terns associated with periodic major disturbance events, this will provide a degree of continuity not previously guaranteed by past practices, although one might ask whether this is in fact altering the character and structure of the forest in the long term.

Obtaining True Value

With the cessation of unsustainable harvesting, there is scope for the owners of small native forests to obtain more realistic prices for their timber, although, like everything, competition from substitute timbers and other materials will influence the economics of native forest management. The price for the high-quality timber grades will ultimately determine the success of sustainable management.

Prices being paid for standing timber of some species are increasing as availability to the sawmiller declines. A tightening of supply may provide further opportunities for forest owners to develop niche markets for a variety of quality timber species, softwood and hardwood, which have not traditionally been of interest to most timber processors and manufacturers who have previously relied on abundant and relatively cheap supplies of versatile timbers like rimu and southland silver beech (*Nothofagus menziesii*).

There have been one or two examples during 1996-1997 of forests being offered for sale as 'going concerns' under registered management plans or permits. This is a positive spin-off of the legislation, where a purchaser of native forest can buy into an enterprise which has a reasonably predictable revenue stream and, equally importantly, has been through all the necessary bureaucratic hoops. There is thus the beginnings of a market in managed private native forests which may fulfil the needs of those owners who wish to capitalise on their interest in the forest. Such developments should put managed native forests on a footing more comparable with that of woodlots and plantations which are traded in New Zealand on a regular basis.

The Native Forest Owner - Post 2000

The General Manager of Agriculture New Zealand (farm consultancy services), was quoted in the Rural Garden magazine in 1996 as saying that large corporate farms will dominate farming within ten years. His basis for saying this is that the profit from small farms (about 3000 stock units on 300 ha), is insufficient for all but minimal family cash drawings and their viability is in doubt. "These farmers will be the new lifestylers" who derive much of their income off-farm. Further, he identified the advantages of large corporate owners as purchasing and marketing power, access to information, technology, know how and capital and economies of scale. There are already signs in New Zealand that a few corporate owners of native forests are interested in expanding their operations by purchasing forestry rights from small forest owners, bringing with them the necessary start-up capital, forest planning, management expertise and access to timber markets.

Similarly, there is scope for owners of small native forests to enter into cooperatives for the efficient management of their collective forest resources. (The Forests Act provides for forests under separate ownership to be managed under one Sustainable Forest Management Plan.) For those owners who have not the capital, expertise or time to implement sustainable forest management on their properties independently such a venture will be an attractive option. It can provide the scale necessary to be able to employ professional management expertise and, for some, may be the only way they can maintain their agricultural/forest unit as a viable enterprise.

Conclusion

While much of this paper has focused on the challenges faced by owners of native forests in adjusting to a new regime, it is encouraging that many of them are taking the opportunity to place the management of their forests and, equally importantly, the marketing of their forest produce on a sustainable footing. Some are also looking at means of applying eco-labelling to their products. Judging by the forest certification and eco-labelling initiatives worldwide, New Zealand owners should move now to develop quality management of their forests for the time when consumer preference for timber products from sustainably-managed forests has a significant impact on markets at home and overseas.

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Deciduous hardwood species – early silvicultural options for growing timber on farms*

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Summary

Although introduced softwood coniferous species dominate New Zealand's timber resource, there is increasing interest in deciduous, broadleaved hardwoods. Small private growers (mostly farmers) have the best sites and most potential to grow a hardwood resource. This paper describes a five-year trial aimed at determining the most practical early silvicultural options for growing timber from deciduous hardwood species on farms. The trial involved 15 species. There were nine deciduous hardwoods species (Quercus canariensis, Q. petraea, Q. cerris, Fraxinus excelsior, Ulmus x hybrid 'Loebel', Prunus avium, Castanea sativa, Paulownia fortunei, Robinia pseudoacacia 'Jaszkiseri'), four evergreen native species (Nothofagus solandri, Dacrycarpus dacrydioides, Podocarpus totara and Kunzea ericoides), and two evergreen introduced conifers (Pinus radiata and Cupressus macrocarpa). Silvicultural treatments involved form pruning, coppicing, plastic treeshelters plus a control. The aim was to produce a target sapling tree with a straight, defect-free stem at least 3 m in length, within as short a time as possible. The most successful treatments were form pruning and standard (ground level) treeshelters. Using these treatments, target size was achieved after only three years in some species. By age five the best treatments had achieved target dimensions in over 50% of trees in nine of the 14 species.

