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Utilisation of Lodgepole Pine

INFORMATION NOTE

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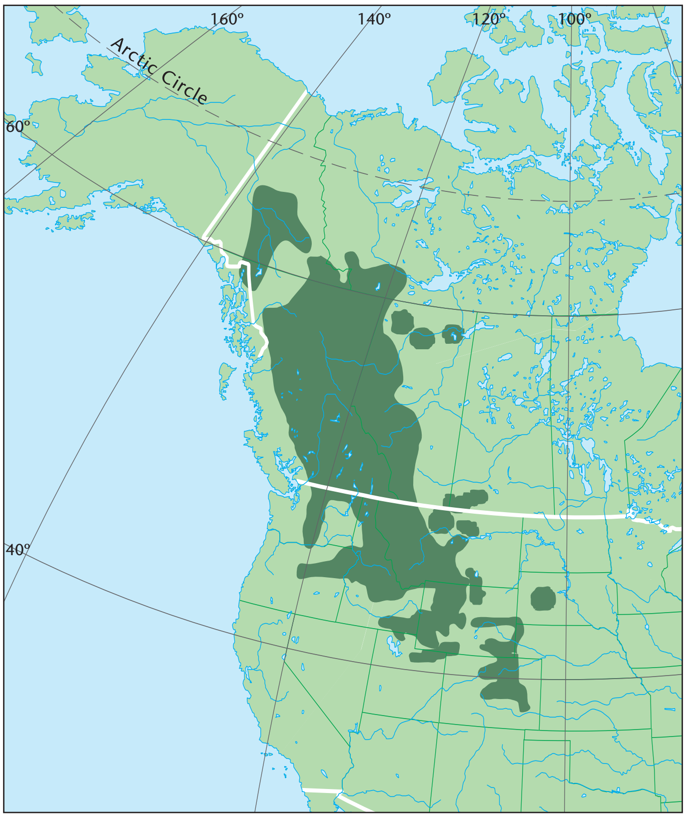
SUMMARY

There are extensive areas of lodgepole pine (*Pinus contorta* Douglas ex Loud.) planted in forests in Scotland which will reach production in the next two decades. The timber properties of three different provenances of lodgepole pine growing at two different sites were examined by means of destructive testing and analysis of sawn battens. For comparison, a smaller sample of Scots pine (*Pinus sylvestris*) was also tested using the same parameters and testing protocol.

BACKGROUND

Lodgepole pine (LP) is a highly variable species with a native range covering large areas of western North America (Figure 1). Provenance differences in vigour and form are known to be similarly large. It has been observed that the South Coastal provenance grows very vigorously in Scotland but displays very poor form. Provenances from further north and inland of the native range tend to grow more slowly but display better form. An extensive review of British experience with lodgepole pine was provided by Lines (1996).

Figure 1 The native range of lodgepole pine.



Because of its tolerance of nutrient poor and moist soils (e.g. Pyatt *et al.*, 2000) lodgepole pine was widely planted on upland sites in Scotland during the 1960s, 1970s and 1980s. *The national inventory of woodland and trees* (Forestry Commission, 2002) estimated that there were 134 076 ha of lodgepole pine high forest in Scotland, representing 10% of the total high forest resource, and that 87% of this area was planted between 1961 and 1990. 63% of the lodgepole pine resource lies within Highland Region, with a further 12% in Grampian Region. These figures apply to all stands of pure and mixed lodgepole pine.

Table 1 shows the area of lodgepole pine with each Forest Enterprise (FE) forest district by provenance.

Table 1

Area (ha) of LP by provenance within each FE forest district.

