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WOODWORKING PROPERTIES OF SCOTS PINE FROM NORTHERN EUROPE AND THEIR COMPETENCE FOR VALUE-ADDED JOINERY PRODUCTS

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Abstract:

Technical performance, visual attraction and haptic properties of wood products depend largely on the output from woodworking, manual or mechanized. The appropriate material, configurations and wear of equipment as well as optimal processes and allowances are linked to particular properties of wood. Large variations in some properties, within-piece or between-piece, can cause significant stress gradients, increasing wear or breakage of the equipment and resulting in heterogeneous quality of the products. We studied the levels of and variations in selected mechanical and physico-morphological properties of sawn timber billets of North-European Scots pine (Pinus sylvestris L.) that affect the technique of and result from woodworking for joinery wood products. We made selected laboratory measurements on billets with respect to vertical and radial locations in sample trees which were cut from 60 mature stands in five sub-regions in Finland and Sweden (north-south gradient). We analysed the following material properties: a) shear strength, tensile strength (perpendicular to grain), Brinell hardness; b) size and quality of knots, defect-free knot whorl intervals, longitudinal grain straightness; c) basic density, annual rings (as background). The results and their applications are shown in detail in the website Scots pine – Excellence and image http://www.metla.fi/metinfo/northernpine/index-en.html.

Key words: *pine wood; wood properties; joinery products; woodworking; secondary manufacturing.*

INTRODUCTION

Wood product industries have to position their activities and products into the current and future market segments and implement new technology, innovation and marketing strategies to be able to compete in the international market and re-gain, or increase, the market share compared to suppliers of substituting materials (Verkasalo *et al.* 2007). Technical performance, visual attraction and haptic properties of wood products with value-add depend largely on the output from woodworking, manual or mechanized. The appropriate material, configurations and wear of equipment as well as optimal processes and allowances are linked to particular mechanical and physical properties of wood. Large variations in some properties, within-piece or between-piece, can cause significant stress gradients, increasing wear or breakage of the equipment and resulting in heterogeneous quality of the products.

Scots pine (*Pinus sylvestris* L.) is an important species in Northern Europe for joinery wood industries where high-level woodworking properties are needed. It is used as solid wood and finger-jointed material both. The main joinery applications where woodworking is important are in windows, doors, floors, interior panels and mouldings, prefabricated wood houses and log houses and factory-made building components (Virtanen 2005, Malinen and Verkasalo 2010). Wood is a highly anisotropic material at any structural level, and Scots pine tends to have larger variations of softwood species according to growth region and silviculture (Hudson 1967, Hakkila 1968, Verkasalo and Leban 1996, 2002, Grekin 2006, Ranta-Maunus 2009, Ranta-Maunus *et al.* 2011, Chuchala *et al.* 2013). The important wood properties in relation to processing and in-situ uses of selected joinery products of Scots pine are listed in Table 1.

The critical wood properties for woodworking are basically mechanical and physical by their nature, but, in parallel, they are often linked to the visual quality of wood (*e.g.*, Hoadley 2000). The key mechanical properties cover shear strength, tensile strength (perpendicular to grain) and Brinell hardness, in some applications compression and tensile strength and stiffness as well (Grekin and Surini 2008). Compression, tensile and shear stresses are usually present in load-bearing applications making the shear strength important (Kollmann and Côté 1968). Shear strength is also important for the potential to make mechanical connections to wooden structural members as well as screwing and nailing ability (Echavarría *et al.* 2007), Tensile stresses perpendicular to grain are crucial to the checking phenomenon of wood, and checks or shakes can in turn completely destroy the tensile strength (Kollmann and Côté 1968). Wood hardness largely affects the fracture mechanics and machinability of wood, and hence the result from woodworking, while being important for the resistance against scratching, wearing, and abrasion (Grekin and Verkasalo 2013). Hardness can actually be derived from several different forces, such as friction, shearing, and compressive forces (Kollmann and Côté 1968). Wood density, being a result from ring width, latewood-early wood relationships and formation of special wood tissue (reaction wood, juvenile wood) is an important physical background factor for the woodworking properties (*e.g.*, Grekin and Verkasalo 2010).

Of the visual determinants, knottiness factors, related to size and quality of knots and defect-free knot whorl intervals (lengths of clear wood sections) as well as deviations of grain directions from straight line are significant. They are of importance in woodworking when aiming to homogeneous wood products with high-quality surface after tooling and stable mechanical connections, including the risk of checking or fracture.

