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FRI research on genetic diversity as a component of biodiversity of forests

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Introduction

Forest biological diversity can be considered in terms of ecosystem, species and genomic richness (UNEP). Loss of biodiversity occurs when species disappear from a community, or ecosystem. Historically, species losses have occurred as a natural consequence of evolution, driven by (sometimes catastrophic) environmental change. However, mankind's interest in biodiversity is very largely driven by the recognition that human influences on the environment are producing rapid (in evolutionary terms) and irreversible changes in biodiversity. Implicit in that interest is an assumption that at least some human-directed influences can be managed to either retard or reverse species loss, and maintain biodiversity, The draft NZIF Position Paper recognises the importance of research in protecting New Zealand forest biodiversity (Section 3 i-v), specifically in areas of:

- taxonomic studies ... in natural environments
- interdisciplinary ecosystem studies to understand processes ... and the functional role of biodiversity
- identifying and monitoring indicators of biodiversity
- protecting and maintaining forest genetic resources
- developing management options to maintain and enhance biodiversity.

Species diversity and genetic diversity of forest trees

The FRI has made a major and long-term contribution to an overall research effort addressing various aspects of forest biodiversity, of both indigenous and exotic forests. Much of the research that has assisted our understanding of forest biodiversity preceded, and contributed to, recent public recognition of its importance. For example, a very high proportion of both native and exotic forest plants have been taxonomically classified, as also have around 50% of insect species in New Zealand. Similarly, FRI researchers are placing a major current emphasis on identifying and monitoring indicators of biodiversity – particularly the use of beetles as an indicator group (Hutcheson, 1994). The rationale for this work is to identify changes in the composition of insect communities that will reflect underlying changes in their habitat. Future research will include studies of indigenous and exotic understorey plant species as indicators of biodiversity.

Just as a large component of biodiversity is concerned with the richness expressed by species variability, so too is genetic diversity within a species of significant importance. The genetic diversity of a production crop needs to be protected, maintained, and if necessary enhanced as part of responsible management of our forest genetic resources.

The genetic resources of New Zealand's major exotic forest tree species have been managed since the 1950s, including low-intensity programmes of species and provenance introduction, test-

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ing and seed stand development, for example, for *Pinus nigra*, through moderate-intensity programmes involving selection of plus-trees and clonal seed orchard establishment, for example, for *Pinus pinaster*, to high-intensity programmes involving testing and mating of large breeding populations, for example, for Douglas-fir, *Eucalyptus nitens*, and *Pinus radiata*. As an indication of the scale of the latter programme, over 6000 individual plus-tree selections have been made for the *P. radiata* breeding population, and over 4000 of these trees have been progeny-tested in order to determine the 50-60 parent trees (or 'clones') that produce all the genetically-improved stock for today's radiata pine plantations. Further introductions of Douglas-fir provenances have also recently been made in California to extend available genetic diversity in the breeding population of that species.

In comparison, relatively few resources have been available to research the genetic diversity of our major indigenous forest tree species. Limited provenance studies have been carried out, or are continuing on, for example, kauri, totara, rimu and native beech species, and results should assist future decisions of 'what to plant where' to conserve genetic diversity. Recent applications of DNA marker techniques show promise of assisting future studies of genetic diversity. For example, a recent DNA marker study of provenances of totara (Richardson *et al.* 1995) has shown that approximately 80% of the total genetic variation of the species is contained within any one provenance, indicating that a major proportion of the existing genetic diversity could be preserved with samples from a relatively small sample of provenance locations.

Management of genetic diversity of *Pinus radiata* in New Zealand

The introduction and domestication of radiata pine has been a major success story for plantation forestry in New Zealand. However, there are trade-offs in genetic diversity inherent in any genetic improvement programme involving intensive selection, since, by definition, the process of selection alters gene frequencies in desired directions and, by so doing, risks a loss of the genes involved in undesirable traits. This trade-off was recognised at the outset for the radiata pine breeding programme, and was countered by successful efforts by New Zealand and Australian scientists to resample and establish trials and stands of native population material from coastal California. Their foresight and timing was particularly fortuitous, since the recent outbreak of pitch canker disease in the native Californian stands has probably precluded any future potential for collection and importation of radiata pine seed. Parallel selection programmes within New Zealand have fully sampled the local land races that developed as a result of seed introductions since the early 1860s.

