Assessment of *Eucalyptus macrorhyncha* wood properties from the NZDFI Waikakaho seedling seed stand

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TABLE OF CONTENTS

EXECUTIVE SUMMARY

Eucalyptus macrorhyncha is a species related to *E. globoidea* but more tolerant of colder climates. The opportunity to expand NZDFI's programme to colder sites with *E. macrorhyncha*, also depends on its wood properties. This work assessed basic density, heartwood quantity, extractive content and collapse on 36 stem cores comprising 5 *E. macrorhyncha* provenances grown at one NZ site.

The sapwood band was comparable in width to that of NZ-grown *E. globoidea* and was narrower than that of *E. bosistoan*a.

In line with other species, basic density of the young NZ-grown *E. macrorhyncha* timber was lower than the reported values for the Australian old-growth resource. However, Australian old-growth *E. macrorhyncha* is reported to be slightly denser than *E. globoidea*.

Collapse was present and comparable to that of NZ-grown *E. globoidea* timber. There were significant differences in collapse between *E. macrorhyncha* provenances.

While heartwood extractive content was predicted with an NIR calibration excluding *E. macrorhyncha*, there were significant differences between provenances. High collapse coincided with high extractive content.

BACKGROUND

E. macrorhyncha was first identified twenty years ago as a potential New Zealand plantation species and was subsequently established in a succession of regional trials. These trials demonstrated the site versatility and high natural insect tolerance of this species. It is reported to produce a light pink-brown-coloured heartwood (Ilic, 2002) with class 2 above-ground and class 3 in ground durable ratings (AS5604, 2005). Selection and improvement of *E. macrorhyncha* could diversify and extend the planting of durable hardwood forests to colder, dry New Zealand environments.

OBJECTIVE

Assess core samples to evaluate the quantity and quality of the heartwood, basic density, and collapse in *E. macrorhyncha.*

MATERIAL AND METHODS

Provenances

Proseed NZ and Marlborough Regional Forests established trials from 2003 to 2006 of Australian unimproved provenance seedlots to test *E. macrorhyncha.*
E. macrohyncha has been represented in NZDFI trials planted in 2011-2018 with over 50 PSPs located across ~20 sites.

A total of thirty-six cores were collected from 18-year-old trees in a seedling seed stand planted at Marlborough Regional Forests Waikakaho Forest with five unimproved Australian provenances. Ten of these are plus trees, from which seed has already been collected. In addition, twenty-six cores were collected from other trees of known provenances (*Table 1*).

Coring

A 14-mm-diameter core, including the pith, was extracted using a purpose-built corer from the 36 trees in October 2023 at ~0.5 m stem height (Figure 1). Most of the trees were 300-400 mm DBH; therefore, the cores obtained only went through to just past the pith. The cores were labelled, packed into plastic bags to avoid drying and transported to the School of Forestry.

Figure 1. Coring an E. macrorhyncha tree using a battery-powered 14 mm diameter corer.

Table 1. Description of E. macrorhyncha provenances, including 10 plus trees

Tree ID	Provenances	Samples	Tree DBH (mm)
	Plus trees		
G3	Gunning	1	345
B4	Bundarra	1	315
G5	Gunning	1	350
S6	Stromlo	1	372
B7	Bundarra	1	380
G8	Gunning	1	317
S9	Stromlo	1	303
G12	Gunning	1	430
B13	Bundarra	1	361
B14	Bundarra	1	430
	Total cores	**10**	
Additional cores		**Samples**	
Avoca		5	
Bundarra		6	
Clare		6	
Gunning		4	
Stromolo		5	
Total cores		**26**	

Heartwood quantity (heartwood radius)

The heartwood radius in the stem was assessed by measuring the heartwood length from the pith with a ruler on the core samples in the green state. The heartwood was highlighted by immersing the cores into an aqueous 0.1% solution of methyl orange that changed heartwood colour to pink while the sapwood remained yellow (*Figure 2*). Additionally, the radius of the stem core was measured. It is important to note that deviating from previous NZDFI studies, the radius instead of diameter of the cores was measured because many of the trees exceeded a DBH of the corer length; the cores did include the pith.

Figure 2. E. macrorhyncha cores with heartwood dyed pink after application of methyl orange.

Collapse

The core samples were then oven-dried at 60°C for two weeks before equilibrating to a stable moisture content (MC) of ~12% at 65% relative humidity and 20°C in a climate-controlled room.

a. Maximal tangential shrinkage (Tangential collapse)

Green core diameter (widest tangential diameter) $\mathrm{D_{green}}$ was assessed by averaging green core diameters at two positions along each core. The narrowest tangential diameters ($\mathrm{D_{dry}}$) of each core equilibrated to ~12% MC were determined in the sapwood as well as in the heartwood. For the latter, the two narrowest tangential diameters were averaged.
The maximal tangential shrinkage in the core was calculated separately for heartwood and sapwood according to the following equation:

$$\text{Maximal tangential shrinkage} = \frac{\mathrm{D_{green}} - \mathrm{D_{dry}}}{\mathrm{D_{green}}} \times 100\ \%$$

b. Maximal volumetric shrinkage (Volumetric collapse)

The green and dry volumes were measured using water-displacement. The volumetric shrinkage was calculated using the following formula:

$$\text{Maximum volumetric shrinkage} = \frac{\mathrm{V_{green}} - \mathrm{V_{dry}}}{\mathrm{V_{green}}} \times 100\ \%$$

where, $\mathrm{V_{green}}$ and $\mathrm{V_{dry}}$ are volumes when green and dried, respectively.

