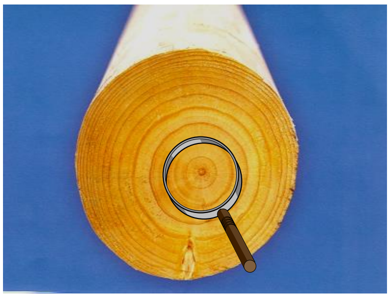
Report on Ribbonwood trial at Winton – wood quality of the Attenuata hybrid



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Executive Summary

- 92 butt logs from the Ribbonwood trial were processed to estimate stiffness of the three taxa tested there, *Pinus radiata, P. attenuata* and a hybrid of the two species.
- The Attenuata Radiata Hybrid showed both higher than average log velocity and board stiffness, with the hybrid having a statistically higher log velocity compared to radiata and the hybrid having a statistically higher stiffness than both other taxa.

1. Background and Methodology

The Ribbonwood trial was established in 1998 to evaluate the performance of the and *P. radiata, P. attenuata* and a hybrid of the two species. It was theorised that the use of the *P. attenuata x P. radiata* hybrid may offer the drought, snow and frost tolerance of *P. attenuata*, whilst retaining the faster growth rates possible with P. radiata. It is being felled now as the farm manager wanted to remove the trees.

A study undertaken in 2022 (Appendix2 T. Fowler and P. Adams Rayonier Matariki Forests) that predicted log grade recovery and financial performance of P. radiata x P. attenuata hybrid. The report demonstrated that the *P. attenuata x radiata* hybrid is significantly outperforming *P. radiata* and *P. attenuata* on the Ribbonwood Station site. The growth rate of the hybrid is clearly higher than *P. attenuata* and the survival along with tree condition is superior to that of *P. radiata*. These differences translate to improved TRV, grade recovery and NPV. At the current age (23 in 2022), the average increase in rate of return over both sites from P. radiata to the hybrid is 5.7%.

Logs were processed in three distinct batches through the sawmill (one for each taxa) and boards were cut to sawing patterns to meet the requirements of the mill. This means boards of varying sizes were produced within each batch. Prior to the bin sorter in the green mill, each green board MOE (Modulus of Elasticity or board stiffness) was measured using the Calibre Equipment ECOUSTIC technology (referred to as "Calibre" in this report). This is an <u>acoustic-derived MOE</u> calculated using the equation:

$$\textbf{Green Board MOE} = \textbf{Green Board Density} \times (\textbf{Green Board Acoustic Velocity})^2$$

The board acoustic velocity is measured when each board end is presented against the Calibre unit and tapped by a retractable hammer while moving along the green chain.

The weight of each green board is measured by weighbridges that are installed with the Calibre unit in the green chain. Board dimensions (length, width, thickness) are measured by in-mill scanners to give volume. This allows the board green density to be calculated.

With this data it is possible to compare the log acoustic velocity distributions and green board MOE distributions for each batch and the overall trial. By doing so, any significant differences in wood quality will be evident.

2. Ribbonwood Trial

1. Data collection/summary

Potential trees were selected using previous assessments and the trial was visited to mark the trees. It was found that the paper selection was not successful in terms of form for sawlogs, so selections were redone by visually assessing each tree. Recovering merchantable butt logs from radiata was particularly difficult due to the survival rate and poor form. Final selections had 22 P. radiata, 29 P. attenuata and 41 hybrids trees marked. These were felled and butt logs delivered to the Niagara mill at Winton. Delivered logs included one extra radiata log.

2. Results and analysis

Three images below show the logs at the mill.

Image 1: Radiata/Attenuata Hybrid logs

Image 2: Attenuata logs

Image 3: Radiata logs

Figure 1 shows the distribution of the log velocities for the 3 taxa. The hybrid shows higher log velocity than the other two taxa with the hybrid being statistically different from radiata but not attenuate at the 95% confidence level.

Table 1 describes the log velocity (measured using the HM220 tool – see Appendix 1), and heartwood percentages for the logs by taxa. Figure 1 shows the distribution of the log velocities for the 3 taxa. The hybrid shows higher log velocity than the other two taxa with the hybrid being statistically different from radiata but not attenuate at the 95% confidence level.

Table 1: Ribbonwood trial log summary

Velocity	**Colour**	**Heartwood %**			**Log velocity**		
Taxa		**min**	**Avg**	**max**	**min**	**Avg**	**max**
		%	**%**	**%**	**km/s**	**km/s**	**km/s**
P. radiata	Green	7	18	28	2.02	2.47	2.94
P. attenuata	Pink	4	16	64	2.12	2.54	3.03
Attenuata radiata Hybrid	Yellow	4	16	25	2.23	2.67	3.45

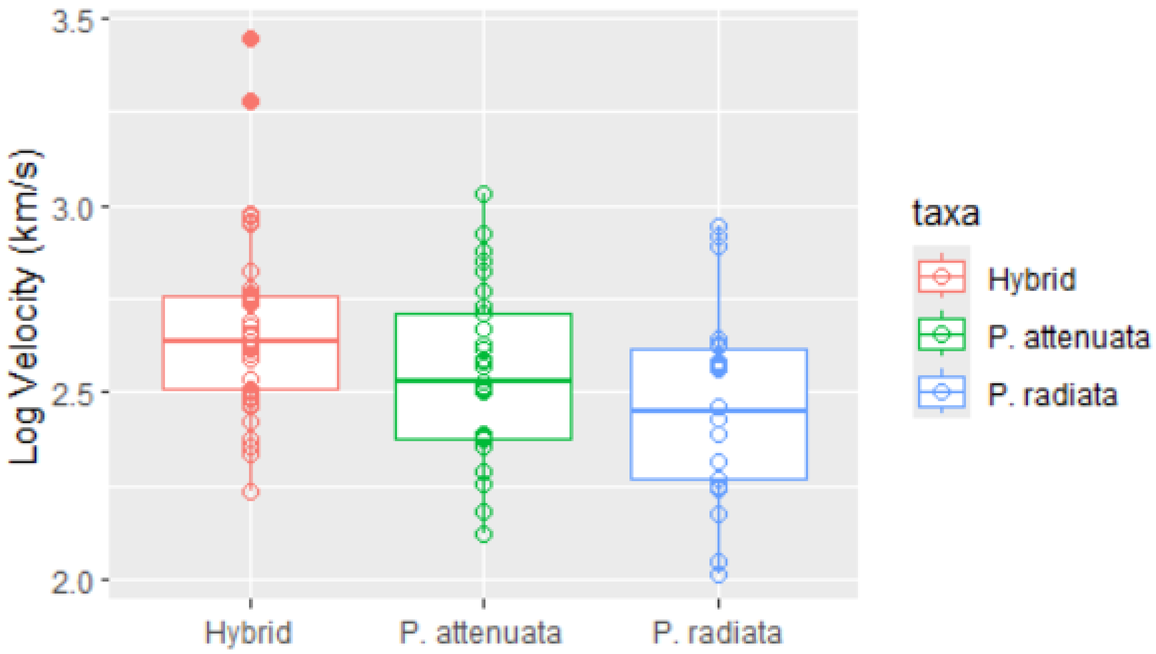

Figure 1: Ribbonwood trial log velocity distribution by taxa

Boards image below from Radiata/Attenuata hybrid logs. There was no obvious visual difference in these boards compared to the other 2 taxa. The mill staff did mention that the hybrid smelled a bit different than radiata – a bit more like Douglas-fir.

Image 4: Attenuata Radiata Hybrid boards

Table 2 shows the board sizes produced from the 3 batches. 150x50mm was the main size produced. The product mix from each taxa was very similar. Up to 17% of the boards had no Calibre stiffness assessment made. This was primarily due to some boards being poorly presented and therefore being unable to be hit by the Calibre tool. This is typical for all trials conducted in the past, with up to 20% of boards having no measurement in some cases.

Table 2: Board volume percentage by board size

Log batch	100x50	150x50	200x50	Other	Not Measured
P. radiata	19	46	10	10	8
P. attenuata	16	50	14	14	8
Attenuata Radiata Hybrid	16	45	16	16	17

Figure 2 shows the green stiffness distribution of the boards.

