An Australian Government Initiative

Joint Venture Agroforestry Program

Rural Industries Research & Development Corporation

Forest & Wood Products Research & Development Corporation

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Murray-Darling Basin Commission

Growing Rainforest Timber Trees

A farm forestry manual for north Queensland

A report for the RIRDC / Land & Water Australia / FWPRDC / MDBC Joint Venture Agroforestry Program

by Mila Bristow
Mark Annandale and Alan Bragg

RIRDC Publication No. 03/010

Photos:
L: Queensland maple in a monoculture plantation
R: Measuring a red mahogany thinning trial

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- Designing Farm Forestry Trials For Species And Provenance Selection
- Designing Silviculture Research Trials
- Site Evaluation For Farm Forestry

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Abbreviations

CRRP	Community Rainforest Reforestation Program
CSIRO	Commonwealth Scientific and Industrial Research Organisation
FWPRDC	Forest and Wood Products Research and Development Corporation
JVAP	Joint Venture Agroforestry Program
PMP	Property Management Planning
QFRI	Queensland Forestry Research Institute, now Department of Primary Industries and Fisheries – Horticulture and Forestry Sciences
RIRDC	Rural Industries Research and Development Corporation

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It was the vision of Rod Keenan (then QFRI) and David Lamb (University of Queensland (UQ) Botany Department) through the Cooperative Research Centre for Tropical Rainforest Ecology and Management (now CRC Rainforest) that initiated this project. On the ground the project was developed and coordinated by QFRI staff Mark Annandale and Mila Bristow, with contributions from Ken Robson and David Taylor, and countless support from Alan Bragg (then Department of Natural Resource and Mines). QFRI staff worked closely with landholders including Errol Wiles and Christine Doan, students and staff from University of Queensland's Botany Department and the Cooperative Research Centre for Rainforest Studies on this and other mixed species work.

The authors would like to particularly thank those who have provided written comments on the draft document. They were: Rohan Allen, Helen Favier, Susan House, Rosemary Lott, Deborah O'Connell, David Osborne, Rowan Reid, and David Taylor. Glenn Bailey (QFRI Extension Officer) wrote part of the information in the soils section of this manual (Chapter 5).

We would also like to acknowledge the considerable editing efforts of Fay Lewis and Rosemary Lott and recognise the superior construct and layout work of Cecile Ferguson.

Foreword

This manual is one in a series which aims to provide practical guidance for people wishing to establish farm forestry projects. It outlines the steps required to successfully establish rainforest timber trees, particularly in plantation situations, in the Wet Tropics of north Queensland. It was written for land managers (including farmers) and intermediaries such as farm forestry or agribusiness advisors.

The chapters in this book discuss what is known about growing native rainforest species on farms, the planning issues that growers need to address and the trees' requirements for successful establishment and early plantation management.

The manual is general in nature because the environment of northern Queensland varies from one part of the region to another. However, it describes general principles that can be applied to different sites and illustrates the management decisions involved, using case studies based on north Queensland research. The final chapter presents a case study based on a mixed species plantation in north Queensland. This demonstrates the site specific issues that were considered, and the management options which were adopted to suit the site. The manual also has a list of publications (entitled *Further reading*, Appendix 1) which contain additional information that may be relevant to your situation.

This project was funded by the Natural Heritage Trust through the Joint Venture Agroforestry Program (JVAP). The JVAP is supported by three R&D corporations—Rural Industries Research and Development Corporation, Land & Water Australia, Forest and Wood Products R & D Corporation, together with the Murray-Darling Basin Commission. The R&D Corporations are funded principally by the Australian Government. State and Australian Governments contribute funds to the MDBC.

This report, a new addition to RIRDC's diverse range of over 1000 research publications, forms part of our Agroforestry and Farm Forestry R&D program, which aims to integrate sustainable and productive agroforestry within Australian farming systems.

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Tony Byrne
Acting Managing Director
Rural Industries Research and Development Corporation

Preface

Publication of this book *Growing Rainforest Timber Trees—A farm forestry manual for north Queensland*, represents a milestone which fills me with a certain amount of pride; a feeling of recognition at last.

I have learned that growing trees is like all forms of agricultural endeavour—it requires care and attention. If you want to get good results you have to commit to your trees as you would any other crop. If you give them the care and attention they really need, you will secure much greater benefits. While trees can surprise by doing well where you find it hard to believe any thing will grow, it still pays to carefully choose the right tree for the particular site and to care for it lovingly. Because our time horizons are so short we cannot replicate the conditions in the forest where a tree will survive in a near dormant state for years waiting for the right change in conditions to burst forth. We need to manage our trees so they grow quickly and efficiently. This guide is part of the armoury required to do that.

The range of uses to which you can put 'your trees' is many and varied. The great thing about trees is that the achievement of one objective does not preclude picking up a few bonuses from accomplishing others at the same time. Your objective may be to produce quality timber but in the process your trees will deliver other benefits as well: improve your visual environment; provide a wildlife habitat; reduce erosion and lower the watertable; provide shelter; and if you pick the species carefully, fodder for stock, all at the same time. We really haven't scratched the surface of medicinal uses of many of these species yet!

I must make this point to you: by joining our band of devotees at this time you are literally coming in at the mezzanine floor. Over the next few years—and you will be part of this new dawning—enormous progress will be made in the way we grow rainforest trees, the time it takes to maturity will decrease and improvement in the yield of quality wood will be nothing short of spectacular.

The range of micro climates and sites in north Queensland preclude this manual from delving into the finer points—it is not designed with that in mind. It is a practical manual that has general application: to guide you and help you avoid the worst pitfalls. However it comes with a host of references to other works so that it is reasonably easy to follow up on finer points and matters of importance to you!

I am sure this book will make the task easier.

Errol Wiles
Landowner
Mixed species trial site

Executive Summary

This silviculture manual is to assist forest growers to plant and manage rainforest timber trees, especially in plantations in the Wet Tropics region of north Queensland. Plantings can range from small woodlots in a mosaic of farmland to industrial-scale plantations. The report focuses on the 'getting started' information required by growers of rainforest timber trees, rather than on other more well-known hardwood or softwood species.

Growers need to take a series of steps to produce rainforest timber trees. The first of these is to identify their specific goals and this will define the balance between environmental services and economic production targets.

Selecting the species to grow is a crucial step. They not only need to grow well on the site, there should also be markets for the timber of the chosen species. The growth rates of most rainforest trees are slow under the conditions of their natural environment compared with other well-researched softwood and hardwood tree species. However, work completed by the Queensland Forestry Research Institute (QFRI) has demonstrated that significant productivity gains can be made in plantations with appropriate species selection, species-site matching, tree breeding and the development of appropriate management practices. Although future market demands are hard to predict, there are strategies which are likely to produce marketable timber.

Further steps include plantation design, site preparation (cultivation techniques, weed control, fertiliser application) and managing established stands of timber (pruning, thinning, weed control, fertiliser application) and guidelines for these stages have been developed. Documenting growers' experiences has provided a set of case studies which illustrate the decision-making processes and results achieved with different species.

Research trials and farmers' and extension officers'experiences have now established a body of information which can provide a foundation for new growers of rainforest timber trees.

1. Introduction

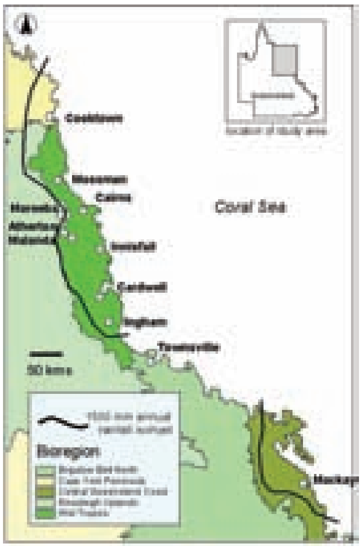


Figure 1.1: Map of North Queensland showing Wet Tropics Region, 1500mm rainfall isohyet, and major towns

Farm forestry is the practice of growing trees for the production of forest products either from purposely planted trees or from sustainably managed native forests. This manual was prepared in the former context.

The Wet Tropics region consists of a narrow coastal plain between Cooktown and Ingham rising to a steep escarpment and the Atherton Tableland, 50 to 100 km from the coast (Figure 1.1). Rainfall varies greatly over short distances, reflecting local topography and weather patterns. The coastal towns of Tully and Innisfail have annual average rainfalls well over 3000 mm; on the tablelands annual averages may be half this. Rainfall declines rapidly west of the escarpment and is highly seasonal with most rain occurring during the period from November to May, although the wettest areas receive appreciable rain in all months of the year.

Topography plays an important part in soil-forming processes and commonly soils on the lower slopes are derived from materials transported from upper slope positions. This results in deeper, more fertile soils in the gullies and shallower, less fertile soils on the slopes. Soils are derived from coarse granite on the mountains, basalt on the Atherton Tableland and extending to the coast in the Innisfail area, and mixed metamorphic or alluvial parent materials on the coastal lowlands.

There has been a long history of Aboriginal occupation and their connection with the land has been maintained in many areas of the Wet Tropics. The Atherton Tableland was opened up for agricultural selection in 1882 with extensive land clearing occurring through to 1910. In the north Queensland region sugar is the major agricultural crop. Tropical fruits, maize, peanuts, vegetables, dairying and beef grazing are also important industries. There was a substantial timber industry based on native rainforests until logging largely ceased with World Heritage listing of most of these forests in 1988. At the industry's peak it supplied about 200 000 m^3 of timber annually to a range of processors. By 2002, about 13 000 ha of plantations comprised mainly of the exotic Caribbean pine (*Pinus caribaea*) and smaller amounts of native hoop pine (*Araucaria cunninghamii*) had been established by the state on land cleared of native forest for the purpose and on marginally productive land purchased from dairy farmers.

Development of a timber industry based on plantations on unproductive cleared private land has been promoted in the region for some time (Gilmour and Reilly 1970; Tracey 1986). In 1992 the Community Rainforest Reforestation Program (CRRP) was established to support this development and to address land degradation problems, improve water quality and train a workforce in plantation management. This multi-objective program established a total of about 2000 ha of plantations of mixed native species from Mackay to Cooktown between 1992 and 1998 with a major emphasis on native rainforest species. The plantations are all small (generally less than 10 ha) and located on nearly 500 different properties.

The establishment of farm forestry plantations requires careful consideration and thorough planning. Some of the main questions to be considered are:

- How can you best integrate tree plantings into your farming enterprise?

- Which species will grow on your land?
- Which timber markets will you target?
- What management operations will be required?

There is a strong demand from landholders and forest growers for relevant information. This manual aims to play a part in addressing this demand. It is the product of a project entitled *Silviculture of Rainforest Cabinet Timbers* funded by JVAP and QFRI and includes results generated within the project, as well as those from other QFRI projects, contemporary literature, and advice from extension officers and forest growers in the north Queensland region.

The manual describes the stages involved in establishing and managing rainforest timber plantations in northern Queensland. It includes chapters on plantation design, species selection, soil evaluation, establishment and management operations, and marketing timber, and ends by documenting the approach taken by one farming family and the experiences that they have gained. Further sources of information are then listed in Appendix 1.

2. Planning to grow rainforest trees

***Farm forestry* is the term used to describe forestry that is planned, managed and conducted at the farm level; it aims to fit into existing farming culture rather than replace it (Reid and Stephen 2001).**

With the right planning it is possible to grow rainforest timber trees successfully. Success includes meeting your aspirations and maximising your benefits and those of the broader community. Once the decision has been made to plant trees, the next steps are to develop a Property Management Plan and to assess the various options for plantation designs. This chapter discusses these steps and then describes three design case studies.

2.1 Property Management Planning

A Property Management Plan (PMP) or whole farm plan allows farmers to identify all the relevant land-use and management options on their property. One of the intentions of developing PMPs is to help landowners secure the long-term viability of their properties. This is partly achieved by assessing the capability of the land, which can lead to improved productivity, prevention of land degradation and protection of biodiversity, as well as other benefits. A PMP is generally made up of a plan drawing, including a base map with an aerial photograph and clear plastic overlays, supported by written information indicating suitable ways to manage each area of the property.

Preparing a PMP involves a site evaluation and selection process and this will help farmers define their forest-related goals (Reid and Stephen 2001) and identify the benefits of reintroducing trees to farms, including timber production, increased farm productivity and the wider environmental and aesthetic benefits (see Abel et al. 1997). More information on preparing PMPs can be obtained from the Department of Primary Industries and Fisheries.

2.2 Plantation design for rainforest timbers

The PMP process helps you to identify areas suitable for farm forestry. Farm forestry designs may include mixed species plantations as woodlots, windbreaks and shelter belts, wide- spaced plantations (*silvopasture*) which allow grazing to continue, and the use of cover crops for the establishment of specific high-value cabinetwood species. Plantation design and species selection are important for the success of the trees. Some suggested designs for planting rainforest species on farms are shown in Figure 2.1.

Further information and detailed descriptions of each of these farm forestry design options can be found in *Design principles for farm forestry* (Abel et al. 1997).

Box 2.1 presents case studies of three design options that have been used in north Queensland.

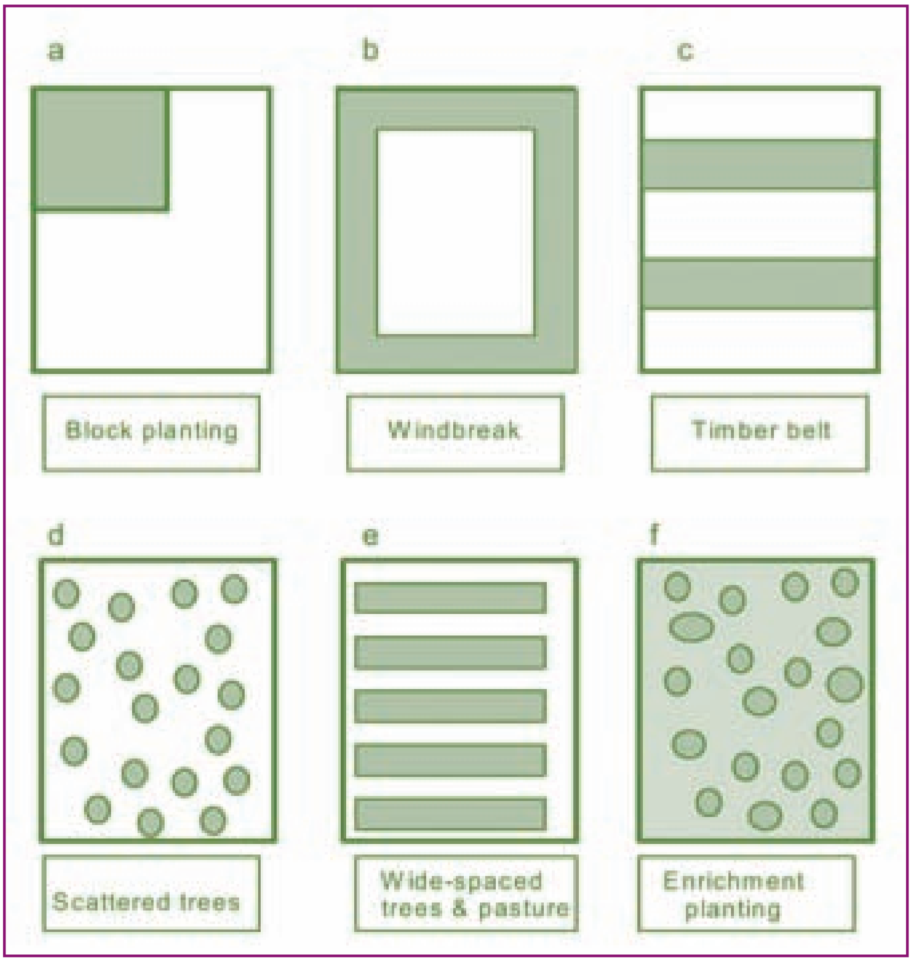


Figure 2.1 A range of plantation design options for rainforest timbers.
In diagrams a to e, shaded areas indicate where the trees are placed on previously-cleared land. In diagram f, the darker ovals represent planted high-value trees within existing forest. Source: redrawn from Young (1987), Abel et al. (1997), and Brooks and Snell (2000).

