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Wood Density, Annual Ring Width and Latewood Content in Larch and Scots Pine

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Abstract

The wood density, annual ring width and latewood content in five different species of larch (*Larix* Mill.) and in Scots pine (*Pinus sylvestris* L.) were investigated using direct scanning X-ray densitometry. In total 106 trees were investigated. Old, 120-150 year, Siberian larch (*Larix sibirica* Ledeb. and *Larix sukaczewii* Dyl.) grown in Krasnoyarsk and Archangelsk and 105 year-old European larch (*Larix decidua* Mill.) grown in Sweden had on an average 20-25 % higher wood density than Swedish Scots pine. The variation in density between different trees of the same species was big. Average wood density of larch trees was 618 (535-670) kg/m^3 in old Siberian larch and 621 (550-665) kg/m^3 in mature European larch timber grown in Sweden. Average wood density for the young, 30-35 years-old, larch trees was 536 (515-560) kg/m^3 for European larch , 451(410-490) kg/m^3 for hybrid larch (*L. x eurolepis* Henry) and 452 (420-490) kg/m^3 for Japanese larch (*L. kaempferi* Lamb.). Corresponding figures for mature Scots pine was 504 (475-555) kg/m^3. The density within the mature zone of the heartwood was 20-40 % higher than in the juvenile wood zone. The density in mature European and Siberian larch heartwood, usually reached 650 kg/m^3 after 25-30 annual rings from the pith.

The density of larch heartwood increased with annual ring width up to 2.5 mm and decreased with annual ring with wider than 3 mm. On an average the latewood content was 40-50 % in old European larch, around 40 % in mature Siberian larch and 20-40 % in young hybrid larch. The latewood content of mature Scots pine was approximately the same as in mature European larch.

The density of 35 year old European larch with narrower ring widths than 4 mm was higher than in old, slow growing Scots pine.

Key words: *Larix*, latewood, *Pinus sylvestris,* wood density, X- ray densitometry, ring width

Introduction

Larch (*Larix* Mill.) is one of the most important elements of the boreal forest. Larch forests essentially encircle the northern hemisphere but have their widest geographical distribution in Siberia. The forests of Siberia are dominated by larch which occupy 50 % of the stock volume (Miluytin and Vishnevetskaya 1995). The wood of Siberian larch was early utilized as construction material for buildings, bridges, ships etc. and appreciated for its mechanical strength and natural durability to decay, especially in open-air conditions and in contact with soil and water (Kharuk 1961, Gorchin and Cherntsov 1966, Lomakin 1990, Polubojarinov *et al.* 2000).

Although larch timber has a good reputation to be used for out-door application, high variability of natural durability has also been noticed. Some authors consider larch wood to be moderately to non-durable (Nilsson 1997, Viitanen *et al.* 1998) while others have found the durability of larch heartwood to be 30-60% higher than the heartwood of Scots pine (Chubinski *et al.* 1990). These different opinions may be associated with different testing methods but more probably with variability among species, genetic origins within species, site of growth, age of tree and variability within and among trees of the same site.

The radial growth rate of the tree and the proportion of latewood within the annual ring are considered to have an influence on the durability and the mechanical strength (Kharuk 1961, Takata *et al.* 2002). The wood density is considered to have a positive correlation to mechanical strength, durability to decay, and resistance to fire (Zobel and van Buijtenen 1989, Gierlinger *et al.* 2002, Barnett and Jeronimidis 2003). Other characteristics of importance are the age of the heartwood. Older heartwood with similar ring width as younger seems to have a higher level of durability (Jacques *et al.* 2002).

The content of extractives in larch heartwood is 5-30 %, which is higher than in any other conifer. Extractives such as arabinogalactan and the flavonoids seem to have a positive correlation to the natural durability of the larch heartwood (Gierlinger *et al.* 2002).

The objectives of this study were to investigate the variation of wood density in different batches of timber of larch and Scots pine, and investigate the influence on the wood density from annual ring width and the contents of latewood. Six different batches of larch and two of Scots pine were compared.

