SFF grant 407602 - Milestone M-3462: Wood properties (Summer 2016/17)

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Background

In February 2015 (as part of the SFF grant 407602), 4032 seedlings from 81 families of *E. bosistoana* were planted at Murrays Nursery, Woodville (see milestone M-3377). The trial was planted in plots of 8 (2x4) consisting of single families (common mother tree, unknown father(s)) repeated 2 – 8 times depending on plant availability. The plants were ~1-4 m tall (at the time of harvest) and had been pruned to obtain a clear stem section 500 mm long at the base (see milestone M-3377). All 4032 trees were felled and 2683 provided the required 500 mm clear-wood section used to assess growth-strain (see milestone M-3461). After the growth-strain assessment, samples were prepared for testing of other wood properties (milestone M-3462). The stumps were left to coppice and Proseed will propagate the selected individuals with superior wood properties from coppice (upcoming milestone M-3489).

Harvest

Trees were harvested on the 7-9th of November and the 5-7th of December 2016 in Woodville and shipped to the School of Forestry, University of Canterbury, Christchurch and processed for growth-strain immediately after arrival. In course of the growth-strain assessment samples for measuring densities, moisture contents, dynamic MoE and volumetric shrinkage were obtained. Sample preparation and green-measurements have been described in detail in the milestone M-3461 report.

Assessment of dry samples

After measuring green traits the 2 half-rounds from each tree were oven-dried at 105 °C for 2 days. Subsequent to oven-drying the samples were placed in a climate controlled room (for ~3 weeks) at 20 °C and 65% relative humidity until they had a constant weight. This resulted in an average equilibrium moisture content of 9.3 %.

The measurement protocol for the air-dry samples was as follows:

1) Measure the length of the sample with callipers
2) Measure the acoustic velocity of the samples with the WoodSpec (Callaghan Innovation) resonance tool (Figure 1)
3) Measure air-dry mass with scales
4) Rewet sample with a damp cloth (to prevent air-bubbles forming on the surface during immersion weighing)
5) Measure volume by water displacement (Figure 2)
6) Pack back into bags sorted by families for long term storage

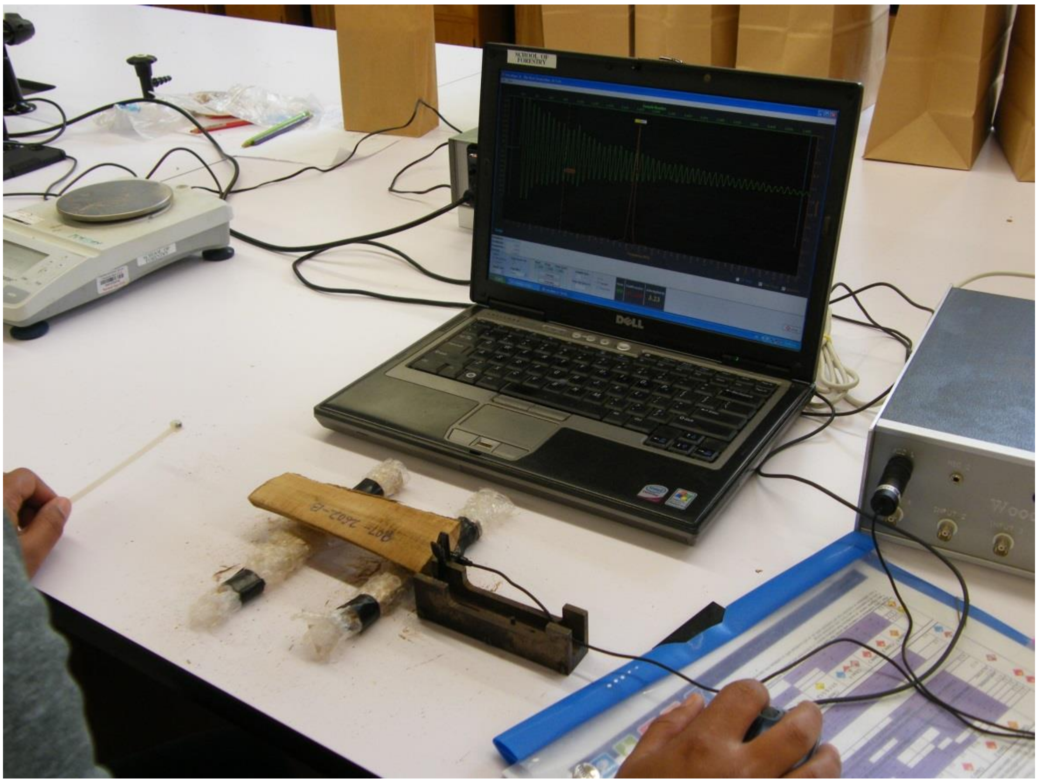

Figure 1: measuring acoustic velocity with the WoodSpec (Callaghan Innovation) resonance tool

