Screening *Eucalyptus bosistoana* for Heartwood

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EXECUTIVE SUMMARY

Some eucalypts produce timber of highest natural durability and rich colour. Only the heartwood of trees can have these properties. However, the amount and quality of heartwood in trees is highly variable. Aim of this project is to produce such high value timber sustainably in New Zealand. At the heart of the initiative is a breeding programme to establish a resource of healthy trees which form quality timber. Breeding populations of *Eucalyptus bosistoana* and other species have been established in New Zealand since 2009. These trees are now of an age where they start to form heartwood. The first step in ensuring a quality resource is to core these trees to obtain samples which enable the assessment of heartwood amount and heartwood properties. A motorised coring tool has been developed with Callaghan Innovation, which allows to extract quickly (~1 min) a larger (~14 mm diameter) core from these small diameter trees leaving only a small (~20 mm diameter) wound. A motorised tree corer is currently not manufactured anywhere in the world and commercialisation of the tool is currently explored.

1119 7 year old *E. bosistoana* trees from 2(3) sites have been cored and analysed for heartwood quantity. Generally bigger trees had more heartwood (R^2 ~0.5) but there are many large trees with little heartwood. This implicates that the largest trees are not necessarily the most valuable. A site influence was also found. The site with the fastest growth did not have the most heartwood. This has implications for growth models if heartwood is the targeted product. It has also been shown that there is variation in heartwood content between the families. This indicates a potential of improving further generations by selection.

Analysis of the cores for extractive content by NIR has been commenced.

INTRODUCTION

New Zealand is known for radiata pine (*Pinus radiata*) plantations, a non-durable timber. Naturally durable timbers mainly come from tropical forests, which due to their high quality and decreasing supply are highly priced. In order to protect non-durable timbers against decay, wood preservatives are used. One of the most widely used wood preservative in New Zealand is the inorganic water-based preservative chrome-copper arsenate (CCA). But, wood preservatives give rise to environmental problems (Townsend et al. 2003). To meet the future demand of durable timber and to reduce the environmental pollution, forest plantations of naturally durable species can be established.

Currently, over $30 million of sawn hardwood timber and $240 million of wooden furniture are imported by New Zealand annually as a result of a lacking suitable domestic resource (Nicholas and Millen 2012). There is a large demand for wood which is renewable and eco-friendly as an architectural material (Cannon and Innes 2008). However, the diversity of natural durability or extractives within a tree species is significant (Gutiérrez, 1999).

Some eucalyptus species have high natural durability. *Eucalyptus bosistoana* has good natural durability, fast growth rate and is able to grow in New Zealand's climate (NZDFI). *E. bosistoana* can grow up to 30-40 m in height, and usually has excellent stiffness, high density and hardness. *E. bosistoana* has rarely been subject to a published scientific study, despite its reported excellent wood properties. Furthermore the species has never been in a genetic improvement program and can be considered wild.

Heartwood is the inner part of a tree stem which has the desired wood properties (Hillis 1987). The outer wood layers contain living cells and are called sapwood. The inner sapwood rings are eventually converted into heartwood. A large number of chemicals can arise during the change from sapwood to heartwood which can make the heartwood rich in extractives (Da Costa and Rudman 1958; Taylor et al. 2002). In some tree species, heartwood can be highly resistant against biological decay. Heartwood extractives can also provide rich colour to the wood. These features can significantly increase the value of timber. Amount of heartwood and heartwood properties like natural durability or colour vary significantly within species due to genetics, environment and tree age (Zobel and Jett, 1995). Breeding can be a good way to reduce variability.
The amount of extractives in the heartwood is the most important factor that influences the natural durability (Anderson et al. 1962). The traditional methods to determine natural durability or the extractive content are time and cost consuming (Anonymous 2007).

