PROOF OF GENETIC GAIN

PUBLISHED APRIL 2019

GF Plus®

RPBC®
Radiata Pine Breeding Co Ltd

The Radiata Pine Breeding Company's programme is delivering substantial gains in growth, form, stiffness and wood density through a programme of selective breeding.

Selective breeding improves the performance of each successive generation of radiata for these key traits. Gains are quantified through improved breeding values estimated annually from measurements in RPBC breeding trials.

RPBC has converted breeding values to a simpler rating scheme called GF Plus™ for 5 key traits: diameter growth, stem straightness, wood density, branching habit, and resistance to *Dothistroma* needle blight. Higher GF Plus™ values indicate more improvement. The tables show the traits and the current range in GF Plus™ values for these traits. GF Plus™ ratings apply to control pollinated (CP) seed and planting stock.

THE GF PLUS™ TRAITS

Traits	Unit of Measure
Growth (DBH)	Diameter at breast height
Straightness	Stem straightness (previously stem form)
Branch habit	Whorl incidence (multi-nodal vs uninodal)*
Wood density	Average breast height outerwood density from a 5 or 10 mm core at 20 years
Corewood stiffness (PME)	Predicted Modulus of Elasticity is measured as acoustic velocity on young stems
Dothistroma resistance	Measured as percentage needle loss

* Multi-nodal means frequent whorls of branches; uninodal means few whorls and long sections of stem between them.

THE GF PLUS™ RATINGS

Traits	GF Plus™ values – 2018		
	Min	Median	Max
Growth (DBH)	0	18	35
Straightness	8	17	24
Branch habit	11	20	29
Wood density	-17	17	49
Corewood stiffness (PME)	9	15	23
Dothistroma resistance	-2	18	40

GENETIC GAIN

Improvements expressed as 'genetic gain' have been quantified by RPBC and Scion using data from five decades of large-scale field trials spanning the length of New Zealand and eastern Australia. Significant gains related to genetic quality and GF Plus™ have been measured in these trials over full rotations. GF Plus™ ratings have been shown to indicate genetic potential but genetic potential does not work in isolation. Environmental factors and silvicultural management in combination with genetics have a significant effect on the growth, form and wood qualities of the final tree crop.

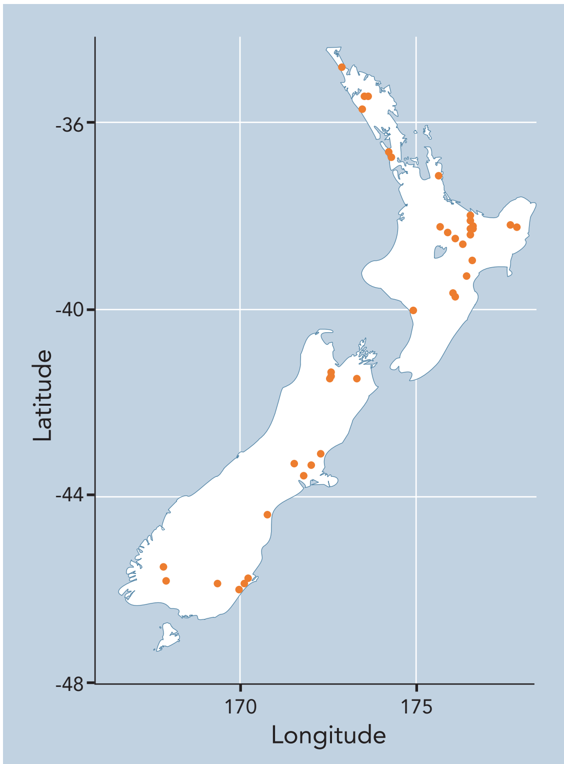

Fig 1: Large block genetic gain trial locations of various designs established by the then FRI between 1978 and 1991.

Genetic gains in growth and wood quality related to genetic improvement have been reported by RPBC and Scion and key points for forest growers are summarised below.

GROWTH GAINS

Productivity is often measured in terms of volume growth, a major driver of profitability in radiata plantations. Volume increases faster over a rotation for genetically improved trees compared with unimproved trees.

