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Impact of stand density management on stem and wood characteristics, lumber properties and financial returns in major species of Eastern Canada

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Resource Assessment & Utilization Program

S-1043

1. **Background**

2. Impact of stand density management on stem and wood characteristics, lumber properties and financial returns in eastern species

3. General conclusions

Part I

Background

- Declining wood supply in eastern Canada

Intensive Forest Management (IFM) is the key to improve productivity 1.5 m^3/ha/yr

Stand Density Management (SDM) is the key to IFM

- Initial spacing: initial planting density
- Early spacing: precommercial thinning (PCT)
- Late spacing: commercial thinning (CT)

Status of stand density management in eastern Canada (I)

Type of Density Regulation	Major species	Estimated area (x 1000 ha)
Initial spacing (Planting)	Spruces, jack pine	190
PCT	Balsam fir, jack pine	125
CT	Spruces, pines	30

Status of stand density management in eastern Canada (II)

- Decisions on initial density & thinning intensity are based exclusively on growth & yield (volume)

- Impact on product quality and returns on the investment unknown

Part I

Objective

Overall Objective

to determine the optimal stand density or thinning intensity required to achieve:

1) quality products

2) the best returns (instead of maximum wood volume)

Integrated Approach to the wood value chain

Stands of different densities & DBH frequency distribution

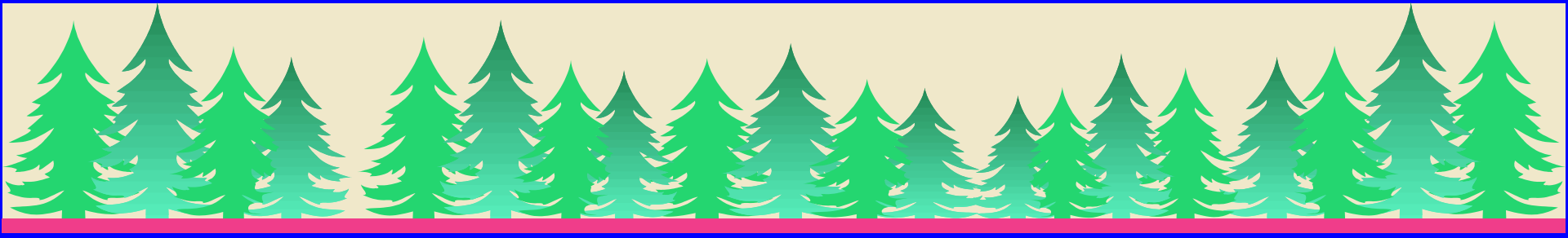
Sample trees of different DBH classes

Product Quality

- External stem/log quality
- Wood/fibre quality
- Chip/pulp properties
- Lumber grade yield
- Lumber strength/stiffness

Economic Return

- Log volume recovery
- Lumber value recovery
- Total stand value
- Silvicultural treatment cost
- Harvesting/manufacturing cost
- Benefit/cost analysis



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Forintek's initiatives on SDM in eastern Canada

Projects Initiated

1) Initial spacing in black spruce
2) Precommercial thinning in balsam fir
3) Precommercial thinning in jack pine
4) Initial spacing in jack pine

