Tree genetic resources for forest biosecurity – a gap in statutory provisions and its ramifications

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Abstract

New Zealand's Biosecurity Act 1993 has extensive provisions for coping with uncontained incursions of injurious organisms, or 'pests'. The Act defines a framework of policy that is of vital importance to the New Zealand forestry industry. The planted forest estate, being predominantly radiata pine (ca. 90%), is especially vulnerable to uncontained forest pest incursions.

The Act specifies protocols for quarantine and containment of pests, but there is a notable gap in respect of conserving, managing and preparing back-up forest genetic material that could be used to combat a possible biotic crisis. The importance of being able to generate and deploy pest-resistant or pest-tolerant genetic material is effectively not recognised. The use of such material can be considered a 'rear' line of defence, but it requires much forward preparation. The potential seriousness of this gap, and how it stands to be exacerbated by commercial, institutional, biological and other policy factors, is reviewed.

Introduction

The need for forest biosecurity in New Zealand is recognised with the Biosecurity Act of 1993. It defines biosecurity policy and specifies protocols for quarantine and the interception and containment of incoming pests. The Act has served the forestry sector well, with many interceptions of potentially invading organisms and some elimination of some that had gained a foothold. However, some pest organisms will enter the country and a few will become established and we then must manage those as best we can.

Managing established pests almost always requires a multi-pronged approach, a key part of which is likely to be using genetically determined resistance or tolerance. For genetic resistance to be a feasible fall-back option, forward

Collection of summer-rainfall pine species, Long Mile Arboretum, Rotorua. Varying in growth rate, and very widely in tree form, these species are generally very healthy but most would need improved possum control. At far right, for comparison, is the fastest-growing provenance of *Pinus contorta*. Source: Photo courtesy of Greg Scott

preparation is essential. Yet the Biosecurity Act contains almost nothing on the conservation, management and exploitation of technologies that would enable a back-up system provided by genetic resistance.

Institutional factors also impede the creation of back-up options. The implied policy framework is a strong driver of both research funding and biosecurity practice, but its deficiencies expose the forestry industry to serious risks from loss of productivity or even forest death should a really serious pest become established.

This paper, which was foreshadowed by Burdon (2010), belongs in the context of the feature issue on biosecurity in the August 2010 issue of this journal.

Our risk profile

New Zealand forest industry is dependent (≥90%) on radiata pine, meaning extreme exposure to the risks of uncontained pest incursions. Elevated risk can be acceptable if the rewards are sufficient, as they often are when growing radiata pine in marginal climates, but it still needs to be accompanied by a robust risk management package.

Also, radiata pine is a winter-rainfall species and its natural climate is not truly matched anywhere in New Zealand. Here it is widely grown on sites with evenly distributed rainfall that often experience summer humidity. Such sites are generally more productive, but the risk of fungal diseases is elevated. At least two existing fungal diseases of radiata pine that are already present in New Zealand are being addressed by genetic selection for resistance.

The possible impacts of climate change must also be considered. We see not only direct impacts but also the prospect of more frequent pest incursions. Either way, we see increased risk, rather than changes in the actual character of the risks.

The historical picture

In the early 1930s, widespread shoot dieback of radiata pine was attributed to a combination of frost and the pathogen *Phomopsis strobi*. In the late 1940s, there was the scare resulting from the Sirex woodwasp epidemic in the central North Island, followed by lesser scares from defoliation of some radiata pine and Douglas-fir stands by geometrid moth larvae. A major scare came with Dothistroma in the 1960s, until it was found it could be countered by copper spraying, with additional protection from selecting for genetic resistance. Swiss Needle Cast appeared in Douglas-fir in the 1960s and has continued to substantially reduce its productivity in the north of the country.

Lesser scares were caused by a Phytophthora species in Northland and some flare-ups of dieback caused by *Diplodia pinea* – in addition to a background level of 'nuisance' damage. More recently, there has been *Nectria*, and more recently still Red Needle Cast caused by *Phytophthora pluvialis* (Scott & Williams,

Pinus pseudostrobus, Long Mile Arboretum. A Mexican species, healthy, often showing good form, with good growth rate. It also has good potential for producing clear cuttings between branch clusters. Source: Photo courtesy of Greg Scott

2013), the eventual impacts of which remain uncertain. In the meantime, Chile has experienced an alarm with severe defoliation and even some death of radiata pine by *Phytophora pinifolia* (Burdon, 2010), which has been followed by some adjustment of species siting and some natural abatement of disease levels.

