Specialty Wood Products Research Partnership

UC UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

Heartwood in *Eucalyptus bosistoana* (JNL Ngaumu 2012 trial)

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FOREST GROWERS RESEARCH

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EXECUTIVE SUMMARY

The ultimate goal of NZDFI breeding programme is to exploit variation in quantity and quality of extractive content to identify superior families in terms of heartwood content and quality. The objective of this study was described in SWP Work Plan 109 and to rank families in terms of extractive content estimated using NIR spectral measurements in 2012 JNL Ngaumu trial established in Wairarapa.

The trees in the trial were of comparable age and only slightly smaller than those in previously assessed *E. bosistoana* breeding trials, which had good heartwood development. However, only 8% of trees had formed heartwood in this 2012 JNL Ngaumu trial, preventing calculation of genetic values for heartwood traits. Consequently, the trial needs reassessment at a later stage if breeding values for heartwood traits are needed.

The site effect (i.e. environmental factors) on heartwood formation was noticed in previous work. However, this trial contained other genotypes than the previous trials and it is unclear if genetic or environmental (or both) contributed to the low heartwood content in this site.

Interestingly, some outstanding individuals with large heartwood and high extractive content were present.

INTRODUCTION

Ground-durable timber is a target product of NZDFI. NZDFI has established a series of breeding trials to deliver growers healthy plants, which produce good amounts of quality timber. The key wood property is natural durability. Natural durability describes the resistance of wood to decay by fungi and insects. Only heartwood, which contains bioactive extractive compounds, has natural durability (AS5604, 2005).

Heartwood quantity

The heartwood diameter varies within a species. Heartwood quantity is partly under genetic control (Hillis, 1987). To maximise value of NZDFI plantations, trees that have a propensity to produce a large volume of heartwood should be selected in a breeding programme.

Heartwood quality

The measurement of natural durability is resource intensive (Harju & Venäläinen, 2006; Li & Altaner, 2016). High resource demands prevent this trait from being included in breeding programmes. However, heartwood extractives are a main factor providing natural durability (Hawley, Fleck, & Richards, 1924). Extractive content is highly variable within *E. bosistoana*, varying at least 10-fold between trees (Sharma, McLaughlin, Altaner, Chauhan, & Walker, 2014; Van Lierde, 2013). As the extractive content can be efficiently measured, NZDFI is selecting genotypes of high extractive content to increase the chances of ground-durable timber in the future deployment population.

The objective of this work (SWP work plan 109) was to screen the *E. bosistoana* breeding population planted at JNL Ngaumu in 2012 for heartwood quantity (diameter) and quality (extractive content).

METHODS

Material

84 *E. bosistoana* families were planted in a single tree plot design in 140 blocks with 36 trees in each block in 2012 at JNL Ngaumu, Wairarapa. In total 5040 trees were planted. In November 2019 trees were assessed for growth and form. 26 Plots were abandoned due to poor survival and form as well as gorse overgrowth. Only trees with a DBH larger than 30 mm were considered for coring. From those, in June 2020, 20 trees were randomly selected from families with more than 20 individuals whereas every individual was cored for families with less than 20 trees of the required size. Due to onset of bad weather (and the by then obvious lack of heartwood), 30 of the 114 blocks were not cored.

In total 1003 cores were assessed for heartwood. Full diameter cores were taken at the bottom of the tree trunk (i.e. ~50 cm height) through the pith for heartwood assessment using a battery powered 14 mm inner-diameter increment corer.

Assessments

Heartwood was highlighted by applying a pH indicator (methyl orange) to the core surface in the green state (Figure 1). Heartwood changed colour to pink while no colour change occurred when applied to sapwood. The total length of the core samples without bark as well as the length of the heartwood was measured in the green state with a ruler. Sapwood depth was calculated as the difference between the 2 measurements.
The surface of the cores was sanded (P 100) to expose clean wood before NIR spectra were collected with a fibre optics probe (Bruker) on the radial-tangential surface every 5 mm along the heartwood. The extractive content was predicted for each spectra using the previously developed model (Li & Altaner, 2016a). Heartwood extractive content for a tree was than calculated as weighted average (representing cross sectional area) of the individual spectra.