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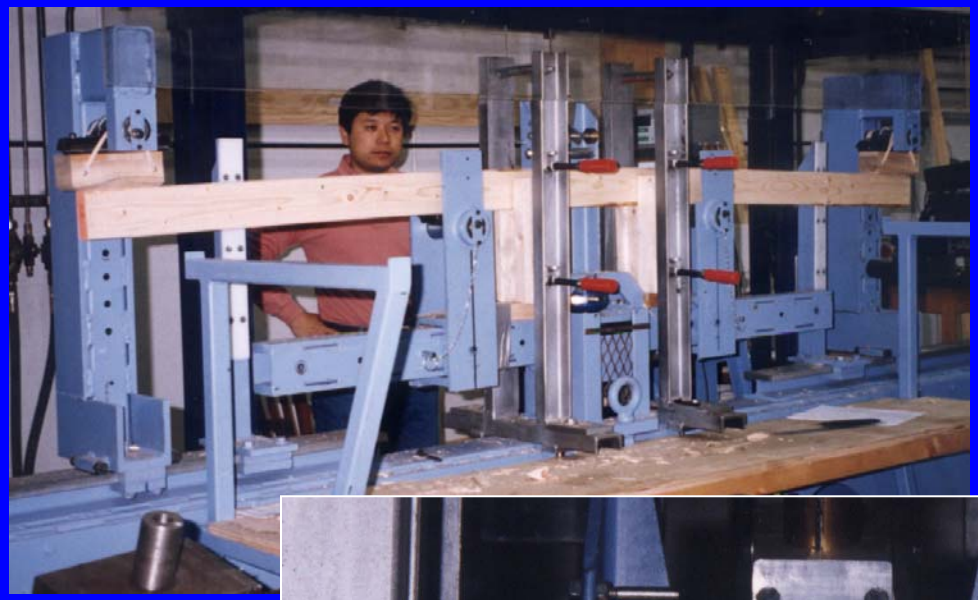

