Forest Condition Monitoring in Finland – National report

Photo: Maija Salemaa

The monitoring of daily and annual growth and other changes in spruce, pine, and birch stem diameters with girth bands in Finland, 2009–2011

By Pentti Niemistö

Summary

Monitoring of daily and annual changes in tree diameters in Finland was performed via automatic and manual girth bands on plots belonging to the European FutMon network. The aim of this study was to date and rate the growth of spruce, pine, and birch. Another aspect of the research was identification of the real growth signals from the girth-band data, including also impacts of temperature, weather conditions, and diurnal rhythm.

The diameter increment of Scots pines and Norway spruces increased year after year in 2009–2011 because of the warm growing season in 2010 and extraordinarily warm one in 2011. In contrast, the diameter increment rate of silver birch in south-eastern Finland decreased over the same time.

On a rainy day, stem diameter suddenly increases as the water content of the stem grows but may decrease again as the water content then falls. These reversible changes in the stem diameter of Norway spruce were as great as 0.5 mm. In silver birch, the reversible changes are smaller than those seen with conifers. In addition, the freezing of stems during winter can be observed as an abrupt decrease in stem diameter. Diurnal rhythm during the growing season was visible in diameter expansion in the evening and at night, with corresponding shrinkage in the morning and daytime.

The manual girth bands produced overestimation in cold weather and underestimation in warm conditions, because of thermal expansion of their plastic material. If temperatures are recorded during the measurement, corrections can be made when results from manual girth bands are used.

Background

Temperatures are the main determinant of the start of the tree growth season in the spring, whereas the end of growth is regulated by the increasing length of nights in late summer. Height growth ceases first, followed by stem diameter growth. Roots continue to grow late into the autumn.

Southern Finland belongs to the southern boreal vegetation zone, while the northernmost part of Finland represents the much colder northern boreal zone. In southern Finland, the diameter increment of common tree species normally starts in May whereas in northernmost Finland it begins in June and usually ceases in August. Outside this period, no diameter increment is normally observed in the harsh climate of Finland.

The measured increase – and occasional decrease – of stem diameter includes both the formation of new cells and changes in the water potential of the stem wood and bark. The effects of rainy periods can be observed as sudden and strong increases in stem diameter. During growing season these increases are partly reversible. A daily pattern of daytime shrinkage and night-time expansion can also be observed, especially during the growing season. In addition, the freezing and melting of stems during winter can be observed as abrupt changes of stem diameter.

The aim of this study was to rate and date the growth and other changes in stem diameter from a daily and an annual perspective in the varying climate conditions of Finland. Another aspect was to compare and test both manual and automatic girth bands for monitoring short and long-term stem diameter changes of the most common trees species in northern Europe. From a longer-term perspective, the results can provide evidence on climate change and may predict the adaptation and growth potential of different tree species in changing conditions.

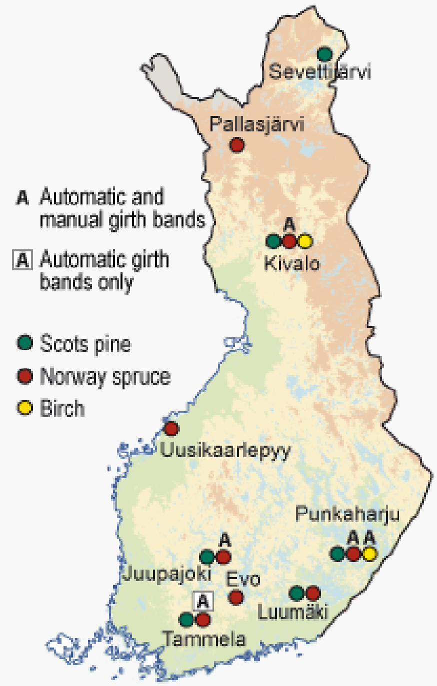

Figure 1. The location of plots with automatic and manual girth bands.

Results

Diameter growth seasons of Norway spruce and silver birch according automatic girth bands

It has been found that birch stem diameter growth begins as soon as the leaves have clearly grown past the budding stage (Niemistö & Beuker 2011). In 2009 and 2010, silver birch began to flower as early as around 1 May in southern Finland, and leaf buds began to open soon after. The automatic girth bands (see Fig 1) were installed in silver birch stands on 25 May 2009, so it was obviously too late to observe the beginning of diameter growth in spring 2009. Later on, the starting dates of diameter increments were 15 May 2010 and 11 May 2011. Every year birch diameter growth ceased between 13 and 15 August (Fig. 2a).