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Introduction

Although coniferous species dominate New Zealand's plantation resource, there is increasing interest in special purpose timber species, including deciduous broadleaved trees (MOF 1995). Species in this group, belonging to genera such as *Acer, Castanea, Fagus, Fraxinus, Juglans, Quercus* and *Ulmus,* can grow well in New Zealand, but generally require better soils and more sheltered sites than conifers. Small private growers (mostly farmers) are the group with the most potential to grow any future hardwood resource (Tilling and Clifton 1984).

Traditional hardwood silviculture overseas has involved management (usually through thinning) of natural mixed-age stands rather than the establishment of new plantations (Evans 1984). Straight boles suitable for quality timber production have been encouraged by close spacing (Kerr 1993) followed by thinning and, sometimes, pruning. Traditional plantation management may not be the most appropriate silvicultural means for establishing and growing a quality hardwood resource on New Zealand farms, where the most suitable sites (sheltered with good soils) are often small. Owners and managers of the best sites are more likely to be able to accept (mentally, physically and financially) the idea of planting a few trees in scattered sites rather than many in a single plantation. If it is not possible to encourage good bole form by close spacing (as in plantations), then other simple, individual-tree techniques are needed to ensure timber quality.

The overall objective of the work described above was to test early silvicultural options for improving the timber potential of individually-grown, deciduous hardwood trees. More specifically, the aim was to grow, as quickly as possible, a target sapling tree which was described as "a healthy tree with a straight, defect-free stem of at least 3 m length".

Table 1. Species included in trial

North block (exposed)	
Black beech	*Nothofagus solandri*
Kahikatea	*Dacrycarpus dacrydioides*
Totara	*Podocarpus totara*
Kanuka	*Kunzea ericoides*
Elm (Dutch elm disease resistant hybrid clone)	*Ulmus* 'Loebel'
Algerian oak – hybrid*	*Quercus canariensis x Q. robur*
Turkey oak	*Quercus cerris*
Sessile oak – hybrid	*Quercus petraea x Q. robur*
Radiata	*Pinus radiata*
Macrocarpa	*Cupressus macrocarpa*

South block (sheltered)	
Wild cherry	*Prunus avium*
English ash	*Fraxinus excelsior*
Algerian oak – hybrid*	*Quercus canariensis x Q. robur*
Robinia	*Robinia pseudoacacia,* clone 'Jaszkiseri'
Paulownia	*Paulownia fortunei*
Sweet chestnut	*Castenea sativa*

* *Not the same seedlot*

Methods

The trial which included nine introduced deciduous hardwood species, plus four native species and two introduced, evergreen conifers (Table 1), was situated in the NZ Forest Research Institute nursery off Oxford Road, Rangiora. The site is flat, with a deep, fertile, Waimakariri silt loam at an altitude of 40 m asl and a mean annual rainfall of 650 mm. Limited space meant that the trial had to be divided into a north and a south block. The north block was exposed with little shelter, while the south block was well sheltered. Planting was carried out in mid-August 1991.

Stock numbers were insufficient to allow all treatments to be applied to all species. (Treatments applied to each of the species are indicated in Table 3.)

The trial included six treatments, five of which involved treeshelters. This is the common name given to tubes (usually made of translucent plastic) up to 2 m in height that are used to physically protect young trees, and to provide a better micro-climate (Tuley 1983; Potter 1991). They are relatively new to New Zealand (Bullivant and Bertram 1996), and the few trials undertaken have shown that, although there are some problems with their use (particularly where grazing animals are involved) they can improve the early survival and growth of some species (e.g. Stace 1993). In this trial, square-section KBC treeshelters were used, except in raised situations where the round-section Tubex brand was used.

Treatments were:

Control (Treatment 1)

All control trees were unmanaged except for the removal of small side branches from the bottom 30 cm in year two to facilitate safe herbicide application.