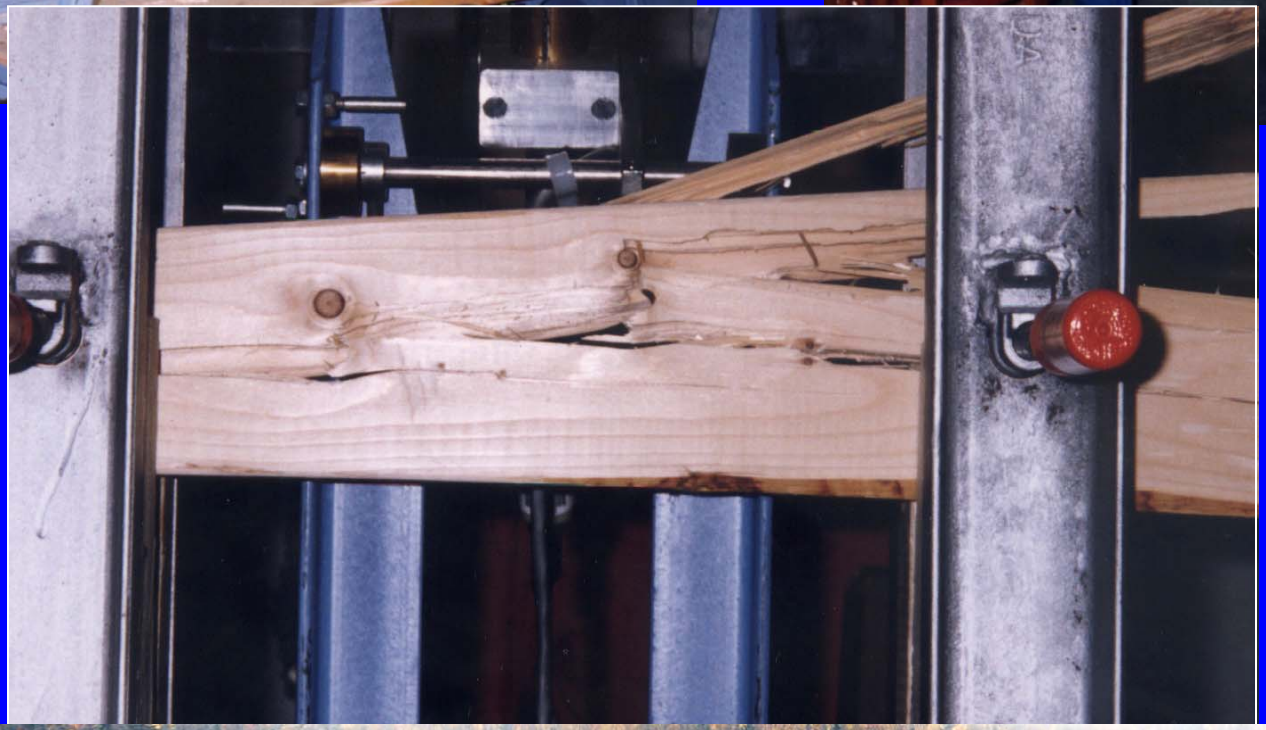

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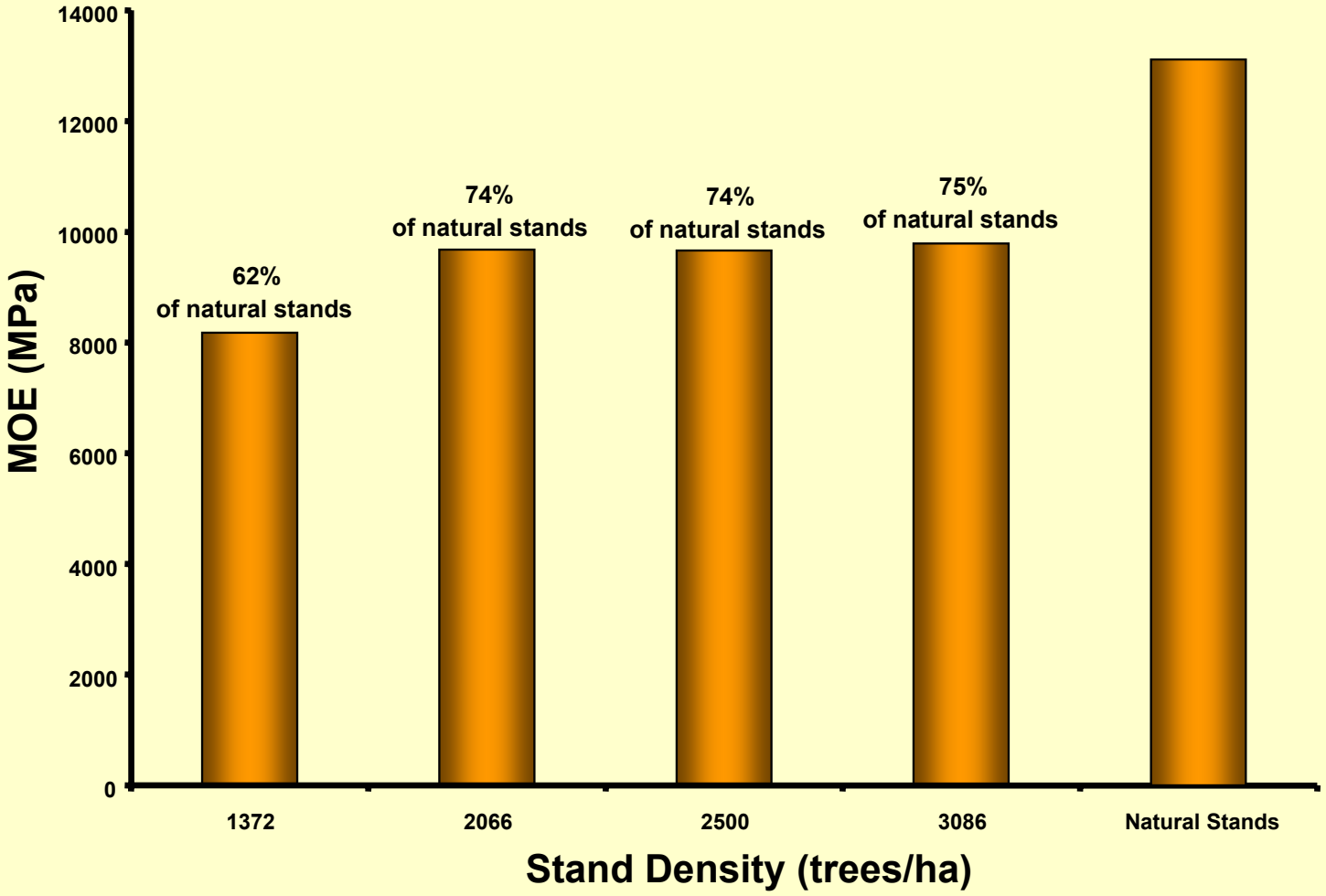
Stem characteristics for the four initial spacings

