V6T 1W5

Ronald D. Hallett  
Natural Resources Canada-Maritimes  
Hugh John Flemming Forestry Centre  
P. O. Box 4000  
Fredericton, New Brunswick  
E3B 5P7

Dr. Charles M. Harrison  
Dept. of Natural Resources  
P. O. Box 2006 Herald Building  
Corner Brook  
Newfoundland  
A2H 6J8

Richard S. Hunt  
Natural Resources Canada  
Pacific Forestry Centre  
506 West Burnside Road  
Victoria, British Columbia  
V8Z 1M5

Dr. Sally E.T. John  
Univeristy of Alberta  
Dept. of Forest Science  
Edmonton  
Alberta  
T6G 2H1

Dennis Joyce  
Ontario Ministry of Natural Res.  
O.F.R.I.  
1235 Queen Street East  
Sault Ste. Marie, Ontario  
P6A 5N5

Dr. C. T. Keith  
 Forintek Canada Corporation  
 800 Montreal Road  
 Ottawa  
 Ontario  
 K1G 3Z5

Dr. John King  
 B. C. Ministry of Forests  
 Research Branch  
 1450 Government Street  
 Victoria, British Columbia  
 V8W 3E7

Dr. Jerome I. Klein  
 Natural Resources Canada  
 Northwest Region Manitoba District  
 200, 180 Main Street  
 Winnipeg, Manitoba  
 R3C 1A6

Vlad J. Korelus  
 Can. Pacific Forest Products Ltd.  
 Tahsis Pacific Region  
 8067 East Saanich Road  
 Saanichton, British Columbia  
 V0S 1M0

Yves Lamontagne  
 Gouvernement du Quebec  
 Ministere des Forets  
 2700 Rue Einstein  
 Ste. Foy, Quebec  
 G1P 3W8

Dr. C. H. A. Little  
 Natural Resources Canada-Maritimes  
 Hugh John Flemming Forestry Centre  
 P. O. Box 4000  
 Fredericton, New Brunswick  
 E3B 5P7

John Major  
 Natural Resources Canada-Maritimes  
 Hugh John Flemming Forestry Centre  
 P. O. Box 4000  
 Fredericton, New Brunswick  
 E3B 5P7

Doug Matthews  
 Can. Pacific Forest Products Ltd.  
 Woodlands Division  
 P. O. Box 1950  
 Dalhousie, New Brunswick  
 E0K 1B0

Dr. R. M. Kellogg  
 Forintek Canada Corporation  
 6620 N. W. Marine Drive  
 Vancouver,  
 British Columbia  
 V6T 1X2

G. K. Kiss  
 B. C. Ministry of Forests  
 Kalamalka Forestry Centre  
 3401 Reservoir Road  
 Vernon, British Columbia  
 V1B 2C7

J. Konishi  
 B. C. Ministry of Forests  
 Silviculture Branch  
 1450 Government Street  
 Victoria, British Columbia  
 V8W 3E7

Mathew Koshy  
 University of British Columbia  
 Faculty of Forestry  
 193 - 2357 Main Mall  
 Vancouver, British Columbia  
 V6T 1W5

Peng Li  
 Ressources naturelles Canada  
 Service canadien des forets-Quebec  
 1055 Rue de P.E.P.S. C.P. 3800  
 Ste. Foy, Quebec  
 G1V 4C7

Dr. Judy Loo  
 Natural Resources Canada-Maritimes  
 Hugh John Flemming Forestry Centre  
 P. O. Box 4000  
 Fredericton, New Brunswick  
 E3B 5P7

Alan G. Mathews  
 Ontario Ministry of Natural Res.  
 Sioux Lookout District  
 District Manager  
 Sioux Lookout, Ontario  
 P0V 2T0

Dr. Jack Maze  
 University of British Columbia  
 Dept of Botany  
 #3529-6270 University Blvd.  
 Vancouver, British Columbia  
 V6T 2B1

Spencer McDougald  
Weyerhaeuser Canada  
Sask. Timberlands  
Box 1720  
Prince Albert, Saskatchewan  
S6V 5T3

Stephan Mercier  
Min. des Ressources naturelles  
Service de L'Amelioration des Arbes  
2700 Rue Einstein  
Ste. Foy, Quebec  
G1P 3W8

Marie-Josée Mottet  
Min. des Ressources naturelles  
Service de L'Amelioration des Arbes  
2700 Rue Einstein  
Ste. Foy, Quebec  
G1P 3W8

Mary Myers  
Dept. of Agric., Fish. & Forestry  
P. O. Box 2000  
Charlottetown  
Prince Edward Island  
C1A 7N8

Cathy Nielsen  
Ontario Ministry of Natural Res.  
Brockville District  
P. O. Box 605 Oxford Ave.  
Brockville, Ontario  
K6A 5Y8

C. L. Palmer  
Lakehead University  
School of Forestry  
Ontario Tree Improvement Council  
Thunder Bay, Ontario  
P7B 5E1

Dr. Yill Sung Park  
Natural Resources Canada-Maritimes  
Hugh John Flemming Forestry Centre  
P. O. Box 4000  
Fredericton, New Brunswick  
E3B 5P7

Dr. R. P. Pharis  
University of Calgary  
Dept. of Biology  
2500 University Drive N. W.  
Calgary, Alberta  
T2N 1N4

Dr. M. D. Meagher  
Natural Resources Canada  
Pacific Forestry Centre  
506 West Burnside Road  
Victoria, British Columbia  
V8Z 1M5

Dr. Alexander Mosseler  
Natural Resources Canada-Maritimes  
Hugh John Flemming Forestry Centre  
P. O. Box 4000  
Fredericton, Fredericton  
E3B 5P7

Tim J. Mullin  
Genesis  
Forest Science Canada Inc.  
P. O. Box 1321  
Truro, Nova Scotia  
B2N 5N2

Dr. Gene Namkoong  
Univ. of B. C. Faculty of Forestry  
MacMillan Building  
193-2357 Main Mall  
Vancouver, British Columbia  
V6T 1Z4

Peter Nitschke  
Ontario Tree Improvement Board  
70 Foster Drive  
Suite 400  
Sault Ste. Marie, Ontario  
P6A 6V5

Dr. M. Pandila  
Saskatchewan Dept. of Parks and  
Renewable Resources  
Forestry Div. P. O. Box 3003  
Prince Albert, Saskatchewan  
S6V 6G1

Dr. William H. Parker  
Lakehead University  
School of Forestry  
Thunder Bay  
Ontario  
P7B 5E1

Dr. Ariane Plourde  
Ressources naturelles Canada  
Service canadien des forets-Quebec  
1055 Rue du P.E.P.S. C.P. 3800  
Ste. Foy, Quebec  
G1V 4C7

Dr. J. Poliquin  
 Universite Laval  
 Fac. de Foresterie et de Geodesie  
 Ste. Foy  
 Quebec  
 G1K 7P4

Dr. Om P. Rajora  
 University of Alberta  
 Dept. of Renewable Resources  
 855 General Services Bldg.  
 Edmonton, Alberta  
 T6G 2H1

Paul Roussel  
 Fraser Inc.  
 27 Rice Street  
 Edmundston  
 New Brunswick  
 E3V 1S9

Dr. R. Savidge  
 University of New Brunswick  
 Fac. of Forestry & Environ. Mgmt.  
 Bag Service No. 44555  
 Fredericton, New Brunswick  
 E3B 6C2

William Schroeder  
 Shelterbelt Centre, P.F.R.A.  
 Agriculture & Agri-Food Canada  
 Indian Head  
 Saskatchewan  
 S0G 2K0

Dale Simpson  
 Natural Resources Canada  
 Maritimes Region  
 P. O. Box 4000  
 Fredericton, New Brunswick  
 E3E 5P7

Dr. Albert Sproule  
 Alberta Forest Service  
 9920-108 Street  
 9th Floor  
 Edmonton, Alberta  
 T5K 2M4

A. Stipanovic  
 Min. des Ressources naturelles  
 Service de L'Amelioration des Arbes  
 2700 Rue Einstein  
 Ste. Foy, Quebec  
 G1P 3W8

A. Rainville  
 Min. des Ressources naturelles  
 Service de L'Amelioration des Arbes  
 2700 Rue Einstein  
 Ste. Foy, Quebec  
 G1P 3W8

Diane M. Roddy  
 Weyerhaeuser Canada Ltd.  
 P. O. Box 1720  
 Prince Albert  
 Saskatchewan  
 S6V 5T3

John Russell  
 B. C. Ministry of Forests  
 Cowichan Lake Research Station  
 P. O. Box 335  
 Mesachie Lake, British Columbia  
 V0R 2N0

Janet M. Schilf  
 Alberta Forest Service  
 Forestry, Lands and Wildlife  
 P. O. Box 750  
 Smoky Lake, Alberta  
 T0A 3C0

S. Segaran  
 Forestry Branch  
 Dept. of Natural Resources  
 300-530 Kenaston Blvd.  
 Winnipeg, Manitoba  
 R3N 1Z4

Ron F. Smith  
 Natural Resources Canada-Maritimes  
 Hugh John Flemming Forestry Centre  
 P. O. Box 4000  
 Fredericton, New Brunswick  
 E3B 5P7

David G. Steeves  
 Dept. of Natural Resources  
 P. O. Box 190  
 Debert  
 Nova Scotia  
 B0M 1G0

Michael Stoehr  
 B. C. Ministry of Forests  
 Glyn Road Research Station  
 1320 Glyn Road  
 Victoria, British Columbia  
 V8W 3E7

Dr. Ben Sutton  
 Forest Biotechnology Centre  
 B. C. Research Inc.  
 3650 Wesbrooke Mall  
 Vancouver, British Columbia  
 V6S 2L2

Kathleen Tosh  
 N.B. Dept. of Nat. Res. & Energy  
 Tree Improvement Unit  
 Kingsclear Forest Nursery R.R.#6  
 Fredericton, New Brunswick  
 E3B 4X7

Dr. Gilles Vallee  
 Min. des Ressources naturelles  
 Service de L'Amelioration des Arbes  
 2700 Rue Einstein  
 Ste. Foy, Quebec G1P 3W8

M. Villeneuve  
 Min. des Ressources naturelles  
 Service de L'Amelioration des Arbes  
 2700 Rue Einstein  
 Ste. Foy, Quebec  
 G1P 3W8

Dr. E. White  
 Natural Resources Canada  
 Pacific Forestry Centre  
 506 West Burnside Road  
 Victoria, British Columbia  
 V8Z 1M5

J. H. Woods  
 B. C. Ministry of Forests  
 Cowichan Lake Research Station  
 P. O. Box 335  
 Mesachie Lake, British Columbia  
 V0R 2N0

Dr. Alvin Yanchuk  
 B. C. Ministry of Forests  
 Research Branch  
 31 Bastion Square  
 Victoria, British Columbia  
 V8W 3E7

Dr. Cheng Ying  
 B. C. Ministry of Forests  
 Research Branch  
 1450 Government Street  
 Victoria, British Columbia V8W 3E7

Peter de Groot  
 Natural Resources Canada  
 Forest Pest Management Institute  
 P. O. Box 490  
 Sault Ste. Marie, Ontario P6A 5M7

Dr. Trevor Thorpe  
 University of Calgary  
 Dept. of Biology  
 2500 University Drive N. W.  
 Calgary, Alberta  
 T2N 1N4

Dr. Margaret H Tripp-Knowles  
 Lakehead University  
 School of Forestry  
 Thunder Bay  
 Ontario  
 P7B 5E1

Brenda J. Vanstone  
 University of Toronto  
 Faculty of Forestry  
 33 Willcocks Street  
 Toronto, Ontario M5S 3B3

Dr. J. F. Webber  
 B. C. Ministry of Forests  
 Glyn Road Research Station  
 1320 Glyn Road  
 Victoria, British Columbia  
 V8W 3E7

Joan Wild  
 Ontario Ministry of Natural Res.  
 Ontario Government Bldg.  
 10th Floor 199 Larch Street  
 Sudbury, Ontario  
 P3E 5P9

Katherine Yakimchuk  
 Pine Ridge Forest Nursery  
 Genetics & Tree Improvement  
 P. O. Box 750  
 Smoky Lake, Alberta  
 T0A 3C0

Dr. Francis Yeh  
 University of Alberta  
 Dept. of Renewable Resources  
 855 General Service Bldg.  
 Edmonton, Alberta  
 T6G 2H1

S. Y. Zhang  
 Forintek Canada Ltd.  
 319 Rue Franquet  
 Ste. Foy  
 Quebec G1P 4R4

---

***C.T.I.A./A.C.A.A. 25th BUSINESS  
MEETING MINUTES***

---

**C.T.I.A./A.C.A.A.  
25th BUSINESS MEETING  
MINUTES**

Alvin Yanchuk chaired the 25th Business Meeting of the CTIA/ACAA held in the David Lam Auditorium, MacLauring Building, Victoria, British Columbia on Thursday August 31, 1995.

**283. Minutes of the 24th Meeting**

(as printed in the proceedings from the 24th meeting (Part I))

Motion: The minutes of the 24th Business Meeting be approved as published.

Moved by: J. Dojack

Seconded by: J. Klein

Carried.

**284. Membership**

**284.1 Honourary Membership**

Motion: That the following members of the CTIA/ACAA be nominated "honourary" membership for the outstanding contributions to the field of genetics and tree improvement in Canada during their career.

Don Fowler	N.R. Canada-Maritimes, N.B.
Chris Heaman	B.C. Ministry of Forests
Kris Morgenstern	University of New Brunswick
Graham Powell	University of New Brunswick
Oscar Sziklai	University of British Columbia
Ben Wang	Petawawa National Forestry Institute
Louis Zsuffa	University of Toronto

Moved by: J. Klein

Seconded by: D. Simpson

Carried.

**284.2 New Active Members**

The names of nominated new active members were presented as follows:

Linda DeVerno	Natural Resources Canada-Maritime Fredericton, New Brunswick
S. Y. Zhang	Forintek Canada Corp. Sainte-Foy, Quebec
Brian Barber	B.C. Forest Service Victoria, British Columbia
Mathew Koshy	Univ. of British Columbia Vancouver, British Columbia.

Motion: That the nominated new active members be duly elected.

Moved by: M. Stoehr

Seconded by: K. Tosh

Carried.

**284.3 New Corresponding Members**

The following were recorded:

Chang-Yi Xie	B.C. Ministry of Forests Victoria, British Columbia
Frederick D. Beall	Natural Resources Canada Sault Ste. Marie, Ontario
Tim Gylander	Weyerhaeuser Canada Ltd. Drayton Valley, Alberta

**285. Chair's Report**

On behalf of the B.C. Forest Service and University of Victoria, I would like to thank you for participating in the 1995 joint meeting of the Canadian Tree Improvement Association and the Western Forest Genetics Association. This is the first joint meeting of these two organizations and we feel the timing could not be better.

I would like to acknowledge and thank: John Russell, Michael Stoehr, and Pat McGuire (Organizing Committee), John Owens (University of Victoria sponsor), Jack Woods (field trips), Michael Carlson (art designs), Sally Aitken (WFGA Chair) and John Barker (Western Forest Products), Yousry El-Kassaby (Pacific Forest Products), Glen Dunsworth (MacMillan Bloedel) for industrial sponsorship of field tours and Joy Lavereau (CTIA Executive Secretary, Editor and Treasurer).

We would like to take this opportunity to acknowledge the pioneering efforts of the late Dr. Alan Orr-Ewing, and dedicate this meeting in his honor.

**286. Treasurer's Report**

The financial statement for the period of July 30, 1993 to July 30, 1995 was prepared by Treasurer Joy Lavereau and was tabled for membership information and acceptance (see attachment #1). The statement shows a balance of \$7,175.53 in the association's account as of July 30, 1995 and G.I.C.'s totalling \$23,000.00.

Motion: That the financial statements as presented be accepted.  
 Moved by: D. Simpson  
 Seconded by: M. Stoehr  
 Carried.

**287. Financial Contributions**

British Columbia Ministry of Forests  
 Centre for Forestry Biology, University of Victoria  
 Western Forest Products  
 Pacific Forest Products  
 MacMillan Bloedel

Motion: That the CTIA/ACAA of the 25th meeting express our sincere appreciation to these contributors.  
 Moved by: J. Klein  
 Seconded by: K. Tosh  
 Carried.

**288. Editor's Report**

The proceedings were printed and distributed to all active members, Canadian universities and libraries, all participants of the 24th meeting, sponsoring and honorary members during April 1995. Two hundred and ninety-seven proceedings were mailed.

A form letter advising the theme of the 24th biennial meeting, the proceeding context and a request for a twenty dollar donation to obtain one copy, was sent to all corresponding members, U.S.A. addresses and other foreign countries. There were 23 donations from Canadian addresses, 20 from U.S.A. addresses and other foreign countries obtained 26.

**289. Educational committee****289.1 Canadian Tree Improvement Association biennial "Sponsored Student Awareness":**

To promote students' knowledge and understanding in tree improvement activities and forest genetics research, the forestry faculties of Canadian universities were encouraged to nominate a student for the sponsorship to attend the 25th CTIA/ACAA meeting. The following students received the award which provided all the costs of meeting, including registration, accommodation, pre-conference tour and travel:

Susan Boyes	Lakehead University
Denise Donelle	University of Moncton
Peggy Hickey	University of New Brunswick
Martin Perron	Laval University
Pia Smets	University of British Columbia
Barb Thomas	University of Alberta
Vasilios Tsarouhas	University of Toronto

Sponsorship of these students is paid by the executive committee of each biennial meeting through registration fees.

**289.2 Canadian Tree Improvement Association biennial "Student Recognition Awards":**

The following students received a cash award, for recognition of oral presentations given at the 25th CTIA/ACAA meeting in Victoria, British Columbia.

John Runions	Forest Biology, Univ. of Victoria Victoria, British Columbia	\$500.00
Rungna Pattaavibool	Forest Biology, Univ. of Victoria Victoria, British Columbia	\$300.00
Martin Perron	Fac. de Foresterie, Univ. Laval Ste. Foy, Quebec	\$200.00

Motion: To grant the 1997 executive committee to establish a series of CTIA/ACAA student recognition awards for oral presentations, posters, or other contributions and draw no more than \$1000.00 per meeting.

**290. Working Groups Reports****Tree Seed Working Group**

The Tree Seed Working Group held its regular Biennial Business Meeting on August 28, 1995. Four issues of the TSWG News Bulletin (No. 20-23) were published in the past two years and distributed to all members (about 250) and 32 Institutions. Hugh Schooley, Editor of the TSWG News Bulletin since 1985, retired from

Forestry Canada in 1995. Hugh was instrumental in developing a sound periodical for tree seed managers and scientists throughout Canada and abroad. His continued support will be deeply missed!

Ron Smith (CFS - Maritimes) has accepted to become our next TSWG News Bulletin Editor.  
Motion: That the name of Ron Smith be accepted as the new Editor.

Moved by: Dave Kolotelo

Seconded by: Howard Frame

Carried.

Thanks Ron for your support!

In 1994, Hugh Schooley organized a Tree Seed Discussion Group on the Internet (see News Bulletin No. 21). It is a great way to correspond with colleagues around the world. Ron Smith has accepted to look after the Discussion Group. The move from Petawawa National Forestry Institute (PNFI) to CFS-Maritimes should occur early this fall. All members of the Discussion Group will be informed of the change in due course.

PNFI has since 1985 covered the printing and mailing cost of the News Bulletin. We would like to acknowledge this continued support over the years. Since PNFI will terminate its mandate as a result of the Federal Government cutbacks, we needed financial support for continuing the publication of the News Bulletin. Dr. Geritt van Raalte, Science Director - Forest Resources, CFS-Maritimes, has agreed to take over the cost related to publishing and mailing the NewsBulletin.

It was suggested that the News Bulletin be available to the Discussion Group on the Internet. I will address Ron Smith on this.

Dave Kolotelo, Peter de Groot, and Guy-É. Caron have accepted to continue as Coordinator of the Tree Seed Processing and Testing Working Party, Coordinator of the Cone and Seed Insects Working Party, and Chairman of TSWG, respectively.

Dave Kolotelo coordinated this year's Workshop in Victoria. The Workshop, like the CTIA/ACAA meeting, was well organized and well attended. Dave also organized two tours to the BC Ministry Tree Seed Center in Surrey on August 27 and September 1. Our sincere thanks to Dave for his dedication towards the success of the Workshop.

For the first time, the TSWG will have its presentations refereed. Dr. D.B. Burgess, Co-Editor of the Forestry Chronicle, has agreed to the publication of a Special Issue sometime in 1996.

The TSWG will host another Workshop at the 26th CTIA/ACAA meeting to be held in Quebec City, in 1997. Stéphan Mercier, Ministère des Forêts du Québec, will coordinate that workshop and will act as liaison to the organizing committee of the 26th CTIA/ACAA meeting.

Finally, a short discussion was had on the role of CFS on seed research throughout Canada. Seed research will now be headed by CFS-Maritimes. It is hoped by all that the National perspective be respected. As Chairman of the TSWG, I will transmit this information to the Administration at CFS-Maritimes.

This concludes my report!

Guy-É. Caron    Chairperson 1991-97

## **291. Business arising from previous meetings**

### **291.1 Distribution of proceedings**

Motion 279.2:    Distribution of the 25th CTIA/ACAA proceedings will be determined by the 1995 executive committee.

Motion:            Distribution of the 25th CTIA/ACAA proceedings will be "gratuitous" copies be sent to all active members, all participants of the meeting, all Canadian universities and libraries, honorary members and sponsors of the meeting.

Moved by: J. Klein  
 Seconded by: M. Stoehr  
 Carried.

### 291.2 Name change of CTIA/ACAA

Motion 279.3: That an official name change be held off, until members were advised of the proposal and that the 1995 executive committee would be responsible for notification of the motion to all active members.

A questionnaire was sent to all active members in March 1995. The results were as follows:

Canadian Tree Improvement Association	= 26 Votes
Canadian Forest Genetics Association	= 9 Votes
Other	= 11 Votes

The 1995 Executive committee stated the name "Canadian Tree Improvement Association" will not be changed.

### 291.3 Retirement

Motion 289.1: That in light of the pending retirement of Dr. E.K. Morgenstern, that the current CTIA/ACAA executive committee compose and send a letter on behalf of the CTIA/ACAA to the Faculty of Forestry, University of New Brunswick urging the Faculty to maintain a staff position in forest genetics.

Kathy Tosh advised a letter was sent to the University of New Brunswick. The faculty was uncertain regarding maintaining a position due to University restraints.

## 292. New Business

### 292.1 Closure of P.N.F.I.

With the closure of Petawawa National Forestry Institute, the Canadian Tree Improvement Association would ask Natural Resources Canada, Maritime Region to take on the responsibility of Editor, Treasurer, and Executive Secretary of the Association.

Natural Resources - Maritimes, confirmed commitment to maintain all aspects of the Canadian Tree Improvement Association.

