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Radiata Management Theme

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Report on the Feasibility of Constructing a Vibration/ultrasonic Tool to Monitor Development of Wood in Seedlings

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Leadership in forest and environmental management, innovation and research

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EXECUTIVE SUMMARY

This report describes attempts to develop an ultrasonic velocity measurement method suitable for green juvenile (1 to 2-year-old) stem wood. The technique developed here will be used for monitoring the growth of the seedlings over periods of time, and also to study the response of seedlings subjected to various stress treatments in task F10205.

Among different transducers and frequencies tested, the 20 KHz Sylvatest Duo proved to be the most effective for measuring ultrasonic speed in 2-year-old seedlings. It is apparent that due to high signal attenuation, lower frequencies around 20 KHz are best for seedling ultrasonic speed measurements. The results of this work reinforce previously published work which suggests that one needs to penetrate into the xylem of the stem in order to get consistent results when using ultrasonic signals. Future work would be aimed at making a truly non-destructive and quick test by transmitting an acoustic wave up through the roots of a potted seedling, and measuring the surface movement produced on the stem by these longitudinal wave vibrations which propagate up the xylem of the stem.

BACKGROUND

The objective of this study is to develop a non-destructive ultrasonic technique to study the wood formation in seedlings. In task F10205, seedlings are being generated from 15 different clones using cryopreserved material. The technique developed here will be useful for monitoring the growth of the seedlings over periods of time, and also to study the response of seedlings subjected to various stress treatments.

INTRODUCTION

Acoustics techniques are widely used not only in research, but in practice in tree evaluation, log and lumber grading, sorting veneer, evaluation of historical wooden structures, selecting wood for musical instruments, etc (Bucur 2006). Acoustics properties are closely related to the mechanical properties of wood, hence they have proved to be quick and relatively cheap means of studying mechanical properties of wood. Ultrasonic time-of-flight (ToF) has been successfully applied to predict MFA in discs and logs (Emms 2007) and stiffness in standing trees using stress wave technique (Huang 2005). However, there are very few reports on the application of the acoustic technique to seedlings. This report describes attempts to develop an ultrasonic velocity measurement method suitable for green juvenile (1 to 2-year-old) stem wood.

METHODS

The following ultrasonic systems were evaluated:
(1) Sylvatest Duo system (22 kHz)
(2) Pundit ultrasonic transducers (54 kHz) & Olympus pulser/receiver
(3) Soft tip ultrasonic transducers (500 kHz) & Olympus pulser/receiver

Seedlings: 2-year-old seedlings with 9-10 mm diameter and 35-40 mm height were obtained from Scion nursery. First ultrasonic ToF was measured placing the whole seedling on a platform and pressing the transducers on to the seedling stem. Then the measurement was repeated with an actual stem piece chopped off from the seedling.

Ultrasonic Systems

Sylvatest Duo

This is a portable device with a transmitter and a receiving probe with rounded tips that measures ultrasonic time of flight (ToF). The kit comes with an automatic data logger for the easy handling of data. Transducers were placed on the seedling stem as shown in Figure 1, with the transmitter at the top end and the receiver at the root end. Measurements were then taken along a 10-cm length from the transmitting transducer at 1-cm increments. There appeared to be limited coupling occurring between the transducer tips and actual wood. To enhance the coupling at the contact point, ultrasonic coupling gels and creating a small bark window on the stem were tried. As water is known to improve the coupling, the seedlings were soaked in water overnight and measurements were taken on wet bark. All these means improved the signal only slightly. To better couple the transducers to the xylem region, blade tips were inserted to reach through the bark into the xylem (Figure 2). This way a better and consistent signal was achieved.

Measurements were taken at a number of places along the length of the stem. By doing this we were able to obtain a value of the acoustic speed along the stem without needing to explicitly calibrate the system – the speed of sound is taken from the gradient of the ToF vs the distance between the probes.

Fig 1: ToF measurements done on the stem with Sylvatest Duo.

Fig 2: ToF measurements done with blades inserted into the stem.

Pundit Transducers

These are much bulkier transducers with wide faces. For our measurements we coupled the wide, flat faces of the transducers to exponential horns with flat tips of small surface area (Figure 3). The transducers were driven by an Olympus pulser/receiver whose output was connected to an oscilloscope. The transducers are quite narrow-band devices. The time-of-flight between two points was determined by observing the sinusoidal signal output of the receiving transducer at the two points and by determining the phase difference between the two signals at those two points. The source transducer was fixed at one point and the receiving transducer was moved from the source in 1-cm increments.

Coupling through these transducers to wood was difficult, and results were inconsistent. Issues were complicated by the airborne coupling occurring through the transducers, requiring the use of cardboard shielding (Figure 4). The 54 KHz signal was highly attenuated by the seedling material.

Fig 3: Ultrasonic speed measurement with Pundit transducers.

Fig 4: Using cardboard to shield airborne coupling.