Forest district	Alaskan total	Inland total	S. Coastal total	Grand total*
Buchan	289	69	381	2409
Dornoch	6451	5902	4410	21486
Fort Augustus	1377	843	869	7439
Inverness	868	390	143	4354
Kincardine	87	22	79	1192
Lochaber	616	1413	1225	5016
Lorne	596	447	399	3505
Moray	156	43	1224	3647
Tay	216	362	323	4920
West Argyll	48	2	321	1365
Ae	3	0	405	1884
Cowal & Trossachs	2	14	260	3284
Galloway	169	151	1795	10028
Scottish Borders	119	6	615	1253
Scottish Lowlands	20	0	1744	2804
Grand total	**11017**	**9664**	**14193**	**74588**

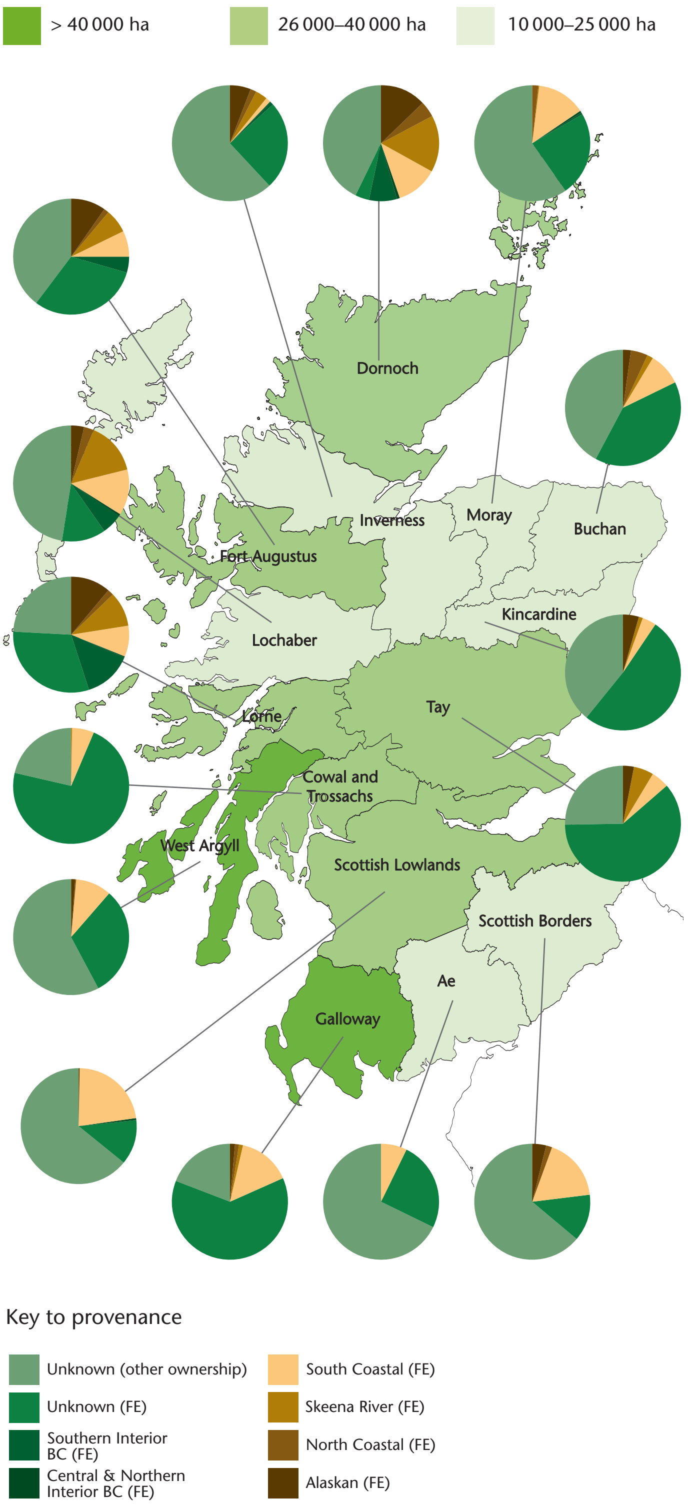
*All provenances.

Figure 2 shows the proportions of LP in Forest Enterprise (FE) Districts broken down by provenance and ownership. The provenance categories used by FE are broader than the seed zones identified by Lines (1996: table 1).

