ANALYSIS OF INTERNAL CHECKING DATA FROM THE GOUDIES AND MATEA PRUNING / THINNING / FERTILISER TRIALS (RO 1083/1&2)

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EXECUTIVE SUMMARY

ANALYSIS OF INTERNAL CHECKING DATA FROM THE GOUDIES AND MATEA PRUNING / THINNING / FERTILISER TRIALS (RO 1083/1 & 2)

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Eight treatments from the Matea Pruning / Thinning / Fertiliser Trial and a corresponding five treatments from the duplicate Goudies Trial had been assessed for signs of internal checks using the **"oven dry method"**. The stands were mature (30 years old) largely unimproved radiata pine, with Matea representing a poorer Kaingaroa Forest site (site index 26m) and Goudies representing a good Kaingaroa Forest site (site index 30m). Sample size was limited by plot size and replication, to around 30 samples per treatment per site. Sample discs were collected from immediately above the butt log, being from approximately 5.0-5.5m stem height. This report presents results of the analysis of the combined database from the internal check assessments of the above two trials.

All treatments assessed from both trials showed some samples with internal checks following processing. No checks were recorded within the heartwood portion of the samples. The growth year of the heartwood boundary was highly variable ranging from the 1980 growth year to 1988, the average being 1983 for the Matea site where heartwood development was slightly more advanced than at the Goudies site.

Overall the analysis indicated that:

- A strong site effect exists with the Matea Trial having significantly worse internal checking than the Goudies Trial.

- The unthinned plots (established at 3000s/ha) in both trials had significantly less internal checking than the thinned plots (final stocking 250s/ha).

- Pruning (3 lifts to 6m) had no significant effect on internal checking. However, pruning is indirectly linked to internal checking in that it cannot be undertaken independent of thinning, particularly from high initial stocked stands.

- Fertilising with nitrogen (applied as urea at 200kg N/ha in spring following thinning) had no significant effect on internal checking.

- Number of checks varied with ring number from the heartwood boundary. Checking was most concentrated in rings 1-5 from this boundary, peaking in ring 2.

- In addition to the overall trend of checking peaking for years just outside the heartwood boundary, there were additional differences between years of ring formation. In both trials, 1989 was a bad year and 1990 a good year. This supports the strong belief that environmental factors have an important influence on the incidence of internal checks.

BACKGROUND

The Goudies and Matea Pruning / Thinning / Fertiliser Trials (RO 1083/1&2) were initiated and designed by Dr Wink Sutton and Dr Russell Ballard and arose from the idea of applying nitrogenous fertilizer to limit growth losses associated with green crown pruning. This is a unique set of silvicultural trials where the effects of all combinations of three major silvicultural practices (Pruning, Thinning and Fertiliser) have been measured on the same site (Sutton and West, 1980). The trials have been measured annually or bi-annually since establishment. Growth response at these trials was analysed and reported in West, 1998.

To evaluate all individual treatment effects and their interactions a full factorial design of three factors - pruning, thinning and fertilising - each at two levels; (1) treated, and (0) untreated was used (Sutton and West, 1980). The treatments are summarised in Table 1.

Table 1: Treatments applied

	Treatments		
	Thin	Prune	Fertilise
Control (C)	0	0	0
Thin (T)	1	0	0
Prune (P)	0	1	0
Fertilise (F)	0	0	1
TP	1	1	0
TF	1	0	1
PF	0	1	1
TPF1	1	1	1
TPF2	1	1	0+1
TPF1+2	1	1	1+1

Where: 0 = No treatment
1 = Standard treatment applied
+1 = Application of N fertiliser at second thinning
Note: Treatments are replicated twice at each site.

Pruning (in three lifts):
1st lift - In spring, best 600 s/ha pruned to 45% of tree height at MCH 5.7m
2nd lift - Best 375 s/ha pruned to a minimum of 4m at MCH 9.2m
3rd lift - Final crop of 250 s/ha pruned to 6m at MCH 12m

Thinning:
At the time of first pruning, plots with thinning treatments were thinned to 600 s/ha. After the 3rd pruning lift plots with thinning treatments were thinned to 250 s/ha. This also included the P and P+F treatments.

Fertiliser:
Nitrogen was applied as urea at a rate of 200 kg N/ha (= 500 kg/ha of urea) in spring immediately following the thinning treatments.

The Goudies Trial (RO 1083/1) was established in 1976 in Compartment 178 (planted in 1971 at 1.8 x 1.8 m, 3000 s/ha). The site is representative of a good Kaingaroa Forest site (site index ca. 30m and 300 Index 23). The Matea Trial (RO 1083/2) is a duplicate of the Goudies Trial, established the following year in Compartment 864 (also planted in 1971 at 1.8 x 1.8 m, 3000 s/ha) which is representative of a poor Kaingaroa Forest site (site index ca. 26m and 300 Index 16), and is reputed to commonly have within-ring internal checking problems.

