Best Practice with Farm Forestry Timber Species

No. 1: CYPRESSES

NZFFA Electronic Handbook Series

Ian Nicholas (Editor)

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FOREWORD

Ian Nicholas

Following the success of the blackwood handbook, several NZFFA (New Zealand Farm Forestry Association) Action groups expressed an interest in producing similar handbooks for their species/genus of interest. After discussion with the groups, it was considered most appropriate to prepare an electronic handbook series. The advantage of this is that as new research results come to hand, relevant portions of the handbooks can be updated. This is important because some of the management systems of these species are still being evaluated and could change within a few years. This electronic handbook series on cypresses, eucalypts, and revised blackwood and redwood has been initiated thanks to the support of the MAF Sustainable Farming Fund with additional support from NZFFA, Ensis, PROSEED, Environment Bay of Plenty, Horizons Regional Council, Rarefind Timbers, The Plantation Management Cooperative and the relevant NZFFA Action Groups. The handbooks have been compiled with the help of farm foresters, or researchers with experience in specific areas, in contributing draft chapters. These have been modified by the editor with assistance from reviewers, to capture the best available knowledge from researchers, farm foresters and land managers.

Visit the farm forestry web site (www.nzffa.org.nz) for the most up to date information available.

Throughout the handbook, text in boxes is used to highlight important information relevant to the chapter. At the end of each chapter, key points are used to summarise the information, along with any suggested reading. A full reference list is provided at the end of the handbook.

For ease of reading, the colloquial name of individual species has been used throughout the handbook in preference to full scientific names, i.e.:

macrocarpa = *Cupressus macrocarpa* Gordon.

lusitanica = *Cupressus lusitanica* Mill.

Leyland cypress = x *Cupressocyparis leylandii (*Jacks. & Dall.) Dall.

ovensii = x *Cupressocyparis ovensii* (A.F.Mitchell)

Lawson cypress = *Chamaecyparis lawsoniana* (A. Murray bis) Parl.

The handbook concentrates on macrocarpa and lusitanica, along with the main hybrids Leyland cypress and ovensii, because of their importance in New Zealand farm forestry,

Grateful acknowledgement is given to the contributing authors who made this handbook possible, the reviewers for their valuable input, Jacqui Aimers for her editing assistance, and to Teresa McConchie and Sally Garner for final formatting and Rina Joy for the web site preparation.

Comments on this handbook and suggested areas for revision, should be sent to the NZFFA Cypress Action Group (see the NZFFA web site for contact details).

DISCLAIMER

The opinions provided in this Handbook have been provided in good faith and on the basis that every endeavour has been made to be accurate and not misleading and to exercise reasonable care, skill and judgment in providing such opinions.

Accordingly, any person who uses the information in this report does so entirely at their own risk.

Neither Ensis nor its parent organisations, CSIRO and Scion, nor any of its employees, contractors, agents or other persons acting on its behalf or under its control, nor NZFFA nor MAF, accept any responsibility or liability in respect of any opinion provided in this Handbook.

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CHAPTER 1 -INTRODUCTION

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Cypresses have been an integral part of the New Zealand landscape. They were planted as early as the 1860s by settlers. Early plantings occurred at Mount Peel in South Canterbury (1864-65), Mount Eden, Auckland (1866) and Wanganui (1867). The main species planted have been macrocarpa and lusitanica. Other species planted have been *Cupressus arizonica*, *C. sempervirens*, and *C. torulosa*. In the early 1950s, it was estimated that there were about 360 ha of pure plantations in State forests, 255 in mixtures and another 405 ha in private plantations.

In recent times well managed plantations of both macrocarpa and lusitanica are being established, although many early plantings were shelter for homesteads and farm stock.

There has also been interest in planting the the Leyland cypress, which is a hybrid between macrocarpa and *Chamaecyparis nootkatensis*.

Lusitanica planted at Greytown on Arbor day 1890

Old macrocarpa planted for homestead shelter

The early utilisation of cypresses (mostly macrocarpa) has come from these old untended shelterbelts. However, cypress timbers currently make up the third most commonly utilised exotic timber species in New Zealand, with approximately 20 000 m^3 cut per year.

With the reduction in utilisation of native species, particularly rimu, cypresses have become important substitutes. Sawmillers are now moving from the old cypress plantings into plantations, with lusitanica also becoming prominent, especially in the North Island. Also relatively new in the market is Leyland cypress. The utilisation of old shelterbelts for firewood is less common as sawmillers will utilise old shelterbelts for sawn timber.

Typical poor form "Old man macrocarpa"

Typical demise of old cypress shelterbelts - a pile of firewood!

Key Points

- Cypresses are an integral part of New Zealand's exotic tree landscape.
- Cypress timbers from old untended stands/shelterbelts have generated a strong market for the timber.
- Plantation cypress timber is now being sought after.

Suggested reading:

Weston 1957

Mortimer 1984

NZFFA 2006

Miller and Knowles 1996

CHAPTER 2 - TIMBER PROPERTIES AND MARKET

Contributing authors Denis Hocking & Ian Nicholas

INTRODUCTION

Macrocarpa is undoubtedly the best known and most widely traded of the “alternative”, exotic timbers, (”alternative” to the major exotic, plantation species of radiata pine and Douglas fir). Information on trade of cypress timber can be found on www.maf.govt.nz However, volumes of timber cut and traded may well exceed any indigenous species, but no reliable statistics are available for timber that is often cut and used by the land owner.

Other cypresses known to be milled and traded include Lawson cypress, lusitanica and very small volumes of Leyland cypress, but macrocarpa dominates the market. The volumes of lusitanica milled may be greater than commonly assumed due to mistaken identification as macrocarpa.

The main source of macrocarpa is old shelterbelt material with only limited areas of mature plantation and very small areas of pruned plantation available, as yet. In turn, the nature of the shelterbelt resource means that much of the wood is of relatively poor quality, with large and/or dead knots or infestation by two-toothed borer, *Ambeodontus tristis* and, not infrequently, pith rot at the base of the tree or some rot around broken branches. This may result in wood that is only fit for firewood, garden sleepers, or other low grade uses. Only very limited volumes of high quality, clear heartwood are produced, estimated at around 2% by one sawmiller. Nevertheless, macrocarpa is widely recognised and sought after as a high quality softwood. It is worth asking the question - how many other species would have been able to sustain a comparable timber trade based on such a limited and poor quality resource?

Macrocarpa, lusitanica and Lawson cypress are approved timber species for building construction. (NZS 3602 2003). This Standard and/or the local Territorial Authority should be referred to for particular building end use approval.

TIMBER PROPERTIES OF THE CYPRESSES

Macrocarpa

A medium to lower density softwood of moderate strength and stiffness, but relatively low surface hardness with good working and finishing characteristics and relatively uniform wood properties from pith to cambium. It is very stable wood, easily sawn with minimal reaction wood, meaning that even small diameter logs of 15-20 cm, and young “teenage” trees, can be sawn. The wood has low shrinkage on drying, but can suffer some collapse when kiln dried. The sapwood is very light brown and typically occupies about five growth rings. The heartwood is darker yellow brown in colour. Heartwood is rated as class 3 for durability, higher than most exotic softwoods, but is not generally regarded as suitable for in-ground use, and nor is it durable in situations where it remains moist. The heartwood cannot be treated with preservative. There is a distinctive spicy odour when freshly sawn. The wood is often compared to kauri.

Lusitanica

Similar to macrocarpa in most respects, but generally somewhat lighter in colour and often with a much wider sapwood band (up to 14 growth rings in some cases). One sawmiller described it as typically weaker and more brittle than macrocarpa, but published data hardly support this. The heartwood is commonly regarded as less durable. Lusitanica can be extremely variable in many aspects, and some traditional cypress "species" such as *Cupressus benthamii* are now regarded as poor performing provenances (especially as regards timber) of lusitanica.

Lawson cypress

Lighter in colour, especially the heartwood, but notably stronger and stiffer than the other cypresses. It also has the strongest and most persistent smell of any cypress and this is regarded as a negative for furniture by some processors. Otherwise it is similar to other cypress. There are very few plantations of Lawson cypress being established.

Leyland cypress

This hybrid has not been utilised to the same extent as the above species, but is likely to become more widely available as shelterbelts age and land uses change. Wood properties are similar to the other cypresses, but with heartwood that starts as a more distinctive yellow and fades to a pale colour more akin to Lawson cypress. Leyland cypress from horticultural shelterbelts makes up a significant part of the cut for one Bay of Plenty sawmill. These are small, unpruned logs, and being open grown they show excessive taper, but they mill very well producing good quality dressing grade timber with excellent stability and tight green knots. Trees as young as 8 years have been successfully milled, although these would have minimal heartwood. Based on the characteristics of the *Chamaecyparis nootkatensis* parent, heartwood durability may exceed that of macrocarpa, although this has not been tested.

Knowledge of the mechanical strength properties of different timber is necessary for matching timber to appropriate end uses. In Table 1, strength properties are listed for the four cypress species and hybrids mentioned above, as well as radiata pine. The mean values are from multiple tests recorded by Forest Research for green timber and timber dried to 12% moisture content. The different strength properties are density, MoR (modulus of rupture, a measure of bending strength), MoE (modulus of elasticity, a measure of stiffness), and hardness (resistance to indentation). It must be noted that the figures are from samples of small clear timber without defect. Knowledge of the effects of defects such as knots, splits, holes, compression and tension wood, and grain deviations, and other factors such as load duration, safety, and durability is necessary before any species can be recommended for a specific use.

> Recent changes in the building code have resulted in untreated cypress timber being considered as similar to untreated pine, a classic case of comparing apples with oranges. The comments provided in Chapter 10 should help building inspectors understand the issues of using heartwood cypress timber as an exterior building material.

In Table 1, it can be seen that density for the cypress species is slightly lower than radiata pine; and the mean values of MoR and MoE are also slightly lower, except for Lawson cypress, which has higher mean values than radiata pine. Hardness mean values are considerably lower for all four types of cypress timber than for radiata pine.

The cypresses are used for a very wide range of end uses including: top quality clearwood, decorative veneer, furniture, joinery, weather boards, sarking, mouldings, panelling, boat building, etc. Timber with tight green intergrown knots is used for some of the above uses, also flooring, decking and structural uses, while poorer quality wood with dead encased knots goes into structural uses, especially “on farm” or “garden pagoda” type structural uses. The poorest quality timber is often used for garden sleepers. Note that though these end uses will tolerate large knots, all external uses need heartwood, or preservative-treated sapwood. Interior uses put little premium on heartwood over sapwood.

Check out latest cypress handbook chapters at www.nzffa.org.nz

Table 1: Mean small clear strength properties by species, from Bier and Britton (1999).

Species	Density (kg/m^3) Basic	12 %	MoR (MPa) Green	12%	MoE (MPa) Green	12%	Hardness (N) Green	12%
Lusitanica								
Mean	**360**	**402**	**45.39**	**69.55**	**5529**	**6471**	**2120**	**2623**
Variation	341-388	370-412	38.64-55.6	55.5-84.50	4049-8338	4510-8883	1962-2320	2296-3900
Number of tests	78	75	78	75	78	75	20	20
Macrocarpa								
Mean	**393**	**436**	**54.02**	**75.96**	**6583**	**7418**	**1937**	**3217**
Variation	380-422	402-543	53.05-56.07	68.7-87.75	5544-7072	5787-7891	-	2482-3633
Number of tests	25	95	25	95	25	95	17	47
Leyland								
Mean	**405**	**423**	**42.48**	**79.89**	**5540**	**6742**	**-**	**1874**
Variation	395-425	413-449	42.45-42.49	73.11-82.62	4787-5923	6138-6985	-	-
Number of trees	89	87	89	87	89	87	-	25
Lawson								
Mean	**422**	**435**	**49.94**	**96.61**	**8178**	**11755**	**1757**	**2475**
Variation	321-490	410-542	41.8-66.7	76.9-133.1	6728-9260	8900-12990	1560-1870	2360-2540
Number of tests	103	117	103	117	103	117	11	11
Radiata pine								
Mean	**407**	**463**	**40.00**	**89.04**	**5673**	**8877**	**2467**	**3980**
Variation	370-536	380-615	23.97-86.8	60-122.9	2890-9286	4590-12850	1812-3635	2305-7292
Number of tests	> 1800	>1800	>1800	>1800	>1800	>1800	>1800	>1800

Cypress sarking

The one recognised problem in the processing of cypress timbers is some collapse and internal checking with kiln drying; however, the only end uses that normally require kiln dried timber are flooring and joinery.

The main limitation on the use of cypress timber, especially by larger processors such as joinery or furniture manufacturers, is the recognised uncertainty of supply, especially of better quality timber. While macrocarpa makes up the bulk of the local cypress trade and most, but by no means all, sawmillers express a preference for it, significant volumes of lusitanica may well be going through cypress channels unrecognised. It is often difficult to know whether this preference is based on solid reliable data or subjective and anecdotal assessment. Some sawmillers do speak glowingly of experiences with lusitanica and all sawmillers recognise lusitanica as an acceptable cypress for most uses, especially higher-value, interior uses. Both macrocarpa and lusitanica are being sold together as cypress timber.

The hybrid cypresses, mainly Leyland cypress, are less well known and are treated with some caution, because many sawmillers are uncertain about end user acceptance. Sawmillers generally recognise them as having equally good wood properties. The 'ovensii' hybrid, much favoured by many planters at present, is even less well known, but appears to be very similar to the Leyland cypress. Some processors market Leyland as a separate line because of its lighter colour and relative newness in the market.

LOG PRICES

Prices, grading criteria, and purchasing preferences vary widely between sawmillers, again reflecting the nature of the shelterbelt resource. There is no nationally accepted grading system for cypress logs, and their very nature makes this difficult. Different sawmills offer their own grading systems based on pruning, diameter, fluting, knot size, knot distribution (one side or uniform), dead versus green knots, sweep, log shape, presence of rot or two-toothed borer.

Some mills buy by log grade, which may be a preferred option for better quality plantations. Others prefer “run of bush” purchases with an average price paid for all grades. Regardless of the method of purchase, the size and nature of the resource means that single mills generally purchase whole stands, in contrast to radiata pine plantations where different grades may go to several different sawmills.

Because of their more irregular form, it can be difficult to accurately measure cypress log volumes, especially with rougher macrocarpa logs. Weight provides a more reliable measure, but the conversion from weight to volume can vary depending on the ratio of wetter heavier sapwood to drier lighter heartwood. Haslett 1986 (FRI Bulletin 119) quotes green density of 820 kg/m^3 for macrocarpa and Leyland cypresses, 910 kg/m^3 for lusitanica, presumably for heartwood.

Top prices paid for cypress logs would appear to be $300-$400/tonne on truck paid for top quality, pruned, macrocarpa and lusitanica veneer logs. These are normally selected on the skid site by the log buyer. Prices quoted for good quality, pruned sawlogs with SEDs (small end diameters) greater than either 30 or 40 cm, range from around $140/tonne on truck to $225/tonne on truck. Better quality unpruned sawlogs (tight green knots) are quoted at around $80-$110/tonne on truck, poorer quality sawlogs at around $40-$50/tonne on truck, down to $30/tonne for “firewood” grade logs.

A recent quote for 21-year-old pruned Leyland cypress, for straight logs down to 200 mm SED, was around $60/tonne on truck. Prices will vary according to location, sawmill experience and current market activities. It is advisable to seek offers from more than one operator.

Sawmillers do comment that it is difficult to predict the likely recovery from cypress logs, especially older macrocarpa logs, some yield much better than expected, others far worse. If the relationship between grower and miller is sufficiently good, payment on the basis of outcut (yield and grade of sawn timber) can be of benefit to both parties. Most sawmills

Check out latest cypress handbook chapters at www.nzffa.org.nz

show little preference for heartwood over sapwood, especially for better quality, higher value, interior, finishing timbers.

TIMBER PRICES

Prices for sawn timber are similarly variable and again different grading rules are used by different traders. One point to note is that timber which is fully air dried is worth around twice as much as green timber off the saw, and if owners are in a position to stack and store sawn timber under cover for around 12 months, returns can be dramatically improved.

Good quality, clear heartwood straight off the saw is commonly quoted at $800-$1,000/m^3 with several sawmillers saying that there are numerous markets at $1,000/m^3. Shorter lengths, under 2.0 m, often trade at some discount. Fully air dried, clear heart is commonly quoted at $1,700 - $2,000/m^3 with one quoted retail price of $2,500/m^3 for all sizes. Some traders do allow very limited defects in their 'clears'. Number 2 clears, normally clear on three sides, trade at a discount to fully clear timber, but volumes are small (No. 2 clears come mainly from pruned logs) and not all traders recognise the grade.

Dressing grade timber, variously defined but basically tight, green, live knots, used for panelling, sarking, other appearance grades and structural uses, trades at around $400-$600/m^3 green, off the saw, and at $1,000/m^3 plus air dried. Dressing grade Leyland cypress timber trades in the same price range.

Lower grade sawn timber with bark encased, dead knots or large green knots trades at around $250 -$350/m^3, but because much of this material is used out of doors, there is more emphasis on heartwood. Note that garden sleepers, larger dimension, 2-m lengths of often very rough timber, used in landscaping, retail at around $400/m^3.

Cypresses do have the advantage that they can be readily sawn on mobile mills. With rough, shelterbelt material, this can allow the recovery of the limited volumes of higher quality timber on site and avoid the transport and mill processing of large volumes of low grade material. However, on-site milling adds extra costs for the grower and there is no guarantee that these costs will be recovered, especially if you are dealing with better quality plantation trees.

The grading of sawn timber is not an exact science and there is plenty of opportunity for disagreement on grades and value. Ideally both seller and purchaser should be present when timber is graded, but this is often not practical, especially with larger volumes. Equally, there is room for disagreement over log grades and values, but each log will be sawn into numerous planks of timber of varying grades, making the grading of sawn timber a much bigger task. Purchasers of sawn timber need to have clear, unambiguous, quantitative grading criteria and all potential sellers of sawn timber should demand a copy of these grading rules and grade prices in advance.

THE FUTURE

As is often pointed out, forecasting is dangerous especially going far into the future. However, it can be said that all cypress sawmillers expressed some concern, often great concern, about future supplies of sawlogs. One did suggest that there is more available than most think, but his confidence was still muted. However, the experience of eucalypt sawmillers in Northland has been that logs are still coming long after they had expected to exhaust the resource.

All the cypress millers expressed confidence in future demand for the timber, especially the better quality grades, and all stated that they would like to expand their cypress processing operations, but felt restricted by log supplies. Several made the point that larger end users such as joinery and furniture manufacturers would like to use locally grown cypress, but are not confident of future supplies of good quality timber. At present it is easier to use radiata pine or imported softwoods such as western red cedar or Fijian kauri.

The main shortfall is perceived to be in clear timber or the better dressing grades and this means that growers would be well advised to fully prune their cypresses and thin to ensure adequate diameters for clearwood recovery. From the end-users' point of view, the species grown is not critical and should be the species or hybrid best suited to the site.

Export prospects are also regarded as very promising for all the cypresses. A study by Alan Somerville suggested that New Zealand-grown cypress timber would be very well received in the Japanese market, though not at the extremely high prices reserved for locally grown Hinoki (*Chamaecyparis obtusa*). Nelson farm forester, Ross Higgins, comments that New Zealand cypress has been sold in Taiwan and there are good prospects in South Korea. All these countries are familiar with and favourably disposed towards cypress timber.

A study by a MSc. Student at Waikato University (Di Maio 1997), looking at international trade of softwoods in the Pacific Rim considered that New Zealand-grown cypresses could substitute for a group of timbers that include yellow cedar, Port Orford cedar, incense cedar, sitka spruce, western red cedar and redwood. All of these timbers are traded as high value softwoods suggesting a potential high value export opportunity for New Zealand-grown cypresses.

There is currently no indication that forest certification is an issue with cypresses. One retailer stated that they had only had one enquiry about certification in the last 10 years.

In addition, locally grown cypresses are recognised as being plantation or shelterbelt trees, planted by people and posing no threat to indigenous biodiversity.

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Japanese market opportunities

Alan Somerville (ex Forest Research Institute) took some samples of New Zealand-grown cypress to Japan, and found that although we can't substitute directly into the highest quality bracket of the Japanese Hinoki market, we have good market prospects if we can produce a clear cypress timber product of uniform quality.

He found that the Japanese have very specific product dimensions. They use square beams called Hashira to build traditional post and beam houses. These beams are 105 mm and 120 mm square, and 3 m or 6 m long, knotty (hidden - foundations) or mostly three faces clear (visible placements). The highest quality Hashira beams sell for extremely high prices on their domestic market. They like the tight ring-widths and clear timber of old-growth Hinoki cypress.

Luigi Gea (Ensis) has suggested that there is the possibility that New Zealand could capture a part of the mouldings market, and only produce Hashira as a by-product from milled centres, with the very small defect core hidden inside the 105 mm and 120 mm square clear beams.

Key Points

- Cypress timber is developing a strong market profile.
- Cypress processors are concerned with the lack of resource.
- Cypress timber has both domestic and export potential.
- Cypress timber is often marketed as one line and not treated as individual species in the market.

