DIVERSIFIED SPECIES TECHNICAL NOTE

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Review of Alternative High Country Species Planting Options

Summary

Considerable work on establishing exotic forest trees on high altitude sites was done in the Craigieburn range from 1953 to 1988. Bare screes and eroded soils were re-habilitated and some hardy species like ponderosa, Corsican and lodgepole pine and silver birch showed surprisingly good productivity. However, most of the successful species have light seeds that are easily transported by the wind and cannot be planted due to current legislation to control the spread of wildings. The summary of this work by Nick Ledgard and Gordon Baker lists the most successful species. *Pinus contorta* and *P. mugo* were the toughest and most hardy, but *P. ponderosa* and *P. nigra* were close behind

This review summarises important findings from the earlier work and incorporates findings from other species and provenance trials whose results have been documented after 2000. The hybrid between *Pinus radiata* and *P. attenuata* can now be produced using parents that have proved to be well-adapted to New Zealand. In particular, the form of the *P. attenuata* parents has been greatly improved by selecting the best trees from well-adapted provenances, making both it and its hybrids good choices for harsh environments. Similarly, the northernmost provenance of *Pinus muricata* from Humboldt county in California was not available for Craigieburn trial work, but has proved its potential on an exposed site above Hanmer forest. Both of these taxons are closed-cone pines adapted to keep their seeds stored in the cones until after the trees are killed by fires. These two pine taxons would be recommended for planting in New Zealand at altitudes of more than 600 metres above sea level.

The earlier work identified spruce (*Picea abies* and *Pi. sitchensis*) and fir (*Abies concolor* and *A. grandis*) as species that maintained good form in exposed conditions. Recent assessments of trials planted from 1955 to 1983 have shown the potential of these species for good growth, but even these species prefer sheltered sites and grow poorly on eroded soils.

PROSEED is currently producing seed of the *P. radiata* x *P. attenuata* hybrid, but the best source of seed of other species is found in the few remaining sites of old species / provenance trials. Scion is currently trying to create new resources of these species via the Genetic Resources task of FFR.

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Introduction

Considerable work has been done in re-habilitating eroded lands at high altitude since 1953. It started with the formation of the Forest and Range Experimental Station (FRES), which was ultimately absorbed into the Rangiora branch of the NZ Forest Research Institute in 1974.

The work focused on eroding lands at altitude in the Craigieburn range of inland Canterbury and the Kaweka range inland from Napier. Other high altitude species trials were planted at over 1000 metres above sea level (m.a.s.l.) at Kariori forest, but these were compromised by malformation caused by possum browsing.

Ash Cunningham wrote up the results of the Kaweka trials in 1975[1], but there was only 7-10 years of growth before the station was closed. The best species were essentially the same as the winners at Craigieburn.

Extensive areas had been degraded by fires and grazing for over a hundred years from their former status as potential range or forest lands. This “problem country” has the redeeming feature of around 1.5 metres of annual precipitation per year – at least double that of the coastal plains. This rainfall can provide good

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conditions for tree growth, but contributes to the erosion problem.

A lot of resources were committed to this work and much valuable information had been gleaned by the time of the breakup of the NZ Forest Service in 1987. The work was ably summarised by Nick Ledgard and Gordon Baker in 1988[2].

Over the course of 35 years of research, a wide range of species of trees, shrubs, clovers and grasses on both intact soils and eroded sites were studied. The focus was on rehabilitation of the land, with longer-term diverse outcomes from erosion control to mixed grazing and forestry, biomass production or ultimately returning a cover of native mountain beech (*Nothofagus solandri* var*. cliffortioides*). The work was well written up, producing over 150 reports, which are all listed in the 1988 report.

Hardy pines such as *Pinus contorta* and *P. mugo* stood out as reliable performers on even eroded, subsoil sites. The shrubby alder species *Alnus viridis* performed well on scree sites and has the potential to re-habilitate them by fixing nitrogen.