Figure 2

Area of lodgepole pine and proportion by provenance in Forest Enterprise Districts.

Key to area



METHOD

Two contrasting experimental sites, Shin and Rosarie (P70), were selected to represent the range of planting sites for LP. The sites were similar in initial planting spacing and age to the bulk of LP stands currently being harvested in north Scotland. Details of the sites and a summary of their management to date are given in Table 2. At each site three named provenances were selected as being typical of the three most commonly planted provenance regions: Longbeach 65(7972)1: (South Coastal); Terrace 65(7114)1: (Inland); and Petersburg 66(7987)3: (Alaskan). The typical form and shape of these provenances are shown in Figure 3.

Table 2

Site factors and conditions from the experiment sites at Shin (Inverness-shire) and Rosarie (Moray).

Site description	Shin	Rosarie
Grid reference	NC 535223	NJ 322487
Soil class	Deep *Molinia*/ *Trichophorum* peat (mainly >1.5 m)	Strong iron pan, SE and NE edges of main block merge to surface water gley
Vegetation	*Molinia, Trichophorum, Narthecium, Calluna, Erica tetralix* and *Myrica*	*Calluna vulgaris*
Elevation	190–220 m	305–330 m
Rainfall	1120–1250 mm	890 mm
Exposure	Exposed northwest–southwest	Fully exposed to northeast and south southwest
Spacing	1.7 m x 1.7 m	1.8 m x 1.8 m
Treatment	Unground rock phosphate applied broadcast at 376 kg ha^{-1}. Beat up in 1971. Summer 1973 top dressing with PK mixture broadcast at 575 kg ha^{-1}. Summer 1979 top dressing with PK at 575 kg ha^{-1} broadcast. Rogue trees removed from several plots. May 1984 lane brashing.	Unground rock phosphate applied broadcast at 49 kg elemental P ha^{-1}. Beat up in 1971 and 72. Loose plants firmed after wind loosening, summer 1972. Additional soil on leeward side straightened. Weedings in early years. Chemically thinned in 1996.

A total of 132 LP trees were selected from the two sites and from these 311 2 m logs were obtained and sawn into 673 battens. A total of eight Scots pine (SP) trees from a separate 1935 spacing experiment, located at Findon on the Black Isle, were also selected for comparison. 24 logs were sawn into 93 battens. All the battens were examined for strength, flexibility and the impact energy required to break each batten.

Figure 3

The three LP provenances investigated had different form and shape, either due to heavy branching or basal sweep.
(a) Alaskan (Petersburg) provenance; (b) South Coastal (Longbeach) provenance; and (c) Inland (Terrace).

MEASURING WOOD QUALITY

The battens were tested for six strength characteristics:

- modulus of rupture;
- modulus of elasticity;
- toughness;
- fracture type;
- impact resistance;
- compression wood.

In addition, stem form was assessed using a laser method to determine the straightness of the stem up to the first 4 m. Branch number and position were measured on the felled trees.

Modulus of rupture and modulus of elasticity

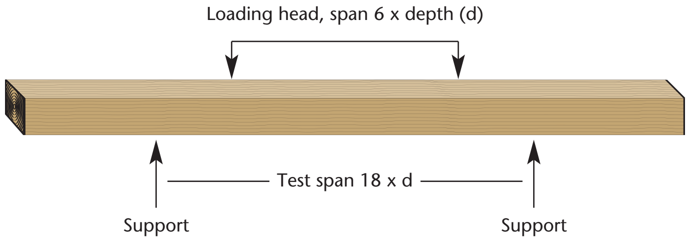
Modulus of rupture (MoR), or bending strength, is the load applied over time to break a batten. MoR is expressed in units of N mm^{-2}.

Modulus of elasticity (MoE), or flexibility, is the displacement from horizontal of a batten with a load being applied over time. MoE is expressed in units of N mm^{-2}.