Analyses of the long term trial data showed that standing volume was approximately 25% greater for highly improved seedlots (GF Plus™ 25) compared with unimproved seedlots (GF Plus™ 10). This is equivalent to 170-250 m^3 ha^{-1} at age 30, depending on site productivity. There was an 11% volume gain in the GF Plus™ 25 compared with a moderately genetically improved seedlot (GF Plus™ 17) over a rotation. Higher volume production means that rotation length could be shortened by between 2 and 4.5 years by growing highly improved material depending on the degree of improvement and site quality[1].

Measured gains in volume are larger on better quality, more productive sites for both improved and unimproved genetic materials, which shows the importance of site quality as well as genetic quality. The strong relationship between volume production and GF Plus™ rating expressed as 'Highly Improved' (GF Plus™ 25) and 'Unimproved' (GF Plus™ 10) is shown in Fig 2 for low, medium and high-quality sites.

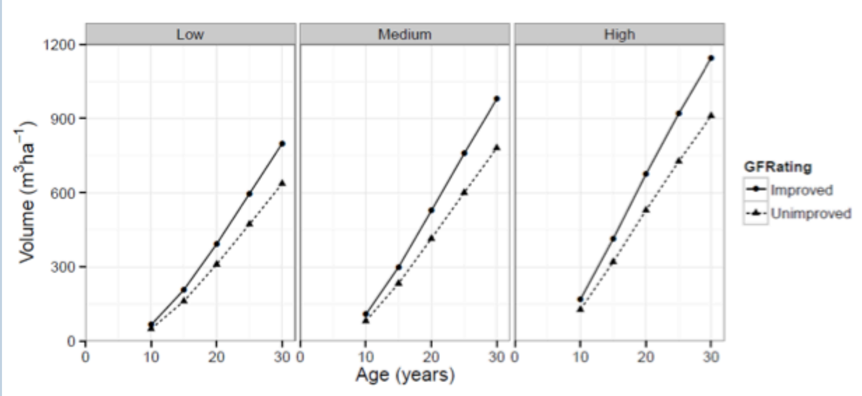

Fig 2: Predicted stand volume yield over time for improved radiata (GF Plus™ 25) grown in a typical radiata pine regime compared with unimproved radiata (GF Plus™ 10) on low, medium and high productivity sites.

Various indices of productivity, for example, Site Index and 300 Index (an index of volume accounting for silviculture) also increased with increasing values of GF Plus™ growth. Site Index, which is indicative of potential stand height, increased 5.6% with the improved seedlots (GF Plus™ 25) compared with unimproved (GF Plus™ 10). This equates to an extra 0.36 m height (ranging between 0.22 and 0.5 m) with each additional unit of GF Plus™. 300 Index values increased 1.6% (± .37%) for each unit increase in GF Plus™ growth.

DENSITY GAINS

Wood density is a key indicator of general wood quality and recovery of high grade lumber is increased in higher density logs. Wood density is highly heritable and gains in this trait have been measured across an extensive range of trials.

Outer-wood density measured at breast height (1.4 m) at 20 years is referred to as an Index of Wood Density. Trial measurements show an increase of 2.16 kg per m^3 for each increase in GF Plus™ for density[2]. Fig 3 shows the correlation between GF Plus™ density and the Wood Density Index (R^2=0.73).

This genetically related gain is equivalent to an increase in the Density Index of 1.75 – 2.70 kg per m^3 for each unit increase in GF Plus™. Genetically improved seedlots planted today have a GF Plus™ value around 27 and for this material the Density Index is expected to be approximately 19 kg per m^3 higher than that of moderately improved seedlots (GF Plus™ 18). Whole log density is predicted to increase between 14 to16 kg per m^3 with an increase in GF Plus™ rating from 18 to 27 based on growth model simulations.