These efforts, combined with more recent additions from Australian, Chilean and South African breeding programmes, have ensured that the breeding population contains most of the existing genetic variation in the species. Genetic diversity in production stands, however, depends critically on how the gene resource is deployed and managed, and these decisions are made not by researchers, but by forest managers.

Decisions to maintain the genetic diversity of production stands of radiata pine will be driven by perceptions of the physical and biological risks associated with not doing so – that is, the risk that a given climatic, or other environmental effect, or attack by pathogens or insect pests, will cause greater damage to forest stands that are more genetically uniform. Implicit in this perception is an assumption that genetically-diverse stands will be able to express genetically based tolerance or resistance to the damaging agent.

This is often not the case, as appeared to occur, for example, with past infestations involving the *Sirex* wood-wasp, which attacked individual trees in poorly-managed forest stands without apparent discrimination on genetic grounds. However, notwithstanding the potential failure of genetic diversity to provide protection against some unknown threats, we should expect responsible managers to recognise that it is prudent to manage for a reasonable level of diversity, particularly if this can be accomplished with negligible associated costs.

Radiata pine plantations established prior to the early 1970s, representing approximately 40% of the current resource, comprise genetic material that predates any products of the tree improvement programme. Thus, their genetic diversity is essentially representative of the diversity present in the initial seed introductions to New Zealand from California – that is, of primarily Ano Nuevo provenance origin, plus a minor proportion of Monterey provenance, conditioned by the effects of a few generations of natural selective forces in the New Zealand environment (Burdon, 1992).

Conversely, stands of genetically-improved seed of clonal seed orchard origin have been increasingly established from the early 1970s onward, and their genetic diversity has been determined by the fluctuating numbers of selected clones utilised as parents. Between 1971 and 1985, around 36 parent clones contributed to establishing about 28% of the existing resource, and a further 20% was established with seed orchard progeny of 120 progeny-tested parent clones between 1985 and 1993. In total, therefore, almost half of the existing plantation resource has been planted with genetically-improved offspring of numerous parents, whose genes have been extensively shuffled and recombined through natural pollination from outside and within clonal seed orchards.

The first of two recent and profound impacts on the genetic diversity of radiata pine plantations resulted from the development of control-pollinated (CP) seed orchards during the 1980s. CP seed production has, since 1993, contributed improved plants for establishment of over 12% of plantations, and is now providing a significant proportion of plant stocks produced for new planting. Increasingly, CP seed stocks are being multiplied vegetatively, and established as 'family' stands, each involving offspring of two highly-selected parents as compared to the mixed-parentage orchard progeny of the past.

Predictions of genetic gain are, of course, greater for this material, but so also is an expectation that these stands will exhibit less genetic diversity, at least for the traits exposed to selection. However, and perhaps surprisingly to some, it is likely that even these single-cross stands represent a very high proportion of the natural genetic diversity of radiata pine. Both theoretical and DNA marker-based studies are indicating that there may be no significant reduction of genetic diversity in these stands, and that continued responsible management practices in the gene resource and breeding programmes could maintain high diversity for similar production stands in the indefinite future.

The second, major potential impact on genetic diversity arises from recent, successful FRI and company research efforts in creating the capability to practise clonal forestry (i.e. the establishment of stands of single, tested genotypes) with radiata pine. Clonal forestry on a large scale is now feasible, using either tissue culture (micropropagation, somatic embryogenesis) and/or vegetative multiplication (stem and fascicle cutting) methods singly, or in 'hybrid' strategies (Menzies and Halliday, 1997). The major benefits from having clonal blocks of trees will be improved crop uniformity and predictability for many characteristics, including wood properties. Clonal forestry is already being practised beyond the research stage by Fletcher Challenge Forests Ltd and will soon also be by Carter Holt Harvey Forests Ltd, and is likely to become the preferred deployment strategy within five to ten years.