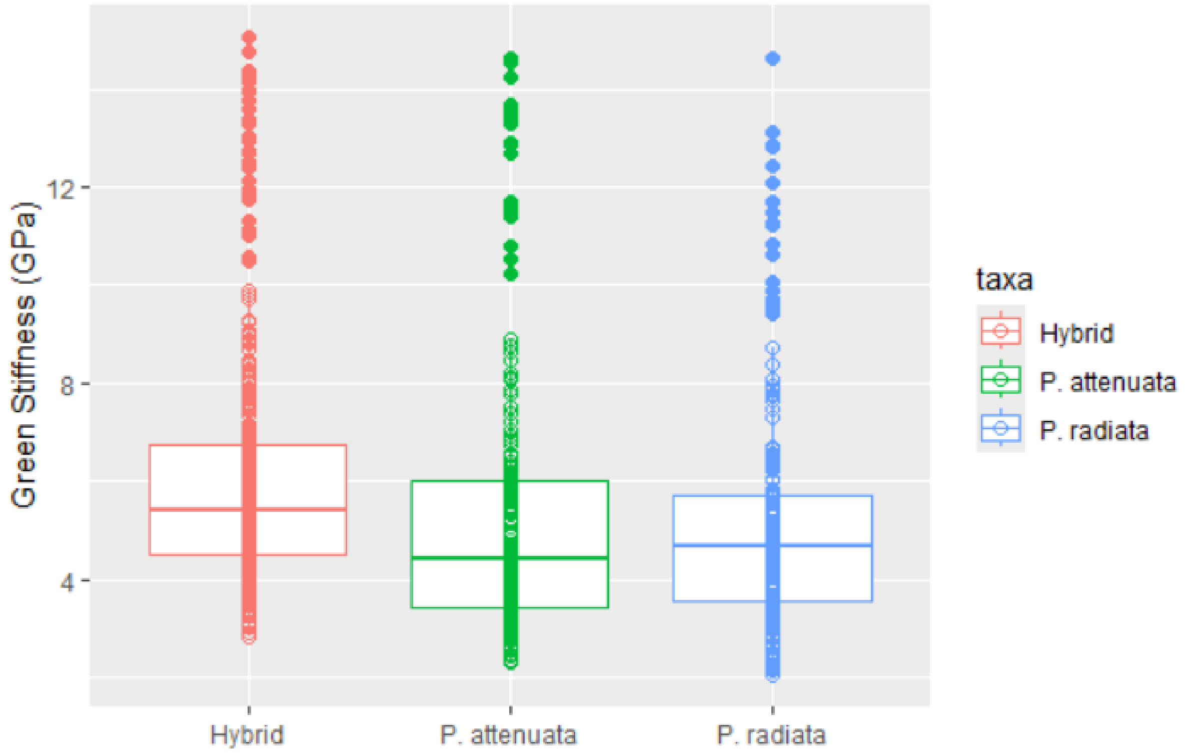

Figure 2: Green stiffness (MOE) distribution by taxa.

Table 3 shows the log and board volumes, recovery and the average green stiffness of the boards by taxa. The hybrid shows slightly higher green stiffness than the other two taxa. This increased stiffness is statistically significant at the 95% level.

Table 3: Predicted structural out-turn of kiln-dried boards

Batch	**Log Vol**	**Board Vol**	**Recovery**	**Average MOE**
Velocity	**m^3**	**m^3**	**%**	**GPa**
P. radiata	13.21	5.93	45	5.13
P. attenuata	12.88	5.49	43	5.35
Attenuata radiata Hybrid	30.90	15.05	49	6.05

The green stiffness measured is based on lengthwise resonance and does not include any other visual override parameters such as knot size, slope of grain, wane and distortion which would reduce the % of in grade timber. The amount of downgrade due to visual override factors can only be assessed by an in-mill sawing study that takes the board through to dry grade out-turn.

Compared to the last set of trial measurements undertaken, Figure 3 shows the DBH of the selected trees versus all the trees by taxa. Unsurprisingly we selected the larger trees for the trial. Figure 4 shows the trial log outerwood density distribution versus all trees by taxa. Very good representation here.

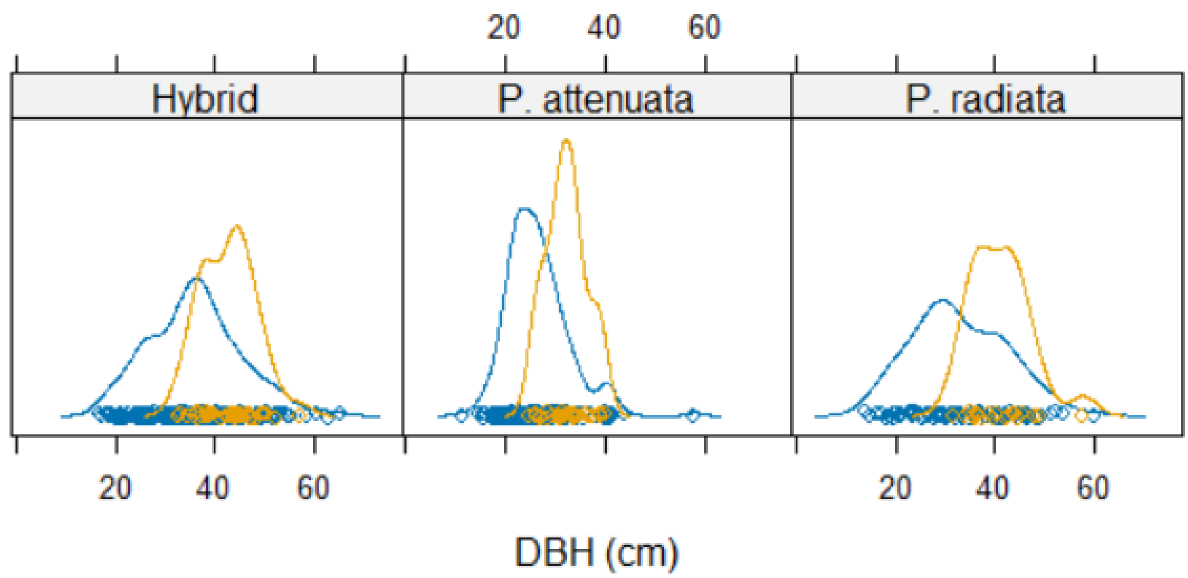

Figure 3: Distribution of trial logs DBH versus all trees by taxa.

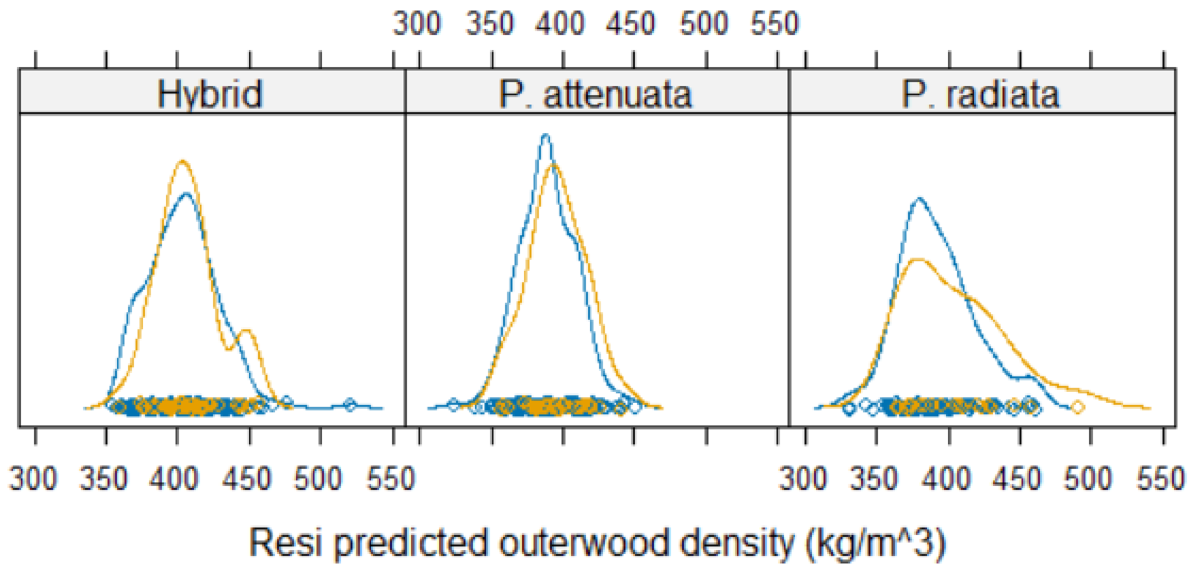

Figure 4: Distribution of trial logs outerwood density versus all trees by taxa.

3. Verification of the Calibre Green Board MOE Measurements

As noted above, the Calibre unit calculates green stiffness from measurements of green density and the acoustic velocity (velocity of sound travelling through the board). It does this by using board size information from the trimmer (to calculate volume) and a weighbridge (weight) to measure the green density. The acoustic velocity in the board is determined using a hammer and microphone.

To verify the data collected by the Calibre unit, 20 green radiata boards were selected which varied in length, thickness, width and heartwood % to cover the expected range of the trial boards. Image 5 below shows board weighing and image 6 shows board velocity determination using the Hitman HM220 tool.

Image 5: Board weighing to determine green density

Image 6: Board velocity determination

Figure 5 shows the manually determined versus Calibre measured green stiffness data. The correlation between the two independent methods is excellent (R^2 = 0.95). However, the manual measure of the estimate of stiffness is 3% greater than the Calibre equivalent.