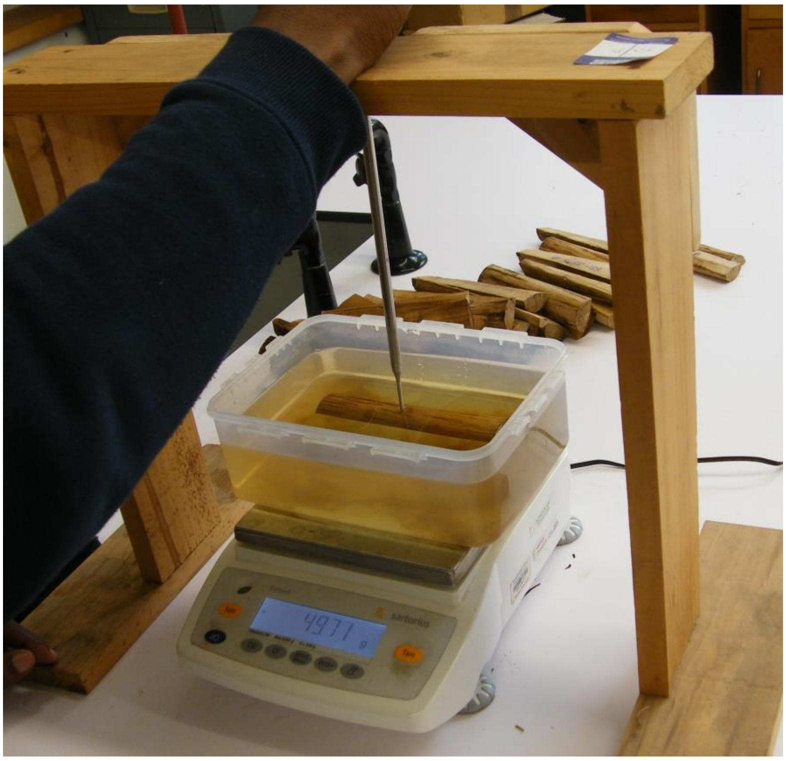

Figure 2: measuring sample volume by water displacement

With the combination of air-dry (moisture content ~9%) and green measurements, calculation of the following derived wood properties for each tree were posable:

1. Growth-strain

$$Growth - strain = \frac{Opening \times Diameter}{1.74 \times Slit\ length^2} \times 1000$$

2. Density (at 9% MC)

$$Density = \frac{'Dry'\ mass\ side\ A + 'Dry'\ mass\ side\ B}{'Dry'\ volume\ side\ A + 'Dry'\ volume\ side\ B}$$

3. Stiffness

$$Stiffness = Acoustic\ velocity^2 \times Density$$

4. Volumetric shrinkage

$$Volumetric\ Shrinkage = \frac{Green\,Volume\ A + Green\,Volume\ B - 'Dry'\ Volume\ A - 'Dry'\ Volume\ B}{Green\,Volume\ A + Green\,Volume\ B}$$

Results

A mixed multivariate 'animal' model was used to estimate genetic parameters of the population and calculate breeding values for individuals and families. The model consisted of fixed (replicates, staking and edge effects) and random plot effects to describe environmental influences. Numerous site and operational effects were checked for significance within this framework, and found to be negligible. The exception was sampling intensity for the diameter trait which was strongly confounded with replicate effects, and hence can be ignored (as replicate effects were already used within the model).

Heritabilities for the growth traits, under-bark diameter and height were high, potentially facilitated by the homogenous environment for growth in the trial (Table 1). High heritabilities were also observed for density, acoustic velocity and stiffness. Heritability of volumetric shrinkage was lower, potentially due to inaccuracies in the green volume data. Growth-strain had the lowest heritability (0.23). The limited accuracy of the 'splitting' test lowers the calculated heritability. Another contributing factor might be local variations of form and growth-strain within each stem. While the site was uniform for growth conditions (higher heritability compared to multi-site trials) the local variation in stem form and growth-strain of the young trees might be comparable to that in 'nature'. In any case a heritability of 0.23 will allow selecting for low growth-strain, especially considering the wide variation of this trait (Table 2).

Table 1 also shows the correlations between the assessed traits. To note are the independence of growth-strain and diameter as well as the positive correlation between growth-strain and stiffness. The former means that it is possible to find large trees with low growth-strain. The latter is more unfavourable as lower growth-strain trees will be less stiff. For *E. bosistoana*, however, this is not too problematic as the trees are of high stiffness. At an age of 21-months the average stiffness was 11.2 GPa (Table 2) which compares to 2-3 GPa for radiata pine at the same age.