Characteristic	Initial stand density (trees/ha)			
	1372	**2066**	**2500**	**3086**
DBH (cm)	20.5	15.9	15.7	15.6
Live crown length (m)	7.8	6.3	6.1	5.6
Live crown width (m)	2.8	2.3	2.0	1.8
Average diameter of the 5 biggest branches (cm)	**2.38**	**1.83**	**1.84**	**1.64**

Stiffness of black spruce lumber from the 4 plantations vs. natural stands



Percentage of the plantation-grown lumber which meets the design requirement for Lumber MOE

Visual Grade	Required design property used in the comparison	Percentage of lumber pieces which meet the MOE design value (%)				
	Mean MOE (MPa)	Stand density (trees/ha)				
		1372	**2066**	**2500**	**3086**	**4 densities combined**
Select Structural	10865	2.7	18.5	17.6	25.0	15.5
No. 2	10044	13.4	39.1	24.5	26.8	24.6
No. 3	9296	8.3	14.3	40.0	66.7	25.0
Grand Total		**6.2**	**23.2**	**20.3**	**26.7**	18.3

The 5th percentile of MOR, mean MOR and mean MOE in relation to visual grade (4 densities combined)

Visual Grade	Sample Size	Mean MOR (and group)	5th percentile MOR	Mean MOE (and group)
Select Structural	547	**42.72 (A)**[1)]	**27.78**	**9195 (A)**
No. 1	12	**39.99 (A)**	**32.53**	**9106 (A)**
No. 2	203	**41.82 (A)**	**24.57**	**8961 (A)**
No. 3	32	**36.99 (B)**	**26.92**	**8258 (B)**
Economy	55	**41.65 (A)**	**24.55**	**8851 (A)**
Grand Total	849	**42.18**	**27.27**	**9081**

1) Waller-Duncun test ***(values sharing the same letter belong to the same group)***

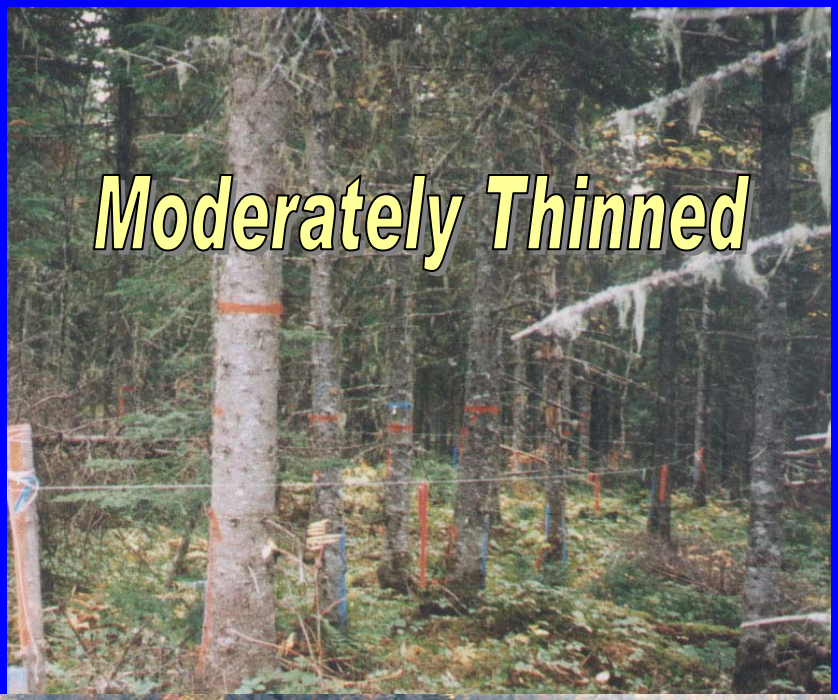
Benefit/cost ratios for the 4 initial spacings

	Initial Stand Density (trees/ha)			
	1372	2066	2500	3086
Total stand value ($/ha)	29581.38	24104.47	29162.34	35228.73
Total cost ($/ha)	16790.59	17080.67	20663.59	24702.66
Benefit/cost ratio	**1.76**	**1.41**	**1.41**	**1.43**

