AMONG AND WITHIN PROVENANCE VARIABILITY FOR DECAY RESISTANCE OF LARCH WOOD TO FUNGI

Dominique Jacques[1], Yannick Curnel[1], Benoît Jourez[1], Luc E. Pâques[2]

1 Centre de Recherche de la Nature, des Forêts et du Bois, Avenue Maréchal Juin 23, B-5030 Gembloux, Belgium.

2 INRA, Unité d'Amélioration, de Génétique et de Physiologie des Arbres forestiers, F-45166 Olivet Cedex, France

Abstract

Decay resistance of Larch wood was examined at the species, provenance and tree levels. To realise this study, 313 trees were harvested in 13 contrasting populations of different ages derived from 2 natural stands (France, Austria) and 4 provenance/progeny trials (Germany, Belgium, France and Great-Britain). The material includes 11 European, 1 Japanese and 2 hybrid larch origins. Wood samples were inoculated with 2 fungi (*Poria placenta* (Fr.) Cke. and *Coniophora puteana* (Schum.ex Fr.) Karst) and laid in a conditioning room for 16 weeks. At the end of the process, the weight loss was recorded and the durability level computed. This study shows that natural durability appears to be dependent on the species with Japanese larch being more durable than European larch. Within European larch, huge differences between provenances have been found, with the old-grown native alpine sources far more durable than those from young low altitude plantations. However, some lowland origins (such as the Polish European larch origin Blizyn or the hybrid from France) statistically compare with Japanese larch durability. At the individual tree level, a huge variability also seems to exist in the 13 examined populations. Beside population comparison, it appears that *Coniophora* is much more aggressive than *Poria* as decaying fungus. High wood density and narrow ring width seem also to increase natural durability of larch but, even for low wood densities, a high variability for natural durability is observed.

Variabilité intra- et inter- provenances de mélèze pour la durabilité naturelle

La durabilité naturelle du mélèze est étudiée aux niveaux espèce, provenance et arbre à partir d'un échantillon constitué de 313 arbres récoltés dans 13 populations contrastées d'âge variable issues de 2 peuplements naturels (France, Autriche) et de 4 tests de provenances/descendances établis dans 3 pays (Allemagne, Belgique, France et Grande-Bretagne). Le matériel comprend 11 origines de mélèze d'Europe, 1 de mélèze du Japon et 2 de mélèze hybride. Les éprouvettes issues de ce matériel ont été soumises à l'attaque de deux champignons (*Poria placenta* (Fr.) Cke. et *Coniophora puteana* (Schum.ex Fr.) Karst) en conditions contrôlées durant 16 semaines. A l'issue de ce test, la perte de masse subie par ces différentes éprouvettes a été enregistrée. L'analyse de ces données fait apparaître que la durabilité naturelle chez le mélèze varie en fonction de l'espèce, le mélèze du Japon semblant le plus durable. Chez le mélèze d'Europe, la durabilité naturelle du bois est également dépendante de l'origine testée, la différence la plus nette s'observant entre les provenances alpines issues de peuplements naturels âgés, qui présentent une durabilité élevée, et les plantations de faibles altitudes, plus jeunes, bien moins performantes. Cependant, l'on trouve aussi des origines de plaine (par exemple Blizyn, une origine du centre de la Pologne ou l'hybride français) qui sont statistiquement comparables au mélèze du Japon pour la durabilité. Au niveau de chacune des 13 populations étudiées, une très forte variabilité entre arbres est également mise en évidence. Enfin il est constaté que l'agressivité de *Coniophora* est plus grande que celle de *Poria* et que l'augmentation de la densité ainsi qu'une largeur de

cerne plus faible conduisent à une amélioration de la durabilité naturelle du mélèze. Mais même pour des densités faibles, une grande variabilité de durabilité naturelle est observée.

