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CENTRE CANADIEN SUR LA FIBRE DE BOIS

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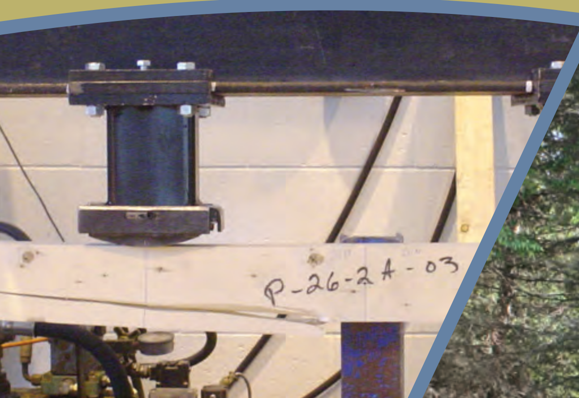

Annotated Bibliography on the Impact of Silviculture and Management on Wood Fibre Attributes for Eight Major Canadian Commercial Tree Species

Bibliographie annotée sur les répercussions de la sylviculture et de l'aménagement sur les caractéristiques de la fibre ligneuse de huit essences commerciales canadiennes importantes

D. Edwin Swift, Anne LeBrun Ruff, Cheryl Leger, Gavin Comeau,
Isabelle Duchesne, and Julia MacKenzie

Canada

The Canadian Wood Fibre Centre brings together forest sector researchers to develop solutions for the Canadian forest sector's wood fibre related industries in an environmentally responsible manner. Its mission is to create innovative knowledge to expand the economic opportunities for the forest sector to benefit from Canadian wood fibre. The Canadian Wood Fibre Centre operates within the CFS, but under the umbrella of FPInnovations' Board of Directors.

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Additional information on Natural Resources Canada, the Canadian Forest Service, and Canadian Wood Fibre Centre research and publications is also available online at: http://cwfc.nrcan.gc.ca. To download or order additional copies of this publication, see our online bookstore at: http://bookstore.cfs.nrcan.gc.ca.

Le Centre canadien sur la fibre de bois réunit des chercheurs du secteur forestier afin d'élaborer des solutions responsables sur le plan environnemental pour les industries forestières du secteur de la fibre de bois du Canada. Sa mission est de produire des connaissances innovatrices qui accroîtront les débouchés économiques pour que le secteur forestier puisse tirer profit des fibres ligneuses canadiennes. Le Centre canadien sur la fibre de bois fonctionne au sein du Service canadien des forêts, mais sous l'égide du conseil d'administration de FPInnovations.

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ABSTRACT

This annotated bibliography contains 518 citations, mostly of North American and European origin. It focuses on the following eight species of commercial importance in Canada: white spruce (*Picea glauca* (Moench) Voss), black spruce (*Picea mariana* (Mill.) B.S.P.), jack pine (*Pinus banksiana* Lamb.), balsam fir (*Abies balsamea* (L.) Mill.), Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco), lodgepole pine (*Pinus contorta* Dougl.), trembling aspen (*Populus tremuloides* Michx.), and sugar maple (*Acer saccharum* Marsh.). The focus of this research was to determine the impact of silviculture on a selected and key group of fiber attributes for fire-origin and second-growth stands.

RÉSUMÉ

Cette bibliographie annotée contient 518 références essentiellement de l'Amérique du Nord et de l'Europe. Huit espèces d'importance commerciale au Canada ont été examinées : épinette blanche (*Picea glauca* (Moench) Voss), épinette noire (*Picea mariana* (Mill.) B.S.P.), pin gris (*Pinus banksiana* Lamb.), sapin baumier (*Abies balsamea* (L.) Mill.), Douglas vert (*Pseudotsuga menziesii* (Mirb.) Franco), pin tordu (*Pinus contorta* Dougl.), peuplier faux-tremble (*Populus tremuloides* Michx.), et érable à sucre (*Acer saccharum* Marsh.). L'objectif de la recherche était d'établir l'impact de la sylviculture sur une suite clée de caractéristiques des fibres pour les peuplements d'origine après-feu et de seconde venue.

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INTRODUCTION

Historically, the forest industry has been one of the greatest contributors to the Canadian economy; however, recent global market changes have challenged the industry. The Canadian Wood Fibre Centre (CWFC), a division of Natural Resources Canada, was established to create innovative knowledge to expand economic opportunities for the forest sector to benefit from Canadian wood fiber. This annotated bibliography, part of a larger project, identifies key fiber attributes of significant importance to the Canadian forest industry and those that confer a competitive advantage on the global market. It is the first in a series of two annotated bibliographies.

This publication constitutes a synopsis of the existing literature to support the production of a position paper by the CWFC (2010) and to provide researchers within the CWFC with a reference base on the subject matter. It focuses on literature relating to fiber attributes for the following eight commercial species across Canada: white spruce (*Picea glauca* (Moench) Voss), black spruce (*Picea mariana* (Mill.) B.S.P.), jack pine (*Pinus banksiana* Lamb.), balsam fir (*Abies balsamea* (L.) Mill.), Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco), lodgepole pine (*Pinus contorta* Dougl.), trembling aspen (*Populus tremuloides* Michx.), and sugar maple (*Acer saccharum* Marsh.). White spruce, black spruce, jack pine, balsam fir, and trembling aspen were selected because they have some of the widest natural ranges across Canada. The other three species were selected because of their economic importance.

After selecting relevant tree characteristics (i.e., wood density, moisture, knots, taper, decay, fiber length, modulus of elasticity [MOE], modulus of rupture [MOR], and microfibril angle) based on wood-science literature, we made a systematic search of the scientific literature and associated databases. The selected literature pertains to the relationship between wood fiber attributes and major forest products, and the effect and impact of stand development and silvicultural practices on wood fiber attributes.

The annotated bibliography is organized alphabetically according to author and contains 518 references from the literature dating back to 1921. English abstracts are provided for each article; if a French abstract was published with the original article, it is also reproduced here. Indices for tree species and subject matter are provided to facilitate the use of this publication.

Table 1 provides an alphabetical listing of abbreviation codes with corresponding scientific names and English common names of species appearing in bibliography. Table 2 is an alphabetical list of English common names with corresponding abbreviation codes and scientific names of species. Table 3 is an alphabetical listing of French common names with corresponding abbreviation codes and scientific names of species. Original abstracts appear below citations, if we were able to obtain copyright permission. Otherwise, we provide brief descriptions that we wrote specifically for this publication and these are so marked in the text. French abstracts written are included only if provided by the publisher.

INTRODUCTION

L'industrie forestière est historiquement l'un des plus gros contributeurs à l'économie canadienne, mais elle est présentement contestée par l'évolution récente du marché mondial. Le Centre canadien de la fibre de bois (CCFB), une filiale de Ressources naturelles Canada, a été mis en place pour créer un savoir innovateur pour accroître les possibilités économiques permettant au secteur forestier de tirer parti de la fibre ligneuse canadienne. Dans le cadre d'un projet plus vaste, cette bibliographie annotée identifie les principaux attributs de fibres ayant importance considérable pour l'industrie forestière canadienne ainsi que ceux qui confèrent un avantage concurrentiel sur le marché mondial. Cet ouvrage est la première publication d'une série de deux bibliographies annotées.

Les objectifs de cette publication sont de fournir un synopsis de la littérature existante afin d'appuyer la production d'un document de position par le CCFB (2010) et de fournir une base de référence aux chercheurs sur la matière. Cette publication est un recueil de littérature sur les caractéristiques des fibres pour huit espèces commerciales du Canada : épinette blanche (*Picea glauca* (Moench) Voss), épinette noire (*Picea mariana* (Mill.) B.S.P.), pin gris (*Pinus banksiana* Lamb.), sapin baumier (*Abies balsamea* (L.) Mill.), sapin de Douglas (*Pseudotsuga menziesii* (Mirb.) Franco), pin tordu (*Pinus contorta* Dougl.), peuplier faux-tremble (*Populus tremuloides* Michx.) et érable à sucre (*Acer saccharum* Marsh.). L'épinette blanche, l'épinette noire, le pin gris, le sapin baumier et le peuplier faux-tremble ont été choisis parce que ces espèces sont réparties naturellement à travers le Canada. Les trois autres espèces ont été sélectionnées en raison de leur importance économique.

Après avoir établi les caractéristiques des arbres concernés (à savoir, la densité du bois, de l'humidité, les nœuds, le défilement, la pourriture, la longueur des fibres, le module d'élasticité (MOE), le module de rupture (MOR), l'angle des microfibrilles) basées sur la littérature en sciences du bois, une approche de recherche systématique de la littérature scientifique et les bases de données associées a été lancée. Les ouvrages sélectionnés se rapportent à la relation entre les caractéristiques de la fibre de bois et les produits forestiers d'importance, et l'effet et l'impact du développement des peuplements et des pratiques sylvicoles sur les caractéristiques de la fibre de bois.

La bibliographie annotée est organisée par ordre alphabétique des auteurs principaux et contient 518 références provenant de la littérature mondiale datant d'aussi loin que 1921. Un résumé en anglais est fourni pour chaque article mentionné. Si un résumé français a été publié avec l'article original, il est également reproduit ici. Un index des espèces et des sujets est fourni afin de faciliter l'utilisation de cet ouvrage.

Le tableau 1 fournit une liste alphabétique des codes utilisés avec le nom commun anglais et le nom scientifique des espèces figurant dans la bibliographie. Une liste alphabétique des noms communs anglais avec les codes correspondants et les noms scientifiques des espèces figurant dans la bibliographie est

The information was compiled using Scopus (http: //www.info.scopus.com/; New York, NY) as the main search engine and RefWorks (www.refworks/com; Bethesda, MD) for data storage. Our literature search ended on 31 December 2009. Although extensive, we realize that our compilation may not include all publications relating to the subject matter; please let us know of any additional references.

To submit comments, corrections, and additions or ask questions about this annotated bibliography, please contact:

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Canadian Wood Fibre Centre
580 Booth Street
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donnée dans le tableau 2. Et finalement, le tableau 3 présente une liste alphabétique des noms français avec les codes correspondants et les noms scientifiques des espèces figurant dans la bibliographie. Lorsque la permission a été obtenue des déteneurs des droits d'auteur, les résumés originaux ont été inclus sous la citation, sinon, les résumés ont été écrits spécialement pour cette publication. Les résumés français ont été inclus s'ils étaient fournis par l'éditeur.

L'information a été compilée en utilisant Scopus (http://www.info.scopus.com/, New York (NY)) comme principal moteur de recherche et RefWorks (www.refworks/com; Bethesda (MD)) pour l'entreposage des données. La recherche de la littérature s'est terminée le 31 décembre 2009. Malgré nos efforts, il se peut que notre liste de publications sur le sujet visé ne soit pas exhaustive. Veuillez nous signaler toute référence à ajouter.

Pour soumettre vos commentaires, corrections, ajouts ou des questions à propos de cette bibliographie annotée, s'il vous plaît contactez :

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CLASSIFICATION TABLES

Table 1. Alphabetical listing of abbreviation codes with corresponding English common names and scientific names of species appearing in the annotated bibliography

TABLEAUX DE CLASSEMENT

Tableau 1. Classement par ordre alphabétique des codes correspondants aux noms communs anglais et aux noms latins des espèces figurant dans la bibliographie

Code	Common Name / Nom commun	Scientific Name / Nom scientifique
AF	Alpine fir (Subalpine fir)	*Abies lasiocarpa* (Hook.) Nutt.
AL	Alder	*Alnus* spp.
AmF	Amabilis fir	*Abies amabilis* (Doug. ex Loud.)
AX	Atriplex	*Atriplex* spp.
BA	Black ash	*Fraxinus nigra* Marsh.
BAS	Basswood	*Tilia americana* L.
BC	Black cherry	*Prunus serotina* Ehrh.
BCT	Black cottonwood	*Populus trichocarpa* Torr. & A. Gray
BE	American beech	*Fagus grandifolia* Ehrh.
BEM	Box elder / Manitoba maple / Maple ash / Box elder maple	*Acer negundo* L.
BF	Balsam fir	*Abies balsamea* (L.) Mill.
BL	Black locust	*Robinia pseudoacacia* L.
BIM	Bigleaf maple	*Acer macrophyllum* Pursh.
BIP	Black pine / European black pine / Corsican pine / Austrian pine	*Pinus nigra* Arnold
BM	Black maple	*Acer nigrum* Michx.
BO	Black oak	*Quercus velutina* Lam.
BP	Balsam poplar	*Populus balsamifera* L.
BPO	Black poplar (Lombardy poplar)	*Populus nigra* L.
BS	Black spruce	*Picea mariana* (Mill.) B.S.P.
BT	Butternut	*Juglans cinerea* L.
BtM	Bigtooth maple	*Acer grandidentatum* Nutt.
CA	Canelo	*Drimys granadensis* L.f.
CDF	Coastal Douglas-fir	*Pseudotsuga menziesii* (Mirb.) Franco var. menziesii
CG	Coigue	*Nothofagus dombeyi* Mirb. (Oerst.)
CM	Chalk maple	*Acer leucoderme* Small
CO	Chestnut oak	*Quercus montana* Willd. (*Quercus prinus* L.)
CP	Carribean pine	*Pinus caribaea* Morelet
DF	Douglas-fir	*Pseudotsuga menziesii* (Mirb.) Franco
DL	Dahurian larch	*Larix gmelinii* (Rupr.) Rupr.
DM	Douglas maple	*Acer glabrum* var. *douglasii* (Hook.) Dippel
DuL	Dunkeld Larch	*Larix marschlinsii* Coaz (*kaempferi* x *decidua*)
EA	European aspen	*Populus tremula* L.
EB	European beech	*Fagus sylvatica* L.
EBi	European birch	*Betula pubescens* Ehrh.
ECT	Eastern cottonwood	*Populus deltoides* Bartr. ex Marsh.
EH	Eastern hemlock	*Tsuga canadensis* (L.) Carr.
EL	European larch	*Larix decidua* Mill.
EO	European oak / English oak	*Quercus robur* L.
ERC	Eastern redcedar	*Juniperus virginiana* L.
ES	Engelmann spruce	*Picea engelmannii* Parry ex Engelm.
EU	Eucalyptus	*Eucalyptus* spp.

Table 1 cont'd... / Tableau 1 suite....

Code	Common Name / Nom commun	Scientific Name / Nom scientifique
EWC	Eastern white cedar	*Thuja occidentalis* L.
EWP	Eastern white pine	*Pinus strobus* L.
FM	Florida maple / Southern sugar maple / Hammock maple	*Acer floridanum* (Chapm.) Pax
FS	French spruce	*Picea excelsa* Lam.
GdF	Grand fir	*Abies grandis* (Douglas ex D. Don) Lindley
GF	Greek fir	*Abies cephalonica* Louden
HK	Hickory	*Carya* spp.
HL	Hybrid larch	*Larix* x *eurolepis* Henry
IDF	Interior Douglas-fir / Rocky Mountain Douglas-fir	*Pseudotsuga menziesii* subsp. *glauca* (Beissn.) A.E.Murray
JL	Japanese larch	*Larix kaempferi* (Lamb.) Carr.
JP	Jack pine	*Pinus banksiana* Lamb.
JPO	Japanese poplar	*Populus maximowiczii* A. Henry
LbP	Loblolly pine	*Pinus taeda* L.
LLP	Longleaf pine	*Pinus palustris* Mill.
LP	Lodgepole pine	*Pinus contorta* Dougl.
LTA	Largetooth aspen, Bigtooth aspen	*Populus grandidentata* Michx.
MM	Mountain maple	*Acer spicatum* Lamb.
MQ	Mesquite	*Prosopis* spp.
NF	Noble fir	*Abies procera* Rehder
NS	Norway spruce	*Picea abies* (L.) Karst.
PiP	Pitch pine	*Pinus rigida* Mill.
PO	Poplar / Aspen	*Populus* spp.
POC	Port-Orford-cedar	*Chamaecyparis lawsoniana* (A. Murray) Parl.
PP	Ponderosa pine	*Pinus ponderosa* Douglas ex C. Lawson
RA	Red ash	*Fraxinus pennsylvanica* Marsh.
RaP	Radiata pine / Monterey pine	*Pinus radiata* D. Don
RE	Red elm / Slippery elm	*Ulmus rubra* Muhl.
RM	Red maple	*Acer rubrum* L.
RO	Red oak	*Quercus rubra* L.
RP	Red pine / Norway pine	*Pinus resinosa* Ait.
RS	Red spruce	*Picea rubens* Sarg.
RW	Redwood	*Sequoia sempervirens* (D. Don) Endl.
SAF	Subalpine fir / Alpine fir	*Abies lasiocarpa* (Hook.) Nutt
SB	Silver birch / Weeping birch	*Betula pendula* Roth.
SC	Southern cypress	*Taxodium distichum* (L.) Rich.
SF	Silver fir / European fir	*Abies alba* Mill.
ShP	Slash pine	*Pinus elliottii* Engelm.
ShP(SF)	Slash pine (South Florida)	*Pinus elliottii* Engelm. var. *densa*
ShP(T)	Slash pine (Typical)	*Pinus elliottii* Engelm. var. *elliottii*
SIM	Silver maple	*Acer saccharinum* L.
SL	Siberian larch	*Larix sibirica* Ledeb.
SLP	Shortleaf pine	*Pinus echinata* Mill.
SM	Sugar maple	*Acer saccharum* Marsh.
SP	Scots pine / Scotch pine	*Pinus sylvestris* L.
SS	Sitka spruce	*Picea sitchensis* (Bong.) Carr.
StM	Striped maple / Moosewood / Moose maple	*Acer pensylvanicum* L.

Table 1 cont'd... / Tableau 1 suite....

Code	Common Name / Nom commun	Scientific Name / Nom scientifique
SuP	Sugar pine	*Pinus lambertiana* Dougl.
SwG	Sweetgum	*Liquidambar styraciflua* L.
SYC	Sycamore	*Platanus* spp.
TA	Trembling aspen / Quaking aspen	*Populus tremuloides* Michx.
TE	Teak	*Tectona grandis* L.f.
TL	Tamarack / Larch	*Larix laricina* (Du Roi) K. Koch
TP	Turkish pine	*Pinus brutia* Tenore
VM	Vine maple	*Acer circinatum* Pursh
WA	White ash	*Fraxinus americana* L.
WB	White birch / Paper birch	*Betula papyrifera* Marsh.
WE	White elm	*Ulmus americana* L.
WF	White fir	*Abies concolor* (Gordon) Lindley ex Hildebrand
WH	Western hemlock	*Tsuga heterophylla* (Raf.) Sarg.
WL	Willow	*Salix* spp.
WO	White oak	*Quercus alba* L.
WP	White pine / Northern white pine	*Pinus strobus* L.
WRC	Western redcedar	*Thuja plicata* Donn ex D.Don
WS	White spruce	*Picea glauca* (Moench) Voss
WTL	Western larch	*Larix occidentalis* Nutt.
WWP	Western white pine	*Pinus monticola* Douglas ex D. Don
YB	Yellow birch	*Betula alleghaniensis* Britt.
YP	Yellow poplar	*Liriodendron tulipifera* L.
General	General to all or a large number of species	
NN	Non-native or exotic species	
SoP	Southern pines	
SPF	Spruce–pine–fir	

Table 2. Alphabetical listing of English common names with corresponding abbreviation codes and scientific names of species appearing in the annotated bibliography

Tableau 2. Classement par ordre alphabétique des noms communs anglais avec les codes correspondants et les noms latins des espèces figurant dans la bibliographie

Common Name / Nom commun	Code	Scientific Name / Nom scientifique
Alder	AL	*Alnus* spp.
Alpine fir (Subalpine fir)	AF	*Abies lasiocarpa* (Hook.) Nutt.
Amabilis fir	AmF	*Abies amabilis* (Doug. ex Loud.)
American beech	BE	*Fagus grandifolia* Ehrh.
Atriplex	AX	*Atriplex* spp.
Balsam fir	BF	*Abies balsamea* (L.) Mill.
Balsam poplar	BP	*Populus balsamifera* L.
Basswood	BAS	*Tilia americana* L.
Bigleaf maple	BIM	*Acer macrophyllum* Pursh.
Bigtooth maple	BtM	*Acer grandidentatum* Nutt.
Black ash	BA	*Fraxinus nigra* Marsh.
Black cherry	BC	*Prunus serotina* Ehrh.
Black cottonwood	BCT	*Populus trichocarpa* Torr. & A. Gray
Black locust	BL	*Robinia pseudoacacia* L.
Black maple	BM	*Acer nigrum* Michx.
Black oak	BO	*Quercus velutina* Lam.
Black pine / European black pine / Corsican pine / Austrian pine	BlP	*Pinus nigra* Arnold
Black poplar (Lombardy poplar)	BPO	*Populus nigra* L.
Black spruce	BS	*Picea mariana* (Mill.) B.S.P.
Box elder / Manitoba maple / Maple ash / Box elder maple	BEM	*Acer negundo* L.
Butternut	BT	*Juglans cinerea* L.
Canelo	CA	*Drimys granadensis* L.f.
Carribean pine	CP	*Pinus caribaea* Morelet
Chalk maple	CM	*Acer leucoderme* Small
Chestnut oak	CO	*Quercus montana* Willd. (*Quercus prinus* L.)
Coastal Douglas-fir	CDF	*Pseudotsuga menziesii* (Mirb.) Franco var. menziesii
Coigue	CG	*Nothofagus dombeyi* Mirb. (Oerst.)
Dahurian larch	DL	*Larix gmelinii* (Rupr.) Rupr.
Douglas-fir	DF	*Pseudotsuga menziesii* (Mirb.) Franco
Douglas maple	DM	*Acer glabrum* var. *douglasii* (Hook.) Dippel
Dunkeld Larch	DuL	*Larix marschlinsii* Coaz (*kaempferi* x *decidua*)
Eastern cottonwood	ECT	*Populus deltoides* Bartr. ex Marsh.
Eastern hemlock	EH	*Tsuga canadensis* (L.) Carr.
Eastern redcedar	ERC	*Juniperus virginiana* L.
Eastern white cedar	EWC	*Thuja occidentalis* L.
Eastern white pine	EWP	*Pinus strobus* L.
Engelmann spruce	ES	*Picea engelmannii* Parry ex Engelm.
Eucalyptus	EU	*Eucalyptus* spp.
European aspen	EA	*Populus tremula* L.
European beech	EB	*Fagus sylvatica* L.
European birch	EBi	*Betula pubescens* Ehrh.
European larch	EL	*Larix decidua* Mill.
European oak / English oak	EO	*Quercus robur* L.
Florida maple / Southern sugar maple / Hammock maple	FM	*Acer floridanum* (Chapm.) Pax

Table 2 cont'd... / Tableau 2 suite....

Common Name / Nom commun	Code	Scientific Name / Nom scientifique
French spruce	FS	*Picea excelsa* Lam.
Grand fir	GdF	*Abies grandis* (Douglas ex D. Don) Lindley
Greek fir	GF	*Abies cephalonica* Louden
Hickory	HK	*Carya* spp.
Hybrid larch	HL	*Larix* x *eurolepis* Henry
Interior Douglas-fir / Rocky Mountain Douglas-fir	IDF	*Pseudotsuga menziesii* subsp. *glauca* (Beissn.) A.E.Murray
Jack pine	JP	*Pinus banksiana* Lamb.
Japanese larch	JL	*Larix kaempferi* (Lamb.) Carr.
Japanese poplar	JPO	*Populus maximowiczii* A. Henry
Largetooth aspen, Bigtooth aspen	LTA	*Populus grandidentata* Michx.
Loblolly pine	LbP	*Pinus taeda* L.
Lodgepole pine	LP	*Pinus contorta* Dougl.
Longleaf pine	LLP	*Pinus palustris* Mill.
Mesquite	MQ	*Prosopis* spp.
Mountain maple	MM	*Acer spicatum* Lamb.
Noble fir	NF	*Abies procera* Rehder
Norway spruce	NS	*Picea abies* (L.) Karst.
Pitch pine	PiP	*Pinus rigida* Mill.
Ponderosa pine	PP	*Pinus ponderosa* Douglas ex C. Lawson
Poplar / Aspen	PO	*Populus* spp.
Port-Orford-cedar	POC	*Chamaecyparis lawsoniana* (A. Murray) Parl.
Radiata pine / Monterey pine	RaP	*Pinus radiata* D. Don
Red ash	RA	*Fraxinus pennsylvanica* Marsh.
Red elm / Slippery elm	RE	*Ulmus rubra* Muhl.
Red maple	RM	*Acer rubrum* L.
Red oak	RO	*Quercus rubra* L.
Red pine / Norway Pine	RP	*Pinus resinosa* Ait.
Red spruce	RS	*Picea rubens* Sarg.
Redwood	RW	*Sequoia sempervirens* (D. Don) Endl.
Scots pine / Scotch pine	SP	*Pinus sylvestris* L.
Shortleaf pine	SLP	*Pinus echinata* Mill.
Siberian larch	SL	*Larix sibirica* Ledeb.
Silver birch / Weeping birch	SB	*Betula pendula* Roth.
Silver fir / European fir	SF	*Abies alba* Mill.
Silver maple	SIM	*Acer saccharinum* L.
Sitka spruce	SS	*Picea sitchensis* (Bong.) Carr.
Slash pine	ShP	*Pinus elliottii* Engelm.
Slash pine(South Florida)	ShP(SF)	*Pinus elliottii* Engelm. var. *densa*
Slash pine (Typical)	ShP(T)	*Pinus elliottii* Engelm. var. *elliottii*
Southern cypress	SC	*Taxodium distichum* (L.) Rich.
Striped maple / Moosewood / Moose maple	StM	*Acer pensylvanicum* L.
Subalpine fir / Alpine fir	SAF	*Abies lasiocarpa* (Hook.) Nutt
Sugar maple	SM	*Acer saccharum* Marsh.
Sugar pine	SuP	*Pinus lambertiana* Dougl.
Sweetgum	SwG	*Liquidambar styraciflua* L.
Sycamore	SYC	*Platanus* spp.

Table 2 cont'd... / Tableau 2 suite....

Common Name / Nom commun	Code	Scientific Name / Nom scientifique
Tamarack / Larch	TL	*Larix laricina* (Du Roi) K. Koch
Teak	TE	*Tectona grandis* L.f.
Trembling aspen / Quaking aspen	TA	*Populus tremuloides* Michx.
Turkish pine	TP	*Pinus brutia* Tenore
Vine maple	VM	*Acer circinatum* Pursh
Western hemlock	WH	*Tsuga heterophylla* (Raf.) Sarg.
Western larch	WTL	*Larix occidentalis* Nutt.
Western redcedar	WRC	*Thuja plicata* Donn ex D.Don
Western white pine	WWP	*Pinus monticola* Douglas ex D. Don
White ash	WA	*Fraxinus americana* L.
White birch / Paper birch	WB	*Betula papyrifera* Marsh.
White elm	WE	*Ulmus americana* L.
White fir	WF	*Abies concolor* (Gordon) Lindley ex Hildebrand
White oak	WO	*Quercus alba* L.
White pine / Northern white pine	WP	*Pinus strobus* L.
White spruce	WS	*Picea glauca* (Moench) Voss
Willow	WL	*Salix* spp.
Yellow birch	YB	*Betula alleghaniensis* Britt.
Yellow poplar	YP	*Liriodendron tulipifera* L.
General to all or a large number of species	General	
Non-native or exotic species	NN	
Southern pines	SoP	
Spruce–pine–fir	SPF	

Table 3. Alphabetical listing of French common names with corresponding abbreviation codes and Latin scientific names of species appearing in bibliography

Tableau 3. Classement par ordre alphabétique des noms communs français avec les codes correspondants et les noms latins des espèces figurant dans la bibliographie

Nom commun / Common Name	Code	Scientific Name / Nom scientifique
Aulne	AL	*Alnus* spp.
Bouleau à papier	WB	*Betula papyrifera* Marsh.
Bouleau jaune	YB	*Betula alleghaniensis* Britt.
Bouleau pubescent	EBi	*Betula pubescens* Ehrh.
Bouleau verruqueux	SB	*Betula pendula* Roth.
Caryer	HK	*Carya* spp.
Cerisier tardif	BC	*Prunus serotina* Ehrh.
Chamaecyparis de Lawson	POC	*Chamaecyparis lawsoniana* (A. Murray) Parl.
Chêne blanc	WO	*Quercus alba* L.
Chêne châtaigner	CO	*Quercus montana* Willd. (*Quercus prinus* L.)
Chêne noir	BO	*Quercus velutina* Lam.
Chêne pédonculé	EO	*Quercus robur* L.
Chêne rouge	RO	*Quercus rubra* L.
Coigüe	CG	*Nothofagus dombeyi* Mirb. (Oerst.)
Copalme d'Amérique	SwG	*Liquidambar styraciflua* L.
Cyprès chauve	SC	*Taxodium distichum* (L.) Rich.
Douglas de Menzies	DF	*Pseudotsuga menziesii* (Mirb.) Franco
Douglas de Menzies - continental	IDF	*Pseudotsuga menziesii* subsp. *glauca* (Beissn.) A.E.Murray
Douglas de Menzies -côtier	CDF	*Pseudotsuga menziesii* (Mirb.) Franco var. menziesii
Drimys de Winter	CA	*Drimys granadensis* L.f.
Epicéa commun	NS	*Picea abies* (L.) Karst.
Épicéa commun	FS	*Picea excelsa* Lam.
Épinette blanche	WS	*Picea glauca* (Moench) Voss
Épinette de Sitka	SS	*Picea sitchensis* (Bong.) Carr.
Épinette d'Engelmann	ES	*Picea engelmannii* Parry ex Engelm.
Épinette noire	BS	*Picea mariana* (Mill.) B.S.P.
Épinette rouge	RS	*Picea rubens* Sarg.
Érable à épis	MM	*Acer spicatum* Lamb.
Érable à feuilles composées	BEM	*Acer negundo* L.
Érable à grandes dents	BtM	*Acer grandidentatum* Nutt.
Érable à grandes feuilles	BlM	*Acer macrophyllum* Pursh.
Érable à sucre	SM	*Acer saccharum* Marsh.
Érable argenté	SlM	*Acer saccharinum* L.
Érable circiné	VM	*Acer circinatum* Pursh
Érable de Floride	FM	*Acer floridanum* (Chapm.) Pax
Érable de Pennsylvanie	StM	*Acer pensylvanicum* L.
Érable gris-blanc	CM	*Acer leucoderme* Small
Érable nain	DM	*Acer glabrum* var. *douglasii* (Hook.) Dippel
Érable noir	BM	*Acer nigrum* Michx.
Érable rouge	RM	*Acer rubrum* L.
Eucalyptus	EU	*Eucalyptus* spp.
Frêne blanc	WA	*Fraxinus americana* L.
Frêne noir	BA	*Fraxinus nigra* Marsh.

Table 3 cont'd... / Tableau 3 suite....

Nom commun / Common Name	Code	Scientific Name / Nom scientifique
Frêne rouge	RA	*Fraxinus pennsylvanica* Marsh.
Genévrier de Virginie	ERC	*Juniperus virginiana* L.
Hêtre à grandes feuilles	BE	*Fagus grandifolia* Ehrh.
Hêtre européen	EB	*Fagus sylvatica* L.
Mélèze de Dahurie	DL	*Larix gmelinii* (Rupr.) Rupr.
Mélèze de Dunkeld	DuL	*Larix marschlinsii* Coaz (*kaempferi* x *decidua*)
Mélèze de l'Ouest	WTL	*Larix occidentalis* Nutt.
Mélèze de Sibérie	SL	*Larix sibirica* Ledeb.
Mélèze d'Europe	EL	*Larix decidua* Mill.
Mélèze du Japon	JL	*Larix kaempferi* (Lamb.) Carr.
Mélèze hybride	HL	*Larix* x *eurolepis* Henry
Mélèze laricin	TL	*Larix laricina* (Du Roi) K. Koch
Noyer cendré	BT	*Juglans cinerea* L.
Orme d'Amérique	WE	*Ulmus americana* L.
Orme rouge	RE	*Ulmus rubra* Muhl.
Peuplier à grandes dents	LTA	*Populus grandidentata* Michx.
Peuplier baumier	BP	*Populus balsamifera* L.
Peuplier de l'Ouest	BCT	*Populus trichocarpa* Torr. & A. Gray
Peuplier de Maximowicz	JPO	*Populus maximowiczii* A. Henry
Peuplier deltoïde	ECT	*Populus deltoides* Bartr. ex Marsh.
Peuplier faux-tremble	TA	*Populus tremuloides* Michx.
Peuplier noir	BPO	*Populus nigra* L.
Peuplier spp.	PO	*Populus* spp.
Peuplier tremble	EA	*Populus tremula* L.
Pin à courtes feuilles	SLP	*Pinus echinata* Mill.
Pin à sucre	SuP	*Pinus lambertiana* Dougl.
Pin argenté	WWP	*Pinus monticola* Douglas ex D. Don
Pin blanc	WP	*Pinus strobus* L.
Pin blanc	EWP	*Pinus strobus* L.
Pin Chilien	RaP	*Pinus radiata* D. Don
Pin de Calabre	TP	*Pinus brutia* Tenore
Pin d'Elliott	ShP	*Pinus elliottii* Engelm.
Pin d'Elliott dense	ShP(SF)	*Pinus elliottii* Engelm. var. *densa*
Pin d'Elliott typique	ShP(T)	*Pinus elliottii* Engelm. var. *elliottii*
Pin des Caraïbes	CP	*Pinus caribaea* Morelet
Pin des marais	LLP	*Pinus palustris* Mill.
Pin gris	JP	*Pinus banksiana* Lamb.
Pin noir d'Autriche	BlP	*Pinus nigra* Arnold
Pin ponderosa	PP	*Pinus ponderosa* Douglas ex C. Lawson
Pin rigide	PiP	*Pinus rigida* Mill.
Pin rouge	RP	*Pinus resinosa* Ait.
Pin sylvestre	SP	*Pinus sylvestris* L.
Pin taeda	LbP	*Pinus taeda* L.
Pin tordu	LP	*Pinus contorta* Dougl.
Platanes	SYC	*Platanus* spp.
Pourpier de mer	AX	*Atriplex* spp.

Table 3 cont'd... / Tableau 3 suite....

Nom commun / Common Name	Code	Scientific Name / Nom scientifique
Prosopis	MQ	*Prosopis* spp.
Pruche de l'Ouest	WH	*Tsuga heterophylla* (Raf.) Sarg.
Pruche du Canada	EH	*Tsuga canadensis* (L.) Carr.
Robinier faux-acacia	BL	*Robinia pseudoacacia* L.
Sapin argenté	WF	*Abies concolor* (Gordon) Lindley ex Hildebrand
Sapin baumier	BF	*Abies balsamea* (L.) Mill.
Sapin blanc	SF	*Abies alba* Mill.
Sapin de Céphalonie	GF	*Abies cephalonica* Louden
Sapin gracieux	AmF	*Abies amabilis* (Doug. ex Loud.)
Sapin grandissime	GdF	*Abies grandis* (Douglas ex D. Don) Lindley
Sapin noble	NF	*Abies procera* Rehder
Sapin subalpine	SAF	*Abies lasiocarpa* (Hook.) Nutt
Sapin subalpine	AF	*Abies lasiocarpa* (Hook.) Nutt.
Saule	WL	*Salix* spp.
Séquoia à feuilles d'if	RW	*Sequoia sempervirens* (D. Don) Endl.
Teck	TE	*Tectona grandis* L.f.
Thuya géant	WRC	*Thuja plicata* Donn ex D.Don
Thuya occidental	EWC	*Thuja occidentalis* L.
Tilleul d'Amérique	BAS	*Tilia americana* L.
Tulipier de Virginie	YP	*Liriodendron tulipifera* L.
Épinette-pin-sapin	SPF	
Général ou se rapport à un grand nombre d'espèces	General	
Non-indigène ou espèce exotique	NN	
Pins australs	SoP	

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Les publications sont regroupées selon espèce et répertoriée par auteur principal, suivi de l'année de publication.

Balsam Fir / Sapin baumier / *Abies balsamea* (L.) Mill.

Achim, A. et al. 2005
Alemdag, I.S. 1984
Balatinecz, J.J. et al. 2001
Bedard, S. et al. 2003
Bendtsen, B.A. 1974
Bendtsen, B.A. 1976
Bernier, P.Y. et al. 2007
Bertrand, V. et al. 1970
Blanchette, R.A. et al. 1994
Cantin, M. 1965
Chui, Y.H. et al. 1997
Clark, J. et al. 1957
Clermont, L.P. et al. 1951
Cown, D.J. et al. 1978
De Montmorency, W.H. 1965
Dery, P.J. et al. 1981
Dokken, M. et al. 1973
Drost, C. et al. 2003
Fujiwara, S. et al. 2000
Gagnon, J.D. et al. 1974
Green, D.W. et al. 1999
Hale, J.D. 1955
Hale, J.D. et al. 1940
Harris, G. 1993
Hazenberg, G. et al. 1991
Heger, L. 1974
Honer, T.G. 1971
Houle, D. et al. 2008
Huffman, D.R. 1977
Hunt, K. et al. 1980
Hussein, A. et al. 2006
Jeremic, D. et al. 2004
Johal, S. et al. 2006
Karsh, M.B. et al. 1994
Kennedy, E.I. et al. 1968
Ker, M.F. 1981
Ker, M.F. 1987
Koga, S. et al. 2002a
Koga S., et al. 2002b
Koga, S. et al. 2004
Laflèche, V. et al. 2008
Lavigne, M.B. et al. 1989
Lihra, T. et al. 2000
Liu, C. et al. 2007
Maeglin, R.R. 1973
McArthur, J.D. 1965
Merette, C. et al. 1985
Meyer, W.H. 1929
Middleton, G.R. et al. 2009
OMNR. 1998
Ouellet, D. 1983
Panshin, A.J. et al. 1980
Pnevmaticos, S.M. et al. 1972
Pothier, D. 2002
Pronin, D. 1971
Robertson, A. 1990
Schneider, M.H. et al. 1989
Schneider, R. 2001
Sharma, M. et al. 2004
Shortle, W.C. et al. 1986
Singh, T. 1984
Singh, T. 1986
Solomon, D.S. et al. 2002
Swift, D.E. et al. 2007
Thor, E. et al. 1974
Timell, T.E. 1973
Tong, Q.J. et al. 2008
Wahlgren, H.E. et al. 1966
Wahlgren, H.E. et al. 1995
Wood, J. et al. 2005
Young, H.E. et al. 1966
Zarnovican, R. et al. 1996
Zhang, S.Y. et al. 1998
Zhang, S.Y. et al. 2008

Sugar Maple / Érable à sucre / *Acer saccharum* Marsh.

Alemdag, I.S. 1984
Anagnost, S.E. et al. 2005
Angers, V.A. et al. 2005
Banal, S. et al. 2007
Bedard, S. et al. 2003
Bragg, D.C. 2006
Bragg, D.C. et al. 1997
Cantin, M. 1965
Choi, J. et al. 2001
Cole, W.G. et al. 1994
Cown, D.J. et al. 1978
Dakak, J.E. et al. 1999
Defo, M. et al. 1999
Forget, E. et al. 2007
Fournier, A. et al. 2006
Green, D.W. et al. 1999
Hartmann, H. et al. 2008
Hernández, R.E. 2007a
Hernández, R.E. 2007b
Jones, T.A. et al. 2004
Juice, S.M. et al. 2006
Kiernan, D.H. et al. 2008
Lhotka, J.M. et al. 2008
Moore, J.D. et al. 2008
Niese, J.N. et al. 1995
Niklas, K.J. 1999
Nyland, R.D. 2005
Ouellet, D. 1983
Panshin, A.J. et al. 1980
Paul, B.H. 1963
Raulier, F. et al. 1998
Roberge, M.R. 1975
Schuler, T.M. 2004
Smith, D.W. et al. 1982
Sonderman ,D.L. 1987
Stark, E.W. 1954
Strong, T.F. et al. 1995
Wan, H.t al. 2006
Webster, C.R. et al. 2003
Zhang, Y. et al. 2005

White Spruce / Épinette blanche / *Picea glauca* (Moench) Voss

Alemdag, I.S. 1984
Barbour, J. 1988
Beaulieu, J. et al. 1985
Beaulieu, J. et al. 2006
Bella, I.E. et al. 1974
Bendtsen, B.A. 1974
Bendtsen, B.A. 1976
Bendtsen, B.A. et al. 1979
Berry, A.B. 1974
Boateng, J.O. et al. 2006
Cantin, M. 1965
Chang, C.I. 1966
Chang, C.I. et al. 1967
Clark, J. et al. 1957
Clermont, L.P. et al. 1951
Corriveau, A. et al. 1987
Corriveau, A. et al. 1990
Corriveau, A. et al. 1991
Dampier, J.E.E. et al. 2007
De Montmorency, W.H. 1965
Defo, M. et al. 1999
Dempster, W.R. et al. 2002
Dokken, M. 1972
Duchesne, I. et al. 2004
Feng, Z. et al. 2006
Fu, S. et al. 2007
Fujiwara, S. et al. 2000
Godt, M.J.W. et al. 2001

Goudie, J.W. et al. 2008
Green, D.W. et al. 1999
Hale, J.D. 1955
Hale, J.D. et al. 1931
Hale, J.D. et al. 1940
Harris, G. 1993
Hatton, J.V. et al. 1996
Hernández, R.E. et al. 2001
Hunt, K. et al. 1995
Ivkovich, M. et al. 2002a
Ivkovich, M. et al. 2002b
Johal, S. et al. 2006
Jozsa, L.A. et al. 1987
Kabzems, R. et al. 2005
Keith C.T. 1961
Keith, C.T. 1974
Kennedy, E.I. et al. 1968
Kennedy, R.W. 1995
Klos, R.J. et al. 2007
Knudson, R.M. et al. 2006
Kranabetter, J.M. et al. 2004
Lam, F. et al. 1991
Maeglin, R.R. 1973
Mallik, A.U. et al. 2008
Man, R. et al. 2004
McClain, K.M. et al. 1994
Merrill, R.E. et al. 1985
Middleton, G.R. et al. 2000
Middleton, G.R. et al. 2002
Middleton, G.R. et al. 2005
Middleton, G.R. et al. 2009
Nienstaedt, H. et al. 1976
OMNR. 1998a
OMNR. 1998b
Ouellet, D. 1983
Packee, E.C. et al. 1992
Panshin, A.J. et al. 1980
Pelletier, G. et al. 2008
Perem, E. 1958
Périé, C. et al. 2000
Pronin, D. 1971
Rajora, O.P. 1999
Roddy, D.M. 1983
Shepard, R.K. 1980
Singh, T. 1984
Singh, T. 1986
Solomon, D.S. et al. 2002
Stump, J.P. et al. 1981
Sutton, R.F. et al. 2003
Swift, D.E. et al. 2007
Syta, D. et al. 1995
Taylor, F.W. et al. 1982
Tong, Q.J. et al. 2008
van Cleve, K. et al. 1976
Wahlgren, H.E. et al. 1966
Wahlgren, H.E. et al. 1995
Wang, E.I.C. et al. 1984
Wang, E.I.C. et al. 1985
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Willcocks, A. et al. 1995
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Yang, K.C. 2002
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Zhang, S.Y. et al. 2008
Zhou, H. et al. 1991a
Zhou, H. et al. 1991b

Black Spruce / Épinette noire / *Picea mariana* (Mill.) B.S.P.

Alemdag, I.S. 1984
Alteyrac, J. et al. 2005
Alteyrac, J. et al. 2006
Antal, M. et al. 1994
Balatinecz, J.J. et al. 2001
Ban, W. et al. 2004
Barbour, J. et al. 1988
Barbour, R.J. et al. 1989
Bendtsen, B.A. 1974
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Benjamin, J. et al. 2007
Bernier, P.Y. et al. 2007
Bertrand, V. et al. 1970
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Boyle, T.J.B. et al. 1987
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Cantin, M. 1965
Chui, Y.H. et al. 1997
Clermont, L.P. et al. 1951
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Dampier, J.E.E. et al. 2007
De Montmorency, W.H. 1965
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Koran, Z. 1967
Koubaa, A. et al. 2000
Koubaa, A. et al. 2002
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Laflèche, V. et al. 2008
Law, K.N. et al. 1997
Lei, Y.C. et al. 2005
Lemieux, H. et al. 2001
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Maeglin, R.R. 1973
Mahendrappa, M.K. et al. 1982
Mallik, A.U. et al. 2008
McClain, K.M. et al. 1994
McKenney, D.W. et al. 1997
McLaren, B.E. et al. 1998
Middleton G.R., et al. 2009
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Park, Y.S. et al. 1988
Payandeh, B. 1989
Pnevmaticos, S.M. et al. 1972
Pronin, D. 1971
Rayirath, P. et al. 2008
Risi J., et al. 1960

Sharma, M. et al. 2004a
Sharma, M. et al. 2004a
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Shi, J.L. et al. 2005
Shi, J.L. et al. 2006
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Singh, T. 1984
Singh, T. 1986
Solomon, D.S. et al. 2002
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Swift, D.E. et al. 2007
Timell, T.E. 1973
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Villeneuve, M. et al. 1987
Wahlgren, H.E. et al. 1966
Wahlgren, H.E. et al. 1995
Wang, E.I.C. et al. 1985
Wang, L. et al. 2000
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Weetman, G.F. 1975
Wells, E.D. 1994
Wood, J. et al. 2005
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Yemele, M.C.N. et al. 2008
Zhang, S.Y. 1998
Zhang, S.Y. et al. 1996a
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Zhang, S.Y. et al. 2002
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Zhang, S.Y. et al. 2006c
Zhang, S.Y. et al. 2008

Jack Pine / Pin gris / *Pinus banksiana* Lamb.

Alemdag, I.S. 1984
Balatinecz, J.J. et al. 2001
Bankowski, J. 1994
Barbour, R.J. et al. 1994
Barton, A.M. et al. 2008
Bell, F.W. et al. 1990
Bell, F.W. et al. 1997
Bella, I.E. et al. 1974a
Bella, I.E. et al. 1974b
Bendtsen, B.A. 1978
Benzie, J.W. 1977
Bernier, P.Y. et al. 2007
Cantin, M. 1965
Cayford, J.H. 1961
Cayford, J.H. 1964
Cayford, J.H. et al. 1967
Chui, Y.H. et al. 1995
Clermont, L.P. et al. 1951
Cown, D.J. et al. 1978
Dampier, J.E.E. et al. 2007
Drost, C. et al. 2003
Duchesne, I. 2006
Eyre, F.H. et al. 1944
Fu, S. et al. 2007
Fujiwara, S. et al. 2000
Gagné, C. et al. 1990
Goble, B.C. et al. 1993
Godt, M.J.W. et al. 2001
Green, D.W. et al. 1999
Grigal, D.F. et al. 1966
Groot, A. et al. 1984
Hale, J.D. 1955
Harris, G. 1993
Hatton, J.V. 1993
Hatton, J.V. et al. 1990
Hatton, J.V. et al. 1996
Hegyi, F. 1969
Huffman, D.R. 1977
Hunt, K. et al. 1995
Janas, P.S. et al. 1988
Kang, K.Y. et al. 2004
Kennedy, E.I. et al. 1968
Klos, R.J. et al. 2007
Laflèche, V. et al. 2008
Larocque, G.R. 2000
Law, K.N. et al. 1997
Law, K.N. et al. 2003
Lo, E. et al. 2001
Maeglin, R.R. 1973
Magnussen, S. et al. 1985
Magnussen, S. et al. 1987
Magnussen, S. et al. 1990
Mattice, C.R. et al. 1975
Middleton, G.R. et al. 2009
Miles, K.B. et al. 2007
Morris, D.M. et al. 1992a
Morris, D. M. et al. 1992b
Morris, D.M. et al. 1994
Morrison, I.K. et al. 1977
Newton, P.F. 2003
Newton, P.F. 2004
Newton, P.F. 2006
Newton, P.F. et al. 2005
Newton, P.F. et al. 2006
Newton, P.F. et al. 2007
Nienstaedt, H. et al. 1976
Okwuagwu, C.O.et al. 1981
Olson, A.R. et al. 1947
OMNR. 1998a
OMNR. 1998b
OMNR. 1998c
OMNR. 1998d
OMNR. 1998e
Ouellet, D. 1983
Panshin, A.J. et al. 1980
Park, Y.S. et al. 1989
Pliura, A. et al. 2006
Pothier, D. et al. 1989a
Pothier, D. et al. 1989b
Pronin, D. 1971
Roddy. D.M. 1983
Roe, E.I. et al. 1950
Savva, Y. et al. 2008
Schneider, R. 2006
Schneider, R. et al. 2008a
Schneider, R. et al. 2008b
Scott, S.L. et al. 1982
Sharma, M. et al. 2004a
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Sinclair, G.D. et al. 1973
Singh, T. 1984
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Smith, C.R. 1984
Smith, C.R. et al. 1988
Spurr, S.H. et al. 1953
Tong, Q.J. et al. 2005a
Tong, Q.J. et al. 2005b
Tong, Q.J. et al. 2006
Tong, Q.J. et al. 2008a
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Villeneuve, M. et al. 1987
Wang, X. et al. 2002
Willcocks, A. et al. 1995
Winston, D. A. 1977
Yang, K.C. et al. 1985
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Zhang, S.Y. et al. 1996
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Amponsah, I.G. et al. 2004
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Bendtsen, B.A. et al. 1979
Bluskova, G. et al. 1997
Brockley, R.P. 2005
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Guernsey, F.W. et al. 1966
Harris, G. 1993
Harris, J.M. 1993
Heger, L. 1974
Hunt, J.F. et al. 2008
Jeffers, J.N.R. et al. 1964
Johnstone, W.D. 2002
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Kennedy, R.W. 1995
Koch, P. 1987
Lam, F. et al. 1991
Lhotka, J.M. et al. 2008
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O'Halloran, M.R. et al. 1972
Panshin, A.J. et al. 1980
Peck, E.C. 1933
Rudnicki, M. et al. 2004
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Alemdag, I.S. 1984
Balatinecz, J.J. et al. 2001
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Campbell, J.S. et al. 1985
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Cown, D.J. et al. 1978
Domke, G.M. et al. 2008
Fernandez, M.P. et al. 2002
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Fujiwara, S. et al. 2000
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Hale, J.D. 1955
Hale, J.D. et al. 1940
Horton, K.W. 1981
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Packee, E.C. et al. 1992
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Penner, M. et al. 2001
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Semple, K.E. et al. 2007
Singh, T. 1986
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Sonderman, D.L. 1987
Stewart, J.J. et al. 2006
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Abdel-Gadir, A.Y. et al. 1993
Acuna, M.A. et al. 2007
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Bendtsen, B.A. et al. 1979
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Chantre, G. et al. 2002
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Dunham, S.M. et al. 2008
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Flewelling, J.W. et al. 2008
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Grotta, A.T. et al. 2005
Gupta, R. et al. 2004
Hale, J.D. et al. 1923
Hann, D.W. 1999
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Hapla, F. 1997
Harrington, T.B. et al. 2009
Harris, J.M. 1993
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Hein, S. et al. 2008
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Henman, D.W. 1963
Jeffers, J.N.R. et al. 1964
Kellogg, R.M. 1989
Kennedy, R.W. 1995
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Knowles, R.L. et al. 2004
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Noone, C.S. et al. 1980
Oliver, C.D. et al. 1986
Olson, A.R. et al. 1947
Panshin, A.J. et al. 1980
Parker, M.L. et al. 1976
Paul, B.H. 1963
Peck, E.C. 1933
Polman, J. E. et al. 1996
Pyles, M.R. 1987
Rathgeber, C.B.K. et al. 2006
Renninger, H.J. et al. 2006
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Rippy, R.C. et al. 2000
Robinson, A.R. et al. 2007
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Roeh, R.L. et al. 1997
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Siddiqui, K.M. et al. 1971
Smith, S.M. et al. 1987
Spicer, R. et al. 2001
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Taylor, A.M. et al. 2003
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Aschim, O.K. et al. 1976
Barbour, R.J. et al. 1990
Barrett, J.D. et al. 1994
Brand, D.G. 1991
Brazier, J.D. 1977
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Burns, R.M. et al. 1990
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Cown, D.J. 2005
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Defo, M. et al. 2009
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Elliott, G.K. 1970
Fournier, R.A. et al. 2003
Gonzalez, J.S. 1990
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Hanley, D.P. et al. 1995
Hillis, W.E. 1962
Jacobs, S.M. et al. 2002
Jessome, A.P. 2000
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Kennedy, E.I. 1965
King, D.A. 2005
Larson, P.R. 1969
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Li, C. 2009
Little, C.H.A. et al. 1987
Lussier, J.M. 2009
MacKenzie, J. et al. 2009
Mäkelä, A. et al. 2006
Markwardt, L.J. 1930
Mencuccini, M. et al. 2007
Molteberg, D. 2004
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Paul, B.H. 1963
Pavel, M. et al. 2009
Peng C. 2000
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Racey, G.D. et al. 1990
Rasmussen, E.F. 1961
Samson, M. 1993
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Standish, J.T. 1983
Suárez, J.C. et al. 2005
Taylor, A.M. et al. 2002
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DF

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LP

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LP; SS

Chang, C I. 1966
WS

Choi, J. et al. 2001
SM; BAS; WA

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General

Cochran, P.H. et al. 2000
LP

Cole, W.G. et al. 1994
SM; WA; BAS

Cyr, G. et al. 2009
BS

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LP; BS; WS

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DF

Feng, Z. et al. 2006
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General

Gagnon, J.D. et al. 1974
BF

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DF

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DF

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DF

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Gonzalez, J. et al. 1993
LP

Goudie, J.W. et al. 2008
WS; ES

Grigal, D.F. et al. 1966
JP

Groot, A. et al. 2008
BS

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DF

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DF

Harrington, T.B. et al. 2009
DF

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DF

Honer, T.G. 1971
BF; BS

Jones, T.A. et al. 2004
SM

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General

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LP

Juice, S.M. et al. 2006
SM

Kellogg, R.M. 1989
DF

Koch, P. 1987
LP

Kranabetter, J.M. et al. 2004
WS; WRC; WH

Larocque, G.R. 2000
JP

Larson, P R. 1969
General

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General

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General

Lei, Y.C. et al. 2005
BS

Lemieux, H. et al. 2001
BS

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Lindgren, P.M.F. et al. 2007
LP

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BS

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BS

Lo, E. et al. 2001
JP

Magnussen, S. et al. 1985
JP

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JP

Maguire, D.A. et al. 1999
DF

Mahendrappa, M. K. et al. 1982
BS

Mäkelä, A. 2002
SP

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General

Man, R. et al. 2004
WS, PO

Man, R. et al. 2008
TA

McArthur, J.D. 1965
BF

McClain, K.M. et al. 1994
BS; WS; RP

Meng, S.X. et al. 2007
LP

Merrill, R.E. et al. 1985
WS

Middleton, G.R. et al. 1989
DF

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LP

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LP

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LP

Middleton, G.R. et al. 2000a
LP

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WS

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WS

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WS

Moore, J.D. et al. 2008
SM

Morris, D.M. et al. 1992
JP

Morris, D.M., et al. 1994
JP

Newton, P.F. et al. 1993
BS

Newton, P.F. et al. 1994
BS

Newton, P.F. 2003
BS

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BS

Noone, C.S. et al. 1980
DF

Panshin, A.J. et al. 1980
JP; DF; BF; WS; BS; SM; LP; General

Park, Y.S. et al. 1989
JP

Paul, B.H. 1963
SM; TA; DF; General

Payandeh, B. 1989
BS

Pelletier, G. et al. 2008
WS

Penner, M. et al. 2001
TA

Polman, J.E. et al. 1996
DF

Pothier, D. et al. 1989a
JP

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JP

Pukkala, T. et al. 1987
General

Raulier, F. et al. 1998
SM

Rudnicki, M. et al. 2004
LP

Schneider, R. 2006
JP

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JP

Sharma, M. et al. 2007
JP

Shepard, R K. 1980
WS

Shepard, R.K. et al. 1990
BS

Sonderman, D.L.1987
RM; SM; YP; BC; BT; TA; BE; RE; HK; RO

Spurr, S.H. et al. 1953
JP; SP

Standish, J.T. 1983
General

Suárez, J.C. et al. 2005
General

Sullivan, T.P. et al. 2006
LP

Tong, Q.J. et al. 2005
JP

Wang, Y. et al. 1998
BS; WS; LP; BP; PO

Webster, C.R. et al. 2003
SM; RM; YB; EH

Weiskittel, A.R. et al. 2006
DF

Young, H.E. et al. 1966
RS; BF; EH; WP; RM; PO

Zarnovican, R. et al. 1996
BF

Zhang, S.Y. et al. 1998
BF

Zhang, S.Y. et al. 2002
BS

Zhang, S.Y. et al. 2005a
JP

Zhang, S.Y. et al. 2005b
BS

Zhang, S.Y. et al. 2006a
BS

Zhang, S.Y. et al. 2006b
JP

Zhou, H. et al. 1991
WS

Zobel, B.J. et al. 1989
General

Density / Densité

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Comprends : densité du bois séché au four; densité du bois séché à l'air; densité des anneaux; densité à l'état vert; densité relative

Abdel-Gadir, A.Y. et al. 1993
DF

Acuna, M.A. et al. 2005
DF

Acuna, M.A. et al. 2006a
DF

Acuna, M.A. et al. 2006b
DF

Acuna, M.A. et al. 2007
DF

Alden, H.A. 1995
General

Alemdag, I.S.1984
ERC; EWC; BF; EH; EWP; JP; RP; BS; WS; TL; BA; RA; WA; LTA; TA; BAS; BE; WB; YB; BC; WE, HK; RM; SIM; SM; RO; WO; BP

Alteyrac, J. et al. 2005
BS

Alteyrac, J. et al. 2006
BS

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TA;LTA;ECT; BCT; BP; BS; JP; BF; NN

Ballard, L.A. et al. 1988
LP

Bankowski, J. 1994
JP

Barbour, J. 1988
WS

Barbour, J. et al. 1988
BS

Barbour, R J. et al. 1989
BS

Barbour, R.J. et al. 1994
JP

Beaulieu, J. et al. 1985
WS

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WS

Bell, F.W. et al. 1990
JP

Bendtsen, B. A. 1974
BS; RS; WS; BF

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RS; WS; BS; BF; SAF; POC; WRC; SuP; WWP

Corriveau, A. et al. 1991
WS

Bendtsen, B.A. 1978
LbP; DF; JP; CP

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HK; RM; RO; WE; YP

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CDF; IDF; SLP; WH; ES; WS; SF; PO; RO

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TA; DF; JP; BS; BF

Bjurhager, I. et al. 2008
EA; TA

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General

Briggs, D.G. et al. 1986
General

Campbell, J.S. et al. 1985
TA

Cannell, M.G.R. et al. 1983
LP; SS

Chang, C.I. 1966
WS

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WS

Chantre, G. et al. 2002
DF

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CDF

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BS; BF

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WS

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WS

Cown, D.J. et al. 1978
BF; JP; SS; RP; DF; WH; SM; WB; TA

De Montmorency, W.H. 1965
BS; WS; BF

Defo, M. et al. 1999
WS; SM

Dempster, W. R. et al. 2002
LP; BS; WS

Dery, P. J. et al. 1981
BF

Domec, J.C. et al. 2002
DF

Donaldson, L. 2008
General

Downes, G.M. et al. 2002
General

Duchesne, I. 2006
JP

Duchesne, I. et al. 2004
WS

Emmingham, W. et al. 2007
DF

Feng, Z. et al. 2006
WS

Fernandez, M.P. et al. 2002
TA

Francis, R.C. et al. 2006
PO

Gagnon, J.D. et al. 1974
BF

Gartner, B.L. 2002
DF

Gartner, B.L. et al. 2002
DF

Gonzalez, J. et al. 1993
LP

Gonzalez, J.S. 1990
General

Gonzalez, J.S. et al. 1978
WH; IF; SS; AMF

Green, D.W. et al. 1999
BF; DF; BS; WS; JP; LP; SM; TA

Green, D.W. et al. 2008
DF; PP

Grigal, D.F. et al. 1966
JP

Gupta, R. et al. 2004
DF

Hale, J.D. 1955
BF; BS; WS; JP; TA; WB

Hale, J.D. et al. 1923
DF; SPF

Hale, J.D. et al. 1931
WS

Hale, J.D. et al. 1940
BS; BF; YB; TA; WB; WS; RS

Hall, J.P. 1984
BS

Hapla, F. 1997
DF

Harris, G. 1993
LbP; ShP; LLP; SLP; PiP; WS; BS; BF;EH; WP;RP;JP

Harris, J.M.1993
EU; EO; DF; SP; TE; LbP; SLP; CP; ShP; ShP[T]; ShP[SF]; LP; PiP; NN

Hatton, J.V. 1993
JP

Hatton, J.V. et al. 1990a
JP

Hatton, J.V. et al. 1990b
DF

Heger, L. 1974
BS; BF; LP

Hegyi, F. 1969
JP

Hernández, R.E. 2007a
SM; NN

Hernández, R.E. 2007b
SM; NN

Hernández, R.E. et al. 2001
WS

Hunt, J.F. et al. 2008
LP

Hunt, K. et al. 1980
BF

Hunt, K. et al. 1995
BS; JP; WS; RS; NS; TL

Ivkovich, M. et al. 2002a
WS; ES

Ivkovich, M. et al. 2002b
WS; ES

Jacobs, S.M. et al. 2002
General

Jeffers, J.N.R. et al. 1964
SP; EL; DF; NS; SS; BlP; JL; NN

Jeremic, D. et al. 2004
BF

Jessome, A.P. 2000
General

Johal, S. et al. 2006
BF; WS; BS; RS

Jozsa, L.A. et al. 1987
WS

Jozsa, L.A. et al. 1992
LP

Jozsa, L.A. et al. 1994
General

Kang, K.Y. et al. 2004
JP

Keith, C.T. 1961
WS

Kellogg, R.M. 1989
DF

Kennedy, E.I. 1965
General

Kennedy, E.I. et al. 1968
WS; BS; RS; BF; RP; JP; EWP; EH; TL; EWC

Kennedy,R.W. 1995
DF; LP; WH; WS; SS; ES; BS; AF; AmF; GdF; NF

Khalil, M.A.K. 1985
BS

Klem, G.S. 1968
NS; SP; LbP; DF; SPF

Knowles, R.L. et al. 2004
DF

Knudson, R.M. et al. 2006
WS

Koch, P. 1987
LP

Koga, S. et al. 2002a
BF

Koga, S. et al. 2002b
BF

Koga, S. et al. 2004
BF

Koubaa, A. et al. 2000
BS

Koubaa, A. et al. 2002
BS

Koubaa, A. et al. 2005
BS

Larson, P.R. 1963
General

Lihra, T. et al. 2000
BF

Liu, C. et al. 2007
BS

Lo, E. et al. 2001
JP

Loo-Dinkins, J.A. et al. 1991
DF

Maeglin, R.R.1973
BF; TL; WS; BS; JP; RP; WP; EH; LTA; TA

Magnussen, S. et al. 1990
JP

Mamdy, C. et al. 1999
DF

Man, R. et al. 2004
WS, PO

Mansfield, S.D. et al. 2007
TA

Markwardt, L.J. 1930
General

McClain, K.M. et al. 1994
BS; WS; RP

Megraw, R.A. et al. 1972
DF

Middleton, G.R. et al. 1992
LP

Middleton, G.R. et al. 1995
LP

Middleton, G.R. et al. 1996
LP

Middleton, G.R. et al. 2000a
WS

Middleton, G.R. et al. 2000b
LP

Middleton, G.R. et al. 2002
WS

Middleton, G.R. et al. 2005
WS

Molteberg, D., 2004
General

Mullins, E.J. et al. 1981
General

Newton, P.F. 2006
BS; JP

Okwuagwu, C.O. et al. 1981
JP

Oliver, C.D. et al. 1986
DF

Packee, E.C. et al. 1992
TL; WS; BS; WB; BP; TA

Panshin, A. J., et al. 1980
JP; DF; BF; WS; BS; SM; LP; General

Park, Y.S. et al. 1989
JP

Parker, M.L. et al. 1976
DF

Paul, B.H. 1963
SM; TA; DF; General

Pelletier, G. et al. 2008
WS

Pliura, A. et al. 2006
ECT; BPO; BCT; JPO; BP

Pnevmaticos, S.M. et al. 1972
BS; BF

Polman, J.E. et al. 1996
DF

Pothier, D. 2002
BF

Pronin, D.1971
RP; JP; WS; BS; BF; TL; EH; TA; LTA

Rathgeber, C.B.K. et al. 2006
DF

Risi, J. et al. 1960
BS

Robinson, A.R. et al. 2007
DF

Roddy, D.M. 1983
JP; WS

Rozenberg, P. et al. 1999
DF

Rudnicki, M. et al. 2004
LP

Schneider, R. 2006
JP

Schneider, R. et al. 2008
JP

Scott, S.L. et al. 1982
JP

Semple, K.E. et al. 2007
TA; ECT; BCT

Sharma, M. et al. 2004
JP; BS; BF

Shatford, J.P.A. et al. 2009
CDF; WH

Shepard, R.K. 1980
WS

Shepard, R.K. et al. 1990
BS

Shi, J.L. et al. 2005
BS

Shi, J.L. et al. 2006
BS; DL; SL; SPF

Shi, J.L. et al. 2007
BS

Shi, S.Q. et al. 1999
General

Siddiqui, K.M. et al. 1971
DF

Singh,T. 1984
AF; BF; WS; BS; JP; LP; TA; BP; TL, WB

Singh, T. 1986
WS; BS; JP; TL; TA; BF

Smith, D.W. et al. 1982
WB; BC; SM

Smith, S.M. et al. 1987
DF

Spurr, S.H. et al. 1953
JP; SP

Stark, E.W.1954
SM; RM; SlM; MM; FM; VM; DM; BtM; CM; BlM; BEM; BM; StM

Swift, D.E. et al. 2007
BF; RS; BS; WS

Syta, D. et al. 1995
WS

Taylor, F.W. et al. 1982
WS

Thor, E. et al. 1974
BF

Tong, Q.J. et al. 2005
JP

Ukrainetz, N.K. et al. 2008
CDF

USDA, Forest Service. 1972
General

Vahey, D.W. et al. 2007
DF

Vargas-Hernandez, J. et al. 1991
DF

Wahlgren, H.E. et al. 1966
EWP; RP; BF; WS; BS; RS; EH; TL

Wahlgren, H.E. et al. 1995
EWP; RP; RS; WS; BS; BF; EH; TL

Wang, E.I.C. et al. 1984
WS

Wang, L. et al. 2000
BS

Wang, T. et al. 2000
LP

Wang, X. et al. 2002
JP; RP

Weiskittel, A.R. et al. 2006
DF

Welham, C. et al. 2002
WS; TA

Willcocks, A. et al. 1995
JP; LP; WS; NS

Winistorfer, P.M. et al. 1996
TA

Wood, J. et al. 2005
BS; BF

Yanchuk, A.D. et al. 1993
WS; ES

Yang, K.C. 1987
General

Yang, K.C. 2002
WS

Yang, K.C. et al. 1994
BS

Yu, Q. et al. 2003
WS

Zarnovican, R. et al. 1996
BF

Zhang, S.Y. 1997
General

Zhang, S.Y. 1998
BS

Zhang, S.Y. 2003
General

Zhang, S.Y. et al. 1996a
BS

Zhang, S.Y. et al. 1996b
JP

Zhang, S.Y.,et al. 1998a
BS

Zhang, S.Y. et al. 1998b
BF

Zhang, S.Y. et al. 2002
BS

Zhang, S.Y. et al. 2004
WS

Zhang, Y. et al. 2005
SM

Zhang, S.Y. et al. 2008
BS; WS; RS; JP; RP; WP; BF; EL; EH; EWC

Zhu, J.Y. et al. 2008a
RP; DF; LP

Zhu, J.Y. et al. 2008b
DF

Zobel, B.J. 1964
General

Zobel, B. 1992
General

Zobel, B.J. et al. 1989
General

Economics / Économie

Acuna, M.A. et al. 2005
DF

Acuna, M.A. et al. 2007
DF

Barbour, R.J. et al. 1990
General

Bell, F.W. et al. 1997
JP

Bragg, D.C. 2006
SM

Brand, D.G.E. 1991
General

Cown, D.J. 2005
RaP; General

Curry, W.T. et al. 1965
NS; DF; EL

Domke, G.M. et al. 2008
TA

Elliott, G.K. 1970
General

Eyre, F.H. et al. 1944
JP

Fleming, R.L. et al. 2005
BS

Fournier, A. et al. 2006
SM; BE

Hanley, D.P. et al. 1995
General

Henman, D.W. 1963
NS; DF; SP; SS; EL; NN

Jagels, R. 2006
TE; BC; RW

Kellogg, R.M. 1989
DF

Ker, M.F. 1987
BF

Knowles, R.L. et al. 2004
DF

Liu, C. et al. 2005
BS

Liu, C. et al. 2007a
BS

Liu, C. et al. 2007b
BS; BF

Lussier, J.M. 2009
General

Magnussen, S. et al. 1990
JP

Mattice, C.R. et al. 1975
JP

McClain, K.M. et al. 1994
BS; WS; RP

McKenney, D.W. et al. 1997
BS

Middleton, G.R. et al. 1989
DF

Middleton, G.R. et al. 2009
DF; WTL; WS; JP; BS; WB; WH; BF; LP

Newton, P.F. et al. 2004
BS

Niese, J.N. et al. 1995
SM; WA; RO; YB; BAS; EH; RM

Nyland, R.D. 2005
SM

Oliver, C.D. et al. 1986
DF

OMNR 1998
JP; BS

Racey, G.D. et al. 1990
General

Roe, E.I. et al. 1950
JP

Schneider, R. 2006
JP

Siddiqui, K.M. et al. 1971
DF

Smith, C.R. et al. 1988
JP

Strong, T. et al. 1995
SM; EWP; EH; WA; YB; BAS; RM

Tong, Q.J. et al. 2005a
JP

Tong, Q.J. et al. 2005b
JP

Tong, Q.J. et al. 2006
JP

Tong, Q.J. et al. 2008
JP

Tuskan,G.A. 1998
PO; SwG; SYC; WL; BL; Aln; EU; MQ; AX; SIM

USDA, Forest Service. 1972
General

van Buijtenen, J.P. 1997
General

Watson, P. et al. 2009
General

Weiskittel, A.R. et al. 2006
DF

Zhang, S.Y. 1997
General

Zhang, S.Y. 2003
General

Zhang, S.Y. et al. 1998
BF

Zhang, S.Y. et al. 2002
BS

Zhang, S.Y. et al. 2005
JP

Zhang, S.Y. et al. 2006
BS

Zobel, B.J. 1984
General

Entomology and Pathology / Entomologie et pathologie

Includes: insects; disease; pathogens; fungus; rot; decay

Comprends : insectes; maladies; pathogènes; champignon; carrie; pourriture

Alden, H.A. 1995
General

Anagnost, S.E. et al. 2005
LbP; BC; SM; CA

Angers, V.A. et al. 2005
SM; BE; YB; BA; EH

Barbour, J. 1988
WS

Berry, A.B. 1974
WS

Blanchette, R.A. et al. 1994
BF; BS; EWP; TA; RM

Brand, D.G.E. 1991
General

Cayford, J.H. et al. 1967
JP

Domke, G.M. et al. 2008
TA

Duchesne, I. 2006
JP

Fernandez, M.P. et al. 2002
TA

Forest Products Research Laboratory 1957
General

Goble, B.C. et al. 1993
JP

Gottschalk, K.W. 1995
General

Green, D.W. et al. 1999
BF; DF; BS; WS; JP; LP; SM; TA

Hanley, D.P. et al. 1995
General

Hartmann, H. et al. 2008
SM

Jagels, R. 2006
TE; BC; RW

Jeremic, D. et al. 2004
BF

Johnstone, W.D. 2002
LP

Jozsa, L.A. et al. 1987
WS

Kellogg, R.M. 1989
DF

Larson, P.R. 1963
General

Lemieux, H. et al. 2002
BS

Middleton, G.R. et al. 1992
LP

Middleton, G.R. et al. 2000
LP

Miller, B. 1996
TA

Moore, J.D. et al. 2008
SM

Mullins, E.J. et al. 1981
General

Oliver, C.D. et al. 1986
DF

Panshin, A.J. et al. 1980
JP; DF; BF; WS; BS; SM; LP; General

Peck, E.C.1933
SLF; LLP; DF; WH; PP; SuP; WWP; RW; WP; SC; SS; WTL; WF

Penner, M. et al. 2001
TA

Schneider, R. 2006
JP

Shortle, W.C. et al. 1986
BF; SF

Smith, C.R. 1984
JP

Smith, S.M. et al. 1987
DF

Taylor, A.M. et al. 2003
DF

Wan, H. et al. 2006
SM; YB; TA

Weiskittel, A.R. et al. 2006
DF

Yu, Q. et al. 2003
WS

Zhang, S.Y. 1997
General

Zhang, S.Y. et al. 2008
BS; WS; RS; JP; RP; WP; BF; EL; EH; EWC

Zobel, B.J. et al. 1989
General

General / Général

Barbour, R.J. et al. 1990
General

Elliott, G.K. 1970
General

Hapla, F. 1997
DF

Bragg, D.C. 2006
SM

Harris, J.M. 1993
EU; EO; DF; SP; TE; LbP; SLP; CP; ShP; ShP[T]; ShP[SF]; LLP; PiP; NN

Hillis, W.E. 1962
General

Jozsa, L.A. et al. 1994
General

Kellogg, R.M. 1989
DF

Kennedy, R.W. 1995
DF; LP; WH; WS; SS; ES; BS; AF; AmF; GdF; NF

Larson, P.R. 1969
General

Li, C. 2009
General

MacKenzie, J. et al. 2009
General

Mullins, E.J. et al. 1981
General

Oliver, C.D. et al. 1986
General

Panshin, A.J. et al. 1980
JP, DF, BF, WS, BS, SM, LP, General

Paul, B.H. 1963
SM, TA, DF, General

Senft, J.F. et al. 1985
General

Seymour, R.S. et al. 1986
General

Stark, E.W. 1954
SM, RM, SlM, MM, FM, VM, DM, BtM, CM, BlM, BEM, BM, StM

St-Germain J.L. et al. 2008
BS

Wang, L. et al. 2000
BS

Yang, K. C. 1987
General

Zhang, S.Y. 1997
General

Zhang, S.Y. 2003
General

Zhang, S.Y. et al. 2008
BS, WS, RS, JP, RP, WP, BF, EL, EH, EWC

Zobel, B. 1984
General

Zobel, B. 1992
General

Genetics / Génétique

Includes: inheritance; phenotypic; provenance trial; family test; seed orchard
Comprends : hérédité; phénotypique; test de provenances; test de familles; verger à graines

Abdel-Gadir, A.Y. et al. 1993
DF

Barbour, J. 1988
WS

Beaulieu, J. et al. 1985
WS

Beaulieu, J. et al. 2006
WS

Bendtsen, B.A. 1978
LbP; DF; JP; CP

Boyle, T.J.B. et al. 1987
BS

Bragg, D.C. 2006
SM

Burns, R.M. et al. 1990
General

Cannell, M.G.R. et al. 1983
LP; SS

Cayford, J.H. et al. 1967
JP

Chang, C.I. 1966
WS

Chang, C.I. et al. 1967
WS

Chantre, G. et al. 2002
DF

Cherry, M.L. et al. 2008
CDF

Chui, Y.H. et al. 1995
JP

Corriveau, A. et al. 1987
WS

Corriveau, A. et al. 1990
WS

Corriveau, A. et al. 1991
WS

Cutter, B.E. et al. 2004
General

Dery, P.J. et al. 1981
BF

Dinwoodie, J.M. 1961
General

Domke, G.M. et al. 2008
TA

Donaldson, L. 2008
General

Downes, G.M. et al. 2002
General

Duchesne, I. et al. 2004
WS

Elliott, G.K. 1970
General

Fernandez, M.P. et al. 2002
TA

Francis, R.C. et al. 2006
PO

Godt, M.J.W. et al. 2001
WS; JP

Gonzalez, J.S. et al. 1978
WH; IF; SS; AMF

Hall, J.P. 1984
BS

Hernández, R.E. et al. 2001
WS

Ivkovich, M. et al. 2002a
WS;ES

Ivkovich, M. et al. 2002b
WS; ES

Jacobs, S.M. et al. 2002
General

Jagels, R. 2006
E; BC; RW

Khalil, M.A.K. 1985
BS

Knowles, R.L. et al. 2004
DF

Knudson, R.M. et al. 2006
WS

Koubaa, A. et al. 2000
BS

Larson, P.R. 1962
General

Larson, P.R. 1963
General

Loo-Dinkins, J.A. et al. 1991
DF

Magnussen, S. et al. 1985
JP

Magnussen, S. et al. 1987
JP

Magnussen, S. et al. 1990
JP

Mamdy, C. et al. 1999
DF

Mansfield, S.D. et al. 2007
TA

Megraw, R.A. et al. 1972
DF

Merrill, R.E. et al. 1985
WS

Middleton, G.R. et al. 2000
LP

Morris, D.M. et al. 1992
JP

Nienstaedt, H. et al. 1976
JP;WS

Okwuagwu, C.O. et al. 1981
JP

Oliver, C.D. et al. 1986
DF

Park, Y.S. et al. 1989
JP

Park, Y.S. et al. 1988
BS

Penner, M. et al. 2001
TA

Pliura, A. et al. 2006
ECT; BPO; BCT; JPO; BP

Rajora, O.P. 1999
WS

Robinson, A.R. et al. 2007
DF

Roddy, D.M. 1983
JP; WS

Rozenberg, P. et al. 1999
DF

Savva, Y. et al. 2008
JP

Semple, K.E. et al. 2007
TA; ECT; BCT

Smith, C.R. 1984
JP

Tuskan,G.A. 1998
PO; SwG; SYC; WL; BL; Aln; EU; MQ; AX; SlM

Ukrainetz, N.K. et al. 2008
CDF

USDA, Forest Service. 1972
General

van Buijtenen, J.P. 1997
General

Vargas-Hernandez, J. et al. 1991
DF

Villeneuve, M. et al. 1987
JP; BS

Wang, T. et al. 2000
LP

Yanchuk, A.D. et al. 1993
WS; ES

Yu, Q. et al. 2001
PO

Yu, Q. et al. 2003
WS

Zhang, S.Y. 1998
BS

Zhang, S.Y. et al. 1996a
BS

Zhang, S.Y. et al. 1996b
BS

Zhang, S.Y. et al. 1996c
JP

Zhang, S.Y. et al. 1998
BS

Zhang, S.Y. et al. 2004
WS

Zhang, S.Y. et al. 2008
BS; WS; RS; JP; RP; WP; BF; EL; EH; EWC

Zobel, B.J. 1964
General

Zobel, B.J. et al. 1989
General

Growth and Yield / Croissance et rendement

Bedard, S. et al. 2003
SM; YB; BE; RM; BF

Bell, F.W. et al. 1990
JP

Bella, I.E. et al. 1974
JP

Boateng, J.O. et al. 2006
WS

Brand, D.G.E. 1991
General

Brazier, J.D. 1977
General

Brockley, R.P. 2005
LP

Burns, J. et al. 1996
BS

Burns, R.M. et al. 1990
General

Cayford, J.H. 1961
JP

Cayford, J.H. 1964
JP

Chang, C.I. et al. 1967
WS

Chui, Y.H. et al. 1997
BS; BF

Cochran, P.H. et al. 2000
LP

Cole, W.G. et al. 1994
SM; WA; BAS

Cyr, G. et al. 2009
BS

Duchesne, I. et al. 2004
WS

Emmingham, W. et al. 2007
DF

Feng, Z. et al. 2006
WS

Fleming, R.L. et al. 2005
BS

Flewelling, J.W. et al. 2008
DF

Forget, E. et al. 2007
SM; YB; BE

Fournier, A. et al. 2006
SM; BE

Fu, S. et al. 2007
BS;WS;WP;JP

Fujiwara, S. et al. 2000
BF; WS; BS; JP; TA

Gartner, B.L. et al. 2002
DF

Goble, B.C. et al. 1993
JP

Groot, A. et al. 1984
JP

Hale, J.D. et al. 1931
WS

Hale, J.D. et al. 1940
BS; BF; YB; TA; WB; WS; RS

Harrington, T.B. et al. 2009
DF

Hillman, G.R. et al. 1998
BS

Hökkä, H. et al. 1999
BS

Houle, D. et al. 2008
BS; BF

Hunt, K. et al. 1980
BF

Ivkovich, M. et al. 2002
WS; ES

Janas, P.S. et al. 1988
JP

Jones, T.A. et al. 2004
SM

Karsh, M.B. et al. 1994
BS; BF

Ker, M.F. 1981
BF

Kiernan, D.H. et al. 2008
SM

King, D.A. 2005
General

Klos, R.J. et al. 2007
BP; WS; TA; BS; JP

Koga, S. et al. 2002a
BF

Koga, S.,et al. 2002b
BF

Laflèche, V. et al. 2008
BS; BF; WB; JP

Larocque, G.R. 2000
JP

Lhotka, J.M. et al. 2008
SM; EB; NS; LP; EWP; SP; LbP; DF

Lindgren, P.M.F. et al. 2007
LP

Lo, E. et al. 2001
JP

Mahendrappa, M.K. et al. 1982
BS

Mallik, A.U. et al. 2008
BS; WS; RP

Man, R. et al. 2004
WS, PO

Man, R. et al. 2008
TA

Marshall, D.D. et al. 1999
DF

McClain, K.M. et al. 1994
BS; WS; RP

McLaren, B.E. et al. 1998
BS

Middleton, G.R. et al. 2000
WS

Middleton, G.R. et al. 2002
WS

Middleton, G.R. et al. 2005
WS

Moore, J.D. et al. 2008
SM

Newton, P.F. 1998
BS

Newton, P.F, 2003a
BS

Newton, P.F, 2003b
BS

Newton, P.F. 2004
JP

Newton, P.F. et al. 1993
BS

Newton, P.F. et al. 1994
BS

Newton, P.F. et al. 2004
BS

Newton, P.F, et al. 2005a
BS

Newton, P.F. et al. 2005b
BS; JP

Newton, P.F. et al. 2006
BS; JP

Noone, C.S. et al. 1980
DF

Park, Y.S. et al. 1989
JP

Payandeh, B. 1989
BS

Peck, E.C.1933
SLF; LLP; DF; WH; PP; SuP; WWP; RW; WP; SC; SS; WTL; WF

Pelletier, G. et al. 2008
WS

Peng, C. 2000
General

Pothier, D. 2002
BF

Rytter, L. et al. 2005
EA; TA

Savva, Y. et al. 2008
JP

Schneider, R. 2001
BF

Schuler, T. M. 2004
SM; RM; RO; CO

Sharma, M. et al. 2004
JP; BS

Sharma, M. et al. 2007
JP

Shatford, J.P.A. et al. 2009
CDF; WH

Smith, C.R. et al. 1988
JP

Solomon, D.S. et al. 2002
BF; RS; BS; WS; EH; EWC; TL

Spurr, S.H. et al. 1953
JP; SP

St-Germain, J.L. et al. 2008
BS

Sucre, E.B. et al. 2008
DF

Sullivan, T.P. et al. 2006
LP

Swift, D.E. et al. 2007
BF; RS; BS; WS

Taylor, A.M. et al. 2003
DF

Tong, Q.J. et al. 2005
JP

Ukrainetz, N.K. et al. 2008
CDF

USDA, Forest Service. 1972
General

Wang, T. et al. 2000
LP

Winston, D.A. 1977
JP

Yang, K.C. 2002
WS

Yang, K.C. et al. 1985
JP; TL

Yu, Q. et al. 2003
WS

Zarnovican, R. et al. 1996
BF

Zhang, S.Y. et al. 1996a
BS

Zhang, S.Y. et al. 1996b
BS

Zhang, S.Y. et al. 2004
WS

Zhu, J.Y. et al. 2008a
RP; DF; LP

Zhu, J.Y. et al. 2008b
DF

Lumber / Bois d'œuvre

Includes: recovery

Comprends : récupération

Acuna, M.A. et al. 2005
DF

Acuna, M.A. et al. 2007
DF

Balatinecz, J.J. et al. 2001a
PO

Balatinecz, J.J. et al. 2001b
TA;LTA;ECT; BCT; BP; BS; JP; BF; NN

Barbour, J. et al. 1988
BS

Barbour, R.J. et al. 1989
BS

Barbour, R.J. et al. 1990
General

Barrett, J.D. et al. 1994
General

Beaulieu, J. et al. 2006
WS

Bella, I.E. et al. 1974
JP

Bendtsen,B.A. 1976
RS; WS; BS; BF; SAF; POC; WRC; SuP; WWP

Bendtsen, B.A. 1978
LbP; DF; JP; CP

Bendtsen, B.A. et al. 1975
HK; RM; RO; WE; YP

Bendtsen, B.A. et al. 1979
CDF; IDF; SLP; WH; ES; WS; SF; PO; RO

Benjamin, J. et al. 2007
BS

Bragg, D.C. 2006
SM

Briggs, D.G. et al. 2008
CDF

Cown, D.J. 2005
RaP; General

Curry, W.T. et al. 1965
NS; DF; EL

Defo, M. et al. 1999
WS; SM

Dinwoodie, J.M. 1961
General

Duchesne, I. 2006
JP

Elliott, G.K. 1970
General

Eyre, F.H. et al. 1944
JP

Fournier, A. et al. 2006
SM; BE

Gonzalez, J. et al. 1993
LP

Goudie, J.W. et al. 2008
WS; ES

Green, D.W. et al. 1999
BF; DF; BS; WS; JP; LP; SM; TA

Green, D.W. et al. 2001
DF

Green, D.W. et al. 2008
DF; PP

Grotta, A.T. et al. 2005
DF

Guernsey, F.W. et al. 1966
LP

Gupta, R. et al. 2004
DF

Hanley, D.P. et al. 1995
General

Hansen, L.W. et al. 2004
RaP; DF

Hapla, F. 1997
DF

Harris, J.M.1993
EU; EO; DF; SP; TE; LbP; SLP; CP; ShP; ShP[T]; ShP[SF]; LLP; PiP; NN

Henman, D.W. 1963
NS; DF; SP; SS; EL; NN

Hernández, R.E. et al. 2001
WS

Jessome, A.P. 2000
General

Jozsa, L.A. et al. 1992
LP

Jozsa, L.A. et al. 1994
General

Kellogg, R.M. 1989
DF

Kennedy, E.I. et al. 1968
WS; BS; RS; BF; RP; JP; EWP; EH; TL; EWC

Kennedy,R.W. 1995
DF; LP; WH; WS; SS; ES; BS; AF; AmF; GdF; NF

Klem, G.S. 1968
NS; SP; LbP; DF; SPF

Knowles, R.L. et al. 2004
DF

Knudson, R.M. et al. 2006
WS

Koga, S. et al. 2002
BF

Lam, F. et al. 1991
LP; WS; AF

Law, K.N. et al. 2003
JP

Lei, Y.C. et al. 2005
BS

Lemieux, H. et al. 2001
BS

Lemieux, H. et al. 2002
BS

Lihra, T. et al. 2000
BF

Liu, C. et al. 2005a
BS

Liu, C. et al. 2005b
BS

Liu, C. et al. 2006
BS

Liu, C. et al. 2007a
BS

Liu, C. et al. 2007b
BS

Liu, C. et al. 2007c
BS

Liu, C. et al. 2007d
BS; BF

Maguire, D.A. et al. 1999
DF

Mamdy, C. et al. 1999
DF

McClain, K.M. et al. 1994
BS; WS; RP

Middleton, G.R. et al. 1989
DF

Middleton, G.R. et al. 1992
LP

Middleton, G.R.,et al. 1995
LP

Middleton, G.R. et al. 2000
LP

Mullins, E.J. et al. 1981
General

Niese, J.N. et al. 1995
SM; WA; RO; YB; BAS; EH; RM

Nyland, R.D. 2005
SM

O'Halloran, M.R. et al. 1972
LP

Oliver, C.D. et al. 1986
DF

Panshin, A.J. et al. 1980
JP; DF; BF; WS; BS; SM; LP; General

Peck, E.C.1933
SLF; LLP; DF; WH; PP; SuP; WWP; RW; WP; SC; SS; WTL; WF

Polman, J.E. et al. 1996
DF

Rayirath, P. et al. 2008
BS

Rippy, R.C. et al. 2000
DF

Roblot, G. et al. 2008
DF; FS

Samson, M. 1993
SP; General

Schneider, M.H. et al. 1989
BF

Schneider, R. 2006
JP

Semple, K.E. et al. 2007
TA; ECT; BCT

Senft, J.F. et al. 1985
General

Seymour, R.S. et al. 1986
General

Smith, W.B. 1986
RP; WP; EH; NS; EL; PO

Standish, J.T. 1983
General

Syta, D.,et al. 1995
WS

Tong, Q.J. et al. 2005a
JP

Tong, Q.J. et al. 2005b
JP

Tong, Q.J. et al. 2006
JP

Tong, Q.J. et al. 2008a
JP

Tong, Q.J. et al. 2008b
JP; BS; WS; RS; BF

Vahey, D.W. et al. 2007
DF

Weiskittel, A.R. et al. 2006
DF

Zhang, S.Y. 1997
General

Zhang, S.Y. 2003
General

Zhang, S.Y. et al. 1998
BF

Zhang, S.Y. et al. 2002
BS

Zhang, S.Y. et al. 2004
WS

Zhang, S.Y. et al. 2005a
JP

Zhang, S.Y. et al. 2005b
BS

Zhang, S.Y. et al. 2006a
BS

Zhang, S.Y. et al. 2006b
BS

Zhang, S.Y. et al. 2006c
BS

Zhang, S.Y. et al. 2006d
JP

Zhang, S.Y. et al. 2008
BS; WS; RS; JP; RP; WP; BF; EL; EH; EWC

Zhang, Y. et al. 2005
SM

Zhou, H. et al. 1991a
WS

Zhou, H. et al. 1991b
WS

Mechanical Attributes / Attributs mécaniques
Includes: hardness; coarseness; shrinkage; failure
Comprends : dureté; masse linéique; retrait; défaillance

Alden, H.A. 1995
General

Barbour, J. et al. 1988
BS

Barbour, R.J. et al. 1989
BS

Barrett, J.D. et al. 1994
General

Bendtsen, B.A. 1974
BS; RS; WS; BF

Bendtsen, B.A. 1978
LbP; DF; JP; CP

Bendtsen, B.A. et al. 1975
HK; RM; RO; WE; YP

Dempster, W.R. et al. 2002
LP; BS; WS

Dokken, M. 1972
WS; WP; RP

Dokken, M. et al. 1973
BF

Donaldson, L. 2008
General

Drost, C. et al. 2003
JP; BS; BF; WP; RS

Duchesne, I. et al. 2004
WS

Forest Products Research Laboratory. 1957
General

Green, D.W. et al. 1999
BF; DF; BS; WS; JP; LP; SM; TA

Guernsey, F.W. et al. 1966
LP

Gupta, R. et al. 2004
DF

Hale, J.D. et al. 1923
DF; SPF

Hale, J.D. et al. 1931
WS

Harris,G. 1993
LbP; ShP; LLP; SLP; PiP; WS; BS; BF;EH; WP;RP;JP

Harris, J.M.1993
EU; EO; DF; SP; TE; LbP; SLP; CP; ShP; ShP[T]; ShP[SF]; LLP; PiP; NN

Hatton, J.V. 1993
JP

Hatton, J.V. et al. 1996
BS; NS; RS; WS; JP; TL

Jagels, R. 2006
TE; BC; RW

Jeremic, D. et al. 2004
BF

Jessome, A.P. 2000
General

Jozsa, L.A. et al. 1992
LP

Kang, K.Y. et al. 2004
JP

Kellogg, R.M. 1989
DF

Kennedy, E.I. 1965
General

Lam, F. et al. 1991
LP; WS; AF

Law, K.N. et al. 1997
JP; BS

Law, K.N. et al. 2003
JP

Mansfield, S.D. et al. 2007
TA

Markwardt, L.J. 1930
General

Middleton, G.R. et al. 2000a
WS

Middleton, G.R. et al. 2000b
LP

Middleton, G.R. et al. 2002
WS

Molteberg, D. 2004
General

Mullins, E.J. et al. 1981
General

Oliver, C.D. et al. 1986
DF

Olson, A.R. et al. 1947
EL; NS; JP; RP; WP; SP; EH; DF

Packee, E.C. et al. 1992
TL; WS; BS; WB; BP; TA

Panshin, A.J. et al. 1980
JP; DF; BF; WS; BS; SM; LP; General

Paul, B.H. 1963
SM; TA; DF; General

Peck, E.C.1933
SLF; LLP; DF; WH; PP; SuP; WWP; RW; WP; SC; SS; WTL; WF

Perem, E. 1958
WS; RP

Robinson, A.R. et al. 2007
DF

Senft, J.F. et al. 1985
General

Seth, R.S. 1990
General

Shi, J.L. et al. 2006
BS; DL; SL; SPF

Syta, D. et al. 1995
WS

Ukrainetz, N.K. et al. 2008
CDF

Wan, H. et al. 2006
SM; YB; TA

Wang, H.H. et al. 2001
CDF; PO

Watson, P. et al. 2009
General

Willcocks, A. et al. 1995
JP; LP; WS; NS

Wimmer, R. et al. 1997
RS; NS; SS; ES

Yang, K.C. 1987
General

Yemele, M.C.N. et al. 2008
BS; TA

Yu, Q. et al. 2001
PO

Zhang, S.Y. 1997
General

Zhang, S.Y. et al. 2008
BS; WS; RS; JP; RP; WP; BF; EL; EH; EWC

Zhou, H. et al. 1991
WS

Modeling / Modélisation
Includes: stand density management diagram
Comprends : diagramme d'aménagement de la densité de peuplement

Achim, A. et al. 2005
BF

Acuna, M.A. et al. 2005
DF

Acuna, M.A. et al. 2007
DF

Alemdag, I.S.1984
ERC; EWC; BF; EH; EWP; JP; RP; BS; WS; TL; BA; RA; WA; LTA; TA; BAS; BE; WB; YB; BC; WE, HK; RM; SIM; SM; RO; WO; BP

Alteyrac, J. et al. 2006
BS

Banal, S. et al. 2007
RM; SM; YB; BE; EH; WAS; BC; WP; RO

Barbour, J. 1988
WS

Barbour, J. et al. 1988
BS

Barbour, R.J. et al. 1989
BS

Barrett, J.D. et al. 1994
General

Bell, F.W. et al. 1997
JP

Bendtsen, B.A. et al. 1979
CDF; IDF; SLP; WH; ES; WS; SF; PO; RO

Bragg, D.C. et al. 1997
SM

Briggs, D.G. et al. 2008
CDF

Campbell, J.S. et al. 1985
TA

Choi, J. et al. 2001
SM; BAS; WA

Coates, K.D. et al. 2003
General

Cole, W.G. et al. 1994
SM; WA; BAS

Dean, T.J. et al. 1986
LP

Deckmyn, G. et al. 2006
General

Defo, M. et al. 1999
WS; SM

Defo, M. et al. 2009
General

Downes, G.M. et al. 2002
General

Dunham, S.M. et al. 2008
DF

Flewelling, J.W. et al. 2008
DF

Goudie, J.W. et al. 2008
WS; ES

Groot, A. et al. 2008
BS

Grotta, A.T. et al. 2005
DF

Hann, D.W. 1999
DF

Hartmann, H. et al. 2008
SM

Hegyi, F. 1969
JP

Hein, S. et al. 2008
DF

Hernández, R.E. 2007a
SM; NN

Hernández, R.E. 2007b
SM; NN

Hökkä, H. et al. 1999
BS

Ise, T. et al. 2008
BS

Karsh, M.B. et al. 1994
BS; BF

Kellogg, R.M. 1989
DF

Kiernan, D.H. et al. 2008
SM

Knowles, R.L. et al. 2004
DF

Koubaa, A. et al. 2002
BS

Koubaa, A. et al. 2005
BS

Larocque, G.R. 2000
JP

Lei, Y.C. et al. 2005
BS

Lemieux, H. et al. 2002
BS

Lemieux, H. et al. 2001
BS

Lhotka, J. M. et al. 2008
SM; EB; NS; LP; EWP; SP; LbP; DF

Liu, C. et al. 2005a
BS

Liu, C. et al. 2005b
BS

Liu, C. et al. 2006
BS

Liu, C. et al. 2007a
BS

Liu, C. et al. 2007b
BS

Liu, C. et al. 2007c
BS

Lo, E. et al. 2001
JP

Lussier, J.M. 2009
General

Maeglin, R.R.1973
BF; TL; WS; BS; JP; RP; WP; EH; LTA; TA

Maguire, D.A. et al. 1999
DF

Mäkelä, A. 2002
SP

Mäkelä, A. et al. 2006
General

Marshall, D.D. et al. 1999
DF

Mencuccini, M. et al. 2007
General

Meng, S.X. et al. 2007
LP

Newton, P.F. 1998
BS

Newton, P.F. 2003a
JP

Newton, P.F. 2003b
BS

Newton, P.F. 2003c
BS

Newton, P.F. 2004
JP

Newton, P.F. 2006a
BS; JP

Newton, P.F. 2006b
BS

Newton, P.F. et al. 1993
BS

Newton, P.F. et al. 1994a
BS

Newton, P.F. et al. 2004b
BS

Newton, P.F. et al. 2005a
BS

Newton, P.F. et al. 2005b
BS; JP

Newton, P.F. et al. 2007
BS; JP

Noone, C.S. et al. 1980
DF

Nyland, R.D. 2005
SM

O'Halloran, M.R. et al. 1972
LP

Oliver, C.D. et al. 1986
DF

Ouellet, D.1983
WP; RP; JP; BF; WS; RS; TL; TA; YB; WB; SM; RM

Peng, C. 2000
General

Pliura, A. et al. 2006
ECT; BPO; BCT; JPO; BP

Pukkala, T. et al. 1987
General

Rathgeber, C.B.K. et al. 2006
DF

Raulier, F. et al. 1998
SM

Rozenberg, P. et al. 1999
DF

Rudnicki, M. et al. 2004
LP

Samson, M. 1993
SP; General

Schneider, R. 2001
BF

Schneider, R. 2006
JP

Schneider, R. et al. 2008a
JP

Schneider, R. et al. 2008b
JP

Sharma, M. et al. 2004
JP; BS

Sharma, M. et al. 2007
JP

Shi, J.L. et al. 2006
BS; DL; SL; SPF

Singh, T. 1986
WS; BS; JP; TL; TA; BF

Singh,T. 1984
AF; BF; WS; BS; JP; LP; TA; BP; TL, WB

Solomon, D.S. et al. 2002
BF; RS; BS; WS; EH; EWC; TL

Standish, J.T. 1983
General

Suárez, J.C. et al. 2005
General

Tong, Q.J. et al. 2006
JP

Tong, Q.J. et al. 2008
JP

van Buijtenen, J.P. 1997
General

Wahlgren, H.E. et al. 1966
EWP; RP; BF; WS; BS; RS; EH; TL

Wang, X. et al. 2002
JP; RP

Wang, Y. et al. 1998
BS; WS; LP; BP; PO

Weiskittel, A.R. et al. 2006
DF

Welham, C. et al. 2002
WS; TA

Winistorfer, P.M. et al. 1996
TA

Zarnovican, R. et al. 1996
BF

Zhang, S.Y. et al. 2005a
JP

Zhang, S.Y. et al. 2005b
BS

Zhang, S.Y. et al. 2006a
BS

Zhang, S.Y, et al. 2006b
BS

Zhang, S.Y. et al. 2006c (BS)

Zhang, Y. et al. 2005 (SM)

Modulus of Elasticity / Modulus d' élasticité
Modulus of Rupture / Modulus de rupture
Includes: microfibril angle; knots
Comprends : angle des microfibrilles; nœuds

Acuna, M.A. et al. 2005
DF

Acuna, M.A. et al. 2007
DF

Alden, H.A. 1995
General

Alteyrac, J. et al. 2006
BS

Anagnost, S.E. et al. 2005
LbP; BC; SM; CA

Balatinecz, J.J. et al. 2001
TA;LTA;ECT; BCT; BP; BS; JP; BF; NN

Ballard, L.A. et al. 1988
LP

Barbour, J. et al. 1988
BS

Barbour, R.J. et al. 1989
BS

Barrett, J.D. et al. 1994
General

Beaulieu, J. et al. 2006
WS

Bendtsen, B.A. 1974
BS; RS; WS; BF

Bendtsen, B.A. 1978
LbP; DF; JP; CP

Bendtsen, B.A. et al. 1975
HK; RM; RO; WE; YP

Bendtsen, B.A. et al. 1979
CDF; IDF; SLP; WH; ES; WS; SF; PO; RO

Benjamin, J. et al. 2007
BS

Bjurhager, I. et al. 2008
EA; TA

Brazier, J.D. 1977
General

Briggs, D.G. et al. 1986
General

Briggs, D.G. et al. 2005
DF

Briggs, D.G. et al. 2008
CDF

Cherry, M.L. et al. 2008
CDF

Curry, W.T. et al. 1965
NS; DF; EL

Dempster, W.R. et al. 2002
LP; BS; WS

Dokken, M. 1972
WS; WP; RP

Dokken, M. et al. 1973
BF

Donaldson, L. 2008
General

Downes, G.M. et al. 2002
General

Duchesne, I. 2006
JP

Forest Products Research Laboratory. 1957
General

Francis, R.C. et al. 2006
PO

Gonzalez, J. et al. 1993
LP

Goudie, J.W. et al. 2008
WS; ES

Green, D.W. et al. 1999
BF; DF; BS; WS; JP; LP; SM; TA

Green, D.W. et al. 2001
DF

Green, D.W. et al. 2008
DF; PP

Grotta, A.T. et al. 2005
DF

Guernsey, F.W. et al. 1966
LP

Gupta, R. et al. 2004
DF

Hanley, D.P. et al. 1995
General

Hansen, L.W. et al. 2004
RaP; DF

Harris, J.M.1993
EU; EO; DF; SP; TE; LbP; SLP; CP; ShP; ShP[T]; ShP[SF]; LLP; PiP; NN

Hein, S. et al. 2008
DF

Henman, D.W. 1963
NS; DF; SP; SS; EL; NN

Hernández, R.E. 2007
SM; NN

Hernández, R.E. et al. 2001
WS

Huffman, D.R. 1977
BS; JP; BF

Hunt, J.F. et al. 2008
LP

Ivkovich, M. et al. 2002
WS; ES

Jacobs, S.M. et al. 2002
General

Jagels, R. 2006
TE; BC; RW

Jeremic, D. et al. 2004
BF

Jessome, A.P. 2000
General

Jozsa, L.A. et al. 1994
General

Kellogg, R.M. 1989
DF

Kennedy, E.I. 1965
General

Kennedy,R.W. 1995
DF; LP; WH; WS; SS; ES; BS; AF; AmF; GdF; NF

Knowles, R.L. et al. 2004
DF

Knudson, R.M. et al. 2006
WS

Koga, S. et al. 2002
BF

Lam, F. et al. 1991
LP;WS;AF

Lei, Y.C. et al. 2005
BS

Lemieux, H. et al. 2001
BS

Lemieux, H. et al. 2002
BS

Liu, C. et al. 2007a
BS

Liu, C. et al. 2007b
BS

Mamdy, C. et al. 1999
DF

Markwardt, L.J. 1930
General

McClain, K.M. et al. 1994
BS; WS; RP

Middleton, G.R. et al. 1989
DF

Middleton, G.R. et al. 1995
LP

Middleton, G.R. et al. 1996
LP

Middleton, G.R. et al. 2000a
WS

Middleton, G.R. et al. 2000b
LP

Mott, L. et al. 1996
BS

Mott, L. et al. 2001
BS

Mullins, E.J. et al. 1981
General

Niklas, K.J. 1999
SM

O'Halloran, M.R. et al. 1972
LP

Oliver, C.D. et al. 1986
DF

Olson, A.R. et al. 1947
EL; NS; JP; RP; WP; SP; EH; DF

Panshin, A.J. et al. 1980
JP; DF; BF; WS; BS; SM; LP; General

Perem, E. 1958
WS; RP

Polman, J.E. et al. 1996
DF

Pyles, M.R. 1987
DF

Rayirath, P. et al. 2008
BS

Rippy, R.C. et al. 2000
DF

Robinson, A.R. et al. 2007
DF

Roblot, G. et al. 2008
DF; FS

Rozenberg, P. et al. 1999
DF

Samson, M. 1993
SP; General

Schneider, R. 2006
JP

Schneider, R. et al. 2008
JP

Semple, K.E. et al. 2007
TA; ECT; BCT

Shi, J.L. et al. 2005
BS

Shi, J.L. et al. 2006
BS; DL; SL; SPF

Shi, J.L. et al. 2007
BS

Shi, S.Q. et al. 1999
General

Silins, U. et al. 2000
LP

Smith, S.M. et al. 1987
DF

Stump, J.P. et al. 1981
RP; WP; WS; HL; DuL

Syta, D. et al. 1995
WS

Tong, Q.J. et al. 2005
JP

Ukrainetz, N.K. et al. 2008
CDF

USDA, Forest Service. 1972
General

Vahey, D.W. et al. 2007
DF

Wang, H.H. et al. 2001
CDF; PO

Wang, X. et al. 2002
JP; RP

Weiskittel, A.R. et al. 2006
DF

Willcocks, A. et al. 1995
JP; LP; WS; NS

Wimmer, R. et al. 1997
RS; NS; SS; ES

Yang, K.C. 1987
General

Yemele, M.C.N. et al. 2008
BS; TA

Zarnovican, R. et al. 1996
BF

Zhang, S.Y. 1997
General

Zhang, S.Y. 2003
General

Zhang, S.Y. et al. 1998
BF

Zhang, S.Y. et al. 2002
BS

Zhang, S.Y. et al. 2004
WS

Zhang, S.Y. et al. 2005
BS

Zhang, S.Y. et al. 2006
JP

Zhang, S.Y. et al. 2008
BS; WS; RS; JP; RP; WP; BF; EL; EH; EWC

Zhou, H. et al. 1991a
WS

Zhou, H. et al. 1991b
WS

Products / Produits

Includes: veneer; oriented strand board; production; grade; utilization; medium density fibreboard; laminated veneer lumber
Comprends : placage; panneau de lamelles orientées; production; classe; utilisation; panneau de fibres à densité moyenne; bois en placage stratifié

Acuna, M.A. et al. 2005
DF

Acuna, M.A. et al. 2007
DF

Aschim, O.K. et al. 1976
General

Balatinecz, J.J. et al. 2001
PO

Balatinecz, J.J. et al. 2001
TA;LTA;ECT; BCT; BP; BS; JP; BF; NN

Barbour, R.J. et al. 1990
General

Barrett, J.D. et al. 1994
General

Bendtsen, B.A. et al. 1975
HK; RM; RO; WE; YP

Bendtsen, B.A. et al. 1979
CDF; IDF; SLP; WH; ES; WS; SF; PO; RO

Benjamin, J. et al. 2007
BS

Bernier, P.Y. et al. 2007
TA; DF; JP; BS; BF

Briggs, D.G. et al. 2005
DF

Cantin, M.1965
BF; JP; RP; WP; BS; WS; WAS; LTA; TA; BA; EB; WB; YB; RM; SM; RO

Cayford, J.H. 1964
JP

Curry, W.T. et al. 1965
NS; DF; EL

De Montmorency, W.H. 1965
BS; WS; BF

Dempster, W.R. et al. 2002
LP; BS; WS

Dokken, M. 1972
WS; WP; RP

Dokken, M. et al. 1973
BF

Duchesne, I. 2006
JP

Elliott, G.K. 1970
General

Forest Products Research Laboratory. 1957
General

Fournier, A. et al. 2006
SM; BE

Fu, S. et al. 2007
BS; WS; WP; JP

Gagné, C. et al. 1990
JP

Gonzalez, J. et al. 1993
LP

Goudie, J.W. et al. 2008
WS; ES

Green, D.W. et al. 1999
BF; DF; BS; WS; JP; LP; SM; TA

Green, D.W. et al. 2001
DF

Green, D.W. et al. 2008
DF; PP

Guernsey, F.W. et al. 1966
LP

Hale, J.D. et al. 1931
WS

Hanley, D.P. et al. 1995
General

Harris, G. 1993
LbP; ShP; LLP; SLP; PiP; WS; BS; BF; EH; WP; RP; JP

Harris, J.M.1993
EU; EO; DF; SP; TE; LbP; SLP; CP; ShP; ShP[T]; ShP[SF]; LLP; PiP; NN

Hatton, J.V. 1993
JP

Henman, D.W. 1963
NS; DF; SP; SS; EL; NN

Hillis, W.E. 1962
General

Horton, K.W. 1981
TA

Huffman, D.R. 1977
BS; JP; BF

Hunt, J.F. et al. 2008
LP

Jagels, R. 2006
TE; BC; RW

Jozsa, L.A. et al. 1994
General

Kellogg, R.M. 1989
DF

Ker, M.F. 1987
BF

Khalil, M.A.K. 1985
BS

Knudson, R M. et al. 2006
WS

Koran, Z. 1967
BS

Lam, F. et al. 1991
LP; WS; AF

Lemieux, H. et al. 2001
BS

Lemieux, H. et al. 2002
BS

Li, C. 2009
General

Liu, C. et al. 2005a
BS

Liu, C. et al. 2005b
BS

Liu, C. et al. 2007
BS

Maguire, D.A. et al. 1999
DF

Markwardt, L.J. 1930
General

McKenney, D.W. et al. 1997
BS

Middleton, G.R. et al. 1989
DF

Middleton, G.R. et al. 1992
LP

Middleton, G.R. et al. 1995
LP

Middleton, G.R. et al. 2000
LP

Middleton, G.R. et al. 2005
WS

Miller, B. 1996
TA

Mullins, E.J. et al. 1981
General

Newton, P.F. 2006
BS

Niese, J.N. et al. 1995
SM; WA; RO; YB; BAS; EH; RM

O'Halloran, M.R. et al. 1972
LP

Oliver, C.D. et al. 1986
DF

Omholt, I. et al. 2008
BS

Panshin, A.J. et al. 1980
JP; DF; BF; WS; BS; SM; LP; General

Pavel, M. et al. 2009
General

Peck, E.C.1933
SLF; LLP; DF; WH; PP; SuP; WWP; RW; WP; SC; SS; WTL; WF

Polman, J.E. et al. 1996
DF

Rasmussen, E.F. 1961
General

Rippy, R.C. et al. 2000
DF

Roblot, G. et al. 2008
DF; FS

Samson, M. 1993
SP; General

Schneider, R. 2006
JP

Semple, K.E. et al. 2007
TA; ECT; BCT

Senft, J.F. et al. 1985
General

Seth, R.S. 1990
General

Seymour, R.S. et al. 1986
General

Shi, J.L. et al. 2005
BS

Shi, J.L. et al. 2006
BS; DL; SL; SPF

Shi, J.L. et al. 2007
BS

Shi, S.Q. et al. 1999
General

Smith, J.H.G. et al. 1971
General

Smith, S.M. et al. 1987
DF

Smith, W.B. 1986
RP; WP; EH; NS; EL; PO

Strong, T.F. et al. 1995
SM; EWP; EH; WA; YB; BAS; RM;

Stump, J.P. et al. 1981
RP; WP; WS; HL; DuL

Syta, D. et al. 1995
WS

Tong, Q.J. et al. 2005a
JP

Tong, Q.J. et al. 2005b
JP

Tuskan, G.A. 1998
PO; SwG; SYC; WL; BL; Aln; EU; MQ; AX; SlM

Wan, H. et al. 2006
SM; YB; TA

Watson, P. et al. 2009
General

Weiskittel, A.R. et al. 2006
DF

Willcocks, A. et al. 1995
JP; LP; WS; NS

Winistorfer, P.M. et al. 1996
TA

Wood, J. et al. 2005
BS; BF

Yemele, M.C.N. et al. 2008
BS; TA

Zhang, S.Y. 1997
General

Zhang, S.Y. 2003
General

Zhang, S.Y. et al. 1995
General

Zhang, S.Y. et al. 1998
BF

Zhang, S.Y. et al. 2002
BS

Zhang, S.Y. et al. 2004
WS

Zhang, S.Y. et al. 2006
JP

Zhang, S.Y. et al. 2008
BS; WS; RS; JP; RP; WP; BF; EL; EH; EWC

Zhou, H. et al. 1991a
WS

Zhou, H.,et al. 1991b
WS

Zobel, B.J. 1984
General

Pulp / Pâte
Includes: extractives; chips
Comprends : produits d'extraction du bois; copeaux

