IMPACT OF PROVENANCE ON WOOD AND FIBRES PROPERTIES OF LODGEPOLE PINE, GROWN IN LATVIA

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Abstract
Lodgepole pine (*Pinus contorta*) samples from three different provenances in Canada were investigated. All trees were the same age and had been grown in Latvia in similar conditions. Lodgepole pine of Summit Lake provenance had higher wood density (503 kg m^{-3}) and a higher late wood content (46%) in comparison to Fort Nelson and Pink Mountain provenances. Investigation of chemical composition of wood indicated Summit Lake provenance wood as superior in cellulose content (49.7%), but no differences in lignin and extractives content were found between samples. Kraft pulp yield of Summit Lake samples (48%) was the highest, but the handsheet strength properties were relatively higher for pulp from Pink Mountain provenance pine wood.
Key words: Lodgepole pine, provenance, fibre, paper strength.

Introduction

Lodgepole pine, *Pinus contorta* Douglas ex Louden var. *latifolia* Engelm. Ex S.Watson, is a valuable and widespread species found throughout western North America, where it is planted as a part of sustainable forestry practice. Historically, trees that were well adapted to the soil and climatic conditions succeeded and thrived, whereas those ill-adapted failed. Over many generations, the successful species have adapted to local conditions resulting in the genetic make-up of wood land that is of local provenance. Today we say that the provenance of a tree describes the seed it grew from and where the seed was collected. Trees grown from imported seed may differ significantly in important characteristics.

A review by Elfving et al. (2001) describes the introduction of lodgepole pine in Sweden. The large-scale introduction of this tree species in Sweden started in the 1970s. The planted area has reached about 600,000 ha, corresponding to nearly 3% of the forested land.

Nevertheless, we did found only few published papers on the impact of provenance on the composition and properties of the lodgepole pine wood and fibres. McLane et al. (2011) investigated climate impacts on lodgepole pine radial growth in a provenance experiment. Sixteen sites in British Columbia, Canada, and Yukon and 12 populations were chosen to represent a broad spectrum of temperature and precipitation levels and geographic locations. The authors found modest differences in sensivity to climate among the populations from climatically divergent provenances growing in the same climatic region that they attributed to local adaption.

At the Latvian State Forestry Institute "Silava" the trials for transferred Scots pine and lodgepole pine provenances are performed (Jansons and Baumanis, 2008; Jansons et al., 2009).

As to the Scots pine (Jansons and Baumanis, 2008), in three experimental places in Latvia provenances from several countries were tested. The introduced pines at 28-years age had significantly thicker branches (German provenances – 9%, Polish – 6%) and crooked stems (German provenances – 35%, Polish – 12%) compared to the local material. Latvian pine provenances exhibited good growth and stem quality characteristics and also survival was higher than that of foreign provenances. The research suggested that use of foreign Scots pine plant material in Latvia is not advisable. The results by Jansons et al. (2009) revealed up to two-fold difference in total above-ground biomass among *Pinus contorta* families indicating the importance of the selection of the appropriate plant material for establishment of biomass plantation. The authors found that biomass production capacity of *Pinus contorta* on average is 3.5 t_{dry} per ha yearly. The number is almost 2.5 times higher than for *Pinus sylvestris* but notably lower as compared to hybrid aspen or Salix clones.

The objective of the present study was to investigate the wood and fibres properties of *Pinus contorta* three provenances, thus supplementing the data obtained earlier (Sable et al., 2012).

Materials and Methods

Samples were collected during 2009 and 2010 on an experimental site in the central part of Latvia (latitude 56°41', longitude 24°27'). Plant production for the experiments started in 1983; planting was carried out in 1985 on dry, sandy soil (*Myrtillosa* forest type). Initial spacing was 1 x 2 m; no thinning had been carried out prior to the collection of sample trees.

Lodgepole pine *(Pinus contorta)* was represented by 26 sample trees, grown from the seeds from 3 provenances from Canada, British Columbia: Pink

Mountain (latitude 57°00', longitude 122°15'-45'), Fort Nelson (latitude 58°38', longitude122°41'), and Summit Lake (latitude 54°24', longitude 122°37').

Wood samples were chosen based on randomized number methods. Approximately 2 cm thick wood discs were made and treated by No. 150 sandpaper to determine the latewood content at the height of 1.3 m. The discs were dried at room temperature and scanned by "Canon 4400" using calibrated "Leica ImagePro6" software.

All tree samples were debarked and wood density samples were made from the stem part at the height of 0.5 to 1.0 m; all wood chemical analyses and kraft cooking were made from the stem wood at the height of 1.0 to 1.3 m.