Introduction

European Larch timber has been traditionally used in outdoor conditions in the Alps for building and it is much appreciated for its good natural durability in addition to its excellent mechanical properties (Collardet and Besset, 1988). Century old buildings made of local Larch wood are still visible all across the alpine range. In addition to the wood quality itself, it seems obvious that the long durability of these constructions relies also on a high ancestral level of building expertise.
Meanwhile, at the European level, the good quality of such a wood does not seem unanimously recognised. In a literature review on Larch heartwood durability, Nilsson (1997) concluded that the majority of papers showed that this property has a large variability and that Larch wood could generally be considered as not durable up to moderately durable (Viitanen *et al.*, 1997) according to the European standards (EN 350-01). It should be noted that works reported in this review are issued from North European countries only and concern thus species and or races of European Larch different from the alpine one and Larch wood grown in much different conditions.

Nevertheless, it seems important to have a clear idea of the main sources of variation that could explain such discordant results.

To better understand the origin of these apparently contradictory observations, the study reported in this paper aims at evaluating the natural durability of European Larch wood through a large and various set of provenances involving a large number of trees harvested in different regions across Europe. The potential impact of more specific factors such as other wood properties (density and ring width) and site effects is also evaluated.

Material and methods

Two-meter long butt logs were collected from 313 trees growing on six different sites across Europe. Three of these sites are IUFRO international provenance tests while the other two are alpine natural stands (Montgenèvre (F) and Langau (A)) and the last one a hybrid Larch progeny test (Clanna, GB). Altogether 13 lots have been analysed including 3 species, namely European Larch, Japanese Larch and hybrid Larch. For European Larch, 5 different provenances have been sampled. Table 1 gives some details about the material collected for this study.

Due to the high number of trees, the harvest was realised during two different periods: the first group was collected in winter 1998-1999 and the second one in 2000. This second set was also felled down during two different seasons, the first half of each provenance was cut in spring 2000 and left in the forest with their branches for the following growing season, and the second part was cut and transported immediately to the saw-mill in autumn.

In each log, a central board was sawn, in which 24 samples, 12 in the inner part and 12 in the outer part of the heartwood of each log, were prepared following standard norm n^r EN 350-1. They were split into 2 groups: 16 were selected for durability test and 8 used as standards to calculate the reference dry matter of the different samples. At the end of the process, 4702 samples were divided into two equal parts: the first one was inoculated with *Poria placenta* (strain FPRL280) and the second one with *Coniophora puteana* (strain FPRL11E). All samples were then stored, using Kolle flasks, in a conditioning room for 16 weeks according to EN 350-1. At the end of the process, mycelium was removed from the samples before drying off at 103 °C to a constant weight. The difference between the reference dry matter weight and the dry matter weight measured after fungi decay gives the loss of dry matter. 274 Scots pine (*Pinus sylvestris* L.) sapwood samples were used as control to determine durability classes.

Table 1. List and details of material included in the study.

Name	Origin	Provenance	Country	Stand	Nb of trees	Age (years)
Group 1						
Montgenèvre-F	Alps	Montgenèvre	F	Coat-An-Noz	18	42
Langau-B	Alps	Langau 38W/41W	B	Nassogne	20	42
Ruda-B	Sudetan Mts	Ruda	B	Nassogne	20	42
Ruda-F	Sudetan Mts	Ruda	F	Coat-An-Noz	20	42
Zabreh-B	Sudetan Mts	Zabreh	B	Nassogne	20	42
Zabreh-F	Sudetan Mts	Zabreh	F	Coat-An-Noz	19	42
Blizyn-D	Central Poland	Blizyn	D	Elm (Brunsleberfeld)	20	42
Ina-F	Japan	Ina	F	Coat-An-Noz	20	42
Group 2						
Hybrid-GB	Hybrid GB	4 FS-families 1	GB	Clanna (Wales)	36	42
Hybrid-F	Hybrid F	DK FS-family	F	Coat-An-Noz	30	42
Montgenèvre-nat	Alps	Montgenèvre (native range)	F	Montgenèvre	30	>220
Langau-nat	Alps	Langau (native range)	A	Langau (38W/41W)	30	185
Ruda-D	Sudetan Mts	Ruda	D	Elm (Brunsleberfeld)	30	42
				Total	**313**	

All the Larch and Scots pine samples with a water content higher than 100 % at the end of the process were rejected (water logging). Finally 4671 Larch samples and 243 Scots pine samples were then used for the statistical analyses. For each Larch sample, the x value (according to EN 350-1) defined as the ratio between the weight loss of a Larch sample and the mean weight loss of the *Pinus sylvestris* samples was determined and was used in the statistical analyses.