Suggested reading:

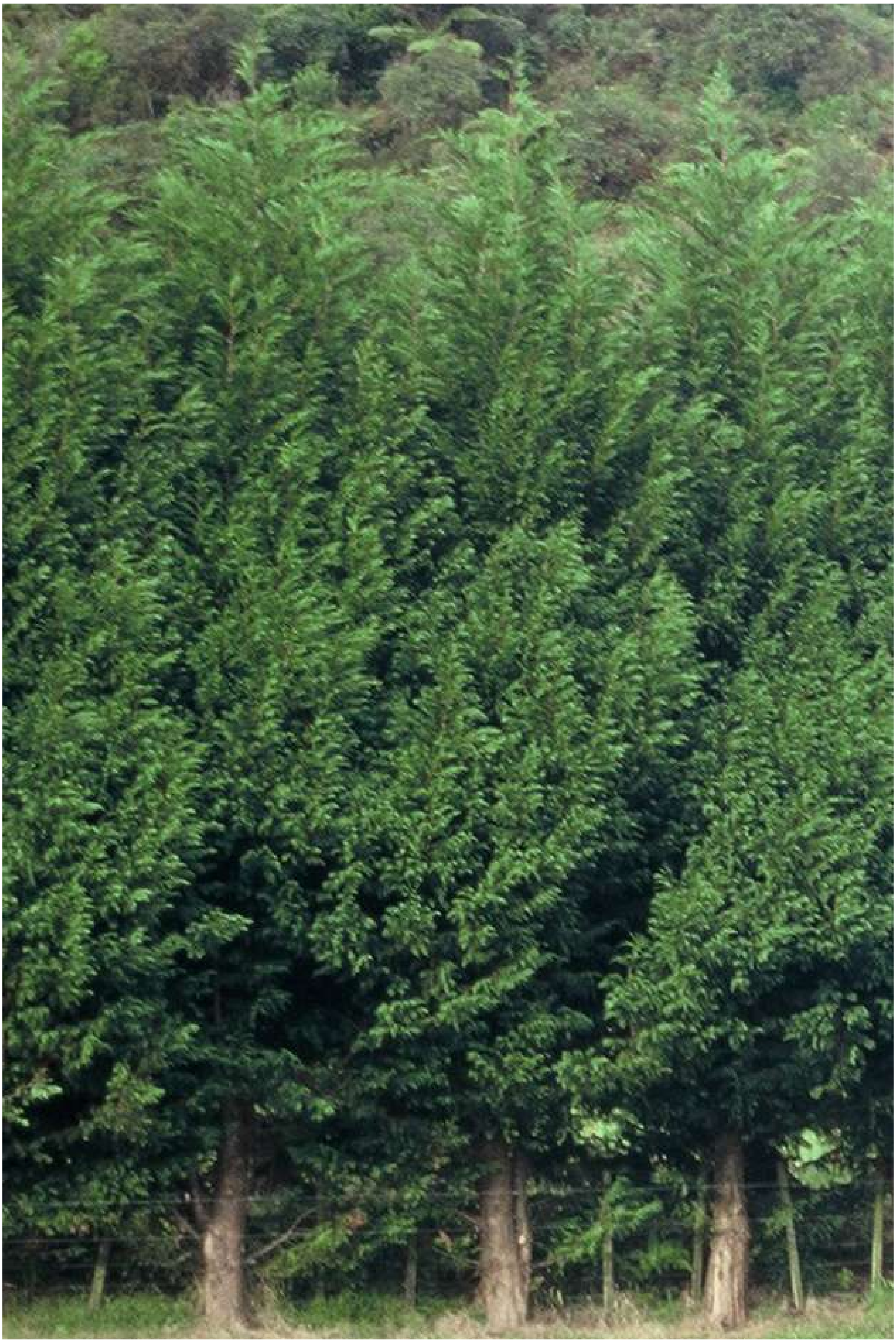
Bier and Britton 1999

Clifton 1990

Di Maio 1997

Haslett 1986

Low, McKenzie, Shelbourne, and Gea 2005



CHAPTER 3 - SITING AND LAND USE OPTIONS

Contributing authors K. Snowden, Ingleby Coxe and Ian Nicholas

LAND USE OPTIONS

Traditional New Zealand farm practices are impacting on the environment in several situations. Examples include the catchments of Lake Taupo and several Rotorua lakes, where lakes suffer from lower water quality because of leached nitrogen and phosphate, which increase algal bloom levels. Issues associated with emissions of excess nitrogen will become wider in extent, affecting rivers and streams. Solutions are being sought by land owners, resource planners, statutory bodies and managers that will enable commercial land-use that has a lower impact on the environment.

Establishing forest crops is not a short-term commercial solution, but should be viewed as an important component of a portfolio of land uses. Forest crops provide a low-cost opportunity for landowners to develop assets that have long-term options. Low cost does not imply low skill requirement, sloppy management, or low value. Rather, wise and well applied crop selection, establishment, and silviculture will underlie success.

Cypresses offer landowners the opportunity to develop cash flow from their land in the long term. Pruned cypress provides land owners with the opportunity to produce high-value wood with strong demand. Ex-farm sites should provide the opportunity to establish sound crops of cypress, though choosing appropriate species for the crop is important.

SITING

Cypresses are site demanding. Key attributes of sites include soil fertility, latitude, aspect, and sunshine hours. Cypresses, including Leyland cypress, macrocarpa and lusitanica, favour fertile and well-drained soils. Damp feet do not encourage a healthy crop.

Cypresses do best on well-drained soils of at least moderate fertility (A horizon depth approximately 10 cm or more) which do not suffer extremes of seasonal moisture fluctuation. These sites typically occur on lower slopes and valley bottoms, or in low-lying, undulating country. A well-distributed rainfall in excess of approximately 800 mm annually is required, with lusitanica preferring mild winters also. The altitudinal limit of about 350 m may also be extended on sites with good air drainage. The best timber form will develop on sheltered sites. Macrocarpa tolerates more exposure than lusitanica - the latter species suffers major damage when exposed to salt-laden winds.

Clonal planting stock has become more readily available, but usually at a premium. Cypress growers are advised to plant tested clonal stock on high-quality uniform sites, in order to achieve a good return on the initial high investment. Poorer-quality variable sites will tend to nullify some of the potential uniformity of clonal stands. (Clonal deployment is discussed more fully in Chapter 5).

A young stand of well-managed macrocarpa at Millers Flat, Otago. Trees that became infected with cypress canker were regularly removed.

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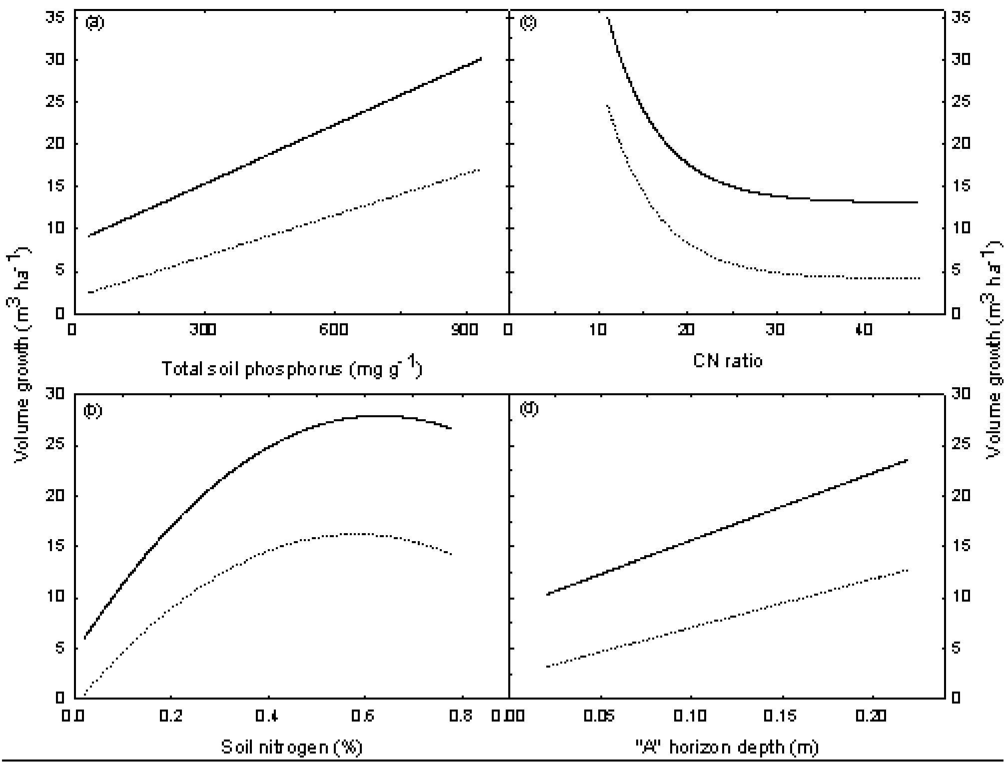
Site variables influencing stand productivity

Nation-wide study of 31 macrocarpa plantations and 18 lusitanica plantations were assessed, for growth and site variables, by Bruce Glass of Forest Research Institute in the early 1980s. He found that soil fertility, soil texture and physiographic features, and the degree of exposure to local and prevailing winds were the main site variables influencing stand productivity and crop selection for both macrocarpa and lusitanica. Fluting in macrocarpa appeared to be related to exposure and temperature, and was also linked to spiral grain. Cypress canker was also strongly linked to exposure.

Preliminary analysis of radiata pine and lusitanica site quality plots

(Watt *et al.* 2005)

A preliminary analysis, including all tree growth data from thirty-one 2-year-old plots spread from Northland to Southland, showed that radiata pine had a 56% larger tree volume than lusitanica. After climate was accounted for, growth of both species was also significantly affected by the CN ratio, soil nitrogen, phosphorus, and depth of the A horizon (see below).



Response curves of volume growth for radiata pine (solid line) and lusitanica (dotted line) plotted against (a) total soil phosphorus, (b) total soil nitrogen, (c) CN ratio, and (d) “A” horizon depth.

NUTRITION

There is little information on cypress nutrition for New Zealand conditions, although there was a surge of interest in the 1980s in determining some base foliar levels. In the information provided below, nitrogen, sulphur, manganese, boron, potassium, calcium, magnesium, iron, zinc and phosphorus are abbreviated as N, S, Mn, B, K, Ca, Mg, Fe, Zn and P, respectively.

Tree size and foliar nutrients

A study of the size of trees and foliar nutrition of 16-year-old lusitanica trees near Whangamata, found that tree size tended to increase with increasing foliar N, S, and Mn concentration, and decreasing B, although the correlations between tree size and foliar nutrient concentrations were not very strong. Of the nutrients determined, nitrogen was considered to be the most likely to be growth limiting. From the foliar N and S concentrations found at this site, it was inferred that concentrations of at least 1.2% N and 0.12 % S are desirable in the foliage of this species for achievement of satisfactory growth rate.

Species comparison

In a study comparing other species and radiata pine, cypresses at 2.5 yrs old had higher foliar K and Ca concentrations, but lower S and Mn concentrations than the other four species (radiata pine, *Eucalyptus fastigata*, *E. fraxinoides*, and *Acacia melanoxylon*.

Nursery study

A study of nursery seedlings found that the foliage and seedling tops of containerised stock had higher levels of N, P, Mg and Zn, and lower levels of Ca and Fe than bare-rooted seedlings, but there was a species difference between macrocarpa and lusitanica.

Glasshouse study

In a glasshouse trial the concentrations of Ca and Mg in the tops of cypress seedlings, raised with a full supply of all nutrients, were much higher than in radiata pine seedlings. This suggests that seedlings of both cypress species have higher requirements of these two nutrients than seedlings of radiata pine. In terms of both height growth and dry matter productivity, the cypress seedlings were more sensitive to drastically restricted N or P supply than the radiata pine seedlings.

Fertiliser Trial

Assessment of a macrocarpa fertiliser trial at Mahinapua on the West Coast of the South Island, , showed that height and root collar diameters for the N+P diammonium phosphate (DAP) treatments 1 year after planting were consistently more than double those of the P only treatment, indicating a clear need for both N and P at this site. Height and diameter increased in response to fertiliser up to an optimal level and then decreased, with the highest rate causing slight growth depression. The optimum rate of DAP (18-20-0) was 90 g/tree, while the optimum rate of Triple Superphosphate (0-20-0) was 85 g/tree. Triple super at 80 g/tree was less effective than DAP, with increments averaging half or slightly less than half those for the equivalent DAP treatment.

Foliar levels

Foliar nutrient levels are presented in Table 2. The data are from the national average for foliar nutrient levels in lusitanica foliage

Table 2: National figures and data from a nationwide project.

Element	N %	P %	K %	Mg %	Ca %	B ppm	Mn ppm	Zn ppm	Cu ppm	Fe ppm
National levels	1.19	0.13	0.90	0.14	1.31	17.4	47.7	11.3	3.3	69
Site quality project	**1.41**	**0.17**	**1.65**	**0.17**	**0.81**	**19.50**	**45.35**	**15.81**	**7.19**	**49.66**

More analysis is required to determine optimum or deficient levels, but these values provide a benchmark.

suggested by the Veritec Forest Nutrition laboratory, and also from average foliar levels of 20-month-old young lusitanica trees from a national site quality survey of 129 plots across 31 sites.

Site and health interactions

Cypress canker (*Seiridium cardinale* and *S. unicorne*) is a health issue for cypresses that should be managed by species selection and choice of appropriate sites. Use of macrocarpa in areas with a high canker risk is not recommended - macrocarpa should not be sited in areas that are warm and moist. There is some evidence that incidents of cypress canker are increasing in the South Island, emphasising the need for care in establishing species that are susceptible to cypress canker.

Leyland cypress appears to be not quite as susceptible to cypress canker as macrocarpa, but not as resistant as lusitanica.

Ensis (formerly Forest Research) has been actively breeding for canker resistance in macrocarpa. Growers interested in macrocarpa should maintain contact with this programme to ensure that suitable stocks for planting become available. More information on this is presented in Chapter 4.

Latitude

Cypress canker affects macrocarpa more than lusitanica. Because cypress canker is more prevalent in northern latitudes of New Zealand, siting cypresses for the impact of canker is valid. Generally, it is recommended that lusitanica is established in the North Island because the species is more resistant to cypress canker. It is unclear whether cypress canker has less impact in cooler zones of the North Island such as Taupo District. Macrocarpa appears to grow well where higher frost frequency limits the development of cypress canker, but some experts maintain that there is still risk of infection on such sites.

Macrocarpa showing damage from canker

Toppled 6-year-old lusitanica in wet, heavy soils in Tongaporutu, north of New Plymouth.

Aspect

The southern therefore cooler aspect is favoured for cypress species other than lusitanica, as a means of limiting cypress canker.

Farm activity and cypresses

Cypresses can induce abortion in cattle if wilted foliage is digested. Farmers should avoid allowing in-calf cattle to graze in or alongside stands of cypress species.

Cypress species can be vulnerable to animal damage. In an interesting case in an Ensis trial, rat damage was observed on the stem of young lusitanica trees. Apparently the rats came from a nearby corn field immediately after the corn was harvested. Considerable possum damage has also been observed in some lusitanica stands, resulting in stem malformation. Possum control is warranted if planting lusitanica in areas known to have high possum numbers. Cattle can also damage trees by stripping bark. Damaged trees are vulnerable to disease and insect damage. The heartwood of standing trees can sometimes be seriously damaged if larvae of either the huhu beetle, or the two-toothed longhorn beetle, gain access via mechanical damage to the bark. More information on insect damage is provided in the chapter on health.

Stability of cypresses

Cypress species, especially lusitanica, can be prone to toppling on some sites. Toppling of young trees can occur in the first 3 years after planting and it appears to be worse on fertile farm sites. Wet conditions, heavy soils, and exposed sites are also risk factors.

While some toppled trees resume upright growth, in the process the stem develops butt sweep and sinuosity, which results in differential stresses in the wood, causing distortion of sawn timber and reduction in log values.

Ingleby Coxe, a farm forester from Northland, has had considerable experience of toppling in both cypress and radiata pine plantings on her Waiotira clay loam property after serious storm events. Ingleby believes that prevention of toppling is easier than correcting it. In May

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1998, every alternate tree in a block of 87 cypresses at Waiotira was wind-proof pruned, the rest were left untouched. The wind proofing involved pruning half the length of foliage from branches above half tree height. All the pruned trees remained straight and upright. All the unpruned trees showed varying degrees of toppling.

Windproofing treatments which have been researched have included pruning off half the branches and pruning back to half branch length. The success of these treatments depends largely on climatic events; they are best treated as insurance or protection from wet and windy storm events on topple-prone sites. However, with severe storm events such as Cyclone Bola, most stands will be vulnerable to topple, regardless of the precautions taken. Fortunately, severe storm events like this are very rare.

Geoff Brann, a farm forester in the Bay of Plenty, recommends hedging young trees with motorised shears to windproof trees (this also keeps branch size small until clearwood lifts).

Methods to prevent topple

Based on trials on clay soils at Waiotira, and discussions with other farm foresters, Ingleby Coxe has the following recommendations for establishing cypresses on a topple-prone property:

1. Match the species to the site, and avoid wet or badly drained areas. Cypresses tend to be unstable in waterlogged clay soils, especially with exposure to strong and changeable winds.
2. Choose well-drained, reasonably sheltered areas.
3. Good planting technique is essential, whether trees are sourced 'bare-root' from the nursery, or grown in containers. Roots should be spread out in a hole deeper than they were planted in the nursery or container, firmed gently, and pulled upwards slightly before the final firming.
4. On fertile farm sites, extra fertiliser should not be applied to young trees, unless specifically advised to correct deficiencies.
5. Wind-proof pruning before the first winter after planting reduces the sail area catching the wind, and gives a chance for the tree to establish a good root system.

While it is human nature to attempt various remedial measures to correct toppling in young trees, such as staking, supporting with strings, and turfing, they are often ineffective. Straightening toppled trees can also cause further damage to the root system. Instead, it is better that the number and distribution of the toppled trees be assessed. If enough potential final crop trees remain, toppled trees could be left to help control branch size and then thinned later, without incurring the costs of remedial treatments. Ingleby has found it effective, with badly toppled lusitanica, to cut the main stem off above a low branch on the upper side of the stem, and let that develop into the new main leader. If done well, only the small amount of timber below the new leader will be unsuitable for the final log.

Key Points

- Cypresses require fertile sites.
- Lusitanica is preferred where cypress canker is a risk. This generally means that macrocarpa should be restricted to cooler sites in the South Island, or should be sited on cool, south-facing slopes elsewhere.
- Beware of abortion in cattle.
- Cypress species can be vulnerable to animal damage. Damaged trees are subsequently vulnerable to disease and insect damage.
- Prevention of toppling is far more effective than undertaking remedial measures after toppling has occurred.
- To avoid toppling, choose suitable sites - well drained and reasonably sheltered.
- Don’t use extra fertiliser on fertile farm sites, unless on expert advice.
- Windproof prune on topple-prone sites.
- If toppling is severe, replanting should be considered.

Suggested reading:

Glass 1984

Hood *et al.* 2001

Nicholas and Hay 1990

Self and Chou 1994

Snowdon 2003

Van der Werff 1988

Watt *et al.* 2005

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CHAPTER 4 - HEALTH

Contributing authors Ian Hood, Judy Gardner, Jacqui Aimers-Halliday

INTRODUCTION

There are a number of insect pests and fungal pathogens that have been recorded in New Zealand on cypress species, but apart from cypress canker, few have significant impact on cypress health. Minor pests and pathogens are mentioned, but most of this chapter will be devoted to the major threat to the health of cypress species – cypress canker.

CYPRESS CANKER

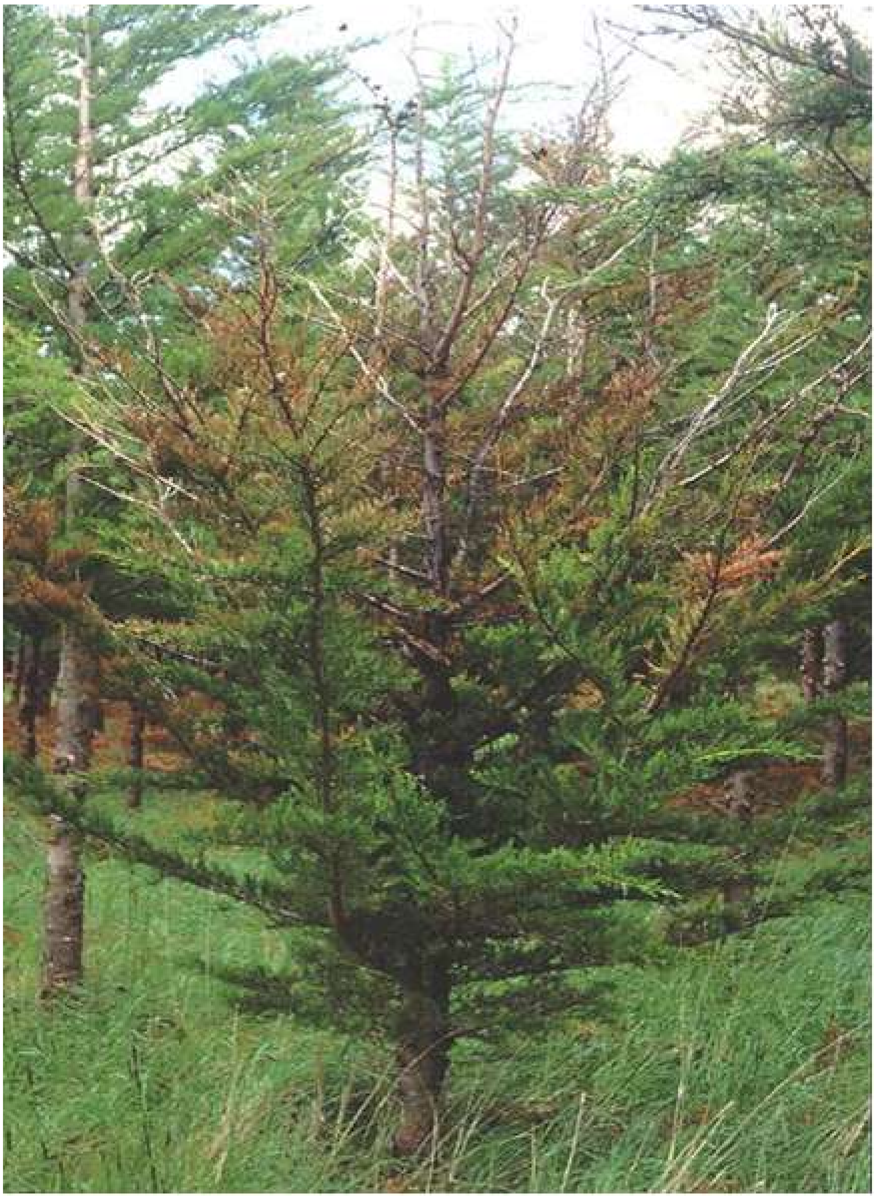
The most important disease of cypresses in New Zealand is cypress canker, which affects a number of species and hybrids, and is the main reason that macrocarpa is not planted more widely as a valuable plantation species. Damage results from infection of stems and branches by two microscopic fungi, *Seiridium unicorne*[1] and *S. cardinale*. *Seiridium cardinale* has been present in this country since at least the 1930s, while *S.unicorne* was reported here in the 1950s. Both species occur on cypresses throughout New Zealand, but *S.cardinale* has been recorded less frequently, except in Canterbury where it appears to be as common as *S. unicorne*.