Basic density

The basic density of the cores was calculated from dry-wood mass (~12% MC) and green volume. The green volume was measured using water-displacement.

$$\text{Basic density} = \frac{\mathrm{W_{dry}}}{\mathrm{V_{green}}}$$

where $\mathrm{W_{dry}}$ is the weight at ~12% MC and $\mathrm{V_{green}}$ is the volume in never-dried condition.

Heartwood quality (Extractive content)

Extractive content was predicted from Near Infrared (NIR) spectra with a multivariate statistical model developed by Li and Altaner (2019) for other durable eucalypt species in the NZDFI programme, i.e. *E. macrorhyncha* was not included in the calibration. NIR spectra were taken on the sanded tangential-radial (i.e., end grain) surface of the oven-dried cores using a fibre optics probe along the heartwood radius every 0.5 cm starting from the pith. The average heartwood extractive content for the tree was calculated by averaging the radial values per core.

Data analysis

Data were analysed with the R software (R Core Team, 2023). Analyses of variance (ANOVA) and post-hoc Tukey tests were performed to compare the differences between the provenances for each wood property. Extractive content dataset was analysed using Welch' ANOVA with a Games-Howell post-hoc comparison test as the data violates the assumption of homogeneity of variances.

RESULTS

Tree size

The core radius ranged from 55 mm to 193 mm, which did not significantly differ ($p > 0.05$) between provenances and plus trees (Figure 3). The core radius of the selected plus trees is also displayed in Figure 3.