Figure 1 Staining *E. bosistoana* cores with methyl orange highlighted heartwood pink. (Note these cores are from a previous trial)

Data analysis

Data was analysed in R (Team, 2104). The bacoNIR package developed by Luis Apiolaza (UC) was used to predict extractive content of the cores.
A linear mixed model was used for the univariate analysis to generate the foundational parameter of the traits.

$$Y_{ij} = \mu + b_i + c_j + \sigma_{ij}$$

Where Y_{ij} is an observation of each trait, μ is the overall mean, b_i is the fixed block effect, c_j is the random family and σ_{ij} is the residual error.

The model was fitted and genetic analysis was done with the ASReml package (Gilmour et al. 2009). The phenotypic and genotypic variation was estimated to compute the narrow sense half-sib heritability (h^2) of each trait using the equation below.

$$h^2 = \frac{Var(A)}{Var(Y)} = \frac{4\sigma_f^2}{\sigma_f^2+\sigma_b^2+\sigma_r^2}$$

Where σ_f^2 is the additive genetic variance for the family; σ_b^2 is the variance for the block and σ_r^2 is the residual variance. The heritability estimated in this study assumed a relationship coefficient among families of one quarter, i.e. true half sib progeny.

The coefficient of genetic variation (CGV) for each trait was determined using equation below.

$$CGV = \frac{\sqrt{4x\sigma_f^2}}{population\ mean}$$

RESULTS

Tree diameter

Core length (under-bark diameter at 0.5 m height) and 2019 DBH measurements (over-bark diameter at breast height) of the trees were compared (Table 1). Generally, a good correlation between the two measurements was found (Figure 2) and the correlation was similar to that found earlier in other *E. bosistoana* trials (SWP-T028, SWP-T046). Main factors contributing to these differences were:

- time lag between measurements and associated tree growth,
- taper as measurements were conducted at different heights,
- bark thickness as bark was removed from the cores,
- occasional loss of material (1-10mm sapwood) while coring.

The latter is not relevant if all the heartwood is recovered and ranking is based on heartwood diameter. It however, affected the accuracy of sapwood and core length data.

