Technical Report

Assessment of *Eucalyptus globoidea* heartwood at Ngaumu

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EXECUTIVE SUMMARY

The third (JNL Ngaumu) of three *E. globoidea* breeding trials has been phenotyped for heartwood properties (Milestone M10 Workplan SWP-WP130). The results were comparable to the assessment of the previous *E. globoidea* trials at Avery and Atkinson. The data has been loaded into the NZDFI Katmandoo 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.

Analysis of the combined data for the 3 breeding trials is currently underway in order to identify GxE interactions as well as investigate if certain topographic features correlate to heartwood properties.

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 fast growth potential 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 JNL Ngaumu in 2011 for heartwood quality and quantity.

METHODS

Trial

An open-pollinated progeny trial of 115 *E. globoidea* families was established in 2011 at JNL Ngaumu, Wairarapa, New Zealand. The trial site was located at latitude - 41° 2' 17" S, longitude 175° 52' 33" E. 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 240 blocks with 30 trees in each block and a different number of individuals per family ranging from 39 to 89, totalling 7,110 trees. The spacing of the trees was 2.4 m × 1.8 m.

The trial was assessed for height in May 2013 at age 1.7 years. In June 2017, at the age of 5.8 years, the trial was assessed for DBH, form and flowering. There was a large variation within the site in terms of growth, some of the blocks did not perform well and were overtaken by gorse. The DBH was measured on randomly selected trees for coring in May 2021.

Sampling strategy

Up to 12 trees with a diameter (DBH measured in year 2017) above 30 mm were randomly selected from each family for sampling. It was realised during labelling the trees for coring in May 2021 that not all selected trees were alive. Some more trees were added to the selection based on availability particularly the families with fewer individuals. But still there were families with only 1 to 2 individuals, in total 929 trees were cored.

Coring

A bark to bark 14 mm diameter core including the pith was extracted using a purpose-built corer from the 929 trees in June 2021 at ~0.5 m stem height (Figure 2). The cores were labelled and packed into plastic bags to avoid drying during the day.

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 1). Additionally, the length of the core (without bark) was measured.

Figure 1: *E. globoidea* cores with heartwood dyed pink after application of methyl orange.

Heartwood quality (Extractive content)

Extractive content was predicted from Near Infrared (NIR) spectra. Spectra was taken on the sanded tangential-radial surface of the oven-dried cores (60°C for a week) using a fibre optics probe. Irrespective of heartwood length only a maximum of six measurements were taken every 0.5 cm starting from the pith in the heartwood region. Heartwood extractive content of each NIR measurement was predicted with a previously developed method and the average heartwood extractive content for the tree was calculated by averaging the radial values.

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 JNL Ngaumu site at age 9.8 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.*8* 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)***
DBH (mm)	170.4	39.6	71.0	285.0	23.2	24.5	1.10 (1.07-1.13)
Core length (mm)	121.0	34.9	38.0	230.0	28.8	33.2	1.33 (1.01-1.62)
Heartwood diameter (mm)	80.1	30.2	0.0	174.0	37.8	41.8	1.23 (0.91-1.51)
Sapwood diameter (mm)	40.9	13.7	5.0	100.0	33.6	22.5	0.45 (0.21-0.65)
Extractive content (%)	2.7	1.6	0.5	25.2	58.5	37.8	0.42 (0.24-0.59)

Core length

Core length was correlated to DBH (Figure 2) and the correlation was similar to that found earlier in *E. globoidea* trials (SW-T092, SWP-T131). The heritability for both DBH (h^2 = 1.10) and core length (h^2 = 1.33) was higher than 1, suggesting deviation of the true relatedness of the trees in the trial from the assumed half-sibling families. The heritability estimate for core length (h^2 =1.33) was also higher than estimated in previously reported *E. globoidea* trials (SWP-T092 (h^2 =0.67), SWP-T131 (h^2 =0.88)). Family rankings for core length are displayed in Figure 3. As expected core length was positively correlated to heartwood diameter (Figure 4)