Plot size is 0.04 ha (20 x 20m) with a 10m surround. Measurement of total plot basal area at the establishment of each trial indicated a scattered site variation, which did not allow conventional blocking. To overcome this, high and low basal area plots were paired to approximate the overall mean. Treatments were then randomly allocated to the plot pairs.

INTRODUCTION

The Matea Trial was clearfelled during winter 2001 at age 30 years. Eight of the 10 available treatments were sampled for an internal check assessment using the **"oven dry method"** (McConchie, 1999 and McConchie D&M, 2001). The results of this assessment have been reported by McConchie et. al. (2002), with the basic data appended. Similarly, the Goudies Trial was clearfelled during spring 2001 at age 30 years. Only five of the available treatments were sampled for a matching internal check assessment. The results of this assessment have also been reported by McConchie and Kimberley (2002), with the basic data appended.

This report primarily focuses on the analysis of the combined datasets from the internal check assessments of the Goudies and Matea Trials. Recent research has shown that seasonal variation in the incidence of within-ring internal checks with respect to harvest date does not occur (McConchie et.al. 2001). As a result we can be confident that although the two trials were harvested in different seasons, this will not have affected the overall results obtained. It should also be noted that these two trials were not designed to test for internal checking at maturity. The highly skewed distribution of checks, between trees and within trees, mean that large sample sizes are preferred, however plot size and number preclude this option. Accepting this limitation, this overall analysis still provides a useful guide to possible site and silvicultural effects on the incidence of internal checking in mature radiata pine. An overview of the field sampling and laboratory procedures is included.

FIELD SAMPLING

Suitable trees were selected and marked prior to felling. For the thinned treatments, the ten inner plot trees were selected, with additional trees selected from the plot surround, but close to the inner plot boundary to achieve a sample size of approximately 30 trees per treatment (2 plots). Selection was restricted to the inner plots of the unthinned treatments for a similar sample size. Unfortunately for the TPF2 treatment at Matea, one plot had been previously felled, so the selections from the plot surround were increased for the remaining plot to achieve a sample size of 19 trees.

Following felling, the tree ID was marked on the butt in case stem markings were lost during extraction. At the skid site, the butt log was removed, followed by a 60mm thick disc for the internal check assessment. This disc was taken from approximately 5-5.5m stem height, representing the butt log small end. Tree ID was marked on all discs together with the clearly identifiable heartwood/sapwood boundary. Discs were then delivered to ***Forest Research*** for processing at the end of each day.

LABORATORY PROCEDURE

Strips approximately 100mm wide and oriented to maximise the heartwood/sapwood boundary rings were marked and labeled on all discs. These strips were then cut out using the band saw in the ***Forest Research*** workshop, and residual wood was discarded. Any samples deemed too thick were reduced to approximately 60mm thick at this stage. Samples were then immediately placed in the laboratory oven and dried at 103°C. Two Contherm Digital Series Ovens with fan extraction and ca. $0.3m^3$ capacity were used to dry the prepared samples. Drying took between 1-2 days. It is not essential that samples are oven dry, as internal checks will occur at moisture levels somewhat above the fibre saturation point for radiata pine of 28-30% moisture content (Dr. Rolf Booker pers. com.). However, drier samples are preferred for sanding. Similar volumes of samples were dried in the ovens at each charge. Overall, sample thickness, sample freshness and oven packing were managed to ensure that all samples were treated as uniformly as possible to ensure that these variables had minimal impact on internal checking.

Following drying, the samples were cut in half (thickness) to reveal internal checks, if present. One half was discarded and the other had the opened face sanded on a belt sander then blown with an air hose to help highlight any internal checks. The following data was then recorded for each sample: plot number, tree number, growth year of the heartwood boundary, total rings affected and the total number of internal checks identified. All internal checks were also recorded by the growth year in which they occurred. The analysis of this data is the basis of this report, which investigates the effect of site and silviculture on the incidence of internal checking

RESULTS

Data

Goudies and Matea Trials are similar in design and contain various combinations of thinning/pruning/fertiliser treatments with two plots per treatment. Selected treatments were sampled from each trial with discs taken at 5m height from 10 to 20 trees in each plot. The plot numbers and treatment combinations are given in Table 2 and the number of trees sampled is given in Table 3.