Acuna, M.A. et al. 2007
DF

Aschim, O.K. et al. 1976
General

Balatinecz, J.J. et al. 2001
PO

Balatinecz, J.J. et al. 2001
TA; LTA; ECT; BCT; BP; BS; JP; BF; NN

Ban, W. et al. 2004
BS

Barbour, R.J. et al. 1990
General

Bell, F.W. et al. 1990
JP

Bluskova, G. et al. 1997
SP; DF; BlP

Briggs, D.G. et al. 1986
General

Chantre, G. et al. 2002
DF

Clermont, L.P. et al. 1951
BF; WS; BS; JP; WB; EH; TA; WP

De Montmorency, W.H. 1965
BS; WS; BF

Dempster, W.R. et al. 2002
LP; BS; WS

Donaldson, L. 2008
General

Drost, C. et al. 2003
JP;BS;BF;WP;RS

Duchesne, I. et al. 2004
WS

Elliott, G.K. 1970
General

Fernandez, M.P. et al. 2002
TA

Fournier, A. et al. 2006
SM; BE

Francis, R.C. et al. 2006
PO

Gagné, C. et al. 1990
JP

Gagnon, J.D. et al. 1974
BF

Green, D.W. et al. 1999
BF; DF; BS; WS; JP; LP; SM; TA

Guernsey, F.W. et al. 1966
LP

Hale, J.D. 1955
BF; BS; WS; JP; TA; WB

Hapla, F. 1997
DF

Harris, G. 1993
LbP; ShP; LLP; SLP; PiP; WS; BS; BF; EH; WP; RP; JP

Hatton, J.V. 1993
JP

Hatton, J.V. et al. 1990a
JP

Hatton, J.V. et al. 1990b
DF

Hatton, J.V. et al. 1996
BS; NS; RS; WS; JP; TL

Hernández, R.E. 2007a
SM; NN

Hernández, R.E. 2007b
SM; NN

Hillis, W.E. 1962
General

Hunt, J.F. et al. 2008
LP

Hunt, K. et al. 1980
BF

Hunt, K. et al. 1995
BS; JP; WS; RS; NS; TL

Hussein, A. et al. 2006
BF

Jagels, R. 2006
TE; BC; RW

Johal, S. et al. 2006
BF; WS; BS; RS

Jozsa, L.A. et al. 1992
LP

Jozsa, L.A. et al. 1994
General

Kang, K.Y. et al. 2004
JP

Kellogg, R.M. 1989
DF

Kennedy, R. 1995
DF; LP; WH; WS; SS; ES; BS; AF; AmF; GdF; NF

Khalil, M.A.K. 1985
BS

Klem, G.S. 1968
NS; SP; LbP; DF; SPF

Koran, Z. 1967
BS

Law, K.N. et al. 1997
JP; BS

Little, C.H.A. et al. 1987
General

Liu, C. et al. 2005a
BS

Liu, C. et al. 2005b
BS

Liu, C. et al. 2007
BS; BF

Mansfield, S.D. et al. 2007
TA

McClain, K.M. et al. 1994
BS; WS; RP

Middleton, G.R, et al. 2000
LP

Molteberg, D. 2004
General

Mott, L. et al. 1996
BS

Mullins, E.J. et al. 1981
General

Oliver, C.D. et al. 1986
DF

Omholt, I. et al. 2008a
BS

Omholt, I. et al. 2008b
BS

Panshin, A.J. et al. 1980
JP; DF; BF; WS; BS; SM; LP; General

Parker, M.L. et al. 1976
DF

Peck, E.C. 1933
SLF; LLP; DF; WH; PP; SuP; WWP; RW; WP; SC; SS; WTL; WF

Pronin, D. 1971
RP; JP; WS; BS; BF; TL; EH; TA; LTA

Robinson, A.R. et al. 2007
DF

Willcocks, A. et al. 1995
JP; LP; WS; NS

Wood, J. et al. 2005
BS; BF

Yang, K.C. 1987
General

Yemele, M.C.N. et al. 2008
BS; TA

Young, H.E. et al. 1966
RS; BF; EH; WP; RM; PO

Zhang, S.Y. 1997
General

Schneider, M.H. et al. 1989
BF

Schneider, R. 2006
JP

Seth, R.S. 1990
General

Shepard, R.K. et al. 1990
BS

Shi, J.L. et al. 2006
BS; DL; SL; SPF

Shortle, W.C. et al. 1986
BF; SF

Siddiqui, K.M. et al. 1971
DF

Sinclair, G.D. et al. 1973
JP

Stewart, J.J. et al. 2006
TA

Taylor, A.M. et al. 2003
DF

Thor, E. et al. 1974
BF

Timell, T.E. 1973
BF; TL; BS; RP; EH

Tong, Q.J. et al. 2005a
JP

Tong, Q.J. et al. 2005b
JP

Ukrainetz, N.K. et al. 2008
CDF

USDA, Forest Service. 1972
General

Vahey, D.W. et al. 2007
DF

Wang, E.I. et al. 1984
WS

Wang, H. et al. 2001
CDF; PO

Zhang, S.Y. et al. 1998
BF

Zhang, S.Y. et al. 2006
BS

Zhang, S.Y. et al. 2008
BS; WS; RS; JP; RP; WP; BF; EL; EH; EWC

Zhu, J.Y. et al. 2008a
RP; DF; LP

Zhu, J.Y. et al. 2008b
DF

Zobel, B.J. 1984
General

Reaction Wood / Bois de réaction
Includes: compression wood; tension wood; spiral grain
Comprends : bois de compression; bois de tension; fil tors

Acuna, M.A. et al. 2006a, b
DF

Alden, H. A. 1995
General

Ban, W. et al. 2004
BS

Barbour, J. et al. 1988
BS

Bell, F.W. et al. 1990
JP

Bendtsen, B.A. 1978
LbP; DF; JP; CP

Blanchette, R.A. et al. 1994
BF; BS; EWP; TA; RM

Brazier, J.D. 1977
General

Briggs, D.G. et al. 1986
General

Dempster, W.R. et al. 2002
LP; BS; WS

Dokken, M. 1972
WS; WP; RP

Donaldson, L. 2008
General

Gonzalez, J.S. et al. 1978
WH; IF; SS; AMF

Green, D.W. et al. 1999
BF; DF; BS; WS; JP; LP; SM; TA

Hanley, D.P. et al. 1995
General

Hussein, A. et al. 2006
BF

Jagels, R. 2006
TE; BC; RW

Jozsa, L.A. et al. 1994
General

Kennedy, E.I. et al. 1968
WS; BS; RS; BF; RP; JP; EWP; EH; TL; EWC

Koubaa, A. et al. 2000
BS

Larson, P.R. 1969
General

Law, K.N., et al. 2003
JP

Lemieux, H. et al. 2002
BS

Middleton, G.R. et al. 1992
LP

Middleton, G.R. et al. 1995
LP

Middleton, G.R. et al. 2000s
WS

Middleton, G.R. et al. 2000b
LP

Middleton, G.R. et al. 2002
WS

Mullins, E.J. et al. 1981
General

Oliver, C.D. et al. 1986
DF

Olson, A.R. et al. 1947
EL; NS; JP; RP; WP; SP; EH; DF

Panshin, A.J. et al. 1980
JP; DF; BF; WS; BS; SM; LP; General

Peck, E.C.1933
SLF; LLP; DF; WH; PP; SuP; WWP; RW; WP; SC; SS; WTL; WF

Perem, E. 1958
WS; RP

Robertson, A. 1990
BF

Schneider, R. 2006
JP

Senft, J.F. et al. 1985
General

Spurr, S.H. et al. 1953
JP; SP

Timell, T.E. 1973
BF; TL; BS; RP; EH

Wang, H.H. et al. 2001
CDF; PO

Willcocks, A. et al. 1995
JP; LP; WS; NS

Zhang, S.Y. 1997
General

Zhang, S.Y. 2003
General

Zobel, B.J. et al. 1984
General

Zobel, B.J. 1989
General

Review / Revue

Alden, H.A. 1995
General

Anagnost, S.E. et al. 2005
LbP; BC; SM; CA

Balatinecz, J. et al. 2001
TA;LTA;ECT; BCT; BP; BS; JP; BF; NN

Barbour, J. 1988
WS

Bell, F.W. et al. 1990
JP

Bell, F.W. et al. 1997
JP

Bendtsen, B.A. 1978
LbP; DF; JP; CP

Brand, D.G.E. 1991
General

Brazier, J.D. 1977
General

Briggs, D.G. et al. 1986
General

Cayford, J.H. et al. 1967
JP

Cutter, B.E. et al. 2004
General

Dinwoodie, J.M. 1961
General

Domke, G.M.,et al. 2008
TA

Donaldson, L. 2008
General

Doucet, R. et al. 1987
BS

Downes, G.M. et al. 2002
General

Elliott, G.K. 1970
General

Jacobs, S.M. et al. 2002
General

Jagels, R. 2006
TE; BC; RW

Klem, G.S. 1968
NS; SP; LbP; DF; SPF

Larson, P.R. 1963
General

Larson, P.R. 1962
General

Little, C.H.A.,et al. 1987
General

Man, R. et al. 2004
WS, PO

Middleton, G.R. et al. 2000
LP

Middleton, G.R. et al. 2009
DF; WTL; WS; JP; BS; WB; WH; BF; LP

Miller, B. 1996
TA

Newton, P.F. et al. 2006
BS; JP

OMNR, 1998a
JP

OMNR. 1998b
JP

OMNR. 1998c
JP

OMNR. 1998d
JP; BS

OMNR. 1998e
BS

OMNR. 1998f
JP; WS; BS

OMNR. 1998g
BS; WS

OMNR. 1998h
BS

OMNR. 1998i
TA; WB; BS; BF

Peng, C. 2000
General

Spurr, S.H. et al. 1953
JP; SP

Taylor, A.M. et al. 2002
General

Taylor, A.M. et al. 2003
DF

USDA, Forest Service. 1972
General

Watson, P. et al. 2009
General

Zobel, B. 1992
General

Zobel, B.J. et al. 1989
General

Silviculture / Sylviculture

Includes: clearcut; shelterwood; seed tree; selection system; regeneration; scarification; herbicide; pruning; fertilize
Comprends : coupe à blanc; mode de régénération par coupes progressives; coupe avec réserve de semenciers; jardinage; régénération; scarification; herbicide; élagage; fertilisation

Angers, V.A. et al. 2005
SM; BE; YB; BA; EH

Banal, S. et al. 2007
RM; SM; YB; BE; EH; WAS; BC; WP; RO

Barbour, J. 1988
WS

Barton, A.M. et al. 2008
JP

Beaulieu, J. et al. 2006
WS

Bedard, S. et al. 2003
SM; YB; BE; RM; BF

Bell, F.W. et al. 1997
JP

Bendtsen, B.A. 1978
LbP; DF; JP; CP

Benzie, J.W. 1977
JP

Bernier, P.Y. et al. 2007
TA; DF; JP; BS; BF

Boateng, J.O. et al. 2006
WS

Bragg, D.C. 2006
SM

Bragg, D.C. et al. 1997
SM

Brand, D.G.E. 1991
General

Brazier, J.D. 1977
General

Briggs, D.G.,et al. 1986
General

Briggs, D.G. et al. 2005
DF

Brockley, R.P. 2005
LP

Cayford, J.H. et al. 1967
JP

Choi, J. et al. 2001
SM; BAS; WA

Coates, K.D. et al. 2003
General

Cochran, P.H. et al. 2000
LP

Cown, D.J. 2005
RaP; General

Curry, W.T. et al. 1965
NS; DF; EL

Cutter, B.E. et al. 2004
General

Dampier, J.E.E. et al. 2007
BS; JP; WS

Domke, G.M. et al. 2008
TA

Doucet, R. et al. 1987
BS

Doucet, R. et al. 1996
BS

Elliott, G.K. 1970
General

Eyre, F.H. et al. 1944
JP

Feng, Z. et al. 2006
WS

Fleming, R.L. et al. 2005
BS

Flewelling, J.W. et al. 2008
DF

Forget, E. et al. 2007
SM; YB; BE

Fournier, A. et al. 2006
SM; BE

Fraser, E.C. et al. 2006
TA

Fu, S. et al. 2007
BS; WS; WP; JP

Gartner, B.L. 2002
DF

Gartner, B.L. et al. 2002
DF

Gartner, B.L. et al. 2005
DF

Gonzalez, J.S. et al. 1978
WH; IF; SS; AMF

Gottschalk, K.W. 1995
General

Goudie, J.W. et al. 2008
WS; ES

Groot, A. et al. 1984
JP

Groot, A. et al. 2008
BS

Hale, J.D. et al. 1931
WS

Hanley, D.P. et al. 1995
General

Harris, J.M.1993
EU; EO; DF; SP; TE; LbP; SLP; CP; ShP; ShP[T]; ShP[SF]; LP; PiP; NN

Hartmann, H. et al. 2008
SM

Hein, S. et al. 2008
DF

Henman, D.W. 1963
NS; DF; SP; SS; EL; NN

Hillman, G.R. et al. 1998
BS

Hunt, K. et al. 1980
BF

Ivkovich, M. et al. 2002a
WS; ES

Ivkovich, M. et al. 2002b
WS; ES

Janas, P.S. et al. 1988
JP

Jones, T.A. et al. 2004
SM

Jozsa, L.A. et al. 1994
General

Juice, S.M. et al. 2006
SM

Kabzems, R. et al. 2005
TA; WS

Kellogg, R.M. 1989
DF

Kiernan, D.H. et al. 2008
SM

Klem, G.S. 1968
NS; SP; LbP; DF; SPF

Knudson, R.M. et al. 2006
WS

Kranabetter, J.M. et al. 2004
WS WRC WH

Larson, P.R. 1962
General

Larson, P.R. 1963
General

Larson, P.R. 1969
General

Lavigne, M.B. et al. 1989
BF

Lindgren, P.M.F. et al. 2007
LP

Liu, C. et al. 2007
BS; BF

Lussier, J.M. 2009
General

Mahendrappa, M.K. et al. 1982
BS

Man, R. et al. 2004
WS, PO

McArthur, J.D. 1965
BF

McKenney, D.W. et al. 1997
BS

McLaren, B.E. et al. 1998
BS

Megraw, R.A. et al. 1972
DF

Merette, C. et al. 1985
BF

Miller, B. 1996
TA

Morrison, I.K. et al. 1977
JP

Mugasha, A.G. et al. 1991
BS

Newton, P.F. 2003
BS

Newton, P.F. 2006
BS

Newton, P.F. et al. 2006
BS; JP

Nienstaedt, H. et al. 1976
JP; WS

Niese, J.N. et al. 1995
SM; WA; RO; YB; BAS; EH; RM

Nyland, R.D. 2005
SM

Oliver, C.D. et al. 1986
DF

OMNR, 1998a
JP

OMNR, 1998b
JP

OMNR, 1998c
JP

OMNR, 1998d
JP; BS

OMNR, 1998e
BS

OMNR, 1998f
JP; WS; BS

OMNR, 1998g
BS; WS

OMNR, 1998h
BS

OMNR, 1998i
TA; WB; BS; BF

Panshin, A.J. et al. 1980
JP; DF; BF; WS; BS; SM; LP; General

Parker, M.L. et al. 1976
DF

Payandeh, B. 1989
BS

Pelletier, G. et al. 2008
WS

Penner, M. et al. 2001
TA

Périé, C. et al. 2000
EWP; WS

Pitre, F.E. et al. 2007
BCT; ECT

Rajora, O.P. 1999
WS

Rathgeber, C.B.K. et al. 2006
DF

Roberge, M.R. 1975
SM; YB

Roddy, D.M. 1983
JP; WS

Savva, Y. et al. 2008
JP

Schuler, T.M. 2004
SM; RM; RO; CO

Scott, S.L. et al. 1982
JP

Seymour, R.S. et al. 1986
General

Shatford, J.P.A. et al. 2009
CDF; WH

Siddiqui, K.M. et al. 1971
DF

Smith, C.R. 1984
JP

Solomon, D.S. et al. 2002
BF; RS; BS; WS; EH; EWC; TL

Sonderman, D.L.1987
RM; SM; YP; BC; BT; TA; BE; RE; HK; RO

Strong, T.F. et al. 1995
SM; EWP; EH; WA; YB; BAS; RM

Sucre, E.B. et al. 2008
DF

Sutton, R.F. et al. 2003
WS

Swift, D.E. et al. 2007
BF; RS; BS; WS

Taylor, A.M. et al. 2002
General

Taylor, A.M. et al. 2003
DF

Tong, Q.J. et al. 2005
JP

Tuskan,G.A., 1998
PO; SwG; SYC; WL; BL; Aln; EU; MQ; AX; SIM

USDA, Forest Service. 1972
General

van Cleve, K. et al. 1976
WS

Webster, C.R. et al. 2003
SM; RM; YB; EH

Weetman, G.F. 1975
BS

Weiskittel, A.R. et al. 2006
DF

Weiskittel, A.R. et al. 2007
CDF

Welham, C. et al. 2002
WS; TA

Wells, E.D. 1994
BS

Winston, D.A. 1977
JP

Yang, K.C. 1987
General

Zahner, R. et al. 1962
JP; RP

Zarnovican, R. et al. 1996
BF

Zhang, S.Y. et al. 2004
WS

Zhang, S.Y. et al. 2006
JP

Zhang, S.Y. et al. 2008
BS; WS; RS; JP; RP; WP; BF; EL; EH; EWC

Zobel, B. 1992
General

Zobel, B.J. et al. 1989
General

Soil / Sol

Barton, A.M. et al. 2008
JP

Bell, F.W. et al. 1997
JP

Bella, I.E. et al. 1974
JP; RP; WS

Boateng, J.O. et al. 2006
WS

Brockley, R.P. 2005
LP

Burns, R.M. et al. 1990
General

Cayford, J.H. et al. 1967
JP

Chang, C.I. et al. 1967
WS

Domke, G.M. et al. 2008
TA

Eyre, F.H. et al. 1944
JP

Fraser, E.C. et al. 2006
TA

Grigal, D.F. et al. 1966
JP

Groot, A. et al. 1984
JP

Hillman, G.R. et al. 1998
BS

Hökkä, H. et al. 1999
BS

Jagels, R. 2006
TE; BC; RW

Juice, S.M. et al. 2006
SM

Kabzems, R. et al. 2005
TA; WS

Klos, R.J. et al. 2007
BP; WS; TA; BS; JP

Kranabetter, J.M. et al. 2004
WS WRC WH

Mahendrappa, M.K. et al. 1982
BS

Mallik, A.U. et al. 2008
BS; WS; RP

McLaren, B.E. et al. 1998
BS

Miller, B. 1996
TA

Morris, D.M. et al. 1992a
JP

Morris, D.M. et al. 1992b
JP

Mugasha, A.G. et al. 1991
BS

Newton, P.F. et al. 2006
BS; JP

Oliver, C.D. et al. 1986
DF

Payandeh, B. 1989
BS

Pitre, F.E. et al. 2007
BCT; ECT

Sucre, E.B. et al. 2008
DF

Tuskan, G.A. 1998
PO; SwG; SYC; WL; BL; Aln; EU; MQ; AX; SIM

van Cleve, K. et al. 1976
WS

Wells, E.D. 1994
BS

Winston, D.A. 1977
JP

Zhang, S.Y. et al. 2004
WS

Zobel, B.J. et al. 1989
General

Thinning / Éclaircie

Includes: precommercial thinning; commercial thinning; strip thinning; diameter limit cut; partial cut; spacing trial; release

Comprends : éclaircie précommerciale; éclaircie commerciale; éclaircie par bandes; coupe à diamètre limite; coupe partielle; essai d'espacement; coupe de dégagement

Achim, A. et al. 2005
BF

Angers, V.A. et al. 2005
SM; BE; YB; BA; EH

Bankowski, J. 1994
JP

Barbour, J. 1988
WS

Barbour, R.J. et al. 1994
JP

Beaulieu, J. et al. 2006
WS

Bell, F.W. et al. 1997
JP

Bella, I.E. et al. 1974
JP

Bendtsen, B.A. 1978
LbP; DF; JP; CP

Berry, A.B. 1974
WS

Bertrand, V. et al. 1970
BF; BS; RS

Brazier, J.D. 1977
General

Briggs, D.G. et al. 1986
General

Briggs, D.G. et al. 2005
DF

Briggs, D.G. et al. 2008
CDF

Brockley, R.P. 2005
LP

Burns, J. et al. 1996
BS

Cayford, J.H. 1961
JP

Cayford, J.H. 1964
JP

Cayford, J.H. et al. 1967
JP

Chui, Y.H. et al. 1997
BS; BF

Coates, K.D. et al. 2003
General

Cochran, P.H. et al. 2000
LP

Cyr, G. et al. 2009
BS

Doucet, R. et al. 1996
BS

Elliott, G.K. 1970
General

Emmingham, W. et al. 2007
DF

Eyre, F.H. et al. 1944
JP

Fleming, R.L. et al. 2005
BS

Flewelling, J.W. et al. 2008
DF

Gartner, B.L. et al. 2002
DF

Goble, B.C. et al. 1993
JP

Gottschalk, K.W. 1995
General

Groot, A. et al. 1984
JP

Groot, A. et al. 2008
BS

Hanley, D.P. et al. 1995
General

Harris, J.M.1993
EU; EO; DF; SP; TE; LbP; SLP; CP; ShP; ShP[T]; ShP[SF]; LLP; PiP; NN

Hatton, J.V. et al. 1990
JP

Hatton, J.V. et al. 1996
BS; NS; RS; WS; JP; TL

Hein, S. et al. 2008
DF

Henman, D.W. 1963
NS; DF; SP; SS; EL; NN

Hillman, G.R. et al. 1998
BS

Hökkä, H. et al. 1999
BS

Hunt, K. et al. 1995
BS; JP; WS; RS; NS; TL

Hussein, A. et al. 2006
BF

Johnstone, W.D. 2002
LP

Jozsa, L.A. et al. 1994
General

Kang, K.Y. et al. 2004
JP

Karsh, M.B. et al. 1994
BS; BF

Ker, M.F. 1987
BF

Koga, S. et al. 2002a
BF

Koga, S. et al. 2004
BF

Kranabetter, J.M. et al. 2004
WS WRC WH

Laflèche, V. et al. 2008
BS; BF; WB; JP

Larson, P.R. 1962
General

Larson, P.R. 1963
General

Larson, P.R. 1969
General

Lavigne, M.B. et al. 1989
BF

Lindgren, P.M.F. et al. 2007
LP

Liu, C. et al. 2007
BS; BF

Lussier, J.M. 2009
General

Man, R. et al. 2004
WS, PO

Marshall, D.D. et al. 1999
DF

Mattice, C.R. et al. 1975
JP

McArthur, J.D. 1965
BF

McKenney, D.W. et al. 1997
BS

Megraw, R.A. et al. 1972
DF

Merette, C. et al. 1985
BF

Middleton, G.R. et al. 2000
WS

Middleton, G.R. et al. 2009
DF; WTL; WS; JP; BS; WB; WH; BF; LP

Miller, B. 1996
TA

Morrison, I.K. et al. 1977
JP

Mugasha, A.G. et al. 1991
BS

Newton, P.F. 2003a
JP

Newton, P.F. 2003b
BS

Newton, P.F. 2003c
BS

Newton, P.F. 2006
BS; JP

Newton, P.F. et al. 1993
BS

Newton, P.F. et al. 1994
BS

Newton, P.F. et al. 2005
BS

Newton, P.F. et al. 2006
BS; JP

Niese, J.N. et al. 1995
SM; WA; RO; YB; BAS; EH; RM

Noone, C.S. et al. 1980
DF

Nyland, R.D. 2005
SM

Oliver, C.D. et al. 1986
DF

OMNR. 1998a
JP

OMNR. 1998b
JP

OMNR. 1998c
BS

OMNR. 1998d
JP; WS; BS

OMNR. 1998e
BS; WS

OMNR. 1998f
BS

Parker, M.L. et al. 1976
DF

Paul, B.H. 1963
SM; TA; DF; General

Pelletier, G. et al. 2008
WS

Penner M. et al. 2001
TA

Pothier, D. 2002
BF

Racey, G.D. et al. 1990
General

Rathgeber, C.B.K. et al. 2006
DF

Roberge, M.R. 1975
SM; YB

Roe, E.I. et al. 1950
JP

Rudnicki, M. et al. 2004
LP

Rytter, L. et al. 2005
EA; TA

Savva, Y. et al. 2008
JP

Schneider, R. 2001
BF

Schneider, R. 2006
JP

Schneider, R. et al. 2008
JP

Schuler, T.M. 2004
SM; RM; RO; CO

Scott, S.L. et al. 1982
JP

Senft, J.F. et al. 1985
General

Seymour, R.S. et al. 1986
General

Sharma, M. et al. 2004
JP; BS; BF

Shatford, J.P.A. et al. 2009
CDF; WH

Shepard, R.K. 1980
WS

Shepard, R.K. et al. 1990
BS

Smith, C.R. et al. 1988
JP

Strong, T.F. et al. 1995
SM; EWP; EH; WA; YB; BAS; RM

Sullivan, T.P. et al. 2006
LP

Sutton, R.F. et al. 2003
WS

Swift, D.E. et al. 2007
BF; RS; BS; WS

Tong, Q.J. et al. 2005a
JP

Tong, Q.J. et al. 2005b
JP

Tong, Q.J. et al. 2006
JP

Tong, Q.J. et al. 2008
JP

USDA, Forest Service. 1972
General

Vahey, D.W. et al. 2007
DF

van Cleve, K. et al. 1976
WS

Weetman, G.F. 1975
BS

Weiskittel, A.R. et al. 2006
DF

Weiskittel, A.R. et al. 2007
CDF

Winston, D.A. 1977
JP

Yang, K.C. 1987
General

Zahner, R. et al. 1962
JP; RP

Zarnovican, R. et al. 1996
BF

Zhang, S.Y. et al. 1998
BF

Zhang, S.Y. et al. 2004
WS

Zhang, S.Y. et al. 2005
JP

Zhang, S.Y. et al. 2006
JP

Zhou, H. et al. 1991a
WS

Zhou, H. et al. 1991b
WS

Zobel, B. 1992
General

Zobel, B.J. et al. 1989
General

Tools / Outils
Includes: machining properties; kiln drying; value added
Comprends : caractéristiques d'usinage; séchage au séchoir; valeur ajoutée

Acuna, M.A. et al. 2006a, b
DF

Alden, H.A. 1995
General

Anagnost, S.E. et al. 2005
LbP; BC; SM; CA

Antal, M. et al. 1994
BS

Barbour, R.J. et al. 1990
General

Barrett, J.D. et al. 1994
General

Benjamin, J. et al. 2007
BS

Bjurhager, I. et al. 2008
EA; TA

Bragg, D.C. 2006
SM

Bragg, D.C. et al. 1997
SM

Briggs, D.G. et al. 2005
DF

Campbell, J.S. et al. 1985
TA

Cherry, M.L. et al. 2008
CDF

Cown, D.J. et al. 1978
BF; JP; SS; RP; DF; WH; SM; WB; TA

Dampier, J.E.E. et al. 2007
BS; JP; WS

Defo, M. et al. 2009
General

Dokken, M. 1972
WS; WP; RP

Dokken, M. et al. 1973
BF

Domke, G.M. et al. 2008
TA

Downes, G.A. et al. 2002
General

Fournier, R.A. et al. 2003
General

Forest Products Research Laboratory. 1957
General

Hanley, D.P. et al. 1995
General

Hansen, L.W. et al. 2004
RaP; DF

Hein, S. et al. 2008
DF

Hernández, R.E. et al. 2001
WS

Hillis, W.E. 1962
General

Huffman, D.R. 1977
BS; JP; BF

Ise, T. et al. 2008
BS

Jagels, R. 2006
TE; BC; RW

Johal, S. et al. 2006
BF; WS; BS; RS

Kellogg, R.M. 1989
DF

Knowles, R.L. et al. 2004
DF

Lam, F. et al. 1991
LP;WS;AF

Lihra, T. et al. 2000
BF

MacKenzie, J. et al. 2009
General

Mamdy, C. et al. 1999
DF

McClain, K.M. et al. 1989
DF

Middleton, G.R. et al. 1992
LP

Middleton, G.R. et al. 1995
LP

Middleton, G.R. et al. 2000
LP

Middleton, G.R. et al. 1994
BS; WS; RP

Molteberg, D. 2004
General

Mott, L. et al. 1996
BS

Mullins, E.J. et al. 1981
General

Newton, P.F. 2003
JP

Newton, P.F. 2004
JP

Newton, P.F. et al. 2007
BS; JP

Niese, J.N. et al. 1995
SM; WA; RO; YB; BAS; EH; RM

Noone, C.S. et al. 1980
DF

Nyland, R.D. 2005
SM

O'Halloran, M.R. et al. 1972
LP

Panshin, A.J. et al. 1980
JP; DF; BF; WS; BS; SM; LP; General

Peck, E.C.1933
SLF; LLP; DF; WH; PP; SuP; WWP; RW; WP; SC; SS; WTL; WF

Polman, J.E. et al. 1996
DF

Rasmussen, E.F. 1961
General

Rayirath, P. et al. 2008
BS

Rippy, R.C. et al. 2000
DF

Schneider, M.H. et al. 1989
BF

Semple, K.E. et al. 2007
TA; ECT; BCT

Sharma, M. et al. 2007
JP

Shi, S.Q. et al. 1999
General

Smith, S.M. et al. 1987
DF

Smith, W.B. 1986
RP; WP; EH; NS; EL; PO

Standish, J.T. 1983
General

Suárez, J.C. et al. 2005
General

Tong, Q.J. et al. 2006
JP

Vahey, D.W. et al. 2007
DF

Wang, H.H. et al. 2001
CDF; PO

Wang, X. et al. 2002
JP; RP

Weiskittel, A.R. et al. 2006
DF

Wimmer, R. et al. 1997
RS; NS; SS; ES

Zhang, S.Y. 1997
General

Zhang, S.Y. 2003
General

Zhang, S.Y. et al. 1995
General

Zhang, S.Y. et al. 1998
BF

Zhang, S.Y. et al. 2005
JP

Zhang, S.Y. et al. 2006
BS

Zhang, S.Y. et al. 2006
JP

Zhang, S.Y. et al. 2008
BS; WS; RS; JP; RP; WP; BF; EL; EH; EWC

Zhang, Y. et al. 2005
SM

Zhou, H. et al. 1991a
WS

Zhou, H. et al. 1991b
WS

Zhu, J.Y. et al. 2008
RP; DF; LP

Zobel, B.J. 1984
General

Zobel, B.J. et al. 1989
General

Tree Characteristics / Caractéristiques des arbres
Includes: taper, earlywood; latewood; mature wood; juvenile wood; heartwood; sapwood
Comprends : défilement; bois initial; bois final; bois mature; bois juvénile; duramen; aubier

Abdel-Gadir, A.Y. et al. 1993
DF

Acuna, M.A. et al. 2007
DF

Alden, H.A. 1995
General

Alteyrac, J. et al. 2005
BS

Amponsah, I.G. et al. 2004
LP

Anagnost, S.E. et al. 2005
LbP; BC; SM; CA

Aschim, O.K. et al. 1976
General

Ballard, L.A. et al. 1988
LP

Ban, W. et al. 2004
BS

Bankowski, J. 1994
JP

Barbour, J. 1988
WS

Barbour, J. et al. 1988
BS

Barbour, R.J. et al. 1989
BS

Barbour, R.J. et al. 1994
JP

Barton, A.M. et al. 2008
JP

Beaulieu, J. et al. 2006
WS

Bella, I.E. et al. 1974
JP; RP; WS

Bendtsen, B.A. 1978
LbP; DF; JP; CP

Bluskova, G. et al. 1997
SP; DF; BlP

Brazier, J.D. 1977
General

Briggs, D.G. et al. 1986
General

Burns, J. et al. 1996
BS

Campbell, J.S. et al. 1985
TA

Cannell, M.G.R. et al. 1983
LP; SS

Chang, C.I. et al. 1967
WS

Chui, Y.H. et al. 1995
JP

Chui, Y.H. et al. 1997
BS; BF

Clark, J. et al. 1957
EWC; EH; WS; RS; BF; YB; GB

Clermont, L.P. et al. 1951
BF; WS; BS; JP; WB; EH; TA; WP

Corriveau, A. et al. 1987
WS

Corriveau, A. et al. 1990
WS

Corriveau, A. et al. 1991
WS

Cown, D.J. et al. 1978
BF; JP; SS; RP; DF; WH; SM; WB; TA

Dakak, J.E. et al. 1999
RM; SM; SLM

Dean, T.J. et al. 1986
LP

Deckmyn, G. et al. 2006
General

Defo, M. et al. 1999
WS; SM

Dempster, W.R. et al. 2002
LP; BS; WS

Dinwoodie, J.M. 1961
General

Dokken, M. 1972
WS; WP; RP

Dokken, M. et al. 1973
BF

Domec, J.C. et al. 2002
DF

Donaldson, L. 2008
General

Drost, C. et al. 2003
JP; BS; BF; WP; RS

Duchesne, I. 2006
JP

Duchesne, I. et al. 2004
WS

Elliott, G.K. 1970
General

Eyre, F.H. et al. 1944
JP

Fujiwara, S. et al. 2000
BF; WS; BS; JP; TA

Gartner, B.L. 2002
DF

Gartner, B.L. et al. 2002
DF

Gartner, B.L. et al. 2005
DF

Goudie, J.W. et al. 2008
WS; ES

Green, D.W. et al. 1999
BF; DF; BS; WS; JP; LP; SM; TA

Green, D.W. et al. 2008
DF; PP

Grotta, A.T. et al. 2005
DF

Hanley, D.P. et al. 1995
General

Hapla, F. 1997
DF

Harris, G. 1993
LbP; ShP; LLP; SLP; PiP; WS; BS; BF;EH; WP;RP;JP

Harris, J.M.1993
EU; EO; DF; SP; TE; LbP; SLP; CP; ShP; ShP[T]; ShP[SF]; LP; PiP; NN

Hatton, J.V. 1993
JP

Hatton, J.V. et al. 1990a
JP

Hatton, J.V. et al. 1990b
DF

Hatton, J.V. et al. 1996
BS; NS; RS; WS; JP; TL

Hein, S. et al. 2008
DF

Henman, D.W. 1963
NS; DF; SP; SS; EL; NN

Hernández, R.E. 2007
SM; NN

Hillis, W.E. 1962
General

Hunt, K. et al. 1995
BS; JP; WS; RS; NS; TL

Hussein, A. et al. 2006
BF

Ivkovich, M. et al. 2002a
WS; ES

Ivkovich, M. et al. 2002b
WS; ES

Jagels, R. 2006
TE; BC; RW

Jeremic, D. et al. 2004
BF

Jessome, A.P. 2000
General

Johal, S. et al. 2006
BF; WS; BS; RS

Jozsa, L.A. et al. 1992
LP

Jozsa, L.A. et al. 1994
General

Kellogg, R.M. 1989
DF

Kennedy, R.W. 1995
DF; LP; WH; WS; SS; ES; BS; AF; AmF; GdF; NF

Klem, G.S.,1968
NS; SP; LbP; DF; SPF

Klos, R.J. et al. 2007
BP; WS; TA; BS; JP

Knudson, R.M. et al. 2006
WS

Koch, P. 1987
LP

Koga, S. et al. 2002a
BF

Koga, S. et al. 2002b
BF

Koga, S. et al. 2004
BF

Koubaa, A. et al. 2000
BS

Koubaa, A. et al. 2002
BS

Koubaa, A. et al. 2005
BS

Larson, P.R. 1962
General

Larson, P.R. 1963
General

Larson, P.R. 1969
General

Lei, Y.C. et al. 2005
BS

Lihra, T. et al. 2000
BF

Little, C.H.A. et al. 1987
General

Liu, C. et al. 2005a
BS

Liu, C. et al. 2005b
BS

Liu, C. et al. 2006
BS

Liu, C. et al. 2007a
BS

Liu, C. et al. 2007b
BS

Liu, C. et al. 2007c
BS

Magnussen, S. et al. 1987
JP

Magnussen, S. et al. 1990
JP

Mäkelä, A. 2002
SP

Mamdy, C. et al. 1999
DF

Megraw, R.A. et al. 1972
DF

Mencuccini, M. et al. 2007
General

Middleton, G.R. et al. 1995
LP

Middleton, G.R. et al. 2000a
WS

Middleton, G.R. et al. 2000b
LP

Middleton, G.R. et al. 2002
WS

Miles, K.B. et al. 2007
JP

Morris, D M. et al. 1992a
JP

Morris, D.M. et al. 1992b
JP

Morris, D.M. et al. 1994
JP

Mott, L. et al. 1996
BS

Mott, L. et al. 2001
BS

Mullins, E.J. et al. 1981
General

Niklas, K.J. 1999
SM

Okwuagwu, C.O. et al. 1981
JP

Oliver, C.D. et al. 1986
DF

Panshin, A.J. et al. 1980
JP; DF; BF; WS; BS; SM; LP; General

Parker, M.L. et al. 1976
DF

Paul, B.H. 1963
SM; TA; DF; General

Pavel, M. et al. 2009
General

Peck, E.C.1933
SLF; LLP; DF; WH; PP; SuP; WWP; RW; WP; SC; SS; WTL; WF

Pnevmaticos, S.M. et al. 1972
BS; BF

Polman, J.E. et al. 1996
DF

Pothier, D., et al. 1989a
JP

Pothier, D. et al. 1989b
JP

Pyles, M.R. 1987
DF

Rathgeber, C.B.K. et al. 2006
DF

Renninger, H.J. et al. 2006
DF

Robinson, A.R. et al. 2007
DF

Roddy, D.M. 1983
JP; WS

Schneider, M.H. et al. 1989
BF

Schneider, R. 2006
JP

Schneider, R. et al. 2008a
JP

Schneider, R. et al. 2008b
JP

Senft, J.F. et al. 1985
General

Sharma, M. et al. 2004
JP; BS; BF

Shepard, R.K. et al. 1990
BS

Shi, J.L. et al. 2005
BS

Shi, J.L. et al. 2006
BS; DL; SL; SPF

Shi, J.L. et al. 2007
BS

Shortle, W.C. et al. 1986
BF; SF

Siddiqui, K.M. et al. 1971
DF

Silins, U. et al. 2000
LP

Sinclair, G.D. et al. 1973
JP

Smith, S.M. et al. 1987
DF

Smith, W.B. 1986
RP; WP; EH; NS; EL; PO

Spicer, R. et al. 2001
DF

Spurr, S.H. et al. 1953
JP; SP

Stark, E.W. 1954
SM; RM; SlM; MM; FM; VM; DM; BtM; CM; BlM; BEM; BM; StM

St-Germain, J.L. et al. 2008
BS

Taylor, A.M. et al. 2002
General

Taylor, A.M. et al. 2003
DF

Tong, Q.J. et al. 2005a
JP

Tong, Q.J. et al. 2005b
JP

Tong, Q.J. et al. 2008a
JP

Tong, Q.J. et al. 2008b
JP; BS; WS; RS; BF

Ukrainetz, N.K. et al. 2008
CDF

USDA, Forest Service. 1972
General

Vahey, D.W. et al. 2007
DF

Vargas-Hernandez, J. et al. 1991
DF

Villeneuve, M. et al. 1987
JP; BS

Wang, H.H. et al. 2001
CDF; PO

Wang, L. et al. 2000
BS

Wang, T. et al. 2000
LP

Wang, Y. et al. 1998
BS; WS; LP; BP; PO

Weiskittel, A.R. et al. 2006
DF

Willcocks, A. et al. 1995
JP; LP; WS; NS

Wimmer, R. et al. 1997
RS; NS; SS; ES

Yanchuk, A.D. et al. 1993
WS; ES

Yang, K.C. 2002
WS

Yang, K.C. 1987
General

Yang, K.C. et al. 1985
JP; TL

Yang, K.C. et al. 1994
BS

Yu, Q. et al. 2003
WS

Zahner, R. et al. 1962
JP; RP

Zarnovican, R. et al. 1996
BF

Zhang, S.Y. et al. 2008
BS; WS; RS; JP; RP; WP; BF; EL; EH; EWC

Zhang, S.Y. et al. 2006
JP

Zhang, S.Y. et al. 2006
BS

Zhang, S.Y. et al. 2006
BS

Zhang, S.Y. et al. 2006
BS

Zhang, S.Y. et al. 2005
BS

Zhang, S.Y. et al. 2005
JP

Zhang, S.Y. et al. 2004
WS

Zhang, S.Y. 2003
General

Zhang, S.Y. et al. 2002
BS

Zhang, S.Y. 1998
BS

Zhang, S.Y. et al. 1998
BF

Zhang, S.Y. et al. 1998
BS

Zhang, S.Y. 1997
General

Zhang, S.Y. et al. 1996
BS

Zhang, S.Y. et al. 1996
BS

é

Zhu, J.Y. et al. 2008a
RP; DF; LP

Zhu, J.Y. et al. 2008b
DF

Zobel, B. 1964
General

Zobel, B.J. 1984
General

Zobel, B.J. 1992
General

Zobel, B.J. et al. 1989
General

ANNOTATED BIBLIOGRAPHY / BIBLIOGRAPHIE ANNOTÉE

Abdel-Gadir, A.Y., Krahmer, R.L., and McKimmy, M.D. 1993. Relationships between intra-ring variables in mature Douglas-fir trees from provenance plantations. *Wood and Fiber Science* **25**(2): 182–191.

Relationships among a variety of densitometric characteristics of juvenile and mature wood from 360 trees growing in two plantations of a 1912 Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) heredity study were examined. Variables included earlywood density (EWD and width (EWW); latewood density (LWD), width (LWW), and proportion (LWP); average ring density (RD); and total ring width (RW). The RD components (EWD andLWD) had strong phenotypic and genetic correlations with their respective RW components (EWW and LWW). However, no phenotypic correlation existed between average RD and total RW, and genotypic correlation was weak. The relationship between wood density and radial growth varied by plantation and genotype. The potential exists for improving wood density in juvenile and mature wood by selection, with only a minor impact on radial growth. Selection during the juvenile period to improve mature wood quality is feasible for RD, EWD, LWW, and LWP. Further, selection to improve juvenile RW does not result in reduced wood density during maturity.

Achim, A., Ruel, J.-C., and Gardiner, B.A. 2005. Evaluating the effect of precommercial thinning on the resistance of balsam fir to windthrow through experimentation, modelling, and development of simple indices. *Canadian Journal of Forest Research* **35**(8): 1844–1853.

A tree-pulling experiment was carried out in stands of balsam fir (*Abies balsamea* (L.) Mill.) to evaluate the effects of early thinning on windthrow resistance. Forty trees from four stands were pulled over. Two stands had received a precommercial thinning 9 and 14 years previously, respectively, and the two others were unthinned controls. There were no significant inter-stand differences in the relationship between the critical turning moments required to overturn or snap the trees and their stem mass. The results were input into a model calculating critical wind speeds using the approach developed for the ForestGALES model. Simulations were run for four different stand densities. The mensurational characteristics for each run were taken from the results of a spacing trial established in balsam fir stands at Green River, New Brunswick. For stem breakage, the model predicted a gradual increase in critical wind speeds with wider spacing. The increase was smaller for tree overturning. The pattern of differences remained very similar after a simulated commercial thinning removing 30% of the basal area. Reductions in critical wind speeds were on the order of 4 $m \cdot s^{-1}$ in all cases. Simple indices were developed that could estimate the relative results given by the model.

Des essais de treuillage ont été réalisés dans des peuplements de sapin baumier (*Abies balsamea* (L.) Mill.) afin de quantifier les effets du dépressage sur la résistance au chablis. Quarante arbres provenant de quatre peuplements ont été renversés. Deux des peuplements avaient reçu un traitement de dépressage respectivement neuf et quatorze années auparavant alors que les deux autres furent utilisés comme témoins. Aucune différence significative entre les peuplements n'a été révélée dans la relation entre les moments de force critiques nécessaires pour briser la tige ou déraciner l'arbre et la masse de la tige. Les résultats ont été entrés dans un modèle calculant des vitesses de vent critiques à partir de l'approche développée pour le modèle ForestGALES. Des simulations ont été exécutées pour quatre densités de peuplement différentes. Les caractéristiques dendrométriques utilisées pour chaque simulation provenaient des résultats d'un essai d'espacement établi dans des peuplements de sapin baumier à Green River, au Nouveau-Brunswick. Dans le cas du bris de la tige, le modèle a prédit une augmentation graduelle de la vitesse critique avec une augmentation de l'espacement. L'augmentation était plus faible dans le cas du déracinement. Les différences de vitesse critique calculées entre les espacements sont demeurées très similaires après la simulation de l'effet d'une éclaircie commerciale prélevant 30 % de la surface terrière. La réduction de la vitesse critique atteignait environ 4 $m \cdot s^{-1}$ dans chaque cas. Des indices simples permettant d'estimer les résultats fournis par le modèle ont été développés.

Acuna, M.A., and Murphy, G.E. 2005. Optimal bucking of Douglas fir taking into consideration external properties and wood density. *New Zealand Journal of Forestry Science* **35**(2–3): 139–152.

During recent years niche markets have begun to demand forest products with specific characteristics. Traditionally markets required products with particular external log properties such as a specific diameter, length, and knot size. However, today's log markets are beginning to include new wood properties, such as basic density and stiffness. Although markets have not accompanied these new requirements with price incentives for producers to meet such demands, the new characteristics are nevertheless valued by these markets. An optimal bucking procedure, which included wood density, was developed. Four hypothetical market scenarios, covering a range of density specifications and price incentives, were evaluated, and results showed that in a density-constrained scenario the total revenue could be substantially less than in a scenario which did not specify density.

Acuna, M.A. and Murphy, G.E. 2006a. Geospatial and within tree variation of wood density and spiral grain in Douglas-fir. *Forest Products Journal* **56**(4): 81–85.

In many parts of the world, log markets are becoming increasingly competitive and complex. Buyers are demanding, and suppliers are offering, logs that have been cut for very specific end-uses and that may be specified in terms of internal as well as external properties. Optimally matching logs to markets requires good measurements and/or predictions of the wood properties in each stem. This information could be used either at the planning stage or in on-board computers installed in harvesters to enhance bucking and sorting. To assess the geospatial and within-tree variation in wood density and spiral grain in Douglas-fir stems, over 400 wood disks were collected from 17 sites in the Cascade and Coastal Ranges of Oregon. Sites were selected from a range of elevations and aspects. Trees selected at each of the sites were of a similar age (28–57 years) and average size (20–54 cm diameter at breast height). Disks came from different vertical positions in each tree. No statistically significant relationship between wood density and either elevation or aspect was found. There was evidence of a weak negative association between wood density and the height in the tree from which the samples were removed. No statistically significant relationship among height, elevation, or aspect was observed for spiral grain. *(Abstract prepared by compilers.)*

Acuna, M.A., and Murphy, G.E. 2006b. Use of near infrared spectroscopy and multivariate analysis to predict wood density of Douglas-fir from chain saw chips. *Forest Products Journal* **56**(11-12): 67-72.

In many parts of the world, log markets are becoming increasingly competitive and complex. Wood properties, such as stiffness, density, spiral grain, and extractives content, are now being considered by log buyers. Real-time assessment of these properties will be a challenge for log supply managers. The utility of near infrared (NIR) technology for predicting wood density in Douglas-fir stems was examined. Wood disks were collected from 17 sites around Oregon. Each disk was cut with a chain saw, of similar gauge to that used on mechanized harvesters/processors, to provide saw chips. NIR spectra were then obtained for the chip samples. Multivariate techniques were used to correlate wood properties with the NIR spectra. Preliminary research results showed that NIR could be used to predict density. Coefficients of determination ranged between 0.89 and 0.95 for calibration models and between 0.56 and 0.85 for validation models. These results indicate that NIR technology could be used by mechanized harvesting equipment for log segregation based on wood density.

Acuna, M.A., and Murphy, G.E. 2007. Estimating relative log prices of Douglas-fir through a financial analysis of the effects of wood density on lumber recovery and pulp yield. *Forest Products Journal* **57**(3): 60-65.

Traditionally forest products markets have required logs with particular external properties such as diameter, length and knot size. However, markets are now beginning to include requirements for new internal properties, such as basic density and stiffness. Although markets have responded to these new requirements with prices that afford only limited incentive for producers to meet such demands, the new characteristics are valued by these markets and are considered key for competitive forest companies to stay in business. This paper presents a general methodology to estimate relative log prices of Douglas-fir when logs of different wood density classes are processed and converted into end products (lumber and pulp). Three log density classes were evaluated. For the lowest basic density class (300–399 kg/m^3), net returns for pulp were about 28 percent lower than the middle class (400–499 kg/m^3). The upper class (500–600 kg/m^3) net return was 32 percent higher than the middle class. For conventional lumber log grades, the percentage differences between the middle density class and lower and upper classes were 9 and 4 percent, respectively. These results show that premium prices for logs can be established when internal properties, such as basic density, are specified.

Alden, H.A. 1995. *Hardwoods of North America.* General Technical Report FPL-GTR-83. United States Department of Agriculture, Forest Service, Forest Products Laboratory, Madison, Wisconsin, USA.

This report describes 53 taxa of hardwoods of North America, which are organized alphabetically by genus. Descriptions include scientific name, trade name, distribution, tree characteristics, wood characteristics (general, weight, mechanical properties, drying, shrinkage, working properties, durability, preservation, toxicity and uses) and additional sources for information. Data were compiled from existing literature, mostly from research performed at the U.S. Department of Agriculture, Forest Service, Forest Products Laboratory, Madison, WI. (*Source: U.S. Department of Agriculture, Forest Service.*)

Alden, H.A. 1997. *Softwoods of North America.* General Technical Report FPL-GTR-102. United States of Department of Agriculture, Forest Service, Forest Product Laboratory, Madison, Wisconsin, USA.

This report describes 52 taxa of North American softwoods, which are organized alphabetically by genus. Descriptions include scientific name, trade name, distribution, tree characteristics, wood characteristics (e.g., general, weight, mechanical properties, drying, shrinkage, working properties, durability, preservation, uses, and toxicity), and additional sources of information. Data were compiled from existing literature, mostly from research conducted at the U.S. Department of Agriculture, Forest Service, Forest Products Laboratory, Madison, Wisconsin. (*Source: U.S. Department of Agriculture, Forest Service.*)

Alemdag, I.S. 1984. *Wood Density Variation of 28 Tree Species from Ontario.* Information Report PI-X-45. Natural Resources Canada, Canadian Forest Service - Petawawa National Forestry Institute, Chalk River, Ontario, Canada.

The basic wood density at different heights along the stem and average basic wood density of stems were studied based on 1652 sample trees of 10 softwood and 18 hardwood species in Ontario. Some equation models were tested relating these variables to various tree characteristics. It was found that the relationships of disk and tree wood densities with measurable tree variables are very weak and developing reliable estimation equations are not easy. However, since variation on tree wood density was found to be small, average wood densities of each species can be used with confidence.

La masse volumique basale du bois a été étudiée à différentes hauteurs ainsi que sa valeur moyenne pour la tige chez 1 652 arbres-échantillons appartenant à 10 espèces résineuses et 18 espèces feuillues en Ontario. Quelques modèles d'équation expriment ces variables en fonction de diverses caractéristiques des arbres ont été éprouvés. Les rapports entre la masse volumique à différentes hauteurs ou la masse volumique moyenne de la tige et des variables mesurables des arbres sont très faibles, et il n'est pas facile d'établir des équations d'estimation fiables. Toutefois, comme la variation de la masse volumique du bois des arbres est faible et fluctue dans un intervalle étroit, les masses volumiques moyennes pour chaque espèce peuvent être employées avec confiance.

Alteyrac, J., Cloutier, A., Ung, C.H., and Zhang, S.Y. 2006. Mechanical properties in relation to selected wood characteristics of black spruce. *Wood and Fiber Science* **38**(2): 229–237.

The relation between ring width, ring density, microfibril angle, and bending properties was analyzed at 2.4-m height on twelve 80-year-old black spruce trees. The moduli of elasticity and rupture were measured in the southernmost radial direction on extracted specimens of size 10 × 10 × 150 mm^3 from pith to bark. Ring density and ring width were measured by X-ray densitometry, and microfibril angle was measured by the Silviscan technology. The impact of these three traits on the moduli of elasticity and rupture was evaluated by explicitly separating the radial variation from the variation among trees using a mixed model analysis. The results obtained show first that the modulus of elasticity is negatively correlated to microfibril angle. This result supports the assumption that the relation between modulus of elasticity and microfibril angle is not dependent on radial growth rate. Secondly, ring density has a lower contribution in predicting the modulus of elasticity than the modulus of rupture. In both cases, ring width was not a significant factor of variation of the moduli of elasticity and rupture.

Alteyrac, J., Zhang, S.Y., Cloutier, A., and Ruel, J.C. 2005. Influence of stand density on ring width and wood density at different sampling heights in black spruce (*Picea mariana* (Mill.) B.S.P.). *Wood and Fiber Science* **37**(1): 83–94.

Thirty-six spruce sample trees were collected from an 80-year-old stand to examine the influence of stand density on selected wood quality attributes and their variation with sampling height. The stand, naturally regenerated from fire in 1906, was located in Chibougamau, 400 km north of Quebec. Each tree was assigned a local stand density ranging from 1390 to 3590 stems/ha, calculated from the number of neighboring trees. The trees were grouped into three stand density categories (1790, 2700, and 3400 stems/ha). Each sample tree was analyzed by X-ray densitometry, and various ring features including ring width and wood density were measured for each ring from pith to bark, at three heights (2.4, 5.1, and 7.8 m) and ring area and earlywood proportion were computed. For all features studied, the variation due to sampling height was larger than that due to stand density. The longitudinal variations for ring density and earlywood density depend largely upon the wood type (juvenile wood or mature wood). A variation of ring density with sampling height in the stem from 425 to 458 kg/m^3 was observed in juvenile wood, but variations with stand density in all the growth ring features studied were small. Notably, it was observed that stand density had more influence on ring width features than on ring density features.

Amponsah, I.G., Lieffers, V.J., Comeau, P.G., and Brockley, R.P. 2004. Growth response and sapwood hydraulic properties of young lodgepole pine following repeated fertilization. *Tree Physiology* **24**(10): 1099–1108. [online] URL: http://treephys.oxfordjournals.org/content/24/10/1099.full.pdf+html.

Because of variability in response of lodgepole pine (*Pinus contorta* Dougl. var. *latifolia* Engelm.) to repeated fertilization, this study was initiated to investigate the effect of fertilization on tree growth and sapwood hydraulic properties in Sheridan Creek and Kenneth Creek, British Columbia. The Kenneth Creek site was established in 1983 following harvesting and broadcast burning. The Sheridan Creek site was established in 1978 following harvesting and drag scarification. Treatment plots were established with three treatments. The control plots were unfertilized. The periodic treatment plots were fertilized every 6 years with nitrogen, phosphorus, potassium, sulfur, magnesium, and boron. The annual treatment plots were fertilized yearly with sufficient nitrogen and other nutrients to maintain nutrient balance. Total height, height to live crown base, and diameter at breast height were measured for 64 trees in each plot at plot establishment and in 2001 or 2002. Stomatal conductance was measured on five trees from each plot by clipping a lateral branch and measuring conductance with steady-state porometer. Needles were clipped and projected leaf area measured with a scanner and image analysis software. Two trees from each plot were destructively sampled. Branches and a 1-m log were cut from each tree, wrapped in plastic, and frozen until measurement. The log was sectioned to measure earlywood, latewood, and total ring width using light microscopy. Branch and log sapwood hydraulic measurements were made with a constant head hydraulic conductivity apparatus with hanging water columns. Steady state was reached with an oxalic acid solution and sapwood identified by switching to fuchsin dye. It was found that basal area increased in fertilized plots, but annual height increment was lower. Lower branch sapwood permeability was found to be higher in annually fertilized trees than in the control. Leaf specific conductivities and Huber values were higher in the lower branches of annually fertilized trees than in the control. It was concluded that annual fertilization results in greater water flow to lower branches, reducing the quantity available for upper branches, and thus reducing their growth. *(Abstract prepared by compilers.)*

Anagnost, S. E., Mark, R.E., and Hanna, R.B. 2005. S_2 orientation of microfibrils in softwood tracheids and hardwood fibers. *International Association of Wood Anatomists (IAWA) Journal* **26**(3): 325–338.

In this study the soft-rot method was applied to measuring the variation of microfibril angle (mfa) in loblolly pine, black cherry, sugar maple and canelo. For loblolly pine and black cherry, measurements of the radial wall indicated a gradual decrease in mfa across the earlywood portion of the growth ring, with an abrupt decrease at the latewood zone for pine, and in contrast only a slight decrease in microfibril angle across an annual ring of black cherry. In loblolly pine microfibril angle measurements indicated that the average microfibril angle in radial sections was very similar to the average for tangential sections of the same block. The average microfibril angles in the intermediate plane, or cell corner, were statistically similar to that of the tangential and radial plane, for pine, cherry, and maple. In canelo, microfibril angles in radial sections were significantly larger than in tangential and intermediate sections. In pine latewood the microfibril angles were less than the average mfa for the entire ring, and the earlywood microfibril angles were greater than the average mfa of the entire ring, thus the average mfa for the growth ring did not represent actual measured mfa values.

Angers, V. A., Messier, C., Beaudet, M, and Leduc, A. 2005. Comparing composition and structure in old-growth and harvested (selection and diameter-limit cuts) northern hardwood stands in Quebec. *Forest Ecology and Management* **217**(2–3): 275–293.

Single-tree selection cutting is sometimes believed to be similar to the natural gap disturbance regime of hardwood forests, but few studies have specifically compared the compositional and structural characteristics of old-growth hardwood stands undergoing natural gap dynamics and hardwood stands previously subjected to partial cuts. This study characterized and compared the composition (saplings and trees) and structure (gaps, foliage distribution, tree diameter and density, snags and coarse woody debris) of old-growth stands (OG), 12-year-old selection cuts (SC), and 28- to 33-year-old diameter-limit cuts (DLC) in sugar maple-dominated northern hardwood stands.

Results showed marked structural differences between OG and harvested stands, with stronger differences between DLC and OG than between SC and OG. The synchronized formation of numerous canopy openings in harvested stands induced a post-harvest recruitment of advance regeneration in both SC and DLC that created a dense foliage layer in the understory. Large living trees (dbh > 39.1 cm) and defective trees were less numerous in SC than OG, which can have a detrimental impact on species dependent on these structural elements, and on the future availability and characteristics of coarse woody debris. Relatively few compositional differences were noticed among stand types, although a greater proportion of mid-tolerant species was found in the post-harvest recruitment cohorts of harvested stands compared to OG, and a lower proportion of beech (*Fagus grandifolia* Ehrh.) saplings was observed in DLC compared to OG and SC.

We argue that even if selection cutting is closer to the natural disturbance regime of hardwood forests than diameter-limit cutting, and therefore representing progress toward the development and implementation of a natural-disturbance-based management, a recurring application of selection cutting might lead to a homogenization of forest structure and composition, a reduction of key structural features and a reduction in biological diversity at both the stand and landscape scales. Some management recommendations are proposed.

Antal, M., and Micko, M.M. 1994. Variation and field estimation of wood quality parameters for black spruce. *Holzforschung und Holzverwertung* **46**(4): 70–72.

Black spruce (*Picea mariana* Mill.) is a commercially important species. This study was undertaken to understand specific gravity variability in black spruce and to validate use of the Pilodyn in measuring specific gravity. Replicated Pilodyn measurements were made on standing trees from which a small area of bark had been removed. Large-diameter increment cores were taken adjacent to the Pilodyn measurements and basic density determined. Six trees were felled and disks removed from predetermined heights. One disk was sawn into wedges for specific gravity determination. Incremental density on extracted ring sections was determined from the second disk. After density determination, the latewood portion of the ring was macerated and the length of 50 tracheids measured. It was found that, the Pilodyn provides a suitable estimate of specific gravity on standing trees. Latewood tracheid length was found to increase with age at all heights. Specific gravity was found to increase with height in the tree. The largest differences in specific gravity were between trees, rather than between stands. *(Abstract prepared by compilers.)*

Aschim, O.K., and McGovern, J.N. 1976. Softwood pulp from Canada's boreal forest rated as prime market pulp. *Pulp and Paper Canada* **60**(9): 130–134.

The fiber dimensions and physical properties of kraft pulps of Canadian boreal softwoods are compared with those of Pacific and southern USA softwoods. Conifers of the boreal forest have a substantially higher content of early wood fibers, which readily collapse into ribbons during sheet formation, thus creating dense, well-bounded papers with high burst and tensile strengths and adequate tear strength. *Picea mariana*, *P. glauca* and *Pinus banksiana* have become the main species for market pulp. *(Abstract prepared by compilers.)*

Balatinecz, J.J., and Kretschmann, D.E. 2001. Properties and utilization of poplar wood. Pages 277–291 *in* D.I. Dickmann et al. *Poplar Culture in North America*. NRC Research Press, National Research Council of Canada, Ottawa, Ontario, Canada.

Although historically considered a weed species, poplars (*Populus* sp.) have become commercially important. This review considers their range, properties, and uses and compares their attributes with their uses. Native poplars are found from Newfoundland to Alaska to Louisiana. They are a fast-growing, intolerant species and hybridize easily. They coppice when cut, eliminating the need for planting unless new clones are desired. Hybrids, especially if selected for pulping, may not have the same solid wood qualities as the parents and may, as a result of rapid growth, contain a greater proportion of juvenile wood. Poplar wood in general is low density with adequate bending strength and stiffness but a high tendancy for shrinkage and cupping during drying. Short vessel elements, compared with softwood tracheids, result in high paper smoothness and opacity, and poplar pulp is often mixed with softwood pulp to produce paper with these qualities as well as strength. Poplar wood is known to contain wet pockets and readily stains and decays. Although low density may be a disadvantage for solid wood products, it leads to ease of peeling and flaking, making poplar suitable for composite products. Poplar has also been considered for bioenergy, phytoremediation, and forage. *(Abstract prepared by compilers.)*

Balatinecz, J.J., Kretschmann, D.E., and Leclercq, A. 2001. Achievements in the utilization of poplar wood—guideposts for the future. *The Forestry Chronicle* **77**(2): 265–269.

From an early status as a "weed tree," poplar has become an important commercial genus in North America during the past 20 years. The many and varied uses of poplar wood now include pulp and paper, lumber, veneer, plywood, composite panels, structural composite lumber, containers, pallets, furniture components, match splints and chopsticks. The high cellulose and relatively low lignin content make poplars well suited for pulp and paper products. The wood can be pulped by all commercial pulping methods, such as mechanical, semi-chemical, sulphate and sulphite processes. Poplar pulps are utilized in fine papers, tissues, paperboard, newsprint and packaging papers. Poplar kraft pulps, when blended with softwood kraft, are particularly well suited for fine paper manufacture because of inherently desirable properties, such as excellent sheet formation, high opacity, good bulk and good printability. While poplar wood continues to be an important raw material in the traditional lumber, veneer and plywood industries, the most remarkable recent achievement in poplar utilization is the phenomenal growth of the oriented strandboard and structural composite lumber industries in North America during the last decade. The future for poplar utilization is bright. On the resource production side, opportunities for genetically modifying important wood properties, such as chemical composition, fibre quality and natural durability of wood, can now be realized. On the resource utilization side, high-value engineered composites and high-yield pulp and paper products will represent the strongest growth sectors for poplar fibre during the coming decades.

À l'origine, une espèce « indésirable », le peuplier est devenu un genre important en terme commercial en Amérique du Nord au cours des dernières 20 années. Les usages multiples et variés du bois de peuplier comprennent maintenant la pâte et le papier, le bois d'œuvre, le déroulage, le contre-plaqué, les panneaux composites, le bois d'ingénierie pour les charpentes, les conteneurs, les palettes, les composantes de meuble, les allumettes et les baguettes. Le fort contenu en cellulose et la relativement faible portion de lignine font en sorte que les peupliers sont recherchés pour la production de pâte et de papier. Le bois peut être transformés en pâte selon tous les procédés commerciaux de mis en pâte qu'il soit mécanique, semi-chimique, au sulfate ou au sulfite. Les pâtes de peuplier sont utilisées dans les papiers fins, les papiers hygiéniques, les cartons, le papier journal et les papiers d'emballage. Les pâtes kraft de peuplier, lorsque mélangées à de la pâte kraft de résineux, sont particulièrement intéressantes pour la fabrication de papier fin par suite des propriétés inhérentes recherchées, comme l'excellente formation de feuille de papier, la grande opacité, une masse adéquate et une bonne qualité typographique. Même si le bois de peuplier continue d'être une importante source de matière brute pour le bois d'œuvre traditionnel, le déroulage et le contre-plaqué, la plus remarquable réalisation récente dans l'utilisation du peuplier réside dans la croissance phénoménale des industries de panneaux à lamelles orientées et dans le bois d'ingénierie pour les charpentes en Amérique du Nord au cours de la dernière décennie. L'avenir de l'utilisation du peuplier est intéressant. Du côté de la production de la ressource, les possibilités entourant la modification par voie génétique des principales propriétés du bois, telles la composition chimique, la qualité des fibres et la durabilité naturelle du bois, peuvent être maintenant mises en fonction. Du côté de l'utilisation de la ressource, les composantes d'ingénierie à grande valeur et les produits de pâte et de papier à haut rendement constitueront les secteurs de croissance les plus importants pour la fibre de peuplier au cours des prochaines décennies.

Ballard, L.A., and Long, J.N. 1988. Influence of stand density on log quality of lodgepole pine. *Canadian Journal of Forest Research* **18**(7): 911–916.

We examined the relationship between stand density and stem quality characteristics for lodgepole pine (*Pinus contorta*). The influence of initial stand density on end of rotation log quality was inferred by analyzing data from unmanaged, rotation-age stands. Quality characteristics examined included first log branch diameters, taper, wood density, and the proportion of sapwood. After differences in diameter at breast height were accounted for, only branch size was strongly influenced by stand density. A strong negative exponential relationship was found between the mean of the five largest branches per first log and number of trees per hectare.

La relation entre la densité de peuplement et les caractères qualitatifs de la tige a été étudiée dans le cas du Pin tordu (*Pinus contorta*). L'effet de la densité initiale du peuplement sur la qualité des billes en fin de révolution a été déduit par comparaison avec des données provenant de peuplements non aménagés et parvenus à l'âge d'exploitabilité. Les caractères qualitatifs étudiés comprenaient le diamètre des branches de la première bille, le défilement, la densité du bois ainsi que la proportion d'aubier. Compte tenu des différences observées dans le diamètre à hauteur de poitrine, seul le diamètre des branches était fortement influencé par la densité de peuplement. Une forte relation exponentielle négative a été trouvée entre la moyenne des cinq plus grosses branches de la première bille et le nombre d'arbres par hectare.

Ban, W., Macosky, D., and Lucia, L.A. 2004. Evaluation of the pulping response of juvenile and mature black spruce compression wood. *Cellulose Chemistry and Technology* **38**(1–2): 79–85.

In order to determine the influence of juvenile and mature compression black spruce (*Picea mariana* (Mill.) B.S.P.) wood on kraft pulping, samples from a tree were visually segregated into juvenile and mature, normal and compression wood. Samples of each were pulped under identical conditions. Juvenile compression and normal wood provided the same yield. Mature compression wood yield was lower than that of normal wood. Although juvenile compression wood kappa number was higher than that of normal wood, the kappa number of both mature compression and normal wood were significantly higher still. Pulp viscosity was similar for all. Pulping selectivity for both juvenile and mature wood decreased from normal to compression wood and selectivities of both normal and compression mature wood were lower than those of juvenile wood. *(Abstract prepared by compilers.)*

Banal, S., Marceau, D.J., and Bouchard, A. 2007. Sapling responses to variations in gap densities and spatial configurations modeled using SORTIE. *Ecological Modelling* **206**(1–2): 41–53.

The objective of this study is to measure the sapling responses to variation in gap densities and spatial configurations in simulated stands using the SORTIE model. The hypothesis is that the cumulative effects and the interaction of several small increases in direct and diffuse light can have important effects on the growth of saplings. Four gap densities were introduced by removing trees until 10%, 20%, 35% and 50% of total basal area was removed. The configuration of the gaps surrounding the saplings was characterized by recording the gaps present in six radial distance intervals, and the number of gaps directly positioned above the saplings. The analysis of the sapling growth before and after the introduction of gaps shows an increase in basal area and in the number of growth release episodes that varies with gap density, with a stronger trend observed in shade intolerant species. Spatial analyses reveal that the combination of increases in light originating from several gaps has an important effect on saplings' growth and can cause growth releases similar to those attributed to a direct gap. These results confirm the value of combining modeling and spatial analysis to study gap dynamics at fine spatial and temporal scales.

Bankowski, J. 1994. *Effect of Growing Space on Wood Density in Jack Pine*. Thesis, University of Toronto, Toronto, Ontario, Canada.

A 65-year-old stand of jack pine (*Pinus banksiana*) in Ontario was destructively sampled in order to obtain the relative density at different heights in the trees. The stand had been spaced previously at 1.7, 2.6, and 3.4 m. The objective was to determine if thinning had an impact on wood relative density and its relationship to crown development and growth rate. Changes in latewood ratio were identified that explained the ring relative density increasing from top to bottom. Nonetheless, the relative density for the entire tree was not affected significantly by thinning the stand. *(Abstract prepared by compilers.)*

Barbour, J. 1988. *A Review of the Literature on the Wood Quality of White Spruce (*Picea glauca*).* (Second of two reports.) Forintek Canada Corporation, Vancouver, British Columbia, Canada.

This literature review considers relative density, tracheid length, physical properties, climatic and geographic property variation, silvicultural treatments, and modelling of growth and properties of white spruce (*Picea glauca*). As early as 1923, concerns were raised regarding the impact of growth rate on relative density, and many studies ensued. Relative density of white spruce has also been studied with respect to between- and within-tree variation and genetic opportunities for improvement. Tracheid length variability within the tree and with changes in growth rate has been studied. Length has been found to increase with growth rate and to initially increase and then decrease with height in the tree; it continues to increase with age. Differences in relative density have been found on various sites throughout the geographic range, but the differences may be attributed to between-tree variation rather than geographic variation. Cambial cell division rate has been found to vary geographically, with higher rates in Alaska than in New England. Although much work has been reported on silvicultural activities with white spruce, only one paper related silvicultural treatments to wood properties. The earliest model related basal increment to relative density. Later models related later and height growth with mixed success. The review concluded that research opportunities exist in the relationship between silvicultural efforts and wood properties and in development of models relating growth to wood properties. *(Abstract prepared by compilers.)*

Barbour, J., and Chauret, G. 1988. *Evaluation of Basic Wood Properties of Black Spruce (*Picea mariana*) from Quebec.* (First of Two Reports.) Forintek Canada Corporation, Vancouver, British Columbia, Canada.

As part of a study evaluating the wood properties of black spruce (*Picea mariana*), this report examined microfibril angle, longitudinal shrinkage, and branch growth characteristics. Microfibril angle was measured by cutting fibers in a microtome and liberating them with a macerating solution. Longitudinal shrinkage measurements were made on cyclohexane and ethanol extracted samples. Branch rings were counted on microtomed sections. Microfibril angle was not found to be normally distributed and did not seem to reach a constant angle in wood near the bark. No direct cause-and-effect relationship was found between microfibril angle and longitudinal shrinkage. Grain angle was not found to be as closely related to longitudinal shrinkage as previously believed. It was found that branch growth characteristics can provide a description of the tree from which the board was cut. *(Abstract prepared by compilers.)*

Barbour, R. J., Fayle, D.C.F., Chauret, G., Cook, J., Karsh, M.B., and Ran, S. 1994. Breast-height relative density and radial growth in mature jack pine (*Pinus banksiana*) for 38 years after thinning. *Canadian Journal of Forest Research* **24**(12): 2439–2447.

Sawlogs are in short supply in northern Ontario, and thinning has been suggested as one way to improve the situation. The only rotation-age jack pine (*Pinus banksiana* Lamb.) thinning trial in the region was examined to assess how commercial thinning influenced wood quality. This report covers an unreplicated trial of a 65-year chronology of pith to bark relative densities and growth rates based on X-ray densitometry of breast-height increment cores taken from trees on two thinned plots (average spacing 2.6 and 3.4 m) and an unthinned control (average spacing 1.7 m). The trees on the treatment plots responded to thinning by producing wood with significantly lower relative density than those on the control plot. This trend continued much longer than reported for other pines and could negatively affect pulp yield or mechanical properties of lumber. Enhanced earlywood growth caused a drop in the proportion of latewood that resulted in the decline in density. Thinning may have improved moisture availability during the early and middle season and encouraged earlywood growth. Density and growth rate differences became apparent soon after treatment. Early, rapid, and inexpensive estimates of the product potential of younger thinning trials are possible using the techniques demonstrated here.

L'éclaircie a été considérée comme une solution à la pénurie de bois de sciage dans le Nord de l'Ontario. Pour établir les effets de l'éclaircie commerciale sur la qualité du bois, un dispositif sans réplication a été installé dans un peuplement de pin gris (*Pinus banksiana* Lamb.) actuellement parvenu à maturité. Le présent travail porte sur une analyse chronologique couvrant 65 ans de la largeur des cernes et de leur densité relative mesurée aux rayons-X depuis la moelle jusqu'à l'écorce. Des carottes de sondage à hauteur de poitrine ont été prélevées dans deux placettes éclaircies à espacement moyen de 2,6 et 3,4 m et dans une placette non éclaircie à espacement moyen de 1,7 m. Dans les placettes traitées, les arbres répondent à l'éclaircie en produisant du bois de densités plus faibles que celles observées dans la placette témoin. Cette tendance se maintient plus longtemps que celle rapportée pour d'autres pins et pourrait affecter négativement la production de pâte ou les propriétés mécaniques du bois. L'augmentation du bois de printemps a provoqué une baisse de la proportion du bois d'été et, par conséquent, une baisse de la densité. L'éclaircie peut améliorer l'humidité disponible au début et à la mi-saison de croissance et ainsi favoriser la formation du bois de printemps. Ces différences de densité et de largeur de cerne sont détectées très tôt après le traitement. Il est donc possible de prédire de façon précoce, rapide et peu coûteuse la qualité des produits pouvant être obtenus à la fin de la révolution dans les peuplements éclaircis en bas âge.

Barbour, R.J., and Kellogg, R.M. 1990. Forest management and end-product quality: a Canadian perspective. *Canadian Journal of Forest Research* **20**(4): 405–414.

The level of silvicultural investment and area of forest land managed in Canada is rising dramatically. Although this will increase growth rates and help maintain the present level of harvest, it may well result in a reduction in the quality of the resource. The present paper illustrates the risk of ignoring this potential problem through examples of experience in utilizing plantation-grown trees in various parts of the world. Relying on technology to solve all resource quality problems may not necessarily make economic sense. Canada's future must lie in the production of "value-added" products that require a high quality resource, permitting the greatest flexibility in conversion options. Information relating silvicultural treatments to end-product quality is at present inadequate. Large integrated studies addressing these questions and the economics of silvicultural investments in terms of end-product value must be initiated for species that will be managed intensively. With relatively long rotations, Canada cannot afford to create a resource that does not match its future marketing strategy.

L'ampleur des investissements en sylviculture de même que les superficies forestières sous aménagement au Canada ont augmenté de façon importante. Ceci va contribuer à augmenter les taux de croissance et à maintenir le niveau actuel de la récolte, mais pourrait aussi résulter en une diminution de la qualité de la ressource. Cet article illustre le risque qui subsiste à ignorer cette question au moyen d'exemples tirés de l'expérience avec l'utilisation d'arbres cultivés en plantation dans diverses régions du monde. Le fait de s'appuyer sur la technologie pour résoudre tous les problèmes liés à la qualité de la ressource n'est pas nécessairement une option économiquement valable. L'avenir du Canada doit résider dans la production de biens qui « ajoutent de la valeur », biens qui exigent une ressource d'excellente qualité permettant une grande flexibilité pour la conversion. Les renseignements disponibles liant les traitements sylvicoles à la qualité des produits finis sont nettement insuffisants. Il faut initier de vastes recherches intégrées portant sur ces questions et sur l'aspect économique des investissements en sylviculture en termes de produits finis pour les essences qui feront l'objet d'un aménagement intensif. Avec des révolutions relativement longues, le Canada ne peut pas se permettre de créer une ressource qui ne soit pas conforme à sa future stratégie de mise en marché.

Barbour, R.J., Sabourin, D., and Chiu, E. 1989. *Evaluation of Basic Wood Properties of Black Spruce (*Picea mariana*) from Quebec. Part II.* Forintek Canada Corporation, Vancouver, British Columbia, Canada.

This report provides information on microfibril angle for black spruce. Longitudinal shrinkage was tested in relation to the microfibril angle. The results were inconclusive because the microfibril angle remained the same for both high and low values of longitudinal shrinkage. The goal was to provide a model to predict warp in lumber. *(Abstract prepared by compilers.)*

Barrett, J.D., and Lau, W. 1994. *Canadian Lumber Properties.* Canadian Wood Council, Ottawa, Ontario, Canada.

This book provides a wealth of information on structural properties of Canada's softwood lumber. The tests were performed on full-sized wood provided by Canadian sawmills. The book covers clear wood properties, structural properties of lumber, the Canadian Wood Council lumber properties project, machine stress-rated lumber, rate of loading, size effect, grade relationships, lumber property relationships, moisture content effect, testing methods, design values in Canadian Standards, design values in U.S. Standards, and an appendix on values for different species. *(Abstract prepared by compilers.)*

Barton, A.M., and Grenier, D.J. 2008. Dynamics of jack pine at the southern range boundary in downeast Maine. *Canadian Journal of Forest Research* **38**(4): 733–743.

Great Wass Island in Maine supports a large population of *Pinus banksiana* Lamb. (jack pine) at its southern range boundary. Nearly monospecific stands occur on outcrops and coastal plateau bogs. In contrast to typical populations of this species, six stands exhibited old trees, multiaged structure, and continuous but pulsed establishment despite a lack of widespread fire. Unfavourable soil conditions appear to explain the presence of self-perpetuating populations in this study area, across the geographic range for *P. banksiana*, and for similar shade-intolerant pine species. *Pinus banksiana* stands on outcrops exhibited synchronous age structure peaks and included many trees over 150 years old. In contrast, coastal plateau bog stands were younger, were not synchronized in terms of age structure, and contained few large dead trees, suggesting turn-of-the-20th century invasion of these bogs. Analysis of historical aerial photographs furthermore reveals substantial infilling of bogs by *P. banksiana* since 1940. Although it appears an inconsistant and slow process, coastal plateau bog infilling warrants further investigation because of the regional rarity of this ecosystem type.

L'île Great Wass, dans l'État du Maine, aux États-Unis, supporte une population importante de *Pinus banksiana* Lamb. à la limite sud de son aire de répartition. Des peuplements pratiquement purs occupent des affleurements et des plateaux côtiers marécageux. Contrairement aux populations typiques de cette espèce, six peuplements comportaient de vieux arbres, avaient une structure multiâge et les arbres s'y établissaient de façon continue, mais épisodique malgré l'absence de feux importants. Des conditions de sol peu favorables semblent expliquer la présence de populations qui se perpétuent, que ce soit dans cette aire d'étude, dans toute l'aire de répartition de *P. banksiana* ou pour d'autres espèces de pins intolérants à l'ombre. Les peuplements de *P. banksiana* établis sur des affleurements étaient caractérisés par des structures d'âge qui culminaient de façon synchrone et par la présence de plusieurs arbres âgés de plus de 150 ans. À l'opposé, les peuplements établis sur des plateaux côtiers marécageux étaient plus jeunes, n'avaient pas de structure d'âge synchrone et comportaient peu de gros arbres morts, ce qui indique que ces tourbières ont été envahies au tournant du 20e siècle. De plus, une analyse de vieilles photographies aériennes révèle qu'il y a eu une colonisation importante de ces tourbières depuis 1940 par *P. banksiana*. Quoique ce processus semble lent et inconsistant, la colonisation des plateaux côtiers marécageux devrait être davantage étudiée à cause de la rareté régionale de ce type d'écosystème.

Beaulieu, J., and Corriveau, A. 1985. Variability of wood density and yield in white spruce, 20 years after planting. *Canadian Journal of Forest Research* **15**(5): 833–838.

The variability of wood specific gravity and yield of 23 white spruce provenances from the Great Lakes–St. Lawrence forest region was studied 20 years after planting at Harrington Forest Farm, Quebec. The results indicate no relationship between wood specific gravity of provenances and their respective growth performance. The southwestern section of this region showed a small decrease in wood specific gravity, but it was compensated for by a strong increase in volume growth, resulting in an important gain in dry weight productivity. The variability of white spruce wood specific gravity was split into three sources: 11% was attributed to provenance differences, 8% to provenance and repetition interaction, and the remainder to differences among trees of the same provenance and experimental error. In a breeding program, a first selection should be made at the provenance level on the basis of volume productivity and a second selection on the basis of wood specific gravity values within the selected provenances, to maximize the overall genetic and economic gain.

La variabilité de la densité du bois et de la production de 23 provenances d'épinette blanche originaires de la région forestière des Grands Lacs et du St-Laurent a été étudiée 20 ans après plantation à la ferme forestière de Harrington au Québec. Les résultats obtenus permettent de conclure que la densité du bois n'est pas liée aux caractéristiques de croissance des provenances. Certaines provenances ont à la fois une croissance rapide et un bois de forte densité. L'inverse se produit aussi. Si un déplacement vers l'ouest, pour ce qui est du choix des provenances, se traduit par une faible diminution de la densité, il en résulte quand même un gain en masse anhydre. La perte en densité du bois est plus que compensée par un gain en volume. La variabilité de la densité du bois a été décomposée en trois parties, soit: 11% dus aux provenances, 8% dus à l'interaction entre les provenances et les répétitions, et 81% dus aux différences entre les individus d'une même provenance et à l'erreur expérimentale. Une première sélection appliquée aux provenances sur la base de leur production volumique et une seconde faite sur les arbres dont le bois est de densité élevée ont été recommandées.

Beaulieu, J., Zhang, S.Y., Yu, Q., and Rainville, A. 2006. Comparison between genetic and environmental influences on lumber bending properties in young white spruce. *Wood and Fiber Science* **38**(3): 553–564.

This study investigated variation in lumber bending properties of white spruce (*Picea glauca* [Moench] Voss) and its correlation with tree growth, wood density, and knot size and number. A total of 242 sample trees from 39 open-pollinated families harvested from 36-year-old provenance-progeny trials at two sites in Quebec, Canada through a thinning operation were processed. The results indicate that mechanical properties of lumber from young white spruce plantation-grown trees are low. It appears that low wood density, the occurrence of numerous knots, and a high proportion of juvenile wood are the main factors contributing to the low lumber stiffness and strength properties. The narrow-sense heritability for lumber stiffness was low to moderate, whereas that of strength was hardly different from zero. Thus environmental growing conditions highly influence white spruce wood mechanical properties. The results also revealed a strong negative correlation between stem volume and lumber stiffness and strength at the family means, which suggests that selection for volume would have an indirect negative effect on lumber quality. However, the absence of such significant correlation at the phenotypic level also suggests that mass selection with vegetative propagation would be a promising avenue for improving white spruce wood properties without having to give up gains in volume.

Bedard, S., and Majcen, Z. 2003. Growth following single-tree selection cutting in Quebec northern hardwoods. *The Forestry Chronicle* **79**(5): 898–905.

Eight experimental blocks were established in the southern part of Quebec to determine the growth response of sugar maple (*Acer saccharum*) dominated stands after single tree selection cutting. Each block contained eight control plots (no cut) and eight cut plots. The intensity of removal varied between 21% and 32% and residual basal area was between 18.2 and 21 m^2/ha. Ten year net annual basal area growth rates in cut plots (0. 35 ± 0.04 m^2/ha) were significantly higher ($p = 0.0022$) than in control plots (0.14 ± 0.06 m^2/ha). The treatment particularly favoured diameter growth of stems between 10 and 30 cm in dbh, whose crowns were released by removing neighbouring trees. These results show that if the same net growth rate is maintained in the next decade most of the cut plots will reach their pre-cut basal area in about 20 years after cutting.

Huit blocs expérimentaux ont été mis en place dans la partie sud du Québec afin de déterminer la réaction de croissance dans les peuplements dominés par l'érable à sucre (*Acer saccharum*) après une coupe de jardinage par arbre. Chaque bloc comprenait huit parcelles témoins (pas de coupe) et huit parcelles traitées. L'intensité de la coupe variait d'entre 21 % et 32 % et la surface terrière résiduelle se situait entre 18,2 et 21 m^2/ha. Les taux de croissance de la surface terrière après dix ans dans les parcelles traitées (0,35 ± 0,04 m^2/ha) étaient significativement plus élevés (p = 0,0022) que dans les parcelles témoins (0,14

± 0,06 m²/ha). Le traitement a favorisé particulièrement la croissance en diamètre des tiges de 10 à 30 cm de diamètre dont les cimes ont été dégagées par l'abattage des arbres voisins. Ces résultats démontrent que si le même taux de croissance se maintient au cours de la prochaine décennie, la plupart des parcelles traitées auront retrouvé leur surface terrière originale en près de 20 ans après le traitement.

Bell, F.W., Baker, W.D., and Vassov, R. 1990. *Influence of Initial Spacing on Jack Pine Wood Yield and Quality—a Literature Review.* Report TR-10. Ontario Ministry of Natural Resources, NWOFTDU, Thunder Bay, Ontario, Canada.

Jack pine (*Pinus banksiana* Lamb.) is a commercially important species in northwestern Ontario. Although direct seeding is a common means of regeneration, planting provides less variable results. This review examines the influence of stand density on eventual wood quality. Initial spacing influences mortality, with wider spaces leading to increased survival and final volume, but not height. Self-thinning occurs after crown closure, and so earlier in closer spacings. Spacing is positively correlated to diameter growth and to proportion of trees in higher diameter classes, but is negatively correlated to total stand volume. Close spacing results in improved stem form. Smaller initial spacing results in smaller knots and lower proportion of juvenile wood, but has little effect on specific gravity. It is likely that wider spacing results in lower extractives content. It was recommended that, as end use dictates required wood quality, initial spacing should reflect the desired end use. As the literature pertaining to jack pine plantations in northwestern Ontario was limited, further research was recommended. *(Abstract prepared by compilers.)*

Bell, F. W., Bastarache, P., and Meyer, L. 1997. *Jack Pine Fertilization: a Review of Literature.* Report TR-111. Ontario Ministry of Natural Resources, NWST, Thunder Bay, Ontario, Canada.

The response of fertilization in jack pine stands depends on soil characteristics, type, amount, and application of fertilizer, and the stand condition. Fertilization was found to increase the speed of self-thinning but did not increase the amount of volume produced. Fertilization should, therefore, be carried out on stands below the self-thinning stage, rather than on stands going through the self-thinning stage. *(Abstract prepared by compilers.)*

Bella, I.E., and DeFranceschi, J.P. 1974. *Commercial Thinning Improves Growth of Jack Pine.* Information Report NOR-X-112. Natural Resources Canada, Canadian Forestry Service - Northern Forestry Centre, Edmonton, Alberta, Canada.

Jack pine (*Pinus banksiana* Lamb.) stands on good sites showed improved tree and stand growth following commercial low and crown thinning at age 40. Data 15 years after thinning suggest that gross pulpwood and sawlog yields (thinning plus final yield) will be greater in treated stands. Growth response to crown thinning occurred later than response to low thinning, but its effect was of longer duration. Therefore, on good sites, a combination of low and crown thinning which removes up to 30–35% of basal area at a stand age of about 40 years may be advantageous because it reduces thinning costs, improves yield, and lowers harvesting and processing costs because of increased tree size.

Par suite d'éclaircies commerciales par le haut et par le bas, au moment ou ils étaient agés de 40 ans, les peuplements de pin gris (*Pinus banksiana* Lamb.) en stations de bonne qualité pousserent mieux. Quinze ans après les éclaircies, les rendements bruts en bois à pâte et en grûmes (éclaircies plus récolte finale) seront plus élevés dans les peuplements traités. La croissance améliorée résultant d'éclaircie par le haut se produisit plus tard que celle résultant d'éclaircie par le bas, mais elle fut d'effet plus durable. Par conséquent, dans les stations de bonne qualité, des éclaircies combinées (par le haut et par le bas) diminuant de jusqu'à 30–35% la surface terrière au moment où le peuplement a 40 ans, peuvent se reveler avantageuses parce qu' elles réduisent les coûts d'éclaircies, amélioent le rendement et diminuent les coûts de récolte et de façonnage en raison des dimensions plus fortes des arbres.

Bella, I.E., and DeFranceschi, J.P. 1974. *Early Results of Spacing Studies of Three Indigenous Conifers in Manitoba.* Information Report NOR-X-113. Natural Resources Canada, Canadian Forest Service - Northern Forest Research Centre, Edmonton, Alberta, Canada.

Jack pine, red pine, and white spruce (*Pinus banksiana* Lamb., *P. resinosa* Ait., and *Picea glauca* (Moench) Voss) were planted at 4-, 6-, and 10-ft (1.3-, 2.0-, 2.6-, and 3.3-m) spacings in an 11 X 11 matrix with four replications on nutritionally poor, sandy fresh sites in the Sandilands Forest Reserve. Eleven growing seasons after planting: (1) There was no significant spacing effect on height growth of any of the species; (2) Diameter growth of jack pine was best at the two intermediate spacings, but diameter growth of red pine was not affected; (3) There was an increase in crown width with spacing for both pines and a deterioration in tree form at wider spacing in jack pine; (4) Jack pine grew over 30% faster in diameter and height than red pine and might be favored for fibre production, while red pine retained better tree form even at the widest spacing, and thus seems more suited for sawlog production in the absence of thinning, provided that current growth trends continue.

On planta quatre fois le pin gris (*Pinus banksiana* Lamb.), le pin rouge (*P. resinosa* Ait.) et l'épinette blanche (*Picea glauca* (Moench) Voss) par espacements de 4, 6, 8, et 10 pieds (1.3, 2.0, 2.6, et 3.3 m) dans une matrice de 11X11, en sol sableux, pauvre et frais dans la Réserve de Sandilands, Manitoa. Onze saisons de croissance après le plantage (1) l'espacement n'eut pas d'effet significatif sur la croissance en hauteur quelle que fût l'espèce; (2) la croissance de diamètre du pin gris se révéla la meilleure aux deux écartements intermédiaires, pendant que le diamètre du pin rouge n'était pas influencé; (3) chez les deux pins, la cime devint plus large avec des espacements plus grands, mais la forme du pin gris se détériora; (4) le pin gris poussa 30% plus vite en diamètre et en hauteur que le pin rouge et de ce fait on peut le préférer pour la production de fibres; tandis que le pin rouge retint une meilleure forme à tous les écartements : il semble donc préférable pour la production de grumes lorsque l'on ne fait pas d'éclaircie et à condition que les tendances de croissance notées continuent.

Bendtsen, B.A. 1974. *Specific Gravity and Mechanical Properties of Black, Red and White Spruce and Balsam Fir.* Research Paper FPL-237. United States Department of Agriculture, Forest Service, Forest Products Laboratory, Madison, Wisconsin, USA.

Ten properties have been evaluated for red, black and white spruce and for balsam fir in both the green and air-dry condition. Of these, five are regarded as commonly used design properties. Forty instances (four species, five properties, two moisture contents) are of particular interest for design; significant changes were found in all but nine, with 95 percent confidence.

Average modulus of elasticity and proportional limit in compression perpendicular to grain are, in about half of the instances studied, significantly higher than previous estimates. In only one case, for the proportional limit of white spruce in the green condition, this study revealed a significant reduction.

Those strength properties where at 5 percent exclusion limit is determined from the average and standard deviation are modulus of rupture, shear strength, and compressive strength parallel to grain. All changed significantly compared to previous estimates, with three exceptions. These were shear strength for green red spruce, and modulus of rupture and compressive strength for dry white spruce. A simultaneous statistical test was used to measure significant differences for these properties. *(Source: U.S. Department of Agriculture, Forest Service.)*

Bendtsen, B.A. 1976. Rolling shear characteristics of nine structural softwoods. *Forest Products Journal* **26**(11): 51–56.

Rolling shear properties were evaluated on a random sample of nine structural softwood species: red, white, and black spruce; balsam fir; subalpine fir; Port-Orford-cedar; western redcedar; sugar pine; and western white pine. Rolling shear strengths in the tangential–longitudinal plane of the five western and four eastern softwoods are about one-fourth to one-fifth of the shear strength parallel-to-grain values obtained from 2-inch block shear tests. Western white and sugar pine are relatively high in shear strength and modulus of rigidity for their density. Black and red spruce are relatively low in shear strength for their density. The stress–strain behavior in rolling shear is characterized, for the species studied, by the Ramberg-Osgood function.

Bendtsen, B.A. 1978. Properties of wood from improved and intensively managed trees. *Forest Products Journal* **28**(10): 61–72.

A limited review of the literature was conducted concerning wood properties of improved trees grown under intensive management. It is concluded that differences between wood properties of trees from the natural and manmade forests are associated with the short-rotation and resulting high proportion of juvenile wood in the harvest of the improved trees. Properties of juvenile wood of conifers and hardwoods and problems encountered in processing and utilizing juvenile wood in solid wood products are discussed. Insights are offered concerning the rapidly changing forest resource and its implication in the solid wood industry, particularly lumber.

Bendtsen, B.A., and Ethington, R.L. 1975. *Mechanical Properties of 23 Species of Eastern Hardwoods.* Research Note FPl-0230. United States Department of Agriculture, Forest Service, Forest Products Laboratory, Madison, Wisconsin, USA.

Important mechanical properties of clear, straight-grained wood of 23 species are tabulated, along with coefficients of variation. These property estimates can be used to match species with kind of material needed for a specific job, or to search for substitutes for a presently used species. Some of the species appear, with allowable properties, in two published plywood manuals. There are no similar hardwood lumber stress grades, but standard methods exist for generating them, should interest develop. *(Source: U.S. Department of Agriculture, Forest Service.)*

Bendtsen, B.A., and Galligan, W.L. 1979. *Mean and Tolerance Limit Stresses and Stress Modeling for Compression Perpendicular to Grain in Hardwood and Softwood Species.* Research Paper FPL-337. United States Department of Agriculture, Forest Service, Forest Products Laboratory, Madison, Wisconsin, USA.

Tables characterizing the stress-compression relationship of wood in compression perpendicular to grain for several species are presented. Complete characterization results are included, as well as selected regression models for characterizing other species. Use of the tables and models is illustrated via discussion and graphs. *(Source: U.S. Department of Agriculture, Forest Service.)*

Benjamin, J., Chui, Y.H., and Zhang, S.Y. 2007. A method to assess lumber grade recovery improvement potential for black spruce logs based on branchiness. *Forest Products Journal* **57**(12): 34–41.

A log-level lumber grade assessment method based on branchiness was developed to bring lumber grade considerations into forest management planning. Existing methods focus primarily on mean or maximum knot size per log. The method developed in this study is based on branch size and location on log surface, internal knot shape, and log size. Assuming a cylindrical log shape with a central pith, a log transformed linear regression model was developed to predict minimum horizontal branch angle (branch azimuth) between successive knots, with respect to log size, that would produce at least one piece of lumber at a desired grade, by product, from the center cant using either an edge or centerline knot pattern. The minimum difference in horizontal branch angle between successive branches decreased with increasing log size if product specifications were held constant and increased with increasing product width if log size remained constant. The above method was demonstrated using a sample of logs from three initial spacings (1.8 m, 2.7 m, and 3.6 m). Although lumber grade recovery improvement potential varied from 0 percent to 40 percent across spacings, no clear trend was evident for improvement potential by spacing at the product and grade level based on a chi-square analysis using a 2x3 contingency table ($X^2$0.05.32 = 7.815, X^2edge = 3.979, and X^2centerline = 2.392).

Benzie, J.W. 1977. *Managers' Handbook for Jack Pine in the North Central States.* General Technical Report NC-32. United States Department of Agriculture, Forest Service, North Central Forest Experiment Station, Saint Paul, Minnesota, USA.

Provides a key for the resource manager to use in choosing silvicultural practices for the management of jack pine. Control of stand composition, growth, and stand establishment for timber production, water, wildlife, and recreation are discussed. *(Source: U.S. Department of Agriculture, Forest Service.)*

Bernier, P.-Y., Lavigne, M.B., Hogg, E.H., and Trofymow, J.A. 2007. Estimating branch production in trembling aspen, Douglas-fir, jack pine, black spruce, and balsam fir. *Canadian Journal of Forest Research* **37**(6): 1024–1033.

Measuring net primary productivity of trees requires the measurement of total wood production of branches. Recent work on balsam fir (*Abies balsamea*) has shown that branch-wood production can be estimated as a function of foliage production. We extend the analysis to four other species found in the Canadian forest: black spruce (*Picea mariana*), jack pine (*Pinus banksiana*), Douglas-fir (*Pseudotsuga menziesii*), and trembling aspen (*Populus tremuloides*). Results show that the ratio of annual branch-wood production to annual foliage production is about 1.0 for conifer species (between 0.86 and 1.12) and 0.56 for aspen during a non-drought year. An analysis using field measurements of litterfall and stem-diameter increment from selected forested sites shows that branch-wood production accounts for a smaller proportion of aboveground net primary productivity in trembling aspen (15%-20%) than in conifer species (25%). Also, litterfall capture of small branches (<1 cm diameter) accounts for only 33% of branch detritus production in conifers and 50% in trembling aspen. This study supports the use of an alternative method for estimating branch-wood production that reduces the potential bias in field estimates of net primary productivity.

La mesure de la productivité nette des arbres requiert une mesure de la production totale de bois dans les branches. Un travail récent sur le sapin baumier (*Abies balsamea*) a démontré que la production en bois des branches peut être exprimée en fonction de la production foliaire. Dans le présent travail, nous étendons l'analyse à quatre autres essences des forêts du Canada : l'épinette noire (*Picea mariana*), le pin gris (*Pinus banksiana*), le sapin Douglas (*Pseudotsuga menziesii*) et le peuplier faux-tremble (*Populus tremuloides*). Les résultats démontrent que le rapport entre la production annuelle de bois et la production annuelle de feuillage est d'environ 1,0 pour les résineux (entre 0,86 et 1,12) et de 0,56 pour le peuplier faux-tremble pendant une année sans sécheresse. Une analyse basée sur les mesures de chute de litière et d'accroissement diamétral obtenu sur quelques placettes forestières montre que la production en bois des branches est une plus petite composante de la productivité primaire nette aérienne chez le peuplier faux-tremble (15 % à 20 %) que chez les résineux (25 %). Aussi, la litière sous forme de petites branches (diamètre < 1 cm) ne compte que pour 33 % et 50 % de la production totale de litière de bois de branche des résineux et du peuplier faux-tremble, respectivement. Cette étude préconise l'utilisation d'une méthode d'estimation de la production en bois des branches qui réduit le biais de mesure de la productivité primaire nette au terrain.

Berry, A.B. 1974. *Crown Thinning a 30-Year-Old White Spruce Plantation in Petawawa: 10 Year Results.* Natural Resources Canada, Canadian Forest Service - Petawawa Forest Experimental Station, Information Report PS-X-49. Chalk River, Ontario, Canada.

This paper describes the 10-year growth results of a crown thinning to residual basal areas of 80, 100, and 140 ft^2 per acre in a 30-year-old white spruce plantation. The diameter increment of individual trees was highest on the area thinned to a residual density of 80 ft^2 of basal area and decreased as residual density increased. At a single density the larger the tree the greater was the diameter increment. Differences in basal area and volume increment per acre between treatments were not statistically significant. Nevertheless the differences were of such a magnitude that they should not be ignored. Ninety percent of the maximum volume growth was put on at basal area densities of 110 ft^2 or more.

Bertrand, V., and Bolghari, H. 1970. *L'effet d'une coupe d'éclaircie dans un peuplement dense d'épinettes et de sapin baumier âgé de 45 ans au sud-est de Québec.* Mémoire N° 1. Service de Recherche, Québec, Québec, Canada.

A commercial thinning of a 45-year-old stand of spruce–fir was performed in order to evaluate the growth and yield of the residual stand. The results show a significant increase in diameter growth, volume, basal area and a decrease in mortality. *(Abstract prepared by compilers.)*

Une éclaircie commerciale sur un peuplement de 45 ans fut effectuée afin d'évaluer l'accroissement et la production du peuplement résiduel. Les résultats démontrent un accroissement significatif du diamètre, du volume, de la surface terrière et une diminution de la mortalité. *(Résumé fourni par les compilateurs.)*

Bjurhager, I., Berglund, L.A., Bardage, S.L., and Sundberg, B. 2008. Mechanical characterization of juvenile European aspen (*Populus tremula*) and hybrid aspen (*Populus tremula* × *Populus tremuloides*) using full-field strain measurements. *Journal of Wood Science* **54**(5): 349–355.

Functional analysis of genes and proteins involved in wood formation and fiber properties often involves phenotyping saplings of transgenic trees. The objective of the present study was to develop a tensile test method for small green samples from saplings, and to compare mechanical properties of juvenile European aspen (*Populus tremula*) and hybrid aspen (*Populus tremula* × *tremuloides*). Small microtomed sections were manufactured and successfully tested in tension parallel to fiber orientation. Strain was determined by digital speckle photography. Results showed significantly lower values for juvenile hybrid aspen in both Young's modulus and tensile strength parallel to the grain. Average Young's moduli spanned the ranges of 5.9–6.6 and 4.8–6.0 GPa for European aspen and hybrid aspen, respectively. Tensile strength was in the range of 45–49 MPa for European aspen and 32–45 MPa for hybrid aspen. The average density (oven-dry) was 284 kg/m^3 for European aspen and 221 kg/m^3 for hybrid aspen. Differences in mechanical properties correlated with differences in density.

Blanchette, R.A., Obst, J.R., and Timell, T.E. 1994. Biodegradation of compression wood and tension wood by white and brown rot fungi. *Holzforschung* **48** (1suppl.): 34–42.

Ultrastructural investigations and chemical determinations of compression wood from *Abies balsamea*, *Picea mariana* and *Pinus strobus* after decay by white or brown rot fungi demonstrated that this type of wood is more resistant to decay than normal wood. Hyphae colonizing compression wood were found in cell lumina and intercellular spaces whereas normal wood cells had hyphae only in cell lumina. Compression wood did not alter the type of cell wall degradation produced by the various fungi tested, but the rate and extent of decay were limited. The white rot fungus, *Trametes versicolor*, caused a nonselective attack at all cell wall components as indicated by erosion of secondary wall layers and middle lamella. A selective removal of lignin occurred throughout the cell walls of wood decayed by the other white rot fungi (*Phellinus pini*, *Phlebia tremellosa* and *Scytinostroma galatinum*) that were evaluated. The brown rot fungi, *Fomitopsis pinicola* and *Oligoporus placentus* caused a diffuse removal of polysaccharides from both compression wood and normal wood. Tension wood from *Populus tremuloides* and *Acer rubrum* decayed by white and brown rot fungi had similar amounts of decay to those observed in normal wood. Ultrastructural observations, however showed striking differences in the progressive stages of decay. Hyphae of *Tremetes versicolor* located in cell lumina did not cause erosion or severe degradation of the adjacent, underlying gelatinous layer associated with tension wood. A typical nonselective degradation of the secondary wall layers and middle lamellae, however, occurred beneath this gelatinous layer. In areas of advanced degradation, the secondary wall and middle lamellae between cell walls were completely degraded leaving only the gelatinous layer and cell corner regions of the middle lamellae. Brown rot fungi were able to degrade the gelatinous layer and other cell wall layers resulting in extensive degradation of polysaccharides.

Bluskova, G., Pishmanova, T., and Valchev, I. 1997. Wood quality and kraft pulp properties of some coniferous species in Bulgarian young plantations. Pages VII-29–VII-33 *in* S.Y. Zhang, R. Gosslin, and G. Chauret, editors. *CTIA/IUFRO International Wood Quality Workshop.*18–22 August 1997, Quebec City, Quebec, Canada. Forintek Canada, Sainte-Foy, Quebec, Canada.

Twenty-four trees were cut to investigate wood quality and kraft pulp properties. Six Scots pine (*Pinus sylvestris*), six black pine (*P. nigra*), and 12 Douglas-fir (*Pseudotsuga menziesii*) trees were cut, and wood-quality characteristics were compared with kraft cooking characteristics and strength properties of unbleached kraft pulp. There were no differences in wood-quality characteristics or kraft pulp properties found between the three species of the same age grown under the same conditions. *(Abstract prepared by compilers.)*

Boateng, J. O., Heineman, J.L., McLarnon, J., and Bedford, L. 2006. Twenty year responses of white spruce to mechanical site preparation and early chemical release in the boreal region of northeastern British Columbia. *Canadian Journal of Forest Research* **36**(10): 2386–2399.

The effects of six mechanical site preparation treatments, two stock-type treatments, and early chemical release on survival and growth of planted white spruce (*Picea glauca* (Moench) Voss) were studied in the BWBSmw1 biogeoclimatic zone of northeastern British Columbia. After 20 years, spruce height and diameter were larger in all mounding treatments than in the control. Early results suggested better spruce performance on large than small mounds, but after 20 years, growth was equally good on small mounds as on mounds with 20 cm mineral capping. Spruce planted on hinge positions in the Bracke patch and blade scarification treatments did not survive or grow well. Early chemical release improved spruce growth equally as well as the mounding treatments. Twenty year spruce survival averaged 71% in the 14 and 20 cm mound treatments, 60% in the early chemical release treatment, and 35% in the Bracke patch and blade scarification treatments. A large stock type was also planted in untreated ground and, after 20 years, had similar survival and growth as the standard stock type. Differences in survival had a large effect on basal area at age 20 years. Trend analysis showed that treatments diverged into two distinct groups with regard to spruce size during the 20 year span of the study.

Les effets de six traitements de préparation mécanique de terrain, de deux traitements avec différents types de plants et de l'application précoce d'un herbicide chimique ont été étudiés sous l'angle de la survie et de la croissance de plants d'épinette blanche (*Picea glauca* (Moench) Voss) dans la zone biogéoclimatique BWBSmw1 du nord-est de la Colombie-Britannique. Vingt ans après l'application des traitements, la hauteur et le diamètre des épinettes étaient plus grands dans tous les traitements de mise en buttes que dans le traitement témoin. Les résultats préliminaires indiquaient que la performance de l'épinette était meilleure sur les grandes buttes que sur les petites, mais après 20 ans, la croissance s'est avérée aussi bonne sur les petites buttes que sur les buttes recouvertes de 20 cm de sol minéral. Les épinettes plantées à des positions charnières des parcelles scarifiées au Bracke et des parcelles scalpées n'ont pas eu de bons taux de survie ou de croissance. L'application précoce d'un herbicide chimique a eu pour effet d'augmenter la croissance de l'épinette autant que dans le cas des traitements de mise en buttes. Le taux moyen de survie de l'épinette après 20 ans était de 71% dans les traitements de mise en buttes de 14 et 20 cm, de 60 % dans le traitement d'application précoce d'herbicide chimique et inférieur ou égal à 35 % dans les traitements de scarifiage au Bracke et de scalpage. Des plants de grande tailles ont aussi été plantés sur un terrain non traité et avaient après 20 ans des taux de survie et de croissance semblables à ceux des plants standard. Une analyse de tendance a montré que les traitements se divisaient en deux groupes en ce qui concerne la taille des épinettes au cours de la période de 20 ans— la durée de l'étude.

Boyle, T.J.B., Balatinecz, J.J., and McCaw, P.M. 1987. Genetic control of some wood properties of black spruce. Pages 198–198 *in* E.K. Morgenstern and T.J.B. Boyle. *21st Annual CTIA Meeting*. 17–21 August 1987, Truro, Nova Scotia, Canada. CTIA and Natural Resources Canada, Canadian Forest Service – Petawawa National Forestry Institute, Chalk River, Ontario, Canada.

Core samples were taken from genetically controlled 15-year-old black spruce (*Picea mariana*; 7x7 diallel cross) and analyzed for specific gravity, diameter growth, and pilodyn penetration. Some trees had disks taken and analyzed for specific gravity, tracheid length and diameter, wood:bark ratio, diameter, growth rate, and moisture content. All trees sampled had their height recorded. Significant relationships were found between specific gravity and height/diameter, specific gravity and pilodyn penetration. *(Abstract prepared by compilers.)*

Bragg, D.C. 2006. Potential contributions of figured wood to the practice of sustainable forestry. *Journal of Sustainable Forestry* **23**(3): 67–81.

The birdseye grain of sugar maple (*Acer saccharum* Marsh.) can showcase the potential of figured wood in sustainable forestry. This poorly understood but valuable grain abnormality commands such a premium that its presence alone can influence timber management. Good forestry and logging practices can help assure that quality birdseye maple logs are not relegated to low-value uses. Birdseye specialty markets have also developed, creating opportunities for pieces of small or irregular dimensions. Even though few have the same promise as birdseye maple, figured grains are found in virtually every tree species, thus increasing the potential for other high-value niche markets. However, the relative rarity and slow formation of figured grains threaten their sustainability, until more research on their genetics, propagation, and silviculture becomes available.

Bragg, D.C., Mroz, G.D., Reed, D.D., Shetron, S.G., and Stokke, D.D. 1997. Relationship between "birdseye" sugar maple (*Acer saccharum*) occurrence and its environment. *Canadian Journal of Forest Research* **27**(8): 1182–1191.

We tested the premise that the "birdseye" grain abnormality in sugar maple (*Acer saccharum* Marsh.) develops from local environmental conditions, with special emphasis on the role of competition in birdseye formation. Previous experience with birdseye maple frequency and the inherent differences in stand structure between old-growth and managed northern hardwoods led to stratification by stand type. Old growth contained considerably more birdseye than managed stands, but the levels in both types exceeded previously published frequencies. Unlike earlier studies, we did not find greater local density (and, presumably, greater competition) surrounding birdseye maples (versus non-birdeyes [*sic*]) in either old-growth (31.5 and 30.9 m^2/ha, respectively) or managed northern hardwoods (25.0 and 23.7 m^2/ha, respectively). Except for diameter, no tree variable strongly correlated with birdseye occurrence. Two plot-level variables, stand density and percent hemlock stems, strongly correlated with stand-level birdseye frequency primarily because of differences related to stand type, not because they represented causal factors. A logistic regression model was developed to estimate the likelihood of birdseye occurrence in an individual tree. Model performance varied, with non-birdseyes being predicted more accurately than birdseye maples. No evidence in this study explicitly supported a competition–birdseye linkage, but the frequency of birdseye in old growth suggests that prolonged suppression may influence birdseye formation from the extended exposure to a highly competitive environment. Management apparently results in decreased birdseye occurrence, a trend that might be ameliorated through retention of higher residual basal area and structure similar to old-growth stands.

Nous avons testé l'hypothèse voulant que le développement de l'anomalie dans le grain du bois d'érable à sucre (*Acer saccharum* Marsh.), qu'on qualifie de moucheture, soit attribuable à des conditions environnementales locales en accordant une importance particulière au rôle de la compétition dans la formation de cette anomalie. Les connaissances déjà accumulées sur la fréquence de l'érable piqué et les différences fondamentales entre les vieux peuplements et les peuplements aménagés de feuillus nordiques nous ont conduits à faire une stratification par type de peuplements. Il y avait beaucoup plus d'érables piqués dans les vieux peuplements que dans les peuplements aménagés mais leur fréquence dans les deux types de peuplements était plus élevée que les fréquences rapportées précédemment. Contrairement aux études précédentes, nous n'avons pas observé localement une plus forte densité, ni présumément une plus forte compétition, autour des érables piqués qu'autour des autres érables, que ce soit dans les vieux peuplements (respectivement 31,5 et 30,9 m^2/ha) ou dans les peuplements aménagés (respectivement 25,0 et 23,7 m^2/ha) de feuillus nordiques. À l'exception du diamètre, aucune caractéristique des arbres n'était étroitement corrélée avec la présence de mouchetures. À l'échelle de la parcelle, deux variables (la densité du peuplement et le pourcentage de tiges de pruche) étaient fortement corrélées à la fréquence de l'érable piqué dans le peuplement. Cette correlation s'expliquait davantage par les différences reliées au type de peuplement que par une relation de cause à effet. Un modèle de régression logistique a été développé pour estimer la probabilité de retrouver des mouchetures dans un arbre. La performance du modèle était variable; il permettait d'identifier avec plus d'exactitude les érables qui n'avaient pas de mouchetures que les érables piqués. Aucun des résultats de cette étude supporte clairement l'hypothèse d'un lien entre la compétition et la présence d'érable piqué. Par contre, la fréquence de l'érable piqué dans les vieux peuplements suggère qu'une suppression prolongée pourrait influencer la formation de mouchetures suite à une longue exposition à un environnement hautement compétitif. L'aménagement semble réduire la fréquence de l'érable piqué mais cette tendance pourrait être modifiée en conservant une surface terrière résiduelle plus élevée et une structure semblable à celle des vieux peuplements.

Brand, D.G., *editor*. 1991. *Canada's Timber Resources. Proceedings of the National Conference on Canada's Timber Resources*. 3–5 June 1990, Victoria, British Columbia, Canada. Natural Resources Canada, Canadian Forest Service - Petawawa National Forestry Institute, Chalk River, Ontario, Canada.

This volume gives the current status of knowledge about, and future visions for, the wood resources in our forest. The purpose defined for the conference was to "review and improve our knowledge of Canada's forests, their area and wood volume, accruals and depletions, and the prospect for sustained yield and sustainable development in the future up to the year 2050."

Brazier, J.D. 1977. The effect of forest practices on quality of the harvested crop. *Forestry* **50**(1): 49–66.

This is a review of the effects of forest practices (spacing, pruning, fertilization, irrigation, forest operations) on wood quality. The objective of forestry practices is to increase the rate of growth, but the impact on end use should not be overlooked. The review includes the influence of forestry practices on knot size and frequency, on density and density variation within the ring and within the tree, on slope of grain, on compression wood, and on other characteristics, such as tracheid length, fibril angle, comparative lignin, cellulose, and hemicelluloses contents, and mechanical damage during forest operations. *(Abstract prepared by compilers.)*

Briggs, D., Ingaramo, L., and Turnblom, E. 2007. Number and diameter of breast-height region branches in a Douglas-fir spacing trial and linkage to log quality. *Forest Products Journal* **57**(9): 28–34.

A Douglas-fir (*Pseudotsuga menziesii*, Mirb. Franco) spacing trial, planted at 480, 540, 750, 840, 1100, and 1680 trees/ha was studied to investigate the relationship between planting spacing, number and diameter of branches in the breast-height region, and first 5 m log quality. The 540 and 840 tree/ha plantings were in a rectangular design with the distance between rows double that between trees within a row while the others were planted in a square design. At age 18, number and diameter of branches > 8 mm in diameter were measured in a 0.61 m region centered at breast height (BH, 1.3 m). There was no significant effect of planting density on number of BH region branches. The rectangular designs had significantly more branches than the square designs, but this difference was small. The mean diameter of BH region branches was significantly related to both planting density and type of design while the largest diameter of BH region branches and branch index of the BH region were related only to planting density. A subsample of trees was climbed to measure the diameter of the largest branch and branch index corresponding to the 5-m butt log. Highly significant relationships were found between the largest branch diameter and branch index of the butt log and the BH region counterpart measures of trees. Measuring the diameter of the largest branch in the BH region provided superior equations predicting the butt log and is a simple, fast measure to acquire in the field.

Briggs, D.G., Kantavichai, R., and Turnblom, E.C. 2008. Effect of precommercial thinning followed by a fertilization regime on branch diameter in coastal United States Douglas-fir plantations. *Canadian Journal of Forest Research* **38**(6): 1564–1575.