Two birch species grew well, *Betula verrucosa* (silver birch) and *B. papyrifera*. However, their very light seeds created problems with wildings.

Pinus ponderosa and *P. nigra* grew surprisingly well with good form on high altitude sites. However, it was worthwhile to provide a vegetative cover to eroded soils by establishing nitrogen-fixing lotus before planting the trees.

Many of the species capable of good height growth suffered damage from buttsweep (larches) and stem and crown breakage (pines and eucalypts). Several members of the *Abies* genus appeared to grow with good form and health, but grew extremely slowly. *A. concolor* grew best, but may have had problems due to a lack of the right species of mycorrhizae.

A number of species of spruce were tried, but none could handle eroded soils. *Picea sitchensis* (Sitka spruce) and *Pi. abies* (Norway spruce) grew with good form on intact soils. Sitka spruce grew better than Norway spruce on lower-elevation sites, but Norway spruce outgrew Sitka spruce on higher-elevation sites. However, spruce aphids became a problem in 1989 when Nick Ledgard and Gordon Baker wrote their report, causing severe defoliation on all spruce species even on the highest altitude sites.

The normal commercial plantation choices of radiata pine and Douglas-fir were tried and more precise fixes on their altitudinal limits were achieved. The growth of a hybrid between *P. radiata* and *P. attenuata* was also evaluated, but the growth of pure *P. attenuata* was not mentioned.

The extremes of climate were also well documented over the length of the study. Winds of over 160 km/h were routinely recorded on several days in spring (September / October) each year at 1400 m.a.s.l. The largest snow dump of one metre inflicted great damage on the native mountain beech as well as the pine plantings when snow froze onto the foliage and provided excessive sail area for strong winds.

Newer Developments

The earlier work was very well conceived, successfully implemented and demonstrated proof of concept. However, there were exotic tree species that were untried and some only tested to less than ten years of age. Also, some of the most successful species have become unpopular due to spreading unwanted plants (wildings).

Pinus attenuata and Hybrids

One development that appeared after the study areas were planted up was the selection of 15 well-formed trees from four provenances of *Pinus attenuata* best adapted to the New Zealand dryland climate out of 43 tested[3]. Most *P. attenuata* trees grown in New Zealand were characterised by poor stem straightness, forking and rough branching, but trees from the best four provenances had straight stems, light branches and vigorous growth. These selections were crossed with selected radiata pine to create hybrids of far better form than earlier hybrids.

These hybrids were planted out in 1998[4,5] on four South Island sites with pure *P. attenuata* from the selected trees and pure radiata pine from the same selected parents used to make the hybrids. The higher elevation trials were thoroughly tested by a severe snowstorm in 2006. The pure *P. attenuata* suffered no damage, the hybrids suffered little damage, while pure radiata pine suffered from toppling and crown damage. Recent inspections in 2011 and 2013 revealed symptoms of boron deficiency in the radiata pine trees, but no symptoms were seen on the hybrid or pure *P. attenuata* trees.

The hybrids were made by PROSEED, who have since planted out trials that feature a hybrid between *P. attenuata* and selected radiata pine from the Cedros provenance (S. van Ballekom, pers. Comm.). The Cedros provenance genes appear to confer even better adaptation to the dry summers experienced over much of the Canterbury and Otago regions.

Two big advantages of *P. attenuata* (figure 1) and its hybrid with *P. radiata* (figure 2) are that they are members of the closed cone pine group. The cones remain closed on the tree long after the seed has ripened. The action of the cones has evolved with an ecology featuring regular fire events. If there is a fire, the cones remain closed and protect the seed from heat, then open to release the seed when the temperature is cool. The other advantage is the large size of the seed, which will not be blown very far from the tree in any event where the cones open to release seed.

Pinus muricata

Pinus muricata is native to California and another member of the closed-cone pine group. Its provenance variation resembles a group of closely related species, rather than different strains of the same species[6]. Natural hybrids between neighbouring provenances are rarely seen and most provenance differences are obvious.