Standard Treeshelters – 1.2 m and 0.75 m with Form Pruning (Treatments 2 and 3)

Square section 1.2 m KBC shelters were tested on all species, but 0.75 shelters were only tested on the four native species and on Algerian oak in the north block. Form pruning was carried out as required in all treeshelter applications, once trees had emerged from the shelters.

Table 2. Influence of tree shelters on height growth after two and five years

Block	Species	Height difference of sheltered trees over control trees (%)			
		1.2 m tree shelter (Treatment 2)		0.75 m tree shelter (Treatment 3)	
		Age 2	Age 5	Age 2	Age 5
North	Black beech	+ 23 *	– 2	+ 19 *	+ 9
	Kahikatea	+ 47 *	+ 38 *	+ 26 *	+ 19
	Totara	+ 53 *	+ 29 *	+ 37 *	+ 15 *
	Kanuka	+ 75 *	+ 71 *	+ 32 *	+ 36 *
	Elm	+ 27 *	+ 14 *	NA	NA
	Algerian oak	+ 56 *	+ 25 *	+ 35 *	+ 18
	Turkey oak	+ 48 *	+ 7	NA	NA
	Sessile oak	+ 90 *	+ 21	NA	NA
	Radiata pine	+ 27 *	– 11 *	NA	NA
	Macrocarpa	+ 22 *	+ 7	NA	NA
South	Wild cherry	+ 15 *	+ 14 *	NA	NA
	English ash	+ 28 *	+ 12 *	NA	NA
	Algerian oak	+ 60 *	+ 5	NA	NA
	Robinia =	+ 3	+ 2	NA	NA
	Paulownia =	– 12	– 9	NA	NA
	Sweet chestnut =	+ 41 *	+ 17 *	NA	NA

* statistically significant difference (p = 0.05)
= Age three and five (i.e. two and four years after coppicing at age one)

Raised Tree Shelters (no form pruning, and shelter raised as tree grew to 2.8 m) (Treatment 4)

Most trees had grown above standard shelter height (1.2 m) after year one. From this point the shelters were raised (supported by a batten) to a maximum top height of 2.8 m, using round-section 1.2 m Tubex shelters.

Form Pruning (Treatment 5)

Form pruning was applied to produce a balanced tree with a clearly defined, straight single leader with side branches of relatively small diameter and horizontal stance. Form pruning was carried out up to a maximum height of 3 m, and consisted of two parts – leader training and branch control:

a) Leader training. Competing leaders and/or vertical branches were removed or tipped back to promote a single straight vertical leader. Leader training was carried out as required at each tree measurement, but the critical input was in the spring, before lignification and when shoots were small. The straightening of shoots and healing of small scars was quickest at this time. As the target tree requires a straight stem only to 3 m, no leader training was attempted above this height.
b) Branch control. Branches, mainly on the lower half of the trees, were removed to the following criteria:
    i) Branches of diameter greater than two-thirds that of the main trunk (at junction), or greater than 3 cm diameter were removed just outside the branch collar (*not* flush pruned as with radiata pine).
    ii) Steeply ascending branches were removed entirely, or the vertical components were removed if some foliage retention was necessary (see iv).
    iii) A balanced crown was retained.
    iv) No more than one-third total foliage was removed at any one time.

Compromise between these criteria was sometimes necessary. In order to facilitate wound occlusion (and for logistical reasons), branch control was carried out in spring and summer only at times of tree measurement.

Coppicing and 1.2 m Shelter with Form Pruning (Treatment 6)

All coppicing was carried out after the first year – in August. Trees were cut neatly at 5 cm above ground with a sloping cut. *Trichoderma* suspension was immediately painted on to all stumps to protect against silverleaf infection. After approximately

Table 3. Influence of treatments on percentage * of trees reaching target specifications ** over time. (No kahikatea, totara or kanuka trees reached target size.)

