FAKOPP
Microsecond Timer Manual

Fakopp Enterprise Bt
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Table of Contents

Introduction....1
- Product Contents....1
- Technical data....2

Principles of operation....2
- Typical radial velocities....5
- Manual and automatic mode....7
- Steps of the evaluation....7
- Measurement in fiber direction....10
- SD02 Vibration Sensor....11
- Testing rod....12
- Troubleshooting guide....13

Microsecond Timer App....14
- Main Page....14
- Tree Page....15
- Measurement Page....18
- Workflow....19

Radial Velocity Appendix....22

Introduction

The Microsecond Timer is a non-destructive testing tool for trees. It has been designed to help determining the structural soundness of trees by measuring time-of-flight on a single path. The measured travel time is indicative of either solid wood or a problem area caused by decay, fungus or other structural damage.

Product Contents

- Microsecond Timer device
- Case
- Steel hammer 100g
- Rubber hammer
- Start & Stop SD02 Vibration Sensors
- Aluminum test bar (44 cm, optional)
- 9V Battery
- Manual

Technical data

Device size without sensors	29 mm x 80 mm x 156 mm
Weight	220 g
Battery	9V
Power consumption before RESET	15 mW
Power consumption after RESET	50 mW
Enclosure material	plastic, not water resistant
Display	LCD screen, 4 digits
Standard deviation time	± 1 µs
Sensors	High sensitivity SD02 vibration sensors
Operating temperature	-10°C–40°C

Principles of operation

The Microsecond Timer measures sound time-of-flight on a single path. The measured time and the distance between the sensors can be used to determine the velocity of sound inside the material. For each species there is reference velocity that can be measured in an intact tree. By comparing the reference and the measured velocity we can reason about the health of the tree in the region measured. Sound propagates faster in an intact tree compared to unhealthy ones, therefore we will measure higher travel times in a tree that has problem areas between the two sensors.

The start sensor (marked with red) should be hit with a hammer to induce a stress wave inside the tree. When the stress wave arrives to the stop sensor the device will display the time it took for the wave to pass from the start to the stop sensor in microseconds. The velocity of stress waves perpendicular to the grain is usually between 1100-2000 m/s depending on the tree species.

General notes

- When measuring trees, the sensor needle must penetrate the bark
- Both sensors need to be firmly in the tree material to provide good coupling for the sound wave
- Use the rubber hammer to drive the sensors into the material
- Try to hit the sensor in the needle direction, not sideways
- Hit the start sensor with the steel hammer, use a percussive hit, allow the hammer to bounce back

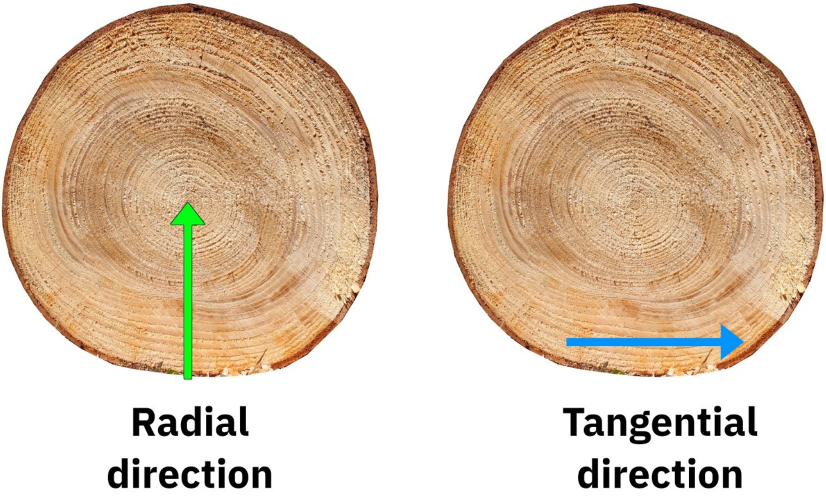
Typical radial velocities

Species	Radial velocity [m/s]
Betula pendula	1650
Picea abies	1550
Abies alba	1400
Abies firma	1450
Pinus sylvestris	1500
Picea mariana	1550
Larix decidua	1700
Quercus robur	1800
Fagus sylvatica	1650
Tilia cordata	1600
Acer pseudoplatanus	1900
Robinia pseudoacacia	2000

This table is a short sample of the Radial Velocity Appendix. Please see the appendix for more species.

The radial velocity is the parameter that is sensitive to internal defects. If the measured velocity is lower than the velocity in an intact tree (reference velocity) then we can conclude that the tree contains some defects. The relative difference between the measured and reference velocity is indicative of the size of the defect.