Forintek's initiatives on SDM in eastern Canada

Projects Initiated

1) Initial spacing in black spruce
2) **Precommercial thinning in balsam fir**
3) Precommercial thinning in jack pine
4) Initial spacing in jack pine



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lumber grade yield and bending strength/ stiffness for the stands of the control, moderate thinning and heavy thinning in balsam fir

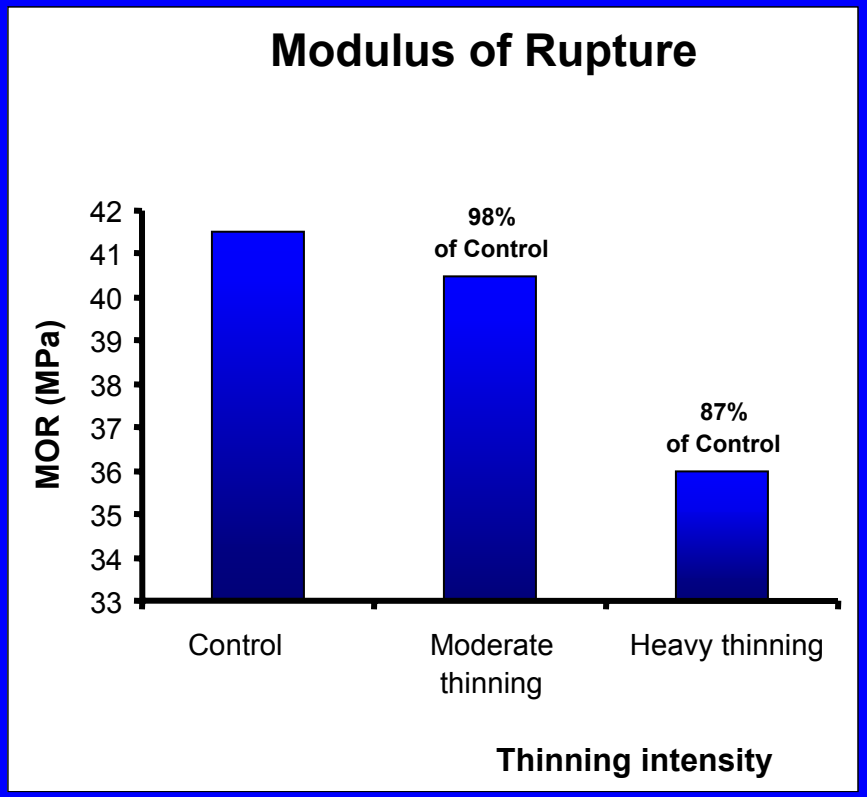
Characteristic	Control	Moderate thinning	Heavy Thinning
Branch diameter (mm)	15.8 (A)[1)]	21.5 (B)	24.7 (C)
Select Structural grade yield (%) (grading based on knots only)	77.7 (A)	59.1 (B)	51.7 (C)
Select Structural grade yield (%)	**59.5 (A)**	**56.8 (A)**	41.3 (B)
No. 2 & Better grades yield (%)	92.8 (B)	97.9 (A)	96.2 (A)
MOE (MPa)	**9211 (A)**	**8837 (A)**	8136 (B)
MOR (MPa)	**41.5 (A)**	**40.5 (A)**	36.0 (B)
Wood density (kg/m^3)	**348 (A)**	**342 (A)**	329 (B)

