Wood properties of exotic larch grown in eastern Canada and north-eastern United States

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The rapid growth performance of exotic larch such as Japanese larch (*Larix leptolepis* (Sieb. et Zucc) Gord.) and European larch (*Larix decidua* Mill.) has attracted the attention of the forestry sector in eastern Canada and north-eastern United States for lumber and pulp production. While growth performance of these species in North America has been well documented, little is known with regards to their wood properties. The objective of this study was to evaluate the primary lumber grade yields, mechanical properties, fiber length, specific gravity and cold-water soluble extractives of larch from plantations in Maine, Nova Scotia, New Brunswick and Prince Edward Island. Samples were obtained from a Japanese (age 31), three European (age 17, 34 and 63) and one Japanese × European hybrid (age 22-27) larch stands. It was found that the structural grade yields of these species were relatively low because of the influence of knots. The mechanical properties (modulus of rupture and modulus of elasticity) of the mature European larch appeared to be comparable with published data for some native softwood species. Fiber length, specific gravity and cold-water soluble extractive content of all samples were similar to those found for other softwood species which are used for pulp production. Fiber length of the juvenile wood of European larch was significantly shorter than that of mature wood. Extractive content was highest in newly formed heartwood. Contrary to common belief, extractive content in young trees may not be low.

Key words: Japanese larch (*Larix leptolepis* Gord.), European larch (*Larix decidua* Mill.), European × Japanese hybrid (*Larix eurolepis*), Wood properties, Lumber yields

Les performances de croissance rapide de mélèzes exotiques tel le mélèze japonais (*Larix leptolepis* (Sieb. et Zucc) Gord.) et le mélèze européen (*Larix decidua* Mill.) ont attiré l'attention du secteur forestier de l'est du Canada et du nord-est des États-Unis au niveau de la production de bois de sciage et de pâte. Alors que les performances de croissance de ces espèces en Amérique du Nord sont très bien documentées, nous savons très peu de chose sur les propriétés du bois de ces espèces. L'objectif de cette étude était d'évaluer les rendements lors du classement primaire du bois, les propriétés mécaniques, la longueur des fibres, la gravité spécifique et les particules solubles à l'eau froide des mélèzes issus de plantations du Maine, de la Nouvelle-Écosse, du Nouveau-Brunswick et de l'Île-du-Prince-Édouard. Des échantillons ont été obtenus d'un peuplement de mélèze japonais (âgé de 31 ans), de trois peuplements de mélèze européen (âgés de 17, 34 et 63 ans) et d'un peuplement de mélèze hybride japonais × européen (âgé entre 22 et 27 ans). L'étude a démontré que les rendements en fonction des classes structurales de ces espèces étaient relativement faibles par suite de la présence de noeuds. Les propriétés mécaniques (coefficient de rupture et coefficient d'élasticité) des mélèzes européens mûrs semblaient être comparables aux données publiées pour quelques espèces natives de résineux. La longueur des fibres, la gravité spécifique, et les particules solubles à l'eau froide en fonction du contenu des échantillons étaient semblables aux résultats répertoriés pour d'autres espèces de résineux utilisés dans la production de pâte. La longueur des fibres du bois juvénile du mélèze européen était significativement plus courte que celle du bois produit à maturité. Le plus grand nombre de particules solubles se retrouvaient dans le bois de coeur récemment formé. Contrairement à la croyance populaire, les particules solubles des jeunes arbres peuvent ne pas être en faible quantité.

Mots clés: mélèze japonais (*Larix leptolepis* Gord.), mélèze européen (*Larix decidua* Mill.), hybride européen × japonais (*Larix eurolepis*), propriétés du bois, rendements du sciage

Introduction

In Europe and Asia, the larch genus (*Larix* Mill.) include some important species for lumber and pulp and paper production. In eastern Canada, the only native larch species is tamarack (*Larix laricina* (Du Roi) K. Koch.). Tamarack generally grows on relatively poor sites and therefore has a slow growth rate (Loo-Dinkins *et al.* 1992). The wood of this species is dense, strong and relatively resistant to decay mainly due to its high extractive content in the heartwood (Mullins and McKnight 1981). These wood characteristics are good attributes for utilization as lumber. When the wood is converted into pulp, the high extractive content can cause problems with some pulping processes (Hatton 1986).