Radial and tangential velocities



For tree health evaluation we measure velocity in the radial direction. However you should take note that there is a small difference in radial and tangential velocities. Normally the tangential velocity is 5-15% smaller compared to the radial velocity.

Moisture content and radial velocity

In healthy tress the moisture content is always above the fiber saturation point (above 30-40% moisture content depending on the species). However when going below the fiber saturation point the measured velocities will be significantly higher.

Temperature effect on velocity

In the 0-40°C range with each 1°C increase in temperature, there is around 3 m/s decrease in measured velocity. This effect is so small that it can be safely ignored during the evaluation.

However below 0°C when measuring frozen trees we can see much higher velocities due to frozen water conducting stress waves very well. For this reason we do not recommend measuring frozen trees using our method.

Manual and automatic mode

- In **manual** mode the RESET button has to be pressed before each hit to the start sensor. Manual mode has longer battery life and less sensitivity for outside noise.
- In **automatic** mode a new measurement is displayed each time you hit the START sensor.
- Pressing RESET while switching on enters Manual mode. Automatic mode is the default. (this was the other way around for devices shipped before May 2023)

Steps of the evaluation

1. Pierce the trunk with the sensors at opposite points (radial direction)
2. Use the rubber hammer to drive the sensors into the material. Take special care not to hit the cable.
3. Make sure that the sensors are firmly in the trunk
4. Turn on the device
5. Hit the START sensor with a hammer in a percussive manner
6. Avoid fast repeated hits, wait 1-2 seconds between each hit
7. To the get the calibrated time-of-flight, subtract the time correction value from the measured time. This can be found in the the calibration document attached to this manual.
8. Determine the velocity by dividing the distance between the sensors with the calibrated time-of-flight:
   Velocity [m/s] = distance [cm] / time [µs] * 10000

Velocity calculation example

Calibrated time-of-flight	**650** µs
Distance	**80** cm
Velocity	**80** / **650** * 10000 = 1230 m/s

Calculating relative velocity decrease (RVD)

Relative velocity decrease is a ratio given by the formula

$$Relative\ \ Velocity\ \ Decrease\ \ [\%] = \left(\frac{V_{ref} - V_{meas}}{V_{ref}} \right) \cdot 100$$

where V_{ref} is the reference velocity that is the radial velocity for a healthy tree, and V_{meas} is the measured velocity.

The RVD should be interpreted as the percentage decrease in radial velocity compared to a healthy tree. For example RVD=30% means there is a 30% velocity decrease in the measured tree compared to a healthy tree. Higher RVD means a worse condition for the measured tree.

Relative velocity decrease RVD calculation example

Species	Larix decidua
Reference Velocity	**1700** m/s
Measured Velocity	**1000** m/s
RVD	((**1700** - **1000**) / (**1700**)) * 100 = 41%

Relative Velocity Decrease and decay area

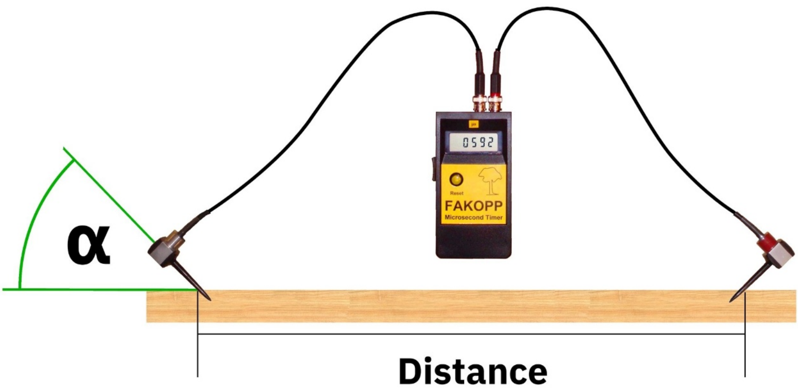
Relative velocity decrease [%]	Decayed area estimate [%]
0	0
5	0
10	0
15	0-10
20	10-20
25	10-20
30	20-30
40	20-40
50	30-50
>50	>50

Approximately there is a linear relation between the RVD and the decay area. The table above gives you information regarding the estimated decayed area size if you have measured the RVD for a tree. For more accurate results we recommend to measure in two perpendicular directions. For even more precise determination of the decay area we recommend using acoustic tomography, ArborSonic3D.