Materials and Methods

Siberian larch (*Larix sukaczewii* Dyl. and *L. sibirica* Ledeb.) from naturally regenerated forests in the

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Table 1. Species, origins, mean age and number of trees of larch and Scots pine used in the investigation.

Batch/Species	Origin	Age	N of trees	Lat N
1. *L. sibirica*	Krasnojarsk (RUS)	150	18	56°
2. *L. sukaczewii*	Archangelsk(RUS)	120	20	65°
3. *L. decidua*	Lyrestad (SWE)	106	17	58°
4. *L. decidua*	Remningstorp (SWE)	35	9	58°
5. *L. x eurolepis*	Blekinge (SWE)	30	19	56°
6. *L. kaempferi*	Remningstorp (SWE)	35	10	58°
7. *Pinus sylvestris* Quality I *	W. Värmland (SWE)	145	8	60°
8. *Pinus sylvestris* Quality IV **	W. Värmland (SWE)	100	5	60°

* Butt log for through and through sawing ** Butt log from the second lowest quality class

Archangelsk and Krasnoyarsk region were compared with planted stands of European larch (*L. decidua* Mill.), hybrid larch (*L. x eurolepis* Henry), and Japanese larch (*L. kaempferi* Lamb.) grown in Sweden. Furthermore, Scots pine (*Pinus sylvestris* L.) from naturally regenerated stands in Sweden was included in the study. The species, sites of growth, mean age of trees, number of trees and latitudes of origin are shown in Table 1.

The stem discs, taken at stump height from bottom logs, were collected from three different saw mills in south Sweden:

Siberian larch from imported timber at the sawmill of Ansgarius Svensson AB, Södra Vi in south Sweden, old European larch from Högbrons saw mill, Lyrestad. Stem discs of young European and Japanese larch were collected in an experimental plantation in Remningstorp, south Sweden. The material of hybrid larch was collected at Vilshults sawmill, Blekinge and stem discs of Scots pine from Ansgarius Svensson AB. The material is named after the saw mills/origins.

The working procedure for the analysis was as follows:

1. Sawing of rectangular wood samples from stem discs including as many annual rings as possible from pith to bark.
2. Micro-sawing with a twin blade circular saw to a thickness of 3.7 mm longitudinal thickness (Bergsten *et al.* 2001).
3. Extraction of extractive compounds in a solution of acetone and water (9:1) for 72 hours.
4. Air drying of wood samples in room temperature for 48 hours. Then the samples were dried in the Woodtrax for 24 hours to reach ca 5 % moisture content.
5. Analysis of extracted wood samples using X-ray micro densitometry (Woodtrax - Cox Analytical System).
6. Analysis of x-ray images with densitometry software (Win Dendro, Regent Instruments). The boundary between early- and latewood was determined as 50 % of min density + max density within each annual ring (Pernestål *et al.* 1995).
7. Wood density values were calibrated with gravimetric measurements. 20 % of the specimens were air dried for 48 hours in 80°C and then weighed and measured with a calliper. Then the procedure was to calculate a linear regression model, comparing air-dry densities with oven-dry densities and then calculate the oven-dry density for the remaining 80 % of the samples. This procedure gave, however, both higher and lower values of oven-dry density compared to the values given in the woodtrax. As a consequence, the results given in the text are wood density values from X-ray densitometry for wood samples with 5 % moisture content.

The age used to demarcate the border between juvenile and mature wood was determined from literature studies. Mostly the border is set at 15-20 years in most *Larix* species (Shiokura and Sudo 1984, Keith and Chauret 1988, Zhu *et al.* 2000), but there is a large variation depending on which variable (tracheid length, growth ring width, latewood density, longitudinal shrinkage etc.) studied (Yang *et al.* 1986). In the present study, the border between juvenile and mature wood was set to 20 growth rings from pith for both larch and pine.

Within each batch of timber, tree mean values for annual ring width, ring density and latewood proportion were calculated.