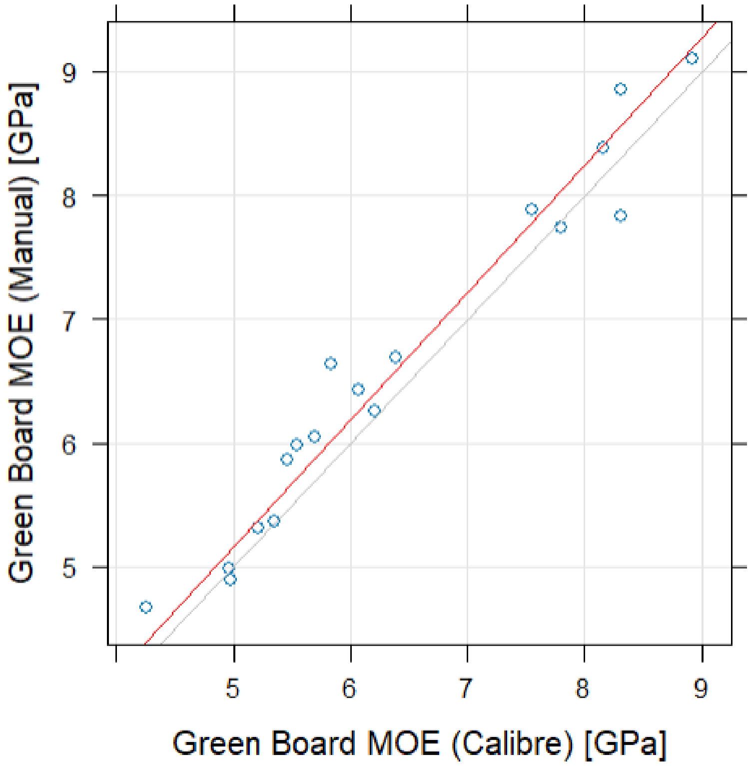

Figure 5: Manual versus Calibre green stiffness correlation

Acknowledgments

We would like to thank the following people for their help during the trial:

- Nick Whyte, Jason and all mill staff - Niagara Sawmill and Timber Remanufacturing
- Jenna Scott and Liam Murphy – Tui Technology
- Jon Harmer, Nathan and crew for the logging and transport.
- Rayonier Matariki Forests for use of their report.

Limitations

Opinions and comments in the report are given in good faith based on judgement and experience. The authors have used all reasonable endeavours to ensure the accuracy and reliability of the information contained in the report and are not liable for any inaccuracies, omissions or errors in the information, nor for any action taken in reliance on this information.

Appendix 1: HM220 log velocity tool

The HITMAN HM220 is a tool that measures the acoustic velocity (or speed of sound) in a cut log or stem. This measurement is commonly referred to as the "log velocity". The speed of sound through wood provides an indication of stiffness. The equation is as follows:

MOE (stiffness) = density x $(\text{acoustic velocity})^2$.

The tool is pushed up against either end of the log, a hammer is used to generate a sound wave and the frequency of vibration of the log is measured. That frequency is turned into the speed of sound inside the log. The tool is used by many logging crews around the world to estimate wood stiffness. Mill studies have consistently shown that the single most important parameter to predict lumber stiffness is log acoustic velocity. The tool can be used to segregate logs so those logs that will deliver higher stiffness can be sent to those customers who target markets requiring stiffer material.

More information about the HITMAN HM220 tool can be found on the supplier's website at:

https://www.fibre-gen.com/_files/ugd/5d1d5f_d807f8a74f1d466f948f325eff025b7a.pdf

Appendix 2: Predicted log grade recovery and financial performance of the *P. radiata x P. attenuata* hybrid

2022

1998 McKenzie Hybrid Trials

Predicted log grade recovery and financial performance of *P. radiata x P. attenuata* hybrids in two high country sites

Technical Report 01/2022

T. Fowler and P. Adams

Forest Services

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Summary

Two trials were installed in 1998 on the Ribbonwood and Balmoral high country stations in the McKenzie country. Their purpose is to compare the growth and performance of *P. radiata*, *P. attenuata* and *P. attenuata x radiata* hybrids on high elevation sites.

Results at age 23 years showed very poor survival for the *P. radiata* (below 50% on both sites). The height and diameter growth for the hybrid and *P. radiata* is significantly greater than *P. attenuata*. The basal area is the most telling metric in terms of performance between the taxa. The hybrid has almost double the basal area of *P. radiata* and *P. attenuata* due to poor survival in *P. radiata* and slower growth rates in *P. attenuata*. These differences translate directly to volume growth, with the hybrid predicted to produce 150 – 300 m^3 per ha more log volume recovery (TRV) compared to *P. radiata* and *P. attenuata*.

Financial analysis predicts that the IRR for the hybrid at age 23 years exceeds 8% for both trials, whereas the *P. radiata* and *P. attenuata* are unable to achieve more than 6.3%. The optimum rotation length for the hybrid differs between the two trial sites due to varying growth rates. At Balmoral Station the optimum rotation is 27 years. In contrast the optimum at Ribbonwood Station is 23, or potentially earlier.

All the findings from the age 23 analysis of these trials demonstrate that the *P. attenuata x radiata* hybrid is superior in terms of growth, log grade recovery and financial performance compared to *P. radiata* and *P. attenuata* on these two high country sites. This is an important message and strengthens confidence in the hybrid as Matariki Forests continues to invest and deploy it in high altitude sites in Southland and Canterbury.

Background and Objectives

This report presents results from the measurement and assessment at age 23 years of the two attenuata hybrid trials at Balmoral Station and Ribbonwood Station in the McKenzie Country. The objectives were to analyse the overall growth and performance of the hybrid with the key focus being predicted log grade recovery (TRV, Total Recoverable Volume) and the financial returns that could be expected. This work follows the 2021 report by Mark Paget (Radiata Pine Breeding Company) on the growth and performance of the genotypes deployed in the trials.

Methods

The two trial sites are located at Balmoral Station, Tekapo and Ribbonwood Station, Omarama. The trials contain three treatments (taxa), *P. radiata*, *P. attenuata* and *P. attenuata x P. radiata*. The site characteristics at Ribbonwood Station are more favorable than Balmoral Station. On average Ribbonwood Station has 300 mm higher annual rainfall and 8 less days with ground frost than Balmoral Station. The trial site is also situated at a slightly lower elevation (30 m) at Ribbonwood Station (Dungey et al, 2010).

The plot size is 36 trees at 3 m x 3 m spacing (0.032 ha). Both trials contain a total of 10 replicates of each treatment. The individual plots are Single Tree Plots with a total of 9 different crosses across all three taxa in the trial. Within these crosses the number of female parents varied. Seedlot types included open pollinated (OP), control pollinated (CP) and polymixes. The seed was sourced both locally in New Zealand and overseas (Dungey et al, 2010).

The measurement took place on the 23rd – 24th at Balmoral Station and 24th – 25th November at Ribbonwood Station by Buck Forestry Services. Within each plot, every tree diameter was measured along with a sample of heights. Heights were calculated using Vertex hypsometers. The trees were also cruised following industry standard cruising methodology. All the measurement data was entered on an Allegro data logger following the Plotsafe RAD05-A cruising template. The position of each tree was assessed, and each stem was numbered according to the plot layout sequence displayed on the trial maps (see Appendix 3).

The mensuration crew noted that the trials were in good condition, the was layout easy to follow and the plot pegs and numbers were readily visible. It was noted upon visual assessment, the mortality in the *P. radiata* plots was significantly higher, and the tree form was poorer compared to the hybrid.

The analysis was conducted using R statistics package, Excel and YTGen. The R statistics package was used to analyse diameter, height and basal area growth of the species and taxa. YTGen (Yield Table Generator) was used to predict the log grade recoveries based on the age 23 growth and assessment data. It was also used to grow the crop on to a rotation age of 30 years. The NZ tree volume and taper function 182 along with the CHH 17 Canterbury plains growth model were selected for the yield predictions.

The financial analysis has been conducted at an 8% discount rate using stated assumptions around log prices and costs (see Appendix 2). Log prices applied were the 12Q New Zealand weighted average. Harvest costs of $40/m^3$ were assumed. No attempt was made to account for additional costs such as overheads, cartage or roading, with the effect that the financial analysis reflects a high level “At Forest Gate” return. The purpose of this analysis is not to provide highly accurate return estimations, but to compare the financial performance in general terms between the species and taxa on these high-country sites.

Results and discussion

The survival of the three species follows a similar trend at the two trial sites. Both *P. attenuata* and the hybrid (*P. radiata x P. attenuata*) achieved high survival above 80%. The *P. radiata* was not able establish itself as successfully on either site with survival rates below 50%.

Clear differences in diameter growth can be seen between the species (Figure 2). The hybrid performed the best over the two sites, but at Balmoral Station *P. radiata* was almost equal. *Pinus attenuata* had lower median diameter in both trials. This reflects the slower growth rate of the species. There was greater variability at Ribbonwood compared to Balmoral, which can be seen in the range of the data.

Figure 3 shows the height growth rate of the hybrid and *P. radiata* is better than the *P attenuata*. Of note is the change in rankings between the two trials. At Balmoral Station, the *P. radiata* is slightly taller than the hybrid, but at Ribbonwood the hybrid is the taller of the two. The spread of the *P. radiata* boxplot at Ribbonwood indicates significant variability in height growth between trees. Upon inspecting the data more closely, the cause for this variability is due to the large proportion of broken tops in the *P. radiata* plots. The reason for the broken tops will primarily be snow damage, as both sites are in areas that receive regular snow over the winter months.

