- to demonstrate species and layout combinations suitable for sheltering irrigated Mackenzie Basin pastures.

Fifteen years down the track AgResearch has a great asset, from both the animal welfare (shade and shelter) and the timber production point of view.

Corsican pine (*P. nigra*) has been the most promising species planted, as it is the most likely timber production tree to survive and grow (albeit slowly) in the extreme conditions. Ponderosa pine has shown potential as well, and it is favoured in some sites because it is less of a problem with wilding spread than either Corsican pine or *P. contorta*.

Early in 1993 considerable silvicultural work was carried out on the recent plantings, with the objective of increasing quality timber production, improving permeability of the shelter, and providing firewood.

Future plantings are planned by AgResearch on Tara Hills to expand the role of the tree in land care, and to measure interactions between soil, animal and plant in this environment. Up to 250 hectares are being brought into the programme.

A comprehensive report on the trees on Tara Hills was produced by Nick Ledgard and Gordon Baker in November 1992, and updated by AgResearch in 1993. The findings of the report can be extrapolated to other high, dry and cold locations – especially in the North Otago and South Canterbury regions. Copies of this report, which is extensively illustrated in colour, are available for $75.00 each (inclusive of GST, postage and packing) from Tim Broad, AgResearch, Invermay Agricultural Centre, Private Bag 50034, Mosgiel; Telephone (03) 489-3809; Fax (03) 489-9024.

Tara Hills, July 1993. Looking south to Ewe Range.

Introduced species and regimes for high-country forestry

Nick Ledgard*

The tree environment

The high-country environment governs which tree species will survive and grow. Soils are often shallow, stony and infertile but it is the climate which mainly determines survival. It has both continental and oceanic influences and is hence characterised by variability, particularly in temperature. Unseasonal temperature fluctuations are common with frosts occurring at any time of the year. Winds are frequent, gusty and often strong. The rainfall gradient is steep, ranging from 500 mm/year to more than 8000 mm/year over a distance of less than 40 km. While these extremes contribute to most failures, the high-country climate, with its mild day temperatures, cool nights, and evenly distributed and adequate moisture, is generally favourable for the growth of hardier woody species over most of its area. Aided by increasing restrictions on burning and declining grazing capacity for farmed stock and wild animals, the high country will almost inevitably witness an increase in woody species. In many situations introduced conifers will be a definite component of this increase, due to their hardy and vigorous character.

Species choice

Introduced trees have been planted in the high country since the early days of pastoralism in the middle of last century. A wide range of species were planted and those that still continue to grow (mainly around homesteads) represent the survivors of what might be called an "historical" trial. With the exception of Naseby Forest in inland Otago (which now occupies 2500 ha), large-scale plantation forestry has not been practised. Although good growth rates for some introduced species were recognised many decades ago (Morrison, 1919), the area occupied was less than 1% of high-country farms in 1978 (Kerr et al, 1979). A survey of all introduced trees in the Canterbury region (1.8 million ha) in the early 1980s found introduced trees to occupy less than 1500 ha (Ledgard and Belton, 1986).

Although many species have been tried in the high country, the most successful have been the conifers. The main species now present are Corsican, ponderosa and radiata pine (*Pinus nigra, P. ponderosa* and *P. radiata* respectively), Douglas fir (*Pseudotsuga menziesii*) and European larch (*Larix decidua*). Other less frequently found conifers are lodgepole, Scots, maritime and Bishop's pine (*Pinus contorta, P. sylvestris, P. pinaster* and *P. muricata*). To date there is little evidence to favour Bishop's pine over radiata on cool high-country sites. The New Zealand Forest Research Institute Ltd (NZFRI) has tested many conifer species in their Craigieburn experimental area (Ledgard and Baker, 1988) and in the Mackenzie Basin (Ledgard and Baker, 1992).

The two most favoured species for commercial forestry are Douglas fir for moister (>800 mm), sloping (less frosty) sites, and Corsican pine for flatter, drier sites (Ledgard and Belton, 1985; Belton

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1993). Ponderosa pine is also a good candidate for the frosty sites particularly in the moister areas. Radiata pine is marginal on the colder sites (due to frost damage when young and snow damage in later life), particularly over 500 m, but has been more successfully planted on northerly faces at lower altitudes. The greater success of radiata pine in Central Otago has led to little use of Corsican pine which has been widely planted further north in Canterbury. The hybrid *P. radiata* x *P. attenuata* is being tested in the hope that it may have increased hardiness while maintaining the good growth rate of radiata.