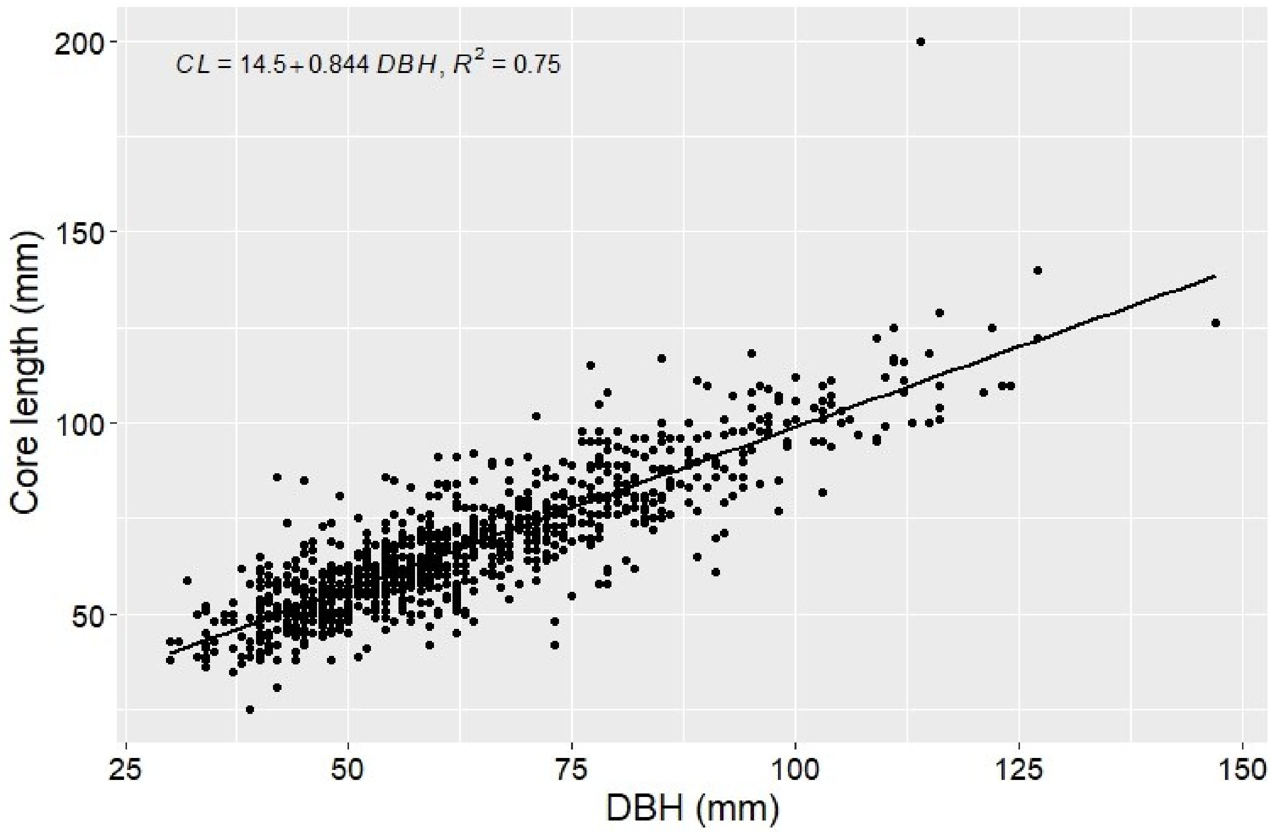

Figure 2 DBH (above-bark) in relation to core length (without bark) (CL) at the stem base for 7.8-year old *E. bosistoana* at JNL Ngaumu.

Wood cores

92% of the cores (924/1003) did not change in colour on application of methyl orange suggesting they did not contain heartwood (Figure 3). These results were different from previous trials (Table 1). The difference can be attributed to site, tree size or genetic makeup as families planted in 2012 (JNL trial) were different to those planted in 2009 and 2010.

Table 1 Summary of average core length and percentage of trees with heartwood in different NZDFI *E. bosistoana* trials.

Site	Planting year	Tree age when measured (years)	Average core length (mm)	Trees with heartwood (%)
Martins	2009	8.5	101.0	82
Lawson	2009	6.7	81.0	57
MDC Cravens	2009	6.7	103.6	69
Martins	2010	6.6	84.7	82
Avery	2010	7.5	76.6	57
JNL Ngaumu	2012	7.8	67.7	8