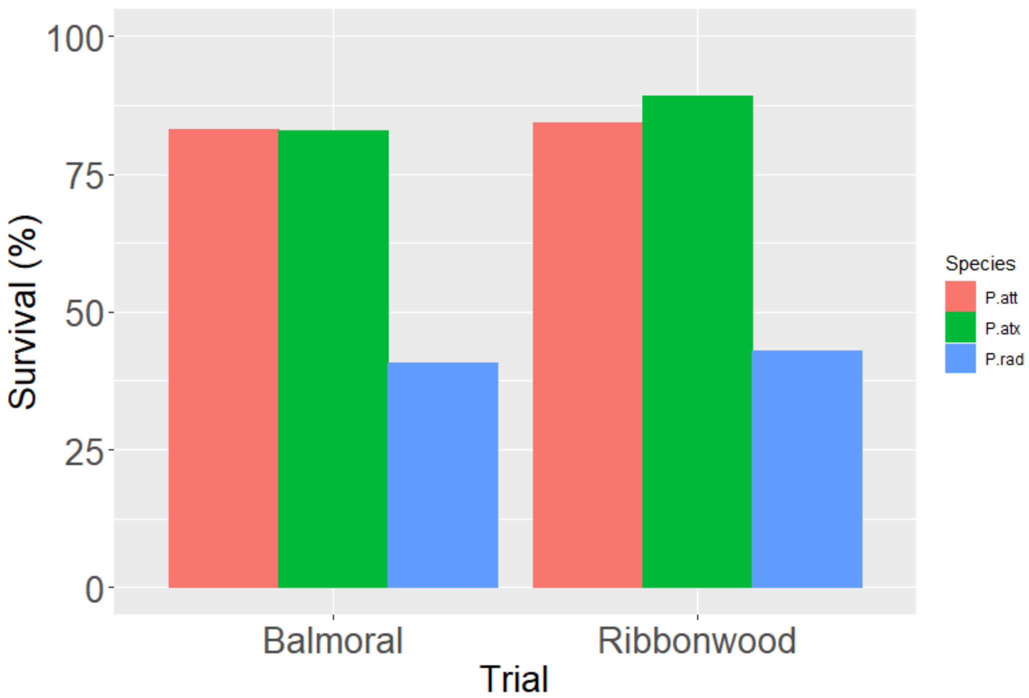

Figure 1: Survival by species at the Balmoral Station and Ribbonwood Station trials.

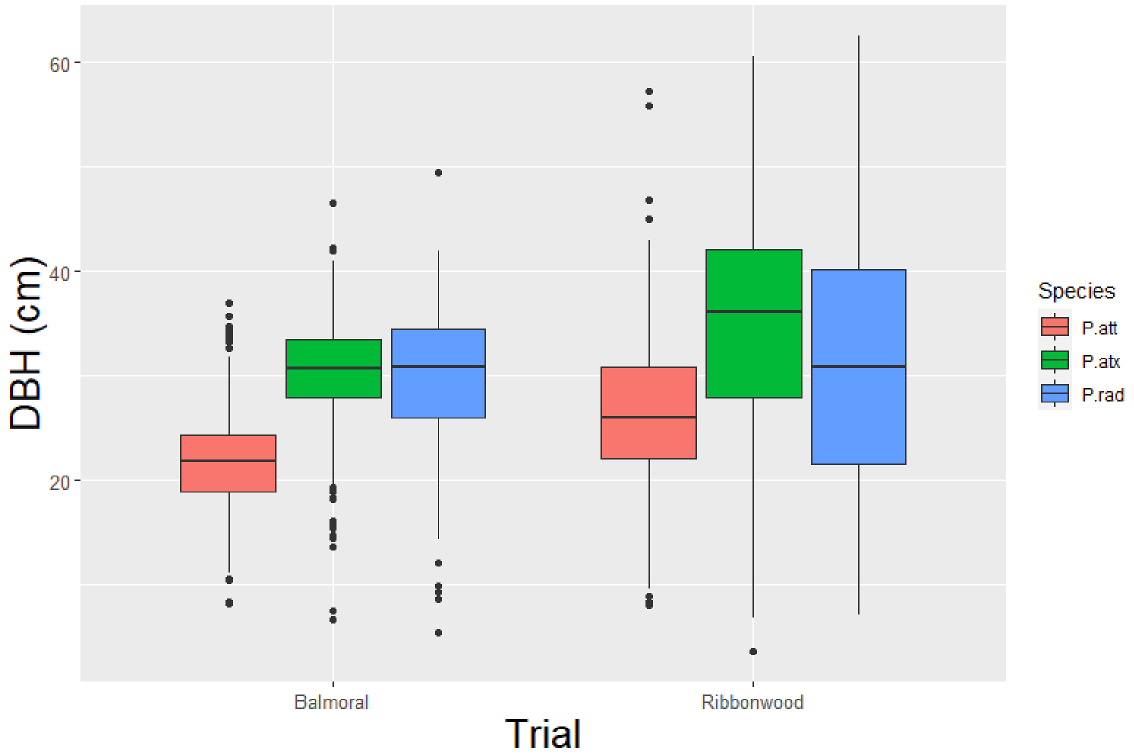

Figure 2: DBH distribution by species at the Balmoral Station and Ribbonwood Station trials.

The boxplots are divided into four quartiles, separated by the median line running through the centre. The length of the boxplots illustrates the range of the data, and any outliers are represented by singular data points beyond the outer quartiles of the plots.

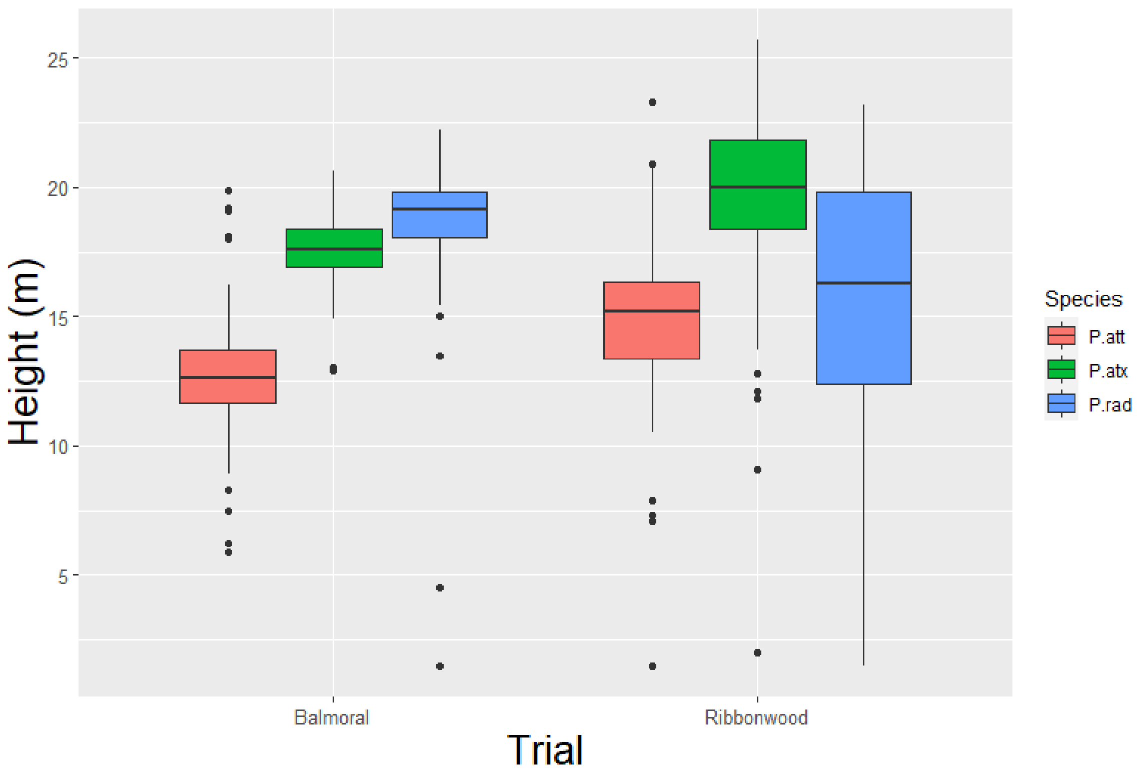

Figure 3: Height distribution by species at the Balmoral Station and Ribbonwood Station trials.