North block

Species	Treatment	Fraction of surviving trees achieving target specifications (%) Year 2	Year 3	Year 4	Year 5
Black beech	1	0	0	0	13
	2	0	0	0	13
	3	0	0	0	13
Elm	1	0	0	0	0
	2	0	40	100	100
	5	0	30	100	100
	6	0	0	90	90
Algerian oak	1	0	0	10	20
	2	0	0	30	70
	3	0	10	20	50
	4	0	40	40	50
	5	0	0	40	60
	6	0	0	0	30
Turkey oak	1	0	0	10	40
	2	0	0	20	50
	4	0	0	20	60
	6	0	0	0	13
Sessile oak	1	0	0	0	20
	2	0	0	0	40
	5	0	0	0	0
	6	0	0	0	0
Radiata pine	1	0	27	100	100
	2	0	0	90	90
Macrocarpa	1	0	0	43	79
	2	0	0	100	100

South block

Species	Treatment	Fraction of surviving trees achieving target specifications (%) Year 2	Year 3	Year 4	Year 5
Wild cherry	1	0	0	0	0
	2	40	100	100	100
	4	60	100	100	100
	5	30	100	100	100
	6	0	29	86	100
English ash	1	0	10	40	40
	2	0	80	90	90
	4	0	88	88	88
	5	0	30	80	100
Algerian oak	1	0	29	57	57
	2	13	75	100	100
	4	14	71	86	86
	5	0	0	83	83
Robinia	5	10	100	100	100
	6	20	90	90	90
Paulownia	5	0	22	22	33
	6	0	44	56	56
Sweet chestnut	5	0	0	0	0
	6	0	0	0	40

* Figures do not include trees that died or were significantly affected by disease, but do include trees which had to be assisted to stay erect.
** Height of 3.5 m, and form of 1 or 2.

two months of coppice regrowth a single new leader was selected and the remainder pruned off. All coppice treatments were form pruned.

Because treatments were to be compared only *within* species and *not* between species, each species was planted in a single group. Each group was then divided into five replicates or blocks, except the four native species which had three replicates. Treatments were randomly applied to individual trees, with a total of between 10 and 15 trees per treatment.

Heights were recorded at planting and approximately once every month during the first two growing seasons. In years three to five assessments were in December, February and April. Form pruning was carried out at these times. Diameters at 1.4 m above ground (DBH), form and numbers of leaders were recorded at the end of year five. Form was classified into five categories, ranging from perfect (1) to multi-leadered trees of very poor form (5). Only classes 1 and 2 were considered acceptable for eventual timber production (i.e. reached 'target' specifications). Trees which died or were severely damaged by animals or wind (stem breakage) were not included in any analyses of height, diameter or form.

Analyses of variance (ANOVAs) were carried out for height at ages one to five, and form and DBH at age five. The analyses were single-tree-plot ANOVAs testing the effects of treatment and row. From the height measurements, planting height was used as a covariate, although for most species its significance had disappeared by age three. Duncan's multiple range test was used to compare pairs of individual treatments. The variation in numbers of leaders per tree was tested using the Kruskal-Wallis nonparametric test, as distribution was non-normal.

Results

Early Survival and Animal Damage

Survival after the first year was 100% in all but two species. Two (10%) *Paulownia* failed to sprout from rooted stumps, and three (8%) hybrid Algerian oaks died early, probably because of poor stock quality. Shelters provided complete protection from small animal damage, whereas hares and rabbits damaged a number of the unprotected trees. Tall, lightly-branched seedlings (e.g. kahikatea – 33% damaged) and the smaller seedlings (e.g. sessile oak – 48% damaged) were the most vulnerable.

Health

Following establishment, the only treatment which lead to health problems was coppicing, where 30% of wild cherry and 20% of Turkey oak failed to re-establish from coppice. Wild cherry was the most susceptible to ill-health, being attacked by aphids in year two (requiring pesticide application) and also by blast and silverleaf (affecting 6% and 8% of all trees respectively). The high temperatures induced within some treeshelters (e.g. 46°C was recorded inside a 1.2 m shelter in February 1993) did not appear to affect the health of any plant.

Height Growth

As the species blocks were not replicated, comparisons between species can only be viewed as indicative.

Standard Treeshelters (Treatments 2 and 3)

Although the shelters resulted in a significant height advantge in all species except *Paulownia* and *Robinia* by age two (Table 2), the difference usually declined considerably by age five, when improvements in height growth were statistically significant only for Algerian oak (north block only), wild cherry, ash, elm, sweet chestnut, and the three native species, kahikatea, kanuka and totara. The longer-term advantage afforded by treeshelters was greater in the native species than it was in the introduced species. Although shelters significantly increased height growth of radiata pine and macrocarpa at age two, this effect was lost by year five, particularly in radiata pine where height growth was significantly reduced by sheltering. The effect of the 0.75 m shelters was similar but less pronounced than for the 1.2 m shelters.

