

Reflections on radiata pine genetic improvement by a clonal forester

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I first read M.D. Wilcox's 1983 review of New Zealand tree improvement on the plane on my way to my post as quantitative geneticist at the FRI in Rotorua. The article helped me realise the importance of maths in a science where a single pulse of breeding (progeny testing, seed orchard archive, pollination, stoolbeds, juvenile cuttings) + crop rotation (about 19 + 28 = 47 yrs) could span my *entire* career. My background had been in short-rotation tropical trees, where the maths were secondary to *actual agronomic results* – yield, quality, ease of management. The maths helped, certainly, but they were secondary. All that was about to change...

Now as I try to reflect on where radiata pine genetics has gotten *to*, I find it useful to use Wilcox to see where it has come *from*. Here is what Mike said:

- with such a slow turnover of generations, ... emphasis must be on stringent selection, since rapid incorporation of new characteristics ... is not possible.
- [numerous breeding objectives including] diameter growth... stem straightness... foliage diseases... multinodality [i.e. multiple branch whorls produced annually].
- wood properties ... strongly inherited but have not featured much because [they are] technically difficult...
- cloning for direct afforestation attractive ... but not yet commercial.

Now, as a contrast, flip to another section of the same book, one of several involving clonal crops: "Apples". Whereas radiata pine breeders were using broad-based genetics based on a *few thousands* of parents, New Zealand apple breeders were using a few *tens* of parents (some genetically related) to produce *thousands* of offspring to find and clonally propagate even *one* new commercial apple. Here is what D.W. McKenzie had to say about apple improvement in NZ in 1983:

- research administrators have expressed impatience with the long time lag involved in apple breeding.
- in 50 years, professionals in several countries have been fully occupied with hybridising apples, yet very few new varieties of proven commercial value

have emerged...

- [as with radiata pine] at least ten breeding objectives, including fruit characteristics, tree health, tree form...

What strikes me are the *similarities* of these programmes. Both involve woody trees with painfully long and surprisingly similar pollen – genetic screening – improved seed cycles (radiata pine progeny tests normally take 8 to 12 years). Both programmes juggle a large number of breeding objectives. Both are aimed at end-products customised to increasingly quality-conscious international markets.

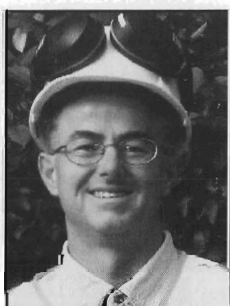
Varietal (clonal) apples are a major New Zealand product success story because of their *customisation*. If apples were as diverse as logs hitting sawmills, there would not be a thriving New Zealand apple industry.

Why, then, are (or at least were) apple and radiata improvement approaches so different? In part, I suggest it reflects some innate human prejudices: (1) that what we eat *must* be consistently right in taste and texture, which explains why we demand clonal apples (and accept what biodiversity risk such clonal crops represent with little fuss); and (2) that big trees *must* be valuable, because standing beneath them makes us feel, well, *good*. It follows that since mills are not *human*, they should be accepting of a range of logs, so long as most are large.

But the forestry industry knows better, and so does much of the forestry world that tracks New Zealand as *the* case study in short-rotation solid wood pine forestry. Big trees provide gross initial volume, but say little about conversion to product. Value requires both merchantable volume *and* conversion, or all of the product ends up as pulp. Open up two trees and they can be wildly different for wood qualities like stiffness or twist. *Nothing* on the outside of such trees will lead you to reliably differentiate which is which. And therein lies the basis for a natural unwillingness to believe that there can be such extraordinary differences in value amongst stems of similar age and external size and shape.

Genetic product development managers like myself increasingly feel pressure from clients to customise radiata pine for both performance *and* uniformity-of-performance at the sawmill. We need to grow the candidate apples *and* taste-test them too.

We customise radiata pine by moving up the genetic uniformity ladder (Fig. 1). In doing so, both performance and crop uniformity through mill can



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improve dramatically, but with it comes an ever-increasing potential of mis-selection; i.e. of producing a 'uniformly' bad crop. This is one reason why apple breeding programmes test thousands of candidate clonal apples to find a single new variety. Testing large numbers of clonal candidates also enables apple breeders to simultaneously capture gains in more traits than is manageable through family breeding.

