FUTURE FORESTS RESEARCH

DIVERSIFIED SPECIES THEME UPDATE

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Theme Leader: Patrick Milne

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Executive Summary

Heidi Dungey briefly described the achievements of the Theme over its short lifetime. It was a pity she was forced to rush, because – taken as a whole – the Theme has notched up some formidable successes across a whole range of species. It is quite a remarkable story attained so quickly, and perhaps we could have spent longer basking in our mutual accomplishments. For those interested only in a particular species – redwoods, for example, or kauri – progress can sometimes seem painfully slow but in terms of the main purpose of broadening New Zealand's perspectives away from a fixation with radiata pine, the Diversified Forests Theme can justifiably look back in pride.

Douglas-fir, is there a genotype x environment interaction?

Do we try to breed a strain of Douglas-fir that will be superior across the whole country, under all growing conditions? Or are there horses for courses? A simple but important question to answer. Charlie Low described four sites from around the country (Kaingaroa, Golden Downs, Manuka Awa, and Gowan Hills) where there are genetic trials. Are the superior trees proportionately better at all sites, and perhaps even better at the best sites? If so, this is of little importance for plant breeders. But if certain genotypes perform well under some situations but not others, this is of great interest.

Charlie assessed all features one at a time. There is clearly an interaction between diameter growth and site – the worst performers at Kaingaroa being some of the best at the colder Southland and South Otago sites. But could this just be because Swiss Needle Cast disease prefers warmer and wetter conditions and SNC affects some genotypes preferentially? Sonic velocity (a surrogate for timber stiffness), on the other hand, showed little such interaction. The situation with malformation and straightness was less obvious – it is more difficult to interpret the data. The analysis can be done with three techniques – ANOVA, variance components, and genetic corrections – and for both families and provenances, and the results and not always consistent. In summary, it appears there is a moderate G x E interaction for diameter both with the choice of family and with the choice of provenance. There is negligible interaction in all respects for sonic velocity, whereas choosing the right family *within* a provenance could be important for straightness.

The best families overall, for DBH, were from Fort Ross, Navarro River, Arcata, Oregon CP, Swanton and Ashley CP. Restricting choice to the top 40 families gained about 9%. Similar gains in straightness were indicated. The obvious benefits of this work are to use existing sites more efficiency (Charlie estimated an increase in NPV of $865/ha) and to better steer the breeding programme.

How best to control wilding Douglas-fir?

Stefan Gous described the extent of the problem: half a million hectares in total, with 200,000 of that on DOC land. Herbicides with three different application methods were used: basal bark spot treatment; aerial spot treatment; and aerial boom application. If we accept the hassle and cost of ground access to individual 3-4 m trees, we can achieve a 95% kill within 3 months using Grazon in oil and 25-50 ml of mixture per tree applied at the base. With spot treatment from a helicopter, you can get 100% mortality by using 500 ml of a combination of Roundup and Answer (5400g glyphosate, 400 g metasulfuron and 2 l oil per 100 litres) applied at the top of the tree crown. This works for trees shorter than about 3 m, but for taller trees higher rates of herbicide must be used. Lastly, blanket coverage was trialled with 400 litres/ha of three different combinations of chemicals. It is too early to assess the efficacy of each treatment in the last situation, although initial indications are that a two-hit approach may be necessary to prevent foliage from sheltering itself.

Basal application of herbicide

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In question time, Stefan confirmed that the timing of application is “absolutely essential” – the optimum months being mid-December to mid-January. A cost of $5,000/ha was “really cheap” but a more typical cost is $15,000/ha. Given than re-infestation can easily occur, this sort of expenditure is clearly unsustainable, so it is necessary to zone off the key areas that really merit treatment. In the longer term we should be considering totally different solutions, such as leaving some land for carbon credits or bioenergy, or engineering sterile Douglas-fir for operational use.

Douglas-fir Seed

Phil De la Mare is well known to members of the old Douglas-fir Cooperative – he used to be the chairman. In collaboration with the members of that Coop, he established a Douglas-fir seed orchard on Ernslaw One land at Ettrick, Central Otago. The purpose was to supply improved seed to both Ernslaw One and to members, allocated on the basis of the highest tenders. Now that importation of Douglas-fir material is prohibited (it can act as a vector for Pine Pitch Canker), this orchard is especially important. The location is particularly suitable because cold air drainage minimises frosts and there is usually a period of drought – which produces a good seed set. Being an old apple orchard, there is a good irrigation structure for when water is required.