Table 2: Plot numbers and treatment combinations sampled for internal checking

		Matea (15 plots)			Goudies (10 plots)		
		Thinning			Thinning		
Prune	Fertilise	None	Late	Early & Late	None	Late	Early & Late
No	No	6,12		2,15	1,5		15,17
	Early	11,19					
Yes	No		1,17	16,18		10,11	2,12
	Early			3,4			
	Early & Late			5,8			
	Late			10			3,8

Table 3: Number of trees sampled for each treatment combination

		Matea (233 trees)			Goudies (157 trees)		
		Thinning			Thinning		
Prune	Fertilise	None	Late	Early & Late	None	Late	Early & Late
No	No	32		29	36		31
	Early	30					
Yes	No		30	31		30	30
	Early			30			
	Early & Late			30			
	Late			19			30

Methods

Because of the non-normal nature of the distribution of checking counts, standard methods of analysis (eg, ANOVA, regression) are inappropriate. To avoid these difficulties, the general approach adopted was to use generalised linear models fitted using the SAS procedure GENMOD. A poisson error distribution with a log link function was assumed, and the SCALE=DEVIANCE option was used to account for any over-dispersion.

Analysis

A generalised linear model was fitted using mean number of checks per disc for each plot as the dependent variable. The sequential analysis of deviance (Table 4) and least squares means (Table 5) from this analysis indicate that Goudies had significantly less checking than Matea, and that the unthinned trees had significantly less checking than the thinned trees. Pruning, fertilising and timing of thinning (ie, early and late versus late only thinning) were not significant. There were no significant interactions. In particular, the effect of thinning was similar at both sites. Note that in this analysis the least squares means for numbers of checks are expressed using a log transformation. These means show the relative effects of each treatment factor and are adjusted to take account of the considerable imbalance in the design so that the effect of each treatment factor can be judged independently of the others. Because of the unbalanced nature of the data, the significance of the site and thinning effects were further tested by using a Type 3 analysis of deviance with a reduced model containing only site, thinning and the interaction between site and thinning (Table 6). This confirmed the results of the previous analysis. Arithmetic means of thinned and unthinned plots at each site are given in Table 7.

Table 4: Analysis of deviance, using a Type I sequential analysis

Source	d.f.	Deviance	Mean deviance	F-value	p-value
Site	1	29.06	29.06	11.54	0.004
Thin	1	18.78	18.78	7.46	0.016
Site x Thin	1	4.08	4.08	1.62	0.224
Thin timing (Thin)	1	1.41	1.41	0.56	0.466
Site x Thin timing (Thin)	1	1.35	1.35	0.54	0.476
Prune	1	0.40	0.40	0.16	0.696
Site x Prune	1	0.14	0.14	0.06	0.815
Fert	1	0.00	0.00	0.00	0.986
Site x Fert	1	4.73	4.73	1.88	0.192
Thin x Fert	1	0.82	0.82	0.32	0.578
Residual	14	35.25	2.52		

Table 5: Least squares means for ln (number of checks) per disc

Treatment factor	Level	LS Mean	s.e.
Site	Goudies	0.75	0.35
	Matea	1.82	0.22
Thinning	Unthinned	0.79	0.45
	Early & Late Thinned	1.65	0.22
	Late Thinned only	1.90	0.46
Pruning	Unpruned	1.23	0.33
	Pruned	1.33	0.32
Fertiliser	UnFertilised	1.26	0.26
	Fertilised	1.30	0.33

Table 6: Analysis of deviance using a Type 3 analysis

Source	F-value	p-value
Site	10.80	0.0035
Thinning	9.15	0.0065
Site x Thinning	1.94	0.18

Table 7: Mean numbers of checks and affected rings per disc for thinning and unthinned plots at each site

Site	Thinning	Mean no. checks per disc	Mean no. rings affected per disc
Goudies	Unthinned	0.10	0.10
	Thinned	3.60	0.95
Matea	Unthinned	4.13	1.23
	Thinned	9.43	2.19

An analysis of checking by ring number was performed using checks per ring as the dependent variable, and using a factorial two-way analysis with tree and ring. A separate analysis was used for thinned and unthinned trees at each site, although the unthinned trees at Goudies were not analysed because of the small number of checked discs. A better fit was obtained using ring number from the heartwood boundary rather than year of formation as the main independent factor (Figure 1). Checking was most concentrated in rings 1 to 5 from this boundary, peaking in ring 2 for both trials (Figure 1). For these analyses, the generalised linear model was run only using trees with at least one check. Trees without checks were excluded because they contained no useful information, and caused model convergence problems. However, to allow realistic comparison of treatments and compartments in Figure 1, the least square means have been adjusted to account for the no-check trees. This was easily accomplished by adding ln(P) to each mean, where P is the proportion of trees with checks.