There are different ways to determine the quantity of extractives in heartwood and the sapwood/heartwood ratio. Near infrared spectroscopy (NIR) is a non-destructive technique that is used for the analysis of agricultural products including wood (Baillères et al 2002). It has been used to determine the quantity of heartwood extractives in some tree species (Taylor et al. 2011; Geladi et al. 2014). We have previously demonstrated that NIR can be used to analyse heartwood extractives in *Eucalyptus bosistoana*. Replacing the traditional time- and cost consuming methods will have benefit for tree selection programs, which rely on the measurement of large numbers of samples.

METHODS

Materials

Eucalyptus bosistoana were planted by NZDFI in 2009 at Lawson's (subdivided into an East facing and a North facing slope) and Craven's Road in Marlborough. 67 families with ~75 replicates were planted. Trials were thinned and pruned. DBH measurements were available for all trees. For the Lawson's North site the 41 families with more than 4 surviving individuals were sampled (4-7 individuals / family), including the largest 3 DBH individuals. In the Lawson's East side a random sample of 6-12 individuals were probed. This included 59 families. Craven's Road sampling strategy was based on selecting the 3 largest DBH individuals of each family and a random sample from the remaining individuals per family. A total of 1-8 individuals was sampled on this site including 60 families. In total 1129 trees were cored from 67 families.

Coring

A coring system was developed with Callaghan Innovation (Figure 1). The tool is battery powered. This reduces fire risk compared to petrol driven machines. Cores (~14 mm in diameter) were taken at the bottom of the trunk (~0.5 m) to maximise heartwood content.

Figure 1: Top: Probing of an *E. bosistoana* tree with the battery powered corer developed for this project. Bottom: Corer and core.

Heartwood assessment

Heartwood was highlighted by applying methyl orange, a pH indicator, onto the cores in the green sate. This stained the heartwood pink. 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 was calculated as the difference between the 2 measurements.

RESULTS

Tree diameter

The length of the cores and the most recent DBH measurements of the trees have been compared. Differences were expected due to a) a time delay between the assessments during which the trees grew, b) the fact that DBH was measured over bark while the core length was measured under bark, c) taper as the cores where sampled at ~0.5 m height and d) that trees usually were not regular cylinders. Shrinkage was not the cause of variation as the cores where measured in the green state. Generally a good correlation between the 2 measurements was found (Figure 2), but some outliers were observed.