In spruce stands in southern Finland, the girth bands were also possibly installed too late in 2009 at Juupajoki and Punkaharju, but in Tammela, diameter growth started on 19 May 2009. In 2010, spruce diameter growth began on 23 May and in 2011 as early as between 12 and 17 May. In 2009, the spruce diameter growth ceased between 17 and 19 August and in 2010 and 2011 on 10 August in southern Finland (Figs. 2b, 2c and 2d).

In Lapland, spruce diameter growth started between 9 and 15 June but ended as early as 9 July in 2009, but in 2010 and 2011 this occurred a month later (Fig. 2e).

Daytime shrinkage and night-time expansion

Day and night rhythm during the growing season was observed as diameter expansion in the evening and night-time and shrinkage in the morning and daytime. It seems to be most intensive in June and July: expansion in spruces from 7 p.m. to 7 a.m. (Fig. 3a) and in Silver birches from 5 p.m. to 5 a.m. (Fig. 3b). In large spruces at Punkaharju (dbh 30–40 cm), the fluctuation between diameters in the afternoon and the early morning was 0.2 mm on average and 0.3

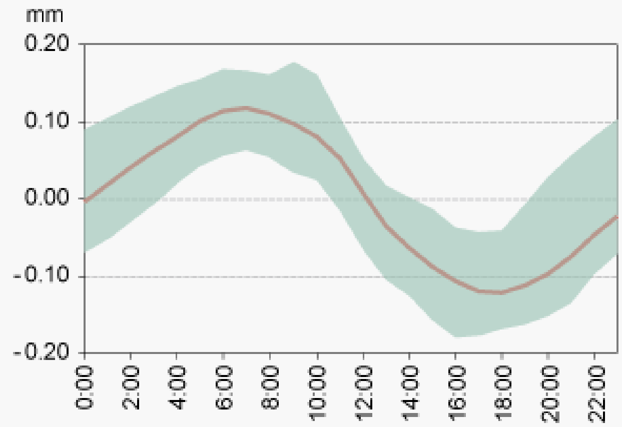

Figure 3a. Day and night rythm of Norway spruce diameter in July 2011: expansion during evening and night, shrinkage during morning and day (the range is shadowed).

mm maximum. In smaller birch stems (dbh 12–16 cm) the difference was smaller, 0.15 mm on average and 0.25 mm maximum.

The shrinkage in the morning and daytime is lower than the expansion, depending on the diameter increment rate during a growing season. The average daily increment in spruce stands was 0.04–0.06 mm during June and July. Therefore, the daily shrinkage is about 70–80% of the expansion that occurred in the previous evening and night. The average daily increment in birch stands was higher, 0.075–0.11 mm and the daytime shrinkage is about 30–50% of the night-time expansion.

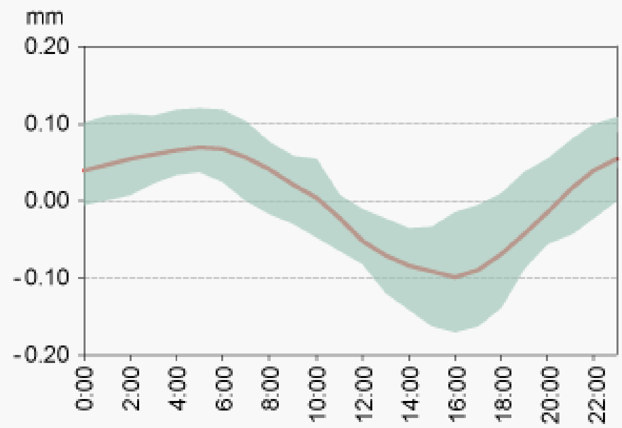

Figure 3b. Day and night rythm of silver birch diameter in July 2011: expansion during evening and night, shrinkage during morning and day (the range is shadowed).

Comparison between automatic and manual girth bands

It was possible to compare the measurements carried out by both types of girth bands, automatic and manual, on the same trees in Punkaharju. On five spruces, the automatic girth bands were installed 3–7 cm above the manual ones. Therefore, the actual difference in growth and other changes of the stem diameter is very low. The mean breast height diameter of spruces was 35 cm and the mean of circumference 110 cm in spring 2009.