These individual data were submitted to variance analyses according to the following linear models:

$Y_{ijkl} = \mu + x_i + y_j + T(x)_{ik} + (xy)_{ij} + yT(x)_{ijk} + D_{ijkl}$ (Tables 3 and 5)

$Y_{ijkl} = \mu + x_i + y_j + (xy)_{ij} + T(xy)_{ijk} + D_{ijkl}$ (Tables 4 and 6)

$Y_{ijl} = \mu + x_i + y_j + (xy)_{ij} + D_{ijl}$ (Table 5)

With:

μ = general mean,
x_i = effect of factor i (Provenance or species; fixed factors),
y_j = effect of factor j (fungus, position in tree, site or felling date; fixed factors),
T_{ijk} = effect of tree k (random factor),
D_{ijkl} = residual error.

Linear regression and Pearson correlations between density, ring width and level of durability (x) have also been calculated. DUNNETT's test is used to test the differences between Japanese Larch used as a control and the other provenances.

Results, discussion and conclusions

1.- Variability among provenances

A huge variability is observed among the different European Larch provenances whatever the fungus tested (Figure 1, Table 2). According to the durability classes from EN 350-1, European Larch could be considered as durable to not durable depending on the origins of wood lots. Given this apparent range of durability, it is not surprising that the studies examined by NILSSON (1997) give apparently contradictory results. In our study, the trees harvested in the French Alps (Montgenèvre natural forest) offer the best resistance to fungi and this result could partly explain the good reputation of Larch in this region. But for the majority of wood lots from lowland plantations, Larch wood durability has to be considered as moderately to slightly durable.

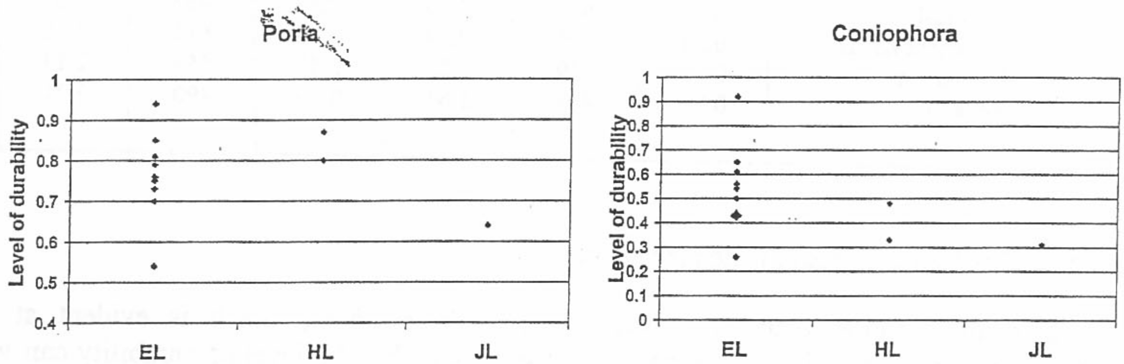

Figure 1.- Level of durability (x) of different provenances of European (EL, natural population in blue, lowland plantation in red), hybrid (HL) and Japanese (JL) Larch for *Poria placenta* and *Coniophora puteana*.

Relative to Japanese Larch control, European Larch seems less resistant to fungus attacks in general. Montgenèvre provenance (natural stand) appears to be the exception. Indeed it shows a significant higher resistance compared to Japanese Larch for *Poria* and a similar behaviour with *Coniophora*. Langau nat, the second tested natural stand, has not a so high resistance to fungi especially against *Poria* showing that a significant difference between the alpine natural stands could also exist. The Polish provenance (Blizyn), the best among European Larch lowland material, is also characterised by a good natural durability and it is also considered as statistically equal to the Japanese control whatever the fungus.