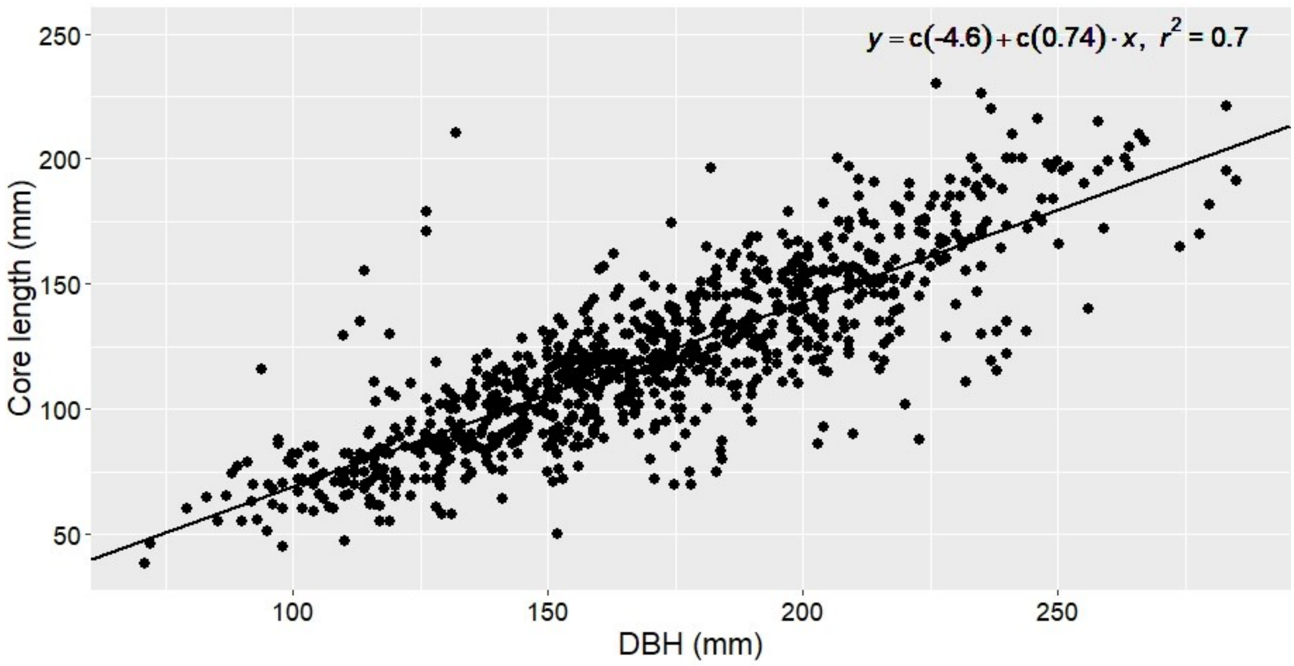

Figure 2: Relationship between core length and DBH for *9.8 years old* E. globoidea at *JNL Ngaumu*

