Technical Report

Assessment of *Eucalyptus globoidea* heartwood at Avery

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EXECUTIVE SUMMARY

The second (Avery) of three *E. globoidea* breeding trials has been phenotyped for heartwood properties. The results are comparable to the assessment of the previous *E. globoidea* trial at Atkinson. The data has been loaded into the NZDFI Kathmandoo database.

The work has shown that heartwood traits in this *E. globoidea* trial were under genetic control and families with more and better heartwood have been identified. The best performing families had twice as much heartwood and extractives as the least performing families. As this is one of three trials of this breeding population the best selection will be possible once all three trials have been assessed and analysed.

The third and last trial (JNL Ngaumu) has been cored in June 2021 and is awaiting heartwood quality measurements (NIR). Once that data is available all three trials can be analysed for GxE effects and more confident statements on superior families and their performance can be made.

INTRODUCTION

The New Zealand Dryland forests Initiative (NZDFI), aims to establish a domestic, sustainable natural durable hardwood industry. The NZDFI has established a breeding program to deliver high value timber. In addition to high growth rate and improved form, favourable wood properties are key objectives in the breeding program to produce high-value timber (Millen et al., 2018). The eucalyptus species in the NZDFI program were chosen preliminarily for their natural durability and their potential fast growth under the climatic conditions in the drier parts of New Zealand. *E. globoidea* is a class 2 ground durable timber and one of several Eucalyptus species planted by NZDFI. *E. globoidea* timber does not reach the exceptional properties as of the class 1 ground durable *E. bosistoana* as it has comparable lower density and higher susceptibility to drying defects such as collapse and honeycombing.

Heartwood quantity and quality

Heartwood quality and quantity are key wood properties for the envisaged utilisation of *E. globoidea* and therefore need to be assessed for their potential incorporation into a breeding program. Heartwood quantity is partly under genetic control (Hillis, 1987) and varies within a species.
Heartwood extractives are a main factor providing natural durability (Hawley et al., 1924). Previous SWP funded research showed that the extractive content (EC) can be predicted with NIR (RMSE ~1%) (Technical report SWP-T040, (Li & Altaner, 2019) and that EC is highly variable (1 – 14%) in *E. globoidea* heartwood.

The objective of this work was to assess the *E. globoidea* breeding population planted at Avery in 2011 for heartwood quality and quantity.

METHODS

Trial

An open-pollinated progeny trial of 163 *E. globoidea* families was established in 2011 at Avery, Marlborough, New Zealand (Fig1). The trial site was located at latitude -41° 43’ 59” S, longitude 174° 09’ 60” E and experienced an annual rainfall of around 600 to 800 mm. The seed was collected from across the natural range of the species in Australia and from three NZ plantation sites with a known seed lot.

Single-tree plots were established in 298 blocks with 36 trees in each block and a different number of individuals per family ranging from 31 to 81, totalling 10,728 trees. The spacing of the trees was 2.4 m × 1.8 m. Due to high mortality, 16 blocks were abandoned, and 12 blocks were replanted with *E. tricarpa* in 2013. There is one PSP located within the trial that was established in 2015. The trial was assessed for height at age 1.7 years in May 2013 and again at the age of 5.3 years in December 2016 for height, basal diameter and DBH. Recently, the trial was assessed for DBH, height, form, flowering and seed development at the age of 9 years in October 2020. The trial has been thinned at the age of 9.2 years in December 2020.

Figure 1: E. globoidea breeding trial at Avery

Sampling strategy

Up to 20 trees with a diameter (DBH) above 50 mm were randomly selected from each family for sampling. Some trees were selected from non-assessed blocks either to have at least 20 individuals per family or to increase the number of individuals as there were families with very few surviving individuals in the assessed blocks, resulting in 2752 trees being cored.

Coring

A bark to bark 14 mm diameter core including the pith was extracted using a purpose-built corer from the 2,752 trees in November 2020 at ~0.5 m stem height (Figure 2). The cores were labelled and packed into plastic bags to avoid drying during the day.

