Tree 55 - the grandad of today's Radiata Pine plantations, is a mighty specimen, but it's not tomorrow's tree.

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RADIATA. THE RACE TO GROW A BETTER TREE

Story: John Ellegard **Photos:** Supplied

IN A SMALL GROVE IN THE SOUTHERN SECTOR OF KINLEITH Forest, not far from the bustling traffic of State Highway 1, is a stand of mature Radiata Pine trees that are unlikely to feel the chatter of a chainsaw blade on their bark any time soon. Or ever, for that matter.

They're too important to chop down. Well, one of them is – the rest are there to protect it.

That special tree goes by the official moniker of 85055. But most people in the forest research and tree breeding community simply refer to it as 'Tree 55'.

Approaching this tree, you can see why it's regarded as special. Tree 55 towers above the rest, a giant among its fellow Pinus radiata kin. Reaching to the sky, it's around 45 metres from ground to the top of its canopy – making it one of the tallest, if not THE tallest Radiata Pine in New Zealand (they can grow up to 60 metres at full maturity).

It also has a wonderfully straight and uniform structure, with a pom-pom of branches sprouting from the top.

If there was a beauty contest for Radiata, Tree 55 would surely win hands down.

Walking back out of this stand and looking across to the surrounding plantation, you're struck by the knowledge that there is a little bit of Tree 55 in every single Radiata in Kinleith Forest. And Kaingaroa Forest, an hour to the east. Same with the forests in Northland, the East Coast, Wairarapa, Manawatu, Taranaki, Wairarapa, Wellington and across the South Island.

Tree 55 is the grandfather to virtually all of the Radiata Pines that have been grown in New Zealand plantations for the past 60+ years.

Back in the 1950s and early 1960s, when scientists at the old Forest Research Institute in Rotorua (the forerunner of Scion) began their quest to improve the humble Radiata, they sent people into the forests to seek out good specimens to breed from.

They identified and selected a number of trees for their superior growth and form to kick start the programme.

They were the first 'plus-trees', used to propagate the next generation through grafting. The grafted pines were planted out in seed orchards away from other Radiata plantations to prevent pollen contamination when they flowered. Seeds from those improved Radiata Pines were collected in 1968 to produce seedlings that went into forests in 1970.

Tree 55 was never considered to be particularly outstanding when it was young, but it displayed nice form and straightness and was good enough to breed from. However, as it matured, Tree 55 began to outgrow its contemporaries and soon became the 'go-to' tree for collecting seeds and grafting material, spreading its genes far and wide through the future Radiata population.

But there was a catch. And it was enough to cause tree breeders to later move away from their reliance on Tree 55.

"Subsequently, we found out that some of its wood properties are not as good and that caused us to drop it out of our breeding programme," says Shaf van Ballekom, General Manager of Proseed NZ, one of New Zealand's leading plantation tree seed producers.

"From the outside, looking at that tree, if you were solely focused on growth, form and straightness, Tree 55 turned into a damn good specimen.

"But it didn't have the required wood density the industry was looking for. Things do change and, depending on the uses you want from the tree, you might be more interested in stiffness than density these days but the two don't automatically correlate with each other.

"Tree 55 actually has some very good mechanical pulping properties, so there are some traits that would make it interesting to some users today. But on the whole, it's had its time."

Researchers and tree breeders now look for a blend of characteristics that will more precisely match the needs of both the forest grower and the end user. Straightness and strong growth are only part of that equation.

Today's Radiata Pine needs to display good DBH (diameter at breast height) when close to harvest age, stiffness (especially for structural uses), minimal branching, the ability to grow in a range

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Above left: Pollinating promising Radiata Pines at the RPBC tree growing orchard near Amberley in north Canterbury.

Above right: Various trial tags on this Radiata at the RPBC orchard, denoting when pollination took place – now it's a case of waiting to harvest the cones.

Facing page: New Zealand's oldest surviving Radiata (Monterey) Pine tree is this Magnificat specimen still growing strong at Mt Peel in the Canterbury high country after 163 years.

of climatic and soil conditions, and to be disease resistant. Density is also important, but that does come at the expense of stiffness, so those two traits need to be balanced. And the faster it grows, the better – trees are now considered mature as young as 25 years of age in warmer areas like Northland or East Coast, and the aim is to get that down into the low 20s within the next rotation. A dozen years ago, when I took over as editor of *NZ Logger*, the average harvesting age of Radiata was around 28-to-30 years. We've come a long way in a short time.