Raised Tree Shelters (Treatment 4)

Raising tree shelters after the first year promoted faster height growth in subsequent years but by year five these trees were never significantly taller than trees where the shelters were not raised (Treatment 2). In addition, the stems of trees with raised shelters were often too weak to support their crowns. Some collapsed and many others had to be artificially supported.

Form pruning (Treatment 5)

Among the deciduous species form pruning significantly improved the height of elm and wild cherry, but had no significant influence on any of the oaks or ash.

Comparison of Treatments 2 (standard shelter) and 5 is effectively a comparison of form-pruned trees with and without treeshelters. Amongst the pruned exotic broadleaved species after five years only ash benefited significantly from shelters.

Coppicing with Shelter and Form Pruning (Treatment 6)

After five years, wild cherry (south block) and elm, Algerian, Turkey and sessile oak (north block) coppiced at the end of year one were generally smaller in height than the non-coppiced controls and sheltered trees with the exception of elm where the coppiced trees were significantly taller than the control, but not the sheltered trees. Coppicing of *Robinia, Paulownia* and sweet chestnut, after year one was a standard treatment, and hence could not be compared with non-coppicing treatments. The use of shelters was the only variable and this significantly improved the height of sweet chestnut only.

Diameter Growth

As the species blocks were not replicated, comparisons between species can only be viewed as indicative. In the north block radiata pine had the largest mean DBH after five years followed by macrocarpa – 112 mm and 94 mm respectively. In the south block *Robinia* (83 mm), wild cherry (78 mm) and Algerian oak (64 mm) grew best. The native species grew slowest, with black beech being the fastest at 29 mm.

Unlike trees receiving treatment, control trees frequently developed multiple stems which were not removed by form pruning. Hence no valid comparisons could be made between diameter growth of the multi-stemmed controls and the single-stemmed trees receiving treatment.

Standard shelters had no significant effect on the form-pruned trees except for sessile oak, where the DBH of sheltered trees was almost double that of unsheltered trees, and elm where shelter significantly reduced DBH by 9%. Raised shelters tended to suppress DBH.

Form and Number of Leaders

Form pruning improved the stem straightness of all species, including the three coppiced species, particularly those tending towards multiple leaders. Elm and cherry were the species most prone to multiple leaders (4.4 and 4.3 leaders/control tree respectively), followed by ash (1.9), Algerian oak (1.6 and 1.3) and Turkey oak (1.3). Tree shelters provided no additional improvement in stem straightness except for sweet chestnut.

Stability

Standard (1.2 m) shelters promoted instability amongst the evergreen, exotic, conifers and the native species. In years three and four stability problems increased, so requiring support by tying to stakes. Fewer problems were encountered with the smaller 0.75 m shelters. By age five most of the radiata pine and macrocarpa and black beech had grown past needing support, but the slower-growing totara and kanuka still needed assistance.

Raised shelters were applied only to

wild cherry, ash and Turkey and Algerian oaks, and in all cases promoted crown instability. Stems were too weak to support their crowns and required artificial support,usually for at least two years after they had emerged from shelter tops at 2.8 m. In a number of cases the supporting battens were broken, and some stems were snapped, but by age five the majority were becoming self-supporting.

Achievement of Target Tree Specifications

The number of trees reaching the target height of 3.5 m, and a form score of 1 or 2, together with the time it took to do so, is given by treatment in Table 3.

Treatment 2 (shelters plus form pruning) and Treatment 5 (form pruning alone) were the most successful in producing target trees. Of the four species receiving Treatment 4 (raised shelters), Turkey oak and wild cherry reached target tree dimensions at an earlier age, but by age five Treatment 2 had generally produced the most target trees. In the good growing conditions of the south block, wild cherry and *Robinia* were the fastest-growing species and by age three all trees in Treatments 2, 4 and 5 (wild cherry) and *Robinia* (Treatment 5) had achieved target specifications. Ash and Algerian oak were close behind with 80% and 75% (respectively) of Treatment 2 trees reaching target size by age three. In the more exposed north block, radiata and elm were the fastest with 100% target trees in Treatments 1 (radiata) and 2 and 5 (elm) by age four. Amongst the oaks in the north block, Algerian and Turkey oak were the best performers with over 50% of Treatment 2 and 5 trees reaching target size by age five. Shelters (Treatments 2 and 3) had no effect on the production of target trees of black beech beyond the control values (13%).