Figure 2: Coring an E. globoidea tree at Avery using a battery-powered 14 mm diameter corer

Heartwood quantity (heartwood diameter)

The heartwood diameter in the stem was assessed by measuring the heartwood length with a ruler on the core samples in the green state on the day of coring. The heartwood was highlighted by immersing cores into an aqueous 0.1% solution of methyl orange that changed heartwood colour to pink while the sapwood remained yellow (Figure 3). Additionally, the length of the core (without bark) was measured.

Figure 3: E. globoidea cores with heartwood dyed pink after application of methyl orange.

Heartwood quality (Extractive content)

The core samples were then oven-dried at 60°C for a week before equilibrating to a stable moisture content at 65% relative humidity and 25°C in a climate-controlled room. Extractive content was predicted from Near Infrared (NIR) spectra taken on the sanded tangential-radial surface of the oven-dried cores using a fibre optics probe a maximum of six measurements along the heartwood every 0.5 cm starting from the pith. Heartwood extractive content of each NIR measurement was predicted with a previously developed method (Li & Altaner, 2016) and the average heartwood extractive content for the tree was calculated by averaging the radial values per core weighted by the representative heartwood area.

Data analysis

Data was analysed with the R software (R Core Team 2019). Univariate analysis was used to generate the foundational parameter of the traits utilising the following linear mixed model:

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

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 with the ASReml package (Gilmour et al., 2009) to generate the correlation between the traits' phenotypic and genotypic variation. The phenotypic and genotypic variation was estimated to compute the narrow sense half-sib heritability (h^2) of each trait according to

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

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-sibling progeny.

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

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

RESULTS

The summary statistics of the measurements in the NZDFI *E. globoidea* breeding population at Avery at age 9.5 years old are given in Table 1. The main traits of interest are natural durability (i.e. extractive content) and heartwood quantity (i.e. heartwood diameter).

Table 1: Descriptive statistics, heritability (h^2) with 95% confidence interval in brackets for E. globoidea wood properties at age 9.5 years; Coefficient of phenotypic variation (CPV) and Coefficient of genetic variation (CGV)

Trait	Mean	Standard Deviation	Min	Max	CPV (%)	CGV (%)	h^2 (r_c=0.25)
Core length (mm)	82.12	21.9	30	177	26.67	25.12	0.88 (0.67, 1.07)
Heartwood diameter (mm)	47.71	23.19	0	145	48.61	30.86	0.47 (0.33, 0.60)
Sapwood diameter (mm)	34.41	13.56	0	136	39.41	29.87	0.72 (0.54, 0.89)
Extractives content (%)	8.29	4.29	-8.4	23.91	51.75	36.29	0.49 (0.35, 0.63)

Core length

Core length was correlated to DBH (0.74; CI_{95} 0.72. 0.76) (Figure 4) and the correlation was similar to that found earlier in *E. bosistoana* trial (R^2 = 0.75: JNL Ngaumu). The heritability estimate for core length was h^2 = 0.39 (CI_{95} 0.21, 0.56), also similar to what was previously reported for *E. globoidea* at age 8 years (SWP-T092). Family rankings for core length are displayed in Figure 5.