These latter observations are in accordance with published literature. In Belgium, a better resistance of the JL heartwood compared to the EL heartwood was observed with *Coniophora cerebella (syn. of C. puteana)* whereas the sapwood of the two species had a similar behaviour (ANONYMOUS, 1950). In Germany, PECHMANN and SCHAILE (1955) got the same results with *Coniophora cerebella* and *Polyporus vaporarius*.

The mean sensitivity of hybrid Larch to fungal attacks seems to be similar to the one observed for European Larch and it is on average less resistant in comparison with Japanese Larch. But DUNETT test shows also that the French hybrid is much better as it does not significantly differ from the Japanese Larch when *Coniophora* is concerned.

Table 2.- Level of durability (x), density and ring width by fungus and provenance.

Provenance	*Poria*			*Coniophora*		
	x	Density (kg/m³)	Ring width (mm)	x	Density (kg/m³)	Ring width (mm)
Group 1						
Montgenèvre-F	0.73	485	5.25	0.56	492	5.16
Langau-B	0.85	474	5.82	0.92	478	5.76
Ruda-B	0.75	469	5.98	0.65	478	5.63
Ruda-F	0.75	517	5.42	0.54	525	5.39
Zabreh-B	0.76	489	4.92	0.60	497	4.75
Zabreh-F	0.79	528	5.17	0.61	537	5.00
Blizyn-D	0.70	503	4.74	0.44	514	4.70
Ina-F (Japanese larch)	0.64	504	4.84	0.31	510	4.90
Group 2						
Hybrid-GB	0.87	415	8.26	0.48	418	7.86
Hybrid-F	0.80	461	4.99	0.33	465	5.03
Montgenèvre-nat	0.54	603	0.99	0.26	611	1.00
Langau-nat	0.81	549	2.13	0.43	553	2.14
Ruda-D	0.94	486	3.64	0.50	490	3.71

2. Variability between trees inside provenances

The different variance analyses indicated a huge tree effect, which is evident at the provenance level. For a given provenance, it also means that the level of durability can vary greatly depending on the trees analysed. For example, if we observe the intra-provenance variability of two good European Larch provenances in term of natural durability (Figure 2), the different trees can be classified from slightly durable to durable for Blizyn and from moderately to very durable for Montgenèvre.

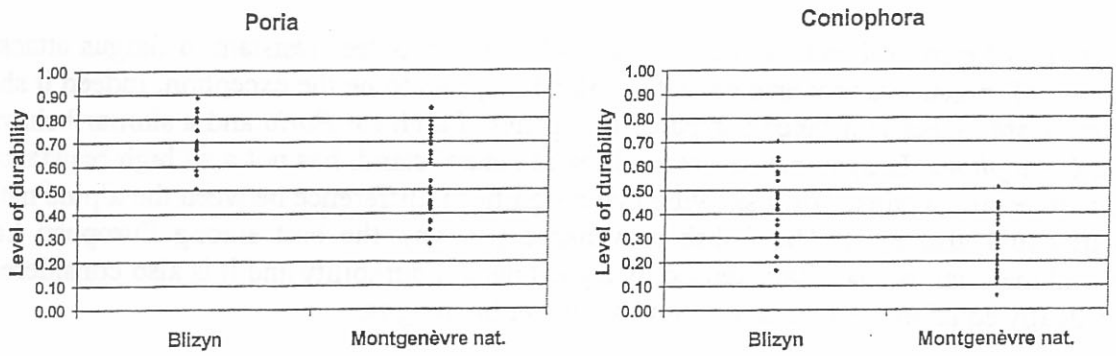

Figure 2.- Tree variability inside two provenances (Blizyn and Montgenèvre nat.) for natural durability against *Poria placenta* and *Coniophora puteana*.

These results point out the importance of the number of trees to be sampled in order to efficiently compare different provenances and/or species and the risk to get wrong conclusions in case of too restricted samples.