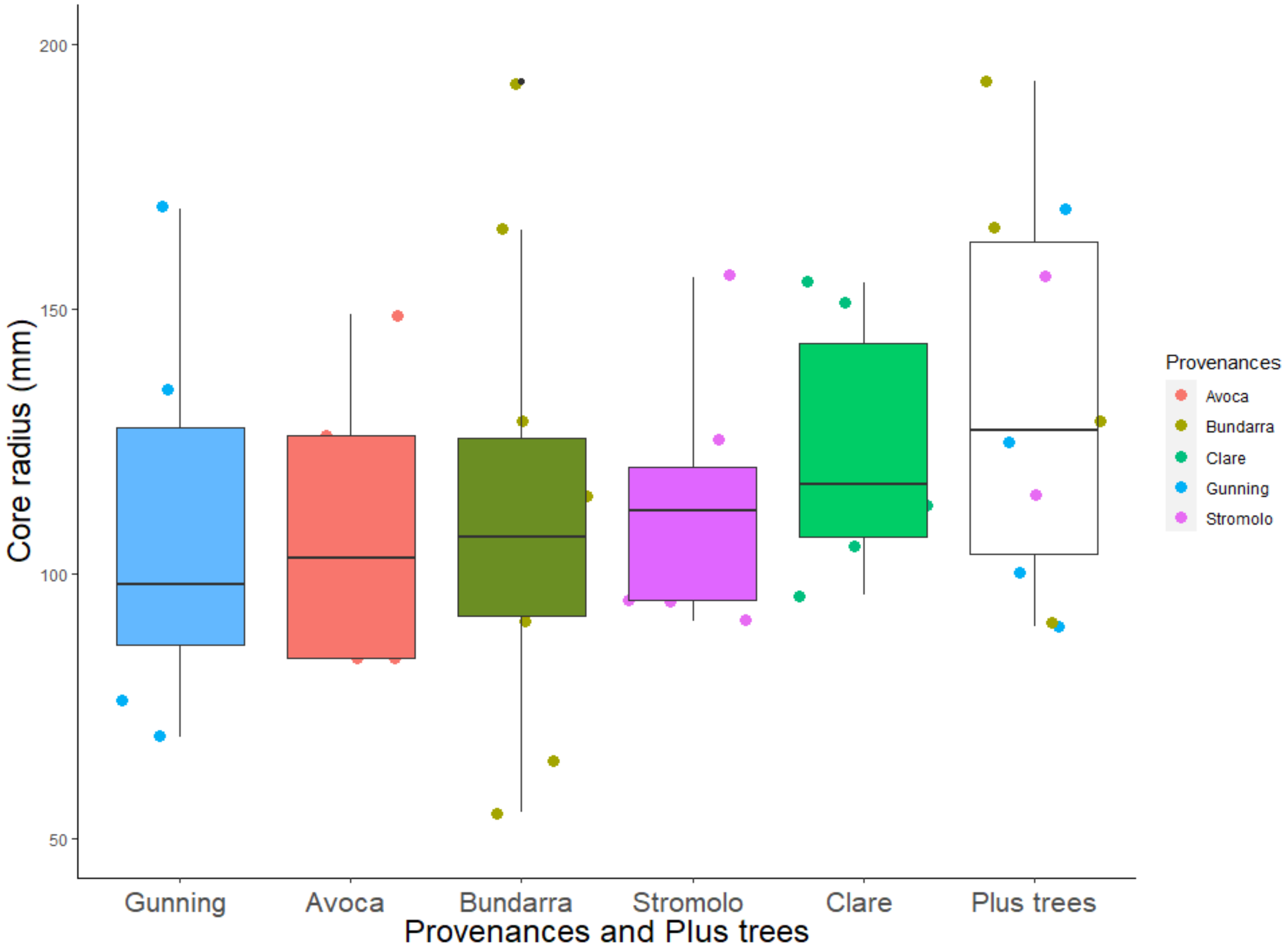

Figure 3. Boxplot of core radius of E. macrorhyncha provenances and selected plus trees ranked by median.

The variability of heartwood and sapwood radius was comparable to that of the core radius, i.e., no significant difference was observed between provenances and plus trees (Figure 4 and Figure 5). The heartwood radius varied between trees and ranged from 33 mm to 170 mm, with a mean of 93.75 mm. The heartwood radius of selected plus trees is also displayed in Figure 4.

The insignificance of growth traits between provenances might be cause caused by a sampling bias towards larger trees and missing sapwood pieces in some cores.