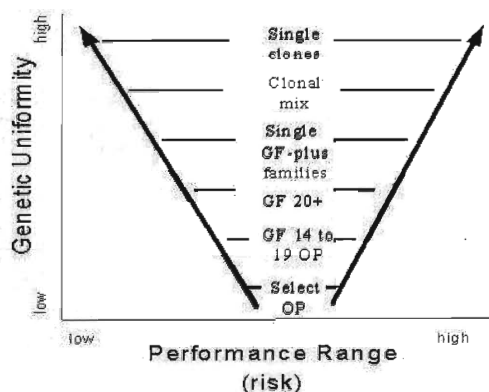


Fig. 1. The "Genetic Uniformity Ladder". Increases of genetic uniformity of different genetic product types are accompanied by increases in the potential range, or risk, of performance. OP means open (or wind) pollinated.

Take an example – stiffness. Wood stiffness is a trait that affects value of a vast range of wood products, and is a top target for the Radiata Pine Breeding Company (RPBC) for their GF-Plus scheme. An average radiata pine tree on an average New Zealand site starts to produce clearwood of structural potential at breast height at age ten years (we tend to use 8 GPa as the useful threshold for stiffness. F5 grade, for example, requires 6.9 GPa in knotty lumber). Our commercial candidate radiata pine clones achieve 8 GPa clearwood stiffness by age 5 to age 18 years (rings 3 to 16). We have even produced pith-in lumber from a farm-grown clone that graded out as F5 in terms of its stiffness (Richardson 2002). Recent work (Sorensson, Nepveu and Kimberley, unpubl.) showed that very large differences in stiffness, roughly 100% in outer rings, can exist amongst age-10 clones of essentially identical growth rate.

It follows from Fig. 1 that the range of average stiffness of single control-pollinated (CP) families should be less than that of clones but still high, and what work has been done bears this out. In a Radiata Pine Breeding Company conversion study of age-13 CP families using butt logs of fairly similar diameter sawn into stud lumber, the percent conversion of studs closest to bark (rings 6 to 9 from pith) ranged from 7% to 84% between CP families. The corresponding value range was \$260 to \$413 per m³ lumber (Sorensson, Kimberley and Lee, unpubl.).

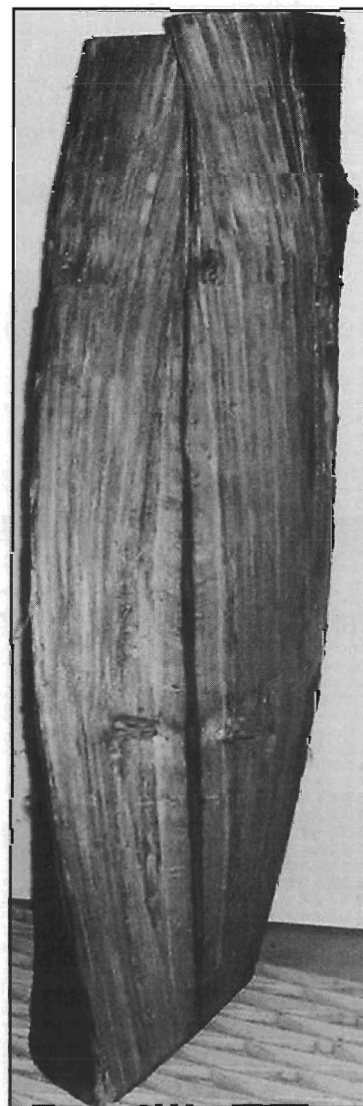


Fig. 2: A heavily spiralled log cut from a 16-yr-old grafted seed orchard clone. Spirality of this extent is rare, but spirality itself is a common feature of pines, particularly in the corewood of logs 2 and 3. Severe spirality contributes to both twist and loss of strength (MOR).

High conversions of elite single clones and CP families into structural products at a young crop age have been achieved. But the customer also needs proof that the risk of mis-selection has been properly managed.