The disease cycle is not fully understood. Minute fruitbodies are present on diseased tissue during much of the year, and asexual spores are carried by rain splash to adjacent trees and branches. Spread by this means appears to be slow and localised, but *S. unicorne* also produces sexual spores, which may be dispersed more widely by means of air currents. Infection is believed to take place through cracks or wounds, though direct entry through softer undamaged tissues may also be possible, and this leads to the formation of purplish and brown patches on branches and stems, which develop into sunken cankers.

Infected branches eventually die back due to the damage caused by the cankers, and apparently also due to a toxin produced by the fungi. The disease may, therefore, be recognised by the appearance of irregular dieback and browning across the crown and by the canker symptoms on stems and branches, accompanied by resin bleeding and bark discoloration. This damage leads to growth loss, limb and stem breakage, malformation, and reduced wood quality, particularly when infection is present in the stem. Mortality may occur in young stands.

A survey throughout New Zealand in 1981-82 found cypress canker at different levels of severity in 36% of plantations and 53% of shelterbelts. A grower survey conducted in 1999-2000 identified the disease in 53% of small rural plantations of macrocarpa. The disease occurs in trees of all age classes. The removal of diseased trees during the operational thinning of young infested macrocarpa stands may reduce the incidence of spores carried to remaining trees, creating an impression that older stands are less susceptible. Cypress canker can be locally severe in some woodlots, but limits to spore dispersal mean that it is still possible to grow stands of macrocarpa free of infection, although more widespread planting could change this situation.

[1] More needs to be known about the fungi that cause cypress canker in New Zealand. The species traditionally called *Seiridium unicorne*, and referred to here as such, may actually be *S. cupressi*, and there is debate as to whether or not there may in fact be three species of *Seiridium* present. This issue has more than just academic interest, since practically it is important to clarify potential differences in virulence towards different cypress hosts.



A 10-year-old macrocarpa, badly damaged by cypress canker

Despite significant research, much remains unknown and anecdotal. Inoculation studies with *S.unicorne* have confirmed that symptoms are more severe at higher temperatures. Surveys have found that the disease tends to be more prevalent in warmer northern parts of the country. There are clear differences in susceptibility between cypress species and hybrids. Lawson cypress, Leyland cypress, and particularly macrocarpa are all prone to disease, but lusitanica shows some resistance. The ovensii hybrid may also be less susceptible, but this requires further testing. According to records held on the Forest Health Database (New Zealand Forest Research Institute), *S. unicorne* has been found mostly on Lawson cypress, Leyland cypress and macrocarpa, while *S. cardinale* has been observed mainly on macrocarpa and has also been reported in New Zealand on Leyland cypress. Lawson cypress is reported overseas to have low susceptibility to *S.cardinale*. Five database records on lusitanica are all of *S. unicorne*.

A number of disease management options are available to those wishing to grow cypresses. In regions particularly prone to the disease, such as warmer parts of the North Island, consideration should be given to using less susceptible species like *Cupressus lusitanica*.

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Whichever cypress species is used, planting stock should be healthy, vigorous, free from obvious symptoms of disease, and come from a nursery that is not surrounded by old diseased Lawson cypress, Leyland cypress and macrocarpa trees or shelterbelts. The disease is favoured when trees are physically stressed and subject to warm conditions, so it is important to give some thought to the planting site. Cooler south-facing sites have been suggested as more likely to discourage the disease, and plants should be protected from both wind and animal stock damage (stock may also physically spread spores between trees). They should not be established near older diseased cypress trees that may allow the disease to spread into the new crop.

If the disease does appear, it is important to remove infected limbs and fell diseased trees as soon as possible. If this procedure is neglected, spores from diseased trees will spread infection to adjacent trees, and the incidence of affected trees may rise rapidly. Even then, the removal of diseased trees during routine operational thinning may still enable a healthy residual crop to be brought through to an economic harvest. Pruning should not be excessive in infested stands as the resultant stress is likely to encourage the disease on infected trees. Fungicide spraying has been recommended in association with the removal of diseased plant material, but this also has been little tested and is unlikely to be of economic value in plantations, woodlots or shelterbelts, although it may be a worthwhile procedure in nurseries.

Research is currently under way to find genetic stock of macrocarpa and lusitanica that is more resistant to the disease, but it may be some years before commercial material becomes available (see below). Even moderate gains through breeding, in conjunction with other disease management procedures, may be sufficient to effectively reduce the rate of disease build-up in a stand, minimising the exposure of residual healthy trees to spores. However, breeding for resistance must take into account the demonstrated differences in virulence within the pathogen populations, particularly for *S. unicorne* where the possession of a sexual spore stage is likely to enhance changes in the natural variation. It is important that any potentially enhanced disease resistance in new releases of cypress stock should be comprehensive and durable, i.e. able to withstand the full range of pathogen virulence, including any response that may develop during the course of a rotation.

Cypress Canker Screening Programme

To overcome the cypress canker problem, many genetically diverse genotypes with multiple resistance mechanisms must be identified. If limited numbers of resistant genotypes are deployed, there will always be the risk of resistance being quickly overcome. Selection for resistance is complex as there are likely to be many different strains of the pathogen, and also, the pathogen may be rapidly evolving. This means that simple resistance mechanisms may be easily overcome by existing genetic diversity in the pathogen (if resistant genotypes were not screened against all known strains of the pathogen) and also by subsequent genetic changes in the pathogen populations. It is, therefore, vitally important that durable resistant mechanisms are developed.

Pathologists from Forest Research (now Ensis) have developed a system to screen large numbers of clones for canker resistance in a greenhouse. They are using an inoculation procedure and have collected and isolated as many of the virulent strains of the pathogen as possible. The aim is to identify resistant genotypes by screening clones that are derived from families showing resistance in the breeding programme. At the same time, tree breeders and propagators have established clonal field trials, with the same clones, to validate the effectiveness of early screening (and also allow for further selection for growth, form, and wood traits). Royalties from sales of canker-resistant cypress clones will help finance further breeding and delivery of superior cypress planting-stock to industry.

Inoculation of a macrocarpa rooted cutting with canker in an early screening programme for resistance to cypress canker.

Macrocarpa rooted cuttings, one month after inoculation. Some clones are immediately susceptible, other clones are showing resistance to this particular strain of cypress canker.

DISEASES OTHER THAN CYPRESS CANKER

Three species of fungi may cause minor dieback on cypresses, but do not produce cankers, they are *Phyllosticta spinarum*, *Stigmina thujina* and *Kabatina thujae*.
None of them are regarded as major pathogens. *Chamaecyparis* species are also susceptible to attack from the fungus *Stigmina thujina*. This, has led to the death of some *Chamaecyparis lawsoniana* on the west coast of the South Island. However, elsewhere in New Zealand, the disease has not proved to be serious. Symptoms first appear on the older inner foliage, resulting in the crowns taking on a hollow appearance.

INSECT PESTS

Insect pests on cypress in NZ

There are three species of insect pests that cause damage to cypresses in New Zealand. These are the introduced cypress bark beetle (*Pholeosinus cupressi*), the native huhu beetle (*Prionoplus reticularis)*, and the native two-toothed longhorn beetle (*Ambeodontus tristis*). The cypress bark beetle is stout, dark brown to black, 3 mm in length and 1.5 mm wide; and the larvae are white curved grubs (length up to 3-4 mm). Both the adult and the larvae do minor feeding resulting in small patches of red foliage, but are considered to be of minor economic importance and control measures are deemed unnecessary.

The native huhu beetle can cause more serious damage. The larvae (grubs) bore into stumps, logs, dead parts of living trees, and untreated sawn timber. In cypresses, the heartwood of living trees can sometimes be seriously damaged if the larvae can gain access via mechanical damage or dead branch stubs. The larvae cannot bore in living sapwood. Similarly, larvae of the native two-toothed longhorn beetle can normally only bore into timbers and dead trees. Again, successful infestation occurs in living trees only where access to the heartwood can be gained through mechanical wounds and dead branch stubs.

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Stump of a young lusitanica tree revealing damage by huhu larvae

Insect pests overseas

Cypress stands in Africa, particularly, Kenya and Malawi, have been decimated by aphid (*Cinara cupressi*) attack. The recent arrival of this pest in South America is a concern, but to date this is not expected to be a problem in New Zealand provided no green material is imported into New Zealand (J. Bain pers comm.).

Key Points

- Cypress canker is the most important disease of cypresses in New Zealand.
- Cypress canker causes growth loss, malformation, and mortality.
- While significant in most parts of New Zealand, severity appears to be somewhat greater in the warmer northern parts of the North Island.
- Establishing stands on sites with a cool southerly aspect can help reduce the risk of cypress canker developing.
- Most cypresses are susceptible to some degree to the disease, but macrocarpa and Lawson cypress are particularly affected. Leyland cypress is also susceptible, but not to the same degree. Lusitanica is largely resistant and the ovensii hybrid may also have resistance, but there are not enough data to verify this.
- Breeding for resistance to cypress canker has been under way for some time.

  Management to reduce the impact of the disease should include the following procedures:

  1. If establishing cypresses on potentially disease-prone sites (eg. warmer, north-facing slopes) choose a more resistant species.
  2. Plant healthy vigorous stock from disease-free nurseries away from diseased trees, shelterbelts, or woodlots that may provide a spore source.
  3. Protect plants from undue stress due to causes such as wind exposure, stock damage, excessive pruning, especially in stands in which the disease is present.
  4. Remove any trees or branches with symptoms of cypress canker as soon as possible during silvicultural operations, to prevent a rapid and unmanageable build-up of infestation within the stand.

- There are fungal pathogens, other than cypress canker, which are associated with minor dieback in cypresses, but none of them are regarded as major pathogens.
- Care must be taken to avoid damage to cypress trees, including animal damage.
- Larvae of the huhu beetle and the two-toothed longhorn beetle can cause some damage to standing trees. Infestation occurs in living trees only where access to the heartwood can be gained through mechanical wounds and dead branch stubs.

Suggested reading:

Aimers-Halliday *et al.* 2006

Fuller 1954

Gea and Low 1997

Hood *et al.* 2001

Newhook 1962

Self 2000

Van der Werff 1984

Van der Werff 1988

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CHAPTER 5 - SEED SOURCE, BREEDING, AND PROPAGATION

Contributing authors Charlie Low, Jacqui Aimers-Halliday and Mike Dibley

INTRODUCTION

We have two species of native cypress: *Libocedrus bidwillii* and *L. plumosa*. However, all cypress species grown in plantations in New Zealand are exotic, and have been introduced from various sources. By the late 1800s, at least 18 different species of *Cupressus* and *Chamaecyparis* had been introduced into New Zealand, many of which proved highly inter-fertile. They were often planted as individuals or in small groups of each species, thus creating opportunities for natural hybridization. The most important species for local industry are lusitanica and macrocarpa. Lusitanica has become more important in the last couple of decades due to its greater resistance to cypress canker.

Lone cypress (macrocarpa), Cypress Point, California

Breeding programmes for both lusitanica and macrocarpa were begun by the Forest Research Institute in the early 1980s – initially aimed at improving growth, form, and health. Breeding for wood density and resistance to cypress canker have been later objectives. The macrocarpa programme includes both selected trees from within New Zealand (i.e. land race) and introductions from native stands in California. The lusitanica material came from New Zealand selections and tree improvement programmes in Kenya and Colombia, but to date, much of the genetic variation in natural stands in Central America remains unexplored. Selections have been made for both breeding population advancement and seed orchard purposes. Improved seed is currently available, but is in short supply. Rooted cutting propagation systems to multiply scarce improved seed have been developed. Clones from several cypress species and their hybrids have been propagated and planted throughout New Zealand. Caution is warranted with extensive planting of single clones, as discussed below.

Information on the characteristics of the cypress species and hybrids mentioned in this chapter, can be found in Tables 1 and 2 of FRI Bulletin No. 124 (a) on the cypresses. This bulletin is part of a series on introduced forest trees in New Zealand.

There are terms which are specific to tree improvement, which are used throughout this chapter. A glossary of these terms is provided at the end of this chapter.

CYPRESS SPECIES

1. Lusitanica

Good form lusitanica, age 9 years, Hawke's Bay

Lusitanica has an extensive natural range from Mexico down through Guatemala, although it is mainly found in scattered stands. *Cupressus arizonica* is sufficiently closely related to be considered by many as a northern provenance of lusitanica. In Mexico, lusitanica grows in sheltered valleys at high altitude, where it is frequently shrouded by mists. Consequently it is surprisingly well-adapted to cold winters, although it grows faster in the warmer climates of Northland and coastal Bay of Plenty in New Zealand.

Most of the domesticated lusitanica from around the world originated from seed brought back to Portugal by the earliest Europeans to visit Mexico, so is of unknown provenance and a restricted genetic base. However, Martin Bannister obtained further seed from Mexico, which he planted in New Zealand's first lusitanica trial of 25 progenies in 1961. Seed was acquired from other countries (Guatemala and Kenya) and some of this was planted by the New Zealand Forest Service in Mangatu and Lismore Forests to establish seed stands. These became the favoured seed stands in the late 1970s and early 1980s.

In 1983, John Miller selected 100 superior trees from New Zealand stands, including the 1961 progeny trial, and obtained seed from them. He also acquired further progenies from improvement programmes in Kenya and Colombia. This seed was used to establish a progeny trial of 108 progenies at two North Island sites (Whakarewarewa and Gwavas) in 1984. John designed the progeny trials to promote a thorough mixing of the families, so that they could subsequently be used for seed production.

The progeny trials were assessed in 1993 and the best individual from each of the best 32 families was selected and grafted as a seed orchard candidate. The best trees in the top 32 families were then selected in 1998 and substantial commercial seed collections are now made annually by PROSEED. The first seed orchard seed is now available from PROSEED. Also, seed was collected from the best individual in all 108 families in 1997 and a second generation breeding population was planted on two sites in 1998. This will advance

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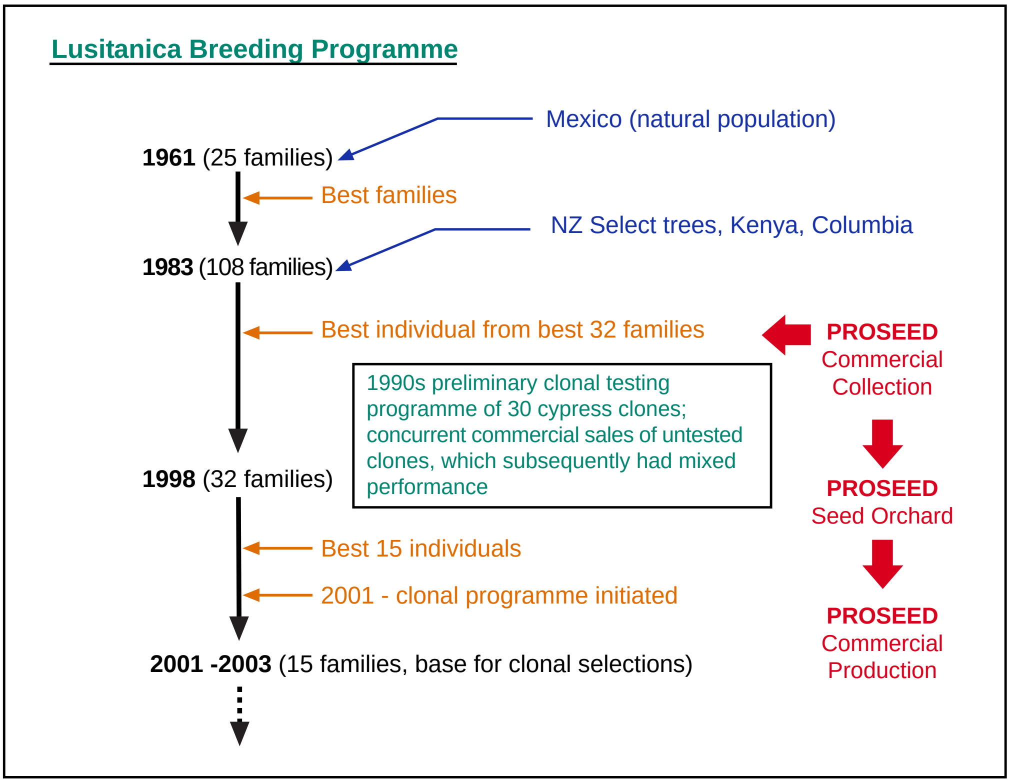
the breeding programme and additional seed will also soon be sown for this. In addition to this, clonal trials using seed collected from the best individuals in 15 of the best families were planted in 2002 and 2003.

Lusitanica crosses quite readily with other cypresses. The New Zealand lusitanica breeding population (the progeny trials) has some genetic diversity from the inclusion of Guatemala and Mexico provenances, but there are visual signs that macrocarpa, *Cupressus sempervirens*, and *C. arizonica* genes are also present at a low frequency.

The good growth exhibited by lusitanica in New Zealand justifies a thorough examination of the available provenance variation in its native range. Only a small part of the genetic base is currently represented in New Zealand. Increasing awareness of the potential of the species and increased planting rates mean that this project should have a high priority.



2. Macrocarpa

Macrocarpa has an extremely restricted natural distribution of 30 hectares, confined to the headlands (Cypress Point and Point Lobos) at either side of Carmel Bay, California. It is thought that early seed collections would have been restricted to Cypress Point.

The native stands are mainly within 200 m of the sea coast and grow slowly on the rocky soils. Presumably they would grow better further inland, but do not get that chance as they would be competing with the much faster-growing radiata pine. The best trees are in Crockers grove at Cypress Point, but only reach 30 m in height, while sheltered sites in New Zealand allow macrocarpa to exceed 50 m in height.

The growth of the first macrocarpa shelterbelts in New Zealand was excellent and tree form in plantations was also good. However, cypress canker eventually found its way to most parts of New Zealand and it devastates young stands in warm climates.

Most seed collections were made in a well-formed and healthy stand at Longwood Forest in Southland and several thousand hectares

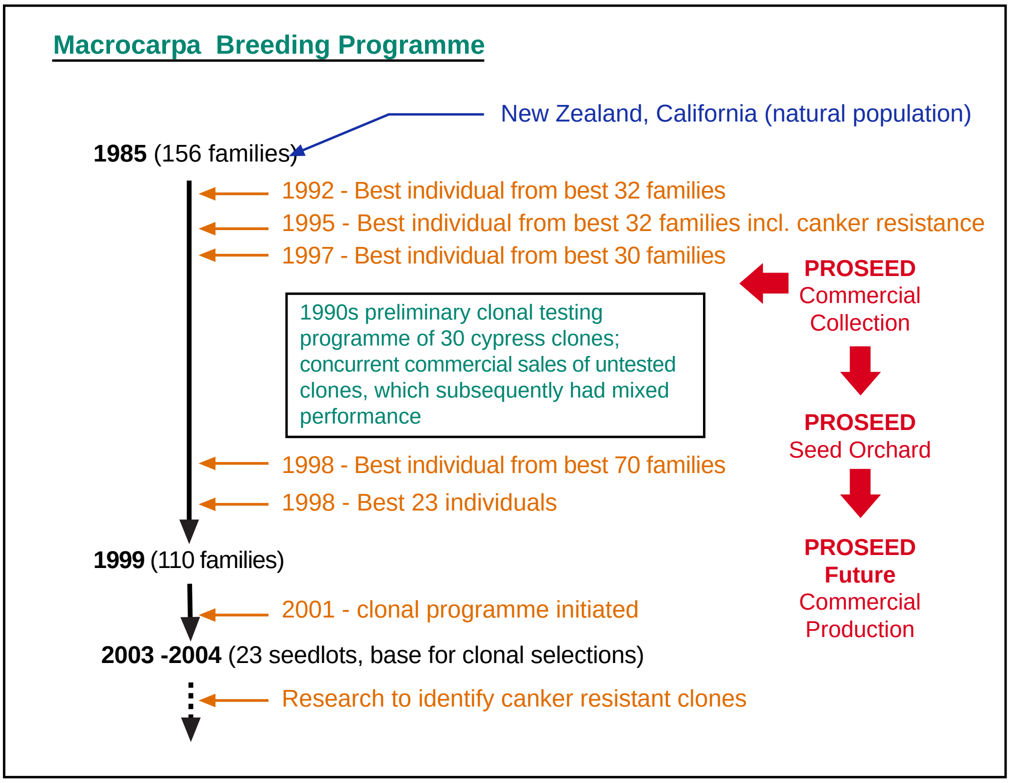
Good form macrocarpa

have been planted from these collections. Unfortunately, the good health of the Longwoods seed stand was due to the cool climate and not genes for resistance to the cypress canker, so some descendent stands have been badly hit by canker.