500 KHz flat tip Transducers

These 500 KHz transducers were tried but could not be used on the seedlings due to the high signal attenuation that occurred within very small distances (1 cm). This is typical of juvenile green wood in seedlings.

RESULTS

Among different transducers tested, the Sylvatest Duo proved to be the most effective for measuring ultrasonic speed in 2-year-old seedlings. It is apparent that due to high signal attenuation lower frequencies around 20 KHz are best for seedling ultrasonic speed measurements.

As shown in Figure 5, the most accurate ultrasonic speed was obtained by inserting blades into the stem. The inverse of the slope of the graph gives the ultrasonic speed of the seedling. The speed value obtained here, 1741 m/sec, is comparable with the stress wave speed reported for loblolly pine seedlings; 1250-1800 m/sec (Huang and Lambeth 2007). Use of ultrasonic gels and creating a bark window for better contact didn't help to improve the signal a great deal. Similarly soaking seedlings overnight did not change the speed. However, soaking in water is not a practical option if the technique is used to monitor continuous changes. It is unclear how much damage is done by inserting razor blades into the xylem. However, by inserting the blades parallel to the stem axis the damage done is kept to a minimum.

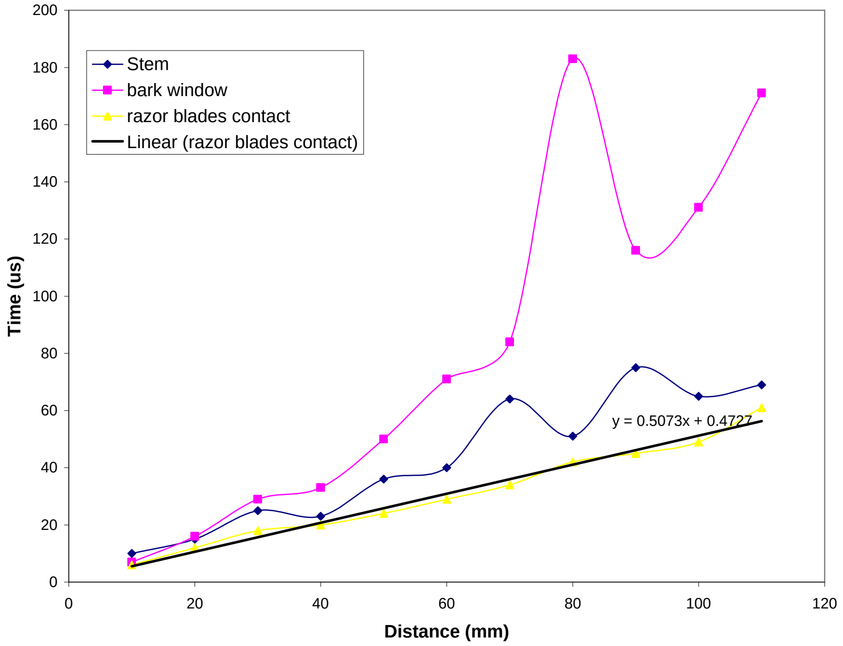

Fig 5: Ultrasonic ToF measurements using Sylvatest Duo in 2 year old seedlings.

PLANNED FUTURE WORK

The results of this work reinforce previously published work which suggests that one needs to penetrate into the xylem of the stem in order to get consistent results when using ultrasonic signals. This penetration may cause some damage which may affect future growth. Future work would be aimed at making a truly non-destructive and quick test by transmitting an acoustic wave up through the roots of a potted seedling, and measuring the surface movement produced on the stem by these longitudinal wave vibrations which propagate up the xylem of the stem.

Initial attempts were made to transmit 54 kHz through the base of a potted seedling, (Figure 6) to explore the potential of this technique as a complete non-destructive method for monitoring speed in growing seedlings. Unfortunately a consistent signal was not obtained at this frequency. It is, however, believed that by lowering the frequency to about 20 kHz (or lower) we will be able to transmit energy into the seedling from a transducer attached to the pot. The acoustic waves in the seedling will then be measured using either light-weight, high-frequency accelerometers, or by using a laser vibrometer. Due to the unavailability of the equipment at Scion it was not attempted, but we are hoping to use a laser vibrometer at AIT Auckland.

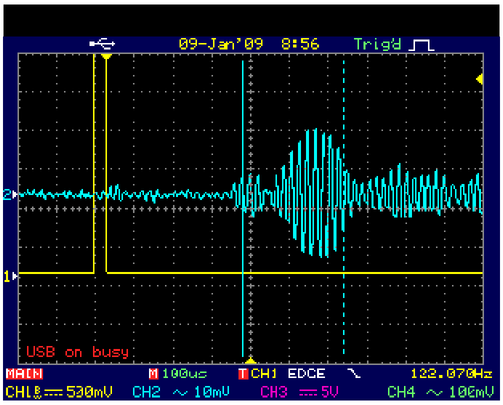

Fig 6: Using Pundit transducers to detect 54 kHz signal transmitted through the base of a potted seedling and the oscilloscope screen shot.

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