The best Douglas-fir comes from coastal California and possibly Southern Oregon, but these things have only recently become clear. The Ettrick seed orchard started off by using the Tramway landrace from Washington State – now known to be second rate in growth, despite the assumption that its far northern origin would offer the hardiest material suitable for harsh Southland conditions. The orchard was rogued for growth, form and wood density. In 2002, clones were taken from three Tramway provenance plus-trees located in Dusky Forest. We now know that wood stiffness is not well related to wood density (microfibril angle is equally important) so stiffness, as measured by sonic velocity, was recently added to the criteria.

Lance Freer setting pollination bags – Ettrick seed orchard

The orchard was further boosted by material from Rankleburn, Pomahaka and Fort Bragg.

Why so many sources of seed? New Zealand has too few seed zones – unlike the Pacific North West that has too many. We have discovered that there is a G x E interaction with Douglas-fir (see discussion earlier) so we will need to match the correct seedlot to our different sites. Phil’s opinion is that in conditions of high incidence of summer drought, the (non-Fog Belt) Fort Bragg material is the safest, whereas if summer drought is less likely it is better to use Pomahaka and Tramway seed – with the latter in conditions of high exposure. Soft spring shoots are easily damaged by wind, so for these regions we need material that starts its growth later in spring. But it takes considerable time to build up levels of seed production, and the reality is that only Tramway seed will be available in large quantities for the next few years.

The Cypresses – Heartwood Durability

Exactly how durable are Leyland and Ovensii cypress clones? Does durability vary with geographical location and its position within the heartwood? These questions were addressed by examining trees from trials in Gwavas Forest (Hawke’s Bay) and Strathallan Forest (Southland). Increment cores were taken from breast height samples and examined for heartwood content. Naylor’s Blue had significantly less heartwood than the other Leylands – so don’t choose that one if the objective is production of durable timber.

Next, a segment of the cores was taken from the heartwood at the pith and the heartwood at the sapwood boundary (work with other species indicates that the latter would normally be the most durable).

Durability was examined in two ways: by using a near infrared (NIR) fibre-optic probe, and by accelerated decay testing using three fungal cultures. Two brown-rot fungi were used that are supposed to attack softwoods like cypresses, and one white-rot fungus (for hardwoods) as a supposedly ineffective control. In contrast to radiata pine sapwood, none of the Leylands lost any weight as a result of the brown-rot fungi, but – surprisingly – there was a slight loss as a result of the white-rot.

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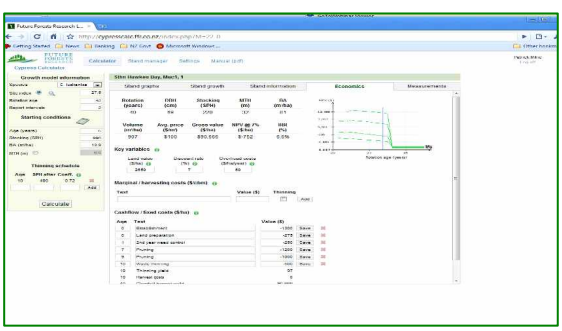
The latter was particularly true with Leylands grown in Southland, with Naylors Blue being the least durable. For Hawke's Bay trees, weight loss through decay in all cases was worse in the inner heartwood than the outer heartwood, as would be expected. Although these results were not statistically significant (like some of the others) the story they tell is fairly convincing. The situation with Southland trees was a little more confused.

Could NIR probes be an effective way of assessing durability? If so, it would have huge benefits to the programme to develop durable cypresses. The NIR predictions were good for Southland trees but unfortunately were not useful in the case of Hawke's Bay. Nothing in biology is simple!

So what are the definitive results, and where do we go from here? Leylands should probably be placed in durability Category 2 (15-25 years) not Category 3 (5-15 years) which is the normal cypress classification. There seem to substantial differences between clones in terms of diameter growth (Leighton Green is best), heartwood content (Naylor's Blue the worst), and site (Hawke's Bay more durable than Southland). NIR probes could be useful but this needs to be re-examined when there is substantially more weight loss from the accelerated decay tests. The study will be repeated with 20 trees from each of *C. macrocarpa* and *C. lusitanica* using the same trial sites.

The Cypresses – A Business Case

In economic terms, can you justify growing cypresses? More fundamentally, how would you go about trying to calculate such a thing? The latter question has just become substantially easier thanks to the Cypress Calculator, now available to members on the website. Users of the Radiata Pine and Douglas-fir Calculators will know how easy it is to make highly complex – and previously almost impossible – calculations using these tools. The Cypress Calculator is nowhere near as sophisticated as these others, but it is a good start.



