Early survival and growth of introduced forest trees in the Canterbury high country

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Abstract

This article describes the results of three comparative species plantings established at Ribbonwood Station (near L. Ohau), Craigieburn Range (upper Waimakariri catchment) and Balmoral Station (near L. Tekapo) in 1983, 1986 and1992. The Craigieburn, Ribbonwood and Balmoral trials tend to confirm earlier reports as to the reliability (if sited properly) of the recognised high country species, Douglas-fir, Corsican and ponderosa pine, but have shown radiata pine to be more hardy and muricata to be less hardy than expected. The indications are that some radiata breeds or 'hybrids' may perform better than others, but no significant difference has been detected between the GF breeds tested. The high country climate can vary dramatically from year to year, and in very dry seasons, which on average appear to occur about once every 5 years, survivals can low on light, drought-prone soils.

Introduction

Over much of the South Island's high country traditional pastoralism is suffering from increasing costs and declining returns (Hughes, 1991). Consequently, there is increasing interest in the potential role of alternative land uses such as plantation forestry using introduced conifers (Belton, 1993). A range of species has been planted since initial settlement over 100 years ago, but the area of plantations is very small, covering less than 0.05% of the area (Ledgard and Belton, 1985). Tree species have been tested by the *Forest Research* over the last 40 years. The initial focus was on species for soil protection (Ledgard and Baker, 1988). Trials comparing production species on plantation sites are relatively recent (Ledgard, 1994a). This article describes comparative species plantings established at Ribbonwood Station (near Lake Ohau), Craigieburn Range (upper Waimakariri catchment) and Balmoral Station (near Lake Tekapo) in 1983, 1986 and 1992 respectively.

Sites

Site characteristics are summarised in Table 1. The Craigieburn and Balmoral sites are close to meteorological stations, Craigieburn Forest and Lake Tekapo (Air Safaris) respectively. The nearest meteorological station to Ribbonwood is at Tara Hills, some 17 km to the south, where mean annual rainfall is 520 mm. Unofficial station records indicate that Ribbonwood has at least 200 mm more annual rainfall than Tara Hills. All sites feature warm summers and cold winters with frosts and snowfalls possible at any time of the year.

Ground frosts occur at Tara Hills and Balmoral on about 160 days annually, and at Craigieburn on 150 days. Temperatures at Craigieburn are rarely below -12° C, but at Tara Hills and Balmoral, values as low as -17° were recorded during the experimental period. It is the unseasonal frosts of more than a few degrees which cause most damage. These occur mostly in the spring when new growth is susceptible to low temperatures, and in the early autumn before tissue hardening has occurred.

Snow falls on approximately 38 days at Craigieburn, 20 days at Balmoral, and 11 days at Tara Hills (probably closer to 20 at Ribbonwood due to the higher rainfall), but rarely exceeds 1 m in depth and does not often persist for more than two weeks.

Table 1. Site characteristics of the three main *Forest Research* high country trial sites

Site	Alt (m)	R'fall (mm)	Ground frosts (days/yr)	Max ground frost (°C) * Winter	Dec/Feb	Aspect	Soil	Vegetation
Ribbonwood	650	800	160	-17.0 (June, 1991)	-4.9 (Dec, 1994)	12°	Craigieburn yellow-brown earth, well drained 20-30 cm topsoil over gravels	Browntop, hard tussock clover, *Hieraclum*. O'sown /topdressed, grazed before planting
Craigieburn	850	1200	150	-12.2 (June, 1991)	-4.4 (Feb, 1989)	2°	Craigieburn yellow-brown earth, 10-15 cm topsoil over poorly drained clays	Browntop/fescue tussock dominated grasslands. No improvement
Balmoral								
Upper terrace	730	580	160	-17.3 (July, 1995)	-5.5 (Dec, 1994)	0°	Pukaki soil, light 40-50 cm stone-free topsoil over compacted gravels	Browntop/hard tussock and bare ground (25%). No improvement.
Lower terrace	700	580	160	-17.3 (July, 1995)	-5.5 (Dec, 1994)	0°	Forks soil, light 0-20 cm stony topsoil over compacted gravels	Scarce. Predominantly *Hieraclum* with 40-50% bare ground

* during experimental period

However, although the snow is generally denser than in overseas continental areas, and thus can cause more tree damage, no snow damage was recorded during the trial periods.