The first hand comparison between the girth band types demonstrated that the diameter increment was slower during the growing season measured by manual bands than by automatic ones (Fig. 4). However, in autumn and especially in cold weather the shrinkage in diameter was small or unobserved by manual girth bands. One explanation is the thermal expansion of the girth band material. The circumference strip of the automatic girth band is made of invar metal with a thermal expansion coefficient of $1.7*10^{-6}$. In practice, this means that thermal elongation is zero. The manual girth bands are made of a plastic material with a coefficient of $75*10^{-6}$, 44-fold compared with invar. This is why the measurement carried out by the manual girth band is an overestimation in cold weather and an underestimation in warm conditions. The elongation of 30 cm in diameter is

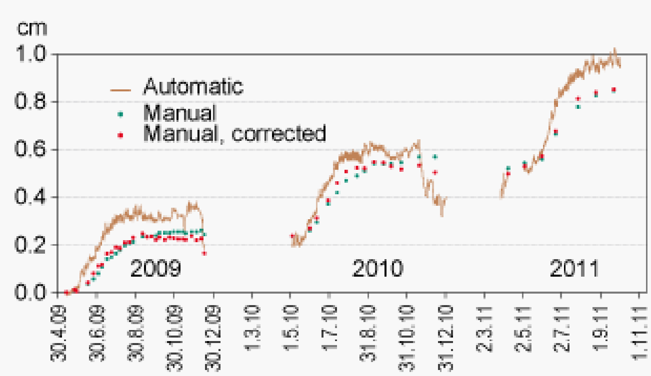

Figure 4. Growth and other changes in diameter of spruces at Punkaharju from spring 2009 to autumn 2011 measured by automatic and manual girth bands.

1.35 mm for the usual temperature range in Finland of –30 °C to +30 °C .

In addition to thermal expansion, there may be other differences between the manual and automatic methods (differences in selecting the place around a stem, bark moisture under the band strip, etc.). However, thanks to the correction of thermal expansion (datum level = +15 °C) the measurements by manual and automatic girth bands were closer (Fig. 4). This correction will be carried out when using the results of manual girth bands. The correction of day and night fluctuation is not needed because the observation time is nearly the same from one observation date to another. However, the observation time was registered and the temperature was defined through it.

The same comparison in Silver birch stands brought equal results, but the differences were not so clear because of smaller trees.

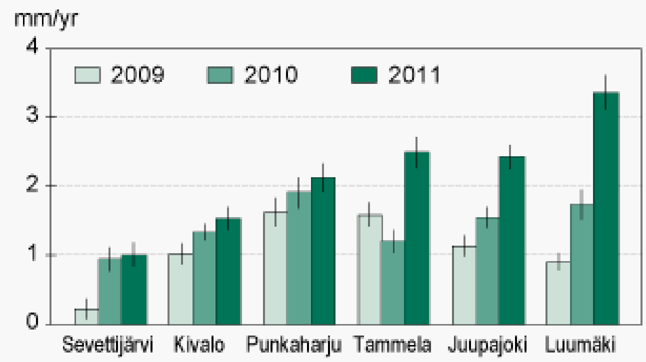

Figure 5a. Diameter growth (mean and standard error of mean, mm) of Scots pine in 2009−2011 according the manual girth bands.

Diameter increment during growing seasons 2009–2011 according manual girth bands

In growing season, 2009 temperatures and rainfalls were close to their long term means in Finland. However the temperature sum was circa 100 dd. above the average and the rainfall was weighted on the beginning of season in the north and on the end of season in the south. Instead, growing season 2010 in southern Finland was very warm (250 dd. above the average) and the summer 2011 was record-breaking in the temperature sum (1600–1800 dd., 350 dd. above the average) and in the duration of effective growing season. In northern Finland temperature sum was equal in 2009 and 2010, but exceptional high in 2011 (>1000 dd., 250 dd. above the average).

