Technical Report

Assessment of NZDFI's 2016 *Eucalyptus quadrangulata* breeding population at NZRC Paparoa

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EXECUTIVE SUMMARY

This report concerns the phenotyping of NZDFI's *E. quadrangulata* 2016 breeding population at NZRC Paparoa for heartwood and predicted extractive content.

Heartwood diameter was not genetically correlated to tree DBH but negatively to sapwood diameter. This would suggest that DBH cannot be used as proxy to select for heartwood quantity.

Genetic control of heartwood quantity (heartwood diameter) and quality (i.e. predicted extractive content) was inconclusive. The weak colour discrepancies of methyl orange treated cores on the dry state and low heartwood extractive content contributed to the larger uncertainty in these values.

INTRODUCTION

The New Zealand Dryland forests Initiative (NZDFI), aims to establish a domestic, sustainable, natural durable hardwood industry (Millen et al., 2018). To achieve this the NZDFI has established a breeding program to deliver well performing planting stock. In addition to fast growth and improved form, favourable wood properties are key objectives in the breeding program to produce high-value timber. 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. quadrangulata* is a class 2 ground durable timber (Bootle 2005) and one of several Eucalyptus species developed by NZDFI.

Heartwood quality and quantity are key wood properties for the envisaged utilisation of *E. quadrangulata* and are therefore included in 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 spectroscopy (RMSE ~1%) (Technical report SWP-T040, Li & Altaner, 2019) and that EC is highly variable (1 to 20%) in other NZDFI eucalypt species.

The NZDFI *E. quadrangulata* breeding populations consists of two trial series. The first series was planted in 2011 at four sites, McNeil (Hawke's Bay), Cuddon (Marlborough), Trimble (Wairarapa) and Martins (Canterbury). The Martin and Trimble trials was later abandoned due to poor survival and growth resulting from poor drainage. The second series was planted in 2016, NZRC Paparoa (Horizons), Webb and Bradshaw (Marlborough). The Webb trail was not successful due to animal damage and was abandoned.
The first open-pollinated breeding population of *E. quadrangulata* was established in a series of progeny trials to evaluate the differences between individual families. NZDFI's aim is for each breeding population to test a minimum of 100 families per species, however, poor flowering in Australia restricted the number of seedlots available at that time to ~20 families. This breeding population of *E. quadrangulata* was extended in 2015 when Proseed obtained a further 88 families from ATSC and Forestry Corporation. 83 Families produced seedlings for field testing in 2016. The University of Canterbury deployed 64 seedlings per family for the UC SFF growth strain testing programme based at Murrays Nursery, Woodville (Altaner 2019).

The objective of this work was to phenotype the 72 families of *E. quadrangulata* breeding populations planted at NZRC Paparoa for heartwood quantity and quality.

METHODS

Trial

An open-pollinated *E. quadrangulata* family progeny trial was established in 2016 at NZRC Paparoa, Horizons. 86 blocks with 36 trees in each block were planted in a single-tree plot design. The trial consists of 72 families with 43 individuals per family and was assessed for height at age 2.7 years in May 2019 as well as DBH at the age of 3.9 years in August 2020.

Sampling strategy

A maximum of 10 surviving trees with a diameter (DBH) above 65 mm were randomly selected from each family. During labelling the trees for coring it was noticed that some of the selected trees were dead. A total of 656 trees were cored in February 2022, including 7-10 individuals per family with one family represented only with 4 individuals. The selected trees were measured again for DBH at the time of coring.

Coring

A bark to bark 14 mm diameter core including the pith was extracted using a purpose-built corer at ~0.5 m stem height. 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 never-dried, fresh cores into an aqueous 0.1% solution of methyl orange that changed heartwood colour to pink, while the sapwood remained unchanged. Additionally, the length of the core (without bark) was measured.