The objective of this paper is to study empirically the level of and variation in selected mechanical and physico-morphological properties of sawn timber billets of Scots pine important in woodworking: a) shear strength (parallel to grain), tensile strength (perpendicular to grain), Brinell hardness, b) longitudinal grain straightness, size and quality of knots, defect-free knot whorl intervals, c) basic density, annual ring width and structure (as background). Special attention is paid to the effects of sub-region and within-tree and between-tree variations.

MATERIALS AND METHODS

Tree, log and wood samples from 60 mature Scots pine dominated stands growing on mineral soils were collected in three sub-regions in Finland (northern, south-eastern, and central inland) and two sub-regions in Sweden (south-central and southern), 12 stands from each (Fig. 1), to cover the geographic spread for latitude and altitude, accordingly, the climate for effective temperature sum. From each sub-region, the stands were selected randomly to represent different forest sites and age classes of mature stands. In Finland, the sampling was based on the sample plot network of the National Forest Inventory (NFI); In Sweden, on the records of the landowner, Sveaskog Ltd. In each stand, eight Scots pine trees covering the diameter range of saw log trees were felled for sampling, the total sample being 480 trees.

Three sample trees per stand were used for wood analysis, 70-cm bolts being cut from butt log, middle log, and top log sections (Fig. 1). From each bolt, 540 of them, approx. 30-mm disc was first sawn from the top end (sample set A). Thereafter, the bolts were sawn through-and-through into approx. 30-mm thick boards, and the boards were slowly dried at room temperature (sample set B). The boards were numbered ascending from the pith outwards, so that the 0-board was the middle, pith enclosed core board, the 1-boards were the first boards outwards from both sides of the pith etc. Furthermore, the 0-board were cut into approx. 30*30*650mm flitches (sample set C). Detailed descriptions of sampling are given by Grekin and Surini (2008) and Grekin and Verkasalo (2010, 2013).

Table 1

Specific wood properties in selected applications for joinery products of Scots pine (a = physical and-mechanical properties, b = morphological properties, c = processing and in-situ use properties)

Window frames	a) Density, shrinkage/swelling, resin concentration, juvenile wood - mature wood, reaction wood, shear strength, tensile strength (perpendicular-to-grain); b) Knottiness, grain orientation, ring width, heartwood/sapwood, resin pockets; c) Dimension and form stability, checking and fracture behaviour, moisture resistance, mechanical connecting and finger-jointing behaviour, gluing behaviour, mould, decay and insect resistance, drying quality, heat insulation
Interior doors	a) Density, shrinkage/swelling, resin concentration, juvenile wood - mature wood, reaction wood, shear strength, tensile strength (perpendicular-to-grain); b) Knottiness, grain orientation, ring width, heartwood/sapwood, resin pockets, colour (stability); c) Dimension and form stability, checking and fracture behaviour, surface roughness, planning, mechanical connecting and finger-jointing behaviour, gluing behaviour, drying and finishing behaviour, noise insulation
Interior panels and mouldings	a) Shrinkage/swelling, juvenile wood - mature wood, reaction wood, shear strength, tensile strength (perpendicular-to-grain); b) Colour, knottiness, grain orientation, ring width, heartwood/ sapwood, resin pockets; c) Dimension and form stability, checking and fracture behaviour, surface roughness, planing and mechanical connecting behaviour, drying and finishing behaviour
Flooring	a) Density, shrinkage/swelling, shear strength, tensile strength (perpendicular-to-grain), hardness, bending properties; b) Colour, knottiness, grain orientation, ring width, heartwood/ sapwood, resin pockets, look of wood but enough homogeneity; c) Dimension and form stability, checking and fracture behaviour, surface roughness, wear resistance, planning, mechanical connecting and finger-jointing behaviour, drying behaviour, acoustic properties, feel of comfort
Furniture components	a) Shrinkage/swelling, juvenile wood - mature wood, reaction wood, shear strength, tensile strength (perpendicular-to-grain), hardness; b) Colour, knottiness, grain orientation, ring width, heartwood/sapwood, no resin pockets, look of wood but enough homogeneity; c) Dimension and form stability, checking and fracture behaviour, surface roughness, wear and scratching resistance, gluing behaviour, planning, mechanical connecting and finger-jointing behaviour, drying and finishing behaviour, feel of comfort
Decking and fencing	a) Density, shrinkage/swelling, juvenile wood - mature wood, , bending and compression strength, hardness; b) Knottiness, heartwood/sapwood; c) Moisture resistance, dimension and form stability, checking and fracture behaviour, impregnation behaviour, mould, decay and insect resistance, mechanical connecting behaviour
Cladding	a) Shrinkage/swelling, juvenile wood - mature wood, reaction wood, shear strength, tensile strength (perpendicular-to-grain); b) Knottiness, heartwood/sapwood, resin pockets; c) Dimension and form stability, checking and fracture behaviour, moisture resistance, mechanical connecting and finger-jointing behaviour, mould, decay and insect resistance, drying behaviour
Load-bearing structures and components (wood houses, log houses)	a) Density, shrinkage/swelling, juvenile wood - mature wood, bending, tensile and compression properties, shear strength, tensile strength (perpendicular-to-grain); b) Knottiness, heartwood/sapwood, grain orientation; c) Dimension and form stability, checking and fracture behaviour, moisture resistance, mechanical connecting behaviour, impregnation behaviour, drying quality