The effect of precommercial thinning in 6- to 13-year-old Douglas-fir (*Pseudostuga menziesii* (Mirb.) Franco var. *menziesii*) plantations with and without fertilization with 224 $kg{\bullet}ha^{-1}$ nitrogen (N) as urea on the mean diameter of the largest limb at breast height (DLLBH) was modeled. DLLBH is a simple, nondestructive field measurement related to log knot indices used to measure log quality in product recovery studies. Model [1] succeeded in predicting mean DLLBH (RMSE = 2.80 and $r_{adj}^2 = 0.84$) using only site, initial stocking, and treatment variables. Model [2], which used only mean tree variables, improved on model [1] and was simpler. However, model [3], which used a combination of both groups of variables, produced the best model. Model [4] successfully predicted mean DLLBH using variables that can be measured with light detection and ranging (LiDAR), a high-resolution remote sensing technology. As the age when the live crown receded above breast height is an important variable in some of the models, model [5] was developed to predict when crown recession above breast height occurs. This study found that mean DLLBH of Douglas-fir plantations can be estimated using variables obtained from stand-level growth models or remote sensing, providing a quality indicator that can be easily measured and verified in the field. *(Abstract prepared by compilers.)*

Nous avons modélisé l'effet de l'éclaircie précommerciale dans des plantations de douglas de Menzies (*Pseudotsuga menziesii* (Mirb.) Franco var. *menziesii*) âgées de 6 à 13 ans, fertilisées ou non à raison de 224 $kg{\bullet}ha^{-1}$ d'urée, sur le diamètre moyen de la plus grosse branche à hauteur de poitrine (DPGBHP). Le DPGBHP est une mesure de terrain simple et non destructive qui est reliée aux indices de nodosité des billes utilisés pour mesurer la qualité des billes dans les études de rendement en produits. Le modèle [1] était efficace pour prédire le DPGBHP moyen (erreur quadratique moyenne = 2,80, $r_{adj}^2 = 0,84$) en n'utilisant comme variable que la station, le coefficient de distribution initiale des tiges et le traitement. Le modèle [2], qui n'utilisait que des variables moyennes prises sur les arbres, a amélioré le pouvoir prédictif du modèle [1] tout en étant plus simple. Cependant, le modèle [3], qui utilisait une combinaison des deux groupes de variables, a donné les meilleurs résultats. Le modèle [4] a prédit avec succès le DPGBHP moyen à partir de variables pouvant être mesurées avec le LIDAR, un instrument de télédétection à haute résolution. Puisque l'âge auquel la cime vivante passe au-dessus de la hauteur de poitrine est une variable importante de certains modèles, le modèle [5] a été mis au point pour prédire à quel âge survient le passage de la cime vivante au-dessus de la hauteur de poitrine. Cette étude a montré que le DPGBHP moyen des plantations de douglas de Menzies peut être estimé à l'aide de variables provenant de modèles de croissance à l'échelle du peuplement ou de la télédétection, ce qui en fait un bon indicateur qui peut facilement être mesuré et vérifié sur le terrain. *(Résumé fourni par les compilateurs.)*

Briggs, D.G., and Smith, W.R. 1986. Effects of silvicultural practices on wood properties of conifers: a review. Pages 108–117 *in* C.D. Oliver, D.P. Hanley, and J.A. Johnson. *Douglas-fir: Stand Management for the Future: Proceedings of a Symposium*. 18–20 June 1985, Seattle, Washington. University of Washington Press, Seattle, Washington, USA.

The response of trees to fertilization, thinning, and a combined treatment was measured after 4 years. The trees were chosen to show radial increment response to assess the effect of this response on density and kraft pulp yield at selected heights in the trees. Density and pulp yield were adversely affected by fertilization, but not by thinning. The increased growth increment obtained by treatment far outweighed minor losses in density or pulp yield percentage. Thinning and fertilization together exerted a partially additive effect on growth increment and weight. Thinning effects took longer to register after treatment, but might be effective for a longer time in sustaining increased growth. The weight of pulp that could be realized as a result of treatment was approximately double that of controls, but unbiased sampling of trees would be expected to reduce this value. *(Abstract prepared by compilers.)*

Briggs, D.G., Turnblom, E.C., and Bare, B.B. 2005. Non-destructive methods and process capability analysis to assess conformance of Douglas fir stands to customer quality specifications. *New Zealand Journal of Forestry Science* **35**(2-3): 170–188.

Largest branch diameter in the breast-height region (LLBH) and acoustic velocity on lower bole were measured on trees in a 20-year-old Douglas fir (*Pseudotsuga menziesii* (Mirb.) Franco) experiment comparing seven density management/fertiliser regimes. The less dense regimes tended to have larger mean branch diameter at breast height, with fertiliser increasing the mean even further. However, except for the densest regimes, the difference between a density regime and its counterpart with fertiliser was not statistically significant. The densest regime had significantly higher mean acoustic velocity than the other regimes, which were all the same except for one with very low velocity attributed to abnormal wood formed after damage by black bears. Although statistical significance may be lacking with respect to mean properties, subtle differences in their distributions may be important to timber sellers where purchasers often pay premiums for stands with higher percentages of trees that meet their process and customer needs. A statistical quality control procedure, process capability analysis, was used to assess the conformance of each regime to specifications for largest branch diameter at breast height and acoustic velocity. Conformance of largest branch diameter to a 35-mm maximum ranged from 84% to 100%, with fertilizer reducing conformance by 10–15%. Conformance of acoustic velocity to a 3.5 km/sec minimum ranged from 15% to 85%, with negligible difference between a thinned regime and its counterpart with fertilizer. Joint conformance ranged from 10% to 85%, with generally lower conformance associated with fertilizer. There is potential for using statistical quality control techniques to assist with timber marketing, harvest planning, and monitoring stand development.

Brockley, R. P. 2005. Effects of post-thinning density and repeated fertilization on the growth and development of young lodgepole pine. *Canadian Journal of Forest Research* **35**(8): 1952–1964.

The effects of factorial combinations of post-thinning density and fertilization on the growth and development of young lodgepole pine (*Pinus contorta* Dougl. ex Loud. var. *latifolia* Engelm.) were investigated in central British Columbia. The effects of density and fertilization (repeated every 5 years) on tree height were small relative to the effects on stem radial growth. Tree radial growth increased with thinning intensity, whereas per hectare growth was greatest at the highest residual density. Fertilizer effects varied across the range of residual densities tested. Tree and stand volume gains following fertilization were less, in both relative and absolute terms, at 600 trees/ha than at 1100 or 1600 trees/ha. Vigorous response of understory vegetation to nutrient additions (and strong competition for water and nutrients) may have reduced the effectiveness of fertilization on tree growth at 600 trees/ha relative to higher stand densities. Results indicate that the combined positive effects of thinning and fertilization on the growth of young lodgepole pine will accelerate stand development, thereby shortening technical rotation length. Results also indicate that significant growth gains following fertilization of thinned lodgepole pine will partially compensate for stand volume losses due to thinning. However, fertilization may be less effective at low stand densities, where negative effects of thinning on harvest volume are greatest.

Les effets combinés de la densité et de la fertilisation après éclaircie sur la croissance et le développement de jeunes pins tordus (*Pinus contorta* Dougl. ex Loud. var. *latifolia* Engelm.) ont été étudiés dans le centre de la Colombie-Britannique. Les effets de la densité et de la fertilisation (répétées tous les 5 ans) sur la hauteur des arbres étaient faibles comparativement aux effets sur la croissance radiale de la tige. La croissance radiale des arbres augmentait avec l'intensité de l'éclaircie, alors que la croissance à l'hectare était maximale lorsque la densité résiduelle était la plus forte. Les effets de la fertilisation ont varié en fonction des densités résiduelles testées. Les gains en volume des arbres et du peuplement après la fertilisation, tant en valeur relative qu'absolue, étaient moindres à une densité de 600 arbres/ha qu'à 1100 ou 1600 arbres/ha. Une réaction vigoureuse de la végétation de sous-bois à l'ajout de nutriments ainsi qu'une forte compétition pour l'eau et les nutriments peuvent avoir diminué l'efficacité de la fertilisation pour la croissance des arbres à une densité de 600 arbres/ha comparativement à des densités plus fortes. Les résultats indiquent que les effets combinés positifs de l'éclaircie et de la fertilisation sur la croissance des jeunes pins tordus accélèreront le développement du peuplement et raccourciront ainsi la durée de la rotation technique. Les résultats indiquent aussi que pour les pins tordus éclaircis, les gains significatifs de croissance causés par la fertilisation compenseront en partie les pertes en volume du peuplement attribuables à l'éclaircie. Cependant, la fertilisation peut être moins efficace dans le cas des peuplements à faible densité, là où les effets négatifs de l'éclaircie sur le volume à récolter sont les plus importants.

Burns, J., Puettmann, K.J., and Perala, D. 1996. Strip thinning and spacing increases tree growth of young black spruce. *Northern Journal of Applied Forestry* **13**(2): 68–72.

Two different thinning methods were applied to three 6- or 7-yr-old black spruce (*Picea mariana*) stands in northern Minnesota that were measured after 20 years. Overall, thinning improved the growing conditions for crop trees. Strip thinning with a 0.6-m leave strip and three widths of cleared strips (1.5, 2.1, and 2.7 m) and spacing to 1.5, 2.1, and 2.7 m resulted in reduced numbers of crop trees, but with larger diameters and, in the spaced thinned plots, greater heights. Because of these contradictory trends, stand volume was unaffected by thinning. Crop tree growth was not affected by the width of the cleared strip, but the distances between the leave trees in the square spacing were positively related to the increased growth response after thinning. The study is still too young to evaluate the economic feasibility of both thinning treatments, but shorter rotations or substantially increased volume seem possible by conducting early thinning of black spruce. *(Abstract prepared by compilers.)*

Burns, R.M., and Honkala, B.H. 1990. *Silvics of North America: Volume 1 Conifers*. Agricultural Handbook 654. United States Department of Agriculture, Forest Service. Washington, D.C., USA.

The silvicultural characteristics of about 200 forest trees species and varieties are described. There is information on habitat, climate, soils and topography, associated forest cover, life history, reproduction and early growth, seed production and dissemination, seedling development, vegetative reproduction, growth and yield, rooting habit, reaction to competition, damaging agents, special uses, and genetics. It covers most of the commercial species for North America and a few exotics as well. *(Source: U.S. Department of Agriculture, Forest Service)*

Campbell, J. S., Lieffers, V.J., and Pielou, E.C. 1985. Regression equations for estimating single tree biomass of trembling aspen: assessing their applicability to more than one population. *Forest Ecology and Management* **11**(4): 283–295.

Estimation equations to predict single tree biomass are costly to develop. Two options exist for obtaining an equation without the expense of developing one. A generalized biomass equation for a species and a region can be used. Alternatively, such tree characteristics as bole geometry and wood density of the trees to be measured can be matched with those characteristics of trees for which a regression equation is available. We consider this latter technique will give more accurate biomass predictions, particularly in stands that differ from the regional average. The applicability of biomass equations to other populations could be more easily assessed if five relevant and easily collected pieces of information were presented. These are: (1) mean DBH; (2) mean height; (3) mean DBH/height ratio; (4) mean absolute form quotient; and (5) mean wood density. These recommendations are illustrated with new biomass estimation equations of two forms for *Populus tremuloides* for each of four geographic regions in western Canada. Differences between equations for the four regions occurred. Two descriptors of tree shape, absolute form quotient and the DBH/height ratio, also differed among regions. The DBH/height ratio and height were both correlated with the accuracy of ready-made biomass estimation equations.

Cannell, M.G.R., Sheppard, L.J., Ford, E.D., and Wilson, R.H.F. 1983. Clonal differences in dry matter distribution, wood specific gravity and foliage "efficiency" in *Picea sitchensis* and *Pinus contorta*. *Silvae Genetica* 32(5–6): 195–202.

Seven clones of both *Picea sitchensis* and *Pinus contorta* growing at a lowland site in Scotland were felled at age 8, and measurements were taken, at each annual height level, of stem, branch and needle dry weights, foliage areas, and the specific gravities and volumes of each annual ring of stemwood. On average, *P. sitchensis* clones had similar stem dry weights to *P. contorta* clones, but only 56% as much branch wood and 61% as much needle dry weight. The branch wood on *P. sitchensis* was "spread" over a long total branch length and the needles were "spread" over a large projected needles area. At ages 6–8 *P. sitchensis* produced 44% more stemwood per unit needle area than *P. contorta*. Within both species, sparsely branched clones were the most efficient stemwood producers, allocating a high proportion of their dry matter to stems, and, at ages 6–8, producing 1.5 to 2.0 times as much stemwood per unit of needles as heavily branched clones. These sparsely branched clones varied in height and total weight, indicating that large genetic gains in stemwood production per tree could be made by selecting simultaneously for rapid growth and a high harvest index. Tallness, sparse branching and, in *P. contorta,* the absence of large basal branches were the most important characters associated with large, efficient stemwood production. Stemwood specific gravities differed by 20–30% between clones and between the innermost and outermost annual ring cylinders. For all clones the specific gravity of the annual cylinders of stemwood decreased linearly with $\log_e$ cylinder volumes, and both the initial specific gravities (the intercepts) and their rates of decrease (the slopes) differed between clones (especially in *P. sitchensis*). That is, the value of juvenile stemwood specific gravities, and clonal rankings, were dependent upon volume growth rates.

Cantin, M. 1965. *The Machining Properties of 16 Eastern Canadian Woods*. Natural Resources Canada, Canadian Forest Service - HQ. Publication No. 111. Ottawa, Ontario, Canada.

The results of five machining tests conducted on sixteen Canadian wood species are presented together with the procedure followed for each test. The operations studied were as follows: turning, planing, boring, mortising and shaping. Some of the variables affecting quality such as specific gravity and rings per inch were also investigated. Species studied comprised ten hardwoods and six softwoods, namely: white ash, largetooth aspen, trembling aspen, basswood, beech, white birch, yellow birch, hard maple, red maple and red oak; balsam fir, black spruce, white spruce, jack pine, red pine, and white pine. A tabular presentation of the results, based on a visual examination of the samples, is included for ready-reference purposes.

Les constatations faites lors de cinq épreuves portant sur l'usinage de seize essences canadiennes sont décrites dans le présent ouvrage, ainsi d'ailleurs que la méthode suivie dans chaque épreuve. Les épreuves ont porté sur les travaux d'usinage suivants: tournage, rabotage, forage, mortaisage et façonnage. Certains des facteurs variables qui interviennent dans le classement des pièces selon leur qualité, la densité et le nombre de cercles annuels au pouce par exemple, ont aussi été étudiés. Les bois mis à l'épreuve comprenaient dix essences feuillues et six résineuses, à savoir: frêne d'Amérique, peuplier à grandes dents, peuplier faux-tremble, tilleul d'Amérique, hêtre à grandes feuilles, bouleau à papier, bouleau jaune, érable à sucre, érable rouge et chêne rouge; sapin baumier, épinette noire, épinette blanche, pin gris, pin rouge et pin blanc. Afin de faciliter le travail de référence, les constatations sont présentées en tableaux; elles sont fondées sur l'examen à vue des échantillons mis à l'épreuve.

Cayford, J.H. 1964. *Results of a 1921 Jack Pine Thinning in Western Manitoba.* Natural Resources Canada, Canadian Forest Service - HQ. Publication No. 1077. Ottawa, Ontario, Canada.

In 1921, a thinning study was begun in a jack pine (*Pinus banksiana* Lamb.) stand of fire origin on the Riding Mountain Forest Reserve, now the Riding Mountain National Park, in western Manitoba. The purpose was "to study the effect of density on the mortality and rate of growth on naturally reproduced jack pine." Following measurement in 1926, the plots were re-established in 1961 providing a 40-year re-measurement period. It appears as if the heavy thinning will result in an increase in the production of saw timber and poles and a decrease in the production of cordwood. Thus its success or failure must be judged in the light of economic considerations, of which utilization practices for a given area are of utmost importance.

Cayford, J.H. 1961. *Results of a 1927 Jack Pine Thinning in Saskatchewan*. Natural Resources Canada, Canadian Forest Service - HQ. Publication No. 1077. Ottawa, Ontario, Canada.

An 18-year-old jack pine stand in the boreal forest region in central Saskatchewan was thinned experimentally in 1927. The stand was located on a weakly podzolized fine to medium siliceous sand which varied from dry to moderately fresh. Four plots were established where the stand averaged 4,100 trees per acre and three where it averaged 2,300 trees. Five plots were thinned to various spacings and the other two were retained for control.

In 1959, within each part of the stand the control plots had a greater number of stems, basal area, and total cubic-foot volume than thinned plots. However, with only one exception, merchantable volumes in both cords and board feet were greater on thinned than control plots. Thinnings to an average spacing of 6.3 feet produced maximum cord and board foot volumes in the less dense portion of the stand. Thinning to 5.9 and 6.6 feet in the denser portion of the stand produced maximum cord and board-foot volumes, respectively. The experiment has demonstrated that a single non-commercial thinning in a dense young stand of jack pine can increase merchantable yield; board-foot increments on thinned plots were two to three times greater than on control plots.

Cayford, J.H., Chrosciewicz, Z., and Sims, H.P. 1967. *A Review of Silvicultural Research in Jack Pine.* Natural Resources Canada, Canadian Forestry Service, Forestry Branch Publication 1173. Ottawa, Ontario, Canada.

The Department of Forestry and Rural Development and its predecessors have been carrying out silvicultural research in jack pine for over forty years. The program had its start in the 1920s in the Provinces of Manitoba and Saskatchewan and at the Petawawa Forest Experiment Station in Ontario. In the late 1940s it was extended into central and northwestern Ontario. In addition, a small amount of research is underway in Quebec, New Brunswick and Newfoundland. This report is an attempt to present the results of all jack pine silvicultural and related research that has been conducted in Canada by the Department and reference to numerous reports, both published and unpublished, are included. The authors wish to emphasize that results of research undertaken by other agencies have not been included in the review; a summary of much of this information is available in P.O. Rudolf's report "*Silvical Characteristics of Jack Pine*" which was published in 1958 by the Lake States Forest Experiment Station, Forest Service, United States Department of Agriculture. Included in the present report is a compendium of research results and conclusions in Parts I and II, an index of all projects in Part III, and individual project summaries in Part IV. Where applicable, reference is made in Parts I and II to the individual project summaries presented in Part IV. Within Parts I and II, abstracts are presented and each of these is followed by a more complete review of results and conclusions. The abstracts are printed in italics. Where individual projects deal with other species in addition to jack pine, only results pertaining to jack pine are presented.

Chang, C.I. 1966. *Specific Gravity Variation in Plantation-Grown White Spruce (*Picea glauca *(Moench) Voss)*. M.Sc.F. Thesis, University of Toronto, Toronto, Ontario, Canada.

Plantation-grown white spruce (*Picea glauca*) was used to determine the relationship of wood specific gravity to stand density, soil moisture, growth rate, age and position (height) in the tree. Growth rate had the strongest relationship to specific gravity. Within the tree, specific gravity is high at the pith and decreases outward to increase again near the bark. On the vertical axis the relative gravity reaches a maximum at breast height and decreases toward the top although there is another high at the tree top. The paper includes a discussion on the tree-breeding potential of white spruce. *(Abstract prepared by compilers.)*

Chang, C.I., and Kennedy, R.W. 1967. Influence of specific gravity and growth rate on dry wood production in plantation-grown white spruce. *The Forestry Chronicle* **43**(2): 165–173.

Two hundred and thirty-two white spruce trees were sampled from 29 plots in 6 localities in southern Ontario. Specific gravities of discs cut at four-foot intervals were determined for each tree. The amount of dry wood substance contained in each tree was obtained by multiplying weighted, whole tree specific gravity by tree volume. Although specific gravity was negatively correlated with growth rate, this reduction in dry weight per unit volume was minor in relation to the increased volumes associated with rapid growth rates.

The equation using the regression of the logarithm of dry wood production on tree age was determined. Trees having dry wood production of more than 1.5 times the standard error of estimate indicated by the regression lines were selected as superior trees. The characteristics of these superior trees together with the environments in which they grew were examined. The absence of any relationship with environmental factors suggested a genetic cause of above-average wood production. Superiority of a tree was mainly due to fast radial growth rate. The prospect of designing a tree breeding program to improve rate of dry wood production is discussed.

Chantre, G., Rozenberg, P., Baonza, V., Macchioni, N., Le Turcq, A., Rueff, M., Petit-Conil, M., and Heois, B. 2002. Genetic selection within Douglas fir (*Pseudotsuga menziesii*) in Europe for papermaking uses. *Annals of Forest Science* 59(5–6): 583–593.

The study aims to identify the feasibility and the relevance of a genetic selection for enhancing the pulping potential of the Douglas fir wood. At first, wood predictors for TMP potential are identified through the refining of thirty trees 17-year-old, using a specific procedure on a 12" Andritz refiner. The variations of TMP physical properties are linked with those of anatomical parameters, but also with within ring density related traits. The brightness of the unbleached TMP is negatively correlated with the red chromatic component of wood. Lignin, holocellulose and extractives content on one hand, Kraft fibre morphology on the other hand are considered to evaluate roughly the wood potential for the Kraft process. Then 15 clones out of 200 are non destructively selected within a 24-year-old German test to evaluate the range of the genetic variation of the papermaking potential. Chemical analyses give evidence of large variations of the chemical composition ratio between clones (holocellulose/lignin ratio). The clone discrimination of the fibre length is weak, but significant differences of fibre coarseness are observed as a consequence of the large variability of the latewood density levels. The industrial selection gain for pulping is discussed on the basis of TMP pilot plant tests which show large differences of physical and optical TMP properties between average wood assortments of each clone. This leads to practical recommendations for breeders considering the expectations of both the pulping and the wood industry.

L'étude vise à connaître la faisabilité et la pertinence d'une sélection génétique pour améliorer le potentiel papetier du bois de Douglas. Dans un premier temps sont identifiés des indicateurs de qualité du bois pour la pâte TMP au travers du défibrage de

30 arbres âgés de 17 ans sur un pilote Andritz 12". Les variations de propriétés physiques des pâtes TMP sont liées à celles de paramètres anatomiques, mais aussi à des variations de densité intra-cerne. La blancheur des pâtes écrues est négativement corrélée à la composante chromatique rouge du bois. Les taux de lignine, holocellulose et taux d'extraits d'une part, les caractéristiques morphologiques des fibres d'autre part, sont mesurés pour évaluer sommairement le potentiel du bois dans le procédé Kraft. Dans un second temps, 15 clones sont sélectionnés parmi 200 de façon non destructive au sein d'un test clonal allemand âgé de 24 ans, afin d'évaluer l'ampleur de la variation génétique du potentiel papetier. Les analyses chimiques mettent en évidence de forts contrastes entre clones du point de vue de la composition chimique (rapport holocellulose/lignine). La différenciation des clones est faible pour la longueur des fibres, à la différence de la masse linéique des fibres, conséquence d'une forte variation de la densité du bois d'été entre clones. Dans une perspective industrielle, le gain potentiel lié à la sélection est discuté sur la base de tests menés dans un pilote TMP qui mettent à jour d'importants écarts de propriétés physiques et optiques des pâtes issues de lots moyens de bois par clone. Ceci conduit à des recommandations pratiques pour les sélectionneurs, tenant compte des attentes respectives de l'industrie des pâtes et de l'industrie du bois.

Cherry, M.L., Vikram, V., Briggs, D., Cress, D.W., and Howe, G.T. 2008. Genetic variation in direct and indirect measures of wood stiffness in coastal Douglas-fir. *Canadian Journal of Forest Research* **38**(9): 2476–2486.

We studied wood stiffness (estimated by modulus of elasticity, MOE), wood density, wood moisture content, and growth in a progeny test (50–130 families per trait; 1–3 sites) of coastal Douglas-fir (*Pseudotsuga menziesii* var. *menziesii* (Mirb.) Franco). We measured MOE directly using lumber bending tests (MOE_{bl}) and indirectly using tools (HM200 and ST300) that can be used to measure acoustic velocity in logs (Vel_{HM}) or standing trees (Vel_{ST}). Acoustic MOEs in logs and standing trees (MOE_{HM} and MOE_{ST}) were obtained from the velocities and green wood density. For backward selection, we estimated genetic gains in MOE_{bl} of 8.6%–12.3%. Relative efficiencies (REs), the relative gains in MOE_{bl} expected from indirect selection for correlated traits, were 78%–93% for the HM200 traits, 57%–58% for the ST300 traits, 38% for the basic wood density of basal discs (Den_{bd}), and 98% for the oven-dry density of logs estimated from the lumber (Den_{ol}). The HM200 is an efficient tool for improving MOE_{bl}, but gains will be lower using the ST300 on standing trees. Indirect selection on Den_{bd} should be used with caution because the RE was low and Den_{bd} was negatively correlated with growth (-0.49 to -0.73).

Les auteurs ont examiné la rigidité du bois (MOE), sa densité, sa teneur en humidité ainsi que la croissance des arbres dans un test de descendance (50–130 familles par propriété et 1–3 sites) de douglas de Menzies typique (*Pseudotsuga menziesii* var. *menziesii* (Mirb.) Franco). Le MOE a été mesuré de manière directe au moyen d'essais de flexion statique (MOE_{bl}) avec des pièces de bois et de manière indirecte au moyen d'appareils (HM200 et ST300) capables de mesurer la vitesse sonique dans des billes (Vel_{HM}) ou dans des arbres sur pied (Vel_{ST}). Les MOE acoustiques (MOE_{HM} et MOE_{ST}) ont été obtenus à partir de ces vitesses et de la densité du bois à l'état vert. Dans le cas de la sélection en retour, les auteurs ont estimé que le gain génétique pour le MOE_{bl} variait de 8,6–12,3 %. L'efficacité relative (ER), soit le gain relatif en MOE_{bl} espéré à la suite d'une sélection indirecte pour les propriétés corrélées, atteignait : 78–93 % pour les propriétés mesurées au moyen du HM200; 57–58 % pour les propriétés mesurées au moyen du ST300; 38 % pour la densité basale des disques de souche (Den_{bd}) et 98 % pour la densité anhydre des billes estimée à partir de pièces de bois (Den_{ol}). Le HM200 s'avère un outil efficace pour l'amélioration du MOE_{bl} alors que les gains reliés à l'utilisation du ST300 avec les arbres sur pied sont plus faibles. La sélection indirecte à partir de la Den_{bd} devrait être pratiquée avec prudence puisque l'ER était faible et que la Den_{bd} était négativement corrélée avec la croissance (–0,49 à –0,73).

Choi, J., Lorimer, C.G., Vanderwerker, J., Cole, W.G., and Martin, G.L. 2001. A crown model for simulating long-term stand and gap dynamics in northern hardwood forests. *Forest Ecology and Management* **152**(1–3): 235–258.

Evaluation of ecosystem management alternatives in forests will require new or revised models capable of simulating the development of multi-aged stands managed on long rotations and with unconventional stand structures. In this paper, we describe the development and testing of an individual tree, crown-based model (CANOPY) designed to simulate canopy gap dynamics and stand structural changes in mature and old-growth northern hardwood forests dominated by *Acer saccharum*. The model was calibrated with data from 63 plots in managed and unmanaged stands, with sample trees ranging in age from 17–311 years. For *A. saccharum*, R^2 values ranged from 0.76 to 0.81 for prediction of basal area increment, 0.45–0.50 for crown radial increment, and 0.63–0.79 for height increment. Equations using field-measured crown size and crown competition variables provided only slightly better predictions than conventional mensurational variables such as DBH and plot stocking level. Use of the model for long-term (250 year) projections of cumulative DBH and crown radius provided a good match to largely independent size–age trends in the data base, but total height appeared to be moderately overestimated for trees >100 years old. Both the field data and simulations suggest that basal area increment of individual trees does not decline with age in these species but actually increases up to the observed maximum of 300 years, which is consistent with nearly linear diameter-age trends often reported for shade-tolerant species. Lateral crown growth of trees with exposed crown margins, however, showed curvilinear decreasing trends with age. These findings suggest that the common assumption of constant radial closure of canopy gaps by border trees could potentially overestimate rates of gap closure and underestimate the probability of successful gap capture by saplings in multi-aged stands.

Chui, Y. H. and Zhang, S.Y. 1995. *Evaluation of Wood Quality in Jack Pine Family Tests*. University of New Brunswick, Fredericton, New Brunswick, Canada.

In 1977, the New Brunswick Tree Improvement Council initiated a study of jack pine (*Pinus banksiana* Lamb.) and collected specific gravity on data from young plus trees. A Pilodyn was used to estimate specific gravity. As others had found that, although useful, Pilodyn measurements can lead to overestimation of genetic correlations, a re-evaluation was undertaken. Pilodyn measurements were re-taken and compared with stress wave measurements and basic density from destructive sampling. Specific gravity of a second plantation was measured by taking increment cores and determining specific gravity of extracted cores using x-ray densitometry. It was concluded that stress wave measurements of young trees may not be reliable. Pilodyn correlation with surface density as measured by basic density decreases with older trees, but the Pilodyn is useful for density extremes. Density was found to be highly heritable, but the relationship between density and growth was site specific. Density was found to be positively correlated to growth. *(Abstract prepared by compilers.)*

Chui, Y. H., Zhang, S.Y., Price, J.C., and Chauret, G. 1997. Early response of balsam fir and black spruce to precommercial thinning. Pages15–21 *in* S. Y. Zhang, R. Gosslin, and G. Chauret, editors. *Timber Management Toward Wood Quality and End-Product Value*. CTIA/ IUFRO International Wood Quality Workshop, 18–22 August 1997, Quebec City, Quebec, Canada. Forintek, Ste-Foy, Quebec, Canada.

> Precommercial thinning is one technique that has been adopted in an effort to forestall predicted fiber shortages. This study evaluated yield as determined from volume and specific gravity (rather than total volume) and compared thinned and unthinned black spruce (*Picea mariana* (Mill.) B.S.P.) and balsam fir (*Abies balsamea* (L.) Mill.) stands. Forty trees from each species from each stand were sampled by taking disks at the stump. Diameter at breast height was also measured. Specific gravity was measured by x-ray densitometry on extracted samples. Growth rate, as determined by ring width, was found to increase after thinning. Latewood percentage was found to decrease with age in black spruce, but was constant for balsam fir. Despite decreases in ring density following thinning, dry fiber weight increased. *(Abstract prepared by compilers.)*

Clark, J., and Gibbs, R.D. 1957. Studies in tree physiology. IV. Further investigations of seasonal change in moisture content of certain Canadian forest trees. *Canadian Journal of Botany* **35**(2): 219–253.

> Complete seasonal patterns of moisture content of the wood and bark of *Betula lutea* (which resembles other species of birch) and of *Tsuga canadensis* are given, along with those of sapwood and heartwood of *Abies balsamea* and *Picea rubens*. Incomplete seasonal data are also presented on the moisture content of the wood of *Picea glauca* and *Thuja occidentalis*.
>
> Minor variations in the water content pattern of yellow birch due to precipitation, evapotranspiration, and winter insolation are described. These variations, examined in the light of climatic data, lend little support to the view that birch die back is due to an increase in temperature or drought, except possibly through their effects on some unknown biotic factor. The practical aspects of tree water content studies are discussed with particular reference to the question of flotation and sinkage of logs.

Clermont, L.P., and Schwartz, H. 1951. The chemical composition of Canadian woods. *Pulp and Paper Magazine of Canada* **52**(13): 103–105.

> Balsam fir, white spruce, black spruce, jack pine, eastern hemlock, white pine, white birch, and aspen were studied. The following characteristics were measured for each species: solubility in cold water, hot water, ethyl ether, and 1% sodium hydroxide solution. Also measured were acetyl, methoxyl, pentosans, ash, lignin, holocellulose, alphacellulose, hemicellulose, and uronic anhydride. The hardwoods contained higher pentosan, hemicellulose, and acetyl contents, but lower lignin contents. *(Abstract prepared by compilers.)*

Coates, K.D., Canham, C.D., Beaudet, M., Sachs, D.L., and Messier, C. 2003. Use of a spatially explicit individual-tree model (SORTIE/BC) to explore the implications of patchiness in structurally complex forests. *Forest Ecology and Management* **186**(1–3): 297–310.

> The discipline of silviculture is evolving rapidly, moving from an agricultural model that emphasized simple stand structures toward a natural disturbance- or ecosystem-based model where stands are managed for multiple species and complex structures. Predicting stand dynamics and future yields in mixed-species complex structured stands cannot be easily accomplished with traditional field experiments. We outline the development and structure of SORTIE/BC, a descendent of the SORTIE model. SORTIE/BC is a light-mediated, spatially explicit, mixed-species forest model that makes population dynamic forecasts for juvenile and adult trees. We use the model to simulate partial cutting prescriptions in temperate deciduous, boreal and temperate coniferous mixed-species forests. The species, amount and spatial pattern of canopy tree removal had a major influence on understory light environments. Low and uniform removal of canopy trees were less successful in favouring the growth and survival of regenerating trees of intermediate to shade intolerant species and the growth of retained canopy trees than patch removal. In the boreal mixedwood, strip-cutting can maintain mixed stands but careful attention must be paid to buffer and strip management to optimize stand growth. We conclude that SORTIE/BC can be very useful to explore and explain the silvicultural implications of complex silvicultural prescriptions for which there are no existing long-term experiments.

Cochran, P. H., and Dahms, W.G. 2000. *Growth of Lodgepole Pine Thinned to Various Densities on Two Sites with Differing Productivities in Central Oregon.* USDA Forest Service, Research Paper PNW-RP-520. Portland, Oregon, USA.

> Plots in two natural lodgepole pine (*Pinus contorta* Dougl. ex Loud.) stands with differing productivities were repeatedly thinned to one of five growing-stock levels (GSLs). Bole area was used to define GSLs. A linear relation between stand density index (SDI) and bole area was found after each thinning on the highly productive site, but the slope of this relation decreased with successive thinnings as trees grew larger. On the site with intermediate productivity, the upper limit for bole area was higher and a curvilinear SDI-bole area relation occurred. A constant bole area level probably does not represent the same competition level across a range of tree sizes. Low incidence of mortality caused by mountain pine beetle (*Dendroctonus ponderosae* Hopkins) occurred at SDIs below 170 for both sites. Concave curvilinear decreases in diameter growth occurred with increasing GSLs. Significant decreases in height growth with increasing GSLs were not detected. A convex curvilinear increase in gross basal-area growth and cubic-volume growth took place with increasing GSLs. Gross total cubic-volume PAIs increased with increasing SDIs for both sites until stand densities reached 95 percent of the normal stand SDI. These cubic-volume PAI-SDI curves then flattened with increasing SDIs. Maximum cumulative net cubic-volume (total and merchantable) and board-foot yields were produced at the intermediate growing-stock level at the high site. Little apparent differences in these yields occurred among the four highest GSLs at the intermediate site. Net total cubic-volume yield was higher for the three highest GSLs than net yields for unmanaged stands from yield tables at comparable sites and ages. These studies have not continued long enough to determine the approximate age of culmination of net mean annual cubic- or board-foot volume increments. Ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.) outgrew lodgepole pine for the range of stand ages on the highly productive site where the growth of both species was examined (33 to 58 years). Ponderosa pine should not be planted on lodgepole pine sites on flats and basins, however, because ponderosa pine is subject to radiation frost damage. Early spacing control coupled with later commercial thinnings to keep stand densities between SDI 114 and SDI 170 should reduce mortality considerably, allow most of the wood produced to be captured by merchantable trees, and greatly increase quadratic mean diameters and live crown ratios over unmanaged stands at the same age. These stands would be more pleasing visually, and their rotation ages may be longer. *(Source: U.S. Department of Agriculture, Forest Service.)*

Cole, W.G., and Lorimer, C.G. 1994. Predicting tree growth from crown variables in managed northern hardwood stands. *Forest Ecology and Management* **67**(1–3): 159–175.

The predictability of individual-tree growth rates for *Acer saccharum*, *Fraxinus americana*, and *Tilia americana* in northern hardwood stands in Wisconsin was studied in relation to crown dimension and crown competition variables measured in the field. Data were collected from 221 destructively sampled trees in eight second-growth stands on above-average sites. The single best independent variable for predicting basal area growth was the projection area of the exposed portion of the crown, which had higher correlations with observed growth than initial stem diameter, diameter-based competition indices, and other crown variables. Basal area growth equations containing total crown projection area, percent exposed crown area, and relative height had R^2 values ranging from 0.77 to 0.88, which represent increases of 13 to 47 percentage points compared with similar equations with only diameter-based competition variables. The most accurate height growth models were functions of total tree height and percent exposed crown area, with R^2 values of 0.74 for the non-linear maple equation and 0.44 for the linear white ash equation.

The results appears to support the hypothesis that significant competitive stress on individual trees is induced only by the ring of competitor trees immediately surrounding the subject tree crown. By using percent exposed crown area as a crown competition variable, this competitive effect can be estimated without direct measurement of any of the competitors, potentially saving much field measurement time during the model calibration phase and eliminating the statistical lack of independence generally associated with plot competition measures.

Corriveau, A., Beaulieu, J., and Daoust, G. 1991. Heritability and genetic correlations of wood characters of upper Ottawa Valley white spruce populations. *The Forestry Chronicle* **67**(6): 698–705.

The degree of inheritance and the genetic correlations of white spruce wood characters were studied from 39 half-sib families of eight populations from the Upper Ottawa Valley, 19 years after planting. The results indicated that these characters differ significantly among half-sib families. Furthermore, the study showed that white spruce wood characters are genetically related. Strong genetic correlations exist between the characters of inner wood and those of outer wood. Moderate to strong genetic control of outer wood characters was found while inner wood characters were found to be much more influenced by environmental factors. Expected genetic gains from a sequential two-step selection strategy were calculated.

Le degré de transmissibilité et de corrélation génétique des caractéristiques du bois de l'épinette blanche a été étudié, 19 ans après plantation. Trente-neuf demi-fratries issues de huit populations ont été échantillonnées dans la vallée de la rivière Outaouais. Les résultats obtenus indiquent que les caractéristiques de bois des demi-fratries diffèrent significativement. De plus, les caractéristiques du bois de l'épinette blanche sont génétiquement liées. Une liaison génétique forte existe entre les caractéristiques du bois près de la moelle d'une part et celles du bois près de l'écorce d'autre part. Il a été démontré que les caractéristiques du bois près de l'écorce sont sous fort contrôle génétique alors que celles du bois près de la moëlle sont davantage influencées par les conditions environnementales. Les gains génétiques espérés d'une sélection en deux étapes ont été calculés.

Corriveau, A., Beaulieu, J., and Mothe, F. 1987. Wood density of natural white spruce populations in Quebec. *Canadian Journal of Forest Research* **17**(7): 675–682.

During genetic sampling of white spruce in 1984, increment cores were taken from 80 populations in order to study wood density variation within species in natural Quebec forests. Results show that wood density differences exist between populations and that wood density is negatively correlated with the width of the growth rings; however, some trees and some populations exhibit both high wood density and rapid growth. A moderate positive link was found between juvenile and mature wood densities at both the individual and population levels. Therefore, breeding programs for the improvement of wood density could be based on selections made on juvenile wood.

Lors de l'échantillonnage génétique des populations d'épinette blanche effectué en 1984, des éprouvettes ont été prélevées dans quelque 80 populations afin d'étudier la variabilité de la densité du bois de cette espèce en forêt naturelle au Québec. Les résultats obtenus démontrent qu'il existe des différences de densité du bois entre les populations et que quoique la densité du bois et la largeur des cernes soient corrélées négativement, il existe des individus et des populations qui présentent une densité du bois élevée et une croissance rapide. On a trouvé une liaison positive modérée entre la densité du bois juvénile et celle du bois mature aussi bien au niveau individuel qu'au niveau de la population. Donc une sélection massale effectuée en vue de l'amélioration génétique de la densité du bois ou de la production en masse ligneuse de l'épinette blanche pourrait être effectuée à bas âge.

Corriveau, A., J. Beaulieu, F. Mothe, J. Poliquin and J. Doucet. 1990. Densité et largeur des cernes des populations d'épinettes blanches de la région forestière des Grands Lacs et du Saint-Laurent. *Canadian Journal of Forest Research* **20**(2): 121–129.

Twenty years after planting, X-ray densitometry and immersion were used to determine the relative density of wood from 28 white spruce populations of the Great Lakes – St. Lawrence forest region. The results showed the same pattern of radial variation in all populations. Wood density decreases for the first few years of growth, then stabilizes for a time, then increases slowly, but steadily. The relative density of wood from white spruce has a slight, negative correlation with the width of the annual growth rings, at either the individual or the population level. However, some populations and individuals do deviate from this trend. Though the populations showed some statistically significant differences in relative density, analysis of variance showed that 85 to 90% was attributable to differences among trees within the same population. This study confirmed the desirability of using relative density as the basis for making mass selections within fast-growing white spruce populations to genetically improve the genetic quality of wood.

Les caractéristiques densimétriques du bois de 28 populations d'épinettes blanches de la région forestière des Grands Lacs et du Saint-Laurent obtenues par photoradiographie et par immersion ont été étudiées, 20 ans après plantation. Les résultats indiquent que ces caractéristiques suivent le même patron de variation radiale, quelle que soit la population. Aux premières années, caractérisées par une dégradation de la densité, succède une phase de stabilisation suivie elle-même d'une lente, mais constante, remontée de la densité. Que ce soit au niveau individuel ou au niveau de la population, les caractéristiques densimétriques du bois de l'épinette blanche sont liées faiblement, mais négativement, à la largeur des cernes de croissance annuelle. Certaines populations et certains arbres s'écartent toutefois de la tendance générale. Bien qu'il existe des différences statistiquement significatives entre les populations quant à ces caractéristiques, une partition de leur variabilité totale révèle que 85 à 90% en est attribuable aux différences entre les arbres d'une même population. Finalement, cette étude confirme la pertinence d'une sélection massale axée sur la densité relative du bois effectuée dans les populations à croissance rapide en vue de l'amélioration génétique de la production d'un bois de qualité chez l'épinette blanche.

Cown, D.J. 2005. Understanding and managing wood quality for improving product value in New Zealand. *New Zealand Journal of Forestry Science* **35**(2–3): 205–220.

Pinus radiata D. Don comprises about 90% of New Zealand's plantation forests. Management practices evolved rapidly during the twentieth century, and are regarded as advanced in terms of the application of sound scientific and economic principles. However, since the 1970s, forest managers in New Zealand have become more aware of the impacts of genetic selection for growth and stem form, and the adoption of more aggressive silvicultural techniques, on the nature of the resource. These trends have resulted in a significant reduction in rotation lengths from more than 40 years to around 25 years. Growing space, tree age, and geographic location create very pronounced patterns of wood property development and, while growth rates can be impressive, some of the resulting wood characteristics are somewhat limiting for demanding end uses.

Scientific studies over the past 20 years or so have defined the important wood characteristics (knot size and distribution, resin pockets, intra-ring checking, density, spiral grain, microfibril angle) that affect product appearance, stiffness, and stability. Two distinct approaches have been adopted to improve the plantation resource:

(1) Identifying and managing variability in the forest
(2) Breeding to manipulate specific characteristics

Value recovery from harvesting is in rapid change from a system based on volume to one based on quality. There is now a strong emphasis on tools for log and lumber segregation, and reliable methods are available for assessing stiffness at all stages from forest to lumber. For the immediate future, traditional forest inventory methods are being enhanced by the inclusion of wood property information such as wood density and predicted stiffness. Acoustic tools in particular have become common for standing tree and log stiffness assessment and a similar approach is being used for lumber and veneer grading; spectroscopic tools are also under development. Tree breeders are actively selecting material to improve future generations, and fortunately the heritability of wood properties is generally high. However, many of these features are costly to evaluate on a routine basis and the search is on for more sophisticated tools to assess performance capability directly. The next challenge is to develop similar cost-effective techniques for predicting product stability. Faster progress will be made when wood processors reward growers for quality wood.

Cown, D.J., and Parker, M.L. 1978. Comparison of annual ring density profiles in hardwoods and softwoods by X-ray densitometry. *Canadian Journal of Forest Research* **8**(4): 442–449.

X-ray densitometry was used to study annual-ring density of 15 softwood and 21 hardwood tree species growing on the University of British Columbia campus. Intraring density profiles and some pith to bark density trends are presented. Radiographs of transverse wood sections gave the best results in most cases, but radial sections of some ring-porous hardwoods provided superior data. A fixed-density earlywood-latewood boundary criterion is satisfactory for the softwoods studied but less appropriate for most hardwoods. The softwoods vary more than hardwoods in intraring density contrast.

La densimetrique aux rayons X fut employée pour l'étude des cernes annuels sur 36 résineux et feuillus croissants sur le campus de l'Université de la Colombie-Britannique. Cet article présent des profils de densité et certaines tendances de densité entre la moelle et l'écorce. Des radiographies de sections transversales du bois donnèrent les meilleurs résultats dans la plupart des cas, mais les sections radiales de certains feuillus à cernes poreux ont fourni de meilleures données. Un critère de densité stable à la limite du bois d'été est satisfaisant pour les résineux étudiés, mais moins adéquat pour les feuillus. Le contraste de densité intra-cernes est plus variable chez les résineux que chez les feuillus.

Curry, W.T., and Endersby, H.J. 1965. *The Effect of Pruning on the Value of Home-Grown Softwoods*. Ministry of Technology, London, UK.

The practical aspects of pruning conifers have been under investigation for many years. Although the importance of pruning in improving the quality of timber has been amply demonstrated, more precise information was needed on the increase in the value of pruned trees to find out whether the improvement in quality is likely to command a sufficient return to cover the cost of pruning.

This report describes an investigation carried out in co-operation with the Forestry Commission to compare the quantity and quality of the sawn timber obtrained from matched pairs of pruned and unpruned trees. The results are analysed to estimate the difference in the value of pruned and unpruned logs and to determine whether this difference is sufficient to justify pruning.

Cutter, B.E., Coggeshall, M.V., Phelps, J.E., and Stokke, D.D. 2004. Impacts of forest management activities on selected hardwood wood quality attributes: a review. *Wood and Fiber Science* **36**(1): 84–97.

Hardwoods are increasingly being viewed as an important raw material component of the forest products industry and this has spurred awareness of the impact of forest management on tree and wood quality. The impacts of various forest management activities in tree and wood quality in hardwoods are presented from the standpoint of the activities themselves rather than that of the wood properties. These silvicultural activities include genetic manipulation, intensive culture, fertilization, and/or irrigation, pruning, thinning, weed control and prescribed fire. A broad literature cited section is included as an aid to future scientists.

Cyr, G., and Thiffault, N. 2009. Long-term black spruce plantation growth and structure after release and juvenile cleaning: a 24-year study. *The Forestry Chronicle* **85**(3): 417–426.

Vegetation management is crucial to meet growth and yield objectives in conifer plantations. But, the combined and long term effects of mechanical release and juvenile cleaning on growth and stand structure have yet to be documented in black spruce plantations. A long-term study was carried out in Quebec (Canada) to evaluate the interactions between initial mechanical release at age 2 years and juvenile cleaning at age 14 years (i.e., a second release treatment) on planted black spruce survival and dimensions at age 24 years. Population structure and stand species composition were also assessed. Results showed that release and juvenile cleaning had an additive, positive effect on survival, diameter at breast height (DBH), height, crown width, crown length, and the last 5-year DBH and height increments. Juvenile cleaning effects were of higher magnitude than release effects, especially on 5-year DBH increment. Combination of both treatments reduced DBH and height variability of saplings, whereas juvenile cleaning alone resulted in a higher proportion of saplings occupying higher height classes. Total merchantable basal area was constant among treatments. But, without juvenile cleaning, hardwoods occupied a higher proportion of the basal area and were taller than spruces. In a context of sustainable forest management, in which conifer plantations are expected to offer high wood yield, our results demonstrate the importance of juvenile cleaning following initial mechanical release to promote crop tree growth and yield.

La gestion de la végétation est essentielle à l'atteinte des objectifs de rendement associés aux plantations de conifères. Cependant, les effets combinés à long terme du dégagement mécanique et du nettoiement sur la croissance et la structure des plantations d'épinette noire ne sont pas documentés. Une étude a été entreprise au Québec (Canada) afin d'évaluer les effets à long terme d'un dégagement mécanique réalisé à l'an 2 et d'un nettoiement réalisé à l'an 14 sur la survie et les dimensions d'épinettes noires, 24 ans après leur mise en terre. La structure de la plantation et la composition en espèces du peuplement ont également été mesurées. Les résultats montrent que le dégagement et le nettoiement ont un effet additif et positif sur le diamètre à hauteur de poitrine (dhp), la hauteur, la largeur et la longueur de la cime, la survie et l'accroissement en hauteur et en dhp des 5 dernières années. Les effets du nettoiement sont de plus grande amplitude que ceux du dégagement, particulièrement sur l'accroissement en dhp des 5 dernières années. La combinaison des deux traitements réduit la variabilité du dhp et de la hauteur des épinettes, alors que le nettoiement seul résulte en une plus grande proportion des épinettes occupant les classes élevées de hauteur. La surface terrière marchande totale du peuplement est similaire entre les traitements. Toutefois, en l'absence de nettoiement, une plus grande proportion de la surface terrière totale est occupée par des feuillus, lesquels s'avèrent plus grands que les résineux. Dans un contexte d'aménagement forestier durable, où un rendement ligneux élevé est attendu des plantations de conifères, nos résultats illustrent l'importance du nettoiement en phase juvénile, suite à un dégagement mécanique initial, afin de favoriser la croissance et le rendement des arbres plantés.

Dakak, J.E., Keller, R., and Bucur, V. 1999. Rays in juvenile wood of *Acer*. *IAWA Journal* **20**(4): 405–417.

Juvenile wood characteristics of multiseriate and uniseriate rays of five species of the genus *Acer* were studied on young trees from France and Canada. Ray height, width, number in width of cells and proportion/mm^2 were determined for the earlywood. Variance analysis was used to discriminate the variability of the characteristics of rays. Simple regression analysis shows some strong correlations between the characteristics of multiseriate and uniseriate rays of each species. Except for *A. saccharinum*, no relationships were established between the ray characteristics and the specific gravity. Except for *A. pseudoplatanus*, no relationships were established between annual ring width and ray characteristics. Principal component analysis focused separately on multiseriate rays and on uniseriate rays revealed differences between *A. saccharum* and *A. saccharinum* (e.g., the proportion and the number of cells in multiseriate rays).

Dampier, J.E.E., Luckai, N., Bell, F.W., and Towill, W.D. 2007. Do tree-level monocultures develop following Canadian boreal silviculture? Tree-level diversity tested using a new method. *Biodiversity and Conservation* **16**(10): 2933–2948.

Concern about forestry practices creating tree-level monoculture plantations exists. Our study investigates tree diversity responses for six early seral boreal forest plantations in Ontario, Canada, representing three conifer species; black spruce (*Picea mariana*), white spruce (*P. glauca*), and jack pine (*Pinus banksiana*), 14 release treatments, and 94 experimental units. Dominance-diversity curves and Simpson's indices of diversity and evenness indicate tree alpha diversity. We propose a new method for assessing diversity, using percentage of theoretical species maximum (%TSM), which is determined by comparing post-disturbance richness (S) with a theoretical species maximum (TSM). Our results support the hypothesis that alternative vegetation release treatments generally do not reduce tree species diversity levels (%TSM) relative to untreated plots. The only %TSM ($P \leq 0.05$) comparison that produced less diversity than in control plots was repeated annual treatments of Vision herbicide at one of the black spruce study sites. Our results generally support the hypothesis that tree monocultures do not develop after vegetation release. Only one out of 94 experimental units developed into a tree layer monoculture (Simpson's reciprocal diversity index = 1). Again this was one of the repeated annual treatments of Vision herbicide at one of the black spruce study sites—a treatment that is atypical of Canadian forest management.

De Montmorency, W.H. 1965. The relationship of wood characteristics to mechanical pulping. *Pulp and Paper Magazine of Canada* **66**(6): 324–348.

Mechanical pulps were prepared from individual balsam fir, white spruce, and black spruce trees that varied in basic density. There was no significant relationship found between the basic density of a tree and the characteristics of the mechanical pulp it produced. Wood from the same trees was also chemically pulped in calcium-base sulfite and kraft pulping methods. Stronger relationships between the basic density of the tree and the characteristics of the resulting pulp existed in these processes. The purpose of the experiments was to compare pulps resulting from the different species. Balsam fir yielded weaker mechanical pulps then the two spruce species, however, it yielded stronger sulfite and kraft pulp. *(Abstract prepared by compilers.)*

Dean, T.J., and Long, J.N. 1986. Validity of constant-stress and elastic-instability principles of stem formation in *Pinus contorta* and *Trifolium pratense*. *Annals of Botany* **58**(6): 833–840.

Independent studies have shown that both the constant-stress and the elastic instability models describe the form of a plant's central stem. Teleologically, the constant stress model states that a stem tapers to equalize stress produced by wind pressure along the stem. The elastic instability model states that stems and branches taper to maintain similar elasticity throughout the tree and that total tree height is limited to about one-quarter of the height at which the stem would buckle under its own weight. We investigated the ability of these two models to describe the central stems of both mature and sapling *Pinus contorta* var. *latifolia* Engelm. We also tested whether these two models are active in petiole formation by systematically defoliating *Trifolium pratense* L. The constant stress model adequately described stem taper in both age classes of *P. contorta* and the petiole form in *T. pratense* regardless of defoliation treatment. The elastic instability model was valid only for the mature *P. contorta* and for the control and perhaps for the moderately defoliated *T. pratense*. The constant stress model appears to be valid for both *P. contorta* and *T. pratense* while the elastic instability model is valid only for larger plants.

Deckmyn, G., Evans, S.P., and Randle, T.J. 2006. Refined pipe theory for mechanistic modeling of wood development. *Tree Physiology* **26**(6): 703–717.

A mechanistic model was developed relating competition, management, and climate to wood tissue development. The model was based on pipe theory. It included transpiration, gravity, water viscosity, carbon required to build the pipes, pipe radius, height, and growth phase. Species-specific constants for radius and height, seasonally active parts, and ring structure (i.e., diffuse vs. ring porous) were used. The model was tested using a growth simulator for oak (*Quercus* sp.) and pine (*Pinus* sp.). This model was found to be sensitive to oak maximum transpiration. It was concluded that, as this modeling approach is simple and requires few parameters, it is useful to improve understanding of xylem development, but it does not yet permit evaluation against observed, rather than simulated, data. *(Abstract prepared by compilers.)*

Defo, M., Fortin, Y., and Cloutier, A. 1999. Moisture content–water potential relationship of sugar maple and white spruce from green to dry conditions. *Wood and Fiber Science* **31**(1): 62–70.

The moisture content–water potential relationship was determined at 40ºC and 60ºC for sugar maple (*Acer saccharum* Marsh.) sapwood and at 60ºC for white spruce (*Picea glauca* (Moench.) Voss.) heartwood from green to dry conditions. The pressure membrane technique was used for high moisture contents and equilibrium over salt solutions for low moisture contents. The results show that at high moisture contents, the equilibrium moisture contents obtained from the green condition are lower than those obtained from full saturation (boundary desorption). It is recommended that the sorption history must be taken into account when modelling wood drying. Water potential at given moisture content increases with temperature. There is a characteristic plateau in the green moisture content–water potential relationship obtained for sugar maple at water potentials between -2,000 and -6,000 J kg^{-1}, which can be attributed to its heterogeneous capillary structure. The maximum concentration of effective pore radius occurs at 0.02 µm in the case of sugar maple, corresponding to the size of the pit membrane openings.

Defo, M., Goodison, A., and Uy, N. 2009. A method to map within-tree distribution of fibre properties using SilviScan-3 data. *The Forestry Chronicle* **85**(3): 409–414.

This paper shows how SilviScan-3 data can be used to map the within-tree distributions of wood properties, and to compute relevant statistics useful for tree-to-tree comparisons. An algorithm named EvaluTreeMap was developed for this purpose, based on subdividing the stem into triangular elements. It was validated using a stem of conical shape with properties exhibiting conical symmetry. To illustrate some applications of the program, it was used for the preliminary evaluation of the impact of Armillaria root disease on the fibre coarseness of Douglas-fir trees.

Cet article illustre comment les données de SilviScan-3 peuvent être utilisées pour représenter la distribution des propriétés du bois à l'intérieur de l'arbre et pour recueillir les statistiques pertinentes permettant des comparaisons entre arbres. Un algorithme dénommé EvaluTreeMap a été développé à cette fin en subdivisant la tige en éléments triangulaires. Il a été validé au moyen d'une forme conique de la tige dont les propriétés reflétaient une symétrie conique. Dans le but d'illustrer certaines utilisations de ce programme, il a été utilisé pour une évaluation préliminaire des effets de la maladie des racines armillaria sur la grossièreté des fibres de sapin de Douglas.

Dempster, W.R., and Burkell, G. 2002. *Weldwood Alberta Fibre Quality Forecasting*. Forest Resource Improvement Association of Alberta (FRIAA) Technical Report, Alberta, Canada.

The study's goal was to identify trends in wood characteristics and fiber attributes and relate these factors to the forest tree, the stand level, and the site variables for improved forest inventories, fiber forecasts, cut block assessments, and pulping processes. Some interesting conclusions were basic wood density increased with stand density, tree slenderness (height:diameter ratio), and crown closure. Wood density decreased with ring width, and trees with larger crowns and larger branches had lower densities. *(Abstract prepared by compilers.)*

Dery, P.J., and DeHayes, D.H. 1981. Variation of specific gravity and tracheid length among balsam fir provenances. Pages 115–127 *in* P.W. Garrett, editor. *27th Northeastern Forest Tree Improvement Conference*, 29–31 July 1981, Burlington, Vermont, USA.

In a balsam fir (*Abies balsamea*) provenance trial in Vermont, the growth rate, specific gravity and the tracheid length were measured. The results varied among the geographical locations: the eastern and central range seeds grew faster, thus they had lower specific gravity and longer tracheids. Results showed that specific gravity and tracheid length were related to growth rate of the tree. The objective was to determine the genetic variation in balsam fir for specific gravity and tracheid length in northern Vermont. *(Abstract prepared by compilers.)*

Dinwoodie, J.M. 1961. Tracheid and fibre length in timber: a review of literature. *Forestry* **34**(2): 125–144.

This literature review focusses on the tracheid and fibre length in timber. It covers the variation in tracheid or fibre length within one growth ring, the variation in length outwards from the pith at any one level in the tree, the variation in tracheid length with increasing height in the tree, the relationship between the increment of the cambium and the length of cells produced, genotypic and ecotypic variations in tracheid length.

Dokken, M. 1972. *Veneer Drying Characteristics of Eastern Canadian Red Pine, White Pine and White Spruce*. Information Report OP-X-47, Natural Resources Canada, Canadian Forest Service, Eastern Forest Products Laboratory, Ottawa, Ontario, Canada.

Studies on the drying characteristics of veneer from eastern Canadian red pine, white pine and white spruce showed that they were similar to western softwoods in that they exhibited a large difference in moisture content between sapwood and heartwood. Information derived from laboratory trials on green moisture content, veneer sheet distribution by wood type, drying time at 300 degrees F and 450 degrees F is presented. The pronounced difference in moisture content between sapwood and heartwood indicates that the drying technique should at least include green sorting, and dry sorting for redrying. Since these species are pitchy, adequate precautions against pitch buildup in the dryer must be taken to control the fire hazard.

Des études sur les caractéristiques du séchage de placage de pin rouge, de pin blanc et d'épinette blanche provenant de l'est du Canada, sont identiques aux espèces de bois mous de l'ouest démontrant leur grande différence d'humidité entre le bois d'aubier et le coeur. Les informations présentées dans cet ouvrage sont tirées d'essais de laboratoire sur l'humidité du bois vert, sur la distribution des feuilles de placage par espèce de bois (aubier ou coeur) et sur le temps du séchage à 300 degrés F et 450 degrés F. La différence d'humidité entre le bois d'aubier et le coeur indique que les deux espèces de bois devraient être séparées avant le séchage, et séparées de nouveau pour le reséchage. Comme ses espèces sont très gommeuses, des précautions adéquates doivent être prises contre l'amassement de cette gomme dans le séchoir afin de contrôler les hasards des feux.

Dokken, M., and Lefebvre, R. 1973. *Drying Veneer Peeled from Seven New Brunswick Balsam Fir Logs.* Information Report OP-X-60, Natural Resources Canada, Canadian Forest Service, Eastern Forest Products Laboratory, Ottawa, Ontario, Canada.

Seven logs of balsam fir (*Abies balsamea* (L.) Mill.) from New Brunswick were peeled into 1/10 and 1/6 - inch veneer and dried at temperatures from 300 degrees F to 450 degrees F in the laboratory's cross flow veneer dryer. The veneer obtained was similar to that from other softwood species in that there was a large difference in moisture content between the sapwood (201%) and heartwood (76%). Areas of wetwood (154%) were also found in the inner heartwood. The wetwood resulted in high moisture content "streaks" ("wet spots") in the dried heartwood veneer. The drying characteristics of this veneer are similar to those of other softwood species in that some procedures such as green sorting, redrying, and stacking for moisture equalization will likely be necessary.

Sept billes de sapin baumier (*Abies balsamea* (L.) Mill.) du Nouveau-Brunswick furent déroulées en placage de 1/10 et de 1/6 pouce d'épaisseur, puis séché à des températures variant entre 300 et 450 degrés F dans le séchoir à placage à circulation d'air latérale du laboratoire. Le placage ainsi produit ressemblait au placage obtenu d'autres essences de bois mou, car il y avait une grande différence dans la teneur en humidité entre le bois d'aubier (201%) et le bois de coeur (76%). Le bois de coeur d'intérieur contenait aussi des régions de bois «mouilleux» (154%). Ces régions ont produit des veines d'une teneur élevée en humidité (« points mouilleux») dans le placage de bois de coeur séché. Les caractéristiques du séchage du placage de sapin baumier ressemblent à celles du placage qu'on obtient d'autres essences de bois mou, car il faudra probablement avoir recours à des procédés comme le tri du placage à l'état vert, le resséchage, et l'entreposage pour permettre l'égalisation de l'humidité.

Domec, J.C., and Gartner, B.L. 2002. How do water transport and water storage differ in coniferous earlywood and latewood? *Journal of Experimental Botany* **53**(379): 2369–2379.

It was predicted that, because of structural differences in the margo and torus, softwood earlywood is more efficient and resistant to embolism than latewood. This theory was tested by measuring water transport capacities of earlywood and latewood within a single ring of Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) trees. Parameters considered included conductivity, vulnerability to embolism, water storage capacity, water potential, and relative water content. Disks were cut from breast height of five trees. Samples were cut under water and maintained in water under vacuum for 48 hours to refill tracheids. Measurements were made on one entire ring before segmenting the ring into early and latewood. Weighted specific conductivity of early and latewood equaled specific conductivity of the entire ring. Earlywood specific conductivity was significantly higher than latewood specific conductivity. Water storage capacity was higher for latewood than earlywood. It was concluded that, as latewood had low water requirements but high water storage and as earlywood had high water efficiency but low water storage, tree conductivity was preserved during dry periods. *(Abstract prepared by compilers.)*

Domke, G.M., Ek, A.R., Kilgore, M.A., and David, A.J. 2008. *Aspen in the Lake States: a Research Review.* Technical Bulletin No. 955, National Council for Air and Stream Improvement, Department of Forest Resources, University of Minnesota, Minneapolis/St. Paul, Minnesota, USA.

Trembling aspen (*Populus tremuloides*) is a major component of the Grand Lake States forests. The research done on trembling aspen has been fragmented in the past; this paper reviews the status of current trembling aspen research and the need for future research. The importance of the industry's need is identified as essential in the research, whether it is economic or ecological. The paper further describes the biology, ecology, and silviculture of trembling aspen. *(Abstract prepared by compilers.)*

Donaldson, L. 2008. Microfibril angle: measurement, variation and relationships—a review. *IAWA Journal* **29**(4): 345–386.

Microfibril angle (MFA) is perhaps the easiest ultrastructural variable to measure for wood cell walls, and certainly the only such variable that has been measured on a large scale. Because cellulose is crystalline, the MFA of the S_2 layer can be measured by X-ray diffraction. Automated X-ray scanning devices such as Silviscan have produced large data sets for a range of timber species using increment core samples. In conifers, microfibril angles are large in the juvenile wood and small in the mature wood. MFA is larger at the base of the tree for a given ring number from the pith, and decreases with height, increasing slightly at the top [of the] tree. In hardwoods, similar patterns occur, but with much less variation and much smaller microfibril angles in juvenile wood. MFA has significant heritability, but is also influenced by environmental factors as shown by its increased values in compression wood, decreased values in tension wood and, often, increased values following nutrient or water supplementation. Adjacent individual tracheids can show moderate differences in MFA that may be related to tracheid length, but not to lumen diameter or cell wall thickness. While there has been strong interest in the MFA of the S_2 layer, which dominates the axial stiffness properties of tracheids and fibres, there has been little attention given to the microfibril angles of S_1 and S_3 layers, which may influence collapse resistance and other lateral properties. Such investigations have been limited by the much greater difficulty of measuring angles for these wall layers. MFA, in combination with basic density, shows a strong relationship to longitudinal modulus of elasticity, and to longitudinal shrinkage, which are the main reasons for interest in this cell wall property in conifers. In hardwoods, MFA is of more interest in relation to growth stress and shrinkage behaviour.

Doucet, R., and Boily, J. 1996. *Accroissement quinquennal de peuplement d'épinette noire soumis au dépressage*. Note de recherche forestiére n° 75, Ministère des ressources naturelles, Direction de la recherche forestière, Sainte-Foy, Québec, Canada.

Although precommercial thinning is a common silvicultural practice and black spruce (*Picea mariana* (Mill.) B.S.P.) is commercially important in Quebec, few studies have been undertaken to examine the impact of precommercial thinning on black spruce stands in Quebec. Thinned and unthinned control plots were established in stands in which advance regeneration had been released by cutting. Before thinning, a survey was made of the site, including soil type, species relative abundance, and diameter at breast height in 1-cm increment classes. Remeasurements were made 5 years after thinning. It was found that diameter growth in thinned stands far exceeded that of unthinned stands. Height growth of thinned stands was also significantly greater than unthinned stands. Volume growth of the 500 largest trees in the thinned stand more than doubled compared with those of the unthinned stand. *(Abstract prepared by compilers.)*

Bien que l'éclaircie précommerciale est une pratique sylvicole courante et que l'épinette noire (*Picea mariana* (Mill.) BSP) est commercialement importante au Québec, peu d'études ont été menées pour examiner l'impact de l'éclaircie précommerciale dans les peuplements d'épinettes noires au Québec. Des parcelles témoins avaient été établies dans des peuplements éclaircis et non éclaircis où la régénération avancée avait été libérée avec une coupe de nettoiement. Avant l'éclaircie, un inventaire a été effectué sur le site, y compris le type de sol, l'abondance relative des espèces, et le diamètre à hauteur de poitrine. Une réévaluation a été faite 5 années suivant l'éclaircie. On a constaté que la croissance en diamètre dans les peuplements éclaircis dépasse de loin celle des peuplements non éclaircis. La croissance en hauteur des peuplements éclaircis était également significativement plus grande que les peuplements non éclaircis. La croissance en volume des 500 plus gros arbres dans le peuplement éclairci est plus que le double par rapport à celles du peuplement non éclairci. *(Résumé fourni par les compilateurs.)*

Doucet, R., and Boily, J. 1987. *Bibliographie annotée sur le marcottage de l'épinette noire*. Mémoire nº 90, Ministère de l'énergie et des ressources naturelles, Direction de la recherche et du développement, Sainte-Foy, Québec, Canada.

A thorough review of the literature was undertaken to better understand the influence of layering in regeneration of black spruce (*Picea mariana* (Mill.) B.S.P.) stands. In total, 44 papers were reviewed, and layering was found to be influential in many cases and, in fact, occurs throughout the range. It was speculated that the paucity of papers may be a result of difficulty differentiating between layering and seed regeneration. *(Abstract prepared by compilers.)*

Un examen approfondi de la littérature a été entrepris afin de mieux comprendre l'influence du marcottage sur la régénération de l'épinette noire (*Picea mariana* (Mill.) BSP). Au total, 44 documents ont été examinés et le marcottage a été identifié comme étant influent dans de nombreux cas et, en fait, il se produit sur toute la distribution de l'épinette noire. Il a été spéculé que la rareté des papiers peut être le résultat de la difficulté à distinguer entre le marcottage et la régénération par semences. *(Résumé fourni par les compilateurs.)*

Downes, G.M., Wimmer, R., and Evans, R. 2002. Understanding wood formation: gains to commercial forestry through tree-ring research. *Dendrochronologia* **20**(1–2): 37–51.

Tree rings provide information on changes in environmental factors over time and a tree's resilience to them. This also can give insight into their wood structure. Cambial growth is controlled by environmental factors interacting with the tree's genotype. Advances in measurement technology in this area have allowed greater insight into wood formation. This kind of information is used in the fields of dendrochronology/ecology and commercial forestry. Understanding wood formation will allow better analysis of tree rings and an increase in timber production. *(Abstract prepared by compilers.)*

Drost, C., Ni, Y., and Shewchuk, D. 2003. Effect of mature and juvenile wood from five wood species on kraft pulp strength. *Pulp and Paper Canada* **104**(11): 33–36.

This study investigated the effect of juvenile and mature wood from sawmill chips and whole-log chips balsam fir (*Abies balsamea* (L.) Mill.), black spruce (*Picea mariana* (Mill.) B.S.P.), red spruce (*Picea rubens* Sarg.), white pine (*Pinus strobus* L.), and jack pine (*Pinus banksiana* Lamb.) on kraft pulp. Two butt logs from each species were selected and chipped. The 20-year annual ring was chosen as the delineation between juvenile and mature wood. Mature wood had longer fibers than juvenile wood. Juvenile wood pulp had higher beatability and mature wood pulp showed higher tear. Of all species tested, jack pine had the longest fibers and, consequently, high tear strengths and low tensile strengths. *(Abstract prepared by compilers.)*

Duchesne, I. 2006. Effect of rotation age on lumber grade yield, bending strength and stiffness in jack pine (*Pinus banksiana* Lamb.) natural stands. *Wood and Fiber Science* **38**(1): 84–94.

The effects of rotation age on lumber visual grade yield and lumber bending properties were studied on 142 jack pine trees sampled in three stands located in Timmins, Ontario. The stands, aged 50, 73, and 90 years were all naturally established after forest fires. The visual grading of a total of 1720 lumber pieces showed that the 50-yr-old stand produced a slightly lower Select Structural grade yield (36.1%) compared to the older stands (73 yr 42.9% and 90 yr 39.3%). When No. 2 and Better grades were combined, the 50-yr-old stand resulted in the lowest volume yield (88.2%), whereas the proportions of No. 2 and Better for the 73- and 90-yr-old stands were comparable (93.0 and 92.6%, respectively). Downgrades due to decay were much higher in the 90-yr-old stand (20.6%) than in the 73- and 50-yr-old stands (5.2% and 0%, respectively). Regarding stand productivity, the 50-yr-old stand showed the highest annual stand increment of 5.25 m^3/ha/year, compared to 3.82 and 3.21 for the 73- and 90-yr-old stands, respectively. The visual grading of 782 board pieces showed no effect of stand age on board quality. In the 90-yr-old trees, wood density decreased steadily from butt to top for all the diameter classes studied (12–30 cm). The study showed that rotation age had a significant impact on lumber bending properties. The lumber bending properties for the 50-yr-old stand were significantly lower than those of the 73- and 90-yr-old stands. The lumber strength (MOR) and lumber stiffness (MOE) values for the 50-yr-old stand were about 16% lower and 19–16% lower than those of the 73- and 90-yr-old stands, respectively. However, no significant differences in lumber bending properties were found between the two older stands. From the viewpoint of lumber properties, a moderate rotation age of about 70 years is preferred in jack pine.

Duchesne, I., and Zhang, S.Y. 2004. Variation in tree growth, wood density, and pulp fiber properties of 35 white spruce (*Picea glauca* (Moench) Voss) families grown in Quebec. *Wood and Fiber Science* **36**(4): 467–475.

Thirty-five fast-growing white spruce families planted at two sites were compared for their growth, wood and fiber properties. The analysis was made at family level, and each family comprised four individual trees. There was a significant difference in growth rate (expressed as mean annual ring width) between the two sites, and trees grew faster at Lac St-Ignace site compared to Valcartier site. The faster tree growth rates recorded at Lac St-Ignace site resulted in significantly shorter fibers for 33 of the 35 families analyzed in comparison to Valcartier, but had no significant effect on basic wood density and fiber coarseness. The pulping properties varied between the three families analyzed at two sites. Overall, the handsheet tear index properties were low but the tensile indices were high. The fastest-growing families at Lac St-Ignace site tended to have lower tear index and pulp yields but slightly higher handsheet densities than the same families grown at Valcartier site. Thus, the white spruce pulps appear more appropriate for better bonded paper grades where surface smoothness and good printability are required rather than for paper grades where high sheet strength is required.

Dunham, S.M., Ganio, L.M., Gitelman, A.I., and Lachenbruch, B. 2008. Partitioning variation in Douglas-fir xylem properties among multiple scales via a Bayesian hierarchical model. *Tree Physiology* **28**(7): 1017–1024.

This research compared hierarchical modeling with other modeling methods. The Bayesian method compared three statistical models (simple linear regression, repeated measures analysis, and hierarchical model). The biological scales for this study were fertilization, position within the treatment, and position within the tree. The hierarchical model is better at estimating the variation and increases the precision in the parameter estimation. *(Abstract prepared by compilers.)*

Elliott, G.K. 1970. Wood properties, silviculture, and genetics. Pages12–21 *in* E. W. Edwardson and T.E. Jones. *The Wood We Grow: Report of the 10th Discussion Meeting*. 20–22 March 1970. Oxford Journals, Edinburgh, Scotland.

Perception of wood quality is strongly dependent on end use. This paper discusses the challenges faced by home-grown United Kingdom wood and the characteristics of its imported competition. Also discussed is the role of silviculture and genetic improvement in wood-quality attributes. Greater understanding of the role of basic wood variability is required by all involved in wood production and utilization. *(Abstract prepared by compilers.)*

Emmingham, W., Fletcher, R., Fitzgerald, S., and Bennett, M. 2007. Comparing tree and stand volume growth response to low and crown thinning in young natural Douglas-fir stands. *Western Journal of Applied Forestry* **22**(2): 124–133.

Two Douglas-fir (*Pseudotsuga menziesii*) stands were studied to determine the impact of tree and stand growth after two types of thinning (low and crown). The study focuses on volume growth (bd ft/ac), volume growth per tree, crown class distribution, net growth by crown class, volume growth per tree per crown class, growth rates, mortality, net yield, periodic annual increment (PAI), and mean annual increment (MAI). The paper also provides some management options. *(Abstract prepared by compilers.)*

Eyre, F.H., and LeBarron, R.K. 1944. *Management of Jack Pine Stands in the Lake States*. USDA Technical Bulletin 863, USDA, St. Paul, Minnesota, USA.

Jack pine, once regarded as a weed tree but now extensively used for pulpwood and other forest products, has excellent possibilities for silvicultural management. The great extent of its distribution in the Lake States, nearly 3 million acres, is due chiefly to fire and to the peculiar seeding habit of the tree. Closed cones accumulate on the trees until a forest fire, running through the stand, opens them and permits seed to fall on the burned soil, a favorable seedbed. Because in many cases jack pine has not regenerated successfully after logging of second-growth stands, studies have been made of the factors governing its reproduction. These investigations, covering 14 years, indicate that in most places where jack pine is found few seed are scattered from standing trees but large quantities are stored on the trees in unopened cones. Logging transfers this seed supply to the slash. If cones lie on or close to the ground, they are opened by the heat of the sun and disperse much of the stored seed. In piles or windrows the cones tend to remain closed. Mineral soil is the most favorable medium for germination of the seed, although a burned duff surface is nearly as good. Young seedlings survive best, also, on mineral soil. They make most rapid growth in full sunlight, requiring little or no shade except in especially hot situations. In order to compete with herbaceous and other ground vegetation young seedlings should have at least an equal start with it. Seedlings germinating in the spring or early summer have a better chance of surviving than those germinating in late summer or autumn, as the latter are more subject to winter killing. Jack pine grows quickly and is relatively short-lived. It begins to decline in growth rate after 50 years and ordinarily matures at about 70 years. Pulpwood is produced as early as 30–35 years. Many stands of this age could well be thinned for such products and then permitted to grow into sawlogs and mine timbers, which command higher prices. Dense younger stands benefit by thinning because they are slow to thin themselves naturally and tend to stagnate. Clear cutting with mechanical ground scarification and scattering of cone-bearing branches is generally recommended for harvesting pure stands of mature jack pine and obtaining natural regeneration. On warm exposure, however, a partial cover of forest should be left as a protective measure. Scarification with an Athens-type disk plow drawn by a tractor has proved successful. Jack pine slash is not considered to be a serious fire hazard, so that the lopping and scattering is entirely practicable. Where growing in mixture with red pine, jack pine may be removed in a series of partial cuttings. In this manner the longer-lived and more valuable red pine may be perpetuated. Much of the large area of deforested pine land in the Lake States is suitable for artificial reforestation with jack pine. Essential requirements of successful planting are ground preparation by plowing furrows, sturdy stock, and aftercare to release seedlings from competing vegetation. Direct seeding with jack pine has been found successful on especially favorable sites. *(Source: U.S. Department of Agriculture, Forest Service)*

Feng, Z., Stadt, K.J., and Lieffers, V.J. 2006. Linking juvenile white spruce density, dispersion, stocking, and mortality to future yield. *Canadian Journal of Forest Research* **36**(12): 3173–3182.

We examined methods of linking density, dispersion, and stocking information from juvenile regeneration surveys with mortality estimates to predict future yield of white spruce (*Picea glauca* (Moench) Voss) in boreal mixedwoods. The study focused on data from 709 stands (7–150 years) and defined a stocked plot (10 m^2) as having one or more acceptable trees. In juvenile surveys, ingress of natural spruce overwhelmed the regular planting pattern, creating clumped dispersion patterns, as indicated by the Morisita index. A function was developed to describe the relationship between stocking, density, and dispersion. In mature, permanent sample plots, only 30%–40% stocking of 10 m^2 plots (700 stems/ha) was needed to achieve full yields. Mortality rates for planted spruce varied from 0.1% to 0.8% per year for juvenile stands and from 1.7% to 3.3% per year for mature stands. For rotation-length predictions in Alberta, 0.7% per year is likely a mean mortality loss. These findings were combined to generate stocking versus time curves at a range of mortality rates. The tallest spruce measured in each juvenile survey plot had the same mortality rate regardless of absolute size, and spruce mortality was reduced when associated with aspen. These findings call into question minimum height requirements and free-to-grow criteria in regeneration standards.

Nous avons étudié des méthodes pour relier les données sur la densité, la dispersion et la distribution provenant d'inventaires de régénération juvénile à des estimations de mortalité de façon à prédire la production future de l'épinette blanche (*Picea glauca* (Moench) Voss) en forêt boréale mixte. L'étude se concentre sur les données provenant de 709 peuplements, âgés de 7 à 150 ans, pour lesquels une placette (10 m^2) a été considérée régénérée lorsqu'elle contenait au moins un arbre acceptable. Dans les inventaires de régénération juvénile, les épinettes qui se sont établies naturellement se superposent à la disposition régulière des plantations, ce qui crée des patrons de distribution en bouquet comme l'indique l'indice de Morisita. Une fonction a été mise au point pour décrire la relation entre la distribution, la densité et la dispersion. Dans les placettes-échantillons permanentes établies dans des peuplements matures, un coefficient de distribution en placettes de 10 m^2 de seulement 30 % à 40 % (700 tiges/ha) était nécessaire pour atteindre la production maximale. Le taux annuel de mortalité des épinettes plantées variait de 0,1 % à 0,8 % dans les peuplements juvéniles et de 1,7 % à 3,3 % dans les peuplements matures. Dans le cas de prédictions pour toute la durée d'une rotation en Alberta, les pertes moyennes dues à la mortalité sont plutôt de 0,7 % par année. Ces résultats ont été combinés pour produire des courbes de coefficient de distribution en fonction du temps pour une gamme de taux de mortalité. Dans le cas de la plus grande épinette mesurée dans chaque placette d'inventaire de régénération juvénile, l'analyse montre que le taux de mortalité était semblable, peu importe la taille absolue des épinettes, et que la mortalité des épinettes était réduite lorsqu'elles étaient en association avec le peuplier. Ces résultats remettent en question les exigences de hauteur minimale et les critères de peuplement établi qui font partie des normes de régénération.

Fernandez, M.P., Breuil, C., and Watson, P.A. 2002. Natural clonal variation of wood extractives in *Populus tremuloides*. *Canadian Journal of Forest Research* **32**(7): 1192–1199.

Analysis of the potential genetic variation in quaking aspen (*Populus tremuloides* Michx.) wood extractives was performed by sampling nine natural clones at breast height. Significant clonal differences were found not only in the levels of total acetone extractives but also in the levels of sterols-triterpenes, steryl esters-waxes, and triglycerides, all of which are known to contribute to pitch formation in pulping and papermaking. In addition, extractive compounds known to elicit toxic effects in aquatic organisms showed statistically significant differences between natural aspen clones. In some cases (e.g., flavonoids), these compounds formed a part of the defense system in the living tree and, thus, were affected in part by the presence of decayed wood.

La variabilité génétique dans les produits d'extraction du bois de peuplier faux-tremble (*Populus tremuloides* Michx.) a été analysée en échantillonnant neuf clones naturels à hauteur de poitrine. Des différences clonales significatives ont été observées dans les quantités totales des produits d'extraction à l'acétone, mais aussi dans les quantités de stérols–triterpènes, de stéryles estérifiés–cires et de triglycérides, tous des composés reconnus pour contribuer à la formation de goudron lors de la fabrication de pâte et de papier. De plus, des produits d'extraction reconnus pour leur effet toxique chez les organismes aquatiques montraient des différences significatives entre les clones naturels de peuplier. Dans certains cas (p. ex. flavonoïdes), ces composés constituent une partie du système de défense chez les arbres vivants et sont par conséquent en partie influencés par la présence de bois carié.

Fleming, R.L., Mossa, D.S., and Marek, G.T. 2005. Upland black spruce stand development 17 years after cleaning and precommercial thinning. *The Forestry Chronicle* **81**(1): 31–41.

Density management is often used by silviculturists to guide stand composition and development. We examined the effects of cleaning (hardwood removal) and four levels of precommercial thinning (0, 20, 35 and 50% basal area removal) on stand development in a dense, 24-year-old upland black spruce (*Picea mariana* [Mill.] B.S.P.) plantation near Beardmore, Ontario. Immediately before treatment, stand densities and basal areas for all species and for black spruce averaged 7375 and 6415 stems/ha, and 27.9 and 20.5 m^2/ha, respectively. Seventeen years after treatment, black spruce total stand volume (V_T) was higher in the cleaned, unthinned plots (243 m^3/ha) than in the untreated controls (171 m^3/ha) while total stand volume increment of all species combined was similar in these two treatments. Compared with cleaning alone, thinning cleaned plots from below increased quadratic mean diameters (D_Q) by up to 9% but decreased V_T by up to 28%. At plantation age 41, increases in black spruce densities of 1000 stems/ha resulted in mean decreases of 0.6 cm in D_Q and mean increases of 43 m^3/ha in V_T. Endemic black spruce stem mortality rates decreased with thinning intensity, with mortality concentrated in the smallest size classes. In some plots, mortality was increased by wind or snow damage, and by root rots. Height increment of dominant trees was unaffected by thinning. Projected yields at age 55 (the physical rotation age—the age at which maximum mean annual increment occurs) suggest the heaviest precommercial thinning could increase quadratic mean diameter from 16.1 to 17.7 cm, but decrease merchantable stand volume from 292 to 225 m^3/ha. Results indicate that total black spruce fibre yields and product value on these sites will be maximized in denser stands. Cleaning appears to offer greater benefits for black spruce fibre production than precommercial thinning.

Les sylviculteurs utilisent souvent l'aménagement en fonction de la densité pour diriger la composition et le développement d'un peuplement. Nous étudions les effets du dégagement (coupe des feuillus) et de quatre niveaux d'éclaircie précommerciale (0, 20, 35 et 50 % de coupe de la surface terrière) sur le développement d'une plantation dense de 24 ans d'épinette noire de site mésique (*Picea mariana* [Mill.] B.S.P.) située près de Beardmore en Ontario. Tout juste avant le traitement, les densités du peuplement et les surfaces terrières pour toutes les espèces et pour l'épinette noire atteignaient respectivement en moyenne 7 375 et 6 415 tiges/ha et 27,9 et 20,5 m^2/ha. Dix-sept ans après le traitement, le volume total du peuplement d'épinette noire (V_T) était supérieur dans les parcelles dégagées et non éclaircies (243 m^3/ha) par rapport aux parcelles-témoins (171 m^3/ha) tandis que l'accroissement total en volume du peuplement, toutes espèces combinées, était semblable dans ces deux traitements. Par comparaison avec seulement le dégagement, les parcelles éclaircies par le bas et dégagées ont connu une augmentation des diamètres quadratiques moyens (D_Q) atteignant jusqu'à 9 %, mais une diminution du V_T allant jusqu'à 28 %. Dans la plantation à l'âge de 41 ans, les accroissements des densités d'épinette noire de 1 000 tiges/ha ont entraîné des diminutions de 0,6 cm du D_Q et des accroissements moyens du V_T de 43 m^3/ha. Les taux de mortalité endémiques des tiges d'épinette noire ont diminué selon la densité de l'éclaircie, la mortalité se concentrant dans les plus petites classes de diamètre. Dans certaines parcelles, la mortalité s'est accrue à cause du vent ou des dégâts provoqués par la neige et par la pourriture des racines. L'accroissement en hauteur des arbres dominants n'a pas été affecté par l'éclaircie. Les rendements projetés à 55 ans (l'âge physique de la révolution – l'âge à laquelle survient le maximum d'accroissement annuel moyen) laissent entendre qu'une éclaircie précommerciale plus intense pourrait accroître le diamètre quadratique moyen de 16,1 à 17,7 cm, mais diminuerait le volume marchand moyen de 192 à 225 m^3/ha. Les résultats indiquent que les rendements totaux en fibre d'épinette noire ainsi que la valeur des produits tirés de ces stations seront maximisés dans des peuplements plus denses. Le dégagement semble offrir des bénéfices plus intéressants au niveau de la production de fibre d'épinette noire que l'éclaircie précommerciale.

Flewelling, J.W., and Marshall, D.D. 2008. *Calibration and Modification for the Pacific Northwest of the New Zealand Douglas-fir Silvicultural Growth Model*. General Technical Report PNW-GTR-754, USDA Forest Service, Portland, Oregon, USA.

This paper describes a growth model for young plantations of Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) growing in the Pacific Northwest. The overall model has three major components. The first is a yield model for diameter and height distributions describing stands prior to pruning or precommercial thinning. The second component is an annual per-acre net increment model adapted from a recent model for Douglas-fir plantations in New Zealand; thinning and pruning are features of the model. The third component is growth equations for cohorts of individual trees; the results from this component are adjusted to match those from the second component. Fitting data are from stand management cooperative experiments, with top heights generally below 75 ft. An intended use of the model is the evaluation of pruning regimes, in conjunction with the

ORGANON model for growth at older ages, and TREEVAL model for clear-wood recovery and economic evaluation. *(Source: U.S. Department of Agriculture, Forest Service.)*

Forest Products Research Laboratory. 1957. *A Handbook of Softwoods*. Department of Scientific and Industrial Research, Princes Risborough, UK.

The first *Handbook of Empire Timbers*, which contained information on both native species and those from the Commonwealth and Empire countries, was issued by the Empire Marketing Board in 1932. By 1939, this book was almost out of print and, as in the meantime the Laboratory had investigated a considerable number of species, it was replaced by two volumes, one on overseas and one on native timbers. These two handbooks, revised at intervals, served a useful purpose during the war and post-war periods, but the time arrived for a revision and enlargment in scope of the earlier books. It was decided that it would be more useful to group the hardwoods and the softwoods in separate volumes, and to bring together in each volume both native and imported timbers. The volume on hardwoods has been published. The present volume on softwoods contains up-to-date information on the softwood species formerly dealt with in both the earlier volumes and also data on a number of additional species. Altogether, the book gives a full description of 49 timbers and another six are described briefly. *(Abstract prepared by compilers.)*

Forget, E., Nolet, P., Doyon, F., Delagrange, S., and Jardon, Y. 2007. Ten-year response of northern hardwood stands to commercial selection cutting in southern Quebec, Canada. *Forest Ecology and Management* **242**(2-3): 764–775.

Trees sampled from 12 uneven-aged sugar maple (*Acer saccharum* Marsh.) dominated stands in southern Quebec were measured 10 years after commercial single-tree selection cutting. Dendrochronological analysis revealed that growth response to treatment was immediate for all three species. Species-specific response was, however, stronger for American beech (*Fagus grandifolia* Ehrh.) than for sugar maple and yellow birch (*Betula alleghaniensis* Britton). When averaged for 5-year periods, species growth during the second 5-year period after treatment remained significantly higher than their growth prior to treatment. Computations of whole stand minimum and maximum mortality (0.04 and 0.20 m^2 ha^{-1} $year^{-1}$) and the associated net growth (0.21 and 0.37 m^2 ha^{-1} $year^{-1}$) were in the range of what was observed in the Quebec Government experimental blocks. Finally, at lower basal areas (i.e., after cutting), the growth of the survivors was correlated with variations in stand basal areas, while it was not the case at higher basal areas (i.e., prior to cutting). This suggests a significant enhancement of the survivor growth in these deciduous forests may only happen with a post-harvest basal area of 18 m^2 ha^{-1} or less. Recommendations with respect to residual basal area and timber improvement rules are proposed that also take into consideration conclusions found in a literature review.

Fournier, A., Woods, M., Stinson, A., and Zhang, T. 2006. *Maximizing the Value of Hardwoods through Intensive Silviculture (Stoke's Study)*. Project No. 3652. Forintek Canada Corp., Sainte-Foy, Quebec, Canada.

Conducted for an industrial partner, this study evaluated the effect of selection cutting on a sugar maple (*Acer saccharum* Marsh.) and American beech (*Fagus grandifolia* Ehrh.) hardwood stand in the Great Lakes–St. Lawrence forest region one rotation later with respect to growth, lumber yield, and product value. The study focused on basal area growth of the stand, individual tree diameter and basal area increase, lumber yield and product values, and the relationship between logging damage, stem defects, and yield and value. Selection harvesting consisted of a single-tree selection partial harvest and tree-length skidding, which resulted in excessive damage to the residual stand. Stand growth was lower than expected. It was found that, although a significant percentage of stems were damaged, they did not greatly contribute to mortality rates. Most of the mortality was attributed to the poor quality of stems left after the harvest. Growth response varied by tree size and species. Pole-sized trees responded more favorably than sawtimber-sized trees. Beech responded more favorably than sugar maple, likely because it was younger and smaller than the maple and benefited more from the additional light admitted by the harvest. It was concluded that product value, relating as it does to absence of stem defects, may be preserved by careful logging. *(Abstract prepared by compilers.)*

Fournier, R.A., Luther, J.E., Guindon, L., Lambert, M.-C., Piercey, D., Hall, R.J., and Wulder, M.A. 2003. Mapping aboveground tree biomass at the stand level from inventory information: test cases in Newfoundland and Quebec. *Canadian Journal of Forest Research* **33**(10): 1846–1863.

A method of estimating and mapping aboveground tree biomass (AGTB) was developed using provincially available forest inventory databases. More specifically, AGTB conversion tables were devised to estimate biomass for stand attributes that are commonly mapped in provincial inventories over the Canadian landscape, i.e., species composition, projected crown density, and dominant tree height. AGTB is first estimated at the tree level using allometric relationships and measured stem distributions that are subsequently summed to estimate plot-level biomass. AGTB conversion tables are then computed from regression models that relate the plot-level biomass values to stand attributes. AGTB can then be mapped over the landscape by assigning the plot-level biomass values to the mapped stands. The method was developed using two provinces, Newfoundland and Labrador (NL) and Quebec, as test cases to assess the adaptation required between different management units. Models used to develop conversion tables from the test areas provided estimates of biomass with R^2 ranging from 0.22 to 0.35 and from 0.31 to 0.64 and root mean square errors of 38 to 47 t/ha and 21 to 41 t/ha for NL and Quebec, respectively, based on an independent validation data set not used in the development of the models. Mapping errors and potential improvements to the models are discussed. To extend the methods developed in this study to a national map of forest AGTB will require significant adjustments to account for differences in regional inventory specifications. Although the method for AGTB mapping can fulfil an important monitoring requirement in forestry, applying it to all provinces, as well as including alternative data sources for areas where inventories do not exist, such as satellite remotely sensed images, requires further research, some of which is currently in progress.

Une méthode pour estimer et cartographier la biomasse aérienne des arbres a été développée en s'appuyant sur les données des inventaires provinciaux disponibles. Plus spécifiquement, les tables de conversion de la biomasse aérienne ont été bâties pour estimer la biomasse à l'aide des attributs des peuplements qui sont communément cartographiés dans les inventaires provinciaux au Canada, c'est-à-dire la composition en espèces, la densité du couvert végétal au sol et la hauteur des arbres dominants. La biomasse aérienne est d'abord estimée pour chaque arbre dans une placette à l'aide des relations allométriques et de la distribution des tiges par classes de dhp. Ensuite, la biomasse des arbres est additionnée pour obtenir la biomasse de la placette. Enfin, les tables de conversion de la biomasse aérienne sont établies à partir des modèles de régression qui relient la biomasse de la placette aux attributs des peuplements. La biomasse aérienne peut ainsi être cartographiée à l'échelle du paysage en assignant les valeurs moyennes de biomasse des placettes aux peuplements cartographiés. Terre-Neuve-et-Labrador et Québec ont été choisis comme provinces pilotes pour développer la méthode et évaluer de quelle façon l'adapter aux différentes unités d'aménagement. L'application des modèles utilisés pour établir les tables de conversion sur la base de données indépendante de celle utilisée pour leur calibration a permis d'estimer la biomasse avec des coefficients de variation de 0,22 à 0,35 et de 0,31 à 0,64 et des écarts-types résiduels de 38 à 47 t/ha et de 21 à 41 t/ha respectivement pour Terre-Neuve-et-Labrador et Québec. Les erreurs de cartographie et les améliorations qui pourraient être apportées aux modèles sont discutées. Si on voulait généraliser l'utilisation de cette étude pour obtenir une cartographie nationale de la biomasse forestière, il faudrait y apporter d'importants ajustements pour tenir compte des différences dans les prescriptions d'inventaire qui varient selon les régions. Bien que la méthode pour cartographier la biomasse aérienne puisse répondre à un important besoin de suivi en foresterie, son application à toutes les provinces ainsi que le recours à des sources de données alternatives lorsque l'inventaire est inexistant, tel que les images satellitaires, exigent d'autres recherches dont certaines sont en cours.

Francis, R.C., Hanna, R.B., Shin, S.-J., Brown, A.F., and Riemenschneider, D.E. 2006. Papermaking characteristics of three *Populus* clones grown in the north-central United States. *Biomass and Bioenergy* **30**(8-9): 803–808.

The papermaking properties of 22 pure and hybrid poplars are being evaluated in an on-going investigation. Twenty of the poplars were harvested after 7.5 years from three different sites in the Midwestern and North Central US. The other two poplars survived at only two of three sites (64 total samples). The Crandon hybrid had the highest growth rate (t ha^{-1} y^{-1}) and wood density (both averaged across the three sites). This poplar had a high cellulose content (compared to the average), a low lignin content and produced bleached kraft fibers at a high yield (wt.% on wood chips). Further, this poplar responded very well to kraft pulping and oxygen delignification and bleached to the highest final brightness ever observed in our laboratory (94.5% Elrepho). It also produced an 18 kappa number unbleached pulp with <0.5% rejects in only two-thirds the time required for sugar maple (*Acer saccharum*).

We also report on clone 220-5 that had the highest area-weighted average microfibril angle. Pulps from this poplar had excellent tensile properties and further improvements are expected with 1–2 years of additional growth that should result in a small, but significant increase in average fiber length. Some results are also presented for clone 313.55 and aspen (*Populus tremuloides*) to demonstrate the many substantial benefits that can be accrued from proper wood selection.

Fraser, E.C., Landhäusser, S.M., and Lieffers, V.J. 2006. Does mechanical site preparation affect trembling aspen density and growth 9–12 years after treatment? *New Forests* **32**(3): 299–306.

Trembling aspen (*Populus tremuloides* Michx.) density and growth were assessed 9–12 years after stand establishment to determine whether mechanical site preparation (MSP) affects crop tree quality. Study sites were either treated with disc trenching or ripper ploughing and planted with white spruce (*Picea glauca* (Moench) Voss) seedlings immediately after harvest (treated) or were undisturbed since harvest (control). Stands were surveyed during the summer of 2002 with standard regeneration survey plots. Results show that aspen stem density and height were lower in MSP-treated areas relative to untreated areas. Diameter growth rates were unaffected by treatment, however the percentage of stem discolouration was higher in untreated control stands compared to site prepared areas. The results of this study indicate that there are no long-term benefits to carry out MSP for aspen promotion. However, as MSP does not appear to seriously harm the aspen crop, we suggest that this treatment can still be used on sites where aspen densities may be low without treatment (e.g., sites with extremely low soil temperatures, poor soil aeration, or vigorous competitive vegetation) or where a mixture of aspen and planted spruce are desired.

Fu, S., Bell, F.W., and Chen, H.Y.H. 2007. Long-term effects of intensive silvicultural practices on productivity, composition, and structure of northern temperate and boreal plantations in Ontario, Canada. *Forest Ecology and Management* **241**(1–3): 115–126.

Long-term interactive effects of site preparation, brush control and fertilization treatments on productivity, composition and structure were examined on jack pine (*Pinus banksiana* Lamb.), black spruce (*Picea mariana* [Mill.] B.S.P.), white pine (*Pinus strobus* L.) and white spruce (*Picea glauca* [Moench] Voss) plantations, 15 years after planting in Ontario, Canada. For all crop species, growth performance increased significantly with site preparation intensity on sites without brush control, but did not change on sites with brush control. The effect of brush control and site preparation on stand volume of crop trees varied among plantations while fertilization had no effect. For the jack pine plantation, stand volume of crop trees increased with brush control and site preparation intensity, while volume of non-crop trees did not differ among treatments. For the black spruce plantation, brush control increased and site preparation marginally affected stand volume of crop trees. However, brush control decreased non-crop tree hardwood volumes, resulting in a significant increase in total stand volume. In the white pine and white spruce plantations, stand volume of crop trees increased while that of non-crop trees declined, resulting in no difference in total stand volume. However, there was a significant shift of stand composition from hardwood dominated, mixed, to crop trees dominated with silvicultural intensity. Height structure changed with increasing silvicultural intensity for all plantations, showing a shift from a hardwood dominated multi-layer canopy (a canopy of two or more layers mixed of crop trees and non-crop trees) to a crop tree dominated canopy with an understory of naturally established shade-tolerant seedlings. We conclude that intensive silviculture is a useful tool for managing stand composition and structure of boreal and northern temperate plantations, but increases in total stand volume may not occur as expected.

Fujiwara, S., and Yang, K.C. 2000. The relationship between cell length and ring width and circumferential growth rate in five Canadian species. *IAWA Journal* **21**(3): 335–345.

Variation in cell length and the relationship between cell length and ring width and circumferential growth rate were studied in jack pine (*Pinus banksiana* Lamb.), balsam fir (*Abies balsamea* Mill.), white spruce (*Picea glauca* Voss), black spruce (*Picea mariana* Britton, Stems and Pogg) and trembling aspen (*Populus tremuloides* Michx.) collected in the natural forest in Ontario, Canada. There was a negative relationship between cell length and ring width in jack pine, balsam fir and black spruce, and a positive relationship in trembling aspen. No relationship was found in white spruce. There was a negative relationship between tracheid length and circumferential growth rate in all conifers. In trembling aspen, fibre length decreased in both higher and lower circumferential growth rate. Circumferential growth rate is a good index of the effect of tree growth on cell length.

Gagné, C., Barbe, M.C., Rémillard, B., and Lapointe, M. 1990. Properties of mechanical and chemimechanical jack pine pulps. Part IV: bleaching studies. *Pulp and Paper Canada* **91**(6): 117–128.

Pulps were produced from aged jack pine (*Pinus banksiana* Lamb.) chips to determine the response of jack pine to sodium hydrosulfite and peroxide. Jack pine pulp brightness was compared to spruce/balsam. Brightness of jack pine pulp was found to increase with either sodium hydrosulfite or peroxide. Sulfite pretreatment, chemithermomechanical pulping, and hydrosulfite bleaching produced jack pine pulp with brightness equivalent to spruce/balsam. Peroxide bleaching was more effective than hydrosulfite in unpretreated pulps. Unbleached jack pine pulps are yellow. Hydrosulfite does not reduce the yellow but does introduce green. Peroxide does reduce yellow, but also introduces green. Peroxide bleaching was found to be more economical than sodium hydrosulfite bleaching. Alum was found to reduce brightness and increase yellowing of jack pine pulps. Process implications of the results were given. *(Abstract prepared by compilers.)*

Gagnon, J.D., and Hunt, K. 1974. Kraft pulping and specific gravity in the uppermost stem of fertilized balsam fir. *Canadian Journal of Forest Research* **5**(3): 399–402.

Samples of five pairs of fertilized and non-fertilized 60-year-old natural balsam fir (*Abies balsamea* (L.) Mill.) growing in the Quebec boreal forest region were pulped by the kraft process and the specific gravity was measured. Analyses carried out 7 years after treatment on the last seven terminal internodes revealed the mean pulp yield of trees fertilized exceeded that of non-fertilized by 7%, while the mean specific gravity was about 6% lower.

Le contenu en pâte kraft et le poids spécifique d'échantillons de sapins baumiers (*Abies balsamea* (L.) (Mill.) ont été déterminés. Ces échantillons provenaient de cinq paires d'arbres fertilisés et non fertilisés d'un peuplement naturel âgé de 60 ans et croissant dans la région boréale du Québec. Les analyses, effectuées 7 ans après traitement sur les sept derniers entre-nœuds de la cime, ont démontré que le rendement moyen en pâte des arbres fertilisés dépassait celui des arbres non fertilisés de 7%, mais leur poids spécifique était diminué d'environ 6%.

Garber, S.M., and Maguire, D.A. 2005. Vertical trends in maximum branch diameter in two mixed-species spacing trials in the central Oregon Cascades. *Canadian Journal of Forest Research* **35**(2): 295–307.

The influence of spacing and competitor species on vertical trends in maximum branch diameter, the thickest branch per whorl, was assessed in two central Oregon spacing studies. One study involved a mix of *Pinus contorta* Dougl. ex Loud. and *Pinus ponderosa* Dougl. ex Laws., the other a mix of *Abies grandis* (Dougl. ex D. Don) Lindl. and *P. ponderosa*. Impacts of autocorrelation became statistically insignificant after introduction of a single random tree effect. Although tree variables such as diameter, height, and crown length were able to account for most stand conditions, models with explicit treatment variables representing spacing and species composition were superior. All profiles of maximum branch diameter were curvilinear and widened with increasing spacing and tree relative height. For trees in mixtures, maximum branch diameter profiles of dominant and subordinate species were wider and thinner, respectively, than the same species in pure stands at the same spacing. However, as spacing increased, profiles of the subordinate species in mixtures had a greater response than those in adjacent pure plots and in the dominant species in the mixture. In contrast, the dominant species had a larger spacing response in the pure plots than in mixed plots.

L'influence de l'espacement et des espèces compétitrices sur la variation verticale du diamètre maximum des branches, la plus grosse branche par verticille, a été évaluée dans deux expériences d'espacement dans le centre de l'Oregon. Une expérience comportait un mélange de *Pinus contorta* Dougl. ex Loud. et de *Pinus ponderosa* Dougl. ex Laws. et l'autre un mélange d'*Abies grandis* (Dougl. ex D. Don) Lindl. et de *P. ponderosa*. Les impacts de l'autocorrélation sont devenus statistiquement non significatifs après l'introduction d'un seul effet aléatoire dû aux arbres. Bien que les variables individuelles telles que le diamètre, la hauteur et la longueur de la cime pouvaient expliquer la plupart des caractéristiques du peuplement, les modèles qui comportaient des variables explicites pour les traitements représentant l'espacement et la composition en espèces étaient supérieurs. Tous les profils de diamètre maximum des branches étaient curvilignes et s'élargissaient avec l'augmentation de l'espacement et de la hauteur relative des arbres. Pour les arbres en mélanges, les profils de diamètre maximum des branches étaient plus évasés pour les espèces dominantes et plus minces pour les espèces dominées que pour les mêmes espèces en peuplement pur avec le même espacement. Cependant, les profils de l'espèce dominée réagissaient davantage à l'augmentation de l'espacement en mélange que dans les parcelles adjacentes de peuplement pur et que l'espèce dominante en mélange. Au contraire, l'espèce dominante réagissait plus fortement à l'espacement en peuplement pur qu'en peuplement mélangé.

Gartner, B. L. 2002. Sapwood and inner bark quantities in relation to leaf area and wood density in Douglas-fir. *IAWA Journal* **23**(3): 267–285.

The relationships between leaf area and sapwood and inner bark quantities (widths, areas, and volumes) were studied in an attempt to understand the design criteria for sapwood quantity in eighteen 34-year-old Douglas-fir (*Pseudotsuga menziesii*) trees with a wide range of leaf areas, sapwood areas, and dry masses of leaf, xylem, bark, and branch. Cumulative leaf area increased from the tip to the base of the crown, and then was constant; none of the other variables had the same distribution, and so whereas there were many significant correlations, none of the factors can be related to leaf area in a simple, causal manner. Leaf area/sapwood area was extremely variable from tree to tree at a given height and within a tree from height to height. Sapwood width was relatively constant from the tip down the stem, supporting the hypothesis that sapwood quantity in this species is related to radial gas diffusion causing either a lethal buildup of CO_2 or a lethal depletion of O_2 at the sap/heart boundary. However, there was no significant correlation between leaf area and either total sapwood density (dry weight/green volume) or the average latewood density in the sapwood which were used as proxies for radial diffusion rate; further research on actual radial gas diffusion in green wood may be informative.

Gartner, B.L., North, E.M., Johnson, G.R., and Singleton, R. 2002. Effects of live crown on vertical patterns of wood density and growth in Douglas-fir. *Canadian Journal of Forest Research* **32**(3): 439–447.

It would be valuable economically to know what are the biological triggers for formation of mature wood (currently of high value) and (or) what maintains production of juvenile wood (currently of low value), to develop silvicultural regimes that control the relative production of the two types of wood. Foresters commonly assume the bole of softwoods produces juvenile wood within the crown and mature wood below. We tested that assumption by comparing growth ring areas and widths and wood density components of the outer three growth rings in disks sampled from different vertical positions of 34-year-old Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) trees. The 18 trees were sampled from one site and had a wide range of heights to live crown. Most of the variance (63–93%) in wood characteristics (growth ring area: total, earlywood, latewood; growth ring width: total, earlywood, latewood; latewood proportion: by area, width; and ring density: total, earlywood, latewood) was due to within-tree differences (related to age of the disk). Stepwise regression analysis gave us equations to estimate wood characteristics, after which we analyzed the residuals with a linear model that included whether a disk was within or below the crown (defined as the lowest node on the stem with less than three live branches). After adjusting for tree and disk position, only 2–10% of the residual variation was associated with whether the disk was in or out of the live crown. There were no statistically significant differences at $p = 0.05$ between a given disk (by node number) in versus out of the crown for any of the factors studied. Moreover, the wood density characteristics were not statistically significant at $p = 0.30$. This research suggests that there was no effect of the crown position on the transition from juvenile to mature wood as judged by wood density. Therefore, we found no evidence to support the concept that tree spacing and live-branch pruning have a significant effect on the cambial age of transition from juvenile to mature wood in Douglas-fir trees of this age.

Il serait utile, d'un point de vue économique, de savoir ce qui déclenche la formation du bois mature (considéré présentement comme ayant une grande valeur) et ce qui maintient la production de bois juvénile (considéré présentement comme étant de faible valeur), de façon à développer des régimes sylvicoles pouvant contrôler la production de chacun de ces deux types de bois. Les forestiers assument couramment que la tige des conifères produit du bois juvénile dans la cime et du bois mature dans la partie inférieure. Nous avons testé cette hypothèse en comparant les composantes de l'aire et de la largeur des cernes annuels ainsi que de la densité des trois cernes annuels extérieur dans chacun des disques prélevés à diverses positions en hauteur sur des douglas de Menzies (*Pseudotsuga menziesii* (Mirb.) Franco) âgés de 34 ans. Les 18 arbres ont été échantillonnés sur le même site et présentaient une grande variabilité dans la hauteur jusqu'à la cime. La plus grande partie de la variabilité (63–93%) dans les caractéristiques du bois (surface des cernes annuels: totale, bois initial, bois final; largeur des cernes annuels: total, bois initial, bois final; proportion de bois final: en surface et en largeur; et densité par cerne annuel: total, bois initial, bois final) provenait de différences intra-arbres (en relation avec l'âge correspondant aux disques). L'analyse de régression par degrés a fourni les équations permettant d'estimer les caractéristiques du bois, après quoi les résidus furent analysés avec un modèle linéaire prenant en compte le fait que les disques se trouvent dans la cime (définie comme étant le plus bas verticille contenant au moins trois branches vivantes) ou en dessous. Après ajustement par arbre et par position de disque, seulement de 2 à 10% de la variation résiduelle était associée à la position du disque, soit dans la cime ou plus bas. Nous n'avons pas trouvé de différence significative ($p = 0,05$), pour aucun des facteurs analysés, entre les disques (définis par numéro de verticille) qu'ils soient situés dans la cime ou en dessous. Qui plus est, les caractéristiques liées à la densité n'étaient pas significativement différentes, même au niveau de $p = 0,30$. Ces résultats laissent croire qu'il n'existe pas d'effet de cime dans la localisation ou dans la transition du bois juvénile vers le bois mature en ce qui concerne la densité du bois. Par conséquent, nous n'avons trouvé aucune preuve pour supporter l'idée que l'espacement ou l'élagage des branches vivantes puisse avoir un effet significatif sur l'âge cambial de transition entre le bois juvénile et le bois mature chez des douglas de Menzies de cet âge.

Gartner, B.L., Robbins, J.M., and Newton, M. 2005. Effects of pruning on wood density and tracheid length in young douglas-fir. *Wood and Fiber Science* **37**(2): 304–313.

To study whether pruning young Douglas-fir (*Pseudostuga menziesii* (Mirb.) Franco var. *menziesii*) hastens the transition from juvenile to mature wood, we investigated the effect on wood properties in an intensively managed young plantation in the Coast Range of Oregon. Ten years after trees were pruned to a fixed height (3.4 or 5.5 m), we investigated the effects on wood density (in 12 trees per pruning treatment, two or three treatment per age class, three age classes, and two heights for a total of 168 cores) and tracheid length (in four trees per treatment, one height and age class only, for 12 trees total). The trees were 13, 16, and 18 years old when pruned in 1988. Removal of 50% of the live crown in young trees caused a small 1-year decline in growth ring width at breast height, but removal of 30% of the live crown did not. In partial contrast, pruning caused no detectable effect on wood density at breast height, presumably because the branches were in the lower crown, and were not contributing much to the growth of the bole. Pruning caused a small increase in wood density at the upper height (5.3 m) in the youngest age class (for which this 5.5 m pruning would be removing vigorous live branch at this height) but not in the the medium age class (for which the pruning would be removing the lower live crown branches at this height) or in the oldest age class (for which there would have been no live branches at 5.5 m). Pruning the youngest trees caused a 3–4 year increase in tracheid length; but the effects that it had were the ones expected if pruning accelerated the transition from juvenile to mature wood. The larger benefit of pruning, especially if done early in rotation, is to shorten branch healing time and provide for a longer period of clear wood production.

Goble, B.C., and Bowling, C. 1993. *Five-Year Growth Response of Thinned Jack Pine near Atikokan, Ontario*. NWR Science and Technology Technical Note TN-23. Ontario Ministry of Natural Resources, Thunder Bay, Ontario, Canada.

Results of the Durie Lake jack pine (*Pinus banksiana*) thinning trial show that 5-year growth increments for diameter at breast height (cm, stem diameter at 1.3 m) and stem volume (dm^3/tree) are approximately 1.5 times greater in the thinned plots than the control. As a result of the increased growth rate, the thinned stands will be available for harvest sooner. In addition, thinning resulted in a narrower range of diameters and should result in a larger and more uniform tree size at harvest time, thereby reducing harvest costs. Trees in thinned plots had less visible damage, larger live crowns, and fewer stem and branch galls than in the control. *(Abstract prepared by compilers.)*

Godt, M.J.W., Hamrick, J.L., Edwards-Burke, M.A., and Williams, J.H. 2001. Comparisons of genetic diversity in white spruce (*Picea glauca)* and jack pine (*Pinus banksiana*) seed orchards with natural populations. *Canadian Journal of Forest Research* **31**(6): 943–949.

Genetic diversity within a white spruce (*Picea glauca* (Moench.) Voss.) seed orchard (consisting of 40 clones) and a jack pine (*Pinus banksiana* Lamb.) seed orchard (31 clones) was assessed and compared with genetic diversity in natural populations within the source area for the orchards. Genetic diversity was determined at 18 allozyme loci for seven white spruce populations and 27 loci for five jack pine populations, and the two orchards. Gene diversity maintained within the seed orchards ($H_e = 0.157$ for white spruce and 0.114 for jack pine) was similar to that found within the source area for each species ($H_e = 0.164$ and 0.114 for white spruce and jack pine, respectively). However, nine white spruce alleles and 12 jack pine alleles identified in the source area were not present in the seed orchards. These alleles occurred at low frequencies in the natural populations (mean frequency = 0.023 and 0.014 for white spruce and jack pine, respectively). Mean genetic identities between the seed orchards and their natural populations were high (>0.99), indicating that common allele occurrences and frequencies were similar between the orchards and their source area. One allele in the white spruce orchard and two in the jack pine seed orchard did not occur within the natural population samples. Simulations indicate that randomly reducing the number of clones within the seed orchards would decrease allelic richness slightly but would have little effect on overall gene diversity.

Les auteurs ont évalué la diversité génétique au sein d'un verger à graines d'épinette blanche (*Picea glauca* (Moench) Voss) comprenant 40 clones et d'un verger à graines de pin gris (*Pinus banksiana* Lamb.) comprenant 31 clones, pour la comparer à celle recensée chez des populations naturelles du territoire d'origine des clones de chaque verger. La diversité génétique fut évaluée pour 18 loci d'alloenzymes chez sept populations d'épinette blanche et pour 27 loci chez cinq populations de pin gris, ainsi que pour les deux vergers. La diversité génétique observée dans les vergers à graines (H_e = 0,157 pour l'épinette blanche et 0,114 pour le pin gris) était similaire à celle observée dans le territoire d'origine de chaque espèce (H_e = 0,164 et 0,114 pour l'épinette blanche et le pin gris, respectivement). Toutefois, neuf allèles d'épinette blanche et 12 allèles de pin gris recensés dans les territoires d'origine n'étaient pas présents dans les vergers. Ces allèles étaient peu fréquents chez les populations naturelles (fréquence moyenne = 0,023 et 0,014 chez l'épinette blanche et le pin gris, respectivement). Les valeurs moyennes d'identité génétique entre les vergers à graines et les populations naturelles correspondantes étaient élevées (>0,99). Ceci indique que la présence et la fréquence des allèles étaient similaires entre les vergers et les territoires d'origine correspondants. Un allèle d'épinette blanche et deux allèles de pin gris observés dans les vergers à graines n'étaient pas présents dans les échantillons des populations naturelles. Des simulations ont révélé que la réduction aléatoire du nombre de clones dans les vergers à graines entraînerait une légère réduction de la richesse allélique mais aurait peu d'effet sur la diversité génétique totale.

Gonzalez, J., Lum, C., and Munro, D. 1993. *Exploring the Use of Average Wood Relative Density of Lodgepole Pine Sites as a Predictor of MSR Yield*. Forintek Canada Corporation, Vancouver, British Columbia, Canada.