All samples were ground in a Wiley mill to pass through a 0.6 mm screen. The ground wood particles were then Soxhlet extracted with acetone for 8 h to quantify the extractable components gravimetrically after rotary vacuum-evaporation, and expressed as a percentage of the original weight of the wood sample. The extracted lignocellulosic material was then air-dried and analyzed for cellulose and lignin contents as follows. For Kürschner cellulose content determination according to TAPPI 203cm-99 (TAPPI, 2000), 2 g of the sample of extracted wood was used. It was transferred to a 250 mL reaction vessel, and 150 mL of nitric acid and ethanol solution was added. Wood samples were heated in a water bath at 92 °C for about 20 min; then the solution was exchanged for a new one. The procedure was repeated 7 times, and finally the fibres were washed with warm deionised water. The dry substance was weighed to determine Kürschner cellulose gravimetrically.

Lignin content was determined by the acetyl – bromide method using UV spectroscopy according to Iiyama and Wallis (1988; 1990), and Hatfield et al. (1999). The method is based on the small weight of the wood screened sawdust sample treated with 25% of acetyl bromide in a glacial acetic acid solution. Perchloric acid was used as a catalyst for the acetylation reaction. Absorption was measured at 280 nm and absorption coefficient was adopted to be equal to 20.0 L (g cm)$^{-1}$. The content of lignin in wood was calculated by the equation (1),

$$w(\%) = \frac{A \cdot V \cdot 100\%}{a \cdot b \cdot m \cdot 1000} \quad (1)$$

where A is the absorption at 280 nm; V is the volume of the mixture, mL; m is the weight of the sample, g; a is absorption coefficient, 20.0 L (g cm)$^{-1}$; and b is the thickness of the cuvette, cm.

Pulp was obtained by kraft pulping procedure. About 200 g of wood chips was cooked in a 2 L laboratory digester at 170 °C. The white liquor contained 57.4 g L^{-1} active alkali as NaOH, sulfidity was 29.8%, and liquor to wood ratio was 4.5 L kg^{-1}. Before cooking, the digester was left overnight at room temperature to impregnate wood chips with chemicals. Then the autoclave was placed into the heating unit and the temperature was increased from room temperature to 170 °C in 104 min, and cooked for 75 min. After the cooking procedure, the autoclave was immediately placed in water - ice bath to terminate the delignification reactions. The kraft pulp fibres obtained were carefully washed with warm water until the filtrate was colourless and the washing waters became neutral. The delignified fibres were treated in a standard PTA disintegrator for 30000 revolutions, then filtered and collected on a Büchner funnel, and dried at room temperature to determine the total kraft pulp yield.

Klason lignin content was determined according to the TAPPI Standard T 222 om-98.

The kraft pulp fibre samples were dried overnight at 50 °C, and the moisture content was measured to determine fiber weight for dimensions and coarseness measurements. Accurately weighed samples were then re-suspended in 20 mL of de-ionized distilled water, and fibre properties (length, width, form, coarseness and fines) were determined on a Lorentzen & Wettre "FiberTester".

Standard handsheets were made according to ISO 5269/2 on a PTA "Rapid-Köthen" handsheets paper machine. Handsheets were prepared at the grammage 75 g m^{-2} to determine tensile and burst strength indices (ISO 1924-1 and ISO 2758, respectively).

Data collected were analysed with appropriate statistical software (SPSS). ANOVA procedure was used for determination of factor (provenance) effect on the inspected properties. If the provenance effect was significant ($p<0.05$), Bonferroni test was used *post hoc* to determine which provenances differed.

Results and Discussion

Obtained measurements on the tree stem diameter at 1.3 m height varied widely, from 7.9 to 17.9 cm (Fig.1). There were slight, but not statistically significant differences between lodgepole pine trees from Pink Mountain (13.1 ± 2.6 cm), Fort Nelson (11.2 ± 2.3 cm) and Summit Lake (13.0 ± 2.3 cm) provenances.

Wood density values for the different provenance pine samples were well separated, with significance $p<0.05$. As shown in Figure 2, Summit Lake

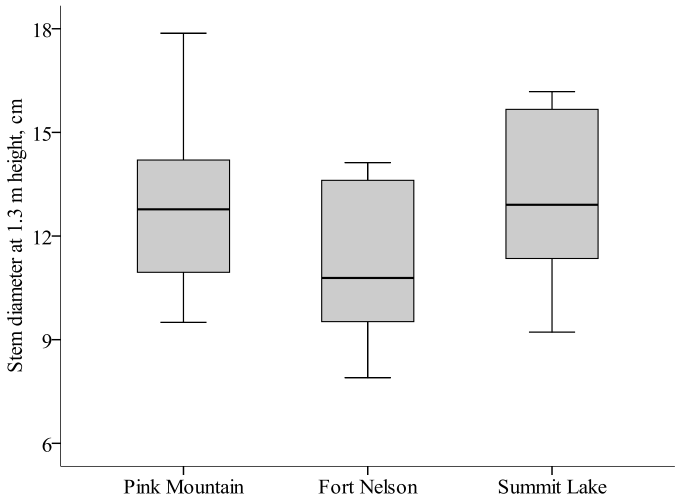

Figure 1. Stem diameter values of lodgepole pine from different provenances.