Shear strength (parallel to grain, radially) was measured on sample set C (N=1,034) by ISO standard 3347 (1976), at 12% MC, and calculated as

$$\tau_{LR} = \frac{F\max}{bl} \text{ [N/mm}^2\text{]} \tag{1}$$

τ_{LR} – shear strength, in N/mm^2
F_{max} – maximum force, in N
b – width of the specimen (radial), in mm
l – height of the specimen, in mm

Tensile strength (perpendicular to grain, tangentially) was measured on a random sample of set B, excluding boards of sample set C (N=314), by ISO standard 3346 (1975), at 12% MC, and calculated as

$$\sigma_T = \frac{F\max}{A} \text{ [N/mm}^2\text{]} \tag{2}$$

σ_T – tensile strength (perpendicular to grain), in N/mm^2

$F\max$ – maximum force, in N
A – surface area of the specimen at the position of the fracture, in mm^2

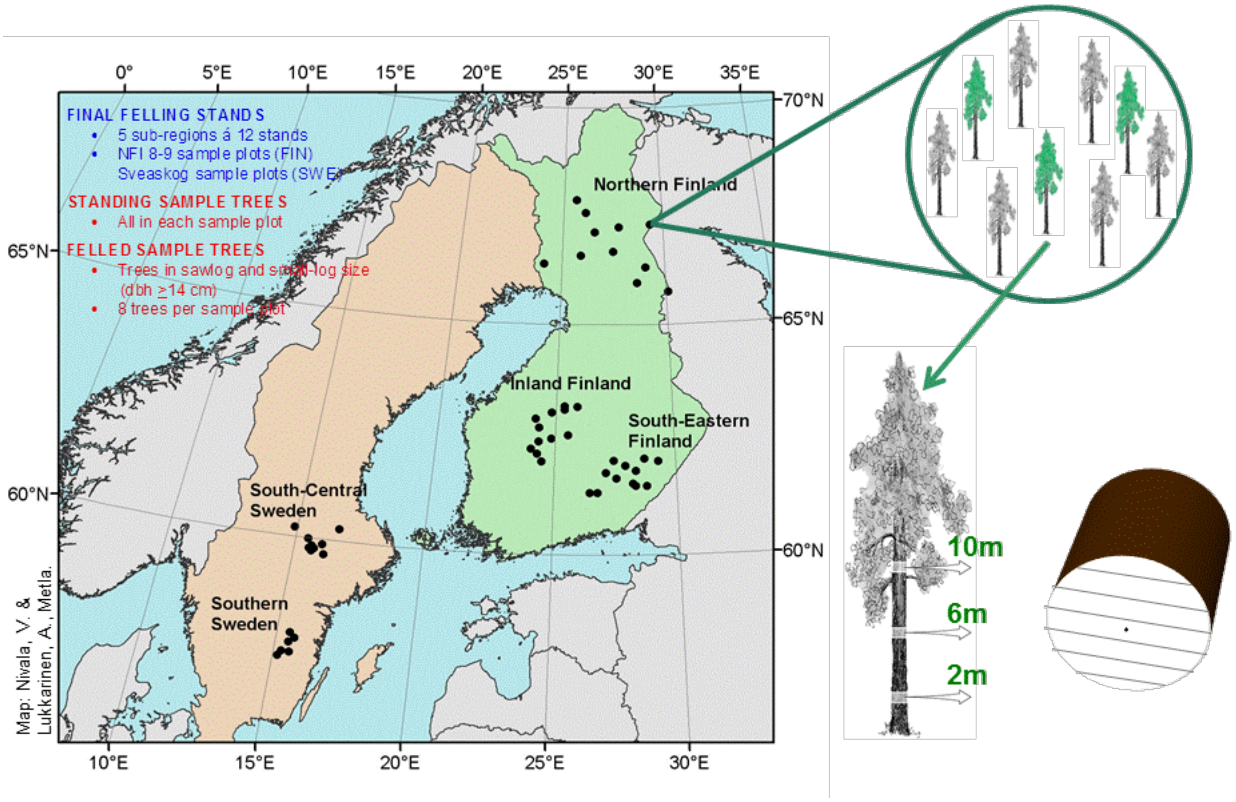


Fig. 1
Geographic sources and sampling of data: sub-regions, stands, trees, logs, sawn timber billets.