Box 2.1 Case studies of design options

The three following case studies are examples of wide-spaced trees, block plantings and enrichment plantings.

Case 1 Wide-spaced trees and pasture

Silvopastoral designs are a common form of farm forestry in sheep and dairy areas of southern Australia and other areas around the world. Wide-spaced designs incorporate trees into grazing systems while maintaining cattle and pasture production. The trees are managed for high-value sawlogs while providing shade and shelter for livestock. There are several issues related to species selection in silvopastoral designs including tolerance to grazing damage, ongoing maintenance requirements such as pruning (open plantings can require greater pruning inputs due to increased crown size and branching patterns in some species) and the variable ability of species to compete for water and nutrients with vigorous pasture species. Trials with the native hoop pine (*Araucaria cunninghamii*) and Queensland kauri pine (*Agathis robusta*) on the Atherton Tableland have shown that these species are suitable for this design option.

Figure 2.2: Queensland kauri pine (*Agathis robusta*) a timber species which is tolerant of grazing, with pasture and dairy cattle in a silvopastoral design

In order to maintain pasture production, trees need to be spaced at wide intervals. For many grazing systems, 250 stems per hectare should be adequate. This could be achieved by, for example, planting at 8 m × 2.5 m spacing (500 stems per hectare) and later thinning to 250 stems per hectare (refer to Box 8.1 in Chapter 8 for conversions between spacing and stocking density). Multipurpose designs need to be flexible so that the trees can perform several functions at the same time.

In a trial, it was found that silvopastoral systems can improve milk yields in dairy cattle by up to 9% by providing shade which kept the cattle cool (Davison et al. undated) and they also potentially supplement income through the sale of timber and other wood products. However, careful management for timber production is required to gain reasonable timber yields (Brooks and Snell 2000).

Case 2
Block planting

Between 1992 and 1998 the Community Rainforest Reforestation Program (CRRP), funded by the Federal Government and State and Local Governments, established over 2000 ha of tropical tree plantings, many of which involved a mixture of rainforest species planted in a block design (Creighton and Sexton 1996). This design option was often used because a farmer nominated a back paddock that was under-utilised or areas of the farm where the farmer wanted to put trees back into the landscape.

Block plantings are commonly used for plantation monocultures of both hardwood and softwood species in traditional, or industrial-style, forestry. Initial stocking is generally greater than 800 stems per hectare. Trees are planted in rows or lines and the interrow spaces managed to control grasses and soft weeds.

By planting more than one species in the blocks, the CRRP made an effort to find combinations of species that worked well in this system. For example, fast-growing, sun-loving species like brown salwood (*Acacia auriculiformis*) and relatively slow-growing, shade-tolerant species such as black bean (*Castanospermum australe*) or northern silky oak (*Cardwellia sublimis*) appear to have complementary light requirements (Keenan et al. 1995), and planting them together may lead to better stand productivity in the long term. This concept is described further in Box 3.2 (Case 3) in Chapter 3 and in Chapter 9.

One benefit of block plantings is that all of the activity is focused in one area, which reduces costs of establishment (e.g. site preparation, fencing) and maintenance (e.g. slashing).

Case 3
Enrichment plantings

Enrichment designs involve planting shade-tolerant, high-value species under an established canopy or nurse crop of existing plantations, regrowth forest or degraded native forest. Enrichment planting was tested in rainforests considered to have less than a desired number of commercial species. Growing space is created in the forest by physically removing small stems by brushing, ringbarking and poisoning. Subsequent regrowth is then maintained to reduce the competition to the planted 'enrichment trees'.

Many species were tested using this method. Some species, for example Queensland maple (*Flindersia brayleyana*) established successfully and grew well and results from underplanting trials with red cedar (*Toona ciliata*) suggest that this would be suitable as a plantation enrichment species. However, the approach is very labour intensive and costly and was not considered to be economical based on the growth rates achieved (Anon. 1983).

This technique can be adapted to enrich single species plantations by establishing rainforest timber trees in gaps that might have come about as a result of deaths or thinnings. Forest growers should keep in mind that considerable damage may occur when the primary stand is harvested if the 'enrichment trees' lag behind in growth.

3. Selecting rainforest timber species that suit the site

Species selection is usually dictated by two factors: which species will grow at economic rates and which species will have markets for their products. This chapter discusses the available information on matching rainforest timber species to sites and Chapter 4 outlines the issues associated with choosing species to suit markets.

Foresters involved with plantation development in the tropics have traditionally looked to fast-growing species with high-value wood. Historically in Australia, plantation research and development have focused on softwood plantations because of the relatively plentiful supply of hardwood timber from native forests and government policies aimed at developing plantations to replace imported softwood.

With a shift in attention to hardwood plantations, many tropical tree species are now considered as potentially suitable for commercial plantation development (Lamb and Lawrence 1993, Russell et al. 1993). In a preliminary economic analysis based on estimates from experts on growth rates and timber values, Russell et al. (1993) identified 26 tropical tree species for plantation development in north Queensland (some of these are discussed in Sections 3.1 and 3.2). They recognised the need to provide more accurate and reliable information on growth rates on different sites in order to support plantation development.

Whether a particular tree species will grow at an acceptable rate on your property depends on the genetic background of the tree, soil and climatic characteristics, and the competition that the trees will be under for resources such as nutrients, light and water. Matching species to sites by considering the growth requirements of the species is an important step which can save time and money (Evans 1992; Bristow 1996). It is important to consider the particular combination of soil type, rainfall, wind, temperature, humidity and frost which occur on your site, and their potential influence on growth of different species.

Methods of evaluating the soil and climate of a site are the focus of the manual *Site evaluation for farm forestry* (Harper et al., in press) and Box 3.1 discusses the different light requirements of some species. Some information on soils in north Queensland is provided in chapter 5.

Box 3.1 Light requirements of species

Rainforest trees are often classified according to their light requirements as sun-loving or shade-tolerant species. Establishing trees in plantation conditions generally implies that the trees will have to grow in high light environments, unless enrichment planting designs are used.

Rainforest species that thrive in full sunlight are often fast-growing pioneer species, for example sarsaparilla (*Alphitonia petriei*) and many of the wattles (*Acacia* species). Eucalypt species in general are sun-loving trees and are sensitive to shade and therefore sensitive to stocking densities (Florence 1996).

Species that can tolerate lower levels of light are called shade-tolerant species and many commercial rainforest timber species fit into this group, including brown tulip oak (*Agyrodendron trifoliolatum*), northern silky oak (*Cardwellia sublimis*) and black bean (*Castanospermum australe*). Studies have shown that black bean trees may not be suited to receiving full sunlight early in their development (Swanborough et al. 1998) and suggest that this species may perform well in moderately shaded positions.

Queensland maple (*Flindersia brayleyana*) and red cedar (*Toona ciliata*) could be described as intermediate species, as they show a broad tolerance to sun and shade (Thompson et al. 1992) while requiring high levels of sun to grow rapidly (Keenan et al. 1997). For these rainforest timber species, controlling the light environment through stocking densities and thinning will influence their form (branching and stem straightness). Managing the light environment with respect to weed control is discussed in Section 6.3.

You may discover some relevant information on species selection by talking to experienced individuals and by reading publications produced by government departments and other research organisations and by any local tree growing groups. Other approaches are to look at what is growing in any natural stands nearby (see Section 3.1), to follow neighbours and local enthusiasts, to find out which species have performed well in trials and demonstration plantings (see Section 3.2 and the case studies in Box 3.2), and to investigate what the market wants (see Chapter 4).

3.1 Which commercial species grew naturally in my area?

Prior to the cessation of rainforest logging on public lands in north Queensland in 1988 following World Heritage listing, there were approximately 150 rainforest tree species recognised as having commercial potential. These were divided into Groups A, B, C, and D (see lists in Appendix 2), based on their market desirability. There was also a non-compulsory group or optional group which included species that were harvested at the harvesters' discretion (Appendix 2). The groups were classified in their order of desirability, with Group A species being the most desirable and valuable and Group D being the least valuable. It should be noted that at the end of Heritage Listing, we knew a lot about native-grown wood characteristics, but little about how to grow the trees.

The 11 species in Group A, including red cedar (*Toona ciliata*), many of the *Flindersia* species and the oaks (*Proteaceae* family), supplied the bulk of the veneer, ply, and cabinet timbers and some were also sold as construction timbers. These species grow to large sizes producing a quality timber, and most importantly they occur in the rainforests throughout the region, which ensured a steady supply. With these qualities they could be easily marketed locally, nationally and internationally.

Of the many other species which were harvested, some had good timber qualities but were not available in large quantities. Often they were bulked with other species for ease of marketing and sold as general construction timbers.

The species you choose should take into account the natural vegetation in close proximity to the planting site, as this can be an indicator of species suitability. Tables in Appendix 3 and Appendix 4 present a range of options for selecting species based on their natural occurrence. These tables are intended only as a guide for farmers—a more thorough investigation of individual species and their suitability is required before planting.

3.2 What foresters tried—plantation trial results

Over many years researchers from the Department of Primary Industries' QFRI (formerly the Queensland Department of Forestry) have implemented and monitored research trials. The trials tested rainforest species for the purposes of increasing timber production by underplanting or enrichment planting in rainforest or by planting single species plantations on cleared land. The species used were both native and exotic rainforest species.

Long-term plantation trials in north Queensland tested rainforest timber species for a variety of designs and purposes. Most species used in enrichment trials (see Case 3 in Box 2.1 in Chapter 2) were from Group A. The most successful species tested in enrichment trials was Queensland maple (*Flindersia brayleyana*, see Figure 3.1). It has also shown promise in plantations, achieving an average height growth up to 2.5 m/yr and diameter growth of 2.7 cm/yr in the establishment phase (up to age five years) on some coastal sites (Keenan and Annandale 1999). Growth increments greater than 2 metres in height or 2 cm girth per year, were also recorded in the mixed species plantation reported in Chapter 9. On cooler, upland areas (e.g. the southern Atherton Tableland) Queensland maple grows more slowly, achieving average height growth of 1.4 m/yr in the establishment phase (Keenan and Annandale 1999) and it is sensitive to frost. As with all hardwood species, over time the annual increments decrease. In older plantings on upland sites the annual diameter increment for Queensland maple can be between 0.7 cm/yr and 1.2 cm/yr depending on stocking density and rainfall (Keenan et al. 1999).

Figure 3.1 Queensland maple (*Flindersia brayleyana*) in a monoculture plantation.
It is a Group A species (see Section 3.1) and has performed well in both monoculture and mixed species plantations and as a high-value enrichment planting species. This picture shows a monoculture plantation, four years old, grown on a weathered red basalt soil near the township of South Johnston. High initial stocking density (>2000 trees per hectare) has led to favourable conditions of rapid site capture and weed control by shading (this is discussed further in Box 3.1).

The native softwood hoop pine (*Araucaria cunninghamii*) proved to be the most successful plantation species and it has been established on many ex-rainforest sites in Queensland (Figure 3.2). The native softwoods (including hoop pine and kauri pine) are relatively slow growing with rotation time length between 40-60 years depending on management.

The exotic softwood *Pinus caribaea* is grown in State government owned plantations in the Wet Tropics. Its fast growth (Tables 3.1 and 3.2) and good form might promote this species to forest growers, however the timber produced competes with other pines in world commodity markets. Growers of this species need to consider questions of resource scale.

The rainforest-margin, high-rainfall species red mahogany (*Eucalyptus pellita)* has performed well on previously cleared land with metamorphic and basalt derived soils on the coastal lowlands of the wet tropics (Tables 3.1 and 3.2). Although not strictly rainforest species, *E. pellita* and other promising eucalypts including *E. cloeziana* and eucalypt hybrids, can produce timber that is dense, durable and has colour and feature that might select them for appearance grade products. Furthermore, they are fast growing (Tables 3.1 and 3.2). *E. pellita* has been the focus of a number of site preparation, fertiliser and weed control trials discussed in chapter 6 and these eucalypts can be grown with rainforest species, such as Queensland maple presented in the case study in chapter 9, to create a mixed species stand.

Exotic species such as West Indian cedar (*Cedrela odorata*, see Figure 3.3), teak (*Tectona grandis*) and the African mahoganies (*Khaya* species) have grown well on coastal lowland sites (Tables 3.1 and 3.2).

Most other rainforest species have not performed very well, largely because of their slow growth, insect and disease problems, and their specific growth requirements. Like the Meliaceae species in Tables 3.1 and 3.2 (*Cedrela odorata*, *Khaya nyasica*, and *Swietenia macrophylla*), the growth of native red cedar (*Toona ciliata*) in plantations is constrained because of the severe attack that it receives from an insect, the cedar tip moth. However, research being conducted in Australia and overseas is showing promise in overcoming the ravages of this insect and so it is possible that the species will be grown successfully in the future (see Figures 3.4 and 3.5).

Early research with growing rainforest timber species has demonstrated that important productivity gains can be made in plantations using good species selection, species-site matching, tree selection and breeding, and through developing appropriate management practices (Keenan et al. 1998a; Dickinson et al. 2000; Keenan and Bristow 2000; Nikles et al. 2000).

Figure 3.2 The native hoop pine (*Araucaria cunninghamii*) proved to be the most successful rainforest plantation species in early experiments.

Trees in this picture are six years old and are widely spaced at 5 m between the rows and 5 m between the trees; providing a stocking density of 400 stems per hectare. This wide spacing of trees (described in Case 1 in Box 2.1 in Chapter 2) allows adequate light through the tree canopy for grass growth and thus grazing by cattle. This species grows well on basalt-derived soils in both upland and lowland regions of the Wet Tropics.

Table 3.1 Stand parameters for surviving taxa in an experiment (708) on red, basalt derived soils near Innisfail, north Queensland

Trees were measured in May 1997, that is 9.5 years after planting (unless specified otherwise). (Adapted from Annandale and Keenan 2000).

Species	Common name	Height (m)	Tallest individual (m)	DBH (cm)	Largest individual DBH (cm)	Basal area (m^2/ha)
Pinus caribaea var. *hondurensis*	Caribbean pine	21.7	24.0	30.8	39.1	49.2
Eucalyptus pellita (Kuranda prov.)	red mahogany	21.3	25.7	23.8	34.0	20.0
E. grandis x E. tereticornis	eucalypt hybrid	27.5	27.7	22.0	32.0	18.5
Cedrela odorata#	West Indian cedar	16.3	23.9	20.1	38.1	23.5
Khaya nyasica	African mahogany	19.9	19.9	18.5	31.1	18.8
Tectona grandis	teak	16.6	19.4	18.5	25.2	18.9
Acacia mangium	brown salwood	16.3	17.6	15.4	28.6	18.8
Agathis robusta	kauri pine	11.1	11.1	14.2	16.8	10.5
Swietenia macrophylla	American mahogany	9.8	5.0 (3.6 yrs)	-	-	8.5 (3.6 yrs)

Data for *Cedrela odorata* is the average for all six tested provenances except for the tallest and largest individual tree data. Note: the number of individuals of each taxa is not equal, and not all taxa are planted at the same stocking density. Figures for the tallest and largest individual trees are not necessarily the same individual.