In fact, Radiata itself has come a long way. From the other side of the Pacific, to be exact.

The birthplace of Radiata is a narrow stretch of the northern Californian coast, just south of San Francisco, plus a couple of islands off the Mexican coast. Its common name is Monterey Pine, after one of the two mainland forest locations. There aren't many trees in the home forests, less than 8,000 hectares in total, and sadly, those few hectares are under threat from pine pitch canker, which is attacking the trees. Contrast that with the millions of hectares of Radiata now grown around the world, from New Zealand, Australia and South Africa to Chile and Spain.

That's not the only contrast. Put a Radiata Pine grown in a modern plantation up against a Monterey Pine in California and you'd swear they're not related at all. The original Monterey Pines have a dense, bushy habit when left to grow wild, often sprouting multiple stems. Most of them look nothing like Kinleith's towering Tree 55. The reason for the difference? More than 100 years of selective breeding and science – mostly undertaken right here in New Zealand.

A minor species on its home turf, the Monterey Pine was never originally intended to become the world's most productive softwood plantation tree. A few seeds found their way to the UK in the 1830s and thence to Australia and New Zealand in the 1850s to be planted as ornamental trees and shelter belts in the newly established colonies. The trees seemed to tolerate the vast range of soil types and took an exceptional liking to our warm, temperate climate.

Among the first to adopt this 'alien' tree were Canterbury farmers, who imported seeds to grow shelter belts for their stock to provide protection against the fierce nor' westerly winds. One of them was wealthy landowner John Acland, who planted his pines at Mt Peel Station in South Canterbury from seeds germinated in Sydney in 1856. One of those first trees, planted out at Mt Peel in 1859, survives to this day and is documented as the oldest Radiata Pine in New Zealand.

Radiata continued to be used largely as a shelter belt tree (much like another Californian import, Macrocarpa) until the early 20th century, when the New Zealand government became increasingly concerned at the rapid depletion of native forests.

The 1913 Royal Commission on Forestry, set up to identify trees that could be grown en masse to supply wood to the nation, zeroed in on Radiata as a highly suitable candidate. Radiata was already being milled in Canterbury and Southland at that stage for use as boxwood for fruit and butter, along with the construction of dwellings.

The choice was made, and by the 1920s and 1930s, nurseries were churning out huge numbers of Radiata seedlings to go into large plantations in the central North Island and other locations to be harvested some 30+ years later, in the 1950s and 1960s.

This was the birth of New Zealand's modern forestry industry. It was also a lesson to the rest of the world in how to transition to sustainable plantation forestry that not only supports the industry, but also allows for the native forests that remain to be protected for posterity in their natural environment. That we still retain more than 25% of our land cover under native trees, against just 3% planted in exotic trees, speaks to the wisdom of the decisions of our forefathers.

But foresters still had to deal with one problem. Radiata was exhibiting much of the wild, hoary growing habit of its Monterey origins. Pruning and dense planting helped, but the 'mongrel' couldn't be completely tamed. The answer was to try and breed out the worst traits and turn the mongrel into a monarch. In the 1950s, that's what the industry set about trying to do.

Alongside the Forest Research Institute, large companies like NZ Forest Products and Fletchers devoted significant efforts to

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Above left: One of the pollination tags up close.

Above centre: Cones with different pollination material growing on one of the trial trees.

Above right: The next generation of trees propagated at the RPBC orchard are planted out, but they won't show their true potential for eight years.

establishing breeding programmes to grow better Radiata Pine trees. But it's a long and laborious process. Effectively, you don't really know how successful those breeding efforts are until the tree is harvested and opened up for milling. That means we are still just two or three rotations down the track in the breeding programme. By contrast, agricultural scientists can produce new varieties of grass, corn or other horticultural plants in a handful of years.

It can be frustrating for forest growers. And sawmillers.

When a log arrives at the mill, it's a bit of a lottery as to what they'll find. To get the most from a log, they want one that is uniformly round, with no sweep or wobble, has a small amount of heartwood to minimise discolouring of the outer wood, no cracks and minimal knot whorls. If the timber is going to be used for structural purposes it needs to be very stiff, too. And it's imperative that the logs arrive at the mill very soon after harvesting to minimise blue sapstain issues.