Brinell hardness was measured perpendicular to grain from a random sample of set B, excluding boards from sample set C, according to the European standard EN1534 (2000), at 12% MC. The boards were processed into approx. 100x150x30mm specimens. In each of them, one to three hardness measurements (total N=2151) were executed along the radius of the stem on the planed outer face of the board, and the measurements were averaged for each specimen (wood specimens A, N=875). Normally, the Brinell hardness should be calculated on the basis of the two orthogonal diameters, one along the grain, and another across the grain, of the residual indentation. Due to major occurrence of the phenomenon called "sinking in", *i.e.* the elliptical indentations in the fibre direction (Doyle and Walker 1985), the hardness calculations were based only on the residual indentation diameters measured across the grain (HB_d). Complementary hardness values were calculated on the basis of the initial depths of the indentations measured by the material testing apparatus itself (HB_h). The hardness values were calculated as FMT-MEC 100 kN material testing apparatus was used in all tests of mechanical properties.

$$HB = \frac{F}{\pi Dh} = \frac{2F}{\pi D\left(D - \sqrt{D^2 - d^2}\right)} \text{ [N/mm}^2\text{]} \qquad (3)$$

HB – Brinell hardness, in N/mm^2
F – force used in test, in N
D – diameter of the indenter, in mm
h – initial depth of the indentation, in mm
d – diameter of the residual indentation, in mm

Knottiness and grain straightness were measured visually on the outer faces of boards in the sample set B (N=3,678). Type, diameter and location (lengthwise, crosswise) of each knot and the through-board angle of a knot sample were recorded, and the lengths of whorl intervals (clear wood section between two subsequent whorls) were measured on each board. Measuring grain straightness started in the butt end of board, or as close it as possible, and ended as close to the top end as possible. The distance between the longitudinal centre line of board and the growth ring line that started in the centre line in the butt end was measured (mm). The value of straightness was calculated as the ratio of the distance of the lines at the end point of measurement and the longitudinal distance of start and end points of the measurement (mm/m). Detailed descriptions of measuring knottiness and grain straightness are given by Verkasalo *et al.* (2005).

Ring width and latewood / early wood proportions were measured in hundredth parts of mm, using a light microscope equipped with automatic image scanning software. Basic density, *i.e.*, oven-dry mass per green volume (□□□$_g$ kg/m^3) was measured using the gravimetric method, all on sample set A (N=2,301). For the tests on the specimens for mechanical properties, the density was determined in the test conditions (□□□ kg/m^3) as well, *i.e.*, at MC 12%).

Sources of variation in the wood properties were analysed using conventional statistics (averages and standard deviations) and simple one-way ANOVA and pairwise Tukey or LSD comparisons to find the differences between sub-regions, tree heights, radial locations *etc*. In addition, the variations in mechanical properties were studied by means of linear mixed models where either the readily available explanatory variables or more detailed independent variables were used (Grekin and Surini 2008, Grekin and Verkasalo 2013). The statistical analyses were executed with the PASW Statistics 17.0 software.

RESULTS AND DISCUSSION

Mechanical properties

Shear strength increased from the north to the south and from the pith outwards, and decreased along with the increasing tree diameter and from the butt to the top of the tree (R^2=35%); see Table 2. Due to the strong relationship between shear strength and wood density (R^2=62%), considering basic density made the effect of tree height negligible (R^2=64%). However, the differences between the sub-regions and the juvenile core and mature middle and surface parts were significant also at a given density. In both analyses, random variation was mostly made up of within-tree variation (75% and 92%), whereas between-stand variation was very small (4%). The average shear strength values were to some degree lower compared to the results from earlier studies, and no such clear trend from the north to the south was found before than in this study (*e.g.,* Siimes and Liiri 1952, Hudson 1967).