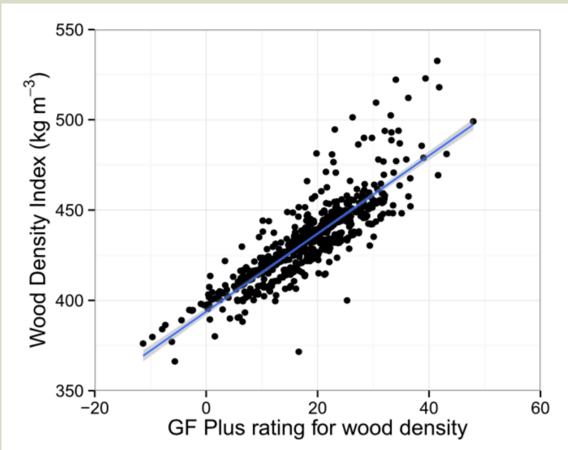

Fig 3: Relationship between GF Plus™ wood density rating and the Wood Density Index for 679 radiata pine families.

[1] M.O. Kimberley, J.R. Moore and H.S. Dungey. *Quantification of realised genetic gain in radiata pine and its incorporation into modelling systems. Can. J. For. Res. 45: 1676-87 (2015).*

[2] M.O. Kimberley, J.R. Moore and H.S. Dungey. *Modelling the effect of genetic improvement on radiata pine wood density. N.Z. J. For. Sci 46: 8-10 (2016).*

It is important to understand that environmental factors, particularly latitude and altitude in NZ, affect the absolute values, or inherent wood density, of a stand and hence the proportion of logs that will exceed the industry threshold of 440 kg per m^3. Log density is substantially higher in Northland, for example, than in Southland/ Otago forests. RPBC-Scion studies indicate that the proportion of logs exceeding the threshold could increase from 23% to 40% with a GF Plus™ rating increase from 18 to 27. The absolute increase will depend on the site. When managed with appropriate silvicultural regimes on appropriate sites, radiata stands are expected to meet industry thresholds for wood quality.

STIFFNESS GAINS

Fig 4: MoE being measured using an ST300.

Stiffness, an indicator of wood strength, is defined as Modulus or Elasticity (MoE). MoE is estimated in standing trees using acoustic tools such as the ST300 (see Fig 4). RPBC is developing breeding values for MoE, referred to as predicted Modulus of Elasticity (PME) from acoustic velocity measurements in breeding trials. As there are relatively few measurements at this stage these data are not available as GF Plus™ ratings. Complex measurements of stiffness across and up stems grown under different regimes and environments have been integrated by Scion to predict stiffness at age 20 years. Standing tree acoustic velocity is a moderate to highly heritable trait, particularly in the corewood, although the genetic control over stiffness appears to vary between sites. Stiffness, like density, is negatively correlated with growth rates.

Based on the positive correlation between stiffness and breeding values for PME (R^2=.76), the Scion models predicting ST300 velocity values for radiata at age 20 can be adjusted for genetic improvement. For each unit increase in PME breeding value there is an increase of 3.5% or 140 m/sec in ST300 velocity at 20 years[3].

Environmental conditions affect ST300 acoustic velocity measures. Mean annual temperature has the largest impact on acoustic velocity so stiffness, like density, is higher in warmer regions (Fig 5). Genetics is the next most influential factor. Stand density also affects stiffness though more work is required to fully integrate stand density effects on MoE in the predictive models.