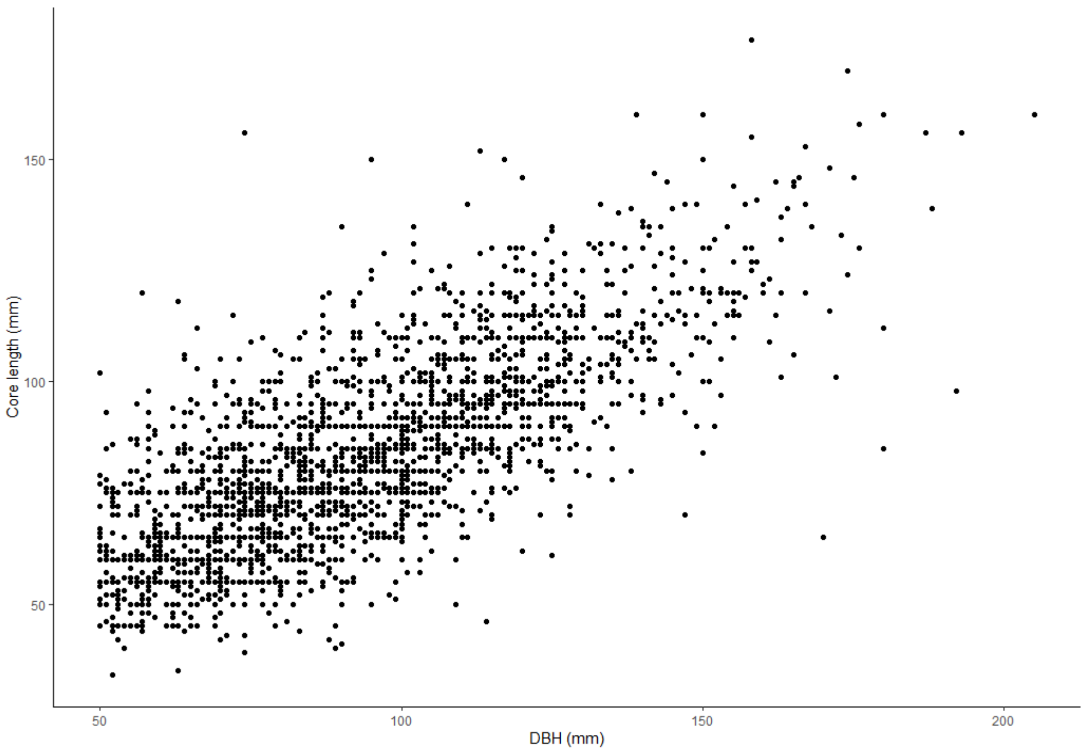

Figure 4: Relationship between core length and DBH for E. globoidea at Avery

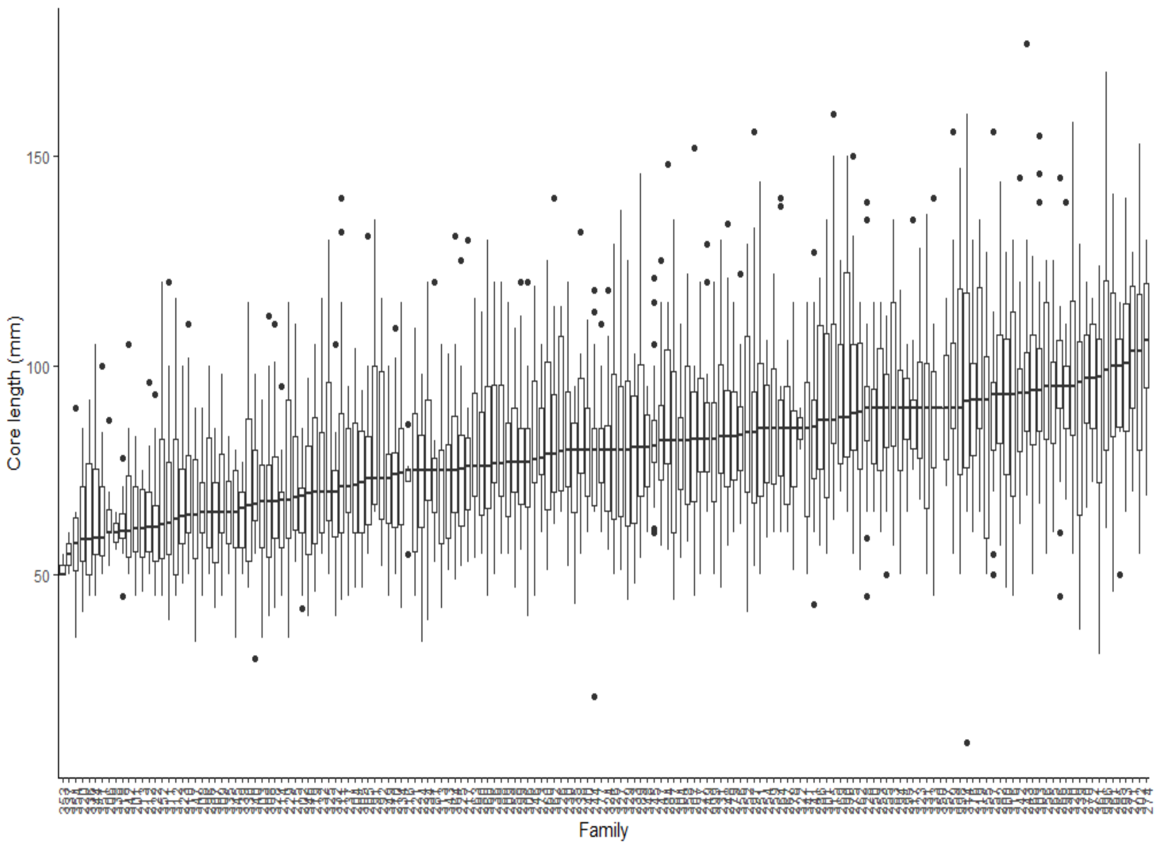

Figure 5: Boxplot of core length of E. globoidea families at Avery at 9.5 years old ranked by mean

Heartwood quantity and quality

Variability of heartwood diameter was comparable to that of tree diameter and sapwood width (Table 1), but lower than those reported for *E. globoidea* (SWP-T092) and *E. bosistoana* (Li et al., 2018). Heritability was h^2 = 0.47; (CI_{95} 0.36, 0.67), lower to what was reported for *E. globoidea* at age 8 (SWP-T092; h^2 = 0.52; CI_{95} 0.36, 0.67). Family rankings for Heartwood quantity are displayed in Figure 6.

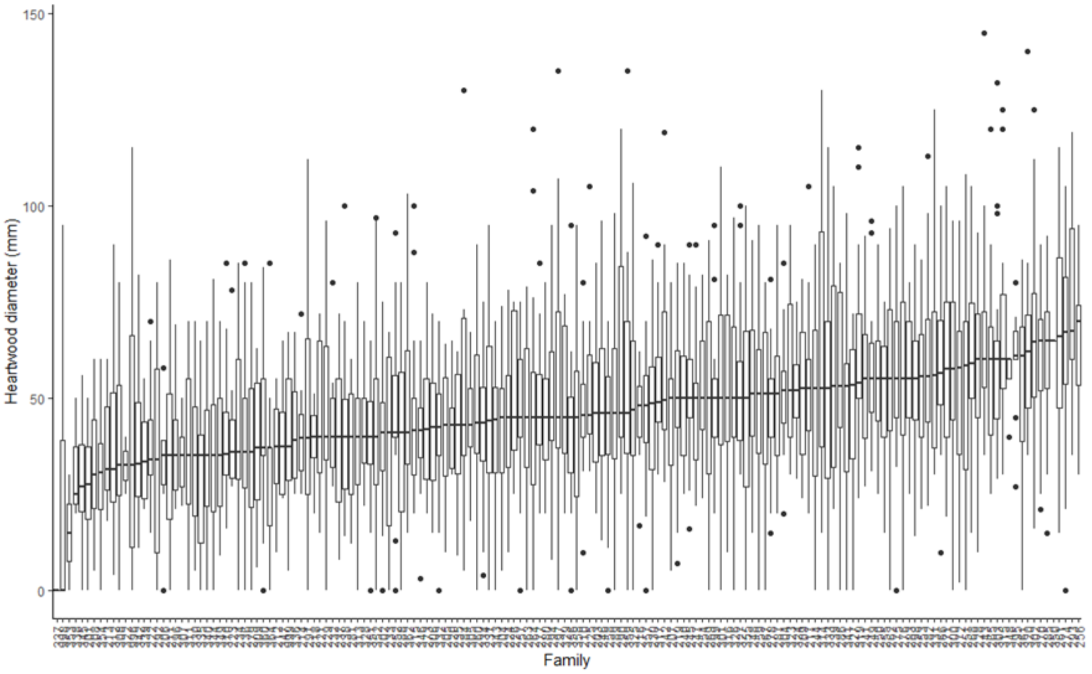

Figure 6: Boxplot of heartwood diameter of E. globoidea families at Avery at 9.5 years old ranked by mean

The heritability estimate for heartwood extractive content was h^2 = 0.49 (CI_{95} 0.35, 0.63) (Table 1, Figure 7), which is similar to the heritabilities for heartwood extractives in the class 1 ground-durable *E. bosistoana* (h^2 = 0.2 to 0.4) at age 7 years old (Li et al. 2018) and *E. cladocalyx* (h^2 = 0.25) at age 8 years old (Bush et al., 2011). However, the heritability estimate of >1 for extractive content previously reported for *E. globoidea* (SWP-T092), suggested deviation of the true relatedness of the trees in the trial from the assumed half-siblings, an observation made also for *E. bosistoana* (Li et al., 2018).