Consistency is the keyword and it starts with producing consistently good seeds and seedlings.

By the 1980s, the industry took the next step to achieving that goal with the publication of the 'Development Plan for Radiata Pine Breeding', which first described an overall Radiata Pine breeding strategy. This led to the creation of the Seed Certification Scheme, which introduced the GF and subsequent GF Plus schemes we are still familiar with today.

The shake-up caused by the demise of the Forest Service and privatisation of public forestry assets in New Zealand some 30 years ago meant the industry needed to take more control of tree breeding. In 1988, the NZ Radiata Pine Breeding Cooperative was formed, jointly funded by industry and government. It was incorporated into a company with only grower and seed-producer shareholders in 2002 to oversee and drive Radiata research and breeding.

It's an important task, but the company itself is not big at all – just two people until recently, with a third joining its tiny team a few months ago. Most of the breeding research and trial measurement work is contracted out.

In short, the task of the Radiata Pine Breeding Company (RPBC) is to oversee the future development of Radiata Pine. It's remit:

- Increase the rate of genetic gain using conventional selection and testing methods, as well as implementing new technologies such as genomic selection (ie using DNA markers to generate a unique DNA fingerprint for an individual tree, identifying which blocks of DNA have been inherited from each parent);
- Manage genetic diversity (having forest gene banks in diverse locations);
- Deliver faster deployment of genetic gain to the production forest (ie, turbocharging the development of better Radiata).

"There's two primary parts to our role," says Brent Guild, who recently stepped down as CEO of RPBC after being brought in three years ago to review the organisation and reset its goals.

"There's control and management of the national breeding population on behalf of all RPBC shareholders; this comprises the establishment and management of breeding orchards, field trials and archives.

"Our improved breeds are 'bulked up' through conventional seed production (Proseed and PF Olsen), while others (Forest Genetics and Arborgen) will bulk up through clonal technologies. The clonal route is a much faster process, albeit more complex, and inherently more risky."

Germplasm is the living tissue from which new plants can be grown and can be either seeds or a part of the plant that is taken for grafting onto new stock.

Prior to 2006, the initial part of the breeding process was contracted out, but 14 years ago, the company established its own breeding orchard at Amberley in mid-Canterbury, overseen by Proseed, which operates its own seed production facility next door. At any one time, there are as many as 2,000 trees grown in the orchard. The top trees are identified as having traits that RPBC is keen to introduce or improve in its breeding population and are cross-pollinated.

"This work involves a traditional approach to plant breeding – crossing one breed with another," says Brent.

It's the way tree breeding by cross pollination has been conducted for many, many years and is watched over by RPBC's Tree Improvement Manager, Mark Paget, who is based in the University of Canterbury's School of Forestry building, not far from the Amberley orchard.

"We are using around 100-to-150 as parents currently, so a lot of older material (trees) of lower genetic worth in the breeding orchard is waiting to be removed," says Mark, adding that the seedlings

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Baby trees being raised from cuttings and seedlings.

Above: Scientist, Catherine Reeves, with seedlings being raised at Scion in Rotorua.
Bottom: Another way of propagating new trees is to take cuttings like these.

produced from the chosen parental crosses are then planted at various test trial sites around NZ and Australia.

"There is also material that isn't reproductively mature yet, so it's in the orchard and it takes a while for it to grow to that stage.

"We have material in test trials all over the country. We also put duplicate material (clones) in the breeding orchard ready to be used once we get results back from their performance in test trials based on the estimated breeding values. We use a selection index which is made up of a combination of growth, form and wood property EBVs (estimated breeding values) on which we base our choices.

"So, any promising trees will also be growing in our breeding orchard so that they are easily accessible and we can get them into the breeding population quickly for the next round of crossing, testing and selection. Anything that hasn't performed very well is removed from the orchard to make room for the next lot of material.

"If we have a very promising tree we will try and collect pollen from it. Or once it starts flowering, we can use it as a female parent. We can store the pollen so we can use it as a male parent. If we don't have it in (the orchard) then we have to go out into the test

trials and collect scions and graft it. But that all takes time."