Table 3.2 Stand parameters for surviving taxa in an experiment (704) on metamorphic red earths, near El Arish, north Queensland.

Trees were measured in September 1997, 10.5 years after planting (unless specified otherwise). (Adapted from Keenan et al. 1998)

Species	Common name	Height (m)	Tallest individual (m)	DBH (cm)	Largest individual DBH (cm)	Basal area (m^2/ha)
Pinus caribaea var. *hondurensis*	Caribbean pine	22.7	29.1	30.9	39.3	69.6
Eucalyptus cloeziana (Pomona prov.)	Gympie messmate	24.5	26.6	29.1	31.8	16.8
Eucalyptus cloeziana (Helenvale prov.)	Gympie messmate	21.8	25.3	23.2	27.5	18.7
Eucalyptus pellita (Kuranda prov.)	red mahogany	17.1	17.5	22.9	25.0	9.1
Acacia mangium	brown salwood	13.7	18.7	21.8	33.9	16.1
Tectona grandis	teak	9.3	11.1	15.3	17.7	8.8
Eucalyptus drepanophylla (age 4 yrs)	ironbark	9.7	12.5	11.3	13.7	-
E. grandis x E. tereticornis (age 3.7 yrs)	eucalypt hybrid	19.0	9.9	11.3	14.6	7.3
Cedrela odorata# (age 4.5 yrs)	West Indian cedar	2.1	4.3	2.6	6.4	0.7

Data for *Cedrela odorata* is the average for all four tested provenances except for the tallest and largest individual tree data. Note: the number of individuals of each taxa is not equal, and not all taxa are planted at the same stocking density. Figures for the tallest and largest individual trees are not necessarily the same individual.

Figure 3.3 The exotic species West Indian cedar (*Cedrela odorata)* has grown well on some sites.
This picture is of an 11-year-old cedar from the Apartado (Colombia) provenance, which performed best of several trial provenances when grown on red basalt-derived soils about 10 km north of Innisfail on the coastal lowlands (experiment 708, refer Table 3.1). In such conditions, different provenances of this species reached on average between 16 and 23 cm diameter in 9.5 years (Annandale and Keenan 1999).

Figure 3.4 Six-month-old red cedar (*Toona ciliata*) planted in an enrichment design underneath a canopy of Caribbean pine (*Pinus caribaea* var. *hondurensis*) monoculture on red basalt soils near old Danbulla nursery on the Atherton Tableland.

Figure 3.5 Red cedar (*Toona ciliata*) in a mixed-species plantation being assessed for cedar tip moth attack before harvest.
This picture shows approximately 50-year-old red cedar growing on basalt soils at Wongabel State forest, near Atherton.

Figure 3.6 Toona ciliata 'wildling' or self-recruit within *Araucaria cunninghammii* plantations at Wongabel State Forest (age approximately 45-50 years).
This photo demonstrates that even though we know that colour takes time (years) to develop, it may not be as long as we think.

Box 3.2 Species selection case studies

Case 1 Single species plantation of hoop pine

Hoop pine (*Araucaria cunninghamii*) plantations form a major component of public forests and consequently, plantation management methods, production data and cost-benefit analyses of hoop pine plantations are available. While the species is suited to wet, fertile sites it has a broader site suitability and is also found naturally in drier areas of the state outside the Wet Tropics. The growth of hoop pine is characterised by slow early development, which implies a significant management commitment at establishment and up to 5 to 10 years of age. Productivity is very high on good sites resulting in trees with stem volumes of 1 to 2 cubic metres in less than 50 years.

The wood of hoop pine is well-known among cabinet-makers as being even-grained and easy to work. Hoop pine has high strength relative to its density, and the clear wood has very good stiffness. Since the 1940s the timber has been used as a raw material for light aircraft manufacture because of its strength and density properties. The timber is still used for this purpose.

Processors of hoop pine are located throughout the areas of Queensland where the species is grown in plantations, and markets for hoop pine products are well developed (Palmer and Leggate 1996).

Hoop pine plantations are one of the few types of forestry venture that can be intensively examined in cost-benefit terms by a potential forest grower. In addition to returns from forest products (thinnings, logs, etc.), cash flow can be generated by grazing cattle on pastures beneath plantations of this species (see Box 2.1). Early returns are available from thinnings from the forest, and plantation value can be estimated during growth and development. This offers an opportunity to gain from its value before the end of a rotation, either by land sale or by identification of the plantation as a capital asset within a wider business.

Case 2
Tropical rainforest timber plantation

Generally held perceptions that rainforest timber trees are all slow-growing, with expected rotation lengths over 50 years (Lamb and Lawrence 1993), are being dismissed for some species. Tropical eucalypts such as red mahogany (*Eucalyptus pellita*) are some of the fastest growing hardwood species in plantation (Keenan and Bristow 2000, see also Tables 3.1 and 3.2). The rainforest timber silver quandong (*Elaeocarpus grandis*) can match the growth rates of fast growing eucalypts on fertile, lowland sites where weed competition is controlled (see Figures 9.6 and 9.7). Research has indicated that productivity of many of the most commonly planted species (Table 3.3) can be increased (Figures 6.3 and 6.4 and Box 6.5).

Figure 3.7 Relatively rapid growth rates have been achieved for Queensland maple (*Flindersia brayleyana*) and silver quandong (*Elaeocarpus grandis)* in a mixed-species planting aged 5.5 years.
(There is a further description of the above site and trees in the case study in Chapter 9).

For the species that are slow growing, establishment and maintenance of plantations is relatively expensive. These require substantial initial tending while the stand captures the site (i.e. the forest develops and captures the site).

Production per annum can be relatively low because some species take many decades to fully develop and express the colour and qualities that make these timbers valuable. However, if the productivity can be increased through improved genetics and silviculture, colour development may not take as long as once thought (Figure 3.6).

The utility of tropical rainforest timber species is broad with differences in durability, strength, hardness, colour and grain affecting the appearance and workability. To realise the maximum returns and high value, these trees need to be grown to optimise clearwood production, and the timbers sold into niche markets to produce products such as furniture and joinery (Palmer and Leggate 1996).

The value of the timbers can be high (in 2002, the average was around $1500 to $2000 per cubic metre of sawn dry wood). Since the quality of these timbers as appearance-grade products is already established, it is expected that the long-term returns from them will be high. Even though the time frame for recovering these returns is relatively long, early research suggests that with genetic and silviculture advances, many growers who have other agricultural income to support the term of forest development should not be deterred. Longer-term production can be maintained through management of harvesting and maintaining the forest as a permanent land-use.

Case 3 Mixed-species eucalypt plantation

Eucalypt plantations potentially offer a great opportunity to an organisation or individual proposing to invest in forestry. Eucalypts are unique in terms of both productivity and wood properties. The native forests of eucalypts have a capacity to regenerate very quickly after disturbance and to endure drought, poor soils, and fire.

Small areas of public plantation forests are now being harvested and the logs sold. An example of plantation-grown Gympie messmate (*Eucalyptus cloeziana*) at Pomona in the south-east of Queensland produced individual trees with volumes of up to 4.0 cubic metres of wood, grown in 37 years. Substantial research is still being carried out on the plantation management, silvicultural and processing requirements of these species, as well as their utilisation.

The wood of eucalypts is on average very dense. This provides superior mechanical properties that have allowed the timbers to be used in engineering construction for many years. The superior durability of some species has allowed their use in external applications from road bridges to power poles. In contrast, the timbers are now being applied in the construction of fine furniture. The broad potential utility of eucalypt timbers makes them a good investment for the forest grower. Like the native softwood hoop pine, the processing facilities and markets for eucalypt hardwoods are well developed.

There are some risks associated with eucalypt plantations. The effects of insect and pathogen attack on plantation monocultures can be devastating. Tree improvement programs focus on selecting resistance to these problems, while silvicultural forest researchers are developing optimal plantation methods to address this challenge.

Source for the three case studies: adapted from Palmer and Leggate (1996).

3.3 What are other people growing in my region?

Local grower groups and cooperatives will be able to tell you what they are growing, and will have experience on local performance and success of different species and provenances. Keep in mind also, that to guarantee market supply and best market price at harvest, it could be useful to plant what other growers are growing and collaboratively market the timber. Table 3.3 shows rainforest timber species commonly grown in north Queensland.

Table 3.3 Commonly grown rainforest timber trees in north Queensland#

Common name	Species name
Hoop pine	*Araucaria cunninghamii*
Red mahogany (large-fruited)	*Eucalyptus pellita* (PNG provenances)
Queensland maple	*Flindersia brayleyana*
Queensland kauri pine	*Agathis robusta*
Brown salwood	*Acacia aulacocarpa/Acacia mangium*
Silver quandong	*Elaeocarpus grandis* (formerly *E. angustifolius*)
West Indian cedar	*Cedrela odorata*
Queensland silver ash	*Flindersia bourjotiana*
Black bean	*Castanospermum australe*

#This is a list generated from what we have observed as being successful in CRRP plantings.

4. Selecting marketable rainforest timbers

4.1 Which species are marketable?

Chapter 3 focussed on selecting timber species suited to the available land. Once a list has been drawn up, it can be refined by considering the timber's end-use and possible buyers. Species with favourable wood properties are likely to have higher market values and be easier to sell than those that do not. In this regard features such as colour, figure, grain, density and workability of the timber are important.

Asking timber processors and looking at the timber market can be useful guides to what species to plant. Questions to consider include:

Which sorts of timber are in demand on the market today?

- A general answer might be timber that is durable, has 'feature' (e.g. colour, grain) and that can be supplied in known or guaranteed amounts.

Which species are other farmers in my region growing?

- Go to growers groups or cooperatives for information. Keep in mind that to provide markets with a reliable supply, it could be useful to plant what other growers are already producing and collaboratively market the timber. Table 3.3 lists the most commonly grown rainforest timber trees in north Queensland.

After thinking about these first two questions, list the species that you might consider. Then ask:

Which timbers will be fashionable in the future?

- Marketing timber requires a different set of skills from those needed to grow the timber. However, market availability must in part dictate what people will buy. Box 4.1 describes a strategy produced by QFRI which addresses marketing issues.

Keep in mind that fashions change and timbers that are in demand today may not be at time of harvest.

Box 4.1 A strategy for growers of rainforest timbers

A suggested strategy for north Queensland rainforest timber growers who wish to choose species and market them is:

- Grow sawlogs of appearance-grade wood, medium density and medium hardness, with natural durability at least above ground.
- Collectively (i.e. as a group of farmers) grow a large volume of two or three marketable species or timber types.
- Aim to primarily supply high-quality joinery and furniture timbers and veneers and develop market exclusivity.
- Commit to attaining the highest levels of wood quality, applying well-developed technical practices and derive a market edge on this basis.
- Focus on large Asian and American markets.
- Provide certification of management.

The remainder of this chapter outlines the issues associated with marketing rainforest timbers.

4.2 Marketing timber—some of the issues

While experts are helpful in informing the community that timber has a bright future both nationally and internationally and that the commercial prospects for some rainforest trees are excellent, there is only limited information on where markets are and how to sell the end product.

Growing trees solely for timber products is a speculative venture that few farmers will take on without some assistance. Investing in new enterprises is daunting enough, especially when no one can give any definite answers on the economics of a project for sale some 30–50 years hence.

The adage that well-grown plantation timber of any species in any location will always attract a processor and a viable market is not necessarily true. Remember to plan for transport distance and costs, export taxes and tariffs, and production and harvest cost efficiencies, and work towards developing new markets by value-adding the resource while maintaining competitive cost structures. It seems that the introduction of rainforest species at this early stage of industry development has less risk if trees are integrated into various other farming activities to address other issues, such as erosion control, shelter belts, windbreaks and stream bank plantings (see *Design principles for farm forestry* Abel et al. 1997, *Trees for shelter* Cleugh 2003 and other JVAP publications).

Most farmers growing trees will only be involved in the growing and selling of the trees, they will not be marketers. The more a farmer wishes to be involved in the whole process, from the growing of timber, through its harvesting, sawing and drying, to its marketing, the more expense and skill will be required. Presently, few farmers in north Queensland have the available volume of timber to cost-effectively market it.

Therefore, it is advisable for growers of small timber volumes to look for an independent service that can market the trees to the highest bidder. However, the tree grower should understand the markets and value-add throughout the various stages of plantation development with pruning, thinning and other inputs to maximise the growth and quality of the end product.

When growers sell their products they need to:

- be realistic in the market place about their prices;
- offer a consistent quality product;
- build relationships and trust with buyers and contractors;
- aim for a transparent selling process;
- know their market and their product.

Growers should not be in a hurry to sell their products. Trees are one commodity that improves with age.

Marketing this new resource (timber that is plantation grown) may not be easy. There are only small areas of plantations of rainforest timber species. It would be unwise to make the assumption that past demand levels, once guaranteed by a continued supply, can be translated into meaningful demand predictions for plantations maturing in 30-50 years. In the future, markets for species well known today may have to be re-established.

To assist future marketing, a greater resource is required—this means that there is a need to promote the growing of rainforest species.

Timber growers' cooperatives can play a central part in maximising the returns to individual growers by coordinating marketing. A cooperative approach can gain real market strength and the critical mass that buyers require for continuity and reliability of supply. Further information on forest farming cooperatives is being developed through a JVAP project titled *Technologies for Managing Native Forests*.

Some of the advantages cooperatives offer are to:

- source and develop market opportunities;
- investigate new technologies;
- operate computerised marketing;
- develop regional databases;
- develop trust and confidence with buyers;
- do necessary advertising and promotion;
- implement quality assurance controls and efficiency standards;
- lobby effectively at all levels of government;
- ensure quality control and a guaranteed supply.

One possible approach would be to market north Queensland as a region that is clean and green and that produces unique certified timber products. By strengthening the links between the forest owners, sawmillers, manufacturers and government, a range of forest and wood products industry benefits could evolve for the region. There are several publications on stand certification (see Sommerville 1992; Vondra 1994; Mangatti 1995). The Australian Forest Growers website also has current information on stand certification.

Domestic and international markets for environmental services are also being developed to pay for catchment and downstream benefits of trees in the landscape.

U. N. Bhati at the Australian National University (ANU) produces regular updates about market trends for the small-scale forest grower in the *ANU Forestry Market Report*. These are easily accessible on the ANU web site at <http://sres.anu.edu.au/associated/marketreport/>.

5. Soils information for growing timber in north Queensland

Tree growers will be assisted by a basic knowledge of the properties of soil and how to describe them. Soil preparation is an important part of establishment silviculture and the productivity of tree plantations is closely related to the properties of the soil.

Soil fulfils three essential requirements for tree growth: supply of moisture, supply of nutrients and provision of mechanical support. Soil fertility, physical condition, drainage and rootable depth are the primary considerations for planning and establishing plantations. Unfortunately, information on optimum site preparation, fertilisers, and soil–species matching for rainforest timber species is lacking. Thus growers will commonly have to rely on their own understanding of the general principles relating tree growth to soil characteristics.

The soils in the Wet Tropics are generally geologically recent compared with those in the rest of Australia, but they are characteristically highly weathered and low in plant nutrients (Webb et al. 1997; Keenan 1998). Tropical rainforests can grow on very nutrient-poor soils in which nutrient cycling is intricate (Jordan 1985). In the early days of agriculture in north Queensland, it was generally supposed that all rainforest occurred on rich soils. Their dependence on nutrient cycling was not recognised and following land clearing crop and grazing production commonly declined as the nutrient store was depleted (Gilmour and Reilly 1970; Keenan 1998). Compared to their condition when first cleared, most agricultural soils in the Wet Tropics are thought to have experienced some level of degradation and reduced primary productivity (Parrotta 1992; Webb et al. 1997; Keenan 1998). This is the land available for growing rainforest timbers in north Queensland.