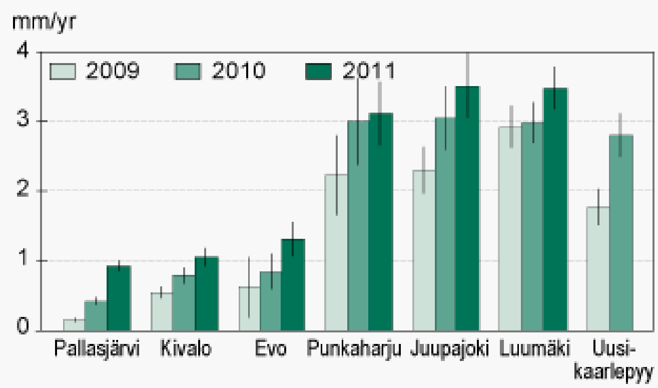

Figure 5b. Diameter growth (mean and standard error of mean, mm) of Norway spruce in 2009−2011 according the manual girth bands.

The diameter increment of Scots pines and Norway spruces in every plot increased year by year in period 2009–2011 (Fig. 5 a-b). In southern Finland, the growing season 2011 can be considered advantageous because of high temperatures and abundant rainfall (50% above the long term average).

In addition, the health and condition of trees was good after previous warm summer. That is why the increment of trees in 2011 could be near to their maximum growth rate in Finland. In 2009 and 2010, the diameter increment rate was 44% and 54% for Scots pine and 71% and 86% for Norway spruce respectively compared to the year 2011. In northern Finland, the trend was equal but the differences between years were larger for spruces than for pines.

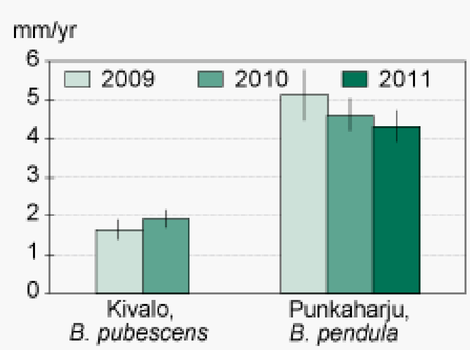

Figure 5c. Diameter growth (mean and standard error of mean, mm) of birch in 2009−2011 according the manual girth bands.

The growth rate of downy birch follows the same trend with pine and spruce, but unfortunately, the monitoring was cancelled in 2011. Instead, the diameter increment rate of silver birch in Punkaharju decreased 16% in the same period 2009–2011 (Fig. 5 c).

Material and methods

Manual girth bands (UMS D1) and automatic girth bands (UMS D6) were installed in May 2009 on the plots belonging to the European FutMon network (Table 1, pdf, fig 1). One experienced person carried out careful installation at the height of 1.3 m. The results of monitoring are now usable up to October 2011.

Table 1 (pdf) presents the basic characteristics for each stand. Note the rather advanced tree ages, which reflect the cold climate of Finland, resulting in long rotation periods. The climatic difference between northern and southern Finland is reflected by the growth difference between the southernmost plots in Tammela (mean temperature sum 1350 dd) and the northernmost plots in Pallasjärvi (700 dd) and Sevettijärvi (600 dd). Norway spruces in Punkaharju have reached a mean diameter of 35 cm in 75 years, while the mean diameter of Scots pines in Sevettijärvi is only 23 cm at the age of 205 years.

Automatic girth bands

Intensive monitoring with automatic data recording once per hour by UMS D6 girth bands was carried out in four Norway spruce stands and in one Silver birch stand, including five sample trees in each (total 25, fig 1, Table 2, pdf). The accuracy of measurement of the stem circumference was 0.01 mm. The intensive monitoring continued in some cases throughout the entire winter, but usually there was a blackout in midwinter because of empty batteries.

Manual girth bands

More extensive manual monitoring by UMS D1 girth bands was carried out in five Norway spruce stands, five Scots pine stands, in one silver birch stand and in one downy birch stand. Manual observations of 190 trees (mostly 15/stand) were taken mainly in two-week periods during the growing season. Outside the growing seasons, the measurements were carried out once per month, but not regularly during hard winters in northernmost stands. The accuracy of measurement of the stem diameter was 0.1 mm. In Punkaharju, both types of girth bands were installed on the same trees, on five spruces and five silver birches, in order to compare these two methods.

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The Finnish Forest Research Institute. [Online report]. Available at http://urn.fi/URN:NBN:fi:metla-201305087580. [Cited 2013-05-07].

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Figures 2a–e.