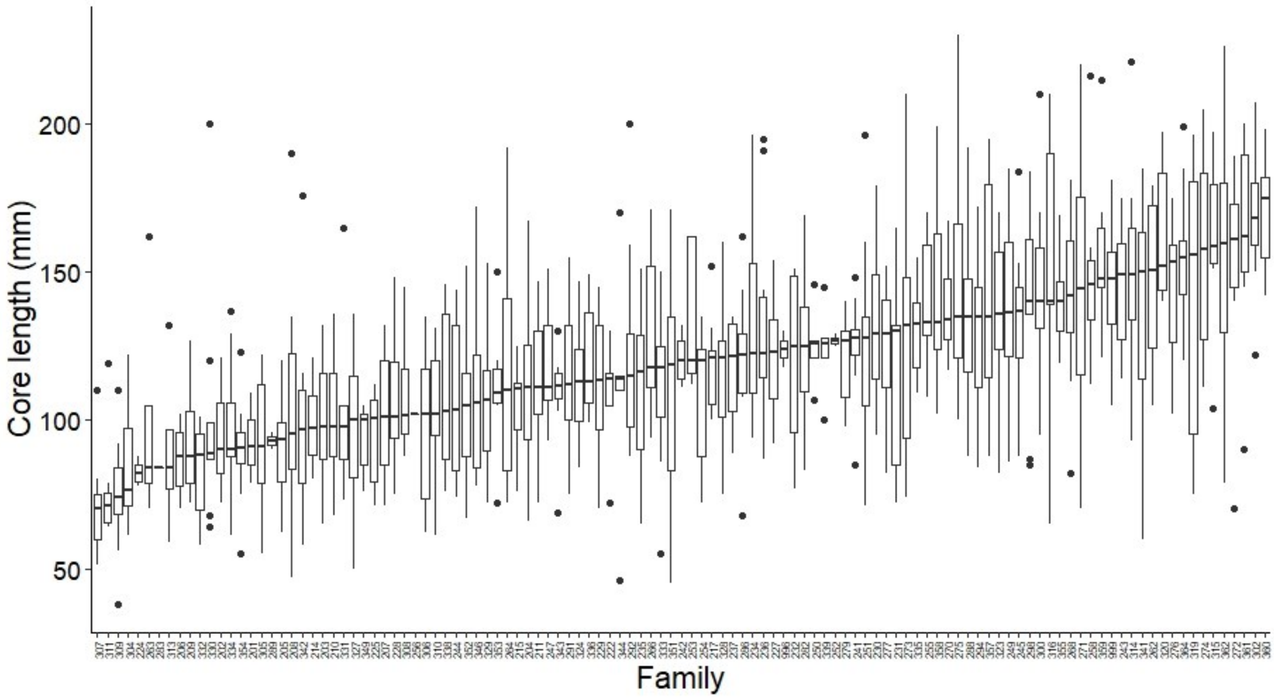

Figure 3: Boxplot of core length of 9.8 years old *E. globoidea* families at JNL Ngaumu, ranked by median

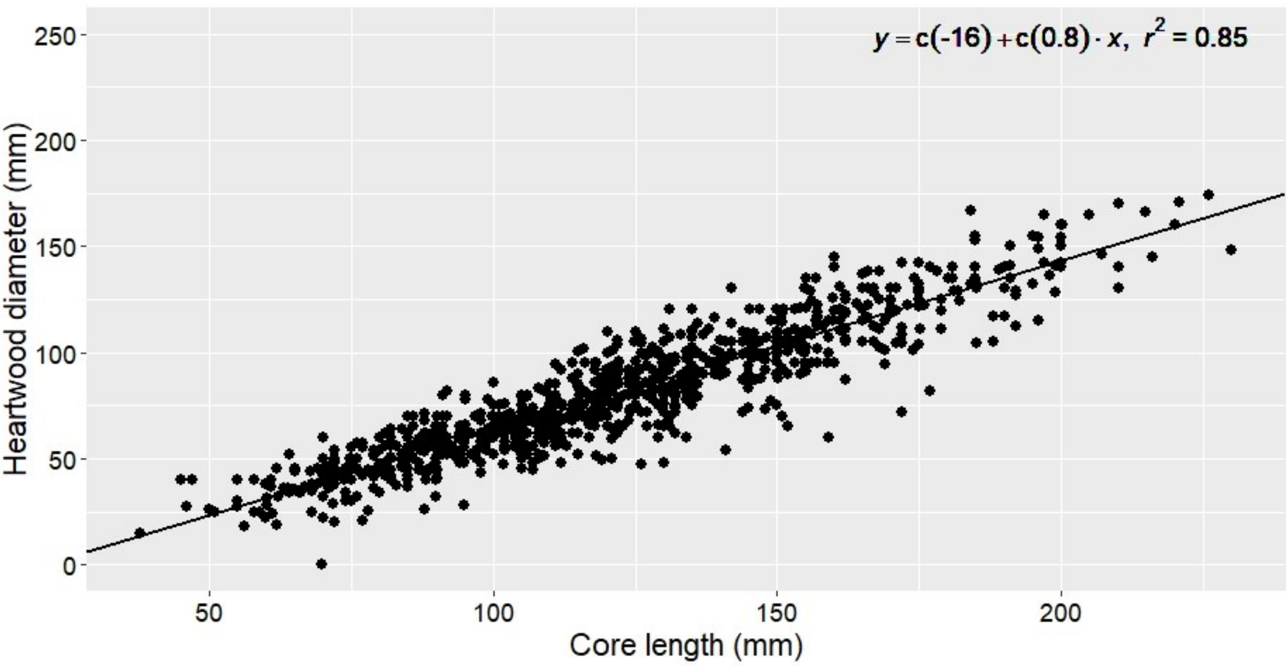

Figure 4: Relationship between core length and heartwood diameter for 9.8 years old *E. globoidea* at JNL Ngaumu