Interest in fast-growing species has led to the initiation of a number of trials of exotic larch species in eastern Canada and north-eastern United States. The major exotic larch species introduced into eastern Canada are Japanese larch (*Larix leptolepis* Gord.), European larch (*Larix decidua* Mill.) and European × Japanese hybrid (*Larix eurolepis*). These faster growing species can produce large volumes of fiber in a relatively short period of time compared with tamarack, but this is achieved at the expense of lower wood specific gravity. Lower specific gravity is usually associated with lower mechanical properties and pulp yield per volume of fiber. On the other hand, there is evidence that the extractive content in fast-grown young trees of these exotic larches is lower compared with tamarack because of the lower percentage of heartwood (Isebrands and Hunt 1975; Isebrands *et al.* 1982; Fowler *et al.* 1988).

While the growth performance of exotic larch species has been well documented (MacGillivray 1969; Ker *et al.* 1983; Park and Fowler 1983; Fowler 1986; Fowler *et al.* 1988; Loo-Dinkins *et al.* 1992), published information on wood quality of exotic larch species is limited. In eastern Canada, Fowler and

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Table 1. General characteristics of sampled larch plantations

Sample	Location	Species	Mean DBH (mm)	No. of trees	Age ¹ (yrs)	Initial spacing/thinning
1	Maine, USA	European × Japanese hybrid	263	13	22/27	2.3 m×2.3 m/ @age 18, 22yrs
2	Maine, USA	European larch	394	21	63	1.8 m×1.8 m/ @age 41 yrs
3	New Brunswick	Japanese larch	261	25	31	3.0 m×3.0 m/ @age 24 yrs
4	Nova Scotia	European larch	227	15	17	3.0 m×3.0 m/ no thinning
5	PEI	European larch	213	26	34	2.0 m×2.0 m/ @age 25, 31 yrs

¹ Year from planting

his co-workers (1988) have conducted limited wood property tests on a sample of 25-year-old Japanese larch. They also estimated the grade yields of their lumber samples. Keith and Chauret (1988) measured specific gravity, fiber dimensions, extractive contents and lignin content of wood from 23- and 28-year-old European larch. In the United States, Olson *et al.* (1947) conducted a study to determine the strength properties and specific gravity of plantation-grown coniferous woods. A 30 year old European larch plantation was sampled for testing by them. More recently, Isebrands and Hunt (1975) studied specific gravity and extractive content of 10-year old Japanese larch, and Einspahr *et al.* (1983) measured fiber lengths, specific gravity and extractive content of young European larch (18 years), Japanese larch (22 years) and European x Japanese larch hybrid (23 years) as part of a study on pulping characteristics. Where appropriate, wood property results from this study will be compared with the studies listed above.

To summarize, exotic larch species can achieve rapid growth rates in eastern Canada, but only limited data on wood properties is available. This study was conducted to help bridge this gap in information by testing materials sampled from plantations of Japanese, European and European x Japanese hybrid larch grown in eastern Canada and north-eastern United States. The objectives were :

1. To study yields for structural grade lumber.
2. To evaluate bending properties of lumber and clear wood.

3. To evaluate fiber length, specific gravity and cold-water extractive content, and their variations within a tree.

4. To provide an initial indication of how wood properties of exotic larch compared with some commercially important soft-wood species.

The first two objectives relate to the utilization of the material as structural lumber whereas the third focuses on pulping quality of the material.

Materials and method

Three European, one Japanese and one European × Japanese hybrid larch plantations were selected to provide the test material. These covered a number of geographical locations and a range of age classes. Details about planting spacing, thinning and number of trees sampled are given (Table 1).

After the trees were felled, they were cut into 3.05 m (10 ft) or 3.6 m (12 ft) sawlogs. Each log was coded to indicate the sample location and its position in the tree stem. These logs were transported to the Wood Science and Technology Centre, University of New Brunswick and converted into rough sawn two-by-four lumber pieces at a local sawmill. The lumber was kiln dried to a nominal 12% moisture content, and planed to the final dimensions of 38 mm × 89 mm. The planed lumber pieces were tested for modulus of elasticity (MOE) and modulus of rupture (MOR) in bending according to standard ISO 8375 (ISO 1985). The moisture content, gross specific grav-

Figure 1. Sampling locations from a disc for fiber length, specific gravity and cold-water soluble extractive content measurements.