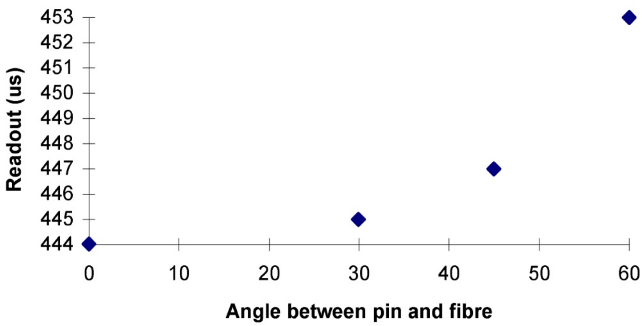
Measurement in fiber direction

Fiber direction measurements are normally done to calculate the modulus of elasticity (MOE) of the wood material. When measuring in fiber direction it is expected to get much higher velocities compared to the radial case. For dry wood the typical fiber direction velocity is between 4000-7000 m/s.

Drive the sensors into the wood as shown below.



The angle of the needle has some effect on the transit time. We recommend an angle between 30°-60°, but never greater than 60°. Above 60° the readout is not reliable.



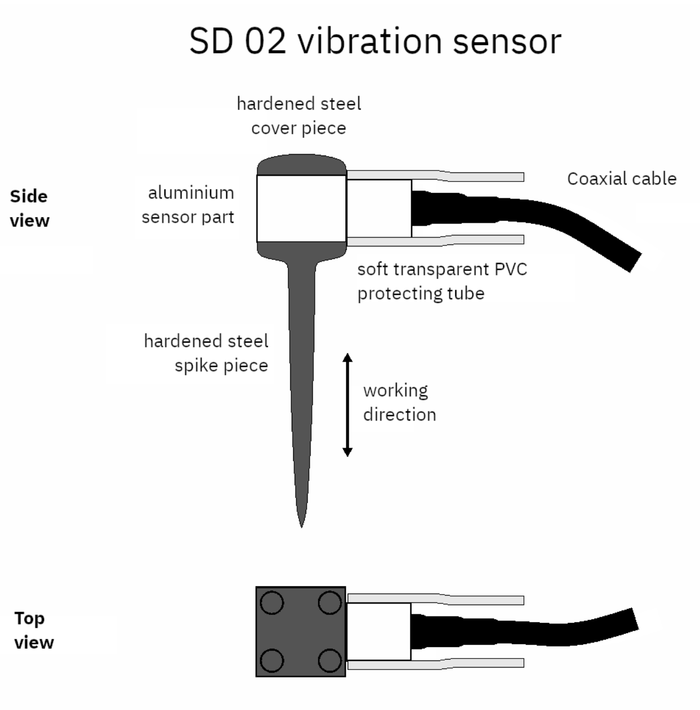
Measuring modulus of elasticity

$$MOE = \rho \cdot v^2$$

MOE [Pa]	Modulus of elasticity measured in Pascal
ρ [kg/m³]	density
v [m/s]	velocity

You can measure MOE in Pascal using the formula above. Here *ρ* is the density of the wood material and *v* is the velocity measured.

SD02 Vibration Sensor



SD02 Technical specification

Mass	Sensor part	22 g
	Total	62 g
Dimensions	Length	99 mm
	Width (cable direction)	40mm (+50mm clearing)
	Width (perpendicular to cable)	20mm
Sensitivity (160Hz)	Charge sensitivity, sensor part	1.35 pC / m / s2 typ.
	Force sensitivity, total	23 pC / N
Resonance Frequency	Sensor	23 kHz typ.
	Total	Depends on sensor coupling
Capacitance	without cable	260 pF ±5%
	cable only	100 pF/m ±5%
Polarity	positive	
Maximum shock resistance	in working direction	10000 m/s^2
	in traverse direction	3000 m/s^2
Temperature	sensor operation	-30°C .. 70°C

Testing rod

An aluminum rod is provided for device validation. Dimensions of the solid rod are 440 mm length; 22 mm diameter. Both ends of the rod accommodates a wooden plug (13 mm diameter, 28 mm length) for sensor coupling. The transit time is 89 ± 2 µs, when the nails are 12 mm deep in the wooden plug. Stress wave velocity in the aluminum bar is 5290 ± 20 m/s at room temperature. Use a light (100 g) hammer for the test.

After intensive use of the calibration rod, replacement of the wooden plugs might be necessary. The test rod is not covered by guarantee.