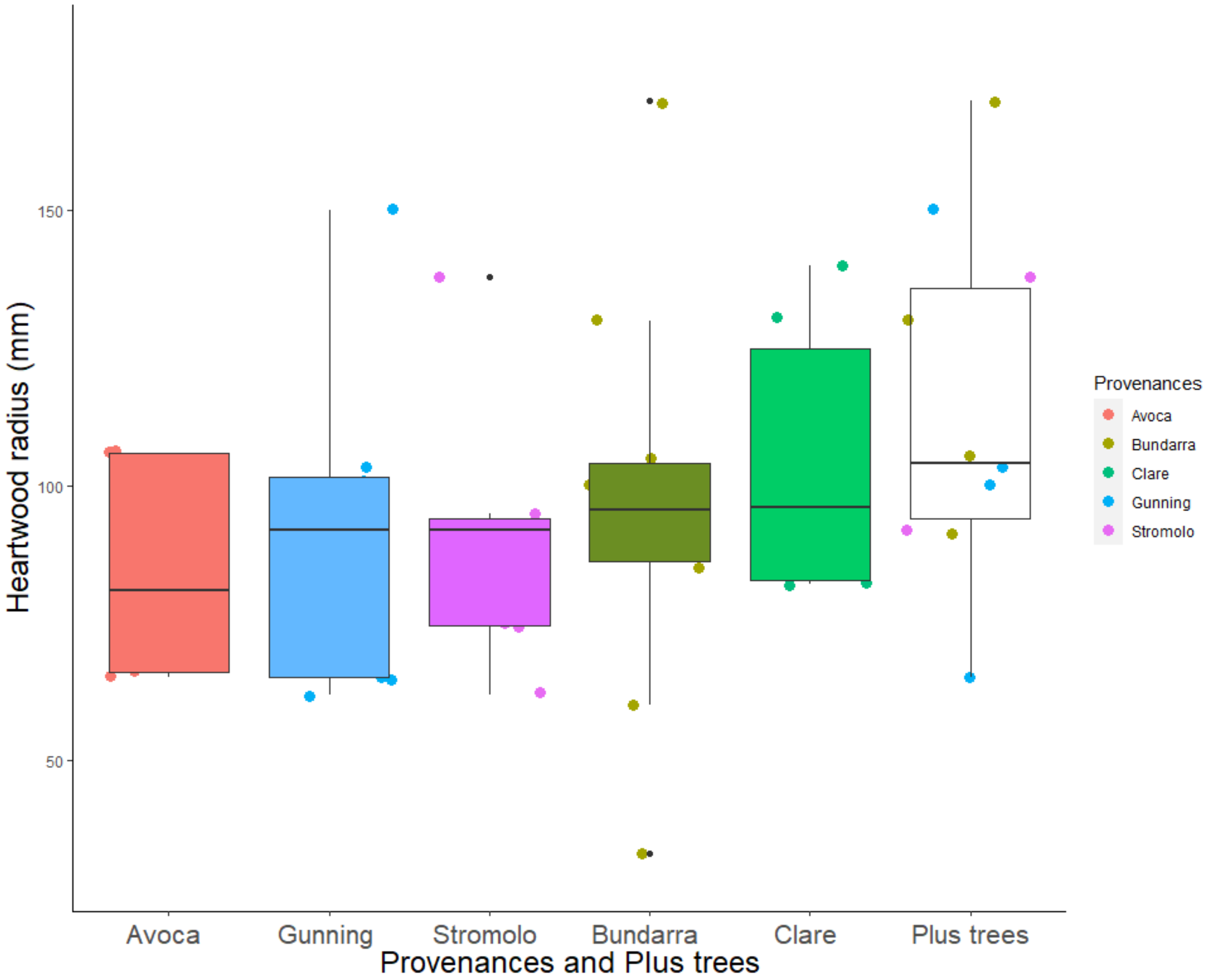

Figure 4. Boxplot of heartwood radius of E. macrorhyncha provenances and selected plus trees ranked by median.

Sapwood depth varied between trees and ranged from 5 mm to 43 mm (Figure 5). The sapwood band of *E. macrorhyncha* at age 18 years was narrower (~20 mm radius) (Figure 5) than that of *E. bosistoana* at age ~7 years (~65 mm diameter) (Li et al., 2018) but similar to *E. globoidea* at age 8 to 9.5 years (~42 mm diameter) (Ghildiyal et al., 2023).

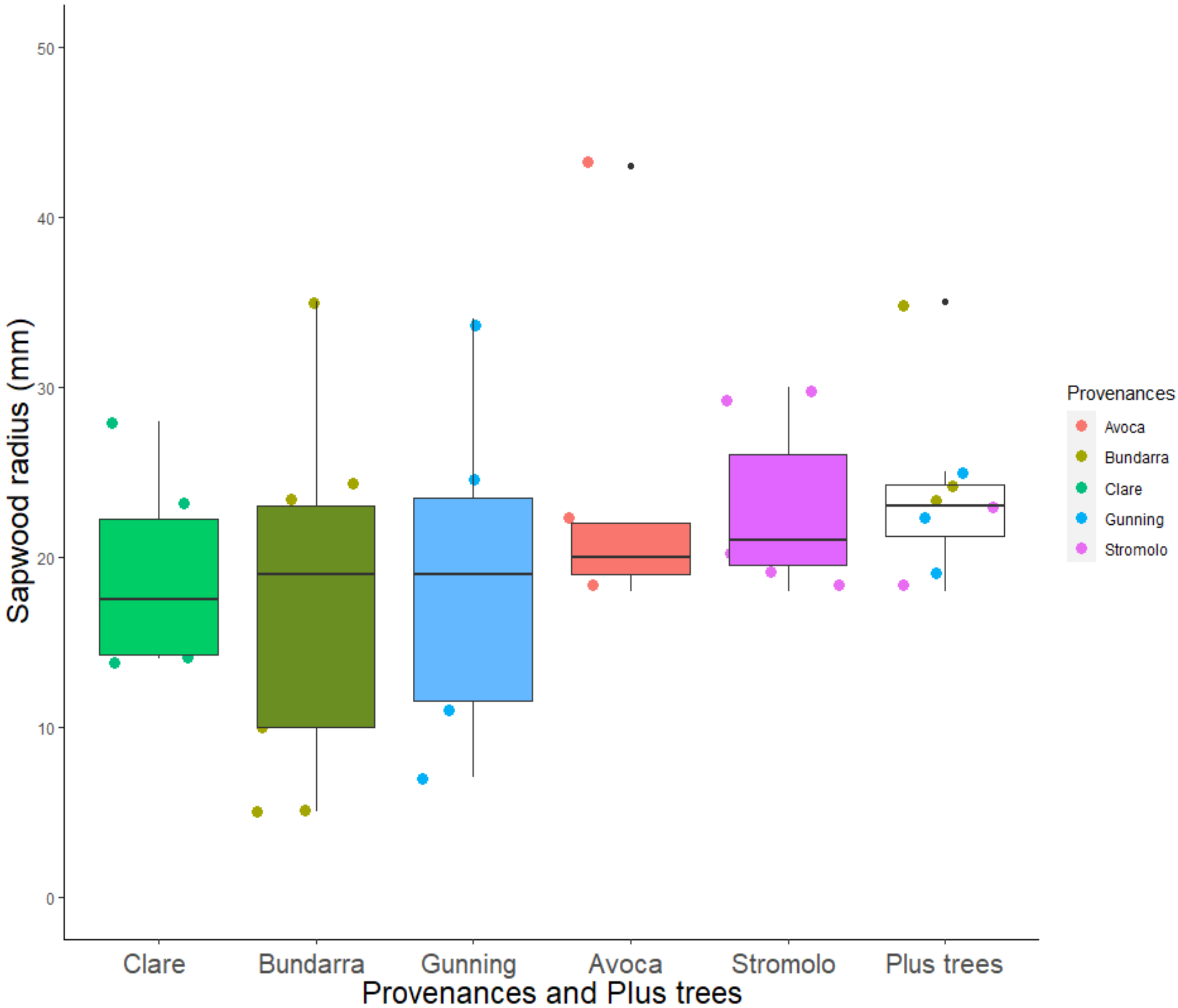

Figure 5. Boxplot of sapwood radius of E. macrorhyncha provenances and selected plus trees ranked by median.