In theory, clonal forestry with radiata pine could eventually focus on only one, or a few, clonal varieties, as is the established practice with many cereal and horticultural crops, with a dramatic concomitant reduction in genetic diversity. In practice, for reasons outlined earlier, forest managers are likely to follow deployment strategies that will distribute sets of genetically-variable clones both spatially, and over time, in a manner designed to reduce the risks of genetic monoculture. How this will be done will provide some interesting challenges for forest researchers!

Conclusions

There is a need to manage the genetic diversity of New Zealand's forest species, along with a need to understand and better manage biodiversity at levels of ecosystems and plant and animal species diversity. The appropriate gene resources, knowledge and availability of research tools are available for managing exotic forest trees. Markedly less available, however, are the resources and knowledge required to protect the biodiversity of our indigenous forest resources, and this is surely where the concerns of foresters should be largely directed.

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Biodiversity and Farm Forestry: A personal view

Bruce Treeby*

When I was asked to do a piece on "biodiversity" for NZ Forestry, I thought, "Hell, that's a big ask, big topic, serious, could be rather dry", but then I thought, "Oh well, I will write about it generally as I see it, and try not to be too dry and serious". Some of it will be tongue in cheek but the reader will never be quite sure. But be assured, farm foresters are interested in issues concerning species diversity, ecosystem diversity and genetic diversity.

In the discussion of a perspective on biodiversity, it helps if the writer states their position. Grant Rosoman of Greenpeace sees biodiversity as being a focus on indigenous biodiversity.[1] While I'm supportive of maintaining and restoring indigenous biodiversity, for me it also includes exotic species. This involves how you grow the different species and the increased security of having a mix of different species, preferably in smaller monocultures, sometimes mixtures, forming a patchwork planted to best match sites with riparian strips of indigenous and high-value exotics and native remnant reserves. I also think that we are on the right track in setting up our Indigenous Forest Section within NZFFA, taking the view that without active management many native forests in private ownership will continue to lose their biodiversity and degrade further. And finally, biodiversity includes people.

I support the view that the more biodiverse an ecosystem is, the more robust it is to changing circumstances. I do feel uneasy about the large-scale blanket planting of radiata pine over the New Zealand landscape if we reflect on some comparisons. Consider the biodiverse indigenous forest cover of podocarp mixed broadleaf trees and the series of strata of smaller trees and shrubs, epiphytes, climbers, and a rich floor of ferns and associated plants and animals and compare it with a monoculture of mainly radiata pine. When you walk into 20-year stands of 350s/ha, it is a dark, sombre, quiet place with a wall-to-wall carpet of dead pine needles that is relieved only by some fungal fruiting bodies which at least introduce some colour, often the poisonous fly agaric. Oh I know that some will say that there is more biodiversity in the pine forest compared to the exotic grass and weed farm land that it replaced, but I'm not even sure of that. But I do think that we have to find ways of getting more of our lowland indigenous flora back into our production landscapes.

Just because, for example, a tui's nest is found in a pine tree, or the fact that kiwi do inhabit pine forests, doesn't convince me that all is well. Is the kiwi there by preference? Nor does the fact that pine trees result in a higher phosphorus level in the soil seem like a big plus. Then there is the monotony of it all, and the cost, for at what point does the pine blanket landscape create an experience for the tourist that is not an essentially New Zealand one? At present 30% of all tourists spend some time in native forests, and tourism is a $5 billion industry and growing. I think my concerns are those of scale and not enough visual biodiversity for the stimulation of the tourist, the New Zealand public and those who work in the rural landscape.

Forest Health Risk

What about the increased forest health and biosecurity risk of having so much of our forest estate in one species? This is magnified by our trend to make more use of clonal material, where the genetic base of the forest is narrowed. We have had experience of the vulnerability of clonal material in poplars used for soil conservation and shelter. We know the forest health risk is increased when you go for monocultures. I know that the Australians are having more forest health problems with their eucalypts now that they are planting species in pure stands. I also appreciate that we grow monocultures because we want to simplify the silviculture, growing trees like a crop of wheat (crop or ecosystem?) and in the process get higher production or wood fibre. But with clones we do reduce the biodiversity and increase the forest health risk.

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