3. Test of different sources of variability

Chemical composition of wood is well known to have a strong influence on the natural durability of wood: it explains in particular the difference between heartwood and sapwood (PECHMANN and SCHAILE, 1955; SCHULTZ *et al.*, 1995; VIITANEN *et al.*, 1998) but also the ageing effect of wood on natural durability (see old trees from native Montgenèvre stand compared to trees from young other stands). This chemical approach is developed in another study of the EU project. In this study, other factors have been tested to evaluate their potential impact on natural durability.

The intensity of wood decay is clearly dependent on the fungus (Table 3). *Coniophora* is statistically more aggressive than *Poria* and, in this case, following the norm EN-350-1, the durability class has then to be defined with the *Coniophora* results. Compared to Scots Pine, Larch is much more resistant to *Coniophora* than to *Poria* and, for this reason, the Larch wood durability class appears better using *Coniophora* instead of *Poria*. It is also statistically observed that the different provenances do not express the same sensitivity towards the two fungi.

The same trend is also confirmed at the individual tree level for a given provenance. The standard error (SE) is also quite different according to the fungus tested, *Coniophora* expressed a greater variability for the different provenances ($0.18 < SE < 0.50$) compared to *Poria* ($0.18 < SE < 0.26$).

Table 3.- Effect of fungus and provenance on the level of natural durability. Anova table.

Variation source	Degree of freedom	Mean square	F value	Level of significance
Fungus	1	67.2154	833.94	***
Provenance	12	5.1885	22.14	***
Tree (provenance)	299	0.2344	3.75	***
Fungus x Provenance	12	1.9498	24.19	***
Fungus x tree (provenance)	299	0.0806	1.29	***
Residual error	4047	0.0626		
Total	4670			

This wood sample also offers two different possibilities to test the 'site' influence on the level of natural durability. In the first case (Table 4), the behaviour of the same two provenances established in two lowland sites (France and Belgium) is compared. The two plantations have the same age and the plants were established at the same spacing (2 x 2 m). In this case, no statistical difference could be observed among sites.

To compare the old-grown natural populations (Langau and Montgenèvre) with the same origins planted in lowland conditions, samples from the inner part of the first ones has been associated with the samples from the outer part of the lowland materials to reduce the possible ageing effect. The results show a significant effect of *Coniophora*, the most agressive fungus,but interestingly not for the *Poria*, the most aggressive fungus. In the former case, the higher resistance to fungus is observed for trees from the Alps.

Table 4.- Site influence on the level of durability of two provenances against *Poria* and *Coniophora*. Anova table.

Variation source	Degree of freedom	*Poria*		*Coniophora*	
		F value	Level of significance	F value	Level of significance
Site (B,F)	1	0.66	ns	0.06	ns
Provenance (Ruda, Zabreh)	1	0.46	ns	0.40	ns
Site x provenance	1	0.16	ns	0.94	ns
Tree (site x provenance)	75	2.68	***	3.11	***
Residual error	511				
Total	589				

Density and ring width also have a significant statistical effect on natural durability whatever the level of variation tested (sample, tree, provenance). Figure 3 shows a clear increase of fungus decay resistance with wood density increase. But, a huge variability is also observed especially for low densities, which is not apparent with high densities. Finally, it appears that the choice of high density tree (>650kg/m³) is always a good way to obtain durable wood products regardless of the fungus but this high density is only reached with Montgenèvre provenance from the Alps. At the provenance level, respectively 8 for *Poria* and 12 for *Coniophora* of the 13 provenances show a significant relationship between density and level of durability, the higher relationship being observed with Montgenèvre provenance. Meanwhile, especially for *Coniophora*, a huge variability among trees is observed and it indicates that it is possible to find trees with high decay resistance to fungi and relative low density which is a characteristics of lowland wood.

The increase of ring width, in a lower extend, has also a negative impact on this characteristics, but this relationship appears much lower and often non-significant when the study is realised at the provenance level (8 or 10 non significant correlations for a total of 13 depending of the fungus).