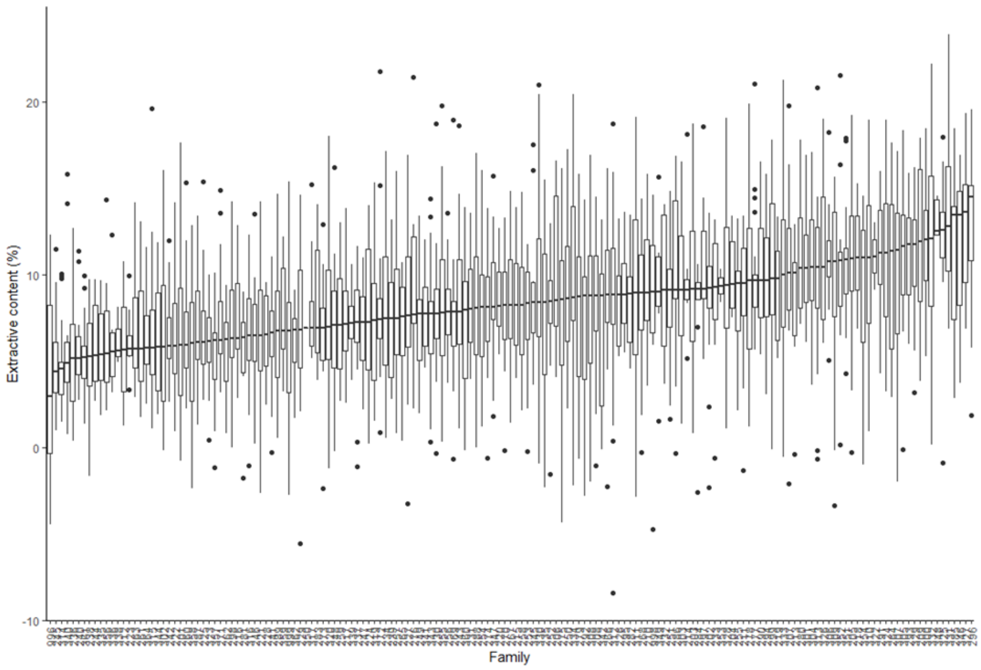

Figure 7: Boxplot of predicted extractive content in heartwood of E. globoidea families grown at Avery at 9.5 years old

Correlation between traits

Genetic correlations between the traits have been determined (Table 2). The main traits of interest are extractive content (i.e. natural durability) and heartwood diameter (i.e. heartwood quantity). The heartwood diameter had a strong and positive correlation (0.88; CI_{95} 0.70, 0.95) to core length indicating that in general larger trees also have more heartwood. Other trials (SWP-T028, SWP-T046) had similar correlation (i.e. *E. globoidea* Atkinson 2011 trial: 0.90) between these traits. While some NZDFI trials had weak (*E. bosistoana* 2012 JNL Ngaumu: 0.16) correlation between heartwood diameter and core length.
Heartwood diameter had a weak and unfavourable (-0.23; CI_{95} -0.38, -0.05) correlation to extractive content, similar to what was reported previously for the *E. globoidea* trial at Atkinson (-0.44; CI_{95} -0.62, -0.25). This implies that the heartwood quantity and extractive content need to be independently selected in the breeding programme. It is worth noting that heartwood diameter was favourable correlated to extractive content in most of the *E. bosistoana* trials suggesting that trees with larger quantities of heartwood also tend to have a more extractives.

Table 2: Genetic correlation between heartwood traits for 9.5-year old E. globoidea at Avery (95% CI in brackets)

Traits	Heartwood diameter	Sapwood diameter	Extractive content
Core length	0.88 (0.70, 0.95)	0.74 (0.70, 0.85)	-0.39 (-0.49, -0.20)
Heartwood diameter		0.35 (0.21, 0.51)	-0.23 (-0.38, -0.05)
Sapwood diameter			-0.48 (-0.70, 0.86)

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