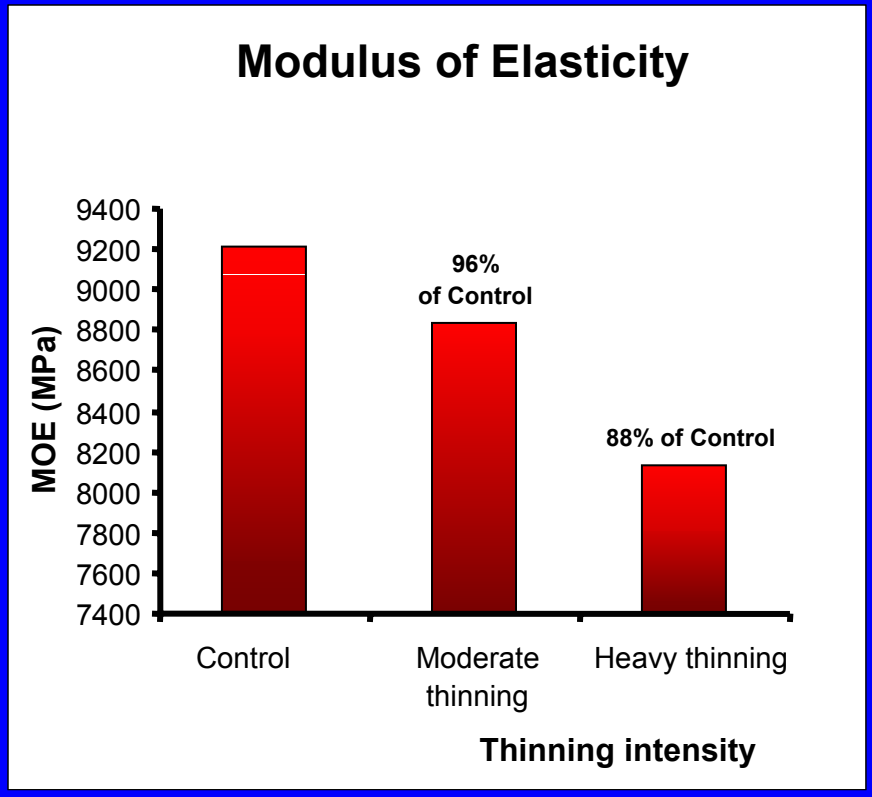
1) Waller-Duncun test *(values sharing the same letter belong to the same group)*


Control


Heavy thinning

Bending properties of lumber from thinned and control balsam fir stands





Estimated benefit/costs ratio for the control and thinned stands in balsam fir

Cost item	1000-2000 (stems/ha)	2000-2500 (stems/ha)	2500-3000 (stems/ha)	3000-3500 (stems/ha)	3500-5000 (stems/ha)	5000-7500 (stems/ha)	>7500 (stems/ha)
Stand Value ($/ha)	14073	13410	14355	14036	12712	12287	12081
Costs ($/ha)	17522	17632	18985	17008	17717	18129	17188
B/C ratio	0.80	0.76	0.76	0.83	0.72	0.68	0.70

Forintek's initiatives on intensive silviculture in eastern Canada

Projects Initiated

1) Initial spacing in black spruce
2) Precommercial thinning in balsam fir
3) **Precommercial thinning in jack pine**
4) Initial spacing in jack pine