Heartwood quantity and quality

The coefficient of phenotypic variance (CPV = 37.8%) in heartwood diameter was between the values reported for 8 year old *E. globoidea* at Atkinson (SWP-T092, CPV = 28.9%) and 9.5 year old *E. globoidea* at Avery (SWP-T131, CPV = 48.6%). Heartwood heritability h^2 = 1.23 (CI_{95} 0.91, 1.51) was also higher to that found in the other two *E. globoidea* breeding trials (SWP-T092; h^2 = 0.52 (CI_{95} 0.36, 0.67) and SWP-T131; h^2 = 0.47 (CI_{95} 0.33, 0.60)). Family rankings for heartwood quantity are displayed in Figure 5.

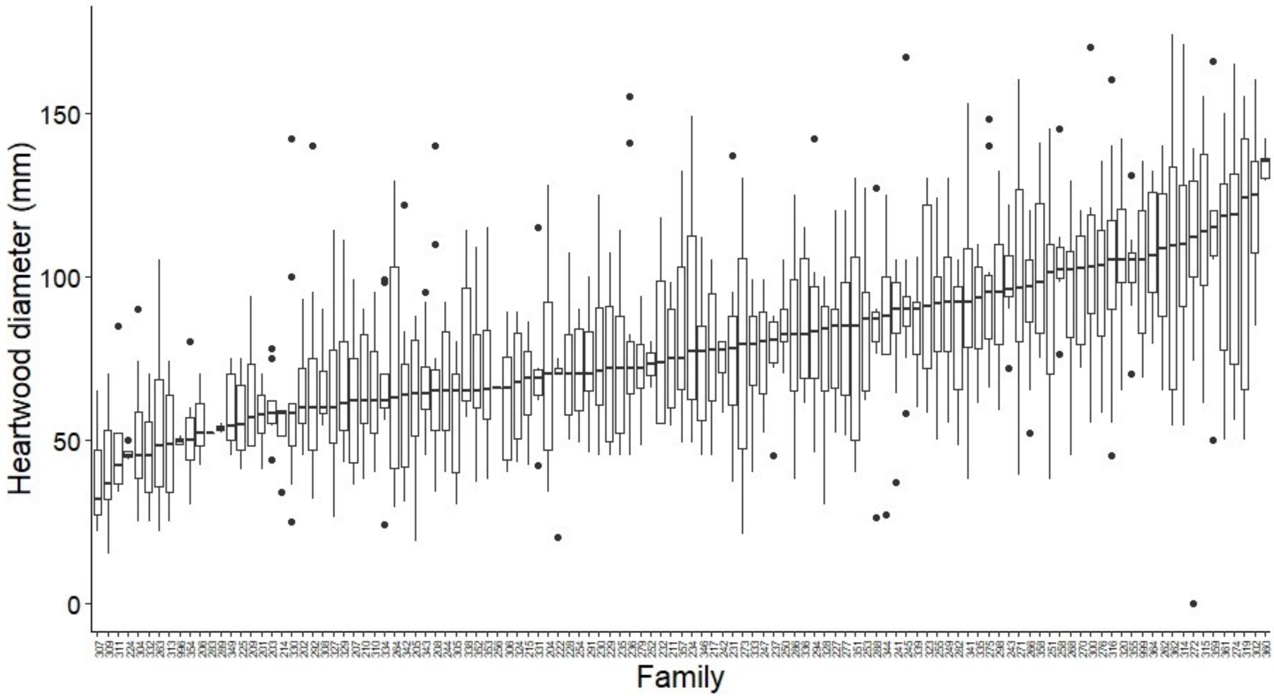

Figure 5: Boxplot of heartwood diameter of 9.8 years old *E. globoidea* families at JNL Ngaumu ranked by median

The heritability estimate for heartwood extractive content was h^2 = 0.42 (CI_{95} 0.24, 0.59) (Table 1, Figure 6). The heritability was comparable to that reported for the *E. globoidea* trial at Avery (SWT-131; h^2 = 0.49 (CI_{95} 0.35, 0.63)). Similar heritabilities for heartwood extractives were found 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). The heritability estimate of >1 for extractive content previously reported for *E. globoidea* at Atkinson (SWP-T092) was likely an effect of the number of spectra taken per core. In Atkinson, spectra was taken along the entire length of heartwood whereas in Avery and JNL Ngaumu only a maximum of six spectra were taken irrespective of heartwood length.