John Miller selected best trees in good stands of macrocarpa throughout New Zealand and also obtained seed from a range-wide collection in the native stands. The seed was sown in 1984 and progeny trials were planted at Gwavas, Mahinapua, and Strathallan Forests in 1985. The trials at Strathallan and Gwavas were designed as potential seed stands. The progeny trials were assessed in 1992 and the best tree in each of the best 32 families was selected as a seed orchard candidate. Some cypress canker was observed, particularly on the Gwavas site. In 1995, the trees on the Gwavas site were suffering heavy infection from cypress canker. The native population families and many New Zealand families were severely affected by canker, but some New Zealand families showed resistance.

The families were then re-ranked using resistance to cypress canker as the most important trait and some of the original seed orchard selections were discarded and new selections chosen. In 1999, PROSEED identified good trees in the top 30 families and now collects seed from these annually. PROSEED has planted a macrocarpa seed orchard at Amberley, but this has not yet produced seed.

Seed was collected from the best individual in about half of the 156 families, from the Strathallan progeny trial, in 1998, and a second-generation breeding population was planted on two sites in 1999. In addition to this, clonal trials of rooted cuttings, derived from seed collected from the best individuals in the best families, were planted in 2003 and 2004. Rooted cuttings from these clones have been inoculated with different strains of cypress canker to identify canker-resistant clones. More information on this is given below and in the chapter on health.



3. Lawson cypress

Lawson cypress (*Chamaecyparis lawsoniana*) is also called Port Orford cedar. It has a relatively small natural distribution on the West Coast of North America on either side of the border between California and Oregon. It has a good reputation in America for timber. Provenance variation is essentially unknown and the origin of the New Zealand stands is similarly unknown.

Lawson cypress was widely planted by the NZ Forest Service and proved to be a healthy species that produced well-formed trees and good timber. However, it grows significantly slower than macrocarpa and lusitanica, so has been largely supplanted by those species. A comparison between seedlots from the Mahinapua seed stand and a commercial stand showed some superiority of growth and form in the progeny of the seed stand.

Most plantations of Lawson cypress have now been felled, so recent seed collections have been mainly in shelterbelts. The native stands in America have restricted access as a root rot fungus is present in some stands and American botanists want to limit the spread of the fungus.

4. Other cypress species

A small number of other cypress species (*Cupressus arizonica*, *C. funebris*, *C. torulosa*, *C. guadalupensis*, *C. pygmaea*, *Chamaecyparis obtusa*, *Ch. nootkatensis*) have been tried, but all grow more slowly than macrocarpa or lusitanica in New Zealand. However, there is scope for hybridising some cypress species with macrocarpa and lusitanica to confer better health and/or wood properties. *Cupressus guadalupensis* is one with potential to improve canker resistance, but there are not many individual trees growing in New Zealand and the native stand is very small and difficult to access. *Cupressus pygmaea* is another under test and early indications are that its growth is slightly slower than macrocarpa, but it has good form and better health.

5. Hybrids and cypress clones

Cypresses have proved fairly amenable to vegetative propagation. The most well-known cypress clones are the various "Leyland cypress" clones. They originated as accidental hybrids of macrocarpa and *Chaemacyparis nootkatensis*, which were spotted as seedlings grown from seed collected from a *Ch. nootkatensis* tree in Britain and multiplied vegetatively, starting with some clones in the late 1800s.

The Leyland clones have been tested on a number of sites and form healthy stands of well-formed trees, with slightly slower growth than lusitanica or macrocarpa, but better wood properties and less taper in the butt log. There are relatively few plantations of Leyland clones in the current New Zealand cypress estate. Presumably the greater cost of Leyland plants has resulted in cypress growers using Leylands mainly for shelterbelts. The slower growth may be due to accumulated maturation during the many cycles of vegetative propagation of these clones, rather than being typical of the true hybrid genotype *per se* (see below). There has been speculation that controlled hybridisations between the two parent species (macrocarpa and *Ch. nootkatensis*) may result in superior, faster growing hybrid genotypes. More recently, there has been great interest in the ovensii clone (an accidental hybrid between lusitanica and *Ch. nootkatensis*), which appears to be performing well, though it is yet to be well tested.

Various clones of lusitanica and macrocarpa have been produced over the last 10-15 years and some have shown good promise. However, there have been some big disappointments from clones that were susceptible to cypress canker or whose growth was disappointing.

> A study undertaken by Bridget Geard in 2001 showed that cypress clones, produced in a preliminary clonal testing programme in the 1990s, generally had poorer diameter growth than cypress seedlings. This was thought to be due to lack of control of maturation in the propagation system, as explained below. Also, these early clones had not been selected for resistance to cypress canker and some of the macrocarpa clones proved to have very poor resistance.

Forest Research (now Ensis) has clonal programmes in both lusitanica and macrocarpa, using rooted cuttings taken from seedlings, which were grown from the best available seed from the breeding programmes. Field testing of these clones is seen as vitally important – to identify superior clones and to compare the performance of rooted cuttings against standard seedling stock. Clonal field trials have been planted on three sites for both lusitanica and macrocarpa, between 2002 and 2005. Rooted cuttings from the macrocarpa clones are also being inoculated with cypress canker in glasshouses over a 3-4 year period to complement the traditional field trials.

This early selection programme is aimed at identifying clonal genotypes that have durable resistance to cypress canker. This is described more fully in the chapter on health in this handbook. Seedlings from the same families were raised to plant into the field trials with the clones, so any effects associated with propagation can be monitored. There were no significant differences between the two plant types in the age 1 and age 2 assessments. Hedged donor plants (developed from the original seedlings) have been retained in the nursery so that promising clones can be multiplied up after field testing and screening for canker resistance.

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Clonal forestry and family forestry

Clonal forestry is the commercial deployment of limited numbers of clones that have been well tested and characterised. It promises maximum genetic improvement at any given time, but is "dead-end" when used in isolation, i.e. further genetic improvements are dependent on breeding new and better genotypes. For this reason, and because it is preferable to start with genetically well-known material, it is far better to have clonal forestry closely associated with well-established breeding programmes.

Another important advantage of clonal forestry is that genetic uniformity allows for customising the propagation, silviculture, processing and utilisation of individual clones. This allows for major cost efficiencies and net value gains.

However, like almost all investments offering high returns, clonal forestry often incurs elevated risks. Tree growers need to be aware of the risks of growing large numbers of single genotypes. Important considerations are: land area planted in clones and the initial investment made; the amount of information on each clone; whether the clones are grown in pure stands or mixtures; the number of different clones planted and the genetic diversity of those clones; the adaptability of each clone deployed; and risk factors such as problems with clonal performance, market shifts, pathogens, pests, and climatic changes. If a clone is well tested, its performance will be well known and it can be well matched to a suitable site and a particular silvicultural regime. The risks associated with growing a well tested clone are much lower compared with growing a poorly tested clone.

Biotic damage, from pests and pathogens, is of particular concern as this can result in widespread failure of vulnerable clones – as has been seen in New Zealand with several macrocarpa clones that have proved susceptible to cypress canker. Selection for resistance to a known damaging agent, such as cypress canker, may be possible. However, this is complex as there are likely to be many different strains of the pathogen, and also, the pathogen may be rapidly evolving. This means that simple resistance mechanisms may be easily overcome by existing genetic diversity in the pathogen (if the clones were not screened against all known strains of the pathogen) and also by subsequent genetic changes in the pathogen populations. It is, therefore, vitally important that durable resistant mechanisms are developed. This was further discussed in the preceding chapter on health.

The thorough testing of clones in replicated field trials is a prerequisite of successful clonal forestry. Clonal propagation, the maintenance of clones during the testing phase, and then the establishment and maintenance of clonal tests, are very costly. Tested clones will come at a premium at the nursery gate. Maintenance of juvenility of clonal stool beds is a costly necessity, because otherwise, by the time clones are field tested, selected clones will be too mature to be successfully propagated.

Establishing plantations of rooted cuttings from tested and selected families (family forestry) is another option. This involves the establishment of nursery stool beds with seedlings from elite families, and cuttings subsequently collected and rooted, with family identity retained throughout. Family forestry is a less expensive option than clonal forestry, as there is no clonal testing or maintenance of clonal identity, and it will deliver some (but not all) of the genetic gain associated with clonal forestry. The cost-benefit of clonal forestry versus family forestry should be explored for cypress species and hybrids.

Seed production and seedling propagation

Cypresses tend to be precocious seeders and seed collection can be done throughout the year. Macrocarpa and lusitanica bear seed crops in most years and heavy crops every few years. The seed is relatively easy to germinate, though stratification is recommended. Leyland cypress and the ovensii clone, which are both *Cupressus* x *Chamaecyparis* hybrids, are apparently largely infertile, but this has not been properly researched. Information about seed collection, extraction, stratification, and nursery practices are in FRI Bulletin No. 124 (a) on cypresses (Miller and Knowles 1996).

Seedlings can either be grown in containers, or lined out in the nursery as bare-rooted planting stock. Both types of planting stock can be grown successfully on most New Zealand farm forest sites. Nursery staff, forestry consultants and local, experienced, tree growers should be able to give advice on the best planting stock for a particular site. Growers are advised to obtain planting stock from reputable nurseries and seedlings should have a minimum diameter of 5 mm and a minimum height of 35 cm. Seedlings are normally topped in the nursery bed at about 35 cm in height. All planting stock should be healthy, vigorous, free from obvious symptoms of disease, and come from a nursery that is not surrounded by diseased cypress trees.

Many nurseries now grow much of their stock based on pre-orders, and may not have excess stock at short notice. The availability of stock is variable, depending on demand. Growers should, therefore, contact their nursery well before planting time. Information on best planting practices is provided in the chapter on establishment and management options in this handbook. If the inappropriate planting stock is planted on a site, or if planting practices are poor, the resulting stand will be compromised, even if the stock was genetically superior and was raised with good nursery practices.

Seed orchards have recently been established by PROSEED for macrocarpa and lusitanica. Seed from these orchards is only just becoming available (for lusitanica), or will be available within the next few years (for macrocarpa). In the meantime, superior seed is available from the progeny trials. Scarce genetically improved seed can be vegetatively multiplied via a nursery stool-bed system (see page 39). This will increase availability of superior planting stock and possibly lower costs per plant. This will be particularly important when controlled pollination seed becomes available (where select pollen is used to pollinate select flowers).

Rooted cuttings propagation

Cypresses can be propagated via tissue culture, but the most effective and cost-efficient method of vegetative propagation in New Zealand is via the rooting of cuttings from nursery stool beds. Simple and inexpensive nursery stool-bed systems, for the cuttings propagation of both lusitanica and macrocarpa, were developed during the 1990s by Forest Research. This is described in a Tree Grower article (Aimers-Halliday *et al.* 2000).

The stool-bed system involves growing seedlings (or juvenile rooted cuttings) in a nursery bed at a fairly wide spacing (rows 1.8 m apart, 1 m spacing within rows) and regularly topping the plants to encourage production of adventitious shoots. A stool-bed system is also critical for multiplication of superior clones. This is particularly so for hybrids because propagation from seed results in the loss of the unique parental combination, and vegetative multiplication is the only method of propagating the sterile *Cupressus* x *Chamaecyparis* hybrids.

Annual hedging of stool plants is essential for delaying maturation, i.e. maintaining juvenility in the cuttings. Maturation is the process of change from embryonic, through to juvenile, then to mature state. It occurs progressively with increasing distance along the stem axis, as the plant grows and develops. The most juvenile tissue persists at the root collar (the root:shoot junction). Maturation in vegetative propagules (also called physiological aging in New Zealand) is generally undesirable in forestry. It has been thoroughly researched with radiata pine and it has been shown that rooted cuttings with an older maturation state at planting will have slower diameter growth, but better form (straighter stem and lighter branching) compared with trees grown from seedlings or juvenile cuttings. There is an ideal maturation state where there is no growth loss, but improved form, with radiata pine this is rooted cuttings of physiological age 3 years.

Less is known about how maturation affects clonal propagation of cypress, but cuttings from more mature donor material tend to be

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more difficult to root, and there also tends to be less vigour in the rooted cuttings. The degree to which maturation is a limitation depends very much on the cypress species being propagated and on particular genotypes within species. Some genotypes are more easily propagated, stool plants show little sign of ageing, and it is these genotypes that are more likely to be cloned *en masse*. However, these easily propagated genotypes don't necessarily have the best characteristics for end product traits. Cypress growers need to ascertain that clonal planting stock is from clones which have a proven field performance in extensive clonal field trials, rather than clones that are merely easy to propagate.

Lusitanica stool plants just prior to taking cuttings, Forest Research nursery, Rotorua.

Standard practices for radiata pine nursery propagation have been applied to cypress species, with mixed success. In particular, severe hedging can result in poor health of cypress stool beds. Nurseries now tend to maintain cypress stool beds at a relatively tall height, rather than keeping hedging as low as with radiata pine. But this higher hedging may result in greater maturation in subsequent cuttings, as compared with cuttings from low hedges.

Once cuttings are collected from nursery stool beds, they need to be rooted in an appropriate propagation environment. Simple and cost-efficient environments are usually sufficient, such as a polythene tent in a greenhouse, or a fog system in a polyhouse. Application of rooting hormones can give mixed results depending on the species and propagation environment. Propagators should trial different hormone treatments for their own particular set up. Some cypress propagators do not use rooting hormone. The appropriate time for setting depends on the species, location, and propagation environment, but cypress cuttings are generally set between April and July. Once rooted, the cuttings can be grown in a containerised system, or lined out in nursery beds to produce bare-rooted planting stock.

Growers are advised to purchase their planting stock from nurseries that have a good track record. This is particularly so when purchasing

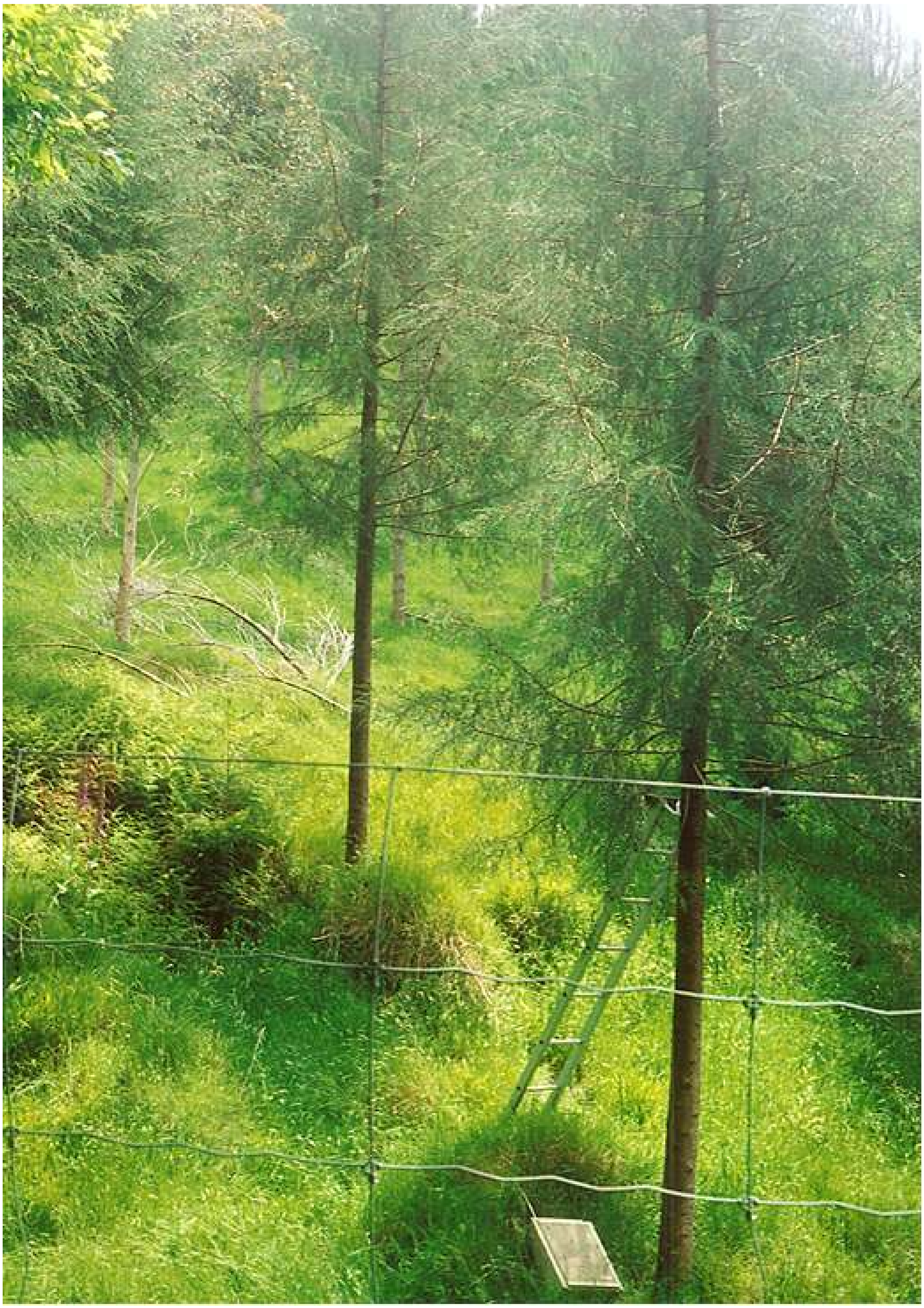
Lusitanica cuttings, ready for planting, Forest Research (Ensis) nursery, Rotorua.

rooted cuttings. There are no published standards, but general recommendations can be made. Growers can ask nursery staff to view the root systems of two or three rooted cuttings, to check that there is a well developed, balanced, fibrous root system. Growers also should check the vigour and juvenility of the shoots. Rooted cuttings should have a minimum diameter of 5 mm and a minimum height of 35 cm. It can be difficult to ascertain maturation (physiological age), but juvenile cuttings will have similar vigour and appearance to seedlings, compared with "aged" rooted cuttings, with an older maturation state, which may have a less upright form and have foliage more akin to that seen on branches of "adolescent" to mature trees.

Maturation is obviously less of a limitation in vegetative propagation of Leyland cypress, with some clones being successfully propagated since the late 1800s. It is speculated, however, that there is a steady decline in vigour of the commercial Leyland clones due to progressive maturation.

Cypress Royalty Scheme

The *Forest Research® Cypress* royalty scheme, currently with Ensis, was designed to capture a return on cypress tree improvement and clonal research investments. A royalty of four cents per seedling and 10 cents per clonal rooted cutting sold is collected at the point of sale (nurseries). The royalty charges are arbitrarily designed to amount to approximately 10 % of the sale price. The collection of royalties is managed by PROSEED, with the funds allocated to the Ensis cypress research programme for further improvement of cypress.



Lusitanica clone exhibiting good form, Paengaroa, Bay of Plenty

Key Points

- Improved seed is currently available for macrocarpa and lusitanica, but is in short supply.
- Lusitanica has become more important due to resistance to cypress canker.
- Only a small part of the genetic base of lusitanica is currently represented in New Zealand. Importation of seed from throughout the wider native range is warranted.
- Cypress species are highly inter-fertile, with great potential for hybridisation.
- There have been some disappointments from earlier releases of clones, which proved susceptible to cypress canker or whose growth was disappointing.
- Growers should ensure they plant quality stock, which is appropriate for the site. If inappropriate stock is planted, or planting practices are poor, the stand will be compromised, even when superior planting stock is used.
- All planting stock should be healthy, vigorous, free from symptoms of disease, and come from a nursery that is not surrounded by diseased cypress trees.
- Growers should be aware of the risks associated with extensive planting of single clones. There is less risk if clones originate from a breeding programme and are well tested in field trials.
- Screening of genotypes for durable resistance to cypress canker is complex, but it is a priority.
- The cost-benefit of clonal forestry versus family forestry should be explored for cypress species and hybrids.

Suggested reading:

Miller and Knowles 1996

Aimers-Halliday *et al.* 2000

Aimers-Halliday *et al.* 2002

Vincent *et al.* 2002

GLOSSARY OF TREE IMPROVEMENT AND PROPAGATION TERMS

Adventitious shoots: New shoots initiated in response to propagation treatments such as topping or hedging.

Bare-rooted planting stock: Plants (seedlings, cuttings or other) grown in open nursery beds rather than containers and lifted and planted with much of the soil gone from their roots.

Breeding: Intensive selection and subsequent mating of top selections to achieve cumulative genetic gain over time.