### 292.2 Funding

The Science and Sustainable Development Directorate and the Petawawa National Forestry Institute have committed 5 000 dollars for the printing and distribution of Part I and Part II of the 25th CTIA/ACAA proceedings.

292.3 Guy Caron asked if the Canadian Tree Improvement Association would be interested in paying the publishing costs of "four" Tree Seed Working Group papers. After some discussion the members decided it was too expensive due to page printing costs. However, the Association would be pleased to publish the four papers in the "Proceedings of the twenty-fifth meeting", Victoria, B.C.

### 292.4 Proposal for Support

Lauren Fins, Professor of Forest Genetics at the University of Idaho sent a proposal to the 1995 CTIA/ACAA Executive Committee requesting support for a project on the "History of Forest Genetics in North America". The funding request of \$3500.00 would be used for travel expenses to record and make available the oral history of forest genetics and tree improvement across North America, as remembered and told by the prominent pioneers of the forest genetics and tree improvement in the U.S. and Canada.

Introduction (of the proposal)

In the earliest days of westward expansion in the United States, forest manipulation consisted of a log-and-move on mentality. The best species and individuals were harvested with little thought to regenerating the stands to the same species mix or to the same level of genetic integrity. Later, when planting began to come into vogue, there was still very little understanding that there were critical adaptive differences between populations of the same species. Seed distribution was hardly monitored and often the criterion for purchase was the lowest price. As a result, many poorly adapted trees were planted throughout the west. As forest geneticists began to study and understand population variation, their work has a major influence on the planting practices in operational forest management. Today, no modern forester would consider planting without first matching the seed source to the planting site . . .

After some discussion, it was decided that the documentation of this historical information was important and that the CTIA/ACAA would put \$2000.00 aside for the proposal, on the condition that L. Fins receive five supporting offers from other sectors.

Motion: That the CTIA/ACAA support Lauren Fins with Two thousand Canadian dollars, for the proposed manuscript "A History of Forest Genetics and Tree Improvement in North America". On the condition, that L. Fin receive five supporting offers from other sectors.

Moved by: M. Meagher  
Seconded by: J. Woods  
Carried.

**293. Future Meeting****293.1 Location of the 1997 meeting**

Michel Villeneuve confirmed that the 1997 CTIA/ACAA meeting be jointly hosted by Yves Lamontagne (Ministere des Forêts), Jean Beaulieu (Natural Resources Canada), and Jean Bousquet (Université Laval) and will be held in Quebec City.

**293.2 Location of the 1999 meeting**

Unfortunately, Weyerhaeuser Canada is unable to jointly host the 1999 CTIA/ACAA meeting with the prairie provinces.

**293.3 Location of the 2001 meeting**

Tentative support from Northern Ontario to hold the 2001 meeting.

**294. Election of New Executive**

The following slate of officers for election to the 1995/97 CTIA/ACAA executive:

Chairperson:	M. Michel Villeneuve Min. des Ressources naturelles
Vice-Chairperson:	MM. Jean Beaulieu (symposium) Ressources naturelles Canada Jean Bousquet (organisation locale) Université Laval
Secretary:	Mme. Arianne Plourde Ressources naturelles Canada

**295. Adjournment**

**Motion:** That the members of the CTIA/ACAA thank the executive for their efforts over the past two years and for an exciting and successful meeting.

**Motion:** That the 25th business meeting of the CTIA/ACAA be adjourned.

**Moved by:** Dennis Joyce

Attachment # 1.

CTIA/ACAA  
Financial Statement  
July 30, 1993 to July 30, 1995

	Cash Balance July 30, 1993	\$ 2,726.78
<hr/>		
<b>Credit:</b>		
Interest earnings (GIC, Account)	\$ 2,214.57	
Donations for 24th Meeting Proceedings	1,387.39	
24th Meeting advance return	1,035.51	
<b>Total Credit</b>	<b>\$ 4,637.47</b>	<b>\$ 4,637.47</b>
<hr/>		
<b>Guaranteed Investment Certificates: (as of July 30, 1993)</b>		
GIC Principal	\$10,000.00	
GIC Principal	8,000.00	
GIC Principal	6,000.00	
<b>Total GIC's</b>	<b>\$24,000.00</b>	
<b>Guaranteed Investment Certificates: (as of July 30, 1995)</b>		
GIC Principal	\$10,000.00	
GIC Principal	7,000.00	
GIC Principal	6,000.00	
<b>Total GIC's</b>		<b>\$23,000.00</b>
<hr/>		
Deposited back into account (from GIC)		<b>\$ 1,000.00</b>
<hr/>		
<i>Debit:</i>		
Forestry Chronicle	\$ 1,118.15	
Film processing	66.37	
Money order fees	3.25	
Service charge	.95	
<b>Total Debit</b>	<b>\$ 1,188.72</b>	<b>\$ 1,188.72</b>
<hr/>		
	Cash balance July 30, 1995	<u>\$ 7,175.53</u>
	Invested GIC balance	<u>\$23,000.00</u>
	<u>Total Holdings</u>	<u>\$30,175.53</u>

---

*ACTIVITY REPORTS*  
*FROM ACTIVE CTIA*  
*MEMBERS*

---

## WESTERN HEMLOCK BREEDING PROGRAM

John King and Charlie Cartwright

B.C. Ministry of Forests  
 Research Branch  
 1450 Government St.  
 Victoria, B.C.  
 V8W 3E7

### First Generation Testing

Three series of tests evaluating 144 low elevation open-pollinated parent are undergoing 15 year measurements, with data analysis confirming 10 year results. Three more recent polycross series test a further 182 parents, with the first 5 year measurements completed in 1994, and preliminary selection made.

High elevation (over 600 m) trial establishment was concluded this year with the out-planting of 91 polycross families on 2 sites. These augment 33 parents out-planted in 1993, and 10 included in Mike Meagher's 1979 series.

### Advanced Generation Testing

Advanced generation breeding is executed in conjunction with the Hemlock Tree Improvement Co-op (Hemtic). The program components are 5 regional units, each comprised of 5 disconnected 6 tree diallels (30 selected parents). Crossing for the 3 northern elements, B.C., Forks and Gray's Harbour, was 80% complete as of '94, with 950 isolations made this spring. The southern 2 elements, Cavenhams and Tilamook, were 50% complete, but similarly strong crossing efforts were made this year. Field test establishment will commence with sowing January '96 and will extend over 2 years, and 12 sites ranging from Northern Vancouver Island to Central Oregon.

### Realized Gain Trials

Verification of per hectare gains has been a recent program focus. Realized gain trials provide not only accurate estimates, but also strong demonstration of the value of selected materials to silviculturists. Three series will be established. The first, out-planted in 1992, has blocks representing the advanced generation (Hemtic) orchard, roqued first generation orchards, and a standard comprised of 14 wild stand seedlots. Early results (height age 4) over 3 sites show gains at 30% for the second generation, and 12% for the roqued orchard. (see figure 1).

### Other Research

Additional substantive program initiatives entail genecology installations. Specifically, provenances from California to Alaska are represented in 5 coastal trials monitored annually for frost damage and survival. Twelve much smaller sites have been planted throughout B.C., covering all the major vegetation zones in which hemlock occurs. Data bearing on seed transfer in general, (but in particular selected southern [Hemtic] material), adaptability, and value of specific provenances will be garnered from these sites.

To ensure product quality, wood and pulp property testing was initiated in 1993. All parents in B.C.'s first generation tests are assessed for specific gravity. In conjunction with Papercan (Vancouver), further screenings for fibre length and other properties of importance to pulp quality are evaluated.

## SITKA SPRUCE BREEDING PROGRAM

### Spruce Weevil Studies

Research of appropriate genotypes for deployment to weevil hazard areas concentrates on mode of inheritance of resistance, and screening selections from putatively resistant populations. A diallel mating design, using parents identified by provenance research and the interior spruce breeding program, has been constructed to investigate trait inheritance. To broaden the base of resistance, 3 series of screenings have been established evaluating 218 open-pollinated parents. Each consists of several disease garden sites, as well as a low hazard area trial to assess growth potential. Identical stock was provided to interested American industry co-operators to establish additional tests. Two further series are planned.

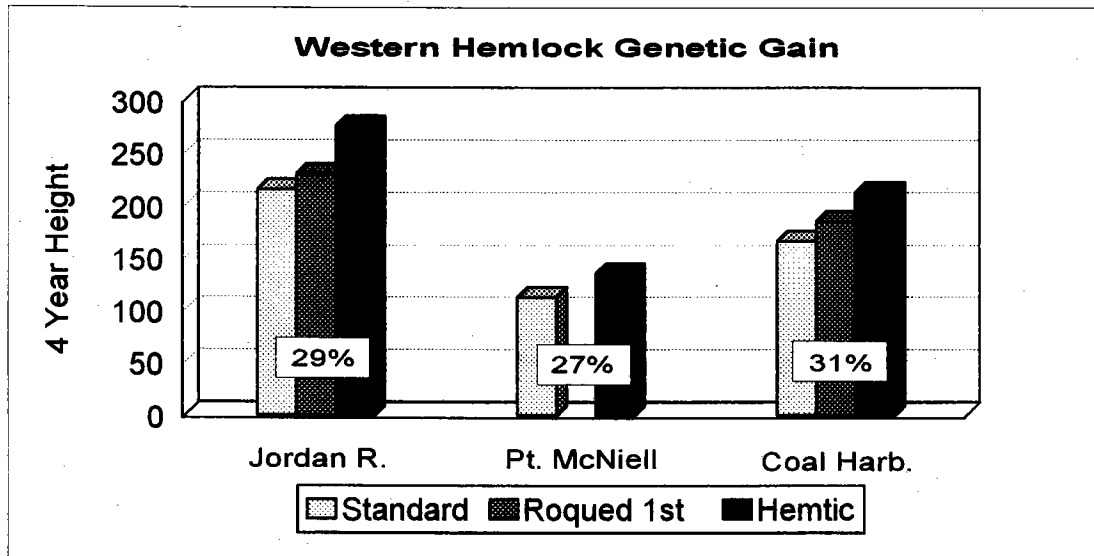
### Low Weevil Hazard Spruce

Testing for low hazard lands has proceeded to the point of completion of crossings the Queen Charlotte / North Vancouver Island seed orchard. As well, selections have been made from provenance tests at Holberg and on the Queen Charlotte Islands. Access to tested parents in European programs will also provide advanced generation materials.

### Hybrid Spruce

Collections from the wild and from hybrid sources in provenance tests started in 1994, with additional forays planned this year. Field testing is envisioned 3 to 4 years hence. The focus of the information gathering is to understand the dynamics of introgression in the hybrid zone, and identify optimal seed sources for the area.

Figure 1.



**LOGEPOLE PINE BREEDING PROJECT EP770****Michael Carlson and John Murphy****B.C. Ministry of Forests  
Kalamalka Forestry Centre  
3401 Reservoir Road  
Vernon, B.C.  
V1B 2C7**

The British Columbia Lodgepole pine breeding project, EP770, began with breeding zone delineation and parent tree selection in 1975. At that time the annual planting of the species was approximately 10 million seedlings. By 1985 a total of 1,562 trees had been selected for testing in 6 breeding zones. Within a year after selection most of these trees had been grafted into clonebanks and wind pollinated seed collected. Between 1984 and 1988, 36 wind pollinated test plantations were established on 18 sites in 6 breeding zones of the B.C. southern and central interior. Total tree heights were measured after 5 field seasons and a site-weighted selection index computed to rank trees in each zone (~300 trees per zone)

Starting in 1990, the top 15-20 % of the tested parents in each zone were grafted and planted at orchard sites in the dry warm southern interior Okanagan Valley. Today (1995) six of the seven rogued first generation orchards are nearly complete with full seed production expected, on average, for all seven by 2005. The annual planting requirement for the species is now more than 70 million. When full orchard production is achieved some 56 million or about 80% of the required number will come from these orchards. Estimated genetic gains for 6 year height range from 5 to 19%.

Controlled crossing to create second generation selection families began in 1995. The pilodyn was used in 10 year old progeny tests to rank parent trees for wood relative density. This information combined with 10-year height rankings was used to construct breeding populations with subpopulations (group) structure emphasizing relative density in some breeding groups and height growth in others. Small partial factorials ranging from 5x5 to single-pair matings are used starting with top ranked parents and descending to parents at about the 40th percentile in each breeding zone.

**PACIFIC FOREST PRODUCTS LIMITED  
SAANICH FORESTRY CENTRE  
TREE IMPROVEMENT PROGRAM AND FOREST GENETICS ACTIVITIES**

**Yousry A. El-Kassaby**

**Pacific Forest Products Limited  
Saanich Forestry Centre  
8067 East Saanich Road  
Saanichton, B.C.  
V8M 1K1**

**Keywords:** seed orchards, seed production, gene conservation, research.

### SEED ORCHARDS

The seed orchard program was reviewed and a consolidation plan for Nootka and Saanichton seed orchard complexes was completed. The number of seed orchards, species, orchard design, and the genetic status of the orchards have changed accordingly. The current state of Pacific's seed orchards is as follows:

1. The Saanichton high-elevation Douglas-fir seed orchard was removed and replaced by three new seed orchards:
  - a. Western hemlock, clonal-row moving front seed orchard was established with the parent material from the Hw co-op (i.e., advanced generation).
  - b. Sitka spruces, clonal-row from trees with known resistance history (i.e., advanced generation).
  - c. White pine, clonal-row with resistance mechanisms as blocks (i.e., advanced generation).
2. The Saanichton low-elevation Douglas-fir seed orchard was upgraded with forward and backward selections, so contamination to the 2nd generation seed orchards is not an issue.
3. New western redcedar seed orchard (hedge) was established.

The seed production for the 1993-95 is as follows:

- 1993-94: 64 kg Douglas-fir, 7 kg western hemlock, 2 kg Pacific silver fir, and 1 kg yellow-cedar.
- 1995 represents the first appreciable cone crop from the Douglas-fir 2nd generation seed orchard.

### Gene Conservation

1. Pacific yew (Y.A. El-Kassaby, Pacific Forest Products Ltd. & A.D. Yanchuk, B.C. For. Serv.):

A study was conducted to appraise the level and structure of genetic diversity and differentiation among populations representing several of Pacific yew natural range geographical regions in B.C. The study revealed that the sampled populations were clustered

within geographic regions and that geographic regions were highly differentiated from each other. The unique structure of genetic differentiation provided information that was critical for the conservation strategy of this species. The adoption of a regional approach to conservation was recommended.

2. *Ex situ* conservation of tree seeds (D.G.W. Edwards, Canadian Forest Service & Y.A. El-Kassaby, Pacific Forest Products Ltd.):

A research project was initiated to evaluate the effectiveness of *ex situ* gene conservation for B.C. forest tree species. The traditional (crop plant) approach to *ex situ* gene conservation relies on rejuvenation of the genetic resource through frequent replacement with fresh seeds. This rejuvenation can not be accommodated in forest trees due to their long sexual maturation process, so seeds must be stored, often for many years. This project evaluates whether their genetic integrity remains unchanging over long term storage.

Evaluations of viability changes during storage were carried out by means of the accelerating aging concept commonly used by biologist and engineers. The species tested include Douglas-fir, Sitka spruce, white spruce, western hemlock, mountain hemlock, and lodgepole pine. In all species, reductions in seed viability were observed as seeds aged. Without exception, all observed reductions in seed viability were genotype specific (i.e., some genotypes experienced more rapid and more substantial losses than others). This indicates that the original genetic constitution of the seedlots was altered during simulated storage. It is recommended that *ex situ* gene conservation for forest tree species should be implemented on an individual genotype basis so that significant changes to the genetic base can be identified. Changes in the protein matrix of seeds is currently being evaluated to determine if constituents can be used as markers to predict viability losses during storage. The identification of these markers will enhance the use of seed banks as a viable option for forest tree gene conservation efforts.

3. Impact of forest management practices on the genetic diversity (Y.A. El-Kassaby, Pacific Forest Products Ltd.):

The results of a decade of research on the impact of forest management practices were summarized. Figure 1 demonstrates the various steps that might affect the genetic diversity. This study evaluated the effect of selection, breeding, seed orchard genetics and management, seed biology and handling, seedling production, and plantation management on the genetic/species diversity. The results could be summarized in the following points:

- |  |  |
|--|--|
| <ol style="list-style-type: none"> <li>a.</li> <li>b.</li> <li>c.</li> <li>d.</li> <li>e.</li> <li>f.</li> <li>g.</li> <li>h.</li> </ol> | <p>Information related to forest tree species domestication was mainly devoted to the genetic consequences of domestication rather than evaluation of the process itself.</p> <p>The process of domestication of forest tree species is fragmented and follows the classical horizontal organization of management systems, thus making evaluation difficult.</p> <p>Systematic monitoring of the various steps of the domestication process (selection-breeding methods and strategies and seed and seedling production) has identified cases of unintentional directional selection where genetic diversity could be affected.</p> <p>Phenotypic selection has been proven to be an effective method for capturing the majority of genetic variation existing in natural populations.</p> <p>The progress from breeding population to production populations did not substantially reduce genetic variability, however, the chance for rare, endemic allelic loss increased with the reduction of the number of parental trees in seed orchards.</p> <p>The utilization of a breeding strategy that provides for sampling over several geographical locations and selection for various goals, as well as adaptation to different environments (i.e., Multiple Population Breeding System) was proven to be effective.</p> <p>Understanding the species biology and the role of biology on genetic diversity was proven to be of great importance.</p> <p>The need for change and/or the implementation of management practices was proven to be effective in enhancing the genetic variability.</p> |
|--|--|

## PUBLICATIONS

- Askew, G.R. and Y.A. El-Kassaby. 1994. Estimation of additive variance from wind-pollinated seed sources. *Theor. Appl. Genet.* 88:267-272.
- Askew, G.R. and Y.A. El-Kassaby. Are natural populations our basis for developing commercial plantations? *Can. J. For. Res.* (submitted).
- Blush, T.D., D.L. Bramlett and Y.A. El-Kassaby. 1993. Reproductive phenology of conifer seed orchards. *In: Advances in Pollen Management. U.S.D.A., For. Serv. Agri. Hbook 698* (Bramlett, D.L., G.A. Askew, T.D. Blush, F.E. Bridgwater, and J.B. Jett, eds.). pp. 15-23.
- Chaisurisri, K. and Y.A. El-Kassaby. 1993. Genetic control of allozyme variants in Sitka spruce. *J. Hered.* 84:206-211.
- Chaisurisri, K. and Y.A. El-Kassaby. 1993. Estimation of clonal contribution to cone and seed crops in a Sitka spruce seed orchard. *Ann. Sci. For.* 50:461-467.
- Chaisurisri, K. and Y.A. El-Kassaby. 1994. Genetic diversity in a seed production population vs. natural populations of Sitka spruce. *Biodiversity and Conservation.* 3: 512-523.
- Chaisurisri, K. and Y.A. El-Kassaby. 1994. Domestication and genetic diversity in Sitka spruce. *In: Proc. International Symposium on Genetic Conservation and Production of Tropical Forest Tree Seed* (Drysdale, R.M., S.E.T. John, and A.C. Yapa, eds.). ASEAN-CANADA Forest Tree Seed Centre Project, Muak-Lek, Saraburi, Thailand. pp. 144-153.
- Chaisurisri, K., D.G.W. Edwards, and Y.A. El-Kassaby. 1993. Accelerating aging in Sitka spruce seed. *Silvae Genet.* 42:303-308.
- Chaisurisri, K., D.G.W. Edwards, and Y.A. El-Kassaby. 1994. Effect of seed size on seedling attributes in Sitka spruce seed. *New Forests* 8:81-87.
- Chaisurisri, K., Y.A. El-Kassaby, and J.B. Mitton. 1994. Variation in the mating system of Sitka spruce associated with genetic variation and with crown level. *Am. J. Bot.* 81: 1410-1415.
- Davidson, R. and Y.A. El-Kassaby. Genetics, conservation, and seed orchard experience of Pacific silver fir in British Columbia. *In: The IUFRO Working Group Joint Meeting* (Douglas-fir, lodgepole pine, Sitka spruce, and true fir) August 1995, Limoges, France (in press).
- Davidson, R., D.G.W. Edwards, O. Sziklai, and Y.A. El-Kassaby. 1995. Genetic variation in germination parameters among Pacific silver fir populations. *Silvae Genet.* (in press).
- Edwards, D.G.W. and Y.A. El-Kassaby. 1993. *Ex situ* conservation of forest biodiversity in British Columbia. *In: Proc. of the Forest Ecosystem Dynamics Workshop, Feb. 1993, Victoria, B.C., Canada.* pp.65-67.
- Edwards, D.G.W., M.D. Meagher, and Y.A. El-Kassaby. 1993. Genetic diversity in mountain hemlock (*Tsuga mertensiana* (Bong.) Carr.). *In: Proc. of the Forest Ecosystem Dynamics Workshop, Feb. 1993, Victoria, B.C., Canada.* pp. 68-71.

- Edwards, D.G.W. and Y.A. El-Kassaby. 1995. Effect of stratification time and genetics on germination parameters in Douglas-fir. *Seed Sec. Tech.* (in press).
- Edwards, D.G.W. and Y.A. El-Kassaby. 1995. The effect of seed stratification and artificial light on the germination of mountain hemlock. *Seed Sec. Tech.* (submitted).
- El-Kassaby, Y.A. 1995. Evaluation of the tree improvement delivery system: Factors affecting the genetic potential. *Tree Physiology* 15:545-550.
- El-Kassaby, Y.A. 1995. The fitness of reproductive-cycle plasticity in yellow-cedar. *Silvae Genet.* (submitted).
- El-Kassaby, Y.A. 1995. Genetics of seed orchard seed: Evaluation of current practices. *In: Seed Orchard Management and Cultural Options for Quality Seed Production.* Can. Tree Improve. Association biennial meeting. August, 1995. Victoria, B.C. (in preparation).
- El-Kassaby, Y.A. and G.R. Askew. 1995. Seed orchard: establishment, management and production of quality seeds of forest trees. *In: Tree Breeding* (Mandal, A.K., ed.). Indian Council of Forestry Research and Education (in press).
- El-Kassaby, Y.A. and G.R. Askew. 1995. Genetic diversity in commercial forest tree plantations: results of domestication. *Can. J. For. Res.* (submitted).
- El-Kassaby, Y.A., J.E. Barker, and B.G. Dunsworth. 1994. Conservation of forest genetic resources - British Columbia's coastal industry perspectives. *In: Conservation of Forest Genetic Resources Workshop*, November 1993, Toronto, Ontario, Canada. (in press).
- El-Kassaby, Y.A., S. Barnes, C. Cook, and D.A. MacLeod. 1993. Supplemental-mass-pollination success rate in a mature Douglas-fir seed orchard. *Can. J. For. Res.* 23:1096-1099.
- El-Kassaby, Y.A., K. Chaisurisri, D.G.W. Edwards and D.W. Taylor. 1993. Genetic control of germination parameters of Douglas-fir, Sitka spruce, western redcedar and yellow-cedar and its impact on container nursery production. *In: Dormancy and barriers to germination*, Proc. IUFRO on Seed Problems, Project Group P2.04-00. Victoria, B.C., April 1991 (Edwards, D.G.W., compiler and editor). pp. 37-42.
- El-Kassaby, Y.A. and C. Cook. 1994. Female reproductive energy and reproductive success in a Douglas-fir seed orchard and its impact on genetic diversity. *Silvae Genet.* 43:243-246.
- El-Kassaby, Y.A., M.D. Meagher and R. Davidson. 1993. Temporal variation in the outcrossing rate in a natural stand of western white pine. *Silvae Genet.* 42:131-135.
- El-Kassaby, Y.A. and G. Namkoong. 1994. Impact of forest management practices on genetic diversity and its conservation. *In: Proc. International Symposium on Genetic Conservation and Production of Tropical Forest Tree Seed* (Drysdale, R.M., S.E.T. John, and A.C. Yapa, eds.). ASEAN-CANADA Forest Tree Seed Centre Project, Muak-Lek, Saraburi, Thailand. pp. 205-213.
- El-Kassaby, Y.A. and G. Namkoong. 1995. Consequences of forest tree domestication on the genetic diversity. *In: Consequences of changes in biodiversity.* IUFRO World Congress, Tampere, Finland. (in press).