Discussion

This trial has shown that the survival, early growth and form of some deciduous hardwood species grown as individual specimens can be improved by certain cultural treatments which can result in the production of trees with more commercial value at maturity. Although results have been obtained only from one site in Canterbury, they have implications for deciduous, broadleaved tree growth in other parts of New Zealand.

Treeshelters

KBC treeshelters decreased seedling damage due principally to hares and rabbits. Protecting new seedlings from animal damage is a major reason for using treeshelters in Britain (Potter 1991). Early height growth (two years) was significantly improved by treeshelters but this advantage over control trees was considerably reduced by age five. By this age, sheltered trees were significantly taller than unsheltered, control trees in only five of the nine deciduous species, and the greatest improvement was only 25% in Algerian oak (north block). Sheltering had no effect on height growth of macrocarpa and reduced it in radiata pine trees after five years. These results are far less dramatic than those reported in Britain by Potter (1991), where sheltered sessile oak trees were reported to be two to four times taller than control trees after five years. The native species generally benefited more from shelters than the introduced species, although the improvement in the fastest-growing species, black beech, reversed from +32% in year two to -2% in year five.

As many of the control trees had more than one leader and the sheltered (Treatment 2) trees were form pruned to ensure one leader, a fairer comparison of the influence of shelters could be gained by comparing the sheltered (but form-pruned) trees with the unsheltered, form-pruned trees. In such a comparison, only ash and sweet chestnut benefit significantly, indicating that, for the other species, shelters provide no long-term growth advantage as long as form pruning is carried out.

Early New Zealand experience with seven species (I. Nicholas, FRI, Rotorua, pers. comm.) and radiata pine (McNab 1992) highlighted problems with stems which were too weak to support themselves. British results demonstrated similar problems after three years, but later showed that if shelters remain in place long enough for sufficient movement of elevated crowns to encourage stem thickening, then most trees were strong enough to remain erect once the support of shelters has gone (Potter 1991).

Loss of stability of standard (ground-level) sheltered trees and bending of stems by wind were major problems with the evergreen coniferous species, radiata and macrocarpa, and three of the native species, kanuka, totara and black beech, (the slow growth and sparse form of kahikatea presented little wind resistance). The denser more compact canopies proved too heavy for their stems, and so they were severely bent by the wind once the shelters had broken away from their supporting stakes. Some stems broke off completely at ground level but none were uprooted. With radiata and macrocarpa instability was worst from age two to four, but no trees blew over in the fifth year. However, loss of stability amongst the sheltered native species was still apparent in the fifth year.

Progressive raising of shelters above ground level, to a height of 2.8 m to promote faster height growth and straighter stems resulted in the production of thin stems which had to be supported by stakes and battens. In many instances the stakes failed and the trees fell over. These problems outweighed any advantages gained in height growth, although by age five many of the stems appeared to be becoming capable of supporting themselves.

The cost of shelters, including supporting stakes and wire stabilisers, is about $NZ 7-8. The stakes may be reusable if treated, but the shelter is unlikely to be recoverable. While this cost may seem excessive, a shelter virtually guarantees the survival of a small seedling (costing $2-4) and its growth through to 1.2 m or taller in one season, for an all-up cost of around $10-12. An initial outlay of at least $8 is common for an unprotected tree of standard (1.2 m) size, with staking costs additional. This gives a comparable total price of around $10 – and survival and good early growth is not so assured. In addition, a small seedling in a shelter is more likely to develop a good, well-balanced root system, than a 1.5 m standard tree which, after a number of years growing within the restrictions of a container, could well be planted out with a deformed root system.

Form Pruning

Form pruning, carried out in spring and sometimes again in mid-summer, markedly increased stem straightness and form, and the number of trees reaching target specifications within the time-span of the trial.