And do they have to wait 25+ years for trees to mature so they can tell which ones have been successful? No. They can tell whether they have a promising specimen by the time the tree reaches eight years of age using data collected from the test trials from which EBVs are calculated.

When they do find a tree that exhibits all the breeding values they are searching for, it is made available to the various germplasm producers for bulking up, and the seed produced becomes the next generation of Radiata Pine. That might seem like a straightforward process, but it's probably the one area where Brent Guild believes there needs to be more action.

He says the new 'material' is not getting out into the forests fast enough. Not so much the larger, corporate forest owners, who are always keen for new, improved stock, but the smaller private forest owners and woodlots, which make up a significant proportion of our plantations.

"The difficulty you have is the non-shareholders, ie, the royalty payers, those who purchase improved genetics via the GF Plus scheme. They might have planted back in the 1990s and their trees would be 25-to-30 years old now and given the way the log market has been over the past few years there are many people who have elected to harvest earlier than they might have," says Brent.

"They will replant once in their lifetime, so they might be thinking, 'what am I getting for my improved genetics?' You are putting in those improved genetics not for yourself but for your children or for a subsequent sale process, but selling an improved plant now for a payback in 30 years' time can be a tough proposition for some to accept."

Tree nurseries tend to respond to customer demand, and for that reason are perhaps conservative or even sceptical in their view.

For these reasons, the standard bearers for the new and improved trees are often the corporate foresters, with the likes of Timberlands leading the way (see article on page 30). But first they have to get their hands on the new stuff and this is the second role of RPBC.

The long lead times in tree breeding are something that have dogged its progress since the early days of the FRI programme in the 1950s. But there are exciting science advances that are expected to revolutionise Radiata Pine breeding very soon.

In 2017, a team at Scion completed a draft assembly of the Radiata Pine genome – a world first. It means there is now an instruction manual for how a Radiata tree grows.

It was a massive task. At 25 billion base pairs, the Radiata Pine genome is eight times bigger than the human genome and it took four years to complete.

For researchers, it has provided the foundation they need to begin the job of deciphering what each of the base pairs of DNA relates to in physical terms, enabling them to identify genes with drought and disease resistance, for example, along with discovering which ones align to the breeding values of RPBC.

That work is already underway, and the most recent milestone achieved by Scion, with financial backing from RPBC, was the

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Seedlings raised by Scion are planted out in their own nursery at Rotorua.

development of a SNP Chip – again, a world first. The SNP Chip is a DNA database of hundreds of thousands of trees and their genomic make-up and it will enable scientists to fast-track the laborious task of identifying desirable traits in individual trees in the lab and at breath-taking speed.

So, instead of waiting eight years to find out if you've got a great tree, you'll know in days or weeks. Maybe even quicker, as the technology improves. Read the separate SNP Chip article on page 32.

Genomics is the tree breeding technology of the future, with much more emphasis on cyber sex than plant sex. A genome is an organism's complete set of DNA, including all of its genes. With genomics, scientists aim at the collective characterisation and quantification of all an organism's genes, their interrelations and influence on the organism.

In addition to Scion, Brent Guild says RPBC also draws on expertise from the University of Canterbury, the University of Otago and even AgResearch is involved now because of its "deep understanding and experience with genomics and the whole area of being able to select the traits off a plate instead of putting things out to test and waiting up to ten years for results".

Genomics will play a key role in speeding up the process of developing new Radiata trees that will grow faster, maybe maturing at 20 years of age with all the required traits of a tree that currently is harvested at 30 years. Trees that will be more resistant to Dothistroma and Red Needle Cast. Trees that will be more resistant to the drought conditions we're expecting under climate change. Trees that will drop their lower branches early to produce knot-free wood so we can continue to have clearwood supplies, without physically having to prune them.

But they won't all be identical clones. Tomorrow's Radiata Pine will be tailored to suit specific sites and climatic conditions, even those found in Australia, because the largest of the 15 shareholders in RPBC is Forestry NSW (with 20%), so there is a clear trans-Tasman focus on the research. To find out how this will happen, read 'Unleashing the genomics genie' on page 33.

The Radiata Pine of the future may look like Tree 55 from the outside, but inside it will be vastly different.

It can look fondly down on its progeny and feel satisfied that the next generation will be better still. And while it may be consigned to history, Tree 55 is unlikely to be forgotten.