Up until now, disease has only threatened and damaged New Zealand's forest tree crops, rather than devastating them. In other parts of the world, occasional major forest biotic disasters have reduced the productivity of valuable tree species, including radiata pine, so much so that they are no longer viable commercial options (Burdon, 2001a).

Economic, social and political factors

These factors all affect the way risk is perceived and the steps people take to manage and mitigate risk.

Public versus private interests

The risk management needs for the forestry sector and New Zealand are often misaligned with the risk

management motivations of the private sector. 'Private' risk exposure is much less than the 'public' exposure (Burdon, 2010). As a consequence, individual players often take less aggressive counter-measures against the risks than might be appropriate at the national level, for a number of reasons.

Much of the forestry sector is owned by overseas companies. While they support the general biosecurity policy that is mandated by the Biosecurity Act, their New Zealand operations may fit into a model of global risk spread, thus reducing their motivation to support forward preparations for meeting a biotic crisis in one small part of their business. Other parties who collectively form a substantial portion of our forestry sector may manage risk by maintaining a portfolio of investments diversified across different sectors. Managing forestry-related risks therefore becomes less important to them.

Lastly, there are groups whose interests may be much more closely tied to the local forestry sector who would be less able to spread risk, such as some iwi. These groups have a stronger motivation to support active counter-measures against the risks. However, active counter-measures are not cheap, and may only be embraced if there is strong commercial motivation or they are strongly mandated through a national forest policy.

Guidelines for public research funding align research programmes with the wishes of industry parties. This is fine if the collective interests of industry match the sector and national interests. In the context of maintenance and active management of collections of material to ensure long-term genetic resilience, there is often substantial misalignment. There is some support for research on species groups such as eucalypts, Douglas-fir, cypresses and redwood, but the research focus is generally on species that occupy niches that are complementary to radiata pine. There are no 'alternative' pines in this species mix. The support for work on what are purely 'contingency' species (Burdon & Miller, 1995) is minimal. Even cataloguing and monitoring the stock we have is essentially unsupported, let alone evaluation, conservation and perpetuation of the material.

A downside of success

The success of radiata pine generally creates steep opportunity costs in growing other species. Highly successful genetic improvement of radiata pine increases such opportunity costs, and the opportunity costs of maintaining the unimproved genetic stocks that may represent crucial genetic variability for the future. A large breeding population is being maintained by the Radiata Pine Breeding Company (RPBC), but the opportunity costs of conserving and perpetuating genetic variability per se will remain a considerable disincentive, at least for individual companies.

Disincentives to forestry investment

The forestry industry is this country's third largest export earner. However, like all our exports it is affected by the fluctuating strength of the New Zealand dollar. A high dollar tends to favour low-risk commodity exports rather than investment in the processing capabilities that could add value to forestry products in New Zealand. The exaggerated value of farm land also acts as a disincentive to invest in forestry (cf. Richards, 2013). As with a focus on commodity exports, this is seemingly a low-risk strategy.

The perception that forestry is not worth investing in, and therefore that mitigating risks to the forestry industry is likewise not worth investing in, is narrow and lacking in vision – a recipe for continued vulnerability. It also brings its own risks of future steep carbon liabilities for the taxpayer.

Human perception of risk

The way people perceive risk affects how they prepare for future eventualities. Humans tend to under-react to abstract events or natural phenomena that might occur some time in a distant future. Combined with the popular perception that risk taking is desirable and something to be rewarded, it is unsurprising that little is being done to prepare to combat a prospective biotic crisis. When such a crisis represents a low probability event of potentially dire consequences, making a cause of it looks an unattractive career option, especially when it is not mandated by policy.

What can we do about it?

There are several ways that we can get ready for a serious uncontained incursion, but they all involve preparedness. Maintenance of genetic diversity within a species is one avenue. Management of diversity across the landscape by ensuring a mix of forest species or of land uses is another, although large-scale pre-emptive diversification from radiata pine has not historically been a success (Burdon, 2001b).

Genetic diversity

Despite appearances, the radiata pine estate is not a monoculture in terms of the genetic diversity across the landscape. Many different genotypes are mixed both within planted areas and between them. It will be important to consider areas where the greatest future risks are for radiata pine and ensure that diversity is not compromised. We predict that these areas will be where both the rainfall and temperature increase simultaneously.

Maintenance of genetic diversity within a species beyond the trees that are planted in the forest for production is yet another back-up system. Genetic diversity in collections from natural stands, or stands that have little improvement, is often high. Although the opportunity cost of maintaining large blocks of this material is often difficult for companies, the material may provide rare characteristics which will enable us to characterise, select and plant out more resilient trees and in the future maintain the viability of the New Zealand forestry industry.