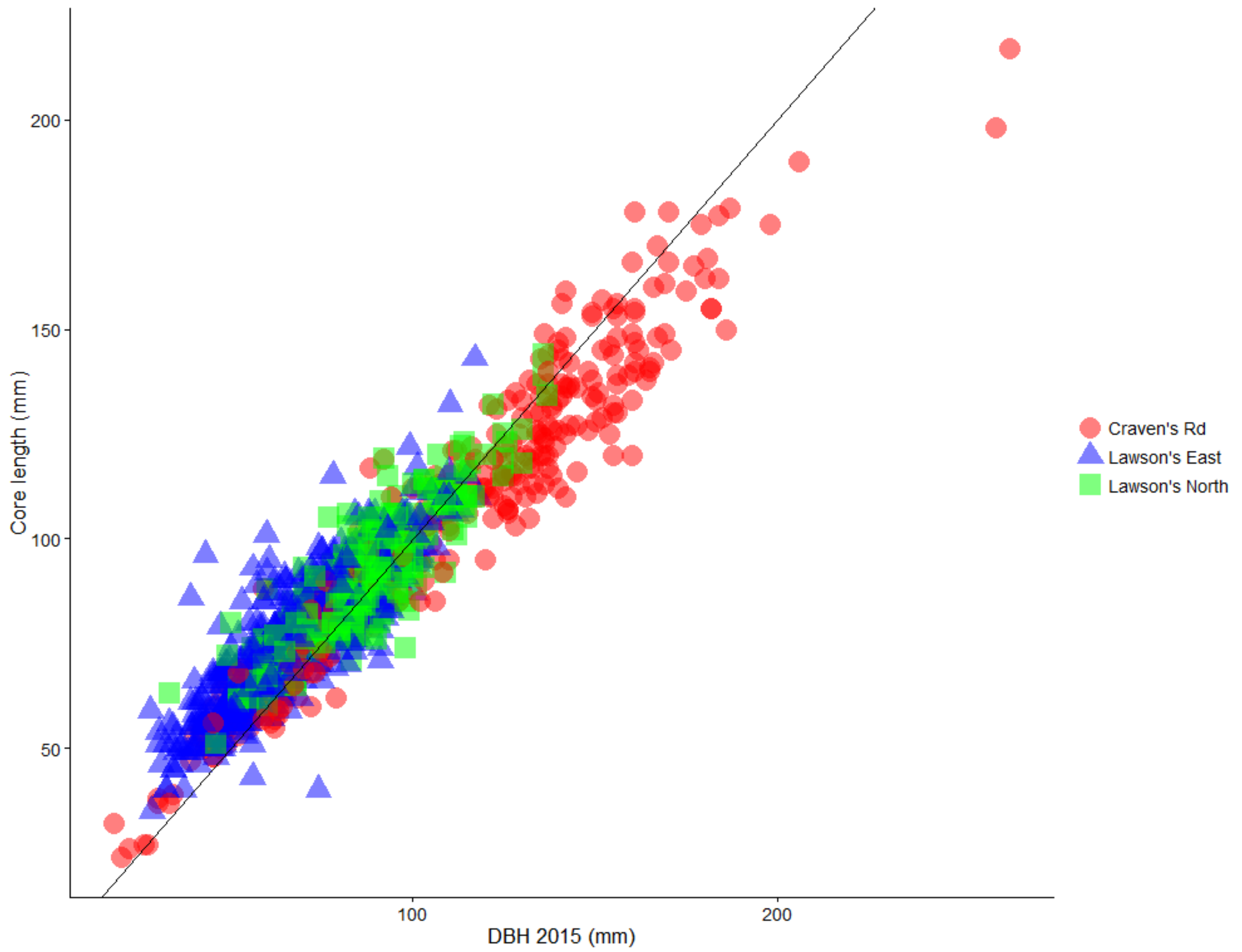

Figure 2: Correlation between most recent DBH measurement and core length

Comparing the 3 sites Craven's Road had with 104 mm the largest median core length followed by Lawson's North (91 mm) and Lawson's East (76 mm) (Table 1). This was matched by DBH values.

Table 1: Median heartwood, sapwood and tree diameters on sites for 7 year old *E. bosistoana*

	Lawson's East	Lawson's North	Craven's Road
Heartwood diameter (mm)	5	32	16
Sapwood diameter (mm)	64	60	81
Core length (mm)	76	91	104
DBH (mm)	66.8	88	105

Heartwood

682 of the 1119 *E. bosistoana* cores (60.9%) contained heartwood at age 7. The mean heartwood diameter over all 3 sites was 18.4 mm with a coefficient of variation (CV) of 1.14 (Table 2). A high variability is one of the requirements for successful breeding. The average sapwood diameter was 69.9 mm with a lower degree of variation.

Table 2: Summary statistics of 7 year old *E. bosistoana* grown in Marlborough, NZ

	Core length	DBH	Heartwood diameter	Sapwood diameter
Minimum (mm)	24	18	0	2
Maximum (mm)	217	264	113	175
Mean (mm)	88.36	84.3	18.4	69.9
CV	0.3	0.39	1.14	0.28
SD (mm)	26.7	33	20.9	19.5

CV: coefficient of variation, SD: standard deviation, DBH: diameter at breast height

The heartwood diameter was correlated to the core length (R^2 ~0.5) (Figure 3). Larger trees generally had more heartwood. But the largest trees not necessarily contained the most heartwood. This highlights the benefit of not only selecting the largest but the trees with the most heartwood. Simply growing the largest diameter trees will not result in the most valuable plantations if heartwood is the target product.

A relationship between tree diameter and sapwood width was only found for the Craven's Road site (Figure 4). An influence of site was also observed. While the trees at Craven's Road were of greater average diameter (median 104 mm) than those on Lawson's North (91 mm), the trees on Lawson's North contained more heartwood (32 mm) than those on Craven's Road (16 mm) (Table 1).