Understanding some key soil properties will help the grower to identify and adopt site-specific management practices. This chapter introduces some of the key properties and Chapter 6 discusses soils in relation to cultivation techniques and nutrition. For a more thorough guide to the description of soils, see McDonald et al. (1990). Another manual in this series (*Site evaluation for farm forestry* by Harper et al., in press), covers the interpretation of soil information for farm forestry, and although it is primarily aimed at southern regions of Australia, the processes described are transferable to northern Queensland.

5.1 Key soil features

Soil information can be obtained from a hole dug with a hand auger or from existing exposures (e.g. pits and road cuttings) that have been scraped to expose fresh soil. Soils are made up of layers that have different characteristics and they are classified using properties of the profile such as colour and texture (Figure 5.1). Generally, the surface soil has an accumulation of organic matter and is dark grey while the proportion of clay in the profile tends to increase with depth.

Figure 5.1 Characterising the soil layers of a soil profile

5.1.1 Soil depth

Soil depth is defined as the distance to an impenetrable layer such as massive clay or rock and is a measure of the amount of soil potentially available for use by plant roots. An important property of a soil is the amount of water it can hold in ways accessible to plants (*plant-available water*) and this is dictated to a large extent by soil depth, as well as soil texture, density, structure and any inclusions such as gravel or boulders. In general the deeper the soil, the more potential storage space for water.

5.1.2 Soil colour

Soil colour should be assessed for each layer. Colour is related to factors such as parent material, soil drainage, aeration, leaching, and soil organic matter content although these relationships vary greatly in different regions. Colour therefore should be interpreted with caution. Soils can form in situ from the weathering of the underlying rock, or from materials that have been transported and deposited at the site. Red and yellow colourings are usually related to the presence of iron. Red soils are formed from parent materials high in iron and are generally better drained than yellow soils. Often, grey colours and mottles (red or yellow streaks within a paler background colour) indicate periodic waterlogging (Isbell 1996). In many profiles, colour changes with depth.

Soil colour may be an indicator of potential limitations or management options. For example, it is known that some red soils 'fix' phosphorus making it unavailable to plants, so higher fertiliser rates may need to be used. Certain tones of grey and green can indicate waterlogging and such soils may require drainage and careful tree species selection. You may need some expert assistance in interpreting soil data.

5.1.3 Soil texture

Soil texture refers to the proportion of clay, silt and sand in the soil and is assessed by moulding moist soil in your hand. Fifteen texture classes are recognised and ways that you can identify six major ones are described in Table 5.1.

Table 5.1 Six major soil texture classes.
To work out the texture of a soil, moisten it in your hand to create a ball and then compare it to the descriptions below. Source: adapted from McDonald et al. 1990.

Texture Class	Soil behaviour when moist
Sand	The soil feels very sandy and falls apart easily
Sandy loam	The soil feels sandy and slightly sticky. It holds together just enough to be handled.
Loam	The soil feels spongy and possibly greasy. It may also feel slightly sandy. When moulded into a ball, it holds together.
Clay loam	The soil holds together strongly and can be moulded and shaped.
Light clay	The soil is easy to mould and shape and behaves like soft plasticine.
Medium or heavy clay	The soil behaves like hard plasticine.

As with other soil properties, texture commonly changes down the profile and should be assessed for each layer. Soil texture has an important influence on soil water holding capacity, nutrient supply, root penetration and soil erodibility. The changes in soil texture from layer to layer down the profile influence drainage and nutrient supply. Heavy clay layers may obstruct drainage of water and cause waterlogging or inhibit root penetration.

5.1.4 Soil structure

The term *soil structure* describes the arrangement of soil particles into aggregates. Soil particles may cluster into units called *peds* and the size and degree of development of these peds dictates the soil structure. Structure classes range from strongly pedal (where more than two-thirds of the soil is structured) to weakly pedal (where less than one-third of the soil is structured) or structureless or *apedal* (where no peds are evident). Strongly structured soils may have relatively high water and oxygen availability for tree roots, facilitating root penetration.

5.1.5 Soil erodibility

Soil erosion needs to be considered before any earthworks such as deep ripping and cultivation take place. Soils vary in their erodibility and evidence of erosion can often be seen in the landscape. In cases where erosion is evident, precautions should be taken to reduce the impact of machinery on the site (see Section 6.1). Erosion hazard increases with the steepness of slopes, so working the soil and planting tree rows along the contour, and maintaining vegetation between the rows (e.g. grasses, woody weeds, small trees) decreases the potential for soil erosion. Seek local advice from an experienced plantation extension officer or manager.

5.1.6 Soil pH

Soil pH is a measure of the acidity of the soil and this affects nutrient availability and ultimately tree growth. Most trees perform best in a soil with a pH between 5.0 and 7.0. Soil pH is assessed in the field using a field pH kit. It simply involves taking a small sample of soil, adding an indicator solution, coating this with a powder and comparing the colour that develops with the calibrated colours provided.

5.2 Additional relevant site information

5.2.1 Topography

Topography plays an important role in soil forming processes. Often soils on lower slopes are formed from materials that were deposited there after being eroded from the slopes above. This results in deeper, more fertile soils in the gullies and shallower, less fertile soils on the slopes, which may be prone to drought. Position in the landscape also influences site temperature, drainage and moisture availability. Frost may be an issue at high altitudes, particularly in low-lying areas and where overland flow of cold air is impeded.

5.2.2 Land-use history

Past land-use affects soil properties. Soils beneath undisturbed, native vegetation are likely to have reached a relatively stable state, but when an area is cleared, soil degradation can occur as a result of soil compaction and erosion. Previous application of fertilisers often has long-lasting effects on soil chemical properties. Knowing something of the site history will help determine management options.

6. Establishing and managing rainforest timber plantations

***Site capture* is a term used to describe the end of the establishment phase of plantation growth. Good, or rapid, site capture refers to good survival and rapid early growth of the trees, with the target trees dominating the site. Site capture is characterised by canopy closure (Evans 1992), which is the stage at which the tree canopies are touching, thereby reducing the ability of weeds and other species to compete for light.**

Good site capture is the sign of successful plantation establishment. This can be achieved through an appropriate choice of species and planting density, as well as adequate site preparation, weed control, fertiliser to meet tree requirements and trees protected from pests and diseases. Failure in any one of these activities (perhaps the result of cost-cutting) may lead to very slow site capture (which could increase costs in the long run (Evans 1992)).

The issues involved with species selection were described in Chapters 3 and 4. This chapter introduces the issues associated with establishing and managing rainforest timber plantations. It discusses stocking density, ground preparation methods (cultivation and weed control, see Figure 6.1) and plant nutrition. The following two chapters describe pruning and thinning operations in detail. The activities contributing to the establishment and post-planting management of a farm forestry project are summarised at the end of the chapter in Boxes 6.6 and 6.7.

Figure 6.1 Preparing the site for tree planting.
The site in the photograph was prepared for trees by removing the existing vegetation (weeds) with a slasher, followed by soil cultivation in rows using two passes of a tractor with offset discs. Prior to planting, germinating weeds were sprayed with a knockdown herbicide (glyphosate at a rate of 4 L/ha) on two occasions. Herbicide was firstly used two weeks after soil cultivation, and again two weeks prior to planting.

6.1 Cultivation

Figure 6.2 Cultivating along contours on slopes and maintaining inter-row vegetation (in this case, grasses) reduces the potential for soil erosion.

Site cultivation is the most important of the treatments for ensuring rapid site capture. The most appropriate forms of cultivation will depend on the conditions of the site and the soil and the vegetation present. Generally, increasing the level of site cultivation will result in increased tree growth and survival (see Box 6.6). The type of site cultivation depends on slope steepness and the degree of soil compaction. For example, on moderate slopes of 0° to 15° it is preferable to cultivate along the contours of a hill rather than up or down the slope (see Figure 6.2), and to avoid cultivating during wet weather. These strategies can reduce soil erosion and compaction and help maintain site quality. On steep slopes (greater than 15°), spot cultivation (that is, planting trees in individual holes) is recommended (see Box 6.1)

Studies in north Queensland with tropical eucalypt species found significant early growth responses with increasing cultivation treatments on coastal alluvial soils. Results with red mahogany (*Eucalyptus pellita*) suggest that ripping the soil with a single tine to a depth of 50 cm resulted in an increase in height of 25% compared with no cultivation. The more intensive site preparation of ripping plus mounding (using two passes with a tractor and offset discs) resulted in the best growth performance. On ripped and mounded sites, tree height was 1.5 times taller than sites with no cultivation, and 1.2 times taller than sites with ripping only (Figure 6.3).

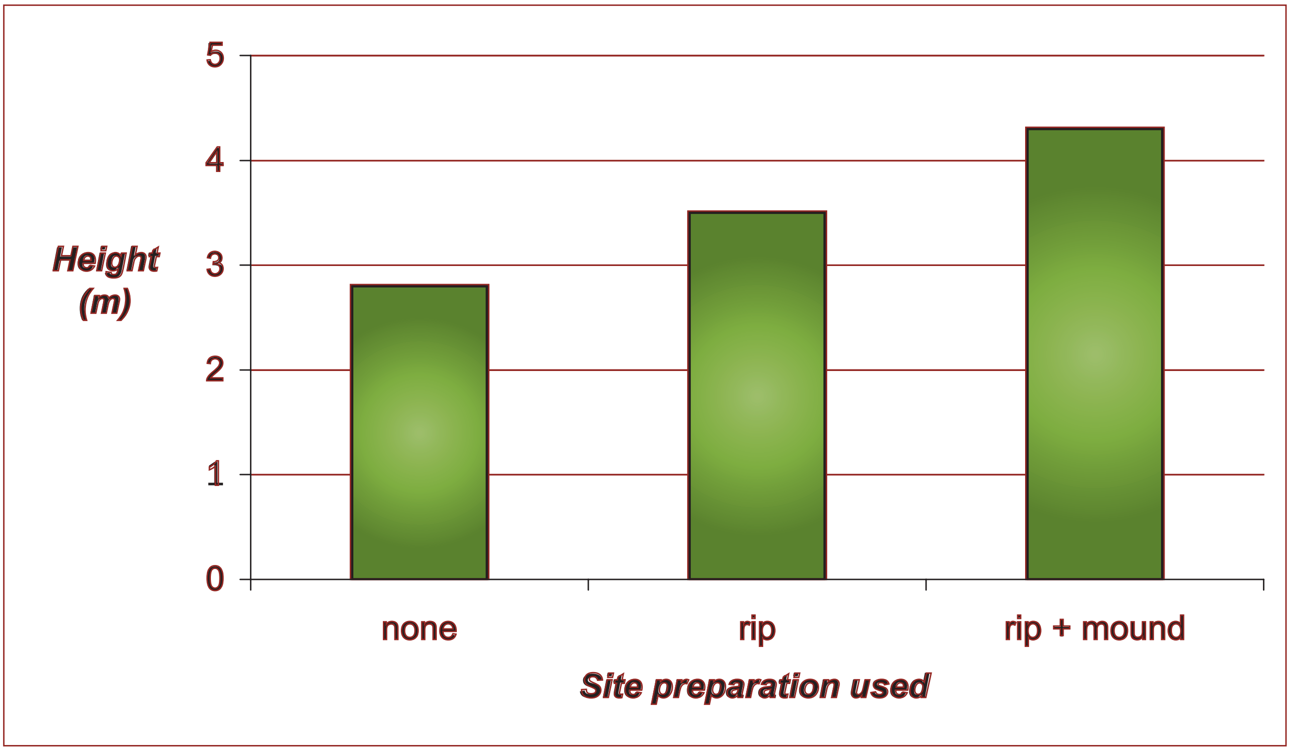


Figure 6.3 Early height growth responses to different levels of cultivation of red mahogany (*Eucalyptus pellita*) in a trial plantation at age 13 months.

Source: adapted from Keenan and Bristow (2000).

These results may be site and species specific. Some cultivation studies in southern Australia have found the relative benefit of different treatments depends on the site, soil and the species tested. Ripping has generally produced greater growth results, although ripping in addition to ploughing and mounding had no effect on survival and growth of slash pine (*Pinus elliottii*) on the coastal lowlands of southern Queensland (Francis et al. 1984).

Box 6.1 Site cultivation guidelines

- On highly compacted areas, for example ex-grazing lands, deep ripping with tines to 60 cm and soil cultivation to between 30 cm and 45 cm is recommended. This will allow root penetration to deeper soil layers and stimulate tree growth.
- On less compacted areas, for example ex-forest or plantation sites, soil cultivation with disc ploughs to 30 cm is adequate.
- On slopes between 0° and 15° where water run-off is minimal and the soil type is not susceptible to erosion, strip cultivation is the cheapest and preferable technique.
- On slopes between 15° and 20° or in areas where soils are easily eroded, spot cultivation (cultivation of tree hole only, not entire tree rows) is recommended.

Source: Department of Primary Industries and Fisheries, Queensland (November 2004)

6.2 Stocking densities

Tree spacing in plantations and the number of seedlings that are planted per hectare (*stocking density*) influences the establishment costs, the scope of thinning regimes and the physical environment in which the trees grow (Lamb et al. 1997). These factors are closely interdependent and can influence the rate of diameter growth, and hence value. Many, and often competing, factors must be taken into account, including the biological attributes of the species, market requirements and the economies of timber production (Florence 1996). Through the process of thinning, the yield of merchantable timber may be increased, and the time taken to achieve a commercial product reduced.

Tree breeding strategies aim to select trees with good form and vigour, suitable branching structure and resistance to pests and to pathogens. However, it will be some time before improved planting stock will be available for many species. As a guide, when establishing trees using unimproved stock, it is advisable to plant a high initial stocking density of trees (e.g. 1000 to 1200 trees per hectare) to ensure that the required number of suitable trees is available for the final harvest. When planting material from improved genetic material, lower stocking rates can be used (see section 8-1).

The recommended stocking density for mixed species plantations is outlined in Box 6.2. Reasons for planting a high initial stocking density are to encourage early site capture and reduce branch development. Even though the final stocking density of trees is likely to range from 100 to 400 trees per hectare, high initial stocking densities can create positive competition between trees, resulting in reduced need for weed control and pruning. In addition, thinning material produced by the excess trees could be used to generate cash flows (e.g. fence posts, vineyard posts, firewood) before final harvest (Florence 1996; Lamb et al. 1997; Reid and Stephen 2001). This is discussed further in the case study presented in Chapter 9.

Box 6.2 Stocking guidelines for tropical plantations

Use an initial stocking rate (or planting density) of at least 1000 trees per hectare. Common settings are 4 m between rows and 2.5 m between trees, or 5 m between the rows and 2 m between trees (see Box 8.1 in Chapter 8 for conversions between stocking densities and distances between rows and trees). This wise inter-row distance allows for easy mechanical weed control (i.e. slashing) while the tighter intra-row spacing leads to relatively rapid site capture. Due to the rapid grass and weed growth in north Queensland, higher initial stocking rates (such as 1333 to 2666 trees per hectare) have sometimes been used to promote site capture in mixed species rainforest plantings. Alternative spacing is discussed in case study 1 in Box 2.1 (Chapter 2) and in Chapter 9.

6.3 Weed control

A newly planted tree will be susceptible to competition from plants that already exist or which establish at the same time. Seedling growth may be stunted where access to light, nutrients, water or space is restricted through competition with surrounding plants.