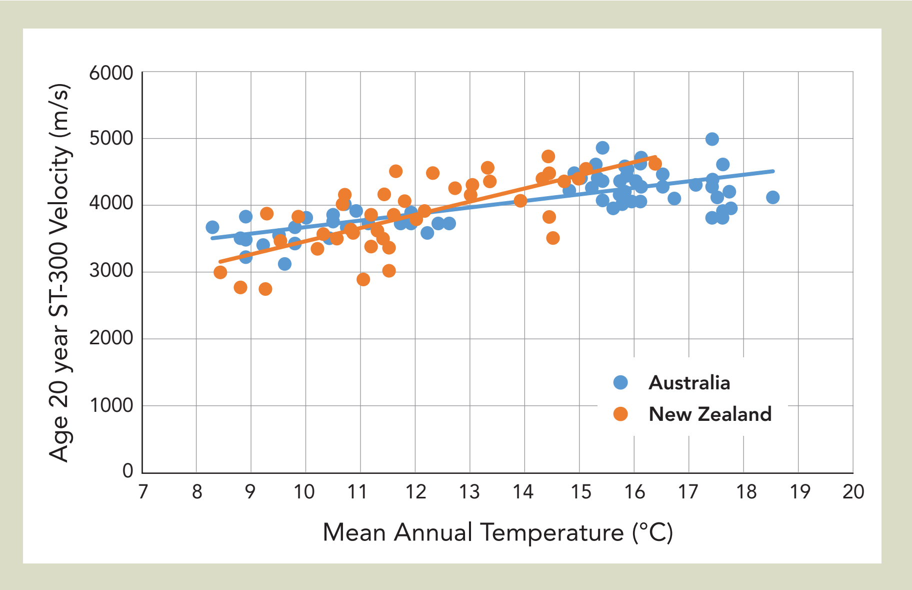

Fig 5: Relationship between acoustic velocity at age 20 years and mean annual temperature in New Zealand and Australian radiata pine stands.

Ongoing measurements of acoustic velocity in genetics trials will enable RPBC and Scion to validate and improve the models predicting increased genetic gain for stiffness.

[3] *J.R. Moore, M.O. Kimberley and H.S. Dungey. Quantification of realised gain for stiffness and its incorporation into Forecaster. RPBC Report November 2017.*

DOTHISTROMA RESISTANCE GAINS

Radiata Pine is highly susceptible to *Dothistroma* needle blight which can cause substantial growth losses in warm and humid climates (Fig 6). Defoliation studies indicate significant growth loss are incurred if more than 25% of the current year's needles are lost from 50% of the trees. If trees are infected for three consecutive years there is a 10% reduction in volume increment for each 10% of the crown infected. Stand level estimates of growth loss are complex due to compensatory growth of uninfected trees[4].

Resistance to needle loss resulting from *Dothistroma* infection is a moderately heritable trait. Radiata with higher GF Plus™ ratings have reduced needle loss. Gains may be modest, up to 20% based on current breeding values, so spraying is still recommended in heavily infected stands. Aim for GF Plus™ values above 20 to increase *Dothistroma* resistance in your seedlot.

Fig 6: *Dothistroma* infected trees.
Image: Paul Adams

STRAIGHTNESS GAINS

Stem straightness reflects the proportion of significantly swept sections of stem. Straightness is a heritable trait and has been increased significantly over decades of tree improvement in New Zealand. Commercial CP seedlots include crosses that are well rated for stem straightness. Trees grown from seedlots with GF Plus™ ratings of more than 20 will be straighter than trees at GF Plus™ 14 but growth rates may be compromised if crosses with very high GF Plus™ straightness values are requested. Aim for ratings of GF Plus™ straightness 18 or more in improved seedlots. Note that GF Plus™ ratings for straightness have not been found to have an effect on the probability of forking[5].

BRANCHING HABIT

Branching habit influences branch size through its effect on the distance between branch clusters (mean internode length, MIL). Branching is highly controlled by genetics, silviculture and site fertility. Multi-nodal trees have shorter internode lengths. Trees with long internodes (uni-nodal) are vulnerable to breakage, particularly in exposed areas, and have poorer stem form and lower growth rates than multi-nodal trees.

CONCLUSION

Log volume and quality determine the value of radiata pine at harvest. Genetic improvements available in commercial CP seedlots provide alternative options to increase value through increased volume at harvest; improvements in wood properties (density and wood stiffness); reduced growth losses due to needle diseases; and improvements in stem form and branching characteristics. It is important to identify your genetic priorities since CP crosses and seedlots highly rated for all traits are rare. Most commercial CP seed and stock available is genetically improved for several traits.

The results from the extensive and intensive research quantifying the gains in genetic improvement provide forest managers with confidence to invest in genetic selections with the level of improvement to meet their needs.

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[4] *L. Bulman, P. Gadgil, D. Kershaw, and J. Ray. Assessment and Control of* Dothistroma *Needle-Blight. Forest Research Bulletin No.229 (2004).*

[5] *https://academic.oup.com/forestry/article/91/3/327/3572449*

Cover image: Phil Taylor