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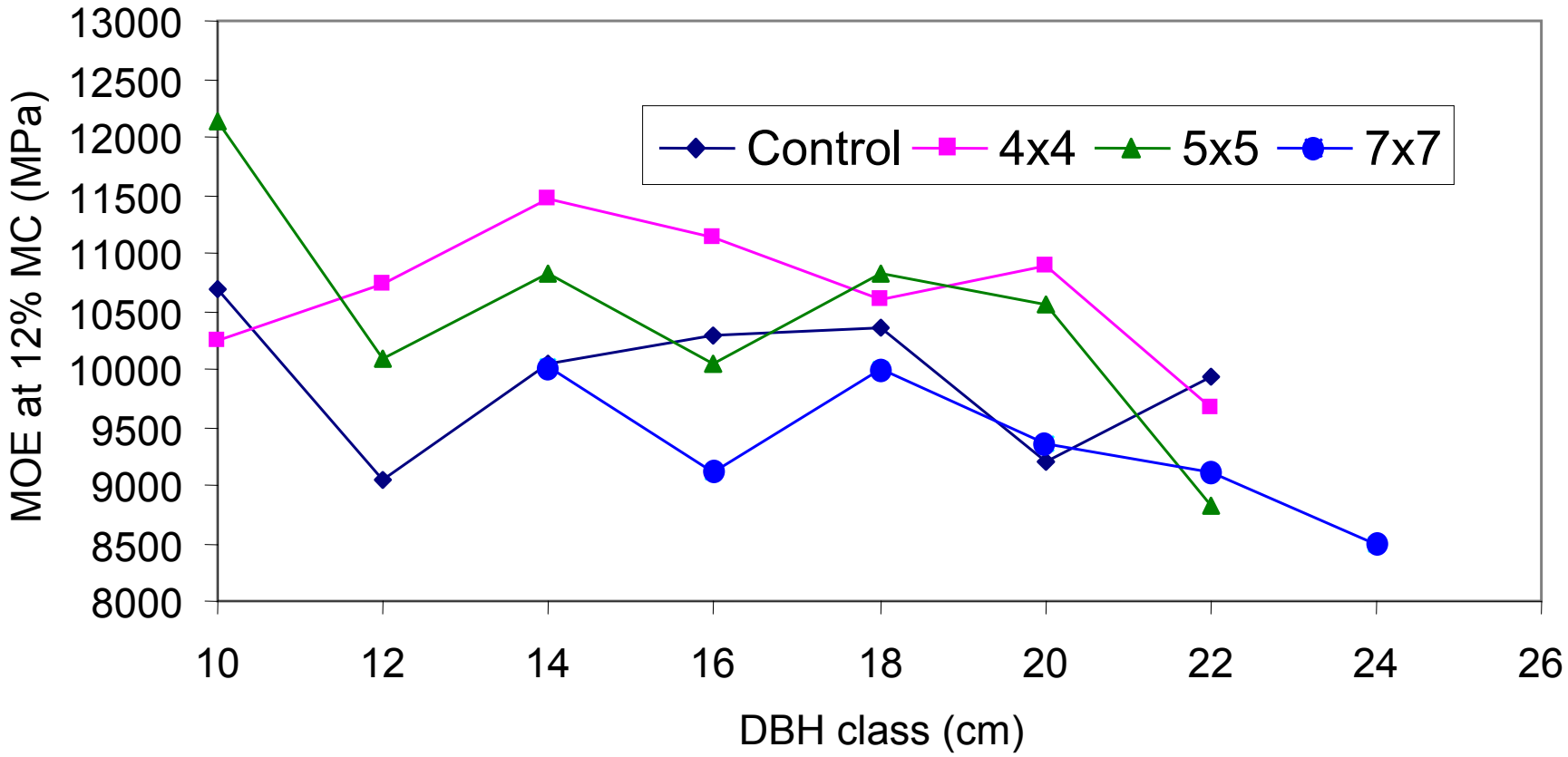
Average tree characteristics for the four densities

Characteristic	Control	4 x 4	5 x 5	7 x 7
Total tree height (m)	14.0	14.5	14.5	15.6
Tree volume (to the 7-cm top) (dm3/tree)	99.7	99.8	112.0	160.3
Stem taper (cm/m)	0.87	0.82	0.90	0.97
Crown width (m)	1.8	2.0	2.1	2.4
Average branch diameter (mm)	20.7	18.9	20.1	25.4
Live crown length (m)	4.4	4.5	4.4	5.3
Proportion of the live crown (%)	33.1	30.7	28.0	32.0
Length of the log without live crown m)	9.3	10.0	10.1	10.3
Mean log volume (dm3)	24.3	23.7	25.8	33.0
Log volume/stem volume (%)	84.2	82.4	84.4	87.3
Log length/stem length (to 7-cm top) (%)	88.3	88.1	89.0	89.3

Distribution of lumber by grade-limiting defects (%)

Defect	spacing (trees/ha)			
	Control	4X4	5X5	7X7
Wane	29,4	32,7	24,5	27,0
Knots	16,4	19,0	21,4	28,9
Others	3,6	3,8	2,5	3,0
SS	50,6	44,5	51,6	41,1
Total	100.0	100.0	100.0	100.0