And therein lies a major headache – it is costly to directly measure conversion (and more so in families than clones because the relatively high variability within families means you have to saw up more trees). Our approach is to destructively test them for key wood performance qualities (stiffness, shrinkage, twist, internal checking, resin pockets etc). We use a custom-built lab to keep testing costs and turnaround time to a minimum, and have destructively tested 1,080 clonal stems in

¹ <http://www.aeu.org.nz/profile.htm>

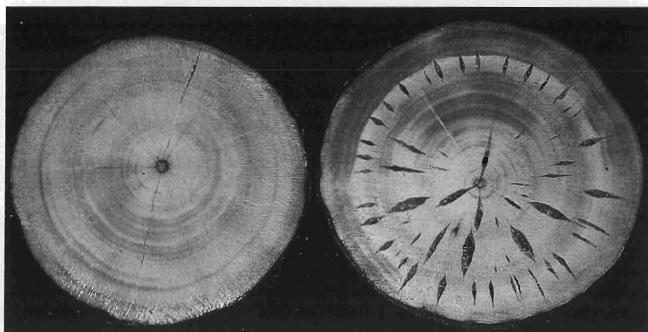


Fig. 3: Closeup of internal checking and collapse in two half-discs from a young tree. Direct testing of wood performance ensures that such trees are never commercially produced.

1½ years of operation. We are, however, fairly unique in our commitment to destructive testing.

With families, the prediction of conversion is normally done using predictive mathematics. Family tree breeders are, I believe, considering the approach taken by our dairy industry, which reports confidence in performance with a “reliability” index from 0 to 100%¹. Family breeders are also eyeing ways to make selection for wood performance more direct within budget constraints (i.e. testing stiffness rather than density, testing twist rather than spirality) and there is some optimism that the new Wood Quality Initiative will provide breeders better screening technologies.

Genetics is *information*, specifically *value* information, not trees. It is as much reliability as performance. Breeders may not often have the luxury in their career to track performance through to final harvest and mill, but if they can produce families or clones that exhibit high value (growth and conversion) at or even before mid-rotation. In the majority of instances these products will only increase in value until rotation end.

The genetic ladder is about uniformity and customisability, but we are just starting to fully grasp the implications of product uniformity of clones of significant age (vs. CP families). It has long been predicted that single clones would show greater crop uniformity for most traits (e.g. stem form, disease tolerance, wood qualities), and that this alone would increase value by reducing the frequency of value-destroying low-performance trees in the thinned crop.

We have begun testing these predictions at a 14-year-old unthinned trial in Kawerau at a current stocking of 600 stems/ha. Here, 16-tree block plots of four randomly chosen clones are trialled against a ‘modern’ 268-based GF22. Our data indicates the clones show substantial improvements in uniformity for traits, including stem form, wood density and even DBH. The 95% range

(i.e. the range that includes 95% of values) amongst trees for outerwood density (rings 9 to 11) was 140 kg/m³ in GF22 and averaged 80 kg/m³ in the four clones (range 67 to 88), for example. Simulations of density uniformity show that the clones contain several times fewer low-density unacceptable stems than this particular GF22 *when average density is held identical*.



Fig. 4: Left: GF22 with some variability in stem shape and size. Middle: Uniformly leaning clone. Right: Uniformly straight clone.

Traditional tree breeding has been a backbone of the plantation pine industry, providing a cost-effective mechanism to transform the wild New Zealand landrace of radiata pine into a modern crop. I have great respect for the impressive achievements, mathematical prowess and decades-long vision of famous breeders like Thulin, Shelbourne, Wilcox, Burdon, Carson and Jefferson.

However, modern pressures to customise products and ensure maximum value returns are forcing many investors to seriously contemplate the newer genetic product options. Clones are one of these, and they are certainly “commercial”. Our company has trialled over ten thousand different clones since 1988, and assisted Fletcher Challenge Forests to establish ten thousand hectares of commercial clonal forest. This year alone we will screen nearly 3,000 new clones for about twenty key criteria; last year we screened nearly 1,600.

Genetically-elite products that balance treestock cost with performance gain, crop uniformity through mill, and risk will be the products of choice. The choice of genetic product affects whether forest investors will compete in a cost-based or value-based marketplace at time of harvest. Whether OP, CP or clonal, I think it boils down to the question: “what is a *fair* price to pay for that treestock?”.

References

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- Wilcox, M.D. 1983: Forestry. Pp 181-193 in Wratt, G.S. & Smith, H.C. (Eds) *Plant Breeding in New Zealand*, Butterworths and DSIR (ISBN 0 409 70137 8).