Breeding population: The population in which breeders carry out intensive selection and genetic recombination. It comprises the selections that are intermated and their resulting offspring. It requires a broader genetic base than the seed production (orchard) population.

Clone: A group of genetically identical plants, which have been vegetatively propagated from a single individual.

Clonal forestry: Establishment of plantations with a restricted number of vegetatively propagated clones. These clones have been tested and selected in clonal tests, the best being subsequently mass produced.

Clonal trial: Evaluation of the relative performance of clones in a replicated field trial

Controlled pollination: Transfer of pollen from a known source to receptive flower parts of known seed parents, all other pollen being excluded (as by covering flowers with isolation bags prior to pollination).

Family: A group of individuals directly related by descent from a common ancestor.

Family forestry: Families deployed operationally in plantations as single family blocks (either directly as seedlings or vegetatively multiplied). These families are usually full-sib, i.e. from controlled pollination.

Genetic diversity: Amount of genetic variation in a population.

Genetic gain: The average improvement in a progeny over the average of the parents. Gain is achieved by selection and mating of top parents.

Genotype: (1) An individual's genetic make-up, or (2) Individual(s) characterized by a certain genetic constitution.

Hedging: Repeated top-pruning of a tree; in this context, to arrest further maturation.

Hybrid: The offspring of parents that have distinct genetic differences. Can apply to the progeny from matings within species (intraspecific) as to those between species (interspecific). Hybrids combine the characteristics of the parents or exhibit new ones.

Hybridisation: The mating of parents that have distinct genetic differences to create hybrid progeny.

Inter-fertile: Related individuals that readily and naturally cross pollinate to produce viable hybrid progeny.

Land race: A population within a species that exhibits adaptive characteristics. This term is often used to describe populations of introduced species that have become adapted over several generations to their new environment through natural selection.

GLOSSARY OF TREE IMPROVEMENT AND PROPAGATION TERMS

Maturation state: (syn. physiological age) A particular developmental state along the continuum of complex physiological changes, which plants undergo as they progress from an embryonic state, through to juvenile and then to a mature condition. Generally dominated by total distance along the stem and/or branch from the original root:shoot junction. However, it can be accelerated by some nursery treatments, or arrested by treatments such as hedging. Very difficult to reverse in woody plants, except during sexual reproduction.

Native population: (syn. native provenance) A group of naturally growing trees found at a particular geographic location, within the native range of the species.

Progeny trial: Evaluation of parents by comparing the performance of their offspring in replicated field trials.

Propagation: Multiplication of plants. Can be either via sexual reproduction (seed production) or via asexual means (vegetative propagation).

Provenance: The original geographic source of seed, pollen, or trees.

Provenance test: A replicated field trial comparing the performance of trees grown from seed collected from different parts of a species' geographic range.

Resistance: Relative ability to endure pests or other damaging influences. It may vary in degree from immunity, in which the attack or influence is completely without effect, to absolute susceptibility, which may result in death.

Seed orchard: A plantation of selected trees, established and managed primarily for the early and abundant production of genetically improved seed. The seed orchard is isolated to reduce pollination from outside sources, and trees with undesirable characteristics are removed, based on ongoing evaluations.

Seed stands: A well-grown stand of trees, with good growth and form, selected and managed for abundant seed production.

Seed stratification: A treatment given to seed to break dormancy and improve germination, which usually involves a moist chilling.

Stool plant: A plant grown in a nursery bed, which has been hedged or topped to produce adventitious shoots, which are subsequently used for vegetative propagation.

Tissue culture: (syn. micropropagation) Growing plantlets from small pieces of plant material on artificial media in a sterile, laboratory environment.

Tree improvement: Usually synonymous with tree breeding, but may also refer to breeding in combination with cultural practices, particularly propagation.

Vegetative propagation: (syn. vegetative multiplication) Multiplication of plants via asexual means, i.e. without sexual reproduction. Includes tissue culture, rooted cuttings, and grafting.

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CHAPTER 6 - ESTABLISHMENT AND MANAGEMENT OPTIONS

Contributing author Patrick Milne

ESTABLISHMENT

Overview

Successful establishment practices will result in an evenly stocked, vigorous, uniform, and stable crop growing at or near its potential for the site. Establishment practices fall into the following five categories: site or land preparation, seedling quality, transport and storage of seedlings, planting practices and post-plant weed control.

The cypresses respond very well to good establishment practices. On benign sites it is sometimes possible to get away with having less than optimum establishment practices; however, as sites become harder and tougher (possible reasons include increasing altitude, aspect, weed competition, exposure, etc.) it is important that these practices tend towards the optimum for the site. These practices are additive so good and poor practices tend to cancel each other out. The most successful option is to strive for good establishment practices all the time.

Site or land preparation

Cypresses respond extremely well to good site or land preparation. This includes vegetation control and / or mechanical cultivation prior to planting. It can be as simple as hard grazing the site with sheep or cattle prior to planting or, at the other extreme, involve one or more of spraying, burning, root-raking, roller-crushing, ripping, mounding, and drainage. Whatever the practice, the objectives are the same – to provide a site which can be easily planted and give the newly planted seedlings the best possible start.

Establishment trials for macrocarpa and lusitanica were set up on a cut-over site (near Rotorua) and a pasture site (near Whangamata). The treatments tested were container-grown seedlings, bare-rooted seedlings, fertilizer application, weed control, and an anti-transpirant dip. Best growth and survival were obtained for container-grown seedlings, with fertilizer and weed control treatments. No response to the anti-transpirant was detected. On the cutover forest site, seedling type, fertilizer, and weed control treatments were more pronounced for macrocarpa than for lusitanica. On the pasture site, growth advantages were associated with bare-rooted seedlings of lusitanica and with bare-rooted seedlings in conjunction with weed control, while survival advantages were associated with container-grown seedlings of macrocarpa and with container-grown seedlings and weed control (Glass *et al.* 1991).

Seedling quality

Under ideal planting conditions, small seedlings transplant better than larger ones, with less interruption to their growth, but in practice a minimum size is required because the seedling must contain sufficient food reserves to survive handling and storage, and to produce new roots and shoots after planting.

Seedlings can be grown either as open ground (bare-rooted) or containerised planting stock, and both can be very successful. The root collar diameter is a good indicator of food reserves. For bare-rooted stock, a diameter of 5 mm for cypresses is recommended.

Transport and storage of seedlings

The transport and handling requirements of cypresses are very similar to those of other commonly planted species, namely radiata pine and eucalypts. They all require careful lifting, handling, packaging, storage, and transport to protect both stems and fragile root systems between the nursery and the planting site. Seedlings should be transported in rigid cartons to protect them from crushing and bruising. Always transport seedlings on their side or lying down. Transporting in an upright position can lead to bruised and damaged root systems. These root systems are fragile and easily damaged and must not be allowed to dry out. These roots are necessary for water capture and are important for early survival.

Ideally, seedlings should be returned to the ground the same day they are lifted; however, this is not always possible, so always store them in a cool place and out of the direct sun. Never let the roots dry out – sprinkle them with water if necessary.

Planting practices

The future root system of a tree is largely determined by the way the roots are positioned at time of planting. It is very easy to plant a seedling incorrectly, with the most common planting faults being:

- Not planting deeply enough
- Not cultivating the soil in the planting hole
- Not creating a hole big enough to accommodate the root system of the seedling without some distortion
- Dragging the roots into the planting hole so that they all point in the same direction which leads to unstable trees with "hockey stick" root systems.

The major factor leading to poor quality planting practices is trying to plant too many trees in an eight hour day. There are 480 minutes in an 8-hour working day – planting 480 trees per day is a minute per tree – this includes time spent walking from tree to tree, replenishing trees, and comfort stops. A minute per tree is not long when you consider that the tree, if it survives and grows, could be growing for 25-30 years. While 480 trees might be a low number to plant on a good site, it might be about right on some harder sites.

Cypress seedlings respond and grow very well when planted into cultivated or loosened soil. If the site has not been cultivated by machine, then it needs to be cultivated by hand at the time of planting. It is very important when planting to ensure that the root collar is buried 5-10 cm. This is particularly important for two reasons. Firstly, on drier sites, planting deeply ensures that the roots are below the soil surface which can dry out quickly. Secondly, on windy sites, planting deeply adds to the rigidity of the newly planted seedling and prevents swaying. Trials have shown that up to half of the stem of a seedling can be buried without affecting height growth the following season.

It is important to ensure that the planting hole is big enough to accommodate all the roots without bending or distorting them. The seedling's roots are placed in the planting hole, and while holding the seedling stem, the planting hole is filled and then given a positive pull-up of 3-5 cm to straighten the roots. Following planting, the soil surface around the seedling is firmed with the sole of the boot, taking care not to strip the foliage or branches from the stem while doing so. In firming the soil, the aim should be to ensure that the surface is sufficiently compact to stop the seedling moving in the wind, but not to compact the soil too tightly around the roots – especially in wet soils.

The recommended time for planting depends very much on the area – particularly on the length of the growing season, which is largely dictated by the climate. Throughout much of the country, particularly in cooler regions, planting in May or June is not recommended because seedlings have to withstand all the vagaries of a winter climate before they can start to make new growth. Planting at the beginning of the growing season is recommended and this could be as late as

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August/September in cooler parts of the South Island. In warmer parts of the upper North Island, earlier planting in July/August is usually warranted, before conditions become too warm and dry.

Well-established lusitanica plantation, Paengaroa, Te Puke

Planting weed control

To get the best survival and early growth from newly planted cypresses, any competing weeds should be eliminated or controlled until the newly planted seedlings are sufficiently well established to dominate the site.

Weeds can be controlled in spots around individual seedlings, in strips along the planting lines or over the whole site. Weed control can be carried out by mowing or slashing, hand or mechanical cultivation, mulching or by the use of chemicals. The most common method of weed control is by the use of chemicals, and there is a wide range available.

The questions to answer when deciding on what chemical to use are: what are the weed species to be controlled, and how tolerant are cypresses to those chemicals? The answers to these questions will determine whether firstly the chemical is suitable and secondly whether the chemical is applied before (pre-plant) or after planting (post-plant). Recommendations are given below:

Recommendations:	
Pre-plant	Post-plant
Scrub (gorse, broom, blackberry)	Grasses, herbaceous weeds
Glyphosate / metsulfron	*Gardoprim, Galant, Versatil*
Grasses, herbaceous weeds	
Glyphosate, Buster, Gardoprim	

MANAGEMENT OPTIONS

Overview

The cypresses produce a high quality, versatile timber which naturally has moderate durability. In addition, with good silviculture, they can also produce a very valuable timber. High quality cypress logs are straight and round in cross-section, with little evidence of fluting. Pruned logs should be of large diameter and yield a high content of clearwood. Unpruned logs should have small green or live branches thus making them suitable for not only structural but also appearance grade timbers.

There are three different management or silvicultural systems used to grow high quality cypress logs -namely pure stands, mixtures, and enrichment planting.

Pure stands or plantations

Cypresses can be managed very effectively as a plantation and in fact, today this is the main method of growing them. Cypress plantation management has had a checkered history. They had the reputation of being a difficult species to grow, which was compounded by the fact that they can also be expensive to grow. Much of this reputation can be attributed to macrocarpa and its susceptibility to cypress canker. This resulted in growers imagining that all cypresses were more difficult to grow than they really were.

There have been numerous silvicultural regimes implemented by growers over the years. Many of these regimes have mirrored developments in radiata pine silviculture and have proved to be less than successful. Today, however, there is an increasing consensus amongst growers towards a standardised cypress silvicultural regime. There is no perfect regime, the cypress industry needs many more years' experience before we have as much information as exists in the pine industry. However, current cypress recommendations (see Chapter 7 & 8) are to have an initial planting of about 1000 stems/ha (3 x 3 m = 1100 stems/ha) with approximately 300 stems/ha pruned to 4.5-6.0 m high, with one or more thinnings following the completion of pruning. Past silvicultural options such as low initial stockings, pre-emptive pruning and very early waste thinnings are no longer practised to any extent.

Mixed plantings (using a nurse or companion species)

This method involves growing cypresses with a nurse or companion species as an intimate mixture on the same site. Although the nurse crop will provide the cypress with protection against exposure, the main aim of it is to modify the environment and in particular the light levels in which the cypresses are growing. This in turn encourages better form and smaller branch development in the cypress crop, but typically it's at the expense of diameter growth.

The cypresses are a very branchy species with many problems caused by steep-angled and large branches. Average steepness of branches and branch size can be dramatically reduced by growing the trees under shade, and this is most easily achieved by using a taller nurse species. Similar effects can be obtained by planting adjacent to the south side of existing tall stands, or even by planting steep southerly faces.

Both eucalypts and radiata pine have been used successfully as nurse species for cypresses, but it requires a serious commitment of both time and money from the grower to ensure success. Mixtures have been tried by numerous growers over the years and apart from the odd rare stand, it is generally regarded as a less than successful method for growing cypresses.

Native scrub enrichment

Cypresses can be planted into cut or crushed lines / lanes, or light wells in regenerating native scrub. Commonly known as scrub enrichment, while not inexpensive it has the advantage of a relatively low initial impact. Good examples of enrichment planting can be found on the East Coast in manuka / kanuka stands and in Westland in regenerating hardwood scrub.

Check out latest cypress handbook chapters at www.nzffa.org.nz

Pine and ovensii in mixture, Roydon Downs, Bay of Plenty.

Cypress planted in hand-cleared lanes of scrub, Southern Hawke's Bay

Key Points

- Cypresses require care in siting and establishment.
- Plantations require pruning and thinning to produce the best logs.
- Mixtures can be successfully established but need care in management.

Suggested reading:

Glass *et al.* 1991.

Check out latest cypress handbook chapters at www.nzffa.org.nz

CHAPTER 7 - PRUNING AND THINNING

Contributing authors Mark Kimberley and Ian Nicholas

INTRODUCTION

Pruning and thinning of cypresses have been topics of considerable debate for many years. Traditional regimes have ranged from very high initial stockings to low stockings. Pruning suggestions have ranged from delayed pruning to vigorous secateur pruning.

Many people can pontificate on the merits of the best regime, but the base facts are as one leading farm forester says: “Plant trees, prune trees, thin trees and fell at end of rotation - end of story - don’t confuse the issue with too much information!”

Pruning and thinning decisions require clear objectives. Reasons for pruning are two-fold – for windproofing by removing crown area (see Chapter 3) and reducing the risk of topple, and also for clearwood production. The issue of how much to prune and how often is still being evaluated.

Make sure you visit the NZFFA web site to check for new information.

Two major silvicultural trial series have been established which provide key information for pruning and thinning decisions:

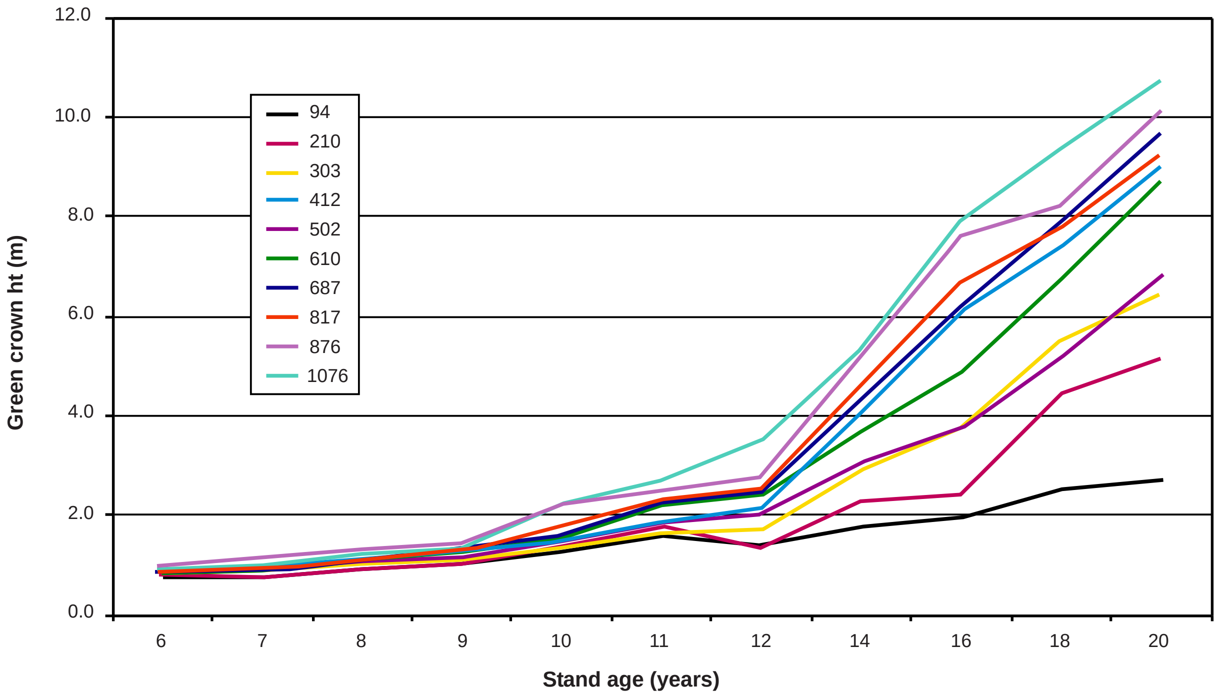
(i) Rotoehu, lusitanica spacing trial, established 1984;

(ii) Cypress regime trials in 1993-95.

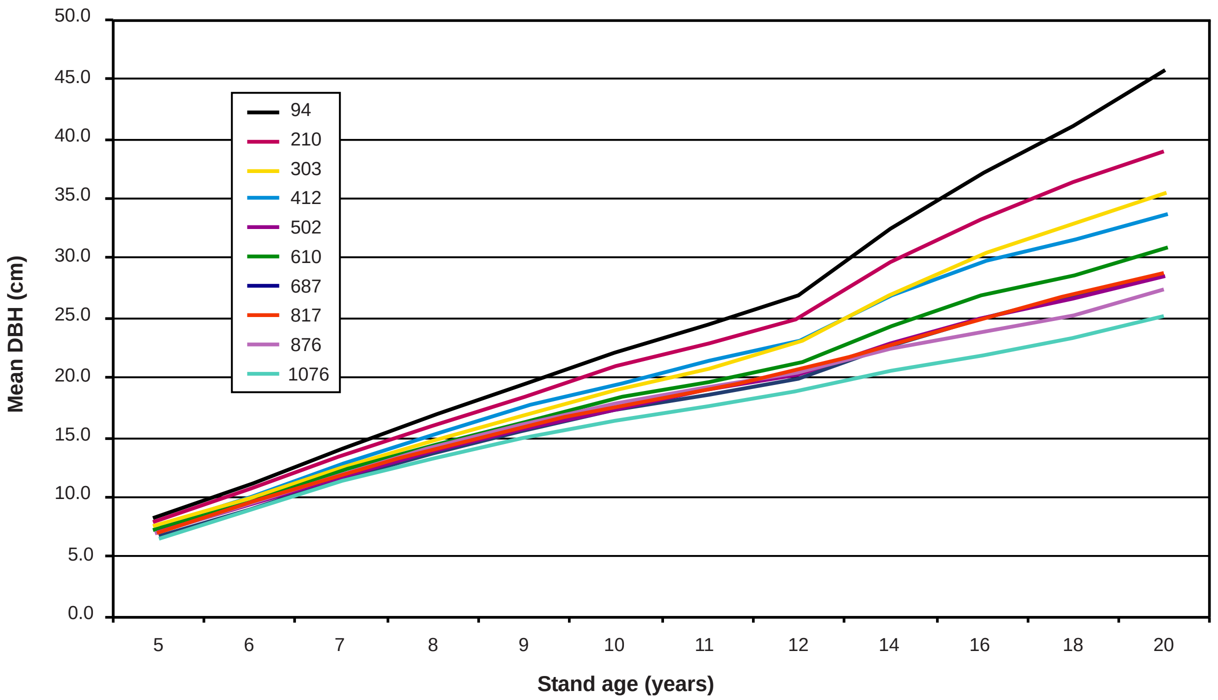
The results from these, and data collected from Permanent Sample Plots throughout the country, help in developing some guidelines for pruning and thinning.

Lusitanica spacing trial results

The cypress spacing trial in Rotoehu Forest provides data, from one site, which help in understanding the effect of stocking on average green crown height, mean diameter (mean DBH), mean top height (MTH), basal area (BA,) and live standing volume. The following age 20 lusitanica data from the Rotoehu trial illustrate the differences and relationships between stand parameters, with age and stocking.



Green crown height trends for different stockings (stems/ha at age 5) for stand age 6-20 years.



Mean DBH trends for different stockings (stems/ha at age 5) for stand age 5-20 years.