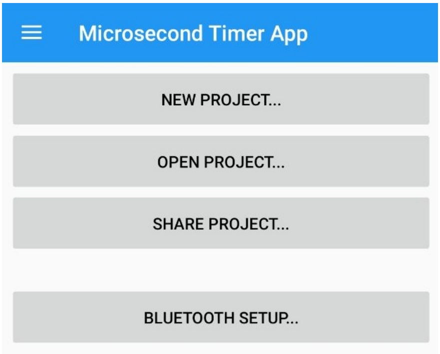
Troubleshooting guide

Phenomena	Possible causes	Action
Screen in blank	Battery low	Replace the battery
	Switch is in wrong position	Switch off & on again
	Battery holder contact error	Disconnect and reconnect the battery
High time scatter	Start & stop sensors are mixed	Make sure that the start sensor connects to the start connector
	Stop sensor has no good coupling	Drive it in the wood for better coupling
	Wrong hammer handling	Let the hammer spring back
	Too light hit	Try hitting the sensor stronger

Microsecond Timer App

Microsecond Timer App is designed to record and evaluate travel time measured by FAKOPP Microsecond Timer on living trees. The Microsecond Timer App can be used with or without a Bluetooth capable unit. In case you have a Bluetooth capable unit, measurements will be transferred to the App, otherwise you can enter the measurements manually.

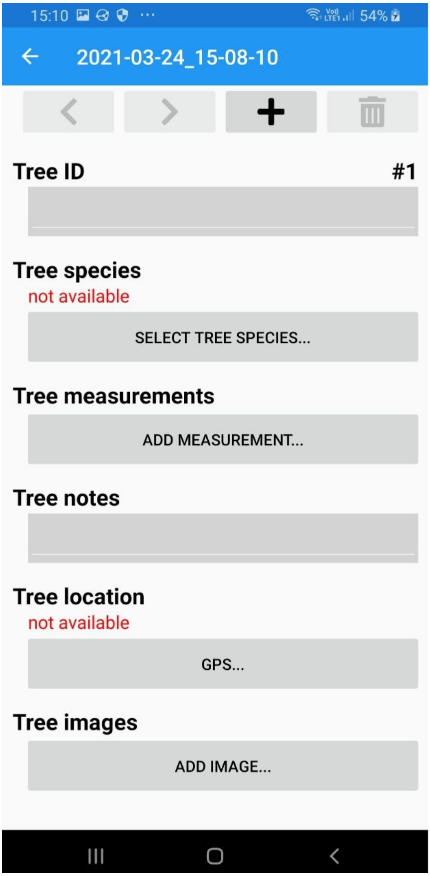
Main Page



- New Project: Creates a new project, asks for a name. When the name is left empty the project name will be the current time.
- Open Project: Open a previously created project
- Share Project: Shares the contents of a project in Excel format
- Bluetooth setup: Opens the Bluetooth device selection page, detailed in the 'Bluetooth Setup' section

Tree Page

After pressing the ‘New Project’ button, you are taken to the tree view page.