Table 1: Heritabilities (diagonal) and correlations (off-diagonal) of E. bosistoana at age 21-months.

	Growth-strain	**Diameter**	**Density**	**Stiffness**	**Vol. shrinkage**	**Height**	**Ac. vel.**
Growth-strain	*0.23*	**<u>0.03</u>**	-0.14	**<u>0.33</u>**	-0.16	0.11	0.45
Diameter		*0.57*	-0.25	-0.30	-0.22	0.93	-0.23
Density			*0.70*	0.49	0.22	-0.16	0.18
Stiffness				*0.77*	-0.05	-0.15	0.94
Vol. shrinkage					*0.39*	-0.38	-0.15
Height						*0.71*	-0.08
Ac. vel.							*0.80*

Variation within and between families for growth-strain can be seen in Figure 3 and Figure 4. Within family variation of growth-strain was large. Families comprise the seed from one tree comprising half- and full-siblings as well as 'selfed' individuals. Consequently future controlled pollinated material will reduce within family variation.

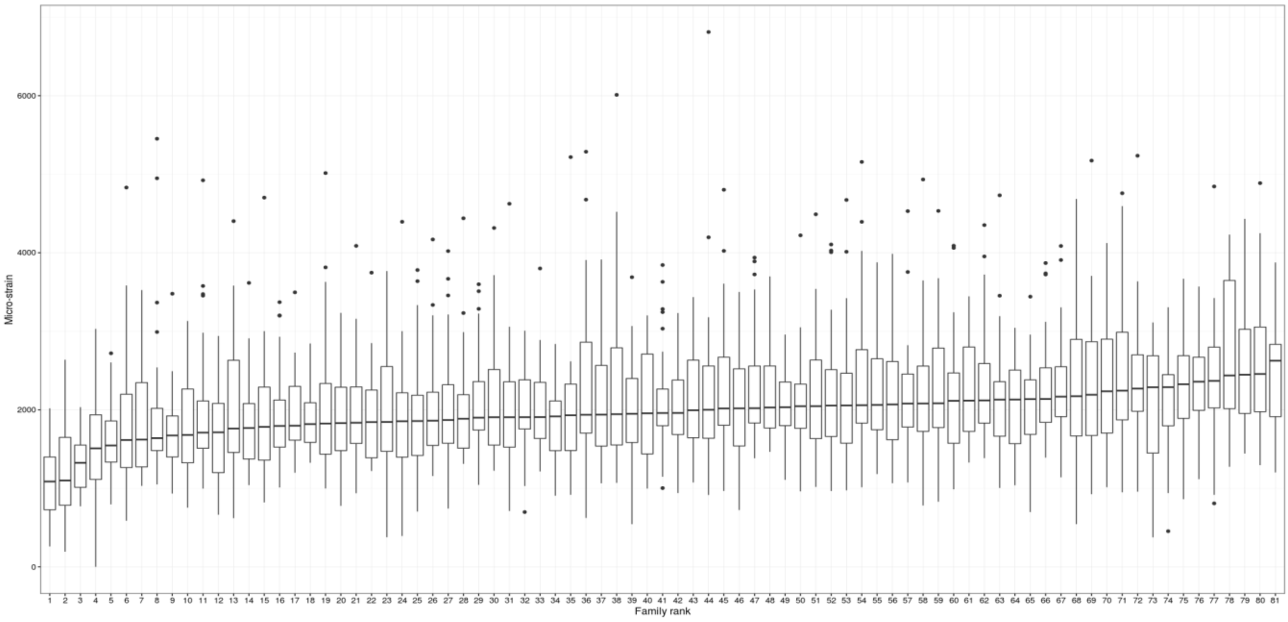

Figure 3: Between and within family variation for growth-strain in E. bosistoana age 21-months.