Weed growth can be prolific in tropical regions and maintaining weed control is a vital factor for early site capture and therefore for successful plantation establishment (Box 6.3). Inadequate weed control in the establishment phase leads to slow tree growth and potentially to death. This is a major cause of rainforest timber plantation failure in north Queensland. Herbicides are an economic method of weed control and may be applied before and after planting. These should be applied as recommended by the manufacturers and in keeping with government regulations and guidelines regarding safe distances from watercourses and avoiding major rainfall events and associated leaching.

Care should be taken when applying herbicides as in some situations their use may burn tree foliage or reduce tree growth (Turnbull et al. 1994).

Box 6.3 Weed control for successfully establishing plantations

Plantations can be successfully established by:

- keeping a weed free strip along the planting rows 1 m each side of the trees using knockdown herbicides (e.g. glyphosate at the manufacturer's recommended rate), followed by:

- pre-emergent herbicides after planting.

Therefore a 2 m-wide, weed-free strip straddles each planting row.

6.4 Nutrition

Commonly, the land available for plantation establishment in north Queensland is on soil types that are too poor to sustain agricultural production or on land that is degraded through previous land-uses or clearing (Jordan 1994; Keenan et al. 1998b). Either through past land management practices or because of inherent geological characteristics, very few Australian soils are able to supply enough of each nutrient required by trees, so it is necessary to supply further nutrients. Deficiencies are caused by two factors:

1. The soil in which the tree grows is too low in that particular nutrient.

2. Whilst the soil contains adequate quantities of a particular nutrient, it is in a form that the plant cannot easily use.

Trees obtain most nutrients by actively absorbing them as dissolved ions in the soil water. Nutrients can also occur in the soil as combinations of elements (i.e. mineral compounds) or they may occur on the surfaces of mineral and organic particles. However, nutrients tied up in these substances are largely unavailable to plants unless they are readily released into the soil water as dissolved ions. As a result, nutrients are often described as available or unavailable.

Fertilisers are generally used in plantation silviculture to correct identified nutritional deficiencies, to lead to more rapid site capture, or to increase timber yields (Evans 1992; Florence 1996; Keenan et al. 1998b). In fast-growing eucalypt plantations fertiliser studies have shown that nitrogen (N) and phosphorus (P) have the greatest impact on growth. Where soils are already fertile, fertiliser application has less effect than on poorer soils. Research in north Queensland has found that many of the sites available for plantation forestry have deficiencies in available nutrients, so the addition of fertilisers generally has the potential to improve site capture.

Another study in north Queensland with tropical eucalypt species found significant early growth responses with the addition of fertilisers and chemical weed control compared with less intensive site manipulation (Keenan and Bristow 2000). Figure 6.4 shows the increase in plot basal area that can be achieved with the use of chemical weed control (compared with interrow slashing and hand weeding only) and fertilisers.

Studies elsewhere in Australia demonstrate the importance of adequate weed control when applying fertiliser. Competing vegetation such as weeds also benefit from the fertiliser and can have a major impact on survival and early growth of planted eucalypts (Wilkinson and Neilson 1990, Little et al. 1994) and many other species (Evans 1992, Nambiar and Sands 1993).

Except in the case of studies of specific deficiencies like that described in Box 6.5 below, many rainforest timber plantation species respond to fertiliser. This suggests that maintaining a well-balanced supply of nitrogen (N), phosphorus (P) and potassium (K) (see Box 6.4) provides the nutritional needs of most tree species (Evans 1992; Keenan et al. 1998b; Webb et al. 2000). The grower

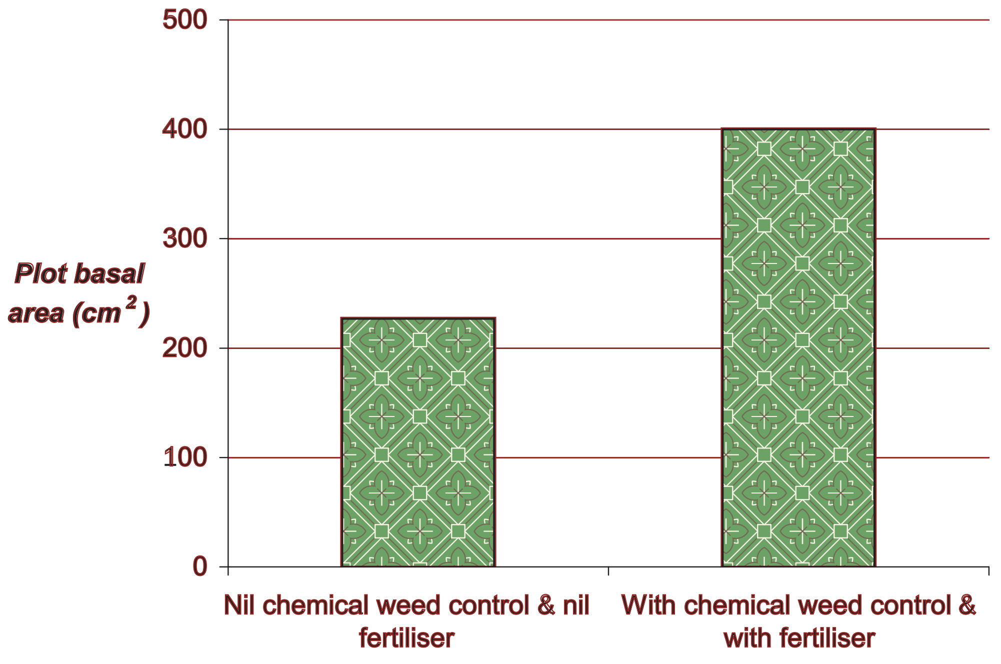


Figure 6.4 Plot basal area response of 13-month-old red mahogany (*Eucalyptus pellita*) trees to chemical weed control and fertiliser.
In early measurements, plot basal area is a measure of site capture. It is the combined girth of all the trees in a set area. For stand management, it is a useful measure of the degree of competition in a stand. Source: adapted from Keenan and Bristow (2000).

should inspect each species at regular intervals for signs of nutrient deficiency.

Timing of application of fertiliser is important, and on the whole, the sooner the fertiliser is applied after planting, the better (Florence 1996; Keenan et al. 1998b). Fertilising soon after planting is recommended because this is when most species, such as eucalypts, acacias and many rainforest timber trees, have their most rapid growth. This is the time of maximum nutritional demand. Exceptions are the native pines, Queensland kauri pine and hoop pine (*Araucareace* family), that grow slower in the first few years, and begin to pick-up pace at about five years of age (Xu et al. 1995). Fertiliser prescriptions for these species reflect this growth pattern.

Box 6.4 Nutrition for successfully establishing plantations

Generally, plantation forestry nutrition studies in Queensland recommend a fertiliser containing N, P and K, with some trace elements, to be used in split applications (the total amount spread over more than one application) over two years. The following table is an example of fertiliser prescriptions based on the results of studies on tropical and subtropical eucalypts in plantation situations.

Table 6.4 Broad fertiliser prescriptions for hardwood plantations in Queensland

Month	Age	Fertiliser	Analysis		Rate (kg/ha)		
			N	P	Fertiliser	N	P
March	0	Staterfos®	10%	21.9%	275	28	60
January	9	Nitram®	34%	0	180	61	0
September	18	Nitram®	34%	0	180	61	0
					Total	150	60

Source: Department of Primary Industries and Fisheries, Queensland (November 2004)

Box 6.5 Case Study: Nutrition experiments with rainforest species

A site near the township of South Johnstone in north Queensland was cleared for agricultural land-use over 30 years ago. In the late 1970s the land was abandoned and transformed to a grassy paddock for grazing cattle. The soil at the site was described as a red podsolic, characterised by low available phosphorus. This soil type is widely distributed across the humid tropics of north Queensland. Trials were undertaken to investigate growth of rainforest timber species on this phosphorus-deficient soil.

Several high-value cabinet timber species were tested for their response to additions of phosphorus. Results showed that when all other elements were controlled, two species, Queensland maple (*Flindersia brayleyana*) and black bean (*Castanospermum australe*) showed little response to additions of a phosphorus-based fertiliser. On the other hand, the other two species tested, West Indian cedar (*Cedrela odorata*) and Queensland kauri pine (*Agathis robusta*), responded strongly in growth to increasing applications of phosphorus.

These results highlight differences in the requirements of rainforest timber trees for nutrients. This type of trial shows the complexities in tree nutrition and indicates that simple prescriptive fertiliser regimes can be difficult to draft and may be inefficient across a range of species.

Source: adapted from Keenan et al. (1998b) and Webb et al. (2000).

6.5 Summary

Boxes 6.6 and 6.7 summarise the activities required to establish and maintain stands of rainforest timber trees. The operations of pruning and thinning are discussed in detail in the following two chapters.

Box 6.6 Plantation establishment—activities summary

Activity	What this means…	Why do it…	Leads to…	How this might be done…
Remove existing vegetation	Removing weeds and grasses from the future plantation area	Soil cultivation is more effective	Weed-free conditions ready for soil cultivation	Burn existing weeds/ grasses
		To reduce short- and long-term competition between trees and weeds	More rapid site capture and growth of tree species	Mechanically slash, then spray herbicides on future tree rows
Soil cultivation	Preparing the site by disturbing the compacted soil	Physically breaks up the soil making it easier for the roots to penetrate the soil Aerates the soil	More rapid establishment of trees through better development of root system	Rip with tine Plough with disks (cultivation) Combination of above
Pre-plant spray	Before trees are planted, herbicides are sprayed onto germinating weeds in tree rows	Ensures the site is completely weed-free at establishment	More rapid establishment of trees through less competition between trees and weeds	Using knockdown herbicides, like glyphosate

Box 6.7 Post-planting plantation management—activities summary

Activity	What this means…	Why do it…	Leads to…	How this might be done…
Weed Control	maintaining weed-free conditions to ensure good survival and growth of trees	maintains competition-free area for the trees to grow	higher survival and growth rates of trees through less competition between trees and weeds	with pre-emergent herbicides, like Simazine®, and spot spraying with knockdown herbicides
Fertilising	applying fertilisers to provide trees with essential nutrients for growth	many soils are limiting in some nutrients (e.g. phosphorus) essential for plant growth	more rapid site capture and higher growth rates of trees increased productivity of stand	multiple applications of a commercial fertiliser in small amounts to each tree
Pruning	remove lateral branches from main stem of tree in stages	maintains good form of trees, and affects recovery, quality and value of timber produced	Clear, knot-free, high quality, high-value timber	one regime might be to prune in two stages, removing no more than 30% of green crown in each operation
Thinning	managing inter-tree competition to reduce the number of trees in the stand over time	to select and maintain trees with good growth rates and form, allowing them to grow to their full potential (in height and girth)	increased sawn timber recoveries from more wide girth trees per hectare	a general guide might be to reduce from original stocking density of 1000 stems per hectare to between 400 and 500 stems per hectare at age 2 to 3, then reduce again to final density between 150 and 250 stems per hectare at age 6 to 10 years

7. Pruning

Safety during pruning operations

Always follow the appropriate safety guidelines for pruning operations. Wear safety boots, safety glasses and safety helmets, and use harnesses if you are carrying out off-ground work.

Few trees in the natural forest are free of defects. Trees are generally crooked or have suffered from fungal and insect infestations, resulting in a significant loss of timber production and quality. The three most important factors that determine timber quantity and quality, and hence value, are:

- straightness;
- length of a single trunk; and
- the amount of knot- and defect-free timber that the trunk can produce.

An intensively managed plantation can significantly reduce this loss. Part of this good management is pruning. Other reasons for pruning include:

- improving aesthetics;
- improving access;
- increasing light and air circulation into dense stands;
- decreasing fire hazard; and
- stand certification.

7.1 The tree defence system

Every injury and infection that a tree receives will be in the tree for the rest of its life. Trees cannot heal themselves, but instead put up barriers to contain infections and to stop further spread to other healthy parts of the tree.

After pruning, a process of permanent protection begins which ultimately prevents the entry of fungi, bacteria and insects through the pruning scar. To seal off the pruning scar the tree produces cells called *callus* which unite and form *woodwood*. The woundwood expands as ribs or rolls about the wound to ultimately seal and protect it. If branches are cut properly a ring, or doughnut, is formed completely around the wound (Figure 7.1).

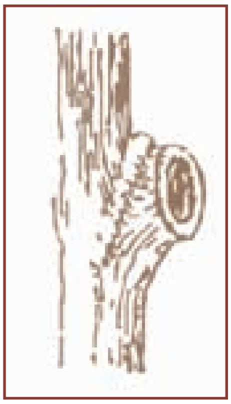


Figure 7.1 The 'doughnut ring' is an indication of wound healing over proper pruning.
Source: Bragg (undated).

Protection zones are formed inside the tree at the base of the pruned branch. They stop disease and organisms entering from the branch into the trunk. Once the woundwood has sealed the pruning scar and the protection zones within are formed, any existing or potential infection is completely sealed off.

Some trees, for example pines, produce a flow of resin over the wound which provides temporary natural protection until the woundwood has sealed the injury. This natural protection has prompted the use of artificial wound dressings on pruning scars. Their value, however, is disputed because they may encourage fungal infection by providing a favourable environment under the dressing or by preventing cut surfaces from sealing as quickly as they would under natural conditions.

7.2 Types of pruning

Four types of pruning are discussed below: *form*, *pre-emptive*, *bud* and *clearwood*. All forms of pruning have a common aim—to produce the maximum amount of 'clearwood' timber (i.e. knot-free and defect-free timber) in order to increase the value of the final product.

Most pruning systems on a stand of trees consist of a number of form and pre-emptive pruning activities, followed by pruning for clearwood production (in multiple lifts) to produce a predetermined log length which is clear of branches (referred to as *bole length*).

In general, at least 50% of the green crown should be left in place after any one pruning operation. Occasionally, poor trees are included in the selection to be pruned so that enough trees will left in the final stand. Pre-emptive pruning such trees may remove in excess of 50% of the green crown and this may temporarily affect the growth rate of the tree.

Box 7.1 Disease control during pruning operations

If pruning diseased branches, dispose of them by burning to reduce the risk of infection. After pruning, always sterilise tools before proceeding to healthy limbs. Household bleach (one part bleach to nine parts of water) can be used and tools scrubbed and immersed for one to two minutes. (Remember that bleach will cause rust on iron implements, and a light oiling before storage could be beneficial.) Ethanol can also be used to sterilise tools.

7.2.1 Form pruning

The purpose of form pruning is to create good stem form and it is simply carried out by removing any leader or branch that may inhibit the formation and growth of a single healthy stem (Box 7.2). Form pruning is practised early in the life of the tree, ideally starting in the nursery, and is mostly concentrated in the first and second years after planting. Correcting defects early in the life of the trees is paramount to developing stronger and healthier trees. While it will be necessary to form prune many trees in the initial planting, the process is simple and requires only a little time to be spent on each tree.

Box 7.2 Form pruning guidelines

Form pruning involves:

- the removal of multi-stems and multi-leaders—the aim is to create a single straight trunk;
- the removal of steeply angled branches which can break or tear off in windy conditions, damaging the main stem, and potentially allowing the entry of pests and diseases (branches that are at angles of less than 30° to the main stem usually have a weak attachment and can also compete with the main leader of the tree);
- the removal of damaged or diseased branches;
- the removal of crossing branches to avoid rubbing and breaking.

Only remove branches falling into the above categories during form pruning.

Tools for form pruning include bypass-type pruning shears and manual loppers for the larger branches.