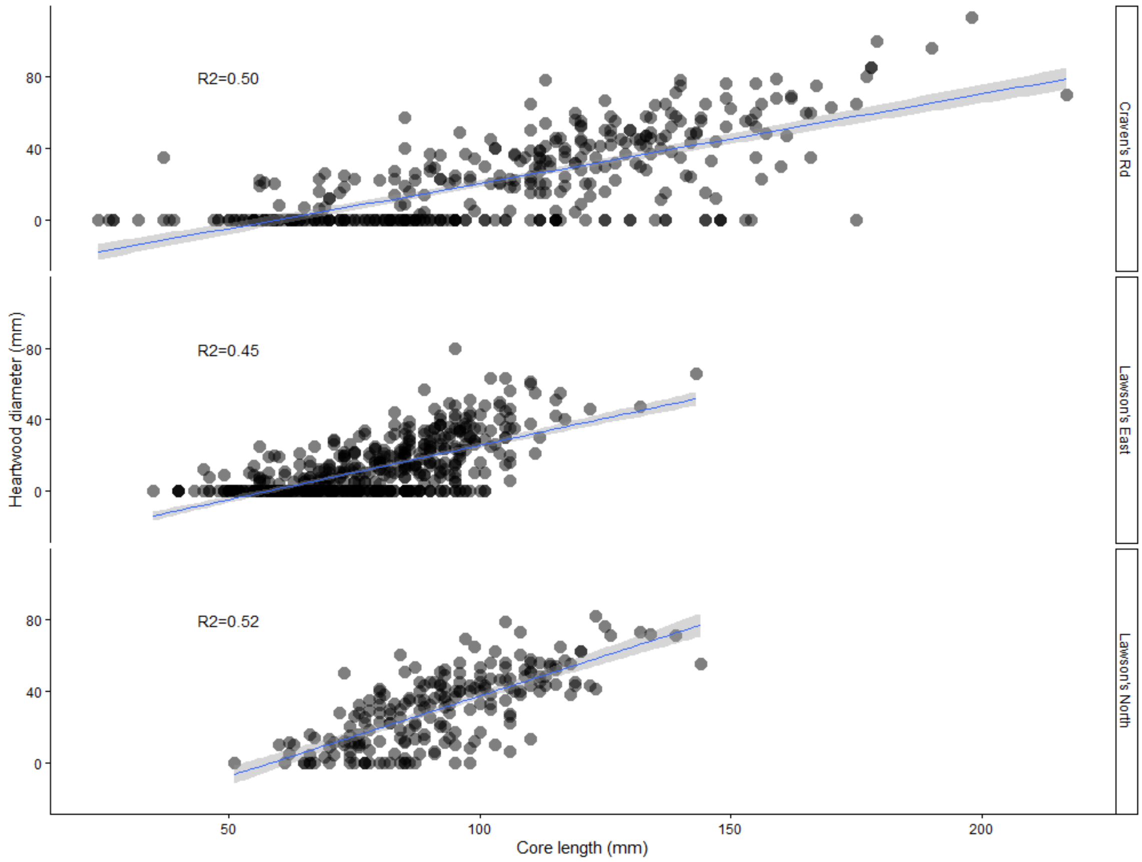

Figure 3: Heartwood diameter in relation to core length for 7 year old *E. bosistoana* on 3 sites