MoR and MoE were tested using a four point bending machine which measures the deflection of the batten under a steadily increasing load until it breaks (Figure 4).

Figure 4

Schematic diagram of a bending strength test on a batten.



Testing was undertaken on battens that fairly represented material of an appearance that would be acceptable in commercial sawn timber markets, e.g. as fence material and palletwood. The moisture content of the battens was variable and hence a correction was applied to the MoE values in order to ensure that results were comparable for a standard moisture content of 18% (on dry basis).

$$\mathrm{Ln}\,(\mathrm{MoE}) = \mathrm{Ln}\,(\mathrm{MoE})_{wet} + c\,(\mathrm{MC}_{wet} - \mathrm{MC}_{dry})$$

Where Ln is the natural log, *c* is a constant – calculated as 0.0172 for lodgepole pine and 0.021 for Scots pine using values published by BRE (Lavers, 1983) – and MC is the percentage moisture content. Any battens above the fibre saturation point of 27% were assumed to have $MC_{wet} = 27$; MC_{dry} was fixed at 18% for all battens.

Table 3 shows the mechanical properties of LP published by Lavers (1983) with LP derived from small clear samples within the UK. No age for the samples was given.

Table 3

Published mechanical properties (20 mm standard) for lodgepole pine (Lavers, 1983).

	MoE	MoR	Maximum compression strength parallel to grain	WTF*	Hardness	Shear
	N mm^{-2}	N mm^{-2}	N mm^{-2}	N mm^{-3}	N	N mm^{-2}
Green	6400	41	18.8	0.168	2270	5.6
Dry	8100	79	38.2	0.108	2940	12.1

*Work to total fracture.

Toughness

Toughness is the energy (Joules) applied under static bending required to break the batten.

Fracture type

There are six main types of fracture found in coniferous timber as illustrated in Figure 5. The two main fracture types observed in this work were simple tension and brash tension as illustrated in Figure 6. Brash tension is associated with sudden failure and can therefore lead to unpredictable performance of timber while in use.

Figure 5

Fracture types found in coniferous timber (USDA, 1987)

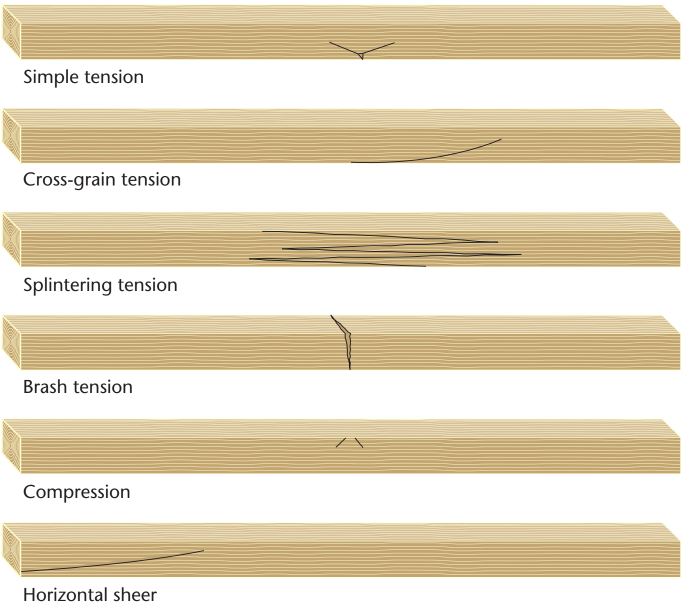


Figure 6

(a) Fibrous break (simple tension) and (b) non-fibrous break (brash tension).

Impact testing

The energy in Joules applied under sudden impact to break a batten. Impact testing was carried out on sawn timber that had been previously tested under four point bending. The original battens with dimensions of 1.9 m x 50 mm x 100 mm were broken in half using an impact hammer, with one half randomly selected for testing.