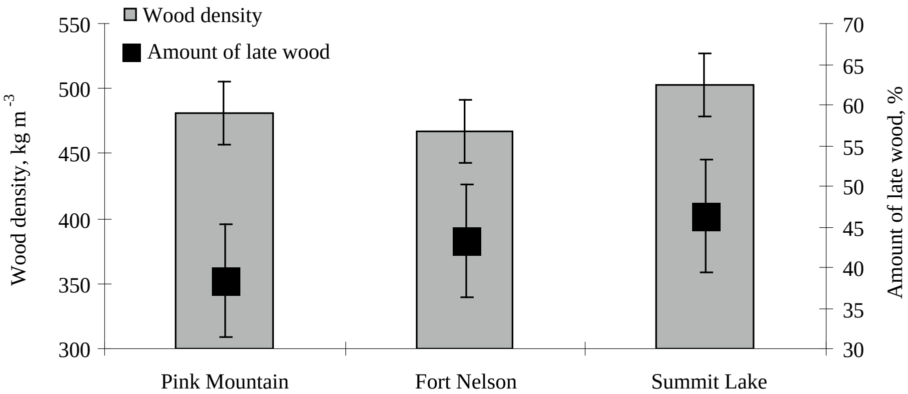

Figure 2. Amount of late wood and density values of lodgepole pine provenances (error bars show standard deviation of mean values).

Table 1

Chemical composition of lodgepole pine wood of different provenances

	Cellulose content, %	Std	Lignin content, %	Std	Extractives content, %	Std	Ash content, %	Std
Pink Mountain	48.7	1.2	26.4	0.8	2.4	0.6	0.3	0.01
Fort Nelson	48.4	0.8	26.4	0.7	2.3	0.7	0.3	0.01
Summit Lake	49.7	1.1	26.3	0.5	2.9	1.2	0.2	0.04

provenance wood with significantly ($p<0.05$) higher density 503 kg m^{-3} overtook Pink Mountain (481 kg m^{-3}) and Fort Nelson (467 kg m^{-3}) samples. Also amount of latewood differed between wood samples. The highest result (36-57%) was observed for Summit Lake samples as compared to Pink Mountain (32-43%) and Fort Nelson (34-54%) pine wood. Not statistically verified, but still visible (Figure 2) correlation among provenances between the amount of latewood and wood density was established.

Analysis of chemical composition of examined samples revealed significant ($p<0.05$) differences in the content of cellulose (Summit Lake sample with result 49.7% was superior to two other provenance's samples), but in cases of lignin and extractives content (see Table 1) no distinctions came out between Pink Mountain, Fort Nelson and Summit Lake samples.

Results of pulping process (Figure 3) revealed significant effect ($p<0.05$) of trees' provenance on pulp yield and set Summit Lake with pulp yield 48.0% as prevailing over Pink Mountain and Fort Nelson with lower numbers (45.8 and 46.8% respectively). Residual lignin content in pulp varied slightly between provenances (4.4 – 5.0%) and accordingly, significant effect of trees' provenance on lignin content in pulp wasn't observed.

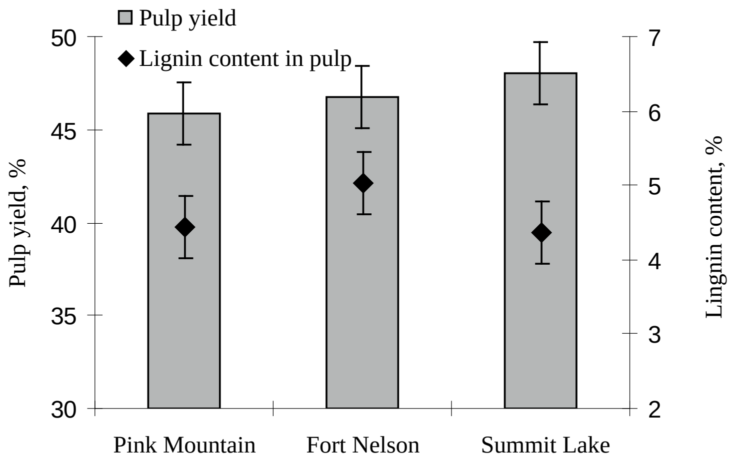

Figure 3. Kraft pulping results of lodgepole pine from different provenances (error bars show standard deviation of mean values).

Study of kraft pulp fibres dimensions showed significant differences in fibre length and shape between the provenances. Distribution (Figure 4) of fibre dimensions indicated Pink Mountain sample as provenance with shorter (2.1 mm) and narrower (31.1 µm) fibres in comparison to Fort Nelson with longer (2.3 mm) and Summit Lake with slightly wider (32.6 µm) fibres.