Introduced broadleaved species are less common and tend to be found in sheltered moist sites. Willows, mainly crack willow (*Salix fragilis*) and poplars, mainly Lombardy (*Populus nigra* 'Italica'), are the common broadleaf species, and are found principally in moist riparian sites. Sycamore (*Acer pseudoplatanus*) and silver birch (*Betula pendula*) are the next most frequent. Other broadleaf trees often encountered, particularly in better sites adjacent to homesteads, are rowan (*Sorbus aucuparia*), oaks (mainly *Quercus robur*), English elm (*Ulmus procera*), common ash (*Fraxinus excelsior*), common lime (*Tilia europaea*), copper beech (*Fagus sylvatica* 'Purpurea'), *Laburnum anagyroides*, wild cherry (*Prunus avium*), golden weeping willow (*Salix babylonica* var. *vitellina*), and silver and black poplars (*Populus alba* and *P. deltoides*).

Current planting of these species is mainly for amenity reasons and birches find particular favour; nurserymen offer a range of attractive cultivars that thrive in the high-country climate. NZFRI has tested 13 birch species at Craigieburn (Ledgard, 1978). Most have survived but *B. papyrifera, B. verrucosa* and *B. pop-*

Douglas fir is the best choice for sloping moist sites. These 10-year-old trees on Ribbonwood Station are part of a thinning/pruning trial established in 1993.

ulifolia have been the most consistent performers.

Eucalypts are also popular, although they are generally marginal, due to their susceptibility to damage by extremes of winter cold. Some of the alpine species, such as *Eucalyptus gunnii* and *E. pauciflora,* have survived and grown well in general plantings and along with *E. glaucescens, E. perriniana, E. rodwayii* and *E. stellulata* have been amongst the best performers in NZFRI species trials at Craigieburn and in the Mackenzie Basin (Ledgard and Baker, 1988 and 1992). *E. nitens* has also grown well but appears more susceptible to extreme frost (<–14°C) damage than the other species.

Growth rate

Rainfall is the major determinant of growth rate (Ledgard and Belton, 1986) – see Table 1. The steep rainfall gradient means that tree growth rates range from some of the worst to be found in the country to some of the best in the world. Some plots in the best conifer stands have basal areas exceeding 160 m^2/ha, volumes of over 2000 m^3/ha, and mean annual increments of greater than 30 m^3/ha. One such stand (7 ha) of Douglas fir is now recognised as probably the most productive for its age in the world. The main reasons for these high volumes are thought to be:

* The low incidence of pathogens, resulting in longer retention of foliage and maximum site occupation.
* The warm day/cool night temperature pattern over the growing season which means low night-time respiration losses of carbon fixed by day-time photosynthesis.

Corsican pine is best suited to the more frosty, flat, drier sites. Apart from sawlogs, there is potential to grow dense roundwood crops on short rotations. Here a 20-year-old naturally regenerated stand is being harvested on Lake Coleridge Station.

TABLE 1: Potential growth rate of Douglas fir and Corsican pine relative to rainfall

Species	Rainfall (mm)	Growth (m^3/ha/yr)
Corsican pine	< 600	6-10
Corsican pine	600 – 800	10-14
Douglas fir	800 – 1000	16-22
Douglas fir	> 1000	22-30

Management regimes

The best management regimes for the high country have been little explored. Land uses tend to be extensive rather than intensive (the average property is 10,000 ha) and usually tend towards cheaper, low input management systems. This favours species such as Corsican pine and Douglas fir which are more suited (than radiata pine) to 'plant and leave' regimes. Establishment is likely to be the major cost and

for this reason, cheaper establishment techniques are being investigated. Planting machines are very suitable and have been used successfully to establish many recent stands (Baker and Ledgard, 1991). Direct seeding could reduce establishment costs by 80% (Belton, 1991), but trial results to date have been variable (Davis, 1989).

Good planting stock quality is essential for successful establishment from planting (Baker and Ledgard, 1981). Correct packaging, seedling storage and handling between the nursery and planting site is also vitally important. During this period seedlings must be kept cool, dormant and with moist root systems, through the use of correct packaging and cool storage (at 1-3°C). Planting stock specifications and cool storage periods are given in Table 2.