- El-Kassaby, Y.A. and Y.S. Park. 1993. Genetic variation and correlation in growth, biomass traits, and vegetative phenology of a 3-year-old Douglas-fir common garden at different spacings. *Silvae Genet.* 42:289-297.
- El-Kassaby, Y.A. and K. Ritland. 1995. Genetic variation in low elevation Douglas-fir of British Columbia and its relevance to gene conservation. *Biodiversity and Conservation* 4: (in press).
- El-Kassaby, Y.A. and K. Ritland. 1995. Impact of selection and breeding on the genetic diversity in Douglas-fir. *Biodiversity and Conservation* 4: (in press).
- El-Kassaby, Y.A. and K. Ritland. 1995. Isozyme genetics: the concepts, interpretations and techniques. *In: Tree Breeding* (Mandal, A.K., ed.). Indian Council of Forestry Research and Education (in press).
- El-Kassaby, Y.A., J. Russell, and K. Ritland. 1994. Mixed-mating in an experimental population of western redcedar, *Thuja plicata*. *J. Hered.* 85:227-231.
- El-Kassaby, Y.A. and A.J. Thomson. 1995. Genetic diversity of container nursery seedlings: implications of common production practices using Douglas-fir as a model. *For. Sci.* (in press).
- El-Kassaby, Y.A. and A.D. Yanchuk. 1994. Genetic diversity, differentiation, and inbreeding in Pacific yew populations from British Columbia. *J. Hered.* 85:112-117.
- El-Kassaby, Y.A. and A.D. Yanchuk. 1993. Isozyme variation of Pacific yew (*Taxus brevifolia*) in British Columbia. *In: The International Yew Resources Conference.* March, 1993. University of California at Berkeley, USA. (in press).
- El-Kassaby, Y.A. and A.D. Yanchuk. 1993. Genetic variation of Pacific yew in British Columbia and its conservation. *In: The IUFRO International Symposium on Population Genetics and Gene Conservation of Forest Trees.* August, 1992. Bordeaux, France (in press).
- Ritland, K. and Y.A. El-Kassaby. 1995. Evolutionary and ecological significance of plant mating systems. *In: Inter. Symp. New Genetical Approaches to Crop Improvement* (Siddiqui, K.A., ed.). Atomic Energy Agricultural Research Centre, Tandojam Sind, Pakistan (in press).
- Thomson, A.J. and Y.A. El-Kassaby. 1993. Interpretation of seed-germination parameters. *New Forests* 7:123-132.

# GENETIC IMPROVEMENT OF INTERIOR DOUGLAS-FIR AND WESTERN LARCH

Barry C. Jaquish

British Columbia Ministry of Forests  
Kalamalka Forestry Centre  
Vernon, British Columbia  
V1B 2C7

**Keywords:** *Pseudotsuga menziesii* var. *glauca*, *Larix occidentalis*, tree breeding, genetic testing.

Tree breeding programmes for Interior Douglas-fir and western larch were initiated in 1982 and 1987, respectively. The objective of both programmes is to develop seed that has been selectively bred to produce trees with improved volume growth and quality, while maintaining acceptable levels of adaptation and genetic diversity. The breeding strategies for both species are based on recurrent selection for general combining ability, wind-pollinated genetic testing, and soil-based clonal seed orchards.

## SELECTION OF BASE POPULATIONS, GENETIC TESTING, AND SEED ORCHARDS

In both programmes, the selection of base populations from wild stands has been completed. Over 1700 Douglas-fir trees were selected in eight breeding zones, and 609 western larch trees were selected in two breeding zones. Nearly all of these selected trees have been propagated by field-grafting and established in clone banks and breeding arboreta.

In total, 1661 Douglas-fir families are in field tests across 39 sites in the eight breeding zones. By spring 1995, 608 western larch families will be in test across 17 sites in the two breeding zones. In all of these tests, individual tree height and condition has, or will be, recorded after three, six and ten field seasons. For Douglas-fir, first-phase clonal seed orchards will be established on the basis of family field performance after six growing seasons. Currently, Douglas-fir seed orchards have been established for the Central Plateau, Cariboo Transition, Quesnel Lake, and Shuswap Lake breeding zones. Field-grafting has begun for the low elevation West Kootenay seed orchard. In 1990, two clonal first-generation western larch seed orchards were established at the Kalamalka Forestry Centre. These western larch orchards are expected to come into production by about 1998.

## SUPPORTIVE RESEARCH

Several research projects have been recently initiated to support the Douglas-fir and western larch tree breeding programs. Studies in Douglas-fir include intervarietal hybridization, elevational displacement of seedlots, genetic variation in juvenile wood relative density, and genetic relationships among traits associated with shoot elongation and total tree height. Studies in western and subalpine larch include estimation of mating system parameters in natural and seed tree stands, genetic variation within and among natural B.C. populations, and interspecific hybridization.

## PUBLICATIONS

- Ponoy, B., Hong, Y-P., Woods, J., Jaquish, B., and Carlson, J.E. 1994. Chloroplast DNA diversity of Douglas-fir in British Columbia. *Can. J. For. Res.* 24: 1824-1834.
- Jaquish, B. 1995. Improving seed supply with natural stand seed collections, seed production areas and seed orchards. In Proc. workshop on management of forest genetic resources. FAO/NAFC/Study Group on Forest Genetic Resources. Colegio de Postgraduados, Institucion de Ensenanza E Investigacion en Ciencias Agricolas, Montecillo, Edo. de Mexico.
- Jaquish, B. and V. Ashley. 1994. Effects of selection for total height growth on components of shoot elongation in Interior Douglas-fir. Poster paper In Abstracts of the annual meeting of the Western Forest Genetics Association. Vancouver, WA.

# GENETIC IMPROVEMENT OF WHITE AND ENGELMANN SPRUCE

Gyula K. Kiss

B.C. Ministry of Forests  
Kalamalka Forestry Centre  
3401 Reservoir Road  
Vernon, B.C.  
V1B 2C7

**Keywords:** Forest genetics, tree breeding, white spruce, Engelmann spruce, insect resistance.

The objective of this project is to produce genetically improved planting stock of white and Engelmann spruce (*Picea glauca* [Moench] Voss and *P. engelmannii* Parry).

Twenty-year height and diameter measurements were carried out for the better performing plantations in the Prince Rupert and East Kootenay Selection Units. A total of nearly 38,000 trees were measured (18,400 in the East Kootenay and 19,500 in the Prince Rupert Selection Units).

In general, trends continued as in previous years. Families that were identified as outstanding performers at age 6 remained outstanding performers at age 20.

Weevil studies were continued. Rory McIntosh is conducting a thorough study of weevil behaviour at the Kalamalka Forestry Centre. He has accumulated a tremendous data base on weevil activities and response by the host.

A national weevil symposium was hosted jointly by the B.C. Forest Service and the Pacific Forestry Centre in Richmond during January 1994. The aim of the symposium was to consolidate scientific knowledge on the white pine weevil and to develop a strategy for future research. The successful symposium had a total of 85 participants. Thirty three papers were presented and the proceedings were published (FRDA report 226).

Wood density assessments continued and continued to surprise as well. While there was no correlation between height traits and pilodyn pin penetration among the PGSU selections, there was a small but significant correlation among the Prince Rupert Selection Unit families ( $r=0.36$ ) and a strong correlation among the East Kootenay Selection Unit families ( $r=0.79$ ). In addition, the spread of pin intrusion in the PGSU families was only two units in magnitude, while the PRSU had a spread of about five units and the EKSU families demonstrated a spread of over 8 units. The ramifications of these results are interesting since it demonstrates that in the EKSU selection fast growth will result in reduced wood density.

A number of crosses were made utilizing putatively weevil resistant and susceptible families. Seedlings were established in demonstration plantations and will be evaluated as attacks take place. Some of the seedlings are potted and will be made available for various studies where caging of weevils is required.

Second generation breed material is being raised in containers and will be out planted in 1996. These plantations will provide the basis for second generation selections.

An open pollinated progeny trial will evaluate the genetic potential of eastern Canadian white spruces in our collection. This will enable us to incorporate outstanding eastern Canadian families into our breeding program. As some of these families exhibit fast growth and strong weevil resistance they will be a great asset to the program.

#### PUBLICATIONS

- Alfaro, I.A., Kiss G., and Fraser G. (Editors) 1994. The white pine weevil: biology, damage and management. Proceedings of a symposium held January 12-21, 1994 in Richmond, British Columbia. FRDA Report No. 226.
- Alfaro, I.A., He, F., Kiss, G., King, J. and Yanchuk, A. 1995. Resistance of white spruce to white pine weevil: Development of a resistance index. For. Ecol. And Management (Submitted).
- Carlson, J., Hong Yong-Pyo and Kiss G. 1994. DNA markers associated with weevil resistance in interior spruce. In: The white pine weevil: biology, damage and management. Proceedings of a symposium held January 12-21, 1994 in Richmond, British Columbia, FRDA Report No 226.
- Kiss, G.K., Yanchuk, A.D., and Alfaro, R.I. 1994. Recent advances in white pine weevil research in British Columbia. In: The white pine weevil: biology, damage and management. Proceedings of a symposium held January 12-21, 1994 in Richmond, British Columbia. FRDA Report No. 226.
- Manville, J.F., Nault, J., Von Rudloff, E., Yanchuk, A., and Kiss, G.K., 1994. Spruce terpenes: Expression and weevil resistance. In: The white pine weevil: biology, damage and management. Proceedings of a symposium held January 12-21, 1994 in Richmond, British Columbia. FRDA Report No. 226.

## WESTERN WHITE PINE IMPROVEMENT PROGRAM FOR BRITISH COLUMBIA

M.D. Meagher, R.S. Hunt, E.E. White, A.K. Ekramoddoullah,  
G.D. Jensen and J. Dronzek

Canadian Forest Service  
Pacific Forestry Centre  
506 West Burnside Road  
Victoria, B.C.  
V8Z 1M5

**Keywords:** *Cronartium ribicola*, *Pinus monticola*, disease resistance proteins, DNA markers.

### "OPERATIONAL" PROGRAM OF SELECTION AND RUST SCREENING

Support for tree selection, seed collection, stock rearing and rust inoculation, plus grafting of selected trees, is provided by the B.C. Forest Service under a Memorandum of Understanding. Following external review of the project in 1994, and in response to other pressures, the decision was made to phase out the program at PFC. Following the 1995 inoculation, our last, we will have screened 291 and 216 trees from the Coastal and Interior areas, respectively. Final examination of stock inoculated in 1995 will require about 6 more years. Seed collections in 1994 were conducted only from trees selected for further study.

Clones of Interior seedlings selected to date will join Idaho selections to form a resistant seed orchard to be established by the BC Forest Service at Vernon for the Interior. This will be the third seed orchard stemming from our program; the other two are on the Coast: one a "forward-selection" orchard composed of seedlings, the other a "backward-selection" orchard based on parents identified by our screenings. Both of these orchards are established by industrial cooperators.

Adequate rust spore density was achieved on 1+1 open-pollination family stock in both 1992 and 1993. Family means of spots per seedling ranged from about 1 to 9. Surviving stock from previous inoculations was examined and seedlings exhibiting "slow canker growth" were cloned. Seedlings remaining uncantered after 2 years are placed in a disease garden for a second inoculation. To the end of 1994, 111 Interior and 219 Coastal clones have been produced.

### RESEARCH PROGRAMME

Rust infection on Idaho F2 material planted in 1984 by the B.C. Forest Service was less than on untested local seedlots, while growth vigour was good, indicating potential for this seed in southern B.C. However, inconsistent results from Coastal sites mean that its use on the Coast cannot be recommended. Analyses of data from the field trials assessed in 1992 led to recommendations concerning seed transfer to and within B.C.

Controlled mating of parents judged superior from our operational rust inoculation ended in 1994. Seedlings will be used in further trials and in field "demonstration" plantations. Two plantations containing families from "wide" vs. "narrow" outcrosses were established in 1994 on B. C. Forest Service seed-orchard sites. Results will test the inference that

western white pine varies little geographically. Final assessment of a "rust races" test was made in 1994; analyses of results are in draft.

Plantations of unselected seedlings from selected parents have been established annually, with the last being planted in 1995. More plantations to contrast families differing in needle spotting and cankering incidence were established, bringing the total to four.

The study involving proteins is being approached in three different ways. In one approach, i.e. pathogenesis-related proteins, resistant (Rr) and susceptible (rr) white pine seedlings were inoculated with white pine blister rust (WPBR) fungus and foliar protein patterns were analyzed by 2-dimensional gel electrophoresis in conjunction with densitometry and computer-assisted gel image analysis. In resistant seedlings, both enhancement and suppression of the biosynthesis of proteins were observed. By contrast, only suppression of the biosynthesis of proteins was observed in susceptible seedlings. Two acidic proteins, 36.7 kDa and 28.1 kDa, were detected in large amounts. The 36.7-kDa protein was suppressed in susceptible seedlings at day 3 while the 28.1-kDa protein was enhanced in resistant seedlings at day 9. In another approach, bark proteins of white pine trees displaying slow canker growth - a form of WPBR resistance - were analyzed. A 10.5-kDa protein unique to this resistance type was identified and partially characterized. In the third approach, a series of monoclonal antibodies (Mabs) to WPBR was generated. Although most Mabs were shown to be cross-reactive to western white pine proteins, two Mabs were specific to WPBR. These two Mabs will be used to identify immunocytochemically the pathogen in resistant and susceptible trees during initial infection. In addition, a "cold" protein was shown to be differentially expressed in resistant and susceptible white pine trees, indicating its potential use as a marker for resistance.

DNA markers, isozymes and virulence phenotype were used to examine population structure and breeding system in the rust. Mendelian segregation of alleles was demonstrated, confirming previous results indicating the rust is heterothallic and out-breeding. Changes in virulence may occur as a result of reassortment of virulence determinants during sexual reproduction. This work was carried out in collaboration with the U.S. Forest Service Institute of Forest Genetics, Placerville, California.

No association with geographic region in B.C. was apparent with DNA markers. A relatively low degree of restriction-site variation was observed, consistent with the view that blister rust in B.C. originated from a single introduction of diseased seedlings and has a relatively limited genetic base.

Clones of two disease-response genes (chalcone synthase and phenylalanine ammonia lyase) have been isolated from white pine. Chalcone synthase is coded by a polymorphic multi-gene family. Work is in progress to determine whether any of these polymorphisms correlate with disease resistance.

#### PUBLICATIONS

- Baker, S.M. 1993. Defense response in western white pine. MSC Thesis, University of Victoria.
- Davidson, J.J. 1994. Analysis of bark proteins in blister rust-resistant and susceptible western white pine (*Pinus monticola*). M.Sc. Thesis. University of Victoria.
- Ekramoddoullah, A.K.M., Taylor, D.W. and Hawkins, B.J. 1995. Characterization of a fall protein in sugar pine, and detection of its homologues associated with frost hardiness of western white pine needles. Can. J. For. Res. (in press).

- Ekramoddoullah, A.K.M. and Davidson, J.J. 1995. A method for the determination of conifer foliage protein extracted using sodium dodecyl sulfate and mercaptoethanol. *Phytochemical Analysis*. 6: 20-24.
- Ekramoddoullah, A.K.M. and Hunt, R.S. 1993. Changes in protein profile of susceptible and resistant sugar pine foliage infected with the white pine blister rust fungus, *Cronartium ribicola*. *Can. J. Pl. Path.* 15: 259-264.
- Ekramoddoullah, A.K.M. and Taylor, D. 1993. Production and characterization of monoclonal antibodies to white pine blister rust fungus, *Cronartium ribicola*. Sixth European Congress on Biotechnology, Firenze, Italy, June 1993. Volume III, WE338 (Abstract).
- Ekramoddoullah, A.K.M. 1993. Analysis of needle proteins and N-terminal amino acid sequences of two photosystem II proteins of western white pine (*Pinus monticola* D. Don). *Tree Physiol.* 12:101-106.
- El-Kassaby, Y.A., M.D. Meagher and R. Davidson. 1993. Temporal variation in the outcrossing rate in a natural stand of white pine. *Silvae Genetica* 42: 131-135.
- Hunt, R. S., 1994. Comment on the letter by Andrivon re: pathogenicity and virulence. *Phytopath.* 84:874-875.
- Hunt, R. S., 1994. The transferability of western white pine to and within British Columbia - blister rust resistance. *Can. J. Pl. Path.* 16: 273-278.
- Hunt, R. S., 1995. A new portable fungal spore collector. *Can. J. Pl. Path.* (In press)
- Hunt, R. S., 1995. Disease incidence can be used to rank families or provenances for relative resistance. *Abstr. Can. J. Plant Path.* (In press).
- Hunt, R. S., and G. A. Jensen, 1995. Conifer tree and plot labels. *Abstr. Can. J. Plant Path.* (In press).
- Hunt, R. S. & M. D. Meagher, 1993. Selection of blister rust resistant white pines. 6th Intern. Congr. Pl. Path. Abstr. 9.5.20, p20.
- Hunt, R. S., D. Norris, M. D. Meagher and G. D. Jensen, 1994. Managing western white pine in the interior of British Columbia. IN: Interior cedar-hemlock-white pine forests: Ecology and management. Symposium Proc. Mar. 2-4, 1993. Dep. Nat. Res. Sciences, Wash. State Univ., Pullman, WA, USA : 307.
- McAfee, B.J., E.E. White, L.E. Pelcher and M.S. Lapp. 1993. Root induction in hard to root conifer species using *Agrobacterium rhizogenes* (Riker *et al.*). *Conn. Plant Cell, Tissue and Organ Culture* 34: 53-62.
- Meagher, M. D., R. S. Hunt, E. E. White, A. Ekramoddoullah, 1993. Western white pine breeding program. IN: D. Reid (Ed.) British Columbia Coastal Tree Improvement Council. Fourth Progress Report 1988-1992.
- Meagher, M.D., and R.S. Hunt, 1995. Early height growth of western white pine provenances in British Columbia. (Submitted).
- Meagher, M.D., and R.S. Hunt, 1995. Heritability and gain of reduced spotting vs. blister rust on western white pine in British Columbia, Canada. (In review).

- Rashid, A., E.L. Camm, and A.K.M. Ekramoddoullah, 1994. Molecular mechanisms of action of  $Pb^{2+}$  and  $Zn^{2+}$  on water oxidizing complex of photosystem II. FEBS Letters. 350: 296-298.
- Sun, L-J., B.J. van der Kamp, J.E. Carlson and E.E. White, 1995. Preliminary study of genetic variation in western gall rust populations in British Columbia, Canada, using molecular markers. Proc. Fourth IUFRO Rust of Pines Working Party, Tsukuba, Japan. Oct. 2-4, 1994.
- White, E.E. and B. Foord. 1993. Molecular markers for population studies in the white pine blister rust pathosystem. Can. Phytopath. Soc. Mtg., UBC, Vancouver. Oct. 19-20.
- White, E.E., R.F. Watkins and D.P. Fowler. 1993. Comparative restriction site maps of chloroplast DNA of *Picea abies*, *P. glauca*, *P. mariana* and *P. sitchensis*. Can. J. For. Res. 23:427-435.
- White, E.E., B.M. Foord and B.B. Kinloch, 1995. Variation in the ribosomal gene cluster of *Cronartium ribicola*. Submitted.

**FOREST GENETICS ACTIVITIES  
AT THE UNIVERSITY OF BRITISH COLUMBIA**

**Gene Namkoong, John Carlson, and Associates**

**Faculty of Forestry  
University of British Columbia  
Vancouver, B.C.  
V6T 1Z4**

**Keywords:** population genetics, genetic diversity, genome mapping, molecular genetics.

Gene Namkoong, Head of the Forest Sciences Department at UBC, was awarded the prestigious Marcus Wallenberg Award on September 22, 1994, in Stockholm for his contributions to population genetics, quantitative genetics and forest conservation research. His acceptance presentation was entitled "An evolutionary concept in breeding." Gene was also successful in securing funding for two chairs in forest genetics who are expected to join the Faculty of Forestry later this year. These two chairs will make a large impact on teaching and research in population, quantitative, and forest conservation genetics at UBC. During Gene Namkoong's first two years at UBC, his research group at UBC has rapidly expanded and includes many visitors from academic and government institutions around the world. The research being conducted by Gene's group includes three main areas: 1) the evolution and maintenance of genetic variance in natural and artificial populations; 2) the evolution and genetics of norms of reaction in forest species; and 3) biodiversity, particularly the impact of habitat disturbance on species and genetic interactions. In John Carlson's group, research relevant to tree improvement includes genetic linkage mapping, DNA markers for early selection, molecular cytogenetics, DNA fingerprinting, DNA diversity, and genetic engineering of specialty tree genotypes. Specific projects are described below.

**MANAGING FOREST TREE GENETIC VARIANCE FOR CLIMATIC CHANGE**

**Mathew P. Koshy and Gene Namkoong**

A method for genetically pre-conditioning populations for the uncertain futures presaged by climatic change is to generate populations with high genetic variance in traits that condition response to climatic variables. Either by selective breeding for population divergence, or using natural provenance differences, F2 and advanced generation hybrids can be developed. These can provide high variances and, depending on the population differences in traits that have diverged, the correlations in the advanced segregating generations can also be different from that which exists in one presently available population. Basic equations for relating the increase in genetic variance to the population divergence for long term selection models on mutation-selection balance are available and can predict the rate of increase in genetic variance as a function of the mutation-selection balance in finite populations. Current research is to extend the predictions to conditions of replicate populations as well as partial intercrossing between replicate and divergent selection populations, and to include pleiotropic and linkage effects. Experimental research is to create 20 sets of non-inbred crosses, each with F1 and F2 families of the same grand-parental genotypes but from widely separated provenances of Douglas fir from coastal and inland sources in British Columbia, Washington, Oregon and California. These are to be grown and tested for growth rhythm and drought response traits and estimates derived for

the predicted genetic variance. The crosses for this study have been already completed. Theoretical models for F2 genetic variance also have been developed. Seeds from these crosses will be collected in September. Growth trials will follow in March, 1996.