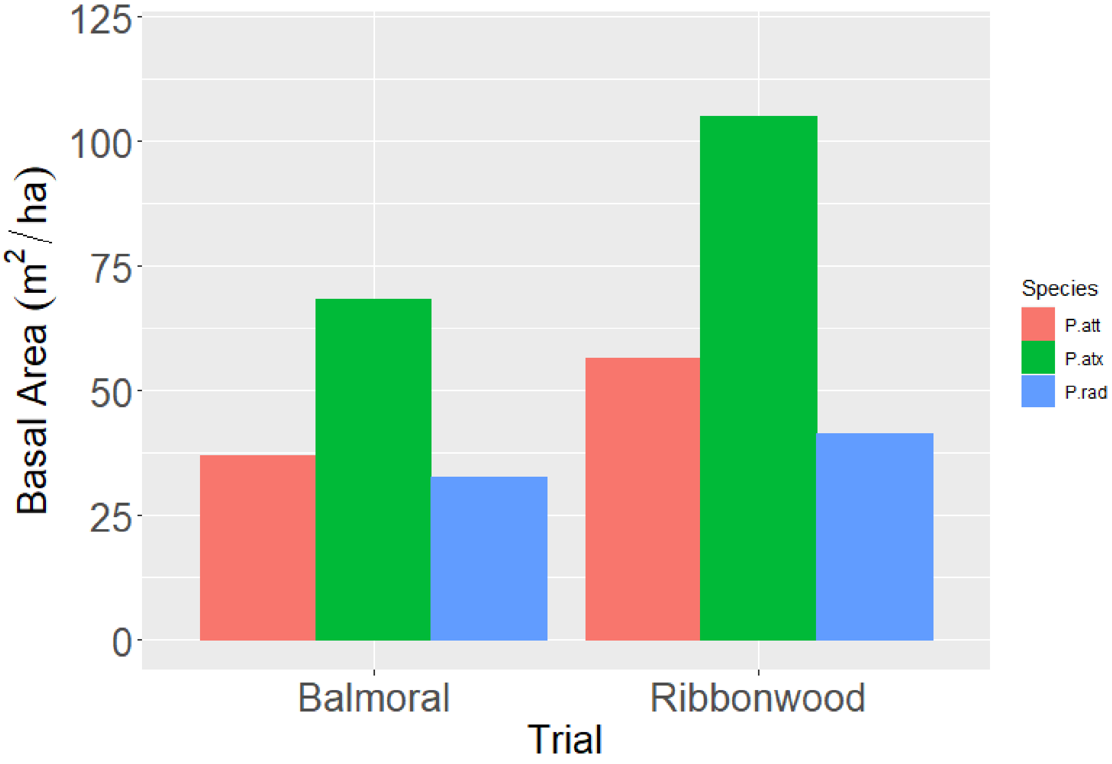

Figure 4: Average basal area by species at the Balmoral Station and Ribbonwood Station trials.

Pinus attenuata and *P. radiata* have significantly lower basal area than the hybrid at both sites but for different reasons (Figure 4). The differences can be explained fundamentally by some of the other key variables. For *P. attenuata*, it is the lower DBH and height growth in comparison to the hybrid that causes the reduced basal area. Conversely for *P. radiata*, it is the poor survival resulting in low stocking that is influencing the basal area. The DBH and height figures above show that the growth was similar between the two species, but the radiata was not able to retain the same stocking as the hybrid, hence the lower basal area per hectare.

The following section displays and explains the results of several analysis of variance (ANOVA) and Tukey multiple comparisons tests. The purpose of these tests is to help identify whether the choice of species has a statistically significant effect on some of the key forest metrics (DBH, height, basal area).

The analyses of variance indicate that the choice of taxa has a significant effect on average DBH, height and basal area at the Balmoral Station site. The multiple comparison displays show that *P. radiata* and the hybrid are not statistically different in terms of diameter and height. However, in terms of basal area, the hybrid is significantly greater. This supports the results illustrated in Figure 4.

At the Ribbonwood Station trial the hybrid is clearly the best performer regarding all three metrics. The multiple comparisons indicate that the hybrid average DBH, height and basal area are all significantly greater than *P. radiata* and *P. attenuata*.

4. Balmoral Statistical Analysis

Table 4: One-way ANOVA (Type II) on the effect of species on average DBH at the Balmoral Station trial.

	Chi-Square	DF	Pr(>Chi-Square))
Species	155.93	2	<2.2e-16 ***

Table 5: Tukey multiple comparisons for average DBH differences between species.

Species	Mean (cm)	DF	Lower CL (cm)	Upper CL (cm)	Group
P.att	22.1	27	20.9	23.2	A
P.rad	29.9	27	28.7	31.0	B
P.atx	30.3	27	29.1	31.4	B

Table 6: One-way ANOVA (Type II) on the effect of species on average height at the Balmoral Station trial.

	Chi-Square	DF	Pr(>Chi-Square))
Species	225.97	2	<2.2e-16 ***

Table 7: Tukey multiple comparisons for average height differences between species.

Species	Mean (m)	DF	Lower CL (m)	Upper CL (m)	Group
P.att	12.5	27	12.0	13.1	A
P.atx	17.3	27	16.8	17.9	B
P.rad	17.7	27	17.1	18.2	B

Table 8: One-way ANOVA (Type II) on the effect of species on average basal area at the Balmoral Station trial.

	Chi-Square	DF	Pr(>Chi-Square))
Species	211.49	2	<2.2e-16 ***

Table 9: Tukey multiple comparisons for average basal area differences between species.

Species	Mean (m^2/ha)	DF	Lower CL (m^2/ha)	Upper CL (m^2/ha)	Group
P.rad	32.7	27	28.8	36.6	A
P.att	37.0	27	33.1	40.9	A
P.atx	68.4	27	64.5	72.3	B

5. Ribbonwood Statistical Analysis

Table 10: One-way ANOVA (Type II) on the effect of species on average DBH at the Ribbonwood Station trial.

	Chi-Square	DF	Pr(>Chi-Square))
Species	29.272	2	4.402e-07 ***

Table 11: Tukey multiple comparisons for average DBH differences between species.

Species	Mean (cm)	DF	Lower CL (cm)	Upper CL (cm)	Group
P.att	26.7	22.8	24.9	28.4	A
P.rad	30.7	22.8	28.9	32.4	B
P.atx	35.3	22.8	33.5	37.0	C

Table 12: One-way ANOVA (Type II) on the effect of species on average height at the Ribbonwood Station trial.

	Chi-Square	DF	Pr(>Chi-Square))
Species	16.987	2	0.0002048 ***

Table 13: Tukey multiple comparisons for average height differences between species.

Species	Mean (m)	DF	Lower CL (cm)	Upper CL (cm)	Group
P.att	14.9	27	13.0	16.8	A
P.rad	15.2	27	13.3	17.1	A
P.atx	19.7	27	17.8	21.6	B

Table 14: One-way ANOVA (Type II) on the effect of species on average basal area at the Ribbonwood Station trial.

	Chi-Square	DF	Pr(>Chi-Square))
Species	141.02	2	< 2.2e-16 ***

Table 15: Tukey multiple comparisons for average basal area differences between species.

Species	Mean (m2/ha)	DF	Lower CL (cm)	Upper CL (cm)	Group
P.rad	41.5	24.2	32.1	50.9	A
P.att	56.4	24.2	47.0	65.8	B
P.atx	105.1	24.2	95.7	114.4	C

6. Predicted log grade recovery

Table 13: Age 23 grade recovery (m^3/ha and percentage of TRV) by taxa at Balmoral and Ribbonwood Station Trials.

Grade	Volume (m^3/ha)					
	Balmoral			Ribbonwood		
	P.atx	P.rad	P.att	P.atx	P.rad	P.att
A	2.09 (1%)	4.42 (2%)	0	44.84 (7%)	11.04 (6%)	4.38 (2%)
K	24.20 (7%)	10.21 (5%)	0.83 (1%)	21.87 (3%)	8.25 (4%)	4.19 (2%)
KI	0	0.98 (1%)	0	14.76 (2%)	7.18 (4%)	3.56 (1%)
L20	43.75 (12%)	15.93 (8%)	5.73 (4%)	70.12 (11%)	19.72 (10%)	21.42 (8%)
L30	3.94 (1%)	3.20 (2%)	0	38.63 (6%)	10.72 (6%)	4.33 (2%)
M30	0	0	0	18.79 (3%)	8.47 (4%)	0
M40	0	0	0	8.36 (1%)	0	0
S20	127.11 (34%)	38.81 (21%)	2.45 (2%)	170.74 (27%)	18.28 (10%)	33.15 (12%)
S30	0	0	0	75.01 (12%)	8.04 (4%)	2.85 (1%)
S40	0	0	0	2.49 (1%)	0	0
Pulp	168.22 (46%)	115.48 (61%)	145.25 (94%)	172.35 (27%)	99.20 (52%)	197.53 (73%)