In order to determine whether knowledge of stand relative density could be useful to plan mill machine-stress-rated lumber production, this study measured lumber relative density of sawn lumber and machine-stress-rated lumber recovery at specified grades. Five sites of differing quality across the length of British Columbia were sampled. Lumber was visually inspected and machine stress rated. Wood samples were taken from the ends of the lumber sawn from the logs to determine basic density. Significant differences were found both within and between regions. Relative density decreased with height in the tree. Machine-stress-rating yield was significantly different for two sites within one geographic region. Bending stiffness was positively correlated to relative density but other factors influenced machine-stress-rating yield. Further study was recommended in order to determine whether field testing before harvest could facilitate mill scheduling. *(Abstract prepared by compilers.)*

Gonzalez, J.S. 1990. *Wood Density of Canadian Tree Species*. Information Report NOR-X-315. Natural Resources Canada, Canadian Forest Service - Northern Forestry Centre, Edmonton, Alberta, Canada.

Total-stem and breast-height wood density data from published and unpublished sources are presented for Canadian tree species grown in and outside of Canada. Calculations for mean density and coefficient of variation were made when necessary. Variations, geographic sources, and characteristics of sample trees are included to assist the reader in making comparisons with the density values presented. Sampling locations, methods of sampling, and density calculations are described. To assist the reader in converting wood density values from green-volume to ovendry-volume basis, the conversion formula and a table of percent volumetric shrinkage are also presented.

Les résultats d'une compilation des données disponibles, publiées ou inédites, sur la densité du bois, pour l'ensemble de la tige et à la hauteur de poitrine, d'arbres canadiens poussant au Canada ou ailleurs sont présentés. Les moyennes et les coefficients de variation ont été calculés au besoin. Pour rendre les comparaisons plus faciles, les variations, les sources géographiques et les caractéristiques des arbres-échantillons sont indiquées. Des détails sur les lieux et les méthodes d'échantillonnage ainsi que sur le calcul de la densité sont aussi inclus. Enfin, une formule de conversion et une table des pourcentages de retrait volumétrique sont fournies pour aider le lecteur à convertir les valeurs de la densité à l'état vert aux valeurs correspondantes à l'état anhydre.

Gonzalez, J.S., and Kellogg, R.M. 1978. *Evaluating Wood Specific Gravity in a Tree Improvement Program*. Information Report VP-X-183. Department of Fisheries and Environment, Western Forest Products Laboratory, Vancouver, British Columbia, Canada.

This report describes the procedures used at the Western Forest Products Laboratory for assessing the specific gravity of increment cores from plus and dominant trees selected by members of the Tree Improvement Board of British Colombia. The outer half of radial increment cores taken at breast height were analyzed for specific gravity using the maximum-moisture-content method. The method of analysis and presentation of the data to the board members are described and illustrated. Estimates of the mean core specific gravity and variance by seed zones in B.C. are given for western hemlock, interior spruce, Sitka spruce and amabilis fir, to serve as a basis of comparison in any further evaluation of these species using the method described. It is recommended that genetic selection for high wood specific gravity be a part of any tree improvement program for coniferous species, where the primary use is for pulp or structural lumber. For the species reported, it should be possible to accomplish this without sacrificing the goal of improved volume growth, if the lower inclusion limit is the mean specific gravity for the species.

Les auteurs décrivent les méthodes utilisées au Laboratoire des produits forestiers de l'ouest pour évaluer le poids spécifique des carottes d'arbres plus et dominants choisis par des membres du Tree Improvement Board en Colombie-Britannique. On mesura le poids spécifique de la moitié supérieure des carottes radiales prélevées à hauteur de poitrine en utilisant la méthode de teneur maximale en humidité. Les auteurs décrivent et illustrent la méthode d'analyse et la présentation des données aux dits membres. Ils fournissent des estimations du poids spécifique moyen et la variance des moyennes pour des zones spécifiques en Col.-Brit. et comprenant la pruche de l'ouest, les épinettes de l'intérieur de la province, l'épinette de Sitka et le sapin amabilis. Elles serviront de base de comparaison lors d'estimation future et identique. Lors des programmes d'amélioration génétique, les auteurs recommandent que l'on choisisse génétiquement du bois de conifères dont le poids spécifique est le plus élevé lorsqu'on le destine à la fabrication de pâte à papier ou de bois de charpente. Concernant les espèces ci-dessus, on devrait pouvoir atteindre ce but sans sacrifier la croissance en volume si la limite minimale d'acceptation était le poids spécifique de l'espèce.

Gottschalk, K.W. 1995. Using silviculture to improve health in northeastern conifer and eastern hardwood forests. Pages 219–226 *in* L.G. Eskew. *Forest Health through Silviculture*. 8–11 May 1995, Mescalero, New Mexico. United States Department of Agriculture, Forest Service, Fort Collins, Colorado, USA.

The traditional role of silviculture was to manipulate forest vegetation to provide wood and related forest products for humanity's benefit over a long period. Silviculturists soon noticed that such manipulation influenced other components of the ecosystem. In particular, insects and diseases responded dramatically to silvicultural practices—both positively and negatively. The use of silviculture to improve the health of northeastern conifers is most used in spruce–fir forests for spruce budworm, white pine and mixed white pine–oak forests for white pine blister rust and white pine weevil and jack pine forests for jack pine budworm. Major pests that can be treated silviculturally in eastern hardwood forest types include beech bark disease in northern hardwoods, gypsy moth and oak decline in oak–hickory types, and defoliators in several types. The long term role of silvicultural treatments in maximizing forest health needs to be evaluated for its influence on other ecosystem component. *(Source: U. S. Department of Agriculture, Forest Service.)*

Goudie, J.W., and Parish, R. 2008. Modelling the impact of silviculture treatments on the wood quality of interior spruce. *Forrex Series* **11**(2): 13–14.

Concern over the quality of wood from second-growth interior spruce has led to the development of equations to predict the average inside bark diameter of branches and maximum knot size along the stem. These equations were linked with information for predicting lumber distributions. The equations were incorporated into existing forest management models used in British Columbia. *(Abstract prepared by compilers.)*

Green, D.W., Falk, R.H., and Lantz, S.F. 2001. Effect of heart checks on flexural properties of reclaimed 6 by 8 Douglas-fir timbers. *Forest Products Journal* **51**(7): 82–88.

A sampling of nominal 6- by 8-inch (standard 140- by 184-mm) Douglas-fir timbers was obtained from an industrial military building in Minnesota. Thirty selected timbers had heart checks (boxed heart splits), which are characteristic of most old timbers installed in dry locations. Sixty selected timbers did not have heart checks. Most of the beams would grade as Select Structural Beams and Stringers by current grading rules. The modulus of elasticity (MOE) of the unchecked beams was greater than the allowable values given in the National Design Specification, but the modulus of rupture (MOR) was low. Analysis of the results suggested that heart checks decrease the mean MOR about 15 percent but have no direct effect on MOE. A good correlation was found between MOE determined by longitudinal stress wave techniques and that determined in static edgewise bending. Results suggest that the feasibility of developing mechanical grading systems for reclaimed timbers might be useful for on-site grading. Additional data are needed on wider beams with heart checks than those used in this study to confirm this hypothesis.

Green, D.W., Gorman, T.M., Evans, J.W., Murphy, J.F., and Hatfield, C.A. 2008. Grading and properties of small-diameter douglas-fir and ponderosa pine tapered logs. *Forest Products Journal* **58**(11): 33–41.

Approximately 375 Douglas-fir and ponderosa pine logs, 3 to 6 inches in diameter, were tested in third-point bending and in compression parallel to the grain. The moisture content at time of test was about 14 percent. Good correlations were found between the modulus of elasticity (MOE) in static bending and those obtained by transverse vibration. Good correlations were also found between modulus of rupture (MOR) and MOE. A species independent relationship was established between ultimate compression stress parallel to the grain and MOR. A mechanical grading system previously developed for 9-inch diameter logs was shown applicable to small-diameter logs.

Green, D.W., Winandy, J.E., and Kretschmann, D.E. 1999. Mechanical properties of wood. Chapter 4 *in* Anonymous. *Wood Handbook: Wood as an Engineering Material.* General Technical Report FPL-GTR-190. U.S. Department of Agriculture, Forest Service, Forest Products Laboratory, Madison, Wisconsin, USA.

The mechanical properties presented in this chapter were obtained from tests of small pieces of wood termed "clear" and "straight grained" because they did not contain characteristics such as knots, cross grain, checks and splits. These properties were represented as the average mechanical properties of the species. Information is provided, where possible, of the nature and magnitude of variability in properties. A discussion of the effect of growth features such as knots and slope of grain on clear wood properties is included. *(Source: US Department of Agriculture, Forest Service.)*

Grigal, D.F., and Sucoff, E.I. 1966. Specific gravity variation among thirty Jack pine plots. *Tappi* **49**(11): 497–498.

The variation of specific gravity within jack pine trees in Wisconsin was investigated. Specific gravity was found to increase as site index increased. The significant variation in specific gravity was largely attributed to effects caused by height to live crown, not age or density. *(Abstract prepared by compilers.)*

Groot, A., Brown, , K.M., Morrison, I.K., and Barker, J.E. 1984. A 10-year tree and stand response of jack pine to urea fertilization and low thinning. *Canadian Journal of Forest Research* **14**(1): 44–50.

This study examined the 10-year effects of a light (20% basal area removed) low thinning and urea fertilization (336 kg N/ha) on a 45-year-old *Pinus banksiana* Lamb. stand. Thinning had no effect other than salvaging potential mortality, while fertilization resulted in an average annual gross volume growth response of about 2 m^3 ha^{-1} $year^{-1}$. Volume growth response to fertilization was greatest in the largest diameter trees, and continued until 10 years after treatment. Growth response did not begin until the second growing season after treatment. There were indications that fertilization had positive effects on form factor.

L'étude porte sur les effets, observés pendant 10 ans, d'une éclaircie faible (20% de la superficie terrière) par le bas et d'une fertilisation à l'urée (336 kg N/ha) sur un peuplement de pin gris (*Pinus banksiana* Lamb.) de 45 ans. L'éclaircie n'a pas eu d'autre effet que de diminuer la mortalité potentielle, tandis que la fertilisation s'est traduite par une croissance annuelle brute en volume d'à peu près 2 m^3 ha^{-1} $année^{-1}$. Cet effet a été maximal chez les arbres à plus fort diamètre et s'est maintenu 10 ans après le traitement. Il n'a pas commencé à se faire sentir avant la deuxième saison de croissance après le traitement. Il y a des indications que la fertilisation a des effets positifs sur le coefficient de forme.

Groot, A., and Saucier, J.P. 2008. Volume increment efficiency of *Picea mariana* in northern Ontario, Canada. *Forest Ecology and Management* **255**(5–6): 1647–1653.

Volume increment efficiency (VIE), a measure related to radiation use efficiency, is defined in this study as the annual total stemwood volume increment divided by the amount of global shortwave radiation intercepted by tree crowns during the photosynthetic season. We examined the influence of ecosite and of stand density on the VIE of *Picea mariana* in northern Ontario, Canada, using two data sets. The VIE of *P. mariana* differed significantly among ecosites, ranging from 0.071 dm^3 GJ^{-1} on poor-quality peatland sites to 0.345 dm^3 GJ^{-1} on fertile mineral soil sites. The VIE of *P. mariana* increased with increasing stand basal area and generally decreased with increasing radiation interception trees, likely because allocation to branches is less in small trees and dense stands. VIE represents a straightforward way to relative volume growth to radiation interception in individual tree growth models.

Grotta, A.T., Leichti, R.J., Gartner, B.L., and Johnson, G.R. 2005. Effect of growth ring orientation and placement of earlywood and latewood on MOE and MOR of very-small clear Douglas-fir beams. *Wood and Fiber Science* **37**(2): 207–212.

ASTM standard sizes for bending tests (either 50–50 mm or 25–25 mm in cross-section) are not always suitable for research purposes that characterize smaller sections of wood. Moreover, the ASTM standards specify loading the sample on the longitudinal–tangential surface. If specimens are small enough, then the effects of both growth-ring orientation and whether earlywood or latewood is on the upper and lower surfaces could affect values of modulus of elasticity (MOE) and modulus of rupture (MOR). The objectives of this study were to assess the effects of growth-ring orientation and latewood/earlywood location on bending properties of Douglas-fir specimens (10–10–150 mm). MOE did not differ with ring orientation, and MOR was about 5% higher when specimens were loaded on the radial rather than the tangential surface (MOE-LT vs. MOE-LR, respectively). The choice of growth-ring orientation did not affect the relative ranking of trees with respect to MOR or MOE. As expected, the variation of MOR and MOE was lower if the loads were applied to the longitudinal–radial surface than the longitudinal–tangential surface. Thus, rather than following the ASTM standard, within-tree variation measured on very small bending specimens can be minimized if loads are applied to the longitudinal-radial surface. When specimens were loaded on the longitudinal–tangential surfaces, there was an effect on both MOE-LR and MOR-LR of whether the top and/or bottom surfaces were earlywood or latewood. The wood type had a large effect on both MOE-LR and MOR-LR when it was the compression surface rather than the tension surface. This result suggests that variance in MOE and MOR measurements in very small specimens can be reduced by tracking whether the top and bottom surfaces are earlywood or latewood.

Guernsey, F.W., and Dobie, J. 1966. *Properties and Utilization of Lodgepole Pine in Western Canada.* Publication No. 1143. Natural Resources Canada, Canadian Forest Service - Headquarters, Ottawa, Ontario, Canada.

In the interior of British Columbia, lodgepole pine, because of its small size at maturity, has in the past been ignored by logging operators in favour of the larger growing species. In Alberta, lodgepole pine, in common with other species is considerably under-utilized, the actual annual cut of conifers in Alberta in a twelve-month period of 1963-64 being only 16 percent of gross allowable annual cut.

In recent years however, advances in logging and milling technology have made the harvesting of small trees more economically attractive than previously and in interior British Columbia the annual cut of lodgepole pine increased by 300 per cent in the period from 1954-64. A large proportion of the timber volumes in Alberta are in the comparatively under-developed northern portion of the Province, but as this area is gradually settled the utilization of all species will increase.

Lodgepole pine is being used and is well suited for a wide variety of products, among them being lumber, pulp, railway ties, utility poles, mining timbers and assorted minor uses such as fence-posts, orchard props, corral rails, and Christmas trees. Historically, the major uses for lodgepole have been for railway ties and mine timbers, but in recent years in Alberta and British Columbia, its use as a lumber species has increased to the extent now of about 70% of its utilization.

Most of the lumber produced from lodgepole pine in western Canada is dimension lumber and is mixed and sold with that of spruce and balsam. Its strength properties, however, are similar to jack pine and superior to both spruce and balsam.

It has been found suitable for pulping and the expansion of the pulp industry in the interior of British Columbia with attendant increases in population and services should contribute considerably to continue growth in the utilization of this species for pulp and lumber.

Dans l'intérieur de la Colombie-Britannique, le pin de Murray, en raison de sa petite taille, même à maturité, a été négligé par les exploitants forestiers en faveur des autres essences de grande taille. En Alberta également, le pin de Murray ainsi que plusieurs autres conifères sont loin d'être exploités à bon escient, la coupe annuelle de conifères 1963-1964) dans la province n'ayant pas dépassé 16 p. 100 de la coupe brute admissible.

Toutefois au cours dernières années, les progrès réalisés dans la technique d'abattage et d'usinage out rendu l'exploitation des essences de petite taille beaucoup plus économique et avantageuse, de sorte que dans l'intérieur de la Colombie-Britannique la coupe annuele globale de pin de Murray a triplé de 1954 à 1964. Une grande partie de forêt exploitables de l'Alberta se trouvent dans le nord relativement peu peuplé de la province, mais il ne fait pas de doute que toutes les essences de cette région seront exploitée à fond, au fur et à mesure qu'elle se peuplera.

Le pin de Murray convient à la fabrication de toutes sortes de produits forestiers, notamment du bois d'œuvre, de la pâte à papier, des traverses de chemin de fer, des poteaux électriques et téléphoniques, des bois de mine, ainsi que des piquets de clôture, des tuteurs d'arbres fruitiers, des barres d'enclos à bestiaux et des arbres de Noël. Dans le passé, on se servait surtout de pin de Murray pour en faire des traverses de chemin de fer et des bois de mine, mais depuis plusieurs années, on en fait du bois d'œuvre en Alberta et en Colombie-Britannique, au point que quelque 70 % de la coupe de cette essence sert à présent à la fabrication de bois d'œuvre.

La plupart des sciages de pin de Murray produits dans l'ouest du Canada sont des bois d'échantillon et ils se vendent mêlés aux bois d'œuvre d'épinette et de sapin baumier. Pourtant, ses qualités de résistance sont supérieures à celles de l'épinette et du sapin baumier, et à cet égard il peut même rivaliser avec le pin gris.

Le pin de Murray convient parfaitement à la fabrication de pâte et du papier dans l'intérieur de la Colombie-Britannique, qui entraînera un accroissement de la population et la multiplication des services, contribuera-t-elle beaucoup à la mise en valeur de cette essence par les industries du papier et du bois d'œuvre.

Gupta, R., Basta, C., and Kent, S.M. 2004. Effect of knots on longitudinal shear strength of Douglas-fir using shear blocks. *Forest Products Journal* **54**(11): 77–83.

An investigation of the effect of knots on the parallel to grain shear strength of wood was conducted using shear block specimens. This included testing of 40 specimens with knots and 40 matched clear specimens. The 40 knot specimens tested included 20 knot specimens with knots parallel to the shear plane as well as 20 specimens with knots perpendicular to the shear plane. Twenty matched specimens of clear wood were tested for each of the two orientations of the knot in the shear plane. All specimens were Douglas-fir and the tests were conducted according to ASTM D 143. Statistical analysis of the data showed no significant difference in the mean shear strength of clear and knotted specimens.

Hale, J.D. 1955. Thickness and density of bark: trends of variation for six pulpwood species. *Pulp and Paper Magazine of Canada* **56**(13): 113–117.

The bark of balsam fir (*Abies balsamea* (L.) Mill.), black spruce (*Picea mariana* (Mill.) B.S.P.), white spruce (*Picea glauca* (Moench) Voss), jack pine (*Pinus banksiana* Lamb.), aspen (*Populus tremuloides* Michx.), and white birch (*Betula papyrifera* Marsh.) was examined for thickness and basic density. Thickness was measured with diameter tape both outside bark and inside after peeling, after felling, at stump height, and at 100-inch intervals to the top of the bole. Although considerable variation can occur, bark tends to increase in thickness with age of the tree and decrease in thickness with height in the tree. Bark density also tends to decrease with height in the tree. White birch bark density was found to decrease slightly with age of the tree. It was noted that, as bark thickness was measured by diameter tape, no allowance was made for crevices, and so thickness may be overstated and density understated. *(Abstract prepared by compilers.)*

Hale, J.D., and Brophy, M.J. 1923. The effect of growth rate on strength of softwoods. *Canada Lumberman* **43**(2): 35–42.

The results of investigating the structure and mechanical properties of wood at the Forest Products Laboratories of Canada indicates that the growth-rate has a very great effect on the physical properties of timber. It is probable that differences in weight of wood from various parts of the tree are due chiefly to differences in growth-rate. From the discussion of rate of growth in softwoods we may draw the following conclusion: -

1) The strength of timber is approximately proportional to its density.
2) The density of timber (and therefore its strength) depends, to a great extent, upon the rate of growth of the tree which produces it.
3) There is an optimum growth-rate for the production of the best quality.
4) The optimum growth-rate may be quite different in different softwood species.
5) Softwoods, such as Douglas-fir, larch, and certain hard pines, which have a high proportion of hard summerwood, have an optimum rate of growth which is more rapid than the optimum rate for such woods as spruce, balsam fir and white pine which have less conspicuous summerwood.
6) The falling-off in strength due to very slow growth is less than the reduction due to very rapid growth.

Hale, J.D., and Fensom, K.G. 1931. *The Rate of Growth and Density of the Wood of White Spruce*. Department of the Interior, Forest Service Circular No. 30, Ottawa, Ontario, Canada.

Four hundred white spruce trees were analyzed in this study covering Saskatchewan and Manitoba. There is a tendency for white spruce with narrow rings to be heavier than wood with wide rings, a situation modified by the fact that there is also the tendency toward increasing density of wood with increased height of the tree, wood at highest levels being found heaviest. The variability in white spruce, which is typical of the fairly uniform softwoods, is not very great, and further tests on the heavy softwoods should show more striking differences in quality due to differences of position in the tree and differences in rate of growth.

Hale, J.D., and Prince, J.B. 1940. *Density and Rate of Growth in the Spruces and Balsam Fir of Eastern Canada*. Department of Mines and Resources Canada, Forest Service Bulletin 94, Ottawa, Ontario, Canada.

This report of a study of the most important pulpwood species of eastern Canada (the spruces (*Picea* spp.) and balsam fir (*Abies balsamea*)) shows that fairly wide variation in the mean density of wood may be found in the same species in stands of comparable type grown in different locations, and that such variations in density are intimately related to recognizable structural characteristics of the wood, which, in turn, are normally related to variations in the rate of growth. Therefore, there is a general relationship between the rate of growth and density that normally causes wood of these species with wide annual rings to be light in weight, whereas wood with narrow rings tends to be heavy. The results of tests are presented in graphic form to show this relationship. *(Abstract prepared by compilers.)*

Hall, J.P. 1984. *The Relationship Between Wood Density and Growth Rate and the Implication for the Selection of Black Spruce (*Picea mariana *(Mill.) B.S.P.) Plus Trees*. Information Report N-X-224. Natural Resources Canada, Canadian Forest Service - Newfoundland Region, St-John's, Newfoundland, Canada.

The relationship between growth rate and wood density was examined in 12 natural stands of black spruce in Newfoundland. Growth rate and density were not closely related. No geographical trends in wood density or growth rates were observed and within-stand variation was considerably greater for growth rate than for density. A method of selection of plus trees for a tree improvement program is suggested which combines the factors of rapid growth rate and high wood density in the selected trees.

On a étudié le rapport entre le taux de croissance et la masse volumique du bois dans 12 peuplements naturels d'épinette noire à Terre-Neuve. Ces deux paramètres n'étaient pas étroitement reliés, et aucune tendance géographique n'a été observée. Dans un même peuplement, le taux de croissance variait beaucoup plus que la masse volumique. On propose, en vue d'un programme d'amélioration des arbres, une méthode de sélection des arbres plus qui combine le choix du taux de croissance rapide et de la masse volumique élevée.

Hanley, D.P., Oliver, C.D., Maguire, D.A., Briggs, D.G., and Fight, R.D. 1995. *Forest Pruning and Wood Quality of Western North American Conifers.* University of Washington, College of Forest Resources, Seattle, Washington, USA.

These proceedings examine the practice of pruning as it relates to biodiversity, wood quality, and economics. The second part focuses on the supply and demand for clear wood and lastly, the third section gives an overview of the policies and environmental concerns about pruning. It also discusses some operational experiences and the biological impact of pruning on trees. *(Abstract prepared by compilers.)*

Hann, D.W. 1999. An adjustable predictor of crown profile for stand-grown Douglas-fir trees. *Forest Science* **45**(2): 217–225.

Methods to predict the crown width of a species in different geographic ranges were developed using the largest crown width (LCW) measurements in different populations of the same species. The crown was divided into two areas; one occurring above the LCW and one occurring below. The crown shapes that resulted from the equations for both sections varied widely. The results of the equations were verified with ocular and physical measurements before and after felling. *(Abstract prepared by compilers.)*

Hansen, L.W., Knowles, R.L., and Walford, G.B. 2004. Residual within-tree variation in stiffness of small clear specimens from *Pinus radiata* and *Pseudotsuga menziesii*. *New Zealand Journal of Forestry Science* **34**(2): 206–216.

Static bending of small clear specimens is one of the most commonly used methods for assessing the stiffness (modulus of elasticity, MoE) of sawn timber and trees. Small clear specimens have traditionally been cut at breast height from the same growth rings on opposing radii, thus seeking to minimize the radial and longitudinal variation. The remaining (residual) variation between small clear specimens determines the precision of the estimate of the tree mean MoE, but has rarely been analyzed in detail because the method originally was not intended for tree-level analysis. To investigate this, axial stiffness measurements previously collected from small clear specimens taken from opposing radii at breast height on New Zealand-grown *Pinus radiata* D. Don and *Pseudotsuga menziesii* (Mirb.) Franco (Douglas fir) were reanalyzed to ascertain the magnitude of the residual variation at breast height. Expressed as coefficient of variance between small clear specimens from the same radial position (growth ring), the variation ranged from 8% to 32% for *P. radiata* and from 7% to 13% for Douglas fir. Using two small clear specimens, the associated margin of error for estimates of mean stiffness of individual trees ranged from 40% to 140% for *P. radiata* and 40% to 60% for Douglas fir. It is recommended that at least four small clear specimens are used (margins of error of 10–40%) when estimating the mean MoE of individual trees from small clear specimens extracted at the same height from the same growth ring.

Hapla, F. 1997. How to bring into accord the silvicultural management and the end-users' interests in case of the douglas-fir. Pages 3–8 *in* S. Y. Zhang, R. Gosslin, and G. Chauret, editors. *Timber Management Toward Wood Quality and End-Product Value*. CTIA/IUFRO International Wood Quality Workshop, Quebec City, Quebec, Canada. Forintek Canada Corporation, Sainte-Foy, Quebec, Canada.

This paper presents the challenges of providing the optimal products to the end-users (sawmills, pulp and paper, panel industry). It provides options for Douglas-fir timber management to find a compromise between volume production and timber quality. It covers many silvicultural systems and their effects on wood quality and yield. *(Abstract prepared by compilers.)*

Harrington, T.B., Harrington, C.A., and DeBell, D.S. 2009. Effects of planting spacing and site quality on 25-year growth and mortality relationships of Douglas-fir (*Pseudotsuga menziesii* var. *menziesii*). *Forest Ecology and Management* **258**(1): 18–25.

Growth and mortality of coast Douglas-fir (*Pseudotsuga menziesii* var. *menziesii*) were studied for 25 years after planting seedlings at 1–6-m spacings on a site of moderate quality in the western Cascade Mountains of Washington. Responses were compared to those from two other studies representing high and low site qualities. Third-year height did not differ among spacings ($P = 0.80$), providing no evidence that close spacing stimulated early growth. Piecewise regression identified the onset of competition-induced mortality when stand density index (SDI [Reineke, L.H. 1933. Perfecting a stand density index for even-aged forests. *Journal of Agricultural Research* **46**, 627–638]) exceeded 52% (S.E. = 4.6) of the species' maximum or when average crown ratio (CR) declined below 52% (S.E. = 0.9). For a range of SDI values, CR averaged 2–7% points greater at the high-quality site than at the moderate-quality site. In a regression analysis of combined data from the moderate- and high-quality sites, relative values of average stem diameter and stand volume (% of maximum values observed per site) 23–25 years after planting increased and decreased with planting spacing, respectively ($R^2 = 0.97$ and 0.91, respectively). Intersection of these relationships at 3-m spacing indicated a point of equivalent relative development of tree size and stand yield. For a range of site qualities, stands planted at 3-m spacing: (1) maintained tree vigor (CR≥50%) and stability (average height:dbh ratio <90), (2) experienced little or no competition-induced mortality through age 25 years, and (3) allocated 25-year growth equitably to development of tree size and stand yield, thereby providing a desirable starting point for subsequent management.

Harris, G. 1993. Comparison of northern softwood and southern pine fiber characteristics for groundwood publication papers. *Tappi* **76**(6): 55–61.

As more mills attempt to produce groundwood paper for publications, competition has heightened. This review examines the differences in fiber attributes between southern pines (*Pinus taeda* L.) and northeastern softwoods (*Picea glauca* Moench Voss, *Picea mariana* (Mill.) B.S.P., *Abies balsamea* (L.) Mill., *Tsuga canadensis* (L.) Carr., *Pinus strobus* L., and *Pinus resinosa* Ait.). Attributes such as fiber coarseness, cell wall thickness, percentage of latewood, and fiber diameter are tallied and discussed. It was generally concluded that southern pines make adequate publication paper, although with slightly lower conventional quality characteristics. Juvenile wood, as harvested from southern pine plantations, results in lower strength but higher opacity and smoothness. Publication paper from groundwood pulp from the northeast has lower costs related to lower specific energy consumption, lower inclusion of kraft pulp to modify paper strength qualities, and lower chemical bleaching costs. It was recommended that northeastern mills focus on paper grades requiring high brightness, low basis weight, and uncoated grades to maximize their competitive advantages. *(Abstract prepared by compilers.)*

Harris, J.M. 1993. Wood quality: forest management and utilization Pages 560–583 *in* Anonymous. *Primary Wood Processing: Principles and Practice*. Chapman and Hall, London, UK.

In this chapter, six species or species families of commercial significance were highlighted and their advantages and disadvantages illustrated to emphasize the importance of a thorough understanding of impact of species, genetics, environment, and silviculture on wood utilization outcomes. Of some 500 species of eucalyptus, only about three, *Eucalyptus delegatensis* (R. T. Bak.), *E. obliqua* (L'Herit.), and *E. regnans* (F. Muell.), are widely planted. They are known to have rapid growth rate, resulting in very juvenile wood used in conversion. Eucalyptus species are known for large between-tree variation, and there is considerable provenance x site variability. European oaks (*Quercus robur* L. and *Q. petraea* (Mattuschka) Lieb.) are ring porous with wide rays and tyloses-occluded vessels. The wood is strong, stable, and durable. Site, silviculture, and genetics can influence the characteristics of these oaks. Teak (*Tectonis grandis* Linn.) is also widely valued for its wood properties, and virgin wood availability is now limited. Second-growth teak, faster grown and younger, does not necessarily possess the desirable characteristics. The southern pines (*Pinus palustris* Mill., *P. echinata* Mill., *P. taeda* L., and *P. elliottii* Engelm.) are known for their strength characteristics, but density varies throughout their considerable range. Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) is another species important for its structural applications. Vast differences, however, exist between the wood of virgin Douglas-fir, which can be up to 700 years old, and second-growth plantation wood. The fact that plantation-grown and virgin wood of the same species or grown in different regions can be so different that they should, in processing terms, be considered to be different wood, underscores the need to conduct provenance, environment, and silvicultural practice testing before selection and the necessity of including wood-property testing in the protocol. The chapter concludes with a call for integration of research and management of tree growth, harvesting, conversion, utilization, and marketing. *(Abstract prepared by compilers.)*

Hartmann, H., Beaudet, M., and Messier, C. 2008. Using longitudinal survival probabilities to test field vigour estimates in sugar maple (*Acer saccharum* Marsh.). *Forest Ecology and Management* **256**(10): 1771–1779.

Tree mortality is a major force driving forest dynamics. To foresters, however, tree mortality is often considered a loss in productivity. To reduce tree mortality, silvicultural systems, such as selection cuts, aim at removing trees that are more likely to die. In order to identify trees with higher risks of mortality, field classifications are employed that assess vigour based on external characteristics of trees. We used a novel longitudinal approach for estimating survival probabilities based on ring-width measurements, initially developed by Bigler and Bugmann [Bigler, C., Bugmann, H., 2004. Predicting the time of tree death using dendrochronological data. *Ecol. Appl.* **14** (3), 902–914], to parameterize a survival probability model for sugar maple (*Acer saccharum* Marsh.) and to test whether field-assessed tree vigour classes corroborated by survival probabilities determined from radial growth history. Data from 56 dead and 321 live sugar maples were collected in stands in western Quebec (Canada) that had undergone a selection cut ≈ 10 years prior to sampling. Our results showed that tree vigour established from external defects and pathological symptoms, using the classification of Boulet [Boulet, B., 2005. Défauts externes et indices de la carie des arbres; guide d'interprétation. Publication du Québec, Sainte-Foy, Quebec. 291 p.], is partially corroborated by growth-driven survival probabilities. Moribund trees had lower survival probabilities than vigorous trees over several years in the period prior to vigour assessment. Intermediate vigour classes showed less obvious tendencies, but this may be due to the growth-independent nature of some defects used for their classification. Although the timing of tree death may not be correctly predicted by the vigour classification (i.e., our results suggest that time of death generally was overestimated), its general agreement with survival probabilities determined from growth series make it a useful tool for tree selection in sugar maple stands under selection management.

Hatton, J.V. 1993. Kraft pulping of second-growth jack pine. *Tappi* **76**(5): 105–113.

Kraft pulping, fiber, and handsheet properties were used to assess the yield and quality of unbleached kraft pulps from second-growth jack pine (*Pinus banksiana* Lamb.). Three trees each from Fort Coulonge and Cote Jaune, Quebec and from Cains River, New Brunswick were sampled. One tree each of low, medium, and high wood density were taken from each site. Bolts were separated into top wood, juvenile wood, and mature wood. Each was pulped using the same kraft pulping parameters. Fibers were analyzed for fiber length, and the pith-to-bark distribution was plotted. Handsheets were prepared and tested for bulk, mechanical, and optical properties. Juvenile wood yield was lower and required more alkali. Juvenile fibers were finer than mature fibers. Mass-weighted average length of fibers increased rapidly for the first 20 years of growth and then continued to increase up to 50 years, but at a slower rate. At all levels of beating, juvenile fibers produced a more dense handsheet than mature fibers. Top wood fibers produced handsheets with better tensile and burst indices. Beaten mature fiber pulps were stronger and freer than juvenile fiber pulps. Use of fast-grown jack pine for kraft pulping will, without process modification, result in lower production, but the juvenile fiber characteristics, notably fiber fineness, provide an opportunity for new paper properties. *(Abstract prepared by compilers.)*

Hatton, J. V., and Cook, J. 1990. Managed douglas-fir forests. IV. Relationships between wood, fibre, pulp and handsheet properties. Pages 51–66 *in* Anonymous. *Annual Meeting - Technical Section, Canadian Pulp and Paper Association, Preprints*. January, Montreal, Quebec, Canada. Pulp and Paper Research Institute of Canada, Pointe-Claire, Quebec, Canada.

Fifty-year-old plantation Douglas-firs were used in order to determine the relationship between wood, fiber, pulp, and handsheet properties. It is concluded that second-growth Douglas-fir is well suited for kraft and mechanical pulps. *(Abstract prepared by compilers.)*

Hatton, J.V., and Hunt, K. 1990. Chemical properties of juvenile and mature wood from second growth jack pine. Pages 861–871 *in* Anonymous. *Proceedings of the TAPPI Pulping Conference*. Toronto, Ontario, Canada, 14–17 October 1990. TAPPI Press, Atlanta, Georgia, USA.

In this study, the variation in within-tree chemistry of second-growth jack pine (*Pinus banksiana* Lamb.), three trees each from Fort Coulonge and Cote Jaune, Quebec and Cains River, New Brunswick were investigated. One low-, medium-, and high-density tree was selected from each site. Bolts were divided into juvenile, mature, and top wood. Moisture content, density (TAPPI T18 m-53), extractives content by Sohxlet extraction, Klason lignin content, 1% caustic solubility, and carbohydrate analysis were performed. Significant between- and within-tree variation was found for density. Juvenile wood had consistently lower density, although the greatest juvenile wood density was similar to the lowest mature wood density on the same site. Juvenile wood had consistently lower moisture content and highest extractive content and 1% caustic solubility. Juvenile

Klason lignin content was higher than that for top wood, but similar to that for mature wood. Top wood had higher arabinose and xylose contents than mature wood. It was concluded that selecting for high density trees should result in no loss of pulp yield. *(Abstract prepared by compilers.)*

Hatton, J.V., and Johal, S.S. 1996. Mechanical pulping of commercial thinning of six softwoods from New Brunswick. *Pulp and Paper Canada* **97**(12): 93–97.

Six plantation-grown softwoods (tamarack (*Larix laricina* (Du Roi) K. Koch), Norway spruce (*Picea abies* Karst.), jack pine (*Pinus banksiana* Lamb.), black spruce (*Picea mariana (*Mill.) B.S.P.), white spruce (*Picea glauca* (Moench) Voss), and red spruce (*Picea rubens* Sarg.)) were tested to determine whether their properties differed from mature old-growth trees. Both chemithermomechanical pulps and thermomechanical pulping process were used for the analysis. There were no obvious differences in the use of second-growth trees versus old growth. *(Abstract prepared by compilers.)*

Hazenberg, G., and Yang, K.C. 1991. Sapwood/heartwood relationships with tree age in balsam fir. *International Association of Wood Anatomists Bulletin* **12**(1): 95–99.

One hundred and one balsam fir (*Abies balsamea* (L.) Mill.) samples were collected from a variety of stand densities from trees aged 4 to 85 years to study sapwood–heartwood relationships with tree age on the basis of five response variables, including number of sapwood and heartwood rings, sapwood and heartwood width, and sapwood basal area. It was found that heartwood expanded more rapidly than sapwood. *(Abstract prepared by compilers.)*

Heger, L. 1974. Longitudinal variation of specific gravity in stems of black spruce, balsam fir, and lodgepole pine. *Canadian Journal of Forest Research* **4**(3): 321–326.

The relationship between disc specific gravity (dependent variable) and relative disc height was investigated for 50 black spruce (*Picea mariana* (Mill.) B.S.P.), 50 balsam fir (*Abies balsamea* (L.) Mill.), and 36 lodgepole pine (*Pinus contorta* Dougl. var. *latifolia* Engelm.). The sample trees represented various geographic areas and sizes. The simplest polynomial adequately describing the relationship was a parabola whose minimum was at mid-stem in spruce and fir and at 70% of the total height in pine. The linear term was significant only in pine and could be detected with 95% confidence if at least 14 trees were sampled. The quadratic term could be detected with 95% confidence if at least 48 spruce, or 8 fir, or 38 pine were sampled. It was concluded that the conflicting evidence in the studies concerned with the longitudinal variation of specific gravity in species of the genus *Picea* may be due to insufficient sample size of trees. Deviations of the sample averages from the fitted values exhibited a pattern that was similar for each species. This similarity suggested that the action of factors governing wood structure in stems of conifers depends more on the relative height in the stem than it does on species, geographic area, and absolute size.

L'auteur étudia le rapport entre le poids spécifique (variable dépendante) et la hauteur relative de rondelles dans les troncs de 50 épinettes noires (*Picea mariana* (Mill.) B.S.P.), 50 sapins baumiers (*Abies balsamea* (L.) Mill.) et 36 pins lodgepoles (*Pinus contorta* Dougl. var. *latifolia* Engelm.). Les arbres échantillons étaient de différentes grosseurs et provenaient de différents endroits. Le polynôme le plus simple représentant ce rapport était une parabole dont le minimum était à mi-hauteur de la tige chez l'épinette et le sapin, et à 70% de la hauteur totale du pin. Le terme linéaire était significatif seulement chez le pin et possédait un seuil de confiance de 95% si l'on échantillonnait au moins 14 arbres. Le terme quadratique possédait le même seuil de confiance si au moins 48 épinettes, ou 8 sapins, ou 38 pins étaient échantillonnés. On peut conclure que les résultats contradictoires pour ce qui concerne la variation longitudinale du poids spécifique chez les *Picea* futent peut-être causés par le trop petit nombre d'arbres-échantillons. Les déviations des moyennes des échantillons par rapport aux valeurs ajustées se comportèrent de la même façon chez chacune des espèces, ce qui fait croire que l'action des facteurs qui gouvernent la structure du bois dans ce cas dépend plus de la hauteur relative du bois dans la tige que de l'espèce d'arbre, l'aire géographique ou la grosseur absolue.

Hegyi, F. 1969. *A Study of Basic Density Variation in Jack Pine.* Internal Report O-17. Natural Resources Canada, Canadian Forestry Service - Great Lakes Forestry Centre, Sault Ste. Marie, Ontario, Canada.

The variation in basic density (or, equivalently, specific gravity) is examined in 55 jack pine trees, representing three age classes, two site types, and two stocking classes. The maximum-moisture-content method and the water-immersion technique, where 2-inch micrometer-hook gauge and custom-built cylinders are used, are outlined in detail and recommended for determining the specific gravity of increment cores and sample disks. These methods facilitate the rapid processing of large numbers of samples. A comparison between determining specific gravity from increment cores and from sample disks showed that the mean difference in specific gravity between the two methods is not statistically significant. Mean bole specific gravity is shown to be well correlated with specific gravity at breast height, so that it may be estimated directly from breast–height increment cores. It is suggested that, for the assessment of productivity in pulpwood stands, horizontal and vertical variation of specific gravity are best studied by dividing the samples, along the diameter, into equal parts. It is concluded that the variation of specific gravity in the three age classes studied is greater within trees than between trees, and is appreciably greater along height than along diameter. *(Abstract prepared by compilers.)*

Hein, S., Weiskittel, A.R., and Kohnle, U. 2008a. Branch characteristics of widely spaced Douglas-fir in southwestern Germany: comparisons of modelling approaches and geographic regions. *Forest Ecology and Management* **256**(5): 1064–1079.

Models of Douglas-fir branch and whorl characteristics were developed from contrasting spacing experiments in southwest Germany. The data set was based on 100 young (20–30 years old), unpruned and partially pruned trees from a 100, 200, and 1200 stems ha^{-1} spacing experiment on Douglas-fir that was replicated 3 times across the region. The material was used to predict (1) the number of branches $whorl^{-1}$, (2) branch angle, (3) status (living/dead) of the branches within the living crown, (4) maximum branch diameter $whorl^{-1}$, and (5) relative diameter of branches within a whorl. For each of these models (except branch status), both a linear and nonlinear, generalized hierarchical mixed effects equation was developed. The comparison of the linear and nonlinear approaches showed that both had a relatively similar level of bias, but the nonlinear equations generally performed better (reduction in mean absolute error of 1.1–69.5%). Overall, individual branch and tree properties were sufficient to give logical and precise predictions of the branch characteristics for the models across the range of sampled stand densities. In addition, the models showed a similar behaviour compared to models on Douglas-fir crown structure from the Pacific Northwest, USA. This suggests that the allometric relationship between tree size and branch characteristics for a given species may be relatively consistent across regions, even ones with highly contrasting growing conditions like in this study. The models performed well across a range of stand conditions and now will be further integrated into an individual tree growth and yield simulations system.

Hein, S., Weisskittel, A.R., and Kohnle, U. 2008b. Effect of wide spacing on tree growth, branch and sapwood properties of young Douglas-fir [*Pseudotsuga menziesii* (Mirb.) Franco] in south-western Germany. *European Journal of Forest Research* **127**(6): 481–493.

The influence of stand density on Douglas-fir [*Pseudotsuga menziesii* (Mirb.) Franco] is conceptually understood, but for wide spacings not well quantified, particularly in Europe. This study used 41 trees from 7 different locations in south-western Germany to compare important tree- and branch-level attributes across three different densities, namely 100, 200, and 1,200 stems ha^{-1}. In general, there were only a few tree and branch attributes that were significantly different between the 100 and 200 ha^{-1} densities. Crown projection area and diameter of the thickest branches were the most important differences between the 100 and 200 ha^{-1} densities. The most obvious and significant differences in this study were between 100 and 1,200 ha^{-1} densities, where nearly every examined tree and branch attributes were statistically significant. However, relative sapwood area, the number of branches, branch angle, and the occurrence of spike knots were insensitive to stand density. Although the two lowest stand densities in this study represent rather extremely wide spacings, these results still have important implications for the development of effective thinning regimes for Douglas-fir in south-western Germany. Important management recommendations from this study include thinned stands should be maintained to at least 200 stems ha^{-1} to maintain high log quality and stand stability. Furthermore, even at stand densities exceeding more than 1,200 trees ha^{-1} planted trees, artificial pruning may even be necessary to produce high quality logs.

Henman, D.W. 1963. *Pruning Conifers for the Production of Quality Timber.* Forestry Commission Bulletin No. 35. Her Majesty's Stationary Office, Edinburgh, UK.

Experimental pruning of conifer crops was begun by the Forestry Commission in 1931 and the results of the experiments have been assessed up to date, but the final assessment, that of the pruned timber, still lies in the future.

The main purpose of this bulletin is to indicate the extent of the experimental work done so far and to present its results; but in the view of the practical interest at present being shown in the subject in Britain an appraisal is included of the aims of pruning, and the experimental results are used, as far as possible, to make provisional recommendations for forest practice.

The foreign literature has been surveyed, but as it is often difficult to relate to British conditions it has been drawn on in making the recommendations only when information from home sources is inadequate. Where the British results disagree markedly with Continental experience, this is indicated. *(Crown copyright material is reproduced with the permission of the Controller of HMSO and the Queen's Printer for Scotland.)*

Hernández, R.E. 2007a. Influence of accessory substances, wood density and interlocked grain on the compressive properties of hardwoods. *Wood Science and Technology* **41**(3): 249–265.

Wood samples of nine tropical hardwoods from Peru and sugar maple wood from Quebec were selected to perform moisture sorption tests associated with parallel-to-grain and tangential compression tests using a multiple step procedure at 25°C. Cold-water and hot-water extractives, sequential cyclohexane (CYC), acetone (ACE) and methanol (MET) extracts, ash content (ASH), wood density and interlocked grain (IG) were evaluated on matched samples too. Wood density corrected for the accessory substances was by far the major factor positively affecting the compressive properties of tropical hardwoods. The total amount of accessory substances is required in order to establish better relationships between physico-mechanical properties and density of tropical hardwoods. For a given wood density, the ultimate stress in parallel-to-grain compression was higher in tropical hardwoods than in temperate hardwoods. However, the compliance coefficients for both types of woods were quite similar. Sequential extraction with organic solvents was the most suitable method for evaluating the effect of extractives on compressive properties of tropical hardwoods. The CYC and ACE fractions did not contribute to variation in these mechanical properties. The substances dissolved in MET affected positively the compliance coefficient s_{11} in parallel-to-grain compression and negatively the compliance coefficient s_{33} in tangential compression. The IG decreased the compliance coefficient s_{11} but also decreased the ultimate stress in parallel-to-grain compression. Finally, variations in compressive properties that were due to changes in equilibrium moisture content (EMC) were clearly influenced by wood density; denser woods were more sensitive to changes in EMC than lighter woods.

Hernández, E. 2007b. Swelling properties of hardwoods as affected by their extraneous substances, wood density, and interlocked grain. *Wood and Fiber Science* **39**(1): 46–158.

Samples of nine tropical hardwoods from Peru and sugar maple wood from Quebec were selected to perform moisture sorption tests associated with swelling tests using a multiple step procedure at 25°C. Cold-water and hot-water extractives, sequential cyclohexane, acetone, and methanol extracts, ash content, wood density, and interlocked grain also were evaluated on matched samples. Swelling properties were highly variable within and among wood species. The wood density corrected for the extraneous substances was the most significant variable positively affecting the transverse and volumetric swelling of tropical hardwoods. Sequential extraction with organic solvents was the most suitable method for evaluating the effect of extractives on swelling properties of tropical hardwoods. The extractives soluble in cyclohexane were the more accessible, but they virtually did not contribute to wood swelling. The substances dissolved in acetone appeared to be located within cell walls. After wood density, these compounds were the most significant variable negatively affecting the radial swelling. The substances dissolved in methanol were located within cell walls. After wood density, this extracted fraction was the most significant variable negatively affecting the tangential swelling. The acetone and methanol extracted fractions positively affected the dimensional stability of tropical hardwoods. Finally, the effect of the interlocked grain on swelling was only indirect given that this grain pattern reduces the equilibrium moisture content.

Hernández, R. E., Bustos, C., Fortin, Y., and Beaulieu, J. 2001. Wood machining properties of white spruce from plantation forests. *Forest Products Journal* **51**(6): 82–88.

The planing, shaping, boring, turning, and mortising properties of white spruce wood from a provenance trial and a natural stand were evaluated according to the ASTM D 1666-87 standard. Wood specimens were machined at 7 percent moisture content using different tools, and the surface quality obtained was visually graded on a scale of 1 to 5 (excellent or defect-free to very poor). The maximum depth of torn grain produced by planing was also measured for eight cutting conditions. White spruce wood from plantation-grown trees performed well for planing, shaping, and boring. However, the turning and mortising properties of this wood were poor. For planing, a higher proportion of defect-free pieces was obtained at a 15-degree rake angle and 20 knife marks per inch. At a 10-degree rake angle, the maximum depth of torn grain even decreased but the presence of fuzzy grain increased. Machining properties appeared not to be significantly affected by the origin of the seed sources, including the natural forest stand. However, as a general rule, denser wood behaved better than light wood for shaping, boring, turning, and mortising processes. Selection of best provenances for wood density, which has been shown to be strongly heritable, could indirectly help to improve wood machining properties. Finally, high-temperature drying did not appear to affect machining performance of this wood as compared with the conventional drying process.

Hillis, W.E. 1962. *Wood Extractives and Their Significance to the Pulp and Paper Industries.* Academic Press, New York, New York, USA.

The textbook covers the biochemistry of wood extractives and how they are formed and distributed. Extractives have a major influence on the pulp-and-paper manufacturing process. They can decrease yield, increase chemical consumption, inhibit the pulping reaction, and corrode the equipment. They can also influence the color of the pulp, influencing the bleaching process. There is also a brief discussion on the impact of silviculture on the extractives and the consequences for the pulp-and-paper industry. *(Abstract prepared by compilers.)*

Hillman, G.R., and Takyi, S.K. 1998. Response of black spruce to thinning and fertilization in a drained swamp. *Northern Journal of Applied Forestry* **15**(2): 98–105.

A split-plot design experiment replicated in four blocks was established to determine the effects of thinning (main plots) and fertilization (subplots) on growth of a 50- to 60-yr-old stagnant stand of black spruce on a shallow peatland (swamp) in Alberta drained in the previous year in a large-scale experimental project to convert it to a future merchantable stand. The thinning treatments were selective hand-spacing to 1600 trees ha^{-1} and no thinning. The hand-broadcast fertilizer treatments were: no fertilizer, nitrogen (N), phosphorus (P), potassium (K), NP, PK, NK, and NPK. Nitrogen as NH_4NO_3 was applied at 200 kg ha^{-1}, P as triplesuperphosphate at 100 kg ha^{-1}, and K as potassium chloride at 100 kg ha^{-1}. After six growing seasons, diameter at breast height, basal area, and volume growth were significantly greater in the thinned treatment than for the same number of large (dominant and codominant) trees in the unthinned treatment. Thinning had no significant effect on height growth. Nitrogen significantly increased dbh, height, basal area, and volume growth, and NP increased the basal area and volume growth. P, K, and PK treatments showed little effects on growth, and P applied alone tended to reduce growth. The results indicated it is beneficial to supplement drainage with thinning or fertilization with N and N-containing fertilizers or with both shortly after drainage, particularly as other researchers have indicated black spruce may take several years to respond to drainage. *(Abstract prepared by compilers.)*

Hökkä, H., and Groot, A. 1999. An individual-tree basal area growth model for black spruce in second-growth peatland stands. *Canadian Journal of Forest Research* **29**(5): 621–629.

A basal area growth model was developed to predict the growth of individual trees in second-growth black spruce (*Picea mariana* (Mill.) B.S.P.) stands on northeastern Ontario peatlands. The data were derived from stem analysis trees collected in 1985 and 1986 from stands harvested 47–68 years earlier. For a period starting from the date of data collection and going back to 10 years from the harvesting, tree basal area growth, diameters, and stand characteristics were retrospectively calculated at 5-year intervals. To estimate previous mortality, self-thinning relationships for black spruce were applied. In the model, 5-year basal area growth of a tree was expressed as a function of tree diameter, stand-level competition, tree-level competition, and peat thickness. There was considerable change in the growth–size relationship over time. A random parameter approach was applied in model construction to account for the spatial and temporal correlations of the observations. The proposed model explicitly incorporates factors normally included in a 'random error' term and, therefore, should provide more sensitive tests of the contributions of the various factors to growth prediction. The estimated model showed only slight bias against the modeling data, and the predicted stand basal area development was comparable with that given in other studies.

Un modèle d'accroissement en surface terrière a été développé pour prédire la croissance d'arbres individuels dans les peuplements d'épinette noire (*Picea mariana* (Mill.) B.S.P.) de seconde venue qui croissent dans les tourbières du nord-est de l'Ontario. Les données proviennent de l'analyse de tiges abattues en 1985 et 1986 dans des peuplements récoltés 47 à 68 ans plus tôt. Pour la période débutant avec l'abattage des tiges et remontant jusqu'à 10 ans après la récolte, l'accroissement en surface terrière, le diamètre et les caractéristiques du peuplement ont été calculés rétrospectivement à intervalle de 5 ans. Les relations spécifiques au processus d'éclaircie naturelle chez l'épinette noire ont été utilisées pour estimer la mortalité. Dans le modèle de croissance, l'accroissement en surface terrière par période de 5 ans, est exprimé en fonction du diamètre, de la compétition au niveau de l'arbre, de la compétition au niveau du peuplement et de l'épaisseur de la tourbe. La relation entre la croissance et la taille change beaucoup dans le temps. Dans la construction du modèle, une méthode de paramétrisation aléatoire a été utilisée pour tenir compte des corrélations spatiale et temporelle dans les données disponibles. Le modèle proposé considère de façon explicite les facteurs habituellement incorporés dans le terme d'erreur aléatoire et devrait donc être plus sensible pour tester dans quelle mesure les divers facteurs contribuent à prédire la croissance. Les prédictions du modèle présentent un léger biais par rapport aux données et la croissance en surface terrière estimée est comparable à celle que rapportent d'autres études.

Honer, T.G. 1971. Crown shape in open- and forest-grown balsam fir and black spruce. *Canadian Journal of Forest Research* **1**(4): 203–207.

Crown radius equations developed from measurements taken on open-grown balsam fir and black spruce were applied to forest-grown trees of the same species. For that part of the crown considered to be growing free of aerial competition, radii were estimated to within +1.5 feet (+45.7 cm) at the 5% significance level. It was concluded that those portions of balsam fir and black spruce crowns estimated to be growing free of aerial competition are not significantly different from similar portions of open-grown trees of the same height and species. Coefficients and related statistics for the general crown–radius equation, $CR = a1L + a2LH + a3L2/H + a4L2$, are given.

Des équations pour prédire le rayon de la cime de sapins baumiers et d'épinettes noires, établi à partir de mesures effectuées sur des tiges croissant en plein découvert, ont été appliquées à des arbres de même essence croissant en peuplements. Les rayons de la partie supérieure, libre de concurrence, de la cime de tels arbres ont été estimés à une précision de ±1.5 pied (± 45.7 cm) au niveau de probabilité de 5%. L'étude a démontré que ces parties de la cime des sapins et épinettes, qui sont présumément libres de toute concurrence, ne sont pas significativement différentes des parties similaires de la cime chez des arbres de plein découvert de même hauteur et de même essence. La forme générale de l'équation servant à prédire le rayon de la cîme est *CR = a1L + a2LH + a3L2/H + a4L2*; les paramètres et les valeurs statistiques pertinentes à cette équation sont aussi indiqués.

Horton, K.W. 1981. *Biomass Yield Tables for Aspen in Ontario.* ENFOR Project P-30(1). Natural Resources Canada, Canadian Forestry Service - Petawawa National Forestry Institute, Chalk River, Ontario, Canada.

Biomass growth and yield tables are presented for fully stocked aspen (*Populus tremuloides* Michx.) stands up to 90 years old in two forest regions of Ontario—the Boreal and the Great Lakes–St. Lawrence. Whole-tree biomass maximum mean annual increments range from 2.2 to 4.7 oven-dry tonnes per hectare per year, forming a plateau between ages 40–70 in the Boreal Region and 30 to 60 in the Great Lakes. Recommended biomass rotation ages are 40 and 30, respectively. Yields in the Boreal exceed those in the Great Lakes by from 18 to *ca.* 30%. Stemwood ovendry mass constitutes 68–72% of above-ground, whole-tree mass.

Houle, D., and Moore, J.D. 2008. Soil solution, foliar concentrations and tree growth response to 3 years of ammonium-nitrate addition in two boreal forests of Quebec, Canada. *Forest Ecology and Management* **255**(7): 2049–2060.

Ammonium nitrate (NH_4NO_3) was applied monthly (from June to October) for 3 years in a balsam fir (*Abies balsamea* (L.) Miller) and a black spruce (*Picea mariana* (Mill.) B.S.P.) boreal forest in Quebec (Canada). The design was composed of nine experimental units of 10 m — 10 m for each site. Application rates were 3 and 10 times the atmospheric N deposition measured at each site, which was 6 and 3 kg ha^{-1} $year^{-1}$ for the fir and the spruce sites, respectively. Soil solution composition (30 and 60 cm), tree growth, and foliar concentrations were analysed. The inorganic N in the soil solution of the control plots of both sites was low, particularly at the spruce site, indicating that these forests are actively accumulating the atmospheric deposited N. Nitrogen additions regularly caused sudden and large inorganic N increases in the soil solution at both sites, both treatments and both sampling depths. However, these increases were transitory in nature and no persistent changes in inorganic N were observed. It was estimated that more than 95% of the added N was retained above the rooting zone at both sites. Nitrogen addition increased N, Ca, Mg, and Mn foliar concentrations at the black spruce site but had no effects at the balsam fir site. After 3 years of N application, tree growth was similar in the control and the treated plots at both sites. Our results show that slow-growing black spruce boreal forests with low ambient N deposition are responsive (in term of foliar N, Ca, Mg and Mn concentrations) to even small increases in N inputs, compared to higher growth balsam fir boreal forests with higher N deposition.

Huffman, D.R. 1977. High-temperature drying effect on the bending strength of spruce–pine–fir joists. *Forest Products Journal* **27**(3): 55–57.

Static bending tests of full-dimension eastern spruce, jack pine, and balsam fir joists showed statistically significant reductions in bending strength as a result of high-temperature drying compared to conventional drying. Linear regressions relating dry MOR to green MOE predicted average reductions of 13.5 percent in pine, 11.0 percent in spruce, and 10.2 percent in fir. In MOE a non-significant reduction of 1.1 percent was predicted for both spruce and fir, and a significant reduction of 2.2 percent for pine.

Hunt, J.F., O'Dell, J., and Turk, C. 2008. Fiberboard bending properties as a function of density, thickness, resin, and moisture content. *Holzforschung* **62**(5): 569–576.

Fibers from treetop residues of lodgepole pine (*Pinus contorta*) and recycled old corrugated containers were used to fabricate wet-formed fiberboard panels over a range of densities from 300 to 1100 kg m^{-3}, a thickness range from 1.3 to 4.8 mm, and phenolic resin contents from 0% to 4.5%. The panels were then tested after conditioning in 50% and 90% relative humidity (RH) environments. Density, thickness, equilibrium moisture content, bending modulus of elasticity (MOE), and modulus of rupture (MOR) were measured for each panel. Panel apparent-density increased with thickness, but this may be due to surface effects rather than true density values. The equilibrium moisture content approximately doubled for the panels in the 90% RH environment, compared to 50% RH. At 50% and 90% RH conditions, equilibrium moisture contents decreased significantly when only 0.5% resin was added and remained essentially the same with increasing resin levels. In this study, both MOE and MOR increased with approximately the square of density. MOE increased, whereas MOR showed no clear effects as thickness and resin amount increased. This research is part of a larger program for developing an understanding of panel properties for engineered three-dimensional fiberboard products.

Hunt, K., and Hatton, J.V. 1995. Specific gravity and chemical properties of commercial thinnings from six softwood species. *Pulp and Paper Canada* **96**(11): 50–53.

Plantations frequently benefit from thinning, but thinned wood may have different characteristics with respect to pulping. This study was undertaken to examine the specific gravity and chemical differences of six species in New Brunswick. Species included were white spruce (*Picea glauca* (Moench) Voss.), black spruce (*Picea mariana* (Mill.) B.S.P), Norway spruce (*Picea abies* (L.) Karst.), red spruce (*Picea rubens* Sarg.), jack pine (*Pinus banksiana* Lamb.), and tamarack (*Larix laricina* (Du Roi) K. Koch). Preliminary increment cores were taken from trees on six sites and measurements made of specific gravity. These data were used to inform tree selection for the main study and ensure that a representation of low-, medium-, and high-density trees was chosen. Three trees of each species were felled, limbed, and bucked into 1.1- to 14-m logs. Disks were cut from the top of each log for moisture content measurement. Two further disks were cut from each log for specific gravity determination, both by densitometry and by TAPPI Standard T218 m-53. The remainder of the logs were chipped and subjected to chemical analyses. Alcohol-benzene, alcohol, hot water, and 1% sodium hydroxide extractive content determinations were made. Klason lignin, including soluble lignin, was also determined. Extractives contents were found to be comparable to mature wood. Extractives contents, specific gravities, and lignin contents were concluded not to adversely influence pulping. *(Abstract prepared by compilers.)*

Hunt, K., Timmer, V.R., and Warren, W.G. 1980. Volume, dry weight and kraft pulping of fertilized balsam fir from Nova Scotia. *Canadian Journal of Forest Research* **10**(3): 362–366.

> Volume, dry weight, density, and kraft pulping data were obtained from control and fertilized, mature balsam fir (*Abies balsamea* (L.) Mill.) from Nova Scotia. Fertilization treatments consisted of 450 kg N/ha; 450 kg N and 112 kg P/ha; and 450 kg N, 112 kg P, and 112 kg K/ha, plus the untreated control. Samples were taken at three height positions in trees: stump, breast height, and mid-stem. Wood laid down for 5 years after treatment was separated from wood laid down for 5 years before treatment, and its density determined before being pulped by the kraft process.
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> Fertilization significantly increased volume and dry weight increment and reversed patterns of growth decline during the response period. Any effect specifically due to phosphorous or potassium fertilization over that of nitrogen could not be detected with certainty. Wood density was reduced by N and NP applications; however, pulp yield was unaffected by the fertilization treatments. The need for tree equivalence prior to treatment is stressed for more precise testing of differences.
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> Le volume, le poids sec, la densité et le rendement en pâte kraft ont été mesurés sur du sapin baumier (*Abies balsamea* (L.) Mill.) mature de la Nouvelle-Écosse soumis à la fertilisation. En plus du témoin, trois traitements furent appliqués: 450 kg N/ha, 450 kg N avec 112 kg P/ha et enfin 450 kg N/ha, 112 kg P et 112 kg K/ha. Les échantillons ont été prélevés à trois niveaux dans l'arbre: à la souche, à la hauteur de poitrine et à la mi-cime. La densité et le rendement en pâte kraft ont été déterminés sur le bois formé cinq ans avant traitement et cinq après traitement.
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> La fertilisation a significativement augmenté l'accroissement en volume et en poids sec pendant la période échantillonnée. L'effet supplémentaire dû à l'application de phosphore ou de potassium conjointement avec l'azote n'a pu être révélé avec certitude. La densité du bois a été réduite par l'application de N et NP bien que le rendement en pâte n'ait pas été affecté par la fertilisation. La nécessité d'une période de référence avant traitement est mise en évidence pour améliorer la précision des différences.

Hussein, A., Gee, W., Watson, P., and Zhang, S.Y. 2006. Effect of precommercial thinning on residual sawmill chip kraft pulping and pulp quality in balsam fir. *Wood and Fiber Science* **38**(1):179–186.

> This study examined the effects of precommercial thinning (PCT) on kraft pulping and pulp properties of balsam fir [*Abies balsamea* (L.) Mill.]. Heavy precommercial thinning of balsam fir stands results in detrimental effects on the kraft pulping and pulp properties of the residual stems. It was found that at a stand density of 1,500 stems per hectare, sawmill residual chips obtained from the stems are more difficult to cook and exhibit a corresponding reduction in pulp yield with concomitant increased cooking chemical consumption. Shorter, finer fibers were observed, and the kappa 30 kraft pulps exhibited improved sheet tensile strength. These results indicate that balsam fir stems from heavily precommercially thinned stands contain a higher proportion of juvenile wood, although a contribution from compression wood cannot be completely ruled out.

Ise, T., and Moorcroft, P.R. 2008. Quantifying local factors in medium-frequency trends of tree ring records: case study in Canadian boreal forests. *Forest Ecology and Management* **256**(1–2): 99–105.

> Growth rings of a tree are simultaneously affected by various environmental constraints, including regional factors such as climate fluctuations and also local, gap-scale dynamics such as competition and stochastic mortality of neighbour trees. Although these local effects are often discarded by dendroclimatologists as random variation, the dendroecological trends may provide valuable information on past forest dynamics. Since dendroecological trends arising from local stand dynamics often have medium-term frequencies with persistence of several years to a few decades, it is usually difficult to separate local, gap-scale forcings from regional, medium-frequency forcings such as El Niño Southern Oscillation or North Atlantic Oscillation. Moreover, conventional dendroecological practices have failed to analyze the continuously changing medium frequency trends. In this study, a continuous index of medium-frequency dendrochronological trends was developed by generalizing previous analytical methods that evaluate relative changes using moving averages. This method was then tested against a tree-ring data set from a site with a known history of release and suppression due to a hurricane disturbance. To quantify the effects of local gap dynamics against the regional, often climatic effects, increments cores of black spruce (*Picea mariana*) were sampled from boreal forests in Saskatchewan, Canada, using a stratified sampling design. Assuming that regional forcings affect trees in the given stand homogeneously, the relative effect of stochastic heterogeneity within stand was quantified. The results closely agreed with conventional dendrochronological observations. In closed-canopy stands, stochastic local effects explained 12.9–35.4% of the variation in tree-ring widths, because interactions between neighbour trees were likely to be intense. In open-canopy stands, on the other hand, the proportion of explained variance was 1.4–10.2%, reflecting the less-intense local tree interactions in low-density stands. These advancements in statistical analysis and study design will help ecologists and paleo-climatologists to objectively evaluate the effects of climate fluctuations, relative to the effects of local, ecological interactions. Moreover, forest managers can apply concepts of filtering medium-frequency trends to assess release and suppression caused by forest management practices, such as selective cutting and forest thinning.

Ivkovich, M., Namkoong, G., and Koshy, M. 2002a. Genetic variation in wood properties of interior spruce. I. Growth, latewood percentage, and wood density. *Canadian Journal of Forest Research* **32**(12): 2116–2127.

> Quantitative genetic variation in growth, latewood percentage, and wood density was investigated for British Columbia's interior spruce (the common name for white spruce, *Picea glauca* (Moench) Voss; Engelmann spruce, *Picea engelmanni* Parry ex Engelm.; and their hybrids). The study included 160 half-sib families from the East Kootenay and Prince George regions. At the time of sampling, progeny tests for those two regions were 20 and 22 years old, respectively. Univariate and multivariate restricted maximum likelihood (REML) estimates of genetic parameters were obtained. Estimates of genetic variances and heritabilities differed greatly across planting sites for the examined traits, especially after transplantation between the regions. Significant negative genetic correlation between overall growth and wood density was found for the East Kootenay progenies, while negative but nonsignificant genetic correlation between these traits was found for the Prince George progenies. Generally, there was no significant decrease in heritability for ring width and latewood percentage in successive growth rings. A general age trend for genetic correlation between those traits was not apparent, except that the correlation remained negative during the observed period. Our results show that it is not possible to select certain families as superior based on 1-year results because of the family by growing season interactions. Nevertheless, genetic age–age correlations for cumulative increments were high, having a decreasing trend with increasing difference in age.

La variation génétique quantitative de la croissance, la proportion de bois final, et la densité du bois ont été étudiées chez l'épinette de l'intérieur (le nom commun pour l'épinette blanche, *Picea glauca* (Moench) Voss; l'épinette d'Engelmann, *Picea engelmanni* Parry ex Engelm, et leurs hybrides) de la Colombie-Britannique. Cette étude portait sur 160 demi-fratries provenant des régions de East Kootenay et de Prince George. Lors de l'échantillonnage, les tests de descendances pour ces deux régions avaient respectivement 20 et 22 ans. Les paramètres génétiques ont été estimés par la méthode de maximum de vraisemblance restreint à partir d'algorithmes fratries et fratries. Les estimations de variance génétique et d'héritabilité étaient très différentes entre les sites de plantation pour les caractéristiques à étude, surtout suite au déplacement d'une région à l'autre. Une corrélation génétique négative significative a été observée entre la croissance et la densité du bois pour les descendances provenant de East Kootenay, tandis qu'une corrélation génétique négative non significative a été obtenue pour ces caractéristiques parmi les descendances de Prince George. En général, il n'y avait pas de diminution significative de l'héritabilité pour la largeur des cernes de croissance et la proportion de bois final d'un cerne à l'autre. La corrélation génétique entre ces deux caractéristiques n'est pas fonction de l'âge du bois, mais elle est demeurée négative pendant la période observée. Nos résultats montrent qu'il n'est pas possible de sélectionner les meilleures familles à partir des données d'une seule saison de croissance à cause des interactions entre les familles et les saisons de croissance. Néanmoins, les corrélations génétiques d'âge à âge pour l'accroissement cumulatif étaient élevées, mais décroissaient avec l'accroissement de l'écart d'âge.

Ivkovich, M., Namkoong, G., and Koshy, M. 2002b. Genetic variation in wood properties of interior spruce. II. Tracheid characteristics. *Canadian Journal of Forest Research* **32**(12): 2128–2139.

In this study, we investigated quantitative genetic variation in tracheid characteristics in two genetic tests of British Columbia's interior spruce (the common name for white spruce, *Picea glauca* (Moench) Voss; Engelmann spruce, *Picea engelmanni* Parry ex Engelm.; and their hybrids). The study included 88 half-sib families from the East Kootenay and Prince George regions. We have developed a technique for quantitative assessment of tracheid characteristics by measuring cross-sectional dimensions. We obtained cell size, wall thickness and their ratio in early, transition-, and late-wood classes within a growth ring. Tracheid length and microfibril angle were measured in the transition wood. A number of tracheid characteristics showed significant genetic variation, but heritability, phenotypic, and genetic correlation estimates varied across test sites within and outside regions of origin of parental trees. Ring width was determined, both phenotypically and genetically, by the number of tracheids and to a lesser extent by the by their mean size. On average, rings with larger tracheids did not have significantly thicker walls. Wider rings had lower mean wall to tracheid size ratio. Faster growth did not result in shorter tracheids in the transition wood. Longer tracheids had lower microfibril angle. There were no particular benefits from considering the anatomical component traits for breaking the negative genetic correlation between growth and wood density.

Dans cette étude, nous avons examiné la variation génétique quantitative des caractéristiques des trachéides chez l'épinette de l'intérieur (le nom commun pour l'épinette blanche, *Picea glauca* (Moench) Voss; l'épinette d'Engelmann, *Picea engelmanni* Parry ex Engelm, et leurs hybrides) de la Colombie-Britannique. L'étude portait sur 88 demi-fratries des régions de East Kootenay et de Prince George. Nous avons développé une technique pour l'analyse quantitative des caractéristiques des trachéides en mesurant leur dimension radiale. Nous avons obtenu le diamètre des cellules, l'épaisseur de la paroi et leur rapport, dans le bois initial, de transition et final. La longueur des trachéides et l'angle des microfibrilles de celluloses ont été mesurés dans le bois de transition. Une variation génétique significative a été observée pour plusieurs caractéristiques des trachéides, mais l'héritabilité et les estimés de corrélation génétique et phénotypique variaient entre les sites au sein de et à l'extérieur des régions d'origine des arbres parentaux. La largeur du cerne de croissance était déterminée sur les plans phénotypique et génétique par le nombre de trachéides et, à un degré moindre, par leur dimension moyenne. En moyenne, les cernes avec des trachéides de plus fort diamètre n'avaient pas des parois significativement plus épaisses. Les cernes plus larges possédaient, en moyenne, un rapport plus faible entre l'épaisseur de la paroi et le diamètre de la cellule. Une croissance plus rapide n'a pas causé la formation de trachéides plus courtes dans le bois de transition. Les trachéides plus longues avaient l'angle des microfibrilles de celluloses plus faible. L'analyse des caractéristiques des composantes anatomiques n'apporte aucun avantage précis pour contourner la corrélation génétique négative entre la croissance et la densité du bois.

Jacobs, S.M. and Drew, D.M. 2002. Using tree physiology to better understand the effect of environmental factors on wood fibre properties. Pages1–10 *in* Anonymous. *Adding Value in a Global Industry*. Durban, South Africa,11 October 2002. Technical Association of the Pulp and Paper Industry in Southern Africa, Durban, South Africa.

This presentation reviews pertinent literature relating wood fiber qualities and tree physiology. A thorough understanding of tree physiology could enable silviculturists to enhance tree growth without compromising wood quality. The authors propose that biotechnology and physiology be considered in an integrated research approach to better understand wood development. *(Abstract prepared by compilers.)*

Jagels, R. 2006. *Management of Wood Properties in Planted Forests. A Paradigm for Global Forest Production.* Forest Resources Development Service, Forest Resources Division, FAO, Rome, Italy.

Plantations will increasingly become the dominant source of global wood production. In this report, the impact on wood characteristics of planting desirable trees in plantations or as exotics is thoroughly discussed. Abrupt transition pines, for example, when planted in hot, moist climates, will tend to become gradual transition. Fast growth of eucalyptus can result in considerable growth stresses released as fracture when harvesting or collapse during drying. Mitigating strategies, such as agro-forestry, provenance testing, and tree improvement trials, are suggested and described. Best practice is suggested for fiber production for various, currently produced wood products, such as paper, reconstituted and engineered wood products, and solid wood products. A warning was given that, should wood properties from plantations and exotics fail to satisfy customer needs, customers will migrate to alternative materials. Therefore, it is imperative to understand the influence of plantation forestry, site, and soil factors, and eventual wood characteristics of wood produced from plantations and by exotics. *(Abstract prepared by compilers.)*

Janas, P.S., and Brand, D.G. 1988. Comparative growth and development of planted and natural stands of jack pine. *The Forestry Chronicle* **64**(4): 320–328.

This study compares growth, yield, and stem quality differences at age 21 between plantations spaced at 2.13 × 2.13 m (2204 stems/ha) and 4.27 × 4.27 m (548 stems/ha), and a nearby natural jack pine stand of identical age (initial density of 29 800 stems/ha). Merchantable volume/ha was greatest at the 2.13 m spacing, followed by the less dense plantation and natural stand. Total volume/ha (trees >1.3 m height) was also greatest in the 2.13 m plantation, followed by the natural stand and the

4.27 m plantation. Individual tree mean merchantable volumes decreased with increasing density. Height growth decreased with increasing density. Height [growth decreased in the natural stand and in the] 4.27 m plantation relative to the 2.13 m plantation. Stem quality of the natural stand was markedly better than in both plantations. A comparison of an older natural stand and a plantation in the same area suggests that superiority of tree form of denser natural stands will continue through to rotation. High mortality in the natural stand was largely the result of snow and ice damage, which caused patchy and irregular stocking. These results imply that widely spaced plantations of unimproved jack pine will produce large individual tree sizes, but at the expense of quality. *(Compilers' note: the text within square brackets was missing in the original abstract.)*

La présente étude traite des différences de croissance, de rendement et de qualité des tiges entre les arbres de 21 ans d'une plantation espacée de 2,13 × 2,13 m (2204 tiges/ha) et d'une autre espacée de 4.27 × 4.27 m (548 tiges/ha) et des pins gris du même âge d'un peuplement naturel avoisinant (densité initiale de 29 800 tiges/ha). Le plus fort volume marchand par hectare se retrouvait dans la plantation espacée de 2,13 m suivit de l'autre plantation et du peuplement naturel. Le plus fort volume total par hectare (arbres de plus de 1,3 m de hauteur) se retrouvait également dans la plantation espacée de 2,13 m, suivit du peuplement naturel et de la plantation espacée de 4,27 m. Le volume marchand moyen des arbres individuels décroissait avec l'augmentation de la densité. L'accroissement en hauteur diminuait dans le peuplement naturel et dans la plantation espacée de 4.27 m comparativement à la plantation à 2,13 m. La qualité de tiges du peuplement naturel était nettement supérieure à celles des deux plantations. Une comparaison d'un peuplement naturel plus âgé et d'une plantation de la même région laisse supposer que les arbres des peuplements naturels plus denses continueront d'avoir un coefficient de forme supérieur pendant toute la rotation. Les dégâts causés par la neige et la glace sont en grande partie à l'origine du taux élevé de mortalité observé dans le peuplement naturel et de la proportion irrégulière et inégale de surface occupée. Ces résultats laissent entendre que des plantations largement espacées de pins gris non améliorés produiront des arbres de haute taille, mais au détriment de la qualité.

Jeffers, J.N.R., and Dowden, H.G.M. 1964. *Moisture Content and Specific Gravity of Fresh-Felled Conifers.* Forestry Commission, London, UK.

This paper gives the results of an analysis of the weighted tree means derived from a survey of moisture content and specific gravity of fresh-felled conifers carried out jointly by the Forestry Commission and the Forest Products Research Laboratory. The data upon which this analysis was based were presented in an early paper (Statistics Section Paper 67).

In the survey, the mainland of Great Britain was divided into eleven Meteorological Regions, and ten trees were taken at random from a maximum of six sites in each region. Determinations of green weight, oven dry weight, and green volume were made on sample sectors taken at intervals of three feet up the tree for each of the trees sampled. The method used in calculating the weighted arithmetic averages of moisture content and specific gravity from these sample sectors is described in detail in Statistics Section Paper 67. The objects of the analysis reported in this paper were: a) To test the significance of the differences between the mean moisture contents and specific gravities of each species for individual sites within each Meterological Region, and to provide estimates of the mean moisture content and specific gravity, and their fiducial limits, for each site. b) To test the significance of the differences between the mean moisture contents and specific gravities of each species for individual Meteorological Regions, and to provide estimates of the mean moisture content and specific gravity, and their fiducial limits, for each Region. c) To estimate the mean moisture content and specific gravity of each species, and their fiducial limits, over all Regions and sites.

The analysis demonstrates clearly that, despite very marked differences between individual trees in moisture content and specific gravity, there are also signficant differences, for all species, between the average moisture contents and specific gravities for sites. These site differences are not satisfactorily explained by grouping them into Meteorological Regions, and for most Regions, there are no significant differences between the mean moisture content or mean specific gravity.

Jeremic, D., Cooper, P., and Srinivasan, U. 2004. Comparative analysis of balsam fir wetwood, heartwood, and sapwood properties. *Canadian Journal of Forest Research* **34**(6): 1241–1250.

Physical, anatomical, chemical, and microbiological properties of wetwood in heartwood were compared with those of sapwood and normal heartwood in balsam fir (*Abies balsamea* (L.) Mill.). Wetwood found only in heartwood of balsam fir had significantly higher moisture content (MC) than normal heartwood but not significantly higher MC than sapwood. No differences in relative density or shrinkage properties were found among tissue types. Wetwood tissue needed longer times to dry to an equilibrium MC of 15%, not only because of its high initial MC, but also because of its lower moisture permeability (diffusion coefficient) in this particular MC range (from initial MC to 15% equilibrium MC). However, there were no significant differences in drying rates for the different tissues when drying from 15% MC to 8% MC. Anatomically, wetwood is similar to normal heartwood, and it has no distinctive characteristics except a greater frequency of bacteria. Energy dispersive X-ray analysis showed that all of the tissues contained the same inorganic elements. Both high-performance liquid chromatography and ash analysis showed that wetwood is chemically closer to normal heartwood than to sapwood. Wetwood was significantly more acidic than either normal heartwood or sapwood. A large number of bacterial genera were found in all three tissues, but there were no consistent or significant differences in bacterial presence or activity among tissue types.

Les propriétés physiques, anatomiques et chimiques du bois de coeur mouillé ont été comparées à celles du bois d'aubier et du bois de coeur normal chez le sapin baumier (*Abies balsamea* (L.) Mill.). Le coeur mouillé présent seulement dans le bois de coeur du sapin baumier avait un contenu en humidité significativement plus élevé que le bois de coeur normal, mais pas significativement plus élevé que celui du bois d'aubier. Aucune différence de densité relative ni de retrait n'a été observée entre ces tissus. Le coeur mouillé nécessitait plus de temps de séchage pour atteindre un degré d'humidité d'équilibre de 15 % non seulement à cause de son contenu initial élevé en humidité, mais aussi à cause de sa plus faible perméabilité (coefficient de diffusion), particulièrement à cette teneur en humidité (entre son contenu initial en humidité et un degré d'humidité d'équilibré de 15 %). Cependant, le temps de séchage des différents tissus n'était pas différent pour passer d'une teneur en humidité de 15 à 8 %. Du point de vue anatomique, le coeur mouillé était semblable au bois de coeur normal et ne possédait aucune caractéristique distinctive à l'exception d'une fréquence plus élevée de bactéries. Les mêmes éléments inorganiques ont été identifiés dans tous les tissus en utilisant la spectroscopie des rayons X par dispersion d'énergie. Tant la chromatographie liquide à haute performance que l'analyse des cendres ont montré que le coeur mouillé était plus semblable au bois de coeur normal qu'au bois d'aubier. De très nombreux genres de bactéries ont été notés dans les trois tissus mais, il n'y avait pas de différences consistantes et significatives dans l'activité et la présence des bactéries entre les tissus.

Jessome, A.P. 2000. *Strength and Related Properties of Woods Grown in Canada.* Publication SP-514E. Forintek Canada Corp: Eastern Division, Sainte-Foy, Quebec, Canada; West Division, Vancouver, British Columbia, Canada.

This report provides tabular data for strength and related properties for all commercial Canadian species. Although sample size was variable, attempts were made to include all regions. Properties were tested according to Amercian Society for Testing and Methods Standard D143 and included basic, nominal, and oven-dry density, impact bending (stress at proportional limit, modulus of elasticity, work to proportional limit, drop of 22.7 kg hammer at complete failure), compression parallel to grain (stress at proportinal limit, maximum crushing stress, modulus of elasticity) compression perpendicular to grain, hardness, shear parallel to grain, cleavage, and tension perpendicular to grain. Number of samples and regions sampled are included. *(Abstract prepared by compilers.)*

Johal, S., Yuen, B., and Watson, P. 2006. The effects of species on the thermomechanical pulping of balsam fir, black spruce, red spruce and white spruce. *Pulp and Paper Canada* **107**(7–8): 41–45.

Balsam fir (*Abies balsamea* (L.) Mill.), black spruce (*Picea mariana* (Mill.) B.S.P.), red spruce (*Picea rubens* Sarg.), and white spruce (*Picea glauca* (Moench) Voss) samples were thermomechanically pulped to determine species differences in the resulting pulps. No significant differences were found between the three spruce species in the areas of refining energy consumption, fiber properties, physical properties, or optical properties. Balsam fir required less refining energy, produced a weaker/thinner sheet, and had better optical properties when compared with the three spruce species. *(Abstract prepared by compilers.)*

Johnstone, W.D. 2002. *Thinning Lodgepole Pine in Southeastern British Columbia: 46-Year Results.* British Columbia Crown Publications, Victoria, British Columbia, Canada.

A permanent sample plot was established in 1952 in southeastern British Columbia. The site was predominantly fire-origin lodgepole pine (*Pinus contorta* Dougl. var. *latifolia* Engelm.) of average age 53 years, with western larch (*Larix occidentalis* Nutt.), Engelmann spruce (*Picea engelmannii* Parry), subalpine fir (*Abies lasiocarpa* (Hook.) Nutt.), and Douglas-fir (*Pseudotsuga menziesii* var. *glauca* (Bessin) Franco) components. At the time of establishment, the area was divided into blocks subjected to control, and light and heavy thinnings. The site has been periodically remeasured. Between 1978 and 1983, it was attacked by mountain pine beetle (*Dendroctonus ponderosae* Hopkins). As a result of the beetle attack and documentation gaps, statistical analysis cannot be applied to the data, and thus only means and trends are presented.Results showed that older lodgepole pine do respond positively to thinning, with the greatest response found in diameter and volume increases. The data also support the hypothesis that heavy thinning reduces mortality from beetle attack. *(Abstract prepared by compilers.)*

Jones, T.A., and Thomas, S.C. 2004. The time course of diameter increment responses to selection harvests in *Acer saccharum*. *Canadian Journal of Forest Research* **34**(7): 1525–1533.

We used dendroecological techniques to analyze the temporal pattern in diameter growth following selection harvests in stands dominated by *Acer saccharum* Marsh. in central Ontario and examined differences in growth responses related to tree size, damage, and orientation relative to canopy gaps. While dendroecological studies have commonly assumed that trees show immediate growth responses to gap creation (i.e., within 1–2 years), we found that the growth enhancement in *A. saccharum* was gradual and did not reach a peak until 3–5 years following gap creation. Trees of intermediate size showed the largest proportional growth increases after gap creation, with the largest responses observed in trees on the north side of gaps. Trees with visible damage to the crown or bole had significantly lower preharvest basal area increments than trees with little or no damage, but showed greater proportional growth responses to gap creation. Both the long observed time delay in tree growth response to canopy opening and the variability in response relative to tree size and damage have important implications for attempts to reconstruct disturbance history using dendroecological methods and to sustainable forest management under selection system silviculture.

Nous avons eu recours à la dendroécologie pour analyser le comportement temporel de la croissance en diamètre après une coupe de jardinage dans des peuplements dominés par *Acer saccharum* Marsh. dans le centre de l'Ontario et nous avons étudié les différentes réactions des arbres selon leur dimension, leurs dommages et leur orientation par rapport aux ouvertures dans le couvert. Alors que les études dendroécologiques tiennent généralement pour acquis que les arbres réagissent immédiatement (c.-à-d., en dedans de 1 à 2 ans) après la création d'une trouée, nous avons découvert que l'augmentation de croissance chez *A. saccharum* était graduelle et atteignait un sommet seulement 3 à 5 ans après la création d'une trouée. Proportionnellement, les arbres de dimension intermédiaire ont connu la plus forte augmentation de croissance après la création d'une trouée et la plus forte réaction a été observée chez les arbres situés du côté nord des trouées. Les arbres avec des dommages évidents dans la cime ou au tronc avaient un accroissement en surface terrière significativement plus faible avant la récolte que les arbres peu ou pas endommagés, mais ils ont proportionnellement le plus réagi à la création de trouées. Autant le long délai observé dans la réaction des arbres après une ouverture du couvert que la variabilité dans la réaction selon la dimension et l'état des arbres ont d'importantes implications pour les tentatives de reconstitution de l'historique des perturbations à l'aide de la dendroécologie et pour l'aménagement forestier durable dans le contexte d'une futaie jardinée.

Jozsa, L.A., and Middleton, G.R. 1994. *A Discussion of Wood Quality Attributes and Their Practical Implications*. Special Publication SP-34. Forintek Canada Corporation, Vancouver, British Columbia, Canada.

This booklet discusses wood-quality attributes in relation to end-use requirement. It describes wood density, density variation, juvenile and mature wood distribution, proportion of heartwood/sapwood, fiber length, microfibril angle, compression wood, knots, grain and extractives and relates these physical features to mechanical performance. It also describes the potential for influencing wood quality through stock density, intensive silviculture, and site selection. *(Abstract prepared by compilers.)*

Jozsa, L.A., and Powell, J.M. 1987. Some climatic aspects of biomass productivity of white spruce stem wood. *Canadian Journal of Forest Research* **17**(9): 1075–1079.

Biomass productivity was determined for white spruce (*Picea glauca* (Moench) Voss) in the boreal forests of Alberta, the Northwest Territories, and Manitoba. Comparisons were made between southern and northern locations, between eastern and western transect locations, and between older (200+ years) and younger (110 years) trees. At 13 sampling locations, X-ray densitometric tree ring data were obtained from the base of the stem, breast height, and from five points equidistant along the stem. Markedly higher stem wood biomass productivity was found for the 110-year-old trees than for the 210-year-old trees in Alberta; averaging ring widths were 3.8 and 1.2 g for the first 100 years of growth in 1 cm thick discs at breast height. These results suggest that climatic warming since the end of the Little Ice Age (ca. 1850) has resulted in higher biomass productivity in the Canadian boreal forests.

La productivité de la biomasse a été déterminée pour l'épinette blanche (*Picea glauca* (Moench) Voss) dans les forêts boréales de l'Alberta, des Territoires du Nord-Ouest et du Manitoba. Des comparaisons ont été faites entre des sites septentrionaux et méridionaux, entre des virées localisées à l'ouest et à l'est et entre des arbres plutôt âgés (200 ans et plus) et jeunes (110 ans). Sur 13 sites d'échantillonnage, on a obtenu par rayons X des données sur la densité du bois des anneaux de croissance à la base de la tige, à hauteur de poitrine et à cinq endroits équidistants le long de la tige. On a trouvé que la productivité de la biomasse du bois de la tige était sensiblement plus élevée pour les arbres âgés de 110 ans que pour ceux de 210 ans en Alberta; les poids moyens des anneaux étaient de 3,8 et 1,2g pour les 100 premières années de croissance pour des disques de 1 cm d'épaisseur à hauteur de poitrine. Ces résultats laissent supposer que réchauffement climatique depuis la fin du petit âge glaciaire (ca. 1850) a résulté en une productivité supérieure de la biomasse dans la forêt boréale canadienne.

Jozsa, L.A., and Sen, P. 1992. *Relative Density Trends in Second-Growth Lodgepole Pine*. Forintek Canada Corp, Vancouver, British Columbia, Canada.

Forest managers need to know the attributes of the wood under their management and the best end uses for that wood. This study was envisioned to determine characteristics of managed stands of 80- to 100-year-old lodgepole pine (*Pinus contorta* var. *latifolia* (Engelm). Characteristics examined were stem size, relative density, and juvenile and mature wood distribution at various stocking densities. Ten trees from each of 11 stands in eastern British Columbia and west-central Alberta were sampled. Disks were taken at breast height and one-fifth intervals of the height of each tree. These disks were tested for extractive free X-ray densitometry, fiber length determination, and chemical analysis. Disks were taken at two heights for shrinkage measurements. Total crown size was also determined and two trees at each site were selected for measurements of live and dead crown branches. Density was not related to height in the tree for trees with large diameters, which were found at lower stocking densities. Small-diameter trees, however, had decreasing density with height in the tree. A negative relationship was found between density and log diameter. Smaller diameter trees, even at low stocking densities, had higher density in lower boles. The difference between mature and juvenile wood density was found in the lower bole. Transition to mature wood depended on extent of live crown and stocking density. No relationship was found between growth rate and stand density. *(Abstract prepared by compilers.)*

Juice, S.M., Fahey, T.J., Siccama, T.G., Driscoll, C.T., Denny, E.G., Eagar, C., Cleavitt, N.L., Minocha, R., and Richardson, A.D. 2006. Response of sugar maple to calcium addition to northern hardwood forest. *Ecology* **87**(5): 1267–1280.

Watershed budget studies at the Hubbard Brook Experimental Forest (HBEF), New Hampshire, USA, have demonstrated high calcium depletion of soil during the 20th century due, in part, to acid deposition. Over the past 25 years, tree growth (especially for sugar maple) has declined on the experimental watersheds at the HBEF. In October 1999, 0.85 Mg Ca/ha was added to Watershed 1 (W1) at the HBEF in the form of wollastonite ($CaSiO_3$), a treatment that, by summer 2002, had raised the pH in the O_{ie} horizon from 3.8 to 5.0 and, in the O_a horizon, from 3.9 to 4.2. We measured the response of sugar maple to the calcium fertilization treatment on W1.

Foliar calcium concentration of canopy sugar maples in W1 increased markedly beginning the second year after treatment, and foliar manganese declined in years four and five. By 2005, the crown condition of sugar maple was much healthier in the treated watershed as compared with the untreated reference watershed (W6). Following high seed production in 2000 and 2002, the density of sugar maple seedlings increased significantly on W1 in comparison with W6 in 2001 and 2003. Survivorship of the 2003 cohort through July 2005 was much higher on W1 (36.6%) than W6 (10.2%). In 2003, sugar maple germinants on W1 were ~50% larger than those in reference plots, and foliar chlorophyll concentrations were significantly greater (0.27 g/m^2 vs. 0.23 g/m^2 leaf area). Foliage and fine-root calcium concentrations were roughly twice as high, and manganese concentrations twice as low in the treated than the reference seedlings in 2003 and 2004. Mycorrhizal colonization of seedlings was also much greater in the treated (22.4% of root length) than the reference sites (4.4%). A similar, though less dramatic, difference was observed for mycorrhizal colonization of mature sugar maples (56% vs. 35%). These results reinforce and extend other regional observations that sugar maple decline in the northeastern United States and southern Canada is caused in part by anthropogenic effects on soil calcium status, but the causal interactions among inorganic nutrition, physiological stress, mycorrhizal colonization, and seedling growth and health remain to be established. *(Copyright by the Ecological Society of America.)*

Kabzems, R., and Haeussler, S. 2005. Soil properties, aspen, and white spruce responses 5 years after organic matter removal and compaction treatments. *Canadian Journal of Forest Research* **35**(8): 2045–2055.

Retaining organic matter and preventing soil compaction are important factors affecting the sustainability of managed forests. To assess how these factors affect short-term ecosystem dynamics, pre-treatment and 1 year and 5 year post-treatment soil properties and post-treatment tree growth responses were examined in a boreal trembling aspen (*Populus tremuloides* Michx.) dominated ecosystem in northeastern British Columbia, Canada. The experiment used a completely randomized design with three levels of organic matter removal (tree stems only; stems and slash; stems, slash, and forest floor) and three levels of soil compaction (none, intermediate (2-cm impression), heavy (5-cm impression)). Removal of the forest floor initially stimulated aspen regeneration and significantly reduced height growth of aspen and white spruce (*Picea glauca* (Moench) Voss). The compaction treatments had no effect on aspen regeneration density. At year 5, heights of both aspen and white spruce were negatively correlated with upper mineral soil bulk density and were lowest on forest floor removal treatments, where minimal recovery from compaction was observed. There was some evidence for recovery of soil properties to preharvest conditions where expansion of herbaceous vegetation increased soil organic matter.

La rétention de la matière organique et la prévention de la compaction du sol sont des facteurs importants qui affectent la durabilité des forêts sous aménagement. Dans le but d'évaluer comment ces facteurs affectent la dynamique à court terme de l'écosystème, les propriétés du sol avant traitement ainsi qu'un et cinq ans après traitement et la réaction de la croissance des arbres après traitement ont été étudiées dans un écosystème boréal dominé par le peuplier faux-tremble (*Populus tremuloides* Michx.) dans le nord-est de la Colombie-Britannique, au Canada. Le dispositif expérimental était complètement aléatoire et comprenait trois niveaux d'enlèvement de la matière organique (seulement la tige des arbres, la tige et les déchets de coupe, la tige, les déchets de coupe et la couverture morte) et trois niveaux de compaction du sol (aucune, intermédiaire (empreinte de 2 cm) et forte (empreinte de 5 cm)). Au début, l'enlèvement de la couverture morte a favorisé la régénération du peuplier et significativement réduit la croissance en hauteur du peuplier et de l'épinette blanche (*Picea glauca* (Moench) Voss). Les traitements de compaction n'ont eu aucun effet sur la densité de régénération du peuplier. Après cinq ans, la croissance en hauteur du peuplier et de l'épinette blanche était négativement corrélée (r^2 > 0,31) avec la densité apparente de la partie supérieure du sol minéral et elle était la plus faible dans les traitements où la couverture morte avait été enlevée et où le rétablissement des propriétés du sol à la suite de la compaction était minimal. Il y avait des indices que le sol avait retrouvé ses propriétés d'avant la récolte aux endroits où le développement de la végétation herbacée avait accru la quantité de matière organique du sol.

Kang, K.Y., Zhang, S.Y., and Mansfield, S.D. 2004. The effects of initial spacing on wood density, fibre and pulp properties in jack pine (*Pinus banksiana* Lamb.). *Holzforschung* **58**(5): 455–463.

Relationships between basic tree and wood properties and species, seed source, geographic location, site conditions and management decisions are very complex. The objective of this study was to quantify the effects of forest management practices on wood density, fibre and pulp properties in jack pine, one of the most important commercial species in Northern America. A better understanding of the relationship between initial spacing and wood and end-product quality should help define improved forest management strategies required to produce quality wood and products in the future. On the basis of the oldest jack pine initial spacing trial established in 1941 by the USDA Forest Service, this study examined the impact of four different initial spacing trials on tree growth, wood density, fibre and pulp properties of jack pine.

The results clearly show that initial stand spacing has a significant effect on all of these properties, and thus it is possible to improve yield and wood and pulp fibre properties of jack pine through stand density regulation. Additionally, a positive effect of pre-commercial thinning on fibre properties was also demonstrated. As a consequence of these results, basic prescription information for decision-making in the establishment of jack pine plantations with desirable pulp properties can be elucidated.

Karsh, M.B., Lavigne, M.B., and Donnelly, J.G. 1994. *Growth Response of the Balsam Fir and Black Spruce Spacing Trials.* Information Report E-X-291. Natural Resources Canada, Canadian Forest Service - Newfoundland Research Centre, St, John's, Newfoundland, Canada.

Initial growth response of plots thinned to a range of spacings in three balsam fir (*Abies balsamea* (L.) Mill) stands and three black spruce (*Picea mariana* (Mill.) B.S.P.) stands are reported. Periodic annual increments of total volume per hectare decreased with increasing spacing. Conversely, the growth per tree, as measured by diameter growth rates, increased with spacing. Plots thinned to closer spacing added more volume per hectare during the first 5 years to trees that will be merchantable than did plots thinned to wider spacings. Site quality, stand density prior to thinning, and stand age at the time of thinning appeared to affect initial conditions and hence growth rates during the first 5 years. Growth rates of a balsam fir trial on the Northern Peninsula, were lower than plots with similar initial basal area in western Newfoundland. Balsam fir plots in the same ecoregion however had similar growth–basal area relationships. For black spruce growing in the same ecoregion, growth rates were lower for plots with high initial densities (i.e., >20 000). All of the black spruce spacing trials responded to thinning. When black spruce occurs in dense stands, precommercial thinning appears necessary to obtain an operable stands at time of harvest. Growth responses after thinning black spruce are comparable to balsam fir when growing on equally productive sites.

Ce rapport fait état de la croissance initiale des arbres de trois peuplements de sapins baumiers (*Abies balsamifera* (L.) Mill.) et de trois peuplements d'épinettes noires (*Picea mariana* (Mill.) B.S.P.) à la suite de divers degrés d'éclaircie. Plus l'espacement était grand, plus l'accroissement périodique annuel du volume total à l'hectare diminuait. Par ailleurs, la croissance individuelle des arbres, telle que mesurée par l'accroissement du diamètre, augmentait avec l'espacement. Le volume des arbres d'avenir des parcelles moins espacées a augmenté davantage à l'hectare pendant les 5 premières années que celui des parcelles plus espacées. La qualité de station, la densité préalable du peuplement et l'âge du peuplement au moment de l'éclaircie semblent avoir influencé sur les conditions initiales et, par le fait même, sur le taux de croissance des 5 premières années. Les taux de croissance des arbres d'une parcelle de sapin baumier de la péninsule Northern étaient plus faibles que ceux des parcelles présentant des surfaces terrières initiales similaires dans l'ouest de Terre-Neuve. Des parcelles de sapins baumiers de la même écorégion présentaient toutefois des rapports similaires entre leurs taux de croissance et leurs surfaces terrières. Dans le cas de l'épinette noire de la même écorégion, les taux de croissance étaient plus faibles dans les parcelles où les densités initiales étaient élevées (c'est-à-dire supérieure à 20 000). Toutes les parcelles expérimentales d'espacement de l'épinette noire ont bien réagi aux traitements d'éclaircie. Dans des peuplements denses d'épinettes noires, il semble nécessaire de pratiquer une éclaircie précommerciale pour obtenir un peuplement convenablement exploitable au moment de la récolte. Après un passage en éclaircie, la croissance de l'épinette noire est comparable à celle du sapin baumier dans des stations tout aussi productives.

Keith, C.T. 1961. Characteristics of annual rings in relation to wood quality. *Forest Products Journal* **11**(3): 122–126.

Some of the apparent controversy indicated in the literature over specific gravity of wood may be related to differences in species studied by different investigators. Such a situation occurs when authors generalize about softwoods as a group. Other important sources of discrepancy include confounding of variable factors and failure to recognize compression wood. Studies reported in this paper were conducted as a part of the research program for the Ottawa Laboratory of Forest Products Laboratories of Canada. Variation in specific gravity of the wood of white spruce was observed in relation to the width of annual rings and distance from the pith in an attempt to reconcile, if possible, conflicting views on this subject. *(Abstract prepared by compilers.)*

Keith, C.T. 1974. Longitudinal and compression creep and failure development in white spruce compression wood. *Wood Science* **7**(1): 1–12.

Samples of white spruce compression wood of different moisture contents were placed in longitudinal compression at various stress levels for a day. Levels of strain recorded for these samples were considerably higher than those recorded previously for normal wood. Signs of loading were not observable in compression wood until it almost reached the breaking point. This was different than what had been observed in normal wood. Relationships between the performance of compression wood in this experiment and its unique structure/chemical composition were made. *(Abstract prepared by compilers.)*

Kellogg, R.M. 1989. *Second-Growth Douglas Fir: Its Management and Conversion for Value.* Special Publication No. SP-32. Forintek Canada Corporation, Vancouver, British Columbia, Canada.

A comprehensive study was made of second-growth Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) to characterize the properties and products that could be expected. The study sampled 348 trees from six sites from across Vancouver Island. Relative density, juvenile–mature wood transition, longitudinal shrinkage, fiber length, strength and stiffness of dimension lumber, and chemical properties were measured. Examination of solid wood products included lumber yields, lumber drying, and heartwood treatability. Pulp characteristics examined included density and chemical properties of juvenile, mature, and top wood, unbleached Kraft pulps, and refiner mechanical pulps. Finally, a system of models was developed to combine the findings into a tool that could guide silvicultural treatments for desired end-uses. It was concluded that second-growth Douglas-fir will have different properties from the wood currently harvested including differences in juvenile wood content, lumber yield, reduced strength and stiffness, lower Kraft pulp yield but denser, smoother, less porous, and generally stronger paper. *(Abstract prepared by compilers.)*

Kennedy, E.I. 1965. *Strength and Related Properties of Woods Grown in Canada.* Departmental Publication No. 1104. Natural Resources Canada (formerly Department of Forestry), Canadian Forest Service - Headquarters, Ottawa, Ontario, Canada.

This publication lists the strength values and main physical properties of most of the woods grown in Canada. The data have been obtained by the systematic sampling and testing of tens of thousands of clear wood specimens using standard procedures. Statistics are provided to inform the reader of the average values and the degree of variability of the properties. Summary tables of the most frequently used averages are presented in both English and metric units.

La présente publication traite des coefficients de solidité et des principales propriétés physiques de la plupart des bois canadiens. Les données ont été recueillies grâce à des échantillonnages et à des essais qui ont porté sur des dizaines de milliers de spécimens de bois clairs, selon les méthodes classiques. Les tableaux statistiques permettront au lecteur de se renseigner au sujet des coefficients moyens de solidité et du degré de variabilité des diverses propriétés physiques des bois canadiens. Des tables des moyennes d'usage le plus courant sont fournies.

Kennedy, E.I., Jessome, A.P., and Petro, F.J. 1968. *Specific Gravity Survey of Eastern Canadian Woods.* Departmental Publication No. 1221. Natural Resources Canada (formerly Department of Forestry and Rural Development, Forestry Branch), Canadian Forest Service - Headquarters, Ottawa, Ontario, Canada.

An extensive survey of the specific gravity of commercial softwoods in the Atlantic provinces was carried out in the summer of 1964. This publication describes the sampling procedure in the logging areas, and the laboratory procedures used in determining the physical properties of specific gravity, percentage summerwood, rings per inch, and moisture content for the 2,243 specimens from 102 sawmills located throughout the four Atlantic provinces.

A statistical analysis of the data is presented. Average specific gravity and measures of variation are given for each of the ten species samples. A comparison of the data from the survey with the data from standard sampling of the species from across Canada is also shown.

The survey indicated that softwoods grown in the Atlantic provinces have average specific gravities closely corresponding to national values for the same species, and the variation from area to area within the survey region was also found in each case to be typical of the species variation across Canada.

Poids spécifique de 10 essences résineuses commerciales qui croissent dans les provinces Atlantiques. Les mesurages, faits au cours de l'été 1964, sont décrits, de même que les méthodes de laboratoire employées pour établir non seulement le poids spécifique mais le pourcentage de bois d'été, le nombre de cernes annuels au pouce et le contenu en eau des 2,243 échantillons provenant de 102 scieries cà et là dans les dites provinces.

À la suite d'une analyse statistique, l'auteur fournit le poids spécifique moyen avec le degré de variation pour chacune des essences concernées. Les chiffres obtenus sont comparés à ceux qui existent déjà pour l'ensemble du Canada, et il s'avère que les uns et les autres concordent. Les variations locales pour les provinces Atlantiques sont les mêmes que pour tout le pays.

Kennedy, R.W. 1995. Coniferous wood quality in the future: concerns and strategies. *Wood Science and Technology* **29**(5): 321–338.

As the raw material base for forest products manufacturing shifts from old-growth to short-rotation plantation stock, the wood from these younger trees will contain larger proportions of juvenile wood. This in turn will influence the quality of forest products obtained. The pattern of specific gravity variation in these trees, which varies among the five most important Pacific Northwest species groups, is reviewed, and the nature of their differences is related to growth habit. The shade intolerance of some species is speculated to manifest itself in an early culmination of annual height increment, after which specific gravity increases rapidly to a maximum. This is contrasted to shade-tolerant species, in which specific gravity may take several decades to attain a minimum value, followed by only moderate increases thereafter. In addition, faster growth rates in widely spaced plantation trees tend to depress specific gravity and advance the age at which these trees reach their minimum value, thereby compounding the overall wood density of deficit of short-rotation trees.

Lower specific gravity, compounded with reduced lignin content in juvenile wood, negatively influences kraft pulp yield, but not pulp quality parameters such as sheet density, burst and tensile strength. Reduced wood density, coupled with larger fibril angles in juvenile wood, reduces average strength and stiffness of lumber from younger plantation trees. Mechanical stress rating needs to be adopted to segregate the strong, stiff material for engineered construction uses, because a large proportion of visually graded lumber from juvenile wood zones will not meet currently assigned stress values. Mechanical stress rating can ensure a continued stream of appropriate engineering grades from future tree supplies.

Ker, M.F. 1981. *Early Response of Balsam Fir to Spacing in Northwestern New Brunswick.* Information Report M-X-129. Natural Resources Canada, Canadian Forest Service - Atlantic Forestry Centre, Fredericton, New Brunswick, Canada.

Young fir–spruce stands in northwestern New Brunswick, spaced 20 years ago, show greatest yield of merchantable fibre at initial spacings of 1.7 x 1.7 m. Maximum mean merchantable volume was 158.3 m^3/ha, 15% above mean unthinned volume, 20 years after spacing. Average tree diameter increased steadily with increasing spacing. Quadratic mean diameter was up to 26% greater and average above-ground biomass of trees > 9 cm diameter was up to 14% greater in spaced stands than in unspaced stands, 20 years after spacing. Conclusions are based on data from 64, one-fifth acre permanent sample plots established between 1959 and 1967 and remeasured at 5-year intervals.

De jeunes peuplements de sapins et épinettes éclaircies il y a 20 ans dans le nord-ouest du Nouveau-Brunswick accusent un rendement maximal en fibres commercialisables, correspondant à des espacements initiaux de 1,7 x 1,7 m. Le maximum de volume marchand moyen se chiffre à 158,3 m^3/ha, soit 15% de plus que dans les peuplements non éclaircis. L'accroissement du diamètre moyen des arbres est directement proportionnel à l'espacement. Le diamètre moyen et la biomasse moyenne des parties épigées des arbres de plus de 9 cm de diamètre y sont respectivement jusqu'à 26 et 14% plus grands que dans les peuplements non éclaircis. Ces conclusions sont fondées sur les données colligées dans 64 placettes d'échantillonnage permanent de 1/5 d'acre établies entre 1959 et 1967 puis remesurées à des intervalles de cinq années.

Ker, M.F. 1987. Effect of spacing on balsam fir: 25-year results from the Green River spacing trials. Pages 58–75 *in* M.D. Cameron and T.S. Murray, editors. *Proceedings of the Precommercial Thinning Workshop.* Natural Resources Canada, Canadian Forest Service - Atlantic Forestry Centre, Fredericton, New Brunswick, Canada.

Five young balsam fir stands were spaced between 1959 and 1961 to four levels of stand density: control, 4 x 4 ft (1.22 m), 6 x 6 ft (1.83 m), and 8 x 8 ft (2.44 m). Forty-eight 0.2-acre sample plots were established in these stands and remeasured at 5-year intervals. Mean values of several stand variables, including volume, basal area, number of stems, total aboveground biomass, quadratic mean diameter, and number of trees per cubic meter are given for each measurement, based on analysis of all data collected up to and including 1986. Mean merchantable volume at 25 years after spacing below 5 ft than the mean control stand volume. Quadratic mean diameter increased with increased spacing and at 25 years after spacing was 29% greater for merchantable trees in the 8 x 8 ft stands than in the unspaced stands. *(Abstract prepared by compilers.)*

Khalil, M.A.K. 1985. Genetics of wood characters of black spruce (*Picea mariana* (Mill.) B.S.P.) in Newfoundland, Canada. *Silvae Genetica* **34**(6): 221–230.

The variation and relative control of genotype and environment over 11 wood characters in black spruce (*Picea mariana* (Mill.) B.S.P.) were studied to identify populations with superior pulping qualities. A four- and three-level cluster sampling scheme was adopted and the statistical and genetic analyses comprised analyses of variance, BONFERRONI *t*-tests, repeatability calculations and multiple regressions.

Trees, discs and populations rank from highest to lowest as sources of variation in most characters. Within trees, the trend varies with character. There are weak north–south trends in relative density, alcohol-benzene and sodium hydroxide solubilities and fibre length and wall thickness. Regression analyses of the squares of longitude and altitude show a negative and a positive influence respectively on sodium hydroxide solubility. Temperature and precipitation appear most frequently in different combinations in other regression equations. Repeatability values are good estimates of heritabilities. All characters except fibre wall thickness have high heritability ($R \geq 0.30$). The environmental factors studied have a significant influence on the non-genotypic portion of variation in all characters except fibre and lumen diameters (tangential section) and alcohol-benzene solubility. Populations 11, 16 and 19–23 have superior pulping qualities.

Kiernan, D.H., Bevilacqua, E., and Nyland, R.D. 2008. Individual-tree diameter growth model for sugar maple trees in uneven-aged northern hardwood stands under selection system. *Forest Ecology and Management* **256**(9): 1579–1586.

An individual-tree diameter model was developed for sugar maple (*Acer saccharum* Marsh.) in northern hardwood stands managed under selection system. We fitted long-term remeasurement data to a linear mixed model to account for the temporal autocorrelation of the remeasurements. The model was evaluated using independent data from two physiographic regions and representing a range of tree diameter classes, residual basal areas and years since cut. We compared our model to several individual-tree models based on data from stands with varied management histories. Several competition indices were also tested for an improvement in model fitting and prediction. Our model had lower bias and prediction error when compared to two previous models, as it better accounted for the increased diameter growth that occurred in trees from appropriately managed stands. The addition of a tree-specific competition index failed to improve model fit and predictive ability over stand-level basal area.

King, D.A. 2005. Linking tree form, allocation and growth with an allometrically explicit model. *Ecological Modelling* **185**(1): 77–91.

The influence of stem allometry on tree growth is explored with a simple model which projects growth for the idealized case where crown proportions, leaf properties and light use efficiency are held constant throughout growth. Here, the tree is regarded as a machine that grows itself by using light energy to synthesize biomass, which is in turn partitioned among its parts so as to maintain a specified allometry. The following model variants were considered. (1) The base case, which approximates a forest-grown tree, shows that the requirement that basal trunk diameter D_b α $H^{1.5}$ (where H is total tree height), to prevent buckling, substantially slows the height growth rate with increasing tree size, as is observed in real trees. (2) The isometric tree, which maintains geometric similarity, such that D_b α H, has a nearly constant height growth rate, attaining 40 m in 1/3 of the time required for the more realistic, base case tree. (3) The "seedling tree", which maintains constant leaf/stem mass (that of a seedling), requiring that D_b α $H^{0.5}$, grows exponentially throughout life, attaining 40 m in 1/20 of the time required for the base case. (4) The "leech tree", which reconfigures its branches, leaves and roots as it grows, rather than turning over these parts, shows that such replacement costs substantially slow growth and reduce shade tolerance. These results demonstrate the strong links between allometry and growth and suggest that differences in support costs are an important cause of observed interspecific differences in height growth rate.

Klem, G.S. 1968. Quality of wood from fertilized forests. *Tappi* **51**(11): 99A–103A.

Fertilization of spruce and fir forests results primarily in an increase in the number of cells produced and a change in the spring–summer wood ratio. Fertilization tends to reduce specific gravity in wood but this is dependent on the growth of the tree prior to fertilization. Fertilization can alter tracheid lengths, which are important when considering pulp characteristics; however, the effects are too small to be considered significant. *(Abstract prepared by compilers.)*

Klos, R.J., Wang, G.G., Dang, Q.L., and East, E.W. 2007. Taper equations for five major commercial tree species in Manitoba, Canada. *Western Journal of Applied Forestry* **22**(3): 163–170.

Taper equations were developed for balsam poplar, trembling aspen, white spruce, black spruce, and jack pine in Manitoba. As stem taper varied between the Boreal Shield and Boreal Plains for trembling aspen, white spruce, and jack pine, separate taper equations were developed for these species. Stem variation at the regional level differed slightly with those at the provincial level when compared with those equations developed in Alberta or Saskatchewan. These results suggest a single taper equation for each species for Manitoba and Saskatchewan may be required. *(Abstract prepared by compilers.)*

Knowles, R.L., Hansen, L.W., Wedding, A., and Downes, G. 2004. Evaluation of non-destructive methods for assessing stiffness of Douglas fir trees. *New Zealand Journal of Forestry Science* **34**(1): 87–101.

Identification and selection of superior trees in forest management and breeding programmes provide a means to improve the properties and value of future wood products. Non-destructive stiffness assessment of standing trees enables selection of individuals for their stiffness, and so the accuracy and cost of four methods for assessing stiffness were evaluated: (1) IML hammer, (2) 5-mm outerwood density cores, (3) Pilodyn penetrometer, and (4) SilviScan-2®.

Sixty 18-year-old *Pseudotsuga menziesii* (Mirb.) Franco (Douglas fir) trees were assessed for stiffness and the results compared with static modulus of elasticity (MoE) measurements of small clears centred on the tenth annual ring at breast height. Data were analysed using linear models and descriptive statistics, and the effects and costs of selection were modelled.

The IML Hammer and outerwood density cores both gave corrected selection differentials of 11–16% with respect to stiffness at a cost of NZ$20–30 per tree selected. The Pilodyn was also quite cheap, but failed to give an informative measure of stiffness. SilviScan-2® provided a more accurate assessment and subsequent higher estimated selection differential of 22% at a cost of around NZ$500 per selected tree. Technology developments currently being implemented may reduce this cost over time. Selection for stem volume growth alone decreased average stiffness by around 10%.

Knudson, R.M., Wang, B.J., and Zhang, S.Y. 2006. Properties of veneer and veneer-based products from genetically improved white spruce plantations. *Wood and Fiber Science* **38**(1): 17–27.