#### DYNAMICS OF GENETIC VARIATION IN RESOURCE USE EFFICIENCY IN LODGEPOLE PINE

Pia Smets and Gene Namkoong

The response of trees to limitations of soil moisture and nitrogen is considered to be a major factor affecting fitness. Therefore, water and nutrient use efficiencies are expected to be major determinants of fitness in the fluctuating environments of forests. Techniques for measuring these efficiencies have been developed such that genetic variations have been detected in efficiency indices in various tree species including conifers. However, two dimensional norms of reaction to simultaneous water and nitrogen variables have not been estimated, and the consequences of derived genotype by environment interactions on the population genetics have not been explored. Therefore, the mechanism for the maintenance of genetic variation in water and nitrogen use efficiencies and the effects of management on the conservation of genetic variation in naturally and artificially regenerated stands remains unknown. This experimental work consists of estimating water and nitrogen use efficiencies on full and half-sib families of lodgepole pine to obtain two dimensional response surface norms of reaction for families, and to test for differences among them. Models of these derived norms of reaction will then be used in analyses of population genetic dynamics. The domains of attraction for genetic polymorphism will be examined for several models of the joint effects of soil moisture and nitrogen availability.

#### A COMPARATIVE STUDY OF GENOTYPE BY ENVIRONMENT INTERACTION IN FOREST TREE SPECIES

Jan Svejgaard Jensen and Gene Namkoong

One of the obvious problems in management of genetic resources is the existence of interaction between genotypes and the environments in which they are in. Some of the interactions, i.e. the relation between growth and origin of some tree species, can be very predictable whereas others are unpredictable. There are several different terms and definitions for interaction and the basic assumptions are often very simplified. The phenotypic trait is a combination of genotypic and environmental effects. If the phenotypic trait could be described by an operator that could "convert" genotypic characters into phenotypic, then there is no interaction. However, if this operator is not to be defined, there would be interaction. The relationship between environment and response is non linear for many traits. Many traits could also work interactively in an unpredictable way. The methods are often developed for agricultural practice with large numbers of genotypes and environments. The purposes of these methods have been selection for stable or unstable genotypes. Later it has become important to group the genotypes on basis of their performance in order to define breeding zones and seed zones. Stability can be described by the variability of genotype performance in different environments, as well as by the slope of performance over different environments compared to mean performance of the genotypes. Another way to describe stability is to measure the change of rank of genotypes over different environments. This is called "true interaction" by many authors, and can be described by the correlation between genotypes. In linear statistics the total interaction is easy to calculate, but it is possible to make a break-down of components. True interactions can be separated from interactions due to heterogeneous variance. The total interaction can be caused both by the nature of the genotypes and the environments. Stability statistics can be divided into different groups depending on whether they are based on the

deviations from the average genotype effect or on the genotype and whether or not they incorporate a regression model on the environmental index. At least ten different statistic parameters have been proposed by several authors. We are applying these methods on different types of materials to investigate their similarities and interrelationships.

#### GENECOLOGY OF DOUGLAS-FIR IN THE SUB-MARITIME SEED-ZONE: TESTING SEED TRANSFER GUIDELINES

Francisco Luna-Lopez J. and Gene Namkoong

This study forms part of a comprehensive study on the genecology of Douglas-fir in the sub-maritime zone undertaken by the Ministry of Forests to determine the patterns of genetic variation within the SM zone, from 49 degrees to 53 degrees latitude and altitudes from 50 to 1200 meters above sea level. This part focuses on seedling shoot and root growth, and physiological traits like water use efficiency and frost hardiness. We will also look into the comparative dynamics of evolution of genetic variance in fitness related traits of Douglas-fir in the coastal, interior and transition zone. A pilot study which included 44 families from nine different sources within the SM zone plus five families from coastal zone evaluated seedling growth and physiological traits and assessed the genetic variability in about 2700 seedlings. During this phase, seedling height, collar diameter, and shoot and root ratio were measured in nursery. Physiological traits like relative water use efficiency using carbon isotope discrimination, relative water content of leaves, seedling water potential and cold hardiness were also measured. Preliminary results showed significant variability between families and between provenances for growth traits. Physiological traits showed significant variability among provenances. In general, provenances from lower altitudes and southern latitudes showed better growth compared to the other provenances. Based on these results an augmented design for the first phase of the study was developed. The augmented design includes 77 families from 17 provenances from the SM zone plus families from coastal and interior zones. A farm field test which follows the nursery trial will evaluate the early growth stages. The information generated in this study will be useful for the definition of boundaries in seed and breeding zones. Subsequent observations in diverse environments will help to establish age trends in genotype x environment interactions and norms of reaction for growth and water use efficiency traits. This study will also help to understand the comparative dynamics of evolution of genetic variance in Douglas-fir in the coastal, interior and transition zones.

#### GENETIC VARIATION IN WESTERN RED CEDAR (*THUJA PLICATA* DONN) SEEDLINGS

Marilyn Cherry and Gene Namkoong

To determine whether the apparent lack of genetic variation in western red cedar (*Thuja plicata* Donn), as previously inferred by isozyme and terpene studies, would hold true for quantitative seedling traits, a provenance study was initiated to investigate patterns of variation in seedling growth and survival characteristics, cold temperature acclimation, and response to inbreeding. Seedlings from ten coastal and ten interior provenances, half with family structure (five families/provenance), were grown for three years at one coastal (Vancouver) and one interior (Salmon Arm) location. Twenty-three potted clones were both self-pollinated and polycrossed at Cowichan Lake; resulting progeny were monitored for growth and frost hardiness. Genetic variation could be detected from the first year, and increased annually. The narrow-sense individual heritability, assuming some inbreeding, of final heights of trees growing in Vancouver was 0.37. Height, root collar diameter, acclimation, and declamation exhibited mainly within-population variation, while variation in dry weight measurements, foliar nutrient content, survival at Salmon Arm, and maximum cold hardiness was evident mainly between

populations. Coastal vs. interior differences were noted in first-year heights, root collar diameter, and in height and survival at Salmon Arm following a severe winter in which trees suffered major desiccation damage. In general, adaptive traits appeared to show more between-population differences, while traits under less selective pressure showed mainly within-population variation. Provenances displaying the greatest variation at the family level were those from the southern B. C. coast. Between-population variability appeared to be highest in the B. C. interior, and lowest in northern B. C. populations. Elevation influenced all traits displaying provenance variation. Location effects occurred, but little genotype by environmental interaction was found. Plasticity was evident in timing of growth initiation and cessation, timing of acclimation and declamation, and in degree of maximum hardiness reached per year. Acclimation was apparently triggered by exposure to low temperatures. Early traits showed little evidence of inbreeding depression, but there seemed to be a trend towards gradual expression of inbreeding depression over time, at least in traits under selective pressure. This research showed that western red cedar is much more complex than previously believed, and substantial genetic variation exists in several traits of this species.

#### BIODIVERSITY MONITORING AND MANAGEMENT: DEVELOPING TOOLS USING PARAMETERS OF DISTURBANCE COMPONENTS

Fredrik von Euler and Gene Namkoong

Understanding the regulation of biodiversity is necessary in order to explain its natural patterns and to predict the effects of human activities. Disturbance agents, both natural such as fires and windblows, and human activities such as logging and pollution affect different arrays of variables of the physical environment. Quantifying disturbance directly in terms of such physical variables is problematic for many reasons: i) Identifying the relevant variables may be difficult, ii) Measuring the variables may not be practicable, and iii) The comparison of disturbance effect of different agents may be impossible. However, regardless of the physical variables, all disturbance agents by definition have some net effect on the abundance of at least some species in a local assemblage, which is expected to affect species packing and species interaction parameters. We are developing practical measures of disturbance based on species interaction and species packing in local species assemblages, and a predictive model for local species richness, based on energy and disturbance information. We are doing this by analyzing species-abundance data from published plot studies. Such data is available from a large number of faunistic and floristic surveys in Canada (e.g. B.C. Ministry of Forests) and around the world. The relationship between species richness, disturbance and energy are being studied for vascular plants, birds, and other classes of organisms. The feasibility of extending methods for species to "higher" taxa such as families will be investigated, and specifically, geographical scale problems will be addressed. Statistical properties of estimators will be evaluated using data generated by simulation models, adapted and extended from published work.

#### GENETIC ANALYSIS OF THE RISK OF CLONAL PLANTATIONS IN FOREST TREES

Yong-Bi Fu, Gene Namkoong and John E. Carlson

Establishment of commercial populations by use of clonal propagules has been made in several tree species and expected to greatly increase with advanced biotechnology in the future. A great concern for clonal forestry is the probability of catastrophic losses in these clonal plantations with a uniformity of genetic diversity due to an unforeseen disastrous event such as insect or pathogen attacks. One possible alternative is to apply a number of clones in such plantations to ensure genetic diversity and protect against risk of extensive loss. What is the minimum (safe) number of clones in forest clonal plantations is an important, but controversial,

question. Some theoretical studies on this question have been made. These studies mainly emphasize the reduction of risk by considering the number of clones and the probability of the event occurrence. We intend in this investigation to address the "effective" genetic diversity for various nature of stochastic events, given a number of clones in a plantation. The effective genetic diversity required to reduce the risk for stochastic events such as forest fire and tropical storm may be low, less depending on the number of clones; for events such as pest and pathogen attacks may be high, thus with the need of using more clones. We examine this issue by specifying various genetic models for the analysis of risk in plantation failure and defining effective genetic diversity for different stochastic events.

## PURGING DELETERIOUS GENES IN VARIOUS TREE BREEDING SCHEMES

Yong-Bi Fu and Gene Namkoong

Every initial breeding population of forest trees has a certain level of genetic load (i.e., deleterious genes). Whether these deleterious genes can be purged to a minimum for an increased population fitness by appropriate breeding means presents a great concern for tree breeders as well as conservation geneticists. The answer to this question is less clear and the fate of deleterious genes is expected to depend on both the nature of the genetic load and the level of applied inbreeding. To address this issue, we are currently conducting a theoretical investigation by computer simulations. Three commonly applied tree breeding schemes are examined: selfing, full-sib mating, and half-sib mating. Various genetic models of inbreeding depression are used that take into account selection and dominance levels as well as multiplicative and synergistic interactions. The overall objective is to examine the behavior of purging deleterious genes and the patterns of offspring fitness in a breeding population over 10 generations by three breeding schemes. This is done first by examining the deleterious genes reducing viability and then those genes influencing fecundity traits. Results obtained so far (mainly on viability selection) appear to suggest that it is possible to purge high numbers of deleterious genes in a breeding population. Practical implications of these findings will be explored.

## ANALYSIS OF DNA DIVERSITY IN WESTERN RED CEDAR

Jeff Glaubitz and John Carlson

We are engaged in a comprehensive study to estimate genetic variation in western red cedar at the DNA level. We have taken the unique and demanding approach of analyzing all three genomes, i.e. the chloroplast, mitochondrial and nuclear genomes, with RFLP markers. Populations were sampled from across the entire natural range of western red cedar, including coastal B.C., interior B.C., the Charlotte Islands, Utah, Washington, Oregon and northern California. This work will result in an extensive RFLP data base, valid for comparison with previous reports on isozymes which uncovered very little genetic diversity in western red cedar. This study is being conducted in collaboration with Y. El-Kassaby, of Pacific Forest Products, Ben Sutton and Craig Newton of B.C. Research, Inc., and John Russell of the B.C. Ministry of Forests and is supported by the Canadian Forest Service's National Forest Genetic Resources Centre and the B.C. Ministry of Forests.

## POPULATION GENETICS OF THE EASTERN WHITE PINE WEEVIL, *PISSODES STROBI*

Kornelia Lewis, John McLean and John Carlson

We have completed an extensive assessment of the extent of genetic variability, population subdivision, and host specificity in weevil populations in British Columbia. We chose RAPD markers, a DNA marker system based on PCR amplification of unassigned loci, with which to obtain data on genetic variability at the DNA level. The data was analyzed by several statistical approaches all of which revealed the same result that weevil populations from the interior of B.C. have greater genetic similarity to populations feeding on Jack Pine in eastern Canada than do B.C. interior weevil populations to those feeding on Sitka spruce in coastal B.C. This information is relevant in the effort to breed for weevil resistance in spruce.

## POPULATION GENETICS OF *ENDOCRONARTIUM*:

LiJuan Sun, Bart Van der Kamp, Eleanor White and John Carlson

We have used RAPD markers and RFLPs to assess the extent of variability at the DNA level, the existence of races, the mode of inheritance (life cycle), and the course of the spread of infection for the western gall rust fungus *Endocronartium harknessii*. Spores from individual galls were sampled from forest stands across the province. Preliminary results clearly indicate that western gall rust is not uniform in British Columbia but rather that variability exists both within and between populations. This variability suggests either the presence of a sexual stage in the life cycle of western gall rust or that substantial somatic recombination events occur. Further studies based on inoculations of seedlings with spores from single galls and multiyear sampling schemes are underway to determine how this variability has been generated.

## PATERNITY ANALYSIS IN A WHITE SPRUCE OPERATIONAL SEED ORCHARD USING RAPD MARKERS

Yong-Bi Fu, Gene Namkoong and John E. Carlson

Paternity analysis with genetic markers (such as isozymes) has been an important tool for understanding how the magnitude of gene dispersal by pollen influences mating system and the composition of seed crops, and provided critical information for seed orchard management. However, the power of this analysis is limited because of the lack of sufficient genetic markers. Random Amplified Polymorphic DNAs (RAPDs) are a new class of genetic markers with great advantages in terms of unlimited number of loci and easiness in assay. In this investigation, we explore the potential of using RAPDs in paternity analysis. DNA fingerprints for all 95 trees in an operational interior spruce seed production orchard were developed using RAPD marker (accomplished earlier by post-doctoral fellows Yong-Pyo Hong and Robin Davidson). The advantage of DNA fingerprinting was demonstrated in that all clones could be uniquely identified and their gametes followed, as opposed to fingerprinting with isozymes in which rare alleles permit the gametes of only a select few trees in the orchard to be followed. For application of the DNA fingerprints in paternity analysis, we first examined the effectiveness of using RAPDs to evaluate the success of supplemental mass pollination, a widely used technique in seed orchard management. We genotyped seeds of eight maternal trees from 4 and 12 mixed pollen donors in an interior spruce seed orchard, as well as maternal and 12 known paternal trees. By implementing a maximum likelihood method, we aim at determining with more confidence the proportion of seeds of a maternal tree from each of 12 mixed pollen donors. Secondly, we will determine the number of offspring per parental trees using paternity analysis with DNA fingerprints to estimate the effective population size in the seed orchard. The estimate

of the effective population size can be made if the number of offspring per parental trees is known. This provides scientific evaluation of effective population size of 20 as presently accepted by the BC Forest Service. We have also recently shown that the RAPD marker system is suitable for DNA fingerprinting and paternity analysis in western hemlock seed orchards. We studied competition among two hemlock pollen sources, and confirmed that fertilization was primarily accomplished by only one superior pollen source, regardless of any timing advantage given to the less viable source. This was assessed using the DNA fingerprints for 6 parental clones. A computer-assisted system was set up during the hemlock seed orchard project for automating the analysis of DNA banding patterns on electrophoretograms for DNA fingerprinting. This project is being conducted in collaboration with Joe Webber and Mike Stoehr of the B.C. Ministry of Forests and Ben Sutton of B.C. Research, Inc.

#### GENETIC LINKAGE MAPS FOR DOUGLAS-FIR AND MARKERS FOR QTLs:

Hesham Agrema, Jason Broome, and John Carlson

We have completed an NSERC strategic research project to construct genetic linkage maps for Douglas-fir with RAPD markers. Two "single-tree" linkage maps were constructed for parent trees DF60 and DF69 from the B.C. Ministry of Forests coastal Douglas-fir tree improvement program. We also constructed a genetic linkage map for the F<sub>1</sub> progeny from cross of DF60 and DF69, using markers from the maps of parent trees DF60 and DF69. With the F<sub>1</sub> linkage map we were able to identify several QTLs for wood density, volume and height. The phenotypic data were collected by B.C. Ministry of Forests staff during 15 years of progeny trials. Our success in mapping QTLs in full-sib progeny from two elite clones of similar provenance encouraged us to conduct studies for mapping further Quantitative Trait Loci governing important traits in Douglas-fir, and with other important families of coastal Douglas-fir. We pioneered the approach of constructing genetic linkage maps for single-trees using haploid megagametophyte DNA. To increase access to the RAPD technology, we have distributed 700 RAPD primers, at cost, to over 200 research groups around the world. DNA markers permit the early selection of genetically superior seedlings. After a DNA marker has been found that is associated with a given trait, its use in indirect selection can greatly accelerate breeding programs and ensures that the best genotypes are deployed from seed orchard and nursery production programs. The QTL markers we detected for wood density in Douglas-fir are presently being evaluated in additional families and progeny tests. This project is being conducted in collaboration with Jack Woods and colleagues of the B.C. Ministry of Forests.

#### GENETIC LINKAGE MAPS FOR WHITE SPRUCE AND DNA MARKERS FOR WEEVIL RESISTANCE

Yong-Pyo Hong, Jeff Glaubitz, and John Carlson

Genetic linkage maps were constructed with RAPD markers for four parent trees in the interior spruce tree improvement program, in collaboration with Gyula Kiss at the B.C. Ministry of Forests Kalamalka Research Station, utilizing megagametophyte DNA and our "single-tree" mapping approach. We have searched for DNA markers from these maps linked to weevil resistance. Destruction of spruce trees by the terminal weevil (*Pissodes strobi*) causes massive loss of spruce trees in B.C. forests, both coastal and interior. We have identified several DNA markers that appear to be associated with weevil resistance based upon preliminary tests with half-sib progeny families in the spruce tree improvement program. Large scale tests with these putative weevil-resistance markers are now underway with over 700 half-sib progeny that

have been well characterized for weevil susceptibility and resistance. We also hope to integrate weevil resistance markers into the spruce clonal propagation program of BC Research, Inc.

#### MOLECULAR KARYOTYPES FOR SPRUCE AND DOUGLAS-FIR

Garth Brown, Vindhya Amarasinghe and John Carlson

We developed a fluorescence *in situ* hybridization (FISH) technique for physically mapping cloned DNA on conifer root-tip chromosomes. With FISH, we have localized the major ribosomal DNA (rDNA) loci to 14 chromosome sites (nucleolar organizers) in white spruce - one rDNA site on each of 7 separate chromosome pairs ( $2n = 24$ ), 12 chromosome sites in Sitka spruce and at least 8 chromosomes in Douglas-fir. We have also mapped two loci for 5S RNA in Douglas-fir, white spruce, and Sitka spruce and a centromeric repeat DNA to several white spruce, and Sitka spruce chromosomes. With these probes, all 24 white spruce and Sitka spruce chromosomes and all 26 Douglas-fir chromosomes can be unambiguously identified in root tip cytological preparations without recourse to morphological characters. This capability should be useful in characterizing spruce hybrids. We are also interested in using FISH to study the organization of the conifer nucleus and for correlating genetic linkage maps with metaphase chromosomes. This requires a FISH protocol with increased sensitivity to permit the reliable mapping of single copy genes on conifer chromosomes, on which we are presently working.

#### ENGINEERING OF SPECIALTY GENOTYPES OF HYBRID POPLAR AND SPRUCE

P. Dharmawardhana, Monica Schmidt, Madoka Gray-Mitsumune and John Carlson

Plantation forestry provides the opportunity for large scale deployment of "clones" derived from tissue culture that have been engineered for traits necessary to achieve maximum productivity. We have established protocols for genetic engineering of hybrid poplar, Douglas-fir and interior spruce. There are numerous traits that can only be obtained in tree species through gene transfer. At this time, we are focusing on modification of the lignin biosynthesis pathway and uptake of heavy metals. We are collaborating with Brian Ellis in the Plant Science Department and Carl Douglas in the Botany Department at UBC on an NSERC Strategic Research Grant project with a long term target of modifying lignin content in hybrid poplar and conifers. Through this research we hope to learn enough about the genes controlling lignin synthesis and the biochemical process of lignification during wood development to devise a strategy for breeding or genetically engineering trees with altered lignin composition. This research might lead to hybrid poplar more suitable for lumber production by an engineered increase in wood density or in spruce with altered lignin composition requiring less or no chemical bleaching during pulp production. We are also interested in transferring genes for heavy metal tolerance and uptake into poplar so that hybrid poplar could be grown on contaminated sites which would accomplish both remediation of those sites and the production of a tree crop. Such research should also lead to poplar hybrids that can accommodate the build up of heavy metals in sludge treated soils.

#### PUBLICATIONS, 1993 - 1995

Amarasinghe, V. and Carlson, J.E. 1994. Subcellular localization of polyamines in embryogenic callus of white spruce. *Canadian Journal of Botany* 72:788-793.