Table 2. Yields for selected structural visual grades

Sample	Species/location	No.	Visual grade (%)					
			SS	No.1	No.2	No.3	E	Reject
1	J × E Hybrid, Maine	74	7	36	43	14	0	0
2	European larch, Maine	277	23	42	23	12	1	0
3	Japanese larch, New Brunswick	126	13	55	26	6	0	0
4	European larch, Nova Scotia	47	0	28	72	0	0	0
5	European larch, PEI	76	9	59	32	0	0	0

Table 3. Properties of lumber material

Sample	Species/location	No.	Lumber bending		Small clear bending		Specific gravity	MC (%)	Growth rate (mm/ring)
			MOE (MPa)	MOR (MPa)	MOE (MPa)	MOR (MPa)			
1	J × E Hybrid, Maine	74	7191 (0.29)	30.98 (0.29)	6178 (0.25)	55.12 (0.18)	0.404 (0.10)	13.00 (0.07)	7.31 (0.28)
2	European larch, Maine	277	10937 (0.28)	43.76 (0.36)	9045 (0.19)	69.62 (0.14)	0.465 (0.097)	13.92 (0.05)	3.58 (0.38)
3	Japanese larch, New Brunswick	126	8440 (0.29)	39.51 (0.30)	7061 (0.24)	63.29 (0.21)	0.442 (0.09)	12.80 (0.05)	5.77 (0.28)
4	European larch, Nova Scotia	47	5934 (0.21)	27.26 (0.29)	5187 (0.17)	50.74 (0.17)	0.401 (0.069)	12.43 (0.04)	9.13 (0.16)
5	European larch, PEI	76	8978 (0.23)	40.53 (0.33)	7431 (0.24)	64.28 (0.15)	0.456 (0.079)	13.30 (0.07)	4.64 (0.33)

Note : Values shown for properties are means with coefficient of variation given in parentheses

Table 4. Comparison of small clear wood bending properties with corresponding data in the literature

Sample	Species/location	MOE (MPa)	MOR (MPa)	Specific gravity	Reference
1	J × E Hybrid, Maine	6178	51.12	0.404	This study
2	European larch, Maine	9045	69.62	0.465	This study
3	Japanese larch, New Brunswick	7061	63.29	0.442	This study
4	European larch, Nova Scotia	5187	50.74	0.401	This study
5	European larch, PEI	7431	64.28	0.456	This study
6	Norway spruce, New Brunswick	7467	55.09	0.355	Chui, 1993
7	Norway spruce, Nova Scotia	7082	46.61	0.331	Chui, 1993
8	Balsam fir, Canada	9653	58.60	0.356	FPL, 1987
9	Black spruce, Canada	10480	78.60	0.434	FPL, 1987
10	Red spruce, Canada	11032	71.00	0.401	FPL, 1987
11	White spruce, Canada	9998	62.74	0.367	FPL, 1987
12	Norway spruce, USA	9929	58.60	0.356	Olson et al, 1947
13	European larch, USA	6964	58.60	0.356	Olson et al, 1947
14	White spruce, USA	9584	64.81	0.420	Olson et al, 1947

ity and growth rate of each bending specimen were determined from a small prism cross-cut from the specimen. In addition, a small clear (defect-free) specimen of dimensions 38 mm × 38 mm × 610 mm was machined from the undamaged part of each failed lumber piece. The small clear specimen was then tested for MOE and MOR according ASTM D143 (ASTM 1992). The rationale for including the small clear bending test was to provide a common basis for comparison with corresponding properties of other species. In total, 600 pieces of lumber and the same number of small clear specimens were tested.