This study examined the suitability of genetically improved fast-growing and short-rotation plantations for veneer-based products. The materials came from a 36-year-old white spruce (*Picea glauca*) half-sib progeny/ provenance trial located in two regions (sites) of Quebec. A total of 270 sample trees were collected for the study, 130 trees from St-Ignace in the Gaspe Region and 140 trees from Valcartier near Quebec City. Veneer from the Valcartier site had a mean wood density of 0.353 g/cm^3 and a mean modulus of elasticity (MOE) of 9.48 GPa (1.375 million psi). Veneer from the St-Ignace site had a mean wood density of 0.345 g/cm^3] and a mean MOE of 8.05 GPa (1.167 million psi). The differences in veneer wood density and MOE between the two sites were statistically significant. Compared to other Canadian species commonly used for veneer products, the genetically improved fast-growing and short-rotation white spruce yielded considerably lower veneer stiffness.

The plantation-grown white spruce veneer from both sites was knotty. Ninety-eight percent of the veneer was classified as visual grade C. The visually graded veneer would be suitable for sheathing grade plywood. With proper stress grading, 14% of the white spruce veneer was suitable for 12.41 GPa (1.8 million psi) grade laminated veneer lumber (LVL), and another 24% of the veneer was suitable for a lower 10.34 GPa (1.5 million psi) grade of LVL, or as core plies for LVL manufacture. The remaining 62% of the stress-graded veneer was suitable for sheathing grade plywood.

Koch, P. 1987. *Gross Characteristics of Lodgepole Pine Trees in North America*. General Technical Report INT-227. United States Department of Agriculture, Forest Service, Ogden, Utah, USA.

Presents gross characteristics of North American lodgepole pine (*Pinus contorta*) as an industrial raw material, based on analysis of complete-tree specimens collected from the full range of var. *latifolia* Engelm. in the US and Canada, and var. *murrayana* (Grev. & Balf.) Engelm. collected from Oregon and California. Compares and correlates with latitude, longitude, elevation and tree diameter: general tree characteristics, dimensions, moisture contents, weights, cubic volumes, and stem taper; and specific gravity, weight, volume and moisture content of tree components, including heartwood and sapwood, foliage, and wood and bark of roots, stem, and branches. Properties of lodgepole pines vary significantly with latitude, elevation, diameter class, and variety. (Source: US Department of Agriculture, Forest Service.)

Koga, S., and Zhang, S.Y. 2002. Relationships between wood density and annual growth rate components in balsam fir (*Abies balsamea*). *Wood and Fiber Science* **34**(1): 146–157.

This study examined relationships of wood density components with annual growth rate components (or annual ring width components) in juvenile wood and mature wood of balsam fir (*Abies balsamea* (L.) Mill.). The relationships were studied at two different levels: 1) inter-tree level (between trees), and 2) intra-tree level (within a tree). In addition, juvenile–mature wood correlations for these characteristics were investigated. Wood density and annual ring width components of individual growth rings were measured by X-ray densitometry. Based on tree averages (at the inter-tree level), wood density is significantly correlated with its components (earlywood density, latewood density) and latewood percentage in both juvenile wood and mature wood; and earlywood density and latewood percentage are the two most important parameters in determining the overall wood density of the tree. Wood density, however, is not significantly correlated with annual growth rate (ring width) in either juvenile wood or mature wood, although a weakly negative correlation tends to strengthen in mature wood. This suggests that the relationship between wood density and annual growth rate in this species may vary with cambial age. Intra-ring wood density variation (IDV) shows a positive correlation with wood density traits, latewood width, and latewood percentage in both juvenile wood and mature wood, whereas a weakly negative correlation of IDV with ring width and earlywood width exists in balsam fir. Latewood traits are the most important parameters in determining the intra-ring wood density uniformity. At the intra-tree level (based on ring averages within a tree), relationships between wood density components and ring width components are similar to those found between the trees, although some relationships, to some extent, vary within tree. For each wood density trait, the juvenile–mature wood correlation is significant but moderate. For this species, earlywood density in juvenile wood seems to be the best parameter for predicting mature wood density.

Koga, S., and Zhang, S.Y. 2004. Inter-tree and intra-tree variations in ring width and wood density components in balsam fir (*Abies balsamea*). *Wood Science and Technology* **38**(2): 149–162.

This study quantified and compared intra-tree and inter-tree variations in ring width and wood density components in balsam fir (*Abies balsamea*) grown in Quebec, Canada. In addition, the study examined correlations between ring width and wood density components at different stem positions from the stump level to the stem top. Ring width and wood density components of individual rings were measured by X-ray densitometry. Both the intra- and inter-tree variations in balsam fir are large, but the inter-tree variation is relatively smaller than the intra-tree variation. Much of the intra-tree variation is due to the radial variation, whereas the axial variation is much smaller. Compared to ring width and its components, wood density characteristics show a considerably smaller variation at both the inter- and intra-tree level. In almost all wood characteristics studied (except for latewood width), the intra- and inter-tree variations are more or less influenced by tree age. Cambial age explains more intra-tree variation in wood density components than ring width, whereas more intra-tree variation in ring width components is due to ring width. Cambial age and ring width explain a comparable percentage of variation in ring density. Only a few of the correlations between ring width and wood density components vary significantly with stem position from the stump to the stem top at the inter-tree level. In balsam fir, a negative correlation between ring density and ring width is significant in the butt log, but the correlation decreases to an insignificant level at and above a height of 3.0 m.

Koga, S., Zhang, S.Y., and Begin, J. 2002. Effects of precommercial thinning on annual radial growth and wood density in balsam fir (*Abies balsamea*). *Wood and Fiber Science* **34**(4): 625–642.

This study examined effects of precommercial thinning (PCT) on annual radial growth (ring width) and wood density in balsam fir (*Abies balsamea* (L.) Mill.). In addition, the responses to PCT were measured and compared at several stem heights (0.2 m, 0.7 m, 1.3 m, 3 m, 5 m, 7 m, 9 m). Fifty-four trees were collected from plots subjected to moderate thinning (nominal stand density of 2,150 stems/ha), and light thinning (nominal stand density of 4,200 stems/ha), and from control plots. Ring width and wood density of individual rings were measured by X-ray densitometry. Our results show that in balsam fir the annual radial growth rate showed a positive response to PCT, especially in the low part of the stem (up to 5 m high), and this response lasted for 7 years. To achieve a significant increase in annual diameter growth in this species, however, a moderate thinning intensity is needed. This study also revealed that the response of annual radial growth to PCT was limited primarily to the earlywood width, whereas the latewood width showed little response. As a result, the latewood percentage was affected by the moderate thinning. The light thinning and the control plots, however, had a comparable earlywood width and latewood percentage. Both earlywood density and latewood density showed little response to PCT. However, the wood density of growth rings tended to decrease following the moderate thinning, due to a decreased latewood percentage. In addition, the moderate thinning might somehow reduce the intra-ring variation in wood density and thus produce more uniform wood. This study also revealed that the responses to thinning in this species tended to weaken appreciably with increasing stem height. The remarkable responses were observed in the low part of the stem (up to 5 m high), whereas little response was found at the upper part of the stem. As a result, an increased stem taper may result from PCT in balsam fir.

Koran, Z. 1967. Electron microscopy of radial tracheid surfaces of black spruce separated by tensile failure at various temperatures. *Tappi* **50**(2): 60–67.

Electron and light microscopy were used to study radial tracheid surfaces under stress as a preliminary study to identify characteristics of black spruce mechanical pulp. Each pair of complementary fracture surfaces was observed separately within the double wall of adjacent tracheids. Temperature influenced the extent of separation that occurred. Increases in temperature reduce bond strength and increase the amount of transwall failure. *(Abstract prepared by compilers.)*

Koubaa, A., Isabel, N., Zhang, S.Y., Beaulieu, J., and Bousquet, J. 2005. Transition from juvenile to mature wood in black spruce (*Picea mariana* (Mill.) B.S.P.). *Wood and Fiber Science* **37**(3): 445–455.

The radial patterns of several intra-ring traits in increment cores of black spruce (*Picea mariana* (Mill.) B.S.P.) plantation trees were modeled with polynomials to characterize their trends and to estimate the transition age from juvenile to mature wood. Wood density, ring width, latewood density, and latewood proportion were obtained by X-ray densitometry. Average radial trends were similar to those reported earlier in *Picea* species. For all traits measured, significant differences were found among diameter classes. Thus, the juvenile wood production period varies with growth rate. In addition, transition age for a given diameter class varies, depending on trait. Hence, transition age needs to be defined more precisely, basing it on biological processes.

Koubaa, A., Zhang, S.Y., Isabel, N., Beaulieu, J., and Bousquet, J. 2000. Phenotypic correlations between juvenile–mature wood density and growth in black spruce. *Wood and Fiber Science* **32**(1): 61–71.

Phenotypic correlations between juvenile–mature wood density and growth were examined based on increment core samples from two plantations, a provenance test and a commercial plantation, of black spruce (*Picea mariana* (Mill.) B.S.P.). The ring density components are significantly correlated to their respective ring width components: earlywood and ring densities are negatively correlated to ring and earlywood widths, respectively, while ring and latewood densities are positively correlated to latewood width. These hold true in both juvenile and mature wood. However, the correlation between ring width and ring density decreases with increasing age. This suggests that the correlation between wood density and growth rate tends to lessen as the tree ages. For each character, the correlation between juvenile and mature wood is significant but moderate. Thus, juvenile wood characters are only indicative of mature wood ones. On the other hand, trees with 12 growth rings from the pith were good predictors of wood density and radial growth of the whole tree. Individual growth rings from the juvenile–mature wood transition zone can be used to predict to some extent the wood density of either mature wood or the whole tree.

Koubaa, A., Zhang, S.Y., and Makni, S. 2002. Defining the transition from earlywood to latewood in black spruce based on intra-ring wood density profiles from x-ray densitometry. *Annals of Forest Science* **59**(5–6): 511–518.

Defining the transition from earlywood to latewood in annual rings is an important task since the accuracy of measuring wood density and ring width components depends on the definition. Mork's index has long been used as an anatomical definition of the transition from earlywood to latewood. This definition is arbitrary and extremely difficult to apply to X-ray densitometry. For X-ray densitometry, a threshold density of between 0.40 to 0.55 g cm^{-3}, depending on species, has been chosen to differentiate

between earlywood and latewood density, but this method has shortfalls. Therefore, new methods need to be developed and integrated into the computational programs used to generate X-ray densitometry data. In this study, we presented a mathematical method. We modelled the intra-ring wood density profiles in 100 plantation-grown black spruce (*Picea mariana* (Mill.) B.S.P.) trees using high order polynomials. The correlation between the predicted and the measured densities is very high and highly significant. Based on this model, we define the transition from earlywood to latewood as the inflexion point. Results indicate that wood density at the earlywood–latewood transition point varies from juvenile to mature wood. This method could be easily integrated into any X-ray densitometry program and allows to compare individual rings in a consistent manner.

Définition de la transition du bois initial au bois final chez l'épinette noire à partir des profiles de densité intra cernes obtenus par densimétrie aux rayons X. La précision de l'estimation des densités et des largeurs du bois initial et du bois final dans un cerne annuel dépend de la définition de la transition du bois initial au bois final. L'indice de Mork a longuement servi pour donner une définition anatomique à cette transition. Cette définition est arbitraire et difficile à appliquer en densimétrie aux rayons X. En général, un seuil de densité variant entre 0,40 à 0,55 g cm^{-3}, dépendamment de l'essence, sert à différencier le bois initial du bois final. Cette méthode a certaines limites et d'autres méthodes doivent être développées et intégrées aux programmes de densimétrie aux rayons X. Nous avons utilisé une approche mathématique pour modéliser les profiles de densité intra cernes dans 100 arbres d'épinette noire (*Picea mariana* (Mill.) B.S.P.). Le point d'inflexion de polynômes aux degrés élevés a servi pour définir la transition du bois initial au bois final. Les corrélations entre les densités mesurées et prédites sont élevées et significatives. La transition du bois initial au bois final varie entre le bois juvénile et le bois adulte. Cette méthode est facile à intégrer dans les programmes de densimétrie aux rayons X et permet d'obtenir des comparaisons consistantes entre cernes annuels.

Kranabetter, J.M., and Coates, K.D. 2004. Ten-year postharvest effects of silviculture systems on soil-resource availability and conifer nutrition in a northern temperate forest. *Canadian Journal of Forest Research* **34**(4): 800–809.

Silviculture systems (clear-cut, partial-cut, and unharvested forest) were compared 9–10 years after harvesting to determine their effects on conifer nutrition and the availability of soil resources, especially nitrogen. These results were used to discuss the effects of silviculture systems on tree growth in relation to the more commonly described effects of light. Differences in soil properties across the silviculture treatments were most apparent in the forest floor. Depth and C/N ratio of the forest floor had decreased slightly in clearcuts, and forest-floor moisture was highest under partial-cut forest. Despite these differences in soil chemistry and soil moisture, no differences were detected in mineralizable N (anaerobic incubation) or *in situ* net N mineralization among treatments. Height growth and foliar mass were reduced under the low-light conditions of the partial-cut forest, but there were no differences in foliar N concentrations of hybrid white spruce (*Picea glauca* (Moench) Voss x *Picea sitchensis* (Bong.) Carriere), western red cedar (*Thuja plicata* Dougl. ex D. Don), or western hemlock (*Tsuga heterophylla* (Raf.) Sarg.) saplings. Mature western hemlock trees in partial-cut forest also had concentrations of foliar N equal to that of mature trees in the unharvested forest. Overall, we detected only minor effects of silviculture systems on soils after 10 years, and we conclude that light availability is likely more responsible for the current differences in tree growth.

Des systèmes sylvicoles (coupe à blanc, coupe partielle et absence de récolte) ont été comparés 9–10 ans après la récolte pour mesurer leurs effets sur la disponibilité des ressources du sol, particulièrement l'azote, et la nutrition des conifères. Ces résultats ont été utilisés pour discuter des effets des systèmes sylvicoles sur la croissance des arbres en relation avec les effets les plus communément décrits de la lumière. Les différences dans les propriétés du sol entre les traitements sylvicoles étaient surtout apparentes dans la couverture morte. L'épaisseur et le rapport C/N de la couverture morte avaient légèrement diminué dans les coupes à blanc et l'humidité dans la couverture morte était la plus élevée dans les coupes partielles. Malgré ces différences dans les caractéristiques chimiques et l'humidité du sol, aucune différence dans l'azote minéralisable (incubation anaérobique) ni dans la minéralisation nette de l'azote in situ n'a été observée entre les traitements. La croissance en hauteur et la masse foliaire étaient réduites dans les coupes partielles où il y avait moins de lumière, mais il n'y avait pas de différence dans les concentrations d'azote foliaire chez les jeunes tiges d'épinette blanche hybride (*Picea glauca* (Moench) Voss × *Picea sitchensis* (Bong.) Carrière), de thuya occidental (*Thuja plicata* Dougl. ex D. Don) et de pruche de l'Ouest (*Tsuga heterophylla* (Raf.) Sarg.). Les tiges matures de pruche de l'Ouest dans la coupe partielle avaient aussi des concentrations d'azote foliaire égales à celles des arbres matures dans la forêt non récoltée. Dans l'ensemble, nous avons seulement observé des effets mineurs dus aux systèmes sylvicoles sur les sols après 10 ans et nous concluons que la disponibilité de la lumière est probablement plus responsable des différences observées dans la croissance des arbres.

Laflèche, V., and Tremblay, S. 2008. *Résultats de cinq ans de la mesure des effets réels du traitement d'eclaircie précommerciale de peuplements à dominance résineuse.* Mémoire de recherche forestière nº 152, Gouvernement du Québec, Québec, Canada.

A large network of plots was installed during the 1990s in Quebec to quantify the impact of precommercial thinning. Growth and yield were measured every 5 years after the initial treatment in softwood and mixedwood (intolerant hardwood). All the stands had a diameter increase after the thinning, the rate of growth was dependent on site quality and the number of stems prior to treatment. The balsam fir stands had the best response in diameter increase. The volume increase was greater in the control plots as the thinned plot had a big decrease in stand density. The plots will continue to be measured in order to assess the impact of precommercial thinning on a merchantable stand. *(Abstract prepared by compilers.)*

Un important réseau de parcelles fut installé durant les années 1990 au Québec afin de quantifier l'impact de l'éclaircie précommerciale. La croissance et le rendement ont été mesurés tous les 5 ans suite au premier traitement dans un peuplement mixte de feuillus intolérants. Tous les peuplements ont eu un accroissement en diamètre suite à l'éclaircie, le taux de croissance était dépendant sur la qualité de site et le nombre de tiges du peuplement initial. Le peuplement de sapin baumier a eu la meilleure réponse en croissance du diamètre. L'accroissement en volume était supérieur dans les parcelles témoins puisque les parcelles éclaircies ont subi une diminution de tiges majeure. Les parcelles seront remesurées afin de quantifier l'impact de l'éclaircie précommerciale sur un peuplement marchande. *(Résumé fourni par les compilateurs.)*

Lam, F., and Morris, P. 1991. Effect of double-density incising on bending strength of lumber. *Forest Products Journal* **41**(9): 43–47.

An experimental study has been conducted to evaluate the effect of a double-density incising method and chromated copper arsenate (CCA) pressure treatment on the bending strength and modulus of elasticity (MOE) of no. 2 and better nominal 2-by 4-inch (38- by 89-mm) spruce–pine–fir lumber. The double-density incising method, developed by Forintek Canada Corp., involved using a system of synchronized pairs of incising rollers with thin sharp teeth to lay down two superimposed patterns of incisions on lumber in the green condition. An incision density of 1,090/ft^2 (11,720/m^2) was achieved, which allowed white spruce, lodgepole pine, and alpine fir to achieve equivalent penetration with CCA by pressure treatment. Approximately 2,000 specimens were sorted into 8 matched groups according to their average flatwise MOE values and were tested in third-point bending. The eight groups were then given various combinations of incising patterns and pressure treatment level. The results indicate that the fifth percentile bending strength was reduced by 25 percent and the mean MOE was reduced by 6 percent in double-density incised and pressure-treated lumber compared with unincised and untreated lumber.

Larocque, G.R. 2000. Performance of young jack pine trees originating from two different branch angle traits under different intensities of competition. *Annals of Forest Science* **57**(7): 635–649.

The performance of young jack pine (*Pinus banksiana* Lamb.) trees, originating from seed orchard trees of two different branch angle traits, was examined under different intensities of competition with morphological measures of crown development and growth efficiency measures. Seedlings were planted under a split-plot design at five initial spacings—0.5 m, 0.75 m, 1.0 m, 1.5 m and 2.0 m, three blocks, two branching characteristics and four replicates. Relative growth rate for diameter at breast height (dbh) increased by nearly twofold from the closest to the largest spacing. Crown width, crown ratio, needle density ratio and leaf weight ratio decreased significantly with decrease in spacing, which indicated that the efficiency of jack pine crowns to occupy their growing space and the proportion of photosynthesizing biomass relative to respiring biomass were negatively affected by competition. Needle nitrogen concentration decreased with decrease in spacing and was significantly related to leaf weight ratio. Variation with tree size in the ratios of dbh increment to needle biomass and to needle nitrogen content indicated that small trees produced stemwood per unit of photosynthetic tissue and per unit of nitrogen more efficiently than large trees in the absence of severe competition and that this trend was gradually reversed as the intensity of competition increased. Branch angle trait did not constitute a significant advantage for crown development and stem growth.

Le développement de jeunes pins gris (*Pinus banksiana* Lamb.), issus d'arbres-parents localisés dans un verger à graines et différenciés par deux caractères d'angle des branches, a été analysé sous différentes intensités de compétition avec des mesures morphologiques de développement des cimes et d'efficacité de croissance. Les semis ont été plantés selon un dispositif en parcelles divises à cinq niveaux d'espacement (0,5 m, 0,75 m, 1,0 m, 1,5 m et 2,0 m), deux classes d'angle des branches, trois blocs et quatre répétitions. Le taux relatif de croissance en diamètre à hauteur de poitrine (dhp) a presque doublé de l'espacement le plus serré à l'espacement le plus large. La largeur de la cime, le rapport cime-hauteur et les rapports de densité et de masse des aiguilles ont diminué de façon significative avec une diminution de l'espacement initial. Ces résultats indiquent que l'efficacité des couronnes du pin gris à occuper leur espace de croissance et la proportion de tissu assurant la photosynthèse par rapport à la proportion de tissu qui respire a été affectée négativement par la compétition. La concentration en azote des aiguilles, qui a diminué avec une réduction de l'espacement, a été reliée de façon significative au rapport de masse des aiguilles. La variation, en fonction de la taille des arbres, des rapports de croissance en diamètre sur la biomasse foliaire et le contenu en azote des aiguilles indique que, en l'absence de compétition sévère, les petits arbres ont produit plus efficacement de la matière ligneuse par unité de tissu photosynthétique et d'azote que les gros arbres et que cette tendance s'est inversée à mesure que l'espacement diminuait. L'angle de branchaison des arbres ne s'est pas révélé présenter un avantage significatif pour le développement des cimes et la croissance des tiges.

Larson, P.R. 1962. A biological approach to wood quality. *Tappi* **45**(6): 443–448.

Although considerable research has been undertaken to understand tree growth, lack of consistency in results may be attributed to attempts to directly correlate tree growth with environmental factors. This literature review discusses the relationship among tree growth, crown development, and modification by external environmental factors. *(Abstract prepared by compilers.)*

Larson, P.R. 1963. Stem form development of forest trees. *Forest Science Monograph* **9**(1): 52–62.

This monograph explores the development of the stem and the variables that affects stem form, such as open-grown trees, crown or tree class, selection forest, site, inheritance, thinning, pruning, butt swell, and anomalous causes. There are four theories for stem form: nutritional, water conduction, mechanistic, and hormonal. Stem form and wood density are also discussed. *(Abstract prepared by compilers.)*

Larson , P.R. 1969. *Wood Formation and the Concept of Wood Quality*. Yale University, New Haven, Connecticut, USA.

This document deals largely with broad concepts and consists of a generalized approach to an extensive subject. Basic patterns of wood growth and its development are presented, as well as the physiology of wood formation. Application of the concept of wood quality is given, as well as some potential applications of silviculture. *(Abstract prepared by compilers.)*

Lavigne, M.B., and Donnelly, J.G. 1989. *Early Results of a Spacing Trial in a Precommercially Thinned Balsam Fir Stand in Western Newfoundland*. Information Report N-X-269. Natural Resources Canada, Canadian Forest Service - Newfoundland Region, St. John's, Newfoundland, Canada.

Plots thinned to close spacing in a young balsam fir stand in western Newfoundland produced up to three times more total stemwood than did plots thinned to wide spacings during the first 5 years after treatments were applied. Growth per tree of large trees was up to two times greater at wide spacings than at close spacings. This difference between spacing is expected to continue after stands completely reoccupy the site. Thinning changed the competitive relationships within plots. Small trees responded more to thinning than did large trees. This effect of thinning is expected to continue until stands fully reoccupy sites; therefore, it will last longer in widely spaced plots than in closely spaced plots. Fertilization does not appear to have increased growth when applied in combination with thinning.

À l'ouest de Terre-Neuve, des parcelles d'un jeune peuplement de sapin baumier éclairci en espacements serrés ont produit trois fois plus de bois de fut que d'autres parcelles éclaircies de façon plus clairsemée au cours des cinq années suivant le traitement. Individuellement, les gros arbres des peuplements clairsemés ont poussé deux fois plus vite que ceux des peuplements serrés. Cet écart entre les types d'espacement devrait se maintenir après que les peuplements aient complètement réoccupé les parcelles. L'éclaircie a changé les rapports de compétition dans les parcelles. Les petits arbres ont mieux réagi que les grands à cette opération, dont les effets devraient se poursuivre jusqu'à ce que les peuplements réoccupent les parcelles compléments; par conséquent, ces effets seront plus durables dans les parcelles à peuplement clairsemé que dans celles à peuplement serré. Appliquée de concert avec l'éclaircie, la fertilisation ne paraît pas avoir accéléré la croissance des peuplements touchés.

Law, K.N., and Valade, J.L. 1997. Effect of wood quality on thermomechanical pulping: a case study on black spruce and jack pine. Pages 3–7 *in* S.Y. Zhang, R. Gosslin, and G. Chauret, editors. *Timber Management Toward Wood Quality and End-Product Value*. CTIA/IUFRO International Wood Quality Workshop, 18–22 August 1997, Quebec City, Quebec, Canada. Forintek Canada, Sainte-Foy, Quebec, Canada.

The response of black spruce (*Picea mariana* (Mill.) B.S.P.) and jack pine (*Pinus banksiana* Lamb.) to identical thermomechanical pulping parameters were compared. After disk refining, fibers were characterized by freeness measurements, handsheet formation with optical and mechanical property measurements, water retention value determination, and microscopic examination. Jack pine was found to produce a greater quantity of fines and shorter fibers, which was attributed to greater freeness, lower water retention, and unchanged coarseness after beating. Jack pine fibers were found to have lower curl and kink indices. The results were linked to the thicker cell wall of jack pine compared with black spruce tracheids. *(Abstract prepared by compilers.)*

Law, K.N., and Yang, K.C. 2003. Characteristics of fibre separation in wood loaded by normal-to-grain compression. *Appita Journal* **56**(1): 42–45.

This paper describes the effect of perpendicular-to-grain compressive loading on fibre separation in wood. Small wood blocks from a green log of jack pine (*Pinus banksiana* Lamb.) were prepared manually in such a way that the compressive load was applied normal to the growth rings. Some blocks had been boiled in water and some treated with sodium sulfite before pressing. SEM studies indicated that fibre separation in all the samples took place predominantly in the S_1 layer, regardless of the treatment. It is believed that such a mechanical pretreatment of chips before refining might help preserve fibre length and reduce specific energy consumption, for a given level of pulp freeness.

Lei, Y.C., Zhang, S.Y., and Jiang, Z. 2005. Models for predicting lumber bending MOR and MOE based on tree and stand characteristics in black spruce. *Wood Science and Technology* **39**(1): 37–47.

In this study a stepwise method was introduced to identify the best variables for predicting lumber static bending modulus of elasticity (MOE) and modulus of rupture (MOR) based on stand and tree characteristics in black spruce (*Picea mariana*). In the initial development of the technique the two equations were fitted independently using ordinary least squares (OLS). A test for cross-equation correlation using black spruce data showed highly significant correlation between the two equations. Since the cross-equation correlation exists between the two equations more efficient parameter estimation can be achieved through joint-generalized least squares better known as seemingly unrelated regression (SUR). A simultaneous system of two equations was derived for black spruce. The two methods were evaluated and compared for some statistical parameters. The results indicated that there is a small difference between the two methods but parameter estimates from seemingly unrelated regression estimation had smaller standard errors in all cases as compared to those from ordinary least squares estimates. Therefore the system estimation methods theoretically perform better for simultaneously interdependent systems of equations and the appropriate system estimation approaches are recommended for estimating coefficients in simultaneously interdependent systems of forestry equations.

Lemieux, H., Beaudoin, M., and Zhang, S.Y. 2001. Characterization and modeling of knots in black spruce (*Picea mariana*) logs. *Wood and Fiber Science* **33**(3): 465–475.

A knot study on black spruce was performed on 21 trees originating from a natural stand located in Quebec. Branch (knot) frequency, distribution, and diameter along different directions in the trees were evaluated. A destructive protocol for dissection was developed to slice each knot into a series of sections for modelling the knot morphology (or internal distribution) within the log. In addition, attempts were made to establish the relationship between external branch parameters and internal knot morphology.

The study showed that there were higher numbers of knots on the southern sides of the trees than on the northern sides, but the knot diameters on average were smaller on the southern sides. This heterogeneous distribution of knots around the stem increase the chance of finding a log rotation that it optimal for lumber grade yield when the knots are considered during breakdown.

The dissection data were smoothed with second degree polynomial equations using SAS program. The equations yielded knot angles and other knot dimensional characteristics. The study indicated that internal knots in black spruce logs showed large variations in their angles, but their diameters could be predicted from the external measurements. This information is particularly important for sawing and grading models that require precise diameter data.

Lemieux, H., Beaudoin, M., Zhang, S.Y., and Grondin, F. 2002. Improving structural lumber quality in a sample of *Picea mariana* logs sawn according to the knots. *Wood and Fiber Science* 34(2): 266–275.

This paper examines the effect of knots on the strength recovery of black spruce lumber. A model was developed and used to simulate sawing and grading of boards from knotty logs. Since a log internal defect scanner was unavailable, the internal knot morphology was modelled from external measurements. A standard cant and flitch sawing pattern was used in the simulations and rotated about the log axis. For each 30° of log rotation, the theoretical lumber grades were obtained based on knot sizes and positions within the boards. A best and worst sawing rotation angle based on the potential lumber grade yield was retained for each of 54 logs simulated. Half of the logs were sawn into 2 X 4 nominal lumber according to the best rotation angle and the other half according to the worst rotation angle. The resulting pieces of lumber were first visually graded according to the knots and then according to all defects followed by dynamic MOE testing and finally tested to destruction using a third-point bending procedure. The results demonstrate that there was little difference in visual grades between the “best” and “worst” groups and that knots played a minimal role in grade determination of the boards. However, there was significant difference in terms of MOE values, where the group of “best” boards showed an overall 15% increase over the “worst” boards. This result significantly impacts the potential MSR yield of the sample pieces of lumber. Bending tests showed a further 25% difference in average MOR between the two groups. These results suggest that there is potential for black spruce to yield higher strength lumber when knots are considered during breakdown. Further refinements should include a model that determines quality in terms of knot position within the board section rather than one that determines quality in terms of potential visual grades.

Lhotka, J.M., and Loewenstein, E.F. 2008. An examination of species-specific growing space utilization. *Canadian Journal of Forest Research* **38**(3): 470–479.

A comparison is made among the size–density relationships of sugar maple (*Acer saccharum* Marsh.), European beech (*Fagus sylvatica* L.), Norway spruce (*Picea abies* (L.) Karst), lodgepole pine (*Pinus contorta* Dougl. ex Loud. var. *latifolia* Engelm.), eastern white pine (*Pinus strobus* L.), Scots pine (*Pinus sylvestris* L.), loblolly pine (*Pinus taeda* L.), and Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco var. *menziesii*). Species-specific minimum density of full site occupancy (N_{MCA}) and average maximum density (N_{AMax}) equations were developed using forest inventory data and existing models. N_{MCA} and N_{AMax} estimates were used to compare species growing space utilization over a range of stand diameters (12–50 cm). Results suggest growing space utilization varies among the evaluated species and that species differences may change over the diameter range evaluated. Analysis also highlights that a growing space usage gradient is present across species. One end of the gradient is occupied by species that maintain higher densities at small sizes and exhibit greater rates of density decline as mean diameter increases. In contrast, other species maintain lower densities at small diameter, but have lesser rates of density reduction as diameter increases. Finally, results highlight the importance of using species-specific models when quantifying size–density relationships and developing stand-density management regimes.

La relation entre la taille et la densité des arbres a fait l'objet d'une comparaison entre l'érable à sucre (*Acer saccharum* Marsh.), le hêtre commun (*Fagus sylvatica* L.), l'épicéa commun (*Picea abies* (L.) Karst.), le pin tordu (*Pinus contorta* Dougl. ex Loud. var. *latifolia* Engelm.), le pin blanc (*Pinus strobus* L.), le pin sylvestre (*Pinus sylvestris* L.), le pin à encens (*Pinus taeda* L.) et le douglas de Menzies (*Pseudotsuga menziesii* (Mirb.) Franco var. *menziesii*). Des équations ont été mises au point pour calculer la densité minimale d'occupation complète de la station (N_{MCA}) et la densité maximale moyenne (N_{MMa}) pour chaque espèce en utilisant des données d'inventaire forestier et des modèles existants. Les estimations de N_{MCA} et de N_{MMa} ont été utilisées pour comparer l'utilisation de l'espace de croissance par les espèces en fonction du diamètre moyen des arbres des peuplements qui variait de 12 à 50 cm. Les résultats indiquent que l'utilisation de l'espace de croissance est différente parmi les espèces étudiées et que ces différences peuvent changer selon l'étendue des diamètres considérés. L'analyse met aussi en évidence un gradient d'utilisation de l'espace de croissance parmi les espèces. Une extrémité de ce gradient est occupée par les espèces qui maintiennent une forte densité lorsque les arbres sont petits et qui ont un taux plus élevé de déclin de la densité lorsque le diamètre moyen des arbres augmente. À l'opposé, d'autres espèces maintiennent une faible densité lorsque le diamètre des arbres est petit, mais leur taux de réduction de la densité est plus faible lorsque le diamètre des arbres augmente. Finalement, les résultats soulignent l'importance d'utiliser des modèles propres à chaque espèce pour quantifier les relations entre la taille des arbres et la densité du peuplement et pour mettre au point des régimes d'aménagement de la densité des peuplements.

Li, C. 2009. Toward full, multiple, and optimal wood fibre utilization: a modeling perspective. *The Forestry Chronicle* **85**(3): 377–381.

The slow growth rates of Canada's considerable forest fibre supply give it exceptional characteristics. It is a challenge for forest managers, researchers, and stakeholders to realize the highest value creation from this opportunity for the benefit of Canadians. Ideally, this should be achieved with full, multiple, and optimal wood fibre utilization, whereby all quality classes of wood fibre are used to their fullest potential, and all possible value creation options are considered. This paper describes the concept of value chains in a global context, and how they can be applied to forestry using a modeling framework. This is followed by a discussion on how this modeling framework can be used to address the optimal use of wood fibre, and how it can be used to address forest management-related issues and concerns.

Les faibles taux de croissance de l'immense source de fibre de bois du Canada permettent à celle-ci d'avoir des caractéristiques exceptionnelles. C'est un défi pour les gestionnaires forestiers, les chercheurs et les intervenants de pouvoir maximiser la valeur de cette ressource au bénéfice de tous les Canadiens. Idéalement, ceci devrait se faire par une utilisation complète, diversifiée et optimale de la fibre de bois, où toutes les classes de qualité de fibre de bois seraient utilisées au maximum de leurs possibilités et où toutes les options de création de valeur seraient étudiées. Cet article décrit le concept de chaîne de valeur dans son contexte général et comment elle peut être utilisée en foresterie au moyen d'un cadre de modélisation. L'article est suivi d'une discussion sur l'utilité du cadre de modélisation pour atteindre une utilisation optimale de la fibre de bois et pour répondre aux questions et aux enjeux reliés à l'aménagement forestier.

Lihra, T., Cloutier, A., and Zhang, S.Y. 2000. Longitudinal and transverse permeability of balsam fir wetwood and normal heartwood. *Wood and Fiber Science* **32**(2): 164–178.

The occurrence of wetwood in balsam fir is a problem in the drying of sawn lumber: drying time increases and moisture content of dried lumber is heterogeneous. Permeability may be used as an indicator of drying rates. Longitudinal, radial, and tangential intrinsic permeability of balsam fir wetwood and normal heartwood was measured in this study. The longitudinal intrinsic permeability was about 2,000 times and 9,000 times higher than the tangential and radial intrinsic permeability, respectively. Wetwood had a higher longitudinal permeability than normal heartwood, but no significant difference was found between the radial and tangential directions. Sampling height in the tree, basic density, and growth ring width had no effect on the intrinsic permeability. An increase of latewood percentage in the growth rings resulted in an increase in longitudinal intrinsic permeability and a decrease in tangential intrinsic permeability. Radial flow seemed to be controlled by ray blockage in wetwood and normal heartwood, which may result in radial impermeability of wood. A poorly drained stand seemed to favour wetwood formation.

Lindgren, P.M.F., Sullivan, T.P., Sullivan, D.S., Brockley, R.P., and Winter, R. 2007. Growth response of young lodgepole pine to thinning and repeated fertilization treatments: 10-Year results. *Forestry* **80**(5): 587–611.

Lodgepole pine in British Columbia was studied to assess the impact of precommercial thinning combined with fertilization to see if it increased productivity. Various combinations of the treatments were made, and pruning was also done in some treatments to mitigate the fast growth of branches. The potential to minimize losses due to the mountain pine beetle and the shortfall in wood supply is also covered. *(Abstract prepared by compilers.)*

Little, C.H.A., and Savidge, R.A. 1987. The role of plant growth regulators in forest tree cambial growth. *Plant Growth Regulation* **6**(1–2): 137–169.

The regulation of cell-division activity in the vascular cambium and of secondary xylem and phloem development is reviewed for temperate-zone tree species in relation to auxins, gibberellins, abscisic acid, cytokinins, and ethylene. Representatives of the first four of these PGR classes (IAA, GA_1, GA_4, GA_7, GA_9, GA_{20}, ABA, Z, ZR, DCA) have been identified conclusively by mass spectrometry in the cambial region in some Pinaceae, but not in any hardwood species. Endogenous ethylene has yet to be definitively characterized in this region in any species. Evidence concerning the source and metabolism of cambial PGRs is scanty and inconclusive for both conifers and hardwoods.

Most cambial PGR research has focused on IAA. Much evidence indicates that this PGR is transported primarily in the cambial region at a rate of about 1 cm h^{-1}, and that the transport is basipetally polar. GC-MS measurements have established that endogenous IAA levels in the cambial region of Pinaceae are highest during earlywood development, and that cambial IAA levels may be considerably lower in hardwoods than in conifers. IAA appears to be involved in the control of cambial growth in conifers and hardwoods in at least three specific ways, viz. maintenance of the elongated form of fusiform cambial cells, promotion of radial expansion in primary walls of cambial derivatives, and regulation of reaction wood formation. In addition, it is well established that exogenous IAA promotes vessel development in hardwoods. In both conifers and hardwoods, exogenous IAA stimulates cambial growth in 1-year-old shoots treated late in the dormant period or after the start of the cambial growing period. However, exogenous IAA has little effect on cambia that are older or are in what is hypothesized to be the resting stage of dormancy. Thus it is uncertain whether IAA is directly involved in the control of cambial growth, or acts indirectly through a process such as hormone-directed transport. It is not yet clear if gibberellins play a role in the control of cambial growth in conifers. However, in hardwoods, there is evidence that they inhibit vessel development and act synergistically with IAA in promoting cambial activity and fiber elongation. In both conifers and hardwoods, foliar sprays of gibberellins increase the accumulation of biomass aboveground, particularly in the main axis, while decreasing it in the roots. There are as yet no definite conclusions to be drawn concerning the involvement of ABA, cytokinins, and ethylene in the regulation of cambial growth in conifers or hardwoods. In conifers, ABA may antagonize the promotory effect of IAA on cambial cell division and tracheid radial expansion under conditions of water stress, but high endogenous ABA levels do not appear to be associated with the formation of latewood or the onset of cambial dormancy. Some evidence suggests that exogenous cytokinins enhance the promotory effect of IAA on cambial growth, particularly ray formation, in both hardwoods and conifers. However, exogenous cytokinins, by themselves, appear to be ineffective. In hardwoods, ethylene-generating compounds satisfy the chilling requirement of the dormant cambium and promote the formation of wood having an apparently greater content of lignin and extractives. Ethylene-generators also affect wood development in conifers and accelerate cambial growth at the application site in both hardwoods and conifers.

Liu, C., Ruel, J.C., and Zhang, S.Y. 2006. Tree-level models for predicting lumber volume recovery of black spruce using selected tree characteristics. *Forest Science* **52**(6): 694–703.

Using four different model forms (linear, polynomial, power, and exponential), six models relating tree characteristics to lumber yield were developed and compared. Data were from 172 trees sampled from six sites of varying density that had not been subjected to silvicultural intervention. Data were entered into the Optitek sawing simulator. The simulated lumber volume produced was used to develop a general, tree-level model to predict lumber recovery. Statistical analysis of the data revealed that diameter at breast height was the best indicator of recovery. Three of the six models developed were validated by sawing the sample trees and comparing actual with predicted recovery. The models performed best on small- and medium-sized trees. The polynomial model form provided the best estimate. *(Abstract prepared by compilers.)*

Liu, C., Ruel, J.C., and Zhang, S.Y. 2007*a*. Immediate impacts of partial cutting strategies on stand characteristics and value. *Forest Ecology and Management* **250**(3): 148–155.

This study evaluated the impacts of partial cutting on stand characteristics, product recovery, and financial return in mature black spruce–balsam fir stands in Quebec. Four harvesting strategies (clearcut with advance growth protection, irregular shelterwood cutting leaving small merchantable stems, and two patterns of selection cutting) were each applied four times in 20 ha harvest blocks representing irregular black spruce–balsam fir stands. Before the four harvesting strategies were applied, there were no significant differences in stand characteristics (i.e., quadratic mean DBH, basal area, and merchantable stem volume) or expected product recoveries (i.e., lumber volume and value, chip volume and value, and total product recovery) estimated using the Optitek sawing simulation package. There was no significant difference in stand characteristics or product recovery values of the harvested stems between the selection cutting approaches ($p > 0.05$). However, significant differences in stand characteristics and product recovery values of the harvested stems existed between these treatments and both of the two other treatments. After cutting, the two selection cutting treatments had the lowest impacts on stand characteristics, as compared to the two other treatments. The selection cutting approach which used temporary skidding trails and where cutting was initially concentrated over half of the stand resulted in the highest benefit/cost ratio, relatively high net income and high total product value of residual trees.

Liu, C., and Zhang, S.Y. 2005*a*. Equations for predicting tree height, total volume, and product recovery for black spruce (*Picea mariana*) plantations in northeastern Quebec. *The Forestry Chronicle* **81**(6): 808–814.

Several regression models with different independent variables were studied for their ability to predict total tree height, total stem volume, and product recoveries (lumber volume, chip volume, lumber value, and total product value) from a sawing simulator. A sample of 172 trees from black spruce plantations was used to fit model parameters and another independent sample of 139 trees was used for model evaluation. The sample encompassed large variations in tree characteristics and tree product recovery. All the fitted models were suitable for predicting their corresponding response variables. Model validation through actual product recovery data from a real stud mill further indicated that the general tree-level models for the product recovery were able to accurately predict product recovery, especially from small- and medium-sized trees, using measured tree characteristics. These models provide a valuable tool for forest managers in determining appropriate management strategies (e.g., stand volume and optimizing stand value).

Quelques modèles de régression selon différentes variables indépendantes ont été étudiés pour leur capacité à prédire la hauteur totale de l'arbre, le volume total de la tige et les produits retirés (volume de sciage, volume de copeaux, valeur du sciage et valeur totale des produits) au moyen d'un simulateur de sciage de bois d'oeuvre. Un échantillon de 172 tiges d'épinette noire en provenance de plantations a été utilisé pour ajuster les paramètres du modèle et un autre échantillon indépendant de 139 tiges a été utilisé pour l'évaluation du modèle. L'échantillon comprenait une forte variation au niveau des caractéristiques des tiges et des produits tirés de ces tiges. Tous les modèles ajustés étaient utilisables pour prédire leurs variables correspondantes de réponse. La validation du modèle au moyen des données réelles de produits en provenance d'une vraie scierie a indiqué que les modèles généraux au niveau de l'arbre en matière de produits retirés sont en mesure de prédire avec précision la production retirée, particulièrement à partir d'arbres de petite et de moyenne taille, au moyen des caractéristiques mesurées de ces arbres. Ces modèles constituent un outil utile pour les aménagistes forestiers au moment du choix des stratégies adéquates d'aménagement (par ex., volume du peuplement et optimisation de la valeur du peuplement).

Liu, C., and Zhang, S.Y. 2005*b*. Models for predicting product recovery using selected tree characteristics of black spruce. *Canadian Journal of Forest Research* **35**(4): 930–937.

The artificial neural network (ANN) model and five traditional statistical regression models were used to predict four parameters of simulated product recovery (lumber volume, lumber value, chip volume, and total product value) from the stud mill simulation based on three basic tree characteristics of black spruce (i.e., diameter at breast height (DBH), tree height, and tree taper). The ANN model (i.e., the three-layer perceptron with error back-propagation algorithm) performed as well as or better than the five statistical regression models in terms of statistical criteria such as R^2, root mean square error, and mean absolute error of predictions. The second-order polynomial with both DBH and tree height predicted the four product recoveries as accurately as the ANN model. This study showed that the ANN model, the second-order polynomial function, and the power function were suitable for the prediction of product recovery using the selected tree characteristics. The models developed in this study allow the estimation of the product recovery of individual trees and of a forest stand before it is harvested. It is evident that these models would be valuable tools for forest resource managers.

Un modèle en réseau de neurones (RN) ainsi que cinq modèles statistiques traditionnels de régression ont été utilisés dans le but de prédire le rendement simulé de quatre paramètres de produits (volume de sciage, valeur du sciage, volume de copeaux et valeur totale des produits), lors de la simulation d'une usine de sciage de bois de colombage d'épinette noire, à partir de trois caractéristiques de base des arbres (c.-à-d., DHP, hauteur et défilement des arbres). Le modèle en RN (c.-à-d., perceptron à trois couches avec un algorithme de rétropropagation de l'erreur) s'est comporté aussi bien sinon mieux que les cinq modèles statistiques de régression sur la base de critères statistiques tels que le R^2, l'erreur quadratique moyenne et l'erreur moyenne absolue des prédictions. La fonction polynomiale du second ordre avec le DHP et la hauteur des arbres prédisait le rendement des quatre produits avec autant d'exactitude que le modèle en RN. Cette étude a démontré que le modèle en RN, la fonction polynomiale du second ordre et la fonction de puissance sont adéquats pour prédire le rendement en produits à l'aide des caractéristiques choisies. Les modèles développés dans cette étude permettent d'estimer le rendement en produits de chaque arbre individuellement et d'un peuplement forestier avant qu'il soit récolté. Il apparaît évident que ces modèles pourraient être des outils très utiles pour les aménagistes forestiers.

Liu, C., Zhang, S.Y., Cloutier, A., and Rycabel, T. 2007*b*. Modeling lumber bending stiffness and strength in natural black spruce stands using stand and tree characteristics. *Forest Ecology and Management* **242**(2–3): 648–655.

Static bending modulus of rupture (MOR) and modulus of elasticity (MOE) were measured on lumber from trees in the natural and mature black spruce stands grown in eastern Canada. A sample of total 157 trees from the 90- to 100-year-old black spruce natural stands covering a range of sites and growing conditions was used for the model development (n = 102) and validation (n = 55). A stepwise regression method was employed to identify the best variables for predicting MOE and MOR using stand/tree characteristics and wood properties. Then, regression equations with different explanatory variables were developed to predict lumber bending stiffness and strength. Based on the results of model validation from the independent data set, the regression models developed were able to predict the lumber bending MOE and MOR satisfactorily, especially for small- and middle-sized trees. The results (equation parameter estimates and predictions) obtained in this study, along with those for plantation-grown black spruce in eastern Canada, will be highly useful in predicting lumber bending static stiffness and strength for both natural and managed black spruce stands.

Liu, C., Zhang, S.Y., Cloutier, A., and Rycabel, T. 2007*c*. Modeling lumber value recovery in relation to selected tree characteristics in black spruce using the Optitek Sawing Simulator. *Forest Products Journal* 57(4): 57–65.

Relationships between tree characteristics and tree-level product value from two types of sawmills (stud mill and optimized random mill) in black spruce (*Picea mariana*) were investigated. A sample of 172 trees (age 90 to 100 yrs) from black spruce natural stands showed large variations in tree characteristics and tree product value. Models were developed and compared according to selected statistical criteria (i.e., R^2 and the mean absolute mean error of predictions). The best fitted models for predicting tree-level lumber value recovery were considered to be the following forms for the two types of sawmills: 1) the second-order polynomial function with diameter at breast height (DBH) alone, 2) the polynomial function with only the cross product term of squared DBH and tree height, and 3) the power function with DBH, tree height, and tree taper. For both types of sawmills, the three final fitted model forms accounted for more than 92 percent of the total variation in lumber value recovery. The relationships in the models, including input–output and interaction factors, were further analyzed by calculating the elasticities of production and scale and the cross partial derivative of output with respect to the inputs. The analyses indicated that tree DBH had the greatest and most positive influence on the tree-level product value, followed by tree height; however, stem taper had a negative effect. The models were useful for estimating lumber value of individual trees and a forest stand before the trees are harvested.

Liu, C., Zhang, S.Y., and Jiang, Z.H. 2007*d*. Models for predicting lumber grade yield using tree characteristics in black spruce. *Forest Products Journal* **57**(1–2): 60–66.

Relationships between six tree characteristics of black spruce (*Picea mariana*) and lumber grade yields from a stud mill were investigated using multiple linear regression. A sample of 139 trees from black spruce plantations showed large variation in tree characteristics and lumber grade yields. In this analysis, square root-transformed lumber grade yield were used to remove the impact of heterogeneous variances and to reduce the influence of extreme values. The multiple linear regression models with tree DBH, tree total height, and stem taper were considered best based on the simplicity and statistical criteria such as r^2 and root mean squared error (RMSE), Those models could explain up to 86 percent and 71 percent of observed variation in the transformed yields of No. 2 and Better and Select Structural lumber, respectively. Tree DBH was found to have the greatest and most positive influence on lumber grade yields, followed by tree height. Stem taper had a negative effect on the lumber grade yield. For a lower-cost estimate of lumber grade yield, linear regression models were further developed using DBH alone as well as using both DBH and tree height, since tree DBH and height are relatively easy to measure and are usually collected for forest inventory.

Lo, E., Wang, Z.M., Lechowicz, M., Messier, C., Nikinmaa, E., Perttunen, J., and Sievanen, R. 2001. Adaptation of the LIGNUM Model for simulations of growth and light response in jack pine. *Forest Ecology and Management* **150**(3): 279–291.

LIGNUM is a whole tree model, developed for *Pinus sylvestris* in Finland, which combines tree metabolism with a realistic spatial distribution of morphological parts. We hypothesize that its general concepts, which include the pipe model, functional balance, yearly carbon budget, and a set of architectural growth rules, are applicable to all trees. Adaptation of the model to *Pinus banksiana*, a widespread species of economic importance in North America, is demonstrated.

Conversion of the model to jack pine entailed finding new values for 16 physiological and morphological parameters, and three growth functions. Calibration of the LIGNUM jack pine model for open grown trees up to 15 years of age was achieved by matching crown appearance and structural parameters (height, foliage biomass, aboveground biomass) with those of real trees. A sensitivity study indicated that uncertainty in the photosynthesis and respiration parameters will primarily cause changes to the net annual carbon gain, which can be corrected through calibration of the growth rate. The effect of a decrease in light level on height, biomass, total tree branch length, and productivity were simulated and compared with field data. Additional studies yielded insight into branch pruning, carbon allocation patterns, crown structure, and carbon stress. We discuss the value of the LIGNUM model as a tool for understanding tree growth and survival dynamics in natural and managed forests.

Loo-Dinkins, J.A., and Gonzalez, J.S. 1991. Genetic control of wood density profile in young Douglas-fir. *Canadian Journal of Forest Research* **21**(6): 935–939.

The relative density profile from pith to bark was examined in young Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) stems at 1.3, 0.7, and 0.4 m above the ground. The trees represented 22 half-sib families growing at two progeny test locations. The objective was to evaluate the reliability of wood samples taken from below breast height (1.3 m) for selection for relative density in young coastal Douglas-fir progeny tests. The relative density profile appeared to be different for the first 6 or 7 years from the pith at the different sampling heights, but the difference decreased with cambial age. Genetic correlation estimates were sufficiently high to indicate identical genetic control at the three sampling heights, but heritability estimates were higher at 1.3 and 0.7 m than at 0.4 m. Sampling at 0.7 m is as effective as at 1.3 m. This allows reliable selection 1 to 2 years earlier than by sampling at 1.3 m.

On a examiné le profil de la densité relative de la moelle à l'écorce chez de jeunes tiges du sapin de Douglas (*Pseudotsuga menziesii* (Mirb.) Franco) suivant les hauteurs de 1,3, 0,7 et 0,4 m au-dessus du sol. Ces arbres représentaient 22 familles issues de descendances monoparentales poussant en deux endroits d'essais de descendances. Le but de l'étude visait à évaluer le rapport des échantillons ligneux prélevés au-dessous de l'hauteur de poitrine afin de sélectionner pour ce critère de la densité relative chez de jeunes arbres d'origine côtière de l'espèce en cause, établi en tests de descendances. Le profil de cette densité est apparu différent pour les premiers 6 ou 7 ans, à partir de la moelle, suivant les diverses hauteurs de prélèvements des échantillons; cependant, ces différences diminuaient avec l'âge cambial. Les calculs de corrélation génétique furent suffisamment élevés pour indiquer un contrôle génétique analogue suivant les trois hauteurs d'échantillonnage puisque l'héritabilité fut plus élevée à 1,3 et 0,7 m de hauteur qu'à celle de 0,4 m. L'échantillonnage à 0,7 m se montre aussi valable qu'à celui effectué à 1,3 m, permettant ainsi d'avancer la sélection de 1 à 2 ans.

Lussier, J.M. 2009. Changing our mental model from growing volume to producing value: the case of uneven-aged hardwood management. *The Forestry Chronicle* **85**(3): 382-386.

The selection system is a common management system in uneven-aged tolerant hardwoods stands in Crown forests of eastern Canada. This silvicultural system aims to produce a sustained yield of products and services at the stand level, using frequent partial cuttings that harvest the mature and valuable portion of the forest, while tending the rest of the stand to increase its productivity and value for future cuttings. Current practices involve the use of empirical partial cutting guides to decide the number of trees to both harvest and maintain at each cutting cycle, typically to maximize long term sawlog and veneer production. This paper demonstrates that by replacing this objective function with the maximization of the net value of the harvest for the whole value chain by using a simple mathematical optimization model, forest management can be greatly improved in terms of profitability. Nevertheless, further developments are needed for improving forest management optimization models in order to better balance short-term profitability and long-term ecological, economic and societal objectives.

Le jardinage est un mode courant d'aménagement des peuplements inéquiennes de feuillus tolérants de l'est du Canada. Ce régime sylvicole vise à atteindre une production soutenue de produits et de services au niveau du peuplement, au moyen de coupes partielles répétées qui permettent de récolter la portion de la forêt ayant atteint la maturité et une certaine valeur, tout en effectuant l'entretien du reste du peuplement dans le but d'accroître sa productivité et sa valeur lors des prochaines coupes. Les pratiques actuelles comportent l'utilisation de guides empiriques de coupe partielle permettant de décider du nombre d'arbres à couper et à retenir lors de chaque cycle d'interventions, habituellement pour maximiser la production à long terme de billes de sciage et de déroulage. Cet article démontre qu'en remplaçant cet objectif par la maximisation de la valeur nette de la récolte de toute la chaîne de valeur au moyen d'un simple modèle mathématique d'optimisation, l'aménagement forestier peut être grandement amélioré en termes de profitabilité. Néanmoins, de plus amples développements sont requis pour améliorer les modèles d'optimisation de l'aménagement forestier de façon à mieux équilibrer la profitabilité à court terme ainsi que les objectifs écologiques, économiques et sociétaux à long terme.

MacKenzie, J., and Bruemmer, G. 2009. Enhancing Canada's forest fibre. *The Forestry Chronicle* **85**(3): 353–354.

In January 2009, leading thinkers from government, industry and academia joined together in Vancouver for the National Workshop on Enhancing the Economic Value of Canada's Forest Fibre to discuss how to better use Canada's forest fibre. At this workshop, 3 key messages surfaced: 1) there is agreement in the forest sector that value should be prioritized over volume; 2) Canada's research institutions are succeeding in adding value at each stage in the forest product value chain; and 3) the Canadian forest sector will succeed if a common and unified message is developed and broadcast that highlights its successes.

Although factors such as the downturn in the economy and biological infestations have recently been garnering media and government attention, the 3 messages highlighted above remind us that the forest sector is capable of continuing down the path of resiliency and reinvention to meet changing market needs. Focusing on the actions contained in these messages will not only help the Canadian forest sector maintain its position as a global forestry leader, but also to enhance it—a message worth celebrating.

Maeglin, R.R. 1973. *Wisconsin Wood Density Survey.* Paper FPL-202, United States Department of Agriculture, Forest Service Research. Madison, Wisconsin, USA.

Eight coniferous and two deciduous tree species common to Wisconsin were evaluated for wood density. Overall core and tree specific gravity means for species are presented, as well as means and variation by diameter class within forest survey units.

The northeastern survey unit of the State had significantly higher core specific gravity for six species. For four other species the values for this area were higher but not significantly. No other trends were found. (Source: U.S. Department of Agriculture, Forest Service.)

Magnussen, S., and Keith, C.T. 1990. Genetic improvement of volume and wood properties of jack pine: selection strategies. *The Forestry Chronicle* **66**(3): 281–286.

Six selection strategies aimed at genetically improving volume production and wood quality factors such as density, heartwood content, and stem taper are compared in a 20-year-old jack pine progeny trial. Selection indices were computed under various assumptions about economic values of the traits under selection and with constraints on the magnitude and direction of expected genetic gain. Stem taper, wood density, and heartwood content were under strong genetic control; however, the low phenotypic variation of wood density limits its potential for genetic improvement. Heartwood content emerged as a trait amenable for rapid genetic improvement. Despite low heritabilities the prospect of improving size-related traits was promising due to substantial phenotypic variation. Economic weights were important for the selection outcome and good progress was reported in all traits when volume received the highest weight. It was feasible to limit genetic gain in individual traits to predetermined relative levels but the cost in terms of reduced gain in unrestricted traits was economically debilitating. Concerns about undesirable concomitant changes in wood density, heartwood, and stem taper when breeding is based solely on growth traits were not confirmed by our data.

Six stratégies de sélection ont été élaborées en vue d'améliorer génétiquement le rendement en volume ainsi que les caractéristiques de qualité de bois, comme la densité, le contenu du duramen et le défilement de la tige. Ces caractères sont comparés lors d'un test de descendance de pin gris de 20 ans. Les indices de sélection sont évalués selon diverses hypothèses quant aux valeurs économiques des caractéristiques de sélection et sous diverses contraintes de l'ampleur et la direction du gain génétique prévu. Le contrôle génétique comprend le défilement de la tige, la densité de bois et le duramen. Puisque la densité de bois montre peu de variation phénotypique, son potentiel d'amélioration génétique est limité. Le contenu du duramen s'avère un caractère qui peut être le plus facilement et le plus rapidement amélioré du point de vue génétique. Bien que les caractères physiques reliés aux dimensions représentent une faible héritabilité, leur amélioration s'annonce bien, grâce à de fortes variations phénotypiques. L'aspect économique, tenant compte des résultats de la sélection, est important. Tous les caractères se développent bien lorsque le volume est considéré comme le plus essentiel. Il est possible de déterminer le gain génétique des caractères individuels à des niveaux relatifs préétablis, toutefois, les frais paraissent élevés, vu le gain réduit quant aux caractères non restreints. Selon nos données, il n'y a pas de changements concomitants non désirables en ce qui concerne la densité de bois, le duramen et le défilement de la tige dans le cas du croisement fondé uniquement sur les caractères de croissance.

Magnussen, S., Smith, V.G., and Yeatman, C.W. 1985. Tree size, biomass, and volume growth of twelve 34-year-old Ontario jack pine provenances. *Canadian Journal of Forest Research* **15**(6): 1129–1136.

Tree size and aboveground biomass in twelve 34-year-old Ontario jack pine (*Pinus banksiana* Lamb.) provenances growing at Petawawa National Forestry Institute (Chalk River, Ontario) were negatively correlated with latitude of origin. The best provenance exceeded the local provenance in tree height and diameter by approximately 10%. The pattern of geographical variation was stable over time, making general and sound predictions of provenance growth based on juvenile performance feasible. Persistent differences among some geographically close provenances indicated the potential for genetic improvement by selecting the best populations within site regions. The results demonstrated have important implications for jack pine breeding and improvement strategies at the provenance level. The provenance averages of aboveground ovendry weight per tree ranged from 44 to 79 kg. The aboveground tree biomass was distributed as follows in seven analyzed provenances: stem wood, 78%; stem bark, 8%; branch wood, 8%; needles, 5%; cones, 1%. Variation in average stemwood mass among provenances was less than the variation in average stem volume because of a strong negative correlation on a single tree basis between stem volume and stem wood density. The mean annual volume and biomass accretion per hectare in the best provenances averaged 10 m^3 and 4 t, respectively. Total stem volume production per hectare varied exponentially with tree height. Mean annual stem volume increment of the best provenances exceeded that of the slowest growing provenances by 22–40%.

Chez 12 provenances de pins gris (*Pinus banksiana* Lamb.) de 34 ans, cultivées à l'Institut forestier national de Petawawa (Chalk River, Ontario), les dimensions et la biomasse aérienne des arbres étaient en relation inverse de la latitude d'origine. La hauteur et le diamètre des sujets de la meilleure provenance dépassaient de 10% ceux des sujets de la provenance locale. Les écarts liés à la géographie sont restés stables dans le temps, ce qui permet de prédire fidèlement et de façon générale la croissance selon la provenance en se fondant sur la performance des jeunes arbres. Les écarts durables entre certaines provenances géographiquement rapprochées montrent la possibilité d'une amélioration génétique par sélection des meilleures populations à l'intérieur de stations dans des régions. Les résultats constatés ont des conséquences importantes sur les stratégies d'amélioration générale et génétique du pin gris, à l'échelle de la provenance. En moyenne, la biomasse aérienne anhydre des arbres variait, selon la provenance, entre 44 et 79 kg. Chez sept provenances analysées, la biomasse aérienne se répartissait comme suit: bois de fût, 78%, écorce de fût, 8%; bois de branches, 8%; aiguilles, 5%; cônes, 1%. L'écart de la masse moyenne du bois de fût, entre les provenances, était inférieur à l'écart du volume moyen du fût, à cause de la corrélation fortement négative, pour un arbre donné, entre le volume du fût et la masse volumique du bois de fût. L'accroissement annuel moyen du volume et de la biomasse chez les meilleures provenances s'élevait à 10 m^3/ha et à 4 t/ha, respectivement. La production totale du volume des fûts, à l'hectare, variait exponentiellement selon la hauteur des arbres. Chez les meilleures provenances, l'accroissement annuel moyen du fût dépassait de 22 à 40% celui des provenances à croissance lente.

Magnussen, S., and Yeatman, C.W. 1987. Early testing of jack pine. I. Phenotypic response to spacing. *Canadian Journal of Forest Research* **17**(6): 453–459.

Six-year results of stem and branch size, stem form, and branch angle in four local jack pine seeds lots showed the expected changes caused by variation in available growing space. Spacing, age, and their interaction had significant effects on all traits examined. Tree height was the only variable in which seed lot differences were of practical importance. Offspring from a bulked-tree seed lot were significantly taller than offspring from average trees. This difference was more pronounced and persistent among dominant trees in the trial. Statistically significant, but practically unimportant, seed lot X spacing interactions were seen in the diameters of stem and branches. More pronounced interactions are expected to exist among for example half- and full-sib progenies. Juvenile spacing trials are recommended in forest tree breeding programs as they allow assessment under conditions comparable to those in older trials.

Des résultats obtenus à l'âge de 6 ans sur les dimensions de la tige et des branches, la forme de la tige et l'angle des branches chez quatre lots de semence de pin gris récoltées localement, montrèrent les changements prévus causés par des variations dans l'espace de croissance disponible. L'espacement, l'âge et leur interaction ont affecté de façon significative toutes les caractéristiques étudiées. La hauteur fut la seule variable pour laquelle les différences entre les lots de semences avaient une importance pratique. Les descendants issus d'un lot de semence formé de plusieurs arbres plus étaient significativement plus grands que la moyenne. Cette différence était plus prononcée et persistante entre les arbres dominants dans le test. Des interactions lots de semences X espacements furent observés pour le diamètre des tiges et des branches. Quoique statistiquement significatives, elles ne présentent aucune importance pratique. Des interactions plus importantes devraient exister, par exemple, entre les descendances frères et demi-frères. Des essais juvéniles avec divers espacements sont recommandés dans les programmes d'amélioration génétique. Ils permettent d'obtenir des informations dans des conditions comparables à celles présentes dans des tests plus âgés.

Maguire, D.A., Johnston, S.R., and Cahill, J. 1999. Predicting branch diameters on second-growth Douglas-fir from tree-level descriptors. *Canadian Journal of Forest Research* **29**(12): 1829–1840.

The quality of lumber and veneer recovered from logs of Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) is directly influenced by the maximum limb size attained on the crop tree. Because limb sizes are influenced by stand-density regimes, a need has arisen for quantitative tools that link a wide array of silvicultural regimes to wood-product quality by accounting for silvicultural effects on crown development. An equation for estimating maximum branch size at a given level within the live crown was developed from data collected on 96 felled sample trees in the Coast Ranges and Cascade foothills of Oregon and Washington. Height and basal diameter of the largest branch within each live whorl were measured on each felled tree, and a predictive equation was developed by various regression techniques. The final mixed-effects nonlinear model estimates maximum branch size as a function of depth into crown and tree diameter at breast height, height, and live crown length.

La qualité du bois scié et du contreplaqué tirés des billes de Douglas (*Pseudotsuga menziesii* (Mirb.) Franco) est directement liée à la dimension maximale des branches sur les arbres récoltés. Étant donné que la dimension des branches est influencée par les régimes de densité des peuplements, il est devenu nécessaire d'avoir un outil quantitatif qui relie une vaste gamme de régimes sylvicoles à la qualité des produits du bois en tenant compte des effets de la sylviculture sur le développement de la cime. Une équation servant à estimer la dimension maximale des branches à un niveau donné dans la cime vivante a été développée à partir des données recueillies sur 96 arbres-échantillons abattus dans la chaîne côtière et au pied de la chaîne des Cascades dans les États de l'Oregon et de Washington. La hauteur et le diamètre à la base de la plus grosse branche dans chaque verticille vivant ont été mesurés sur chaque arbre abattu et une équation de prédiction a été développée en utilisant diverses techniques de régression. Le modèle final, un modèle non linéaire à effets mixtes, permet d'estimer la dimension maximale des branches en fonction de la profondeur dans la cime, de la hauteur et du diamètre à hauteur de poitrine de l'arbre, et de la longueur de cime vivante.

Mahendrappa, M.K., and Salonius, P.O. 1982. Nutrient dynamics and growth response in a fertilized black spruce stand. *Soil Science Society of America Journal* **46**(1): 127–133.

A fertilization study was done in central New Brunswick with nitrogen and phosphorus on a black spruce stand. The stand was monitored over a period of 10 years, during which time it was observed that growth rate was dependent on the nutrient level in the leaves as well as the growth rate of the tree before fertilization. *(Abstract prepared by compilers.)*

Mäkelä, A. 2002. Derivation of stem taper from the pipe theory in a carbon balance framework. *Tree Physiology* **22**(13): 891–905.

The pipe theory is used to develop a model for stem taper prediction. The simulation evaluated the stem taper, cumulative branch distribution, comparison with the uniform stress theory, disused pipes, and heartwood. Stem form development is dependent on water conductance and mechanical constraint, which the pipe theory can represent. *(Abstract prepared by compilers.)*

Mäkelä, A., and Valentine, H.T. 2006. Crown ratio influences allometric scaling in trees. *Ecology* **87**(12): 2967–2972.

Allometric theories suggest that the size and shape of organisms follow universal rules, with a tendency toward quarter-power scaling. In woody plants, however, structure is influenced by branch death and shedding, which leads to decreasing crown ratios, accumulation of heartwood, and stem and branch tapering. This paper examines the impacts on allometric scaling of these aspects, which so far have been largely ignored in the scaling theory. Tree structure is described in terms of active and disused pipes arranged as an infinite branching network in the crown, and as a tapering bundle of pipes below the crown. Importantly, crown ratio is allowed to vary independently of crown size, the size of the trunk relative to the crown deriving from empirical results that relate crown base diameter to breast height diameter through crown ratio. The model implies a scaling relationship in the crown which reduces to quarter-power scaling under restrictive assumptions but would generally yield a scaling exponent somewhat less than three-quarters. For the whole tree, the model predicts that scaling between woody mass and foliage depends on crown ratio. Measurements on three boreal tree species are consistent with the model predictions. (© *Ecological Society of America*.)

Mallik, A.U., Hossain, M.K., and Lamb, E.G. 2008. Species and spacing effects of northern conifers on forest productivity and soil chemistry in a 50-year-old common garden experiment. *Journal of Forestry* **106**(2): 83–90.

Black spruce, white spruce, and red pine monocultures were established and monitored for their long-term effects on stem volume and soil chemistry. The plantations were established near Thunder Bay, Ontario in 1950, at three different spacings for each species. Soil fertility, soil pH, and nutrient loads were measured in 2000, and stem volumes were measured in 2002. Red pine had the highest volume in all three of the spacings; white spruce and black spruce, in that order, were next. Nutrient loads were higher under white spruce and red pine. Higher calcium levels in the red pine soil were suggested as being the reason for the higher volumes. *(Abstract prepared by compilers.)*

Mamdy, C., Rozenberg, P., Franc, A., Launay, J., Schermann, N., and Bastien, J.C. 1999. Genetic control of stiffness of standing Douglas fir from the standing stem to the standardized wood sample, relationships between modulus of elasticity and wood density parameters. Part I. *Annals of Forest Science* **56**(2): 133–143.

The Institut national de la recherche agronomique (Inra) developed a tree-bending machine, similar to the device elaborated by Koizumi and Ueda, and used it to measure the stiffness of standing tree trunks (modulus of elasticity, MOE). There are moderate or good relationships between trunk MOE and MOE based on destructive samples successively sawn in the study stems: the modulometre is able to rank genetic units for a trait related to the MOE of the wood of the stem. Our study showed that there exists a strong genetic effect on trunk MOE. This trait and the MOE measured on destructive samples are moderately related (best r^2 from 0.37 to 0.42) with ring density parameters (based on trimming the ring in two parts: earlywood and latewood), and closely related (best r^2 from 0.58 to 0.73) with parameters describing the shape of a mean density profile segment, mostly located in the latewood part of the ring.

Modélisation du module d'élasticité à l'aide de données microdensitométriques: méthodes et effets génétiques. 1re partie. L'Inra a fabriqué une machine servant à mesurer la rigidité du tronc des arbres sur pied (Module d'elasticité du tronc de l'arbre sur pied, MEP), inspirée de celle imagée et construite par Koizumi et Ueda au Japon. Des mesures de module de Young en flexion statique réalisées sur des échantillons de taille variable débités dans les troncs des arbres sur lesquels on a mesuré le MEP sont assez bien ou bien liées avec les mesures sur pied: le modulomètre semble donc capable de classer des unités génétiques pour le module de Young du bois. À partir de la mesure du MEP de cinq clones de douglas X quatre arbres non sélectionnés sur les propriétés de leur bois, on a mis en évidence l'existence d'un très fort contrôle génétique du MEP. Ce caractère et le module d'élasticité des échantillons destructifs découpés dans les troncs sont modérément liés (les meilleurs r^2 vont de 0,37 à 0,42) aux paramètres microdensitométriques basés sur la découpe du cerne en bois initial et final, et bien liés (les meilleurs r^2 vont de 0,58 à 0,73) à des paramètres de polynômes décrivant la forme d'un segment de profil plutôt vers la fin (bois final) du cerne.

Man, R., and Greenway, K.J. 2004. Meta-analysis of understory white spruce response to release from overstory aspen. *The Forestry Chronicle* **80**(6): 694–704.

Meta-analysis was used to summarize the research results on the growth response of understory white spruce to release from overstory aspen from different studies available from published and unpublished sources. The data were screened for the suitability for meta-analysis. Treatment effect sizes were calculated using response ratio from mean cumulative increments of released and control trees since release in height, diameter, and volume and modeled using a polynomial mixed effect regression procedure. Predictor variables include linear, quadratic, and cubic components of three independent variables—initial tree height, number of years after release, and residual basal area at release—and their linear interactions. Models with a reasonable predictive power were developed for height, diameter, and volume response, but no significant model was identified for survival. The models developed in this study can be applied to predict the growth response of understory white spruce to release, based on the growth of unreleased control trees, initial tree height, residual basal area at release, and time since release. The individual tree prediction can be easily scaled up to stand level if residual tree density and distribution is known.

Une méta analyse a été utilisée pour résumer les résultats de recherche sur la réaction en terme de croissance de l'épinette blanche en sous-étage dégagé d'un couvert de tremble à partir de différentes études tirées de sources ayant fait l'objet ou non de publication. Les données ont été filtrées pour les besoins de la méta analyse. Les dimensions de l'effet du traitement ont été calculées au moyen d'un ratio de réaction tiré des accroissements cumulatifs moyens des arbres dégagés et des arbres-témoins depuis le dégagement en hauteur, en diamètre et en volume et modélisé selon une procédure de régression polynomiale à effet mixte. Les variables de prédiction comprenaient les éléments linéaires, quadratiques et cubiques de trois variables indépendantes—la hauteur initiale de l'arbre, le nombre d'années après le dégagement et la surface terrière résiduelle après le dégagement—ainsi que leurs interactions linéaires. Des modèles démontrant un niveau raisonnable de prédiction ont été élaborés pour la réaction en hauteur, en diamètre et en volume, mais aucun modèle significatif n'a été retenu pour la survie. Les modèles élaborés au cours de cette étude peuvent être utilisés pour prédire la réaction de croissance d'un sous-étage d'épinette blanche, en fonction de la croissance des arbres-témoins non dégagés, de la hauteur initiale des arbres, de la surface terrière résiduelle après le dégagement et du temps écoulé depuis le traitement. La prédiction pour chaque arbre peut être facilement amenée au niveau du peuplement à la condition que la densité des arbres résiduels et leur distribution soient connues.

Man, R., Kayahara, G.J., Rice, J.A., and MacDonald, G.B. 2008. Response of trembling aspen to partial cutting and subsequent forest tent caterpillar defoliation in a boreal mixedwood stand in northeastern Ontario, Canada. *Canadian Journal of Forest Research* **38**(6): 1349–1356.

The growth response and mortality of trembling aspen (*Populus tremuloides* Michx.) were monitored 1, 3, 5, and 11 years after partially harvesting an aspen-dominated mature mixedwood stand in northeastern Ontario. Both diameter and height of aspen trees responded positively to harvesting. However, 3 years after harvest, the growth rates of residual aspen were severely suppressed by 3 years of moderate to severe defoliation by forest tent caterpillar (*Malacosoma disstria* Hbn.). The diameter growth of surviving trees almost recovered, but due to continuous crown dieback in the 6 years after defoliation ceased, height growth did not. Over the 11 years after harvest, 70% of residual aspen died, with 80% of that mortality occurring in the 6 years after defoliation. Trees in the lower canopy and in the partial cut had higher mortality rates than those in the upper canopy and in the uncut control. Increased mortality at the individual tree level was generally associated with greater foliage loss. Aspen growth and mortality were associated with defoliation levels, particularly for trees in partial cut treatments. Partial cutting and crown class strongly influenced the response of aspen trees to insect defoliation and should be considered when selecting residual trees during harvesting.

La réaction en croissance et la mortalité du peuplier faux-tremble (*Populus tremuloides* Michx.) ont été mesurées 1, 3, 5 et 11 ans après une coupe partielle dans un peuplement mixte dominé par le peuplier faux-tremble dans le nord-est de l'Ontario. Tant le diamètre que la hauteur des tiges de peuplier faux-tremble ont réagi positivement à la coupe. Cependant, 3 ans après la coupe, le taux de croissance des peupliers faux-tremble résiduels a été sévèrement réduit à la suite de 3 années de défoliation modérée à sévère causée par la livrée des forêts (*Malacosoma disstria* Hbn.). La croissance en diamètre des arbres qui ont survécu s'est presque rétablie, mais pas la croissance en hauteur à cause du dépérissement continu de la cime durant les 6 années qui ont suivi la fin de la défoliation. Au cours des 11 années qui ont suivi la coupe, 70 % des peupliers faux-tremble sont morts et 80 % de la mortalité est survenue au cours des 6 années qui ont suivi la fin de la défoliation. Le taux de mortalité était plus élevé en sous-étage et dans la coupe partielle que dans l'étage dominant et la parcelle témoin non coupée. Sur une base individuelle, un taux de mortalité plus élevé était généralement associé à une perte de feuillage plus importante. La croissance et la mortalité du peuplier faux-tremble étaient associées à l'intensité de la défoliation, particulièrement chez les arbres dans la coupe partielle. La coupe partielle et la classe de cime ont fortement influencé la réaction des tiges de peuplier faux-tremble à la défoliation par les insectes et devraient être prises en compte dans le choix des arbres résiduels lors de la coupe.

Mansfield, S.D., Parish, R., Goudie, J.W., Kang, K.Y., and Ott, P. 2007. The effects of crown ratio on the transition from juvenile to mature wood production in lodgepole pine in western Canada. *Canadian Journal of Forest Research* **37**(8): 1450–1459.

Crown depth, tree spacing, and stand density have major effects on wood quality and fibre characteristics of trees. Lodgepole pine (*Pinus contorta* Doug. ex Loud.) trees from a mixture of plantation and fire origin stands were employed to determine how crown ratio, a surrogate for stand density, affected mature wood production. In total, 104 trees were sampled, ranging from 24 to 110 years of age, from stands in western Alberta and interior British Columbia, Canada. Samples taken along the bole were measured for wood density, which was subject to segmented regression analysis to identify the transition point from juvenile to mature wood production. On average, the lodgepole pine trees were 31 (±17 SD) years old before mature wood production began. A mixed-effects model, in which combination of fixed effects (tree age, height of the sample disc relative to crown base, and crown length) and random effects (site, trees nested in sites, and discs nested in both trees and sites) proved to be the best predictor of years of mature wood production along the bole. The transition from juvenile to mature wood was shown to be below the crown base in trees <50 years old with deep crowns, and above the crown base otherwise.

La longueur de cime, l'espacement entre les arbres et la densité du peuplement ont des effets importants sur la qualité du bois et les caractéristiques des fibres chez les arbres. Des tiges de pin lodgepole (*Pinus contorta* Doug. ex Loud.) provenant d'un mélange de plantations et de peuplements issus de feux ont été utilisées pour déterminer comment le rapport cime/hauteur total, un substitut pour la densité du peuplement, a affecté la production de bois adulte. Au total, 104 arbres âgés de 24 à 110 ans ont été échantillonnés dans des peuplements de l'ouest de l'Alberta et de l'intérieur de la Colombie-Britannique, au Canada. Des échantillons ont été prélevés le long du tronc pour mesurer la densité du bois qui a été soumis à une analyse de régression segmentée pour identifier le point de transition entre le bois de jeunesse et le bois adulte. Les tiges de pin lodgepole commençaient à produire du bois adulte après avoir atteint l'âge moyen de 31 ans (erreur type = ±17). Un modèle à effets mixtes, dans lequel une combinaison d'effets fixes (l'âge de l'arbre, la hauteur de la rondelle échantillonnée relativement à la base de la cime et la longueur de cime) et d'effets aléatoires (la station, les arbres imbriqués dans les stations et les rondelles imbriquées dans les arbres et les stations) s'est avérée le meilleur prédicateur des années de production de bois adulte le long de la tige. Il a été démontré que la zone de transition entre le bois de jeunesse et le bois adulte était située vers la base de la cime chez les arbres de moins de 50 ans avec une longue cime et au-dessus de la base de la cime dans les autres cas.

Mansfield, S.D., and Weineisen, H. 2007. Wood fiber quality and kraft pulping efficiencies of trembling aspen (*Populus tremuloides* Michx.) clones. *Journal of Wood Chemistry and Technology* **27**(3–4): 135–151.

The natural variation in wood and pulp fiber quality of 15 aspen (*Populus tremuloides* Michx) clones, represented by 47 trees, was assessed from 4 different sites in British Columbia, Canada. Kraft pulping trials revealed substantial variation in the pulping efficiencies, illustrated by differences of 6% in total pulp yield, ~30% differences in H-factor required to attain a target kappa of 21, and differences of up to 2 ISO brightness units in bleachability of kappa 21 pulp. Clearly, enormous variation exists in the natural stands of aspen, and presents some exciting opportunities for selecting clonal aspen for targeted end-product applications. A comprehensive characterization of wood chemical composition, wood density, and fiber properties indicated that pulp yield is directly related to syringyl lignin monomer composition, and not inherent wood density, regardless of geographic locations, whereas pulp bleachability and viscosity appear to be associated with the inherent cell wall thickness of the starting wood resources (fiber coarseness). These findings suggest that geographic location imparts influences on wood fiber coarseness traits, while substantial genetic variability exists on all sites. [online] URL: http://tandf.co.uk/journals

Markwardt, L.J. 1930. *Comparative Strength Properties of Woods Grown in the United States.* Tech. Bull. No. 158. United States Department of Agriculture, Forest Service, Washington, D.C., USA.

The information contained in this bulletin is of value in making comparisons of species of wood in order to determine the choice of species for specific uses. Technical terms have, as far as possible, been omitted from the body of the bulletin, and the various properties determined from over a quarter million tests have been combined into simple comparative figures. This bulletin supplements but does not supersede United States Department of Agriculture Bulletin 556, Mechanical Properties of Woods Grown in the United States, (4)3 from which the comparative figures have been derived. Since Bulletin 556 was issued, additional tests have been made and some additional species have been tested. In all cases, the comparative figures presented here are based on the latest avaliable results. Bulletin 556 should be used when technical data on the properties of clear wood are required by engineers, architects, and others, or when, in the judgment of the user, it is more applicable than the comparative figures presented here.

Although this bulletin gives figures only on weight, shrinkage, and strength, it is of course evident that other properties and factors, such as resistance to decay, painting and finishing qualities, tendency to leach coloring matter, size and character of prevalent defects, marketing practices, and the like must also be considered in selecting a species or in determining the suitability of a wood for different uses. Attention is also called to the fact that, because of the considerable variation in properties of all species of wood, it is often possible to select individual pieces of a weak species exceeding in strength the average of a stronger one, and to segregate to wood of a species into classes according to weight and strength, so that each class may be directed to the uses for which the class is best suited. In this way the variability of wood may be turned from a liability to an asset. (*Source: United State Department of Agriculture, Forest Service.*)

Marshall,D.D., and Curtis, R.O. 1999. Thinning in the Pacific Northwest: results from the LOGS study. Pages 61–68 *in* Anonymous. *Thinning in the Maine Forest*, proceedings of conference, 15–16 November 1999, Augusta Civic Center, Augusta, ME. University of Maine, Orono, Maine, USA.

This paper provides the results from the regional Douglas-fir levels-of-growing-stock (LOGS) study. It was done in order to produce a thinning schedule for Douglas-fir. It showed that thinning had a huge influence on the growth rate of trees and stands alike. From the data, the authors were able to produce updated growth-and-yield models for the region. *(Abstract prepared by compilers.)*

Mattice, C.R., and Riley, L.F. 1975. *Commercial Strip Thinning in a 45-Year-Old Jack Pine Stand*. Information Report O-X-233. Natural Resources Canada, Canadian Forest Service - Great Lakes Forestry Centre, Sault Ste. Marie, Ontario, Canada.

During the fall of 1970, a 45-year-old jack pine (*Pinus banksiana* Lamb.) stand near Chapleau, Ontario was commercially thinned, under contract, by means of a conventional shortwood logging system. Approximately 51.8 ha (128 acres) were thinned, with clear-cut corridors 5.0 m (16.5 ft) wide being separated by 6.3 m (20.5 ft) wide rows of residual trees. The purpose of the trial was to determine whether such an operation was economically feasible. The trial consisted of work studies of the felling and forwarding operations. A revenue–cost statement was obtained from the contractor.

The thinning proved to be operationally feasible and profitable, and the contractor earned a net revenue of $2.35/cu. m (5.59/cord). These results indicate considerable potential for the application of commercial strip thinning in the boreal forest.

À l'automne de 1970, un peuplement de Pin gris (*Pinus banksiana* Lamb.) âgé de 45 ans et situé près de Chapleau, Ontario fut soumis à une éclaircie commerciale, sous contrat. Les coupes s'effectuèrent de façon classique, en billes courtes. On éclaircit environ 52.8 ha (128 acres) en coupant à blanc des bandes de 5.0 m (16.5 pi) de largeur séparées par des bandes de forêt résiduelle de 6.3m (20.5 pi) de largeur. On voulait savoir si une telle opération était rentable. Pour ce faire, on analysa le travail accompli lors des coupes et du transport des billes. L'entrepreneur nous a fournit ensuite un rapport sur les coûts et revenus.

L'opération s'avère faisable au point de vue opérationnel et, en outre, elle fut profitable. L'entrepreneur réalisa un profit net de $2.35/m^3 (5.59$/corde). On peut conclure que l'avenir des éclaircies commerciales par bandes dans la forêt boréale s'avère prometteur.

McArthur, J.D. 1965. A release experiment in dense ten-year-old balsam fir in Gaspé. *Pulp and Paper Magazine of Canada* **66**: 395–400.

A full and partial release were applied to a balsam fir stand in the Gaspé. Both treatments caused height and diameter growth to increase significantly, the live crown ratio to increase, and stand density to decrease. All these responses were more significant in full release than in partial release. *(Abstract prepared by compilers.)*

McClain, K.M., Morris, D.M., Hills, S.C., and Buse, L.J. 1994. The effects of initial spacing on growth and crown development for planted northern conifers: 37-year results. *The Forestry Chronicle* **70**(2): 174–182.

A spacing trial was established near Thunder Bay, Ontario in 1950. This trial consisted of black spruce (*Picea mariana* (Mill.) B.S.P.), white spruce (*Picea glauca* (Moench) Voss), and red pine (*Pinus resinosa* Ait.) each established at three different spacings: 1.8 m, 2.7 m, and 3.6 m. This study examines the differences in growth and crown development as attributed to initial spacing, after 37 years. In addition, a benefit/cost analysis was performed to evaluate the economic efficiency of the various species/spacing combinations. Diameter at breast height, live crown length, and crown width, all exhibited significant ($P < 0.001$) increases as initial spacing increased, irrespective of species, but, height demonstrated a decreasing trend ($P < 0.020$). Gross total and merchantable stem volume per tree increased for all species as initial spacing increased; however, volume production per unit area decreased significantly for all species as spacing increased. The shift to higher-valued products from the wider-spaced plantations appeared to provide the best economic return. As a result of both greater merchantable volumes and greater percentages of these volumes available as a higher-valued product, benefit/cost ratios for red pine (0.995 to 1.337) were greater than those for the spruces (0.595 to 0.866). Although red pine currently represents less than 4% of Ontario's total regeneration effort, the results from this study suggest it deserves further consideration on some boreal sites.

Une plantation a été réalisée à titre expérimental près de Thunder Bay en Ontario en 1950. Cet essai portait sur l'épinette noire (*Picea mariana* (Mill.) B.S.P.), l'épinette blanche (*Picea glauca* (Moench) Voss), et le pin rouge (*Pinus resinosa* Ait.) chacune des espèces plantées selon trois espacements : 1.8 m, 2.7 m, et 3.6 m. Cette étude se penche sur les différences en croissance et en développement de la cime en fonction de l'espacement initial, 37 ans plus tard. De plus, une analyse des bénéfices en fonction des coûts a été effectuée afin d'évaluer l'efficacité économique de différentes combinaisons d'espèces et d'espacement. Le diamètre à hauteur de poitrine, la longueur de la cime vivante et le diamètre de la cime ont tous démontré des augmentations significatives ($P < 0.001$) en fonction de l'augmentation de l'espacement initial, pour toutes les espèces, mais la hauteur suivait une tendance inverse ($P < 0.020$). Le volume total et le volume marchand par arbre a augmenté pour toutes les espèces à mesure que s'accroissait l'espacement initial, alors que le volume par unité de surface diminuait significativement pour toutes les espèces en fonction de l'augmentation de l'espacement. Le changement vers des produits de plus grande valeur tirés des plantations à espacement plus grand semble procurer le meilleur retour sur l'investissement. Les résultats à la fois au niveau des volumes marchands supérieurs et du plus fort pourcentage de ces volumes disponibles en tant que produit de valeur supérieure ont permis d'obtenir des ratios des bénéfices en fonction des coûts pour le pin rouge (0.995 à 1.337) plus élevés que ceux des épinettes (0.595 à 0.866). Même si le pin rouge ne représente actuellement que moins de 4% de l'effort total de régénération en Ontario, les résultats de cette étude démontrent qu'il mérite de plus amples considérations sur certains sites de la forêt boréale.

McKenney, D.W., Beke, N., Fox, G., and Groot, A. 1997. Does it pay to do silvicultural research on a slow growing species? *Forest Ecology and Management* **95**(2): 141–152.

This paper reports the results of a case study in the characterization of economic benefits of forestry research. An *ex ante* perspective is adopted given most of the impacts will occur well into the future. Improved methods of anticipating the benefits of research and technological change in forestry are needed given the increasing scarcity of research resources in the sector. The approach employed in this paper attempts to reflect the role of time lags in research, development and adoption, as well as the adoption costs, uncertainty and policy change. Both deterministic and stochastic cost–benefit algorithms were employed to calculate the benefits of silvicultural research on black spruce (*Picea mariana* [Mill.] B.S.P.), a relatively slow growing boreal tree species. Despite preconceptions that such research is not economically viable, the results suggest that silvicultural research on slow growing species may be a worthwhile investment. To be worthwhile from a wood growing perspective real stumpage values must increase through time. *A priori* justification of this particular silviculture and hence the research project also included improved wildlife habitat conditions. However, these benefits are ill-defined and probably should not be used as a rationale for either the research or the silvicultural practice itself without further study.

McLaren, B.E., and Jeglum, J.K. 1998. Black spruce growth and foliar nutrient responses to drainage and fertilization: Wally Creek, Ontario. *The Forestry Chronicle* **74**(1): 106–115.

We report tenth-year growth and yield improvements in the Wally Creek area, an experimental, systematic drainage project established in 1984 and fertilized in 1986, in a forested Ontario peatland. We analyzed and compared results for dominant–codominant and intermediate black spruce in two site types. Response of trees to NPK-fertilization was more immediate than to drainage. Response to drainage took about five to seven years, whereas response to fertilization occurred earlier, from three to five years. Some indication of an asymmetric response, with larger trees experiencing higher growth increases, was observed for the OG 11 (Ledum) site type, while yield increases were potentially higher in the OG 12 (*Alnus* herb-poor) site type. Drainage was most effective in combination with fertilization. Consistent for both site types were increases in phosphorous associated with fertilization. The Wally Creek project is a benchmark in the analysis of growth and yield response from intensive peatland silviculture.

Ce rapport résume 20 ans de croissance et d'amélioration du rendement d'un projet expérimental de drainage systématique d'une tourbière forestière de l'Ontario, établi dans la région de Wally Creek en 1984 et fertilisé en 1986. Les auteurs ont analysé et comparé les résultats obtenus des épinettes noires de l'étage dominant–codominant et intermédiaire provenant de deux stations. Les réactions des arbres à une fertilisation NPK ont été plus immédiates que celles en fonction du drainage. Les réactions au drainage ont nécessité de cinq à sept ans avant d'être apparentes, tandis que les réactions à la fertilisation se sont produites plus tôt, entre trois et cinq ans après le traitement. Une certaine indication de réactions asymétriques, notamment chez les arbres plus gros enregistrant des accroissements plus importants de croissance, a été relevée dans la station de type OG 11 (Ledum), tandis que les accroissements du rendement ont été potentiellement supérieurs dans la station de type OG 12 (*Alnus* peu herbacée). Le drainage était le plus efficace en combinaison avec la fertilisation. Les accroissements pour les deux stations étaient uniformes au niveau du phosphore associé à la fertilisation. Le projet de Wally Creek constitue un jalon important de l'analyse des réactions de croissance et de rendement pour la sylviculture intensive des tourbières.

Mead, D.J., and Pimentel, D. 2006. Use of energy analyses in silvicultural decision-making. *Biomass and Bioenergy* **30**(4): 357–362.

Plantation managers use a variety of decision-support systems to assist in deciding on optimum silvicultural treatments. Often these include computer-based growth simulation models that include an economic analysis. We recommend that energy analyses should be added as an additional tool to ensure that fossil and other energy is used wisely and to meet other objectives such as reducing environmental impacts.

In this study, selected silvicultural inputs were evaluated for hypothetical *Eucalyptus grandis* and *Pinus taeda* plantations. Silvicultural treatments resulted in very large differences in energy output:energy input ratios, with very high ratios being associated with treatments that result from a change of site quality by overcoming major soil limiting factors. Machinery choice and other material inputs such as fertilizers and herbicides also influenced energy balance ratios. The use of nitrogen fertilizers was an energy-intensive option. The coppice eucalyptus plantation often had higher energy balance ratios than the pine because of its faster growth rate and higher basic wood density. Evaluating a combination of silvicultural treatments was not as helpful for optimizing energy balance ratios as evaluating them separately.

Yield responses vary widely with species, sites and a range of operational factors. Thus determining the yield response required for a silvicultural treatment to meet a prescribed energy output:input ratio would allow managers to quickly evaluate treatments. In this study, we used an energy balance ratio of 25 as a criterion. Some treatments would have met this standard while others were marginal or the responses could not meet the criterion. However, the selection of the critical ratio needs further study.

Net energy yield per hectare, evaluated for various silvicultural options, would be a useful measure in planning energy-use systems for forest estates that supply bioenergy industries. It was a less sensitive measure than energy balance for comparing different silvicultural treatments.

Megraw, R.A., and Nearn, W.T. 1972. Detailed DBH intensity profiles of several trees from Douglas-fir fertilizer/thinning plots. Pages 1–9 *in* Anonymous. *Symposium on the Effect of Growth Acceleration on Wood Properties*, 10–11 November 1971, Madison, Wisconsin. United States Department of Agriculture, Madison, Wisconsin, USA. [online] URL: http://www.dtic.mil/cgi-bin/GetTRDoc?Location=U2&doc=GetTRDoc.pdf&AD=AD0740639.

Two Douglas-fir trees (*Pseudotsuga menziesii* (Mirb.) Franco.) from each of four treatment plots were sampled by increment core. The plots were either unthinned-unfertilized, unthinned-fertilized, thinned-unfertilized, or thinned-fertilized. The increment cores were conditioned to 50% relative humidity and x-rayed; the x-rays were then converted to density profiles. It was found that, for these trees from this site, fertilization influenced individual fiber density such that latewood density was reduced and earlywood density was increased. Ring specific gravity was unchanged, but juvenile growth was prolonged. Trees that had higher initial specific gravity as a result of genetics continued to have higher specific gravity. *(Abstract prepared by compilers.)*

Mencuccini, M., Hölttä, T., Petit, G., and Magnani, F. 2007. Sanio's laws revisited. Size-dependent changes in the xylem architecture of trees. *Ecology Letters* **10**(11): 1084–1093.

Effective hydraulic modeling requires understanding of xylem architecture, but data may be found that support two competing theories. This paper reports on a literature review. The data found in the review were used to develop a numerical model that attempts to demonstrate physiological explanations for differences. Finally, the data were used to determine which of the competing theories, Sanio's second law or metabolic scaling theory, is most applicable to trees. Twenty-four studies in all were used, which provided 48 profiles from 101 tree analyses. Optimal hydraulic tapering was modeled. Conduit tapering was found to vary inversely with distance from the top of the tree. It was generally concluded that Sanio's second law best describes gymnosperms and possibly tall angiosperms. *(Abstract prepared by compilers.)*

Meng, S.X., Lieffers, V.J., and Huang, S. 2007. Modeling crown volume of lodgepole pine based upon the uniform stress theory. *Forest Ecology and Management* **251**(3): 174–181.

A new model was proposed based on the uniform stress theory to predict crown volume of lodgepole pine (*Pinus contorta* var. *latifolia* Engelm.). Uniform stress theory states that trees tend to develop a balance between the size of the stem and the bending moment applied at the stem, to maintain mechanical stability. Bending moment is produced when trees receive a drag created by friction as wind acts on the crown. Data from permanent sample plots of natural stands of lodgepole pine across Alberta, Canada were used for model construction. Mean wind speed was estimated for each plot based on the Canadian Wind Energy Atlas. Diameter at breast height, a measure of leverage from the center of the crown to breast height, and wind speed were used as predictor variables. The new models explained 69.4 and 60.6% of total variation for crown volume and crown radius, respectively, when lodgepole pine trees were sampled from various subregions. Inclusion of relative depth to zero plane displacement and stand relative density resulted in virtually no improvement of the regression. The prediction of crown size with these models could be used for modeling mortality and growth of individual trees, and estimation of crown cover of stands.

Mérette, C., and Martel, J. 1985. *Réaction d'une sapinière d'une dizaine d'années suite à une coupe de nettoiement de différentes intensités 22 années après l'expérience.* Rapport d'étape No. 2. Gouvernement du Québec, Québec, Canada. [online] URL: http://www.mrnf.gouv.qc.ca/publications/forets/entreprises/ReactionSapiniereCoupeNettoiement.pdf.

Response of a balsam fir stand following a precommercial thinning at different intensities (500–6800) is examined 22 years after treatment. Densities between 1500–2250 and 2250–2750 trees/ha have the best response in terms of volume increase. Results were compared with the yield tables produced by Vézina and Linteau (1968) and Ker (1976). The recommendation is to carry out precommercial thinning in similar stands to reduce stand density to 1500–1750 stems/ha. *(Abstract prepared by compilers.)*

Merrill, R.E., and Mohn, C.A. 1985. Heritability and genetic correlations for stem diameter and branch characteristics in white spruce. *Canadian Journal of Forest Research* **15**(3): 494–497.

Heritabilities were calculated for several traits in a selected population of 20-year-old *Picea glauca* (Moench) Voss. The population had been modified by selection for rapid height growth at ages 12 and 18 years. Heritability estimates were moderate for branch angle and low for stem diameter, branch diameter, and number of branches per whorl. The genetic correlations among the traits indicated a negative relationship between rapid growth and desirable branch characters, although the correlations were generally small. The use of a two-stage selection procedure, selecting initially for rapid growth and subsequently for desirable branching traits, appears feasible in this population.

Les héritabilités de plusieurs caractéristiques ont été calculées dans une population sélectionnée de *Picea glauca* (Moench) Voss, âgée de 20 ans. Cette population a été modifiée aux âges de 12 et 18 ans par une sélection des arbres pour leur croissance rapide en hauteur. L'héritabilité était modérée pour l'angle des branches et faible pour le diamètre des tiges, le diamètre des branches et le nombre de branches par verticille. Les corrélations génétiques entre les caractéristiques ont indiqué des relations négatives entre la rapidité de croissance et les caractéristiques désirables des branches, mais ces corrélations étaient généralement faibles. L'utilisation d'une procédure de sélection en deux étapes, pour la rapidité de croissance en premier lieu et pour les caractéristiques désirables des branches en second, semble possible pour cette population.

Meyer, W.H. 1929. *Yields of Second-Growth Spruce and Fir in the Northeast*. Tech. Bull. No. 142. United States Department of Agriculture, Forest Service, Washington, D.C., USA.

In this presentation of spruce and fir yields it has seemed best to present the material under two main divisions. The first includes the presentation of the table and charts with only a general discussion of their use and a few remarks on the application of yield tables as a whole. The second part takes up some of the technical considerations of the study, the characters of the material upon which the tables are based, the reliability and limitations of the various tables, and a discussion of several of the tables based on observations of permanent sample plots. *(Source: U. S. Department of Agriculture, Forest Service.)*

Middleton, G.R., Carter, R.E., Munro, B.D., and Mackay, J.F.G. 1989. *Losses in Timber Values Associated with Distorted Growth in Immature Douglas-Fir.* FRDA Report 050. Natural Resources Canada, Canadian Forest Service - Pacific Forestry Centre, Victoria, British Columbia, Canada.

Lumber yields from a sawmill recovery study were used to quantify variation in tree values associated with growth distortion, prevalent in two stands of late immature Douglas-fir located in the Wetter Maritime CWH-biogeoclimatic subzone on the west coast of Vancouver Island, British Columbia. The objective was to gain preliminary information on the variation in timber values associated with distorted growth (sinuosity and branching) to establish sampling requirements for the development of statistically significant value-based stem distortion classes.

Following preliminary sampling of 200 potential study trees, 42 were selected according to size, branching, and sinuosity. These trees were felled, transported to a sawmill, and converted to lumber. Lumber grade and volume yields were recorded and used to calculate values for each study tree. These values were found to be 43% lower than those obtained in a previous second-growth Douglas-fir study. This lower value, however, was due primarily to rapid rates of growth in the distorted trees, which resulted in timber that failed to meet annual ring count requirements for No. 2 and higher structural grades.

Analysis of variance was used to test preliminary branching and sinuosity indices for their effect on tree value. The test, although not statistically significant, indicated that it should be possible to establish differences in value between moderate and severe classes of both sinuosity and branching. Trees classed as severe for either trait had an average value that was approximately 10% lower than that of trees classed as moderate for both traits. The two traits had a cumulative effect on value, such that trees that were classified as severe for both had an average value that was 20% lower than trees classed as moderate for both. Based on the variation in tree values recorded in the study, it was determined that a minimum of 20 trees per class would be required to establish statistically significant differences in average tree values between moderate and severe sinuosity and branching classes.

To investigate the possibility that growth distortion could result in an increase in drying defects, lumber obtained from distorted trees was kiln dried. Drying resulted in a significant occurrence of crook in the widest lumber (2 x 8), but there was no discernible relationship between drying degrade and degree of sinuosity.

Further sampling is recommended to confirm the results of this study and to determine if the indices developed here are based on the most appropriate criteria for assessing the effect of growth distortion. Some quantitative testing should be undertaken to determine if growth distortion is generally associated with very rapid rates of growth rate are indicative of actual lumber strength values. Research should also be undertaken to develop modified drying practices for reducing wrap, which occurs when lumber from second-growth Douglas-fir is kiln dried. *(Abstract prepared by compilers.)*

Middleton, G.R., Jozsa, L.A., Munro, B.D., and Sen, P. 1996. *Regional Comparisons of Wood Density and Branch Size in Low Stand Density Lodgepole Pine*. Special Publication SP-36. Forintek Canada Corp., Vancouver, British Columbia, Canada.

A previous study yielded some surprising results, and the current study was designed to verify them. The previous study found abnormally low modulus of rupture and modulus of elasticity results at a spacing of 700 stems/ha for lodgepole pine (*Pinus contorta* Dougl. ex Loud.). It was suspected that the results could be explained by large knot size and low specific gravity. In the current study, 30 trees each from six biogeoclimate zones in British Columbia were selected. Two increment cores per tree were taken and used to determine basic specific gravity. Branch diameter of branches in the first 5 m of height was recorded, as were height and pathological observations. Modulus of elasticity was not measured in the current study but rather estimated using the regression equation developed in the first study. This regression equation related diameter and specific gravity at breast height to modulus of elasticity. A second regression equation was developed from data in the first study, which related specific gravity at breast height and knot size to modulus of elasticity, and this equation was also used to predict modulus of elasticity in the current study. Trees in the current study were found to have slightly higher specific gravity than those in the first study. Larger trees tended to have lower specific gravity. Considerable site variation was found for branch size. It was concluded that low stand density results in trees with low wood specific gravity. *(Abstract prepared by compilers.)*

Middleton, G.R., Jozsa, L.A., Palka, L.C., Munro, B.D., and Sen,P. 1995. *Lodgepole Pine Product Yields Related to Differences in Stand Density*. Special Publication SP-36. Forintek Canada Corp., Vancouver, British Columbia, Canada.

The objective was to evaluate the effect of stand density on wood characteristics and on lumber grade and yield for lodgepole pine. This report provides information on wide spacing and large-diameter trees, wood-quality concerns, and finally, the characterization of lodgepole pine in relation to stand density. The lumber recovery factors such as; piece size, effect, knots, wood density, lumber strength and stiffness, juvenile wood, and dry kiln are described, as well as their implications for forest management. *(Abstract prepared by compilers.)*

Middleton, G.R., and Munro, B.D. 2000. *Preliminary Characterization of Yukon Lodgepole Pine in Terms of Utilization Potential*. Publication No. W-1641. Forintek Canada Corp., Vancouver, British Columbia, Canada.

The project's aim was to compile a literature review of the characteristics of pines and then compare it to Yukon lodgepole pine. A small study was undertaken to determine and predict potential for special wood traits of Yukon lodgepole pine and also to determine the attributes that convey value-added production. *(Abstract prepared by compilers.)*

Middleton, G.R., and Munro, B.D. 2002. *Wood Density of Alberta White Spruce—Implications for Silviculture Practices*. Report No. W-1913. Forintek Canada Corp., Vancouver, British Columbia, Canada.

Wood density, an indicator of wood strength, is well known to be related to growth rate, but few studies have been reported for white spruce (*Picea glauca* (Moench) Voss). In this study, 108 trees of rotation age from three natural stands in Alberta were sampled in 30 cm, 40 cm, and 50 cm diameter classes. For each sample tree, X-ray densitometry of extracted increment cores taken at breast height was used to determine wood basic relative density. Significant differences for density were found between diameter classes. Density was found to be inversely related to diameter class. No significant differences were found between stands. Results found agreed with those in the literature in that density was negatively related to annual growth rate. It was recommended that effect of thinning on wood density be considered before undertaking such silvicultural operations. *(Abstract prepared by compilers.)*

Middleton, G.R., and Munro, D. 2005. *Effect of Growth Rate on Wood Density of Saskatchewan White Spruce—Implications for Silvicultural Practices.* General Revenue Project No. 3480. Forintek Canada Corp., Vancouver, British Columbia, Canada.

This project was undertaken to quantify the effects of different growth rates on white spruce (*Picea glauca* (Moench.) Voss.) in Saskatchewan to confirm previously reported trends. One hundred and ten trees were sampled from three natural stands in Saskatchewan. Extracted increment cores taken from breast height were used to determine specific gravity. Signficant differences in specific gravity were found between diameter classes, and specific gravity was found to be negatively related to diameter. No significant differences were found between sites. In general, white spruce specific gravity in Saskatchewan was slightly higher than in Alberta and British Columbia, but care must still be taken when implementing growth-enhancing silvicultural techniques. *(Abstract prepared by compilers.)*

Middleton, G.R., Munro, B.D., and Oliveira, L.C. 1992. *Developing Methods to Sort and Dry Lodgepole Pine for Maximum Joinery Yields*. Publication No. 917. Forintek Canada Corp., Vancouver, British Columbia, Canada.

Recognizing that forest resources, while renewable, are finite, it makes sense to derive the best uses from them. Added-value products can achieve this aim, and many British Columbia mills are now producing lodgepole pine (*Pinus contorta* Dougl. var. *latifolia* Engelm) joinery products for the European market. It is advantageous to them to assess standing timber, sort logs, and understand the best drying methods to achieve high yields and high quality yields. Trees were sampled from two northern sites, two southern sites, and one central site in British Columbia. Sixty trees were chosen from each of the sites except the central site, from which 100 trees were chosen. Standing timber was assessed for diameter at breast height, tree height, lean, sweep, spiral grain, height to live crown, height to first dead stub, number of branch-free quarter panels in the first two logs, estimates of number of branches in the first two logs, dominance, and evidence of pathogens. Logs were custom sawn to joinery specifications. Difficulties were encountered at the saw mill, as it could not process logs smaller than 15 cm top diameter. Timber and log qualities to produce good lumber may be used to assess timber and logs for joinery quality. Log size is positively related to joinery quality and yield. Stand age was found to be positively related to stain decay. Sawmill cutting pattern and errors in the pattern significantly influence yield and quality. It was recommended that assessments of standing timber take place before deciding to produce joinery. It was also recommended that sorting of logs prior to sawing could limit joinery downgrade. *(Abstract prepared by compilers.)*

Middleton, G.R., Munro, B.D., and Sadlish, J. 2000. *Influence of Growth Rate on Strength and Related Wood Properties of Boreal White Spruce*. Report OP97301-ORE. Forintek Canada Corp. and Science Council of British Columbia, Vancouver, British Columbia, Canada.

Boreal white spruce on good sites in northeastern British Columbia grows faster than that in the rest of the province. This can have a negative effect on desirable wood attributes. Trees of varying ages and diameters were sampled to determine at what point during a tree's growth the increased growth rate become detrimental in terms of wood quality. Wood density, modulus of rupture (MOR), modulus of elasticity (MOE), and ultimate compression strength (UCS) were all found to decline as diameter at breast height (dbh) increased. Branch size and longitudinal shrinkage increased as dbh increased. Heartwood percentages were lower in the lower age classes. Spiral grain angle and compression wood were unaffected by growth rate. *(Abstract prepared by compilers.)*

Middleton, G.R., and Zhang, S.Y. 2009. Characterizing the wood attributes of Canadian tree species: a thirty-year chronicle. *The Forestry Chronicle* **85**(3): 392–400.

In 2007 Forintek Canada Corp merged with the other forest research institutes—Paprican, FERIC and the newly formed Canadian Wood Fibre Centre (CWFC)—to become FPInnovations. This merger offers opportunities for synergies across a range of research activities from the forest to final product markets, and the first step to achieving these synergies is to provide a better understanding of past and current research roles. This paper chronicles delivered results from the Resource Program in response to Forintek member priorities. Of necessity due to limited resources, the Resource Assessment Program at Forintek was built on both internal and external collaboration. It was also built on a legacy of wood quality research inherited from the Eastern and Western Wood Product Laboratories of the Canadian Forest Service from which it was formed through privatization in 1979. FPInnovations now has custody of this legacy. This paper was prepared as a contribution to a workshop organized by the CWFC to promote better understanding of research capabilities residing within FPInnovations. It is aimed at identifying opportunities for future collaboration by describing Forintek's resource characterization program and our members' priorities for future wood quality research in Canada.

En 2007, Forintek Canada Corp. a fusionné avec d'autres instituts de recherches forestières – Paprican, FERIC et le tout nouveau Centre canadien sur la fibre de bois – pour devenir FPInnovations. Cette fusion offre des opportunités de synergies pour un ensemble d'activités de recherche allant de la forêt aux marchés de produits finis et la première étape vers l'atteinte de ces synergies est l'établissement d'une meilleure compréhension des missions de recherche antérieures et actuelles. Cet article fait état des résultats atteints par l'entremise du Programme sur la ressource en réponse aux priorités des membres de Forintek. Découlant d'une réduction des ressources, le Programme d'évaluation de la ressource de Forintek a été élaboré en tenant compte de collaborations internes et externes. Il a été également élaboré en fonction de l'héritage reçu des travaux de recherche sur le bois effectués par les Laboratoires de recherche sur le bois de l'Est et de l'Ouest du Canada du Service canadien des forêts à partir desquels Forintek a été créé en 1979 suite à une privatisation. FPInnovations est maintenant le légataire de cet héritage. Cet article a été rédigé en tant que contribution à un atelier du CCFB visant à établir une meilleure compréhension des capacités de recherche de FPInnovations. Il cherche à identifier les opportunités de collaborations futures en décrivant le programme de caractérisation de la ressource de Forintek ainsi que les priorités de nos membres en termes de recherche sur la qualité du bois au Canada.

Miles, K.B., and Omholt, I. 2007. Thermomechanical pulp from jack pine. *Journal of Pulp and Paper Science* **33**(3): 171–176.

As the preferred black spruce (*Picea mariana* (Mill.) B.S.P.) resource is declining, mills are attempting to use more of species such as jack pine (*Pinus banksiana* Lamb.) in their pulps. This study compared pilot plant pulps produced using black spruce and jack pine. Pulps were tested according to PAPTAC standards. Eight samples were examined using Silviscan, which determines x-ray density, cell dimensions, and cell wall thickness. It was found that, for the same diameter log, jack pine was younger than black spruce and, therefore, provided more juvenile wood. Jack pine fiber length was shorter, with thicker walls and a lower ability to absorb energy. It was concluded that spruce furnishes better paper because of better bonding abilities resulting from its fiber properties. *(Abstract prepared by compilers.)*

Miller, B. 1996. *Aspen Management: a Literature Review.* NEST Technical Report TR-028. Ontario Ministry of Natural Resources, Sault Ste. Marie, Ontario, Canada.

All aspen research in the Great Clay Belt Region has been compiled and summarized in this report for forest managers to use in northeastern Ontario. Harvesting, regenerating, thinning, controlling regeneration densities, and the effects of fire on aspen are all covered in this report. *(Abstract prepared by compilers.)*

Molteberg, D. 2004. Methods for the determination of wood properties, kraft pulp yield and wood fibre dimensions on small wood samples. *Wood Science and Technology* **37**(5): 395–410.

A trial set-up with methods for sampling, treatment and analysis of small wood chips are presented in this paper, to determine important wood and fibre properties, like basic density, dry density, volume swelling of wood, Kraft pulp yield, fibre length, fibre coarseness, fibre width, lumen width and fibre wall thickness. The required time for one sample is about 1.5 man-hour, but this requires relatively larger series and trained personnel. Acceptable measurement accuracy is achieved when the volume of the wood sample is at least 1.5 ml, except that of wood volume swelling. To gain acceptable measurement accuracy for volume swelling, the wood volume should be increased to at least 3 ml, and preferably more than 5–6 ml per sample. The level of pulp yield and wood density do not show a significant effect on the measurement accuracy for fibre cross-section dimensions. Fibre coarseness, on the other hand, has a significant influence on these accuracies. A double measurement of fibre coarseness will improve the accuracy to an acceptable level. The method presented here may, together with information about trees and growth locations, form the basis for greater insight into the mechanisms involved in development of wood and fibre properties in trees, which in turn may provide better control and utilisation of wood for pulp and paper production.

Moore, J.D., and Houle, D. 2009. Soil solution and sugar maple response to NH_4NO_3 additions in a base-poor northern hardwood forest of Quebec, Canada. *Environmental Monitoring and Assessment* **155**(1-4): 177–190.

Nitrogen additions (NH_4NO_3) at rates of three- and ten-fold ambient atmospheric deposition (8.5 kg ha^{-1} $year^{-1}$) were realised in an acid- and base-poor northern hardwood forest of Quebec, Canada. Soil solution chemistry, foliar chemistry, crown dieback and basal area growth of sugar maple (*Acer saccharum* Marsh.) were measured. Except for a transitory increase of NO_3 and NH_4 concentrations, there was no persistent increase in their level in soil solution 3 years after N treatments, with the exception of one plot out of three, which received the highest N addition, beginning to show persistent and high NO_3 concentrations after 2 years of N additions. Three years of N additions have significantly increased the N DRIS index of sugar maple but not N foliar concentration. Potassium, Ca and Mn foliar concentrations, as well as P and Ca DRIS indices, decreased in treated plots after 3 years. No treatment effect was observed for basal area growth and dieback rate. One unexpected result was the significant decrease in foliar Ca even in the treated plots that received low N rates, despite the absence of significant NO_3-induced leaching of Ca. The mechanism responsible for the decrease in foliar Ca is not known. Our results, however, clearly demonstrate that increased N deposition at sites with low base saturation may affect Ca nutrition even when clear signs of N saturation are not observed.

Morris, D.M., Bowling, C., and Hills, S.C. 1994. Growth and form responses to pre-commercial thinning regimes in aerially seeded jack pine stands: 5th year results. *The Forestry Chronicle* **70**(6): 780–787.

In 1986, a thinning trial was established in a 9-year-old jack pine stand near Dryden, Ontario. Four blocks consisting of five thinning regimes (1 m × 1 m, 1.5 m × 1.5 m, 2 m × 2 m, 2.5 m × 2.5 m, 3 m × 3 m) and a control plot were established using a randomized complete block design. Once thinned, a series of measurements were taken in 1986 and repeated in 1991 to determine growth and form responses. Results identified highly significant responses for DBH growth and individual stem volume growth. Height response did not vary among the spacing levels. Changes in crown dimensions and stem taper were used to evaluate form responses to thinning. A highly significant decline in all form variables was found in response to increased spacing. Although the increased growth in individual trees provides an opportunity to produce a wider array of products, it appears to be at a cost of reduced form characteristics. Specific management implications for the Dryden Crown Forest are discussed.