- Brown, G.B., Amarasinghe, V. Kiss, G. and Carlson, J.E. 1993. Preliminary karyotype and chromosomal localization of rDNA loci for white spruce by fluorescence *in-situ* hybridization. *Genome* 36:310-316.
- Carlson, J.E., Hong, Y-P, Brown, G.R., and Glaubitz, J.C. 1994. FISH, DNA Amplification Markers and conifers. In: *Plant Genome Analysis*, ed.: P.M. Gresshoff CRC Press, pp. 69-82.
- Carlson, J., Hong, Y-P., and Kiss, G. 1994. DNA markers associated with weevil resistance in interior spruce. In: *The White Pine Weevil: Biology Damage and Management*, eds. R.I. Alfaro, G. Kiss, R.G. Fraser. *Proc's of Symp.*, Jan 19-21, 1994, FRDA Report 226, Canadian Forest Service and B.C. Ministry of Forests Publ. pp. 158-168.
- Dharmawardhana, D.P., Ellis, B.E. and Carlson, J.E. 1995. A  $\beta$ -glucosidase from lodgepole pine xylem specific for the lignin precursor coniferin. *Plant Physiology* 107: 331 - 339.
- Ekberg, I., Eriksson, G., Namkoong, G., Nilsson, C., and Norell, L. 1993. Genetic correlations for growth rhythm and growth capacity at ages 3-8 years in provenance hybrids of *Picea abies*. *Scand. Jour. Fr. Res.*
- Koshy, Mathew P. and Donald T. Lester. 1994. Genetic variation of wood shrinkage in a progeny test of Douglas-fir. *Can. J. For. Res.* 74: 1734- 1740.
- Lewis, K., Carlson, J.E., and McLean, J. 1994. Data analysis of RAPD markers to establish genetic differentiation among populations of the white pine weevil (*Pissodes strobi*). *Proc. Annual Meeting of the Entomology Society of America*. December, 1994, In press. \_\_\_ *Ibid.* *Proc. Entomology Society of British Columbia Biennial Meeting*, October, 1994. In: *Entomology Society of British Columbia Newsletter*. In press.
- Lewis, K., McLean, J., White, E., and Carlson, J.E. 1994. Using RAPD markers to investigate genetic diversity of the : White Pine Weevil (*Pissodes strobi*). In: *The White Pine Weevil: Biology Damage and Management*, eds. R.I. Alfaro, G. Kiss, R.G. Fraser. *Procs of Symposium*, Jan 19-21, 1994, FRDA Report 226, Canadian Forest Service and B.C. Ministry of Forests Publ. pp. 184-202.
- Namkoong, G., Bishir, J., and Roberds, J.H. 1993. Evolutionary effects of density dependent selection in Plants. *Genetical Res.* 62: 57 - 62.
- Namkoong, G. 1994. An evolutionary concept of breeding. The Marcus Wallenberg Foundation, Falun, Sweden. 7 pp.
- Namkoong, G. 1994. Causes and effects of genetic erosion. In R.M. Drysdale *et. al.* eds., *Proc. Int'l Symp. on Genetic Conservation and Production of Tropical Forest Tree Seed*. ASEAN-Canada, Forest Tree Seed Centre Project, Thailand, pp. 139-143.
- Namkoong, Gene. 1994. Impact of global change on genetic diversity of temperate ecosystems. In T.J.B. Boyle and C.E.B. Boyle (eds.). *Diversity, Temperate Ecosystems, and Global Change*. Springer Verlag Berlin Heidelberg. NATO ASI Series 120: 145-156.
- Namkoong, G. 1994. Ethics in tree breeding and conservation. In *Proc. Marcus Wallenberg Foundation Symp. No. 9*. Falun, Sweden, pp. 17-18.
- Namkoong, G. 1994. Breeding strategies of resistance. In R.I. Alfaro *et al.* (eds.), *The White Pine Weevil: Biology, Damage and Management*. FRDA Rep. #226, pp. 218-221.

- Ponoy, B., Hong, Y-P, and Carlson, J.E. 1994. Genetic diversity in chloroplast DNA in Douglas-fir in British Columbia. *Canadian Journal of Forest Research* 24: 1824 - 1834.
- Ponoy, B. 1993. Genetic variability in Douglas-fir based on molecular and genetic markers and morphological traits. Ph.D. thesis, UBC, 175 pp.
- Sun, LJ, Carlson, J.E., and van der Kamp, B.J. 1995. A rapid procedure for preparing high molecular weight DNA from rust aeciospores for RAPD analysis. Proc. 4th IUFRO Rusts of Pines Working Party Conference, October, 1994, Tsukuba, Japan. pp. 143-148.
- Sun, LJ, Carlson, J.E., and van der Kamp, B.J. 1995. Preliminary study of genetic variation in western gall rust fungus populations in British Columbia, Canada, using molecular markers. Proc. 4th IUFRO Rusts of Pines Working Party Conference, October, 1994, Tsukuba, Japan. pp. 149 -155.

# **YELLOW-CEDAR, WESTERN REDCEDAR AND PACIFIC YEW GENETIC RESEARCH, CONSERVATION AND IMPROVEMENT**

**J. H. Russell**

**B. C. Ministry of Forests  
Cowichan Lake Research Station, Box 335  
Mesachie Lake, B. C.  
V0R 2N0**

## **YELLOW-CEDAR PROVENANCE RESEARCH**

Preliminary results from 5 year data from the yellow-cedar range-wide provenance study have shown minimal growth and maladaptation differences related to seed-source elevation among coastal British Columbia populations, when grown at low elevation (<200 m). This has prompted a revision to seed transfer guidelines, with an unlimited downward transfer of seed sources. Frost-hardiness of seed sources when grown at high elevation sites also appears to be unrelated to elevation of source-origin, however, this will need to be further evaluated.

## **YELLOW-CEDAR BREEDING**

Twelve partial diallels from wild-stand phenotypic selections are completed, and the first series of cloned progeny tests have been sown. Four tests will be out-planted in 1997 with one-year-old rooted cuttings from 96 full-sibs (6 diallels), represented by 20 clones per family and 3 ramets per clone per site. The next series will be outplanted in 1998. Twelve more diallels are currently being completed.

## **REDCEDAR GENETIC STUDIES**

Preliminary data from various redcedar genetic studies (Ministry of Forests, University of British Columbia, B.C. Research, Pacific Forest Products) have shown that genetic variation in morphological, physiological and molecular traits exists contrary to earlier isozyme results, and that some of the variation is adaptive. As well, there is evidence of high selfing rate in seed orchards, minimal inbreeding depression in flowering, seed and early growth traits, and delayed inbreeding depression in growth upon out-planting.

## **PACIFIC YEW GENE CONSERVATION**

Five hundred clones from throughout the range of Pacific yew in British Columbia have been planted in the gene archives at Cowichan Lake Research Station.

## PROGRESS REPORT FOR CANADIAN TREE IMPROVEMENT ASSOCIATION

Ben C.S. Sutton

Forest Biotechnology Centre  
B.C. Research Inc.  
3650 Wesbrook Mall  
Vancouver, B.C.  
V6S 2L2

My work involves research direction of the Forest biotechnology Centre. About two thirds of the activities of the Centre are directed towards tree improvement-related technologies. These include: Somatic embryogenesis of conifer species, molecular genetics and physiological genetics. The principal scientists in these areas of research are Dr. David Cyr and Ms. Fiona Webster in somatic embryogenesis, Dr. Craig Newton in molecular genetics and Dr. Steven Grossnickle in ecophysiology.

### SOMATIC EMBRYOGENESIS RESEARCH AND DEVELOPMENT

Somatic embryogenesis (SE) work over the past two years has been focused on three principal areas: 1). Large scale establishment and testing of embryogenic clones for the interior spruce tree improvement program in British Columbia (B.C.). 2). Scale up and operational implementation of SE production systems. 3). Application of SE to Sitka spruce weevil resistant families. Progress in each of these is summarized below.

#### Development of a clonal selection program for interior spruce using somatic embryogenesis

This work was initiated to apply SE to the interior spruce breeding program by establishing a clone bank and deploying plants (somatic seedlings) for clonal selection trials, and in parallel, to address the limitations of this technology. The limitations include: a significant influence of genotype on the success of the process and the need to define and exploit clonal variation for accelerated selection. This follows a project in which 263 genotypes were established from 12 families between 1991 and 1992, 200 of these were delivered to the nursery in 1993 and planted in the field in 1994 and 1995. The strategy for clonal selection using SE has been outlined in a 1993 publication involving BCRI and the B.C. Ministry of Forests (Sutton et al. 1993).

Over the last two years establishment, storage and deployment of embryogenic lines from a range of elite weevil-resistant crosses of interior spruce (Prince George selection unit, *Kalamalka arboretum*) have been pursued intensively. To date, 656 genotypes from 18 families have been successfully produced and stored in cryopreservation. Approximately 50% of these genotypes, without cultural improvements, produce suitable numbers of embryos for somatic seedling production. For the first round of clonal selection field trials from these crosses (spring 1996), 320 lines from 11 families were delivered to the nursery in March 1995 in sufficient number to be deployed on two to three field sites. BCMoF personnel will subsequently deploy these somatic seedlings in the field trials (Chris Hawkins, Red Rock Res. Stn. B.C.). In the next two years we anticipate bringing the total number of genotypes deployed from these families to 1,000. This will allow selection of the top 5% of the clones within five or six years, based on weevil resistance and growth.

Significant progress has been made on the other objectives of the project including the development of methods to improve induction from recalcitrant families. For maturation, a protocol for improving performance of poor clonal lines has been developed and was assessed using 100 genotypes from the 1994-95 embliing production run for clonal selection trials. Selected physiological studies of genotypic variation between clones were initiated during the summer of 1994 and are still in progress. Emphasis has been placed on 6 clones representing high, medium and low growth-ranked families. Preliminary results from these studies indicate very significant clonal differences with respect to seasonal water relations, photosynthetic and transpiration rates, and instantaneous water use efficiency.

#### Somatic Embryogenesis Development for Weevil Resistant Sitka Spruce

Reforestation with Sitka spruce in B.C. has declined dramatically, largely because of the risk of severe damage of young stands by terminal weevil (*Pissodes strobi*). SE technology represents a significant opportunity to multiply weevil resistant material rapidly and also to select and maintain individual progeny in a juvenile state. During 1991 and 1992, B.C. Research delivered a total of 8,500 seedlings of Sitka spruce from SE. This work showed that, while deployment of plants was possible, SE of this species required further development for routine use. In view of this, a development project was initiated in 1994 with the goal of improving the induction and stabilization of embryogenic cultures, improving embryo production and establishing lines (genotypes) from resistant families for field testing and subsequent operational production.

We have used seed for induction of embryogenic clones from 9 open pollinated families and 3 provenance sources which have substantially increased resistant to weevil. Research on this material indicated that media formulation had a significant impact on induction frequencies. Additional promotive factors have been identified. With the best treatments, initial induction frequencies approached those presently achieved for interior spruce, with values for 8 sources ranging from 23 to 52 %. Currently, approximately 200 genotypes from the 12 sources have been produced and cryopreservation is being completed. BCRI anticipates deploying more extensive trials of somatic seedlings from weevil resistant open pollinated families in 1996 and 1997. This will result in planting stock with an average 30% increase in weevil resistance (based on progeny test results). Selection of individual lines and deployment of full sib families (not currently available) will result in further improvement in next few years.

#### Large scale production systems for somatic embryogenesis

In order to use SE in operational reforestation, production volumes in the hundred's of thousands to millions, must be achieved. For this reason we have engaged in an intensive effort to implement rapid multiplication of somatic embryos, bulk handling systems and efficient nursery delivery. This has resulted in a system which can be used to produce several hundred thousand embryos, dry them and germinate them in bulk without the need for individual handling. Following bulk germination the small germinants are transferred to nursery containers. Development of the somatic seedlings, while somewhat slower immediately following transplant, allows the production of good quality planting stock. Using this system approximately 30,000 plants were produced in 1994 and a further 100,000 in 1995. These production runs incorporated about 40 clones from top ranked families of the interior spruce breeding program (Prince George selection unit). Field trials have been deployed by the Ministry of Forests, Fletcher Challenge Canada and Northwood Pulp and Timber in the central interior of B.C..

In the last year we have published data from earlier nursery production and field trials in which somatic seedlings were compared with genetically related seedlings. This data showed that the somatic seedlings reached all stock quality requirements for reforestation and

had survival and growth increments in the field which were similar to the seedlings (Grossnickle et al. 1994; Grossnickle and Major 1994a; Grossnickle and Major 1994b).

## MOLECULAR GENETICS RESEARCH AND PHYSIOLOGICAL GENETICS

The primary focus of molecular genetics research has been the development of genetic markers for specific applications in tree improvement and seed orchard management. These have included pure population genetics studies in which information about population structure is required in order to provide a basis for designing breeding units and defining seed transfer guidelines. In addition, an intensive effort has been made to identify and develop highly polymorphic markers which can be used reliably in distinguishing seed orchard parents. The latter enables one to measure pollen contributions, pollen contamination and selfing.

### Development and application of highly polymorphic markers

Two types of markers have been developed and applied over the past two years: 1). Hyperpolymorphic DNA probes derived from the nuclear genome. 2). PCR primers which are used to detect polymorphisms in the chloroplast genome.

An extensive screening of regions of the spruce genome led to identification and cloning of a highly polymorphic region. This can be used as a probe to generate fingerprints for resolving individual spruce trees and for detecting contributions of unique alleles to the progeny in seed orchards. This probe has recently been used in a study of genetic diversity (with Dr. Michael Stoehr, Ministry of Forests B.C.). The objective of this study was to determine the influence of seed orchard production and reforestation on genetic diversity in interior spruce. For this purpose three stands from each of two watersheds were sampled to represent the native forest. As a comparison seed orchard parents, seed derived from this orchard and a plantation planted with seedlings grown from the orchard seed, were also sampled. The data set consists of DNA fingerprints for a total of about 600 trees. Final analysis of the results of this study will be completed in the near future.

Using an analogous region to that identified as polymorphic in spruce, a study was initiated with western red cedar. In this case, an important issue was to determine the rates of selfing in individual red cedar families. Conventional approaches using isozymes had proved somewhat challenging since very little polymorphism was detected in this species. Using the highly polymorphic region (not homologous with the equivalent region from spruce) it is possible to detect relatively high levels of polymorphism and to use this to estimate selfing. This work is continuing with the Ministry of Forests in association with Dr. John Russell (breeder for western red cedar).

Chloroplast polymorphism has been exploited specifically for studying seed orchard management issues. A report a few years ago by Hipkins and Strauss demonstrated that significant polymorphism exists in a specific region of the Douglas-fir chloroplast genome. We developed PCR primers which amplify this region and used them in a series of tests with an experimental (2nd generation) meadow orchard at Saanich B.C.. Pollen contributions from within the orchard and from outside the orchard were measured. Rates of selfing of the individual parents were also determined. One example of a management practice, supplemental mass pollination (SMP), was studied; in this case the effect of flowering phenology on the receptivity individual clones at the time of SMP was evident. The principal advantages of this method over those available previously is the ability to distinguish most individual trees unambiguously (70%) under operational conditions; this results from the high degree of polymorphism and the uniparental inheritance. Our recent results suggest that, using the same

generalized approach, it should be possible to achieve similar, or higher, levels of discrimination in a routine manner with a range of the commercial conifer species.

#### Genetic and physiological analysis of Sitka / interior spruce hybrids

We recently published a paper showing that ribosomal DNA could be used to determine the extent of hybridization between Sitka and interior spruce. This information is expressed as an index (Si rDNA) which reflects the relative abundance of the ribosomal DNA banding patterns specific to each species. When applied in a survey of spruce in northwestern B.C. a gradation of introgression was found which followed longitudinal and topographical trends (Sutton et al. 1994).

Another study has been conducted in 1993 and early 1994 to determine the relationship between the index (Si rDNA) of a range of hybrids and physiological traits of adaptive significance (Grossnickle et al. 1995). The objective was to determine the physiological significance of hybrid make-up as determined by DNA markers and to use this information in defining the tolerance limits for moving hybrids within the introgression zone. Seed sources ranging from pure Sitka spruce to interior spruce, as well as intermediate types, were used in the study. Clear relationships with the DNA index could be shown for frost hardiness, drought tolerance and gas exchange characteristics. As might be expected, interior spruce types were considerably more hardy with respect to drought and frost but had lower photosynthetic rates under optimal conditions. However, when seedlings were soil-droughted, interior spruce populations maintained higher net photosynthetic rates due to their inherent drought tolerance. We are optimistic that such information can be used to deploy spruce hybrids in an optimal fashion for plantation forestry.

#### CONCLUDING REMARKS

Studies are continuing in the evaluation of clonal material derived from SE and we are linking up with other researchers using this material. We have observed, as might be predicted, that variation within clones is substantially less than within seedlots or families. It appears there is considerable potential for using embryogenic clones for a range of research studies which can then be integrated to provide a much more precise understanding of plant function and the role of genetic variation. Such studies should lead to a better fundamental understanding of spruce physiology as well as adding to the selection criteria which can be used in the breeding program.

Finally, B.C. Research Inc. gratefully acknowledges the support of the B.C. Ministry of Forests, the National Research Council of Canada (collaborative work with the Plant Biotechnology Institute and direct funding), the Science Council of British Columbia, and industrial clients including: Pelton Reforestation, Western Forest Products, Canadian Forest Products, Pacific Forest Products, MacMillan Bloedel, International Forest Products, Northwood Pulp and Timber and Fletcher Challenge Canada, who supported work in one way or another over the years.

#### SELECTED REFERENCES

- Grossnickle, S.C., B.C.S. Sutton, R.S. Folk and J.R. Gawley. 1995. Relationship between nuclear DNA markers and physiological parameters for Sitka x interior spruce populations. *Tree Physiol.* (submitted for publication).

- Grossnickle, S.C., J.E. Major and R.S. Folk. 1994. Interior spruce seedlings compared to emblings produced from somatic embryogenesis. I) Nursery development, fall acclimation and over-winter storage. *Can. J. For. Res.* 24:1376-1384.
- Grossnickle, S.C. and J.E. Major. 1994a. Interior spruce seedlings compared to emblings produced from somatic embryogenesis. II) Stock quality assessment prior to field planting. *Can. J. For. Res.* 24:1385-1396.
- Grossnickle, S.C. and J.E. Major. 1994b. Interior spruce seedlings compared to emblings produced from somatic embryogenesis. III) Physiological response and morphological development on a reforestation site. *Can. J. For. Res.* 24:1397-1407.
- Sutton, B.C.S., S.C. Pritchard, J.R. Gawley, C.H. Newton, Kiss, G.K. 1994. Analysis of Sitka/interior spruce introgression in British Columbia using cytoplasmic and nuclear DNA probes. *Can. J. For. Res.* 24:278-285.
- Sutton, B.C.S., S.C. Grossnickle, D.R. Roberts, J.H. Russell, G.K. Kiss. 1993. Somatic embryogenesis and tree improvement in interior spruce. *Journal of Forestry.* 91:34-38.

## SEED PRODUCTION RESEARCH - BC MINISTRY OF FORESTS

Joe Webber and Michael Stoehr

Glyn Road Research Station  
1320 Glyn Road  
Victoria, British Columbia  
V8W 3E7

**Keywords:** supplemental mass pollination, seed orchard management, alternate seed orchard design, flower induction, pollen management.

### SEED PRODUCTION RESEARCH

Restructuring of our seed production research program began in 1992 and is now fully implemented. We have three main components to this program. Acquiring basic knowledge of the reproductive biology of all tree improvement species including studies on cone induction, pollen management, supplemental pollination technique, and seed and cone maturation. This information forms the basis for seed orchard management research which is currently emphasizing the genetic quality of orchard production in mature orchards and cultural techniques for the establishment of new orchards (i.e., amabilis fir). The third component of our research is wild stand production, including studies on the factors affecting natural reproduction in wild stands and successful regeneration in partial cuts. Included in all of these three research areas are new studies on genetic diversity from seed orchards, plantations and natural stands.

#### Clonal Row Douglas-fir Orchard

A Douglas-fir (*Pseudotsuga menziesii*) micro orchard was established in 1991 with the long term objective of determining area based yields and genetic quality of seed produced from parent trees arranged in clonal rows and maintained under 2 crown pruning regimes (tree height kept at 2 and 3 meters). Two of the four blocks were first induced in 1994 using GA<sub>4</sub>/7 only and the remaining two blocks were treated in 1995 (girdling plus GA<sub>4</sub>/7) as part of our biennial induction scheme. The 1995 flowering response to the 1994 induction produced an average of about 20 seed cones and 200 pollen cones per tree. We found no significant flowering response to three dosages levels of GA<sub>4</sub>/7 but variation due to clones was significant.

The evaluation of supplemental mass pollination (SMP) efficacy was enhanced by our ability to determine the male parent of a Douglas-fir embryo or seedling using DNA techniques. The pollen parents are identified by amplifying a hypervariable region of the embryo chloroplast DNA using the Polymerase Chain Reaction (PCR). By pre-screening potential pollen donors for a SMP polymix, easily identifiable male parents can be selected. In addition, if all orchard clones are genotyped this way, estimates of outside orchard pollen contamination can also be obtained. In this study, six clones out of 20 growing in the clonal row orchard received an SMP treatment by directly applying pollen to unbagged individual female strobili. SMP efficacy ranged from 40% to 74% depending on the female parent. Outside orchard pollen contamination was reduced to 9%, a reduction of 9% from untreated, open-pollinated controls (18% outside contamination on average).

To test the hypothesis that natural selfing may be higher in this hedged, clonal row orchards, we used the same genetic marker as described above to determine the paternal

parent in open-pollinated seeds collected from individual clones of this orchard. If the hypervariable chloroplast DNA fragment in the embryo is of the same size as the hypervariable chloroplast DNA fragment of the associated megagametophyte, then the embryo is a self. In a study of approximately 86 seeds (on average) from each of six open-pollinated families, natural selfing rates ranged from 0 % to 18%, with an average of 5.5%. Thus, clonal rows and hedged crowns do not seem to contribute to natural selfing in this Douglas-fir clonal row orchard. Both the SMP efficacy and selfing study have been carried out in cooperation with BC Research Inc., Vancouver.

#### Container Seed Orchard Research

The advantages of a container approach to seed production is fully appreciated but not yet realized in interior spruce. Experience to date with white/engelmann spruce container orchards at Cobble Hill and Skimikin Seed Orchards has shown consistent flowering (pollen and seed cones) resulting from the induction protocol but yields have seldom exceeded 10-15 filled seed per cone (FSPC). In spite of several attempts to improve pollen quality and pollination technique, yields have remained disappointingly low. In the past two years, we have focused on the pre- and post-pollination environmental (temperature) conditions the grafts (in particularly the root) were exposed to. In general, exposing the developing cones to constant temperatures of 24°C during the pre-zygotic cone development results in significantly fewer seeds than lower temperatures. However, even the best yields did not exceed 25-30 FSPC. Last year, we concentrated on pre-pollination conditions and attempted to protect the pots (root development) from direct exposure to sun. The spring of 1994 was relatively cool and seed yields were considerably better (average about 40-45 filled seed per cone). However, comparable yields at the Cobble Hill Container Orchard were still low (12 filled seed per cone). We will continue to use the container approach for seed production research but the operational pilot program has been disbanded.

#### Pollen Management Manuals

A manual (Webber and Painter 1995) describing the *ex situ* handling and application of Douglas-fir pollen is now in print. This manual details the procedures for collecting, drying, extracting storing, testing and reapplying pollen to meet specific orchard management objectives. A similar manual has been distributed for interior spruce (Webber 1991) and a seed production manual for western hemlock, emphasizing both pollen handling and techniques for crown management and cone induction in both soil-based and container stock, is in preparation.

#### Western Larch Flower Induction

Seed orchards of western larch (*Larix occidentalis*) have been established but significant production will not be available for a few more years. We are taking two approaches for enhancing western larch seed production. First we are investigating various seed orchard flower induction techniques. Results from a 1994 GA<sub>4/7</sub> by girdling trial showed that GA<sub>4/7</sub> alone resulted in a small increase in both seed and pollen cone production but the single treatment of girdling was significantly better and a combination treatment of GA<sub>4/7</sub> and girdling was best. Timing of these treatments was also significant. Treatments applied at long-shoot (LS) bud flush were significantly better than when applied at about 80% elongation of LS. Our second approach to increasing western larch seed production is to test the feasibility of inducing natural stands. A young natural stand of western larch (12-15-years-old) growing near Invermere, BC was girdled in 1994 but no flowering occurred. A second girdling treatment has been re-applied to the same trees and in 1996 we will compare flowering response to single and repeated girdling.