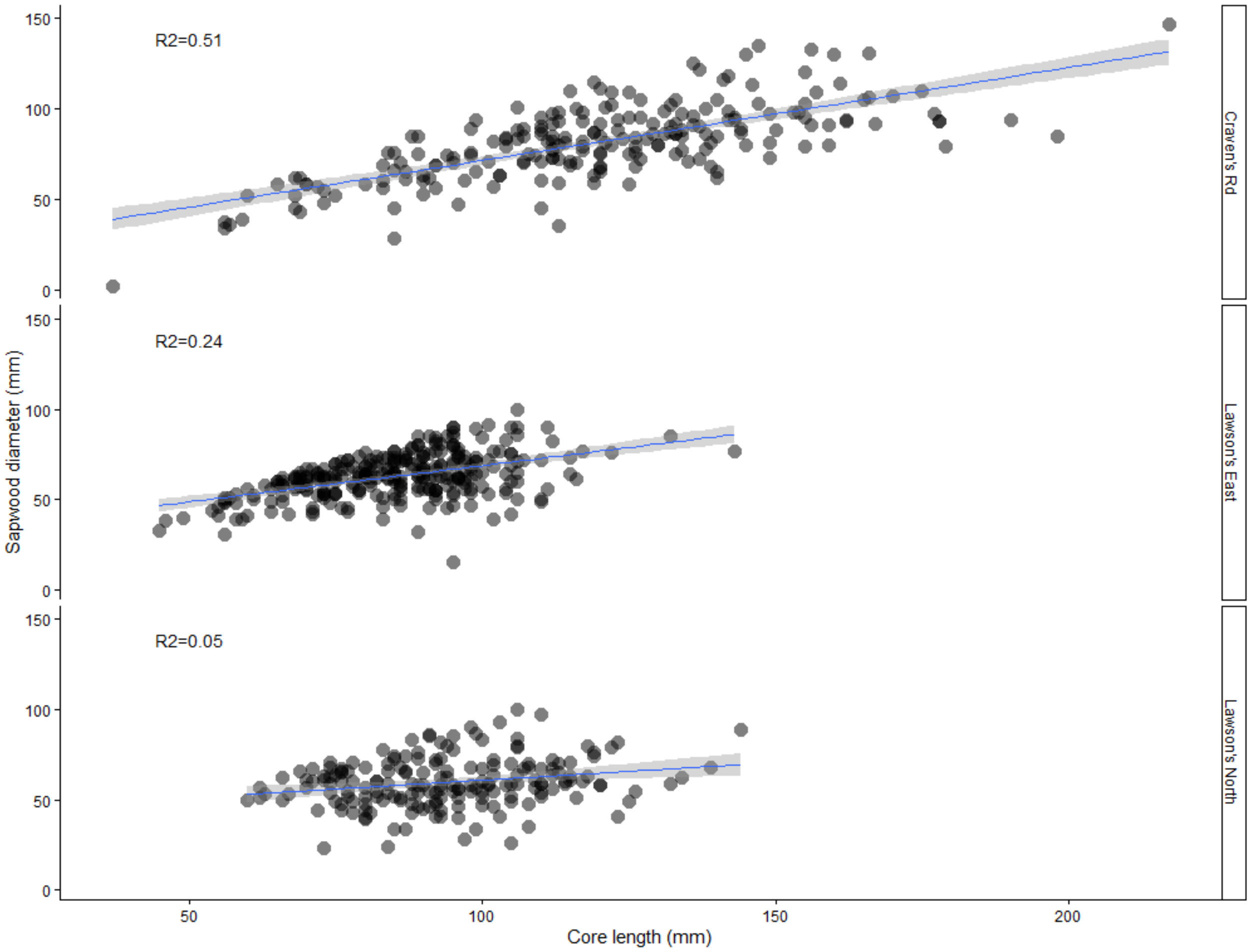

Figure 4: Sapwood diameter in relation to core length for 7 year old *E. bosistoana* on 3 sites

Family differences

Figure 5 shows the 67 assessed *E. bosistoana* families ranked for heartwood diameter at age 7 for all sites. A phenotypic variation in heartwood diameter was observed between the families. This is one of the requirements for genetic selection. A similar finding was observed for sapwood diameter and core length (Figures 6 and 7).

The Spearman correlations of the heartwood, sapwood and core length family rankings are presented in Table 3. Overall families producing bigger trees had also more heartwood (Spearman 0.67). They also tended to have a wider sapwood band. However, there was no correlation between the rankings for heartwood and sapwood diameter. Note: these numbers are dominated by the Lawson's east site as it contained most trees.