Strong, gusty winds are frequent at Craigieburn and Balmoral, particularly at the latter which is flat and had no vegetation over 50 cm tall when the trial was established. Such winds can significantly increase moisture stress during the

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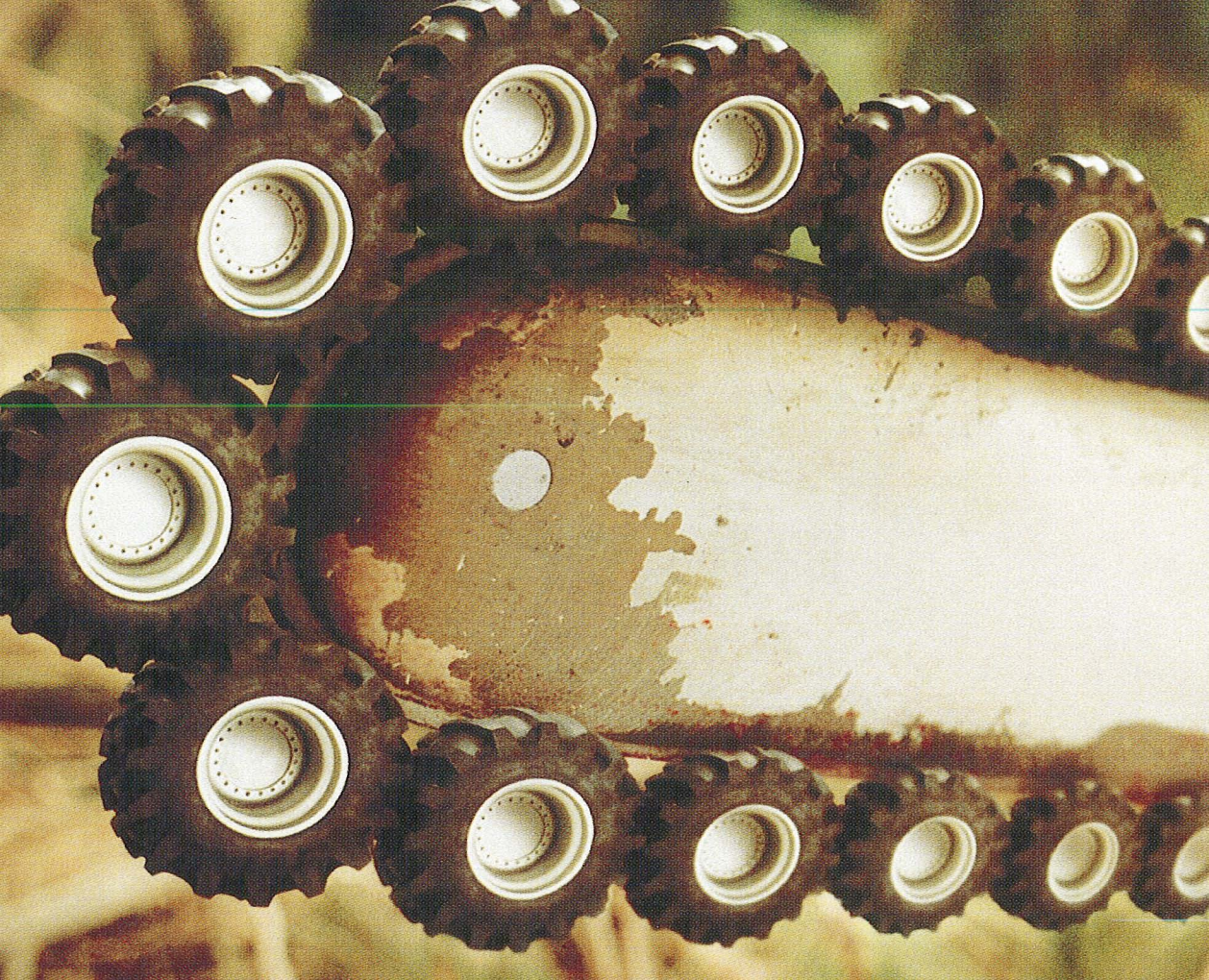

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The Craigieburn trial site - 850 m altitude, 1200 mm annual rainfall.

growing season (September - March). Ribbonwood is a more sheltered site, on a SE-facing slope protected from the prevailing wind.