We are also monitoring pollen cloud density and meteorological factors to help explain crop periodicity, cone abortion and cone yields.

#### Abies amabilis and Abies lasiocarpa Seed Production

Harvesting activity in the mid- to high-elevation areas has increased in the last few years and so has interest in seed procurement of amabilis and sub-alpine fir. Established amabilis fir seed orchards have yet to produce any significant seed (they have produced considerable pollen crops, however). While the grafts seem to be sexually mature, they lack vigour and crown development and are unresponsive to the few induction studies attempted. It is our hypothesis that early cultural treatments of the grafts as well as the warm, dry Saanich peninsula orchard sites were not conducive to establishing vigorous crown development. Cultural studies have begun with the objectives of determining the barriers to establishing vigorous crowns in amabilis fir. This material will also be used for future flower induction studies. We will begin similar studies for sub-alpine fir in 1995.

#### Pollen Contamination Effects

The long-term effects of out-side seed orchard pollen contamination on growth rate, phenology, growth rhythm and ultimately, survival are being studied in coastal-interior transition Douglas-fir (*Pseudotsuga menziesii*). We initiated a trial that compared seedlings sired by outside orchard (coastal) pollen with seedlings sired by within-orchard pollen. Nursery results indicated that seedlings from the contaminating pollen sources grew significantly faster in a coastal climate (Stoehr et al. 1994). To further evaluate their performance in the field, plantations were established on a coastal, an interior and a transition zone site. Parameters evaluated will be bud flushing, growth differences (early growth, time and amount of maximum growth rate, growth cessation) and survival.

#### Genetic Diversity and Tree Improvement

We also investigated the effects of domestication on the genetic diversity of interior spruce (*Picea glauca x engelmannii*). The genetic diversity of a total of 360 trees from nine natural stands representing three watersheds in the Shuswap-Adams low elevation breeding zone (SAL) was measured using isozymes. Simultaneously, the 100 clones of the SAL seed orchard were also evaluated. Finally, 120 seeds from a bulked seed lot of the SAL orchard and 120 seedlings raised from the same seed lot and growing in a 2-year-old plantation were also evaluated. Results indicated that the orchard is genetically very similar to the natural stands. The seed lot was genetically very diverse, however, there were some alleles present that were the result of outside-orchard pollen contamination. The diversity in the plantation was still high, but suggests some unintentional directional selection in the nursery. A follow-up to this study will be done on families collected in the orchard and natural stands to assess variation levels in quantitative traits in a common garden study.

Other studies, such as pollen monitoring and the rating of orchard seed lots (Xie et al. 1994), effects of crown pruning (Stoehr et al. 1995) and identification of constraints to seed production in alternate silvicultural systems with western larch as seed tree stands and shelterwoods are ongoing.

#### PUBLICATIONS

Bonnet-Masimbert, M., and Webber, J.E. 1995. From flower induction to seed production in forest tree orchards. *Tree Physiology* 15:419-429.

- Stoehr, M.U., J.E. Webber and R.A. Painter. 1994. Pollen contamination effects on progeny from an off-site Douglas-fir seed orchard. *Can. J. For. Res.* 24:2113-2117.
- Stoehr, M., C. Hollefreund, J. Webber, C. Hewson and S. Ross. 1995. Effects of crown-pruning on seed and pollen cone production and crown dimensions in two lodgepole pine seed orchards in British Columbia. *New Forests* (in press).
- Webber, J.E. 1995. Pollen management for intensive seed orchard production. *Tree Physiology* 15:507-514.
- Webber, J.E., and Painter, R.A. 1995. Douglas-fir pollen management manual. 2nd Ed., BC Ministry of Forests, Research Program Working Paper WP02/1995. (in press)
- Xie, C.Y., J. Woods and M. Stoehr. 1994. Effects of seed orchard inputs on estimating effective population size of seedlots - a computer simulation. *Silvae Genet.* 43:145-154.

## COASTAL DOUGLAS-FIR BREEDING AND GENETIC RESEARCH

J. H. Woods

B. C. Ministry of Forests  
Cowichan Lake Research Station, Box 335  
Mesachie Lake, B. C.  
V0R 2N0

**Keywords:** Douglas-fir, breeding, advanced generation, inbreeding, selection, genealogy.

### BACKGROUND

The coastal Douglas-fir breeding program is directed primarily at sites from 0 to 700m elevation west of the coast mountains and south of 51 degrees latitude in coastal B. C. First-generation selection and breeding was completed in the 1960's and early 70's for this zone, and testing proceeded with both diallel and open-pollinated material. Second-generation selections began in 1991.

### SECOND-GENERATION BREEDING

Selection for a second-generation breeding population is currently about 80 percent complete. Propagation and early cone induction is a priority. Both potted and soil-based ramets are being used for breeding as we learn more about how to handle grafts from young Douglas-fir trees, and how to induce flowering within 2 to 3 years of grafting. Induction methods used are principally stem injections of GA<sub>4/7</sub> in combination with either girdling or root pruning.

The breeding strategy entails a complimentary mating design, with a polymix used for GCA testing all clones. The population is divided into small sublimes of from 12 to 20 clones, and full-sib mating within sublimes is being done so each clone is included in at least two crosses. Inbreeding is avoided in this generation and there is no coancestry between sublimes. Breeding is complete for the first three sublimes, and nearly complete for an additional five sublimes.

### REALIZED-GAIN TRIALS

Linking genetic gain predictions with growth and yield information systems is needed when improved material is being extensively used operationally. Realized-gain trials will provide the data to 1. link stem-volume breeding values predicted from progeny test data with actual area-based yield gains, 2. evaluate breeding and selection strategies in a more operational setting, 3. modify growth models (TASS) to account for predicted genetic gain, and 4. demonstrate genetic gains.

A first series of Douglas-fir realized-gain trials was established in 1992 with four genetic levels and a single stand density. Early results are promising, and show height gains to be close to those predicted. Seed from non-tested first generation orchards is showing early height gains of about seven percent over natural-stand seed. A second series of trials will be

planted in the spring of 1996 with three genetic levels, four stand densities and three levels of site index.

#### SUPPORT RESEARCH

Research in support of the breeding program continues, including low-level inbreeding effects, early selection, wood density evaluation and cooperative work on frost and drought hardiness. In addition, testing to evaluate geographic patterns of genetic diversity in the coast-interior transition zone is progressing with a field project and a cooperative project with the University of B. C. (Francisco Luna, Dr. Mathew Koshy and Dr. Gene Namkoong). The UBC work will investigate patterns of early growth, frost hardiness and water-use efficiency.

## PROVENANCE RESEARCH

Cheng C. Ying

B.C. Ministry of Forests  
Research Branch  
1450 Government St.  
Victoria, B.C.  
V8W 3E7

One major initiation in the past two years was the assessment of pest damage at lodgepole pine provenance trials. We have assessed test plantations at 59 locations throughout interior British Columbia and extending into southern Yukon Territory. The main objectives are to develop predictive models for the assessment of pest hazard of planting sites, and to study patterns of provenance variation in pest tolerance as a supplement to seed transfer guidelines and selection of resistant seed sources for planting and tree improvement.

Our assessments focus on stem rusts, needle diseases, pine terminal weevil and rodent damage, the most common above-ground pests plaguing plantation lodgepole pine. We have nearly completed the field assessment and comprehensive analyses of the data are in progress. Large site differences and provenance variation were evident. Particularly interesting is the high resistance to stem rust, western gall rust in particular, of provenances from the lodgepole and jack pine contact zone. Degree of resistance, expressed as number of infection sites, showed positive correlation with the distance of provenance origin to the boundary of the contact zone. We advance the hypothesis that jack pine introgression may be evolutionarily related to the resistance of lodgepole pine to western gall rust. High resistance of these provenances from the hybridization zone is unequivocal - stable across diverse site environment. Unraveling the genetic and physiological mechanism of resistance requires inter/multi-discipline approach.

Lodgepole pine is now the number one planting species, accounting for about 35% of the total planting in British Columbia. The pest information is not only of commercial value to tree improvement and integrated pest management, it also provides a valuable database for climate modeling to assess the impact of global warming on forest pests.

Because of the potential for short rotation and value-added products, hardwood species are becoming an important component in plantation silviculture. This has created opportunities for studying genetics of hardwood species. On the coast, we have started studies for black cottonwood, red alder, bigleaf maple and Sitka alder since 1992. We have completed the nursery testing and established three long-term field tests of red alder. Provenance sampling of black cottonwood is nearly completed, which covered all the major river drainages on the coast. Nursery testing and isoenzyme studies of Sitka alder are in progress. A study of bigleaf maple will be started this year. All the hardwood studies are cooperative involving scientists inside and outside B.C. Ministry of Forests. In about five years, we will have a solid knowledge base on seed transfer, seed source selection, and genetic potential in selection and breeding of coast hardwood species.

## GENETICS AND TREE IMPROVEMENT RESEARCH AT THE UNIVERSITY OF ALBERTA

Bruce P. Dancik, Om P. Rajora, Phambu D. Khasa, and Associates

Department of Renewable Resources  
The University of Alberta  
Edmonton, Alberta  
T6G 2H1

**Keywords:** Molecular, population, evolutionary, and conservation genetics; molecular markers for disease resistance and other quantitative traits; genome mapping; speciation and biosystematics; chloroplast, mitochondrial and nuclear DNA; RAPD, RFLP and microsatellite DNA; isozymes; genetic implications of silvicultural management; tree breeding; mycorrhizae.

During the past two years, our research activities continued in the areas of molecular, population, evolutionary and conservation genetics, speciation, biosystematics, genetic implications of silvicultural management, and molecular markers for disease resistance and other quantitative traits, and genome mapping. We also initiated a project on genetic implications of silvicultural management of eastern white pine (*Pinus strobus* L.) in Ontario, and on ectomycorrhizal inoculation of conifer seedlings.

Since the last report, two graduate students completed their degree programs in forest genetics.

### MOLECULAR, POPULATION AND EVOLUTIONARY GENETICS, SPECIATION, AND BIOSYSTEMATICS

#### Isozyme studies

Data analysis has been completed and manuscript preparation is in progress for a (Rajora and Dancik) study completed earlier on population genetic structure, variation and evolution of Engelmann spruce (*Picea engelmannii* Parry), white spruce (*P. glauca* (Moench) Voss) and their putative natural hybrid complex in Alberta. Phambu. D. Khasa (Ph.D., Laval University), who joined us as a postdoctoral fellow in 1994, and Dancik have completed a genetic diversity study in two closely related tropical species *Racosperma auriculiforme* (Cunn. ex Benth.) Pedley and *R. magnum* (Willd.) Pedley using multivariate analysis of allozymes and morphometric traits. *Populus* isozyme studies with Dr. Burton V. Barnes, University of Michigan, continue.

#### Molecular Genetics

Om Rajora published his studies on intraspecific and interspecific chloroplast (cp) DNA variation and genome relationships of *Populus* species and hybrids. He also completed examination of variation in cpDNA and nuclear genes in trembling aspen (*P. tremuloides* Michx.) in Alberta, and RAPD variation of *P. x canadensis* cultivars. Rajora, with the assistance of research assistant Manjit Sekhon, completed a study on genetic diversity of white spruce populations in Saskatchewan. Khasa is studying the population genetic structure and evolution of the *P.*

*engelmannii*-*P. glauca* complex using RAPD analysis and has identified species-specific RAPD markers. Khasa and Dancik have also started a study on population genetic diversity, breeding systems in *Larix lyallii* Parl. using microsatellite DNA analysis, in collaboration with Barry Jaquish of the B.C. Ministry of Forests.

#### Variation and differentiation

Barbara Thomas is completing a Ph.D. study, under the supervision of Ellen Macdonald and Bruce Dancik, on variation and differentiation of trembling aspen in Alberta. She studied morphology and gas exchange traits. Rob Wright completed a Ph.D. study on the genecology of seedling root growth, stomatal frequency and seed mass in jack pine (*Pinus banksiana* Lamb.) under the supervision of Ross Wein and Bruce Dancik. Christine Hansen has completed an M.Sc. study on genetic variation in early field performance of white spruce in central Alberta. Leonard Barnhardt is completing his M.Sc. study on early performance of Douglas fir (*Pseudotsuga menziesii* (Mirb.) Franco) on five ecologically diverse sites in southwest Alberta.

#### MOLECULAR MARKERS FOR DISEASE RESISTANCE AND OTHER QUANTITATIVE TRAITS, AND GENOME MAPPING

Rajora, and Dancik, with the assistance of research associate Faten Kamel-Aly and research assistant Renato Vitic, completed the study on trembling aspen decay and stain and genetic fingerprinting of clones. DNA variation related to wood decay resistance in aspen has been identified, and data analysis and manuscripts preparations are in progress. We have also developed and initiated a project on molecular markers for quantitative traits and genome mapping in aspen.

The study on identifying molecular genetic markers for resistance to western gall rust (WGR), caused by *Endocronartium harknessii* (J.P. Moore) Y. Hiratsuka, in jack pine progressed well. Om Rajora, with the assistance of Renato Vitic, has identified about a dozen potential DNA markers for WGR resistance. F<sub>1</sub> hybrid seeds from the reciprocal controlled crosses within between WGR-resistance and WGR-susceptible genotypes have been collected, and are ready for raising F<sub>1</sub> progeny for genetic linkage mapping analysis.

#### GENETIC IMPLICATIONS OF SILVICULTURAL MANAGEMENT, AND GENE CONSERVATION

Rajora and Dancik, with the assistance of Manjit Sekhon, partially completed the study on determining the impacts of silvicultural practices on genetic diversity in white spruce using RAPD analysis, and the study is in progress using RFLP analysis. Heather Cobban began a M.Sc. study to examine genetic diversity in white spruce artificial regeneration vs. natural stands using microsatellite DNA analysis.

Rajora, George P. Buchert of the Ontario Forest Research Institute and Dancik conducted a project on genetic implications of silvicultural management of eastern white pine in Ontario. The study was initiated by Buchert and has been conducted by Rajora in partnership with BioGenetica Inc. Rajora has completed the genetic diversity analysis of the preharvest and postharvest and the mating system analysis of preharvest old-growth populations of white pine using allozymes. The data analysis and the first manuscript from the study has been completed. We continue the study by examining genetic diversity of preharvest and postharvest populations and natural regeneration using microsatellite DNA, RAPD and RFLP analyses.

As an expansion of the on-going white spruce study in Saskatchewan, Rajora initiated a project on determining genetic diversity of white spruce populations from ecologically-distinct sites in the Prince Albert Model Forest to develop ecosystem gene inventories and to assist gene conservation strategies.

#### TREE IMPROVEMENT

Rajora maintained collaboration with the Western Boreal Aspen Cooperative regarding the trembling aspen improvement program. Dancik and Rajora taught a short-course in tree improvement to industrial foresters.

Ruichuan Zhang is continuing his Ph.D. program under the supervision of Dancik and Dick Pharis (U. of Calgary) on biochemical and genetic approaches to very early selection of *Pinus radiata*. Deogratias Rweyongeza began an M.Sc. study (supervised by Dancik and Francis Yeh) on assessment of growth performance of Scots pine (*Pinus sylvestris* L.) on three sites in Alberta.

#### MYCORRHIZAL RESEARCH

Khasa and Dancik have initiated a project on inoculation techniques for ectomycorrhizal development on conifer seedlings with Alberta Environmental Protection.

#### ACKNOWLEDGMENTS

Support for the various studies above was provided by NSERC research grants (operating and strategic) and postgraduate scholarships, Canada-Alberta, Canada-Saskatchewan, and Canada-Manitoba Partnership Agreements in Forestry, Prince Albert Model Forest Association Inc., Canadian Forest Service, Ontario Ministry of Natural Resources, and Alberta Environmental Protection Ministry.

#### PUBLICATIONS

- Barrett, J.W., R.N. Beach, B.P. Dancik, and C. Strobeck. 1994. A genomic clone of a type I *cab* gene encoding a light harvesting chlorophyll *a/b* binding protein of photosystem II identified from lodgepole pine. *Genome* 37: 166-172.
- Dancik, B.P. 1993. Learning from error. *Schol. Publ.* 24: 269-273.
- Khasa, P.D., and B.P. Dancik. 1995. Rapid identification of white-Engelmann spruce species by RAPD markers. *Theor. Appl. Genet.* (in press).
- Khasa, P.D., P. Li, G. Vallée, S. Magnussen, and J. Bousquet. 1995. Early evaluation of *Racosperma auriculiforme* and *R. mangium* provenance trials on four sites in Zaire. *For. Ecol. Management* (in press).
- Khasa, P.D., G. Vallée, J. Bélanger, and J. Bousquet. 1995. Utilization and management of forest resources in Zaire. *For. Chron.* (in press).
- Khasa, P.D., G. Vallée, P. Li, S. Magnussen, C. Camiré and J. Bousquet. 1995. Performance of five tropical tree species on four sites in Zaire. *Commonwealth For. Rev.* (in press).

- Khasa, P.D., G. Vallée, and J. Bousquet. 1995. Provenance variation in rooting ability of juvenile stem cuttings from *Racosperma auriculiforme* and *R. mangium*. *Forest Science* 41: 305-320.
- Khasa, P.D. 1993. Acid scarification and hot water soaking of *Racosperma auriculiforme* seeds. *For. Chron.* 69: 331-334.
- Rajora, O.P., and B.P. Dancik. 1995. Chloroplast DNA variation in *Populus*. I. Intraspecific restriction fragment diversity within *Populus deltoides*, *P. nigra*, and *P. maximowiczii*. *Theor. Appl. Genetics* 90: 317-323.
- Rajora, O.P., and B.P. Dancik. 1995. Chloroplast DNA variation in *Populus*. II. Interspecific restriction fragment polymorphisms and genetic relationships among *Populus deltoides*, *P. nigra*, *P. x canadensis*, and *P. maximowiczii*. *Theor. Appl. Genetics* 90: 324-330.
- Rajora, O.P., and B.P. Dancik. 1995. Chloroplast DNA variation in *Populus*. III. Novel chloroplast DNA variants in natural *Populus x canadensis* hybrids. *Theor. Appl. Genetics* 90: 331-334.
- Rajora, O.P., and J.D. Mahon. 1995. Paternal plastid DNA can be inherited in lentil. *Theor. Appl. Genetics* 90: 607-610.
- Rajora, O.P., and J.D. Mahon. 1994. Inheritance of mitochondrial DNA in lentil. *Theor. Appl. Genetics* 89: 206-210.
- Rajora, O.P., L. Zsuffa, and F.C. Yeh. 1994. Variation, inheritance and correlations of growth characters and *Melampsora* rust resistance in full-sib families of *Populus*. *Silvae Genetica* 43: 219-226.
- Thomas, B.R. and D.T. Lester. 1992. An examination of regional, provenance and family variation in cold hardiness of *Pinus monticola*. *Can. J. For. Res.* 22: 1917 - 1921.

**TREE IMPROVEMENT PROGRAMME  
ALBERTA LAND AND FOREST SERVICE**

**C.R. Hansen, N.K. Dhir, K. Yakimchuk, J.M. Schilf,  
L. Barnhardt, C. Andriuk, N.W. Antoniuk, S. Hoberg, M.A. Mochulski**

**Forest Management Division  
Land and Forest Service  
Edmonton, Alberta  
T5K 2M4**

**Keywords:** Tree breeding, genetic improvement, provenance studies, species testing, seed orchards, progeny testing, white spruce, lodgepole pine, aspen.

This report summarizes the progress of the Alberta Land and Forest Services (L.F.S.) genetics and tree improvement programme for the period 1993-1995.

#### PROGRAMME DEVELOPMENT

In order to provide additional resources for the growing programme needs and new projects, a new *revolving fund* function was started in 1994 at the Tree Improvement Centre to raise revenues to supplement regular tree improvement budgets. Programme development during the report period emphasized broadening partnerships with forest industry with particular attention to smaller forestry operators in the province. Three new industries (Manning Diversified Forest Products Ltd., Canadian Forest Products Ltd.- Hines Creek and Vanderwell Contractors (1971) Ltd.) joined the cooperative tree improvement program during 1994-95.

#### GENETIC IMPROVEMENT

##### Assembly of Breeding Stock

Field selection of superior parent trees to provide material for L.F.S. and L.F.S./Industry cooperative projects continued. Due to budget constraints and increased industry participation, L.F.S. selections were minimal including only two Scots pine (*Pinus sylvestris*) and two tamarack (*Larix laricina*). Selections made as part of the L.F.S./Industry projects included 131 white spruce (*Picea glauca*), 45 black spruce (*Picea mariana*), 14 lodgepole pine (*Pinus contorta*) and two jack pine (*Pinus banksiana*). Industry participants in these cooperative projects included Alberta-Pacific Forest Industries, ANC Timber Ltd., Blue Ridge Lumber (1981) Ltd., Canadian Forest Products Ltd., Manning Diversified Forest Products, Millar Western Industries Ltd., Sunpine Forest Products Ltd., Weldwood of Canada Ltd., and Weyerhaeuser Canada Ltd.

##### Genetic Testing

White spruce progeny trials for breeding Region "D" were measured in 1993 at 10 years from seed. Eight- and 10-year heights were measured and plant vigour and white-pine weevil damage were assessed. Significant family differences were found for all traits. Heritabilities for 10-year height were 0.19 (individual) and 0.74 (family) and gains of 5% in height

are predicted relative to the unselected population if the top 50% of families are selected. Progeny trial results will form the basis for the first roguing of the Region "D" seedling seed orchard.

Field testing of selected aspen (*Populus tremuloides*) clones was initiated in 1993. Aspen propagated by root suckers from 9 phenotypically superior clones and from 4 clones selected for divergent wood quality were established in two trials.

Field screening of lodgepole pine half-sib families for resistance to western gall rust (*Endocronartium harknessii*) continued. Of 126 inoculated families from breeding Region "C", 20 resistant, 13 intermediate and 45 susceptible families were outplanted in 1993 on a high infection field site to confirm field resistance and susceptibility. In 1993, 112 families from breeding Region "B1" were greenhouse inoculated and 18 resistant, 13 intermediate and 38 susceptible families were outplanted in 1994 on a high infection field site.

Lodgepole pine half-sib family tests for breeding Region "B2" were measured at age 6 in 1994. Mean survival for the two test plantations was 87% and 85%. Mean incidence of western gall rust was 25% and 1.6%, respectively and mean severity of infection was 0.72 and 0.05, respectively. Severity was assessed on an arbitrary scale of 0 (no WGR symptoms) to 6 (maximum infection as evidenced by multiple stem and branch galls). Mean height of the two plantations was 51 cm and 60.5 cm, respectively.