Un essai d'éclaircie a été effectué en 1986 dans un peuplement de pin gris âgé de 9 ans situé près de Dryden en Ontario. Quartre blocs représentant cinq niveaux d'éclaircis (1 m × 1 m, 1.5 m × 1.5 m, 2 m × 2 m, 2.5 m × 2.5 m, 3 m × 3 m) ainsi qu'une parcelle témoin ont été établis selon une distribution complètement aléatoire. Suite à l'éclaircie, un série de mesure a été effectuée en 1986 et répétée en 1991 afin de déterminer la croissance et les modifications de la forme des arbres. Les résultats ont indiqué des réponses très significatives au niveau de la croissance en diamètre et en volume pour chacune des tiges. La croissance en hauteur n'a pas beaucoup varié en fonction des niveaux d'éclaircis. Les changements dans les dimensions de la cime et le défilement de la tige ont été utilisés pour évaluer les modifications des formes suite à l'éclaircie. Une diminution très significative de toutes les variables associées à la forme a été identifiée en réponse à l'augmentation de la distance entre les tiges. Même si la croissance accrue de chaque arbre constitue une possibilité de produire un plus grand éventail de produits, il semble que cela s'effectue au détriment des caractéristiques de la forme. Les implications spécifiques au niveau de l'aménagement des forêts publiques de la région de Dryden sont abordées.

Morris, D.M., and Forslund, R.R. 1992. The relative importance of competition, microsite, and climate in controlling the stem taper and profile shape in jack pine. *Canadian Journal of Forest Research* **22**(12): 1999–2003.

The purpose of this study was to identify the relative importance that environmental factors have on the taper and profile shape of mature jack pine (*Pinus banksiana* Lamb.) stems. A total of 60 dominant trees from six different stands (10 per stand) were felled and measured to determine stem size, taper, and profile shape. Total height, basal age, and diameters at three locations (breast height, 20% total height, and 70% total height) were collected. The last two diameters were then used to calculate stem taper and profile shape. Data on competition (4 variables) and microsite (10 variables) were collected. Climatic variables (6) were interpolated from nearby weather station data. From the regression results, several environmental factors from all three categories (competition, microsite, and climate) proved to be very important in determining taper and shape. The most relevant measures from each category, respectively, were percent canopy opening (taper) or total basal area (shape), slope, and growing degree-days. When combined in a multilinear regression, these environmental variables, along with stand age, explained 61.9% of the variation in stem taper and 38.6% in stem shape. Although these values represent a significant proportion of the variation in stem profile characteristics, further exploration into additional factors (e.g., bending and stress caused by wind action, nutrition, genetics) affecting stem taper and shape is required.

Le but de cette étude est d'identifier l'importance relative qu'ont des facteurs environnementaux sur le défilement et le profil des tiges mûres de pin gris. Soixante arbres dominants provenant de six peuplements différents (10 arbres/peuplement) ont été abattus et mesurés afin d'en déterminer la dimension, le défilement et l'évolution du profil. La hauteur totale, l'âge à la souche et les diamètres à trois niveaux (hauteur de poitrine, 20 et 70% de la hauteur totale) ont été recueillis. Les deux derniers diamètres ont été utilisés pour calculer le défilement et le profil des tiges. Des mesures de compétition (4 variables) et de microsite (10 variables) ont été effectuées. Les variables climatiques (6) ont été calculées à partir des données d'une station météorologique voisine. Les analyses de régression indiquent que plusieurs facteurs environnementaux issus des trois catégories (compétition, microsite et climat) conditionnent de façon importante le défilement et la forme. Les variables les plus importantes de chaque catégorie sont, respectivement, le pourcentage d'ouverture de la canopée (défilement) ou la surface terrière totale (forme) et le nombre de degrés-jours. Une équation linéaire multiple de ces variables environnementales combinées à l'âge du peuplement explique 61,9% de la variation du défilement et 38,6% de la variation de la forme de la tige. Bien que ces valeurs représentent une proportion significative de la variation de caractéristiques de la forme de la tige, il est nécessaire d'explorer la contribution de facteurs additionnels (c'est-à-dire la flexion et le stress occasionnés par le vent, la nutrition et la génétique) pouvant affecter le défilement et la forme de la tige.

Morris, D.M., and Parker, W.H. 1992. Variable-quality form in mature jack pine stands: quantification and relationship with environmental factors. *Canadian Journal of Forest Research* 22(3): 279–289.

The purpose of this study was to determine quantitatively to what extent various stem, crown, and branching attributes conformed to subjective evaluations of form for jack pine (*Pinus banksiana* Lamb.) in northwestern Ontario and which environmental variables were associated with the form-related variation. Six fire-origin stands established on deep soils were selected on the basis of their form and subjectively evaluated as good (2), medium (2), or poor quality (2). Ten dominant trees were randomly chosen from each stand, and 26 attributes were determined for each sampled tree. These attributes were categorized as growth (2), stem form (6), crown form (6), or branch characters (12). Data on surrounding stand conditions and microsite were also collected. Climatic factors for each stand were interpolated from nearby weather station data. These data were analyzed by canonical discriminant analysis. The first function separated the poor-quality stands from the other two classes, while the second function separated the average- from the good-quality stands. Important variables in the first canonical function were related to stem and crown characters, whereas branch characters were also important in the second canonical function. First and second canonical descriminant axis scores were used as two new summary variables representing qualified estimates of jack pine form and were regressed against environmental data. While competition and spacing variables explained much of the observed variation, climatic and soil moisture variables were also important. From the present results it is unclear whether these variables affect form directly or indirectly by modifying competition and spacing variables over the course of stand development.

L'objet de l'étude est de déterminer à quel point les différentes caractéristiques de la tige, de la cime et des branches sont conformes aux évaluations qualitatives de la forme du pin gris (*Pinus banksiana* Lamb.) dans le nord-ouest de l'Ontario. Une étude des variables environnementales associées aux variations de la forme a aussi été effectuée. Six peuplements d'origine de feu établis sur des sols profonds ont été choisis en fonction de la forme des arbres, qui a été évaluée subjectivement comme étant bonne (2), moyenne (2) ou de mauvaise qualité (2). Dix arbres dominants ont été choisis au hasard dans chaque peuplement et 26 caractéristiques sont mesurées sur chaque arbre-échantillon. Les caractéristiques liées à la croissance (2), la forme de la tige (6), la forme de la cime (6) ou la ramification (12) ont été regroupées en catégories. Des données sur les conditions générales des peuplements et des microsites ont aussi été notées. Les facteurs climatiques de chaque peuplement sont interpolés à partir des données de la station météo la plus près. Ces données sont analysées par analyse discriminante canonique. La première fonction sépare les peuplements de mauvaise qualité des deux autres classes, alors que la deuxième fonction sépare la moyenne des peuplements de bonne qualité. Les variables importantes dans la première fonction canonique sont liées aux caractéristiques de la tige et de la cime, alors que les caractéristiques de ramification sont importantes dans la seconde fonction canonique. Les valeurs des deux premières composantes canoniques ont été considérées comme deux nouvelles variables de synthèse représentant des estimations quantifiées de la forme du pin gris. Des régressions entre ces variables de synthèse et les données environnementales ont également été produites. Les variables de compétition et d'espacement expliquent le mieux la variation observée, toutefois les variables climatiques et de l'humidité du sol sont importantes. À partir de ces résultats, il ne semble pas que ces variables affectent la forme directement ou indirectement, par une modification des variables de compétition et d'espacement sur la direction du développement du peuplement.

Morrison, I.K., Winston, D.A., and Foster, N.W. 1977. *Effect of Nitrogen Fertilization and Low Thinning on Growth of Semi-Mature Jack Pine Forest, Chapleau, Ontario: Fifth-Year Results*. Information Report O-X-267. Natural Resources Canada, Canadian Forest Service - Great Lakes Forestry Centre, Sault Ste. Marie, Ontario, Canada.

The effect of simultaneous urea fertilization and low thinning on jack pine (*Pinus banksiana* Lamb.) was tested in the factorial experiment in the Chapleau area of north central Ontario. The experiment, initiated in 1970, was in a 45-year-old, relatively thrifty, close stand of fire origin on a Site Class I sandy site. Typical of wild stands of the area, the experimental stand had no previous history of intermediate cutting. Three levels of N (0, 168, and 336 kg N/ha) supplied as urea were tested, as was thinning-from-below (conventionally by felling, and by silvicide injection) for a 20% BA reduction. After five years, the following response variables were determined: mean DBH increment, BA increment, % BA growth, and total and merchantable volume increments. Analysis of variance revealed highly significant (1%) treatment effects for N in relation to all response variables and for thinning in relation to mean DBH increment only. No interactions were significant. Better treatments produced gains in PAI over controls in the order of 1.2 to 2.0 m^3/ha/yr. While both treatments produced significant responses over control at least in relation to some parameters, lack of interaction between them suggests that there is no particular advantage in carrying them out simultaneously.

Lors d'une expérience factorielle effectuée dans la région de Chapleau, au centre-Nord de l'Ontario, les auteurs ont étudié l'effet de la fertilisation à l'urée et de l'éclaircie par le bas simultanées sur le pin gris (*Pinus banksiana* Lamb.). Amorcée en 1970, l'expérience a eu lieu dans un peuplement serré de 45 ans, venu par suite d'un incendie sur une station sablonneuse de classe I. Typique des peuplements naturels de la région, le peuplement expérimental n'avait pas subi de coupe intermédiaire par le passé. Trois concentrations de N (0, 168 et 336 kg N/ha) sous forme d'urée ont été essayées avec l'éclaircie par le bas (abattage conventionnel, puis injection de silvicide) en vue de réduire la ST de 20%. Après cinq ans, les variables de réponse suivantes ont été déterminées: accroissement moyen du dhp, accroissement de la ST, % d'augmentation de la ST, enfin accroissement des volumes total et marchand. Les analyses de variances ont révélé des effets très significatifs (1%) de N pour toutes les variables de réponse et l'éclaircie quant à l'accroissement du dhp moyen seulement. Il n'y avait aucune interaction significative. Les meilleurs traitements produisirent des gains dans l'APA (accroissement périodique annuel) de l'ordre de 1.2 à 2.0 m^3/ha/an par rapport aux témoins. Les deux traitements ayant eu des réponses significatives, du moins pour quelques paramètres, l'absence d'interaction de l'un à l'autre porte à croire que le fait de les administrer simultanément ne comporte aucun avantage particulier.

Mott, L., Shaler, S.M., and Groom, L.H. 1996. A technique to measure strain distributions in single wood pulp fibers. *Wood and Fiber Science* **28**(4): 429–437.

Environmental scanning electron microscopy (ESEM) and digital image correlation (DIC) were used to measure microstrain distributions on the surface of wood pulp fibers. A loading stage incorporating a fiber gripping system was designed and built by the authors. Fitted to the tensile substage of an ESEM or a Polymer Laboratories MINIMAT tester, it provided a reliable fiber straining mechanism. Black spruce (*Picea mariana* (Mill.) B.S.P.) latewood fibers of a near-zero microfibril angle displayed a characteristically linear load elongation form. ESEM was able to provide real-time, high magnification images of straining fibers, crack growth, and complex single fiber failure mechanisms. Digital images of single fibers were also captured and used for subsequent DIC-based strain analysis. Surface displacement and strain maps revealed nonuniform strain distributions in seemingly defect-free fiber regions. Applied tensile displacements resulted in a strain band phenomenon. Peak strain (concentration) values within the bands ranged from 0.9% to 8.8%. It is hypothesized that this common pattern is due to a combination of factors including the action of microcompressive defects and straining of amorphous cell-wall polymeric components. Strain concentrations also corresponded well to locations of obvious strain risers such as visible cell-wall defects. Results suggest that the ESEM-based DIC system is a useful and accurate method to assess and, for the first time, measure fiber micromechanical properties.

Mott, L., Urquhart, S., and Eichhorn, S.J. 2001. Relationship between micro-fibril angle and strength of black spruce fibers. *Journal of Materials Science Letters* **20**(14):1325–1326.

The relationship between strength of black spruce fibers and microfibril angle was investigated. Tensile tests were carried out on fibers obtained from inner and outer ring portions of spruce. Load-elongation curves indicated that the fibers exhibited linear elasticity and strain hardening. Microfibril angles were measured by the pit aperture method using a polarizing microscope. Measurements indicated that the microfibril angle of inner fibers was larger than that of outer fibers in agreement with other studies. *(Abstract prepared by compilers.)*

Mugasha, A.G., Pluth, D.J., Higginbotham, K.O., and Takyi, S.K. 1991. Foliar responses of black spruce to thinning and fertilization on a drained shallow peat. *Canadian Journal of Forest Research* **21**(2): 152–163.

A thinning and fertilization experiment was established in 1987 in a 50- to 60-year-old black spruce (*Picea mariana* (Mill.) B.S.P.) stand growing on a shallow, boreal (central Alberta), minerotrophic peatland drained in 1986. The experiment was a split-split plot design with thinning as the main factor, fertilization as the sub-factor, and distance from drainage ditch as the sub-sub-factor. Current and 1-year-old foliage, collected during late August 1988, was analysed for mass and N, P, and K. Black spruce responded to thinning, fertilization, and distance from a drainage ditch. Thinning alone increased foliar N and P concentration and unit needle mass by 12, 30, and 16%, and foliar N and P content by 30 and 41%, respectively. The relative increases in foliar mass and N concentration and content of current *Picea mariana* needles in N, NP, and NPK treated plots were generally higher in unthinned subplots and distant sub-subplots than in thinned subplots and proximate sub-subplots, suggesting that N was more limiting in unthinned plots and distant sub-subplots. Although the addition of P and K alone or in combination elevated foliar P and K concentrations and contents, there were no concomitant significant changes in unit needle mass, suggesting that P and K were not limiting.

Une expérience d'éclaircie et de fertilisation a été mise en place en 1987 dans un peuplement de 50–60 ans d'épinette noire (*Picea mariana* (Mill.) B.S.P.) croissant dans une tourbière mince boréale, minérotrophe et drainée en 1986, dans le centre de l'Alberta. Le dispositif expérimental était du type parcelle moitié-moitié avec l'éclaircie comme facteur premier, la fertilisation comme sous-facteur et la distance du fossé de drainage comme sous-sous-facteur. Le feuillage de l'année courante et d'un an recueilli à la fin août 1988 a été analysé pour la masse, et pour N, P et K. L'épinette noire a répondu à l'éclaircie, la fertilisation et la distance du fossé de drainage. L'éclaircie seule s'est traduite par une augmentation des concentrations foliaires en N et P et par la masse unitaire des aiguilles par 12, 30 et 16% et par le contenu foliaire en N et en P par 30 et 41% respectivement. Les accroissements relatifs en masse foliaire, en concentrations en N et en contenus en N, NP ou NPK des aiguilles de l'année courante des parcelles traitées étaient généralement plus élevés dans les sous-parcelles non éclaircies et les sous-sous-parcelles distantes des fossés de drainage que dans les sous-parcelles éclaircies et les sous-sous-parcelles à proximité des fossés de drainage et suggéraient que N était plus limitant dans les parcelles non éclaircies et dans les sous-sous-parcelles distantes des fossés de drainage. Bien que l'ajout de P et de K seuls ou combinés ait élevé les concentrations foliaires en P et K ainsi que les contenus, il n'y avait pas de changement concomitant significatif dans les masses unitaires des aiguilles, ce qui suggère que P et K n'étaient pas limitatifs.

Mullins, E.J., and McKnight, T.S. 1981. *Canadian Woods: Their Properties and Uses.* Ministry of Supplies and Services Canada, Ottawa, Ontario, Canada.

This book examines wood structure, physical and mechanical properties, chemistry, drying, preservation, sawmilling, and gluing of commercial species in Canada and the future of the wood industry. Various types of utilization are looked at under the following headings: Panel products; Houses and structures; Other uses and processes; Pulp and paper; and Residues. *(Abstract prepared by compilers.)*

Newton, P.F. 1998. Regional-specific algorithmic stand density management diagram for black spruce. *Northern Journal of Applied Forestry* **15**(2): 94–97.

This stand density management diagram was developed for managed black spruce (*Picea mariana* (Mill.) B.S.P.) stands in Newfoundland, New Brunswick, Quebec, and Ontario. The diagram is used to calculate yields, mean height, density, mean volume, stem volume, quadratic mean diameter, and basal area with the use of site-specific curves and initial densities. *(Abstract prepared by compilers.)*

Newton, P.F. 2003a. Stand density management decision-support program for simulating multiple thinning regimes within black spruce plantations. *Computers and Electronics in Agriculture* **38**(1): 45–53.

The utility of currently available software programs for use in black spruce, *Picea mariana* (Mill.) B.S.P., density management is becoming limited due to the increasing complexity of treatments. Consequently, the objectives of this study were to develop and subsequently demonstrate a decision-support program for stand density management involving multiple thinning treatments applicable to plantations established in Ontario, Quebec, New Brunswick and Newfoundland. The resultant PC-based program enables forest managers to predict 75-year size–density trajectories for three density control regimes simultaneously, given a common planting density. Specifically, the program: (1) graphically illustrates the expected site-specific trajectories for each regime within the context of a stand density management diagram; (2) calculates and tabulates annual, treatment-specific and cumulative rotational yield estimates and associated performance indices for overall productivity, relative product value, and degree of optimal site occupancy; and (3) graphically illustrates production curves for volumetric yield and product size. Additionally, instructions on acquiring an executable version of the program via the Internet are included.

Newton, P.F. 2003b. Stem analysis program for coniferous forest tree species. *Computers and Electronics in Agriculture* **39**(1): 61–66.

The objectives of this study were to describe and demonstrate a PC-based stem analysis program applicable to coniferous forest tree species. From annual ring-width xylem sequences obtained from cross-sectional samples located at multiple stem heights, the program computes: radial and longitudinal ring-width sequences, apical growth increments, sectional and cumulative volume production patterns, and stem developmental profiles. Computations are based on the following geometric assumptions: (1) the stump, tip and sections in between are treated as geometric solids of revolution resembling a cylinder, cone, and frustum of a cone, respectively; and (2) for sections in which increments are not continuous throughout, computations are based on a geometric solid of revolution resembling a cone. The program corrects for slant-based sectional length measurements using the Pythagorean theorem and eliminates the need to externally predict height for a given age via a linear interpolation procedure. The utility of the program is demonstrated via a comparison of the longitudinal radial growth patterns of jack pine, *Pinus banksiana* Lamb., trees that developed under different density management regimes.

Newton, P.F. 2003c. Yield prediction errors of a stand density management program for black spruce and consequences for model improvement. *Canadian Journal of Forest Research* **33**(3): 490–499.

The objectives of this study were to (i) quantify the prediction error associated with estimating density (N (stems/ha)), quadratic mean diameter (D_q (cm)), basal area (G (m^2/ha)), total volume (V_t (m^3/ha)), and merchantable volume (V_m (m^3/ha)) using a stand density management decision-support program (SDMDSP) developed for black spruce (*Picea mariana* (Mill.) B.S.P.) plantations and (ii) given objective i, assess model adequacy by examining the relationship between prediction error and model input variables (prediction period, site index, initial density, and number of thinning treatments) by yield variate. Specifically, the SDMDSP was evaluated by comparing its yield predictions with corresponding measured values (n = 44) within 19 black spruce plantations. The resultant tolerance intervals indicated that 95% of the relative errors associated with future predictions would be within the following limits 95% of the time (minimum–maximum): (i) -27.3 to 29.7% for N, (ii) -26.1 to 14.3% for D_q, (iii) -48.3 to 26.1% for G, (iv) -64.3 to 37.7% for V_t, and (v) -87.0 to 73.0% for V_m. Graphical analysis indicated that errors for V_t and V_m were associated with the data from thinned plantations. This result is discussed within the context of residual stand structure variation and response delay from which recommendations for model improvement are derived.

Cette étude porte sur un modèle d'aide aux décisions d'aménagement basé sur la densité du peuplement et développé pour les plantations d'épinette noire (*Picea mariana* (Mill.) BSP). Elle avait pour objectifs (i) de quantifier les erreurs de prédiction du modèle reliées à la densité (N (tiges/ha)), au diamètre moyen quadratique (D_q (cm)), à la surface terrière (G (m^2/ha)), au volume total (V_t (m^3/ha)) et au volume marchand (V_m (m^3/ha)), et (ii) étant donné l'objectif i, d'évaluer la fiabilité du modèle en examinant les relations entre les erreurs de prédiction des variables de rendement considérées et ses variables d'intrant (période de prédiction, indice de qualité de station, densité initiale et nombre d'éclaircies). Plus particulièrement, le modèle a été évalué en comparant ses prédictions de rendement aux valeurs mesurées correspondantes (n = 44) dans 19 plantations d'épinette noire. Pour 95 % des erreurs relatives associées aux prédictions futures, les intervalles de confiance seraient les suivants, 95 % du temps (minimum–maximum) : (i) –27,3 à 29,7 % pour N, (ii) –26,1 à 14,3 % pour D_q, (iii) –48,3 à 26,1 % pour G, (iv) –64,3 à 37,7 % pour Vt et (v) –87,0 à 73,0 % pour V_m. Les analyses graphiques montrent que les erreurs de V_t et de V_m sont associées aux données provenant des plantations éclaircies. La discussion débouche sur des recommandations pour améliorer le modèle en tenant compte de la structure des peuplements après éclaircie et du délai de leur réponse aux traitements.

Newton, P.F. 2004. A stem analysis computational algorithm for estimating volume growth and Its empirical evaluation under various sampling strategies. *Computers and Electronics in Agriculture* **44**(1): 21–31.

The objectives of this study were to describe and subsequently evaluate a computational stem analysis algorithm applicable to coniferous forest tree species. Specifically, the algorithm was designed to estimate annual volume growth rates given ring-width xylem sequences obtained from cross-sectional samples located at multiple stem heights. Volumetric computations were based on the following geometric assumptions: (1) the stump, tip and sections in between were treated as geometric solids of revolution resembling a cylinder, cone, and frustum of a cone, respectively; and (2) for sections in which increments were not continuous throughout, computations were based on a geometric solid of revolution resembling a cone. Furthermore, the algorithm incorporates a correction for slant-based sectional length measurements using the Pythagorean theorem and eliminates the need to predict heights for a given age by the use of a linear interpolation procedure. The algorithm was evaluated by measuring the difference between the estimated and observed annual volume growth rates derived from 53 semi-mature jack pine (*Pinus banksiana* Lamb.) trees using eight systematic sampling strategies: two sample sizes (five and ten cross-sectional samples per tree) and four elliptical-based radial selection procedures (one randomly selected semiaxis per cross-section; two semiaxes consisting of the minimum and maximum semiaxes per cross-section; two semiaxes along the major axis per cross-section; and four semiaxes along the minor and major axes per cross-section). Based on the resultant prediction intervals, estimation error was minimized when sampling four semiaxes along the minor and major axes from 10 equal-distance cross-sectional samples per tree. Specifically, approximately 95% of the relative errors would fall within the −9.19 to 5.85% interval, 95% of the time. The results of this study demonstrate the importance of quantifying estimation error for a given sampling strategy when using the stem analysis approach.

Newton, P.F. 2006a. Asymptotic size–density relationships within self-thinning black spruce and jack pine stand-types: parameter estimation and model reformulations. *Forest Ecology and Management* **226**(1–3): 1–11.

The objective of this study was to quantify the asymptotic relationship between mean volume ($\overline{u}$ (dm^3)) and density (N (stems/ha)) within self-thinning (1) upland black spruce (*Picea mariana* (Mill.) B.S.P.) stands (denoted PIm_{UL}), (2) jack pine (*Pinus banksiana* Lamb.) stands (denoted PNb), (3) upland black spruce–jack pine mixed stands (denoted PImPNb) and (4) lowland black spruce stands (denoted PIm_{LL}). The data set consisted of 789 $\overline{u}$ - N mid-point measurement pairs (number of pairs by stand-type = 175 PIm_{UL}, 201 PNb, 203 PImPNb and 210 PIm_{LL}) derived from 274 permanent sample plots (PSPs; number of PSPs by stand-type = 99 PIm_{UL}, 64 PNb, 52 PImPNb and 59 PIm_{LL}) situated throughout the central portion of the Canadian Boreal Forest Region. Based on the logarithmic model specification of the self-thinning rule ($\log_{10}(\overline{u}) = \alpha_{0(i)} + \alpha_{1(i)} \log_{10}(N)$ where $\alpha_{0(i)}$ and $\alpha_{1(i)}$ are intercept and slope coefficients specific to the *i*th stand-type, respectively), the analysis consisted of three basic steps: (1) data splitting and subsequent selection of nine asymptotic $\log_{10}(\overline{u})$–$\log_{10}(N)$ interval subsets per stand-type; (2) obtaining parametric and non-parametric (bootstrap and jackknife) parameter estimates for each interval subset employing ordinary least squares (OLS), bisector OLS (BIS) and reduced major axis (RMA) regression techniques, yielding a total of 81 sets of parameter estimates for each stand-type; (3) given (2), identifying the relationships and corresponding interval subset that exhibited the smallest parameter estimate variances by stand-type and subsequently selecting among the nine parameterization methods, the most appropriate relationship based on applicability of the statistical assumptions employed. The results indicated negligible differences among the regression methods and estimation procedures in terms of parameter estimates and associated variances. Conceptually, however, it was concluded that the BIS method combined with the bootstrap estimation procedure was the most appropriate given that (1) the BIS method implicitly acknowledges the underlying symmetrical bivariate relationship between the variables and (2) bootstrapping incorporates underlying distributional information in parameter estimation. Numerically, the resultant estimates and associated 95% confidence limits for the intercept and slope parameters were respectively: 7.288 (5.931/8.286) and -1.552 (-1.837/-1.153) for PIm_{UL} (product moment correlation coefficient (r) = -0.969); 6.216 (6.032/6.373) and -1.214 (-1.261/-1.161) for PNb (r = -0.997); 6.145 (5.908/6.353) and -1.181 (-1.242/-1.111) for PImPNb (r = -0.993); 7.433 (6.574/7.890) and -1.562 (-1.680/-1.309) for PIm_{LL} (r = -0.979). Hence the observed thinning exponents for the PIm_{UL} and PIm_{LL} stand-types were consistent with that predicted by both the geometric (-1.5) and allometric (-1.33) formulations, whereas those for the PNb and PImPNb stand-types were not. An alternative formulation of the self-thinning relationship for jack pine stands is postulated based on the frictional interaction among tree crowns.

Newton, P.F. 2006b. Forest production model for upland black spruce stands—optimal site occupancy levels for maximizing net production. *Ecological Modelling* **190**(1–2): 190–204.

The objective of this study was to develop a forest production model for determining optimal density management regimes for upland black spruce (*Picea mariana* (Mill.) B.S.P.) stands based on the maximization of net production. This objective was attained via the development of an allometrically extended stand density management diagram (SDMD), which was used to describe the mass dynamics of biotic and abiotic tree components by initial density regime, site quality and fine root turnover rate. Specifically, periderm, stem, branch, foliage and abiotic crown masses were estimated employing multivariate allometric regression functions based on data derived from 125 destructively sampled trees. Below-ground mass estimates were obtained using generalized allometric relationships derived from the literature. Abiotic masses included three basic components: (1) allometrically estimated retained woody debris consisting of abiotic crown structures that remained attached to the main stem; (2) fine woody debris arising from needle loss, root turnover, and abscission of modular components; (3) coarse woody debris arising from trees which incurred mortality through self-thinning. The algorithmic version of the model (1) simultaneously calculates periodic annual net production estimates (mg/ha/year) by 10-year intervals over 100-year rotation lengths for eight initial density conditions, (2) given (1), determines the occupancy level for which net production is maximized for each stage of development (decade interval), and (3) given (2), determines the optimal size–density trajectory within the context of a SDMD. Additionally, results derived from multiple model simulations employing a range of initial densities (1500, 1650,...,16,350 stems/ha), site indices (9, 10,..., 15 m) and fine root turnover rates (0.2, 0.3,...,0.8 proportion/year), indicated that black spruce productivity was maximized when site occupancies were maintained slightly below the zone of imminent competition mortality. Instructions for acquiring an executable version of the model through the Internet are also included.

Newton, P.F., and Amponsah, I.G. 2005. Evaluation of Weibull-based parameter prediction equation systems for black spruce and jack pine stand types within the context of developing structural stand density management diagrams. *Canadian Journal of Forest Research* **35**(12): 2996–3010.

The objective of this study was to evaluate the predictive ability of Weibull-based parameter prediction equation (PPE) systems developed for natural (density unregulated) and managed (density regulated) black spruce (*Picea mariana* (Mill.) B.S.P.) and jack pine (*Pinus banksiana* Lamb.) stand types (n = 6), using (1) seemingly unrelated regression (SUR) employing a recursive system specification, (2) cumulative density function regression (CDFR) in which the location parameter was estimated indirectly employing a minimum diameter function (denoted $CDFR_{(1)}$), and (3) CDFR in which the location parameter was estimated directly from stand-level variables (denoted $CDFR_{(2)}$. An Ontario-based calibration data set consisting of diameter frequency distributions and associated stand-level variables derived from 1591 permanent sample plot (PSP) measurements was used to develop SUR-based, $CDFR_{(1)}$-based, and $CDFR_{(2)}$-based PPE systems. The calibration data set and an Ontario-based independent test data set, which consisted of stand-level variables and associated diameter frequency distributions derived from 244 PSP measurements, were used to evaluate the resultant PPE systems. Based on the approximate equivalency among the PPE systems in terms of (1) goodness-of-fit indices, (2) lack-of-fit statistics, (3) prediction error indices, and (4) stand-level product value prediction error, all three parameterization methods were found to be of equal utility, irrespective of stand type.

L'objectif de cette étude consistait à évaluer la capacité de prédiction de systèmes d'équations de prédiction des paramètres (EPP) basés sur la fonction de Weibull et développés pour des types de peuplements naturels (densité non régularisée) et aménagés (densité régularisée) d'épinette noire (*Picea mariana* (Mill.) B.S.P.) et de pin gris (*Pinus banksiana* Lamb.) (n = 6), en utilisant (1) une régression sans corrélation apparente (RSCA) avec une spécification de système récursif, (2) une fonction de régression de densité cumulative (FRDC) dans laquelle le paramètre de localisation a été estimé indirectement à partir d'une fonction de diamètre minimum (désignée par $FRDC_{(1)}$), et (3) une FRDC dans laquelle le paramètre de localisation a été estimé directement à partir de variables de peuplements (désignée par $FRDC_{(2)}$). Les systèmes d'EPP basés sur la RSCA, la $FRDC_{(1)}$ et la $FRDC_{(2)}$ ont été développés à partir d'une banque de données de calibration de l'Ontario constituée des distributions de fréquence de diamètres et des variables de peuplement associées qui ont été dérivées de 1591 mesures de placettes-échantillons permanentes (PEP). La banque de données de calibration et une banque de données indépendantes de l'Ontario, constituée de variables de peuplement associées à des distributions de fréquence de diamètres dérivés de mesures de 244 PEP, ont été utilisées pour évaluer les systèmes d'EPP ainsi développés. Les systèmes d'EPP étant à peu près équivalents en termes (1) d'indice de qualité d'ajustement, (2) de statistique de déficit d'ajustement, (3) d'indice d'erreur de prédiction, et (4) d'erreur de prédiction de la valeur des produits au niveau du peuplement, les auteurs ont conclu que les trois méthodes de paramétrisation étaient d'égale utilité, peu importe le type de peuplement.

Newton, P.F., and Amponsah, I.G. 2006. Systematic review of short-term growth responses of semi-mature black spruce and jack pine stands to nitrogen-based fertilization treatments. *Forest Ecology and Management* **237**(1–3): 1–14.

Based on a meta-analytical review of experimental results presented in the scientific literature, the objective of this study was to quantify the short-term growth responses (periodic basal area growth (ΔBA; m^2/ha/decade), periodic total volume growth (ΔTV; m^3/ha/decade) and periodic merchantable volume growth (ΔMV; m^3/ha/decade)) of semi-mature black spruce (*Picea mariana* (Mill.) B.S.P.) and jack pine (*Pinus banksiana* Lamb.) stands to nitrogen-based fertilization treatments (one-time dosages of nitrogen (N), N and phosphorus (P), N and potassium (K), and NPK). Specifically, five fertilization treatments were assessed: (1) [84 ≤ kg N ha−1 < 140] denoted N; (2) [196 ≤ kg N ha−1 < 252] denoted 2N; (3) [196 ≤ kg N ha−1 < 252] + [84 ≤ kg P ha−1 < 140] denoted 2NP; (4) [196 ≤ kg N ha−1 < 252] + [84 ≤ kg K ha−1 < 140] denoted 2NK; (5) [196 ≤ kg N ha−1 < 252] + [84 ≤ kg P ha−1 < 140] + [84 ≤ kg K ha−1 < 140] denoted 2NPK. Analytically, the procedure consisted of three sequential steps: (1) identifying relevant fertilization studies via a systematic search of the scientific literature and associated electronic databases; (2) obtaining and critically reviewing the identified publications for their specific applicability in terms of species, experimental approach, treatments applied, growth parameters measured, and duration of response; (3) determining the mean percent change in periodic growth of the fertilized stands relative to comparable unfertilized control stands by growth parameter, treatment, site quality class and species, employing regression analyses. In total, 112 and 161 fertilized-control observational growth response pairs were derived from 24 black spruce and 37 jack pine experimental installations, respectively. Results indicated that among the 30 black spruce relationships assessed (3 response variates × 5 treatments × 2 site quality classes), black spruce stands situated on (1) good and excellent quality sites exhibited significant ($p \leq 0.05$) and consistent positive responses (concurrent increases in all three growth measures) to N and 2NP treatments (i.e., mean increases of 22.6% in ΔBA, 16.9% in ΔTV and 17.9% in ΔMV); (2) poor and medium quality sites exhibited largely insignificant and (or) inconsistent responses to fertilization (i.e., a significant ($p \leq 0.05$) mean increase of 12.6% in ΔBA to the 2N and 2NPK treatments ($p \leq 0.05$) only). Among the 45 jack pine relationships assessed (3 response variables × 5 treatments × 3 site quality classes), jack pine stands situated on (1) good quality sites exhibited significant ($p \leq 0.05$) and consistent responses to all five treatments (i.e., mean increases of 17.3% in ΔBA, 15.4% in ΔTV and 14.5% in ΔMV); (2) medium quality sites responded significantly (p ≤ 0.05) and consistently to N, 2N, 2NK and 2NPK treatments (i.e. mean increases of 28.3% in ΔBA, 22.1% in ΔTV and 22.7% in ΔMV); (3) poor quality sites exhibited significant ($p \leq 0.05$) and consistent responses to 2NK and 2NPK treatments (i.e., mean increases of 23.5% in ΔBA, 19.5% in ΔTV and 19.5% in ΔMV). The delineation and selection of a single optimal treatment for a given site quality class was not possible given insignificant ($p > 0.05$) differences among the various treatments that exhibited significant ($p \leq 0.05$) mean responses. The overall result of this review suggests that short-term productivity of black spruce stands situated on good and excellent sites and jack pine stands situated on good, medium and poor sites, could be enhanced during the later stages of stand development through N-based fertilization treatments.

Newton, P. F., and Amponsah, I.G. 2007. Comparative evaluation of five height-diameter models developed for black spruce and jack pine stand-types in terms of goodness-of-fit, lack-of-fit and predictive ability. *Forest Ecology and Management* **247**(1–3): 149–166.

The objective of this study was to comparatively evaluate five nonlinear models on their ability to describe the relationship between total height (H; m) and diameter at breast-height (D; cm) within six commercially-important boreal stand-types. Specifically, the five models evaluated were as follows: (1) the constrained (i.e., H = 1.3 when D = 0) Chapman-Richards-based model proposed by Peng, Zhang and Liu [Peng, C., Zhang, L, Liu, L., 2001. Developing and validating nonlinear height-diameter models for major species of Ontario's boreal forests. NJAF 18, 87-94; denoted Model 1] which excludes consideration of stand-level effects; (2 and 3) the constrained Chapman-Richards-based models proposed by Sharma and Zhang [Sharma, M., Zhang, S.Y., 2004. Height-diameter models using stand characteristics for *Pinus banksiana* and *Picea mariana*. Scand. J. For. Res. 19, 442-451; denoted Models 2 and 3] which includes consideration of stand-level density effects through the explicit inclusion of density-based predictor variables (density (N; stems/ha) and basal area (G; m^2/ha)); and (4 and 5) constrained and unconstrained allometric-based models (denoted Models 4 and 5, respectively) derived from a multivariate expansion of the equation of simple allometry which includes consideration of stand-level effects via the explicit inclusion of density and stand developmental predictor variables (relative density index (R; %/100) and mean dominant height (HD; m), respectively). The six stand-types considered were (1 and 2) natural (density unregulated) and managed (density regulated) upland black spruce (*Picea mariana* (Mill.) B.S.P.) stands (denoted $PIm_{UL(N)}$ and $PIm_{UL(M)}$, respectively), (3 and 4) natural and managed jack pine (*Pinus banksiana* Lamb.) stands (denoted $PNb_{(N)}$ and $PNb_{(M)}$, respectively), (5) natural black spruce–jack pine mixed stands (denoted $PImPNb_{(N)}$), and (6) natural lowland black spruce stands (denoted $PIm_{LL(N)}$). The full dataset, consisting of 26741 H-D measurements and associated stand-level variables (N, G, R and HD) obtained from 985 sample plots situated throughout the central portion of the Canadian Boreal Forest Region, was randomly subdivided into calibration and validation subsets of approximately equal size by stand-type. Parameter estimates for each model were obtained using the calibration subsets in combination with nonlinear regression (Models 1–3) and multiple regression (Models 4 and 5) analyses. Employing the validation subsets, the calibrated models were evaluated using goodness-of-fit, lack-of-fit and prediction error indices at both the diameter class and stand levels. The results indicated that the best performing models were as follows: (1) Model 3 for $PIm_{UL(N)}$; (2) Model 5 for $PIm_{UL(M)}$; (3) Model 4 for $PNb_{(N)}$; (4) Model 5 for $PNb_{(M)}$; (5) Model 2 for $PImPNb_{(N)}$; and (6) Model 5 for $PIm_{LL(N)}$. Collectively, these results (1) reconfirm the utility of explicitly incorporating stand-level variables within the model specification when developing H-D models, (2) demonstrate the superiority of the newly introduced allometric-based H-D composite model, which incorporates both stand density and developmental effects for four of the six stand-types assessed, and (3) provide a suite of calibrated functions and associated performance metrics for potential use in product recovery and value estimation, stand structural analyses, growth and yield projection systems, and carbon budgeting models. Furthermore, given the success of the allometric-based models derived from the multivariate expansion of the equation of simple allometry, suggests that this modeling approach may have wider applicability in the (1) development of prediction equations for other important dimensional relationships used in forest management (e.g., localizing stem taper, volume and biomass equations) and (2) study of allometry in general (e.g., provide analytical direction in the assessment of population-level effects on allometric scaling relationships).

Newton, P.F., Lei, Y., and Zhang, S.Y. 2004. A parameter recovery model for estimating black spruce diameter distributions within the context of a stand density management diagram. *The Forestry Chronicle* **80**(3): 349–358.

The objectives of this study were to develop and subsequently demonstrate a parameter prediction approach for estimating black spruce (*Picea mariana* (Mill.) B.S.P.) diameter frequency distributions within the context of a stand density management diagram (SDMD). The approach consisted of three sequential steps: (1) obtaining maximum likelihood estimates for the location, scale and shape parameters of the Weibull probability density function for 153 empirical diameter frequency distributions; (2) developing and evaluating parameter prediction equations in which the Weibull parameter estimates were expressed as functions of stand-level variables based on stepwise regression and seemingly unrelated regression techniques; and (3) explicitly incorporating the parameter prediction equations into the SDMD modelling framework. The results indicated that the Weibull function was successful in characterizing the diameter distributions within the sample stands: the fitted distributions exhibited no significant ($p \leq = 0.05$) differences in relation to their corresponding observed distributions, based on the Kolmogorov-Smirnov test. The parameter prediction equations described 94, 94 and 89% of the variation in the location, scale and shape parameter estimates, respectively. Furthermore, evaluation of the recovered distributions in terms of prediction error indicated minimal biases and acceptable accuracy. As demonstrated, incorporating the parameter prediction equations into an algorithmic version of the SDMD enabled the prediction of the temporal dynamics of the diameter frequency distribution by initial density regime and site quality. Additionally, an executable version of the resultant algorithm with instructions on acquiring it via the Internet is provided.

Les objectifs de cette étude étaient de développer et par la suite d'utiliser une approche de récupération de paramètres pour estimer les distributions de fréquence de diamètre de l'épinette noire (*Picea mariana* (Mill.) B.S.P.) dans le cadre d'un diagramme d'aménagement de la densité d'un peuplement (SDMD). L'approche comportait trois étapes séquentielles : (1) l'obtention du maximum vraisemblable d'estimés pour les paramètres du site, de l'échelle et de la forme de la fonction de probabilité de densité de Weibull pour 153 distributions empiriques de fréquence de diamètre; (2) le développement et l'évaluation des équations de récupération des paramètres dans lesquels les estimations des paramètres selon Weibull étaient exprimées en tant que fonctions des variables du peuplement selon des techniques de régression par étape et d'autres techniques de régression apparemment sans rapport, et (3) l'intégration explicite des équations de récupération des paramètres dans le cadre du travail de modélisation SDMD. Les résultats démontrent que la fonction Weibull a réussi à représenter les caractéristiques des distributions de diamètre pour les peuplements échantillons : les distributions ajustées n'ont montré aucune différence significative ($p \leq = 0.05$) relativement aux distributions correspondantes observées, selon un test Kolmogorov-Sminov. Les équations de récupération des paramètres décrivaient 94, 94 et 89% de la variation pour respectivement les paramètres estimés du site, de l'échelle et de la forme. De plus, l'évaluation des distributions récupérées en terme de prédiction de l'erreur indiquait des biais minimes et une précision acceptable. Comme démontré, l'incorporation des équations de récupération des paramètres dans une version algorithmique du SDMD a permis la prédiction de la dynamique temporelle de la distribution de la fréquence des diamètres selon le régime initial de densité et la qualité de la station. De plus, une version utilisable directement de l'algorithme final accompagné des instructions relatives à son obtention par Internet est fournie.

Newton, P.F., Lei, Y., and Zhang, S.Y. 2005. Stand-level diameter distribution yield model for black spruce plantations. *Forest Ecology and Management* **209**(3): 181–192.

The objectives of this study were to develop and demonstrate a stand-level diameter distribution yield model and associated algorithm for black spruce (*Picea mariana* (Mill.) B.S.P) plantations. Employing a parameter prediction approach within the context of a stand density management diagram (SDMD), model development consisted of four sequential steps: (1) obtaining maximum likelihood estimates for the location, scale and shape parameters of the Weibull probability density function (PDF) for 296 empirical diameter frequency distributions; (2) developing and evaluating parameter prediction equations in which the parameter estimates of the Weibull PDF were expressed as functions of stand-level variables employing stepwise regression and seemingly unrelated regression techniques; (3) explicitly incorporating the parameter prediction equations into the SDMD modelling framework; and (4) developing an associated PC-based algorithm and demonstrating its utility in density management decision-making. The results indicated that the parameter prediction equations described 74.4, 87.1 and 66.8% of the variation in location, scale and shape parameter estimates, respectively. Incorporating the parameter prediction equations into the structure of the SDMD enabled the prediction of the temporal dynamics of the diameter frequency distribution by density management regime, site quality and region. An algorithmic version of the model is provided as a decision-support aid in which forest managers are able to simultaneously contrast multiple density management regimes in terms productivity, product value and optimal site occupancy.

Newton, P.F., and Weetman, G.F. 1993. Stand density management diagrams and their development and utility in black spruce management. *The Forestry Chronicle* **69**(4): 421–430.

A stand density management diagram for black spruce (*Picea mariana* (Mill.) B.S.P.) was developed using data derived from 49 0.081-ha permanent sample plots and 257 open-grown sample trees located throughout central insular Newfoundland. The diagram illustrated the reciprocal equation of the competition–density effect, self-thinning rule, approximate crown closure line, zone of imminent competition–mortality, and isolines for relative density, quadratic mean diameter and merchantability ratio. Mean prediction error for natural stand trajectories over a 30-projection period were 2.5 dm^3 for mean volume, 306 stems/ha for density, 16.1 m^3/ha for merchantable volume, 14.3 m^3/ha for total volume, and 1.9 m^2/ha for basal area. Implementation procedures using a combination of monoareal and polyareal sampling methods were described and the potential application of the diagram for evaluating thinning alternatives was demonstrated. Limitations of the diagram and future research directions were identified.

Un diagramme d'aménagement en fonction de la densité du peuplement pour l'épinette noire (*Picea mariana* (Mill.) B.S.P.) a été élaboré à partir des données dérivées de 49 parcelles échantillons permanentes de 0.081 ha et de 257 arbres échantillons ayant poussé sans compétition dans la partie centrale de Terre-Neuve. Le diagramme illustre l'équation réciproque de l'effet de la compétition et de la densité, les règles d'auto-éclaircie, le niveau de fermeture approximative du couvert, la zone de mortalité imminente découlant de la compétition, et les isolignes de densité relative, de diamètre moyen obtenus par la moyenne quadratique et du ratio d'arbres de valeur marchande. L'erreur moyenne de prédiction pour l'évaluation de peuplements moyens au cours d'une période de 30 projections était de 2.5 dm^3 pour le volume moyen, de 306 tiges/ha pour la densité, de 16.1 m^3/ha pour le volume marchand, de 14.3 m^3/ha pour le volume total et de 1.9 m^2/ha pour la surface terrière. Les procédures d'implantation selon une combinaison de méthodes d'échantillonnage pour une population et pour plusieurs populations sont décrites et l'utilisation potentielle du diagramme pour l'évaluation des possibilités d'éclaircie est illustrée. Les limites du diagramme et l'orientation future des recherches sont identifiées.

Newton, P.F., and Weetman, G.F. 1994. Stand density management diagram for managed black spruce stands. *The Forestry Chronicle* **70**(1): 65–74.

A stand density management diagram for managed black (*Picea mariana* (Mill.) B.S.P.) stands was developed using data derived from 37 variable-size temporary and permanent sample plots, and 257 open-grown sample trees. The plots were situated within 15 plantations and 4 precommercially thinned stands located throughout central and western Newfoundland, north-western New Brunswick and northern Ontario. The basic components of the diagram included: (1) an approximate crown closure line (2) the self-thinning rule (3) expected size-density trajectories and (4) isolines for dominant height, relative density index, quadratic mean diameter and merchantability ratio. The utility of the diagram was demonstrated by deriving yields for various initial spacings by site class and subsequently evaluating various outcomes in terms of operability criteria. In addition, the potential of estimating the time of crown closure by initial spacing and site class is discussed in relation to minimizing the adverse effects of *Kalmia angustifolia* (L.) on black spruce growth and development.

Un diagramme d'aménagement selon la densité du peuplement dans le cas des peuplements aménagés d'épinette noire (*Picea mariana* (Mill. B.S.P.) a été construit à partir des données extraites de 37 parcelles échantillons temporaires et permanentes de dimensions variables, ainsi que de 257 arbres-échantillons de plein champ. Les parcelles ont été établies dans 15 plantations et dans 4 peuplements ayant subi une éclaircie précommerciale située dans le centre et l'ouest de Terre-Neuve, dans le nord-ouest du Nouveau-Brunswick et dans le nord de l'Ontario. Les principaux éléments du diagramme comprennent : (1) une courbe de fermeture approximative du couvert, (2) une règle d'éclaircie naturelle, (3) des trajectoires prévues de dimension–densité et (4) des courbes indiquant la hauteur maximale, la densité relative, le diamètre selon la moyenne quadratique, et le rapport de valeur marchande. L'utilité du diagramme a été démontrée par le calcul du rendement en fonction de divers espacements initiaux sur une classe de station et l'évaluation subséquente des diveres conséquences en fonction des critères d'exploitabilité. De plus, la possiblité d'estimer l'époque de la fermeture du couvert en fonction de l'espacement initial et de la classe de station est discutée sous l'aspect de la minimisation des effets négatifs du *Kalmia angustifolia* (L) sur la croissance et le développement de l'épinette noire.

Nienstaedt, H., and Jeffers, R.M. 1976. *Increased Yields of Intensively Managed Plantations of Improved Jack Pine and White Spruce.* General Technical Report NC-21. United States Department of Agriculture, Forest Service, Rhinelander, Wisconsin, USA.

Increased growth resulting from provenance selection, breeding based on progeny tests, and the direct use of vegetatively propagated, superior individuals of white spruce and jack pine are discussed. Volume increases in provenance selection of 20–30 percent in white spruce, and 10–20 percent in jack pine are expected. The direct use of cloning of superior individuals may increase the gains 100 percent in white spruce and 50 percent in jack pine provided research can develop needed techniques. Some silvicultural aspects of intensive plantation management are also considered. *(Source: U.S. Department of Agriculture, Forest Service.)*

Niese, J.N., Strong, T.F., and Erdmann, G.G. 1995. Forty years of alternative management practices in second-growth, pole-size northern hardwoods. II. Economic evaluation. *Canadian Journal of Forest Research* **25**: 1180–1188.

Potential economic returns to tree quality were analyzed for four uneven-aged cutting treatments and a control in a Wisconsin northern hardwood stand. The economics of tree quality changes were analyzed over a 20-year period (1971–1992), using a marginal analysis that included tree grade, lumber volume yields, reported lumber values, and hardwood management costs. Net present values were highest for the heavy individual tree selection (60 ft^2/acre, 13.8 m^2/ha) treatment, and residual tree quality improved significantly. The medium selection (75 ft^2/acre, 17.3 m^2/ha) treatment had the greatest improvement in tree quality as well as high economic returns. The light selection (90 ft^2/acre, 20.7 m^2/ha) had the highest residual stand value but low harvest revenues. An 8-in. (20.3-cm) diameter-limit treatment had the lowest economic returns and the poorest tree quality.

Les rendements économiques potentiels relatifs à la qualité de l'arbre ont été analysés pour quatre types de récolte et un témoin en forêt inéquienne dans un peuplement feuillu nordique du Wisconsin. L'économique des changements qualitatifs de l'arbre a été étudié au cours d'une période de 20 ans (1971–1992), à l'aide d'une analyse marginale qui comprenait la classe de qualité de l'arbre, les rendements en volume de sciage, les valeurs des bois d'oeuvre obtenus et les coûts de gestion du feuillu. Les valeurs présentes nettes les plus élevées ont résulté du jardinage par pied d'arbre de forte intensité (60 pi^2/acre, 13,8 m^2/ha) et la qualité de la tige résiduelle s'est améliorée significativement. Le jardinage de moyenne intensité (75 pi^2/acre, 17,3 m^2/ha) donnait la plus grande amélioration de la qualité de l'arbre de même que des rendements économiques élevés. Le jardinage de faible intensité (90 pi^2/acre, 20,7 m^2/ha) fournissait la plus grande valeur du peuplement résiduel, mais des revenus de récolte faibles. Un traitement par diamètre limite à 8 pouces (20,3 cm) donnait les plus bas rendements économiques et la plus pauvre qualité de tige.

Niklas, K.J. 1999. Variations of the mechanical properties of *Acer saccharum* roots. *Journal of Experimental Botany* **50**(331): 193–200.

The hypothesis of biomechanical plasticity was tested by determining longitudinal and transverse variations in compressive strength and stiffness of roots from a sugar maple (*Acer saccharum* Marsh.) tree that had been heavily pruned on one side, such that it was assumed that the three remaining roots experienced different stresses. One old lateral root was sampled from each remaining side. Stiffness measured in bending and torsion were determined for each sample. Strength tended to decrease from the base to the tip of the root. Samples from the upper surface of the three roots were stronger and stiffer. The biomechanical plasticity theory was found to be true for the sample tree. *(Abstract prepared by compilers.)*

Noone, C.S., and Bell, J.F. 1980. *An evaluation of eight inter-tree competition indices.* Research Note 66. Oregon State University, Corvallis, Oregon, USA.

Eight competition indices were compared. The indices were of two types: those that used crown overlap and those that used diameter or distance to the neighboring tree. Data used in the evaluation were taken from a single study undertaken to examine the effect of stand density on growth. Although differences were found in computation time, no single index was found to be superior to the others. It was noted that the analysis was undertaken using a single data set, and results should be used with caution. *(Abstract prepared by compilers.)*

Nyland, R.D. 2005. Diameter-limit cutting and silviculture: a comparison of long-term yields and values for uneven-aged sugar maple stands. *Northern Journal of Applied Forestry* **22**(2): 111–116.

Models were used to compare long-term yields and values under the diameter-limit cutting and selection-system cutting. It was found that annual yields and revenue under the selection-system cutting were higher than those under the diameter-limit cutting. Diameter-limit cutting in an uneven-aged stand will result in lower and less frequent yields. Its only advantage is a short-term financial gain in the initial entry. Selection-system cutting yields higher volume and more valuable sawtimber over time. *(Abstract prepared by compilers.)*

O'Halloran, M.R., Bodig, J., and Bowden, D.C. 1972. Nondestructive parameters of lodgepole pine dimension lumber in bending. *Forest Products Journal* **22**(2): 44–51.

Lodgepole pine dimension lumber was collected from seven Colorado and Wyoming sawmills. The sampling included a total of 277 specimens in four visual stress grades. Two testing techniques, one in continuous deflection and the other in transverse vibration, were used to obtain non-destructive parameters. The final phase of testing was a static test to destruction of each piece as a joist under third-point loading. An extensive statistical analysis was employed in testing homogeneous variance, normality, and the goodness of fit of a series of models in order to obtain the best empirical model for the relationship between

strength and stiffness. Correlation coefficients ranged from 0.28 to 0.69 in the estimation of MOR. A table is presented showing the relationship for allowable working stresses based on a lower 95 percent tolerance limit as compared to the Western Wood Products Association and West Coast Lumber Inspection Bureau machine grades.

Okwuagwu, C.O., and Guries, R.P. 1981. Estimates of general and specific combining ability and heritability for juvenile wood specific gravity and tracheid length in jack pine. Pages 128–137 *in* Anonymous. *Proceedings, 27th Northeastern Forest Tree Improvement Conference*, 20–31 July 1980, Burlington, Vermont. United States Department of Agriculture, Forest Service, Reforestation, nurseries and genetic resources, Burlington, Vermont, USA.

Analysis of combining ability of full-sib progenies of jack pine at 5 years of age was undertaken to assess the potential of breeding jack pine for wood quality. Specific gravity varied due to the general combining ability, whereas tracheid length was attributed to specific combining ability. Jack pine lends itself well to breeding for wood properties, i.e., specific gravity. *(Abstract prepared by compilers.)*

Oliver, C.D., Hanley, D.P., and Johnson, J.A., editors. 1986. Douglas-fir: stand management for the future: proceedings. Contribution No. 55, University of Washington Press, Seattle, Washington, USA.

These proceedings summarize management of coastal Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco). Topics discussed include overviews of the status of the resource, wood quality, markets for products, the link between stand management and product values, biological potential of Douglas-fir, assessment of current and future ways of estimating growth and yield, as well as non-consumptive concerns and policy issues associated with stand management. *(Abstract prepared by compilers.)*

Olson, A.R., Poletika, N.V., and Hicock, H.W. 1947. *Strength Properties of Plantation-Grown Coniferous Woods.* Bulletin 511. Connecticut Agricultural Experiment Station, New Haven, Connecticut, USA.

Although many plantations are now approaching merchantable age, little data exist with respect to strength characteristics of plantation-grown wood. A hurricane in 1938 damaged many plantations older than 25 years and salvage operations permitted collection of samples for mechanical testing. Samples of Austrian pine (*Pinus nigra* Arnold), jack pine (*Pinus banksiana* Lamb.), red pine (*Pinus resinosa* Ait.), Scotch pine (*Pinus sylvestris* L.), eastern white pine (*Pinus strobus* L.), Norway spruce (*Picea abies* (L.) Karst.), and European larch (*Larix decidua* Mill.) were taken. Forest-grown wood was generally found to be stronger than plantation-grown wood. The greatest differences were found with red pine. *(Abstract prepared by compilers.)*

Omholt, I., and Miles, K.B. 2008a. Preheating and refining of mechanical pulp at high temperature Part I: fibre separation and initial development. *Journal of Pulp and Paper Science* **34**(1): 39–44.

In order to determine appropriate process conditions, the effect of high temperature preheating and refining on fiber characteristics was studied. Black spruce (*Picea mariana* (Mill.) B.S.P.) chips were pulped under identical conditions except for preheating temperature. One series was prepared at 138°C and the second at 158°C. The resultant pulps were examined for shive content, fiber length, and quasi-static compression. Higher preheating temperatures resulted in lower shive content. Although fibers were initially longer, higher specific energy resulted in shorter fibers. Fines were found to develop at the same rate, with increasing specific energy for both temperatures. Higher temperatures resulted in higher stress and strain at a given specific energy. It was concluded that, although there are advantages to higher preheating temperatures, high refining specific energy should be avoided. *(Abstract prepared by compilers.)*

Omholt, I., and Miles, K.B. 2008b. Preheating and refining of mechanical pulp at high temperature. Part II: final pulp properties. *Journal of Pulp and Paper Science* **34**(1): 46–50.

The impact of higher-than-normal preheating and refining temperatures on black spruce (*Picea mariana* (Mill.) B.S.P.) pulp qualities was examined by varying the preheating temperature. Fines content, fines development, and tensile index were similar across temperatures. Energy required for a given freeness was related to the degree of fiber shortening from the primary refining stage. Long fiber content and fiber length decreased with increasing preheating temperature. No advantage to increasing the preheating temperature was found. *(Abstract prepared by compilers.)*

Ontario Ministry of Natural Resources (OMNR). 1998a. *Clearcutting and Its Alternatives for Upland Black Spruce.* Technical Report #7. Northwest Science & Technology, OMNR, Thunder Bay, Ontario, Canada.

The technical report consists of a brief literature review on the ecology and silvics of jack pine and black spruce. It also includes case studies illustrating the silvicultural systems used for black spruce. More information is needed for the shelterwood and two-stage harvest systems and the conditions under which these systems may be appropriate. *(Abstract prepared by compilers.)*

OMNR. 1998b. *Commercial Thinning of Jack Pine.* Technical Report #2. Northwest Science & Technology, OMNR, Thunder Bay, Ontario, Canada.

The technical report consists of a brief literature review on the ecology and silvics of jack pine. It also includes a case study on commercial thinning of jack pine on two sites. The objective of the thinning operation was to increase the growth and value of the jack pine trees left on site after removing dominants and codominants. The remaining crop trees will be harvested for sawlogs and poles in 15 years. *(Abstract prepared by compilers.)*

OMNR. 1998c. *Early Stand Tending in Jack Pine Plantations.* Technical Report #6. Northwest Science & Technology, OMNR, Thunder Bay, Ontario, Canada.

The technical report consists of a brief literature review on the ecology and silvics of jack pine. It illustrates a case study on early stand tending in jack pine plantations on three different sites. There appears to be less information available on the critical timing of these operations for stand development phases. In order to maximize value from the investment of stand maintenance operations, tending and thinning should occur at the point when the trees start to exhibit a reduction in growth

rate due to competition. *(Abstract prepared by compilers.)*

OMNR. 1998d. *Mixed Planting of Jack Pine, Black and White Spruce*. Technical Report #10. Northwest Science & Technology, OMNR, Thunder Bay, Ontario, Canada.

The technical report consists of a brief literature review on the ecology and silvics of jack pine, black spruce, and white spruce. It illustrates case studies of mixed species plantations with varying degrees of silviculture management. The planting of mixed species provides many benefits. The lack of long-term data on growth and yield, cost:benefit ratios, and conclusive results regarding interplanting demonstrate the need for more trial plantations and studies. *(Abstract prepared by compilers.)*

OMNR. 1998e. *Natural Regeneration in Boreal Mixedwood Forests*. Technical Report #1. Northwest Science & Technology, OMNR, Thunder Bay, Ontario, Canada.

The technical report consists of a brief literature review on the ecology and silvics of trembling aspen, white birch, black spruce, and balsam fir. It also includes case studies that look at regeneration following wild fire as well as harvesting. This case study illustrates that the boreal mixedwood forest is a stratified, successional mixture with commercially valuable pioneer species and less valuable, late-successional species. *(Abstract prepared by compilers.)*

OMNR. 1998f. *Pre-Commercial Thinning in Black Spruce*. Technical Report #11. Northwest Science & Technology, OMNR, Thunder Bay, Ontario, Canada.

The technical report consists of a brief literature review on the ecology and silvics of black spruce. It also includes a case study on precommercial thinning of black spruce. The study concludes that, 9 years after thinning the stand, there was little response in diameter growth, but considerable decrease in total stand volume. *(Abstract prepared by compilers.)*

OMNR. 1998g. *Spot Seeding of Jack Pine and Black Spruce*. Technical Report #8. Northwest Science & Technology, OMNR, Thunder Bay, Ontario, Canada.

The technical report consists of a brief literature review on the ecology and silvics of jack pine and black spruce. It also includes a case study on spot seeding of jack pine and black spruce with and without shelters. Seed shelters can improve seed bed conditions and can also be used on productive sites in order to obtain reasonable survival and growth rates. *(Abstract prepared by compilers.)*

OMNR. 1998h. *The Establishment of Black and White Spruce on Ontario's Boreal Mixedwood Sites*. Technical Report #5. Northwest Science & Technology, OMNR, Thunder Bay, Ontario, Canada.

The technical report consists of a brief literature review on the ecology and silvics of black spruce and white spruce. It illustrates a case study of a boreal site that was scarified, planted, and chemically released. These stand treatments were done to promote the successful establishment of black spruce and white spruce on boreal mixedwood sites. *(Abstract prepared by compilers.)*

OMNR. 1998i. *The Use of Fire for Natural Jack Pine Regeneration on Cutovers*. Technical Report #9. Northwest Science & Technology, OMNR, Thunder Bay, Ontario, Canada.

The technical report consists of a brief literature review on the ecology and silvics of jack pine. It also includes a case study on using fire to obtain natural jack pine regeneration on cutovers. This requires a great deal of local knowledge about site and soil types and the diversity and dominance of pre-fire species. *(Abstract prepared by compilers.)*

Ouellet, D. 1983. *Biomass Prediction Equations for Twelve Commercial Species in Quebec*. Information Report LAU-X-62E. Natural Resources Canada, Canadian Forest Service - Laurentian Forest Research Centre, Sainte-Foy, Quebec, Canada.

Biomass prediction equations were constructed for twelve commercial species from sampling conducted throughout Quebec. The coniferous species studied include eastern white pine (*Pinus strobus* L.), red pine (*Pinus resinosa* Ait.), jack pine (*Pinus banksiana* Lamb.), balsam fir (*Abies balsamea* (L.) Mill.), white spruce (*Picea glauca* (Moench) Voss), red spruce (*Picea rubens* Sarg.), and tamarack (*Larix laricina* (Du Roi) K. Koch). The deciduous species are trembling aspen (*Populus tremuloides* Michx.) yellow birch (*Betula alleghaniensis* Britt.), white birch (*Betula papyrifera* Marsh.) sugar maple (*Acer saccharum* Marsh.), and red maple (*Acer rubrum* L.). The equations are designed to predict the green and ovendry masses of the total above-ground tree, the stem, the merchantable stem, the wood and the bark of the merchantable stem, and the crown. The equations use the diameter at breast height and the total height as predictors.

Des équations de prédiction de la biomasse forestière de douze essences échantillonnées à travers le Québec ont été construites. Ces essences sont pour les résineux : le pin blanc (*Pinus strobus* L.), le pin rouge (*Pinus resinosa* Ait.), le pin gris (*Pinus banksiana* Lamb.), le sapin baumier (*Abies balsamea* (L.) Mill.), l'épinette blanche (*Picea glauca* (Moench) Voss), l'épinette rouge (*Picea rubens* Sarg.), et le mélèze laricin (*Larix laricina* (Du Roi) K. Koch). Pour les essences feuillues, ce sont : le peuplier faux-tremble (*Populus tremuloides* Michx.), le bouleau jaune (*Betula alleghaniensis* Britt.), le bouleau blanc (*Betula papyrifera* Marsh.), l'érable à sucre (*Acer saccharum* Marsh.) et l'érable rouge (*Acer rubrum* L.). Ces équations ont pour but de prédire les masses vertes et anhydres de l'arbre total (partie située au-dessus du niveau du sol), de la tige, de la partie marchande de la tige, de son bois et de son écore, ainsi que de la cime. Les équations utilisent le diamètre à hauteur de poitrine et la hauteur totale de l'arbre comme variables explicatives.

Packee, E.C., Quang, P.X., and Ressa-Smith, R. 1992. Bolewood specific gravity of Alaskan northern forest trees. *Forest Products Journal* **42**(1): 29–34.

The quality of wood of northern forest species within Alaska has been questioned. One measure of wood quality is specific gravity (SG). Ovendry SG for the six northern forest species found in Alaska was directly determined for samples obtained from breast height sections and at other locations along the stem. Results indicate that SGs of the softwood are similar to those reported elsewhere and those of the hardwoods exceed those reported for eastern North America, but are less than the means for the Canadian Prairie provinces. Except for aspen, SG trends up the bole within the first log are similar to results found in Canada; aspen exhibits a statistically nonsignificant negative trend. Breast height ovendry SG for tamarack = .54, white spruce = .40, black spruce =.48, paper birch = .58, balsam poplar = .37, and quaking aspen = .41. Green-volume SG was also calculated and similarly compared.

Panshin, A.J., and de Zeeuw, C. 1980. *Textbook of Wood Technology: Structure, Identification, Properties and Uses in Commercial Woods of the United States and Canada*. Vol. 1, fourth editon. College Series in Forest Resources. McGraw-Hill, New York, New York, USA.

As in previous editions, the book is divided into two main parts. Part 1 (Formation, anatomy, and properties of wood) has been updated with the addition of new material, including scanning electron micrographs. Part 2 (Wood identification and descriptions of wood by species) remains essentially the same. *(Abstract prepared by compilers.)*

Park,Y.S., and Fowler, D.P. 1988. Geographic variation of black spruce tested in the Maritimes. *Canadian Journal of Forest Research* **18**(1): 106–114.

Range-wide provenance tests of black spruce (*Picea mariana* (Mill.) B.S.P.) established at 10 locations in the Maritime provinces were evaluated. Based on the 14-year data, the genetic variation in the species is predominantly clinal. The magnitude of provenance × location interactions is moderately large, and stability of provenances varies widely. Trees of Maritime origin generally performed well, suggesting that there is little advantage in going outside the region to obtain black spruce seed. Seed transfer recommendations are summarized, and three overlapping breeding zones are delineated for the Maritime provinces.

Les auteurs ont évalué des plantations comparatives d'épinettes noires (*Picea mariana* (Mill.) B.S.P.) établies dans 10 endroits des Maritimes dans le cadre de tests de provenance à l'échelle de l'aire d'extension naturelle de cette espèce. Les données recueillies pendant 14 ans permettent de voir que la variabilité génétique de l'espèce est surtout clonale. L'ampleur des interactions entre la provenance et l'emplacement est moyennement importante et la stabilité des provenances varie énormément. La performance des arbres provenant des Maritimes a été généralement bonne, laissant supposer que l'obtention de semences d'épinettes noires de l'extérieur de la région présente peu d'avantages. Les auteurs résument les recommandations relatives aux semences à utiliser et délimitent trois zones d'amélioration génétique qui se chevauchent dans les Maritimes.

Park, Y.S., Simpson, J.D., Fowler, D.P., and Morgenstern, E.K. 1989. *A selection index with desired gains to rogue jack pine seedling seed orchards.* Information Report M-X-176. Natural Resources Canada, Canadian Forest Service - Atlantic Forestry Centre, Fredericton, New Brunswick, Canada.

Jack pine (*Pinus banksiana* Lamb.) family tests at four locations in New Brunswick were evaluated at age 10 for height, diameter, volume, stem straightness, branch characteristics, and wood density. Significant variance due to families was found for all traits ranging from 3.4 to 10.0 percent of respective total phenotypic variance. Family x location interaction variance was small but significant for all traits except for wood density. There were negative genetic correlations between growth and quality traits, the largest of which was between volume and wood density (r = -0.706). A multi-trait selection index was developed, using volume, stem straightness, and branch characteristics for roguing families from seedling seed orchards. The index was based on the maximum gain in volume that could be attained while keeping stem straightness and branch characteristics at the population mean. Genetic gains at the suggested level of roguing, i.e., retaining the 60 best families out of 164, were estimated as 7.6 percent of the overall mean for volume while stem straightness and branch characteristics remained unchanged.

On a étudié 6 traits (hauteur, diamètre, volume, rectitude du fût, caractéristiques des branches et densité du bois) du pin gris (*Pinus banksiana* Lamb.) de 10 ans faisant l'objet de tests de famille dans 4 stations du Nouveau Brunswick. On a constaté pour tous les traits des écarts significatifs imputables aux familles, soit de 3,4 à 10% de la variance phénotypique totale de chacun. La variance de l'interaction entre la famille et la station était faible mais significative dans tous les cas sauf celui de la densité du bois. Les corrélations génétiques étaient négatives entre l'accroissement et la qualité, particulièrement dans le cas de la corrélation entre le volume et la densité du bois (r = -0,706). Le volume, la rectitude du fût et les caractéristiques des branches ont été utilisés pour constituer un indice de sélection multitraits permettant de rejeter les familles indésirables dans les vergers à graines. L'indice est fondé sur le gain maximum de volume qu'il est possible d'atteindre tout en conservant en moyenne un fût rectiligne et de bonnes caractéristiques des branches pour l'ensemble de la population. Le taux de rejet proposé, 104 familles sur 164, les gains génétiques son estimés à 7,6% de la moyenne générale sur le plan du volume, tandis que la rectitude du fût et la caractéristiques des branches demeurent inchangées.

Parker, M.L., Hunt, K., Warren, W.G., and Kennedy, R.W. 1976. Effect of thinning and fertilization on intra-ring characteristics and kraft pulp yield of douglas-fir. Pages 1075–1086 *in* Anonymous. *Applied Polymer Symposium*, 19–23 May 1975, Syracuse, New York, USA. John Wiley & Sons Inc., Syracuse, New York, USA.

A combination of treatments (fertilization, thinning) was established for Douglas-fir to assess tree response to the treatments. Those responses were then correlated to wood density and kraft pulp yield. Wood density and pulp yield were negatively affected by fertilization but thinning had a positive effect. Thinning impacts took longer to manifest themselves but they had a long-term impact. *(Abstract prepared by compilers.)*

Passialis, C., and Kiriazakos, A. 2004. Juvenile and mature wood properties of naturally-grown fir trees. *Holz als Roh - und Werkstoff* **62**(6): 476–478.

The production of a juvenile-type wood results from normal physiological processes. There is not much that foresters can do to avoid it. Wood characteristics change rapidly within the juvenile zone in the direction from the pith to the bark. Juvenile wood is characterized by faster growth rate, lower density and strength, shorter fibers and greater microfibril and fiber angle when compared with mature wood. Also, lignin and hemi-cellulose content are higher in the juvenile wood while alpha cellulose is lower. Juvenile wood adversely influences the quality of wood products. Higher proportions of juvenile wood are produced from fast growing plantations due to the faster growth rate and the shorter rotation time compared to natural stands. The age of transition from juvenile to mature wood formation can vary among different species and properties and is depended on genetic factors and silvicultural management (Robertson 1985).

Paul, B.H. 1963. *The Application of Silviculture in Controlling the Specific Gravity of Wood.* Technical Bulletin No. 1288. United States Department of Agriculture, Forest Service, Madison, Wisconson, USA.

A number of environmental factors appear to influence the growth of trees and certain standard characteristics related to wood quality. These factors may be interacting so that the direct specific influence of one or another is not obvious. However, the combined effect of several factors of a particular environment may be indicated by amount of annual growth (ring width), by proportional amounts of springwood and summerwood, or by specific gravity (density).

Sometimes the relationship of ring width to specific gravity for a given species is sufficiently clear to warrant rather definite quality evaluations, but more often this relationship varies during the life of the stand. Because of this variation, a history of environmental changes must be considered. It has become very important, therefore, to learn what conditions of growth influence wood properties most noticeably and to find out how silvicultural practice can improve wood quality.

This bulletin contains the results of studies conducted at the Forest Products Laboratory that reveal the great variability in wood quality as indicated by specific gravity determinations and other tests. It also explains how, within natural limits, the quality of wood can be improved through the art of silviculture. *(Source: U.S. Department of Agriculture, Forest Service.)*

Pavel, M., and Andersson, B.O. 2009. A model for predicting the value of forest stands in various market conditions in British Columbia. *The Forestry Chronicle* **85(**3): 387–391.

A model for predicting the value of forest stands was developed at FPInnovations – FERIC Division. The model uses standard cruise data collected in British Columbia (BC) and company sort descriptions to predict the distribution of wood volume by species and grade sort for each proposed harvest site. The model is capable of quickly analyzing different scenarios (i.e., different sort sets) to reflect changing market conditions. Within the model, a taper equation is applied to each tree to calculate the diameters inside the bark, and quality and pathological descriptors from cruise data are used. A Dynamic Programming algorithm is used to predict the combination of logs that maximizes the value of each stem, and results are summarized and extended from individual trees to cruise plots, then to harvest blocks and/or stands. The model was successfully tested for second-growth stands with relatively few defects on Coastal BC. Improvements are being implemented to enhance its applicability to more complex stands.

Un modèle de prédiction de la valeur des peuplements forestiers a été élaboré par la division FERIC de FPInnovations. Le modèle utilise les données habituelles d'inventaire forestier en Colombie-Britannique et la description des classes de qualité retenues par l'entreprise pour prédire la distribution des volumes de bois par espèce et par classe de qualité de chacun des blocs de coupe proposés. Le modèle est capable d'analyser rapidement différents scénarios (par ex., différents regroupements de classes de qualité) afin de refléter les conditions variables du marché. Une équation de défilement de la tige est incluse dans le modèle pour être utilisée dans le calcul des diamètres sous écorce de chaque arbre, en plus des descripteurs de la qualité et de la pathologie en provenance des données d'inventaire. Un algorithme de programmation dynamique est utilisé pour prédire le choix de billes qui maximise la valeur de chaque tige et par la suite les résultats sont résumés et transposés de chaque arbre à l'ensemble des parcelles d'inventaire, puis aux blocs de coupe et, ou encore, aux peuplements. Le modèle a été essayé avec succès dans des peuplements de seconde venue ayant relativement peu de défauts sur la Côte de la C.-B. Des améliorations sont en cours dans le but d'accroître son applicabilité dans le cas de peuplements plus complexes.

Payandeh, B. 1989. Growth of black spruce trees following fertilization on drained peatland. *The Forestry Chronicle* **65**(2): 102–106.

Stem analysis of 67 peatland black spruce trees from previously drained experimental areas in northeastern Ontario that had been fertilized was used to examine effects on growth of individual trees. Stepwise multiple linear regression analysis was used to express pre- and post-fertilization diameter and volume growth as a function of site, stand and individual tree characteristics and amelioration treatments.

Results indicated that, on average, diameter growth increased by 4% after fertilization. Standard volume equations, in comparison with sectional volume summation, underestimated both inside- and outside-bark tree volumes by about 3%.

L'analyse des tiges de 67 épinettes noires poussant en sol tourbeux dans des stations expérimentales antérieurement asséchées puis fertilisées du nord-est de l'Ontario a permis d'examiner l'effet de ces facteurs sur l'accroissement individuel. Pour exprimer le diamètre avant et après la fertilisation ainsi que l'accroissement en volume en fonction de la station, du peuplement et des caractéristiques de chaque arbre de même qu'en fonction des traitements d'amélioration, on s'est servi de régressions linéaires multiples pas à pas.

Les résultats montrent que, en moyenne, l'accroissement en diamètre augmente de 4% après la fertilisation. Les équations ordinaires du volume sous-estimaient d'environ 3% le volume des arbres sous l'écorce et sur l'écorce, comparativement à la sommation des volumes de sections de tige.

Peck, E.C. 1933. *Specific Gravity and Related Properties of Softwood Lumber.* Technical Bulletin 343. United States Department of Agriculture, Forest Service, Washinton, D.C., USA.

Lumber is frequently compared in terms of its weight, that is, a thousand board feet of lumber of a given species weighs so many pounds. For exact comparisons, however, a more definite term must be used. In this bulletin, therefore, the term specific gravity is used. The average specific gravity and the range in specific gravity for the wood of a species are, in the absence of actual test data, criteria of the character of the wood, and may be used to estimate the strength properties; wearing qualities; shrinkage characteristics; and woodworking, painting, gluing, and nail-holding properties; as well as the shipping weights; fuel value; heat conductivity; and pulp yields. Specific-gravity values may be converted into any other form for practical use provided the moisture–shrinkage relation is known. In the past, many data have been gathered on the specific gravity of wood, but usually on a small number of logs or trees. It is the purpose of this bulletin to present specific-gravity data, based on tests of sections of lumber of 14 of the commercially important softwood (coniferous) species. The principal difference between this study and former studies is the manner of selecting the test specimens. The data presented here are classified according to the commercial terms or designations of the lumber and not according to botanical classification, although in most instances the two are approximately the same. In addition to presenting the specific-gravity values for lumber, an effort is made to indicate their effect on the various properties and characteristics of the wood. The effect of specific gravity on some of the properties of wood has been determined, but on many others it is still unknown. *(Source: U.S. Department of Agriculture, Forest Service.)*

Pelletier, G., and Pitt, D.G. 2008. Silvicultural responses of two spruce plantations to midrotation commercial thinning in New Brunswick. *Canadian Journal of Forest Research* **38**(4): 851–867.

A midrotation commercial thinning experiment conducted in two independent spruce plantations compared several tree selection strategies as both early (age 19 or 24 years) single and double (again at age 30 or 34 years) entries over a 16-year period. A delayed (age 30 or 32 years) single-entry thinning and unthinned portions of the plantations served as references for the other treatments. With the exception of 50% systematic row thinnings, removal intensities were held relatively constant at about 40% of stand basal area. All of the thinning treatments satisfied the objectives of focusing diameter and volume growth on a reduced number of stems and making merchantable volume available during the rotation. Early-single entry thinning allowed 30–50 m^3/ha to be harvested, increasing quadratic mean diameter and mean merchantable volume per stem at the end of the observation period by 10% and 24%, respectively, over unthinned stands. A second thinning removed an additional 48–64 m^3/ha and increased diameter and volume gains to 25% and 71%, respectively. Only marginal differences were observed between the tree-selection strategies, and there were no overall gross total or gross merchantable volume gains or losses associated any of the thinning treatments relative to the unthinned plantations.

Une expérience sur l'éclaircie commerciale appliquée en milieu de rotation dans deux plantations indépendantes d'épinette a permis de comparer plusieurs stratégies de sélection des arbres sur une période de 16 ans dans le cadre d'une éclaircie hâtive (19 ou 24 ans) unique ou répétée plus tard (30 ou 34 ans). Une éclaircie unique et tardive (30 ou 32 ans) de même que les portions non éclaircies des plantations ont servi de témoins pour les autres traitements. À l'exception des éclaircies systématiques en rangée à 50 %, toutes les autres intensités d'éclaircie ont été maintenues relativement constantes autour de 40 % de la surface terrière. Tous les types d'éclaircie ont atteint les objectifs de concentrer la croissance en diamètre et en volume sur un nombre réduit de tiges et de rendre disponible un certain volume marchand au cours de la rotation. L'éclaircie hâtive unique a permis de récolter 30 à 50 m^3/ha et d'augmenter le diamètre moyen quadratique et le volume marchand moyen par tige à la fin de la période d'observation de respectivement 10 % et 24 % par rapport aux peuplements non éclaircis. Une deuxième éclaircie a enlevé un volume additionnel de 48 à 64 m^3/ha et a produit des gains en diamètre et en volume de respectivement 25 % et 71 %. Les différences entre les stratégies de sélection des tiges étaient seulement marginales et, globalement, il n'y a pas eu de gain ou de perte en volume total brut ou en volume marchand brut associés aux traitements d'éclaircie par rapport aux plantations non éclaircies.

Peng, C. 2000. Growth and yield models for uneven-aged stands: past, present and future. *Forest Ecology and Management* **132**(2–3): 259–279.

Growth and yield modeling has a long history in forestry. Methods of measuring the growth of uneven-aged forest stands have evolved from those developed in France and Switzerland during the last century. Furthermore, uneven-aged growth and yield modeling has progressed rapidly since the first models were pioneered by Moser and Hall (1969) (Moser Jr., J.W., Hall, O.F., 1969. For. Sci. 15, 183–188). Over the years, a variety of models have been developed for predicting the growth and yield of uneven-aged stands using both individual and stand-level approaches. Modeling methodology not only has moved from an empirical approach to a more ecological process-based mechanistic approach, but also has incorporated a variety of techniques, such as, (1) systems of equations, (2) nonlinear stand table projections, (3) Markov chains, (4) matrix models, and (5) artificial neural network models. However, modeling the growth and yield of uneven-aged stands has received much less attention than that of even-aged stands. This paper reviews the current literature regarding growth and yield models for uneven-aged stands, discusses basic types of models and their merits, and reports recent progress in modeling the growth and dynamics of uneven-aged stands. Furthermore, future trends involving integration of new computer technologies (object-oriented programming and user-friendly interfaces), tree visualization techniques, and the spatially explicit application of geographical information systems (GIS) into uneven-aged modeling strategies are discussed.

Penner, M., Robinson, C., and Woods, M. 2001. The response of good and poor aspen clones to thinning. *The Forestry Chronicle* **77**(5): 874–884.

The response of good and poor clones of trembling aspen (*Populus tremuloides* Michx) to thinning was assessed 16 years after treatment. Prior to the thinning treatment, the clones had been assessed as either poor or good using a rating matrix that considered height, diameter, quality and vigour of the clones. Results indicate that the 250 largest DBH stems ha^{-1} did not respond to thinning, irrespective of clone rating. The growth of these dominant trees was unaffected by smaller competitors. Considering all trees, the non-thinned (control) good clones were indistinguishable from the thinned good clones in terms of top height, basal area, quadratic mean DBH, volume/ha, and trees/ha 16 years after treatment. For the good clones, 16 years of self-thinning yielded the same result as a single manual thinning. Due to a slower rate of self-thinning, the non-thinned poor clones retained some of the small stems longer and thus had a higher basal area and volume than the thinned poor clones. Thinning did not increase the piece size of the dominant trees so there was no associated increase in value.

Thinning good and poor clones of trembling aspen did not increase the standing volume or piece size. Therefore, thinning is recommended only for good clones and only if it is profitable on its own. The literature on the benefits of thinning of aspen is contradictory. This may be due, in part, to undocumented clonal differences.

La réaction des bons et des mauvais clones de peuplier faux-tremble (*Populus tremuloides* Michx) suite à une éclaircie a été évaluée 16 ans après le traitement. Les clones avaient été évalués avant le traitement d'éclaircie comme étant mauvais ou bons selon une matrice de classement qui considérait la hauteur, le diamètre, la qualité et la vigueur des clones. Les résultats indiquent que les 250 tiges/ha ayant le fort dhp n'ont pas eu de réaction suite à l'éclaircie, sans égard au classement des clones. La croissance de ces arbres dominants n'a pas été affectée par les compétiteurs de plus petite taille. Considérant tous les arbres, les bons clones non éclaircis (témoins) ne pouvaient pas être distingués des bons clones éclaircis en terme de hauteur de la cime, de surface terrière, de moyenne quadratique du dhp, du volume à l'hectare et du nombre de tiges à l'hectare 16 ans après le traitement. Dans le cas des bons clones, 16 années d'autoéclaircie ont donné le même résultat qu'une seule éclaircie manuelle. Par suite du taux plus lent d'autoéclaircie, les mauvais clones non éclaircis ont conservé de plus petites tiges plus longtemps et en conséquence avaient une surface terrière et un volume plus élevés que les mauvais clones éclaircis.

L'éclaircie n'a pas augmenté la taille des tiges des arbres dominants de telle sorte qu'il n'y a pas eu d'augmentation associée de la valeur. L'éclaircie de bons et des mauvais clones de peuplier faux-tremble n'a pas augmenté le volume sur pied ou le volume par tige. En conséquence, l'éclaircie est recommandée seulement pour les bons clones et seulement si l'opération est profitable par elle-même. La littérature sur les bénéfices de l'éclaircie chez le peuplier est contradictoire. Cela peut être provoqué, en partie, par le manque d'information sur les différences clonales.

Perem, E. 1958.*The Effect of Compression-Wood on the Mechanical Properties of White Spruce and Red Pine*. Technical Report No. 13. Department of Northern Affairs and National Resources, Ottawa, Ontario, Canada.

The presence of compression-wood is one of the causes of abnormal variation in the properties of softwoods which may affect normal use. The peculiar shrinkage pattern of compression-wood—excessive shrinkage along the fibre and less than normal shrinkage across the fibre direction—causes wooden members which contain pronounced forms of compression-wood to warp and twist. Thus their use for critical purposes is inadmissible. Furthermore, the presence of compression-wood has been found to have a degrading effect on some of the mechanical properties of wood. Ultimate stress in tension parallel to fibre direction and modulus of elasticity values have been found to be definitely lower for compression-wood than for normal wood. In other mechanical properties, the strength of wood which contains compression-wood has been found to compare sometimes favourably, sometimes unfavourably with normal wood, depending on the species, the character of compression-wood, the test performed, and the condition of the wood at the time of testing.

The study reported herein was carried out at the Ottawa Laboratory of the Forest Products Laboratories of Canada with two local softwood species—white spruce and red pine—for which no information as regards the properties of compression-wood was available. Since there is normally a wide range in the intensity of compression-wood, from mild forms which are not very abnormal in appearance to extreme forms in which almost the whole annual rings consist of dark compression-wood tissue, the emphasis was laid on the study of the properties of the specific types of compression-wood.

Périé, C., and Munson, A.D. 2000. Ten-year responses of soil quality and conifer growth to silvicultural treatments. *Soil Science Society of America Journal* **64**(5): 1815–1826.

A study was undertaken to evaluate the combined response of scarification, fertilization and herbicide application on white spruce (*Picea glauca* (Moench) Voss.) and white pine (*Pinus strobus* L.) plantation soil and tree growth. Organic layer samples were taken and organic layer depth was measured. Water content was determined gravimetrically using the oven-dry method and organic content was measured gravimetrically before and after ignition. Total nitrogen was measured using the Kjeldahl method. Cation analysis was determined by inductively coupled plasma emission. Phosphorous was determined by the Bray II method. Carbohydrates were measured chromatographically. Microbial biomass was determined by the fumigation-extraction procedure. Five white spruce and five white pine trees were chosen per plot and height and diameter at breast height were measured. Samples of current foliage were taken from the upper third of the live crown. Dry mass of the needles was determined. Total nitrogen, phosphorous, and cations were determined as for soil. Vector analysis was used to evaluate silvicultural techniques. Results were compared with those found 4 years after treatment. Scarification and herbicide alone or with fertilization were found to have increased tree growth. Negative impacts on soil organic matter from scarification and herbicide were still evident, but the nature of the impact had changed from a nitrate-dominated cycle to an ammonium-dominated cycle. It was concluded that no nutritional deficiency currently existed and may not manifest until later in the rotation. *(Abstract prepared by compilers.)*

Pitre, F.E., Cooke, J.E.K., and Mackay, J.J. 2007. Short-term effects of nitrogen availability on wood formation and fibre properties in hybrid poplar. *Trees - Structure and Function* **21**(2): 249–259. [online] URL: http://www.springerlink.com/content/4t72mtq414489623/fulltext.pdf.

The application of nitrogen-containing fertilisers is one approach used to increase growth rates and productivity of forest tree plantations. However, the effects of nitrogen fertilisation on wood properties have not been systematically assessed. The aim of this work was to document the impacts of nitrogen fertilisation on wood formation and secondary xylem fibre properties. We used three fertilisation treatments in which the level of ammonium nitrate was adjusted to 0, 1 and 10 mM in a complete nutrient solution applied daily over a period of 28 days in standardised greenhouse experiments with clonal material of *Populus trichocarpa* (Torr and Gray) × *deltoides* (Bartr. ex Marsh). We showed that there was a short-term and repeatable response in which xylem fibre morphology and secondary cell wall structure adapt to a shift in N availability. Under high-nitrogen exposure, xylem fibres were 17% wider and 18% shorter compared to the adequate nitrogen treatment. A very significant thickening of the fibre cell walls was also observed throughout the stem of trees receiving the high-N treatment. It appeared that cell wall structure was greatly affected by the high-N treatment as fibres developed a modified inner cell wall layer. Histological observations indicated that the internal cell wall layer was enriched in cellulose and chemical determinations showed that wood contained more holocellulose. Together, these results indicate that the response of poplar to nitrogen availability may involve marked effects on secondary xylem formation.

Pliura, A., Zhang, S.Y., Bousquet, J., and MacKay, J. 2006. Age trends in genotypic variation of wood density and its intra-ring components in young poplar hybrid crosses. *Annals of Forest Science* **63**: 673–685.

Age related dynamics of genotypic, phenotypic and environmental variation, clonal repeatability and genotypic correlation for wood density and its intra-ring components were analysed in four poplar hybrid crosses, *Populus deltoides* x *P. nigra*, *P. trichocarpa* x *P. deltoides*, *P. maximowiczii* x *P. balsamifera*, and *P. balsamifera* x *P. nigra*, as well as *P. deltoides*. Using X-ray densitometry, measurements were taken on increment cores sampled in four clonal trials at 10 and 12 years of age from ramets of 19 clones. Wood density of all hybrid crosses was highest at the pith and decreased with increasing cambial age. The significance of the hybrid cross effect increased with age for mean wood density, dry fibre weight, and ring width. The coefficient of genotypic variation of cumulated mean wood density was rather stable over the 10-year period at all three sites, and ranged from 4.8–6.8%. Clonal repeatability increased with age from 0.46 to 0.79, mainly because of decreasing random variation. Corresponding genotypic parameters for individual rings varied greatly with age and across sites. Significance of the site effect on wood density tended to decrease with age. Significant negative genotypic correlations between ring width and wood density were found at only two of the four sites and they weakened with age. Age–age genotypic correlations between wood densities at ages 10 and younger were strong and significant from age 6 and over. This trend suggests that selection before this age would be unreliable.

Variabilité génotypique interannuelle de la densité du bois et de ses composantes intracerne chez de jeunes peupliers hybrides. La dynamique inter-annuelle de la variabilité génotypique, phénotypique et environnementale, de la répétabilité clonale et des corrélations génotypiques entre paramètres de densité du bois ont été analysées pour quatre hybrides de peuplier : *Populus deltoides* x *P. nigra*, *P. trichocarpa* x *P. deltoides*, *P. maximowiczii* x *P. balsamifera*, et *P. balsamifera* x *P. nigra*, ainsi que pour *P. deltoides*. Les mesures ont été effectuées par microdensitométrie à rayon X sur des carottes échantillonnées à partir des ramets de 19 clones issues de quatre tests clonaux (âge : 10 et 12 ans). Les résultats montrent que la densité du bois de tous les hybrides est la plus élevée près de la moelle puis qu'elle diminue avec l'âge cambial. L'effet statistique du type d'hybrides augmente avec l'âge pour la densité moyenne, le poids sec des fibres et la largeur de cernes. Les coefficients de variation génotypique pour la densité moyenne du bois sont stables au cours des 10 ans sur 3 sites et s'élèvent à 4.8–6.8%. La répétabilité clonale augmente avec l'âge de 0.46 à 0.79. Les paramètres génotypiques pour les caractéristiques individuelles des cernes varient fortement avec l'âge et les sites. Le degré de signification de l'effet site tend à décroître avec l'âge pour la densité du bois. Des liaisons négatives significatives entre largeur de cernes et densité du bois sont observées sur seulement 2 des 4 sites et leur intensité s'affaiblit avec l'âge. Les liaisons génotypiques entre densité du bois à 10 ans et à des âges plus jeunes sont fortes et significatives à partir de 6 ans et au-delà. Une sélection avant cet âge semble donc peu fiable.

Pnevmaticos, S.M., Jaeger, T.A., and Perem, E. 1972. Factors influencing the weight of black spruce and balsam fir stems. *Canadian Journal of Forest Research* **2**(4): 427–433.

The factors influencing green weight of black spruce and balsam fir stems were investigated. It was found that for black spruce stems, moisture content and sapwood content could be predicted by the age and height of the tree. For balsam fir, however, it was difficult to establish meaningful correlations. Stem bark volume was well correlated for both species with diameter at breast height. Regression equations for stem green density with different combinations of independent variables estimated at breast height were developed; it was found that breast height specific gravity and moisture content were the most important variables in predicting stem green density. Stem wood volume was very well correlated with stem weight immediately after felling.

Les facteurs qui influencent le poids des tiges d'épinettes noires et de sapins baumiers à l'état vert, ont été étudiés. On a découvert que dans le cas de l'épinette noire, l'âge et la hauteur de l'arbre sont de bonnes indications pour déterminer la teneur en humidité et la quantité de bois d'aubier. Il était toutefois difficile dans le cas du sapin baumier d'établir des corrélations valables. Il existe pour les deux espèces étudiées, une bonne corrélation entre le volume en écorce de la tige et le diamètre à hauteur de poitrine. Des équations de régression ont été développés avec différentes combinaisons de variables indépendantes pour estimer la densité des tiges vertes. Il a été trouvé que le poids spécifique et la teneur en humidité à hauteur de poitrine sont les variables les plus importantes dans la prédiction de la densité des tiges vertes. Il existe entre le volume en bois de la tige et son poids, une corrélation très élevée, immédiatement après l'abattage.

Polman, J.E., and Militz, H. 1996. Wood quality of Douglas fir (*Pseudotsuga menziesii* (Mirb.) Franco) from three stands in the Netherlands. *Annals of Forest Science* **53**(6): 1127–1136.

This study examines wood quality of Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco), using 19 trees from three different stands in the Netherlands and comparing tree age, diameter at breast height, height, branchiness, ring width, and physical–mechanical properties of sawn timber. Values for bending strength and density were higher compared with other European timber species, and visual grading of sawn wood showed promising results for management and marketing of Douglas-fir in the Netherlands. *(Abstract prepared by compilers.)*

Pothier, D. 2002. Twenty-year results of precommercial thinning in a balsam fir stand. *Forest Ecology and Management* **168**(1–3): 177–186.

A precommercial thinning trial, conducted in 1978 in a 20-year-old balsam fir (*Abies balsamea* [L.] Mill.) stand in the province of Quebec, Canada, produced a broad range of stand densities over 60 permanent plots. Plots were measured at 5-year intervals until 1998 and the data were analyzed to verify the principal effects that are expected from this treatment in terms of individual tree growth and production per hectare. The diameter growth during the 20-year period following thinning was inversely related to the residual density. The increase in diameter of trees in thinned plots accumulated mainly during the first 10-year period. One explanation why thinning did not increase the diameter throughout the entire 20-year inventory period involves a spruce budworm (*Choristoneura fumiferana* [Clem.]) outbreak that occurred during this period. Total volume per hectare after 20 years was proportional to residual stand density, while merchantable volume per hectare was similar through the range of densities. If trees larger than 15 cm in diameter at breast height are considered exclusively, then thinning significantly increased 20-year stand yield. Therefore, the most important effect of precommercial thinning is to increase the volume per hectare of large diameter trees. Any conclusions on the impact of this treatment on stand yield must take into account the minimum usable diameter that is considered.

Pothier, D., Margolis, H.A., Poliquin, J., and Waring, R.H. 1989. Relation between the permeability and the anatomy of jack pine sapwood with stand development. *Canadian Journal of Forest Research 19*(12): 1564–1570.

The anatomical characteristics of sapwood from the base of the live crown of trees from 11 jack pine stands (*Pinus banksiana* Lamb.) of different age and site quality were related to the patterns of change of longitudinal sapwood permeability (k) previously observed to occur among these stands. Tracheid length (L_t) increased rapidly from a minimum of 1.9 mm to a plateau of around 3.6 mm as stand age and site quality (productive class) increased. Sapwood relative water content (R_s) measured before saturation ranged from 78 to 85% for the majority of trees. Samples taken from trees growing on poor sites, however, exhibited significantly lower values of R_s, which probably resulted in their remaining below saturation during the determination of sapwood permeability. The lower R_s values were assumed to be reflective of more adverse water balances during the growing season associated with rapidly drained and (or) shallow soils. Tracheid lumen diameter (D_l) was positively correlated with k within age-classes 15 and 35, but not thereafter. The initial relation between D_l and k is thought to be associated with corresponding increases in the area of pit membranes, which determines the number of pores within a pit membrane. Values of k were never more than 60% of the values calculated by Poiseuille's law for ideal capillaries (k_c) and were generally less than 40%. Values of k tended to approach k_c with increasing L_t and decreasing D_l. Overall, Poiseuille's law by itself could not explain the changes in hydraulic properties of jack pine sapwood with stand development. However, L_t and R_s could together account for 72% of the variation in k. Young stands that had different k depending on site quality generally had corresponding differences in L_t, R_s, and (or) D_l. Mature stands that had reached maximum k on all quality sites no longer showed differences in L_t, R_s, or D_l.

Les caractéristiques anatomiques de l'aubier à la base de la cime vivante d'arbres de 11 peuplements de pin gris (*Pinus banksiana* Lamb.) de qualités de station et d'âges différents ont été reliées aux changements précédemment observés de perméabilité longitudinale de l'aubier (k). Parallèlement à une augmentation de l'âge et de la qualité des peuplements, la longueur des trachéides (L_t) a rapidement augmenté, passant d'une valeur minimale de 1,9 mm jusqu'à une valeur maximale d'environ 3,6 mm. Les valeurs de la teneur en eau de l'aubier (R_s) mesurée avant saturation se sont situées entre 78 et 85% pour la plupart des arbres. Des échantillons provenant d'arbres croissant sur des stations pauvres ont eu de faibles valeurs de R_s, ce qui les a probablement maintenus en deçà de la pleine saturation lors de la détermination de la perméabilité de l'aubier. Ces faibles valeurs de R_s sont probablement le reflet de bilans hydriques défavorables associés à des sols minces et (ou) à des drainages excessifs. Le diamètre du lumen des trachéides (D_l) a été positivement corrélé à *k* pour les classes d'âges de 15 et 35 ans, mais n'a montré aucune corrélation pour les peuplements plus âgés. La relation entre D_l et *k* est probablement attribuable à la relation entre D_l et la taille de la membrane des ponctuations qui affecte le nombre de pores de cette membrane. Les mesures de *k* n'ont jamais atteint plus de 60% des valeurs calculées par la loi de Poiseuille pour des capillaires idéaux (k_c) et ont généralement été inférieures à 40%. Les mesures de *k* ont approché les valeurs de k_c lorsque L_t augmentait et D_l diminuait. D'une façon générale, la loi de Poiseuille par elle-même n'a pu expliquer les changements des propriétés hydrauliques des peuplements de pin gris survenant lors de leur développement. Cependant, L_t and R_s ont expliqué 72% de la variation totale de *k*. Les jeunes peuplements présentant des valeurs différentes de *k* en fonction des qualités de station ont généralement montré des différences correspondantes de L_t, R_s, et (ou) D_l. Toutefois, les peuplements à maturité ayant atteint une valeur maximale de *k* sur toutes les qualités de station n'ont pas montré de différences dans les valeurs de L_t, R_s, ou D_l.

Pothier, D., Margolis, H.A., and Waring, R.H. 1989. Patterns of change of saturated sapwood permeability and sapwood conductance with stand development. *Canadian Journal of Forest Research* **19**(4): 432–439.

The saturated sapwood permeability (*k*) of jack pine (*Pinus banksiana* Lamb.) from stands of different ages and site qualities was measured using a constant water flow apparatus. Saturated sapwood permeability at the base of the live crown (BLC) increased with age and reached a plateau just beyond 4 x 10^{-12} m^2. The rate at which this plateau was reached, however, was dependent on site quality. Such age-related increases in *k* can partially explain how trees can maintain similar daytime leaf water potentials at different stages of stand development. Within age-classes 15 and 35, *k* at BLC was greater on the better-quality sites and was strongly correlated with both diameter and height growth. For age-class 120, *k* at BLC was not significantly different among sites. Saturation sapwood permeability at BLC could be predicted from age and site quality, using a negative exponential functions ($R^2 = 0.66$). The ability to predict changes in *k* with stand development has potential for improving leaf area estimates derived from sapwood area–leaf area correlations. Sapwood conductance from ground level to the upper third of the crown decreased with age for good-quality sites and increased with age for poor-quality sites. It corresponded to the pattern of average annual height growth over the last 5 years ($R^2 = 0.61$). The number of annual rings contributing to the sapwood at a given age was independent of site quality. This suggest that the historical reconstruction of a tree's leaf area and growth efficiency is possible even after the formation of significant amounts of heartwood.

La perméabilité de l'aubier saturé (*k*) de Pins gris (*Pinus banksiana* Lamb.) provenant de peuplements d'âges variés et de qualités de station diverses a été mesurée à l'aide d'un appareil maintenant un débit constant. Les résultats indiquent que *k* mesurée à la base de la cime vivante (BCV) a augmenté avec l'âge des arbres jusqu'à ce qu'elle ait atteint un plateau légèrement supérieur à 4 x 10^{-12} m^2. Cependant, la vitesse d'atteinte de ce plateau a été influencée par la qualité de station. Une telle augmentation de *k* avec l'âge peut partiellement expliquer la constance du potentiel hydrique foliaire des arbres à divers niveaux de leur développement. Pour chacune des classes d'âge 15 et 35, *k* à BCV a été supérieure sur les meilleures qualités de station et a fortement été corrélée aux croissances en diamètre et en hauteur. Pour la classe d'âge 120, *k* à BCV n'a pas été significativement différent entre les stations. La perméabilité de l'aubier saturé pourrait être prédite par les variables âge et qualité de station en utilisant une fonction exponentielle négative ($R^2 = 0.66$). La prédiction de la variation de *k* en relation avec le développement des peuplements pourrait améliorer les estimations de superficie foliaire faites à partir des superficies d'aubier. La conductance de l'aubier calculée à partir du niveau du sol jusqu'au tiers supérieur de la cime, a diminué avec l'âge des peuplements sur les meilleures qualités de station, mais a augmenté avec l'âge des peuplements sur les stations plus pauvres. Les valeurs moyennes de conductance de l'aubier par peuplement ont varié de façon similaire à la croissance en hauteur moyenne des 5 dernières années ($R^2 = 0.61$). Le nombre de cernes annuels dans l'aubier n'a pas significativement varié entre les qualités de station pour toutes les classes d'âge étudiées. Ce résultat suggère que la reconstruction historique de la superficie foliaire et de l'indice d'efficacité de croissance d'un arbre est possible malgré une formation importante de bois de cœur.

Pronin, D. 1971. *Estimating Tree Specific Gravity of Major Pulpwood Species of Wisconsin.* Research Paper FPL - 161. United States Department of Agriculture, Forest Service, Forest Products Laboratory, Madison, Wisconsin, USA.

In the work reported in this paper, estimates are made of the specific gravity of the merchantable bole of nine wood species of commercial importance for pulpwood. Increment cores were taken from stems at breast height of trees over the range of the species and from trees of a variety of diameter sizes. The trees were felled, and the specific gravity determined for both the increment core and the merchantable bole. The relationship between the specific gravity of the core and that of the bole is expressed as a regression equation (11,14).

Trees of the following nine species were sampled: red pine (*Pinus resinosa* Ait.), jack pine (*Pinus banksiana* Lamb.), white spruce (*Picea glauca* (Moench) Voss), black spruce (*Picea mariana* (Mill.) B.S.P.), balsam fir (*Abies balsamea* (L.) Mill.), tamarack (*Larix laricina* (DuRoi) K. Koch), eastern hemlock (*Tsuga canadensis* (L.) Carr), quaking aspen (*Populus tremuloides* Michx.), and bigtooth aspen (*Populus grandidentata* Michx.).

The intensity of sampling for each species was roughly proportional to the volume of standing timber of the species within the Forest Survey units of Wisconsin. *(Source: U. S. Department of Agriculture, Forest Service.)*

Pukkala,T., and Kuuluvainen, T. 1987. Effect of canopy structure on the diurnal interception of direct solar radiation and photosynthesis in a tree stand. *Silva Fennica* **21**(3): 237–250.

The utilization of direct radiation was studied in five model stands of Poisson-type tree distribution and cone-shaped crowns. The radiation extinction depended on the self-shading of the crown and the shading caused by other trees. The results indicate that at low sun elevation a stand populated by very narrow-crowned trees is most effective in light interception and photosynthesis. At high sun elevation, a broad-crowned canopy is best illuminated and most favourable for photosynthesis. A stand with a two-storey canopy is effective in all latitudes when the crowns are moderately narrow. In two-storey canopies, the foliage of the lower storey can be better illuminated than in the lower parts of the upper storey, because of the smaller self-shading in the small crowns of the lower storey. A canopy where the crown volume is concentrated on few big crowns is less effective than a canopy consisting of many small crowns.

Pyles, M.R. 1987. Structural properties of second-growth Douglas-fir logging spars. *Transactions of the American Society of Agricultural Engineers* **30**(1): 65–69.

Spars are often chosen just by experience, but knowledge of tree base stiffness and modulus of elasticity are key in determining structural characteristics. The study compared tree taper and base stiffness as well as the modulus of elasticity to compute the stress on the spar tree. It concludes that taper and base flexibility must be addressed when using spar trees. *(Abstract prepared by compilers.)*

Racey, G.D., and Pletch, M. 1990. *Pre-commercial Thinning and Mechanical Cleaning: Multiple Benefits from Stand Improvement*. Technical Note TN-06. Ontario Ministry of Natural Resources, Thunder Bay, Ontario, Canada.

Precommercial thinning and mechanical cleaning were carried out in the Dryden Crown Management Unit to respace naturally regenerated, aerially seeded, or planted jack pine (*Pinus banksiana* Lamb.) or to release planted white spruce (*Picea glauca* (Moench) Voss). The operations were performed by local contractors, and the cost–benefit of the project was favorable—especially if economic benefits to the community were considered—because, with low barriers to entry, previously unemployed contractors were able to bid on the operation. The operation also resulted in conditions beneficial to deer (*Odocoileus virginianus*), moose (*Alces alces*), black bear (*Ursus americanus*), ruffed grouse (*Bonasa umbellus*), and snowshoe hare (*Lepus americanus*), which included improved browse and habitat. The project was concluded to be cost effective, beneficial to both the local community and wildlife, and effective in establishing productive crop-tree growing conditions. *(Abstract prepared by compilers.)*

Rajora, O.P. 1999. Genetic biodiversity impacts of silvicultural practices and phenotypic selection in white spruce. *Theoretical and Applied Genetics* **99**(6): 954–961.

Forest-management practices relying on natural and/or artificial regeneration and domestication can significantly affect genetic diversity. The aim of the present study was to determine and compare the genetic diversity of the pristine old-growth, naturally and artificially regenerated, and phenotypically selected white spruce, and to determine the genetic-diversity impacts of silvicultural practices. Genetic diversity was determined and compared for 51 random amplified polymorphic DNA (RAPD) loci for the adjacent natural old-growth, naturally regenerated and planted white spruce stands at each of four sites, one oldest plantation and open-pollinated progeny of 30 phenotypic tree-improvement selections of white spruce from Saskatchewan. Each of the 420 white spruce individuals sampled was genetically unique. The old-growth stands had the highest, and the phenotypic selections the lowest, genetic diversity. The genetic diversity of the natural regeneration was comparable to that of the old-growth, whereas the genetic diversity of the plantations was comparable to that of the selections. On average, the genetic diversity of the old-growth and natural regeneration was significantly higher than that of the plantations and selections. The mean percentages of loci polymorphic, the number of alleles per locus, the effective number of alleles per locus, heterozygosity, and Shannon's index were 88.7, 83.8, 72.2, and 66.7; 1.89, 1.84, 1.72, and 1.67; 1.69, 1.62, 1.53, and 1.46; 0.381, 0.349, 0.297, and 0.259; and 0.548, 0.506, 0.431, and 0.381 for the old-growth stands; natural regeneration; plantations; and open-pollinated progeny of selections, respectively. Reduced genetic diversity in the plantations and selections suggest that their genetic base is relatively narrow, and should therefore be broadened in order to maintain genetic diversity, and sustainably manage and conserve white spruce genetic resources.

Rasmussen, E.F. 1961. *Dry Kiln Operator's Manual.* Handbook No. 188. United States Department of Agriculture, Forest Service Agricultural, Madison, Wisconsin, USA.

This manual describes kiln-drying principles and the maintenance of kilns, and gives step-by-step instructions for operating a kiln successfully. The drying process is important for value-added products as well as the utilization of our forest products. The manual presents the defects that may occur during drying and the proper storage of dried wood. *(Abstract prepared by compilers.)*

Rathgeber, C.B.K., Decoux, V., and Leban, J.M. 2006. Linking intra-tree-ring wood density variations and tracheid anatomical characteristics in Douglas fir (*Pseudotsuga menziesii* (Mirb.) Franco). *Annals of Forest Science* **63**(7): 699–706.

In this study, a geometric approach was used in order to model the relationships between intra-tree-ring wood density variations and tracheid anatomical characteristics. One Douglas fir was studied in detail. Anatomical slides of 256 tree-rings were compared with the corresponding density profiles. Radial and tangential tracheid diameters decline from earlywood to latewood by 50% and 15%, respectively. At the same time, radial and tangential cell-wall thicknesses increase by 110% and 132%, respectively. Wood density exhibits an S-shape profile with a slight decrease of 10% at the beginning of a ring and an increase of 212% thereafter. Model simulations showed that wood density increase is mainly due to cell-wall thickening in tangential and radial directions as well as cell size reduction in radial direction. Simulations also showed that the knowledge of tracheid anatomical characteristics is not sufficient to fully explain wood density decrease at the beginning of earlywood.

Relations entre les variations de densité à l'intérieur du cerne et les caractéristiques anatomiques des trachéides pour le sapin de Douglas (*Pseudotsuga menziesii* (Mirb.) Franco). Un modèle géométrique a été utilisé dans le but de modéliser les relations entre les variations de densité à l'intérieur du cerne et les caractéristiques anatomiques des trachéides. Un sapin de Douglas a été étudié en détail. Des images numériques de coupes anatomiques de 256 cernes ont été comparées aux profils de densité correspondants. Du bois initial au bois final, les diamètres radiaux et tangentiels des trachéides diminuent de 50 % et 15 % respectivement, pendant que les épaisseurs radiales et tangentielles des parois cellulaires augmentent de 110 % et 132 % respectivement. La densité du bois présente un profil en forme de S, avec une légère diminution de 10 % au début du cerne et une augmentation de 212 % ensuite. Le modèle a montré que l'augmentation de la densité est principalement due à l'épaississement des parois cellulaires dans les directions tangentielles et radiales et à la diminution du diamètre radial des cellules. Ce modèle a également montré que la connaissance des caractéristiques anatomiques des trachéides n'est pas suffisante pour expliquer complètement la diminution de densité constatée au début du bois initial.

Raulier, F., Ung, C.H., and Begin, J. 1998. Analytical estimation of branchwood volume in sugar maple, linked to branchiness. *Trees - Structure and Function* **12**(7): 395–405.

An analytical link is proposed between branchwood volume and branchiness. A segmented linear model with one parameter is used to describe the branch basal area density along the tree bole and integrated to find a function describing the cumulative branch basal area. It appears that the bases of insertion of the branches defining the base of the light crown correspond to the maximum branch basal area density along the bole. This function is then used together with an individual branch volume equation to find a model that estimates branchwood volume. This model is calibrated with data gathered in 15 stands dominated by sugar maple (*Acer saccharum* Marsh.) in southern Quebec. A comparison is made with other models of branchwood volume found in the literature.

Rayirath, P., Avramidis, S., and Mansfield, S.D. 2008. The effect of wood drying on crystallinity and microfibril angle in black spruce (*Picea mariana*). *Journal of Wood Chemistry and Technology* **28**(3): 167–179.

The effect of drying on wood cellulose crystallinity, crystallite size, and microfibril angle was investigated using wide angle X-ray diffraction. Forty replicated specimens of black spruce (*Picea mariana*) wood were dried at constant temperatures of 40°C and 80°C and relative humidities of 34% and 47% in attempts to attain samples possessing final moisture content of 15% and 8% at each temperature. X-ray evaluation of wood specimens, comparing individual samples pre- and post-drying, revealed that both the mass fraction of crystalline cellulose and crystallite width increased with drying. In contrast, mean microfibril angle of the wood was not significantly affected by drying. It was also apparent that the changes in wood ultrastructure resulting from drying were not influenced by the drying conditions, including temperature, relative humidity, and final moisture contents.

Renninger, H.J., Gartner, B.L., and Grotta, A.T. 2006a. No correlation between latewood formation and leader growth in Douglas-fir saplings. *IAWA Journal* **27**(2): 183–191.

The width of earlywood and latewood in conifer xylem may have a profound effect on water transport and storage, vulnerability to embolism, and wood strength, yet the controls over the timing of latewood formation are unclear. Tracheids differentiating in the cambial zone are influenced by IAA, indole-3 acetic acid, the radial concentration gradient of which appears to either increase cell expansion (earlywood) or increase cell wall deposition (latewood). There are suggestive data that latewood begins to form when the growth of the leader stops, but definitive results are lacking. Height growth was measured in 14 Douglas-fir (*Pseudotsuga menziesii*) saplings at 10 dates between May and August, from the beginning of the growing season until after height growth had ceased. The cambium was also pinned six times between June and July, to induce xylem scarring at known dates. After height growth ceased, saplings were harvested and transverse sections of the wood were made at the pin insertion points. The date at which 95% of the height growth had occurred and the date at which latewood formation had begun were estimated. Analysis showed no correlation of these data, suggesting that the two phenomena may occur around the same time, but that one is not causal of the other.

Renninger, H.J., Gartner, B.L., and Meinzer, F.C. 2006b. Effects of release from suppression on wood functional characteristics in young Douglas-fir and western hemlock. *Canadian Journal of Forest Research* **36**(8): 2038–2046.