Heartwood quality (extractive content)

The core samples were then oven-dried at 60°C to constant weight. 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. Measurements were taken every 0.5 cm in the heartwood region. Heartwood extractive content of each NIR measurement was predicted with a previously developed calibration (Li & Altaner, 2016) 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 package (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 effect 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. quadrangulata* breeding population at Paparoa at age 5.5 is 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 and heritability (h^2) (95% confidence interval in brackets - 95% CI spanning 0 are coloured grey) for E. quadrangulata (NZRC Paparoa) at age 5.5 years. CPV: Coefficient of phenotypic variation; CGV: Coefficient of genetic variation.

Trait	Mean	Standard Deviation	Min	Max	CPV (%)	CGV (%)	h^2 (r_c = 0.25)
DBH (mm)	**101.72**	**19.72**	**54**	**175**	**19.39**	**5.52**	**0.08 (-0.07,0.24)**
Core length (mm)	**97.64**	**19.34**	**52**	**158**	**19.82**	**5.71**	**0.08 (-0.08,0.25)**
Heartwood diameter (mm)	**35.19**	**25.36**	**0**	**110**	**72.08**	**35.72**	**0.25 (0.05,0.47)**
Sapwood diameter (mm)	**62.51**	**21.37**	**0**	**140**	**34.19**	**14.41**	**0.17 (-0.01,0.35)**
Extractives content (%)	**1.91**	**0.80**	**0.71**	**10.68**	**41.88**	**4.71**	NA

Tree diameter

Trees grew faster on the NZRC Paparoa site than in the previously assessed trials. Tree DBH (101.7 mm) and core length (97.6 mm) at age 5.5 years (Table 1) was comparable to two ~9-year older *E. quadrangulata* trials assessed at Cuddon (DBH 105.1 mm; core length 95.6 mm) and McNeil (DBH 113.3 mm; core length 99.9 mm). The phenotypic correlation (Figure 1) between core length and DBH was also similar and consistent with what was found for other NZDFI species.

The coefficients of genetic variation for both DBH and core length (Table 1) for the 2016 *E. quadrangulata* breeding population were comparatively lower than those observed for the 2011 breeding population (Cuddon: DBH 14.01; core length 11.83 and McNeil: DBH 10.15 and core length 9.08). This was surprising as the 2016 population included on ~20 families while the 2016 population included ~80 families. Also, unexpectedly, the typically heritable tree diameter traits (DBH: h^2 = 0.53 and 0.15; core length h^2 = 0.39 and 0.14 for Cuddon and McNeil, respectively) were not under genetic control in this trial (Table 1).