7.2.2 Pre-emptive pruning

Pre-emptive, or corrective, pruning is the removal or shortening of branches in order to prevent or restrict such branches from developing to a size that may impact on the form, productivity, and health of the tree at a later date (Box 7.3). Pre-emptive pruning removes branches or reduces their leaf area. It concentrates on larger than normal branches or branches with the potential to become too big before the next pruning. Pre-emptive pruning is carried out before the first clearwood pruning lift and in conjunction with any form pruning. Both form and pre-emptive pruning activities can continue to be applied throughout all the follow-on clearwood pruning lifts.

Pre-emptive pruning can also involve the removal of several, but not all, branches from a cluster or whorl of branches, a common occurrence with rainforest species (for example, silver quandong, *Elaeocarpus grandis*). This selective pruning can prevent structural damage to the stem that could result from pruning a complete whorl in one operation. It will provide for easier access for pruning the remaining branches in subsequent pruning events.

Box 7.3 Pre-emptive pruning guidelines

Pre-emptive pruning involves removing up to 30% of the branch foliage to reduce leaf area, ensuring that enough leaf material is left to prevent the death of the branch.

If there is uncertainty about the removal of a branch, growth can be slowed by tipping (removing up to 30% of the branch foliage to reduce leaf area). The branch can then be removed at the next pruning visit.

Through regular observations it will be possible to differentiate between certain species and trees that need steady pruning, and those that show good form without too much interference.

Tools for pre-emptive pruning include manual shears, hand saws and loppers and ladders for high branches.

7.2.3 Bud pruning

The removal of branch buds from the axis of the leaf and main stem of some rainforest trees, notably *Flindersia* species, has proven to be a successful method in preventing branch development and subsequent pruning. Buds are simply pinched out (with fingers), broken or cut out of the axis before they develop hard, woody tissue. This is a cost-saving procedure as branches do not regrow at these points, which reduces the need for later, more intensive pruning. Bud pruning is a useful technique in young stands of rainforest species that can develop heavy early branching when growing in exposed (high light) situations. It can also encourage apical dominance or height development (Figure 7.2).

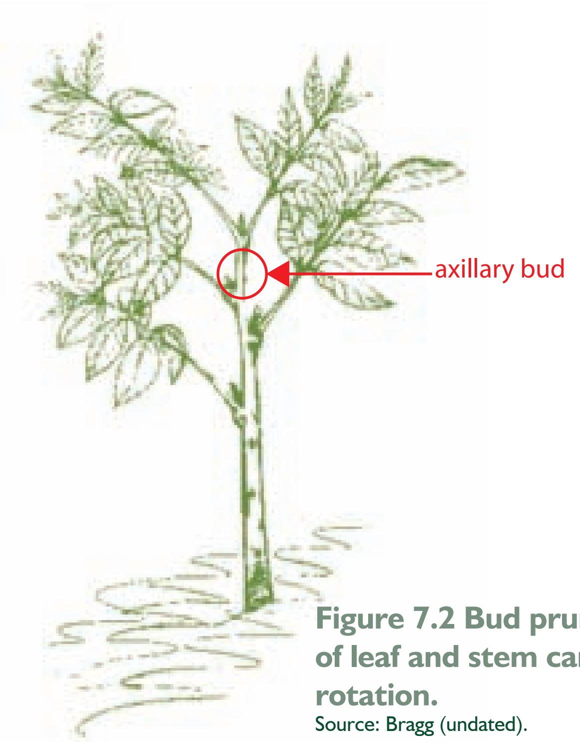


Figure 7.2 Bud pruning. Early removal of the bud between the axis of leaf and stem can save intensive pruning activities later in the rotation.
Source: Bragg (undated).

7.2.4 Clearwood pruning

Defects caused by knots or branch stubs cause the timber value to be downgraded. Knots interfere with the grain of the timber and reduce its strength and appearance qualities—see *Design principles for farm forestry* by Abel et al. (1997), Bird (2000) and Reid and Stephen (2001). Knot and defect-free timber is called *clearwood*. Clearwood is commonly valued for appearance uses including furniture, flooring and joinery work (Reid and Stephen 2001). Clearwood production relies on the timely operation of pruning to a specified height on the bole of the tree (Box 7.4). This process is generally done in stages, or lifts, over a period of years to create a product that is free of knots. After pruning, the wood produced outside the knotty core of the tree will be clearwood (Figures 7.3 and 7.4).

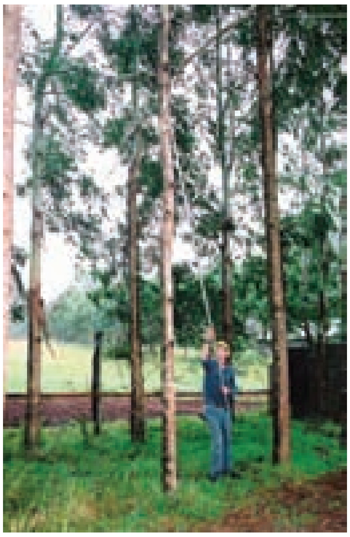


Figure 7.3 Clearwood pruning up to 6 m height

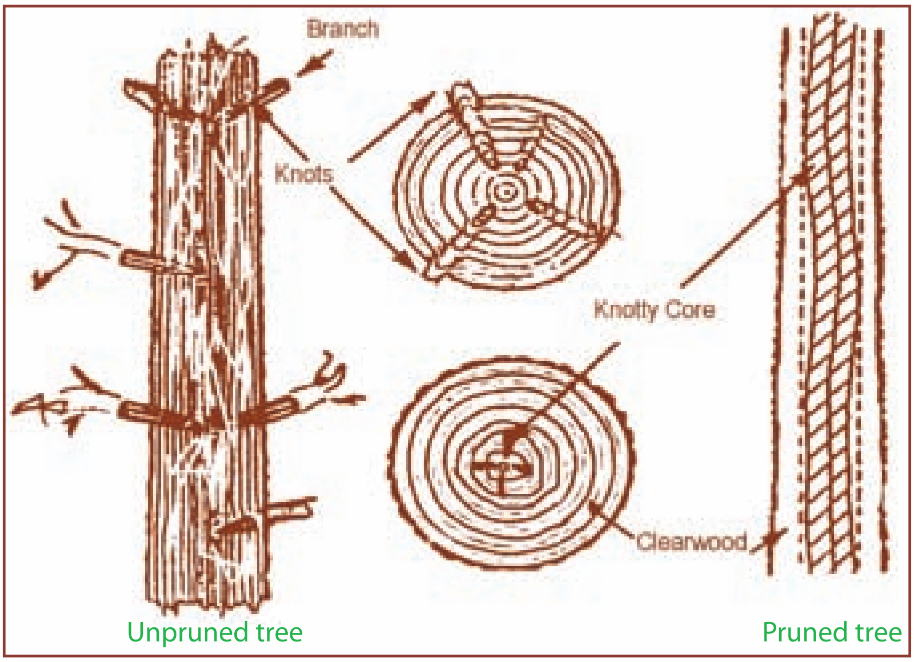


Figure 7.4 Cross and longitudinal sections showing the effects of pruning and not pruning.
Source: DNR (undated).

The knotty core is made up of the diameter measured over the pruned stubs plus the diameter involved in the healing over of the stubs. If, for example, you want to restrict the diameter of the knotty core to less than 13 cm, and you expect that a callus about 1.5 cm thick (or 3 cm of the diameter of the tree) is required to seal the wounds, then you would need to prune when the tree diameter was 10 cm or less. Figure 7.4 demonstrates the importance of early pruning to minimise the size of the knotty core.

Box 7.4 Clearwood pruning—which trees and to what height?

It will only be necessary to clearwood prune a select number of trees for a final crop. As all trees do not grow at the same rate, it is necessary to take into account the height of each individual tree. This is known as *variable height pruning*—each tree is treated individually according to its pruning requirements.

Pruning should be done to a height which will produce a high-value log (Reid and Stephen 2001). A common recommendation with rainforest timbers is to prune the final target trees to 6 m bole height. Some veneer mills only require logs 2.5 m or 3 m long, whereas many sawmills prefer log lengths of 5 m to 6 m. Without knowing the final market of the growing stand, one suggestion is to prune to 6.5 m or 7 m, because taking into account a stump of about 0.5 m, this would allow for two veneer logs or one long sawlog (Reid and Stephen 2001).

7.3 When to prune

Pruning is best timed to remove small living branches so that wound closure can be rapid. Pruning live branches when the tree is young (Box 7.5) also accelerates the transition from juvenile wood to mature wood below the live crown. If pruning lags behind the rise in green crown, it will result in the development of dead branches as the stand of trees grows. When these are removed a proportion of the core can contain branch stubs, bark, and resin pockets, which result in substantial downgrading of the timber. Regular pruning can avoid this. Large limbs usually indicate that pruning has been delayed.

The risk of decay establishing after pruning increases with increasing branch diameter. As a guide, remove branches before they reach 3 cm in diameter. Once branch size exceeds 4 cm in diameter, the need to prune should be questioned because there is a large risk of decay developing in branches beyond this size.

A light form pruning and the pruning of dead branches can be done throughout the year. Heavier pruning should be concentrated in late winter and early spring, preferably during dry periods. At this time fungal activity is less and rapid tree growth is imminent, hastening wound closure.

Box 7.5 When to prune to produce quality timber

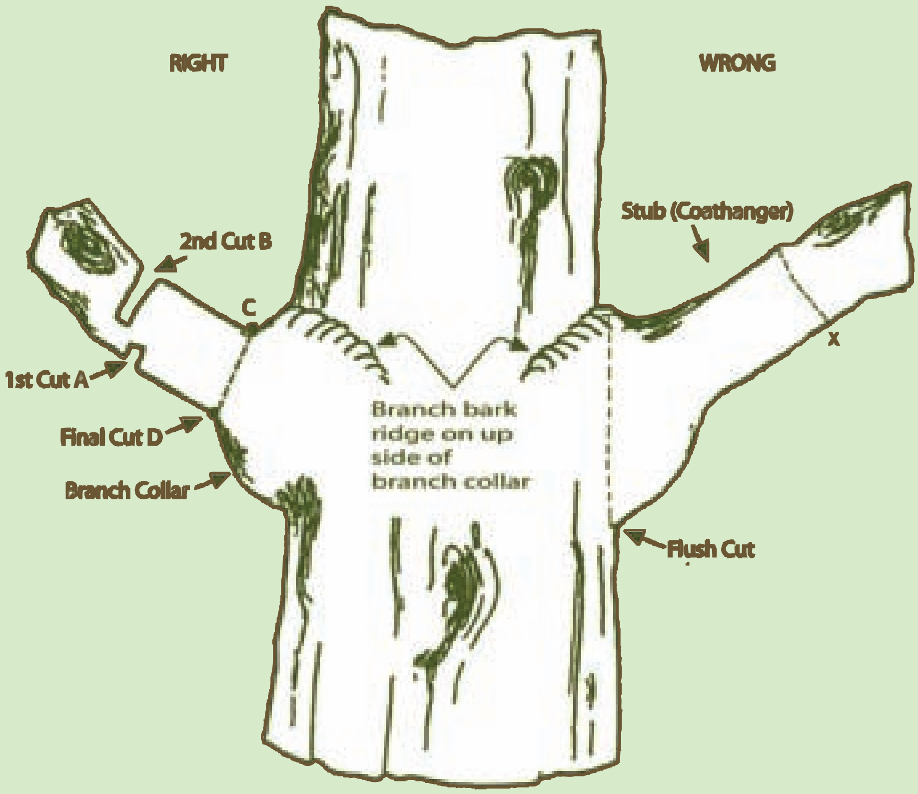
- **Bud prune:** from age 6 months to age 3 years as required.
- **Pre-emptive prune:** at age 1 year, or when trees reach 2 m in height.
- **Select** and mark trees for retention and therefore long-term pruning.
- **Clearwood prune**: at age 2 years and onwards, or once trees reach 6 m in height, at regular intervals.

7.4 The basics: how to cut the branch

As a general guide, each branch should be pruned such that the cut is approximately at right angles to the branch and close to, but not into, the *branch collar* (Reid and Stephen 2001). This is illustrated in Box 7.7. Branch collars are the rings of wood about the bases of branches where the bark and wood of the branch and trunk come together and overlap. They form a shoulder or bulge at the base of the branch. All woody plants have branch collars; in some trees these can be quite large, in others quite small and inconspicuous. Proper pruning cuts are based on the branch collar and care must be taken not to injure or remove the collar when pruning.

Box 7.6 The pruning cut

Take care to avoid injuring the branch collar



Pruning steps:

Step 1

- Stub cut the large branch (up cut A, down cut B). B is located about half the branch thickness from A.

Step 2

- Locate points C and D where the branch meets the branch collar. Cut from C to D with care and as close as possible to the branch collar. The cut angle will depend on the species and size of the branch. For most species the cut should be approximately right angles to the main stem. Do not cut or injure the branch collar.

Small branches can be removed with one cut. Large branches need to be undercut before the final cut is made. Once the weight of the branch has been removed the remaining stub can be safely cut off without damaging the tree.

Source: Treeby (1994).

Figure 7.5 The unique branch stub ejection of the species Kauri pine: it ejects the branch stubs, so pruning can be conducted further back from the branch collar.

Cuts through the branch collar injure stem tissue and can result in decay. In most tree species, cutting flush with the main stem can injure stem tissue, delay or prevent woundwood formation, and provide entry to pests and diseases. Leaving branch stubs (sometimes called coathangers) will also cause pest and disease problems in most species. An exception to this rule is Queensland kauri pine (*Agathis robusta*). If live branches of this species are cut, branch stubs are ejected; allowing for cuts to be made further back along the branch (Figure 7.5).

The *branch bark ridge* is the raised bark that forms within the branch crotch. It indicates the angle of the branch core in the tree. It can be a useful guide in determining the angle of cut for branch removal. Do not prune behind the branch bark ridge.

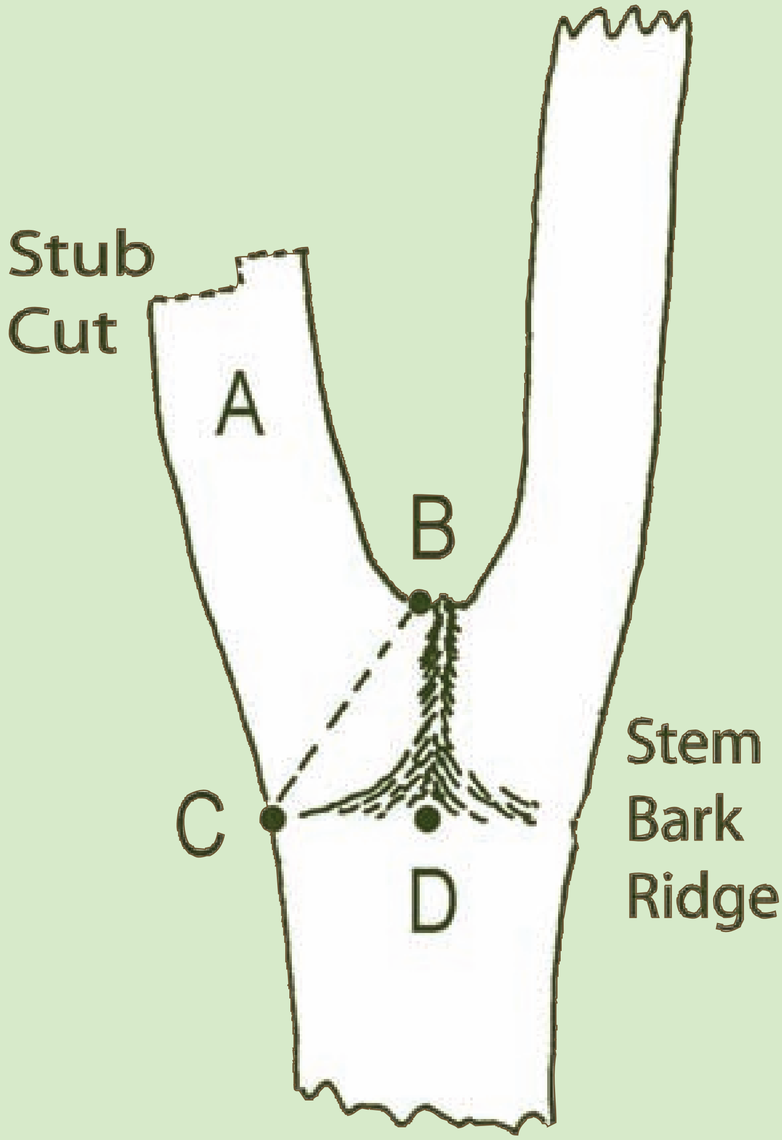
7.5 Co-dominant stems

Co-dominant stems (or *double leaders*) are stems that grow from the same position, usually at steep angles, and are sometimes the result of the *leader* (i.e. the main stem) being damaged. Unlike branches, co-dominant stems do not have branch collars; however, there will be a bark ridge between the stems. To prune such trees, select the strongest and straightest leader and remove the others (Box 7.7).