"Tree 55 is still visited and still regarded as the grandpappy of just about everything," says Brent.

"It's big and it had all of those visual cues that really capture the imagination. It is iconic and a lot of people know about it and genetically it is linked back into the programme and it's just got a status. But it has been superceded and is becoming less important with time as our programme continues. It's just there for posterity, a heritage tree." NZL

DOUBLING WOOD VOLUME WITHOUT ADDING MORE LAND

Logging contractors could be harvesting twice as much wood from the same blocks in Kaingaroa Forest within the next 30 years.

THE RADIATA PINE OF TOMORROW WILL HELP Timberlands achieve its ambition of doubling wood volume from its forests without having to add more land.

And it won't take several generations and hundreds of years to get there...the goal will most likely be reached within 50 years. That's just two rotations.

It won't, of course, all be down to genetics and tree selection, as other factors will contribute to the outcome.

"To achieve that, we would need to look closely at the silviculture practices we employ, the genetic material, fertiliser and nutrition practices we employ and be smarter in the use of technology in the way we manage those crops. The sum of all those things will see a lift in productivity," says Dean Witehira, Tree Crop Manager with Timberlands.

Dean has been working at Kaingaroa Forest for more than 20 years and he's seen a lot of change over that time and is excited about what is yet to come.

"We see a real opportunity to propagate elite germplasm that is being developed through our clonal testing programme," he says.

"At KT we have control of our own propagation and deployment supply chain. We clonally test material in our own trials on our own sites, to see which ones are the winners and then deploy that material out to the forest.

"We are seeing some benefits arise from that in our forests. Some of it's through tidying up some of our operations and procedures and ensuring that we establish 100% of the area we intend to plant, good land-prep, good management of weeds through that establishment phase.

"When you are running a successful genetics and deployment programme you need to be able to package up your best germplasm inside a well spec'd tree. These seedlings then need to be looked after all the way to the forest and planted onto a site that has benefitted from good land prep and good management. All these things can add up to a lift in forest productivity and that flows through to the rest of the rotation."

Dean goes on to say that one of the challenges facing Timberlands (and all forest owners) is the uncertainty of future markets and what Radiata might look like down the track.

"I think that we need to make sure we grow a solid wood product that is able to be used for a wide range of purposes. To do that we need a tree crop that produces high volume, has good wood properties, small branches and is straight," he says.

"If we do this, then we retain some optionality around where we send our log products, such as into a sawn timber market or other reconstituted fibre markets. A solid all-rounder that grows across a variety of sites, generates a lot of volume while also having good form, is the tree we are seeking to produce. Disease resistance is also a desirable trait."

Even without the genetic advancements already flagged by scientists, Timberlands has seen marked improvements through its approach.

"If you go back to 2003, we were running about 16.5 MAI (mean annual increment – ie m3/ha per year) and now we are running about 25 MAI. Our long-term goal is to get to 50 MAI, so that is doubling of our current MAI," says Dean.

Timberlands is a shareholder in the Radiata Pine Breeding Company and Dean has been a director of that company for 15 years and has been very close to what's been going on there.

He says: "There are some very exciting opportunities on the horizon. Some of the things Scion has been doing on genomic selection mean that theoretically if we could screen material or see if it's got the genes that drive growth or give it disease resistance or form, we can then do an early selection and find out quickly if we have a really good tree, instead of eight years – that could be a game-changer.

"We could screen more material and make more gain, more quickly and that would increase the realised genetic gain and help us to double productivity."

It's still very early days, he adds: "If you look at tree breeding and all plant breeding globally – you look at maize, it's probably been running for 50 generations and there has been continuous improvement for traits that are being selected.

"With Radiata, we're really only on our third generation and we've already made gains, so there's a way to go yet and I believe there is a real opportunity to keep driving that up."

One issue that Timberlands is already working on is how to upscale its nursery to grow twice as many trees as it has in the past and the company is already working on expansion plans and how technology can play a part, too.

The rewards are mouth-watering. Doubling the amount of wood generated from Kaingaroa Forest could double the value of the forest, along with creating many more new jobs, providing a range of environmental benefits and ensuring Kaingaroa retains its status as an iconic plantation forest that benefits all New Zealanders, because every one of us is a shareholder in the business through a stake held by government's Superannuation Fund. NZL

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