Project name

Tree Navigation

Tree name

Species selector

Measurement page

Tree notes input

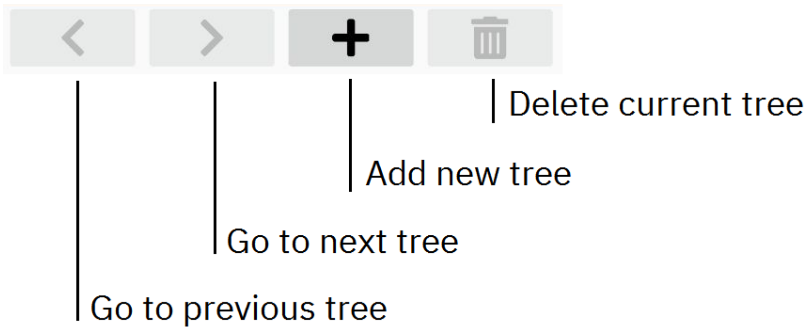
GPS location recorder

Tree Gallery

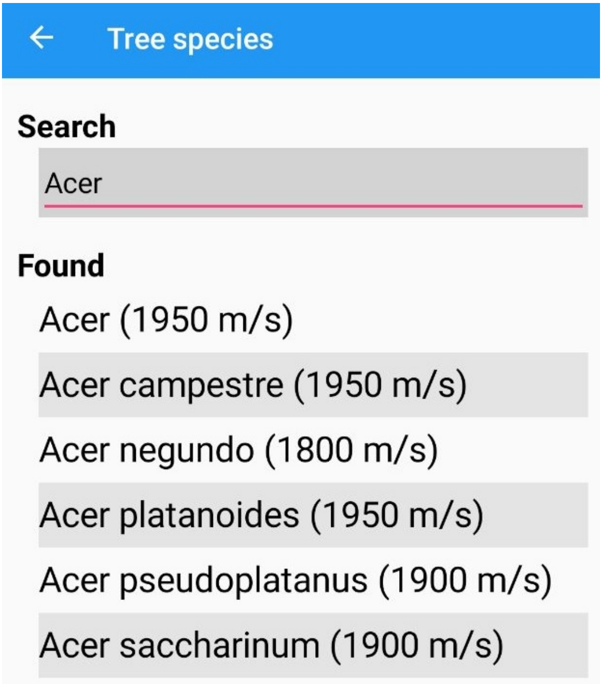
This page contains all the data for a single tree.

Tree Navigation

Tree navigation buttons provide a means to add, delete and switch between different trees. The buttons are detailed below.



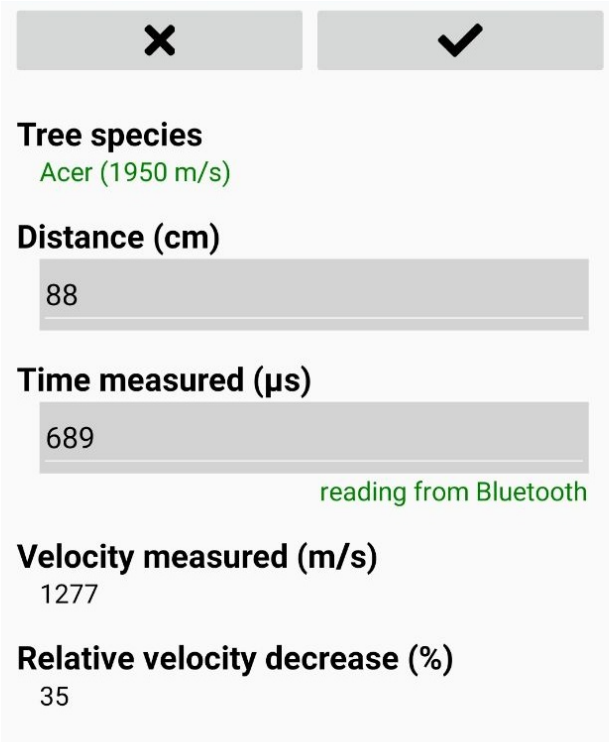
Species Selector



The Species Selector page has an input box active, here you can start typing the species name.

After entering a few characters the species names will appear below. From the list you must select the species that you are measuring. If you don’t type anything, you will see a list of recently selected species.

Measurement Page



The measurement page is where you can enter a single measurement. Only after selecting the tree species you can start recording measurements. A single measurement consists of both a distance and a time measurement. The time measurement can be entered manually or read from a Bluetooth enabled device.

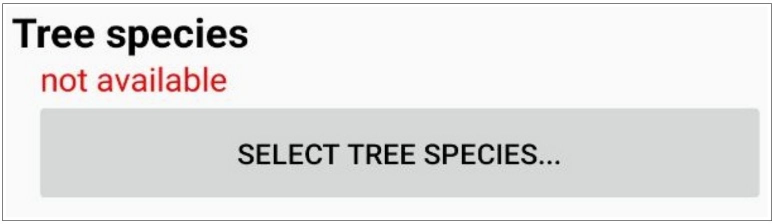
When you have finished entering the data, tap the check-mark on the top-right corner to go back to the Tree Page. The measurement page displays both the **Velocity** and the **Relative velocity decrease** (RVD).

Workflow

Start by creating a new project. For every tree you can follow these steps

1) Enter a name or identifier for the tree

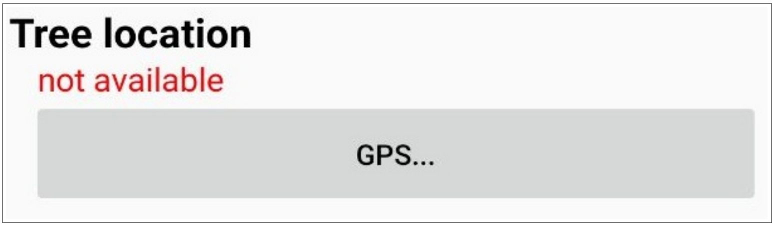
2) Select a tree species



3) Add measurements. You can press this button several times to add several measurements.