Tensile strength perpendicular to grain increased from the south to the north and decreased from the pith outwards and along with the increasing tree diameter and from the butt to the top of the tree (R^2=25%); see Table 3. No significant correlation were found between tensile strength and wood density, but considering ring width made the effect of tree diameter negligible; still no improvement was found in the explanatory power (R^2=26%). In both analyses, random variation was almost entirely made up of within-tree variation (97% and 99%). The average tensile strength values were at a similar level to the results of earlier studies, and no such clear trend from the north to the south was found before (*e.g.*, Hudson 1967) than in this study, albeit some divergence of results owing to different set-up and sampling. The significantly higher tensile strength in the northernmost sub-region compared to the other sub-regions was mainly due to the narrower rings, with the crack tips being probably more infrequent there due to the narrower early wood bands. The decrease in tensile strength from the pith to the bark was obviously due to the decrease in ring width, rather than the different annual ring orientation or curvature.

Table 2

Shear strength parallel to grain by tree height and sub-region, with the respective basic density, average ring width and number of specimens: means and standard deviations (in parentheses)

Tree height, m	Sub-region	Shear strength N/mm^2	Basic density kg/m^3	Ring width mm	N
2	Northern Finland	8.6 (1.17)	415 (43)	1.17 (0.87)	69
	Inland Finland	8.8 (1.18)	432 (53)	1.64 (1.06)	70
	S-E Finland	8.8 (1.28)	432 (53)	2.12 (1.41)	88
	S-C Sweden	9.1 (1.20)	447 (54)	1.85 (1.32)	85
	Southern Sweden	9.6 (1.24)	462 (49)	1.62 (1.04)	85
6	Northern Finland	7.8 (0.84)	378 (27)	1.30 (0.94)	64
	Inland Finland	8.0 (0.85)	393 (37)	2.03 (1.38)	73
	S-E Finland	8.4 (1.01)	405 (41)	2.40 (1.42)	79
	S-C Sweden	8.6 (1.02)	411 (35)	1.99 (1.11)	80
	Southern Sweden	8.9 (1.08)	428 (43)	1.79 (1.12)	82
10	Northern Finland	7.8 (0.72)	377 (27)	1.20 (0.73)	45
	Inland Finland	8.0 (0.90)	391 (29)	1.78 (0.97)	54
	S-E Finland	8.1 (0.81)	397 (32)	2.35 (1.22)	66
	S-C Sweden	8.3 (0.86)	396 (31)	2.12 (1.20)	66
	Southern Sweden	8.5 (0.84)	405 (28)	2.02 (1.49)	77

Table 3

Tensile strength perpendicular to grain by sub-region and board number (from pith to bark), with the respective basic density (□□□$_g$) and number of specimens (N): means and (standard deviations)

Sub-region	**Board nr – from pith to bark**								
	1			**2**			**3**		
	σ_T **N/mm^2**	□□□$_g$ **kg/m^3**	**N**	σ_T **N/mm^2**	□□□$_g$ **kg/m^3**	**N**	σ_T **N/mm^2**	□□□$_g$ **kg/m^3**	**N**
Northern Finland	4.4 (0.79)	373 (20)	17	3.7 (0.97)	401 (42)	23	3.5 (0.61)	413 (36)	9
Inland Finland	3.8 (1.21)	402 (40)	25	3.2 (0.81)	437 (49)	28	3.1 (0.83)	430 (51)	10
S-E Finland	3.7 (0.82)	407 (34)	31	3.1 (0.68)	439 (38)	27	2.9 (0.79)	442 (34)	11
S-C Sweden	4.1 (0.83)	411 (29)	20	3.2 (0.75)	437 (41)	28	2.8 (0.69)	440 (39)	15
Southern Sweden	3.8 (0.81)	412 (34)	20	3.1 (0.79)	454 (52)	29	2.7 (0.68)	446 (39)	21

Table 4

Brinell hardness based on diameter (HB$_d$) and depth (HB$_h$), N/mm^2, by sub-region, with the respective density at 12% MC (□□□), kg/m³, and number of specimens (N): means and (standard deviations)

Sub-region	***HB$_d$*** **N/mm2**	***HB$_h$*** **N/mm2**	□□□□ **kg/m^3**	**N**
Northern Finland	14.9 (2.86)	19.0 (5.07)	492 (46)	131
Inland Finland	16.9 (3.31)	21.4 (5.33)	521 (57)	144
S-E Finland	16.7 (3.56)	20.9 (5.49)	522 (57)	221
S-C Sweden	16.9 (3.42)	19.0 (4.47)	523 (51)	178
Southern Sweden	16.7 (3.35)	19.2 (4.32)	543 (57)	196

Geographic origin as well as the longitudinal and radial location of the specimen within a tree affected Brinell hardness. Geographic effects depended on whether the values of HB_d or HB_h were applied (Table 4). Generally, the averages of HB_d were much lower in the northernmost region compared to other regions (one-way ANOVA; F=9.255, df=4, p<0.000). The averages of HB_h appeared clearly higher in central and south-eastern Finland and at similar level in south-central and southern Sweden compared to the northernmost region. If the indentation was placed on latewood section the hardness was clearly higher compared to early wood and combined early wood and latewood.