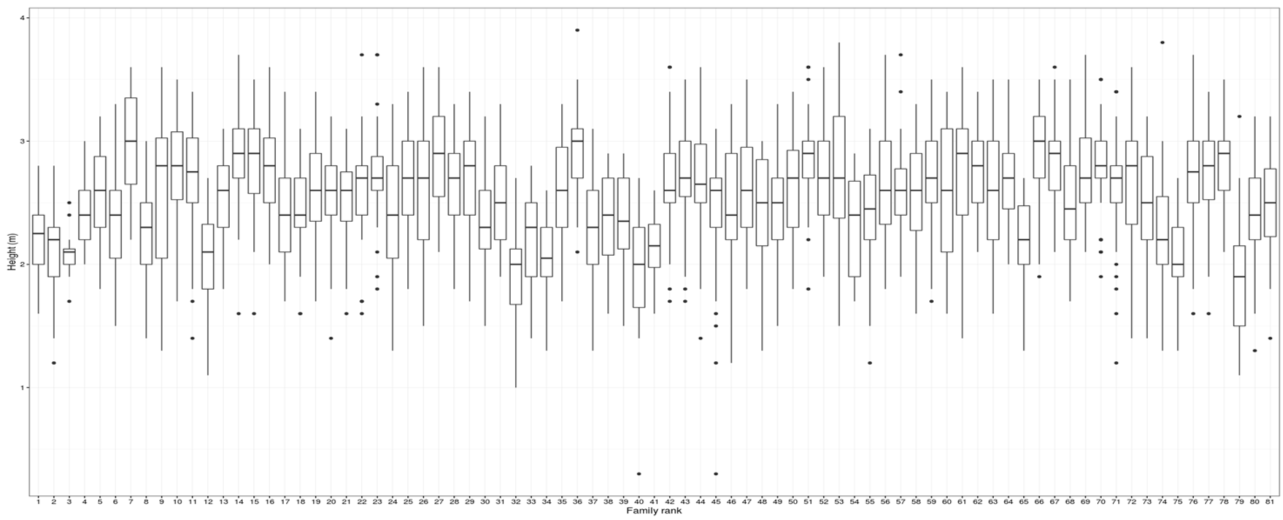

Figure 4: Between and within family variation for height in E. bosistoana age 21-months. Families ranked for growth-strain.

Selection for propagation

The primary objective was to remove high growth-strain individuals from the breeding populations without reducing the genetic diversity or compromising the other traits. This is to ensure good gains can be achieved for other traits in future generations. Secondary to this there is the option to identify the 30-40 most promising individuals for larger scale propagation.

The selection strategy to select 1000 (~25%) individuals was as follows:

First some trees were excluded from the selection:

1) Of the 4032 trees planted only the 2683 trees which were assessed for growth-strain were considered
2) Trees grown from coppice were removed from data analysis (i.e. leading shoot broke or died after planting)
3) Trees needed to have an under-bark diameter (at base) of >25 mm
4) Trees need to have a growth-strain of <3000 µstrain

Then, to keep the best trees without compromising other traits and to ensure that the selected population can support a future breeding programme the top trees in each family for several traits were selected. This leads to smaller gains in the selected population but ensures a broad genetic base. The criteria for selection within each family were as follows:

1) Lowest 3 growth-strain
2) Highest 1 acoustic velocity
3) Lowest 2 dry-density
4) Stiffest 1
5) Largest 3 under-bark diameter
6) Tallest 1

This resulted in the selection of 688 trees. Some trees fulfilled several criteria therefore reducing the number of theoretically possible selections under these criteria.

Finally the remainder of 312 to 1000 trees were selected by global index selection with giving growth-strain and under-bark diameter equal weight. This biased the selection to larger and lower growth-strain families.

4 to 29 individuals from each family were present in the selection. It needs to be mentioned that ease of propagation is also under genetic control and it is expected that some individuals/families will not be able to be propagated successfully. Propagation success can be seen as another selection criterion, while they may have been selected here, they may not propagate and hence be removed from the breeding population.

The genetic gains of the new breeding population selected after the above criteria are given in Table 2. It represents a selection intensity of 1 in 4 (low intensity compared to more traditional breeding programs). The genetic gains are limited but it has to be kept in mind that this is not a selection for deployment but a well characterised 2nd breeding generation which conserved a broad genetic base allowing selection for more traits like tree health and heartwood. A more realistic selection for deployment would be 1 in 100 and significant gains can be achieved. For example if purely selected for growth-strain the magnitude could be reduced by ~50%. The target growth-strain level still needs to be determined i.e. the growth-strain threshold which is acceptable for processing. This could be achieved by a larger processing (peeling/sawing) trial, which at the current time is unfeasible due to funding restrictions and trees which will not be of significant size until approximately 2019.

Table 2: Genetic gains of new breeding population, potential gain of top selections and mean values for E. bosistoana

	New breeding population multivariate	**Top 1%** univariate	**Mean**	**Coefficient of variation**
Growth-strain (µs)	-108	-912	2072	0.36
Diameter (mm)	3.1	13.6	36	0.24
Density (kg/m^3)	-6.6	-88.5	815	0.06
Stiffness (GPa)	-0.42	2.6	11.2	0.17
Vol. shrinkage (%)	-0.2	-4	20	0.19
Height (mm)	231	944	2,388	0.25
Ac. vel. (km/s)	-0.06	0.44	3.69	0.08

Future work

- Cuttings from coppice of the selected trees are currently being propagated (milestone M-3489).
- The remaining 89 *E. bosistoana* and 31 *E. argophloia* families will be harvested later this year. The timing is constrained by propagation, i.e. coppice should be available in early summer.
- Plans to seek a 1-year extension for this SFF programme to screen another 2 NZDFI species for wood properties and establish a new breeding population.