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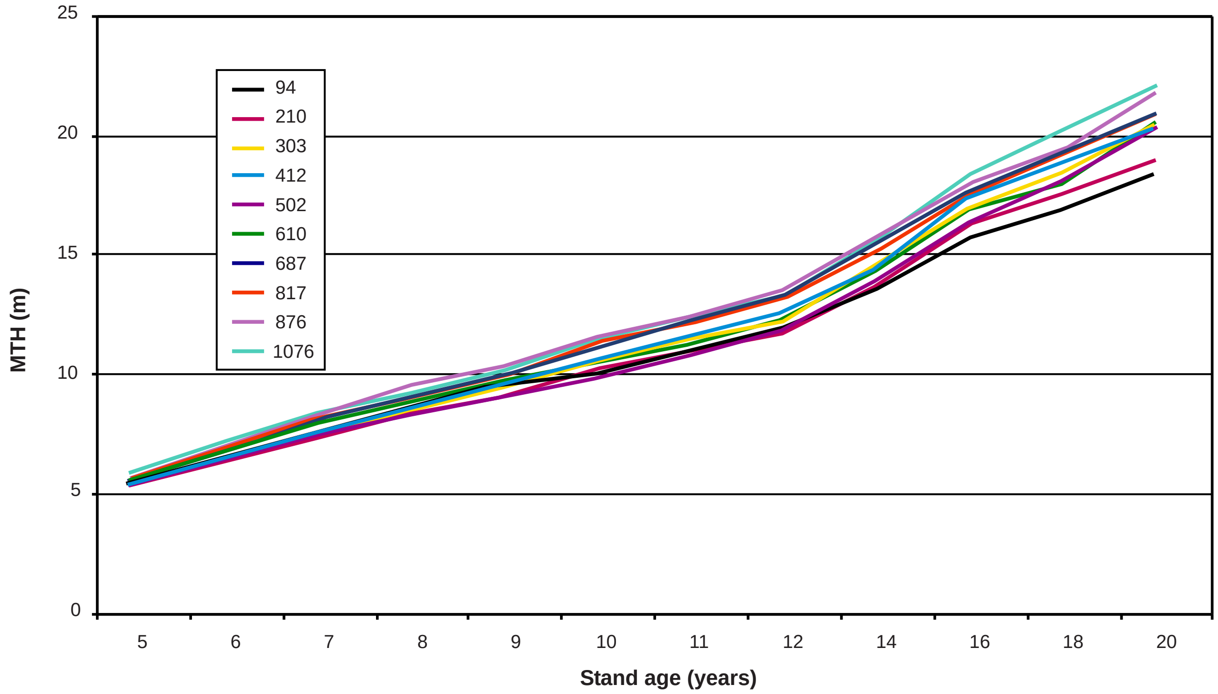
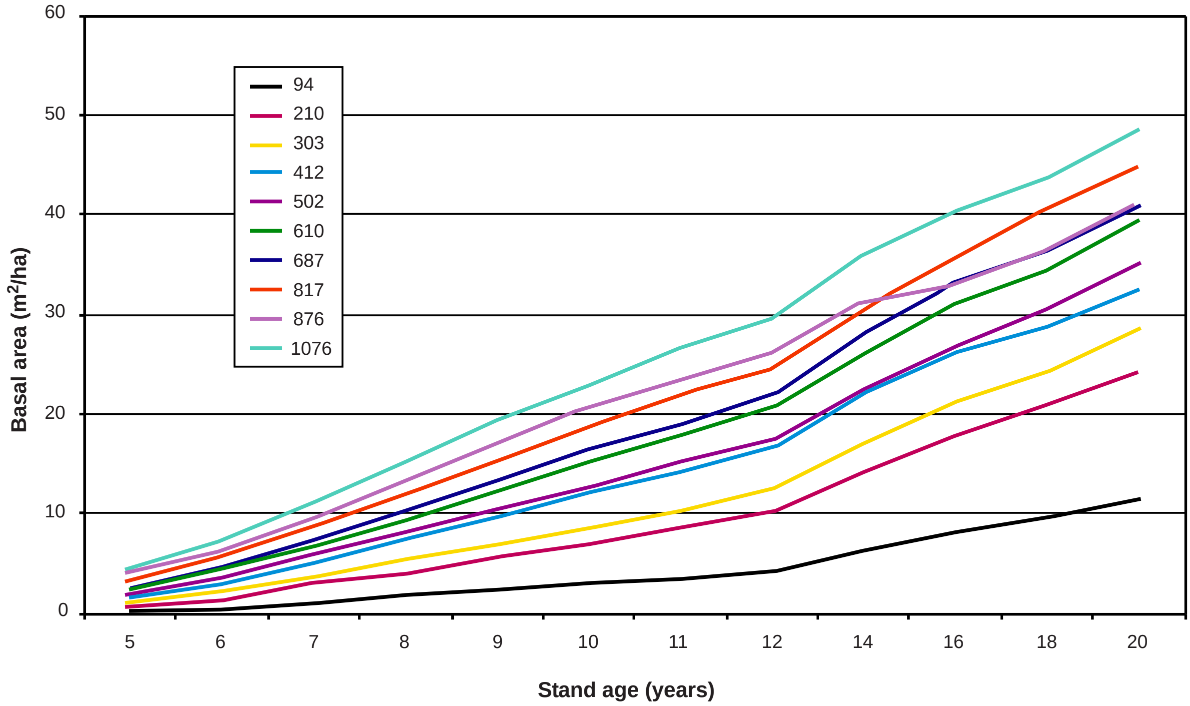
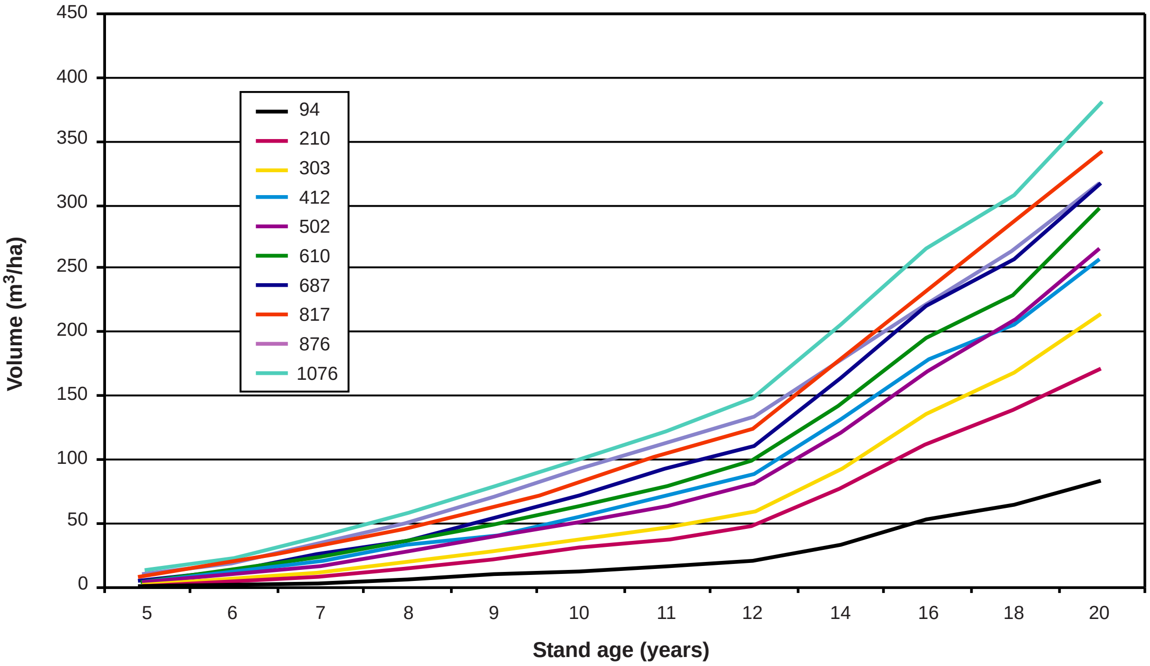


Mean top height trends for different stockings (stems/ha at age 5) for stand age 5-20 years.



Mean basal area trends for different stockings (stems/ha at age 5) for stand age 5-20 years.



Total volume trends for different stockings (stems/ha at age 5) for stand age 5-20 years.

Low stockings result in large diameter logs and lower green crowns, but lower total standing volumes per hectare. High stockings increase the total volume production on a site, encourage height growth, stem straightness, branch size control, but have trade-offs such as smaller diameters, higher green crowns (lower branch death over time), and longer rotations than stands with lower stockings if a given minimum piece size is to be produced.

If the objective is to produce large commercial logs that maximise clearwood and have live green knots in top logs, then the results of these trials suggest that pruning to leave 5 m green crown and thinning to maintain diameter growth is the better option. This means not pushing the green crown too high, too fast, and thinning in stages to 300 stems/ha.

Current recommendations are that pruning should be done below a 12 cm stem diameter (or to retain at least 5 m green crown).

Research data on pruning height are not available, but pruning above 6 m is probably warranted only on stands grown for longer rotations (approximately 40 years).

Suggestions about regimes that have short rotations, or high stockings, are not supported by the research data and/or current market signals. Short rotations will produce minimal heartwood percentage. Also small branches mean small logs, and the current premium for clearwood suggests butt log diameter should be one of the main drivers in silvicultural decisions.

There are two other significant projects that have looked at branching of lusitanica in the Rotoehu spacing trial:

Influence of stocking on the growth and mortality of lusitanica branches in New Zealand

This study by Mansikkala (2002) looked at how stocking levels influenced timber defects, in particular growth and mortality of branches. Seven trees from the stocking range of 270 – 1250 stems/ha were destructively sampled at age 17 years. Branches from stem heights ranged from 2 to 8 m above ground.

The results showed that there was a relationship between stocking and the delay between the time when a branch stops growing and the time for the branch to die. This delay averaged 6 years. Not surprisingly, the study showed that as stocking increases, the mortality of branches occurs sooner and the delay is shorter.

There was no relationship between stocking and branch size, this was attributed to the small sample of trees studied. The study also confirmed that there is no branch shedding in lusitanica.

Modelling second-log branching characteristics of lusitanica that affect log quality

This study by Sim (2002) of second-log (6-12 m) branches in 17-year-old lusitanica reported a strong linear relationship between branch size characteristics and DBH; dead branch size characteristics were also strongly related to height and stocking.

A non-linear model was developed to predict the frequency of dead branches greater than 15 mm within the second log. The diameter of the individual tree stem, and stand height and stocking were the most important parameters that related to the quality of the branch characteristics in the second log.

The size of branches within the second log linearly increased as stem diameter (DBH) increased.

The size of dead branches within the second log linearly increased if the trees were taller and/or the stocking was higher.

The report stated: “Forest managers will need to make compromises between branch diameter and the diameter and frequency of dead branches because both cannot simultaneously be minimised by stand management”.

Lusitanica regime trial, East Coast, age 6 years.

Regime trial treatments

The eight treatments, as described in Table 3, were designed to test a range of pruning regimes. Most of these treatments were applied to trials in three North Island locations. Analysis of the most recent treatments has yet to be undertaken on some sites.

Table 3. Silvicultural treatments in main trial (Northland). Initial stocking was 1000 stems/ha.

Treatment	**Thinning: Stocking/Age** (Stems/ha Age(years)	**Pruning severity**
1	unthinned (currently 700 stems/ha)	unpruned
2	early: 700/5	unpruned
3	early: 700/5 400/9	unpruned
4	late: 700/9 400/13	unpruned
5	early: 700/5 400/9	moderate - 6 m crown
6	late: 700/9 400/13	moderate - 6 m crown
7	early: 700/5 400/9	severe - 4 m crown
8	late: 700/9 400/13	severe - 4 m crown

Preliminary results

The thinning and pruning treatments had no effect on mean tree height. However, there were significant treatment effects for DBH (diameter at breast height), stem volume, and basal area.

Table 4. Comparison of the eight treatments in Northland trial at age 13 years.

Treatment	**DBH (diameter)** (cm)	**MTH* (Mean Top Height)** (m)	**Stem Volume** (m^3/ha)	**Basal Area** (m^2/ha)
1	26.2 d	17.9 a	251 a	37.4 a
2	27.4 cd	17.6 a	252 a	38.2 a
3	31.3 a	17.7 a	205 bc	30.1 b
4	29.4 b	17.8 a	187 bcd	27.8 bc
5	31.5 a	17.2 a	201 bc	31.0 b
6	31.1 a	18.1 a	207 b	30.7 b
7	28.5 bc	16.4 a	157 d	25.3 c
8	28.8 bc	18.3 a	174 cd	26.0 c

*Mean Top Height (mean height of the 100 largest-diameter stems/ha)
Values in a column followed by the same letter do not differ significantly (p = 0.05).

Preliminary conclusions from regime trials

- Moderate pruning (6 m crown remaining) had no significant effect on growth.
- Severe pruning (4 m crown remaining) significantly reduced diameter growth; however, this loss was modest, amounting to less than 2 cm , or less than 1 year's growth. This compares with radiata pine, which loses about 1.4 years of diameter growth in a typical 6 m pruning treatment.
- Delaying thinning significantly reduced crop diameter in the unpruned plots, but had no effect in the pruned plots.
- None of the silvicultural treatments (thinning/stocking/pruning) had any effect on height growth.

PRODUCTION THINNING

One of advantages of the cypresses is the flexibility they offer regarding possible harvest age. Small diameter (15-20 cm) straight logs as young as 15 to 20 years old mill well, producing stable timber right to the pith. This is in contrast to radiata pine, where there are often stability problems with timber milled from the juvenile cores of the first 10-15 growth rings. At the other extreme, cypresses 60 years old or more can produce premium logs, at an age when radiata pine will have far too much resinous heartwood to be acceptable for many uses.

The quality of young cypress logs opens the possibility of production thinning on accessible sites - the recovery and utilisation of thinned trees. Moreover, this can be repeated several times providing a useful cash flow in mid-rotation. Log prices will vary depending on sawmill preferences, log diameter, and log quality (straightness, knot size, fluting, heartwood content, etc.) but $70-100/tonne at mill door is commonly achieved.

Several production thinning regimes are possible:

- Simply removing trees with little regard to log quality to ensure optimum spacing and growth rates for remaining trees. Such a regime emphasises value at final harvest.
- Removal of the smaller, co-dominant and sub-dominant trees that are suffering increasing competition and are likely to show little diameter

growth and value addition in future years. The downside here is that these trees may be under-sized for commercial thinnings.

- Removal of the larger, more valuable, dominant trees relieving suppression of the smaller co-dominant and sub-dominant trees and allowing them to resume growth. There is a need to be realistic here and ensure that all remaining trees do have adequate green crown to ensure adequate, future growth. This regime emphasises early returns.
- Since cypresses can be grown on much longer rotations than radiata pine, there is the option of 'thinning to extinction', occasionally removing the largest trees till even the small sub-dominant trees have reached harvestable size.

With relatively shade tolerant species such as the cypresses, it may only be a short step from “thinning to extinction” to continuous cover forestry, in which selective logging and *in situ* regeneration are used in a manner similar to the sustainable management of indigenous forests. Continuous cover forestry is being advocated as an environmentally advantageous regime in some quarters.

Anyone considering production thinning needs to remember that it does require cheap, easy access and logging conditions, plus a very competent logging crew who will avoid damaging standing trees. Production thinning is, inevitably, more costly than a clearfell operation.

Key Points

- Early pruning can help reduce toppling.
- Cypresses need pruning for clearwood production.
- Prune below 12 cm stem diameter.
- Leave 5 m green crown when pruning.
- Thin to 300 stems/ha by age 10 years.
- Cypresses can offer production thinning options.

Suggested reading:

Mansikkala 2002

Sim 2002

Hay *et al.* 2005

CHAPTER 8 - CYPRESS GROWTH MODEL AND EXAMPLE REGIMES

Contributing author Pascal Berrill

INTRODUCTION

Cypress regimes are still evolving, but the regime outlined in Table 5 is currently recommended. This aims to produce a reasonable volume of logs/ha of sufficient diameter for efficient utilisation of clearwood from butt logs and top logs with a reasonable proportion of green crown. As more experience is gained and further evaluations of regimes are carried out, this regime is likely to be modified in the future.

Table 5: Proposed silvicultural regime for cypress saw logs (initial stocking 1000 stems/ha)

Age (years)	**Pruned height** (m)	**Number pruned** (stems/ha)	**Thin to** (stems/ha)
6	2.5	600	600
8	4.0	400	
10	6.0	300	300

GROWTH MODEL

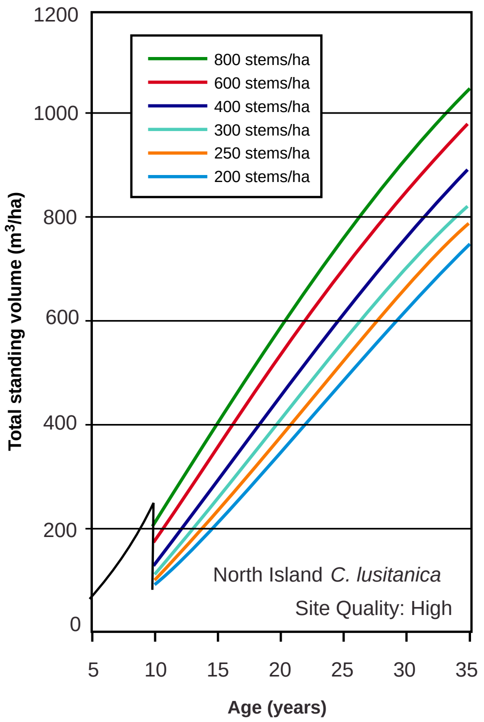
A preliminary growth model has been developed for New Zealand-grown macrocarpa and lusitanica plantations. Functions that predict mean top height and basal area growth, mortality, thinning, initial basal area, and volume were developed using data collected from permanent sample plots in most regions of New Zealand (Table 6). Maximum MAI was probably underestimated in some regions where young or thinned stands were yet to reach peak MAI. The model is referred to as "preliminary" because most plots were located in young stands, and had not been re-measured many times. The model relies heavily on data from a smaller number of older stands for predictions to later ages. These older stands may or may not adequately represent the types of sites and seedlots being planted more recently.

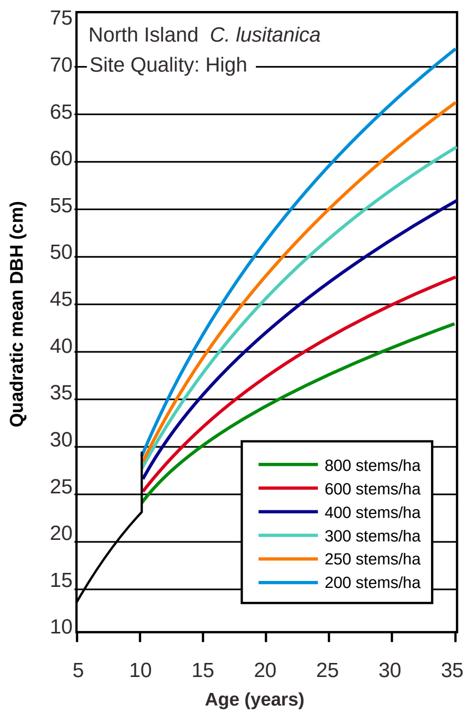
Table 6: Lusitanica and macrocarpa sample plot count, maximum age and mean annual volume increment (MAI) by geographic region of New Zealand.

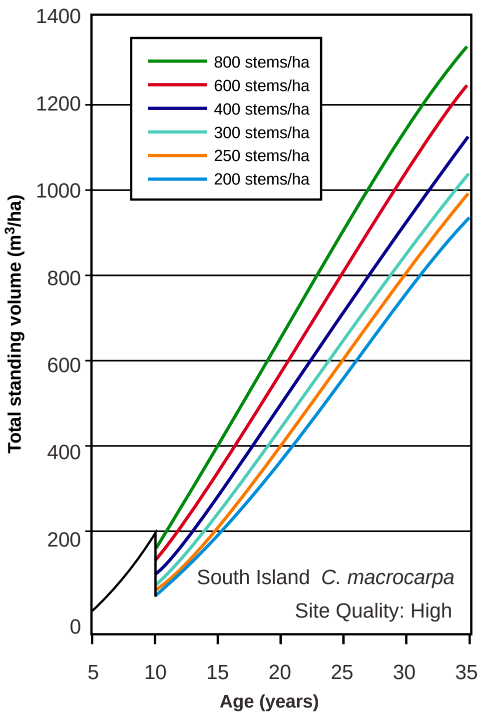
	Region	Lusitanica No. plots	Lusitanica Max. age	Lusitanica Max. MAI (m^3/ha)	Macrocarpa No. plots	Macrocarpa Max. age	Macrocarpa Max. MAI (m^3/ha)
North Island	Northland	34	41	19.3	4	42	17.2
	Auckland	6	8	11.0	-	-	-
	Bay of Plenty	47	41	24.6	20	39	15.6
	Waikato	33	67	19.8	23	61	22.6
	Gisborne	20	31	20.3	3	4	6.3
	Hawkes Bay	10	28	26.0	-	-	-
	Taranaki	1	32	19.6	1	33	29.0
	Wanganui/Manawatu	3	31	17.5	10	34	20.0
	Wellington	3	13	18.5	6	51	22.9
	All regions	**157**	**67**	**26.0**	**67**	**61**	**29.0**
South Island	Nelson	1	13	11.4	8	36	4.7
	West Coast	8	14	9.2	7	16	18.9
	Canterbury	-	-	-	21	55	16.9
	Otago	-	-	-	53	72	36.1
	Southland	-	-	-	7	18	16.4
	All regions	**9**	**14**	**11.4**	**96**	**72**	**36.1**

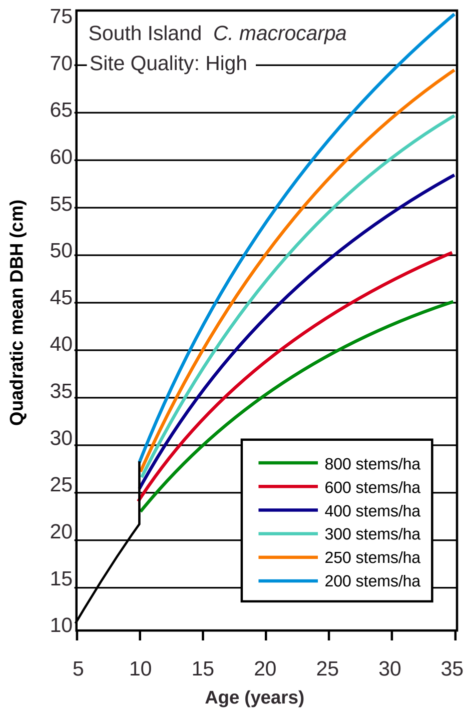
The model can be started with default or user-defined values for tree height, diameter, age and stocking. The model user can schedule thinning, and "grow" the trees forward in time, observing the influence of stocking and site quality on average tree diameter and total standing volume. The model can be used to find the rotation length needed to achieve a target average tree diameter for any given stocking, or to find the stocking needed to produce a target average tree diameter over a set rotation length.