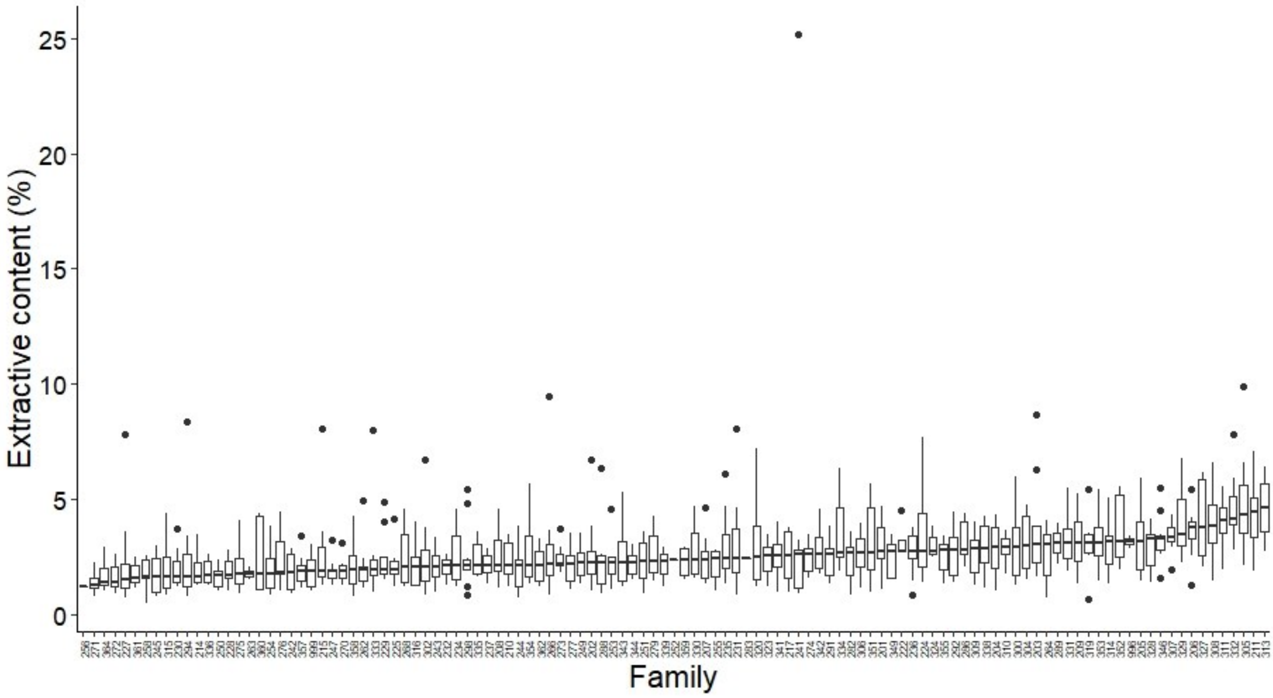

Figure 6: Boxplot of predicted extractive content in heartwood of 9.8 years old *E. globoidea* families grown at JNL Ngaumu

Genetic 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 (0.99; CI_{95} 0.90, 0.98) to core length indicating that in general larger trees also have more heartwood. Other *E. globoidea* trials (Atkinson 2011: 0.90, Avery 2011: 0.88) had similar correlation (i.e.) between these traits. Heartwood diameter had a strong and unfavourable (-0.76; CI_{95} -0.96, -0. 57) 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 it is difficult to find trees with good and a lot of heartwood.

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

Traits	***Core length***	***Heartwood diameter***	***Sapwood diameter***	***Extractive content***
DBH	0.96 (0.93-0.99)	0.94 (0.90-0.98)	0.87 (0.69-1.04)	-0.69 (-0.90- -0.49)
Core length		0.99 (0.98-1.00)	0.84 (0.70-1.00)	-0.79 (-0.96- -0.63)
Heartwood diameter			0.77 (0.53-1.00)	-0.76 (-0.96- -0.57)
Sapwood diameter				-0.84 (-1.10- -0.58)

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