Two series of white spruce progeny tests were outplanted in 1994. The trials for breeding Region "E" are comprised of 64 open-pollinated half-sib families and those for breeding Region "H" are comprised of 54 families. Three field trials were planted in each of the two regions.

A field trial was established in 1994 in cooperation with B.C. Ministry of Forests to evaluate resistance of a set of lodgepole pine open-pollinated families and seed sources to porcupine and snowshoe hare damage. The test material contained in the trial originate from Alberta and B.C. seed sources found to be less susceptible to porcupine and snowshoe hare damage in a northern latitudinal provenance test series in British Columbia.

In 1995, stock was seeded for Siberian larch (*Larix siberica*) provenance/progeny trials that will be outplanted in 1996. The trials are comprised of 58 open-pollinated half-sib families from Charga, Southern Siberia. The seed was obtained from the National Forest Genetic Resources Centre, Petawawa National Forestry Institute.

### Seed Orchards

The first improvement thinning of the Region "B1" seed orchard was completed in 1993. Thinning was based primarily on 11-year field performance results from four half-sib family field trials. In addition, 6-year performance results from the field trials and seed orchard performance results assessed in 1992, were taken into account.

The objective of the thinning was to remove one half of the poorest families in each set of 12 families. Accordingly, family sets were ranked by height, gall rust susceptibility and survival. A total of 8,146 trees were removed leaving 8,354 trees for seed production.

The Region "C" lodgepole pine seedling orchard consisting of 3,400 seedlings from 114 families was established at the Blue Ridge seed orchard site near Whitecourt in August 1994. Outplanting of the Region "D" white spruce clonal orchard at the Blue Ridge seed orchard commenced. These two projects are done cooperatively with Blue Ridge Lumber Ltd. The Region "G" white spruce clonal orchard located at Huallen was expanded in 1994 to meet

industry's increased seed needs. This project is done cooperatively with Weyerhaeuser-Grande Prairie and Canadian Forest Products-Grande Prairie. Establishment of the Region "B2" lodgepole pine clonal seed orchard at Huallen commenced. This project is done cooperatively with Weyerhaeuser-Grande Prairie and Weldwood. The Region "F" Douglas-fir (*Pseudotsuga menziesii*) orchard and the Region "Z" western larch (*Larix occidentalis*) clonal seed orchards were established near Brooks. The site proved to be unfavourable and the orchards were relocated to a site at the Crop Diversification Centre-South, also near Brooks, during the spring of 1995.

Production of grafts for the Region "I" white spruce and the Region "B2" lodgepole pine projects is underway. Grafting is also being done for two new black spruce projects.

Work is being done on getting two additional seed orchard sites for new seed orchard developments. A site near Olds and a site near Fairview are being pursued.

The first year that any collectable amount of seed was produced in any seed orchard was 1993. Sufficient seed was collected to meet 2% of the 1994 reforestation requirements. White spruce did not flower in 1994. The only seed orchard crop collected was from the Region "B1" lodgepole pine seedling seed orchard at Huallen. From this orchard, 8.3 kg of seed was collected. A crop twice as large is projected for 1995.

In 1995 the Huallen Seed Orchard Cooperative was formed with all industries having a share in the seed orchards established at Huallen. Management and maintenance of the site has been contracted out to the Tree Improvement Centre - Commercial Partnership Operations.

## TREE IMPROVEMENT RESEARCH

### Species Testing

The species testing program has been ongoing since 1978. Results from numerous field trials throughout Alberta on various site types have identified Douglas-fir, Scots pine and Siberian larch as promising new forestry species in Alberta. Since the late 1980's species testing has concentrated on identifying appropriate site types and promising seed sources of native and exotic species for forestry use in Alberta.

Sixteen year assessments of two U.S.S.R. Scots pine seed source trials established in central Alberta (54°04' N, 112°12' W) and northern Alberta (59°08' N, 117°34' W) were completed. Survival at both sites was good, averaging 88% at the central Alberta site and 78% at the northern site. The best Scots pine seedlot in the central and northern Alberta test sites outperformed the local lodgepole pine seed sources by 21% and 12%, respectively. Mean heights were 6.1 m and 5.0 m, respectively, for the central and northern Alberta sites. This compares to 4.8 and 4.3 m, respectively, for the control lodgepole pine seed sources. Ten and twelve year results indicated that the top five performing seedlots at each site originated from latitudes similar to those of the test sites. This was also the case for the central Alberta site following the sixteen year assessment. At the northern site, however, this was no longer the case. Four of the top five seedlots at the northern site originated from latitudes 52°23' N to 55°42' N. A southern Siberian seedlot from Kustanaisk Krai, U.S.S.R. (52°80' N, 63°50' E) was ranked third at the central Alberta site and first at the northern site. The Scots pine plantation at central Alberta continues to suffer significant porcupine damage. The lodgepole pine control trees were left untouched.

In 1994 a Douglas-fir planting was established at Pine Ridge Forest Nursery with proven hardy northern seedlots. Test material was grown with seed collected from more

northerly stands in Alberta and established in transplant beds for four years at Pine Ridge to screen out less winter hardy trees prior to establishing a field planting. Winter hardy seedlings were established in a replicated planting containing white spruce as a 'check'.

A comprehensive review of 21 Siberian larch demonstration and research plantings and 22 Siberian larch operational reforestation plantings is underway. Objectives of the review are to evaluate the suitability of Siberian larch for large scale reforestation projects; identify appropriate areas and site types in Alberta where Siberian larch can be used; and, develop appropriate reforestation policy regarding the use of exotic tree species.

### Provenance Studies

Fifteen year height performance of a Canada range-wide white spruce provenance trial in central Alberta was assessed in 1993. Mean survival and height for the plantation were 80% and 242 cm, respectively. The top ten performing seed sources had mean survival and height of 87% and 298 cm, respectively. The top ten performers included seed sources from Saskatchewan, Manitoba, Ontario and Quebec. Mean survival and height of the two local seed sources were 90% and 258 cm, respectively.

To carry out more detailed field testing of the promising exotic seed sources identified in this trial, three white spruce provenance trials were established in 1993 and 1994. Two additional Canada range-wide seed source trials were also established in 1993 to supplement information gained from the central Alberta trial.

In the early fall of 1993, Interior Douglas-fir (*Pseudotsuga menziesii* var. *glauca*) provenance trials representing eight native Alberta sources established on five ecologically diverse sites were assessed for three year field survival, total height and plant health score. Preliminary results from these trials indicate substantial provenance differences for all three traits. Percent survival and 3-year total height also showed relatively strong clinal relationships with geographic variables. Growth and survival showed a significant ( $P=0.05$ ) inverse correlation. Northern and lower elevation provenances tended to grow faster but exhibited poorer early survival in comparison to southern and higher elevation sources. Site by provenance interactions were significant ( $P=0.05$ ) for percent survival but not for total height or plant health score.

The range of performance for traits by site was also large with the best performance for all three occurring on a site near Rocky Mountain House which was furthest outside the natural range for Douglas-fir. These results indicate significant early provenance and site effects for these traits and the possible opportunity for movement of Douglas-fir outside its natural range, but also the need for careful decisions about deployment on sites both within and outside its natural range.

### Seed Production Studies

A study to monitor the effect of relocation using large tree spades on the growth, flowering and seed production of a white spruce seedling seed orchard and a lodgepole pine seedling seed orchard located at Pine Ridge Forest Nursery was continued. Three years after transplanting, trees in the lodgepole pine seed orchard showed significant reductions in height growth and crown width but not in diameter growth when compared to undisturbed trees. Mean height of the transplanted and undisturbed trees was 4.6 m and 5.0 m, respectively. The transplanted lodgepole pine trees produced significantly more cones than the undisturbed trees. Mean number of cones produced was 158 and 56, respectively, for the transplanted and undisturbed trees. Mean number of seeds per cone was 23 and 16 for transplanted and undisturbed trees, respectively. The same trend in cone production and number of seeds per

cone was observed four years after treatment. The transplanted trees produced an average of 174 cones per tree and 18 seeds per cone compared to 84 cones per tree and 19 seeds per cone for the undisturbed trees. These trends suggest that the use of large tree spades may be an effective cultural treatment to reduce height growth and promote increased cone production in lodgepole pine seedling seed orchards.

Similar results for growth characteristics were observed in the white spruce seedling seed orchard. Transplanting significantly reduced height, crown and diameter growth of the white spruce. Mean heights, crown widths and diameters for the transplanted trees three years after treatment were 4.8 m, 2.7 m and 7.9 cm, respectively, compared to 4.3 m, 2.2 m and 6.8 cm, respectively, for the undisturbed trees. Three years after treatment the white spruce seed orchard experienced a significant cone crop. The transplanted trees produced on the average 207 cones per tree and 25 seeds per cone compared to 98 cones per tree and 23 seeds per cone for the undisturbed trees. Results suggest that transplanting enhances cone production without affecting seed yield.

Fifteen year results were summarized on flowering and seed production monitoring of white spruce grafts of northern Alberta origin, outplanted at four geographically diverse locations in British Columbia and Alberta. The study corroborated earlier results that indicate that Pine Ridge Forest Nursery and the Grande Prairie seed orchard sites are suitable for establishing grafted white spruce seed orchards. Results indicate that commercial cone crops can be expected at these sites every five to six years.

Grafts from early flowering white spruce trees grown under an accelerated growth rearing regime were established in a seed production study. Forty-eight grafts from three clones were established in the trial. Scions were collected from three white spruce trees in an experimental seed orchard established in 1980 with 1-year old stock grown under 24-hour lights and given high rates of macro-nutrients. These trees began producing significant numbers of female flowers at 4 years of age.

In 1992, work commenced on developing an ocular flower/cone production rating system for white spruce and lodgepole pine seed orchards in Alberta. The objective of the system is to provide seed orchard managers with a reliable tool to predict flower and cone crops. Analysis of data has shown that the ocular system consistently underestimates realized cone crops. The system is being reviewed to decide if it can be modified to become a practical tool for seed orchard managers to reliably estimate flower and cone crops.

Over the past three years there has been a significant increase in interest shown by the forest industry in Alberta for the use of native black spruce for operational reforestation in Alberta. A seed production monitoring program has been set up to develop information on the early flowering and seed production characteristics of black spruce grafts in managed seed orchards. Information will be used to plan and manage black spruce seed orchards being established and/or expanded.

#### Grafting Program

In 1994, a study was initiated to delineate patterns of graft incompatibility in a Scots pine seed orchard. The grafts are between 5- and 8-years from time of grafting and show needle chlorosis and stunting, differential growth of scion and rootstock at the graft union, abundant flowering and insect infestations. Clonal differences in incompatibility will be investigated.

## PLANT PROPAGATION, WOOD AND SEED TECHNOLOGY

### Plant Propagation

During the report period stock production consisted of 15,994 seedlings for rootstock utilization, 8,497 coniferous and hardwood seedlings for experimental trials and 5,347 grafts.

A total of 441 white spruce secondary grafts and 842 white spruce grafts from new selections were completed in 1994. A 71% success rate and a 54% success rate respectively were achieved. With an 83% success rate, 337 lodgepole pine grafts were completed. Other species grafted included 419 black spruce and 40 Scots pine. Use of an artificial cold hardening period was implemented on an operational scale in 1994. A reduction of the time required to produce grafts for outplanting is achieved by introduction of a second growth cycle in a 12-month period.

In 1994, a total of 1,297 hardwood seedlings were produced for supply to Alberta Pacific Forest Industries. These seedlings were grown from seed from 27 balsam poplar (*Populus balsamifera*), 7 trembling aspen (*Populus tremuloides*), and 48 cottonwood (*Populus deltoides* var. *occidentalis*) seedlots.

In 1995, a total of 7,200 seedlings were produced for a Siberian larch provenance/progeny trial. These seedlings were produced from seed collected in 1990 in Charga, Southern Siberia.

### Wood Technology

Relative density and fibre length measurements of wood samples collected from selected parent trees continued. Species tested were white spruce, lodgepole pine, black spruce, jack pine, tamarack and willow (*Salix*). A total of 356 relative density and 335 fibre length assessments were completed. Based on the recommendation of Dr. Lars Bach from the Alberta Research Council, an additional 461 fibre length assessments were completed on the 77-80 age bracket for wood samples received prior to 1993.

### Seed Technology

A total of 120 seedlots were added to the genetics seed bank. Of these seedlots, 51% were white spruce, 18% were lodgepole pine, and 29% were black spruce. The seedbank presently contains 3,735 seedlots.

Quality of seedbank seedlots continues to be monitored annually by testing a set of reference seedlots representing about 2% of seedbank entries. New seedlots are added to the testing program every few years to replace depleted seedlots and sample new seedbank entries. Mean germination of lodgepole pine seedlots in the seedbank has declined from 87 percent in 1981 to 83% in 1995 and mean germination of white spruce seedlots has declined from 91% in 1981 to 85% in 1994. Mean germination of aspen, plains cottonwood, and balsam poplar, has declined 5 to 16% after 4 years of testing.

The ultra-low temperature seed storage study started cooperatively with the National Tree Seed Centre at Petawawa, is now in its 7th year. Average germination for white spruce after 7 years storage at -80°C was found to be 79 percent compared to a baseline mean germination of 82% at commencement. For lodgepole pine, mean germination at -80°C storage was 87% compared to an average baseline germination of 84% at -20°C storage. The study is considered complete after 7 years of testing and results indicate that -80°C storage temperature does not offer any advantage over conventional -20°C storage.

# QUANTITATIVE AND POPULATION GENETICS, APPLIED TREE BREEDING AND IMPROVEMENT AT THE UNIVERSITY OF ALBERTA

Francis C. Yeh, Rongcai Yang and Associates

Department of Renewable Resources  
University of Alberta  
Edmonton, Alberta  
T6G 2H1

**Keywords:** Quantitative and population genetics, genomic mapping, early selection, applied tree breeding and improvement, isozyme, RAPD and quantitative trait.

During the past two years, our research continued with theoretical and experimental investigations of population genetic structure in lodgepole pine (*Pinus contorta* Dougl.) and trembling aspen (*Populus tremuloides* Michx.), and retrospective early genetic evaluation and selection in lodgepole pine and jack pine (*P. banksiana* Lamb.). The scope of our research has also extended to include *Cunninghamia lanceolata* Lamb. from People's Republic of China (Yeh *et al.* 1994), *Pterocarpus macrocarpus* Kurz. from Thailand (Liengsiri *et al.* 1995) and *Picea sylvestris* L. from Sweden (Yazdani *et al.* 1995). We also initiated new studies of western gall rust (*Endocronartium harknessii* (J.P. Moore) Y. Hiratsuka) to investigate geographic variation, resistance breeding, host-fungus interaction and QTL.

## GENETIC STRUCTURE AS REVEALED BY ISOZYMES, RAPDS AND QUANTITATIVE TRAITS

A major focus was on developing the genetic framework for studying "multilocus genetic structure" at isozyme loci (Yang and Yeh 1993; Yeh *et al.* 1994). We found multilocus genetic structure was extensive in natural populations and the estimates of multilocus population differentiation were on average, more than three times the single-locus estimates at isozyme loci. Results suggests that population subdivision, founder effect, occurrence across diverse environments and historical events were contributing factors in the generation and maintenance of multilocus genetic structure.

The use of random amplified polymorphic DNA (RAPD) in trembling aspen from 8 populations in Alberta proved useful for studying nucleotide divergence between populations (Chong *et al.* 1994) and genetic structure (Yeh *et al.* 1995). We could differentiate among all trees in any population from their multi-band RAPD phenotypes amplified with 5 random primers. Shannon's phenotypic diversity index ranged between 0.58 and 0.69, averaging 0.65. Analysis of molecular variance showed the among-population component accounted for 2.6% of the variation and significantly different from zero at the 2% level of probability. This is identical to the 3% among-population differentiation at isozyme loci (Jelinski and Cheliak (1992). Isolation by distance might have been an important factor in the genetic differentiation of this clonal angiosperm. Agreement between patterns of population structure revealed by isozymes and RAPDs in trembling aspen from Alberta might suggest that neutral forces were likely to be invoked than selection to explain the maintenance of genetic variation.

We developed *F*-statistics for quantitative traits to estimate population differentiation and completed a comparative study of genetic structure of lodgepole pine using both quantitative traits and isozymes (Yang *et al.* 1995). Two of 6 quantitative traits were neutral

and the remaining 4 were under divergent selection. In contrast, all 19 isozymes tested neutral. This suggests that it is important to choose judiciously among the available markers for assessing diversity and genetic structure.

## APPLIED TREE BREEDING AND IMPROVEMENT

We conducted collaborative research on genetics and breeding of lodgepole pine with the Alberta Land and Forest Service and the Alberta Tree Improvement Cooperative and on genetics and breeding of jack pine with Northern Forestry Centre, Forestry Canada. Retrospective early testing and selection, multiple trait index selection, geographic variation and host-fungus interaction in western gall rust (WGR) incidence, and mapping for WGR resistant genes have been major components of our studies.

### Retrospective Early Testing And Selection

We reported the pattern of genetic variation among seedling traits in the greenhouse for two growth periods (Wu *et al.* 1995a). We completed the theoretical framework and experimental verification on genetic gains due to retrospective early selection under three selection schemes: (1) early selection for tree field traits based on single seedling traits, (2) early selection for tree field traits based on multiple seedling traits and (3) index selection combining early seedling and tree field traits (Wu *et al.* 1995b). We also examined the effect of GE interaction on greenhouse-field correlations in retrospective studies (Wu *et al.* 1995c; Lu 1995). Our results in lodgepole and jack pine suggested that, growing seedlings under carefully designed greenhouse conditions (*e.g.*, large number of families, effective experimental layout on greenhouse benches, seed weight adjustment, selection of target early traits, use of suitable genetic and statistical equations, and the possible mimicking of field [nutrient/moisture] conditions) allowed retrospective test to be an effective tree improvement tool. Collaborative research with Dr. R.P. Pharis showed that gibberellin class of hormones were useful early traits for indirect selection of field growth.

Early testing also facilitated the study of genetic variation in traits of total biomass partitioning (stem, branch, needle and root) and architecture (harvest index, shoot-root biomass ratio and sturdiness quotient) in a large number lodgepole pine families (Wu and Yeh 1995). Levels of heritability and genetic correlation suggest that selection procedures that exploit additive genetic variance and covariance might be practiced.

### Western Gall Rust Resistance

Geographic variation in WGR isolates across British Columbia, Alberta, Saskatchewan, Manitoba and Ontario suggested host (lodgepole and jack pine) specificity as revealed by RAPDs (Li *et al.* 1995). We also initiated a half-sib QTL analysis using RAPDs to identify host (lodgepole pine) loci involved in WGR resistance. We believe future breeding for WGR resistance will be more efficient using known RAPDs to select and track resistant genotypes because size of breeding population will be made small and pedigree for resistance will advance at a faster rate.

## ACKNOWLEDGMENTS

We thank Drs. N.K. Dhir, J. Klein and Y. Hiratsuka for collaboration and advice, and the Natural Sciences and Engineering Research Council of Canada, Canada/Saskatchewan Partnership Program in Forestry, Canada/Alberta Partnership Program in Forestry, Centre For

International Forestry, Petawawa National Forestry Institute and Alberta Environment Protection for financial support.

#### PUBLICATIONS & REFERENCES

- Chong, D.K.X., Yeh, F.C., Aravanopoulos, F.A. and Zsuffa, L. 1995. DNA fingerprinting of *Salix* L. by polymerase chain reaction with the M13 universal primer. *Scan. J. For. Res.* 10:27-31.
- Chong, D.K.X., C.C., Yeh, F.C. and Chuong, S. 1994. Chloroplast DNA inheritance in the *stellaria longipes* complex (Caryophyllaceae). *Theor. Appl. Genet.* 88:614-618.
- Chong, D.K.X., Yang, R.C. and Yeh, F.C. 1994. Nucleotide divergence between populations of trembling aspen (*Populus tremuloides*) estimated with RAPDs. *Current Genetics* 26:374-376.
- Jelinski, D.E. and Cheliak, W.M. 1992. Genetic diversity and spatial subdivision of *Populus tremuloides* (Salicaceae) in a heterogeneous landscape. *Am. J. Bot.* 79:728-736.
- Li, C.X., Yeh, F.C. and Hiratsuka, Y. 1995. Geographic variation among isolates of western gall rust (*Endocronartium harknessii* (J.P. Moore) Y. Hiratsuka) as revealed by random amplified polymorphic DNA. (In Review).
- Liengsiri, C., Yeh, F.C. and Boyle, T.J.B. 1995. Genetic structure of a tropical tree, *Pterocarpus macrocarpus* Kurz. from Thailand. *For. Ecol. & Manage.* (In Press).
- Lu, P.X. 1995. Genetic response of jack pine seedlings to nutrient and water treatments: Implications for early genetic evaluation. M.Sc Thesis, University of Alberta. 119 pages.
- Wu, H.X.M. and Yeh, F.C. 1995. Genetic effect on biomass partition and breeding for tree architecture in *Pinus contorta* spp. *latifolia* from central Alberta. *For. Sci.* (In Press)
- Wu, H.X.M., Yeh, F.C., Pharis, R.P., Dancik, B.P., Jiang, I.B.J., Dymock, I. and Dhir, N.K. 1995a. Genetic parameters among traits of growth, bud, branch and biomass in *Pinus contorta* spp. *latifolia* from central Alberta. *Scan. J. For. Res.* 10:12-21.
- Wu, H.X.M., Yeh, F.C., Pharis, R.P., Dhir, N.K. and Dancik, B.P. 1995b Retrospective Study In Lodgepole Pine (*Pinus Contorta* Dougl. var. *Latifolia* Engelm.) From Alberta. (In Review).
- Wu, H.X.M., Yeh, F.C., Dhir, N.K., Pharis, R.P. and Dancik, B.P. 1995c. Genotype-by-environment interaction and genetic correlation of greenhouse and early field performance of lodgepole pine. (In Review).
- Yang, R.C. and Yeh, F.C. 1993. Multilocus structure in *Pinus contorta* Dougl. *Theor. Appl. Genet.* 87: 568- 576.
- Yang, R.C., Yeh, F.C. and Yanchuk, A. 1995. Genetic structure of *Pinus contorta* spp. *latifolia* as revealed by isozymes and quantitative traits. (In Review).
- Yazdani, R., Yeh, F.C. and Rimsha, J. 1995. Genomic mapping of *Pinus sylvestris* (L.) Using random amplified polymorphic DNA. *For. Genet.* (In Review).

- Yeh, F.C., Shi, J.S., Yang, R.C., Hong, J.S. and Ye, Z.H. 1994. Genetic diversity and multilocus associations in *Cunninghamia Lanceolata* (Lamb.) Hook from People's Republic of China. *Theor. Appl. Genet.* 88:465-471.
- Yeh, F.C., Chong, D.K.X. and Yang, R.C. 1995. RAPD variation within and among natural populations of trembling aspen (*Populus tremuloides* Michx.) From Alberta. *J. Heredity* (In Press).