Compression wood

Compression wood was measured on the cross sectional face of discs cut from the logs and using specific software to measure the percentage of compression wood on each surface of the discs. The interpretation differs from batten measurement, because even a skilled observer can confuse compression wood with late wood.

RESULTS

The data were analysed to assess the broad mean differences between the logs and battens at a site and provenance level. Then a more detailed statistical analysis was undertaken, on a batten by batten basis, to examine factors associated with MoE, MoR, impact resistance and toughness. Table 4 gives a summary of the results for these wood properties, indicating the general trend for each provenance.

The percentage of compression wood measured on the battens showed highly significant differences between the sites and the provenances ($p<0.001$, Table 5).

Figure 7 shows the mean percentage of compression wood measured on discs by provenance.

Fracture type was assessed after the battens had been broken during 4-point bending. The data were analysed using a probabilistic decision tree method that aims to provide the best prediction via the answers to a series of questions. The system can be weighted to take into account the different value placed on a right or wrong answer, for example: predicting a simple tension fracture, when in fact the batten fails with a brash tension fracture, is far worse for potential users than if the batten fails with a cross-grain tension fracture. This analysis showed that provenance was a better determinate of fracture type than site or percentage compression wood area. This analysis indicated that if a batten had been cut from South Coastal LP it would be safest to assume that it will break with a brash tension fracture.

Table 4

Summary of wood properties.

Wood property	Shin	Rosarie	Findon (SP)	South Coastal	Alaskan	Inland	General trend*
MoE ($N\ mm^{-2}$)	4953	6518	9623	5749	5491	6370	T>L>P
MoR ($N\ mm^{-2}$)	26.3	28.2	38.44	28.87	28.41	25.53	L>P>T
Impact (J)	254.8	271.5	411.6	218.7	370.1	248.7	P>T>L
Toughness (J)	167.73	156.45	261.94	153.8	223.14	124.11	P>L>T

*L = South Coastal; P = Alaskan; T = Inland.

Table 5

Mean percentage compression wood area per batten for sites and provenances (average standard error of difference in brackets).

Site	Mean (1.02)	South Coastal	Alaskan	Inland
Shin	23.08	35.56	19.34	14.34
Rosarie	16.42	20.92	18.60	9.75
Provenance mean (1.25)		28.24	18.97	12.04

Figure 7

Mean percentage of compression wood measured on discs by provenance (bars show 95% confidence limits).

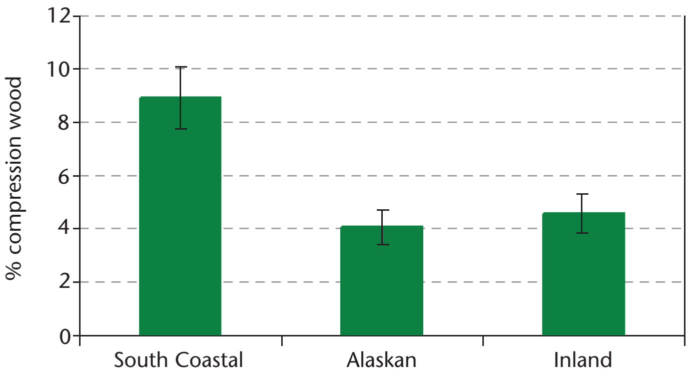


Figure 8

Mean impact energy required to break battens from different locations and provenances (bars show 95% confidence limits).