The risk exposure to the radiata pine forest estate has been of concern for years. The probability of a major

biotic catastrophe may be low, but the potentially dire consequences mean that there is still a significant risk. Although the RPBC actively manages its archives of trees to maintain genetic diversity, a coherent strategic approach is lacking and there are gaps in effective policy at several levels.

Diversifying planted forest species

Mitigating large-scale risks of any serious uncontained incursions should consider landscape-level diversity. The concept behind this is that there is not a continuous availability of host (tree) material, and that barriers of other land use or other species prevent or at least slow the spread of the pest. However, the very rapid spread of Dothistroma suggests that this approach may fail for a highly mobile pest. In addition to this, it will be worth considering whether other forest trees are better planted on some sites, as is the case in Chile where eucalypts are now planted on the sites badly affected by *Phytophthora pinifolia*.

Possible radiata pine substitutes

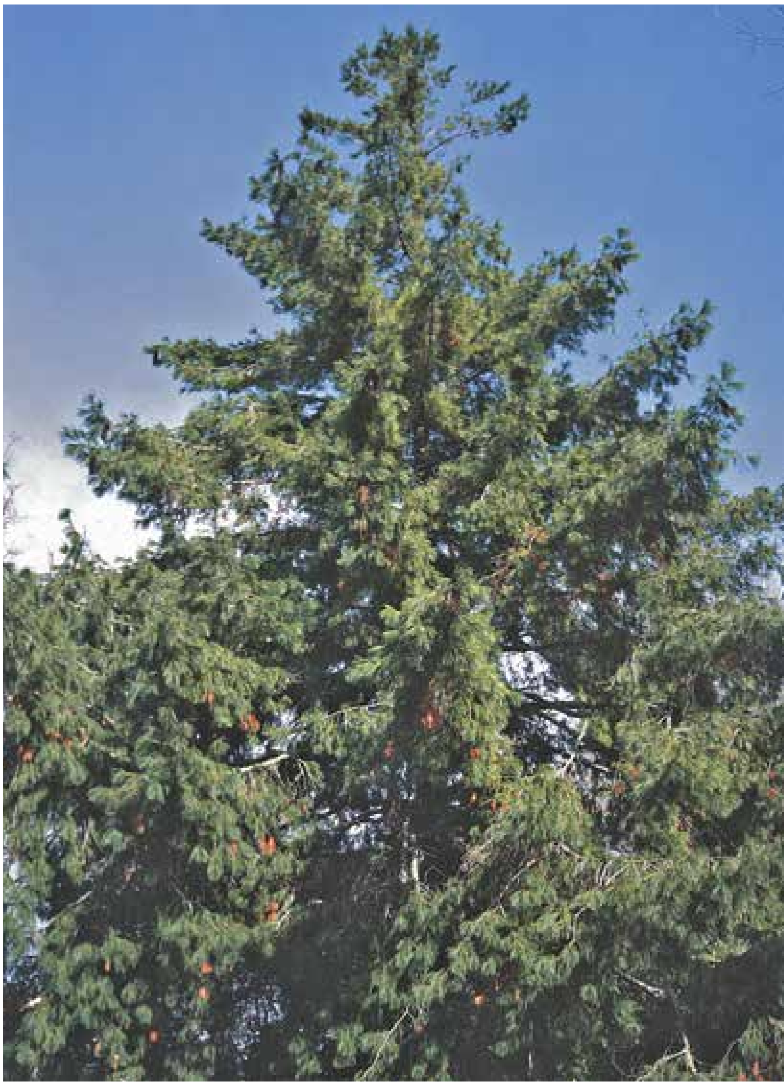
Any species that could play a role in increasing the long-term resilience of our forests would ideally meet at least one of the following requirements:

1. Be a viable substitute for radiata pine, with a sufficiently large growing range to support a viable forestry industry.
2. Be amenable to hybridisation with radiata pine, with traits that include resistance and complement most of radiata's existing advantages.
3. Contain resistance genes with the potential to be incorporated into radiata pine by genetic manipulation.

Unfortunately, few species can approach the growth rate and broad site tolerances of radiata pine and remain attractive for solid wood utilisation. Several species that perform well by international standards, but which do not currently compete commercially with radiata pine in New Zealand, might be acceptable replacements should it become impossible to grow radiata pine satisfactorily. Such species are 'contingency' species (Burdon & Miller, 1994). For some sites Douglas-fir is a contingency species, as well as a special purpose species, but it is somewhat restricted in its utilisation.