MOE in relation to DBH and spacing



Estimated benefit/costs ratio for the control and thinned stands in jack pine

	Control	4 x 4	5 x 5	7 x 7
Stand value ($/ha)	22127	23304	24450	28264
Costs ($/ha)				
Scenario 1 (manual thinning)	18568	20355	19507	20668
Scenario 2 (semi-mechanized)	18568	20134	19287	20448
B/C ratio				
Scenario 1	**1.19**	**1.14**	**1.25**	**1.37**
Scenario 2	**1.19**	**1.16**	**1.27**	**1.38**

Forintek's initiatives on intensive silviculture in eastern Canada

Projects Initiated

1) Initial spacing in black spruce
2) Precommercial thinning in balsam fir
3) Precommercial thinning in jack pine
4) **Initial spacing in jack pine**


5 x 5


5 7


7 x 7


9 x 9

Most Important is Stem Deformations in Plantation Grown Jack Pine

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Average Tree Characteristics for the 4 Spacings

Characteristic	Spacing (feet)			
	5x5	5x5 to 7x7	7x7	9x9
Tree DBH (cm)	**16.2**	**17.7**	**18.8**	**19.8**
Tree height (m)	16.8	17.5	17.2	17.5
Live crown length (m)	4.4	4.8	4.7	5.5
Crown width (m)	2.6	2.7	3.4	3.8
Proportion of live crown (%)	25.1	26.4	27.2	31.4
Length of the log below live crown (m)	**12.4**	**12.8**	**12.4**	**11.9**
Branch diameter - 5 largest (mm)	**29.1**	**32.5**	**34.0**	**37.0**
Log volume per tree (dm^3)	**144.2**	**191.0**	**199.2**	**215.2**

Grade Limiting Defects in 2" Lumber (lumber volume affected)

Limiting Defect	Spacing (feet)			
	5x5	5x5 to 7x7	7x7	9x9
Wane	14.6	18.1	13.3	17.3
Coloration & Decay	**20.0**	**19.8**	**17.0**	**14.4**
Knots	**28.9**	**33.8**	**46.1**	**47.6**
Others	2.2	1.3	3.4	1.5
No defects (SS)	**34.3**	**27.0**	**20.2**	**19.3**
Total	**100.0**	**100.0**	**100.0**	**100.0**

Estimated Benefit/Cost Ratio for the 4 Spacings

Item	Spacing (feet)			
	5x5	5x5 to 7x7	7x7	9x9
Stand value ($/ha)	$9 453	$16 643	$11 491	$12 258
Costs ($/ha)	$9 083	$13 587	$8 571	$8 119
B/C ratio[1,2]	1.04	1.22	1.34	1.51

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General Conclusions

Impact on product quality

- Thinning or increased stand density generally leads to a larger crown size, bigger branches and larger stem taper. Product quality thus tends to decrease. Yet, the impact depends upon

Thinning intensity: A significant impact only when the residual density is lower than 2,000 trees/ha (critical density)

Timing: earlier density regulation (initial spacing) has a more significant impact.

Branchiness (species): more significant impact in species with larger branches (pine)

General Conclusions

Impact on product quality *(continued)*

- In terms of lumber strength/stiffness, spruce (N)>pine (N)>fir (N)>spruce (P).
- Knots are secondary (to wane) to the lumber downgrades in black spruce (small branches), but become more important in species with larger branches (jack pine)
- The real concern is that the spruce plantations produce much weaker lumber and consequently a high percentage of the lumber does not meet the design requirements.

General Conclusions

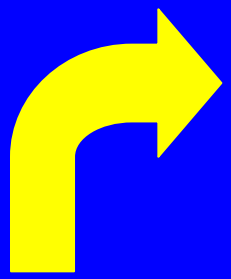
Impact on financial return *(continued)*

- Accelerate diameter growth, but a moderate or stronger thinning intensity is required to achieve a significant increase in average tree diameter.
- Thanks to a larger tree diameter, thinned stands have a higher value recovery per m^3 wood, and lower logging and processing costs.
- Thinned stands tend to have a higher financial return.

General Conclusions

Impact on financial return *(suite)*

- Do not forget our silvicultural objectives:
  - Maximize wood volume for pulp and paper
  - **Produce large piece sizes**
  - **Produce quality sawlogs**
  - **Maximize saw timber volume and value**



Intensive Silviculture

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