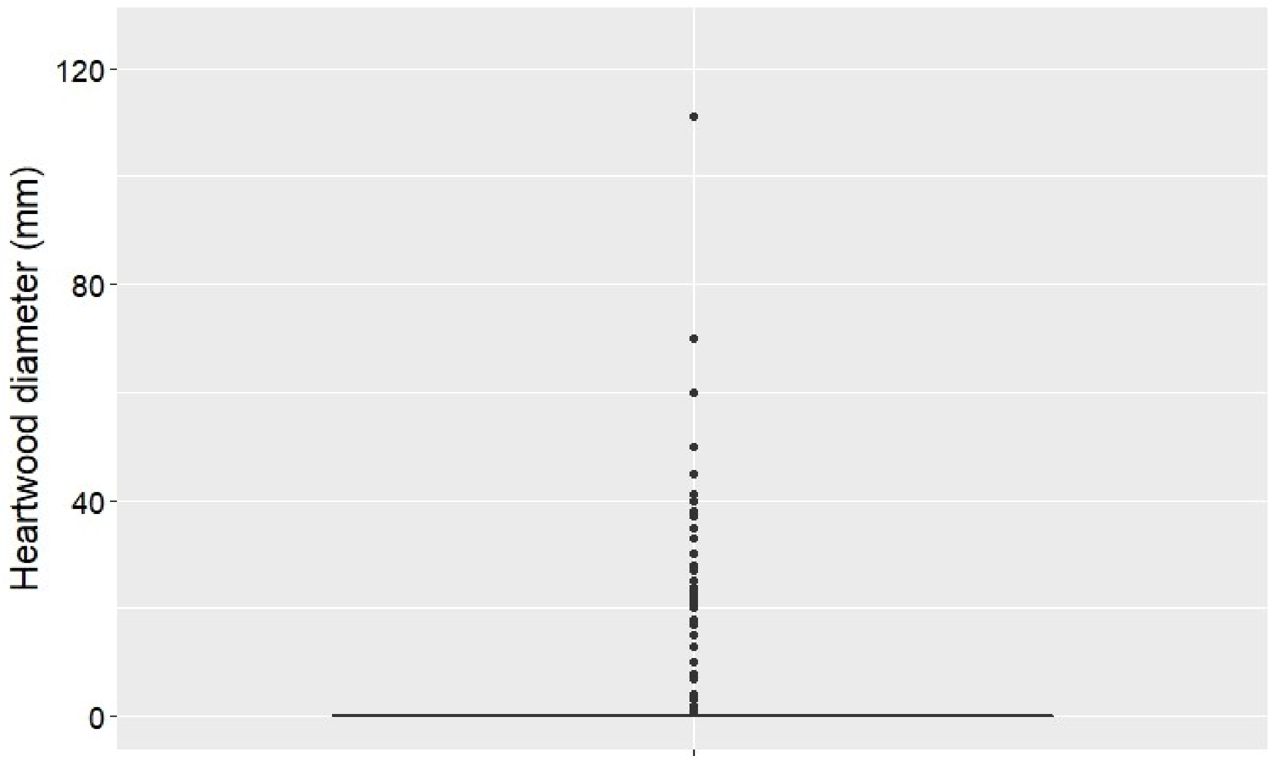

Figure 3 Boxplot for heartwood diameter for 7.8-year old *E. bosistoana* at JNL Ngaumu.

The mean heartwood diameter was 1.83 mm with a negligible coefficient of genetic variation of 0.30% (Table 2). Genetic values could be calculated for heartwood traits. The average sapwood diameter was 65.8 mm with a coefficient of genetic variation of 12.8%.

Table 2 Summary statistic of 7.8-year old *E. bosistoana* heartwood features grown at JNL Ngaumu. SD= standard variation, CPV= coefficient of phenotypic variation, CGV=coefficient of genetic variation, h^2 = heritability, CI $_{95}$ =95% confidence interval, CL = core length, HWD= heartwood diameter, SWD = sapwood diameter.

Variable	Min (mm)	Max (mm)	Mean (mm)	SD (mm)	CPV %	CGV %	h^2 (CI_{95})
DBH	30	147	63.0	18.4	29.2	13.6	0.22 (0.06, 0.36)
CL	25	200	67.7	17.9	25.7	12.5	0.22 (0.07, 0.37)
HWL	0	111	1.83	9.55	436.6	0.30	0*
SWD	0	129	65.8	16.5	25.1	12.8	0.26 (0.10, 0.42)

*no CI_{95} as 92% of the cores have no heartwood

Core length and heartwood diameter

The heartwood diameter was not correlated with core length as most of the trees had either no or negligible amounts of heartwood (Figure 4). Although other trials (SWP-T028, SWP-T046) had comparatively better correlation (e.g. for Martins 2009 trial the r^2 was 0.58 and for Avery 2010 trial it was 0.43) between these traits, in those trials larger trees with little or no heartwood were also observed. This shows that the largest trees do not necessarily produce the largest volume of the target product (heartwood) and selection for heartwood diameter rather than DBH is beneficial.