The Ribbonwood trial

Twenty-five species (nineteen conifers and six broadleaf hardwoods - Table 2) known to be capable of reasonable growth in the high country, were planted in demonstration blocks on Ribbonwood Station near L. Ohau. Conifer survival after 11 years was over 90% for all species, except Mexican cypress (*Cupressus lusitanica* - 80%) and Western White pine (*Pinus monticola* - 5%). The White pine established well initially, but trees have continued to die annually for no obvious reason, although root rots are suspected.

Survival, height, diameter and volume growth are given in Table 2. Although the site was relatively uniform, comparisons between species are indicative only, as the blocks of species were not replicated. Among the conifers, radiata pine was the best performer, in terms of both diameter and height growth. Muricata pine (*Pinus muricata*), hybrid larch (*Larix eurolepis*), ponderosa and Corsican pine (*Pinus ponderosa* and *P. nigra*), and Douglas-fir (*Pseudotsuga menziesii*) also ranked highly. Another good performer was Leyland cypress (*Cupressocyparis leylandii* - clone 'Haggerston Grey'). Although this was slightly behind Mexican cypress, its form was far superior.

Among the broadleaf species, only Shining gum (*Eucalyptus gunnii*) and the Grey birch (*Betula populifolia*) performed satisfactorily in terms of survival and growth. The eucalypt trees were the tallest in the whole trial. The broadleaves were particularly attractive to rabbits and hares, and despite the application of repellents, were regularly browsed when young.

Table 2. Ribbonwood trial. Survival, diameter, height and 'volume' growth of 25 species after 11 years' field growth.

Species		Survival (%)	Average Dbh cm (SD)		Average Ht m' (SD)		Maximum Ht (m)	Volume' dbh^2 x ht
Conifers								
Pinus radiata	Radiata pine	90	26.9	(4.0)	10.1	(1.2)	12.1	0.731
Pinus muricata	Muricata pine	95	22.2	(1.6)	8.1	(0.8)	9.5	0.399
Larix eurolepis	Hybrid larch	95	16.3	(3.0)	8.3	(0.7)	9.2	0.220
Pinus ponderosa	Ponderosa pine	100	17.2	(2.6)	5.8	(0.7)	7.4	0.172
Pinus nigra	Corsican pine	100	16.3	(2.6)	6.0	(0.6)	6.6	0.159
Pseudotsuga menziesii	Douglas-fir	95	14.0	(3.6)	7.6	(1.0)	9.2	0.149
Cupressus lusitanica	Mexican cypress	80	11.7	(3.4)	5.6	(0.8)	6.6	0.077
Cupressocyparis leylandii (Hag Grey)	Leyland cypress	95	10.5	(3.1)	6.3	(0.9)	8.0	0.070
Pinus monticola	Western White pine	5	9.0	(1.4)	4.6	(0.3)	4.8	0.037
Cupressus arizonica	Arizona cypress	100	8.5	(2.7)	4.5	(0.8)	6.0	0.033
Cedrus deodara	Deodar cedar	95	8.4	(1.9)	4.5	(0.7)	5.8	0.032
Seq. giganteum	Mountain redwood	90	8.6	(4.5)	3.6	(1.3)	6.1	0.027
Picea abies	Norway spruce	90	6.7	(1.6)	4.0	(0.7)	5.4	0.018
Pinus uncinata	Mountain pine	100	6.7	(1.9)	3.4	(0.7)	4.8	0.015
Tsuga heterophylla	Mountain hemlock	90	6.1	(1.9)	3.9	(0.7)	5.8	0.015
Cham. lawsoniana	Lawsons cypress	100	6.2	(1.6)	3.7	(0.6)	4.8	0.014
Thuja plicata	Western red cedar	100	5.8	(1.3)	4.2	(0.5)	5.2	0.014
Abies concolor	White fir	100	6.0	(1.5)	3.4	(0.6)	4.8	0.012
Cedrus atlantica	Atlantic cedar	90	4.3	(1.2)	2.9	(0.6)	3.9	0.005
Broadleaves								
Eucalyptus gunnii	Shining gum	90	16.3	(3.4)	10.6	(1.5)	13.2	0.282
Betula populifolia	Grey birch	90	7.0	(1.7)	6.1	(0.9)	7.8	0.030
Alnus glutinosa	Black alder	30	5.8	(1.8)	4.8	(0.9)	6.0	0.016
Acer pseudoplatanus	Sycamore	55	3.6	(1.4)	3.4	(0.8)	5.4	0.004
Castanea sativa	Sweet chestnut	0	-		-		-	-
Gleditsia triacanthos	Honey locust	0	-		-		-	-