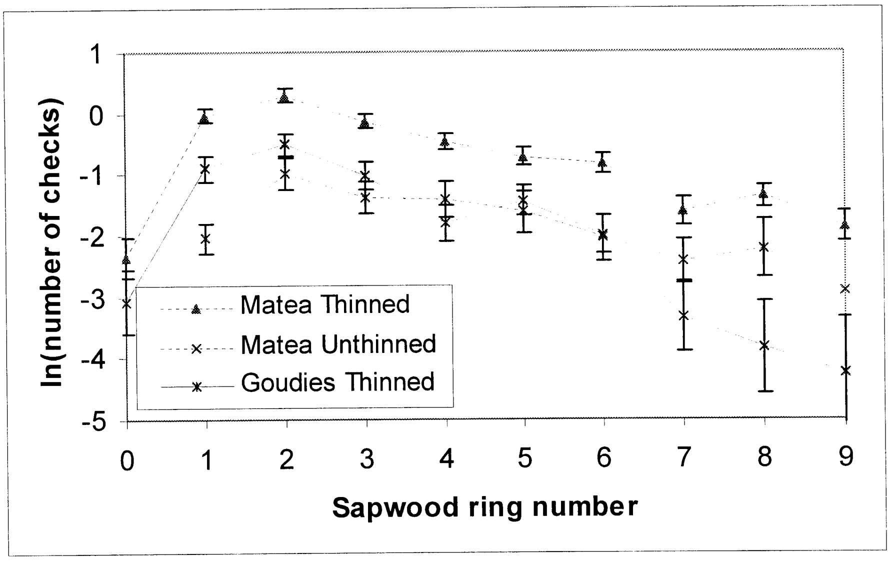

Figure 1: Number of checks versus ring number from heartwood boundary. Least square means and standard errors are shown. Standard errors should be used only for comparing rings within a treatment or site.

A similar analysis was performed for actual year of ring formation rather than ring number from the heartwood boundary (Figure 2). Interpretation is difficult because of the marked reduction in checks inside the heartwood boundary centered on the 1983 ring for both trials, and the more gradual reduction towards the outer rings, both visible in Figure 1. However, there are clearly differences between years with some years producing disproportionate numbers of checks, and others fewer than expected (Figure 2). For example, in both trials, 1989 was a bad year for checking while 1990 was a relatively good year. This pattern supports the strong belief that environmental factors have an important influence on the incidence of internal checks.

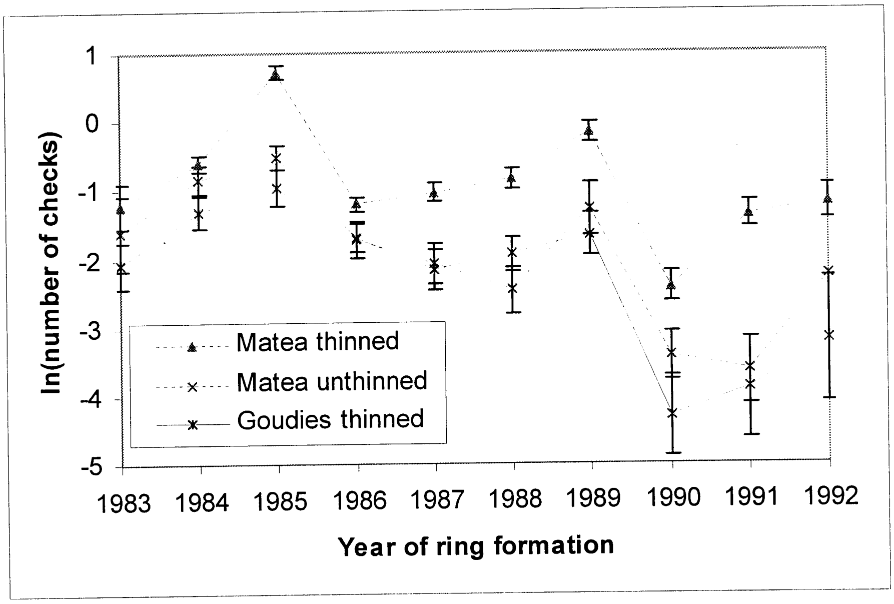

Figure 2: Number of checks versus year of ring formation. Least square means and standard errors are shown. Standard errors should be used only for comparing rings within a treatment or site.

CONCLUSIONS

- The Matea Trial (RO1083/2) had significantly worse internal checking than the Goudies Trial (RO1083/1).
- The unthinned plots (established at 3000s/ha) in both trials had significantly less internal checking than the thinned plots (final stocking 250s/ha).
- Pruning (3 lifts to 6m) had no significant effect on internal checking.
- Fertilising (Nitrogen applied as urea at 200kg N/ha, in spring immediately following thinning) had no significant effect on internal checking.

- Number of checks varied with ring number from the heartwood boundary. Internal checks were most concentrated in rings 1 to 5 from this boundary, peaking in ring 2.

- In addition to the overall trend of internal checks peaking for years just outside the heartwood boundary, there were additional differences between years of ring formation. In both trials, 1989 was a bad checking year and 1990 a good year.

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