If carried out in spring, when young growth has not lignified, the work required in leader training is minimal. Winter frosts and insects may kill the terminal bud on the leader of a deciduous tree, and once growth commences a number of secondary buds will begin competing for leadership. If left untouched a multi-leadered top will result. However, pre-emptive pruning with a pair of secateurs when the young shoots are only 5-10 cm long is often sufficient to turn a potential problem tree into one of desirable form. A second visit in mid-summer may be needed to remove later development of competing leaders, but if the spring treatment has been done correctly repeat visits are not normally needed.

The use of treeshelters without form pruning was not tested. Inside the shelters some side branches grew up and out the top, and would have competed with the leader if not pruned back. Radiata pine developed a rounded, 'lollipop' top above the 1.2 m shelters and required form pruning to become single leadered. Birds landing on shelters frequently broke young emerging radiata shoots, further encouraging multi-leadering.

Branch control was directed at the larger branches, particularly those with ascending habits. These were either tipped or removed if they reached a basal diameter greater than two-thirds that of the main stem (at junction) or if they reached 3 cm diameter at their base. A home-made 3 cm gauge (FRI 1995) was used to determine when this critical branch size is exceeded. Determining whether to tip or remove a branch before it reaches 3 cm in diameter can be difficult, because if green crown surface area is reduced too severely, diameter growth will be slowed significantly. For this reason tipping (removal of the outer half of a branch) was sometimes preferred. Branch control was carried out in the spring at the same time as leader training. This was not only practically convenient but at this time occlusion of pruning scars was most rapid.

Bole or clearwood pruning (removal of all stem branches) is different from branch control. Bole pruning was not a trial treatment and it was practised only to a height of 3 m when trees were approaching 6 m in height and if some lower branch suppression and die back was occurring (e.g. wild cherry).

This system of leader training and branch control is very similar to that promoted for Tasmanian blackwood (*Acacia melanoxylon*) by Brown (1997) and FRI (1995). Brown found that leader training took very little time or effort but led to dramatic improvements in blackwood form, and eliminated the need for a nurse crop. FRI advocated the improvement of timber potential by annual form pruning and the use of a 3 cm gauge for determining which branches to remove.

Coppicing

Coppicing (with shelter and form pruning) of elm, Algerian oak (north block), Turkey oak and wild cherry delayed the production of target trees compared with the sheltered and form-pruned trees (Treatment 2) or trees form pruned only (Treatment 5). Tree shelters are helpful for protecting coppice growth from animal or spray damage. In addition they may enhance early growth rate and form, as they did for sweet chestnut, although there was no shelter advantage after coppicing for *Robinia* and *Paulownia.*

Achieving Target Tree Status

Apart from the four native species, among which only 13% of black beech reached target tree status, and sessile oak and sweet chestnut where 40% achieved this goal, there was at least one treatment in the remaining species which promoted most trees to the target of 3.5 m height with a form score of 1 or 2. Less than 50% of control trees reached the target, due mostly to poor form, the exceptions being the two evergreen conifers, radiata and macrocarpa, where 100% and 79% of trees attained target tree status by year five, and Algerian oak (south block) where 57% of control trees reached the target.

Trees in the more sheltered south block performed best, with wild cherry achieving 100% target status in all four treatments tested and *Robinia* achieving 100% and 90% target tree in treatments five and six respectively (the only treatments applied to this species). However the performance of *Robinia* in another trial near the north block and elsewhere in Canterbury field trials has been disappointing. In general, the performance of the other species grown in the south block can be expected to be poorer on more exposed sites.

Conclusions

The results from this trial indicate that, if the target is to grow broadleaved trees for quality timber production, then some cultural treatments are advisable. Of the treatments tested, form pruning (Treatment 5) was the most effective. Combining form pruning with treeshelters (Treatment 2) sometimes promotes quicker success (such as in ash and Algerian oak in the south block), but this advantage was declining or had disappeared by year five. Standard shelters are however effective in protecting seedlings from animal damage and promoting faster early growth. Raised shelters may promote height growth but will depress diameter growth and encourage instability. Coppicing was invariably slower in achieving target tree status but can be used to give growers a 'second chance'.

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