The Craigieburn trial

In 1986, seven conifer species (Table 3) were planted as 2/0 bare-rooted seedlings in 8 blocks. Each block contained one 10-seedling row of each species. Domestic stock was excluded for the first year. At the same time, all seven species were also planted in single (unreplicated) rows at Rangiora nursery (50 m asl, 750 mm annual rainfall).

At Craigieburn, survival of Lodgepole pine (*Pinus contorta),* Scots pine *(P. sylvestris),* Corsican pine, European larch and Douglas-fir exceeded 95%. High mortality (54%) was observed in radiata pine.

There was some browsing of lateral branches, particularly during the first year of sheep access. However, the effect on stem height was considered to be insignificant (Crozier and Ledgard, 1990). Lodgepole pine exceeded 3 m in height and was the tallest species, with Scots pine, European larch and

Table 3. Craigieburn trial. Survival and height growth of 7 species after 8 years' field growth. Data for survival and height growth of equivalent stock planted in Rangiora Nursery at the same time are shown for comparison.

Species	Craigieburn Surv %	Craigieburn Ave Ht * (m)	Craigieburn Max Ht (m)	Rangiora nursery ** Surv %	Rangiora nursery ** Ave Ht (m) (SD in brackets)	Rangiora nursery ** Max Ht (m)
Scots pine	100	2.7 b	4.1	100	3.8 (0.6)	4.7
European larch	96	2.7 b	5.0	100	4.2 (0.7)	5.0
Corsican pine	99	2.7 b	3.7	100	4.7 (0.5)	5.6
Ponderosa pine	80	2.1 c	3.1	100	3.0 (0.6)	4.1
Radiata pine	46	1.5 d	3.1	100	9.2 (1.2)	11.5
Douglas-fir	95	0.9 e	1.8	95	5.0 (0.7)	6.0
Lodgepole pine	99	3.3 a	4.0	100	5.5 (0.7)	6.3

* Values followed by the same letter are not significantly different at the 5% level.
** No replication.

Corsican pine all ranking second equal. Ponderosa pine were just over 2 m tall and ranked fifth. Radiata pine and Douglas-fir suffered from frosting on this flat site and height was less than half that of the fastest-growing species.

All of the species except Scots pine survived better at Rangiora, and grew taller by at least 1 m. Height difference between the two sites was greatest for radiata pine (6 m) and Douglas-fir (3 m).

The Balmoral trial

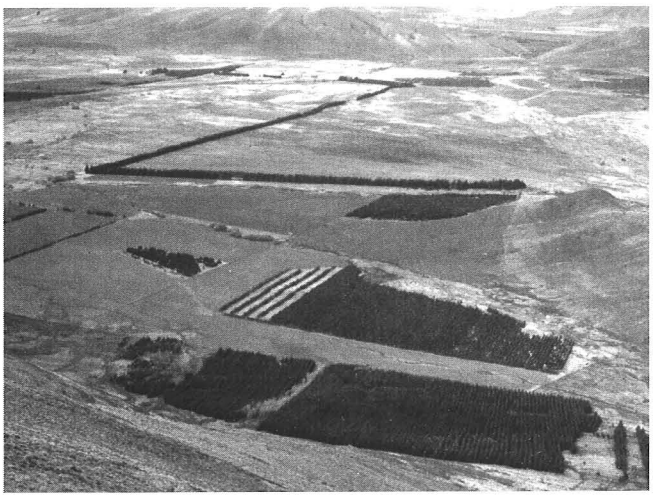
In 1992, four species, including four radiata pine breeds and one radiata 'hybrid', were planted in a replicated trial repeated on two terraces (Table 4). The soil on the lower (younger) terrace is formed from outwash gravels and is an excessively drained, highly drought-prone stony soil of the Fork series. In contrast, the Pukaki soil on the upper (older) terrace is formed from deposits of loess and is less prone to drought, having a stone-free depth of 40-50 cm.