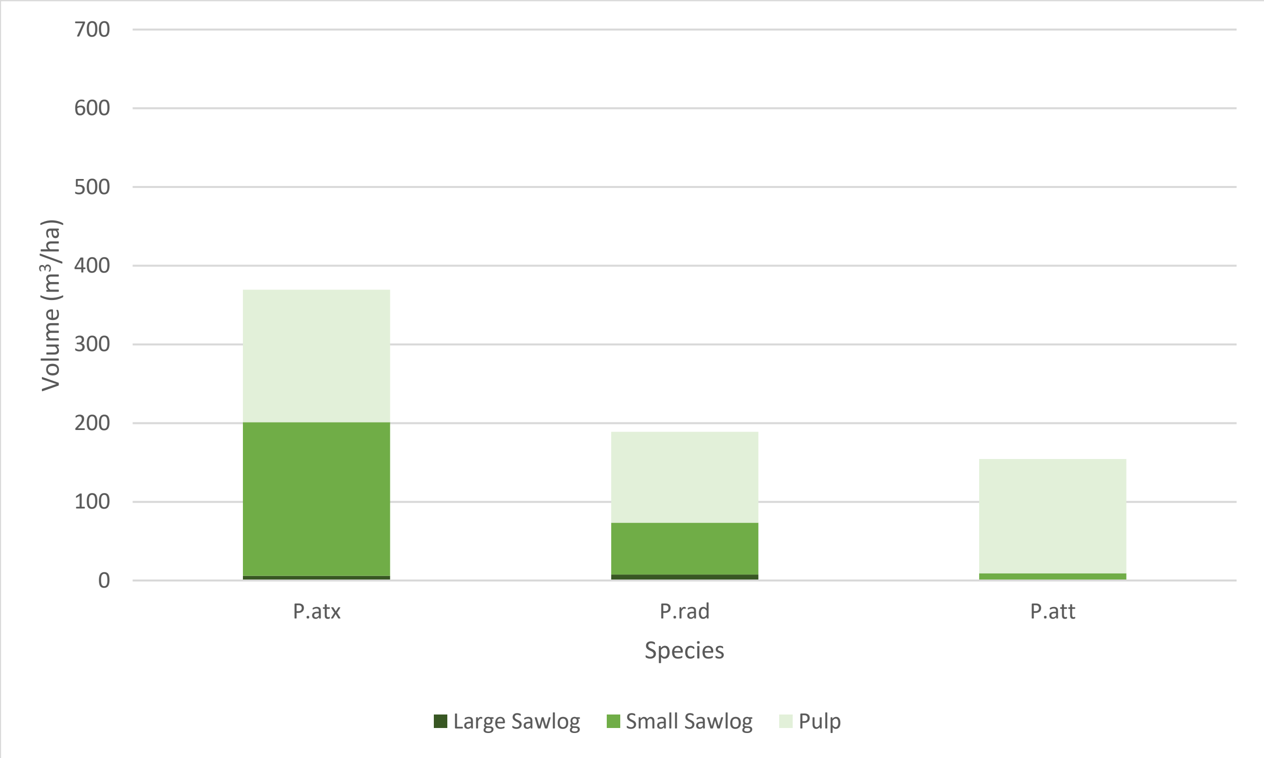

Figure 5: Age 23 TRV and grade recovery by species at the Balmoral Station trial.

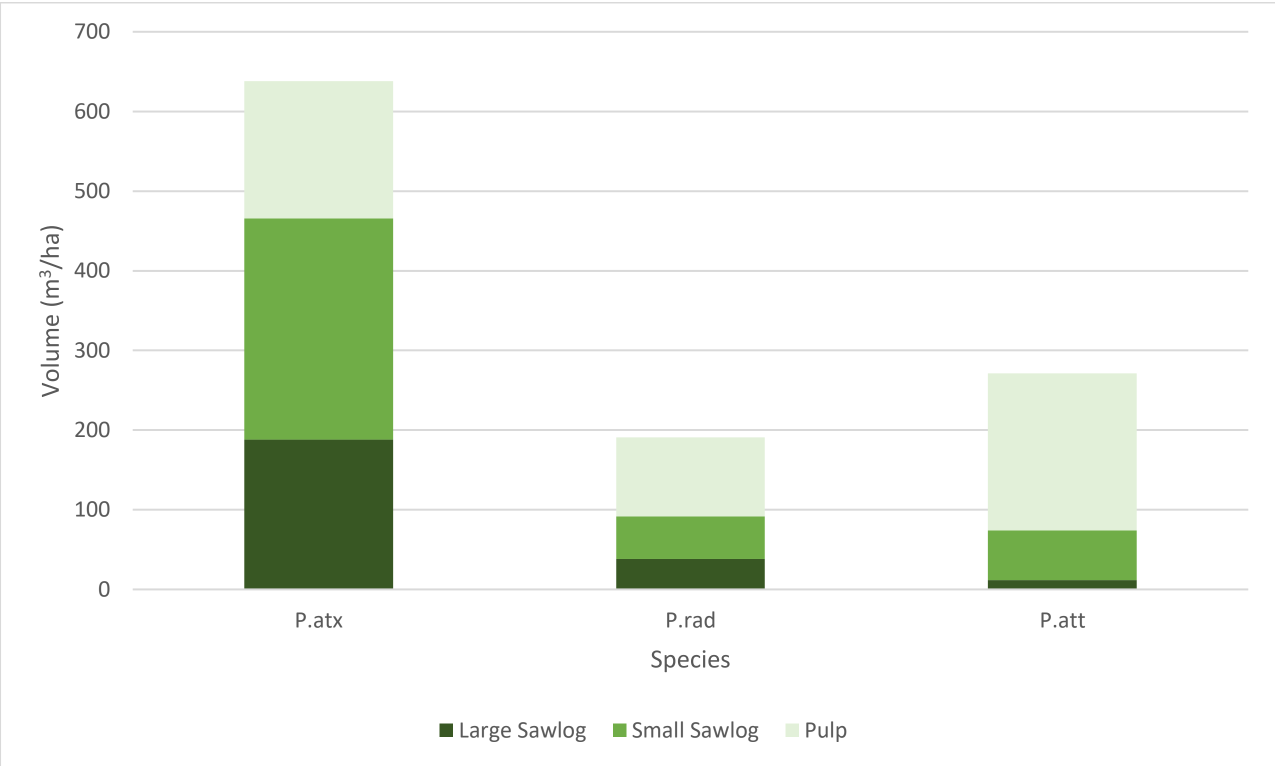

Figure 6: Age 23 TRV and grade recovery by species at the Ribbonwood Station trial.

Table 13 and Figures 5 – 6 illustrate that the total recoverable volume (TRV) is higher at the Ribbonwood trial than the Balmoral trial. At both sites the hybrid plots have much greater volume than the *P. radiata* and *P. attenuata*. The grade mixes show that the hybrid stands are also able to produce more valuable logs such as A, K, S30, S20, L30 and L20 sawlog grades. The other two species at both sites are unable to supply the range of grades, primarily producing pulp logs.

The factors mentioned earlier such as slower growth rates for *P. attenuata* and poor survival along with snow damage for the *P. radiata* are the main contributors to the trends displayed above. The Ribbonwood Station trial site is in a more sheltered area compared to the Balmoral Station site and has better drainage. Site factors such as these will be contributing to the growth patterns observed and ultimately the differences in TRV between the trials.

7. Financial Analysis

The NPV of growing the hybrid is higher than the two species at both trial sites (Figures 7 – 8). This reflects the improved growth and survival of the hybrid compared to the *P. radiata* and *P. attenuata*. The hybrids at the Ribbonwood trial have a significantly greater NPV compared to Balmoral Station. This comes as no surprise when comparing the TRV's in the grade recovery section above. The TRV at the Balmoral trial is over 250 m^3 lower than Ribbonwood, which leads directly to reduced value of the stand.

The optimum rotation lengths for the hybrid vary between the two sites. At Balmoral Station, the optimum is reached at age 27 with an IRR of 9.5%. In contrast, the ideal rotation age at Ribbonwood Station is younger, at 23 or possibly earlier. The IRR of the hybrid at the Ribbonwood trial age 23 is 13.5% (Figure 9).

The NPV's displayed above are only indicative. Their primary purpose is to display the financial differences between the species. It should be noted again that some inputs that will influence the NPV's and IRR's were not included in the analysis. Appendix 1 explores some scenarios of how the cartage distance will affect the NPV for the two trail sites.

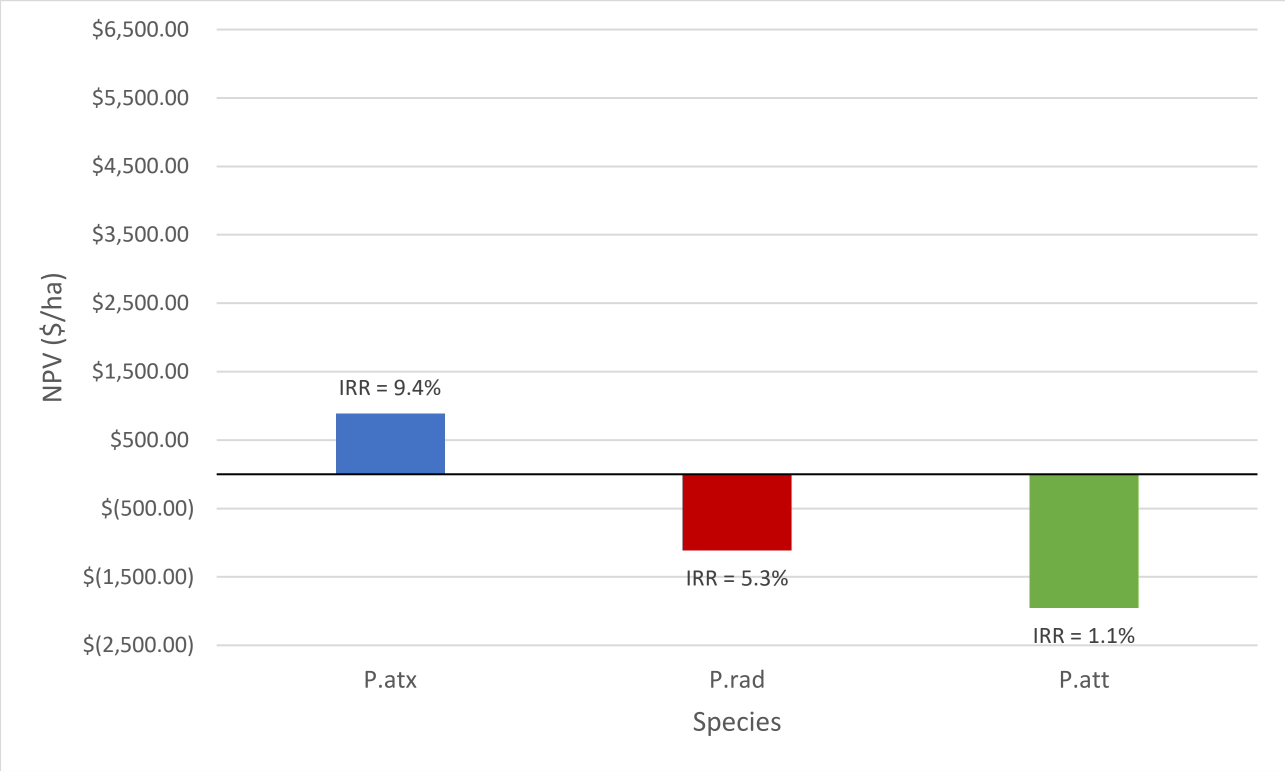

Figure 7: NPV and IRR age 23 by species at the Balmoral Station trial (at forest gate).