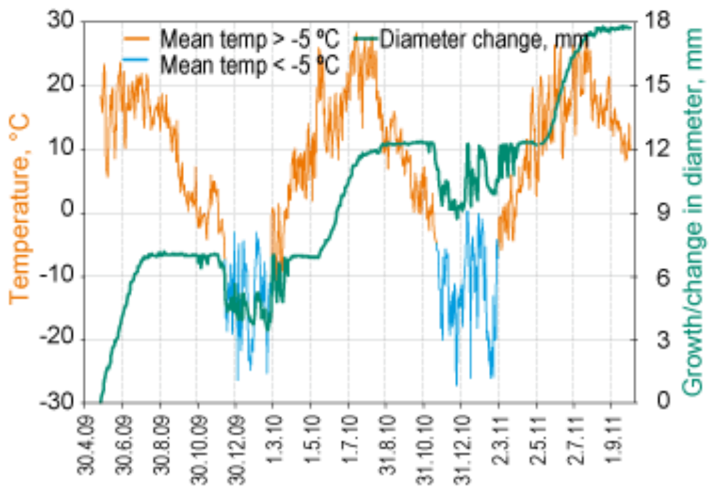

Figure 2a. The influence of temperature on the growth and other chances in Silver birch diameter at Punkaharju between 2009–2011.

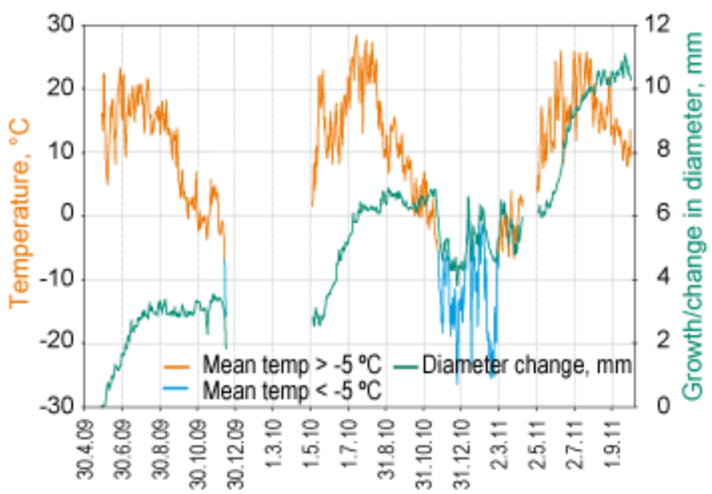

Figure 2b. The influence of temperature on the growth and other chances in spruce diameter at Punkaharju between 2009–2011.

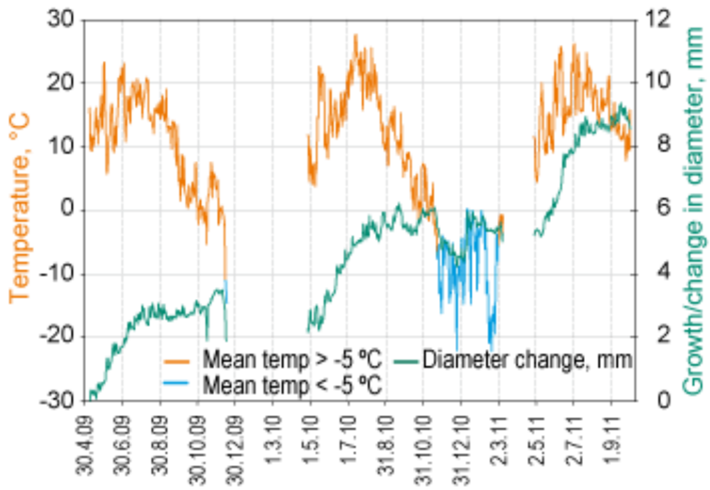

Figure 2c. The influence of temperature on the growth and other chances in spruce diameter at Tammela between 2009–2011