The relationship between HB_d and HB_h was different in different regions; R^2 ranged from 50% in southern Sweden to 87% in northern Finland. The relationship between HB_h and HB_d was heteroscedastic: the higher the hardness the larger also the variation between the two hardness determination methods. With the best fit model approx. 50% of the hardness variation could be described. Wood density was the most important variable affecting hardness and simple linear relationship was found between hardness and wood density. After the effect of density had been removed, some variation still could be explained by the geographic origin and longitudinal and radial location of the specimen within a tree. The region affected the hardness most probably via varying average annual ring width, whereas height position within a tree and board number from the pith described the curvature of the annual rings in the specimens.

Physico-morphological properties

The average diameter of sound knot was 14.0mm with no significant differences between the sub-regions, contrary to the larger differences in the diameters or dry knots (12.4mm) and decayed knots (20.6mm) (Fig. 2). The more southerly the location the larger the dry and decayed knots were, and the Finnish and Swedish origins differed significantly as groups. The average knot angle (0°=vertical), 90° = horizontal) decreased significantly from 90° in the northernmost region to 90° in the southernmost region.

The defect-free zone between subsequent whorls (whorl interval) ranged from 156mm in the northernmost region to 276mm in the southernmost region, the sub-regional variation being significant in boars 0, 1 and 2 (≈ centre yield of sawn timber). The sub-regions could be put into homogeneous subsets according to Fig. 3. The distributions of the whorl intervals demonstrated quite small sub-regional differences in the pith-enclosed boards, but the differences showed up clearer from the pith outwards.

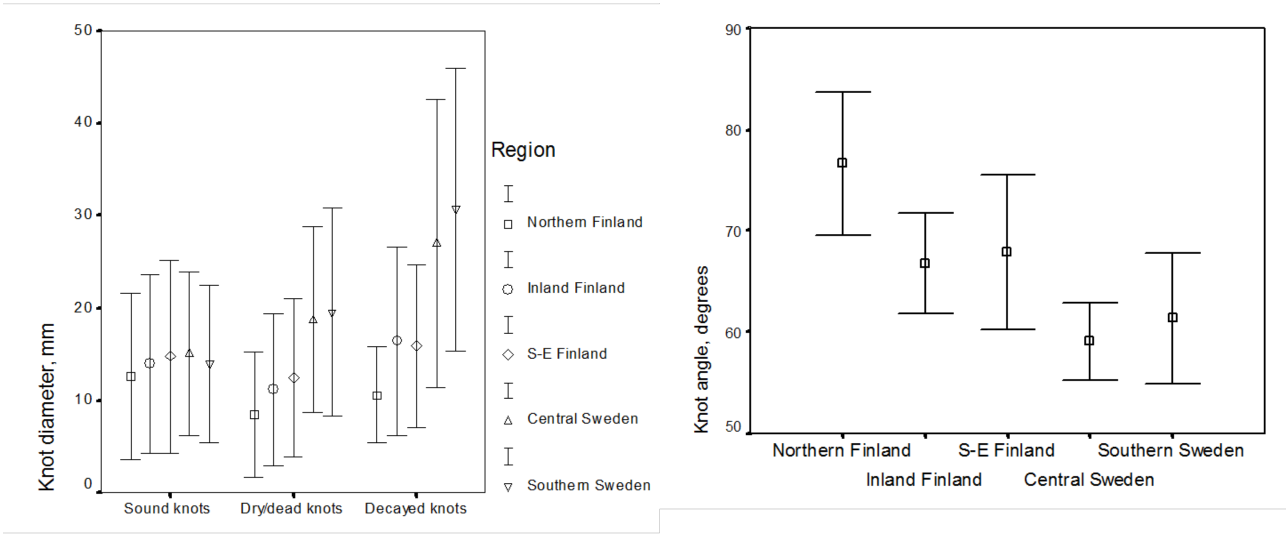
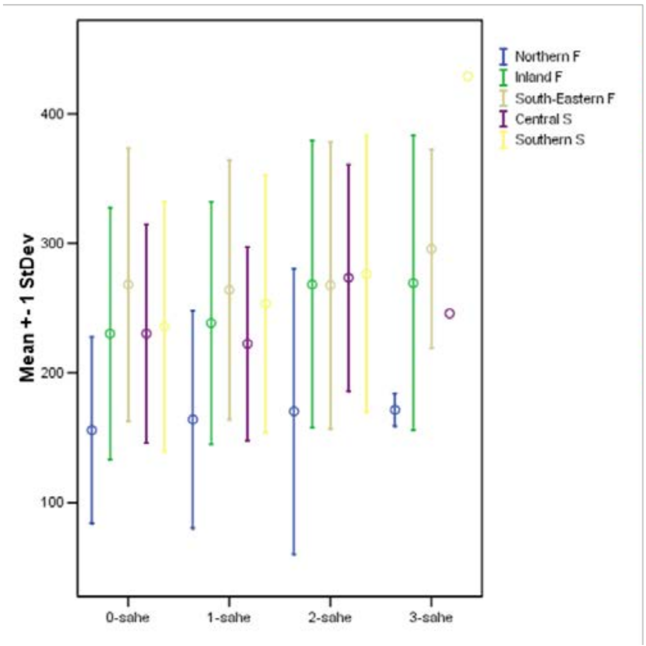