On both terraces, trees were assessed for survival and height after 5 years' field growth (Table 4).

Survival was greater than 86% on both terraces, with the exception of muricata pine (12%) on the lower terrace. Height growth was greater in all species on the better soil of the upper terrace. Radiata pine ex Guadalupe was the best performer, although not significantly faster than the 'hybrid' radiata x *P. attenuata* on the upper terrace. Amongst the radiata pine breeds there was no significant difference in height growth.

The trial described above was planted in 1992. However, the high country climate can vary dramatically from year to year. Varying degrees of frost and drought can have a considerable impact on seedling survival and early growth. For this reason, ponderosa pine (upper terrace only) and radiata pine (GF 17 seedlings), Corsican pine and Douglas-fir were also planted in 1993 and 1994.

The three pine species survived well during their first growing seasons on the upper terrace. However, on the lower terrace there was a major drop in survival in 1995 of the trees planted in the spring of 1994. Radiata pine survivals at the end of the 1994/95 season were 36%, compared to first-year survivals of 100% and 94% after the 1992/93 and 1993/94 seasons, while Corsican pine fell to 40% after the 1994/95 season from 100% in both the two prior seasons. The main reason appeared to be an extremely dry 1994/95 December, January and February period. This dry period also caused some deaths in the 3- and 2-year-old pine seedlings planted in 1992 and 1993 respectively, particularly of muricata pine on the lower terrace (survival dropped from 88% for 2-year-old trees to 12% at the end of the third year). The same drought killed nearly all first-year Douglas-fir on the lower terrace, as well as a third of the 2-year-old seedlings. Three years later, the1997/98 summer also featured dry conditions with strong winds and high temperatures. During this season the remaining 1992/94-planted pines suffered minor losses on both terraces, but Douglas-fir survival dropped to 28% (1993-planted) and 48% (1994-planted)



Courtesy of Forest Research

The Ribbonwood Stations (near L. Ohau) trial site - 650 m, 800 mm annual rainfall.

Table 4. Balmoral trial. Survival and height of trees planted in 1992 after 5 years' growth.

Species	Upper terrace Survival * (%)	Upper terrace Height * (cm)	Lower terrace Survival * (%)	Lower terrace Height * (cm)
Radiata pine ex Guadalupe »	100 a	240 a	96 a	185 a
'Hybrid' *P. rad x attenuata* #	96 a	234 ab	99 a	158 b
Radiata (mean of 3 breeds)	98 a	221 b	96 a	162 b
Muricata pine	86 b	218 b	12 b	117 **
Ponderosa pine	97 a	169 c	93 a	105 c
Corsican pine	100 a	155 c	99 a	117 c
Radiata breeds ***				
Radiata seedl'gs GF 17	99 a	217 a	97 a	165 a
Radiata seedl'gs GF 28	100 a	215 a	95 a	163 a
Radiata cutt'gs GF 25	96 b	230 a	97 a	158 a

» Seedlot number - FRI 90/299
Grown from seed from a single open-pollinated *P. radiata x P. attenuata* hybrid tree at L. Coleridge arboretum
* Values in each column grouping followed by the same letter are not significantly different at the 5% level.
** Not included in analysis as survival too low
*** Analysed separately

on the upper terrace and 10% and 0% respectively on the lower terrace.

Another major feature of the 1994/95 season was a heavy frost on December 22 (-5° C) which killed new growth and severely checked all Douglas-fir (particularly the first-year seedlings) on both terraces, but in itself caused few deaths.