Ten provenances have been trialled in New Zealand, but only two were planted commercially, the provenance from Mendocino county (blue foliage) and Marin county (green foliage). The Marin provenance was disappointing, partly for slow growth but also because possum damage gave it a reputation for poor form. The Mendocino provenance showed promise, with healthy foliage, a tolerance of poor soils and the ability to rival growth rates of radiata pine albeit at higher stockings than radiata pine can manage.

Two of the best three *P. muricata* provenances have only been planted in trials and small seed stands. On good, low elevation sites the provenance from Sonoma county (green foliage) is the best provenance; one that could challenge radiata pine.

The northernmost provenance from Trinidad Head in Humboldt county (figure 3) has the most potential on cold exposed sites. In one trial planted at 820 m.a.s.l. at Jollies Pass above Hanmer forest it was a clear winner at age 28 years over other *P. muricata* provenances, *P. radiata* and *P. contorta*. It was not only best for growth rate, but was the only taxon that had good numbers of undamaged stems. A seed stand planted on nutrient-deficient serpentine soils in Golden Downs forest had excellent growth rate and very good form at the time of harvest at age 30.

In general, Mendocino blue *P. muricata* has not done well on high-altitude, exposed sites because its good foliage health provides too much sail area for strong winds. The Trinidad Head provenance has slightly slower growth, but its finer branching make it a contender for planting on high-altitude sites, especially where dothistroma needlecast is a problem. However, the more open crown of the pure *P. attenuata* would be a better choice for sites exposed to strong winds on colder, drier sites.

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Species in the *Abies* Genus

A comprehensive trial of many of the members of the *Abies* genus[7] was planted on nineteen sites from 1959 to 1968. Unfortunately, none of the sites was at high altitude, so the high altitude species, such as *A. magnifica* and *A. procera* were unable to demonstrate any special abilities. Their only contribution to knowledge was that after fifty years the high altitude species cannot survive at low altitude and even dominant trees start to die off.

Experience in the UK[8] has shown that *A. procera* handled exposed conditions better than *A. magnifica*. *A. procera* also tolerated poorer soils than other *Abies* species. Assessments of the trials from age 47 revealed that two of the low elevation members of the *Abies* genus (*A. grandis* and *A. religiosa*) had the best growth rate but the somewhat higher altitude species, *A. concolor* (figure 4) was close behind. *A concolor* had noticeably narrower crowns than *A. grandis* and carried much higher stocking in unthinned plots. *A. concolor* was the best species tried at Craigieburn, but *A. magnifica* and *A. procera* were not tried, probably due to difficulties in obtaining seed.

The Craigieburn trials identified problems with really poor initial growth – not unusual for high-elevation trials, but the same thing was observed in the lower elevation trials. Individual trees in the low elevation trials started into good growth well before the rest of the trees and this good growth mainly happened in proximity to tutu bushes (*Coraira sarmentosa*) or bracken (*Pteridium esculentum*) patches. Whether this was caused by better soil fertility or the association with beneficent mycorrhizae or even both factors is not well understood. Both the addition of duff from under spruce trees and fertiliser increased growth in the 1959 trial at Hanmer.

The Spruces

Early plantings identified that Sitka spruce (*Picea sitchensis*) has the best growth of any spruce species grown in New Zealand. Provenance trials from the southern end of the range were planted on low elevation sites from 1959 to 1971. Their early performance was disappointing and the species was written off for commercial use when the spruce aphid (*Neomyzaphis abietina*) had a population explosion in the mid-1980s and seriously defoliated most stands of spruce[9].

Norway spruce (*Picea abies*) had been tried in early plantings[8], but grew very slowly and its use was discontinued in favour of Sitka spruce. A visit by European forester Hubert Wellendorf stimulated renewed interest and a provenance trial was planted on seven sites in 1981 along with one seedlot of Sitka spruce and one of Douglas-fir. Some of the sites were at high altitude or exposed to strong winds.