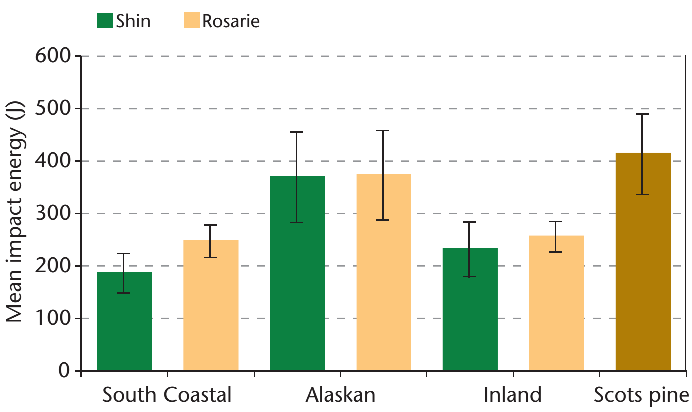
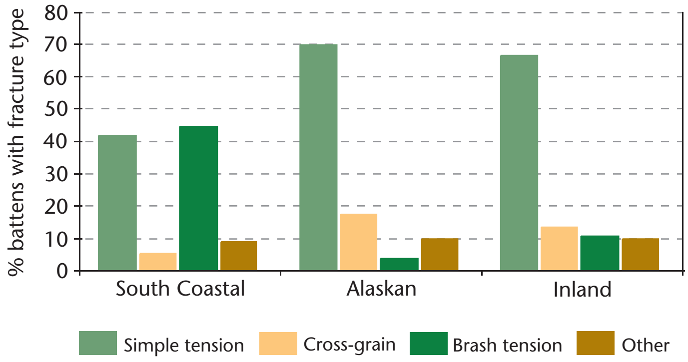


Figure 9

Fracture type breakage by provenance.



DISCUSSION

- The lodgepole pine material in this experiment generally performed more poorly than that tested by Lavers (1983). It is possible that this could be due to our samples coming from younger trees with less mature wood. However, the Scots pine values for MoR and MoE were very close to published figures (Lavers, 1983).
- Alaskan provenance performed similarly to Scots pine in terms of toughness and impact energy required to break the timber.
- The branch and knot sizes appear to be highly correlated with MoR, MoE and toughness. There were significant provenance differences with South Coastal having the highest MoR, Inland the highest MoE, and Alaskan the greatest impact energy resistance.
- Provenance appears to be the controlling factor in fracture type, with South Coastal most likely to produce battens that fail with a brash tension fracture. The different levels of compression wood in a batten allow for a better prediction of fracture type. High levels of compression wood are associated with brash tension fracture. Trying to maximise recovery by cutting out bends does not remove the presence of compression wood.

- It was noticeable that material from Shin behaved more poorly than that from Rosarie for MoR, MoE and impact resistance. However, due to lack of replication with material from different sites, it would not be possible to extend these findings to other sites of similar type with any certainty. The fact that the trees were more heavily branched at Shin is a possible explanation for battens from this site performing poorly when compared with Rosarie.

- Fracture type and impact resistance appear to be more strongly determined at a provenance level. South Coastal performed particularly poorly in this respect. This is likely to be linked to the presence of compression wood, but without being able to test South Coastal battens with low levels of compression wood it is impossible to determine whether the behaviour is predominantly due to provenance, i.e. genetic in character, or a consequence of the growth habit observed at the two experimental sites.

CONCLUSIONS

Comparative tests on the timber properties of Alaskan provenance LP have revealed performance similar to Scots pine. It appears to be a generally slow-growing tree providing good quality timber. The timber performs as well as Scots pine tested under rigorous conditions and could be used for many different markets, including construction, small roundwood, pallet and fencing.

Trees of Inland provenance LP grow straight and, like Alaskan, are slow-growing and produce relatively good quality timber. However, the timber properties of this provenance may be unpredictable due to within-provenance variability and should probably only be used for the small roundwood markets.

Trees of South Coastal provenance LP are fast growing, compared with the other two provenances, but produce thick, heavy branches and have a strong tendency to basal sweep. Although, statistically, the branches do not appear to have an effect on overall timber quality, there is an increase in compression wood and a distinct fracture type associated with this provenance. The timber is prone to brash fracture on impact and so is only suitable for uses where there is a static load. South Coastal timber is also suitable for applications such as wood fuel.

FUTURE RESEARCH

There is now a need to obtain better estimates of the location and extent of the South Coastal provenances so that they may be marketed to best effect.

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