The following graphs show various simulated model runs designed to demonstrate the influence of final crop stocking, multiple thinnings and site quality on cypress growth and yield for North Island lusitanica(top) and South Island macrocarpa (bottom). In the following examples, starting values for 1100 stems/ha planted on a high-quality site (90th percentile of all NZ data) were grown to age 10, and thinned to a range of final crop stockings demonstrating the influence of stocking on volume and tree size.

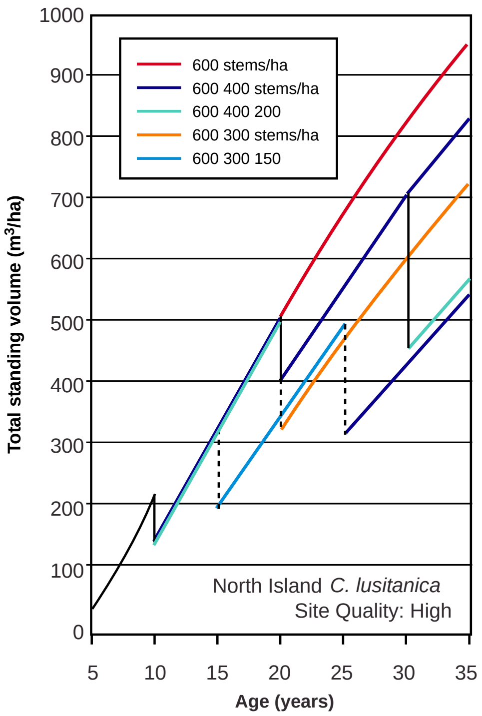

800 stems/ha
600 stems/ha
400 stems/ha
300 stems/ha
250 stems/ha
200 stems/ha
North Island C. lusitanica
Site Quality: High
Total standing volume (m³/ha)
Age (years)

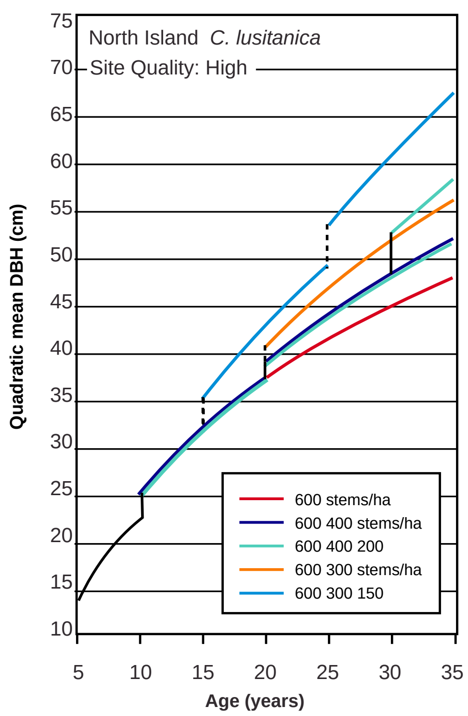

North Island C. lusitanica
Site Quality: High
800 stems/ha
600 stems/ha
400 stems/ha
300 stems/ha
250 stems/ha
200 stems/ha
Quadratic mean DBH (cm)
Age (years)

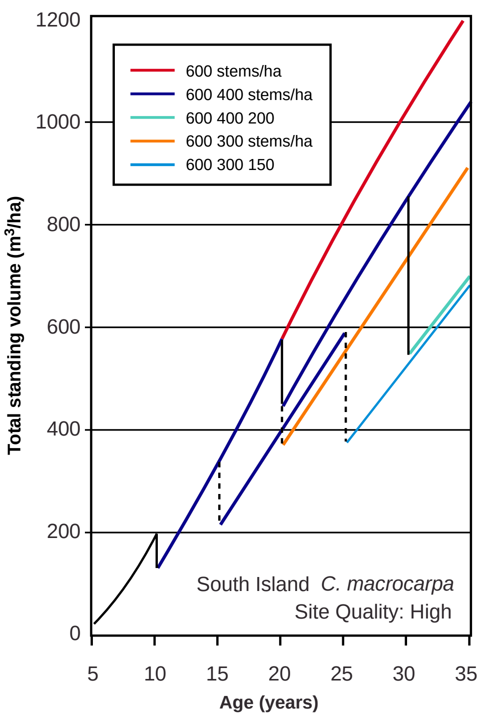

800 stems/ha
600 stems/ha
400 stems/ha
300 stems/ha
250 stems/ha
200 stems/ha
South Island C. macrocarpa
Site Quality: High
Total standing volume (m³/ha)
Age (years)

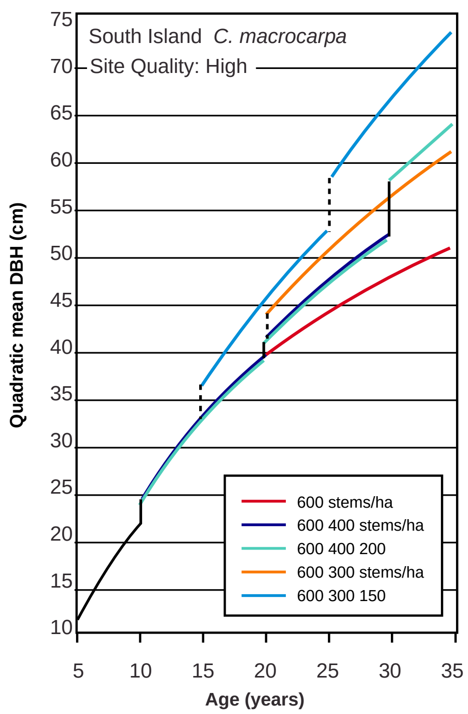

South Island C. macrocarpa
Site Quality: High
800 stems/ha
600 stems/ha
400 stems/ha
300 stems/ha
250 stems/ha
200 stems/ha
Quadratic mean DBH (cm)
Age (years)

Thinning is modelled "from below" where smaller trees are removed. The following graphs show 1100 stems/ha thinned to 600 stems/ha at age 10, and various later thinnings again for lusitanica (top) and macrocarpa (bottom). Total standing volume is reduced, but average tree diameter increases as a result of thinning:

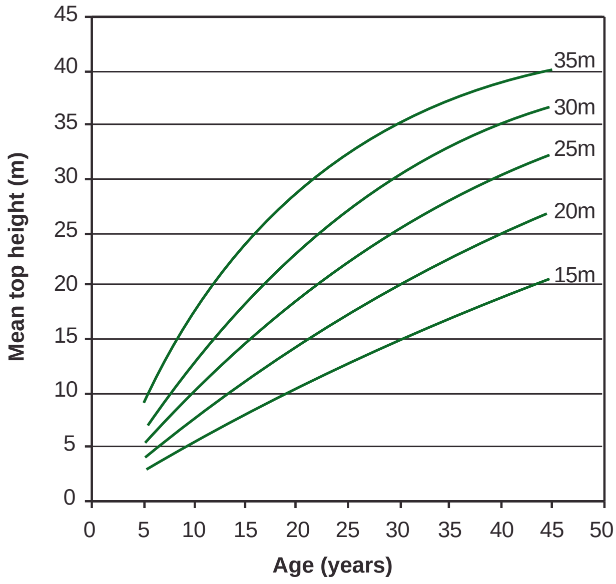




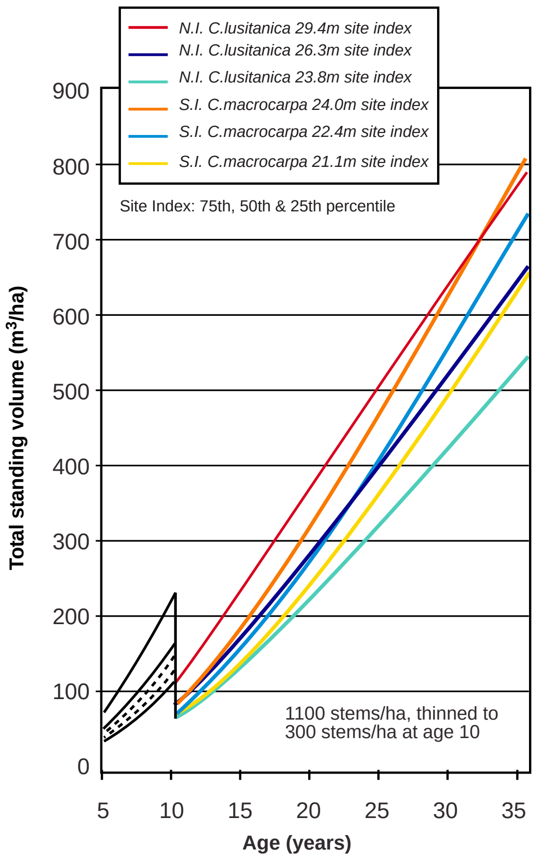


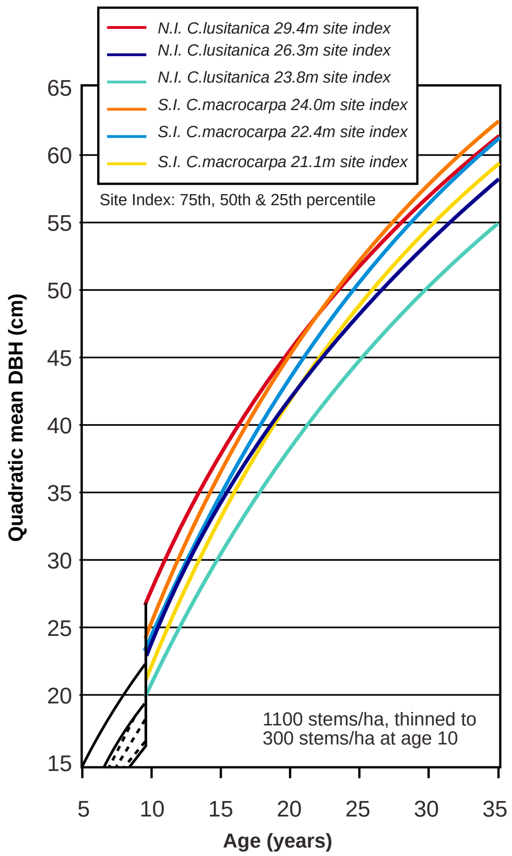


The graph on the right shows site index curves that approximately encompass the range of cypress mean top height and age data around New Zealand. Site Index is the expected height at a given age (30 years for cypresses). Mean top height is the average height of the 100 largest-diameter stems/ha.

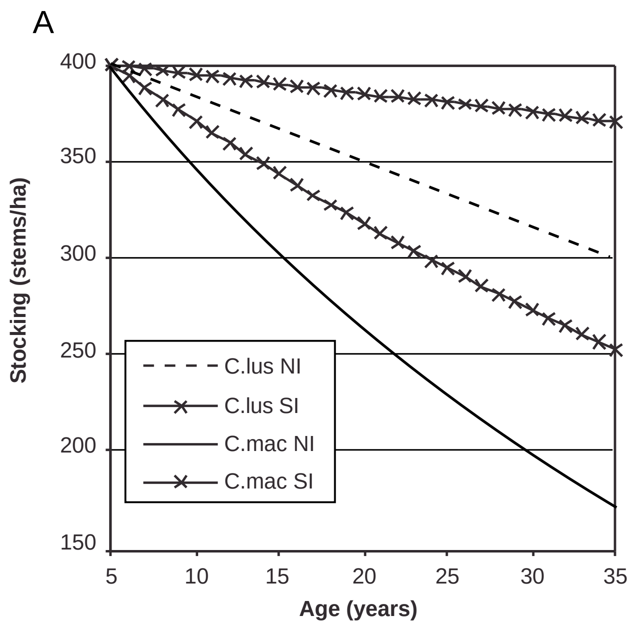


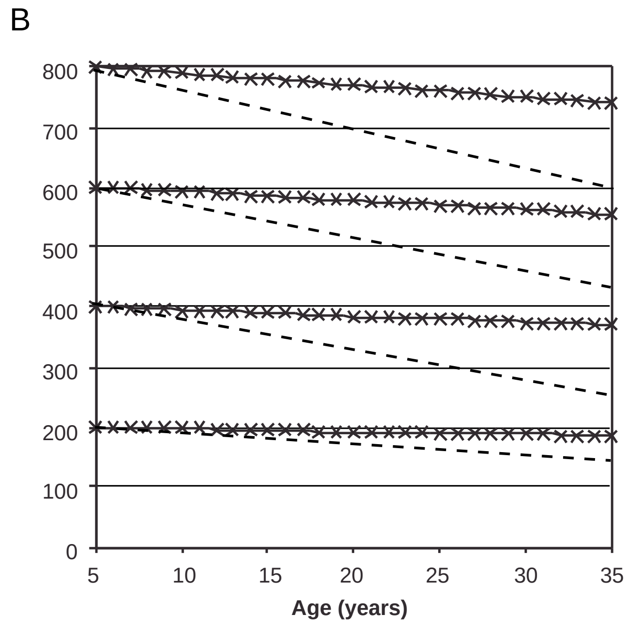
Cypress growers should set up sample plots to monitor tree growth and obtain starting values for growth model projections. Tree growth data from your own land, or possibly neighbouring land, probably give better starting values than the model defaults. Height and age data give site index (defined as mean top height at base age 30 years), while stocking and average diameter give basal area (m^2/ha) starting values. In the graphs below, the 75th, 50th and 25th percentile of NZ data show the important influence of site quality on growth rate i.e., 300 stems/ha of lusitanica on the poorer site reach 50 cm average diameter 6 years later than 300 stems/ha on the better site:





The data used to develop the cypress growth model showed that cypress mortality varies widely between species and sites. The following graphs show mortality model predictions for 400 stems/ha at age 5 (A), and North Island lusitanica and South Island macrocarpa stands with 200, 400, 600 and 800 stems/ha at age 5 (B):





The cypress growth model does not consider the effect of pruning intensity on tree growth. The model considers pruning effects implicitly (by default) because data used to develop the model came mostly from pruned stands, but prediction errors may result if starting values are obtained from young stands where severe early pruning has temporarily slowed diameter growth.

For example, annual pruning to leave 1 m of green crown length has temporarily slowed the diameter growth of these age-4 lusitanica trees planted on an ex-pasture site near Gisborne.

Lusitanica pruned annually to 1 m green crown length, resulting in reduced diameter growth.

The preliminary model predictions of cypress growth and yield presented in this chapter may be quite different from growth on your land, but should help with decisions such as management regime design by demonstrating the important influence of stocking and site quality on tree and stand growth. Model users are reminded that total standing volume includes non-recoverable waste volume such as defects, breakage, tops and cutting waste that can account for a significant portion of total standing volume. Further research is needed to identify and quantify the influence of various factors affecting cypress log grade recovery.

Key Points

- Current regimes suggest final crop stocking of 300 stems/ha, pruned to 6 m.
- The cypress growth model can be used to design regimes that match the owner's objectives, such as finding the optimal stocking for a given rotation length and target tree size.
- Final crop stocking has a major influence on volume production and average tree diameter development.
- Site quality also has a major influence on volume production and average tree diameter development.

Suggested reading:

Berrill, 2004.

Somerville, 1993.

Hay *et al.* 2005.

CHAPTER 9 - ECONOMIC ANALYSES

Contributing authors John Cawston and Ian Nicholas

Prime logs ready for loading.

INTRODUCTION

The economics of growing cypresses are of considerable interest to many. How does the investment in cypress forestry compare with other land uses? As with many economic discussions, it can be summarised by the words "it all depends!"

Published economic studies of cypress forestry have shown a range of values, reporting IRRs (internal rate of return) from 4 to 8%. In comparison, the same studies calculated radiata pine figures range from 4 to 9.9%

However cypress forestry is not as refined as radiata pine forestry, which means that there are more assumptions used in an economic analysis of cypress forestry than with radiate pine. This means that calculated returns often tend to err on the conservative side. The following is presented as a guide only and should not be used as a basis for any large-scale investment. Seek professional advice before making a significant investment in a cypress forestry project. The values used are based on best estimates, but note that land values have not been included in these calculations.

Using the recommended regime discussed in Chapter 8, the range of log types from MARVL analysis, an estimate of cypress forestry has been conducted. With a rotation length of 35 years, this example estimates an IRR of 8%.

Table 7: Estimated costs used in financial analysis

Operation	Stand age	Cost ($/ha)
Land cost		0
Land prep	0	40
Tree stocks	0	375
Planting	0	250
Releasing etc	0	235
First prune	6	825
First thin	6	350
Second prune	8	300
Third prune	10	650
Second thin	10	350
Annual costs		60

The estimated costs used for the economic analysis are shown in Table 7. As more experience is gained and larger areas of plantations are established better information on costs will be derived.

Other costs

Management (15% of costs)
Roading, log, load, and fees $47/m^3$

Harvesting operations in progress

Yields

The calculation of yields at rotation age is difficult because of a lack of well-tended stands. Evaluation of MARVL analysis, actual recoverable volumes, data from the national PSP data base, and growth model predictions have been used to estimate recoverable yields.

Total standing volume is estimated as 600 m^3/ha. Of this it is estimated that 92% is recoverable volume, resulting in 550 m^3 available for utilisation.

This is estimated to be made up of 250 m^3 of pruned and 250 m^3 of branched sawlog material. Within the pruned component it is estimated 80% is high-quality pruned logs and 20% is lower-grade pruned logs. Within the branched sawlogs, it is estimated that 60% is small-branched logs and 40% is large-branched material. It is estimated that 10% of the branched material is non-sawlog or firewood material.

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Revenues

Revenues are based on 250 m^3 of prime pruned sawlogs, 150 m^3 of second grade pruned sawlogs, 150 m^3 of small-branched logs,
100 m^3 of large-branched sawlogs, and 50 m^3 of firewood. With log values per cubic metre of $240, $160, $90, and $60/ and $0, respectively, this provides a total estimated revenue of $52,000/ha. More data collection and full details of harvested tended cypress stands are required to validate these estimates.

Sensitivity

The base case estimates an IRR of 8%. Sensitivity to changed variables, but keeping everything else consistent, provides an indication of important aspects of the economic analysis. Revenue needs to lift to $72,000 for this evaluation before IRR reaches 9%. If yield is reduced by 25%, IRR drops from 8% to 7%.

If land cost at $4,000/ha is included, IRR drops to 5.6%. If seedling costs are doubled IRR is reduced to 7.7%.

As the figures used in this analysis are of a general nature, more detailed site-specific analysis figures evaluated by professional advisers on a case by case basis should be used before investing in cypress forestry .

Macrocarpa logs of variable quality ready for loading.

Key Points

- Analysis of cypress forestry suggests possible IRR of around 8%.
- Improved log prices will mean a significant improvement in IRR.
- Seek professional input before large investment in cypress forestry.

Suggested reading:

Cavanna and Glass 1985

Maclaren 2005

Herbert 1994

CHAPTER 10 - UTILISATION

Contributing authors John Turner, David Page and Ian Nicholas

Preparing 21-year-old cypress trees for sawing

INTRODUCTION

Considerable experience has been gained in processing cypress logs.

Commercial experience has shown all cypresses are easy to saw, and there are few signs of growth stress. Saws and cutting patterns normally used for cutting radiata pine are satisfactory. Detailed research evaluations have helped understanding of the issues in cypress utilisation. These evaluation have covered a range of stand types. The following summarises four of them.

SAWING STUDIES

(i) Lusitanica - Whangamata

In 1988, 22 trees of 58-year-old lusitanica from Tairua Forest, near Whangamata, were selected for a timber grade study. Logs were selected on the basis of a MARVL assessment comprising 5 log types:

A. Pruned (>30 cm SED)

B. Small branches (<6 cm)

C. Medium branches (6-14 cm)

D. Small log (20-30 cm SED)

E. Large branch (>14 cm, and >30 cm SED)

The weight to volume conversion factor for logs averaged 1.122m^3/tonne, and 75% of volume was heartwood. Eighty-four logs were recovered, and overall sawn conversion was 58%.

Pruned logs were sawn to 25 and 40 mm thickness, and unpruned logs predominantly sawn to 54 mm for structural timber, or later re-sawing to 25 mm boards.

Yields from the pruned logs (A) were good, 78% of sawn boards graded to NZS 3631 1988 were Select B or better, including No. 1 cuttings (Premium). Yields from log types B and C were a little disappointing as appearance grades (B and C, 46% and 32% Premium respectively) due to high incidence of dead/or decayed knots; however, grade outturn as structural timber was better (B logs) 86% and (C logs) 41% No.1 framing). Small logs (D) sawed well as either appearance (62% premium) or structural grades (58% No.1 framing). Big branched logs (E) were considered marginal as sawlogs with 34% premium, or 25% No.1 framing, due to large intergrown knots.