Wood quality

Basic density

The basic density of the *E. macrorhyncha* stem cores ranged from 424 to 640 kg/m^3 and did not significantly differ among provenances and plus trees ($p > 0.05$) (Figure 6). This was lower than the reported 680 kg/m^3 (Ilic, 2002) or 690 kg/m^3 (Bootle, 2005) for Australian grown *E. macrorhyncha*. Note that these studies also reported a lower basic density of 620 kg/m^3 and 680 kg/m^3 for Australian grown *E. globoidea*, respectively.

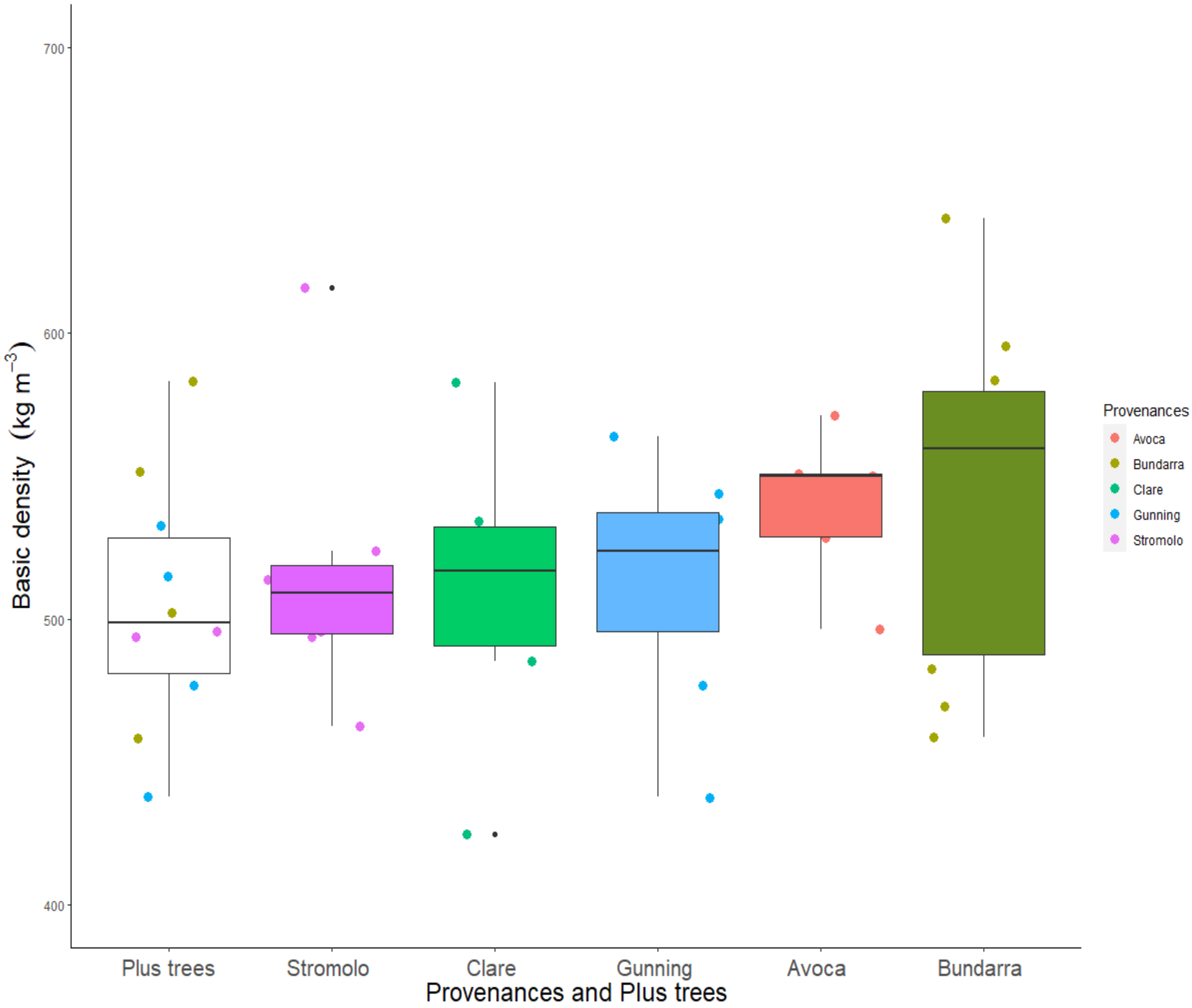

Figure 6. Boxplot of basic density of E. macrorhyncha provenances and selected plus trees ranked by median.