From the first four plantations, cross sectional discs were obtained from three trees for measurement of fiber length, specific gravity and cold-water extractive content. These trees encompassed the DBH range for the plantation from which they were selected. For each of the three selected trees, a 50 mm thick disc was cut at the stump, 3.0 m and 6.0 m heights for samples one, two and four. For sample three, four discs at stump, 3.6 m, 7.2

m and 11.0 m heights were obtained. The sampling locations for these tests on a disc (Fig. 1) included five measurements from the pith to bark for each property. Three measurements were in heartwood and two in sapwood. The objective was to observe any difference between sapwood and heartwood rather than radial age, particularly with respect to extractive content. The specific gravity was measured based on oven-dry weight and green volume. The method used for determining cold water-soluble extractive content largely followed TAPPI standard T207 OM-88 (TAPPI 1988) with minor modifications. The modifications to T207 OM-88 were introduced to accommodate difficulties in filtering. Fiber length was determined using a common method in which the wood is macerated in an acidic solution and then strained. A computer-based system was used to measure fiber lengths. Lengths of forty randomly selected complete fibers were measured for each sample, and the mean calculated to represent fiber length at each location.

Table 5. Basic wood properties of larch

Sample	Species/location	Fiber length (mm)	Extractive content (%)	Specific gravity
1	J × E hybrid, Maine	3.108 (0.26)	4.45 (0.51)	0.390 (0.11)
2	European larch, Maine	3.845 (0.16)	5.73 (0.63)	0.442 (0.15)
3	Japanese larch, New Brunswick	3.029 (0.20)	6.02 (0.56)	0.441 (0.12)
4	European larch, Nova Scotia	2.783 (0.19)	7.84 (0.48)	0.395 (0.17)

Note : Values shown for properties are means of all readings taken for the sample with coefficient of variation given in parentheses

Table 6. Comparison of basic wood properties with corresponding data in the literature

Species/Location	Age (yr)	Fiber length (mm)	Extractive content ² (%)	Specific gravity	Reference
J × E hybrid, Maine	22/27	3.108	4.45 (C)	0.390	This study
European larch, Main	63	3.845	5.73 (C)	0.442	This study
Japanese larch, New Brunswick	31	3.029	6.02 (C)	0.441	This study
European larch, Nova Scotia	17	2.783	7.84 (C)	0.395	This study
Japanese larch, USA	22	3.16	7.4 (H)	0.384	Einspahr et al, 1983
European larch, USA	18	3.02	3.90 (H)	0.395	Einspahr et al, 1983
J × E hybrid, USA	23	2.75	4.2 (H)	0.413	Einspahr et al, 1983
Jack pine, USA	55	3.20	2.3 (H)	0.436	Einspahr, et al 1983
Tamarack ¹	—	3.6	—	—	Hatton, 1986
Western larch ¹	—	5.0	—	—	Hatton, 1986
European larch ¹	—	3.6	—	—	Hatton, 1986
European larch, Ontario and Quebec	23/28	2.3	7.99 (H)	0.40	Keith and Chauret, 1988
White pine ¹	—	—	2.1 (H)	—	Hillis, 1962
Douglas fir ¹	—	—	6.5 (H)	—	Hillis, 1962
Red pine, New Brunswick	55	3.09	—	0.380	Kaya, 1990
Japanese larch, USA	10	—	2.0 - 6.0 (H)	0.3 - 0.45	Isebrands and Hunt, 1975

¹ Location and age not known for these samples.

² C = Cold-water soluble extractive content, H = Hot-water soluble extractive content