Results and discussion

The timber batches of Siberian larch (1&2) and the quality I batch of Scots pine had the lowest mean annual ring width, about 1 mm (Table 2). The highest mean annual ring widths were recorded for the hybrid larch (batch 5), 4.6 mm.

Figure 1 illustrates the influence of the mean annual ring width on the wood density. In the younger trees (30-35 year old) the juvenile wood and sapwood were included in the density/ring width analysis, since these parts constituted the greater parts of the samples, while in the older trees only heartwood from year 20 was

Table 2. Mean annual ring width, mean wood density and latewood proportion of the investigated material.

Batch/Species	Origin	Mean annual ring width (year 1-20), mm	Mean annual ring width, mm	Mean density, kg/m^3 (Min – Max)	Latewood proportion, %
1. *L. sibirica*	Krasnoyarsk (RUS)	2.38	1.08	639 (565-670)	39
2. *L. sukaczewii*	Archangelsk(RUS)	1.45	1.00	598 (535-650)	39
3. *L. decidua*	Lyrestad (SWE)	2.88	1.92	621 (550-665)	42
4. *L. decidua*	Remningstorp	3.62	3.29	536 (515-560)	34
5. *L. x eurolepis*	Blekinge (SWE)	5.54	4.60	451 (410-490)	30
6. *L. kaempferi*	Remningstorp	4.53	3.94	452 (420-490)	29
7. *Pinus sylvestris* Quality I *	W. Värmland	1.05	1.11	506 (475-555)	39
8. *Pinus sylvestris* Quality IV **	W. Värmland	2.12	1.58	502 (475-540)	39

* Butt log for through and through sawing ** Butt log from the second lowest quality class

included in the analysis. The young fast growing larches indicate a relatively high wood density in annual growth rings up to 3 mm and indicate a clear reduction in wood density in wider annual rings than 4 mm. In contrast to the old larch, it was in the young larch material possible to compare the very narrow rings (less than 1 mm) with the very wide annual rings (more than 8 mm). The wood density of all the young larches was higher than the wood density of Scots pine at similar annual ring width. Comparing the three young larch batches at similar annual ring width, the wood density of European larch was higher than that of Japanese larch and the hybrid larch showed the lowest density.

The highest mean density was found in the older European larch (Lyrestad) and the Siberian larch from Krasnoyarsk (Table 2). However the wood density of all three different old larches was more than 600 kg/m^3 irrespective of annual ring width. It is though, important to remember that these values were taken from mature heartwood only. No sapwood or juvenile wood was included.

Comparing these results with other studies on the density of larch wood reveals that in this study, the values are quite high. Hakkila and Winter (1973) studied the density of Siberian larch wood grown in Finland and found the basic density to vary between 443 and 525 kg/m^3 depending on at which height of the stem the samples were from. Values from stump height were almost 20 % higher in basic density than samples from the top of the stem.

Other studies made on Siberian larch grown in Russia show, however, that the density can be a lot higher. Chubinsky *et al.* (1998) reported mean densities between 640-660 kg/m^3. Koizumi *et al.* (2003) studied 5 different stands of Siberian larch from three different sites in south Siberia and found the mean density of the heartwood to range from 641 kg/m^3 (Altai) to 779 kg/m^3 in Baikal. These values are for unextracted samples, and will therefore be higher compared to extracted samples.

The highest wood density of European larch was at ring widths between 0.5-1 mm. However, the density of annual rings up to 2 mm had a higher density than the narrowest annual rings. The timber from Krasnoyarsk showed a similar pattern. The differences in ring widths up to 2.5 mm were, however, small. A marked reduction of density was found in annual rings wider than 3 mm. The Siberian larch from Archangelsk showed the lowest density in annual ring widths between 1-2 mm while higher density existed in both narrower and wider annual rings.