Little is known of wood properties in trees that were initially suppressed and subsequently released from suppression. The purpose of this study was to assess differences in growth ring width, specific conductivity (K_s), tracheid dimensions, moisture content, and wood density in suppressed Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) and western hemlock (*Tsuga heterophylla* (Raf.) Sarg.) trees and trees released from suppression averaging 12–18 years of age. Growth ring width was 370% higher for Douglas-fir and 300% higher for western hemlock trees released from suppression, and K_s was 182% higher for Douglas-fir and 42% higher for western hemlock trees released from suppression. Earlywood width was approximately four times greater after release in both species, whereas the relative increase in latewood width was much greater in Douglas-fir. Tracheids were 25% wider and 11% longer in released Douglas-fir trees. In western hemlock, released trees had 19% wider tracheids that were approximately the same length as those in suppressed trees. Moisture content was 66% greater in released Douglas-fir and 41% greater in released western hemlock. Wood density decreased by 21% in Douglas-fir trees and by 11% in western hemlock trees released from suppression. However, wood density of released trees did not differ from average reported values, implying that wood from released trees may be suitable for many of its traditional applications.

On connaît peu de choses des propriétés du bois dans les arbres initialement supprimés et dégagés par la suite. Le but de cette étude consistait à évaluer les différences dans la largeur des cernes annuels, la conductivité spécifique (K_s), la dimension des trachéides, le contenu en eau et la densité du bois entre des tiges supprimées et des tiges dégagées de douglas de Menzies (*Pseudotsuga menziesii* (Mirb.) Franco) ainsi que de pruche occidentale (*Tsuga heterophylla* (Raf.) Sarg.) ayant en moyenne 12–18 ans. La largeur des cernes annuels était 370 % plus grande chez les tiges de douglas de Menzies et 300 % plus grand chez les tiges de pruche occidentale dégagées et K_s était 182 % plus élevée chez les tiges de douglas de Menzies et 42 % plus élevée chez les tiges de pruche occidentale qui avaient été dégagées. La largeur du bois initial était approximativement quatre fois plus grande après le dégagement chez les deux espèces tandis que l'augmentation relative de la largeur du bois final était beaucoup plus forte chez le douglas de Menzies. Les trachéides étaient 25 % plus larges et 11 % plus longues chez les tiges dégagées de douglas de Menzies. Chez la pruche occidentale, les trachéides des tiges dégagées étaient 19 % plus larges et avaient approximativement la même longueur que chez les tiges supprimées. Le contenu en eau des tiges dégagées était 66 % plus élevé chez le douglas de Menzies et 41 % plus élevé chez la pruche occidentale. La densité du bois des tiges dégagées a diminué de 21 % chez le douglas de Menzies et de 11 % chez la pruche occidentale. Cependant, la densité du bois des tiges dégagées ne différait pas des valeurs moyennes déjà rapportées, ce qui implique que le bois des tiges dégagées peut convenir à plusieurs des usages traditionnels.

Rippy, R.C., Wagner, F.G.,Gorman, T.M., Layton, H.D., and Bodenheimer, T. 2000. Stress-wave analysis of Douglas-fir logs for veneer properties. *Forest Products Journal* **50**(4): 49–52.

Visual characteristics of logs have not been good predictors of the strength and stiffness (modulus of elasticity (MOE)) of lumber and veneer products. However, several studies have shown that stress-wave analysis of logs has successfully predicted the MOE of structural lumber and veneer. The purpose of this study was to determine whether stress-wave analysis of Douglas-fir (*Pseudotsuga menziesii* [Mirb.] (Franco)) logs could also predict the MOE of veneer. Longitudinal stress-wave speed was measured in 25 35-foot (10.7-m) Douglas-fir butt logs. The logs were then cut into 8-foot (2.4-m) bolts plus trim and peeled into veneer. The veneer was dried and scanned using a commercial stress-wave analyzer, and the inverses of log and veneer stress-wave speeds were compared. The inverses of log stress-wave speeds averaged 82.6 µsec./ft. (271.0 µsec./m) and ranged from 71 to 91 µsec./ft. (233.0–298.6 µsec./m). The inverses of veneer stress-wave speeds averaged 63.2 µsec./ft. (207.4 µsec./m) and ranged from 51.6 to 128.9 µsec./ft. (169.3–422.9 µsec./m). Lower inverse stress-wave speeds for veneer indicate higher MOE. One-third of all veneer and inverse speeds lower than 58.3 µsec./ft. (191.3 µsec./m) (high-MOE suitable for laminated-veneer lumber (LVL)). Of this high-MOE veneer, 83 percent came from the bottom two bolts of all logs, indicating that the high-MOE veneer was often located near the base of the study trees. In addition, 43 percent of the veneer produced from logs with the lowest inverse speeds (≤82 µsec./ft. (≤269.0 µsec./m)) had high MOE, and only 20 percent of the veneer produced from logs with the highest inverse speeds had high MOE. These findings indicate that stress-wave analysis could be used to sort Douglas-fir togs for the production of high-MOE veneer.

Risi, J., and Zeller, E. 1960. *Specific Gravity of the Wood of Black Spruce (*Picea mariana *Mill. B.S.P.) Grown on a* Hylocomium–Cornus *Site Type*. Contribution No. 6. University of Laval, Fonds de recherche forestière, Sainte-Foy, Quebec, Canada.

As specific gravity is a good indication of wood quality, a study was done on a stand of black spruce grown on a *Hylocomium–Cornus* site type. The three major influences on specific gravity are chemical composition of the wood, size of the tracheids, and the thickness of the cell wall, but there are many indirect factors that also affect specific gravity. This study focused on the frequency distribution of specific gravity, the percentage of summerwood, and the width of the rings. The differences in specific gravity between trees and within trees were also identified and analyzed. It is also suggested that hereditary factors may influence specific gravity. *(Abstract prepared by compilers.)*

Roberge, M.R. 1975. Effect of thinning on the production of high-quality wood in a Quebec northern hardwood stand. *Canadian Journal of Forest Research* **5**(1): 139–145.

In 1963, two intensities of thinning were carried out in a 60-year-old northern hardwood stand of fire origin. Yellow birch (*Betula alleghaniensis* Britt.) made up as much as 40% of the total number of trees 9 cm dbh and up. By 1973, both sugar maple (*Acer saccharum* Marsh.) and yellow birch had responded to thinning, the former more than the latter. The percentages of yellow birch trees had not changed regardless of treatment. There were between 120 and 129 trees/ha of the 25–39 cm diameter class in the unthinned as well as in the thinned areas. Basal areas of the trees 9 cm dbh and up had increased by 5.4, 7.6, and 8.1 m^2/ha in the unthinned, 20% thinned, and 40% thinned area, respectively. A decrease in stem quality was not observed, even at the 40% thinning intensity. Both thinning intensities were thus successful except that they somewhat favored sugar maple at the expense of the yellow birch.

En 1963, deux intensités d'éclaircie furent conduites dans un peuplement feuillu septentrional de 60 ans venu après feu. Le bouleau jaune (*Betula alleghaniensis* Britt.) comportait autant que 40% du nombre total d'arbres de dhp de 9 cm et plus. En 1973, et l'érable à sucre (*Acer saccharum* Marsh.) et le bouleau jaune avaient répondu à l'éclaircie, le premier plus que le second. Les pourcentages d'arbres de bouleau jaune n'avaient pas changé quel que fut le traitement. Il y avait entre 120 et 129 arbres/ha de la classe de diamètre de 25–39 cm dans l'aire non éclaircie aussi bien que dans les aires éclaircies. La surface terrière des arbres de dhp de 9 cm et plus avait augmenté de 5.4, 7.6 et 8.1 m^2/ha dans l'aire non éclaircie, éclaircie à 20% et à 40%, respectivement. Aucune diminution ne fut observée dans la qualité des tiges, même à l'intensité de 40%. Les deux intensités d'éclaircie furent donc réussies excepté qu'elles favorisèrent quelque peu l'érable à sucre aux dépens du bouleau jaune.

Robertson, A. 1990. Directionality of compression wood in balsam fir wave forest trees. *Canadian Journal of Forest Research* **20**(8): 1143–1148.

Wind is often cited as one of the main causes of compression wood formation. While many papers have alluded to direction of compression wood, this paper provides a detailed circular statistical analysis of the angular distribution of compression-wood zones in balsam fir trees. Discs were sampled from trees in a balsam fir (*Abies balsamea* (L.) Mill.) wave forest in northwestern Newfoundland, from sapling to mature stages. The directionality, with respect to compass bearing of compression-wood zones in basal discs was found to be initially randomly distributed around the pith, becoming unidirectional towards the northeast at about 10 mm from the pith. Random circular distribution of compression-wood zones mostly within 10 mm of the pith is interpreted as resulting from a combination of environmental perturbations, such as glaze and rain loading, and asymmetric crown growth due to competition. Because of the very high density of immature stands, wind turbulence is not expected to be a major factor stimulating compression wood in saplings. The role of snow loading, which causes bending of stems for long periods during the winter (dormant season), is uncertain. In older trees, i.e., beyond approximately 10 mm from the pith, compression wood gradually becomes directional towards the northeast, indicating that prevailing southwesterly winds are mainly responsible for compression-wood formation.

Le vent est souvent cité comme l'un des principaux agents de la formation de bois de compression. Alors que plusieurs articles ont déjà fait allusion à l'orientation de ce bois de compression, le présent article entend donner une analyse statistique circulaire détaillée de la répartition angulaire des zones de bois de compression dans les sapin baumiers (*Abies balsamea* (L.) Mill.). Dans une forêt onduleuse du nord-ouest de Terre-Neuve, on a prélevé des disques sur des sapins baumiers à divers stades de leur croissance (des gaules aux adultes). Dans les disques de base, selon les relèvements de la boussole, on a observé que le bois compressé était d'abord réparti au hasard tout autour de la moelle, avant de devenir unidirectionnel (vers le nord-est) au-delà d'environ 10 mm de la moelle. La répartition aléatoire des zones de compression en deçà de 10 mm de la moelle résulterait ici d'un ensemble de perturbations environnementales comme l'accumulation de verglas et de pluie, associées à une croissance asymétrique des couronnes due à la compétition au sein du peuplement. À cause de la très forte densité des peuplements immatures, il est normal que le vent ne joue pas un rôle majeur dans l'apparition du bois de compression dans les gaulis. L'action de l'accumulation de neige, qui cause un fléchissement prononcé des branches durant de longues périodes en hiver (saison de dormance), reste à déterminer. Dans les arbres plus âgés (autrement dit, au-delà d'environ 10 mm de la moelle), le bois de compression prend graduellement une orientation nord-est, ce qui indique que les vents dominants du sud-ouest sont principalement responsables de la formation du bois de compression.

Robinson, A.R., Ukrainetz, N.K., Kang, K.Y., and Mansfield, S.D. 2007. Metabolite profiling of Douglas-fir (*Pseudotsuga menziesii*) field trials reveals strong environmental and weak genetic variation. *The New Phytologist* **174**(4): 762–773.

Metabolomics is a recent branch of functional genomics. It is used to identify and quantify low molecular weight metabolites in active tissues. Practical difficulties have restricted potential use. The technique was used and evaluated in an investigation of the influence of family and environment on wood formation and tree growth in Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco).

Ten trees from each of ten families were sampled. Xylem was exposed and then scraped into a vial that was immediately frozen in liquid nitrogen. An increment core was taken at breast height, and tree height was measured. Xylem samples were ground, and metabolites were extracted and submitted for gas chromatography/mass spectrometry with a two-phase methanol/chloroform method. Increment cores were measured for microfibril angle, earlywood density, latewood proportion, latewood density, fiber coarseness, and fiber length. Data were subjected to multivariate statistical analysis, including multivariate discriminant analysis, factor analysis, canonical correlation analysis, and canonical discriminant analysis. Heritabilities were calculated. Heritabilities indicated that, although some genetic control was indicated, variability was also controlled by site, and site by genetics interaction. The metabolomics technique was found to be useful for this study. *(Abstract prepared by compilers.)*

Roblot, G., Coudegnat, D., Bleron, L., and Collet, R. 2008. Evaluation of the visual stress grading standard on French spruce (*Picea excelsa*) and Douglas-fir (*Pseudotsuga menziesii*) sawn timber. *Annals of Forest Science* **65**(8 Article 812): 1–4.

In this paper an evaluation of the visual grading standard for softwood sawn timber was made. In order to do so, visual grading according to EN 518 and theoretical grading according to EN 338 and EN 384 (measurements of MOE, MOR and density) were applied to lumber. Two batches of 111 and 102 French boards were graded, respectively, of spruce (*Picea excelsa*) and Douglas-fir (*Pseudotsuga menziesii*). For the visual grading the most discriminant criterion was noted: knots, cracks, wane, etc. Finally, the results of the two grading methods were compared, and it was shown that the visual stress grading gave quite low results for our two French species.

Évaluation de la norme de classement mécanique visuel sur des sciages français d'épicéa (*Picea excelsa*) et de Douglas (*Pseudotsuga menziesii*). Cette étude a pour objectif d'évaluer la pertinence des résultats du classement visuel de la norme EN 518 sur des sciages de bois français. Pour cela 111 pièces d'épicéa (*Picea excelsa*) et 102 pièces de Douglas (*Pseudotsuga menziesii*) ont été classées en suivant d'une part le classement visuel de la norme EN 518 et en réalisant d'autre part un classement dit théorique suivant les normes EN 338 et EN 384 (mesure du Module de Young (MOE), contrainte de rupture (MOR) et masse volumique). Pour le classement visuel, le critère le plus discriminant a été relevé pour chaque planche : nœuds, fentes, flaches. Finalement une comparaison entre les résultats des deux techniques de classement a été réalisée, et le faible rendement du classement visuel sur nos deux essences a été montré.

Roddy, D.M. 1983. Jack pine and white spruce tree improvement: Prince Albert Pulpwood. Pages 154–157 *in* C.W. Yeatman. *Proceedings of the Nineteenth Meeting of the Canadian Tree Improvement Association.* 22–26 August 1983, Toronto, Ontario, Canada. Canadian Tree Improvement Association, Toronto, Ontario, Canada.

This paper provides a summary of the tree improvement program at Prince Albert Pulpwood. It details the successes of the seed orchard and describes the selection and progeny testing sites. A wood specific gravity study was done in order to assess each selected tree in the program because an increase in wood density yields better fiber quality and quantity. *(Abstract prepared by compilers.)*

Roe, E.I., and Stoeckeler, J.H. 1950. Thinning over-dense jack pine seedling stands in the Lake States. *Journal of Forestry* **48**(12): 861–865.

Jack pine (*Pinus banksiana* Lamb.) typically reproduces prodigiously after fires, resulting in very dense stands. The utility and timing of thinning were investigated in a stand regenerated by direct seeding after a burn. At 5 years after regeneration, the stand was found to have an average of 13 000 stems per hectare. The stand was thinned to plots of 4 x 4, 6 x 6, and 8 x 8 ft spacing. The stands were measured and rethinned at age 10, but the 8 x 8 foot spacing was replaced by cutting all trees within a 3-ft radius of crop trees. Mortality was found to be caused by snowshoe hare girdling. Basal area was greatest in unthinned plots, but concentrated in larger diameter stems in thinned plots. Thinning at or before 5 years of age is recommended. Mechanical thinning is not recommended as it damages remaining stems. *(Abstract prepared by compilers.)*

Roeh, R.L., and Maguire, D.A. 1997. Crown profile models based on branch attributes in coastal Douglas-fir. *Forest Ecology and Management* **96**(1–2): 77–100.

Crown size and crown dimensions are important variables for imparting biological realism to individual-tree growth models. Models for estimating crown profile in Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) were developed from attributes of individual whorl branches, including basal diameter, total length, angle of origin, and height from ground. The prediction system consisted of four equations to predict whorl branch basal diameter, branch length, branch angle of origin, and corresponding radius. The system is entered with three standard individual tree measurements: diameter at breast height (DBH), total height, and height to crown base. Four approaches were developed for modeling crown profile with this system of equations, distinguished by parameter estimation method, modeling data subset, and the specific form by which whorl branch diameter was represented (mean vs. maximum diameter). A system-of-equations parameter-estimation technique (modified three-stage least squares) was applied to account for the correlation of error terms across the equations, and this procedure was compared with ordinary and nonlinear least squares methods. The resulting crown profile prediction systems were evaluated under both theoretical and empirical criteria. The recommended system appears to perform well against validation data on both an equation (branch) level and system (crown profile) level.

Rozenberg, P., Franc, A., Mamdy, C., Launay, J., Schermann, N., and Bastien, J.C. 1999. Genetic control of stiffness of standing Douglas fir: from the standing stem to the standardised wood sample, relationships between modulus of elasticity and wood density parameters. Part II. *Annals of Forest Science* **56**(2): 145–154.

Fairly strong positive relationships between stiffness and density have often been reported. No stronger relationships have been found when using parameters of density profiles based on an earlywood–latewood boundary. In this study, we attempt to model the relationships among the stiffness of different samples and simple parameters derived from microdensity profiles; not established according to an earlywood–latewood boundary. Furthermore, we try to determine if there is a genetic variation for the relationship between stiffness and density. From the results, we find that the strongest relationship between a single density parameter and stiffness is $r^2 = 0.78$, whereas it is $r^2 = 0.37$ when involving a classical within-ring density parameter. At clone level, r^2 ranges from 0.88 to 0.95, while it is 0.51 for the bulked samples. The mathematical form of the models differ from one clone to another: there is a genetic effect on the models. This could mean that different clones different build their stiffness in different ways.

Modélisation du module d'élasticité à l'aide de données microdensitométriques : méthodes et effets génétiques. 2e partie. On a souvent mis en évidence d'assez fortes relations entre la rigidité et la densité du bois. Ces relations n'étaient pas plus fortes quand on a essayé d'expliquer la rigidité à l'aide de paramètres microdensitométriques intracerne basés sur une limite bois initial–bois final. Dans cette étude, nous tentons de modéliser la rigidité d'un échantillon de bois à l'aide de paramètres simples calculés à partir de profils microdensitométriques, mais non basés sur la limite classique bois initial–bois final. De plus, nous cherchons si les modèles décrivant cette relation sont différents d'une unité génétique à l'autre. Les résultats montrent que les modèles bâtis à l'aide de nos nouveaux paramètres sont plus précis que ceux construits à l'aide des paramètres intracernes classiques (par exemple, pour les mêmes échantillons, r^2 passe de 0,37 à 0,078 quand la rigidité est expliquée à l'aide d'un de ces nouveaux paramètres, plutôt qu'à l'aide de la densité du bois final). Au niveau clonal, le r^2 varie de 0,88 à 0,94, alors que tous échantillons confondus, il est seulement de 0,51. De plus, la forme mathématique des modèles est différente d'un clone à l'autre. Donc il existe un effet génétique sur la relation rigidité-densité. Si ces résultats sont confirmés, cela signifie que différents clones ont différentes manières de construire leur rigidité.

Rudnicki, M., Silins, U., and Lieffers, V.J. 2004. Crown cover is correlated with relative density, tree slenderness, and tree height in lodgepole pine. *Forest Science* **50**(3): 356–363.

Even-aged lodgepole pines were examined to determine if there was a relationship among tree height, relative density, and bole slenderness with respect to crown shyness. In stands less than 12 m in height, the crown closure was found to relate to relative density. In stands greater than 15 m in height, the crown closure was negatively related to the slenderness coefficient (tree diameter/height). Crown closure declined as stand height increased. *(Abstract prepared by compilers.)*

Rytter, L., and Stener, L.G. 2005. Productivity and thinning effects in hybrid aspen (*Populus tremula* L. x *P. tremuloides* Michx.) stands in southern Sweden. *Forestry* **78**(3): 285–295.

Growth and yield of aspen (*Populus tremula* L. X *P. tremuloides* Michx.) hybrid clones were evaluated and compared with suckers. Ten sites across Sweden were included in the study. Sites were subjected to no thinning, medium thinning, and heavy thinning. Diameter of stems and heights of some trees were measured. Measurements were used to calculate volume. By age 12, the root sucker stands were taller than the planted clone stands. Diameter growth was similar between root sucker and the best clone stands. Current annual increment was initially higher in root sucker stands. No significant differences were found in stands before thinning treatments. Current annual increment was higher in unthinned stands, but no significant differences were found in mean annual increment across treatments. It was estimated that productivity in terms of mean annual increment will meet growth targets, indicating that short-rotation forestry is competitive for Sweden. *(Abstract prepared by compilers.)*

Samson, M. 1993. Modelling of knots in logs. *Wood Science and Technology* **27**(6): 429–437.

A geometrical model was derived to describe knots in logs and on the surface of lumber beams sawn from those logs. Each knot is defined by 7 parameters related to the shape and position in the stem. A computer simulation program was written to study knot shapes on a variety of observation planes. An initial investigation on the shape of knots in Scots pine logs and lumber beams suggests that the model is sufficiently accurate to describe knottiness in this species. Potential applications of this model include automated lumber grading, computerized log reconstitution and yield optimization studies.

Savva, Y., Bergeron, Y., Denneler, B., Koubaa, A., and Tremblay, F. 2008. Effect of interannual climate variations on radial growth of jack pine provenances in Petawawa, Ontario. *Canadian Journal of Forest Research* **38**(3): 619–630.

Effect of interannual climate variations on radial growth was compared among jack pine (*Pinus banksiana* Lamb.) of diverse geographical origins in a 41-year-old common garden experiment in Petawawa, Ontario. Provenance experiments established from seeds transferred from different parts of a species range (from the northern United States to northern Canada) to the same environment might be considered as a simulation model of climate change and a shift of climate zones. The following questions are addressed: Did the response of growth to interannual climate variations differ among the provenances transferred within the experimental site? What climatic factors affect interannual growth variations of jack pine provenances? Tree-ring chronologies for 16 populations were developed for the period 1970–2004. The best climate predictors of radial growth were precipitation of June and March of the current year and precipitation of December of the previous year. Although climatic factors affecting growth were similar between the provenances, absolute radial growth was proportional to the growth potential of the provenances. We conclude that variability due to seed origins is not a significant source of variation for dendroclimatic studies of jack pine. Increased frequency of summer droughts might result in a growth decrease in jack pine.

Nous avons étudié les relations entre le climat et la croissance radiale annuelle de provenance de pin gris (*Pinus banksiana* Lamb.) établis depuis 41 ans dans un jardin commun à Petawawa en Ontario. Des tests de descendance établis dans des conditions similaires à partir de graines provenant de différentes parties de l'aire de distribution de l'espèce (depuis le Nord des États-Unis jusqu'au nord du Canada) simulent des changements climatiques et des transitions entre différentes zones bioclimatiques. Nous avons tenté de répondre aux questions suivantes : Est-ce que la relation entre la croissance radiale interannuelle et le climat varie en fonction des provenances? Quels sont les facteurs climatiques qui contrôlent la croissance radiale des différentes provenances? Des chronologies de la croissance radiale couvrant la période 1970–2004 ont été développées pour 16 provenances. Les facteurs climatiques les plus corrélés avec la croissance radiale sont les précipitations pour juin et mars de l'année en cours et les précipitations de décembre pour l'année précédente. Bien que les facteurs climatiques contrôlant la croissance sont les mêmes pour toutes les provenances, la croissance absolue variait en fonction du potentiel de croissance de chaque provenance. Nous concluons que la variabilité due à la provenance des graines ne constitue pas une source importante de variation dans la réponse dendroclimatique chez le pin gris. Une augmentation de la fréquence des sécheresses durant la période estivale pourrait entraîner une diminution de la croissance du pin gris.

Schneider, M.H., and Zhou, L. 1989. Characterization of wetwood from four balsam fir trees. *Wood and Fiber Science* **21**(1): 1–16.

Balsam fir wetwood has lower longitudinal permeability to both water and air than sapwood, but higher than heartwood. Based upon the average initial flow of water in sapwood, wetwood, and heartwood, a ratio of 45:6:2 was calculated. The ratio of average air permeability of sapwood to wetwood to heartwood was 50:9:1 calculated at an average mean pressure of 0.5 atmosphere (38 cm Hg). The low permeability of wetwood and heartwood results from pit aspiration and incrustation of bordered pit membranes. Scanning electron microscopy suggested that deposits on wetwood-bordered pit membranes facilitated greater flow through wetwood than heartwood. Sapwood and wetwood moisture contents were comparable, and were higher than heartwood. Extractive content values of green wetwood were between those for sapwood and heartwood.

Schneider, R. 2001. *Effet d'une éclaircie précommerciale 28 ans après traitement sur la productivité d'une sapinière en Gaspésie*. Thesis, Université Laval, Quebec, Canada.

A precommercial thinning was done in 1969 and 1970 in a balsam fir stand that regenerated from a 1955 clearcut in the Gaspésie area. The effects on the evolution of the stand and the released stems to three thinning intensities were studied. At the stand level, merchantable volume yields vary according to initial density classes and also according to thinning intensity. The opposite was observed for the individual stems, where intensity played a greater role than initial density. *(Abstract prepared by compilers.)*

Une éclaircie précommerciale a été effectuée en 1969 et 1970 dans un peuplement de sapin baumier régénéré naturellement suite à une coupe à blanc en 1955 dans la région de Gaspésie. L'impact sur l'évolution du peuplement et sur les tiges dégagées suite à trois intensités d'éclaircie a été étudié. Au niveau du peuplement, le rendement en volume marchand varie en fonction de la classe de densité du peuplement initial et aussi en fonction de l'intensité de l'éclaircie. L'opposé a été observé pour les tiges individuelles où l'intensité de l'éclaircie joue un rôle plus important que la densité initiale. *(Résumé fourni par les compilateurs.)*

Schneider, R. 2006. *Effet de l'éclaircie commerciale sur la croissance et la qualité du bois du pin gris.* Dissertation, Université Laval, Quebec, Canada.

This thesis covers the impact of commercial thinning on tree growth and wood quality with economic considerations. Five jack pine stands were studied in eastern Canada. Ring density, earlywood and latewood density, and wood-bending properties were measured to assess wood quality. Financial value of the residual stand was calculated using the models. *(Abstract prepared by compilers.)*

Cette dissertation porte sur l'effet de l'éclaircie commerciale sur la croissance et la qualité du bois avec des considérations économiques. Cinq peuplements de pin gris furent étudiés dans l'Est du Canada. La qualité du bois fut mesurée à partir de la densité des cernes, du bois initial et final ainsi que les propriétés de flexion du bois. La valeur financière des peuplements résiduels fut obtenue à l'aide de modèles. *(Résumé fourni par les compilateurs.)*

Schneider, R., Berninger, F., Ung, C.H., Bernier, P.Y., Swift, D.E., and Zhang, S.Y. 2008a. Calibrating jack pine allometric relationships with simultaneous regression. *Canadian Journal of Forest Research* **38**(10): 2566–2578.

Allometric equations for estimating foliage biomass, sapwood area, and branch basal area from tree diameters and crown lengths for jack pine (*Pinus banksiana* Lamb.) in eastern Canada were calibrated using mixed models. A first model is presented that relates branch foliage biomass to branch diameter and relative position within the crown. These results show that a branch's foliage biomass is inversely proportional to its depth within the crown. At the tree level, foliage biomass was found to be proportional to crown length and to vary with stem age and slenderness. Pipe model parameters (sapwood area and branch basal area to foliage biomass) were also calculated. The sapwood area to foliage biomass parameter is proportional to stand density, whereas branch basal area to foliage biomass is constant. The tree-level allometeric models were calibrated using a mixed-effects seemingly unrelated regression to account for between-model correlations.

Des équations allométriques visant à estimer la biomasse foliaire, la superficie d'aubier et la surface terrière des branches à partir du diamètre des arbres et de la longueur de la cime de pins gris (*Pinus banksiana* Lamb.) de l'est du Canada ont été étalonnées à l'aide de modèles mixtes. Le premier modèle qui est présenté relie la biomasse foliaire des branches au diamètre des branches et à leur position relative dans la cime. Ces résultats indiquent que la biomasse foliaire des branches est inversement proportionnelle à sa profondeur dans la cime. À l'échelle de l'arbre, nous avons observé que la biomasse foliaire était proportionnelle à la longueur de la cime et qu'elle variait aussi en fonction de l'âge de l'arbre et de son élancement. Les paramètres du modèle tubulaire (superficie d'aubier et surface terrière des branches en fonction de la biomasse foliaire) ont aussi été calculés. Le paramètre associé à la superficie d'aubier en fonction de la biomasse foliaire est proportionnel à la densité du peuplement alors que celui de la surface terrière des branches en fonction de la biomasse foliaire est constant. Les modèles allométriques à l'échelle de l'arbre ont été étalonnés en utilisant la technique de régression sans corrélation apparente à effets mixtes pour tenir compte des corrélations entre les modèles.

Schneider, R., Zhang, S.Y., Swift, D.E., Begin, J., and Lussier, J.M. 2008b. Predicting selected wood properties of jack pine following commercial thinning. *Canadian Journal of Forest Research* **38**(7): 2030–2043.

This paper examined the impact of commercial thinning on selected wood properties of jack pine (*Pinus banksiana* Lamb.). Wood properties evaluated include wood density (ring density, earlywood ring density, and latewood ring density), percentage of latewood in the ring, and wood bending properties. Nonlinear, mixed-effect models have been developed using data from three commercially thinned sites in eastern Canada. Ring density followed the same pattern as percentage of latewood, in which cambial age, relative height, and ring width were found to have important effects. Earlywood and latewood ring densities changed within the juvenile wood zone until a plateau was reached. Ring width affected earlywood and latewood ring densities mainly in narrow rings. Wood bending stiffness (measured by modulus of elasticity) and strength (measured by modulus of rupture) increased with cambial age and wood density; whereas, wood strength was also affected by ring width. Commercial thinning did not influence the developed models, but it had an indirect effect through increased ring width.

Cette étude a examiné l'impact de l'éclaircie commerciale sur certaines propriétés du bois de pin gris (*Pinus banksiana* Lamb.). Ces propriétés incluaient la densité du bois (densité des cernes, densité du bois initial et densité du bois final), la proportion de bois final dans chaque cerne et les propriétés mécaniques en flexion. Des modèles non linéaires mixtes ont été développés à partir de données provenant de trois stations qui avaient subi une éclaircie commerciale dans l'est du Canada. La densité des cernes s'est révélé être fortement influencée par l'âge cambial, la hauteur relative et la largeur des cernes, suivant ainsi un patron de variation similaire à celui de la proportion de bois final. La densité du bois initial et celle du bois final ont changé à l'intérieur de la zone de bois juvénile pour atteindre un plateau par la suite. La largeur des cernes a aussi affecté ces densités, en particulier dans le cas des cernes étroits. Les modules d'élasticité (MOE) et de rupture (MOR) en flexion ont augmenté avec l'âge cambial et la densité du bois. De plus, le module de rupture a été affecté par la largeur des cernes. L'éclaircie commerciale n'a pas changé les paramètres des modèles, mais elle a eu une influence indirecte à cause de son effet sur la largeur des cernes.

Schuler, T.M. 2004. Fifty years of partial harvesting in a mixed mesophytic forest: composition and productivity. *Canadian Journal of Forest Research* **34**(5): 985–997.

Long-term silvicultural trials contribute to sustainable forest management by providing a better scientific understanding of how forest ecosystems respond to periodic timber harvesting. In this study, species composition, diversity, and net periodic growth of tree species in a mixed mesophytic forest in the central Appalachians were evaluated after about a half century of management. Three partial cutting practices on 18 research compartments and on 3 unmanaged reference compartments were evaluated (1951–2001) on 280 ha. Single-tree selection, diameter-limit harvesting, and timber harvesting in 0.162-ha patches were assessed on three northern red oak site index$_{50}$ (SI) classes: 24, 21, and 18. Shannon-Weiner's diversity index (H') declined from the first (1951–1959) to last (1987–2001) measurements and was related to both SI (P = 0.004) and treatment (P = 0.009). Sugar maple (*Acer saccharum* Marsh.) and red maple (*Acer rubrum* L.) were the two most abundant species in recent years (1987–2001); in contrast, in initial inventories (1951–1959), northern red oak (*Quercus rubra* L.) and chestnut oak (*Quercus prinus* L.) were most abundant. Net periodic annual increment (PAI) of merchantable trees (DBH ≥ 12.7 cm) was related to both SI (P = 0.004) and treatment (P = 0.003). Mean PAI ranged from 4.6 $m^3 \cdot ha^{-1} \cdot year^{-1}$ for single-tree selection to 2.5 $m^3 \cdot ha^{-1} \cdot year^{-1}$ for unmanaged reference areas across all SI classes. The decline of oak species suggests that only intensive and specific forest management focused on maintaining oak species can obtain historical levels of diversity.

Les expériences sylvicoles à long terme contribuent à l'aménagement forestier durable en procurant une meilleure compréhension scientifique de la façon dont les écosystèmes forestiers réagissent à une récolte périodique de matière ligneuse. Dans cet article, la composition en espèces, la diversité et la croissance périodique nette des espèces arborescentes dans une forêt mésique mixte de la zone centrale des Appalaches ont été évaluées après un demi-siècle d'aménagement. Trois méthodes de coupe partielle dans 18 compartiments expérimentaux et trois compartiments témoins non aménagés ont été évaluées (1951–2001) sur une superficie de 280 ha. La coupe de jardinage par pied d'arbre, la coupe à diamètre limite et la coupe par trouées de 0,162 ha ont été évaluées pour trois classes d'indice$_{50}$ de station du chêne rouge : 24, 21 et 18. L'indice de diversité de Shannon–Weiner (H') a diminué du premier (1951–1959) au dernier (1987–2001) inventaire et était relié à la fois à l'indice de station (P = 0,004) et au traitement (P = 0,009). L'érable à sucre (*Acer saccharum* Marsh.) et l'érable rouge (*Acer rubrum* L.) étaient les deux espèces les plus abondantes au cours des dernières années (1987–2001), alors que le chêne rouge (*Quercus rubra* L.) et le chêne châtaignier (*Quercus prinus* L.) étaient les espèces les plus abondantes lors des premiers inventaires (1951–1959). L'accroissement périodique net des tiges marchandes (dhp ≥ 12,7 cm) était relié à la fois à l'indice de station (P = 0,004) et au traitement (P = 0,003). L'accroissement périodique moyen pour l'ensemble des catégories d'indice de station variait de 4,6 $m^3 \cdot ha^{-1} \cdot an^{-1}$ dans le cas du jardinage par pied d'arbre à 2,5 $m^3 \cdot ha^{-1} \cdot an^{-1}$ dans les compartiments témoins non aménagés. La disparition des espèces de chênes montre que seul un aménagement forestier intensif et spécifique qui met l'accent sur le maintien des espèces de chênes peut atteindre des niveaux historiques de diversité.

Scott, S.L., Barker, J.E., Morrison, I.K., and Foster, N.W. 1982. Basic density of jack pine wood influenced by fertilization and thinning. *The Forestry Chronicle* **58**(1): 44–46.

Basic wood density was measured at eight bole positions within and below the green crown in a jack pine (*Pinus banksiana* Lamb.) fertilization and thinning trial near Chapleau, Ontario. Analysis showed a 6% reduction of average density in wood laid down during the first 5 years following treatment. A significant height × fertilizer interaction was noted during the same period indicating that bole density gradients specific to fertilized trees should be used to calculate biomass gains from fertilization if substantial underestimates of response are to be avoided. The portion of the bole where the wood changed most rapidly from low density, juvenile-type to higher density mature-type wood appeared to be just beneath the base of the green crown.

La densité du bois a été mesurée à huit endroits du tronc, à l'intérieur et sous la cime du pin gris (*Pinus banksiana* Lamb.) soumis à des essais de fertilisation et d'éclaircie près de Chapleau en Ontario. L'analyse montre une réduction de 6% de la densité moyenne dans le bois produit durant les cinq années postérieures au traitement. Une interaction significative, hauteur–fertilisant, a été notée durant la même période, indiquant que les gradients de densités du tronc, spécifiques aux arbres fertilisés, pourraient servir dans les calculs de gains de biomasse dus à la fertilisation, si des sous-estimations substantielles de réponse sont à éviter. La portion du tronc, où le bois montre le changement le plus rapide en terme de densité, passant d'une faible densité, typique au bois juvénile à une densité supérieure, typique au bois adulte, se situe juste à la base de la cime vivante.

Semple, K.E., Vaillant, M.H., Kang, K.Y., Oh, S.W., Smith, G.D., and Mansfield, S.D. 2007. Evaluating the suitability of hybrid poplar clones for the manufacture of oriented strand boards. *Holzforschung* **61**(4): 430–438.

Clonal trees from five different plantation-grown, industrially relevant hybrid poplar genotypes of the same age, grown on a common site in British Columbia, Canada, were tested for their performance in strand production and properties of oriented strand board (OSB). The results were compared against a benchmark mill-run OSB furnish derived from native aspen (*Populus tremuloides*). Variation in solid wood density among the hybrid poplar clones was shown to influence the compaction ratio and densification of the OSB, which in turn led to variation in board strength properties. After accounting for specimen density using co-variate statistical models, it was apparent that there were significant effects of genotype on bonding strength and thickness swell. Lower density wood from the fastest growing *P. deltoides* x *P. trichocarpa* (DTAC 7) clone resulted in better mat compaction and higher bond strength, whereas higher density wood from a *P. trichocarpa* x *P. deltoides* (TD 50-184) clone resulted in lower compaction and bonding strength. Flexural strength (rupture and elastic moduli) and nail pull through were not as significantly affected by either board density or genotype when adjusted for density. The study clearly demonstrates that fast grown, large diameter wood of lower initial wood density from hybrid poplar is highly suited for OSB production.

Senft, J. F., Bendtsen, B.A., and Galligan, W.L. 1985. Weak wood: fast-grown trees make problem lumber. *Journal of Forestry* **83**(8): 477–484.

The "rising truss" problem has been growing in recent years and indicates a potentially growing problem in timber production. This situation, in which trusses bow, causing ceilings and walls to separate, may be traced to increasing juvenile wood content in lumber from plantations. Plantations were originally conceived to provide fiber supply for pulp and paper and are generally well suited to that purpose, however, plantation-grown timber is increasingly used in structural applications. Even when plantations produce timber with the same specific gravity, an indicator of strength, as natural stands, the proportion of juvenile wood is higher. Juvenile wood has very different properties than mature wood. The tracheid lengths are shorter, and shorter tracheids have lower tensile strength. Average specific gravity is usually lower. Microfibril angle is higher, leading to increases in shrinkage and warp and the "rising truss" problem. Plantation and mill managers must consider the origin of timber before it is sawn into lumber and consider that longer plantation rotations may be economically beneficial for lumber production. Alternatively, limitations on pith-associated wood may be necessary for use of plantation-grown timber in certain structural applications in order to prevent users of structural products from switching to alternative materials. *(Abstract prepared by compilers.)*

Seth, R.S. 1990. Fibre quality factors in papermaking: the importance of fibre length and strength. Pages 125–141 *in* Anonymous. *Material Research Society Symposium Proceedings*. Materials Research Society, Vancouver, British Columbia, Canada.

This study examined the effect of fiber length and fiber strength on handsheet properties. Shorter fibers reduce mechanical properties but have little influence on optical and structural properties. Reductions in fiber strength reduce sheet mechanical properties. *(Abstract prepared by compilers.)*

Seymour, R.S., Hannah, P.R., Grace, J.R., and Marquis, D.A. 1986. Silviculture: the next 30 years, the past 30 Years Part IV. *The Northeastern Journal of Forestry* **84**(7): 31–38.

In New England and the middle-Atlantic states, 66% of the land surface is forested. In the last 30 years, growing stock volumes have increased greatly as second-growth forests of oak, northern hardwoods, white pine, and spruce–fir matured at much the same time. Even-aged silviculture expanded as harvesting shifted from remnants of old-growth forests to second-growth stands. Successful regeneration increasingly resulted from variations of shelterwood cutting. As forests mature and old-field reversion ceases, the following developments are likely: ingrowth may decline abruptly, causing inventories to level off and eventually decline; silvicultural emphasis will shift from intermediate practices to regeneration; and greater use will be made of management that encompasses multiple usage of forest areas. *(Abstract prepared by compilers.)*

Sharma, M., and Zhang, S.Y. 2004a. Height–diameter models using stand characteristics for *Pinus banksiana* and *Picea mariana*. *Scandinavian Journal of Forest Research* **19**(5): 442–451.

Height–diameter relationships based on stand characteristics (stand density, basal area and site index) were investigated for jack pine and black spruce trees using the data from permanent growth study plots in northern Ontario, Canada. Approximately half of the data was used to estimate model parameters and the rest was used for model evaluation. Multiple Chapman-Richards growth functions with parameters expressed in terms of various stand characteristics were fitted to determine the best models for predicting height. Models providing the most accurate predictors of height included basal area, trees ha^{-1} and diameter at breast height. The inclusion of site index did not increase predictive accuracy.

Sharma, M., and Zhang, S.Y. 2004b. Variable-exponent taper equations for jack pine, black spruce, and balsam fir in eastern Canada. *Forest Ecology and Management* **198**(1–3): 39–53.

A variable-exponent taper equation was developed for jack pine (*Pinus banksiana* Lamb.), black spruce (*Picea mariana* (Mill.) B.S.P.) and balsam fir (*Abies balsamea* (L.) (Mill.)) trees grown in eastern Canada. The equation was derived from the dimensionally compatible taper equation. Stem analysis data from several of Forintek's research projects on these tree species grown across eastern Canada were used to fit the taper equation, and the equation was then evaluated with independent data collected by Forintek and other organizations in eastern Canada.

The taper equation presented in this paper was superior to the segmented polynomial, variable-exponent, and variable-form taper equations developed for different tree species in estimating diameters along the bole. Moreover, stand density or thinning effect on the taper of these tree species was examined, and the taper equation was modified in order to incorporate this effect.

Sharma, M., and Zhang, S.Y. 2007. Stand density management diagram for jack pine stands in eastern Canada. *Northern Journal of Applied Forestry* **24**(1): 22–29.

It has long been known that a relationship exists between tree growth and stand density. A stand density management diagram is a mathematical tool enabling foresters to maximize yield. In this study, a stand density management diagram was developed for jack pine (*Pinus banksiana* Lamb.) in Ontario and Quebec. Data collected by the respective provincial ministries from their permanent sample plot programs, 125 plots in Ontario and 232 in Quebec, were used to develop the models and resultant graphical relationships. The diagrams were evaluated using an independent data set. Using any two of mean total tree volume, quadratic mean diameter, trees per hectare, or average total height of dominant and codominant trees, the other parameters may be easily estimated from the diagram. The effect of stand interventions may easily be decided in the field without computer simulation. *(Abstract prepared by compilers.)*

Shatford, J.P.A., Bailey, J.D., and Tappeiner, J.C. 2009. Understory tree development with repeated stand density treatments in coastal Douglas-fir forests of Oregon. *Western Journal of Applied Forestry* **24**(1): 11–16.

Stand density management was evaluated for its ability to increase the growth rate of understorey regeneration in Douglas-fir stands. Different climatic sites were used. Thinning occurred in the early 1980s, and Douglas-fir and western hemlock established themselves in the understorey. In 1997, the stands were thinned a second time to release the understorey. Following this treatment, western hemlock grew rapidly and the response of Douglas-fir was only minimal. Heavy thinning or tighter control of western hemlock regeneration is required to increase Douglas-fir growth and vigor in the understorey. *(Abstract prepared by compilers.)*

Shepard, R.K. 1980. *Specific Gravity and Growth Rate of Row Thinned White Spruce (*Picea glauca *(Moench) Voss) Plantations*. Progress Report No. 11. University of Maine, School of Forest Resources, Cooperative Forestry Research Unit, Orono, Maine, USA.

Wood quality is often expressed in the form of specific gravity and it can be affected when a stand is thinned. This study looks into the effects of row thinning on specific gravity for white spruce plantations. It concludes that specific gravity is not increased by row thinning, thus no compression wood was formed as a result of the uneven crown opening. *(Abstract prepared by compilers.)*

Shepard, R.K. and Shottafer, J.E. 1990. Effect of early release on specific gravity and wood yield of black spruce. *Forest Products Journal* **40**(1): 18–20.

Ten dominant or co-dominant trees were sampled from a 29-year-old, released black spruce stand and ten of comparable diameter at breast height (DBH) from a 77-year-old, unthinned stand. A variety of tree characteristics were measured, and specific gravity was determined. The older trees had significantly less taper, shorter crowns, approximately 1.75 times more volume, and 10 percent higher specific gravity (0.435 vs. 0.396). It appears that early release or planting may lead to trees of markedly different characteristics from trees of equivalent DBH but growing in un-thinned stands.

Shi, J.L., Riedl, B., Deng, J., Cloutier, A., and Zhang, S.Y. 2007. Impact of log position in the tree on mechanical and physical properties of black spruce medium-density fibreboard panels. *Canadian Journal of Forest Research* **37**(5): 866–873.

Mechanical and physical properties of medium-density fibreboard (MDF) panels made from black spruce (*Picea mariana* (Mill.) BSP) top, middle, and butt logs were studied. The analysis of variance and analysis of covariance were both performed to examine the impact of log position in the tree on panel modulus of rupture (MOR), modulus of elasticity (MOE), internal bond (IB), linear expansion (LE), thickness swell (TS), and water absorption. Results indicate that MOE and IB strength of MDF panels made from top and middle logs were significantly superior to those of panels made from butt logs; however, there was no significant difference in MOE and IB between panels made from top and middle logs. Water absorptions of top and middle log panels were significantly lower than that of panels made from butt logs, and the difference in water absorption between panels made from top and middle logs was not significant. TS of top log panels was the smallest among the panels from the three log positions in the tree and was significantly different from those of middle and butt log panels. TS of butt log panels was the highest, which was significantly different from that of top and middle log panels. The differences in LE among the panels made from top, middle, and butt logs were not significant. The comparison of MOR of top, middle, and butt log panels was dependent on panel density because of the interactions among the three groups. Top and middle log panels showed superior properties, because the thinner cell walls of fibres from top and middle logs resulted in an increased compaction ratio compared with the butt log panels. Panel density affected both panel MOR and MOE considerably; however, its impact on IB, LE, TS, and water absorption was not significant in this study. The equations describing the linear relationships between MOR, MOE, and panel density were developed.

Les propriétés physiques et mécaniques de panneaux de fibre à densité moyenne (MDF) fabriqués à partir de billes d'épinette noire (*Picea mariana* (Mill.) BSP) prélevées à la base, au milieu et au sommet du tronc ont été étudiées. Les analyses de variance et de covariance ont été utilisées pour étudier l'impact de la position des billes dans l'arbre sur le module de rupture (MOR), le module d'élasticité (MOE), la cohésion interne (CI), l'expansion linéaire (EL), le gonflement (G) et l'absorption d'humidité. Les résultats indiquent que le MOE et la force de CI des panneaux de MDF fabriqués à partir de billes prélevées au milieu et sommet du tronc étaient significativement plus élevés que ceux des panneaux fabriqués à partir de billes de pied. Cependant, il n'y avait pas différence entre le MOE et la CI des panneaux fabriqués à partir de billes prélevées au sommet ou au milieu du tronc. L'absorption d'humidité par les panneaux fabriqués à partir de billes prélevées au milieu et sommet du tronc était significativement plus faible que celle des panneaux fabriqués à partir de billes de pied et il n'y avait pas de différence significative entre les panneaux fabriqués à partir de billes prélevées au milieu ou au sommet du tronc. Le G des panneaux fabriqués à partir de billes prélevées au sommet du tronc était le plus faible des trois types de panneaux et était significativement différent de celui des panneaux fabriqués à partir de billes prélevées au milieu et à la base du tronc. Les différences entre les valeurs de EL des panneaux fabriqués à partir de billes prélevées au sommet, au milieu ou à la base du tronc n'étaient pas significatives. La comparaison du MOR entre les trois types de panneaux dépendait de la densité des panneaux à cause des interactions entre les trois groupes. Les panneaux fabriqués à partir de billes prélevées au milieu ou au sommet du tronc avaient des propriétés supérieures parce que les parois cellulaires étaient plus minces dans les billes du milieu et du sommet produisant un rapport de compaction plus élevé comparativement aux panneaux fabriqués à partir de billes de pied. La densité des panneaux affectait considérablement le MOR et le MOE des panneaux mais, son impact sur les valeurs de CI, EL, G et l'absorption d'humidité n'était pas significatif dans cette étude. Les équations qui décrivent les relations linéaires entre le MOR, le MOE et la densité des panneaux ont été développées.

Shi, J.L., Zhang, S.Y., and Riedl, B. 2005. Effect of juvenile wood on strength properties and dimensional stability of black spruce medium-density fiberboard panels. *Holzforschung* **59**(1): 1–9.

Strength properties and dimensional stability of medium-density fiberboard (MDF) panels made from black spruce (*Picea mariana* [Mill.] BSP.) 0–20, 21–40, and over 40-year-old fiber were studied. An analysis of covariance (ANCOVA) was performed to examine the differences in modulus of rupture (MOR), modulus of elasticity (MOE), and thickness swell (TS) of the three types of panels, while panel density was treated as a covariate in order to adjust the mean values that were partly attributed to panel density. The results indicate that MOR, internal bond (IB), and water absorption of MDF panels made from 0–20-year-old fiber, which contained 100% juvenile wood, were significantly superior to those of panels made from 21–40 and over 40-year-old fiber; but linear expansion (LE) of MDF panels made from 0–20-year-old fiber was significantly larger than that of panels from the other two age classes. The differences in MOR, IB, water absorption, and LE between panels made from 21–40 and over 40-year-old fiber were not significant. The comparisons of panel MOE and TS were relatively dependent on panel density due to existence of interactions among the three age groups.

Shi, J.L., Zhang, S.Y., and Riedl, B. 2006. Multivariate modeling of MDF panel properties in relation to wood fiber characteristics. *Holzforschung* **60**(3): 285–293.

Properties of medium density fiberboard (MDF) panels in relation to wood and fiber characteristics were investigated. Laboratory MDF panels were manufactured from raw fiber materials from black spruce [*Picea mariana* (Mill.) BSP], three hybrid poplar clones (*Populus* spp.), two exotic larch (*Larix gmelinii* and *Larix sibirica*), and a mix of spruce, pine, and fir wood chips. The panels were evaluated for modulus of rupture (MOR), modulus of elasticity (MOE), internal bond (IB), linear expansion (LE), thickness swelling (TS), and water absorption (WA). These properties were analyzed as response variables. As predictor variables, various wood and fiber characteristics were measured, including wood density, pH, base buffering capacity and fiber coarseness. Multiple linear regression analysis was performed to develop functional relationships between panel properties (response variables) and wood fiber characteristics (predictor variables). Ten dummy variables were created and incorporated into the analysis to examine the effects of wood species or type on MDF panel properties. MOR was negatively related to arithmetic fine percentage. MOE was negatively affected by the percentage of small particles (>200 mesh) and wood pH. IB strength was negatively related to arithmetic fine percentage and fiber pH, but positively related to the percentage of small particles (>200 mesh). Wood density affected LE. TS was negatively affected by arithmetic mean fiber length. Arithmetic mean fiber width had a negative effect on panel WA. The presence of dummy variables in the models for MOE, IB and LE indicates that wood fiber characteristics other than those measured in this study significantly affected these panel properties. The study indicates that the refining process can play a significant role in manipulating MDF panel properties.

Shi, S.Q., and Gardner, D.J. 1999. An evaluation of analysis methods to eliminate the effect of density variation in property comparisons of wood composites. *Wood and Fiber Science* **31**(2): 164–172.

The objective of this research was to evaluate commonly used data analysis methods in property comparisons of wood composites to eliminate the effect of the density variation among broad test specimens and to suggest a more reasonable and robust method. The methods reviewed included average, specific strength, and analysis of covariance. The indicator variable method was also applied to the property comparison and compared to the other methods. The modulus of rupture of wood fiber/polymer fluff composites manufactured with different material combinations and press temperatures was tested in the experiment for evaluation of the different analysis methods. The results of this study indicated that the statistical analysis method employed was very important in the study of the physical and mechanical properties of wood composites. The specific strength method is limited to the analysis of strength comparison for the high density composites. The analysis of covariance can be applied to all the property comparisons for either high or low density composites in eliminating the density variation effect. However, error exists in the property comparison using the analysis of covariance when the slopes of the regression lines of property vs. specific gravity (SG) are different for the different composites being tested. The indicator variable method is shown to be more reliable than the specific strength and analysis of covariance methods because it compares the linear regression lines of property vs. SG by testing both the intercept and slope based on the data in the whole specific gravity range of test specimens.

Shortle, W.C., and Bauch, J. 1986. Wood characteristics of *Abies balsamea* in the New England States compared to *Abies alba* from sites in Europe with decline problems. *IAWA Journal* **7**(4): 375–387.

The increasing concern about the health conditions of forests in the United States and Europe led to a comparative study of wood characteristics of *Abies balsamea* (L.) Mill. in the New England states, and *Abies alba* Mill. in the Federal Republic of Germany. The advanced visible disease in *Abies alba* at several sites can be documented by means of many structural and physiological alterations. In eased trees a suppression of the annual growth increment is obvious, and the individual transverse area of early and latewood cells decreases. The moisture content diminishes in the sapwood significantly and at the same time, wetwood develops and expands into the sapwood. The element content per gram of wood does not significantly differ between healthy and diseased trees of the same stand. The content of soluble sugars increases in diseased trees, while the starch content is drastically reduced. However, parallel to the growth suppression the total amount per year of elements, soluble sugars and starch is significantly less in diseased trees than in healthy ones. In addition, accessory compounds appear to increase with the progress of disease. Cambial electrical resistance is strongly related to damage classification, and thereby to cambial growth.

A corresponding study of *Abies balsamea* on trees without well-defined symptoms of disease was conducted to evaluate the possibility of latent symptoms indicative of early stages of disease. A paired sample of balsam firs with healthy and declining crowns was taken from representative locations across northern New England. Structural features were similar to healthy and diseased silver fir—a prolonged suppression of cambial growth, a reduction of sapwood basal area, and a reduction of the transverse area of tracheids. Physiological parameters were different—no reduction of sapwood water content, a significant decrease in soluble sugar content, and no change in oxalate ions. Differences in function between the two species may explain why *A. balsamea* may not be able to survive long enough to develop the degree of disease observed in *A. alba*. These differences in physiology make it difficult to decide if influences similar to Germany may be causing a decline of balsam fir in the United States.

Siddiqui, K.M., Gladstone, W.T., and Marton, R. 1971. *Influence of Fertilization on Wood and Pulp Properties of Douglas Fir*. Report, State University of New York, Syracuse, New York, USA.

A naturally regenerated stand of Douglas-fir was fertilized with urea, which resulted in a significant increase in volume growth, but decreased the wood specific gravity slightly. Pulp yield is increased by fertilizing because it lowers the extractives content and increases the S_2 wall layer in the tracheids of earlywood. The lower specific gravity of fertilized wood can be explained by the smaller percentage of latewood and the reduction in thickness of the wall. *(Abstract prepared by compilers.)*

Silins, U., Lieffers, V.J., and Bach, L. 2000. The effect of temperature on mechanical properties of standing lodgepole pine trees. *Trees - Structure and Function* **14**(8): 424–428.

To estimate strength parameters of living lodgepole pine stems over a range of temperatures (-16 to +17°C), trees were winched near or past the point of breakage, during which the applied force and deflection of the stem were measured. Trees were 43 years old, 10 m tall, and since the experiments were conducted in the late winter and early spring, when the soil was frozen and the roots were held rigid, the resistance of the stem to deflection could be isolated from the resistances of the root and soil. Static flexure theory for cantilever beams was used to estimate stress, strain, Young's modulus (E), and modulus of rupture (MOR) of the stem. Trees were stiffer and stronger in the winter when wood was frozen, with a nearly 50% increase in E and MOR compared with the spring, when wood was thawed. In winter stems failed on the tension side, while in spring stems buckled on the compression side. Compared with strength estimations reported in the literature from small samples of clear green wood at standard temperatures, modulus of elasticity (MOE) estimates of the whole stem were 35% lower in spring, and in winter MOR exceeded published values by 53%. This suggests that the sway behavior of trees is probably temperature dependent in northern forests and whole-tree strength characteristics should be considered in wind sway models used in these regions.

Sinclair, G.D. and Dymond, D.K. 1973. The distribution and composition of extractives in jack pine trees. *Canadian Journal of Forest Research* **3**(4): 516–521.

The distribution of acetone-soluble extractives in jack pine trees of different diameters, and at different locations within a single tree was studied. The amount of extractives varied from 3% in a 10 cm diameter tree to 9.6% in a 50 cm diameter tree. Within a single tree the top had the least amount of extract, 2.7%, while the needle bearing twigs had the greatest amount, 4.6%. Gas–liquid chromatographic analysis of the extracts showed that the composition was relatively similar for all sizes of trees and within one tree except in the top and the branches. The heartwood of the tree had a much higher extractive content than the sapwood and contained a higher concentration of resin acids, pinocembrin, and pinobanksin.

Cet article traite de la distribution des substances extractibles à l'acétone dans des arbres de pin gris de différents diamètres, et à différentes positions à l'intérieur d'un même arbre. La quantité de substances extraites a varié de 3% dans un arbre de 10 cm de diamètre à 9.6% dans un arbre de 50 cm de diamètre. À l'intérieur d'un même arbre, la cime renfermait la plus faible proportion de substances extractibles, soit 2.7%, alors que les rameaux porteurs d'aiguilles en renfermaient 4.6%, quantité la plus élevée. L'analyse des extraits par chromatographie en phase gazeuse a montré que la composition était relativement uniforme, indépendamment du diamètre des arbres, de même qu'à l'intérieur d'un même arbre, à l'exception de la cime et des branches. Le bois de coeur de l'arbre renfermait un contenu en substances extractibles plus élevé que celui de l'aubier et une concentration plus grande en résines acides: pinocembrine et pinobanksine.

Singh, S., and Roy, D.N. 1996. The effect of recycling on chemical properties of the thermomechanical pulp. *Journal of Wood Chemistry and Technology* **16**(4): 421–437.

This study was designed to elucidate the effect of recycling on the chemical properties of thermomechanical pulps made from mature and juvenile woods of black spruce, jack pine and eastern white cedar. The amounts of organics components and the concentrations of trace elements were examined on each recycle, up to four cycles. The extractive contents were decreased after each cycle with an overall reduction of 70 to 85%. In the case of lignin, the trend was different from cycle to cycle but was more or less the same for all pulps. The lignin was reduced by 5% after four cycles. The reverse trend was true with holocellulose. Calcium and manganese concentrations were reduced for all the pulps while chlorine and sodium had no specific trend. Aluminum concentration was too small to infer any trend. These variations were not dependent on species and age of the wood.

Singh, T. 1984. Variation in the ovendry wood density of 10 Prairie tree species. *The Forestry Chronicle* **60**(4):217–221.

Ovendry wood density (g/cm^3) determinations were made on disk subsamples collected from 600 trees belonging to 10 major softwood and hardwood species of the three Prairie provinces. Ten disks were obtained from each tree stem: four from equally spaced sections of the merchantable stem, three from similar sections along the nonmerchantable stem, and three additional disks obtained at stump height, breast height, and near the top. The relationships between specific gravity and associated tree variables such as age, height, diameter, and volume were examined. Because of variations in the wood density at relative heights within a species, weighted wood density was determined for the entire tree stem, and prediction equations were derived for its estimation from the wood density at breast height. The variability of wood density increased significantly for the older stem sections near the base but was insignificant for the more recent height growth toward the tip.

On a déterminé la masse anhydre (g/cm^3) du bois dans des rondelles provenant de 600 arbres appartenant à 10 espèces importantes de feuillus et de conifères des trois provinces des Prairies. On a obtenu pour chaque arbre 10 rondelles : quatre de sections équidistantes de la partie marchande, trois de sections similaires de la partie non marchande et trois autres prélevées à hauteur de la souche, à hauteur de poitrine et près du sommet. On a examiné les rapports entre la densité relative et des variables connexes des arbres comme l'âge, la hauteur, le diamètre et le volume. Comme la masse volumique varie à différentes hauteurs au sein d'une même espèce, on a calculé une valeur pondérée pour la tige entière et formulé des équations permettant de l'estimer à partir de la masse volumique à hauteur de poitrine. La variabilité est nettement plus grande pour les parties plus âgées de la tige près de la base, mais elle est négligeable pour l'accroissement plus récent en hauteur près du sommet.

Singh, T. 1986. Wood density variation of six major tree species of the Northwest Territories. *Canadian Journal of Forest Research* **16**(1): 127–129.

Wood density measurements on green and ovendry volume bases were made and their variations were statistically analyzed for six major tree species of the Northwest Territories. These values, based on samples from 336 trees, showed that the species had highly significant ($P < 0.01$) differences among various diameter size classes, but these differences decreased in significance toward the top. A predictor model was derived for estimating volume-weighted average basic wood density of a tree from its basic wood density at breast height. The lowest wood density in the majority of the species was in a band of varying length including or approaching the midpoint of the tree bole. Such information on density gradients is useful in allocating parts of a tree for optimum use.

On a mesuré la densité d'éprouvettes de bois vert et anhydre des six principales essences des Territoires du Nord-Ouest et soumis ses variations à l'analyse statistique. Les valeurs tirées de 336 arbres ont montré des différences très significatives ($P < 0,01$) selon les 10 positions échantillonnées selon la hauteur le long de la tige. Près de la base du fût, les différences étaient très significatives ($P < 0,01$) parmi les diverses classes de diamètre, mais ces différences se sont atténuées vers la cime. On a construit un modèle pour prédire la moyenne pondérée de la densité basale apparente d'un arbre à partir de sa densité basale à hauteur de poitrine. Chez la majorité des essences, la densité minimale était observée dans une bande de longueurs variables englobant ou approchant le centre du fût. Grâce à ces renseignements sur les gradients de densité, on peut utiliser au mieux les différentes parties d'un arbre.

Smith, C.R. 1984. Jack Pine Symposium. Pages 1–195 *in* C.R. Smith and G. Brown. *Canada–Ontario Joint Forestry Research Committee Symposium Proceeding.* 18–20 October 1984, Timmins, Ontario, Canada. COJFRC Symposuim Proceedings O-P-12. Natural Resources Canada, Canadian Forest Service - Great Lakes Forest Research Centre, Sault Ste. Marie, Ontario, Canada.

The purpose of the *Jack Pine Symposium* was to provide researchers and forest managers with an opportunity to discuss the state of the art of jack pine management in Ontario and to present findings from some of the more recent and more relevant research into the species. Invited speakers from the Maritimes, Quebec, Manitoba, Saskatchewan and the Lake states provided an overview of the current status of jack pine covering the biological range of the species outside Ontario. In addition, papers were presented on subjects ranging from seed collection and management through the various aspects of plantation management. Representatives of the four northern administrative regions of OMNR presented summaries for their respective areas and a final overview of management in Ontario concluded the proceedings. There were short question and answer periods at appropriate points in the discussion.

Smith, C.R., and Oerlemans, W.J.A.M. 1988. *Ten-Year Growth Response and Financial Evaluation of Commercial Strip Thinning of Jack Pine: a Case Study.* Information Report O-X-396. Natural Resources Canada, Canadian Forest Service - Great Lakes Forestry Centre. Sault Ste. Marie, Ontario, Canada.

In 1970, a 45-year-old jack pine (*Pinus banksiana* Lamb.) stand near Chapleau, Ontario was commercially strip thinned, under contract, by means of a conventional shortwood logging system. Corridors were clear-cut to a width of 5.0 m with 6.3-m-wide residual strips.

Ten-year growth data showed good response among crop trees. An increase in mean tree volume between 18 and 22% (.02 to .06 m^3) by age 70 is predicted. Including the volume harvested from thinning, the net gain by age 70 may be about 20 m^3/ha.

On the basis of estimates of growth, costs and prices, a positive net present value (NPV) is possible as a result of strip thinning at discount rates of 4% or more. Sensitivity analysis showed that NPV is very sensitive to mean DBH and density.

Trees at or near the edge of the residual strips responded better than those near the middle. A slight narrowing of the cut and leave strips may increase the yield. However, as an alternative, it is recommended that investigations be carried out combining strip thinning with individual selective tree thinning from below in wide residual strips to achieve a higher utilization of site productivity potential.

En 1970, un peuplement de 45 ans de pins gris (*Pinus banksiana* Lamb.) situé près de Chapleau, en Ontario, a subi une éclaircie commerciale en bandes suivant la méthode classique d'exploitation en bois court. Les bandes coupées à blanc faisaient 5,0 m de large et étaient espacées de 6,3 m.

Les données sur l'accroissement après 10 ans indiquent un effet positif de l'éclaircie sur les arbres du peuplement final. À 70 ans, leur volume moyen devrait avoir augmenté de 18 à 22% (0,02 à 0,06 m^3). Si l'on inclut le volume récolté lors de l'éclaircie, le gain net à 70 ans pourrait être d'environs 20 m^3/ha.

D'après les estimations de l'accroissement, des coûts et de prix, une valeur actualisée nette positive semble possible à la suite de l'éclaircie en bandes pour un taux d'actualisation de 4% ou plus. Une analyse de sensibilité a indiqué que la valeur actualisée nette est très sensible au dhp moyen et à la densité.

Les arbres situés sur la lisière de la bande non coupée ou à proximité ont été plus favorisés que ceux qui se trouvent plus près du centre. Un léger rétrécissement des bandes coupées et non coupées pourrait augmenter le rendement. Toutefois, on recommande une autre option en vue d'assurer une meilleure utilisation du potentiel de productivité des sites, soit de combiner l'éclaircie en bandes avec une éclaircie sélective, individuelle, par le bas dans les bandes larges non coupées.

Smith, D.W., and Tumey, P.R. 1982. Specific density and caloric value of the trunk wood of white birch, black cherry and sugar maple and their relation to forest succession. *Canadian Journal of Forest Research* **12**(2): 186–190.

Studies in the specific density and caloric level per unit volume of trunk wood of three deciduous tree species of differing successional positions support the thesis that tree wood properties are related to the differing successional positions of trees. White birch (*Betula papyrifera* Marsh.), black cherry (*Prunus serotina* Ehrh.), and sugar maple (*Acer saccharum* Marsh.) were chosen as being characteristic of early, middle, and late stages in forest succession. Wood cores were taken for these species from three different stands in southern Ontario and specific density, calorie value, and caloric level per unit volume were determined.

Sugar maple had a higher specific density and caloric value than black cherry or white birch but only small differences were evident between black cherry and white birch. Specific density was found to be the least variable measure, but caloric level per unit volume was also useful, although less accurate. These latter estimates proved to be indicative of the successional positions of the three species.

Smith, J.H.G., and Kozak, A. 1971. Thickness, moisture content, and specific gravity of inner and outer bark of some Pacific Northwest trees. *Forest Products Journal* **21**(2): 38–40.

Improved methods involving bark thickness and percentages and corrections for volumes lost in voids are discussed. Tabulated averages and measures of variation in thickness, moisture and specific gravity provide new data about both inner and outer bark for 19 tree species of the Pacific Northwest, 13 conifers, and 6 hardwoods.

Smith, S.M., Graham, R.D., and Morrell, J.J. 1987. Influence of air-seasoning on fungal colonization and strength properties of Douglas-fir pole sections. *Forest Products Journal* **37**(9): 45–48.

Long-term air-seasoning of poles to reduce sapwood moisture content before pressure-preservative treatment has been associated with fungal colonization that can severely reduce wood strength. In this study, decay fungi were more frequently isolated from poles as air-seasoning time increased; however, fungal invasion seemed to be retarded in poles treated with ammonium bifluoride. Static bending of 1 x 1 x 16-inch beams removed from air-seasoned pole sections showed that modulus of elasticity (MOE) was unchanged over 3 years, work to maximum load was decreased after 2 years, and modulus of rupture (MOR) was lower after 3 years. All strength values were within an acceptable range for Douglas-fir. Beams cut from the outer heartwood of poles had higher MOR and MOE than beams cut from the sapwood or inner heartwood. Sapwood beams had the highest work to maximum load strength. Results of static bending tests and measurements of specific gravity, Pilodyn-pin penetration, and compression strength indicate that poles can be air-seasoned for as long as 3 years without adversely affecting pole strength. Poles must be sufficiently heated during preservative treatment to eliminate fungi that become established during air-seasoning, because many fungi could continue to cause decay of poles in service.

Smith, W.B. 1986. Treatability of several northeastern species with chromated copper arsenate wood preservative. *Forest Products Journal* **36**(7–8): 63–69.

This paper discusses the treatability of several northeastern species and the effects of incising upon treatability, as determined by preservative penetration and gain-in-weight retention. Eight-foot-long red pine, eastern white pine, eastern hemlock, gypsy moth-killed eastern hemlock, Norway spruce, European larch, and bigtooth aspen 2 by 4's and 4 by 4's were kiln-dried to below 15 percent moisture content as end matched 4-foot pairs, and then one of each pair was incised. All specimens were then treated with CCA-C via full-cell impregnation. The average unincised and incised, respectively, solution retention levels for the 2 by 4's were 41 and 42 pounds per cubic foot for (pcf) for red pine, 41 and 41 pcf for eastern white pine, and 29 and 32 for bigtooth aspen. More significant retention gains due to incising were found in eastern hemlock (32 and 36 pcf), Norway spruce (25 and 31 pcf), and European larch (12 and 16 pcf). Sapwood penetration in each species was good, and significant heartwood penetration was found in eastern white pine.

Solomon, D.S., and Zhang, L. 2002. Maximum size–density relationships for mixed softwoods in the northeastern USA. *Forest Ecology and Management* **155**(1–3): 163–170.

The maximum size–density relationships or self-thinning lines were developed for three mixed-softwood climax forest habitats (hemlock–red spruce, spruce–fir, and cedar–black spruce) in the northeastern USA. The plot data were collected from an extensive data base used in growth studies from 1950 to 1970, and represented a wide range of species compositions, sites, management options, and densities. Plots having late successional species compositions with relative density index higher than 0.7 were selected as the most fully-stocked plots for model development. Reduced major axis regression was used to fit the self-thinning lines to the data. The differences between the three forest habitats were tested using the 95% confidence intervals of the coefficients of the self-thinning lines. The results indicated that there were no differences between the hemlock–red spruce and spruce–fir habitats for both relationships of the mean tree volume versus number of trees, and the quadratic mean tree diameter versus number of trees. Thus, these two habitats were combined to develop a single self-thinning line. However, the cedar–black spruce forest habitat required a separate self-thinning line. These maximum size–density relationships can be readily used to construct stand density management diagrams.

Sonderman, D.L. 1987. *Stem-Quality Changes on Young, Mixed Upland After Crop-Tree Release*. Research Paper NE-RP-597. United States Department of Agriculture, Forest Service, Broomall, Pennsylvania, USA.

Relative change of several types of stem defects was studied over an 8-year period to determine the effects of crop-tree thinning on the development of tree quality. Special interest was given to changes in relative quality associated with defect indicators of crop trees compared to trees in unthinned plots. The relative quality classes of the crop trees went from"poor" to "medium" for red maple and "poor" to "good" for aspen. The oaks stayed in the poor classification and yellow poplar remained unchanged in the medium classification. Results showed a decrease in the number of epicormic branches on the crop trees, and an increase in the size of live limbs. *(Source: U.S. Department of Agriculture, Forest Service.)*

Spicer, R., and Gartner, B.L. 2001. The effects of cambial age and position within the stem on specific conductivity in Douglas-fir (*Pseudotsuga menziesii*) sapwood. *Trees - Structure and Function* **15**(4): 222–229.

Specific conductivity (K_s, $m^2s^{-1}MPa^{-1}$) describes the permeability of xylem and is determined by all aspects of xylem anatomy that create resistance to the flow of water. Here we test the hypothesis that K_s is a function of radial and vertical position within the stem, rather than solely a function of cambial age (ring number from the pith), by measuring K_s on samples excised from 35-year-old Douglas-fir [*Pseudotsuga menziesii* var. *menziesii* (Mirb.) Franco] trees at six heights and two or three radial positions. Sapwood K_s decreased from the cambium to the heartwood boundary, and the difference between outer and inner sapwood increased with height in the tree. Beneath the live crown, inner sapwood had 80–90% the K_s of outer sapwood, but only 55% just 10 m higher in the stem (about 10 nodes down from the tree top). Outer sapwood K_s peaked near the base of the crown and declined toward both the base and top of the stem. These patterns can be explained by two superimposed effects: the effect of cambial age on the dimensions of tracheids as they are produced, and the effect of xylem aging, which may include accumulation of emboli and aspiration of bordered pits. Tracheid lumen diameter and earlywood and latewood density and width, all factors known to vary with cambial age, were measured on different trees of the same age and from the same stand. Lumen diameter increased with cambial age, whereas the proportion of latewood and growth ring density increased after an initial decrease in the first 5 years. Our results suggest that the effect of cambial age on xylem anatomy is not sufficient to explain variation in K_s. Instead, physical position (both vertical and radial) in the stem and cambial age must be considered as determinants of conductivity.

Spurr, S.H., and Hsiung, W.-Y. 1953. Growth rate and specific gravity in conifers. *Journal of Forestry* **52**(3): 191–200.

Since ancient times, rate of growth has been associated with specific gravity and wood quality. Large numbers of studies have been conducted, often with conflicting results. This paper reviews the literature relating growth rate and specific gravity—particularly in jack pine (*Pinus banksiana* Lamb.)—from the perspective of measurement, what determines specific gravity, effect of sample position in the tree, growth rate, and silviculture. Oven-dry weight and wet volume are preferable for specific gravity measurement. Measurements made from increment cores have been lower, but not statistically lower. Wood specific gravity measurements include the wood substance, with its average specific gravity of 1.5, plus void space. Differences between and within species and trees are the result of differences in pore volume. Extraneous substances, although of low specific gravity themselves, increase specific gravity of wood by filling pore spaces. It is recommended that specific gravity studies include wood chemical composition, variation in lumen sizes, and cell wall thickness variation. Specific gravity variation varies by position in the tree, generally although not always decreasing with height and increasing from pith to bark. The changes with height may be related to taper. Overmature trees may produce lower specific gravity wood close to the bark. It has not been established whether the horizontal relationship is related to age or position as the factors are confounded. Although growth rate is generally assumed to influence specific gravity, the data are poorly correlated. Sampling decisions influence the results as ring width, age, and horizontal position in the tree vary together and can confound results. The relationship between specific gravity and crown size and class is ill defined. Many attempts to determine relationships between site and specific gravity have failed, in part because the influence of age was not recognized. Other studies, however, have found that poor sites result in lower specific gravity, likely as a result of little latewood production. Silvicultural practices are expected to be able to increase specific gravity if the practice can increase the proportion of latewood produced. Silvicultural control can be difficult, however, and high specific gravity is not optimal for all uses. *(Abstract prepared by compilers.)*

Standish, J.T. 1983. *Development of a System to Estimate Quantity of Biomass Following Logging in British Columbia Forests to Specified Recovery Criteria*. ENFOR Project No. 7952. Talisman Land Resource Consultants, Vancouver, British Columbia, Canada.

A three-year study was conducted aimed at producing at least a first approximation of a system to estimate the amount of biomass remaining following logging in B.C. Forests. Eleven hundred and fifty-five trees representing 22 species and varieties were sampled, and simple and multiple linear regression equations were developed for predicting total above-ground and component fresh and oven-dry mass. Unweighted linear equations were used because additivity of component regression coefficients was desired. Simple linear regressions with an intercept and DH as the independent variable, despite several limitations, may give reasonable predictions to bole components and total above-ground biomass, but often are relatively poor predictions of crown components. Multiple linear equations using volume (calculated from B.C. Ministry of Forests volume equations), DBH, height and their interactions generally improved the precision and accuracy of biomass estimates, particularly for crown components. A biomass estimation model which interfaces with the B.C. Ministry of Forests inventory system was developed. This computer model generates biomass data, including biomass remaining following logging at user-specified levels of utilization, according to individual strata (forest cover types) and other levels in the inventory system.

Stark, E.W. 1954. *Wood Anatomy of the Aceraceae Indigenous to the United States*. Bulletin 606. Purdue University, Forest Experiment Station, Station, Lafayette, Indiana, USA.

This bulletin describing the wood anatomy of Aceraceae is the last in a series of four that included Juglandaceae, Betulaceae, and Magnoliaceae species, all native to the United States. Aceraceae includes two genera, *Acer* and *Dipteronia*. *Dipteronia* comprises two species in China, whereas *Acer* is widespread throughout the northern hemisphere, with 13 species indigenous to the United States. The bulletin describes the general characteristics of Aceraceae wood and includes a key to the woods. The characteristics and anatomy of the wood of *A. circinatum* Pursh., *A. floridanum* (Chapm.) Pax, *A. floridanum* var. *villipes* Rehd., *A. glabrum* var. *Douglasii*, *A. grandidentatum* Nutt., *A. leucoderme* Small, *A. macrophyllum* Pursh., *A. negundo* L., *A. negundo* var. *californicum* (Torr. and Gray) Sarg., *A. negundo* var. *interius* (Britton) Sarg., *A. negundo* var. *violaceum* Jaeg. and Beissn., *A. nigrum* Michx. F., *A. pensylvanicam* L., *A. rubrum* L., *A. rubrum* var. *tridens* Wood, *A. saccharinum* L., *A. saccharum* Marsh., *A. saccharum f. glaucum* (Schmidt) Pax, and *A. spicatum* Lam are described. *(Abstract prepared by compilers.)*

Stewart, J.J., Kadla, J.F., and Mansfield, S.D. 2006. The influence of lignin chemistry and ultrastructure on the pulping efficiency of clonal aspen (*Populus tremuloides* Michx.). *Holzforschung* **60**(2): 111–122.

The variation in wood chemistry among aspen clones of similar age, harvested from a common site in northern British Columbia, Canada, was evaluated. The aspen clones were evaluated for ease of chemical pulping and differed by as much as 4.5% in pulp yield at a common H-factor. The results demonstrate both the need for understanding the resource and the substantial opportunities that exist in natural populations of trees for selecting superior clones for reforestation and afforestation. The syringyl/guaiacyl ratio, as determined by nitrobenzene oxidation, was directly correlated with the ease of pulping, whereas thioacidolysis results were not as predictive. These results were supported by quantitative NMR analysis, which demonstrated differences in the amount of β-O-4/Ar groups and the degree of condensation. Furthermore, it was shown that, in addition to total lignin content, which differed by as much as 5%, structural differences in the lignin may influence pulping efficacy. Among the other parameters evaluated, the distribution of molecular mass and methoxyl content is relevant for pulping. More specifically, among the fractions isolated in this study [milled wood lignin (MWL), MWELsol, and MWELinsol], the insoluble fraction was the most indicative of the pulping efficiency.

St.-Germain, J.L., and Krause, C. 2008. Latitudinal variation in tree-ring and wood cell characteristics of *Picea mariana* across the continuous boreal forest in Quebec. *Canadian Journal of Forest Research* **38**(6): 1397–1405.

Wood anatomical features measured in tree-rings are useful indicators of environmental change and wood quality. The effect of latitude on the wood anatomy of mature black spruce (*Picea mariana* (Mill.) BSP) was investigated along a 500 km transect from 47°N to 52°N across the continuous boreal forest in Quebec, Canada. Total tree-ring width, earlywood width, latewood width, latewood proportion, cell numbers, tracheid length, radial diameter, lumen diameter, and cell wall thickness were measured using image analysis on samples from 15 mature stands. Our results suggest that tree-ring, earlywood, and latewood widths, cell numbers, latewood radial cell diameter, and cell wall thickness decrease with latitude. No significant trend was observed for latewood proportion, despite a slight increase with latitude ($p = 0.0856$). However, the high variability in radial growth seen along the gradient might explain the absence of a significant relationship. Latitude and the associated growth rate reduction had no effect on tracheid length. The existence of a latitudinal pattern of variation in black spruce wood anatomy may be the result of tree adaptation to differing environmental conditions along the gradient

Les propriétés anatomiques des cernes annuels sont de bons indicateurs des changements environnementaux et de la qualité du bois. Les variations dans les propriétés anatomiques du bois de l'épinette noire (*Picea mariana* (Mill.) BSP) ont été étudiées le long d'un gradient latitudinal (47°N à 52°N) traversant la forêt boréale continue de la province de Québec (Canada) sur une distance de 500 km. La largeur des cernes, du bois initial et du bois final, la proportion de bois final, le nombre de cellules, la longueur et le diamètre radial des cellules, le diamètre du lumen et l'épaisseur des parois cellulaires ont été mesurés à l'aide de l'analyse d'image sur des échantillons provenant de 15 peuplements matures. Nos résultats suggèrent que la largeur des cernes (bois initial et final), le nombre de cellules, le diamètre radial et l'épaisseur des parois des cellules de bois final diminuent avec l'augmentation de la latitude. Aucune tendance significative n'a été observée pour la proportion de bois final malgré une légère augmentation ($p = 0{,}0856$) en passant du sud au nord de la zone à l'étude. Toutefois, la grande variabilité dans la croissance radiale des arbres échantillonnés le long du gradient pourrait expliquer cette absence de relation. Finalement, la latitude et la diminution de croissance radiale qui y est associée n'ont pas eu d'effet sur la longueur des trachéides. L'existence d'un patron de variation latitudinale dans l'anatomie du bois de l'épinette noire serait le résultat de l'adaptation des arbres aux conditions changeantes de leur environnement le long du gradient étudié.

Strong, T.F., Erdmann, G., and Niese, J.N. 1995. Forty years of alternative management practices in second-growth, pole-size northern hardwoods I. tree quality development. *Canadian Journal of Forest Research* **25**: 1173–1179.

The effects of six cutting methods on tree quality were observed for 20 years in a northern hardwood stand in Wisconsin. Cutting treatments included an uncut control, three levels of individual tree selection (heavy, medium, and light), crop tree release, and diameter limit. Average annual diameter growth was least in the control treatment (0.13 in./year, 0.33 cm/year) and greatest in the heavy individual tree selection and diameter-limit cuts (0.18 in./year, 0.46 cm/year). Cull in trees in 1992 was significantly higher in the control and diameter-limit treatments. Changes in merchantable height (number of 16-ft (4.9-m) logs) over the period were not significantly different among treatments, but average merchantable heights were significantly greater in the individual tree selection treatments in 1992. Average tree grade increases were significantly better in the medium selection plots than in all other treatments except the crop tree release. Nearly a third of the sawlog-size trees in both the control and diameter-limit treatments were below sawlog grade, significantly more than in the other treatments. Only 2% of the trees in the heavy selection plots were below grade. Tree quality improved the most overall in the medium selection plots. Stand structure in this treatment also most closely matched that recomended by guides developed to sustain yield over long periods of cutting under uneven-aged management.

Les effets de six méthodes de coupe sur la qualité des arbres ont été étudiés pendant 20 ans dans un peuplement de feuillus nordiques au Wisconsin. Les traitements incluaient un témoin non coupé, trois intensités de coupes de jardinage par pied d'arbre (fort, moyen et faible), une coupe de dégagement et une coupe à diamètre limite. La croissance annuelle moyenne en diamètre a été la plus faible dans le traitement témoin (0,13 pouce/an, 0,33 cm/an) et la plus forte dans la coupe de jardinage par pied d'arbre de forte intensité et la coupe à diamètre limite (0,18 pouce/an, 0,46 cm/an). En 1992, les défauts dans les arbres étaient significativement plus importants dans le témoin et la coupe à diamètre limite. Les changements dans la hauteur marchande (nombre de billes de 16 pieds (4,9 m)) pendant la période n'étaient pas significativement différents entre les traitements, mais la hauteur marchande moyenne était significativement plus élevée dans la coupe de jardinage par pied d'arbre en 1992. L'augmentation moyenne de la classe de qualité des arbres était significativement plus forte dans la coupe de jardinage d'intensité moyenne que dans tous les autres traitements à l'exception de la coupe de dégagement. Presque un tiers des arbres de dimension suffisante pour le sciage dans le témoin et la coupe à diamètre limite étaient de qualité inférieure à la qualité requise pour le sciage; ce qui était significativement plus élevé que dans les autres traitements. Seulement 2% des arbres dans la coupe de jardinage de forte intensité étaient de qualité inférieure à la qualité requise pour le sciage. Dans l'ensemble, la qualité des arbres a augmenté le plus dans la coupe de jardinage d'intensité moyenne. Également dans ce traitement, la structure du peuplement se rapprochait le plus de celle qui est recommandée par les guides développés pour assurer un rendement soutenu sur de longues périodes d'exploitation dans un système d'aménagement inéquienne.

Stump, J.P., Smith, L.A., and Gray, R.L. 1981. Laminated veneer lumber made from plantation-grown conifers. *Forest Products Journal* **31**(4): 34–40.

Research was undertaken to determine the feasibility of upgrading the products of small, low quality plantation-grown timber in New York State by demonstrating that laminated veneer lumber (LVL) could yield structural grade lumber. Veneers, cut 0.20 inch thick from white pine, red pine, spruce, and larch were laminated using a phenol-resorcinol adhesive cured at 90°F to produce 300 nominal 2-inch by 4-inch by 8 foot and 300 nominal 2-inch by 10-inch by 8-foot specimens containing veneers of either single species (homogeneous LVL) or a random selection from all four species (mixed LVL). Full-scale two-point flexure tests were performed to determine modulus of elasticity (MOE) and modulus of rupture MOR) data. Allowable design stresses (F_b) were calculated to account for variability in MOR, duration of load, and a factor of safety. Compared to lumber grades of corresponding naturally grown species, all homogeneous LVL were equivalent to No. 2 or better in average MOE values. Similarly, mixed LVL equaled select structural grades for red pine and larch lumber. F_b values were equal to No. 1 and better for all LVL except for 2 by 10 larch and 2 by 10 mixed LVL. Compared with Douglas-fir and southern pine lumber grades, all 2 by 4 LVL had F_b equal to No. 2 except white pine LVL. We conclude that a structural lumber product (mixed LVL) can be produced from conifer plantations within New York. This large natural resource can be used to serve the structural lumber requirements of the Northeast.

Suárez, J.C., Ontiveros, C., Smith, S., and Snape, S. 2005. Use of airborne LiDAR and aerial photography in the estimation of individual tree heights in forestry. *Computers & Geosciences* **31**(2):253–262.

This paper describes the use of aerial photography and airborne LiDAR to estimate individual tree heights in forest stands. The advantages and disadvantages in the use of LiDAR systems are revised and a data fusion analysis with digital aerial photography is proposed. An example of the use of these techniques in a forested area in Scotland is presented. An algorithm has been developed to extract a high-resolution digital terrain model of the bare ground. This provided a tree canopy model as the difference between the laser first pulse and the model of the underlying terrain. Information about individual trees was obtained by image segmentation and classification. This analysis provided a good method of estimating individual tree canopies and heights.

Sucre, E.B., Harrison, R.B., Turnblom, E.C., and Briggs, D.G. 2008. The use of various soil and site variables for estimating growth response of Douglas-fir to multiple applications of urea and determining potential long-term effects on soil properties. *Canadian Journal of Forest Research* **38**(6): 1458–1469.

Estimating the growth response of Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) stands after nitrogen (N) fertilization is difficult because of the high site variability present in the Pacific Northwest. Our objective was to determine how site and soil variables relate to stand response to repeat applications of 224 kg N•ha^{-1} as urea once every 4 years. The unstandardized residuals of two dependent variables (total cumulative volume and 4-year periodic annual increment, or PAI) were regressed against site and soil variables using stepwise regression. Data were stratified by three different stand density treatments: unaltered stand density (SD), one-half SD (SD/2), and one-quarter SD (SD/4). Both total cumulative volume and 4-year PAI after the second application of urea was significantly higher in the fertilized plots ($p = 0.008$; 0.009), whereas only total cumulative volume was significant after the third fertilizer application ($p = 0.021$). Thinning effects were highly significant ($p < 0.001$) for all three fertilizer applications. The strongest related stand, site, or soil variable to fertilization response existed between percent N at the 30–50 cm depth and total cumulative volume ($R^2 = 0.833$) for the SD/2 stand density management regime. Regression analysis showed that C, N, NH_{4+}, and NO_{3-} concentration data explained the most variation, while stand and site variables contributing the least. The results demonstrate that multiple applications of urea provide significant increases in total volume, but effects of successive applications diminish over time.

Il est difficile d'évaluer la réaction en croissance de peuplements de douglas de Menzies (*Pseudotsuga menziesii* (Mirb.) Franco) après une fertilisation azotée (N) à cause de la grande variabilité des stations du Nord-ouest américain. Notre objectif était de déterminer comment les variables du sol et de la station étaient reliées à la réaction du peuplement à la suite d'applications répétées de 224 kg N•ha^{-1} sous forme d'urée à tous les quatre ans. Les résidus non standardisés de deux variables dépendantes (volume total cumulatif et accroissement annuel périodique (AAP) pendant une période de quatre ans) ont été mis en relation avec des variables de sol et de station à l'aide de la régression pas à pas. Les données ont été stratifiées selon trois traitements de la densité du peuplement : densité du peuplement non altérée (SD), 50 % de la densité du peuplement (SD/2) et 25 % de la densité du peuplement (SD/4). Le volume total cumulatif et l'AAP pendant une période de quatre ans étaient significativement plus élevés dans les parcelles fertilisées après la deuxième application d'urée (*p* = 0,008 et 0,009) alors que seul le volume total cumulatif était significativement plus élevé après la troisième application de fertilisant (*p* = 0,021). Les effets de l'éclaircie étaient très significatifs (*p* < 0,001) pour les trois applications de fertilisant. La relation la plus étroite entre une variable de peuplement, de station ou de sol et la réaction à la fertilisation était celle qui existait entre le pourcentage d'azote à une profondeur de 30 à 50 cm et le volume total cumulatif (R^2 = 0,833) dans le cas du régime d'aménagement de la densité du peuplement SD/2. Une analyse de régression a montré que la concentration en C, N, NH_{4+} et NO_{3-} expliquait la plus grande partie de la variation alors que les variables du peuplement et de la station y contribuaient le moins. Les résultats démontrent que des applications multiples d'urée produisent des augmentations significatives du volume total, mais que les effets d'applications successives diminuent avec le temps.

Sullivan, T.P., Sullivan, D.S., Lindgren, P.M.F., and Ransome, D.B. 2006. Long-term responses of ecosystem components to stand thinning in young lodgepole pine forest: III. Growth of crop trees and coniferous stand structure. *Forest Ecology and Management* **228**(1–3): 69–81.

Enhanced growth of crop trees and development of late-seral structural characteristics in second-growth stands in temperate and boreal forest zones could be achieved by silvicultural practices such as pre-commercial thinning (PCT). This study was designed to test the hypotheses that large-scale stand thinning, at a 15-year period after PCT, would enhance: (i) productivity and structural features (crown volume, diameter, height, and volume growth of lodgepole pine (*Pinus contorta*) crop trees); and (ii) coniferous stand structure (abundance, species diversity, and structural diversity of coniferous tree layers). Replicate study areas were located near Penticton, Kamloops, and Prince George in south-central British Columbia, Canada. Each study area had three stands thinned to densities of ~500 stems/ha (low), ~1000 stems/ha (medium), and ~2000 stems/ha (high), with an unthinned young pine and old-growth pine stand for comparison.

An overall analysis of tree growth in thinned stands, across these regional replicates, indicated that lodgepole pine grew significantly faster in mean diameter in the low- than either of the medium- or high-density stands. There was no difference in mean height growth among stand densities over the 15-year period since PCT. Mean tree volume increment was significantly higher in the low-density than in the high-density stands. Mean stand volume increment (m^3/ha) was similar in the medium-density (108.53) and high-density (132.51) stands, both of which were significantly higher than the low-density stands (72.88). Mean crown volume of crop trees was significantly greater in the low-density (52.8 m^3) and medium-density (42.9 m^3) stands than in the high-density (27.8 m^3), unthinned (11.7 m^3), or old-growth stands (30.9 m^3 pine only). This measure of crown size was similar among pine trees in the low-density, medium-density, and all conifers (43.2 m^3) in the old-growth stands. Other measurements of crown architecture followed this same pattern. Mean densities of understory trees were similar among stands for height classes up to 3 m. Mean species diversity and structural diversity of coniferous tree layers were highest in the low- and medium-density stands than in other treatment stands. Our results support the hypotheses that PCT enhances productivity (diameter and volume growth, but not height growth) and structural features (crown architecture) of young lodgepole pine, as well as diversity of coniferous tree layers in thinned stands. Accelerated development of some structural features of late-seral forest appeared in our young managed stands.

Sutton, A., and Tardif, J. 2005. Distribution and anatomical characteristics of white rings in *Populus tremuloides*. *IAWA Journal* **26**(2): 221–238.

'White rings' have been reported to occur within trembling aspen (*Populus tremuloides* Michx.) during years of intense early defoliation by the forest tent caterpillar (*Malacosoma disstria* Hbn.). This study was undertaken to 1) assess the distribution of white rings within trembling aspen stems and 2) to quantify the anatomical differences between white rings and the 'normal' rings formed in the previous year. Both stem analysis and image analysis were used. Several cross sections from six trees were dated and the presence of white rings on each disc was recorded. The development of white rings from the base up to about 70% of stem height was found to be uniform. Results from the comparison of eleven white and normal rings indicated that white rings were narrower and less dense than normal rings. The anatomical variable with the most discriminating power was average fiber wall thickness. White rings have smaller fiber diameter with little secondary cell wall thickening resulting in a higher proportion of fiber lumen. Possible mechanisms involved in the formation of white rings are discussed. It is speculated that defoliation affects the growth hormone complex inducing earlier cessation of xylem growth and reallocation of reserves to the production of new foliage. The occurrence of white rings in many diffuse-porous species stresses the potential for identification of periods of intense defoliation episodes. Increased interest in the dendroecology of diffuse-porous species may confirm their widespread occurrence.

Sutton, R.F., and Weldon, T.P. 2003. White spruce establishment in two boreal Ontario mixedwoods: 13-year results. *The Forestry Chronicle* **79**(1): 127–131.

An experiment to investigate techniques for establishing white spruce (*Picea glauca* (Moench) Voss) in boreal Ontario mixedwood was begun in 1985 in Oates Twp. Eight 25-tree plots were established in each of nine treatments: three mechanical site preparation treatments (none, disk-trenching, and toothed-blading) in combination with three kinds of chemical weed control (none, Velpar L® at the time of planting, and Vision® during the second growing season). The experiment was repeated the following year in the adjacent township of Oswald. The mechanical treatments were applied as planned, but the herbicide treatments deviated somewhat from the plan. Fifth-year results were reported in this journal in 1995. In the eighth growing season, a ground-spray release treatment with Vision® was applied to four randomly selected 25-tree plots in each original treatment. Performance of white spruce after 13 growing seasons was significantly influenced by site preparation: survival averaged 65 and 79% without release in the blading and trenching treatments, respectively, and 22% in the untreated control; with release, survival averaged 74 and 80% in the blading and trenching treatments, respectively, and 24% in the untreated control. Growth was greatest in the bladed treatment, poorest by far in the untreated control. The ineffectiveness of herbicides in these experiments is surprising in view of successes elsewhere. The modest response to release was significant for 13th-year increment.

Une étude pour évaluer les techniques d'établissement de l'épinette blanche (*Picea glauca* [Moench] Voss) dans les forêts mélangées du Nord de l'Ontario a débuté en 1985 dans le canton d'Oates. Huit parcelles de 25 arbres ont été établies dans chacun des neuf traitements : trois traitements mécaniques de préparation du terrain (pas de traitement, scarifiage par sillons et coupe à la cisaille dentée) combinés avec trois traitements chimiques de contrôle de la végétation indésirable (aucun traitement, Velpar L® au moment de la plantation, et Vision® au cours de la deuxième saison de croissance. L'étude a été répétée l'année suivante dans le canton adjacent d'Oswald. Les traitements mécaniques ont été réalisés tel que prévu, mais les traitements de phytocides ont quelque peu dévié du plan. Les résultats après cinq ans ont été présentés dans cette revue en 1995. Au cours de huitième année de croissance, un traitement de dégagement par pulvérisation terrestre de Vision® a été réalisé dans quatre parcelles de 25 arbres choisies au hasard dans chacun des traitements originaux. La performance de l'épinette blanche après 13 années de croissance a été significativement influencée par la préparation du terrain: le taux de survie était en moyenne de 65 et de 79 % sans dégagement dans les traitements à la cisaille et de scarifiage par sillon, respectivement, et de 22 % pour le témoin sans traitement; avec dégagement, le taux de survie était en moyenne de 74 et de 80 % dans les traitements à la cisaille et de scarifiage par sillon, respectivement, et de 24 % dans le témoin sans traitement. La croissance a été la plus importante pour le traitement par cisaille, et de loin la plus faible dans les parcelles témoins sans traitement. L'inefficacité des phytocides dans ces essais est surprenante lorsqu'on considère les succès obtenus ailleurs. La réponse modeste au dégagement a été significative pour l'accroissement de la treizième année.

Swift, D. E., Penner, M., Gagnon, R., and Knox, J. 2007. A stand density management diagram for spruce–balsam fir mixtures in New Brunswick. *The Forestry Chronicle* **83**(2): 187–197.

Balsam fir (*Abies balsamea* (L.) Mill.), red spruce (*Picea rubens* Sarg.), black spruce (*P. mariana* (Mill.) BSP), and white spruce (*P. glauca* (Moench) Voss) often form mixed stands throughout northeastern North America. After harvesting operations or natural disturbances, the resulting natural regeneration may require thinning prescriptions to achieve the desired future stand structure and associated forest products. Stand density management diagrams (SDMDs) can assist the forest manager in examining potential yield implications of stand density management decisions. Data from New Brunswick, Nova Scotia, and Quebec indicate a single SDMD is not appropriate for mixtures of balsam fir and spruce (red and black). The maximum size density line is flatter for mixtures than for pure species stands and the quadratic mean diameter isolines are affected by the species composition. The top height isolines are independent of species composition. The results indicate the SDMD for spruce–balsam fir mixtures needs to be dynamic, incorporating the species proportions. The SDMD has been incorporated into software that prompts the user for the balsam fir fraction and generates the appropriate SDMD.

Le sapin baumier (*Abies balsamea* (L.) Mill.), l'épinette rouge (*Picea rubens* Sarg.), l'épinette noire (*P. mariana* (Mill.) BSP) et l'épinette blanche (*P. glauca* (Moench) Voss) constituent souvent des peuplements mélangés dans le nord-est de l'Amérique du Nord. À la suite de l'exploitation ou d'une perturbation naturelle, la régénération naturelle résultante peut nécessiter des prescriptions d'éclaircie afin d'atteindre la structure désirée de peuplement dans le futur ainsi que pour obtenir les produits forestiers qui y sont associés. Les schémas d'aménagement de la densité des peuplements (SADP) peuvent aider un gestionnaire forestier en examinant les implications potentielles au niveau du rendement suite à des décisions d'aménagement de la densité du peuplement. Les données en provenance du Nouveau-Brunswick, de la Nouvelle Écosse et du Québec indiquent qu'un schéma unique n'est pas approprié pour les peuplements mélangés de sapin baumier et d'épinette (rouge et noire). La courbe de densité maximale est plus plate dans le cas des peuplements mélangés que dans le cas des peuplements purs et les isolignes de la moyenne quadratique des diamètres dépendent de la composition en espèces. Les isolignes de la hauteur maximale sont indépendantes de la composition en espèces. Les résultats indiquent que le SADP pour les peuplements mélangés de sapin et d'épinette doit être dynamique et tenir compte des proportions des espèces. Le SADP fait partie d'un logiciel qui souligne à l'utilisateur la proportion de sapin baumier et génère le schéma adéquat.

Syta, D.E., Curtis, K.C., Gasbarro, A.F., and Sampson, G.R. 1995. A mechanical evaluation of Alaska white spruce. *Forest Products Journal* **45**(2): 78–81.

The mechanical properties of Alaska white spruce were tested and the results are reported and compared to similar results for white spruce harvested from the contiguous United States. The reported mechanical properties were obtained using small clear specimens, tested in accordance with the requirements of ASTM D 143. Allowable design values for Alaskan white spruce were developed from these data using ASTM D 245 techniques as if the material were graded to the standards of the Northeastern Lumber Manufacturers Association and the Western Wood Products Association. Data from this testing program are shown to possess relatively low coefficients of variation with respect to other such published data sets for small, clear specimen testing. It is believed that the low coefficient of variation is due to the state–of–the-art electronic testing equipment used in this testing program.

Taylor, A.M., Gartner, B.L., and Morrell, J.J. 2002. Heartwood formation and natural durability—a review. *Wood and Fiber Science* **34**(4): 587–611.

This paper reviews recent literature on the formation of heartwood and on the components that affect natural durability. It includes discussions about the function of heartwood in living trees, factors influencing the natural durability of heartwood, the process of heartwood formation, and the variations in heartwood quantity and quality. Heartwood formation is a regular occurrence in tree stems, and heartwood may have many different properties from sapwood, including natural decay resistance. A greater understanding of the heartwood formation process could allow control of heartwood production. Recent research involving enzymatic analyses have provided valuable insight into the biochemical processes involved in heartwood formation. Further study of the role natural durability plays in living trees would help to bring together many of the disparate strands of research relating to heartwood.

Taylor, A.M., Gartner, B.L., and Morrell, J.J. 2003. Co-incident variations in growth rate and heartwood extractive concentration in Douglas-Fir. *Forest Ecology and Management* **186**(1–3): 257–260.

Extractives can have a major impact on the properties of heartwood; however, our understanding of the process of heartwood formation and extractives production is limited and there are few data on how environment affects heartwood extractive content. This study assessed the relationship between growth ring width and extractive content of heartwood in Douglas-fir (*Pseudotsuga menziesii* [Mirbel] Franco) trees. The radial growth rates of the sampled trees were variable over their 53–61 years, in part, because of recent stand thinning treatment. The year that each heartwood increment was formed was estimated by assuming that the trees maintained the same number of growth rings of sapwood in the past as they had at the time of sampling. Growth ring width increased after the recent thinning and there was an associated increase in the extractive content of the heartwood estimated to have been formed at the same time. In addition, there appeared to be a rough correlation between growth ring width and extractive content in the time before the thinning. These results suggest that silvicultural treatments that affect growth rate may affect wood durability in Douglas-fir.

Taylor, F.W., Wang, E.I.C., Yanchuk, A., and Micko, M.M. 1982. Specific gravity and tracheid length variation of white spruce in Alberta. *Canadian Journal of Forest Research* **12**(3): 561–566.

Specific gravity and tracheid lengths were measured for increment cores from 10 trees in each of four selected white spruce (*Picea glauca* (Moench) Voss) stands in Alberta. The data show large specific gravity differences among sample stands and from tree to tree within stands. Longer tracheids were found in mature wood of trees grown in the more northern stands sampled. A few trees were intensively examined to determine the variation of properties within the stem. The complex variation patterns from pith to bark and stump to crown are reported with comments on the importance of these variation patterns to breeding programs for the improvement of the wood properties. A somewhat unusual finding was that white spruce produces wood in top logs that is of equal or greater specific gravity and tracheid length than wood produced in butt logs.

On a mesuré la densité et la longueur de trachéides dans des barrettes de sondage prélevées chez 10 arbres de chacun de quatre peuplements choisis d'épinette blanche (*Picea glauca* (Moench) Voss), en Alberta. Les mesures montrent des différences importantes de densité entre les peuplements étudiés et entre les arbres d'un même peuplement. On a trouvé des trachéides plus longues dans le bois âgé des arbres croissant dans les peuplements échantillonnés les plus nordiques. Quelques arbres furent l'objet d'examen particulier en vue de déterminer la variation des propriétés à l'intérieur d'une même tige. Les auteurs rapportent des exemples de changement complexe du coeur à l'écorce et de la souche à la cime; ils s'accompagnent de commentaires sur l'importance de ces changements dans des programmes de croisement génétique pour l'amélioration des propriétés du bois. De façon quelque peu exceptionnelle, on a trouvé que l'épinette blanche produit dans les billes du sommet d'un arbre, du bois de densité et des trachéides de longueur égales ou supérieures au bois produit dans les billes de souche.

Thor, E., and Barnett, P.E. 1974. Taxonomy of *Abies* in the southern Appalachians: variation in balsam monoterpenes and wood properties. *Forest Science* **20**(1): 32–40.

Analysis of terpenes found in the bark blisters of south appalachian *Abies* were used to determine variations in the species. Variations were found among balsam, Fraser, and intermediate fir. No evidence was found to support the theory that intermediate fir is a hybrid. It is suggested that the scattered fir are the result of a once continuous fir forest in this region, and that only one species of fir exists with three varieties (balsam, Fraser, intermediate). *(Abstract prepared by compilers.)*

Timell, T.E. 1973. Studies on opposite wood in conifers. Part 1: Chemical composition. *Wood Science and Technology* **7**(1):1–5.

Opposite wood, normal side wood and compression wood were isolated from leaning stems of *Abies balsamea, Larix laricina, Picea mariana, Pinus resinosa* and *Tsuga canadensis* and were subjected to analysis for lignin and relative carbohydrate composition. There were no statistically significant differences between the data obtained for opposite wood and side wood. Contrary to some earlier reports, opposite wood has exactly the same content of lignin, cellulose and hemicellulose as has corresponding normal wood.

Tong, Q.J., and Zhang, S.Y. 2005. Impact of initial spacing and precommercial thinning on jack pine tree growth and stem quality. *The Forestry Chronicle* **81**(3): 418–428.

The objective of this paper was to investigate the impact of initial spacing and pre-commercial thinning (PCT) on tree growth, characteristics and stem quality in plantation-grown jack pine (*Pinus banksiana* Lamb.) after 58 years of growth. Four spacings including three initial spacings without PCT treatment, i.e., 1.52 x 1.52 m (5 x 5 ft), 2.13 x 2.13 m (7 x 7 ft) and 2.74 x 2.74 m (9 x 9 ft) and one initial spacing with PCT treatment (5 x 5 ft thinned to 7 x 7 ft at age 14), were chosen to analyze diameter at breast height (DBH) distribution, survival, and various tree and stem quality characteristics (e.g., DBH, total tree height, stem volume, crown size, branch, taper, sweep and wobbling). Tree mortality during the first 25 growth years was quite low for all four spacings, while after 25 years, survival for the four spacings rapidly declined. The decrease in survival for spacing 5 x 5 was the steepest, followed by spacings 7 x 7, 9 x 9 and finally the PCT-treated stand. DBH distributions for all four spacings were significantly different from each other, and five years after PCT, the 5 x 5 to 7 x 7 spacings had a similar DBH distribution to that of the constant 7 x 7 spacing. Mean DBHs differed significantly among the initial spacings. The 5 x 5 spacing produced significantly smaller trees than did the other three spacings through the years, and the 9 x 9 spacing produced significantly larger trees. PCT had positive effects on DBH growth, and yielded longer merchantable stems and better stem quality. PCT had little effect on crown development. Initial spacing significantly affected diameter growth, crown width and branch development, commercial stem length and volume, stem taper and stem deformation. Narrower spacing produced smaller but better quality stems. Spacing 7 x 7 had the worst stem quality in terms of overall sweep and wave-like transversal deformation (wobbling). A narrow initial spacing followed by a PCT treatment may provide a compromise solution for both tree growth and stem quality.

L'objectif de cet article était d'étudier l'incidence de l'espacement initial et de l'éclaircie précommerciale (EPC) sur la croissance des arbres, les caractéristiques et la qualité des tiges de pin gris (*Pinus banksiana* Lamb.) issu de plantation après 58 ans de croissance. Quatre espacements comprenant trois espacements initiaux sans traitement d'EPC, c'est-à-dire, 1,52 m x 1,52 m (5 pieds x 5 pieds), 2,13 m x 2,13 m (7 pieds x 7 pieds) et 2,74 m x 2,74 m (9 pieds x 9 pieds) et un espacement initial suivi d'une EPC (5 x 5 éclaircis à 7 x 7 à 14 ans) ont été retenus pour étudier la distribution du diamètre à hauteur de poitrine (dhp), le taux de survie et les différentes caractéristiques de la qualité des arbres et des tiges (par ex., le dhp, la hauteur totale de l'arbre, le diamètre de la cime, les branches, le défilement, la courbure et le balancement). La mortalité des tiges au cours des 25 premières années de croissance a été très faible dans le cas des quatre espacements, tandis qu'après 25 ans, la survie des tiges de ces quatre espacements a décliné rapidement. La chute de la survie dans le cas de l'espacement de 5 x 5 a été la plus prononcée, suivie des espacements 7 x 7, 9 x 9 et finalement par le peuplement traité par EPC. La distribution des dhp pour les quatre espacements était significativement différente les unes des autres et cinq ans après l'EPC, l'espacement de 5 x 5 éclaircis à 7 x 7 démontrait une distribution des dph semblable à l'espacement constant de 7 x 7. Le dhp moyen variait de façon significative selon les espacements initiaux. L'espacement initial de 5 x 5 a engendré des arbres significativement plus petits que dans le cas des trois autres espacements au cours des ans et l'espacement 9 x 9 ont produit des arbres significativement plus gros. L'EPC a entraîné des effets positifs sur l'augmentation du dhp et a produit des tiges marchandes plus longues et de meilleure qualité. L'EPC a eu peu d'effet sur la croissance de la cime. L'espacement initial a eu une incidence significative sur la croissance en diamètre, le diamètre de la cime et le développement des branches, sur la longueur de la tige marchande et son volume, sur le défilement de la tige et sa déformation transversale. Un espacement plus étroit a engendré des tiges plus petites mais, de meilleures qualités. L'espacement 7 x 7 a entraîné la pire qualité de tige en terme de courbure générale et de déformation transversale semblable à des ondulations. Un espacement initial étroit suivi d'une EPC pourrait constituer une solution de compromis tant au niveau de la croissance de l'arbre que de la qualité de la tige.

Tong, Q.J., and Zhang, S.Y. 2006. Modelling jack pine lumber value recovery in relation to tree characteristics using Optitek simulation. *Forest Products Journal* **56**(1): 66–72.

This study intended to link tree characteristics to lumber value yield in jack pine. A sample of 154 jack pine trees was measured and scanned, and then sawing was simulated using Optitek with optimized lumber value recovery (LVR) under two sawmill layouts. Simulation results suggest that LVR and total product value recovery (TPVR) increased with diameter at breast height (DBH), and the dimension mill yielded an average of 30 percent more lumber value from an individual tree than did the stud mill. Twelve models of various forms and variable combinations were selected to describe the LVR and TPVR in relation to tree characteristics. Stem volume was found to be the best predictor of LVR and TPVR produced from jack pine for both dimension and stud mills. The second-order polynomial model forms involving either DBH only or both DBH and tree height were able to explain over 95 percent of the total variance in the product value, while the power, exponential, and reciprocal forms did not exhibit statistical adequacy. Model validation using actual LVR data from a real stud mill indicated that three model forms, including two polynomial models involving either DBH exclusively or both DBH and tree height and the two-segmented simple linear model of stem volume, were able to accurately predict jack pine LVR using basic tree measurements or their derived forms from forest inventory data.

Tong, Q.J., and Zhang, S.Y. 2008. A correction model for estimating jack pine tree-level lumber recovery accurately using forest inventory data. *Forest Products Journal* **58**(3): 65–70.

This study proposes an approach to directly estimate lumber recovery from individual trees using forest inventory measurements. In this approach using tree measurements and taper equation, three-dimensional virtual stems were reconstructed for lumber recovery simulation, and simulated lumber recoveries from the virtual stems were compared with those from the real-shape stems to investigate the lumber recovery differences between the two types of stems. Lumber volume recoveries from jack pine real-shape stems were lower than those of the virtual stems due to stem deformations. There were no significant differences in the number of lumber pieces produced for each dimension (except for 1 by 3 board). The lumber volume recovery of the real-shape stems was linearly corrected with that of the virtual stems with an intercept coefficient not different from zero. As the linear models will allow for stem deformations to be taken into consideration when lumber recovery is estimated from the virtual stems reconstructed from forest inventory data, they will thus lead to a more accurate estimation of lumber recovery directly from forest inventory data.

Tong, Q.J., and Zhang, S.Y. 2008. Stem form variations in the natural stands of major commercial softwoods in eastern Canada. *Forest Ecology and Management* **256**(6): 1303–1310.

Stem form is often used as a sawlog assortment criterion and has an important effect on lumber recovery and mechanical properties. Based on 7018 stems collected from the natural stands in three regions in eastern Canada, this study quantified the variations in stem form (taper, sweep and eccentricity) for five major commercial softwood species, viz., jack pine (*Pinus banksiana* Lamb.), black spruce (*Picea mariana*), white spruce (*Picea glauca*), red spruce (*Picea rubens*) and balsam fir (*Abies balsamea*). The majority of the stems had a diameter at breast height (DBH) ranging from 10 to 32 cm and total tree height from 10 to 20 m. Stem taper and butt taper increased steadily from 0.38 to 1.75 cm/m and from 0.74 to 4.23 cm/m, respectively, with DBH increasing from 8 to 48 cm. Stem sweep and basal sweep ranged from 0.12 to 7.28 cm/m and from 0.12 to 9.85 cm/m, respectively, with mean values of 0.87 and 0.95 cm/m. There were no significant differences in stem sweep and basal sweep between DBH classes and both sweeps distributed over a wide range within DBH classes, species and regions. About 0.77% of the stems and 1.2% of the butt logs had seriously curved shapes (sweep >3.0 cm/m). Eccentricity (ratio of smaller diameter to larger diameter) at the breast height (0.96) was very close to 1. Balsam fir and jack pine had the best and worst stem forms, respectively, while stem forms in black spruce were in-between. Butt logs were most seriously curved in red spruce and most tapered in white spruce. Region C (mainly eastern Quebec and the Atlantic provinces) produced stems with smaller butt taper, basal sweep and stem sweep and larger eccentricity compared with other regions in eastern Canada. Overall stems in eastern Canada have a good stem form in terms of taper, sweep and eccentricity. The evaluation of stem form provides valuable timber quality information for the wood industry to optimize wood processing as well as for forest managers to define appropriate silvicultural regimes to improve stem form and economic value.

Tong, Q.J., Zhang, S.Y., and Thompson, M. 2005. Evaluation of growth response, stand value and financial return for pre-commercially thinned jack pine stands in northwestern Ontario. *Forest Ecology and Management* **209**(3): 225–235.

This study examined the impact of pre-commercial thinning (PCT) on tree growth, product recovery, stand value and financial return in jack pine stands in northwestern Ontario. Ten sites composed of both control and PCT stands representing various stand densities (2000–6000 trees/ha) and stand ages (26–36 years old) were selected for this study. Three thousand and eighty-two trees were measured for DBH and total height, and were reconstructed in 3-D using a taper equation for jack pine. The reconstructed virtual trees were then "sawn" using the software package Optitek to obtain optimal lumber value recovery, which was then used to determine total product value per tree and financial return. The quadratic mean DBHs of trees from the PCT stands were significantly larger than those from the control stands for all 10 sites. Six of ten PCT stands had significantly taller trees than did the controls of the same sites. With increasing stand density, tree DBH decreased in the control stands while no consistent pattern could be recognized for the DBH of the PCT stands. The increment in average DBH due to PCT increased with increasing thinning intensity. PCT reduced total tree volume per hectare, benefited merchantable stem volume per hectare, and improved the total lumber volume and value recovery per hectare. On average, the PCT stands produced approximately $2760 and $1770/ha (or 19.6 and 16.1%) more product value per hectare for the dimension mill and stud mill, respectively. PCT also significantly reduced logging and lumber conversion costs. Higher total product values and lower total costs resulted in higher benefit/cost (B/C) ratios in the PCT stands than did in the control stands. The increased financial return due to PCT is associated with the magnitude of difference in quadratic mean DBH resulting from PCT. The B/C ratio difference between control and PCT stands increased with increasing thinning intensity. Overall, this study indicates that PCT appears to be an economically viable silvicultural investment for jack pine stands in northwestern Ontario.