Table 7. Variation of lumber properties with log position in stem¹

Sample	Species/Location	Log ²	No.	Lumber bending		Small clear bending		Specific gravity	MC (%)
				MOE (MPa)	MOR (MPa)	MOE (MPa)	MOR (MPa)		
1	J × E Hybrid, Maine	1	38	6827 (0.36)	31.04 (0.31)	5772 (0.28)	55.48 (0.18)	0.404 (0.116)	12.98 (0.06)
		2	36	7575 (0.19)	30.93 (0.27)	6607 (0.19)	54.74 (0.18)	0.403 (0.089)	13.01 (0.07)
2	European, Maine	1	100	11071 (0.27)	47.28 (0.36)	8783 (0.22)	59.30 (0.16)	0.470 (0.101)	14.19 (0.07)
		2	86	11417 (0.28)	45.12 (0.32)	9434 (0.20)	71.86 (0.11)	0.464 (0.103)	13.84 (0.04)
		3	91	10336 (0.28)	38.61 (0.37)	8964 (0.16)	67.85 (0.13)	0.461 (0.084)	13.70 (0.05)
3	Japanese, New Brunswick	1	73	8256 (0.31)	40.05 (0.31)	7083 (0.27)	65.37 (0.20)	0.448 (0.094)	12.80 (0.05)
		2	53	8693 (0.25)	38.77 (0.29)	7030 (0.20)	60.42 (0.20)	0.434 (0.081)	12.80 (0.04)
4	European, Nova Scotia	1	133	5974 (0.21)	28.73 (0.30)	5102 (0.28)	51.70 (0.16)	0.407 (0.061)	12.42 (0.04)
		2	14	5841 (0.22)	23.79 (0.21)	5386 (0.21)	48.48 (0.19)	0.388 (0.077)	12.45 (0.04)
5	European, PEI	1	45	8878 (0.25)	43.84 (0.33)	7131 (0.27)	6374 (0.17)	0.466 (0.069)	13.28 (0.04)
		2	31	9123 (0.20)	35.73 (0.27)	7866 (0.19)	65.05 (0.13)	0.441 (0.082)	13.33 (0.09)

¹ Values shown for properties are means with coefficient of variation given in parentheses

² Log position : 1 = base log, 2 = second log from base, 3 = third log from base

Figure 2. Axial variation of specific gravity.

Figure 4. Axial variation of cold-water soluble extractive content.

Figure 3. Axial variation of fiber length.

Results and Discussion

Yields for Structural Grade Lumber

Structural grading was performed according to Canadian visual grading rules (NLGA 1987) by a grading inspector from the Maritime Lumber Bureau, Amherst, Nova Scotia. The grades sorted were: Select Structural (SS), No.1, No.2, No.3 and Economy (E). The grade yield results are summarized (Table 2).

Knots are a primary growth feature governing visual grade yields. The presence of knots, their size and distribution, in most cases, determines the grade of a piece of lumber. The size and frequency of knots were relatively large compared with lumber of other native softwood species. This explains the relatively low yields for the SS grade. The grade yields for Japanese larch were, however, better than those obtained by Fowler *et al.* (1988)

for the same species. They obtained 45% and 38% yields for No.1 and No.2 grades respectively.

Lumber Properties

The summary statistics for all tested properties are shown (Table 3). When considering mechanical properties it is perhaps not surprising to find that the mature European larch of sample two produced wood with the best quality. Taking into consideration the age and growth rate, it seemed appropriate to compare mechanical properties of samples 1, 3 and 5. The Japanese larch has similar mechanical properties to those of European larch despite a 20% faster growth rate. The European $\times$ Japanese hybrid from Maine, USA has somewhat lower mechanical properties, perhaps due to its faster growth rate which led to a lower wood specific gravity.

The small clear bending tests were included to enable a comparison with corresponding properties for other native and exotic softwood species. Such a comparison (Table 4) indicated that MOE and MOR of the mature European larch sample was comparable with those of native balsam fir, white spruce, black spruce and red spruce. Not surprisingly the two juvenile larch samples (1 and 4) had vastly inferior MOE and MOR values. The Japanese larch sample from New Brunswick and European larch sample from PEI had similar MOE and MOR values. Their properties were comparable with plantation grown Norway spruce of similar age from New Brunswick and Nova Scotia (Chui 1993). The larch samples, however, had much higher mean specific gravities than Norway spruce.

Basic Properties of Wood Material

Basic wood properties including fiber length, cold-water soluble extractive content, and specific gravity were determined for samples one, two, three and four. The juvenile European larch from Nova Scotia had a high cold-water soluble extractive content, low specific gravity and short fiber length, indicating that the wood is less suitable for use as pulping material compared with the other samples (Table 5). It must be stressed, however, that this is most probably an age effect rather than a

Figure 5. Radial variation of specific gravity.

species effect, as it seems certain that with increasing age fiber length and specific gravity will improve (see sample two). The finding with respect to extractive content is contrary to the previous belief that juvenile wood has lower extractive content because of the small proportion of heartwood in a juvenile stem (Isebrands and Hunt 1975). The extractive content of juvenile wood deserves further study. The other three more mature samples had significantly better wood properties from the standpoint of pulp production.