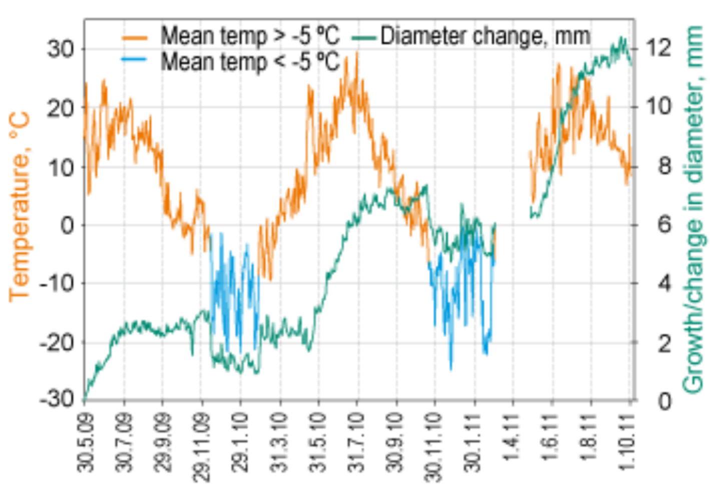

Figure 2d. The influence of temperature on the growth and other chances in spruce diameter at Hyytiälä (between 2009–2011).

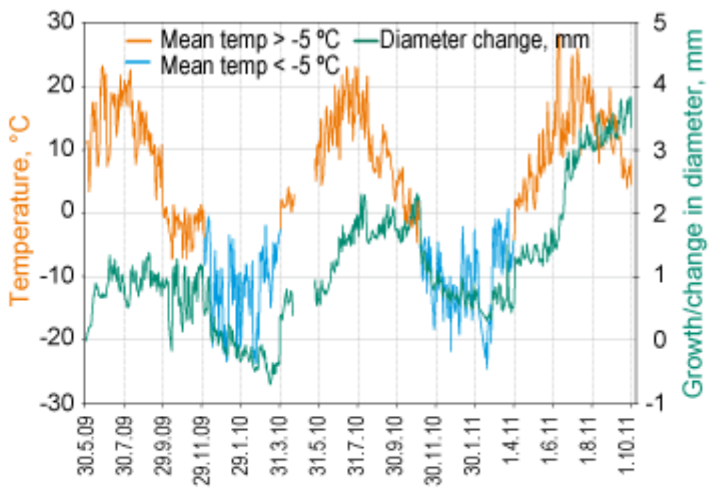

Figure 2e. The influence of temperature on the growth and other chances in spruce diameter at Kivalo between 2009–2011.

Table 1. Stand characteristics of plots used for monitoring diameter growth in Finland.

Location		Temperature sum dd	Site		Age yrs	DBH of sample trees	
						Mean, cm	St. deviation
	***Scots pine**, Pinus silvestris*						
South	Tammela	1313	VT	4	65	0.2	3.2
South	Luumäki	1395	CT	5	50	10.2	4.4
South	Punkaharju	1348	VT	4	85	20.6	3.9
South	Juupajoki	1173	VT	4	85	15.1	3.6
North	Lieksa	1116	EVT	4	135	18.6	5.6
North	Kivalo	920	EMT	4	60	28.4	2.8
North	Sevettijärvi	658	UVET	5	205	19.2	6.8
	Norway spruce, *Picea abies*						
South	Tammela	1313	MT	3	65	25.0	1.0
South	Lammi*	1260	OMT	2	175	32.3	8.4
South	Luumäki	1395	MT	3	50	26.3	7.0
South	Punkaharju	1348	OMT	2	75	35.0	5.7
South	Juupajoki	1173	OMT	2	85	28.1	6.2
South	Uusikaarlepyy	1158	OMT	2	60	26.7	4.2
North	Oulanka	836	HMT	3	175	18.3	3.0
North	Kivalo	920	HMT	3	75	16.5	3.1
North	Pallasjärvi	708	HMT	3	165	18.3	7.9
	Silver birch, *Silver birch*						
South	Punkaharju	1348	OMT	2	25	16.1	1.5
	Downy birch, *Betula pubescens*						
North	Kivalo	920	HMT	3	50	17.6	4.1

** started in spring 2010*

Table 2. The breast height diameter (dbh, cm) of sample trees used for intensive growth monitoring by automatic girth bands in Finland from 2009.

Tree species	Location	Tree 1	Tree 2	Tree 3	Tree 4	Tree 5	Mean
Silver birch	Punkaharju	14.6	15.5	12.6	15.6	13.6	14.3
Norway spruce	Punkaharju	30.6	30.4	45.5	36.6	32.2	35.0
Norway spruce	Tammela	24.8	24.6	26.0	23.7	26.0	25.0
Norway spruce	Juupajoki	21.4	24.5	26.0	28.0	21.4	24.2
Norway spruce	Kivalo	18.3	15.6	11.6	16.7	18.2	16.1