Significant overlap exists between contingency species and species that might be crossed with radiata pine to obtain hybrids with the aim of extending the environmental tolerances and/or biotic resistances, yet retaining key attributes of radiata pine.

A number of other pine species that are relatively closely related to radiata pine, and therefore may be able to hybridise with it, are promising (Dungey et al., 2003). These include *Pinus attenuata, P. muricata, P. tecunumanii, P. oocarpa, P. greggii* and *P. pringlei* (the last four being from Mexico/Central America), with various useful attributes from resistance to snow and cold, to drought and disease resistance. The hybrid with radiata pine's close relative knobcone pine (*P. attenuata*) is the first off the block in New Zealand. It is produced very readily, is cold- and snow-tolerant, and is suitable for central South Island sites (Dungey et al., 2013). However, sites that are at all conducive to Dothistroma needle blight must be ruled out for this hybrid.



Pinus ayacahuite, Rotorua. From Mexico/Central America, it is the fastest-growing 'soft' (five-needled) pine with acceptable cold-hardiness. Source: Photo courtesy of Charlie Low

To utilise hybridisation, issues around the cross-compatibility of radiata pine with other species need to be resolved before the potential hybrids can be fully evaluated. Given the time needed to rear and assess hybrids, and then produce resistant plants in sufficient numbers, it could take a decade to introduce further hybrid-based solutions.

The tree species of contingent interest include a number of Mexican/Central American pines, but only a few currently have even weak crossability with radiata pine. Pine species from this region, the main centre of diversity for the genus *Pinus*, are summer-rainfall species and are likely to have very different spectra

of disease resistance from radiata pine. Such pines are resistant to Dothistroma and mostly to pitch canker (Hodge & Dvorak, 2000).

Genetic manipulation to introduce resistance genes into radiata pine will entail major research, development and time, although the range of prospective donor species is much wider. Current New Zealand regulatory frameworks still greatly hamper the release of such material into the field, but change may be encouraged by a combination of a biotic crisis and this technology becoming available.

New Zealand has stocks of many of these potential contingency species, mostly in tiny parcels facing a precarious future. They are subject to continual attrition, even when under nominal covenant protection. Existing small stands can be left vulnerable to windthrow after surrounding radiata pine crops are harvested, or can be felled accidentally. Such incidents may not be frequent but, in the absence of active renewal of contingency species stocks, their cumulative impact becomes considerable. Even collecting the seed of such species remains a big challenge.

Replacing plant germplasm lost through such attrition is becoming more difficult. In some cases, the original native populations may have disappeared. Even if they have not, the global spread of pests and pathogens is leading to tighter border controls that restrict the movement and importation of material. Pre-emptive replacement of germplasm is becoming a political and/or financial impossibility. On the brighter side, DNA technology allows plant material to be screened for latent pathogens more effectively and efficiently.

Think laterally

One common thread to alarms arising from fungal diseases affecting radiata pine in New Zealand and Chile, from the appearance of Dothistroma onwards, is that they have all resulted from 'left field' organisms; those with no prior history of being significant pathogens (Burdon, 2010). Meeting the future challenges of new and unknown threats calls for an approach that is proactive and strategic, rather than reactive and tactical. This involves the active management of tree species to maintain diversity and build genetic resilience to pests and diseases in general. The RPBC is currently working on building cross-resistance to two existing diseases into its breeding population.

Concluding remarks

New Zealand needs proactive management at the national level to fill the gap in its forest biosecurity policy. A portfolio of solutions that utilise resistance genes is needed to ensure the country is ready to meet future biotic crises that could decimate radiata pine. Multiple options are indicated, as there is no way of predicting the nature of the next crisis or what tools and resources might be needed to fight it.

Central to any approach is available genetic material, including variations within species and among species. Solutions include the deliberate increase and management of genetic diversity within a species' planted area(s), and across the landscape. The availability of hybrids, new pine species, or alternative forest genera such as eucalypts or Douglas-fir will help to mitigate long-term risks. Genetic manipulation to insert resistance genes looks to be a key risk mitigation technology, but current regulations would need a further overhaul for it to be implemented when it is developed.

Our general message was presented by Rowland Burdon, 10 years ago, at the FOA/MAF Forest Biology Workshop in February 2006 held in Rotorua. The closing line was 'Please prove me wrong!' We are still waiting.

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