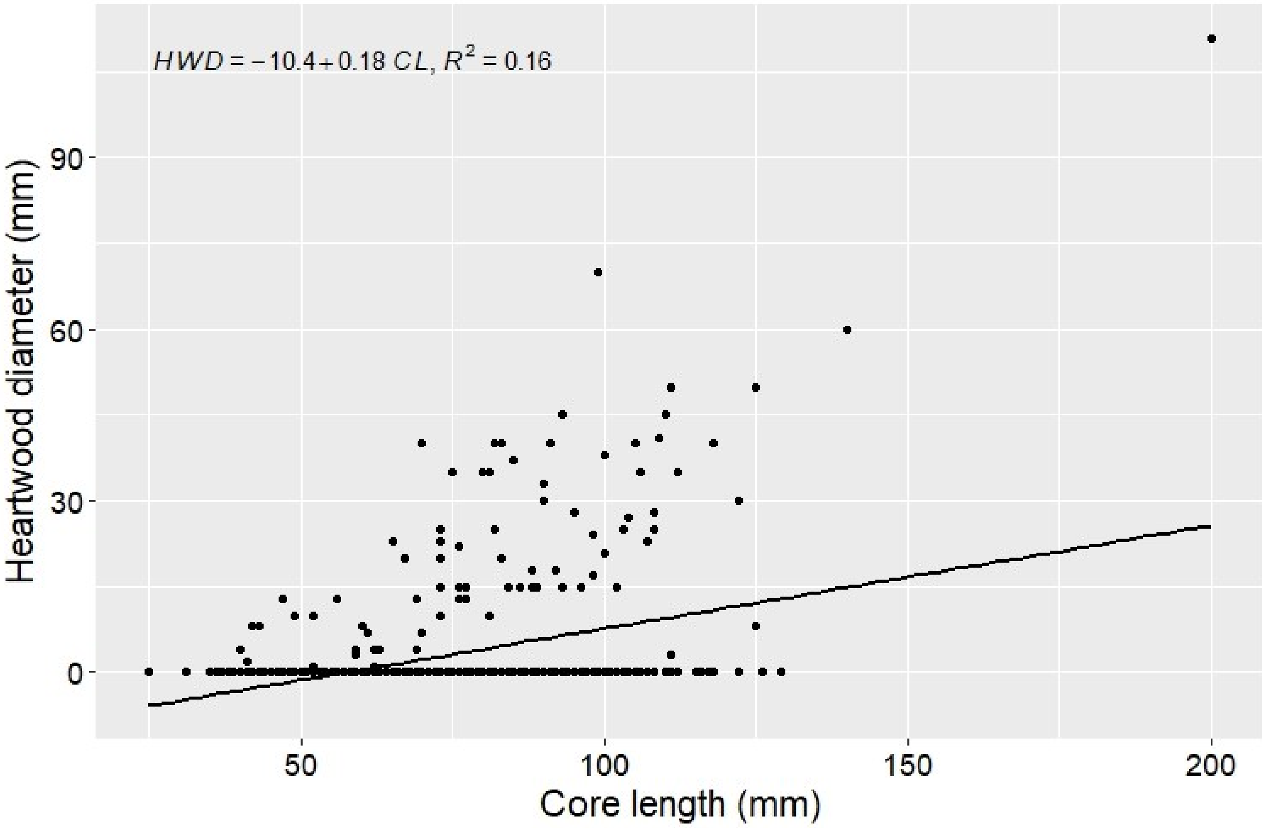

Figure 4 Heartwood diameter (HWD) in relation to core length (CL) for 7.8-year old *E. bosistoana* at JNL Ngaumu.

Heartwood diameter and extractive content (EC)

Heartwood diameter and EC were correlated (Figure 5) i.e. trees with larger quantities of heartwood tend to have a higher amount of extractives. Tress with high extractive content are more likely to be more durable. It is important to note, that the extractive content showed a large variability ranging from 0.68 to ~21% (Table 3). This again confirms earlier findings at Avery, Martin and Craven Road (SWP-T046, T028). This large variability can be exploited to screen for heartwood quality, as the trait is heritable.