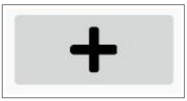
4) Add notes regarding the state of the tree you are measuring

5) Record the GPS location for the tree



6) Take images of the tree

7) After finishing with a tree, use the "New Tree" button to proceed to the next tree



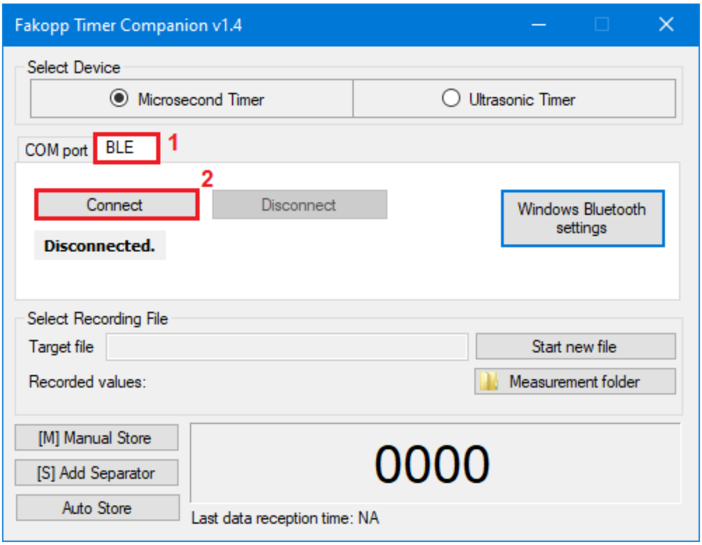
Use this workflow for each tree. When you are finished, use the "SHARE PROJECT" button from the main page to share your data in Excel format.

2023 May Revision

Automatic / Manual mode selection has been changed for devices shipped after 2023 May. After 2023 May the automatic mode is the default when turning the device on. Entering manual mode can be done by pressing the RESET button when switching the device on.

BLE (Bluetooth Low Energy)

Devices marked with the BLE marker have an internal Bluetooth Low Energy module. The usage for the Android software: the new hardware will appear as MSTIMER in the Bluetooth list, select this instead of SerialADT. For the PC Microsecond Timer Companion, you have the select “BLE” instead of “COM” to make a connection:



Radial Velocity Appendix

Species	Radial velocity [m/s]
Abies alba	1400
Abies firma	1450
Abies nordmanniana	1400
Acer campestre	1950
Acer negundo	1800
Acer platanoides	1950
Acer pseudoplatanus	1900
Acer saccharum	1900
Aesculus hippocastanum	1650
Ailanthus altissima	1700
Alnus glutinosa	1600
Alnus incana	1600
Prunus amygdalus	1700
Betula pendula	1650
Broussonetia papyrifera	1800
Calocedrus decurrens	1900
Carpinus betulus	1900
Castanea sativa	1400
Catalpa bignonioides	1550
Celtis australis	1750
Celtis occidentalis	1750
Chamaecyparis lawsoniana	1650

Species	Radial velocity [m/s]
Cladrastis lutea	1600
Corylus colurna	1700
Elaeagnus angustifolia	1650
Fagus sylvatica	1650
Fraxinus excelsior	1950
Fraxinus pennsylvanica	1750
Ginkgo biloba	1700
Gleditsia triacanthos	1850
Juglans nigra	1600
Juglans regia	1650
Koelreuteria paniculata	1650
Larix decidua	1700
Liriodendron tulipifera	1650
Maclura pomifera	1500
Morus alba	1800
Paulownia tomentosa	1250
Phellodendron	1600
Picea abies	1550
Picea pungens	1600
Pinus nigra	1600
Pinus ponderosa	1550
Pinus strobus	1600
Pinus wallichiana	1600
Pinus sylvestris	1500

Species	Radial velocity [m/s]
Platanus acerifolia	1650
Populus adenopoda	1500
Populus alba	1400
Populus canescens	1400
Populus euramericana	1400
Populus nigra	1400
Populus nigra 'Italica'	1200
Populus simonii 'Fastigiata'	1400
Prunus avium	1800
Pseudotsuga menziesii	1400
Pyrus pyraster	1750
Quercus cerris	1800
Quercus petraea	1800
Quercus robur	1800
Quercus robur 'Fastigiata'	1600
Quercus rubra	1650
Robinia pseudoacacia	2000
Salix babylonica	1550
Sophora japonica	1950
Tilia cordata	1600
Tilia platyphyllos	1550
Tilia tomentosa	1650
Ulmus minor	1800