Table 4 reveals more differences between the 3 sites. The Lawson's East and Craven's Road sited followed the above described pattern. However, in Lawson's North, where the trees had the most heartwood but were not the largest trees, the sapwood diameter rankings were not correlated to the tree size rankings but negatively to the heartwood diameter rankings. Families with more heartwood tended to have less sapwood.

Table 3: Spearman correlations between heartwood, sapwood and core length family rankings for 7 year old *E. bosistoana* over 3 sites

	Heartwood diameter	Sapwood diameter
Core length	0.67	0.56
Heartwood diameter	1	-0.14

Table 4: Spearman correlations between heartwood, sapwood and core length family rankings for 7 year old *E. bosistoana* on 3 sites

	Lawson's East		Lawson's North		Craven's Road	
	HWD	SWD	HWD	SWD	HWD	SWD
Core length	0.64	0.51	0.72	0.09	0.69	0.71
Heartwood diameter	1	-0.24	1	-0.59	1	0.06

HWD = heartwood diameter, SW= sapwood diameter

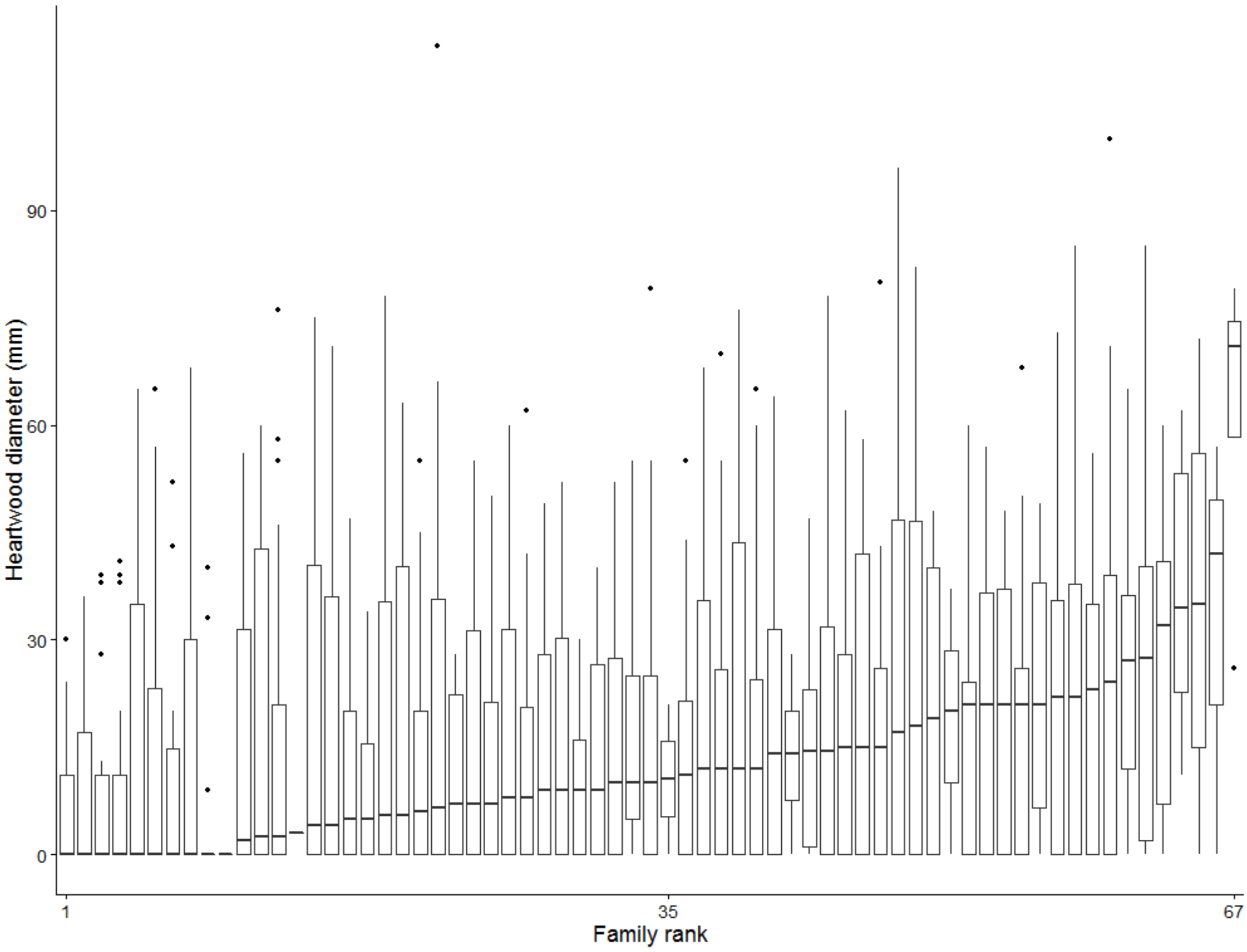

Figure 5: 67 families *E. bosistoana* ranked for heartwood diameter at age 7 on 3 sites

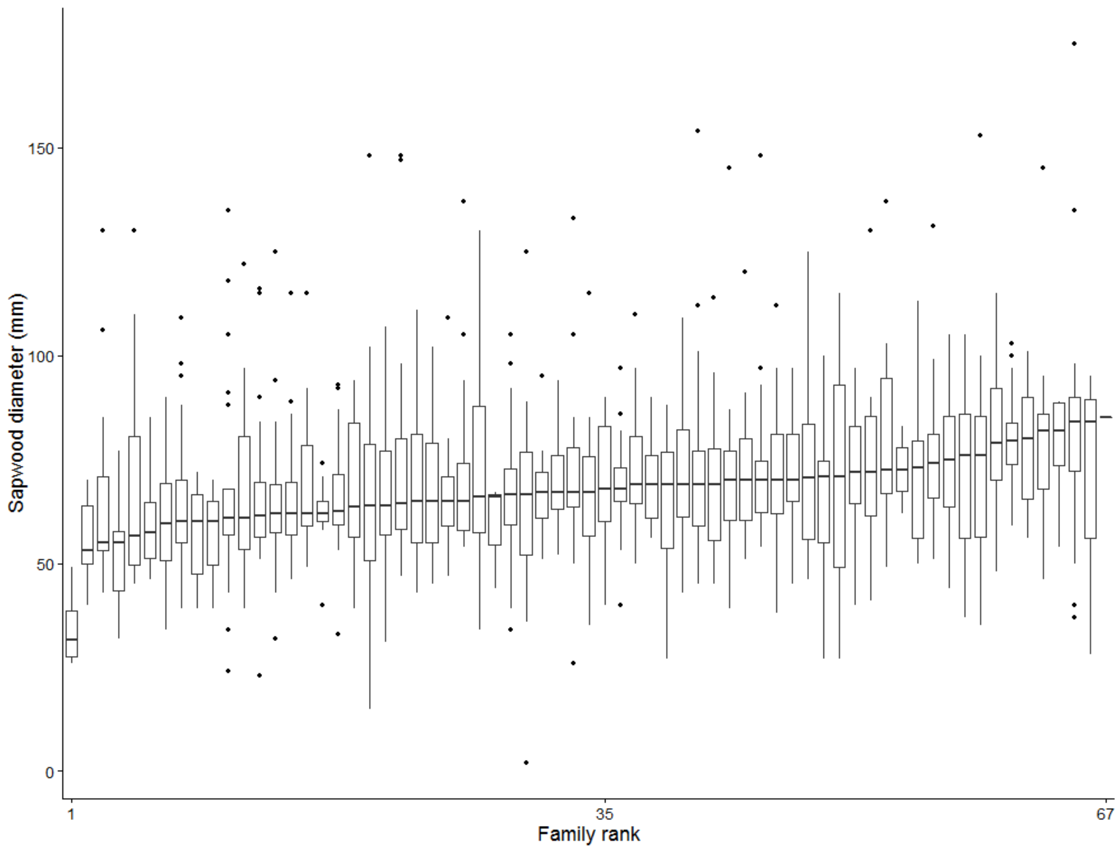

Figure 6: 67 families *E. bosistoana* ranked for sapwood diameter at age 7 on 3 sites