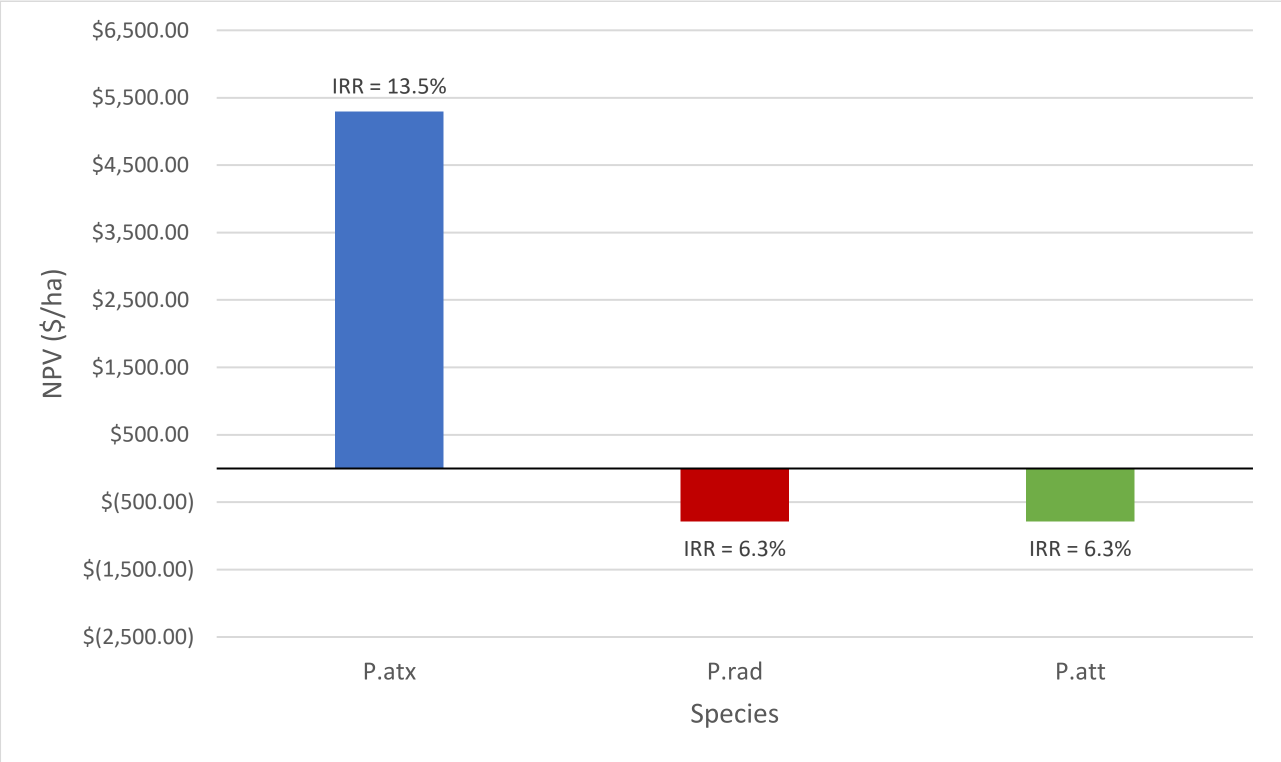

Figure 8: NPV and IRR age 23 by species at the Ribbonwood Station trial (at forest gate).

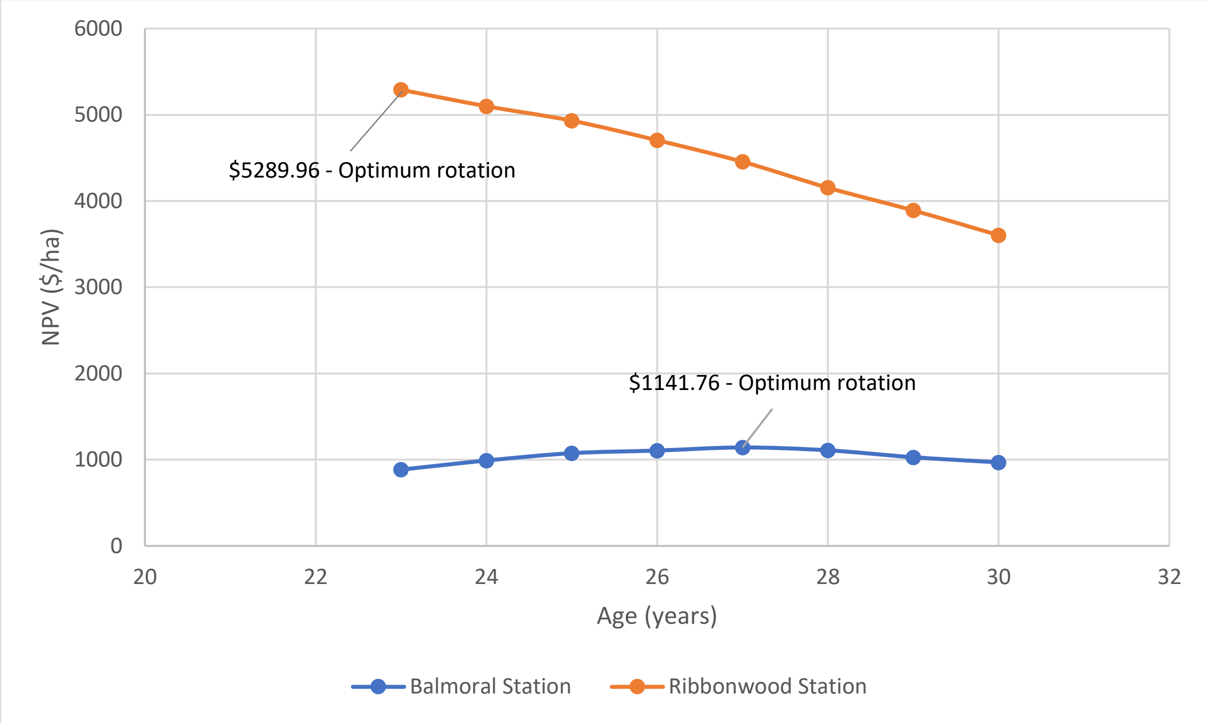

Figure 9: Hybrid NPV at the Balmoral and Ribbonwood Station trials by rotation age.

Conclusion

These two important trials demonstrate that the *P. attenuata x radiata* hybrid is significantly outperforming *P. radiata* and *P. attenuata* on both the Balmoral Station and Ribbonwood Station sites. The growth rate of the hybrid is clearly higher than *P. attenuata* and the survival along with tree condition is superior to that of *P. radiata*. These differences translate to improved TRV, grade recovery and NPV. At the current age (23), the average increase in rate of return over both sites from *P. radiata* to the hybrid is 5.7%. Despite some costs not being included in the analysis, this clearly indicates that the hybrid is a significantly more valuable crop on these two high country sites. The findings from these trials support Matariki Forests' decision to deploy the hybrid on high altitude sites as an extension of the *P. radiata* range.

Recommendations

- It is important that we understand the wood properties and the utility of logs from these trials and so it is recommended that a processing study be undertaken on selected logs from both sites at about age 25 – 26 years (2023 or 2024).
- A final measurement of the trials should be completed in the months leading up to final harvest. This, in conjunction with the prior measurements, will provide a full picture of the growth of the trees in these two trials.
- The third trial site at Eyrewell forest should be considered for a similar measurement and assessment in 2022 or near harvest age and the results used to contrast the two McKenzie trials.

References

Dungey, H., Low, C., Ledgard, N., & Stovold, G. (2010). Alternatives to Pinus radiata in the New Zealand high-country: early growth and survival of P. radiata, P. attenuata and their F hybrid. *New Zealand Journal of Forestry Science*, *41*, 61–69.