Pruning co-dominant stems can be the most difficult of the pruning operations as it frequently requires the stem to be cut from below because there is insufficient room to operate a saw from above (Box 7.7).

Box 7.7 Pruning co-dominant stems

Stem A has been selected for removal



To remove stem A, cut from B to C or from C to B with care. B is located just to the left of the stem bark ridge.

Always stub-cut the stem to be removed and then make the final cut.

Points C and D are approximately opposite. This can be a useful guide for the cutting angle if you cannot determine the position of C.

Source: DNR (undated).

8. Thinning

Thinning is a stand management activity requiring the removal of selected trees. If you are growing for high quality sawn timber, appropriately timed thinning activity is essential, with or without a commercial market for the thinnings. Manipulating positive and negative competition to maintain optimum growth rates and to regulate and maintain adequate growing space is one of the most important aspects of stand management (Evans 1992; Reid and Stephen 2001).

Careful management of a plantation necessitates the careful regulation of the stand stocking. Thinning eliminates or reduces the competition for the retained trees, providing them with more space, moisture, and nutrients. These trees will then grow larger crowns and larger root systems and this equates to faster growth, and healthier, fatter trees. The market will pay more for defect-free large diameter trees. Thinning is also a mechanism to reduce disease and insect problems in the stand, and to retain trees with better form and vigour.

Researchers have investigated thinning prescriptions for eucalypts species (Florence 1996; Dickinson et al. 2000) and for some rainforest timber species (Brown et al. 1997; Lamb et al. 1997), however most species' thinning prescriptions are only beginning to be developed. Understanding the principles behind thinning operations, including biological attributes of the species, market requirements and the economics of wood production (Florence 1996), provides farmers with guides for managing their stands.

8.1 Stocking density and thinning

The number of trees planted per hectare (the *stocking density*, see Box 8.1) can influence the rate at which trees will grow in diameter, and hence their value. Through the process of thinning, the yield of timber may be increased, and the time taken to achieve a commercial product reduced (Florence 1996).

Box 8.1 Stocking densities (trees per hectare) resulting from different row and tree spacings

Distance between rows (m)	Average distance between trees along each row (m)										
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	5.0	6.0	7.0	8.0
3	3333	2222	1667	1333	1111	952	833	667	556	476	417
3.5	2857	1905	1429	1143	952	816	714	571	476	408	357
4	2500	1667	1250	1000	833	714	625	500	417	357	312
4.5	2222	1481	1111	889	741	635	556	444	370	317	278
5	2000	1333	1000	800	667	571	500	400	333	286	250
5.5	1818	1212	909	727	606	519	455	364	303	260	227
6	1667	1111	833	667	556	476	417	333	278	238	208
6.5	1538	1026	769	615	513	440	385	308	256	220	192
7	1430	952	714	571	476	408	357	286	238	204	179
7.5	1333	889	667	533	444	381	333	267	222	190	167
8	1250	833	625	500	416	357	312	250	208	179	156
9	1111	741	556	444	370	317	278	222	185	159	139
10	1000	667	500	400	333	286	250	200	167	143	125

Species choice and plantation design will dictate management guidelines for a plantation. For example, trees grown for pulp production or for fence posts are planted at high stocking densities, require no thinning and will be harvested within 5 to 8 years after planting. The low value product from these systems matches the low input costs (Reid and Stephen 2001). Growing rainforest timber for a high-value product such as sawn timber warrants more careful management (i.e. pruning and thinning) throughout the rotation to maximise the value of the logs.

The current use of unimproved planting stock (natural wide genetic variation in rainforest timber tree populations) and the variable site requirements of different species means that not all planted trees will perform well. This is one of the reasons behind the recommendations to plant more trees than will reach final harvest (Box 8.2), which allows poorly performing trees to be removed.

Box 8.2 Stocking density guidelines for rainforest timber species

Plant at high stocking densities—for example, at least 1000 trees per hectare where the final density is expected to be between about 150 to 250 trees per hectare—as this should allow all poorly performing individuals to be culled.

Assess the stand when the trees are 3 m to 4 m high and remove the poorest-performing trees. With many rainforest species, this can be done using a brush hook or a machete.

Early results from spacing trials with rainforest timber species (Lamb et al. 1997) have shown that both Queensland maple (*Flindersia brayleyana*) and silver quandong (*Elaeocarpus grandis*, Figure 8.1) grow taller when grown at higher stockings (up to 2000 trees per hectare compared with just 42 trees per hectare). In addition, branch shading at higher stocking densities led to trees releasing lower branches, resulting in a saving on pruning costs. This suggests that with these two species, early competition between trees encourages better growth and form (Lamb et al. 1997). In contrast, with hoop pine (*Araucaria cunninghamii*) maximum stem volume growth was achieved at a relatively low stocking density of 305 trees per hectare and live branches were retained at stocking densities up to 2150 trees per hectare (Lamb et al. 1997). Consequently, the pruning prescriptions and costs will differ for this species.

Figure 8.1 Thinning in a silver quandong (*Elaeocarpus grandis*) plantation at age 2 years on soils derived from basalt on the coastal lowlands of the Wet Tropics.

In this stand the stocking density was reduced from 800 trees per hectare to 400 trees per hectare at age 2 years. Tree diameter and height growth is being monitored and the second (final) thinning operation will take place between ages 5 and 6 years. The stand will be reduced to a final stocking density of 200 trees per hectare.

Pruning and thinning go hand in hand (Evans 1992). When considering stocking densities this relationship is inverse: high stocking densities tend to lead to minimal pruning but extensive thinning operations while lower stocking densities lead to greater pruning but less thinning. It should also be kept in mind that when only a selection of trees is pruned, any unpruned trees in the plantation gain an advantage. For this reason, and to minimise costs, pruning and thinning are usually carried out at the same time.

For most rainforest timber trees prescriptions have not been developed for when to thin and to what stocking density. Therefore, this chapter outlines some basic principles to guide farmers to assess when their own stands need thinning.

8.2 Assessing the stand: live crown ratio

There are a number of ways to evaluate whether a stand is ready for thinning. One technique is evaluating the *live crown ratio*. The live crown ratio is the depth of the live part of the crown expressed as a percentage of the total height of the tree. *Live crown width and stem diameter ratio* is another measure used to help determine the time to thin. Guidelines for applying the two ratios to make decisions about thinning are described in Box 8.3.

Box 8.3 Guidelines for applying live crown ratios and live crown width and stem diameter ratios to thinning decisions

Live crown ratio varies between species, but also with the stocking level of the stand. A general live crown ratio of 35% may be used as a guide. If the ratio is less than 35% then the trees are ready for thinning—that is, tree growth has slowed down because of competition between trees.

A guide for *live crown width* and *stem diameter ratio* for broad-leafed rainforest timber trees might be a width to diameter ratio of 20 to 1 (e.g. a tree with a crown width of 200 cm and a stem diameter of 10 cm). If the crown width is less than 20 times the stem diameter (i.e. the ratio is less than 20:1), then thinning the stand will create more growing space for the target trees.

It follows that if, for example, the aim is to grow trees of 40 cm stem diameter, they would ultimately need to develop crown widths of about 8 m. Therefore, stands would need to be thinned progressively to achieve an 8 m × 8 m spacing between trees. This spacing equates to 156 trees per hectare, which is within the suggested range of final stocking densities for many rainforest timber trees.

8.3 Assessing the stand: basal area

Basal area is a good measure of stand dynamics and is easily collected. It is a useful guide to determine the timing of thinning and how much to thin. Basal area is the cross-sectional area of a tree stem measured at a height of 1.3 m. The *stand basal area* of a fully stocked plantation frequently lies in the range 20 m^2/ha to 50 m^2/ha.

Stand basal area can be estimated by measuring a few small plots of known area or by point sampling methods with optical instruments (Box 8.4). Point sampling is a good method for determining just the basal area, while plots of known area are recommended for determining stocking density (number of trees or stems per hectare). Commonly, several plots of known area are marked out and remeasured at intervals during a plantation rotation—they are then called 'permanent plots' (Figure 8.2).

Figure 8.2 Measuring a red mahogany (*Eucalyptus pellita*) thinning trial.
Trees in the foreground are at a low stocking density (wide spacing) and are shorter and fatter than the trees in the background, which are at high stocking (close spacing).

Box 8.4 Point sampling for assessing stand basal area

Wedge prisms are readily obtained from:

- Australian MasterTreeGrower Program
  Department of Forestry
  Institute of Land and Food Resources
  The University of Melbourne Victoria 3010

  Phone: 03 8344 5011

  Fax: 03 9349 4172

  email: rfr@unimelb.edu.au

  web: www.mtg.unimelb.edu.au

One type of optical instrument used for point measurements is the wedge prism.

A range of wedge prisms is available. The most commonly-used ones are named *basal area factor prisms 1* to *5*. The different ones suit stands with different ranges of basal areas. In stands with a basal area range from about 20 m^2/ha to 50 m^2/ha, it is recommended that a basal area factor prism of from 2 to 5 is used.

The operator stands over the selected measurement point and holds the wedge prism vertically at eye level and looks through it at a tree. The wedge prism makes it look as though the section of the tree stem visible through the prism has shifted sideways relative to the rest of the tree stem. The optically shifted stems of some trees—the wider and closer ones—will still fall partly within the boundaries of the 'real' tree stem which can still be seen above and below the wedge prism. Such trees are counted 'in'. However, the optically shifted stems of some trees—the smaller and further away ones—will fall outside the tree stem's real boundaries. These trees are 'out'. The operator rotates 360° counting all of the 'in' trees. The number of trees are recorded and multiplied by the factor of the prism to give the basal area in metres square per hectare for that measurement point. Basal area wedge prisms and calculating basal areas are discussed extensively in Reid and Stephen (2001).

Sampling points are established at a number of locations. It is recommended:

- or a planted area of about 0.5 ha to 2.0 ha that appears uniform, select 8 points;
- for a planted area of about 2.0 ha to 10.0 ha that appears uniform, select 12 points;
- for a planted area over 10 ha that appears uniform, select 16 points.

Where there are several acceptable trees and it is difficult to determine which one to remove you need to consider the resultant spacing and distribution of the retained trees. Envisage a well-spaced, evenly distributed, freely growing stand and try not to create large gaps that will not be well utilised by the retained trees. If you are reducing a stand to a certain number of trees per hectare, keep the tree spacing that corresponds to that number in mind as it can be a guide for good distribution (e.g. 400 trees per hectare is equivalent to 5 m × 5 m spacing). Marking for thinning gets more difficult over time. Over consecutive thinning operations the better stems will be left standing; and this means that eventually some good trees will have to be thinned to promote the growth of the most exceptional trees. Markets are not currently available in north Queensland for most small-diameter trees removed in thinning operations (the *thinnings*).

Thinning can be carried out mechanically, by injecting herbicide into tree stems, or by ringbarking. Most thinnings from mechanical operations go 'to waste' on the plantation floor. This practice is expensive in time and money. Stem-injection of herbicide has the advantages of:

- less fire risk;
- fewer access problems; and
- less damage to retained trees and to any understorey species you may wish to protect.

Ringbarking is another option if you do not wish to use herbicides. Both stem-injection and ringbarking leave dying trees standing and this has the disadvantage of safety problems. Injecting herbicide into stems has the additional disadvantage of the risk of 'flash back'—transfer of the herbicide by root contact from the injected tree to retained trees resulting in their death (Dickinson and Huth 2002).

8.4 Time of thinning

In most locations thinning activities can be done at any time, but in north Queensland it would be preferable not to thin just before the cyclonic season. Rather, thin stands just after it to give the trees ample time to strengthen and expand their crowns and root systems into the new space made available by the thinning. In addition, thinning in the dry season (when humidity is lower) means the pruning wounds are less susceptible to fungal problems associated with wet weather.

If there is a market available to take thinning material, timing of later-age thinnings can be matched to the best market prices.

8.5 Recommendations

General thinning guidelines are outlined in Box 8.5 and the case study in Box 8.6 illustrates their application.

Box 8.5 Thinning guidelines for a rainforest timbers plantation

- Plant at high initial stocking densities.
- When trees are 4 m to 5 m tall (match timing with pruning operations), select the best-performing trees.
- Reduce stocking density by 50% when trees average 8 m in height, removing poor performers.
- Reduce stocking density again by 50% when trees average 15 m in height.

Box 8.6: Case study Practice with fictional species *Arborea magnifica*

As an example, let's create a fictitious species, calling it *Arborea magnifica*. It is a sun-loving species, well known and researched. Its market is for large pruned logs. It is a crown-shy species, which means that competition sets in and the growth rates slow when the crowns, or canopies, touch. It is not a fast grower; rotations are as long as 50 years to get logs over 50 cm diameter. The thinning prescriptions have been determined to maximise and maintain growth. It is planted at 3.0 m × 2.5 m (i.e. 3.0 m between rows and 2.5 m between trees along the rows). We have 3 ha of this species planted.

By looking at the table in Box 8.1 we can see that the initial 3.0 m × 2.5 m spacing gives a stocking density of 1333 trees per hectare. To monitor what is happening in our 3 ha stand, we establish a permanent growth measurement plot recording the growth in height and stem diameter at regular intervals. Recommendations for our fictitious species suggest the first thinning should commence when the stand reaches 8 m in height. At this stage the recommendations are that the stand be thinned to half of the initial stocking density—that will reduce the stand to 666 trees per hectare. This first thinning operation will be non-commercial as there is no market for these small thinnings.

Which trees should we choose? To halve the stocking density we have to remove 1 tree in 2, or 2 trees in 4, or 4 in 8, and so on. As we are removing half of the trees it is no harder to mark the ones to remove than to mark the ones to retain. We decide to mark the ones to remove and to put a paint slash mark on each side of them along the row. It is good practice to select half of the trees in a small group of trees, rather than just choosing the poorer of every pair. For example, focus on a block of 12 trees, selecting 3 rows and 4 trees in each row, and look for 6 trees to mark for removal in that block. In our example stand, we use this method and note 2 gaps as a result of deaths in our block of 12 trees. As a result we need only find 4 trees to remove. In selecting the trees for thinning we are looking for defects such as bends, less-than-average growth, crookedness, damage, and we consider spacing, dominance, and vigour. We mark 4 unsatisfactory trees and move to the next 12 trees in the next group along the 3 rows. Once we have marked trees for removal in the whole 3 ha plantation, we cull these trees and prune the retained 666 trees.