Calculator screenshot

Let's assume there is a good domestic and export market for high quality lusitanica logs grown on a clearwood regime (a not unreasonable assumption) and an actual 70 hectare site in Wairarapa. We also have to make a number of cost, price and regime assumptions – but there is no better person to do this than Patrick Milne, the chairman of the Diversified Species Theme, pioneer of many cypress developments, and presenter of this study. His results show that – without any revenue from carbon credits – the project would make a net loss if the investors are expecting a real rate of return of 7%. This is to be expected because most radiata forestry would also fail to jump this hurdle. On the other hand, if carbon revenues are included profitability is huge. The current problem is that carbon growth is assumed using MAF's "lookup tables" which includes a broad-brush generalisation for all softwoods. If and when MAF allow the use of a "measurement approach" this might alter the picture depending on the mixture of "other softwoods" that MAF used to create their lookup table in the first place.

What have we learned from this study? We have discovered that production thinning is likely to be profitable (unlike with radiata pine); we can make some reasonable assumptions regarding growth, costs and values but we need to better refine the breakdown of volume into log grades; the "productivity surface" for determining the best place to grow cypresses could be improved to link a particular property with the surface; and, lastly, although it takes a little time to use to Calculator effectively, it is versatile and easy to use.

Redwood Taper Functions

Our experience with radiata pine has taught us similar concepts for other species: to estimate the volume of wood accurately – and particularly the volume by log grade – we need to know how the diameter of the stem changes along its length. A tree is absolutely not a perfect geometrical shape, with the exact shape being influenced by how it is grown.

Dean Meason's study was limited by the small size of the dataset. He categorised sites in terms of height growth, divided into high, medium and low. For each of these sites, he then measured stem diameters from the ground to the tip and constructed equations to represent each situation. It seems that taper does indeed vary according to site – not surprising when you consider that a major determinant of height growth was exposure to wind, and foresters are very aware of how wind affects taper. Interestingly, there was very

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little difference in taper above breast height but large differences below that height. In other words, exposure to wind encourages butt flare – it is well known that trees stabilise themselves against wind by building stronger bases and coarse roots. The best fit for tree shape below breast height is a neiloid equation and the best fit above that point is the better known paraboloid.

Redwood Breeding Options

Toby Stovold discussed the philosophy of tree breeding with respect to redwoods. He listed the stages in breeding, starting with a Breeding Strategy (defining populations, and whether CP or OP is to be used), going on to the Breeding Plan (key activities and monitoring of progress) and finally the Breeding Operations (who, what, where and when). He argued that selection intensity is the key, and that – as a rule of thumb – we needed 150 unrelated individuals to establish the breeding populations. Scion have 70 and would need to obtain the rest from industry. An alternative approach is to convert a trial to a seed stand, and use giberellic acid to induce flowering (this seems to work). We make CP crosses, plant the trial, and wait. Trouble is, this process is unlikely to be completed within one funding cycle.

There was some interesting discussion during question time. It was pointed out that Douglas-fir has great regional variation, and presumably the same would apply with redwoods. Therefore it doesn't make sense to lump 150 plus trees together in an orchard regardless of their origin. Secondly, redwood has very poor germination rate – it's adapted for vegetative reproduction – and therefore the seed from such an orchard could be prohibitively expensive. Wade Cornell and Rob Webster concurred: a clonal route is a better option for redwoods. Simon Rapley noted that redwoods are one of the only conifers where you can assess fully mature trees for the entire range of desirable characteristics – growth, colour, durability, etc – and then take clones from them. He also thought that the best parent trees for New Zealand conditions would be found already growing in New Zealand. Heidi summarised by suggesting that the Theme takes clones from the best trees and plants these across many environments. Test them. Growers could then select clones suitable for similar sites, or else clones that were robust across a wide range of sites.

Eucalypts – New Trials and Models

Dean Meason is convinced that the best way to model eucalypts is with 3PG. This is quite a move away from the old empirical system used for other species (i.e. they grow a certain way because we have measured them growing that way). 3PG is a semi-physiological approach that involves other measurements (soil data, Leaf Area Index, temperature, rainfall, etc) and a deeper understanding of how trees grow. It is widely used in Australia. To provide the base data to construct the model, trials have been established with *E.fastigata*, *E.nitens* and *E. regnans*. These must be measured and analysed.