Tuskan, G.A. 1998. Short-rotation woody crop supply systems in the United States: what do we know and what do we need to know? *Biomass and Bioenergy* **14**(4):307–315.

Short-rotation woody crop (SRWC) supply systems have been proposed over the past 20 years as a means of rapidly producing biomass for fiber and fuels. The U.S. Department of Energy, through the Biofuels Feedstock Development Program and its partners, has selected model species, developed silvicultural systems and created genetically improved clonal planting stock for use in SRWC supply systems. Spacing, fertilizer and pesticide prescriptions have been developed for several species and regions within the U.S. Breeding and genetic improvement projects continue to identify and select plant materials which display increased productivity and pest resistance. Genetic transformation, somaclonal variation and marker-assisted selection are being used to supplement traditional breeding work. Harvesting and handling methods are currently relying on traditional combinations of existing equipment. Nevertheless, technical and environmental issues related to: (1) long-term use of fertilizers and irrigation; (2) deployment of clonal planting stock; and (3) development of customized harvesting equipment remain as unresolved issues related to further deployment and commercialization of SRWC systems. Overall determination of SRWC sustainability will require resolution of these issues.

Ukrainetz, N.K., Kang, K.Y., Aitken, S.N., Stoehr, M., and Mansfield, S.D. 2008. Heritability and phenotypic and genetic correlations of coastal Douglas-fir (*Pseudotsuga menziesii*) wood quality traits. *Canadian Journal of Forest Research* **38**(6): 1536–1546.

Genetic control and relationships among coastal Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco var. *menziesii*) growth and wood quality traits were assessed by estimating heritability and phenotypic and genetic correlations using 600 trees representing 15 full-sib families sampled from four progeny test sites. Heritability estimates ranged from 0.23 to 0.30 for growth traits, 0.19 for fibre coarseness, from 0.21 to 0.54 for wood density, from 0.16 to 0.97 for cell wall carbohydrates, and 0.79 and 0.91 for lignin content at two sites, Squamish River and Gold River, respectively. Glucose content, indicative of cell wall cellulose composition, and lignin were shown to be under strong genetic control, whereas fibre coarseness was shown to be under weak genetic control. Phenotypic correlations revealed that larger trees generally have longer fibres with higher fibre coarseness, lower density, lower carbohydrate content, a greater proportion of cell wall lignin, and higher microfibril angle. Genetic correlations and correlated response to selection suggest that breeding for height growth would result in a reduction in wood quality, whereas breeding for improved earlywood density in Douglas-fir would result in negligible reductions in volume and appears to be an ideal target for selecting for improved wood quality (density) while maintaining growth in the sample population.

Les auteurs ont étudié le contrôle génétique et les relations entre la croissance et les caractères de qualité du bois chez le douglas vert (*Pseudotsuga menziesii* (Mirb.) Franco var. *menziesii*), en estimant l'héritabilité et les corrélations phénotypiques et génétiques à partir de 600 arbres représentatifs de 15 familles biparentales échantillonnées dans un test de descendances établis dans quatre stations. L'héritabilité de la grossièreté des fibres a été estimée à 0,19 et elle variait de 0,23 à 0,30 pour les caractères de croissance, de 0,21 à 0,54 pour la densité du bois et de 0,16 à 0,97 pour les hydrates de carbone de la paroi cellulaire. Dans le cas du contenu en lignine, elle a été estimée à respectivement 0,79 et 0,91 dans les stations de Squamish River et de Gold River. Il s'avère que la lignine et le contenu en glucose, un indice de la composition en cellulose de la paroi cellulaire, sont soumis à un fort contrôle génétique, alors que la grossièreté des fibres est soumise à un faible contrôle génétique. Les corrélations phénotypiques ont révélé que les arbres de grande taille ont généralement des fibres plus longues et plus grossières, une plus faible densité du bois, un contenu plus faible en hydrates de carbone, une plus grande proportion de lignine dans la paroi cellulaire et un angle plus grand des microfibrilles. Les corrélations génétiques et la réponse corrélée à la sélection indiquent que les croisements pour améliorer la croissance en hauteur se traduiraient par une réduction de la qualité du bois, alors que les croisements pour améliorer la densité du bois juvénile chez le douglas vert se traduiraient par une réduction négligeable du volume. Cette dernière stratégie semble idéale pour améliorer la qualité du bois (densité) tout en maintenant les qualités de croissance dans la population échantillonnée.

USDA, Forest Service. 1972. *Proceedings of the Symposium on the Effect of Growth Acceleration on the Properties of Wood.* 10–11 November 1971. Forest Products Laboratory, Madison, Wisconsin. [online] URL: http://www.dtic.mil/cgi-bin/GetTRDoc?AD=AD740639&Location=U2&doc=GetTRDoc.pdf.

These conference proceedings contain a number of topics and papers including fiber morphology considerations in paper properties; influence of fertilization on wood and pulp properties of Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) ; effect of irrigation and fertilization on wood quality of young slash pine (*Pinus elliottii* Engelm.); effects of fertilization on stem, wood properties, and pulping characteristics of slash pine; response in growth and wood properties of American sycamore (*Platanus occidentalis* L.) to fertilization and thinning; detailed diameter at breast height density profiles of several trees from Douglas-fir fertilization and thinning plots; patterns of wood density distribution and growth rate in ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.); influence of irrigation and fertilization on growth and wood properties of quaking aspen (*Populus tremuloides* Michx.); effect of fertilizer on the growth rate and certain wood quality characteristics of sawlog red oak (*Quercus rubra* L.), yellow-poplar (*Liriodendron tulipifera* L.), and white ash (*Fraxinus americana* L.); related aspects of the morphology of loblolly pine (*Pinus taeda* L.) and papermaking; volumes, wood properties, and fiber dimensions of fast- and slow-grown spruce pine (*Pinus glabra* Walt.); wood properties of young loblolly and slash pines; the three-rings-per-inch dense southern pine (*Pinus* spp.); and a symposium summary.

Vahey, D.W., Zhu, J.Y., and Scott, C.T. 2007. Wood density and anatomical properties in suppressed-growth trees: comparison of two methods. *Wood and Fiber Science* **39**(3): 462–471.

Interest in the commercial value of small-diameter timber has led to testing core samples with SilviScan to characterize density and transverse fiber dimensions. Data showed that latewood density and tracheid diameter in suppressed-growth material can vary spatially on a scale comparable to the 50-µm resolution of the instrument used in our testing. An optical imaging method called Ring Profiler was developed to determine what effect SilviScan's resolution had on the measurements. A single suppressed-growth specimen of Douglas-fir was used to develop the method. Ring Profiler measurements of the specimen showed that SilviScan overestimated latewood tracheid radial diameters by 59% in growth rings averaging 200-µm width. In those same growth rings, SilviScan latewood density was found to be 19% too low. In all growth rings measured by Ring Profiler, latewood wall thicknesses were anisotropic. Radial and tangential values averaged 13% less than the isotropic wall thickness calculated from SilviScan data. Ring Profiler density measurement from binarized images of wood cross-sections was found to correlate well with SilviScan X-ray density ($r^2 = 0.907$); however, better images and an objective method for thresholding are needed for accuracy over a large sample space. With these improvements and automated scanning of samples, Ring Profiler could be an attractive, inexpensive complement to SilviScan.

van Buijtenen, J.P. 1997. Marker aided selection for wood quality. Pages 11–16 *in* S.Y. Zhang, R. Gosslin, and G. Chauret, editors. *Timber Management Toward Wood Quality and End-Product Value.* CTIA/IUFRO International Wood Quality Workshop, 8–22 August 1997, Quebec City, Quebec, Canada. Forintek, Ste-Foy, Quebec, Canada.

Marker-aided selection for wood quality is problematic as it is a form of indirect selection. A more intensive selection method (marker-only selection) is preferable economically. The author provides examples with different models. *(Abstract prepared by compilers.)*

van Cleve, K., and Zasada, J.C. 1976. Response of 70-year-old white spruce to thinning and fertilization in interior Alaska. *Canadian Journal of Forest Research* **6**(2): 145–152.

Applications of 112 kg/ha N as NH_4NO_3, 56 kg/ha P as treble superphosphate, and 112 kg/ha K as KCL in combination with thinning of 61% of initial basal area increased diameter increment 3.6 times over the control within one summer. Fertilizer was applied annually at these rates for 5 years to maintain high levels of tree nutrition and accurately assess growth response. After 5 years, growth increment continued. Thinning alone resulted in significant increases in soil moisture content and moderate increases in soil temperature. Change in soil temperature and moisture regime did not appear to affect tree nutrition. For 70-year-old white spruce (*Picea glauca* (Moench) Voss) growing on upland sites, a combination of both thinning and fertilization appears necessary to obtain maximum growth response.

Des applications d'engrais (NH_4NO_3, 112 kg/ha N; superphosphate triple, 56 kg/ha P; KCL, 112 kg/ha K) alliés à une éclaircie de 61% de la surface terrière initiale, ont provoqué en un été une augmentation de l'accroissement en diamètre des tiges de 3.6 fois celui des parcelles témoins. Les engrais ont été appliqués à ces taux chaque année durant 5 ans afin de maintenir un haut niveau de nutrition et de permettre une juste appréciation des réponses de croissance. Après 5 ans, l'augmentation de croissance se poursuivait encore. L'éclaircie seule s'est traduite par une augmentation significative dans la teneur d'humidité du sol et par une élévation modérée de la température du sol. Les changements dans la température et le régime d'humidité du sol ne semblent pas avoir affecté la nutrition des arbres. Pour *Picea glauca* croissant sur stations bien drainées, les traitements combinés d'éclaircie et de fertilisation semblent nécessaire à l'obtention d'une forte réponse de croissance.

Vanninen, P., Härkönen, S., Enkenberg, J., and Mäkelä, A. 2006. PuMe—interactive learning environment employing the pipequal model for forest growth and wood quality. *New Zealand Journal of Forestry Science* **36**(2–3): 280–292.

Process-based models have advanced to a level which enables their utilization for evaluating forest management options, as well as their use in environmental education. To date, such applications are relatively rare, but they could be promoted by means of appropriate interactive and user-oriented interfaces for model simulation.

The PuMe-software has been constructed as an interactive tool for forestry studies at secondary and university levels. The objective was to build an interactive and user-oriented interface for running a forest growth model with either user-designed or pre-determined inputs of forest management options such as stocking densities, thinning practices, site fertilities, and fertiliser application. The PipeQual model was chosen as the growth simulator because of its versatility in predicting traditional forestry characteristics, stem structure (stem shape, knot zones, heartwood, and sapwood), biomass, and carbon balance.

The first version of PuMe is now in test-use in forestry education by universities and secondary schools, and by individual forest owners. However, it is applicable only to *Pinus sylvestris* L. (Scots pine) under a limited set of conditions. In an ongoing project, PuMe II, the software will be developed further by adding various new features: simulation of spruce growth, forest damage, fertilizer application, pruning, and more flexible thinning methods. Especially, a new module will be incorporated to allow for a more detailed visualization of stem properties (growth rings, wood density, fibre properties).

Vargas-Hernandez, J., and Adams, W.T. 1991. Genetic variation of wood density components in young coastal Douglas-fir: implications for tree breeding. *Canadian Journal of Forest Research* **21**(12): 1801–1807.

The genetic control of wood density components (earlywood density, latewood density, and latewood proportion) and their relationships with overall density in coastal Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco var. *menziesii*) were examined to assess the usefulness of this information in breeding for wood density. The genetic relationships of wood density with intraring density variation and bole volume growth were also investigated. Increment cores were taken at breast height from 15-year-old trees of 60 open-pollinated families. Averages across each core for overall wood density, its components, and intraring density variation were determined by using X-ray densitometry. Bole volume at age 15 for the same trees was derived from tree height and diameter at breast height measurements. Although wood density components varied significantly among families and were under moderate genetic control (individual-tree heritability (h_i^2) > 0.24), none had a higher heritability than overall density ($h_i^2 = 0.59$). Density components had strong genetic correlations with overall density ($r \geq 0.74$) but were also strongly related among themselves ($0.57 \leq r \leq 0.92$). Thus, density components have limited value in improving the efficiency of selection for overall density. Overall density was positively correlated with intraring density variation ($r = 0.72$) and negatively correlated with bole volume ($r = -0.52$). Comparison of several selection indices incorporating wood density and one or more growth traits, however, showed that it is possible to obtain substantial gains in bole volume without loss in (or even with a modest increase in) wood density. By restricting the response in wood density, the change in intraring density variation can also be limited.

Le contrôle génétique des composantes de la densité du bois (densité du bois de printemps, densité du bois d'été et proportion et bois d'été) et leurs relations avec la densité globale ont été étudiés chez le sapin de Douglas de la côte (*Pseudotsuga menziesii* (Mirb.) Franco var. *menziesii*), afin de vérifier l'utilité de ce type d'information pour l'amélioration quant à la densité du bois. Les relations génétiques de la densité du bois avec la variation de densité au sein d'un même cerne annuel et la croissance en volume de la tige ont aussi été étudiées. Des carottes ont été prélevées à hauteur de poitrine chez des arbres âgés de 15 ans représentatifs de 60 familles issues de pollinisation libre. Pour chaque carotte, des moyennes de densité générale, des composantes de cette densité et des variations de densité intracerne ont été obtenues par densitométrie aux rayons X. Pour les mêmes arbres, le volume de la tige à 15 ans fut calculé à partir des mesures de leur hauteur et de leur diamètre à hauteur de poitrine. Quoique les composantes de la densité du bois montraient une variation significative parmi les familles et se retrouvaient sous contrôle génétique modéré (héritabilité individuelle au niveau de l'arbre (h_i^2) > 0,24), aucune de ces dernières n'affichait d'héritabilité supérieure à celle de la densité globale (h_i^2 = 0,59). Les composantes de la densité montraient de fortes corrélations génétiques avec la densité globale ($r \geq 0{,}74$) et étaient aussi fortement corrélées entre elles ($0{,}57 \leq r \leq 0{,}92$). Les composantes de la densité ont donc une valeur limitée quant à améliorer l'efficacité de la sélection pour la densité globale. La densité globale était positivement corrélée avec la variation de densité intracerne (*r* = 0,72) et négativement corrélée avec le volume de la tige (*r* = –0,52). Toutefois, la comparaison de quelques indices de sélection incorporant la densité du bois et un ou plusieurs caractères de croissance a montré qu'il était possible d'obtenir des gains intéressants en volume de la tige sans perte (ou même avec une augmentation modérée) en densité du bois. En restreignant la réponse en densité du bois, le changement en variation de densité intracerne peut aussi être limité.

Villeneuve, M., Morgenstern, E.K., and Sebastian, L.P. 1987. Variation patterns and age relationships of wood density in families of jack pine and black spruce. *Canadian Journal of Forest Research* **17**(10): 1219–1222.

Increment cores were analyzed in the laboratory to determine variations in wood density from pith to bark in plantations of black spruce (*Picea mariana* (Mill.) B.S.P.) and jack pine (*Pinus banksiana* Lamb.). The sample consisted of 12 open-pollinated families of 20-year-old black spruce and 10 of 22-year-old jack pine. The prediction of future wood density appears possible at ages 6–7 in jack pine and 12–15 in black spruce. For jack pine, narrow-sense heritabilities ranged from 0.49 to 0.93 on an individual tree basis and from 0.55–0.73 on a family basis.

Des carottes de sondage ont été analysées en laboratoire pour déterminer les variations de densité du bois depuis la moelle jusqu'à l'écorce dans des plantations d'épinettes noires (*Picea mariana* (Mill.) B.S.P.) et de pins gris (*Pinus banksiana* Lamb.). L'échantillon était constitué de 12 demi-fratries d'épinettes noires âgées de 20 ans et 10 de pins gris âgés de 22 ans. Il semble possible de prédire la densité future du bois aux environs de 6 à 7 ans pour le pin gris et de 12 à 15 ans pour l'épinette noire. Pour le pin gris, les héritabilités au sens restreint varient de 0,49 à 0,93 en fonction des individus et de 0,55 à 0,73 en fonction des familles.

Wahlgren, H.E., Baker, G., Maeglin, R.R., and Hart, A.C. 1995. *Survey of Specific Gravity of Eight Maine Conifers.* United States Department of Agriculture, Forest Service, Forest Products Laboratory, Madison, Wisconsin, USA.

The Maine Wood Density Survey was undertaken to evaluate the specific gravity of eight coniferous species in Maine. The survey was divided into two parts: 1) To develop equations for estimating tree specific gravity from increment core specific gravity. This was completed and published as Forest Service Research paper FPL 61. 2) To evaluate the specific gravity of the resource by mass sampling established growth plots in Maine. The results are reported in this paper. Summarization of specific gravity by diameter classes within species showed no trends but has characterized average core and tree specific gravity and their respective ranges for the eight coniferous species. This comparison of specific gravity data should be of help to those using and studying the species involved. Plottings of the distribution of tree specific gravity indicates a normal distribution, whereas similar treatment of data for diameter at breast height shows extremely skewed results. Balsam fir and red spruce data separated by age class and tree specific gravity was plotted over diameter at breast height. The result for red spruce was a clear family of curves with age. However, for balsam fir, only the spruce–fir region data responded similarly. The southern and combined data were highly inconsistent. Analysis of groupings by stand type, height, and density (crown cover) within species suggested no relationships with specific gravity. *(Source: U. S. Department of Agriculture, Forest Service.)*

Wahlgren, H.E., Hart, A.C., and Maeglin, R.R. 1966. *Estimating Tree Specific Gravity of Maine Conifers.* Research Paper FPL 61. United States Department of Agriculture, Forest Service, Forest Products Laboratory, Madison, Wisconsin, USA.

The data have shown varying degrees of precision in the single core-to-tree specific gravity relations for eight Maine conifers. The proportion of variation in tree specific gravity associated with the regression on single core specific gravity ranged from 27 percent in eastern hemlock to 56 percent in tamarack. Based on the assumption that a reduction of 0.002 in the standard deviation from regression represents a worthwhile gain in precision, the following conclusions were reached: 1. Comparisons of single-core sampling with two-core sampling favors single-core for seven of the eight species investigated. The one exception was balsam fir. 2. Multiple regression equations involving two independent variables result in added precision for red pine, tamarack, and hemlock. 3. No added improvement was indicated in any three- or four-variable regression. Plottings of cross section specific gravities at various heights showed patterns that appear to be characteristic of the species. The large between-tree variation in specific gravity at all heights in the stem indicates why predicting tree specific gravity with a high degree of precision may be difficult. *(Source: Department of Agriculture Forest Service, Forest Service.)*

Wan, H., Yang, D.Q., and Zhang, C. 2006. Impact of biological incising to improve phenolic resin retention and hardness of various wood species. *Forest Products Journal* **56**(4): 61–67.

In this study, aspen, yellow birch and sugar maple samples were treated with four different fungi for 2, 4 and 8 weeks, for biological incising to improve wood permeability. The four fungal species were *Ophiostoma piceae* (wood staining fungus), *Gliocladium roseum* (mold fungus), *Trametes versicolor*, and *Irpex lacteus* (white-rot fungi). The fungal bio-incised wood samples and control samples not exposed to fungi were then impregnated with a low molecular weight phenol-formaldehyde (PF) resin and cured in an oven to improve wood hardness. The treated wood samples were tested for hardness according to European standard EN 1534. Generally, bio-incising improved the PF resin uptake in wood, which improved wood hardness. The impact of bio-incising on the hardness of PF resin-treated wood samples was also related to wood species, bio-incising time, and fungi species. Microscopic examination of aspen samples treated with *T. versicolor* showed that fungal hyphae had moved from cell to cell through the pits. Such bio-incising behavior seems to improve wood permeability by leading PF resin to pass through the pit pairs between neighboring cells. Since the hardness of bio-incised wood samples was not always improved, the application of bio-incising treatment to improve the hardness of resin-impregnated wood should be based on the wood species and fungal type. The bio-incising time period is also very crucial.

Wang, E.I.C., and Micko, M.M. 1984. Wood quality of white spruce from north central Alberta. *Canadian Journal of Forest Research* **14**(2): 181–185.

Wood specific gravity and tracheid lengths were measured from increment cores and discs of 10 white spruce (*Picea glauca* (Moench) Voss) trees from each of four stands in the Slave Lake forest of north central Alberta. Such measurements were used to indicate the variation of wood properties among trees and within individual stems. The specific gravity of white spruce grown in the Slave Lake area was somewhat greater than that found in the Edson and Footner Lake areas reported earlier. Tracheid length was comparable to that found in trees from Footner Lake and longer than that from the Edson trees on the same age basis. Within a tree, growth rate affected wood specific gravity negatively. However, no correlation was evident between these parameters among trees. Seven trees were examined intensively to determine the variation of properties within the stem. The complex variation patterns from pith-to-bark and stump-to-crown are reported. Contrary to the Edson and Footner Lake trees, a very high corewood specific gravity was not observed. Tracheid length increased from pith to the periphery and from stump to crown.

La densité du bois et la longueur des trachéides du bois d'épinette blanche (*Picea glauca* (Moench) Voss) ont été mesurées à partir de barrettes de sondage et de disques extraits de 10 arbres dans chacun des quatre peuplements situés dans la forêt du Lac des Esclaves au centre-Nord de l'Alberta. De telles mesures ont été utilisées à titre d'indicateur de la variation des propriétés du bois entre les arbres et à l'intérieur des arbres eux-mêmes. La densité des arbres d'épinette blanche croissant dans la région du Lac des Esclaves s'est avérée quelque peu supérieure à celle observée dans les régions d'Edson et du Lac Footner telles que rapportées précédemment. La longueur des trachéides s'est avérée comparable à celle de la régions du Lac Footner et supérieure à celle observée chez les arbres de la région d'Edson sur la base d'un âge comparable. À l'intérieur d'un arbre, le taux de croissance influe négativement sur la densité. Toutefois, aucune corrélation entre ces paramètres n'a pu être mise en évidence entre les arbres. Sept arbres ont été mesurés en détail de façon à déterminer les variations à l'intérieur de la tige. On a pu rapporter des modes complexes de variations de la moelle vers l'écorce et depuis la base vers le houppier. En opposition aux arbres provenant d'Edson et du Lac Footner, une densité élevée du bois de jeunesse n'a pas pu être observée. On a également observé un accroissement de la longueur des trachéides depuis la moelle vers la périphérie de l'arbre et depuis la souche vers le houppier.

Wang, E.I.C., Micko, M.M., and Mueller, T. 1985. Drainage effect on growth and wood quality of some bog grown trees in Alberta. *The Forestry Chronicle* **61**(6): 489–493.

Growth rate, wood relative density and tracheid length variation were examined for three species: black spruce (*Picea mariana* (Mill.) B.S.P.), white spruce (*Picea glauca* (Moench) Voss), and tamarack (*Larix laricina* (Du Roi) K. Koch), from two drained wetland sites of north-central Alberta. Increased rates in radial and volume growths were noted for tamarack, white spruce, and to a lesser extent, black spruce. The increases were particularly remarkable in younger trees. Accompanying the rapid growth, wood relative density and tracheid length tend to decrease after drainage, at least for a period of several years. In certain trees, the marked decreases in wood relative density might affect the end use of the trees.

Le taux de croissance, la densité relative du bois et les variations de longueur des trachéides ont été étudiés pour trois espèces: l'épinette noir (*Picea mariana* (Mill.) B.S.P.); l'épinette blanche (*Picea glauca* (Moench) Voss); et le mélèze (*Larix laricina* (Du Roi) K. Koch), provenant de deux tourbières humides drainées du centre nord de l'Alberta. Un accroissement du taux de croissance radiale et en volume fut remarqué chez le mélèze, l'épinette blanche et à un moindre niveau chez l'épinette noire. L'accroissement était particulièrement remarquable chez les jeunes arbres. Parallèlement à la croissance rapide, la densité du bois et la longueur des trachéides tendent à diminuer après drainage, du moins pour quelques années. Chez certains sujets, une décroissance marquée dans la densité relative du bois peut différer l'utilisation finale de ces arbres.

Wang, H.H., Drummond, J.G., Reath, S.M., Hunt, K., and Watson, P.A. 2001. An improved fibril angle measurement method for wood fibres. *Wood Science and Technology* **34**(6): 493–503.

A rapid, reliable technique for the observation and measurement of the fibril angle in wood cell walls has been developed. Sonication in the presence of solutions of certain cobalt and copper salts (5%, wt/vol) was found to be most effective in facilitating fibril angle visualisation. Latewood fibre fibril angle, which previously had been difficult to measure, was also visible, though less frequently. This method has been successfully applied to a number of softwood species including coastal Douglas-fir whose prominent spiral thickenings make it difficult to determine the fibril angle by other methods. The method was also used to determine the fibril angle of some hardwood species as well as a non-woody material, flax straw. It can also be used to determine the microfibril angle of pulp fibres although this procedure is less convenient than with wood sections.

Wang, L., Payette, S., and Begin, Y. 2000. A quantitative definition of light rings in black spruce (*Picea mariana*) at the Arctic treeline in northern Quebec, Canada. *Arctic, Antarctic, and Alpine Research* **32**(3): 324–330.

Light rings in black spruce (*Picea mariana* [Mill.] B.S.P.) at the arctic treeline are characterized by pale-colored latewood made of a single or very few latewood cell layers with thin-walled cells. Their widespread occurrence and their high frequency greatly facilitate the cross-dating procedure in dendrochronological studies. In this study, black spruce tree-ring density and wood structure were analyzed for light ring characteristics along with the mechanism of their formation according to ambient temperature. Light rings were quantitatively categorized into three classes based on the maximum tree-ring density using a normalized standard distribution. A light-ring chronology was established according to this classification. The results indicate that the grade of light ring was positively related to the frequency of light rings obtained from visual light-ring chronologies. The following anatomic variables were examined: number of cell layers of latewood, number of cells of the whole ring, percentage of latewood in the total ring width, and mean latewood cell-wall thickness. Among these anatomic variables, the mean latewood cell-wall thickness represents the best quantitative descriptor of a typical light ring as recognized by optical examination. The main causal factors of light rings are insufficient length of the growing season or cool summers.

Wang, T., Aitken, S.N., Rozenberg, P., and Carlson, M.R. 1999. Selection for height growth and Pilodyn pin penetration in lodgepole pine effects on growth traits wood properties and their relationships. *Canadian Journal of Forest Research* **29**(4): 434–445.

The effects of selection using indices of height growth and wood density based on Pilodyn pin penetration (PIN) and the relationships among growth traits and wood properties were investigated in lodgepole pine (*Pinus contorta* Dougl. ex Loud. var. *latifolia* Engelm.). Four subpopulations were constructed by selecting 10 open-pollinated families in each of four categories: (i) fast height growth and high wood density, (ii) slow height growth and high density, (iii) fast height growth and low density, and (iv) slow height growth and low density. Eleven-year growth, PIN, and wood-density traits generated from X-ray densitometry were analyzed. We found that selection of subpopulations using indices of height and PIN resulted in significant differences among subpopulations in most growth and wood-density parameters. However, PIN underestimated the wood density of families with large diameter. Disk density was found to be moderately negatively correlated with diameter growth, weakly negatively correlated with stem volume, but not significantly correlated with height. Selection for latewood proportion to improve wood density in lodgepole pine is likely to result in a reduction in growth and biomass production; however, selection for total latewood volume or simply height has the potential to increase both growth and wood density.

Les effets de la sélection utilisant les indices de croissance en hauteur et de densité du bois basés sur la pénétration de la tige du pilodyne (PTP) et les relations entre les caractères de croissance et les propriétés du bois ont fait l'objet de cette étude chez le pin tordu latifolié (*Pinus contorta* Dougl. ex Loud. var. *latifolia* Engelm.). Quatre sous-populations ont été construites en sélectionnant 10 familles issues de pollinisation libre parmi chacune de ces quatre catégories : (i) croissance en hauteur rapide et densité du bois élevée, (ii) croissance en hauteur lente et densité élevée, (iii) croissance en hauteur rapide et densité faible et (iv) croissance en hauteur lente et densité faible. La croissance de 11 ans, la PTP et les caractères de densité du bois générés par densimétrie aux rayons X ont été analysés. Nous avons trouvé que la sélection des sous-populations utilisant les indices de hauteur et de PTP résulta en des différences significatives entre les sous-populations pour la plupart des paramètres de croissance et de densité du bois. Cependant, la PTP sous-estima la densité du bois des familles de fort diamètre. La densité des disques était modérément corrélée négativement à la croissance en diamètre et faiblement corrélée négativement au volume de la tige, mais pas corrélée significativement à la hauteur. La sélection sur la proportion de bois final pour améliorer la densité du bois du pin tordu latifolié risque de résulter en une baisse de la croissance et de la production de biomasse. Cependant, la sélection sur le volume total de bois final ou simplement la hauteur a le potentiel d'augmenter à la fois la croissance et la densité du bois.

Wang, T., Aitken, S.N., Rozenberg, P., and Millie, F. 2000. Selection for improved growth and wood density in lodgepole pine: effects on radial patterns of wood variation. *Wood and Fiber Science* **32**(4): 391–403.

Changes in growth and wood density traits were investigated across annual rings of 12-year-old trees from four selected subpopulations in lodgepole pine (*Pinus contorta* Dougl. Ex Loud var. *latifolia* Engelm) based on X-ray densitometry profile data. Four subpopulations were constructed based on height growth and wood density as follows: 1) fast growth and high wood density (FH); 2) slow growth and high density (SH); 3) fast growth and low density (FL); and 4) slow growth and low density (SL). Annual ring density was initially high, declined with age until age 10, and then plateaued. Significant differences among subpopulations were found for ring density, earlywood and latewood densities, ring width, earlywood width, latewood proportion, and earlywood width after age 6. Wood density decreased less from the pith to the bark in both overall and earlywood densities in the FH subpopulation, resulting in denser, more homogeneous wood than in other subpopulations. This suggests that it may be possible to increase wood density and homogeneity in juvenile wood of this species by selecting FH families. Overall ring density may be better improved by selecting for earlywood and latewood components separately. The earliest age at which families combining fast growth and high wood density can be accurately identified is about 7 years.

Wang, X.,Ross, R.J., Mattson, J.A., Erickson, J.R., Forsman, J.W., Geske, E.A., and Wehr, M.A. 2002. Nondestructive evaluation techniques for assessing modulus of elasticity and stiffness of small-diameter logs. *Forest Products Journal* **52**(2): 79–85.

Many of the forests in the United States have large areas that contain trees of small diameter, mixed species, and undefined quality. Because these areas are overstocked, they are at risk from attack by insects, disease, and uncontrollable wildfires. Therefore, it is essential to find cost-effective products for the fiber from these trees. A critical need is the development of nondestructive technologies for evaluating the potential quality of stems and logs obtained from trees in such ecosystems. Longitudinal stress wave and transverse vibration nondestructive evaluation (NDE) techniques are frequently used to assess the modulus of elasticity (MOE) of lumber. Strong correlations between MOE values obtained from these techniques and the static MOE of lumber have been shown to exist. The objective of this research was to investigate the use of these NDE techniques to evaluate the flexural stiffness and MOE of small-diameter logs. A total of 159 red pine and jack pine logs were obtained from northern Michigan in the United States and assessed nondestructively using longitudinal stress wave, transverse vibration, and static bending techniques. Statistical relationships between stiffness and MOE values obtained from each technique were then examined. Results of this study demonstrated that strong relationships exist between the log properties determined by longitudinal stress wave, transverse vibration, and static bending techniques. Longitudinal stress wave and transverse vibration techniques can be used to sort small-diameter logs with reasonable accuracy.

Wang, Y., Titus, S.J., and LeMay, V.M. 1998. Relationships between tree slenderness coefficients and tree or stand characteristics for major species in boreal mixedwood forests. *Canadian Journal of Forest Research* **28**(8): 1171–1183.

The slenderness coefficients of trees, defined as the ratio of total height to diameter at 1.3 m above ground, have been widely used as an index of the resistance of trees to windthrow. For many European coniferous species, slenderness coefficients have been intensively studied, but very little information is available for the tree species in boreal mixedwoods of Canada. By applying correlation analysis and graphical approaches to permanent sample plots data from Alberta, the relationships between slenderness coefficients and tree or stand variables were investigated for the five major species in boreal mixedwoods. Tree slenderness coefficients were found to be negatively correlated with tree diameter at breast height (DBH), height, crown length and age, but positively correlated with stand density level, species composition and site index values. For three coniferous species, the results were consistent with those found for European coniferous species in literature. However, for the two deciduous species, no similar studies were found for comparison. The graphical results indicated that about 50% of the sampled stands of the data had a slenderness coefficient over 100 and may be at high risk of windthrow. Models were also developed to predict slenderness coefficient values from (i) DBH only and (ii) DBH and stand variables combined. The negative decay function was found to be the best for this prediction purpose. Potential application of these models include selecting windfirm residual trees in a partial cutting and developing windthrow hazard rating systems.

Le facteur d'élancement des arbres, défini comme étant le rapport de la hauteur totale au dhp, a été largement utilisé comme un indice de la résistance de l'arbre au chablis. Pour plusieurs conifères européens, le facteur d'élancement a été intensivement étudié, mais très peu d'information est disponible pour les essences des forêts boréales mixtes au Canada. En appliquant l'analyse de corrélation et les approches graphiques aux données de placettes permanentes de l'Alberta, les relations entre le facteur d'élancement et les variables de l'arbre et du peuplement ont été étudiées pour les cinq principales essences des forêts boréales mixtes. Le facteur d'élancement est négativement corrélé au dhp, à la hauteur, à la longueur du houppier et à l'âge de l'arbre, mais positivement corrélé à la densité du peuplement, à la composition spécifique et à l'indice de qualité de station. Les résultats de trois essences résineuses concordent avec ceux rapportés dans la littérature pour les conifères européens. Cependant, pour deux essences feuillues, aucune étude similaire n'est disponible aux fin de comparaison. Les résultats graphiques montrent qu'environ 50% des peuplements échantillonnés ont des valeurs du facteur d'élancement supérieures à 100, indiquant un risque élevé au chablis. Des modèles sont aussi développés pour prédire le facteur d'élancement à partir (i) du dhp seul et (ii) du dhp et des variables de peuplement conjointement. La fonction de décroissance s'est avérée la meilleure parmi ces modèles. Les applications potentielles de ces modèles comprennent la sélection des arbres résiduels résistants au vent dans les coupes partielles et le développement de systèmes d'évaluation du risque au chablis.

Watson, P., and Bradley, M. 2009. Canadian pulp fibre morphology: superiority and consideration for end use potential. *The Forestry Chronicle* **85**(3): 401–408.

Four physical attributes of fibres confer the end use potential of a pulp, namely fibre length, fibre coarseness, fibre strength and uniformity. Long, slender, fine fibred pulps, which are low in thick-walled summerwood content, provide superior reinforcement strength. The natural species endowment that Canada enjoys can, when accompanied by superior operational performance and technical vision, result in significant advantages for strategically focused companies and their customers. Factor and multivariate analysis of more than 60 industrial pulp samples confirm that on the basis of fundamental morphological differences, Canadian pulps exhibit clear superiority. Canadian northern bleached softwood kraft pulp is the undoubted industry leader, yet unrealized potential still exists, and additional research effort is required, to maintain this market position.

Quatre propriétés physiques des fibres de conifères déterminent le potentiel d'utilisation finale d'une pâte, soit la longueur de la fibre, sa grossièreté, sa résistance et son uniformité. Les pâtes formées de fibres longues et minces qui contiennent peu de bois d'été aux parois épaisses permettent d'accroître la résistance à un niveau supérieur. Le grand choix d'espèces naturelles dont bénéficie le Canada permet, lorsqu'une performance opérationnelle attentive et qu'une vision technique supérieure sont en place, de générer des bénéfices significatifs pour les entreprises stratégiquement orientées et pour leurs clients. Une analyse factorielle et multivariée de plus de 60 échantillons de pâte industrielle confirme qu'en fonction des différences morphologiques fondamentales, les pâtes produites au Canada détiennent une supériorité évidente. La pâte kraft blanchie produite à partir de résineux nordiques du Canada s'avère être incontestablement le leader mondial, quoique son plein potentiel n'est pas encore atteint et que des efforts additionnels de recherche sont requis afin de maintenir cette position sur les marchés.

Webster, C.R., and Lorimer, C.G. 2003. Comparative growing space efficiency of four tree species in mixed conifer–hardwood forests. *Forest Ecology and Management* **177**(1–3): 361–377.

The influence of shade tolerance, canopy position, and tree size on growing space efficiency (GSE) in mixed stands of co-occurring conifer and hardwood species was investigated in hemlock–northern hardwood forests. Three alternative measures of two-dimensional growing space—total crown area (TCA), exposed crown area (ECA), and a projection of the total available growing space (AGS)—were investigated to clarify the comparative importance of shaded and illuminated crown regions and unoccupied space in the forest canopy. GSE was expressed as ratios of stem volume increment and biomass increment per unit of growing space. Late-successional, shade-tolerant species have often been portrayed as slow growing, inefficient users of their growing space; however, hemlock (*Tsuga canadensis*), which is one of the most shade-tolerant conifers in North America, was the most efficient canopy tree in our sample across all measures of GSE. Likewise, the mid-tolerant yellow birch (*Betula alleghaniensis*) tended to be less efficient than the more shade-tolerant maples (*Acer rubrum* and *Acer saccharum*). For all species, volume increment per unit of growing space increased with increasing tree height and canopy position, but within a given stratum decreased with increasing crown size. The relative efficiency of each species did not appear to be influenced by the measure of growing space employed. In most cases, volume and biomass increments per unit of ECA and AGS were significantly greater ($p < 0.05$) for intermediate than dominant crown class trees. However, for a given level of ECA or AGS, efficiency did increase with increasing relative height, which suggests that efficiency is influenced by the relative vertical position of growing space in the forest canopy. In general, the shaded area of a crown (i.e., TCA – ECA) was not a significant predictor of volume increment once height and ECA were known, suggesting that once 100% canopy closure is reached, packing trees more tightly may not increase stand-level production. However, mean volume increment per unit of TCA scaled more accurately to the stand-level than mean volume increment per unit of ECA. Potential scaling problems associated with mixed-species stands are discussed.

Weetman, G.F. 1975. Ten-year growth response of black spruce to thinning and fertilization treatments. *Canadian Journal of Forest Research* **5**(2): 302–309.

A 65-year-old upland black spruce (*Picea mariana* Mill. B.S.P.) stand near Baie Comeau, Quebec, was thinning and fertilized with urea; each treatment was at 2 levels in a split plot factorial design. The trees responded to the nitrogen addition after 1 year and to thinning after 7 years. The trees were still growing faster in response to most treatments after 10 years. Trees of all size classes responded to the treatments. The periodic increment was not increased by 25% thinning, but was increased by 50% thinning and was always increased by nitrogen additions. Absolute increases over control values ranged from 130 to 290 ft^3 (11 to 24.6 m^3) for an application of 100 lb N per acre (112 kg N per hectare) and 238 to 297 ft^3 (20 to 25.2m^3) for 400 lb N per acre (444 kg N per hectare) (1 ha = 104 m^2). Some synergistic effect of combined thinning and fertilizer treatment is indicated. Mortality losses in the 10-year period were appreciable because of excessive stand density. The roles of thinning and fertilizer treatments in black spruce management are discussed.

Un peuplement de *Picea mariana* (Mill.) B.S.P., situé près de Baie-Comeau, Québec, a été éclairci et fertilisé à l'urée, utilisant un dispositif factoriel à parcelles subdivisées ("split plot"). Les arbres ont répondu à l'addition d'azote après un an et à l'éclaircie après sept ans. L'augmentation du taux de croissance attribuable aux traitements est encore perceptible après 10 ans. Les arbres de toutes les classes de diamètre ont répondu aux traitements. L'accroissement au cours de la période n'a pas été augmenté par une éclaircie de 25% mais a été augmenté par une éclaircie de 50%, et par les divers traitements de fertilisation azotée. Les augmentations absolues par rapport au témoin ont varié de 11 à 24.6 m^3 pour une application de 112 kg N par hectare, et de 20 à 25.2 m^3 pour une application de 444 kg N par hectare (1 ha = 104 m^2). On fait état de l'effet synergique découlant des traitements combinés d'éclaircie et de fertilisation. Les pertes par mortalité au cours des 10 années furent élevées, en raison de la densité excessive du peuplement. On discute des rôles des éclaircies et de la fertilisation dans l'aménagement des forêts d'épinette noire.

Weiskittel, A.R., Maguire, D.A., and Monserud, R.A. 2007. Response of branch growth and mortality to silvicultural treatments in coastal Douglas-fir plantations: implications for predicting tree growth. *Forest Ecology and Management* **251**(3):182–194.

Static models of individual tree crown attributes such as height to crown base and maximum branch diameter profile have been developed for several commercially important species. Dynamic models of individual branch growth and mortality have received less attention, but have generally been developed retrospectively by dissecting felled trees; however, this approach is limited by the lack of historic stand data and the difficulty in determining the exact timing of branch death. This study monitored the development of individual branches on 103 stems located on a variety of silvicultural trials in the Pacific Northwest, USA. The results indicated that branch growth and mortality were significantly influenced by precommercial thinning (PCT), commercial thinning, fertilization, vegetation management, and a foliar disease known as Swiss needle cast [caused by *Phaeocryptopus gaeumannii* (T. Rohde) Petr.]. Models developed across these data sets accounted for treatment effects through variables such as tree basal area growth and the size of the crown. Insertion of the branch growth and mortality equations into an individual-tree modeling framework, significantly improved short-term predictions of crown recession on an independent series of silvicultural trials, which increased mean accuracy of diameter growth prediction (reduction in mean bias). However, the static height to crown base equation resulted in a lower mean square error for the tree diameter and height growth predictions. Overall, individual branches were found to be highly responsive to changes in stand conditions imposed by silvicultural treatments, and therefore represent an important mechanism explaining tree and stand growth responses.

Weiskittel, A.R., Maguire, D.A., and Monserud, R.A., Rose, R., and Turnblom, E.C. 2006. Intensive management influence on Douglas fir stem form, branch characteristics, and simulated product recovery. *New Zealand Journal of Forestry Science* **36**(2–3): 293–312.

Intensive management may adversely affect lumber yield and quality by increasing knot size and creating a more conical stem form with a greater average rate of taper. This study was initiated to examine the impact of management on simulated lumber yield and quality. Stem diameter and branch size and location of 223 *Pseudotsuga menziesii* (Mirb.) Franco (Douglas fir) stems ranging in age from 5 to 65 years and from a wide variety of stand conditions were intensively measured. Stand conditions included varying levels of vegetation management, precommercial thinning, commercial thinning, fertilizer application, and severity of infection by *Phaeoctyptopus gaeumannii* (Rohde) Petrak (Swiss needle cast). In addition, 86 virtual logs were created and processed by AUTOSAW. Significant changes in both stem form and branch characteristics were observed among the stand conditions examined, with maximum branch size being the most responsive to silvicultural regime and disease severity. Changes related to fertilizer and thinning were not significant enough to adversely affect simulated lumber quality and yield. Indices of branch size were poor predictors of simulated log grade yield. Although quantification of branch size and location is important for understanding crown structure, growth potential, and the vertical distribution of biomass, factors such as juvenile wood percentage and wood density may exert more control over simulated product quality in the young Douglas fir analyzed in this study.

Welham, C., Seely, B., and Kimmins, H. 2002. The utility of the two-pass harvesting system: an analysis using the ecosystem simulation model FORECAST. *Canadian Journal of Forest Research* **32**(6): 1071–1079.

The ecosystem model FORECAST was used to simulate the yield potential in Saskatchewan mixedwoods of the two-pass harvesting system. The simulated two-pass stand consisted of an overstory population of pure trembling aspen (*Populus tremuloides* Michx.) with a white spruce (*Picea glauca* (Moench) Voss) understory. The aspen was removed at year 60, and yields of the understory spruce and resprouting aspen were simulated for 80 years thereafter. The two-pass simulations were compared with two simulated conventional harvesting systems. The first system consisted of a single final harvest at year 140. In the second system, a clearcut was conducted at year 60. White spruce was then planted in the subsequent year at 400, 600, or 800 stems/ha, and aspen also permitted to resprout. Growth was then simulated for a further 80 years. FORECAST projections indicated that the two-pass system might be effective for releasing the white spruce understory, achieving at least a twofold gain in spruce volume relative to conventional methods. Furthermore, total volumes exceeded those derived from the unmanaged stand, while second rotation yields of aspen declined with spruce understory density. These simulations suggest the two-pass harvesting system has strong potential as a tool for mixedwood management.

Le modèle d'écosystème FORECAST a été utilisé pour simuler le rendement potentiel du système de récolte à deux étapes dans les forêts mélangées de la Saskatchewan. La simulation a porté sur un peuplement constitué d'un étage dominant composé seulement de peuplier faux-tremble (*Populus tremuloides* Michx.) et d'un sous-étage d'épinette blanche (*Picea glauca* (Moench) Voss). Le peuplier a été récolté à 60 ans et les rendements de l'épinette en sous-étage et des rejets de peuplier ont été simulés pour les 80 années suivantes. Les simulations du système à deux interventions ont été comparées aux simulations de deux systèmes de récolte conventionnels. Le premier système comporte seulement une coupe finale à 140 ans et le second une coupe à blanc à 60 ans. Dans les années subséquentes, l'épinette blanche est plantée à raison de 400, 600 ou 800 tiges à l'hectare en laissant le peuplier produire des rejets et la croissance est simulée pour un autre 80 ans. Les prévisions du modèle FORECAST indiquent que le système à deux étapes pourrait être efficace pour dégager l'épinette en sous-étage, dont le volume serait au moins doublé comparativement aux systèmes conventionnels. De plus, les volumes totaux dépassent ceux qui sont obtenus dans un peuplement non aménagé alors que le rendement du peuplier diminue lors d'une seconde révolution à cause de l'augmentation de la densité de l'épinette en sous-étage. Ces simulations montrent que le système de récolte à deux étapes a un fort potentiel comme outil pour l'aménagement des peuplements mélangés.

Wells, E.D. 1994. Effects of planting spacing and refertilization on growth and nutrition of black spruce (*Picea mariana* (Mill.) B.S.P.) planted on a minerotrophic peatland in Newfoundland, Canada. *Canadian Journal of Forest Research* **24**(7): 1302–1311.

In 1973, a black spruce (*Picea mariana* (Mill.) B.S.P.) plantation was established in central Newfoundland on a minerotrophic, open peatland that had been ditched at 1.8 m spacings. The seedlings were planted at spacings of 1.2, 1.8, and 2.4 m and spot fertilized with a mixture of 71 g urea, 99 g ground rock phosphate, and 41 g potassium sulfate. In 1985, 12 years after establishment, concentrations of N (0.90%), P (0.10%), and K (0.28%) suggested that nutrient deficiencies were limiting growth. Consequently, P, P-K, and N-P-K were applied in the amounts of 60 kg/ha P, 100 kg/ha K, and 200 kg/ha N. Controls (no refertilization) were also included in the experiment, although these plots had been spot fertilized in 1973. Between 1985 and 1991, height growth, needle weight, and needle nutrients were not significantly different among planting spacing treatments. Height growth was greatest in the P-K treatment, whereas needle weights were greatest in the N-P-K treatment in 1987. Uptake of nitrogen was significantly improved by application of P-K as well by application of N-P-K. Concentrations of N, P, and K increased to levels of 2.43, 0.25, and 0.60%, respectively, following application of fertilizers containing those elements. However, by 1991, those concentrations had decreased to 1.10, 0.14 and 0.43%, respectively. The effects of refertilization on uptake of Ca, Mg, and Cu were mainly nonsignificant.

En 1973, on a planté des épinettes noires (*Picea mariana* (Mill.) B.S.P.) au centre de Terre-Neuve dans une tourbière minérotrophe ouverte où des fossés avaient été creusés par intervalles de 1,8 m. Les jeunes arbres avaient été plantés à intervalles de 1,2, de 1,8 et de 2,4 m, et avaient reçu des traitements localisés d'engrais composés de 71 g d'urée, de 99 g de phosphorite en poudre et de 41 g de sulfate de potassium. En 1985, 12 ans après la plantation, les concentrations de N (0,90%), de P (0,10%) et de K (0,28%) suggérant que des carences alimentaires limitaient la croissance des arbres, on a procédé à une nouvelle application de P, de P–K et de N–P–K dans les proportions suivantes: P, 60 kg/ha; K, 100 kg/ha; et N, 200 kg/ha. Des témoins (privés de ce supplément d'engrais) ont aussi été inclus dans l'expérience, même s'ils avaient reçu un traitement d'engrais localisé en

1973. Entre 1985 et 1991, la croissance en hauteur, le poids des aiguilles et le contenu nutritif des aiguilles n'ont pas révélé de différences attribuables à l'espacement au moment de la plantation. La croissance en hauteur était supérieure dans le cas du traitement au P–K, alors que le poids des aiguilles était le plus élevé seulement chez les épinettes traitées au N–P–K en 1987. L'absorption de N a été fortement accrue par l'application de P–K et de N–P–K. Après l'application d'engrais contenant ces éléments, les concentrations de N, de P et de K ont augmenté pour atteindre respectivement 2,43, 0,25 et 0,60%. Cependant, en 1991, ces concentrations avaient diminué pour se situer à 1,10, 0,14 et 0,43%, respectivement. Les effets de la seconde fertilisation sur l'absorption de Ca, de Mg et de Cu ont été essentiellement insignifiants.

Willcocks, A., and Bell, W. 1995. *Effects of Stand Density (Spacing) on Wood Quality*. Technical Note TN-007. Ontario Ministry of Natural Resources, Northeast Science & Technology (NEST), South Porcupine, Ontario, Canada.

The effects of stand density on wood quality are examined in this report. It summarizes literature on the subject and shows trends in specific gravity, fiber lengths, knot sizes, diameters, and heights as affected by stand densities. It is concluded that spacing to 3 m results in little loss of wood quality. *(Abstract prepared by compilers.)*

Wimmer, R., Lucas, B.N., Tsui, T.Y., and Oliver, W.C. 1997. Longitudinal hardness and Young's modulus of spruce tracheid secondary walls using nanoindentation technique. *Wood Science and Technology* **31**(2): 131–141.

Using a mechanical properties microprobe, measurements of hardness and elastic modulus of tracheid walls in the longitudinal direction of spruce wood were obtained by continuously measuring force and displacement as a diamond indenter impressed a cell wall. Maximum mechanical properties were found at the edges of the walls of angular shaped tracheids. Both the hardness and elastic modulus of latewood cell walls were higher than cell walls in the earlywood. The high spatial resolution of this new concept of mechanical testing allows a direct comparison with ultrasound and microchemical parameters of lignified cells, which opens a wider area of application for the understanding of intrinsic wood properties.

Winistorfer, P.M., Young, T.M., and Walker, E. 1996. Modeling and comparing vertical density profiles. *Wood and Fiber Science* **28**(1): 133–141.

The vertical density profile of pressed wood panels is influenced by the manufacturing process and is important to panel end-users. Modeling the vertical density profile and making statistical comparisons among profiles resulting from different manufacturing treatments are critical to understanding and improving panel properties. Nonparametric regression analysis was used to model the vertical density profile of aspen (*Populus tremuloides*) oriented strandboard panels. A methodology is presented to compare vertical density profile curves. Twenty-seven laboratory panels were manufactured at 608 kg/m^3 incorporating three levels of furnish moisture content (4%, 8%, 12%) and three levels of press closure rate (20 s, 60 s, 100 s) in a replicated, experimental design. The nonparametric regression technique called cubic splines was used to fit the data, R^2 ranged from 0.985 to 0.998. Detailed discussion is presented that describes the method and interpretation of the nonparametric regression analysis. Statistical comparison of vertical density profile curves among treatment levels revealed that the 4% furnish moisture content level was significantly different ($P = 0.015$) from the 8% and 12% levels; the 8% level was not significantly different ($P > 0.99$) from the 12% level. Vertical density profile curves for all press closure rate treatments were significantly different ($P < 0.003$).

Winston, D.A. 1977. *Fertilization and Strip Thinning in 45-Year-Old Jack Pine in Ontario*. Information Report O-X-256. Natural Resources Canada, Canadian Forest Service - Great Lakes Forestry Centre, Sault Ste. Marie, Ontario, Canada.

Fertilization with nitrogen and phosphorous was carried out on a 45-year-old jack pine (*Pinus banksiana* Lamb.) stand in which a commercial strip thinning operation had been conducted the previous year. The same fertilizer treatments were carried out on portions of an adjacent unthinned control stand. Despite a 40% reduction in growing stock, trees in the thinned portion produced as much total volume increment as did the unthinned control over a 4-year period. A fertilizer treatment of N 168 kg/ha plus P 112 kg/ha on the thinned stand produced 5 m^3/ha and 7.5 m^3/ha more wood (total volume) than did the thinned and unthinned controls, respectively. In the unthinned portion of the stand, total volume increment increased with increasing fertilizer N to the N 336 P 112 kg/ha level, which produced 17 m^3/ha over the control. It is suggested that strip thinning and fertilization deserve greater consideration in jack pine silviculture.

On a fertilisé à l'azote et au phosphore un peuplement de pin gris (*Pinus banksiana* Lamb.) âgé de 45 ans, qui avait subi une coupe commerciale d'éclaircie par bandes un an auparavant. On a appliqué le même traitement de fertilisation à des portions témoins d'un peuplement voisin non éclairci. Malgré une diminution de 40% du matériel sur pied, les arbres de la portion éclaircie ont produit un accroissement de volume total aussi important que la portion témoin non éclaircie, au cours d'une période de 4 ans. Une fertilisation à raison de N 168 kg/ha plus P 112 kg/ha du peuplement éclairci a produit plus de bois (5 m^3/ha et 7.5 m^3/ha) (volume total) que les portions témoins éclaircies et non éclaircies, respectivement. Dans la portion non éclaircie du peuplement, l'accroissement en volume total augmenta en proportion de l'augmentation de N, jusqu'au niveau N 336, P 112 kg/ha, qui produisit 17 m^3/ha de plus que le témoin. L'auteur propose de donner plus d'importance aux coupes d'éclaircies par bandes subséquement fertilisées dans les traitements sylvicoles du pin gris.

Wood, J., Miles, K., Wong, D., and Sitholé, B. 2005. Wood quality variations in black spruce and balsam fir: do they explain seasonal variations in pulp properties? Pages 65–76 *in* Anonymous. *91st Annual Meeting of the Pulp and Paper Technical Association of Canada*. Montreal, Quebec, Canada, 7–10 February 2005. Pulp and Paper Technical Association of Canada, Montreal, Quebec, Canada.

Thermomechanical pulp mills experience seasonal variations in pulp quality, particularly in brightness. It is hypothesized that the variation may be related to seasonal differences in wood supply. Six trees each of black spruce (*Picea mariana* (Mill.) B.S.P.) and balsam fir (*Abies balsamea* (L.) Mill.) were sampled every 3 months for 2 years. The logs were debarked, chipped, and sampled for extractives content and basic wood density. The chips were then pulped and bleached and brightness determined. Balsam fir extractives content was higher than that of black spruce, but neither demonstrated seasonal variation. Spruce density was higher than balsam fir. Balsam fir moisture content was higher than spruce, which had no seasonal variation. The balsam fir, however, had the highest moisture content in the summer. Balsam fir pulp was more variable than spruce pulp. No seasonal variation was detected for brightness. It was concluded that seasonal differences in pulp do not arise from seasonal changes in the wood supplied to the mill. *(Abstract prepared by compilers.)*

Yanchuk, A.D., and Kiss, G.K. 1993. Genetic variation in growth and wood specific gravity and its utility in the improvement of interior spruce in British Columbia. *Silvae Genetica* **42**(2–3): 141–148.

Juvenile wood specific gravity (SG) from increment cores was assessed by the maximum-moisture content (MMC) method in 40 open-pollinated families of interior spruce from two 15-year-old progeny test sites in north-central British Columbia to examine: (1) the magnitude of family difference of SG and growth traits; (2) phenotypic, genetic and family mean correlations among traits, and; (3) to develop an approach for using these parameters for the prediction of parental breeding values. Differences among the 40 families for mean SG were large (range 0.38 to 0.44), as indicated by high individual (h^2_i = 0.47 + 0.03) and family mean (h^2_f = 0.67 + 0.11) heritabilities. Genetic correlations between both height and diameter growth and SG were near zero, whereas phenotypic correlations were significant ($P < 0.05$) at -0.40 and -0.46, respectively. Family differences using the Pilodyn (PIN) apparatus, as an indirect measure of SG, were significant ($P < 0.05$) and exhibited a moderate family heritability (0.48 + 0.25). The genetic correlation between PIN and SG, as assessed by the MMC method, was -0.80 + 0.10. Family selection for SG using PIN data was expected to be 68% as efficient as direct family selection for SG based on the MMC values. Parental breeding value predictions for height growth and SG, based on height and PIN data at age 15, indicate that height may be improved by approximately 11% without a substantial change in SG. The development of slight negative genetic correlations between SG and growth traits in the last few growth rings, as suggested by the PIN data, might have two consequences. First, gains in both SG and growth will be more difficult to attain if the negative trend continues. Second, the ability to successfully select for SG at early ages (less than 15 years) will be problematic.

Yang, K.C. 1987. Wood properties, wood qualities and silvicultural treatments. *Quarterly Journal of Chinese Forestry* **20**(2): 7–28.

This review considers the impact of silvicultural treatments such as spacing, thinning, irrigation, pruning, and rotation on specific gravity, fiber length, growth rings, and percentage of latewood and juvenile wood. It also provides a description of the impact of wood properties on finished products. *(Abstract prepared by compilers.)*

Yang, K.C. 2002. Impact of spacing on juvenile wood and mature wood properties of white spruce (*Picea glauca*). *Taiwan Journal of Forest Science* **17**(1): 13–29.

As the literature provides no clear guide to the effect of spacing on wood quality, a study was undertaken to determine the effect of spacing for white spruce (*Picea glauca* (Moench) Voss) grown in northwestern Ontario. Three spacings, 1.8 m, 2.7 m, and 3.6 m, were chosen. After 38 years, increment cores were taken from 10 trees in each spacing, and these were analyzed for growth rate, extracted relative density, and tracheid length. Tracheid length was used to determine the juvenile–mature wood boundary. Juvenile growth rate increased to a certain point and then decreased. The largest increases were in the widest spacings. Juvenile relative density initially decreased and then increased and was significantly higher in the closest spacing. Juvenile tracheid length increased outward from the pith. A significant difference was found only between the two extreme spacings. Mature growth rate was highest in the middle spacing, which was significantly different from the closest spacing but not from the widest spacing. No significant differences in mature relative density or tracheid length were found between the spacings. It was concluded that spacing influenced juvenile wood properties more than mature wood properties. *(Abstract prepared by compilers.)*

Yang, K.C., and Hazenberg, G. 1992. Impact of spacings on sapwood and heartwood thickness in *Picea mariana* (Mill.) B.S.P. and *Picea glauca* (Moench) Voss. *Wood and Fiber Science* **24**(3): 330–336.

The impact of spacing on sapwood and heartwood thickness was studied in a 38-year-old plantation in northern Ontario. Ten trees each of *Picea mariana* (Mill.) B.S.P. and *Picea glauca* (Moench) Voss grown at spacings 1.8 m x 1.8 m, 2.7 m X 2.7 m and 3.6 m x 3.6 m were randomly selected for the study. Tree diameter, sapwood and heartwood thickness, both as a ring count and as a length measure, and sapwood and heartwood basal area were measured. For both species, it was found that the effect of the 1.8-m x 1.8-m spacing usually was significantly different from that of the other two levels. Only for sapwood basal area in *Picea mariana* were all three levels of spacing declared statistically significant from each other. Sapwood basal area increased with increased spacing for this species. For *Picea glauca*, the maximum sapwood basal area occurred at the second level of spacing. Sapwood basal area occupied approximately half of the total tree basal area at age 38. The number of sapwood rings in *Picea glauca* showed no significant differences over the levels of spacing. It is concluded that spacing plays an important role and has various degrees of impact on tree diameter and heartwood and sapwood thickness.

Yang, K.C., and Hazenberg, G. 1994. Impact of spacing on tracheid length, relative density, and growth rate of juvenile wood and mature wood in *Picea mariana*. *Canadian Journal of Forest Research* **24**(5): 996–1007.

Ten 38-year-old trees of *Picea mariana* (Mill.) B.S.P., grown at each of three spacings (1.8 × 1.8, 2.7 × 2.7, and 3.6 × 3.6 m), at Stanley, 30 km west of Thunder Bay, Ont., were used to study the impact of spacing on growth rate, relative density, and tracheid length of juvenile and mature wood. Increment cores of 12 mm diameter were extracted from the south aspect of each tree at breast height. The boundary of juvenile and mature wood was demarcated by the variation in tracheid length, which varied among trees from ring 11 to 21. Average growth rate, relative density, and tracheid length were obtained between the pith and boundary point (juvenile wood) and beyond the boundary point (mature wood). Differences between the levels of spacing for the three response variables in both juvenile and mature wood were tested using contrasts. Properties of juvenile and mature wood were found to be affected differently by the plantation spacing. Juvenile wood has a faster growth rate and shorter fibres than mature wood. Relative density was similar in both wood zones. The growth rate in juvenile wood was found to be significantly different among the spacing levels. For mature wood, only the growth rate at the 3.6 × 3.6 m spacing was significantly different from the other two spacing levels. The highest relative density, 0.39, in both juvenile and mature wood was found at the 1.8 × 1.8 m spacing. No significant difference in the relative density between the two wider spacings was observed. At the widest spacing, the relative density was 8% lower than that at the 1.8 × 1.8 m spacing. The longest fibre lengths were found at the intermediate 2.7 × 2.7 m spacing, 2.05 mm in juvenile wood and 2.94 mm in mature wood. Tracheid lengths of the 3.6 × 3.6 m spacing were significantly shorter than those of the other two spacings. The relative density and tracheid length of plantation grown wood were lower than those of natural grown wood by at least 5% for relative density and 33% for tracheid length.

Dix épinettes noires (*Picea mariana* (Mill.) B.S.P.) de 38 ans croissant avec des espacements de 1,8 x 1,8 m, 2.7 x 2,7 m et 3,6 x 3,6 m à Stanley, 30 km à l'ouest de Thunder Bay en Ontario, ont été utilisées pour étudier l'effet de l'espacement sur le taux de croissance, la densité relative et la longueur des trachéides dans le bois juvénile et le bois mature. Des carottes de 12 mm de diamètre furent extraites du côté sud de chaque arbre à hauteur de poitrine. La limite entre le bois juvénile et le bois mature a été déterminée sur la base de la variation dans la longueur des trachéides et se situait selon les arbres entre le cerne annuel 11 et 21. Le taux de croissance moyen, la densité relative et la longueur des trachéides furent mesurés du coeur à la limite du bois juvénile et de la limite du bois juvénile dans le bois mature. Les différences entre les niveaux d'espacement pour les trois variables dépendantes dans le bois juvénile et le bois mature furent testées à l'aide d'analyses de contrastes. Les propriétés du bois juvénile et du bois mature étaient affectées différemment par l'espacement. Le bois juvénile avait une croissance plus rapide et des fibres plus courtes que le bois mature. La densité relative était semblable dans les deux zones. Le taux de croissance du bois juvénile variait de façon significative selon l'espacement. Dans le cas du bois mature, seul le taux de croissance pour l'espacement de 3,6 x 3,6 m était significativement différent du taux de croissance pour les deux autres espacements. La plus forte densité relative, 0,39, tant dans le bois juvénile que dans le bois mature a été observée pour l'espacement de 1,8 x 1,8 m. Aucune différence significative dans la densité relative n'a été observée entre les deux espacements les plus larges. Avec l'espacement le plus large, la densité relative était de 8% inférieure à celle de l'espacement de 1,8 x 1,8 m. Les fibres les plus longues ont été observées avec l'espacement intermédiaire de 2,7 x 2,7 m: 2,05 mm dans le bois juvénile de 2,94 mm dans le bois mature. Les trachéides étaient significativement plus courtes avec l'espacement de 3,6 x 3,6 m qu'avec les deux autres espacements. La densité relative et la longueur des trachéides des arbres cultivés en plantation étaient inférieures à celles des arbres qui croissent naturellement d'au moins 5% pour la densité relative et de 33% pour la longueur des trachéides.

Yang, K.C., Hazenberg, G., Bradfield, G.E., and Maze, J.R. 1985. Vertical variation of sapwood thickness in *Pinus banksiana* Lamb. and *Larix laricina* (Du Roi) K. Koch. *Canadian Journal of Forest Research* **15**(5): 822–828.

Variation of sapwood thickness, in terms of a linear measurement (sapwood width) and a growth ring count (sapwood ring), in relation to age, height, aspect, and radial growth rate was studied in jack pine (*Pinus banksiana* Lamb.) and tamarack (*Larix laricina* (Du Roi) K. Koch). In general, jack pine has more sapwood rings and a greater sapwood width than tamarack. In jack pine, the number of sapwood rings steadily declined with increasing height, but in tamarack, the number of sapwood rings at first increased and then declined with increasing height. Sapwood width tended to show a species-specific constant thickness along the trunk, but both species exhibited a slight increase at the base and at the crown. The number of sapwood rings shows strong correlation with age, height, and sapwood radial growth rate, but not with sapwood width. In both species, the south aspect of the tree has wider sapwood and fewer sapwood rings than the north aspect. There is no statistical relationship between sapwood width and the number of sapwood rings.

Les variations de l'épaisseur de l'aubier, exprimée de mesure linéaire ou de nombre de cernes annuels, ont été étudiées en relation avec l'âge, la hauteur, l'aspect et le taux de croissance radiale chez le pin gris (*Pinus banksiana* Lamb.) et le mélèze laricin (*Larix laricina* (Du Roi) K. Koch). De façon générale, le pin gris montre un aubier plus important tant sur le plan de la largeur que du nombre de cernes que le mélèze laricin. Chez le pin gris, le nombre de cernes annuels diminue constamment en fonction de la hauteur alors que chez le mélèze laricin, le nombre de cernes annuels augmente d'abord, puis diminue avec la hauteur dans la tige. L'aubier tend vers une épaisseur constante propre à l'espèce le long du tronc, bien que les deux espèces aient montré une légère augmentation au pied de l'arbre et dans le houppier. Le nombre de cernes annuels de l'aubier est fortement relié à l'âge, la hauteur et le taux de croissance radiale, mais pas à la largeur de l'aubier. Chez les deux espèces, le côté sud de la tige a montré un aubier plus large, contenant moins de cernes que le côté nord. Il n'existe aucune corrélation statistique entre la largeur de l'aubier et le nombre de cernes annuels de ce dernier.

Yemele, M.C.N., Cloutier, A., Diouf, P.N., Koubaa, A., Blanchet, P., and Stevanovic, T. 2008. Physical and mechanical properties of particleboard made from extracted black spruce and trembling aspen bark. *Forest Products Journal* **58**(10): 38–46.

Bark residues are mostly used for thermal energy production. However, a better utilization of that resource could be as raw material for particleboard (PB) manufacturing. Bark is also a source of numerous extractives used in several fields including pharmacology and adhesive production. This study aims at analyzing the effect of hot water extracted bark particle content and size on the physical and mechanical properties of bark PBs including the modulus of elasticity (MOE), modulus of rupture (MOR), internal bond (IB), Janka hardness (HJ), thickness swelling (TS) and linear expansion (LE). Moreover, these properties were compared both to a control (100% wood particles) and to PB made from the same content of unextracted bark. The results showed that, while the mechanical properties of the PB made from extracted black spruce and trembling aspen bark decreased with increasing bark content, LE increased. PB made of fine particles often showed higher IB and lower TS values. Hot water extraction of the bark had a detrimental effect on all the physical and mechanical properties of the PBs produced except for the Janka hardness, where no significant decrease was found. The MOE and MOR of the PBs made from 50 percent black spruce and trembling aspen bark met the requirements of the ANSI standard for commercial (M-1) and underlayment (PBU) grades. In contrast, the dimensional properties (TS and LE) of all the boards did not fulfill the minimum requirements of the ANSI standard.

Young, H.E., and Guinn, V.P. 1966. Chemical elements in complete mature trees of seven species in Maine. *Tappi Journal* **49**(5): 190–197.

Wood and bark samples of mature aspen, balsam fir, hemlock, red maple, red spruce, white birch, and white pine were examined. The trees were broken down into eight sections. Analysis for aluminum, boron, calcium, copper, iron, magnesium, manganese, molybdenum, nitrogen, phosphorus, potassium, and zinc were conducted in each section. Dry weight of the section and the percentage of elements sampled were used to estimate the amount of each element in its section. Differences among species, within species, and between sections on a single tree were recorded. *(Abstract prepared by compilers.)*

Yu, Q., Pulkkinen, P., Rautio, M., Haapanen, M., Alén, R., Stener, L.G., Beuker, E., and Tigerstedt, P.M.A. 2001. Genetic control of wood physicochemical properties, growth, and phenology in hybrid aspen clones. *Canadian Journal of Forest Research* **31**(8): 1348–1356.

To better understand the genetic control of wood chemical and fibre properties in hybrid aspen, genetic relationships of these with growth and phenological traits were examined. In all, 18 hybrid aspen clones were sampled in the 13- and 14-year-old clone trials in Sweden. Strong clone within family effects were present for growth and wood properties. The repeatability estimates across two sites were 0.85, 0.65, 0.56, 0.54, and 0.65 for alkali soluble lignin content, arithmetic average fibre length, coarseness, diameter, and height, respectively. Genetic correlations generally exceeded the corresponding phenotypic correlations. The phenotypic and genetic correlations were negative between fibre count and height growth (-0.64 and -0.65, respectively) and between fibre count and length of growth period. The result suggests that the length of the growth period could be a good predictor of clone differences in fibre count. The estimated correlations were unfavourable, in the sense that clonal selection directed at increasing the fibre count is expected to produce an indirect genetic decline in growth. Intersite genetic correlations indicated that wood characters were more stable than growth traits.

Afin d'élucider le contrôle génétique des propriétés chimiques du bois et celles des fibres chez le peuplier hybride, les auteurs ont étudié les relations au plan génétique entre ces paramètres et la croissance ainsi que les caractères phénologiques. En tout, 18 clones hybrides de peuplier ont été échantillonnés au sein de tests clonaux âgés de 13 et 14 ans établis en Suède. Des effets clonaux importants au sein des familles ont été observés pour la croissance et les propriétés du bois. Les estimations de reproductibilité d'un site à l'autre étaient respectivement de 0,85, 0,65, 0,56, 0,54 et 0,65 pour le contenu en lignine soluble en milieu alcalin, la moyenne arithmétique de la longueur des fibres, la grosseur du grain, le diamètre et la hauteur. En général, les corrélations génétiques étaient plus élevées que les corrélations phénotypiques correspondantes. Les corrélations phénotypiques et génétiques étaient négatives entre le nombre de fibres et la croissance en hauteur (-0,64 et -0,65, respectivement), et entre le nombre de fibres et la durée de la saison de croissance. Ces résultats indiquent que la durée de la saison de croissance pourrait être un paramètre adéquat pour prédire les différences de nombre de fibres entre clones. Les corrélations estimées n'étaient pas favorables, puisqu'il est probable que la sélection clonale destinée à augmenter le nombre de fibres entraîne une réduction indirecte de la croissance au plan génétique. Les corrélations génétiques estimées entre les sites ont indiqué les propriétés du bois étaient plus stables que les caractères de croissance.

Yu, Q., Yang, D.Q., Zhang, S.Y., Beaulieu, J., and Duchesne, I. 2003. Genetic variation in decay resistance and its correlation to wood density and growth in white spruce. *Canadian Journal of Forest Research* **33**(11): 2177–2183.

This study investigated the genetic variation of white spruce (*Picea glauca* (Moench) Voss) in decay resistance and its correlation with wood density and growth. Three fungi were examined, a brown-rot fungus (*Gloeophyllum trabeum*), a white-rot fungus (*Trametes versicolor*), and a standing-tree-decay fungus (*Fomitopsis pinicola*). The decay resistance was inversely related to the growth rate of the fungi on heartwood blocks. A total of 270 trees of 35 families were harvested from 36-year-old provenance-progeny trials at two sites through a thinning operation. The narrow-sense heritabilities of white spruce decay resistance to brown rot and white rot were 0.21 and 0.27, respectively. There were no significant differences in resistance to standing-tree-decay fungus among the families. The phenotypic and genetic correlations between the growth rate of brown rot on heartwood blocks and wood density were positive, but the genetic correlation between wood density and the growth rate of white rot on heartwood blocks was negative but not significant. The results indicate that the different species of fungi have different relationships with the annual growth of trees and wood density, and suggest that selection for wood density in white spruce might lead to an increase in resistance to white rot, but a decrease in resistance to brown rot.

Cette étude porte sur la variabilité génétique de l'épinette blanche (*Picea glauca* (Moench) Voss) pour la résistance à la carie et sa corrélation avec la densité et la croissance du bois. Trois champignons ont été étudiés : un champignon de carie brune (*Gloeophyllum trabeum*), un champignon de carie blanche (*Trametes versicolor*) et un champignon de carie qui s'attaque aux arbres sur pied (*Fomitopsis pinicola*). La résistance à la carie était inversement proportionnelle au taux de croissance des champignons sur des blocs de bois de cœur. Un total de 270 arbres appartenant à 35 familles ont été récoltés lors d'éclaircies dans des tests de provenances et de descendances établis sur deux sites depuis 36 ans. L'héritabilité au sens strict de la résistance de l'épinette blanche à la carie brune et à la carie blanche était respectivement de 0,21 et 0,27. Il n'y avait pas de différence significative entre les familles pour la résistance au champignon de carie qui s'attaque aux arbres sur pied. Les corrélations phénotypiques et génétiques entre le taux de croissance de la carie brune sur les blocs de bois de cœur et la densité du bois étaient positives. Par contre, la corrélation génétique entre la densité du bois et le taux de croissance de la carie blanche sur les blocs de bois de cœur était négative mais, non significative. Les résultats indiquent que les différentes espèces de champignons ont différentes relations avec la croissance annuelle des arbres et la densité du bois et que la sélection pour la densité du bois chez l'épinette blanche pourrait entraîner une augmentation de la résistance à la carie blanche, mais une diminution de la résistance à la carie brune.

Zahner, R., and Oliver, W.W. 1962. The influence of thinning and pruning on the date of summerwood initiation in red and jack pines. *Forest Science* **8**(1): 51–63.

The influence of thinning and pruning on the date of summerwood initiation was studied for red pine (*Pinus resinosa* Ait.) and jack pine (*Pinus banksiana* Lamb.). The change from large to small diameter cells was delayed in the thinned treatment due to soil moisture regime. Pruning alone did not have much impact on jack pine and only a slight impact on red pine. The effect of pruning and thinning together was not greater than thinning alone. *(Abstract prepared by compilers.)*

Zarnovican, R., and Laberge, C. 1996. *Effect of Precommercial Thinning on the Production of Young Fir Stands on the Upper North Shore.* Information Report LAU-X-118. Natural Resources Canada, Canadian Forest Service - Laurentian Forestry Centre, Sainte-Foy, Quebec, Canada.

Analysis of balsam fir morphological and growth data from 16 plots in the Les Escoumins management unit on the Upper North Shore was made to assess the effects of precommercial thinning on sawlog quality, radial growth and volume production. The results indicate that precommercial thinning significantly stimulates radial growth of residual stems. However, this increase in radial growth was more significant on the stump than on the dbh. The effect of precommercial thinning on radial growth was maximal 4 years after the treatment and ceased after 7 years. Precommercial thinning had a significant impact on the qualitative parameters of the logs. In thinned stands, stem taper was greater than in control stands, principally because thinning promoted lower bole growth. Finally, precommercial thinning increased the number of live whorls as well as the knottiness on the first 8-foot section. Comparison of the yields indicates that heavy precommercial thinning, in addition to affecting the quality of the logs, can also affect the production level of fir stands. Finally, the report proposes a density model for fir stands based on dominant height and the spacing factor.

À partir des données morphologiques et des données sur la croissance du sapin baumier récolté dans 16 parcelles de l'UG - Les Escoumins sur la Haute-Côte-Nord, le rapport analyse les effets de l'éclaircie précommerciale sur la qualité des billes de sciage, sur la croissance radiale et sur la production en volume. Les résultats obtenus indiquent que l'éclaircie précommerciale stimule de façon significative la croissance radiale des tiges résiduelles. Cependant, cette augmentation de la croissance radiale est plus importante à la souche qu'au dhp. L'effet d'éclaircie sur la croissance radiale est maximal 4 ans après le traitement et s'estompe 7 ans après. Les résultats démontrent également que l'éclaircie précommerciale influence de façon significative les paramètres qualitatifs des billes. Les tiges éclaircies par rapport aux tiges témoins ont un empattement plus grand à cause de la répartition du bois sur la tige et, par conséquent, un défilement également plus grand. Finalement, l'éclaircie précommerciale augmente le nombre des verticilles vivants ainsi que la nodosité sur le premier tronçon de 8 pieds. La comparaison de la production en volume des parcelles éclaircies et des parcelles témoins avec la table de production du CAAF indique que l'éclaircie précommerciale intense, en plus d'affecter la qualité des billes, peut aussi affecter le niveau de production des sapinières. Enfin, le rapport propose un modèle de densité pour les sapinières, basé sur la hauteur dominante des peuplements et sur le facteur d'espacement.

Zhang, S.Y. 1997. Wood quality: its definition, impact, and implications for value-added timber management and end uses. Pages 17–39 *in* S.Y. Zhang, R. Gosslin, and G. Chauret, editors. *Timber Management Toward Wood Quality and End-Product Value*. CTIA/IUFRO International Wood Quality Workshop, 18–22 August 1997, Quebec City, Quebec, Canada. Forintek Canada Corp., Quebec, Quebec, Canada.

As forest operations worldwide have moved from use of old growth to managed forests, wood characteristics have changed. One difficulty in managing these changes is that there is currently no definition of wood quality that expresses the needs of all users and producers of wood. A satisfactory definition of wood quality is proposed, and the literature reviewed with respect to wood attributes and variability of those attributes in relation to wood processing and end uses, particularly for solid wood products. Discussion centers particularly on stem diameter, stem straightness, stem taper, tree age, bark, stem decay, knottiness, reaction wood, growth stresses, slope of grain, juvenile wood, heartwood/sapwood, anatomical characteristics, chemical components, ring characteristics, moisture content, wood density, dimensional stability, mechanical properties, durability, permeability, aesthetics, machinability, fire resistance, finishing characteristics, and engineering properties. Other wood properties such as acoustic, thermal, and electrical are mentioned. These characteristics are discussed in the context of harvesting, lumber production, pulp production, engineered panel and structural member production, joinery, turning, and veneer production. *(Abstract prepared by compilers.)*

Zhang, S.Y. 1998. Effect of age on the variation, correlations and inheritance of selected wood characteristics in black spruce (*Picea mariana*). *Wood Science and Technology* **32**(3): 197–204.

The variation, correlations and inheritance of various intraring wood characteristics in 15-year-old black spruce (*Picea mariana*) trees from 40 half-sib families grown in New Brunswick were examined. The emphasis was placed on the effect of age on these genetic parameters. With increasing (cambial) age, ring width and ring density tend to exhibit a constant tree-to-tree variation whereas most other characteristics exhibit a smaller tree-to-tree variation. The heritability for latewood characteristics does not seem to change appreciably. Other characteristics (except RDmi), however, tend to be less heritable when the tree grows older. Correlations between ring density and most intraring characteristics tend to be weaker with increasing age. This implies that fast-growth in this species will have less negative effect on wood density when the tree grows older.

Zhang, S.Y. 2003. Wood quality attributes and their impacts on wood utilization. Pages 1–6 *in* Anonymous. *Forests Source of Life*. XII World Forestry Congress, Quebec, Quebec, Canada. Food and Agriculture Organisation, Rome, Italy.

This presentation considers the quality and processability of wood and how it is expected to change with increasingly intensive management over shorter rotations. Wood-processing aspects considered include bucking, debarking, harvesting, lumber conversion, lumber drying, lumber grading, lumber volume recovery, manufacturing costs, transportation, storage, and visual grading. Wood-property aspects considered include aesthetic characteristics, anatomical characteristics, bark, chemical composition, dimensional stability, durability, engineering properties, finishing characteristics, fire resistance, growth stresses, heartwood:sapwood ratio, juvenile wood, knottiness, machinability, mechanical properties, moisture content, reaction wood, ring characteristics, stem decay, stem diameter, stem form, stem taper, tree age, wood density, and wood permeability. *(Abstract prepared by compilers.)*

Zhang, S.Y., and Chauret, G. 1995. *Industrial Bark Utilization: Perspectives for Major Eastern Canadian Softwoods.* Forintek Canada Corp., Ste-Foy, Quebec, Canada.

Considerable quantities of bark are produced every year from the processing of wood. These stockpiles present both an environmental challenge and a waste of potential product, but little work has been undertaken in Canada to either understand the resource or exploit its potential. This review examines the properties of bark from eastern North American cedar, fir, pine and spruce. It recommends that an update of bark properties from all major eastern Canadian species be undertaken and, as a second step, that opportunities to convert the bark to value-added products be explored. *(Abstract prepared by compilers.)*

Zhang, S.Y., Chauret, G., Ren, H.Q., and Desjardins, R. 2002. Impact of initial spacing on plantation black spruce lumber grade yield, bending properties, and MSR yield. *Wood and Fiber Science* **34**(3): 460–475.

For decades, initial spacing of 2 m x 2 m has been used for black spruce (*Picea mariana*) reforestation in eastern Canada. In recent years, however, wider spacings for black spruce are being advocated to reduce establishment costs and accelerate tree growth. Wider spacings will affect not only the return on investment but also the quality of products from the plantations, both of which are critical to the success of reforestation programs. As part of a multidisciplinary project, this study evaluated and quantified the impact of initial spacing on lumber grade yield, bending properties, and MSR yield in this species. Furthermore, visual grades on the plantation-grown lumber were compared for their bending properties and their compliance to the current grade requirements for bending stiffness.

A total of 139 sample trees were collected from 4 different spacings (3.086, 2.500, 2.066, 1.372 trees/ha) in a 48-year-old initial spacing trial, and 849 pieces of 2-in.-thick lumber from the 4 spacings were graded visually and tested for bending strength and stiffness. With decreasing initial stand density from 3.086 to 2.066 trees/ha, branch diameter showed a steady increase. However, the 3 higher stand densities (3.086, 2.500, and 2.066 trees/ha) had a comparable Select Structural (SS) grade yield thanks to the relatively small branches in this species. Lumber strength and stiffness in those 3 spacings were also quite comparable. When the initial stand density was further reduced to 1.372 trees/ha, however, a remarkable decrease in the SS grade yield due to knots occurred, and lumber strength and stiffness also decreased significantly. The real concern occurred when the plantation-grown lumber was compared to that from natural stands currently being processed in eastern Canada. On average, the plantation-grown black spruce lumber stiffness was 28.9% lower than that of lumber from natural stands. As a result, a high percentage of the plantation-grown lumber did not meet the bending design values. However, the percentage of the compliance to the design values tended to increase with increasing initial stand density. This article discusses the possible causes for the significantly lower bending properties of the plantation-grown lumber, and potential solutions for increasing lumber properties and the percentage of the compliance.

Zhang, S.Y., Chauret, G., Swift, D.E., and Duchesne, I. 2006. Effects of precommercial thinning on tree growth and lumber quality in a jack pine stand in New Brunswick, Canada. *Canadian Journal of Forest Research* **36**(4): 945–952.

A naturally regenerated jack pine (*Pinus banksiana* Lamb.) trial established in 1966 in New Brunswick was studied to determine how three precommercial thinning intensities (1.22 m × 1.22 m, 1.52 m × 1.52 m, and 2.13 m × 2.13 m) and a control (154 trees in total) affected tree growth and lumber quality. Mild (thinned to 1.22 m) and moderate (1.52 m) thinning had a modest impact on tree growth after 34 years (stand age 59). However, intensive thinning (2.13 m, or 2212 stems/ha) increased tree height by 13.1% compared with the control, whereas tree diameter and merchantable stem volume per tree increased by >20% and >75%, respectively. Yields of No. 2 and better increased slightly with increasing thinning intensity, but lumber bending properties decreased with increasing thinning intensity. There was, respectively, >20% and >15% difference in lumber strength (modulus of rupture) and stiffness (modulus of elasticity) between the mild (1.22 m) and intensive (2.13 m) thinnings. Intensive precommercial thinning (2.13 m) is recommended for increased volume growth, but rotation age (>59 years) should not be reduced if lumber bending properties are of concern.

Un test de régénération naturelle de pin gris (*Pinus banksiana* Lamb.) établi en 1966 au Nouveau-Brunswick a été étudié pour déterminer comment trois intensités d'éclaircie précommerciale (1,22 m x 1,22 m; 1,52 m x 1,52 m; 2,13 m x 2,13 m) et un témoin (154 arbres au total) ont affecté la croissance des arbres et la qualité du bois. Les éclaircies faible (1,22 m) et modérée (1,52 m) ont eu un impact modeste sur la croissance des arbres après 34 ans (peuplement âgé de 59 ans). Cependant, la hauteur des arbres a augmenté de 13,1 % comparativement au témoin tandis que le diamètre et le volume marchand ont augmenté respectivement de plus de 20 et 75 % à la suite de l'éclaircie forte (2,13 m ou 2212 tiges/ha). Le rendement en bois d'oeuvre de qualité n° 2 et meilleure a augmenté légèrement avec l'augmentation de l'intensité de l'éclaircie mais les propriétés du bois en flexion se sont détériorées. Il y avait une différence respective de plus de 20 et 15 % dans la résistance mécanique et l'élasticité du bois entre les éclaircies faible (1,22 m) et forte (2,13 m). L'éclaircie forte est recommandée pour augmenter la croissance en volume mais la période de révolution (59 ans) ne devrait pas être raccourcie si les propriétés du bois en flexion sont importantes.

Zhang, S.Y., and Chui, Y. H. 1996. Selecting dry fiber weight for higher and better quality jack pine fiber production. *Wood and Fiber Science* **28**(2): 146–152.

Sixteen-year-old half-sib jack pine (*Pinus banksiana* Lamb.) families planted in New Brunswick were evaluated for wood density, growth traits (DBH, tree height, and bole volume), and dry fiber weight (wood density x bole volume). The variation and inheritance of these traits and their relationships were studied. The implications of these genetic parameters for optimum gains in wood quality and wood quantity (bole volume) were discussed. The results indicate that wood density and tree height exhibit considerably less phenotypic variation but a remarkably higher heritability compared to DBH and bole volume. Dry fiber weight shows the largest phenotypic variation but a moderate heritability. There exists a positive genetic correlation between wood density and all growth traits. This suggests that selection for growth traits would not necessarily lead to a reduction in wood density in this species. Compared to traditional selection for bole volume, however, selection for dry fiber weight would result in higher genetic gains not only in dry fiber weight (+12.9% vs. 9.9%), but also in wood density (1.8% vs. 0.8%) and bole volume (9.8% vs. 8.2%). Therefore, this selection strategy would achieve both higher and better quality fiber production compared to traditional selection for volume alone.

Zhang, S.Y., Corneau, Y., and Chauret, G. 1998. *Impact of Precommercial Thinning on Tree and Wood Characteristics, Product Quality and Value in Balsam Fir.* Project No. 1108. Forintek Canada Corp., Ste-Foy, Quebec, Canada.

This study was carried out to evaluate the effect of precommercial thinning on timber yield, quality, and value in balsam fir stands. One stand near Amqui, Quebec was selected as the test site. The stand had regenerated naturally following harvest in 1948, and thinning plots were established in 1960. One hundred and fifty trees were sampled from the site. Measurements and determinations were made of bark thickness, branch diameter, chip volume and value recovery, clear log length, heartwood content, live crown length and width, log volume recovery, lumber dimension recovery, lumber grade recovery, lumber strength and stiffness, lumber value recovery, lumber volume recovery, moisture content, total value recovery, tree diameter, tree height, tree taper, tree volume, and wood density. Trees from thinned stands were shorter and greater in diameter but had greater taper and thicker branches. In general, lumber recovery was greater from thinned stands. Lumber grade recovery was slightly lower. Although moderate thinning did not affect bending strength and stiffness, they were reduced after heavy thinning. It was concluded that, to maximize value, the densest initial stands profit most from thinning. *(Abstract prepared by compilers.)*

Zhang, S.Y., and Jiang, Z.H. 1998. Variability of selected wood characteristics in 40 half-sib families of black spruce (*Picea mariana*). *Wood Science and Technology* **32**(1): 71–82.

Based on 15-year-old black spruce (*Picea mariana*) trees from 40 half-sib families sampled from 9 blocks of a family test in New Brunswick, this study examined intertree and intratree variation in various wood density and ring width characteristics. Of various variance components of the intertree variation, a remarkable variance component due to family was found in wood density characteristics (viz. average wood density, average earlywood density and latewood density of the tree), and these characteristics are thus under strong genetic control (h_i^2 ranging from 0.60 to 0.86, and h_f^2 from 0.56 to 0.68). It, to a lesser extent, applies to ring width characteristics at the tree level (viz. average ring width, and average earlywood width, latewood width and latewood percent of the tree) that show a lower heritability (h_i^2 from 0.18 to 0.28, and h_f^2 from 0.22 to 0.36). Both block and block × family interaction contribute little to the total intertree variation encountered in 40 families from 9 blocks, while tree-to-tree variation within the family accounts for most (over 3/4) of the total intertree variation. Compared to the intertree variation (tree-to-tree variation within the family), the intratree variation in various wood characteristics studied is considerably larger in this species. It appears that most intraring wood density characteristics show a relatively smaller intertree variation but a relatively larger intratree variation as compared to ring width characteristics (except latewood width and latewood percent). Latewood width and latewood percent show the smallest intertree variation and the largest intratree variation. Between the two sources of the radial intratree variation, cambial age explains much more variation in most intraring wood density characteristics, while ring width accounts for more variation in earlywood width, latewood width and intraring density variation. This indicates that wood density of growth rings in this species is dependent more on cambial age than ring width (growth rate). Among various wood density and ring width characteristics studies, maximum (latewood) density shows the strongest response to calendar year. This characteristic is thus a useful dendroclimatic parameter in this species.

Zhang, S.Y., and Koubaa, A. 2008. *Softwoods of Eastern Canada: Their Silvics, Characteristics, Manufacturing and End-Uses.* Special Publication SP-526E. Forintek Canada Corp., Ste-Foy, Quebec, Canada.

This book summarizes the silvics, characteristics, manufacturing, and end uses of 10 eastern Canadian softwoods, as well as exotic larches. Silvics include distribution, growth, and habitat; major diseases and insects; regeneration; taxonomy; tree description; and tree improvement and silvicultural practices. Wood characteristics include bark structure and properties; chemical properties; mechanical properties; physical properties; variations in wood properties; and wood anatomy, as well as the relationship between growth and wood properties. Manufacturing aspects include composite products manufacturing; lumber conversion; lumber drying; manufacturing of poles and posts; pulp and paper manufacturing; secondary manufacturing; and treatability and preservation. End-use considerations include bark uses; composite products; lumber; pulp and paper; and secondary uses. *(Abstract prepared by compilers.)*

Zhang, S.Y., Lei, Y.C., and Bowling, C. 2005. Quantifying stem quality characteristics in relation to initial spacing and modeling their relationship with tree characteristics in black spruce (*Picea mariana*). *Northern Journal of Applied Forestry* **22**(2): 85–93.

The relationship among tree growth, stem quality, and stand spacing in black spruce was examined. Trees were selected from the 1950 spacing trial near Thunder Bay, Ontario. When spacing increased, branch size, clear log length, crown size, diameter at breast height, taper, tree height, and volume all increased. Black spruce may require a larger spacing in order to achieve a response. Crown width may be the best density indicator for black spruce. Wider spacings result in a decrease in stem quality, and tighter spacings result in higher volumes. *(Abstract prepared by compilers.)*

Zhang, S.Y., Lei, Y.C., and Jiang, Z.H. 2006. Modelling the relationship of tree-level product value with tree characteristics in black spruce. *The Forestry Chronicle* **82**(5): 690–699.

The establishment of the relationship between tree-level product value and tree characteristics will allow for predicting the potential value of individual trees and a stand directly using tree characteristics. Using statistical and elasticity analysis methods, this study examined the relationship of tree-level product value with selected tree characteristics in black spruce (*Picea mariana*). The study was based a sample of 139 trees from 48-year-old black spruce plantations grown in Ontario, Canada. The sample trees showed large variation in tree characteristics and tree-level product value. Models were developed and compared on the basis of statistics of the estimated and predicted criteria. Results show that the model, including only tree DBH, tree height and stem taper, is the best in describing the relationship of the tree-level product value with tree characteristics. Furthermore, relationships including input–output and interaction factors in the model were analyzed by calculating the elasticity of production and scale and the cross partial derivative of output with respect to the inputs. The analyses indicate that tree DBH has the largest and positive influence on tree-level product value, followed by tree height; however, stem taper has a negative effect on tree-level product value. When tree DBH, tree height and stem taper each increase by 1%, the quantities of output elasticity show 2.53%, 0.64% and -0.37% changes in the product value, respectively; while the scale elasticity shows a 2.81% increase in tree-level product value with a simultaneous 1% change in tree DBH, tree height and stem taper. Results indicate that the model is suitable for predicting tree-level product value using those tree characteristics from forest inventory and also reflects biological behaviour.

La mise en place d'une relation entre la valeur d'un produit tiré d'un arbre et les caractéristiques de ce dernier permettra de prédire la valeur probable de chaque arbre et du peuplement directement au moyen des caractéristiques dendrométriques. Cette étude examine au moyen des méthodes d'analyse statistique et d'élasticité la relation entre la valeur d'un produit tiré d'un arbre et les caractéristiques d'arbres sélectionnés parmi des épinettes noires (*Picea mariana*). L'étude repose sur un échantillon de 139 arbres d'une plantation d'épinette noire de 48 ans établie en Ontario au Canada. Les arbres-échantillons ont démontré une ample variation des caractéristiques des arbres et de la valeur des produits tirés de ces derniers. Des modèles ont été élaborés et comparés en fonction de statistiques provenant de critères estimés et prédits. Les résultats indiquent que le modèle, incluant seulement le dhp des arbres, la hauteur et le défilement de la tige, est ce qu'il y a de mieux pour décrire la relation entre la valeur du produit tiré d'un arbre et les caractéristiques de celui-ci. De plus, les relations comprenant les facteurs portant sur les intrants et les extrants et sur les interactions au sein du modèle ont été analysées par le calcul de l'élasticité de la production et de son niveau et de la dérivée partielle de l'extrant relativement aux intrants. Les analyses ont démontré que le dhp de l'arbre exerçait la plus importante et la plus positive influence sur la valeur du produit tiré de l'arbre, suivi par la hauteur de l'arbre; cependant, le défilement de la tige avait un effet négatif sur la valeur du produit tiré de l'arbre. Lorsque le dhp, la hauteur et le défilement de la tige étaient augmentés chacun de 1 %, les quantités de l'élasticité des extrants indiquaient des changements respectifs de 2,53 %, 0,64 % et de 0,37 % de la valeur du produit, tandis que l'élasticité du niveau indique un accroissement de 2,81 % de la valeur du produit tiré de l'arbre avec un accroissement simultané de 1 % du dhp, de la hauteur et du défilement de la tige. Les résultats démontrent que le modèle permet de prédire la valeur du produit tiré de l'arbre au moyen de ces caractéristiques tirées de l'inventaire forestier et reflète également le comportement biologique.

Zhang, S.Y., and Liu, C. 2006. Predicting the lumber volume recovery of *Picea mariana* using parametric and non-parametric regression methods. *Scandinavian Journal of Forest Research* **21**(2): 158–166.

Three model forms (polynomial, power and exponential) and a local regression (LOESS) model with different variables were studied for their goodness of predicting lumber volume recovery from two types of sawmill (stud mill and optimized random mill). Explanatory variables used to predict lumber volume recovery were three basic tree characteristics: diameter at breast height (dbh), tree height and tree taper. Based on the selected statistical criteria such as R^2, mean absolute prediction error (MAE) and root mean square error (RMSE), the polynomial functions, power functions and the local regression (LOESS) model, in general, had excellent abilities to predict lumber volume recovery. The simplified second-order polynomial model with both dbh and tree height variables predicted the lumber volume recovery almost as accurately as did the LOESS model with the same predictor variables. Model validation using independent data from a real stud mill indicated that the two model forms were able to forecast lumber volume recovery from measured tree characteristics, especially for small and medium-sized trees.

Zhang, S.Y., Liu, C., and Jiang, Z.H. 2006. Modeling product recovery in relation to selected tree characteristics in black spruce using an optimized random sawing simulator. *Forest Products Journal* **56**(11/12): 93–99.

The artificial neural network (ANN) model and five traditional statistical regression models were employed to predict four simulated product recovery parameters (lumber volume, lumber value, chip volume, and total product value) from the optimized random sawmill simulation in black spruce using three basic tree characteristics (i.e., diameter at breast height, tree height, and stem taper). The ANN model (i.e., the three-layer perceptron with error back-propagation algorithm) performed as well as or better than the five statistical regression models in terms of statistical criteria such as r^2, root mean square error (RMSE), and mean absolute error (MAE) of predictions. The results showed that the ANN model, the second-order polynomial function, and the power function were suitable for predicting the product recovery using the selected tree characteristics. The models developed in this study are useful for the estimation of the product recovery of individual trees and of a forest stand before it is harvested, and thus are of value to the forest industry.

Zhang, S.Y., and Morgenstern, E.K. 1996. Genetic variation and inheritance of wood density in black spruce (*Picea mariana*) and its relationship with growth: implications for tree breeding. *Wood Science and Technology* **30**(1): 63–75.

Based on 15-year-old spruce (*Picea mariana*) trees of 40 open-pollinated families grown in New Brunswick, this study examined the genetic variation and inheritance of wood density, and its relationship with growth trait (tree diameter, tree height and bole volume). Implications of these genetic parameters for wood quality improvement were discussed. Although wood density, earlywood density and latewood density show smaller phenotypic variation than growth traits, a larger part of the variation in these traits is due to families. These traits are under strong genetic control (h_i^2 ranges from 0.60 to 0.86, and h_f^2 ranges from 0.56 to 0.68). Wood density has a strong genetic correlation with earlywood density and latewood density (+0.72 and -0.73, respectively), but earlywood density and latewood density are strongly related to each other. As a result, wood density components have little value in improving the efficiency of selection for overall wood density. Overall wood density shows negative genetic correlations with growth traits (ranging from -034 to -0.41). To achieve optimal genetic gains, therefore, index selection for multiple traits is essential. This study reveals that selection for dry mass weight would result in remarkably higher genetic gain in gross fibre yield than selection for bole volume alone (+14.15% and +9.28%, respectively). Furthermore, selection for dry mass weight would result in less reduction in wood density, and while holding wood density at zero change, it is still possible to obtain huge genetic gain in gross fibre yield.

Zhang, S.Y., Simpson, D., and Morgenstern, E.K. 1996. Variation in the relationship of wood density with growth in 40 black spruce (*Picea mariana*) families grown in New Brunswick. *Wood and Fiber Science* **28**(1): 91–99.

This study examined variation in the relationship of wood density with growth traits (DBH, tree height, and bole volume) in 15-year-old half-sib families of black spruce (*Picea mariana*) grown on two different sites located in northern New Brunswick. Effect of genotype and environment on wood density was also briefly discussed. Although a moderately negative relationship between wood density and growth generally exists, the relationship, to some extent, varies with genotype and environment. A nonsignificant or even a weak positive relationship between wood density and growth can be found in some families. Moreover, the negative relationship between wood density and growth appears to be weaker in families growing in a more favorable environment. This study indicates that it is possible to select some families that not only grow fast, but also maintain high wood density.

Zhang, S.Y., and Tong, Q.J. 2005. Modeling lumber recovery in relation to selected tree characteristics in jack pine using sawing simulator Optitek. *Annals of Forest Science* **62**(3): 219–228.

End uses and product recovery are important considerations in forest management decision-making. This study was intended to develop general tree-level lumber volume recovery models for jack pine. A sample of 154 jack pine trees collected from natural stands was scanned to obtain 3-D stem geometry for sawing simulation under two sawmill layouts, a stud mill and a random mill with optimized bucking, using sawing simulator Optitek. Three model forms were chosen to describe the quantitative relationship between simulated lumber volume recovery and tree characteristics. It was found that lumber volume recovery of individual trees from both sawmills could be well estimated from DBH using a second-order polynomial equation. Adding tree height into the model resulted in a small but significant improvement in the goodness of the model. Adding tree taper into the model that already included DBH and tree height no longer improved the goodness significantly. The power function form involving only DBH or both DBH and tree height as variables was also found to be suitable for the stud mill; exponential forms were least suitable. The second-order polynomial model with DBH alone was the most suitable model when inventory records DBH only, while the second-order polynomial model and the power model involving two variables (DBH and tree height) for the random mill and the stud mill, respectively, were better when both DBH and tree height are available.

L'utilisation finale et le rendement en produits sont des considérations importantes dans la prise de décision en aménagement forestier. Cette étude vise à développer des modèles généraux de rendement en volume au niveau de l'arbre du pin baumier. Un échantillon de 154 arbres de sapin baumier récoltés dans des peuplements naturels a été scanné pour obtenir la géométrie 3-D des tiges pour effectuer la simulation selon deux configurations d'usine, soit une scierie de bois de colombage et une usine variable avec tronçonnage optimisé avec le simulateur de sciage Optitek. Trois formes de modèles ont été choisies pour décrire la relation quantitative entre le rendement en sciage simulé et les caractéristiques de l'arbre. Il semble que le rendement en sciage d'arbres individuels provenant des deux scieries peut être bien estimé à partir du DHP en utilisant une équation polynomiale de deuxième ordre. L'ajout de la hauteur de l'arbre aux résultats du modèle est une petite amélioration, mais tout de même significative pour la validité du modèle. Toutefois, l'ajout du défilement de l'arbre à un modèle incluant déjà le DHP et la hauteur de l'arbre n'améliore pas significativement la validité. Les équations de fonction puissance impliquant seulement le DHP ou le DHP et la hauteur de l'arbre comme variables se sont avérées appropriées pour l'usine de colombage, alors que les équations exponentielles l'étaient moins. Le modèle polynomial de deuxième ordre (modèle 2) avec DHP seulement est le modèle le plus approprié lorsque l'inventaire enregistre seulement le DHP, alors que le modèle polynomial de second ordre et le modèle fonction puissance impliquant 2 variables (DHP et hauteur de l'arbre pour l'usine variable et l'usine de colombage, respectivement, sont meilleurs lorsque le DHP et la hauteur de l'arbre sont disponibles.

Zhang, S.Y., Yu, Q., and Beaulieu, J. 2004. Genetic variation in veneer quality and its correlation to growth in white spruce. *Canadian Journal of Forest Research* **34**(6): 1311–1318.

This study investigated the genetic variation in veneer quality of white spruce (*Picea glauca* (Moench) Voss) and its correlation with tree growth and wood density. A total of 270 sample trees from 35 families were harvested from 36-year-old provenance-progeny trials at two sites through a thinning operation. A 36-cm long bolt was collected from each sample tree at an 8-foot (or 2.45 m) height for this veneer quality study. The results indicate that conversion of fast-grown white spruce into veneer and plywood may present some problems. Low wood density, numerous knots, and possibly a high proportion of juvenile wood appear to be major factors contributing to low veneer stress grading, resulting in a production of low-quality veneer. This study also showed that the environmental factors at the two sites played an important role in determining veneer quality and tree radial growth. The narrow-sense heritability for veneer density, veneer modulus of elasticity, and veneer roughness were 0.62, 0.13, and 0.14, respectively. The results revealed considerable phenotypic variation and relatively high additive genetic variation in the veneer modulus of elasticity. The phenotypic and genetic correlations between ring width and veneer density or veneer modulus of elasticity were negative. A positive phenotypic and genetic correlation was found between veneer density and veneer modulus of elasticity. This suggests that selection for tree volume growth in white spruce would lead to a decrease in wood density and veneer stiffness.

Cette étude a porté sur la variation génétique de la qualité du bois de placage d'épinette blanche (*Picea glauca* (Moench) Voss) et sa corrélation avec la croissance des arbres et la densité du bois. Un total de 270 arbres-échantillons appartenant à 35 familles ont été récoltés lors d'une d'éclaircie dans des tests de provenances et de descendances âgés de 36 ans à deux endroits différents. Une bille de 36 cm a été récoltée sur chaque arbre-échantillon à une hauteur de 8 pieds (ou 2,45 m) pour cette étude de la qualité du bois de placage. Les résultats indiquent que la conversion d'épinettes blanches à croissance rapide en bois de placage ou de contre-plaqué pouvait présenter certains problèmes. La faible densité du bois, le grand nombre de noeuds et possiblement la forte proportion de bois juvénile semblent être les principaux facteurs qui contribuent à déclasser le bois de placage lors du classement mécanique, entraînant la faible production de bois de placage de bonne qualité. Cette étude a aussi démontré que les facteurs environnementaux jouaient aux deux endroits un rôle important dans la détermination de la qualité du bois de placage et dans la croissance radiale des arbres. L'héritabilité au sens strict de la densité du bois de placage, de son module d'élasticité et de sa rugosité étaient respectivement de 0,62, 0,13 et 0,14. Les résultats ont révélé qu'il y avait une variation phénotypique considérable et une variation génétique additive relativement élevée dans le module d'élasticité du bois de placage. Les corrélations phénotypiques et génétiques entre la largeur des cernes annuels et la densité du bois de placage ou son module d'élasticité étaient négatives. Une corrélation génétique et phénotypique positive a également été décelée entre la densité du bois de placage et son module d'élasticité. Ces résultats indiquent que la sélection des arbres pour la croissance en volume entraînerait une diminution de la densité du bois et de la rigidité du bois de placage chez l'épinette blanche.

Zhang, Y., Wan, H., and Zhang, S.Y. 2005. Characterization of sugar maple wood–polymer composites: monomer retention and polymer retention. *Holzforschung* **59**(3): 322–329.

In this study, sugar maple samples were impregnated with three impregnants by a vacuum and pressure process and in situ polymerized by a catalyst-thermal procedure. The effects of polymeric monomers and their combination on monomer retention by volume (MRV) and weight (MRW) and polymer retention (PR) were analyzed and the wood was examined by scanning electronic microscopy (SEM). The three methacrylates chosen as impregnants were methyl methacrylate (MMA), hydroxyethylene methacrylate (HEMA) and ethylene glycol dimethacrylate (EGDMA). The formulation combination was determined by a mixture design. MRV was similar, regardless of formulation combination, which indicated that these methacrylates show similar permeability into sugar maple. However, MRW was different between formulation combination due to differences in monomer density. MRV was inversely related to wood density. PR was related to the combination of impregnants and inversely related to wood density. The impregnants resided in the vessel and the lumen. The morphology of polymers in the wood was different for different treatments due to the distinct molecular structures formed from each polymer.

Zhou, H., and Smith, I. 1991. Influences of drying treatments on bending properties of plantation-grown white spruce. *Forest Products Journal* **41**(2): 8–14.

Influences of drying treatments on bending strength properties of plantation-grown white spruce lumber were studied. One hundred and ninety pieces of nominal 2 X 4 structural lumber were divided into four groups. One group in the green condition was used as a control, and the other three groups were dried to a target moisture content (MC) of 12% using mild, moderate, and harsh conventional drying schedules. Modulus of rupture (MOR) and modulus of elasticity (MOE) of each specimen were determined using a four-point bending arrangement. The conventional drying treatments significantly influenced bending strength and stiffness of lumber. The mildly dried material represented the maximum strength increase with average ratios of dry to green 1.55 for MOR and 1.44 for MOE. Harsh drying conditions reduced the ratios to 1.15 and 1.22, respectively. Thus, the more severe the drying condition, the smaller the ratios. It was also found that the low visual stress grade material in this research was less sensitive to MC change than the high visual stress grade material. *(Abstract prepared by compilers.)*

Zhou, H., and Smith, I. 1991. Factors influencing bending properties of white spruce lumber. *Wood and Fiber Science* **23**(4): 483–500.

Wood strength studies have traditionally relied upon small clear, defect free samples. This study was designed to understand the influence of conventional drying schedules knots, slope of grain, relative density, ring width, and proportion of juvenile wood on bending strength and stiffness of full-scale samples. Fifty-one logs from 14 white spruce (*Picea glauca* (Moench) Voss) trees were harvested and included both dominant and suppressed trees. Juvenile wood was defined as the inner 15 rings for bottom logs and 12 rings for top logs. Juvenile wood at the ends of each log were painted to aid in identification after sawing into lumber. Lumber was dried using conventional kiln schedules equating to slow-mild, medium-severe, and fast-severe. Bending strength and stiffness were measured in 4-point bending. Knots were evaluated according to British Standard BS4978-1988. Slope of grain was measured on all 4 faces of the lumber using a scribe. Lumber was visually graded and bending stiffness tests conducted on both edges to determine the weakest edge. Bending strength was determined using weakest edge down. Failure pattern was recorded. It was found that drying schedules can significantly influence lumber strength properties with mild conditions resulting in greater strength. Knots were implicated in most bending failures. Relationships between strength and slope of grain were weak, possibly as a result of confounding by other factors, but lumber with sloped grain resulted in greater drying defects. Low strength was also associated with wide growth rings and high juvenile wood content. It was concluded that plantation-grown white spruce may result in lower grade yield and consequently low value lumber.

Zhu, J.Y., Vahey, D.W., and Scott, C.T. 2008. Some observations of wood density and anatomical properties in a Douglas-fir sample with suppressed growth. *Wood and Fiber Science* **40**(2): 225–232.

This study used ring width correlations to examine the effects of tree-growth suppression on within-tree local wood density and tracheid anatomical properties. A wood core sample was taken from a 70-yr-old Douglas-fir that grew under various degrees of suppression in a natural forest setting. SilviScan and an imaging technique were used to obtain wood density and tracheid cross-section dimensions. The results indicated that wood and tracheid properties correlate to annual-ring width very well. The results also reveal that growth suppression may increase the uniformity of wood density and tracheid cell-wall thickness in both radial and tangential directions.

Zhu, J.Y., Vahey, D.W., Scott, C.T., and Myers, G.C. 2008. Effect of tree-growth rate on papermaking fibre properties. *Appita Journal* **61**(2): 141–148.

Measurements of wood density and anatomical properties of wood disks were conducted by SilviScan (CSIRO Australia) and a new imaging technique. The disks included red pine (*Pinus resinosa* Ait.) obtained from a never-thinned experimental forest with five different plantation densities and Douglas-fir (*Pseudotsuga menziesii* var. *glauca* (Beissn.) Franco) and lodgepole pine (*P. contorta* Engelm.) (one normal growth and the other suppressed growth), both supplied by a sawmill. The results indicated that the effect of tree growing conditions can be effectively characterised by radial annual growth rate. Growth suppression produced wood with less distinction in wood density, tracheid radial diameter, and wall thickness between earlywood and latewood.

Zobel, B. 1992. Silvicultural effects on wood properties. *IPEF International* **2**: 31–38.

The relationship between silvicultural treatments and wood properties is examined. Fertilization, stocking, pruning, and other practices can alter the growth rate and thus specific gravity. For each of these treatments, the paper provides a brief overview of the effects of specific gravity on wood mechanical properties. *(Abstract prepared by compilers.)*

Zobel, B.J. 1964. Breeding for wood properties in forest trees. *Unasylva* **73–74**: 26.

This paper provides an overview of wood characteristics that can be influenced by breeding. It gives an explanation of how genetic control is measured and of the genetic gains and improvements possible. The inheritance of wood properties is discussed for natural stands, provenance tests, and individual trees. Breeding trees for better wood involves genetics and the environment. *(Abstract prepared by compilers.)*

Zobel, B.J. 1984. The changing quality of the world wood supply. *Wood Science and Technology* **18**:1–17.

The reasons for changes in wood quality and utilization are related to the trends toward harvesting smaller, younger and lower-quality timber, wider use of formerly waste wood, unconventional uses of wood, and improved forest management and new wood manufacturing techniques.

1. An unequal distribution of timber along with increasing costs of forest ownership and management is forcing short-rotation forestry, which results in small-sized timber, low-quality wood, and a high proportion of juvenile wood and knots. This is true for almost all forest regions although it has been most evident in tropical plantations. The economic pressures for short-rotation ages will become increasingly great, especially in those areas where a timber imbalance in age class distribution occurs.

2. Especially in the tropics, many forestry organizations are planting exotic species on a massive scale and are producing a large volume of “different” wood. The trend toward using exotics is very strong. The trees attain a merchantable size at young ages, with thinning being standard; this produces a large proportion of juvenile wood. Such wood is not desirable for some products, based on current quality criteria, and may be distinctly different from the wood that the same species produces in its indigenous environment. Huge amounts of it are now becoming available, requiring a reassessment of both manufacturing techniques and product type and quality.

3. Better utilization in forest harvesting operations results in the use of mill residues of bark and sawdust and forest residues of bark, limbs, leaves, stumps and roots that formerly were considered to be waste. There is also greater utilization of previously unwanted species, including some which were once considered to be of limited value and often were destroyed during regeneration programs. Of great importance are the technological developments that are enabling a greater utilization of the grossly differing woods found growing together in tropical forests, rather than using only a few species and destroying the rest.

4. Wood quality is very responsive to both silvicultural and genetic manipulation. The improvements possible in wood will partially offset some quality declines caused by young wood and lower quality trees. The quickest and easiest method of changing wood quality is to control age of harvest.

5. New industries are developing which use wood as a source of energy and organic chemicals. In some areas, wood for energy is primarily obtained from large forests being planted solely for energy needs and is secondarily obtained as a salvage product from the forest. From 20 to 50% of the wood harvested in the world is for firewood, which often results in a marked reduction of the quality of the wood used for industrial purposes. Currently some research is focused to grow trees which will yield improved energy and chemicals. 6. New manufacturing techniques, such as oriented strand-board and the end-gluing of short, clear wood segments from low-quality logs, are enabling the production of high-quality products from low-quality timber. These manufacturing techniques result in products that differ markedly from those previously available but they are stable and of excellent quality. However, a strong sales program will be needed to assure acceptance of the different products.

Zobel, B.J., and van Buijtenen, J.P. 1989. *Wood Variation: Its Causes and Control.* Springer-Verlag, Heidelberg, Germany.

This book is a reference on wood variation. Topics include wood variation and wood properties; the effect of provenance variation and exotic plantations on wood properties; variation within and among trees; wood property variation as related to tree form and reaction wood; the effect of growth rate on wood properties; wood properties affected by environmental, biological, and other external agencies; the effect of silvicultural practices on wood properties; control of wood properties by breeding; and the future importance of knowing and manipulating wood variability. *(Abstract prepared by compilers.)*

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