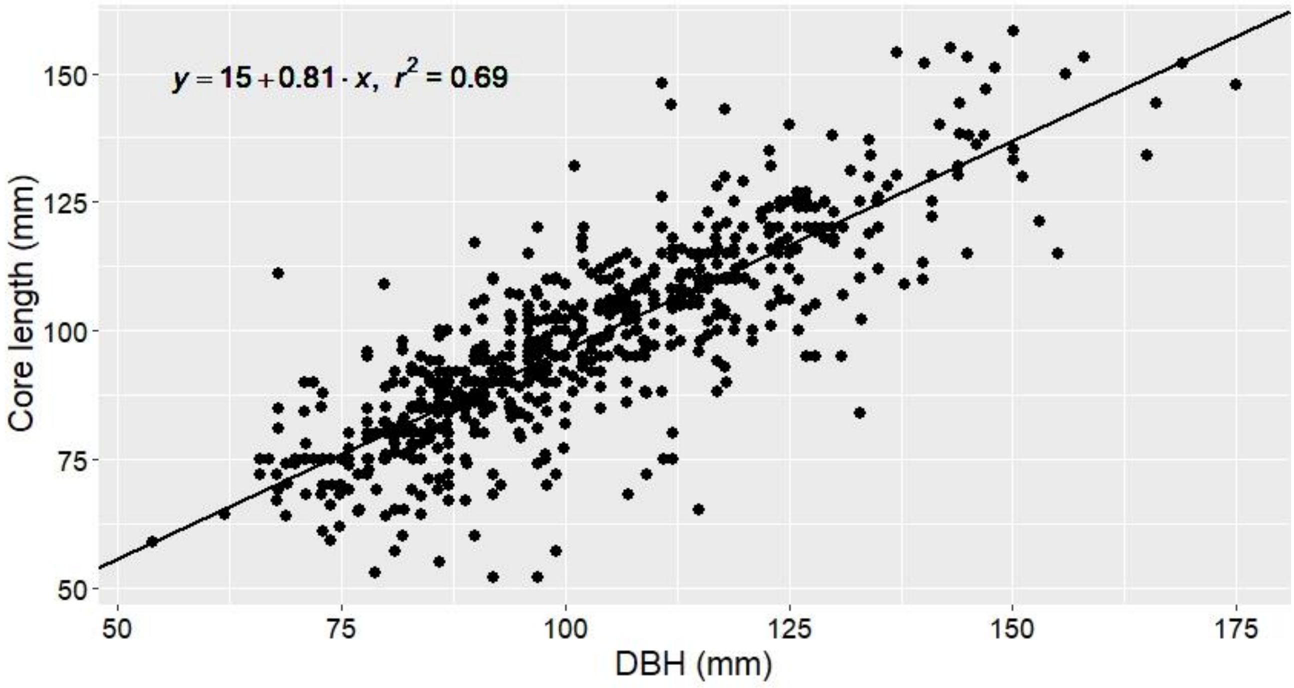

Figure 1: Relationship between core length and DBH for E. quadrangulata aged 5.5 years at NZRC Paparoa

Heartwood quantity

The pink colour in the heartwood region due to application of methyl orange in green state was not very prominent in dry samples. In most of the cores even in the green state, the region close to pith was either with no colour or with very faint colour in comparison to region closer to the transition zone. Nevertheless, heartwood diameter was measured from transition zone to transition zone including the non or faintly stained zone around the pith. Heartwood diameter heritability was comparable to that of the Cuddon site (h^2=0.27).

Heartwood quality

As expected due to less prominent colouration of heartwood region the extractive content predicted using NIR spectra was very low. The extractive content was not heritable (Table 1). This was consistent with previously assed *E. quadrangulata* trials at age ~9 years old.

Genetic correlation between traits

Genetic correlations between the traits have been determined (Table 2). Consistent with DBH being not heritable (Table 1), no correlations were observed between DBH and core length or heartwood diameter. For context, strong correlation were found for the 2011 *E. quadrangulata* trials (Cuddon: 0.99; McNeil 0.95).

A strong negative correlation was found between sapwood diameter and heartwood diameter, consistent with the 2011 *E. quadrangulata* trials (Cuddon: -0.85; McNeil -0.86). This implies that trees with more heartwood tend to have less sapwood. These results differed to that reported for *E. bosistoana* (Li, Apiolaza et al. 2018) and *E. globoidea* (SWP-T092) where sapwood diameter was positively correlated to heartwood diameter.

Similarly to DBH, the heartwood extractive content in this trial was not heritable and not correlated to other traits.

Table 2: Genetic correlation between traits for 5.5 year old E. quadrangulata at NZRC Paparoa (95% CI in brackets – values with a 95% CI spanning 0 are coloured grey.

Traits	Core length	Heartwood diameter	Sapwood diameter	Extractive content
DBH	0.44 (-0.55,1.52)	0.59 (-0.07, 1.27)	-0.50 (-1.73, 0.66)	NA
Core length		0.78 (0.20, 1.36)	-0.43 (-1.69, 0.82)	NA
Heartwood diameter			**-0.91 (-1.18, -0.65)**	NA
Sapwood diameter				NA

CONCLUSION

Analysis of DBH data showed surprising results, as the trait was not heritable but phenotypically correlated to core length, suggesting correctness of the data.
Core data was consistent with previous assessments of *E. quadrangulata*:

- a negative correlation between heartwood and sapwood diameter and
- low and not heritable levels of heartwood extractives.

The low heartwood extractive levels might be a consequence of the young age of the trees when assessed and another assessment when more heartwood has formed should be considered.

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