Also, a sawing study of *regnans* has been published (Journal of Forestry, August 2010), which shows that – if the processing infrastructure existed and the markets were as established as in Australia – growing that species for sawn timber would be more profitable than radiata pine using 8% discount rate. This could be done using rotation lengths of only 20 years.

Breeding *Eucalyptus regnans* in New Zealand

Des Stackpole's presentation dealt with a similar subject to Toby Stovold's earlier one on redwoods – how to start a breeding programme for a new species. Des emphasised that the key to good *regnans* is shelter. On a sheltered site you can get good results even from 20-year old trees (see the above sawing study). New Zealand needs to breed *regnans* so that we can improve form and branching habits and create a reliable supply of seed. Internationally, eucalypts from the *Symphomyrtus* subgenus (*grandis*, *globulus*, *camaldulensis*) are preferred because these can be planted up hill and down dale, whereas the ash species that we favour in NZ (*regnans*, *fastigata*, *delegatensis*) tend to be site specialists. The programme should be based on recurrent selection for General Combining Ability (GCA) so that progeny are good all-rounders – not freaks that do well in special circumstances and whose offspring is unreliable.

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Magnificent 45 yr-old E. regnans – Long Mile

A Kaingaroa trial was established in 1991 using 9600 seedlings from 301 families, measured at age 3 and again at age 16. The age 3 survival was 82% (not bad!) with a remarkable height of 4.7 m and a reasonable foliar health. At 16, the diameter was 28.7 cm on the 36% that had survived. The heritabilities of, and the correlations between, various traits were calculated. There were some positive correlations (e.g. tall trees at age 3 tend also to be fat and straight trees at age 16) but also some negative ones (e.g. big trees tend to have big branches and poorer form). Positive correlations mean that we can select for one feature and get both, whereas negative ones mean that we must be careful – fortunately there were no worrying negative ones.

One problem that has arisen is that the superior trees we have identified do not necessarily produce a lot of seed. If we restrict the choice to those trees with seed we substantially reduce the advantages of breeding. Where to now? We have identified a good base population from which to breed. We should now choose those that have wood properties.

Eucalypts – Durable Poles, Drier Sites

Paul Millen's presentation on the NZDFI (NZ Drylands Forest Initiative) was the type where you sit up and take notice. He described how he is in the process of establishing a series of trials using 5 species of eucalypt, chosen for their natural durability and their ability to grow well in the drier eastern parts of New Zealand. He says there is a huge market for naturally durable posts in vineyards, where contamination from the CCA treatment of pine has been discovered in the soil and may soon be unacceptable for wine-growing.

Secondly, radiata pine posts are very weak and break easily. They are very expensive to replace and there is a problem with disposal of the treated timber – they can't just be burnt. Marlborough alone needs between 450 and 750,000 posts per year just to replace breakages.

But there is also a more general need to substitute for imported hardwoods, to reduce soil erosion, and to sequester carbon. Durable Australian hardwoods have an established market. Recent examples include timber sawn for cross-arms fetching AUD$1400/$m^3$; export poles from 30-year Blackbutt selling at AUD$300/$m^3$ FOB; or NZD$2,666 and $5,333 paid for each cubic metre of Karri and Grey Ironbark used on the Wellington waterfront. Traditionally grown "durable" NZ woods (*E.botryoides*, *E*. muelleriana, *E*. saligna, *C*. *macrocarpa* or *Robinia*) just do not compare well with H4 radiata pine, which will guarantee 16 years of trouble-free use.

Paul has tried very many species (most people will never have heard of some of them!) over seven years of trials. He has now reduced the contenders to just five, with the most promising being *E. bosistoana*. His criteria are pretty strict: durability of at least 15 years, good growth, very high stiffness and strength, drought resistance, frost tolerance, proven record of timber use, and potential for breeding hybrids. This is pioneering stuff, and – to counter the absence of suitable material within NZ – seed was collected from 106 families in Victoria and New South Wales. Some of the collection sites have very low rainfalls (590 mm!) and low minimum temperatures (just above freezing).

So will Paul's vision actually work in New Zealand? To find out, he has recently established major trials on three locations in Marlborough and Canterbury. He wants to screen his trees at an early age for both growth and wood quality. The initiative has widespread support from many leading organisations and individuals. If New Zealand is going to find a profitable use for some of our drier farmland, and if it is going to provide an alternative to imported tropical hardwoods, the NZDFI appears to be the most likely bet. It would not be an exaggeration to describe this work as inspirational.

Dryland eucalypt trial - Marlborough