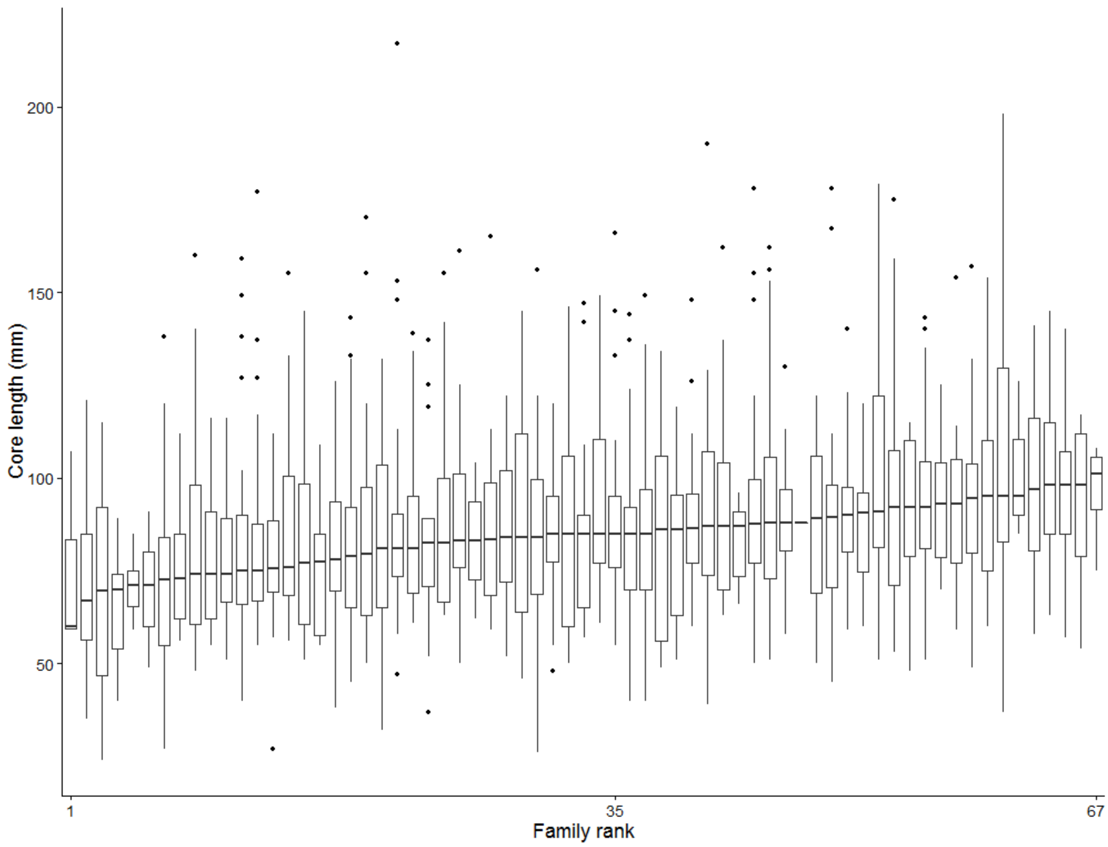

Figure 7: 67 families *E. bosistoana* ranked for core length at age 7 on 3 sites

CONCLUSION

- Core length was correlated to DBH measurements.
- The influence of site was different for tree growth (core length) than heartwood diameter, i.e. the site with the largest trees did not have the most heartwood.
- Phenotypic variation in heartwood diameter between the families was observed. This indicates potential to improve heartwood quantity in *E. bosistoana* by selection.

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