A recent assessment of the Norway spruce trials (C. Low, unpublished data) revealed that the reputedly fast-growing provenances of Norway spruce grew more slowly than Sitka spruce. The Sitka spruce managed about one centimetre of diameter growth per year while the Norway spruce grew at 0.7 cm. However, the form of all of the Norway spruce trees (figure 5) was extremely good even on exposed sites where some of the Douglas-fir trees suffered damage-induced malformation. The Norway spruce stems were conspicuously straight and the branching was light and regularly distributed.

Douglas-fir and Sitka spruce were growing faster than any Norway spruce seedlot on all sites. On the North Island sites the Sitka spruce (from Big Lagoon, California) had better growth than the Douglas-fir (Ashley seed stand origin) and all of the spruce trees seemed to be extremely healthy.

Some of the newer Norway spruce trials were planted onto cutover sites and some were planted into grass. Tree growth on all sites was much better than in the earlier (1959) trials planted into grass, where the trees looked sick and grew slowly. John Miller[10] had observed this poor growth in earlier stands, but this time nursery staff had access to those earlier stands and collected leaf litter to inoculate the seedlings with the right mycorrhizae.

Assessments of the 1959 Sitka spruce provenance trials at age 47 (C. Low, unpublished data) revealed that the Sitka spruce has increased its rate of growth substantially and has caught up to Douglas-fir. Foliage health appears to be better than that of Douglas-fir and there was no undergrowth beneath the trees. It is likely that pest-eating ladybirds introduced by Scion to improve the health of eucalypts had controlled the spruce aphids that caused massive defoliation in the 1980s.

The Eucalypts

Over twenty species of eucalypts were tried at Craigieburn and only the hardiest “snow gums” like *Eucalyptus pauciflora* could handle really high altitudes, although *E. delegatensis* and *E. nitens* could grow reasonably well below 800 m.a.s.l. One hardy eucalypt species not tried at Craigieburn was *E. dendromorpha* (Budawang ash), a rare eucalypt found only on the top of Mount Budawang in New South Wales. Budawang ash was the best species tried out of 47 eucalypt species planted at 900 m.a.s.l. in southern Kaingaroa forest in 1977. However, the only recent planting of this species at a similar altitude has been severely damaged by unusually strong blustery winds in March 2012 after appearing to be established successfully.

Other cold-tolerant eucalypts such as *E. nitens* and *E. delegatensis* were prone to damage from a combination of snow and strong winds if planted above 800 m.a.s.l.

The Cypresses

The cypresses did not perform particularly well at Craigieburn. *Chamaecyparis lawsoniana* performed better than members of the more vigorous *Cupressus* genus that were tried.

Chamaecyparis nootkatensis (figure 6) was not tried, although it is adapted to high elevations and snowy sites in Canada. Canadian tree breeder, John Russell sent some *Ch. nootkatensis* seed from selected parents to New Zealand in 1993 and the resultant plants were planted out onto nine sites from 1996 to 1998. Recent inspections have revealed that the tree crown is bushy until it reaches the height of 2-3 metres, then changes to an extremely narrow crown with drooping branches.

At the highest elevation site (Ribbonwood station, 660 m.a.s.l, near Omarama) the tree heights varied from two to 4.5 metres at age ten. The trees were all healthy and had survived a big snow dump two years previously without damage. A further inspection at age thirteen found them still healthy, undamaged and growing well.

Douglas-fir

No discussion of high country species would be complete without mentioning Douglas-fir. Some of the early work near Craigieburn involved planting from 600 m.a.s.l. to well above 1000 metres. The trees could grow, but tree growth and form became poor with increasing altitude.

A recent study by Stuart Kennedy[11] looked at wood density and wood stiffness in this high altitude planting. He found that the wood density and acoustic velocity (a surrogate for wood stiffness) of the wood got worse with increased height above sea level. Height growth also decreased with increasing altitude.