The lower density of the juvenile wood (first 20 years) was visible in different kinds of larch as well as in Scots pine (Figure 2). The sapwood was almost non-existing in the old Siberian larch from Archangelsk and Krasnoyarsk, while the sapwood of the 106 year-old European larch grown in Sweden indicated a marked lower density. This big difference between heart- and sapwood is a bit surprising, considering that extracted samples were used. One explanation could be that many of the European larch stems demonstrated a strong increment in diameter during the last 10-15 years of growth, with year rings wider than 3 mm. This could lead to a lower density in the sapwood. Another possible explanation is the deposit of arabinogalactanes in the heartwood (Koizumi *et al.* 2003). The arabinogalactanes are not dissolved with the acetone extraction, and they will increase the density of the heartwood.

The young European and Japanese larches and the hybrid larch have formed heartwood but probably not yet formed any mature heartwood. Still the wood density of the young European larch was higher than the density of the old Scots pines.

Figure 3 illustrates the mean annual percentage of latewood comparing the same larch species and the Scots pine. The first 20 annual rings of the larches constituted the juvenile wood and had usually a latewood content less than 30 % of the annual rings. After this period the young larches had a latewood content of approximately 40 %, while the old Scots pine and the European larch had about 40-50% latewood. The latewood content of the mature Siberian larches was about 40% of the annual ring.