Extractive content

Natural durability is a key trait for the intended use of *E. macrorhyncha* timber. The predicted extractive content in heartwood varied between provenances ($p < 0.05$) (Figure 7). Differences were significant between the Bundarra and Clare ($p < 0.01$), between the Bundarra and Avoca ($p < 0.05$), and between the Bundarra and Gunning ($p < 0.05$) provenances. However, the mean extractives in the plus trees did not significantly differ from the mean extractives in each provenance ($p > 0.05$) (Figure 7).

The mean predicted extractive content in the heartwood of this species were 1.47%, ranging from 0.61% to 3.22% (Figure 7).The range was lower compared with those of *E. bosistoana* (7.5% to 9.6%) at age 7 years old (Li et al., 2018), but comparable with those of *E. globoidea* at 8 to 9.5 years old (Ghildiyal et al., 2023). It is important to note that we do not have a NIR calibration for extractive content for *E. macrorhyncha* and here reported values are obtained by applying a calibration build from other NZDFI eucalypt species. However, as previous work showed that such calibrations were to some degree transferrable between species (*E. bosistoana*, *E. globoidea*, *E. argophloia*) it is at likely that, while not necessarily the absolute extractive content values, the ranking between the *E. macrorhyncha* are accurate (Li and Altaner, 2019).

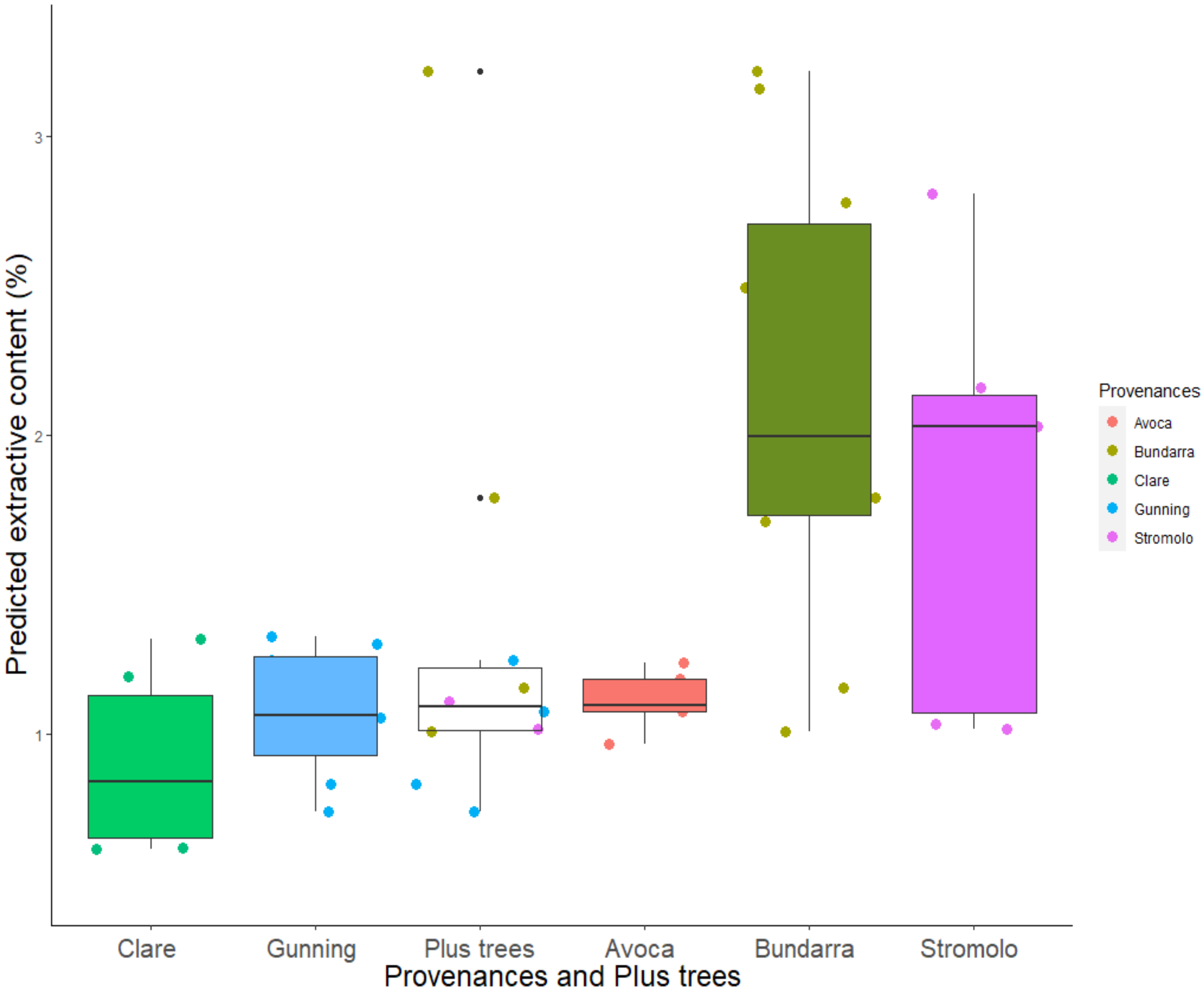

Figure 7.Boxplot of predicted extractive content of E. macrorhyncha provenances and selected plus trees ranked by median. Note: extractive content was predicted from NIR with a calibration of durable NZDFI species excluding E. macrorhyncha.