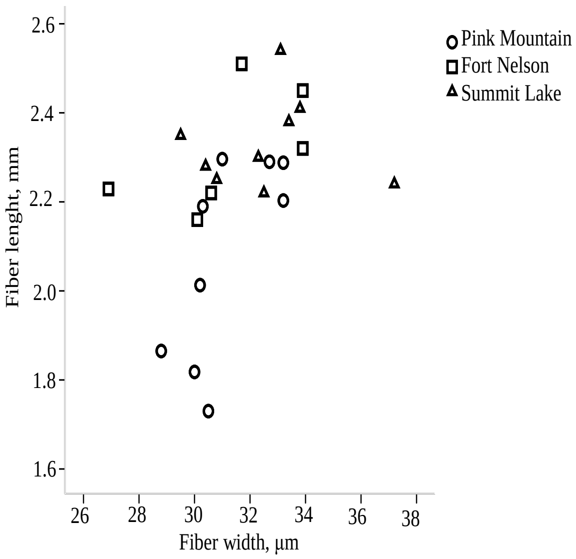

Figure 4. Kraft pulp fibres' dimensions of lodgepole pine from different provenances.

Fibre properties, previously discussed and also reflected in Table 2, are responsible for paper quality and strength parameters. Trees' provenance had varied effect on shape factor, amount of fines in pulp and coarseness. There were considerable ($p<0.05$) differences in shape factor values, where Summit Lake sample showed higher results over Fort Nelson and in coarseness measurements, the result of Summit Lake was higher than that of Pink Mountain.

Table 2

Kraft pulp fibres' properties of lodgepole pine from different provenances

	Shape factor, %	Amount of fines in pulp, %	Coarseness, mg m^{-1}
Pink Mountain	93.3	1.9	149
Fort Nelson	92.6	1.6	165
Summit Lake	93.8	1.8	177

Figure 5 reflects handsheet strength properties of the investigated pulp samples. Calculations of data showed significant ($p<0.05$) effect of trees' provenance on all parameters, except burst index, where no considerable differences between the samples were found. Pink Mountain provenance surpassed others in all paper strength parameters. Breaking length and tensile index values of Pink Mountain lodgepole pine pulp were higher (3.7 km and 36.7 N m g^{-1} respectively) than that of Summit Lake wood pulp (2.9 km and 28.8 N m g^{-1}). Also, significant differences in stretch indices were observed – Summit Lake samples were noticeably ($p<0.05$) behind others.

Summarizing the data on pulp and handsheet properties, lodgepole pine fibres from Pink Mountain provenance seem to offer paper with more promising properties.

Conclusions

1. When comparing lodgepole pine tree samples from different provenances, Summit Lake pine samples indicated higher wood density, amount of late wood and higher cellulose content when

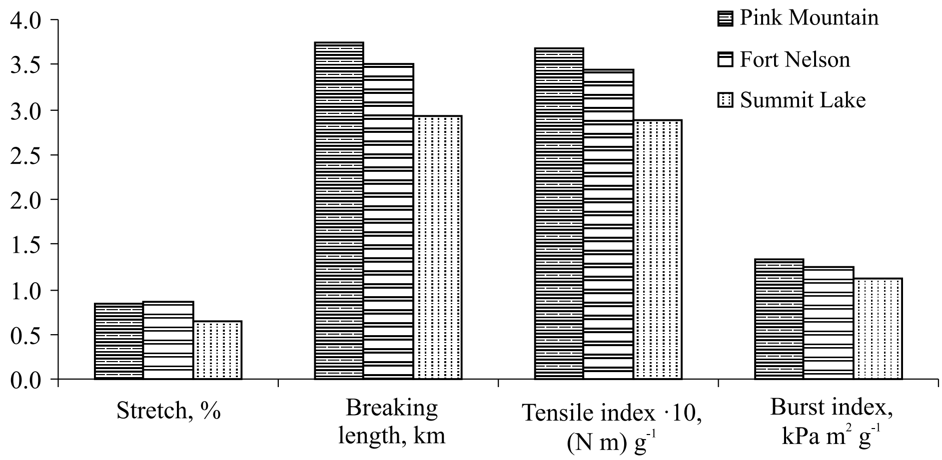

Figure 5. Handsheet strength properties of lodgepole pine from different provenances.

compared to other studied trees' provenances – Pink Mountain and Fort Nelson.

2. Higher kraft pulp yield was observed for lodgepole pine samples from provenance Summit Lake, but no significant differences in residual lignin content in pulp between provenances was noticed.
3. Pink Mountain provenance's pine pulps had shorter and narrower fibres in comparison with other provenances, still in majority of paper strength parameters – breaking length and tensile index - they were in the forefront.

Acknowledgements

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