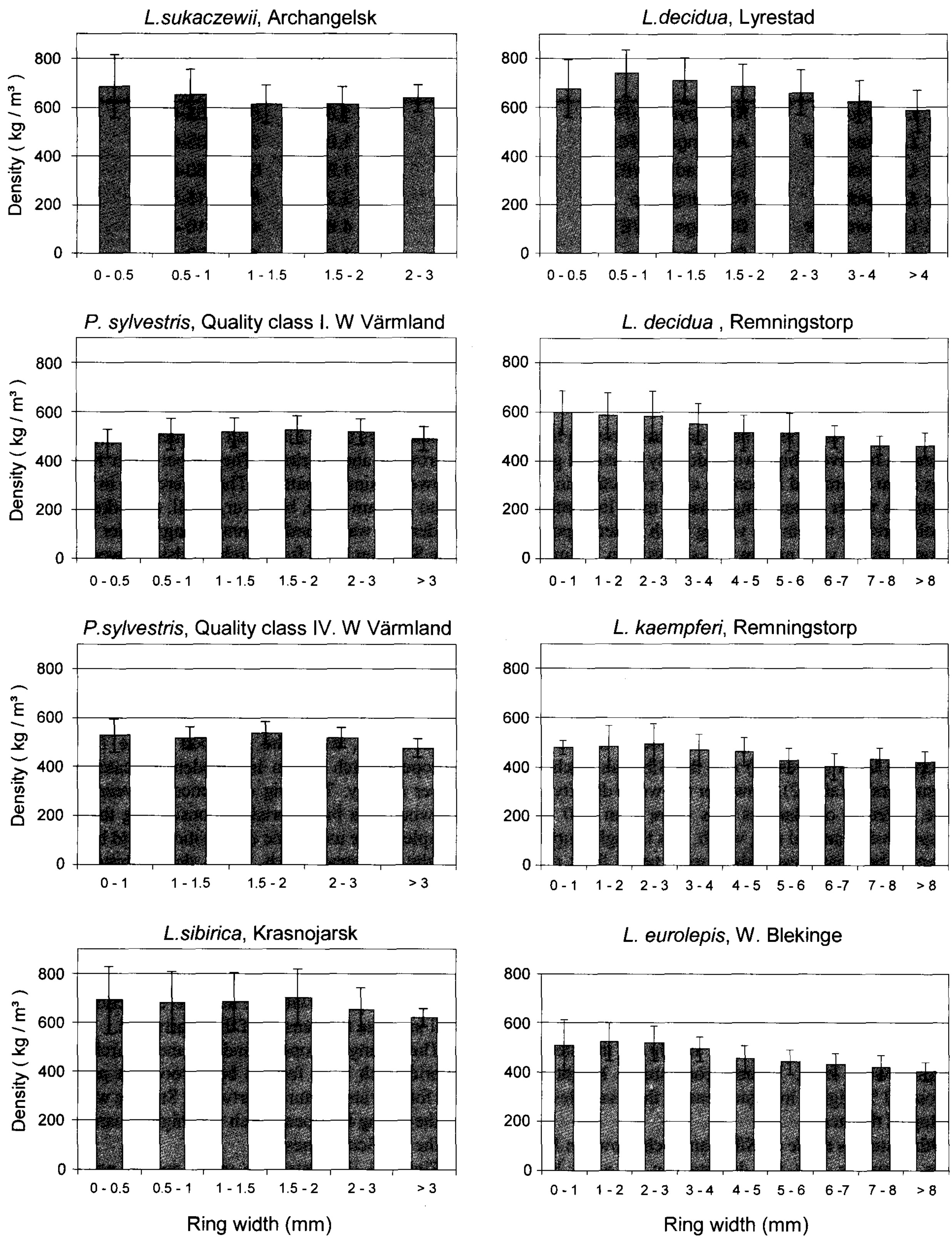

Fig. 1. Wood density of larch and Scots pine in relation to different annual ring width.

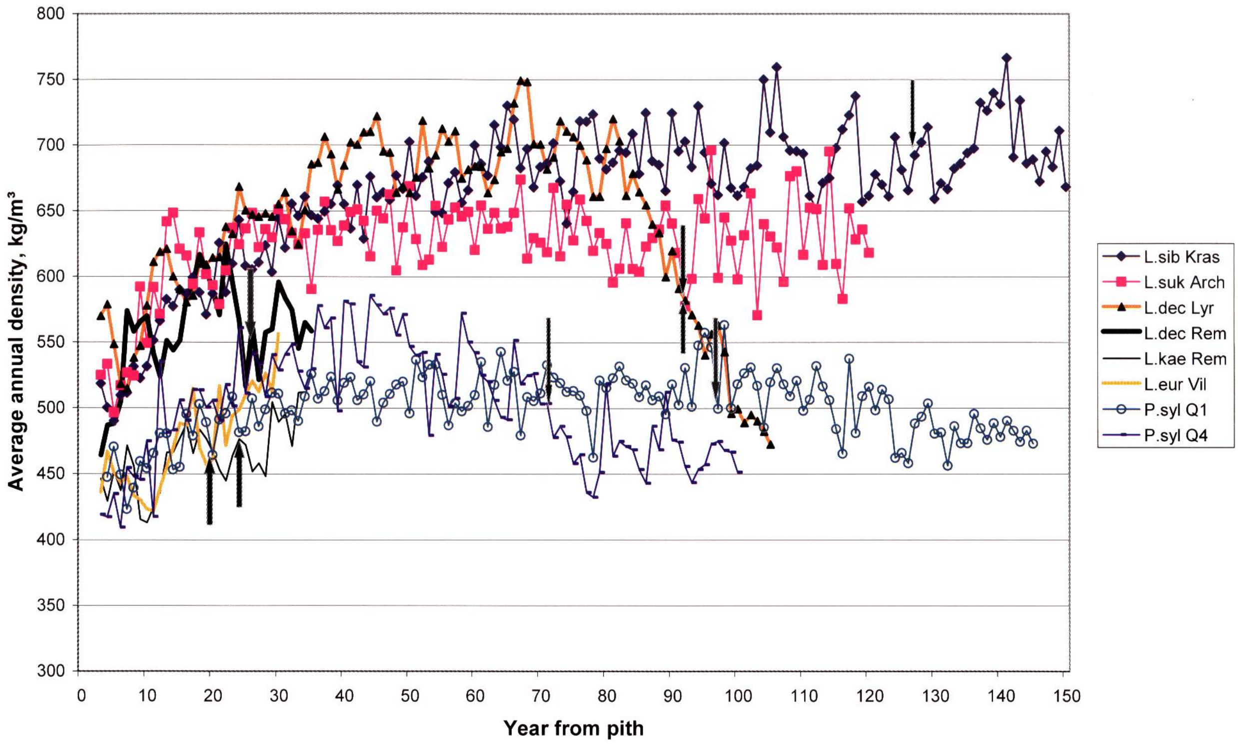

Fig. 2. Mean annual wood density from pith to bark of six different batches of larch and two of Scots pine. The arrows indicate the border between heartwood and sapwood.