Fig. 2
Means (markers) and standard deviations (bars) of knot diameters by knot type and knot angle in the sawn boards, by sub-region.



0-board	Subset 1	Subset 2	Subset 3
Northern Finland	—		
Inland Finland		—	
Central Sweden		—	
Southern Sweden		—	
South-Eastern Finland			—

1-board	Subset 1	Subset 2	Subset 3
Northern Finland	—		
Central Sweden		—	
Inland Finland		—	—
Southern Sweden			—
South-Eastern Finland			—

2-board	Subset 1	Subset 2
Northern Finland	—	
South-Eastern Finland		—
Inland Finland		—
Central Sweden		—
Southern Sweden		—

Fig. 3
Means (markers) and standard deviations (bars) and Tukey comparisons of the lengths of defect-free zones (mm) between subsequent whorls (whorl interval) by board number and sub-region

Grain straightness evaluation was rather subjective and the results reflected the through-through cutting pattern and measurements on the face of board. The level of grain deviation from straight was rather high, especially compared to the results from measurements in the edge typical for cant sawn timber (Fig. 4). In boards nr 1 (≈ centre yield), the more southerly the location the better grain straightness was observed, in general. The sub-regional differences were still small in the butt log section of a tree, but clearer in the higher log positions. In boards nr 3 (≈ side boards), on the contrary, the more southerly the location the more the grains deviated from straight, especially in the higher log positions. Within the northernmost sub-region the results indicated slightly improving grain straightness toward north, except the contrary effects in the top log section of tree. For Scots pine, large deviations from grain straightness in sawn timber are often associated with small log diameter, large taper and butt swelling as well as large sweepness of logs.

