



CHAPTER 5 - SEED SOURCE, BREEDING, AND PROPAGATION

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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.

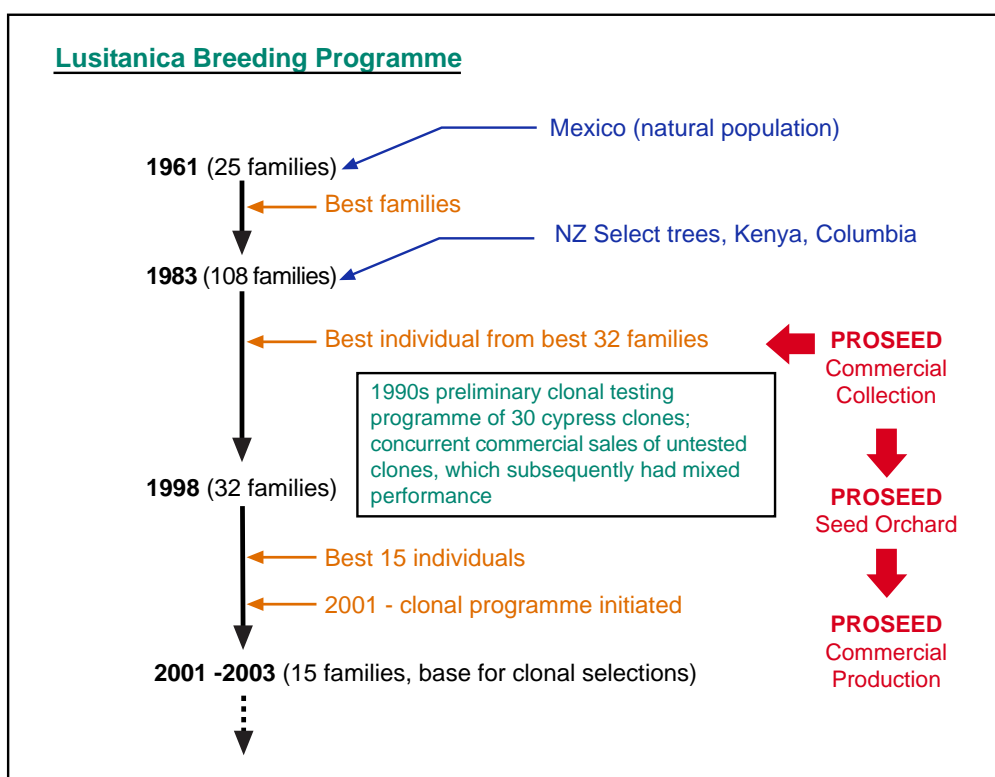
The progeny trials were assessed in 1993 and the best individual from each of the best 32 families was selected and grafted as a seed orchard candidate. The best trees in the top 32 families were then selected in 1998 and substantial commercial seed collections are now made annually by PROSEED. The first 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

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 Crocker's 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

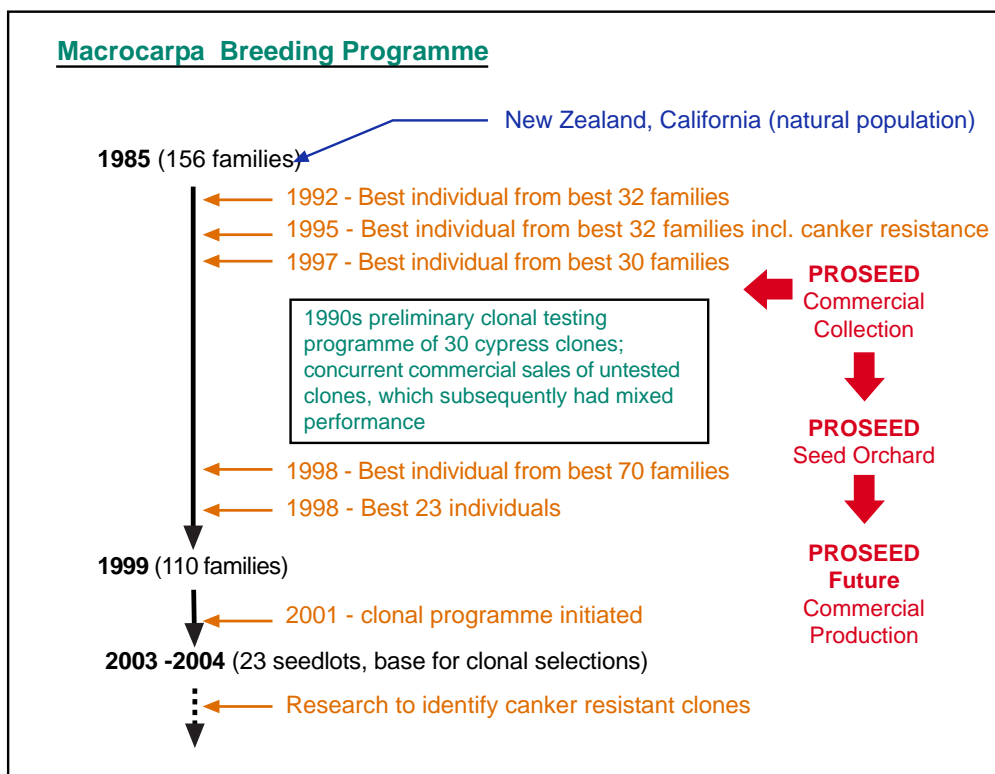
were designed as potential seed stands. The progeny trials were assessed in 1992 and the best tree in each of the best 32 families was selected as a seed orchard candidate. Some cypress canker was observed, particularly on the Gwavas site. In 1995, the trees on the Gwavas site were suffering heavy infection 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.

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

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.