Timber from the unpruned logs was tested for bending stiffness (MoE) as a plank and, when results were combined with earlier small clear tests on samples from the same location, indicated that the timber should perform structurally as well as 30-year-old radiata pine.

(ii) Macrocarpa - Wanganui

In 1991, 15 trees of 27-year-old macrocarpa from Lismore Forest (near Wanganui) producing 15 pruned butt, 15 unpruned second, and 9 unpruned third logs, were sawn and graded as boards. Additionally, pulp trials were carried out on chipped mill off-cuts and pulp log samples.

Sawn conversion was 52% for butt, 49% for second and 43% for third logs. The lower conversion of the upper logs was associated with smaller size and asymmetry. Pruned butts produced 73% clears and clear cuttings of sawn timber (graded to a modified NZS 3631 1978). The corresponding values for second and third logs were 13% and 8% respectively. However, a large proportion of the remaining timber in the second and third logs made dressing grade. It was noted that 10 of the 15 trees had insect attack (mainly NZ two-tooth longhorn borer), associated with large pruned branch stubs. This attack affected 5% of sawn timber. Heartwood in logs averaged 70% butt, 64% second, and 56% for third logs.

Investigation of pulping properties indicated that macrocarpa might be used for Kraft pulp as a part mix with more favoured species, but was unlikely to be used for thermomechanical or chemithermomechanical pulp.

In 1993, an end-use study by two experienced macrocarpa timber users, assessed the 27-year-old plantation grown macrocarpa. A broad number of processing operations were assessed including sawing (crosscutting), planing, turning, sanding, nailing, gluing, staining, using clear and tight knot (<50 mm) timber. Both users agreed that this younger timber was suited to the same remanufacturing uses as older timber. No effect of tree age on the machining properties was observed, although the wider growth rings were considered less visually attractive. Of particular note was reference to the dried quality of the samples assessed. The wood was very stable during and after resawing and this was attributed to the evenness of drying of the samples.

Check out latest cypress handbook chapters at www.nzffa.org.nz

(iii) Macrocarpa, lusitanica and Leyland cypress - Rotorua

Pruned demonstration plots of cypress, aged 21 years and grown in Rotorua, were harvested in 2003. Twenty trees of lusitanica, seven macrocarpa, and twelve of Leyland cypress were sawn to 50 mm thickness, slowly air dried, and finally kiln dried. Sawn timber recovery was 50-60% for all log height classes and species except for butt logs of macrocarpa, attributed to fluting and taper. The trees were cut into 3-m sawlogs, sawn to 150 × 50 mm and 100 × 50 mm sizes, slowly air-dried, then kiln-dried and dressed. Lumber was graded visually as appearance and structural grades. All boards were tested for long-span bending stiffness and some were tested for bending stiffness and strength.

With appearance grading, lusitanica produced the best recovery of 48% Dressing and 24% Merchantable, Leyland 38% Dressing and 44% Merchantable, and macrocarpa 33% Dressing and 21% Merchantable. Knot checking was the worst defect in lusitanica, surface checking in macrocarpa, and loose pruned branch stubs in Leyland cypress. Visual framing grades were highest for Leyland cypress 78% No. 1 Framing, 71% for macrocarpa, and 59% for lusitanica, the latter mainly due to warp, a major cause of degrade for this species.

Bending stiffness (MoE) of lusitanica was 4-6 GPa, while macrocarpa and Leyland cypress were 6-8 GPa. Bending strength (MoR) for the above three species was 21.3 MPa, 31.4 MPa, and 28.0 MPa respectively.

Macrocarpa and Leyland cypress had similar stiffness properties to radiata pine from forest sites (though these were from appreciably older and larger-diameter trees). Note that these figures for strength properties differ from those in Table 1, because Bier and Britton reported on data for small clears only, harvested from mature stands, compared with boards from young stands in this study.

The cypress appearance and structural lumber characteristics are expected to have improved with material from older trees benefiting from the addition of more rings of outerwood. Despite the known uniformity of wood density, wood stiffness increased strongly from pith to bark, suggesting that cypress corewood requires further evaluation.

> The conclusion from the study was that there was no superior cypress for timber properties – the different taxon sampled had good and bad points.

Sawing 21-year-old cypress logs.

(iv) Macrocarpa-Wairarapa

In 1985, 15 trees from a high-pruned woodlot in the Wairarapa were sawn. The stand was 52 years old, standing at 415 stems/ha, mean diameter at breast height of 56 cm, and a mean height of 29 m.

Fifteen trees across the quality spectrum were selected for sawing. This provided 28 pruned logs and 29 unpruned, ranging in length from 3.7 to 5.5 m. The smallest tree was 27 cm DBH and the largest 88 cm.

Overall conversion of the study was 54%, Premium grades 72%, 42% clears and 30% of select. Factory grade was 4%, Utility grade was 15%, and box or rough grade 9%.

Key silvicultural comments from this atypical stand were:

High initial stocking allowed excellent selection for form.

Delayed final thinning ensured branch size was well controlled.

Two log prunings improved the crop.

Defect cores were well controlled.

Rotation age could have been reduced, but this would have reduced heartwood percentage.

Check out latest cypress handbook chapters at www.nzffa.org.nz

DRYING

Macrocarpa timber from shelterbelt trees is particularly difficult to dry. It is prone to collapse and internal checking. Plantation-grown wood appears to be less susceptible to these problems. For shelterbelt trees, it is recommended that wood is initially air-dried down to around 30% moisture content (mc) in protected, evenly filleted stacks before final kiln drying. Plantation-grown macrocarpa can be kiln dried from green provided low temperatures (40-45°C) are used for the majority of the drying cycle. Because of the need for such low temperatures, dehumidification drying is recommended as the ideal method for drying. Although lusitanica and Leyland cypress are similar in drying properties to plantation macrocarpa, air drying down to 30% mc before kiln drying is still recommended to minimize any drying variability and tendency to knot check.

A 1979 drying study of lusitanica indicated knot checking was the worst defect. Slight crook and twisting did occur. The variability of drying from green in a kiln, trying a number of schedules, suggested that the wood should be air dried to below 30% mc before finishing in a kiln. Suggested kiln schedule after air drying was 60/50°C.

Two drying studies (1967 and 1969) of macrocarpa found that it was not possible to dry the timber sawn from knotty shelterbelt logs without considerable degrade whether air dried, forced air dried, or kiln dried. Air drying and forced air drying resulted in surface and end checking, and kiln drying in end and internal checking. Air drying before kiln drying eliminated internal checking but exterior degrade was just as bad. It was concluded that macrocarpa of this type would be more suitable for rough farm construction and similar uses.

A 1985 paper reviewing the drying of NZ cypress species, identified old shelterbelt macrocarpa as having excessive collapse and internal checking after kiln drying. Careful air drying, followed by mild kiln or dehumidification (less than 50°C) was recommended.

Plantation-grown macrocarpa and lusitanica could be kiln dried from green if temperatures were kept below 45°C; however, air drying before kiln drying was preferable. Lawson cypress and Leyland cypress showed generally low shrinkage and were not prone to internal checking or collapse when kiln dried from green (71/60°C schedule).

For all cypresses in general, preliminary air drying to 30% mc followed by kiln drying will give best results.

Lawson cypress is not so prone to collapse or internal checking and can be kiln dried from green. Timber that is 50 mm thick is reported to take 4-5 days at 70/60°C, including 6 hours of final conditioning for drying stress relief at 75/74°C. The more even the final drying moisture content to the equilibrium moisture content, the more stable the wood will be.

DURABILITY AND PRESERVATION

The cypress species, macrocarpa, lusitanica and Lawson cypress all have heartwood in Australasian durability Class 3, i.e., in testing of ground contact 50 x 50 mm stakes, they have been shown to have an average life of 5-15 years. The average life is towards the upper end of this range but a few early failures occurred in the tests. The sapwoods are all perishable but can be treated by boron diffusion, although in practice timber containing sapwood is confined to interior use only.

No information is available for NZ-grown Leyland cypress timber, but overseas reports indicate it is likely to be as durable as the others.

Away from ground contact but fully exposed to the weather the average life of 50-mm-thick cypress heartwood is 15-25 years. This is similar to the durability that could be expected from timber treated to the H3.1 specification with light organic solvent preservatives (LOSP), although there is usually more variability in naturally durable timber than in treated radiata pine sapwood. Horizontal, upward facing surfaces, end grain, and joint areas where water can be trapped are most susceptible to decay. If the surfaces are only partly exposed to the weather, are vertical or steeply sloping, and not end grain, the chances of decay are relatively low and service life will be considerably longer.

Large dimension components are likely to have a much longer service life than 50-mm -thick timber, e.g., 100-mm-thick timber could be expected to have approximately twice the service life of 50-mm-thick material. Any decay that develops will be progressive so the effective dimension of components may diminish with time. If components are carrying a heavy load, or are in a critical structural situation, then they may need to be replaced in a shorter time.

Cypress heartwood is resistant to preservative penetration (refractory species) and there is little to be gained by putting it through a preservative treatment process. The sapwood is not durable and poor penetration is likely when conventional pressure processes are used. It can be treated when freshly sawn using boron and diffusion processes, but this type of treatment is unsuitable for components that are exposed to the weather.

There are brush-on preservative products available which may extend the life of untreated wood in low-to-moderate decay-hazard situations. Products containing water repellents and wood preservative chemicals are the most effective, but they should be regarded as providing relatively short term, surface protection only. Our testing indicates that the service life of sapwood or some less durable heartwood can be extended by regular coating. The effect of preservative/water repellent mixtures on moderately durable heartwood is less clear and regular use may do little more than reduce variability.

The pale colour of Lawson cypress heartwood makes it difficult to differentiate between heartwood and sapwood in finished products. Pieces containing sapwood should be segregated out immediately after sawing if timber is to be used in external situations.

In Table 2A of NZS 3602:2003 “Timber and wood-based products for use in building”, dressing heart grade macrocarpa (*Cupressus macrocarpa*), Mexican cypress (*C. lusitanica*) and Lawson cypress are listed as suitable for external weatherboards without preservative treatment. In clause 111.2.5 of the Standard these same species are also listed as suitable for use in the “no finish” or “stained finish” condition.

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Outdoor cypress furniture

MACHINING

All cypresses machine as well as radiata pine with the same knife settings. They are reported to have slightly higher blunting properties than radiata and extractives can build up on knives.

Reported working properties:

Sawing – no problems.

Planing and moulding – good finish, even in areas of “cross grain” surrounding large knots provided knives are sharp.

Turning – turns well at higher speeds, similar tear out on end grain to radiata. Keep knives sharp and free of extractive buildup.

Boring – generally good, tendency for sides of hole to be torn if using twist drill.

Chiselling – some difficulty with lower density wood. The soft wood tends to compress rather than cut, sharp chisels are essential.

Sanding – Generally sands well, with little clogging. Care with sanding lower density wood. Lawson can irritate the mucous membrane.

Screwing and nailing – Recommended to predrill to avoid tendency to split.

Gluing – A variety of wood glues may be used.

Bending - The cypresses are reported to have poor steam bending properties.

Key Points

- No major utilisation problems
- Heartwood percentage related to age
- Sawing conversions range from 40-60%
- Drying schedules available

Suggested reading:

NZS 3602:2003

Haslett 1986

Haslett *et al.* 1985

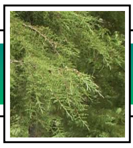
Clifton 1990

Park and Smith 1987

Somerville 1993

Low *et al.* 2005

http://www.scionresearch.com/nzjfs+articles+to+download.aspx.



CHAPTER 11 - SUMMARY

Ian Nicholas and Denis Hocking

The cypresses, specifically macrocarpa from Monterey, coastal California, lusitanica from the mountains of central Mexico, the Leyland and ovensii hybrids and, on some very dry sites, *Cupressus torulosa*, are well suited to plantation forestry under New Zealand conditions. They are relatively straightforward to grow and tend, flexible in rotation length, and produce highly regarded, high quality, and high value timbers.

Generally cypresses prefer well-drained sites with moderate to good fertility and rainfall greater than 800 mm. Macrocarpa and Leyland cypresses are better suited to colder and more exposed sites, but macrocarpa in particular is very susceptible to cypress canker on warm exposed sites. Lusitanica and ovensii prefer sheltered sites with lusitanica thriving on warmer sites. Lusitanica does not tolerate salt-laden winds. However, cypresses are sometimes being successfully grown outside these ranges and they should be regarded as guides, not limits.

The most serious problem with cypresses is the disease, cypress canker. But this reflects, in large part, our insistence on growing macrocarpa in preference to other cypresses, and putting it on inappropriate warm, exposed sites.

Cypresses are poised to be the third most important genus in New Zealand plantation forestry. They already have excellent market acceptance, with a substantial price advantage over radiata pine and a major premium for quality. Export prospects for eastern Asia are very promising, but currently the domestic market remains under-supplied.

Success with cypresses needs good matching of species and sites, good establishment, and timely and appropriate silviculture. As in all commercial undertakings, neglect is not a good recipe for success.

Breeding programmes for both macrocarpa and lusitanica were started in the early 1980s, and more recently clonal programmes have been initiated, including selections for canker resistance. There is also interest in breeding new hybrid genotypes for New Zealand conditions and this is currently being researched.

CHAPTER 12 - REFERENCES AND WEBLINKS

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www.ensisjv.com	www.timberworks.com
www.kiwibackyard.co.nz	

GLOSSARY

Anti-transpirant: A treatment given to planting stock that limits water loss via transpiration and, therefore, minimises stress during and immediately after planting.

Adventitious shoots: New shoots initiated in response to propagation treatments such as topping or hedging.

Appearance grade: Grades of timber for finishing and other uses determined basically from the appearance of the better face and edge, usually clearwood.

Bare-rooted planting stock: Plants (seedlings, cuttings or other) grown in open nursery beds rather than containers and lifted and planted with much of the soil gone from their roots.

Basal Area: The cross sectional area of all tree stems in a stand, measured at breast height and per hectare of land.

Basic Density: The average density of the wood at 0% moisture content.

Breeding: Intensive selection and subsequent mating of top selections to achieve cumulative genetic gain over time.

Breeding population: The population in which breeders carry out intensive selection and genetic recombination. It comprises the selections that are intermated and their resulting offspring. It requires a broader genetic base than the seed production (orchard) population.

Cambium: A layer of rapidly growing cells between the bark and the wood, from which new wood and bark develop.

Chemithermomechanical (CTMP) pulp: A high yield pulp, where wood particles have been cooked with various chemicals, and have been softened by preheating under pressure, prior to refining.

Clearwood: A length of timber which is free of knots due to branch removal, usually achieved by pruning.

Clearfell or Clearcut: Harvesting of trees in which essentially all trees are removed in one operation.

Checking: The separation of wood fibres on a piece of timber during the drying process.

Clone: A group of genetically identical plants, which have been vegetatively propagated from a single individual.

Clonal forestry: Establishment of plantations with a restricted number of vegetatively propagated clones. These clones have been tested and selected in clonal tests, the best being subsequently mass produced.

Clonal trial: Evaluation of the relative performance of clones in a replicated field trial.

Compression wood: Reaction wood formed on the lower side of crocked or leaning stems. Characterised by dense, heavily lignified cells and tends to cause distortion and splitting during the drying of timber.

Continuous cover forestry: Silvicultural management of stands, via selective harvesting of stems, so as to retain a canopy cover.

Controlled pollination: The transfer of pollen from a known source to receptive flower parts of known seed parents, all other pollen being excluded (by covering flowers with isolation bags prior to pollination).

DBH: Diameter at breast height of tree stems, at 1.4 m in New Zealand.

Family: A group of individuals directly related by descent from a common ancestor.

GLOSSARY

Family forestry: Families deployed operationally in plantations as single family blocks, (either directly as seedlings or vegetatively multiplied). These families are usually full-sib, i.e. from controlled pollination.

Fluting: The development of longitudinal grooves in the lower part of the tree stem. Can lead to loss of harvestable timber, due to deviation from a circular cross section and included bark.

Genetic diversity: Amount of genetic variation in a population.

Genetic gain: The average improvement in a progeny over the average of the parents. Gain is achieved by selection and mating of top parents.

Genotype: (1) An individual's genetic make-up, or (2) Individual(s) characterized by a certain genetic constitution.

Hardness: A property of timber that enables it to resist indentation.

Heartwood: The inner, nonliving part of a tree stem. Natural chemicals are often deposited in the heartwood, making it more durable and darker in colour than sapwood.

Hedging: Repeated top-pruning of a tree; in this context to arrest further maturation.

Hybrid: The offspring of parents that have distinct genetic differences. Can apply to the progeny from matings within species (intraspecific) as to those between species (interspecific). Hybrids combine the characteristics of the parents or exhibit new ones.

Hybridisation: The mating of parents that have distinct genetic differences to create hybrid progeny.

Inter-fertile: Related individuals that readily and naturally cross pollinate to produce viable hybrid progeny.

Intergrown knots: A live knot that is wholly intergrown with fibres of the surrounding wood.

IRR (Internal Rate of Return): The discount rate that equates the various costs and benefits anticipated in future years of forestry (or other) operations.

Knots: A cross section of a branch that is imbedded in timber. The knots can either be live knots (branch was living when the tree was cut) or dead knots (from a dead branch) which often fall out.

Land race: A population within a species that exhibits adaptive characteristics. This term is often used to describe populations of introduced species that have become adapted over several generations to their new environment through natural selection.

MARVL: Method to Assess Recoverable Log Type by Volume.

MAI (Mean Annual Increment): The total increment of a stand up to a given age, divided by that age. Includes thinnings as well as standing crop.

Maturation state: (syn. physiological age) A particular developmental state along the continuum of complex physiological changes, which plants undergo as they progress from an embryonic state, through to juvenile and then to a mature condition. Generally dominated by total distance along the stem and/or branch from the original root:shoot junction. However, it can be accelerated by some nursery treatments, or arrested by treatments such as hedging. Very difficult to reverse in woody plants, except during sexual reproduction.

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GLOSSARY

Mean (arithmetic mean): the average value for a set of observations, obtained by dividing the sum of all observations by the total number of observations.

MoE (modulus of elasticity): A measure of stiffness in sawn timber.

MoR (modulus of rupture): A measure of bending strength in sawn timber.

Mouldings: High grade timber, usually clearwood, sawn for specific end uses, e.g., skirting.

MTD: (Mean Top Diameter): The average diameter of the largest 100 stems/ha in a stand.

MTH (Mean Top Height): The average height of the largest 100 stems/ha in a stand.

Native population: (syn. native provenance) A group of naturally growing trees found at a particular geographic location, within the native range of the species.

Physiographic: Pertaining to the landform and underlying geology.

Pith: The central core of a stem & roots, representing the first year of growth.

Progeny trial: Evaluation of parents by comparing the performance of their offspring in replicated field trials.

Propagation: Multiplication of plants. Can be either via sexual reproduction (seed production) or via asexual means (vegetative propagation).

Provenance: The original geographic source of seed, pollen, or trees.

Provenance test: A replicated field trial comparing the performance of trees grown from seed collected from different parts of a species' geographic range.

PSP plots (Permanent Sample Plots): permanent plots that have been set up throughout the plantation estate, to provide growth information for the national database on the plantation resource.

Resistance: The relative ability to endure pests or other damaging influences. It may vary in degree from immunity, in which the attack or influence is completely without effect to absolute susceptibility, which may result in death.

Sapwood: The outer layers of a tree trunk, which are composed of living cells and conduct water up the tree. Generally lighter in colour than heartwood.

Sarking: Internal roof panelling.

Sawlog: A log that meets standards for diameter, length and defect, which is intended for sawing.

SED: The small end diameter of a sawlog.

Seedlot: A collection of seeds, usually of known origin.

Seed orchard: A plantation of selected trees, established and managed primarily for the early and abundant production of genetically improved seed. The seed orchard is isolated to reduce pollination from outside sources, and trees with undesirable characteristics are removed, based on ongoing evaluations.

Seed stands: A well-grown stand of trees, with good growth and form, selected and managed for abundant seed production.

Seed stratification: A treatment given to seed to break dormancy and improve germination, which usually involves a moist chilling.

GLOSSARY

Shelterbelt: A strip of trees established to shelter farm or horticultural land from prevailing winds.

Site index: A measure of forest site quality expressed as the average height (actual or potential) in a specific stand of trees, at a specific age (30 years for cypresses).

Standing volume: The total volume of harvestable trees in a stand.

Stocking: The number of trees in a given area of a stand.

Stool plant: A plant grown in a nursery bed, which has been hedged or topped to produce adventitious shoots, which are subsequently used for vegetative propagation.

Thermomechanical (TMP) pulp: A high yield pulp, where wood particles have been softened by preheating under pressure prior to refining.

Tissue culture: (syn. micropropagation) Growing plantlets from small pieces of plant material on artificial media in a sterile, laboratory environment.

Tree improvement: Usually synonymous with tree breeding, but may also refer to breeding in combination with cultural practices, particularly propagation.

Veneer: A thin sheet of attractive wood, used to cover wood of lesser value.

Vegetative propagation: (syn. vegetative multiplication) Multiplication of plants via asexual means, i.e. without sexual reproduction. Includes tissue culture, rooted cuttings, and grafting.

Virulence: The ability of an organism to cause disease.