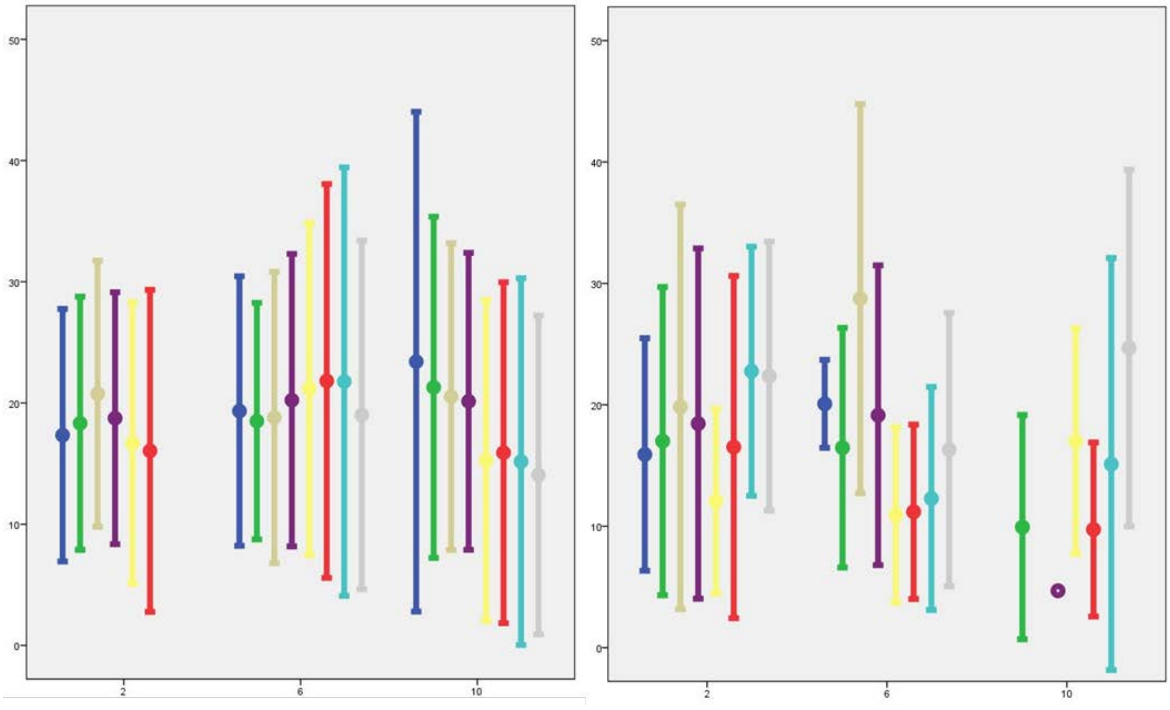


Fig. 4
Means (markers) and standard deviations (bars) of the grain straightness values (mm/m) in boards number 1 (left) and number 3 (right), by tree height in metres (1=butt log, 6=middle log, 10=top log) and sub-region (from left to right: Northern Finland (four left columns), Inland Finland (yellow), South-eastern Finland (red), South-Central Sweden (light blue), Southern Sweden (grey).

CONCLUSIONS

North-European Scots pine provides suitable wood material for joinery products of multitude as regards especially shear strength, increasing toward the more southerly origins, and also tensile strength (perpendicular to grain), decreasing toward the more southerly origins. The northernmost pine wood has a lower hardness, and, albeit the effect of measurement method, the highest level is indicated in the Finnish central inland and south-eastern lake region. The geographic and within-tree differences in shear strength and hardness are much linked to basic density and, most probably, juvenile – mature wood effects. Instead, density did not affect tensile strength. It is notable that, in all previous studies, density of Sots pine wood has still showed up to grow from northern toward central Europe, due to the higher latewood percentage (*e.g.*, Verkasalo and Leban 1996, 2002,Chuchala *et al*. 2013).

Larger within-tree variations in the wood properties are the drawback of Scots pine, also compared to alternative softwood species. Grekin (2006) performed a literature review to benchmark Scots pine to alternative softwood species regarding the mechanical properties related to woodworking (Table 5). His results are, however, relative and do not reveal the uncertainties in sampling, for example, the quantity and quality of the data for individual species.

Table 5
Benchmarking of Scots pine to some alternative softwood species for the competence of selected woodworking properties (Grekin 2006)

Property	***Pinus taeda***	***Pinus radiate***	***Pinus contarta***	***Pinus ponderosa***	***Picea abies***	***Pseudotsuga menziesii***	***Thuja plicata***
Shear strength ||	+	+	+	+	+	+	+
Tensile strength	-	0	+	0	+	+	+
☐	-	+	+	…	+	-	0
Brinell hardness	-	+	0	0	+	-	+
Basic density	+	0/+	0/+	…	-	-	0/-
- Radial var.	+	…	-	…	-	…	-
- Vertical var.							

It seems that the visual properties might be more prominent competitive factors for Scots pine than the mechanical properties in woodworking, at least as regards the yield and aesthetics of the products. Small dry or decayed knots, underlined with large knot angle (horizontal knots), as well as smaller ring width, seem advantages for North-European Scots pine, the properties also improving toward the north. The advantages seem prevalent also against the more southerly grown Scots pine in Europe, according to some previous findings (*e.g.*, Verkasalo and Leban 1996, 2002, Ranta-Maunus *et al*. 2011, Chuchala *et al*. 2013). However, consistent with the increasing annual height growth and forest site fertility, the length of potential clear wood sections, *e.g.*, for finger-jointing, clearly increase toward the south. Grain straightness seems the better in the centre yield the more southerly origin is considered, the differences being, however, rather small in wood from butt logs. In side boards, grain straightness improved from the south to the north especially in the higher log positions.

Compilation of available research results on and industrial applications of the woodworking properties in joinery products, among other data on logs, wood and wood products, is available in detail in the website Scots pine – Excellence and image http://www.metla.fi/metinfo/northernpine/index-en.html. The information is aimed to support marketing planning, sourcing of logs and sawn timber and product and technology innovations among wood product industries and related bodies of research and development work.

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