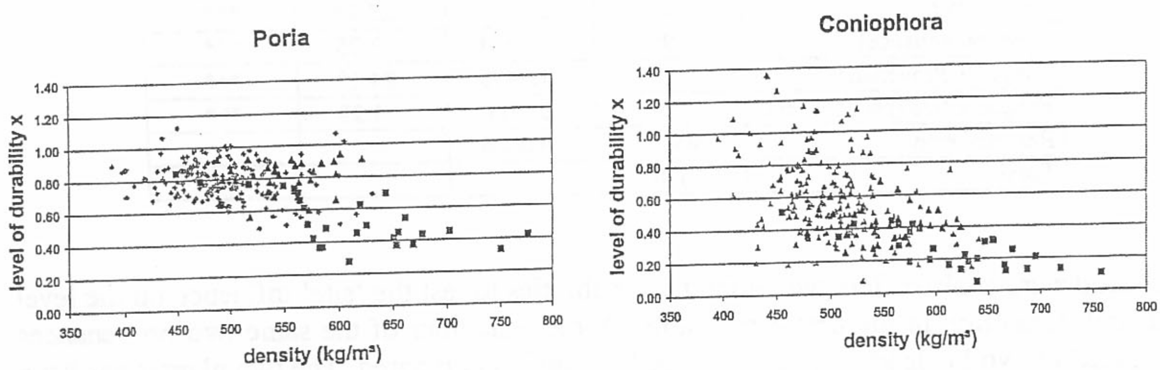

Figure 3.- Distribution of level of natural durability versus density for European provenances at the tree level (n=226), lowland plantation in green, Langau in blue and Montgenèvre nat. in red.

For European Larch, the inner and outer parts of the heartwood appear to have a significantly different sensitivity to fungi and this effect is particularly important at the provenance level with the two Alpine provenances. This confirms many published results (e.g.VIITANEN (1997) and CHARRON (2000)) and should be partly related to chemical accumulations from pith to bark. The outer part offers a better resistance to fungus attacks whatever the fungus

(Table 5). When the density or the ring width is used as a covariable, the effect of position along the radius disappears for the lowland provenances but stay very highly significant for the Alpine provenances. This stresses once again the influence of these two variables on the resistance to fungus attacks but also shows that in old trees from Alpine provenances, the outer part of a tree has specific characteristics others than density which improve decay resistance to fungi.

For the two other species, the results show obvious differences (Table 5). No significant effect of the radial position is observed for Japanese Larch whilst hybrid Larch seems to have an intermediate response depending on the fungus. This confirms the results of CHARRON (2000) for these two species. As in this study, he has also found a different behaviour of fungi in hybrid Larch according to the radial position.

Table 5.- Effect of radial position on the level of durability for 3 species and 2 fungi (P: *Poria*, C: *Coniophora*).

	Natural populations (59 trees)		Lowland European Larch (141 trees)		Hybrid Larch (62 trees)		Japanese Larch (18 trees)	
Fungus	P	C	P	C	P	C	P	C
Position	***	***	ns	**	ns	***	ns	ns
With covariable:								
Density	***	***	-	ns	-	*	-	-
Ring width	***	***	-	ns	-	ns	-	-

The felling period, which has the reputation to influence the quality of the wood, does not show any influence on the durability of the European Larch: differences among spring and fall felling periods are very low and not significant (Table 6).

Table 6.- Effect of felling date (spring and fall) on the level of durability (x) of European Larch for two fungi.

	Fungus	
Felling date	*Poria*	*Coniophora*
Spring	0.76	0.40
Fall	0.73	0.37
Statistical test	ns	ns

The high variability observed in this study at the species, provenance and tree level indicates that natural durability could probably be increased by genetic selection as already suggested by VIITANEN *et al.* (1998) for Siberian Larch.

From a practical point of view, in addition to respecting the general rules for wood uses, the choice of wood of high density sawn in the outer part of the logs could also improve the natural durability of the products and contribute in this way, to the reputation of Larch wood building.

At this stage, for Larch grown in lowland conditions, it seems that Japanese Larch performs better than European Larch. But on one side, we have observed a very high variability among European Larch provenances and on the other side, results in this study on Japanese Larch are based on only one origin. A complementary study using different Japanese Larch origins should be tested to confirm this first evaluation.

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