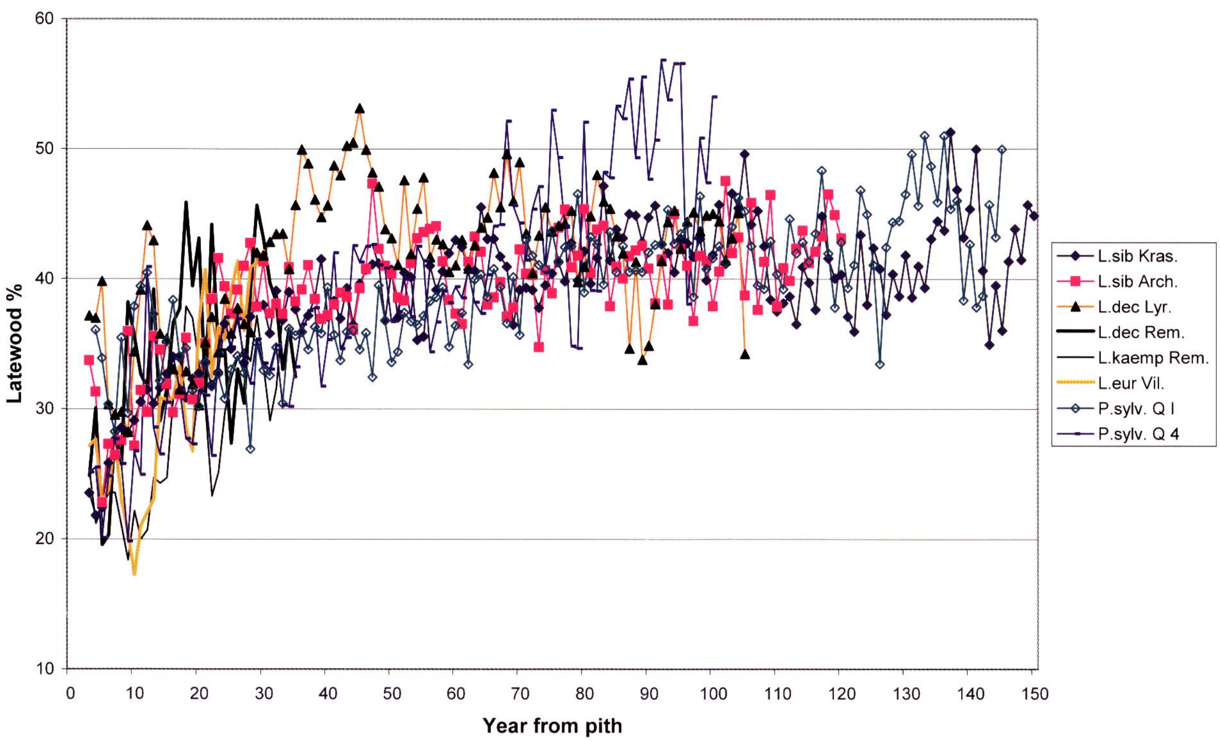

Fig. 3. Percentage of latewood from pith to bark for six different batches of larch and two of Scots pine.

Conclusions

Both native Siberian larch and planted mature European larch timber grown in Sweden had a wood density at stump height exceeding Scots pine with 20 to 25 %.

Ring widths up to 2.5 mm had the highest density. Ring widths wider than 3 mm were associated with a marked reduction in wood density. Scots pine showed a similar pattern with a wood density that was almost constant up to 3 mm wide annual rings. 35-year-old European larch with ring widths up to 4 mm had a higher wood density than slow grown old Scots pine with narrow rings.

The wood density of mature heartwood is 20-40 % higher compared to the wood of the juvenile wood zone. 30-35 years of growth is needed to reach a density of ca 650 kg/m^3 in Siberian and European larch. After 50 years of age the latewood content in Scots pine was at least as big as in old Siberian larch.

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