Collapse

The tangential collapse in the heartwood and volumetric collapse of selected plus trees from different provenances are also displayed in Figure 8 and Figure 9, respectively.

Collapse was observed for this species, and it varied between provenances ($p < 0.05$) (Figure 8). Maximal tangential collapse was more prominent in heartwood compared to sapwood (data not shown), consistent with observations for *E. globoidea* (Ghildiyal et al., 2023). Maximal tangential in heartwood and volumetric collapse were significantly higher in the Stromolo and Bundarra provenances compared to the Clare provenance ($p \leq 0.05$) (Figure 8 and Figure 9). The lower collapse for the Clare provenance appears to be related to the lower heartwood extractive content (Figure 7**Error! Reference source not found.**) rather than lower basic density (Figure 6). This indicates that a reduction in cell wall permeability due to the incorporation of extractives is leading to negative pressure during drying exceeding cell wall strength for this species.

Tangential collapse in heartwood for this species (mean = 18.36%) was similar to what was reported for its closely related species, *E. globoidea* (mean = 17 to 26%) (Ghildiyal et al., 2023). Collapse of has also been reported for South African plantation-grown (Poynton, 1979) and

Australian old-growth (Bootle, 2005) *E. marcrorhyncha* timber. For context, collapse was absent in NZ grown *E. bosistoana*.