MPI, (2021), Indicative New Zealand Radiata Pine Log Prices. *Ministry of Primary Industries*. Wood product markets | Te Uru Rākau – New Zealand Forest Service | NZ Government (mpi.govt.nz)

Paget, M. (2021). *P. attenuata* x *P. radiata* Hybrid trial analysis report. *Radiata Pine Breeding Company*.

Appendix 1: Cartage analysis

The cartage cost used for the following analysis is a benchmark market rate (Q4 2021) of $0.27/m^3/km

8. Balmoral Station cartage

The nearest large centre to Balmoral Station with markets for the timber (sawmills, port, firewood) is Timaru. The distance from Balmoral Station to Timaru is 110 km. This means that it will cost approximately $29.7 per cubic meter to cart the logs to market.

Figure 10 below illustrates that the NPV of the hybrid at varying cartage distances. When carting 110 km (Balmoral Station – Timaru), the NPV is -$873. The IRR at this distance is 6.0%. The cartage distance at which exactly 8% return on investment (8% IRR) is 55 km. Therefore, to achieve an 8% return or higher at Balmoral Station the cartage must be between 0 – 55km. This is unlikely to be feasible due to the absence of markets within that range.

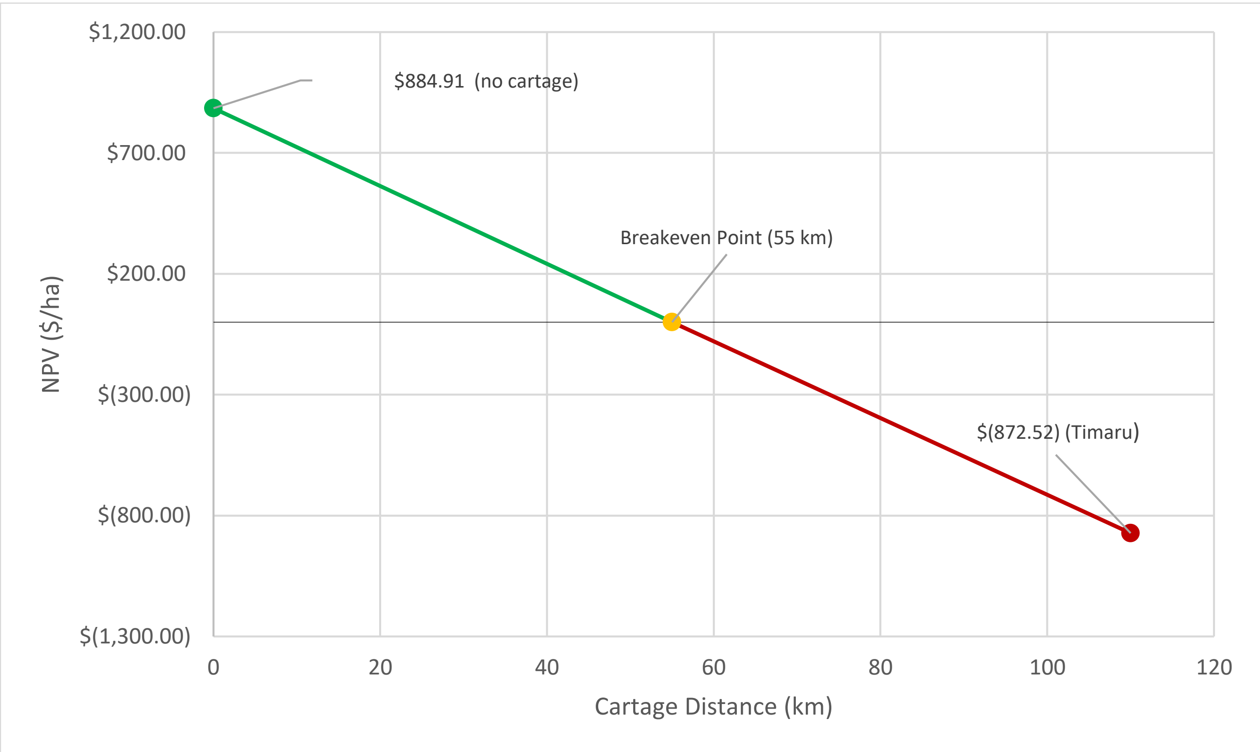

Figure 10: Hybrid NPV at varying cartage distances for the Balmoral Station trial.

9. Ribbonwood Station cartage

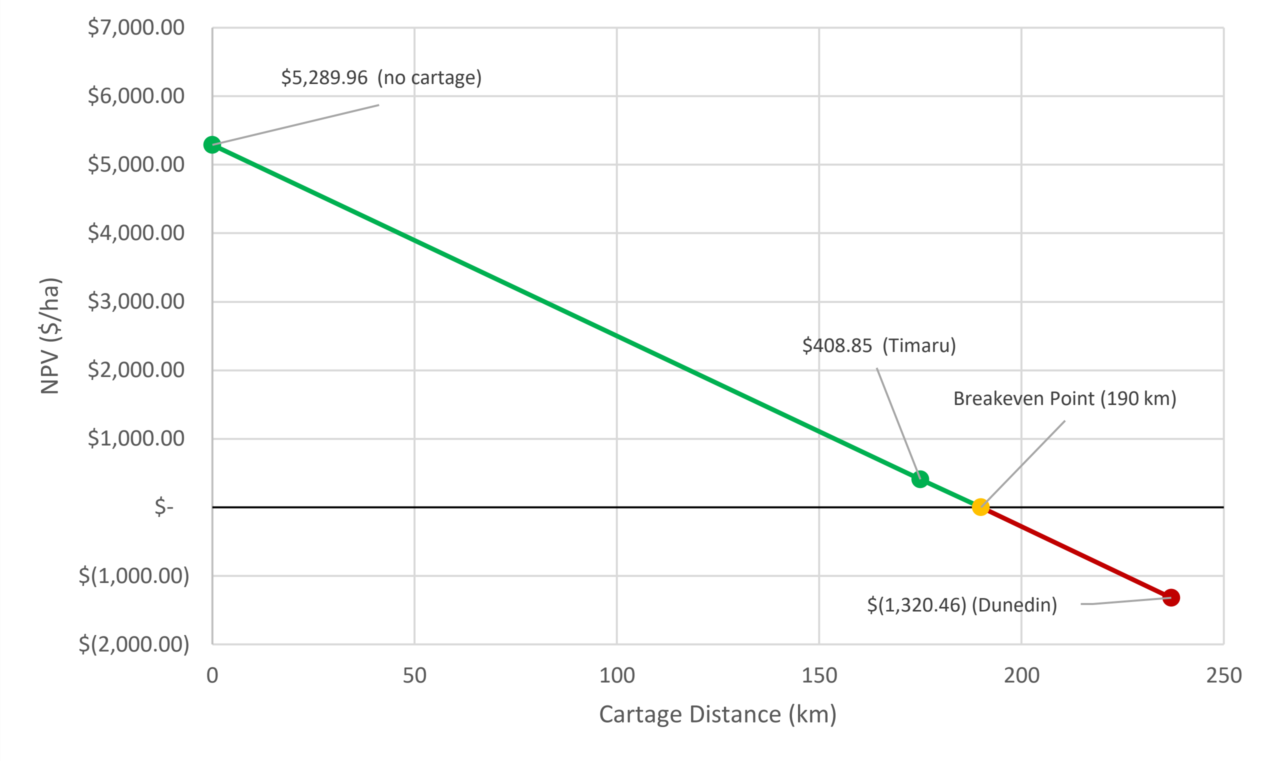

Figure 11: Hybrid NPV at varying cartage distances for the Ribbonwood Station trial.

The Ribbonwood Station is located further south than Balmoral Station, near Omarama. The distance to the Timaru markets is 175 km. It will cost approximately $47.3 per cubic meter to cart the logs up to Timaru.

Figure 11 shows that even with the high cartage costs the Ribbonwood Station trial returns a positive NPV when carting to Timaru at $409/ha. This equates to an IRR of 8.7%. The breakeven point is 190 km, which means it is possible to achieve an 8% return when carting the logs anywhere from 0 – 190 km.

Appendix 2: Price & Cost Assumptions

Table 16: Estimated current log prices for analysis (12 month average MPI, 2021).

Grade	Price ($/m^3)
A	164
K	154
KI	133
S40	148
S30	143
S20	130
M40	142
M30	138
L30	142
L20	130
Pulp	57

Table 17: Estimated costs for analysis.

Cost	Price ($)
Harvest Cost	40/m^3
Cartage Cost	$0.27/km/m^3
Establishment Cost	2,500/ha

Appendix 3: Ribbonwood Trial layout

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TITLE: 1998 P. RADIATA X P. ATTENUATA HYBRID TRIAL
LOCATION: RIBBONWOOD STATION
FOREST OWNER: COLIN MCKAI
ESTABLISHMENT DATE: 18/8/98 SPECIES: *P.RADIATA/ P.ATTENUATA*
PLANTED AREA: 1 HA PLANTED STEMS: 1080 TRIAL NUMBER: FR352/3
MAP NUMBER: 586 DRAWN BY: GT STOVOLD DATE: 10/9/99
CONTACT: GENETIC IMPROVEMENT OF RADIATA PINE PHONE: (07) 347-5899