When comparing these properties with other species (Table 6) it should be noted that the sampling methods differed. For instance, Einspahr *et al.* (1983) measured fiber length at the fifteenth growth ring of three trees, while Kaya (1990) gave the weighted average fiber length for a complete stem based on the readings measured at regularly spaced locations both along the

stem and from the pith to bark of one tree. Nonetheless, the quoted values are probably close to the "true" average of the sample tested in each case. Examination of the results shows that, with the possible exception of the juvenile European larch from Nova Scotia, the three measured properties of the tested larch samples were similar to those of some native and exotic softwood species planted in North America. This indicates that substituting traditional softwood species with exotic larch for pulp and paper appears feasible.

Axial Variation of Wood Properties

Mean lumber properties when the results are segregated based on position of test pieces along tree stem (Table 7) showed that the mechanical properties of lumber do not appear to differ along the tree stem. The lack of a clear trend for these exotic larch

Figure 6. Radial variation of fiber length.

Figure 7. Radial variation of cold-water soluble extractive content.

species is different from that observed for plantation grown Norway spruce (Chui 1993), which showed a very pronounced decreasing trend for mechanical properties with increasing height in the tree stem.

For specific gravity, a trend of decreasing specific gravity with increasing height in a tree stem was noted, with the exception of European larch from Maine (sample two) which showed an increase in specific gravity from disc three to four (Fig. 2). The cause of this slight deviation is not known.

Fibers at stump level (disc one) were shorter than those at higher levels (Fig. 3). No clear differences in fiber length were detected among the other heights. It is not known why this trend occurred, but it was similar to results obtained by Keith and Chauret (1988) for European larch. For the cold-water soluble extractive content, the trends were also unclear (Fig. 4). A study by Isebrands and Hunt (1975) on 10-year-old Japanese larch showed that the central part of the base of a tree contained a higher extractive content than other parts of the tree. This agrees with results obtained here for samples two (European larch) and three (Japanese larch), but not with the other two. Thus, further investigations are required if a better understanding of variation in extractive content is desired.

Radial Variation of Basic Wood Properties from the Pith to Bark

The variation of specific gravity from the pith to bark is illustrated (Fig. 5). Each value is an average obtained for all heights. Positions one and five correspond to the locations closest to the bark and pith respectively. There was an initial reduction in specific gravity going from the pith to bark, and then an increase towards the heartwood/sapwood boundary. Afterwards, with the exception of the Japanese larch, a slight drop in specific gravity was observed moving from the heartwood/sapwood boundary towards the bark. This trend belongs to the Type two density variation as defined by Panshin and De Zeeuw (1980), and appears similar to that for European larch tested by Keith and Chauret (1988).

Fiber length clearly increased from the pith to bark (Fig. 6). This was largely due to the shorter fiber length found in the juve-

nile wood (Larson 1969; Kaya 1990). The ratio of mature to juvenile fiber lengths could be as high as two (sample one). This highlights the problems encountered with the presence of juvenile wood in pulping material. The extractive content results (Fig. 7) showed an interesting trend in which the highest content is found in the heartwood close to the heartwood/sapwood boundary. Again, similar findings were obtained by Keith and Chauret (1988). This phenomenon is probably a result of the large amount of chemicals formed at the early stage of heartwood formation. As expected, extremely low extractive content was found in the sapwood portion.

Conclusions

1. Yields for structural grade lumber of exotic larch species are low because of the size and distribution of knots in processed lumber.
2. Mechanical properties of wood from mature European larch are comparable with corresponding published data for some commercially important native softwood species (e.g. black spruce, white spruce, red spruce and balsam fir). In contrast with most softwood species, no significant axial variation in mechanical properties was observed in this species. The younger larch samples exhibited lower mechanical properties, in comparison with the published data.
3. Fiber length, specific gravity and extractive content of the exotic larch species were similar to published data for some commercially important softwood species, indicating the potential for substituting these exotic larch species with traditional pulping species.
4. Contrary to the common belief, the youngest European larch (age 17) sample had the highest mean extractive content.
5. From the pith to bark the highest extractive content was detected in the newly formed heartwood.

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