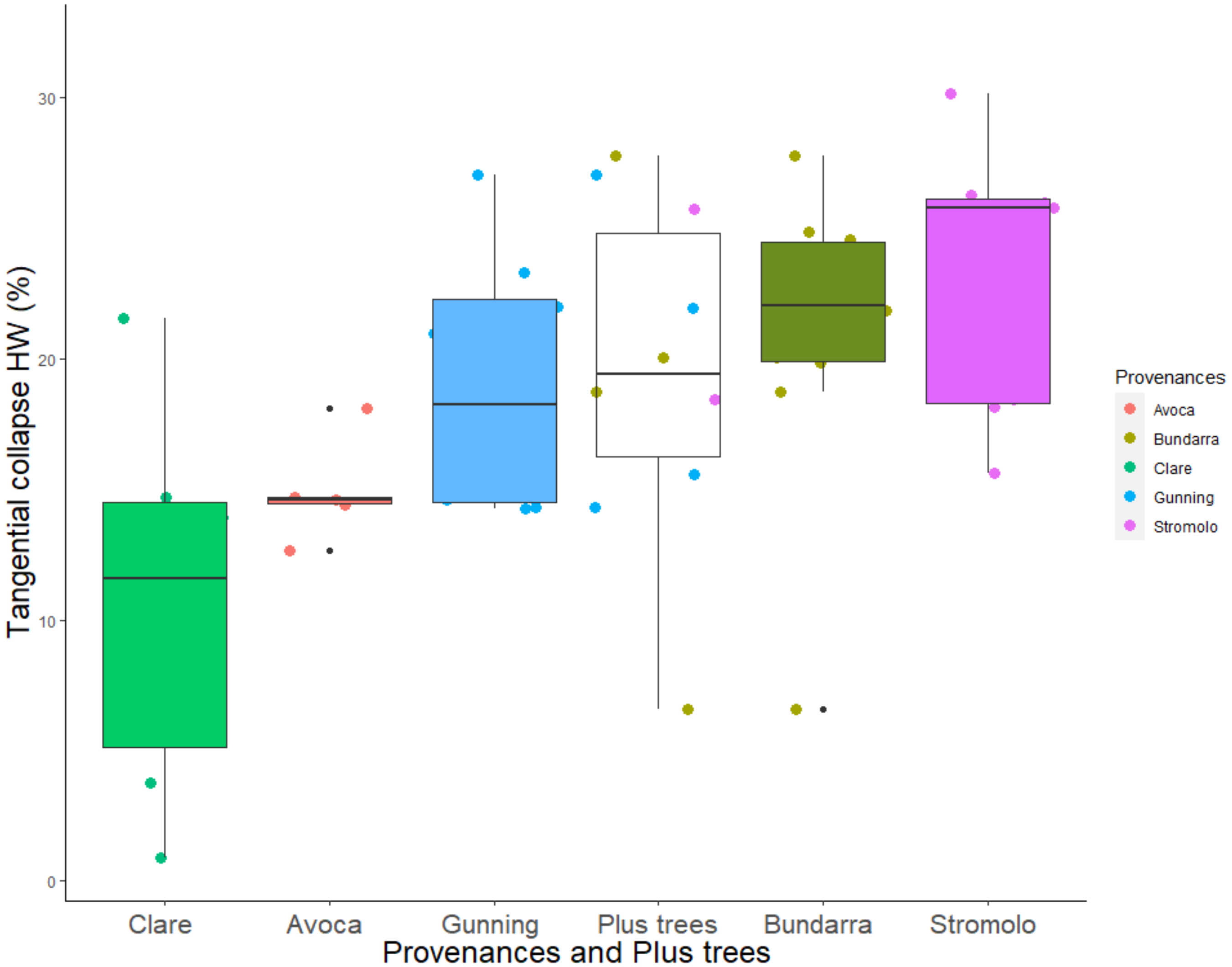

Figure 8. Boxplot of tangential collapse in heartwood of E. macrorhyncha provenances and selected plus trees ranked by median.

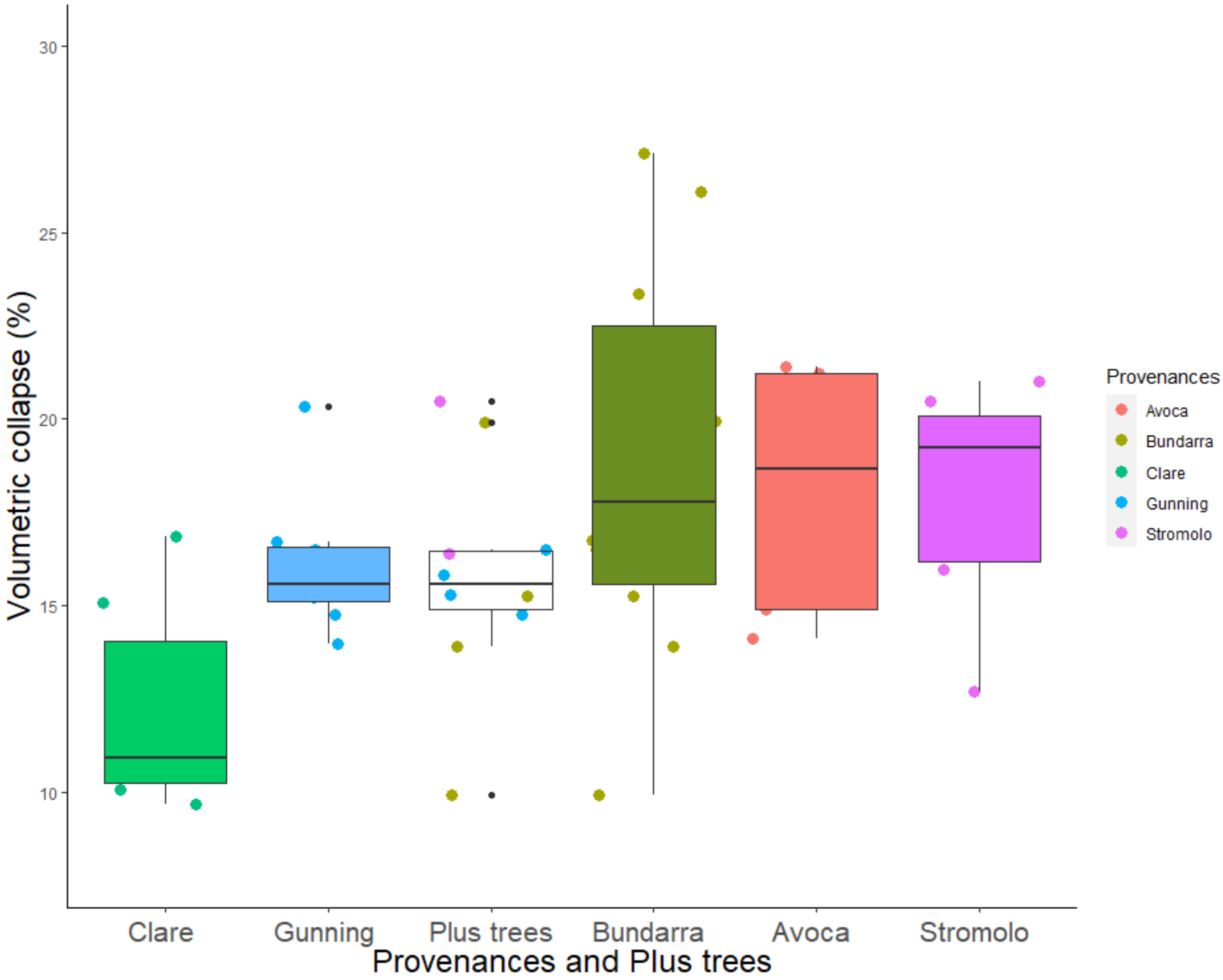

Figure 9. Boxplot of volumetric collapse of E. macrorhyncha provenances and selected plus trees ranked by median.

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