Planting is normally done in late winter or early spring. Although weeds are not a major problem in the high country, post planting control with herbicides is recommended, particularly for Douglas fir which can 'sulk' and grow very slowly in early years if not free of competition.

Douglas fir is usually planted at 1200-1600 stems/ha, waste thinned to half stocking at age 12-15 and clearfelled between ages 35 and 50. Another option involves production thinning around year 25 and clearfelling around year 50. As long as branches are kept below 38 mm in diameter, good structural grade timber can be produced without pruning. NZFRI has recently established a 45-plot thinning and pruning trial in a nine-year-old Douglas fir stand at its Ribbonwood Station trial site.

Corsican pine can be grown either for sawlogs or roundwood. Initial stocking depends on rainfall (with lighter stockings in lower rainfall areas) but for sawlogs this species is often planted at 4 x 2 m (1250 stems/ha) with a first thinning to half stocking (for small posts or waste) at age 12-15. Given good planting stock and establishment, harvesting should be possible between age 40-50. NZFRI has also recently established thinning and pruning trials of this species at its Ribbonwood Station site. The more densely planted roundwood option is attractive in that rotations can be shortened to around 25 years and high stockings can be carried through to harvest. Wilding stands are being sampled to determine the most desirable stocking densities. It appears that stands have to be dense (at least 1600 stems/ha) in order to minimise problems due to excessive taper.

Ponderosa pine should be planted at 1250 stems/ha, thinned to around 500 stems at age 12 (mean top height of 6-8 m) and harvested as sawlogs from year 45 on. Ponderosa could have an agroforestry role with trees grown at wide parkland spacings. Its reduced regenerative vigour and relative palatability of seedlings makes it a better choice for agroforestry than Corsican pine, which would more readily colonise inter-tree spaces unless high-density mob stocking with sheep was regularly practised. In open-grown situations ponderosa pine (while maintaining good stem form) can be very tapered with large branches, which reduces market acceptability. The effect of pruning on stem form and branch diameter will be determined in trials at Craigieburn and Ribbonwood Stations.

Conclusions

There is little doubt that the future will see increasing frequency of woody species in the high country and that introduced trees will be an obvious component. Land owners and managers wishing to diversify their land uses are very likely to consider forestry involving introduced conifers. New Zealand is lucky in that the vast character of the high country with its large holdings and varied landforms is capable of absorbing a significant element of conifer forest which need not impact negatively on environmental and landscape values. Most people view farm forestry as the most desirable means of integrating plantation trees into existing land uses. The challenge is to carry out this integration in the most acceptable manner possible.

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TABLE 2: Recommended seedling specifications and cool storage periods for bare-rooted tree stocks for high-country planting.

Species	Age	Root collar diam. (mm)	Shoot length (mm)	Max cool storage (weeks @ 2°C)
Corsican pine	2	8	20	10
Ponderosa pine	2	10	25	10
Radiata pine	1	5	30	4
Douglas fir	2	10	45	6

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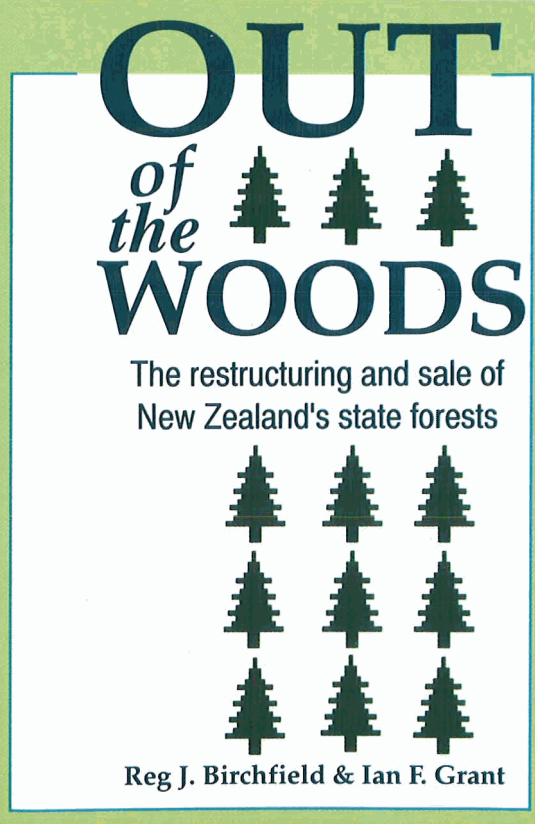

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