## PFRA SHELTERBELT CENTRE - TREE IMPROVEMENT SUMMARY

W.R. (Bill) Schroeder

Shelterbelt Centre, PFRA  
Agriculture and Agri-Food Canada  
Indian Head, Saskatchewan  
S0G 2K0

**Keywords:** shelterbelt, windbreak, progeny test, seed orchard, provenance test.

The primary objectives of the tree improvement programme at the PFRA Shelterbelt Centre is to develop genetically superior trees and shrubs for shelterbelt and agroforestry planting in the prairie provinces of western Canada. From 1991 to 1993 the programme has focused on poplar (*Populus* spp.), Scots pine (*Pinus sylvestris* L.), Siberian larch (*Larix sibirica* Ledeb.), green ash (*Fraxinus pennsylvanica* Marsh. var. *subintegerrima* (Vahl.) Fern.), bur oak (*Quercus macrocarpa* Michx.) and choke cherry (*Prunus virginiana* var. *melanocarpa* (A. Nells.) Sarg.

### SCOTS PINE

Two full-sib and four half-sib progeny tests were evaluated in 1994. Three superior families with superior form, colour and density were identified. These families are being used for production of Christmas tree in the prairies. Progeny tests were established in multi-row forestbelts. The performance of families for forestry applications will be investigated. All Scots pine seed grown for shelterbelt and agroforestry plantings in 1995 originates from a one hectare seedling seed orchard located at the Shelterbelt Centre. This orchard provides the prairie tree planters with fast growing, drought tolerant Scots pine with minimal winter browning.

### SIBERIAN LARCH

Three larch species trials were evaluated in 1994. Data showed that Siberian larch was well adapted to prairie growing conditions. Other larch species, including *Larix eurolepis*, *Larix gmelinii* and *Larix olgensis* were not as well adapted. Roguing of a 1987 clonal seed orchard was completed. This seed source has proven to be superior to other sources tested. This source establishes easily and has superior growth and form.

### GREEN ASH

Collections of green ash seed from xeric habitats in the northern Great Plains have been completed. A total of 30 populations have been sampled. Seedlings are being propagated for outplanting in 1996. The sources will be utilized for drought tolerance screening. This is a co-operative project with the USDA Forest Service at Lincoln, Nebraska.

A three hectare first generation clonal seed orchard has been completed. The orchard will be coming into production within the next two to three years. Progeny tests

initiated in 1989 were evaluated in 1993. Superior families were identified and data collected is being used to rogue the seed orchard.

#### POPLAR

The native population of plains cottonwood in southern Saskatchewan was sampled in 1994. Seed and cuttings were collected from 15 populations in the Saskatchewan River Valley. Seed is being propagated for progeny testing and cutting beds of superior trees have been established.

In 1995, a new female poplar *P. x 'CanAm'* selected from an open pollinated population of *P. x 'Walker'* was introduced for planting in the northern Great Plains. 'CanAm' was released co-operatively with the USDA, Agriculture Research Service and the USDA, Natural Resources Conservation Service. 'CanAm' is a vigorous tree with superior drought resistance.

#### BUR OAK

In 1993, range-wide provenance tests of bur oak were planted at two sites in Saskatchewan and one in Manitoba in 1993. Sixty families are included in the test. This is a co-operative project with the USDA, Forest Service, USDA Agriculture Research Service, and USDA, Soil Conservation Service. Objectives of the project are to: 1.) determine the nature and extent of genetic variation present among open-pollinated progenies of bur oak from selected sources in the Great Plains; 2.) identify best adapted sources of bur oak for planting in the Great Plains; and 3.) provide germplasm that can be used for selection and trait improvement as well as advanced generation breeding.

#### CHOKE CHERRY

The native range of choke cherry in Manitoba and Saskatchewan was sampled in 1993 and 1994. A total of 175 population were collected. Germplasm is being propagated for provenance testing in 1996. Protocols for micropropagation of superior plants were streamlined.

#### NATIVE PLANT COLLECTIONS

Assembly of native woody plant germplasm is under way. This project focuses on the collection and genetic improvement of native shrub seed sources for use in conservation tree plantings. Seventeen different species have been collected with emphasis placed on silver buffaloberry, round-leaved hawthorn, snowberry, Wood's rose, and highbush cranberry. In 1993 and 1994 over 350 accessions were collected.

#### PUBLICATIONS

Schroeder, W.R. and Walker, D.S. 1993. Propagation projects. Annual Report, PFRA Shelterbelt Centre, Agric. Canada, Indian Head, Sask. p. 6-19.

Schroeder, W.R. 1993. International plant material directory. Proc. 4th Int. Symp. Windbreaks and Agroforestry. Viborg, Denmark. p.79-85.

Schroeder, W.R. 1994. Genetic improvement for prairie tree plantings. *J. Arboric.* 20(1):46-49.

Schroeder, W.R. and Walker, D.S. 1994. Propagation projects. Annual Report, PFRA Shelterbelt Centre, Agric. Canada, Indian Head, Sask. (in press).

AGRICULTURE AND AGRI-FOOD CANADA, MORDEN RESEARCH  
STATION TREE IMPROVEMENT REPORT

C.G. Davidson, R.D. Browne, S. Gobin , R.J. Enns and L. Dyck

AAFC-Morden Research Centre  
Unit 100-101-Route 100  
Morden, MB  
R6M 1Y5

**Keywords:** *Populus, Acer, Tilia, Fraxinus, Betula*, shrubs, genetic resources, jack pine, *Pinus banksiana*, asexual propagation, rooted cuttings

The primary goal of the Morden tree improvement program is the development of superior hardy plants for the landscape industry in prairie Canada. A diversity of species of both trees and shrubs are involved in the various projects.

POPLAR (*Populus*)

Goal

Development of superior fast growing, cold tolerant and disease resistant clones.

Progress

Approximately 30 selections have been made over the last three years. These include both inter-specific and intra-specific hybrids. Selected populations were approximately 20 years old and near mature size.

ASH (*Fraxinus*)

Goal

Development of new inter-specific hybrids and the selection of superior green and white ash clones.

Progress

Two new hybrids between black and Manchurian ash will be introduced to the commercial industry this season. Both are very hardy and have superior growth rates and form. Both hybrids are perfect flowered, unlike either parent. A population of white ash seedlings are being screened using a ultra-low temperature freezer with the goal of identifying individuals with good cold tolerance. Green ash seedling populations are being evaluated for growth and resistance to ash plant bug.

### BIRCH (*Betula*)

#### Goal

To identify sources of resistance to bronze birch borer.

#### Progress

A second generation of seedlings derived from putatively resistant parental material was sown and will be field planted for further study. Parental lines have been propagated and will be evaluated further under different environmental conditions.

### LINDEN (*Tilia*)

#### Goal

To develop superior inter-specific hybrids adapted to prairie growing conditions.

#### Progress

A little leaf linden has been selected as a maternal parent based on seed germination testing. Controlled crossing using a diversity of other *Tilia* species is underway.

### MAPLE (*Acer*)

#### Goal

To select superior Red maple and hybrids between Red and Silver maple for prairie growing conditions.

#### Progress

Controlled crossing between *Acer* species is underway with *in vitro* embryo rescue techniques being deployed. Success to date has been limited.

### OTHER SPECIES

A wide range of shrubby species including *Rosa*, *Potentilla*, *Ribes*, *Amelanchier*, *Philadelphus*, *Weigela* are being developed for landscape potential. A wide range of characteristics are being evaluated but cold tolerance is a principal issue in all studies.

### GENETIC RESOURCES

The Morden Research Centre has been identified as a "node" on the Agriculture and Agri-Food Canada genetic conservation network. Hardy landscape plants in the Morden arboretum are part of this program.

## MANAGEMENT RELATED STUDIES

Goal

Asexual propagation of jack pine for application in tree improvement programs.

Progress

Research activities have focussed on developing procedures for operational asexual propagation of jack pine (*Pinus banksiana* Lamb.). A more detailed summary of results appears elsewhere in this proceeding and two abstracts are presented in the poster section. Methodology for rooting jack pine long shoots cuttings has been developed which has yielded rooting frequencies of 80-100% for cuttings from plant < 3 years old, 40-60% from plants 4-6 years old and 20-40% from plants 7-10 years old. Investigations into strategies for improving shoot multiplication and rooting frequencies has involved induction of proliferated dwarf shoots through pruning and cytokinin treatments and the *in vitro* culture of cotyledons from germinating seedlings. Using these approaches, targeted goals for operational propagation are expected to be met. Furthermore, field trials are underway to assess performance of rooted cuttings. Additional field trials will be planted in 1996 and 1997. An operational manual outlining key features for asexual propagation of jack pine is under preparation and should be available by April 1996. Financial support from the Canada-Manitoba Partnership Agreements in Forestry is gratefully acknowledged. The authors also appreciate cooperation and support provided by Mr. John Dojack (Manitoba Department of Natural Resources) and Ms. Dianne Roddy (Weyerhaeuser Canada Ltd.).

## MANITOBA'S TREE IMPROVEMENT PROGRAMME

J. Dojack  
G. Falk

Manitoba Forestry Branch  
300-530 Kenaston Blvd.  
Winnipeg, Manitoba  
R3N 1Z4

**Keywords:** Jack pine, black spruce, white spruce, seed orchard, co-operative.

The tree improvement programmes established for jack pine (*Pinus banksiana* Lamb.), black spruce (*Picea mariana* (Mill.) B.S.P.) and white spruce (*Picea glauca* (Moench) Voss) are being managed through the co-operatives with Repap Manitoba, Pine Falls Paper Company and Canadian Forest Service. This report highlights the progress which occurred from 1993-1995.

### JACK PINE

The Hillside Pedigree Orchard was expanded in 1994 with the addition of 1,312 seedlings of 18 full sib. families. The first cone crop was harvested from the initial orchard in the fall of 1994 producing 2.9 kg seed.

A second 50% roguing was completed at the Interlake jack pine mass selection seed orchard (MSSO) in 1994. A third 50% roguing was completed at the Cranberry Portage MSSO also in 1994. In 1995 a third 50% roguing is planned for the Root Lake MSSO and a fourth and final roguing at the Simonhouse orchard.

### BLACK SPRUCE

In June of 1994 a 7.0 hectare seedling seed orchard was established in the Nelson River breeding zone in co-operation with Repap Manitoba.

An ongoing maintenance programme on existing family tests and seed orchards is being undertaken with members of the co-operatives.

### WHITE SPRUCE

Due to budgetary restraints, a change in strategy from a container seed orchard program for the Saskatchewan River Breeding Zone to a soil based clonal orchard planted in June, 1995, was undertaken.

Height measurements were taken, five years after planting, on 2 family tests in the Mountain Breeding Zone.

## SUMMARY

The current tree improvement programmes are progressing well. The past experience of working within co-operatives has been very positive. "Memorandums of Understanding" have been prepared to enter into new co-operatives in breeding zones where harvesting will increase.

## TREE IMPROVEMENT UNDER THE CANADA-MANITOBA PARTNERSHIP AGREEMENT IN FORESTRY

J.I. Klein

Natural Resources Canada  
Canadian Forest Service  
Winnipeg, Manitoba  
R3C 1A6

**Keywords:** *Pinus banksiana*, jack pine, seed orchards, mass selection, Best Linear Prediction, stem quality, western gall rust, wood density.

Forest genetics by the Canadian Forest Service in the prairie provinces started about 1960, but the earliest project that is still active is the jack pine (*Pinus banksiana* Lamb.) breeding programme for parts of Manitoba and Saskatchewan, which began in 1967. From 1970, when the former Winnipeg centre closed, until 1991, forest genetics staff were located in Edmonton. Family test and clone bank plantations were established for the breeding programme from 1972 to 1977, as were provenance test plantations for jack pine and black spruce (*Picea mariana* (Mill.) B.S.P.). Breeding program results supported establishment of a jack pine seed orchard programme in Winnipeg under the Canada-Manitoba Forest Renewal Agreement of 1984-89. When the Canada-Manitoba Partnership Agreement in Forestry (CMPAIF) began in 1991, forest genetics staff were relocated to Manitoba District Office.

The CMPAIF tree improvement programme was intended to assist the Province of Manitoba in gaining independent tree improvement capability, while maintaining the ability to respond to opportunities in the other prairie provinces, and to capture forest genetics knowledge available from the region's test plantation assets. Programme activities are intended to (1) continue establishment and development of jack pine seed orchards, (2) develop more efficient delivery of genetic improvement, especially by controlled pollination and vegetative propagation, and (3) initiate a second generation of jack pine breeding.

The Canadian Forest Service forest genetics programme in this region will end in 1996.

### JACK PINE SEED ORCHARDS

Development of the Northern and Interlake mass selection seed orchards by Manitoba Forestry Branch continued. By 1998, plots planted with 48 or 25 trees from one stand at 1-m spacing in 1986 and 1987 will have been thinned in four mass selection steps to 1-3 trees, and harvesting of cone crops will begin. Tree pair measurements taken at each thinning are showing a useful amount of genetic variation among the 32 source stands for each seed orchard, and a substantial phenotypic effect of mass selection. A plan has been drafted for genetic quality verification and second-generation breeding following completion of mass selection.

The Hillside Road jack pine seed orchard comprises 6 ha planted in 1988 with first-cousin progenies and a 4-ha expansion area planted in 1994 with full-sib progenies. All of the parent trees were in family test plantations, mated in 1985 after selection on 10-year measurements (Klein 1986), or in 1992 after selection on 15-year measurements (Klein 1992). Both

sets of progenies were rescored based on breeding values of height, dbh, stem quality, resistance to western gall rust, and wood density at 20–21 years, estimated by Best Linear Prediction (BLP). The new scores are being used for genetic upgrading of the seed orchard. Four 1988 entries with the lowest scores of the 18 planted were replaced by 1992 progenies to accomplish the first step. Planting of grafts of high-scoring family test trees unrelated to any of the progeny entries, in the expansion area, will complete the upgrade. Most of the required grafts are now on hand. The first cone crop was harvested in 1993, with relatively balanced contributions from the 14 entries planted in 1988.

#### APPLIED TREE IMPROVEMENT RESEARCH

Gain capture from superior jack pine genotypes by controlled pollination offers the prospect of greater genetic control and flexibility compared with reliance on wind pollination. Early results from trials of crown shaping and nitrogen fertilization suggest that sufficient numbers of seed cone flowers might be produced on trees kept under 2 m in height, while pollen production on these trees is suppressed by high doses of nitrogen. That outcome would improve prospects for relatively efficient controlled mating. A research contract conducted by Morden Research Station, Agriculture and Agri-Food Canada has come close to achieving a system for vegetative multiplication of control-pollinated jack pine seedlots.

Results from all CMPAIF tree improvement experiments, including flowering response to crown shaping and nitrogen fertilization, quantification of realized gain, a retrospective progeny test (all of these with jack pine), and cultural treatments to enhance early growth of black spruce seed orchard seedlings, will be reported in the coming year.

#### SECOND GENERATION BREEDING OF JACK PINE

Selection of candidate parents has been completed for the second generation of the eastern breeding district jack pine breeding program, using BLP based on family test performance to 21 years from planting. The best 64 unrelated trees had a mean predicted gain of 18% for wood dry weight, and 10% for stem quality and resistance to western gall rust (*Endocronartium harknessii* (J. P. Moore) Y. Hiratsuka) (Klein 1995). A draft breeding plan is under consideration by Manitoba Forestry Branch. Matings to produce second generation progenies will be performed on grafts of 116 candidate parents, most of which are now growing in containers.

#### PUBLICATIONS AND REFERENCES

- Klein, J.I. 1986. Selection and mating of family-test trees for a jack pine seed orchard. *In Proc. IUFRO Joint Meetg. Working Parties on Breeding Theory, Progeny Testing, and Seed Orchards*, Oct. 1986, Williamsburg, VA., U.S.A. *Edited by* A.V. Hatcher and R. J. Weir. pp. 521-526.
- Klein, J.I. 1992. Selection and mating of jack pine family test trees to produce seed orchard progenies for Saskatchewan and Manitoba. *Forestry Canada, Winnipeg, Manitoba and Canada-Manitoba Partnership Agreement in Forestry*.
- Klein, J.I. 1993. Tree improvement under the Canada-Manitoba Partnership Agreement in Forestry. *In Proc. 24th Meetg. Can. Tree Improve. Assoc.*, Aug. 15–19, 1993, Fredericton, New Brunswick. *Edited by* J. Lavereau. Natural Resources Canada, Chalk River, Ontario. Part 1, pp. 111–113.

## CONE AND SEED PEST MANAGEMENT

Peter de Groot

Canadian Forest Service - Sault Ste. Marie  
P.O. Box 490  
Sault Ste. Marie, Ontario  
P6A 5M7

**Keywords:** Seed orchards, insects, pest management, monitoring and decision tools.

This report outlines my activities in seed orchard pest management from 1993-95.

### CONE AND SEED PEST MANAGEMENT

Studies to develop a pheromone-based pest management system for cone beetles, *Conophthorus* spp., centered around the development of a practical and easy-to-use trap and bait system. The effects of trap type, lure type and dosage, trap colour and height, and the use of monoterpenes were investigated. Manuscripts describing these studies are in preparation and should be published within the next reporting period. The chemical identification of the pheromones and the results from earlier work were published (Birgersson et al. 1995; Pierce et al. 1995). A life history study of the white pine cone borer, *Eucosma tocullionana* Heinrich, was completed and the manuscripts are in preparation. A life table study of jack pine cones was published (de Groot and Fleming 1994). Reviews of cone and seed insects, their management and monitoring were published (de Groot 1994; de Groot 1995a; de Groot 1995b, de Groot et al. 1994; Turgeon et al. 1994).

### CONE CROP MONITORING AND DECISION SUPPORT SYSTEM

A Cone Crop Monitoring System (CCMS), Information Management System (IMS) and the Decision Support System (DSS) were developed for seed orchard management. The CCMS collects and processes data on the size of the cone crop and expected damage. The IMS provides information on the damage potential of insect pests, pest control products registered in Canada for cone and seed insects, and estimates the efficacy of the products. The DSS uses this data and information and asks the user for additional information about protection costs and seed values to calculate the consequences of various decisions. Although developed specifically for use in jack pine and black spruce seed orchards in Ontario, many of the procedures and much of the information are applicable to conifer seed orchards in most of North America. A user manual that provides step-by-step instructions on the use of the systems on IBM compatible PCs and a field data logger, and a copy of the software (DOS-based), will be available in late 1995 or early 1996.

## PUBLICATIONS

- Birgersson, G.O., G.L. DeBarr, P. de Groot, M.J. Dalusky, H.D. Pierce, J.H. Borden, H. Meyer, W. Francke, K. Espelie, and C.W. Berisford. 1995. Pheromones in the white pine cone beetle, *Conophthorus coniperda* (Schwarz) (Coleoptera: Scolytidae). *J. Chem. Ecol.* 21: 143-167.
- de Groot, P. and R.A. Fleming. 1994. Analysis and modeling of cohort life tables of jack pine seed cones. *Can J. For. Res.* 24: 1579-1592.
- de Groot, P., J.J. Turgeon and G.E. Miller. 1994. Management of cone and seed insects in Canada. *For. Chron.* 70: 745-761.
- de Groot, P. 1994. Monitoring cone crops in jack pine seed orchards: why bother? pp. 51-58. *In* JJ Turgeon and P. de Groot, editors, *Proc. of Integrated Pest Management of Cone and Seed Insects*, Sault Ste. Marie, Ontario, September 1993. *Can. For. Serv., Inf. Rep. FPM-X-89.*
- de Groot, P. 1995a. Pheromone-based pest management in seed orchards in Canada. pp 50-54 *In* Research, development and commercialization of semiochemicals in insect pest management in Canada. *Proc. Workshop held in conjunction with the annual meetings of the entomological societies of Manitoba and Canada, October, 1994.*
- de Groot, P. 1995b. Integrating biological control into seed orchard pest management: A perspective about the future. *In*. *Proc. 4th IUFRO conference of the Cone and Seed Working Party, S2.07-01. Beijing, China (in press).*
- Pierce, H.D., P. de Groot, J.H. Borden, S. Ramaswamy and A.C. Oehlschlager. 1995. Pheromones in the red pine cone beetle, *Conophthorus resinosae* Hopkins, and its synonym, *C. banksianae* McPherson (Coleoptera: Scolytidae). *J. Chem. Ecol.* 21: 169-185.
- Turgeon, J.J, A. Roques and P. de Groot. 1994. Insect Fauna of coniferous seed cones: Diversity, host plant interactions and management. *Annu. Rev. Entomol.* 39: 179-212.

## POLLEN CONTAMINATION REDUCTION SOFTWARE

**Franco Di-Giovanni**

**76 Ptarmigan Drive  
Guelph, Ontario  
N1C 1B6**

**Phone: 519-821-5608**

**Fax: 519-821-3568**

**Keywords:** pollen dispersal, pollen contamination, seed orchards, *Picea mariana*, *Pinus banksiana*.

Joint (University of Guelph, Environment Canada and Ontario Ministry of Natural Resources [OMNR]) pollen dispersal studies have been on-going at the Island Lake seed orchard, near Chapleau, Ontario since 1989. These studies were completed in 1994 and have resulted in the production of computer software that can be used to manage pollen contamination at any seed orchard (POLDISP v.1.0).

The software is based on a Lagrangian Markov-chain atmospheric dispersal model which was modified to simulate the dispersal of contaminant pollen from the surrounding natural stand into the Island Lake seed orchard. Pollen diffusion in the atmosphere, impaction on tree branches and receptive seed cones and deposition to the ground are all included in the model.

Model inputs, including physical and vegetation data and meteorological data, were collected at Island Lake during the pollination season for *Picea mariana* and *Pinus banksiana* in 1992 and 1993. These specific input data were used with the model to predict pollen dispersal at that site. Predicted pollen dispersal was compared to the measured dispersal of artificially released and natural pollen. Model predictions and measured dispersal agreed reasonably well providing a validation of the model at the Island Lake site.

The model was incorporated into an interactive program shell which can be used to examine strategies which reduce pollen contamination at other orchards. In order to use the model at other orchards, the model inputs were generalised; thus, the generalised model should be tested at a site other than the original. Discussions are on-going with OMNR to that end.

Where pre-existing contamination problems have been identified at a seed orchard, the software will predict the relative effectiveness of different, physical, anti-contamination scenarios envisioned by the seed orchard manager. These physical anti-contamination scenarios may be the establishment of buffer zones of varying width, or the establishment of wind breaks (to provide pollen filtration) of any particular configuration. The project final report is available, and the software and user manual are available at the discretion of the OMNR from Randy Ford (Phone: 705-567-3372).

Other publications have resulted as spin-off's from this work:

Di-Giovanni, F., Kevan, P.G. and Nasr, M.E. 1995. Settling velocities of some pollen and spores and their variability. *Grana* 34: 39-44.