Table 3 Predicted extractive content (EC) by NIR in 7.8-year old *E. bosistoana* heartwood grown at JNL Ngaumu.

	Minimum (%)	**Maximum (%)**	**Mean (%)**	**CV**	**SD (%)**
EC	0.68	21.11	10.75	0.48	5.10

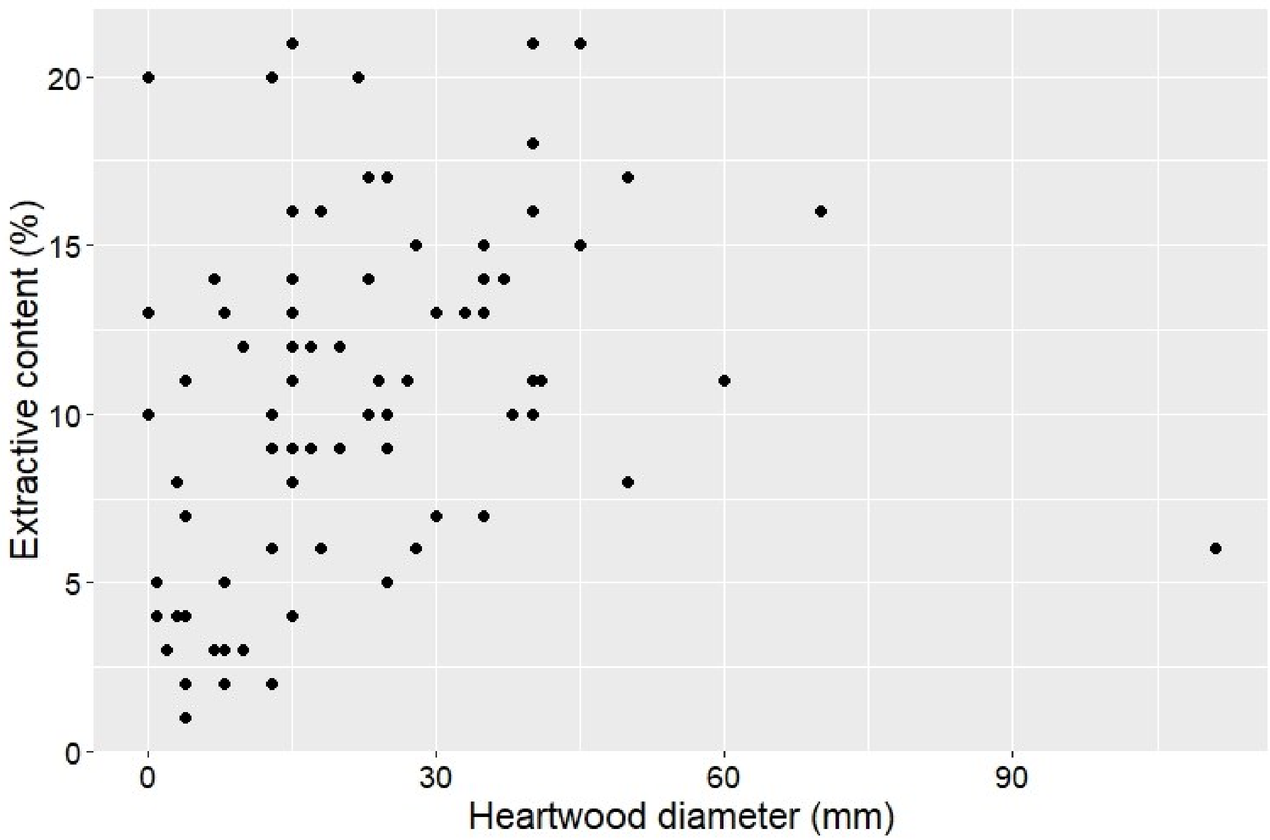

Figure 5 Heartwood diameter in relation to extractive content for 7.8-year old *E. bosistoana* at JNL Ngaumu.

ACKNOWLEDGEMENTS

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