Discussion

The Craigieburn, Ribbonwood and Balmoral trials tend to confirm earlier reports (Ledgard and Belton, 1985) as to the reliability (except in extremely dry seasons on light soils) of the two 'best bet' (Ledgard, 1994b) higher altitude plantation species, Corsican and ponderosa pine, and the susceptibility of Douglas-fir to frosting on flat sites. Douglas-fir performs best on south-facing, moist slopes and should not be planted on flat sites where cold air ponds and spring frosts can be devastating. Along with Douglas-fir, radiata pine also performed poorly at the highest and wettest site (Craigieburn), where frost damage was observed. However, at the colder and drier Balmoral site it has performed well to date. The reasons for this display of cold tolerance, where frosts down to -17.3 °C were recorded, are unclear. However, despite having endured an extremely cold winter and hard spring frosts, the trees at Balmoral are still young, and there are sufficient records of radiata pine failure on frost-prone, higher altitude sites (NZ Forest Research Institute, 1976; Ledgard and Belton, 1985) to support recommendations for considerable caution with its use on flat frosty high country sites. It should be preferred only on sloping sites, particularly the warmer slopes facing north. The relatively young age of the Balmoral trial also means that the better growth of the radiata ex Guadalupe and the lack of any significant difference in height between the radiata GF 17 and 28 seedlings and the GF 25 cuttings, should be considered as indicative only. More time is needed before recommendations can be made for use of radiata pine clones or cuttings in the high country.

The better growth of the conifers in the Rangiora nursery relative to those of identical age and origin at Craigieburn is due either to the lower altitude (and longer growing season) or to the higher fertility of the ex-nursery soil. The availability of moisture, which has been identified as a major determinant of growth in the high country (Ledgard and Belton, 1985) is not a reason, as the Craigieburn site receives over 50% more rainfall than Rangiora. At Balmoral, the better soil conditions (increased fertility and / or moisture retention) on the upper terrace appear the most likely reason for the improved growth (23-38%) over trees on the lower terrace, as the sites only differ by 1 km in distance and 30 m altitude, and climatic conditions appear very similar.

Most mortalities occurred on the hardest trial site (the lower terrace at Balmoral) after 2 months of hot, dry mid summer weather during the 1994/95 season. Rainfall for December, 1994 and January, February 1995 was only 5, 15 and 28 mm compared to the normal average of 50, 47 and 42 mm respectively. This period was the driest recorded during the last 20 years. Long-term rainfall records indicate that the likelihood of any 2 successive growing season (September - March) months each receiving less than 25 mm is about 20%, so droughts of this severity occur relatively frequently. Another drought season occurred in 1997/98, when low rainfall in September / October (23 and 10 mm respectively) was followed by an exceptionally high number of hot (over 25° C) and windy days.

Other conifers such as Scots pine, Lodgepole pine and European larch have demonstrated good early performance in these trials but experience elsewhere (Ledgard and Belton, 1985) shows them to slow down considerably in volume growth as they mature. Lodgepole and Scots pine have the added disadvantage of being the conifers most prone to wilding spread (Ledgard, 1988) and having low market acceptance in New Zealand. Muricata pine has been considered as a hardier species than radiata (NZ Forest Research Institute, 1973), but has proven to be less drought tolerant (Balmoral) or slower (Ribbonwood) in these trials.

On moist, sheltered sites such as at Ribbonwood there are other timber conifers which will readily survive high country conditions but will generally not grow as fast as the pines, larch and Douglas-fir. Most of these have been in the high country for some time - the main newcomer of interest being Leyland cypress. This hybrid deserves more attention as a producer of good quality, naturally durable (above ground) timber. Trials indicate that the best clones for the high country are Stapehill and Ferndown. Macrocarpa (*Cupressus macrocarpa*) is known to be less hardy than the leyland cypresses, and was therefore not included in the trial.

Of the broadleaf species in these trials only grey birch (*Betula populifolia*) and *Eucalyptus gunnii* have performed satisfactorily. A few trees of *E. pauciflora* are also surviving well at Ribbonwood, and growth elsewhere indicates this species to be just as hardy as *E. gunnii*. Although *E. gunnii* has grown well at Ribbonwood, this species along with 18 other eucalypt species planted in 1981 at Tara Hills (30 kms away) on a flat, more frost-prone site, have not survived well - most being killed to ground level (although many subsequently coppiced) by a -19°C frost in July, 1995 (Ledgard, 1998).

On moist sites the poplar and willows are known to be hardy, and other species (such as some species of *Quercus*, *Fagus* and *Acer*) will grow if given reasonable soils and/or good shelter, but generally they are much more site demanding than the conifers.

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