The 1996 seed source trial was planted on exposed sites[12] from 300-700 m.a.s.l. to see if faster growing seedlots would find such sites too challenging. An assessment at age eight years showed that even improved seedlots from slower-growing strains from Washington state suffered leader damage.

Conclusions

It was difficult to understand why so much money had been invested in rehabilitating eroded lands, achieved good results, yet the work has not been applied elsewhere. There are large areas of eroded land where money is being spent on animal control, yet re-habilitation

to productive forestland has not been attempted.

However, our knowledge of which species could tolerate harsh conditions and produce commercial products has been improved in anticipation that high country rehabilitation will happen eventually. One topic that has not been addressed is whether a mixture of species that mimics the highly productive forests of the Pacific Northwest would be more productive than pure stands. At the very least, using a shade tolerant species like *Tsuga heterophylla* (western hemlock) in mixture with more light demanding species such as Douglas-fir or Sitka spruce would add greatly to overall volume production.

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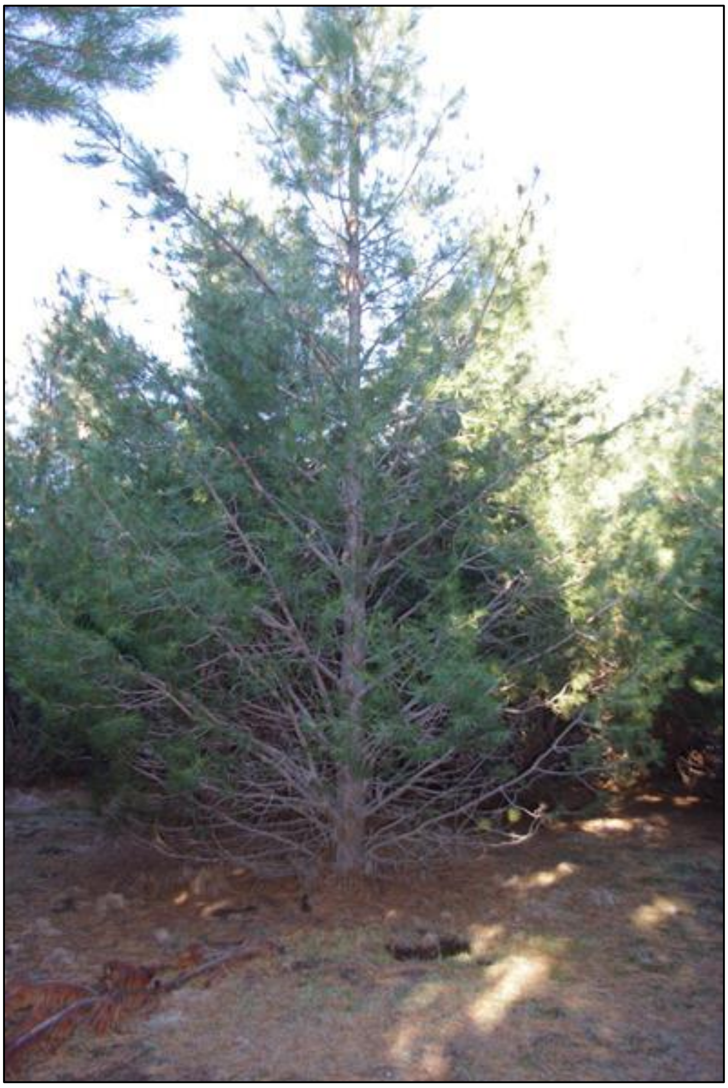

Figure 1. A 15-year-old *Pinus attenuata*, growing near Lake Tekapo

Figure 2. A 15-year-old hybrid between *Pinus radiata* and *P. attenuata*

Figure 3. ***Pinus muricata*** **from Trinidad Head in Humboldt county, California**

Figure 4. 40-year-old *Abies concolor* at Berwick forest

Figure 5. 30-year-old Norway spruce at Blackmount forest

Figure 6. 9-year-old *Chamaecyparis nootkatensis*, Kaingaroa forest