A couple of years go by. Regular observations of the permanent measurement plots show us that our hypothetical stand has reached an average of 15 m in height, and the recommended prescription suggests it is now due for a second thinning with the aim of reducing the stand by half again to 333 trees per hectare. We aim to generate some revenue from the thinned trees, and luckily, prior to the operation, we find a market. The second thinning is performed using the same method as before—choosing small groups of trees and taking out half of them. Following thinning, the remaining trees are again pruned, and monitoring is continued.

Future management prescriptions for our fictitious species suggest that throughout the growth of our stand the standing basal area cannot be allowed to go beyond 14 m^2/ha. We measure again (perhaps two years on) from our basal area prism measuring points and the data from 12 points tells us we have a standing basal area of 20 m^2/ha. Thus we need to remove 6 m^2/ha. We examine our plot and point calculations and determine that this amount can be accounted for by removing poorly formed trees in the size class with stem diameters below 25 cm. The thinnings are sold commercially and pruning is repeated. This process of basal area reduction is carried on until the rotation is complete.

9. Mixed species plantations—a case study

9.1 Farmer's perpective

Errol and Margaret Wiles' property borders the eastern side of the Russell River on the humid tropical lowlands of north Queensland, near the township of Babinda. The property is approximately 40 ha in total with more than 70% covered in native rainforest.

When the Wiles family bought the property over a decade ago, there were about 8 ha of river frontage and 4 ha of sloping foothills cleared from previous sugar cane production.

Agriculture was abandoned on these 12 cleared hectares in about the late 1970s, and they were allowed to degenerate into grassland.

Errol and Margaret bought the property with timber production in mind. They also had long-standing aims of creating a wildlife habitat in amalgamation with an aesthetic landscape. Their plan was to manage both their native forest for timber production and establish high-value timber trees on cleared land, in the hope that they and their family would be continuously able to source timber over many generations. Errol and Margaret are well on the way to achieving their goals. Their house block is the only piece of the property not planted up to timber trees. They have learnt many lessons in tree growing and management, and now have regular visits from their cassowary friends (Figure 9.1).

Figure 9.1 Cassowary

Errol and Margaret have always been keen supporters of tropical forestry research, so when QFRI were looking for a trial site in late 1996, they jumped at the chance to be involved. The trial was designed as a mixed species experiment—Box 9.1 discusses the reasons for experimenting with mixed species plantations.

Box 9.1 Why grow more than one species?

Plantation mixtures have been established for three broad reasons:

- potentially greater production,
- site protection, and
- nature conservation, and aesthetic benefits.

Researchers have listed the potential benefits of planting more than one species in more detail (summarised in the Table below). For example, planting in mixtures may lead to earlier site capture with some rainforest species, particularly those which are not sun-loving species. A combination of a faster-growing species with higher-value rainforest species may result in higher establishment success.

Table 9.1 Potential benefits of mixtures compared with monocultures.

Source: adapted from Lamb (2001) who sourced the information from Ewel (1986), Brown and Ewel (1987), Binkley (1992), Kelty (1992), Wormald (1992), Lamb and Lawrence (1993), Keenan et al. (1995), Kelty and Cameron (1995) and Montagnini et al. (1995).

Potential benefit of mixed species plantings	Because of …
Reduced competition	**differences in growth rates** **differences in root structure and depth** **differences in canopy structure**
Reduced insect and pest damage	**target species may be 'hidden' in space or too distant for transfer** **more than one species decreases the risk of attack**
Improved nutrition	**inclusion of nitrogen-fixing species in mixtures** **faster leaf litter decay and improved nutrient turn-over**
Improved financial returns	**early harvest of fast-growing and easily marketed species leaving slower-growing but more valuable species to develop over time** **harvest also acts as a thinning allowing improved growth of residual trees**

Complementary mixtures might also be less susceptible to fungal, insect or animal damage than monocultures. Research has shown that when red cedar (*Toona ciliata*) is grown in combination with other species, the incidence of cedar tip moth attack is reduced (Keenan et al. 1995). Other studies have also identified nutritional advantages with mixed species plantings when nitrogen-fixing species, such as *Acacia* species, are included in the mixture in nitrogen-deficient soils (Khanna 1997; Binkley et al. 2000).

Also, planting mixtures could provide greater economic returns than using monocultures of rainforest species. By targeting a range of products it may be possible to reduce the farmer's market risk.

9.2 The mixed species trial

As previously discussed, growing rainforest timber trees in plantations involves a series of decisions about species and site selection, plantation establishment, and stand management. For softwood species, considerable research effort has resulted in relatively precise management prescriptions to achieve desired management outcomes. However, few such prescriptions have been prepared for hardwood species in Australia in general (see recent exceptions for tropical and subtropical eucalypts at www.dpi.qld.gov.au/hardwoodsqld/). A particular challenge is to develop management prescriptions for mixed species plantations, which was the type of experimental planting on the Wiles' property.

More than one species can be incorporated into the farm design in many ways. Figure 9.2 shows some possible layouts for plantings incorporating three species on a site.

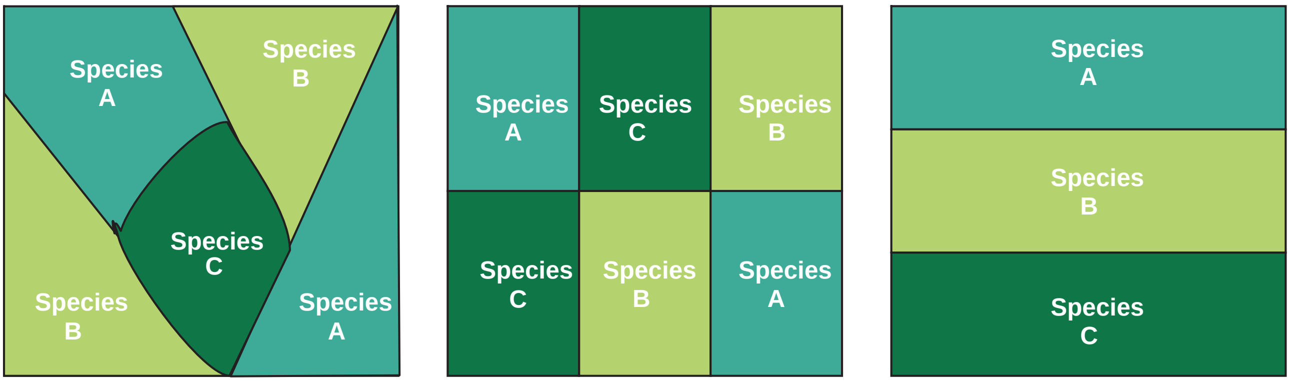


Figure 9.2 More than one species planted in a block.
Source: redrawn from ***Design principles for farm forestry*** Abel et al. 1997.

The concept of capturing and manipulating differences between species seems a simple one. The objective of this experiment was to design and test a simple mixed species planting and to determine which species can benefit from being grown in mixtures and which particular species should not be grown in mixtures.

9.3 How did we prepare the site for planting?

In the dry season, the site was prepared by burning the existing grasses and weeds then using broad-acre cultivation with several passes with a disc-plough. This cultivation broke up the surface soil to a depth of 40 cm, creating a fine tilth. About three months before planting, at the onset of the first summer storms, tree rows were ploughed at 2 m spacing. One month before planting we applied the herbicide glyphosate (4 L/ha) to control germinating grasses and soft weeds. Then we waited for heavy rains (about 100 mm in the week prior to planting) to create ideal conditions for planting the trees.

9.4 What species did we try, why and what design was used?

Four species were used in this trial, all suited to the coastal lowlands but with considerably different growth rates, canopy and root structures, uses and other features. Timber characteristics of these species are described in the *Timber Species Series* notes in Appendix 5.

The species used were:

silver quandong	*Elaeocarpus grandis*
red mahogany	*Eucalyptus pellita*
Queensland maple	*Flindersia brayleyana*
brown salwood	*Acacia aulacocarpa*

Silver quandong is a sun-loving, rainforest timber tree that has a distinctly whorled branching pattern and shallow, buttress roots. The white, straight-grained timber, although on the Group C list when harvested from native forests (see Section 3.1), was sought after for boat building as it was good for steam bending and easily worked (Bootle 1983). The blue fruits of this species are a favourite of fruit-eating rainforest birds such as the cassowary.

Red mahogany is a fast growing, sun-loving eucalypt species that occurs naturally in an open forest formation. It was not listed on the commercial rainforest timbers list (see Section 3.1) as it is a eucalypt species and generally not classified with other rainforest timbers. It has a distinct tap root. The timber is red and very dense.

Queensland maple was a well-known Group A list timber species when harvested from natural stands and is a prized veneer and turning species. The trunk is not buttressed and it is known to be shallow-rooted. The tree has been described as an intermediate species in terms of the amount of sun it prefers to grow in, but several studies have pointed out that its canopy growth, and thus form, is closely linked to how much sun it receives (Thompson et al. 1988; Lamb et al. 1997).

Brown salwood is a nitrogen-fixing species that occurs commonly in the rainforest and open woodlands of the north Queensland Wet Tropics area. It is a fast-growing, sun-loving species that is often found colonising recently disturbed areas such as road verges. The timber has similar features to the well-marketed Tasmanian blackwood (*Acacia melanoxylon*), although it was only on the Group D list in north Queensland.

We wanted to test these species on their own and when grown amongst each of the others to see if we could improve the growth rates, and hence decrease rotation time and increase the financial benefit using mixed species plantations.

The mixture treatments consisted of planting these species with one other in a 'pairwise' mix (two species planted in alternating rows in a stand). The monocultures were used as a comparison and consisted of pure stands of each of the four species (Figure 9.3). We chose this simple mix to gain an understanding of how each of these species influences others. That is, how one species was competing for resources with one other species. We could have mixed the species up in random order, or added more species, but that would have made investigations into competition very complex. From such simple mixtures, we hope to be able to recommend species that grow well together, and those that do not.

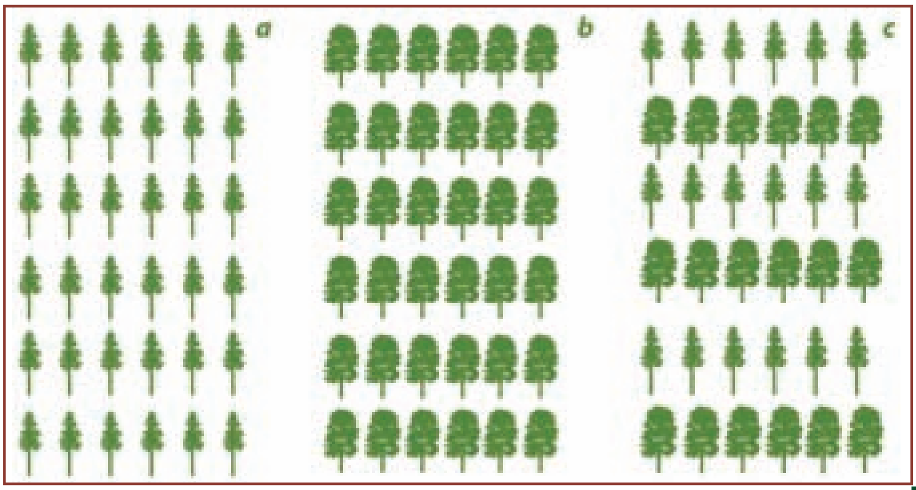


Figure 9.3 The designs investigated were a: species A in a monoculture; b: species B in a monoculture and c: a pairwise mixture (alternating rows) of species A and B.

The trees were planted with 2 m between rows and 2 m between trees within rows to give an initial stocking of 2500 stems per hectare. This close stocking density was chosen from an experimental viewpoint to monitor competition between and within the trees—stands with a high stocking density show the effects of competition at an earlier age.

9.5 What did we do after planting?

Directly after planting, the trees were fertilised at a rate of 150 g of DAP (diammonium phosphate) per tree (equivalent to 300 kg/ha). DAP has nitrogen:phosphorus:potassium (N:P:K) ratios of 17:19:5. Due to the high stocking density of the trees, this single application 'starter dose' provided about 65 kg/ha of N, 71 kg/ha of P and less than 20 kg/ha of K. Fertiliser was applied to each individual tree in a ring about 30 cm to 40 cm from the central stem.

Post-planting weed control was performed manually using a knapsack and directly spraying weeds (avoiding seedlings) with glyphosate (at a rate of 4 L/ha). The plantation received two sprays in the first 12 months. The high stocking density and the good survival and growth rates of all the trees in the first 12 months led to rapid site capture. This resulted in little weed competition and low herbicide requirements—after the first 12 months, weed control was minimal and necessary only in some plots.

9.6 How did we manage the stand?

Our original plan was to thin the plantation to approximately 500 trees per hectare at age 2 years. However, because of good growth rates it was decided to 'control' the competition between the trees for a longer period of time, so as to accumulate more information about competition in the various treatments. As a result, the entire stand was thinned by 50% (to 1250 trees per hectare) at age 2 years, followed by form pruning selected trees.

All plots were pruned and thinned with all species being grown for sawlogs. The stand was thinned again by 50% at age 4 years to 625 trees per hectare, and selected trees (approximately 300 trees per hectare) were pruned to a height of 8 m (for the red mahogany and silver quandong) or to 5 m (for the other species). The stand will be thinned again by 50% at age 5.5 years.

9.7 Problems along the way

The trial has been monitored for insect and other pathogenic problems. Problems experienced in this trial include:

Chrysomelid leaf beetles (*Rhyparida discopunctualata*) and tip sucking bugs (*Mictis profana*) were found at age 6 months. They caused considerable damage to the brown salwood saplings (Figure 9.4). These were not treated and trees have recovered, although form was badly affected.

The site was damaged by tropical cyclones at age 1 year and again at age 2 years. Many trees were knocked down (especially brown salwood) and some tops broken out (especially red mahogany, Figure 9.5).

Figure 9.4 Tip sucking bug caused tip dieback in brown salwood (*Acacia aulacocarpa*)

Figure 9.5 Damage from tropical cyclone, at age 2 years.

9.8 What did we find out?

All species grew rapidly in the first 4 years after planting. Results showed that this high-rainfall coastal lowlands site is well-suited to growing red mahogany, silver quandong and Queensland maple in plantations (Figures 9.5 and 9.6).

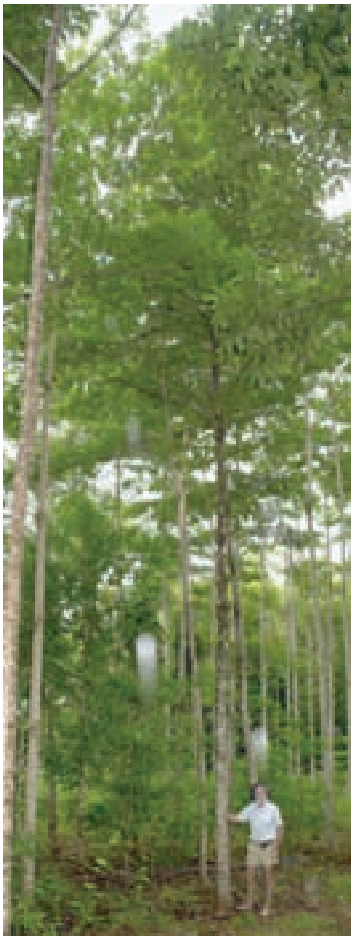


Figure 9.7 Errol Wiles standing amongst a 5.5 year old silver quandong (*Elaeocarpus grandis)* plot.

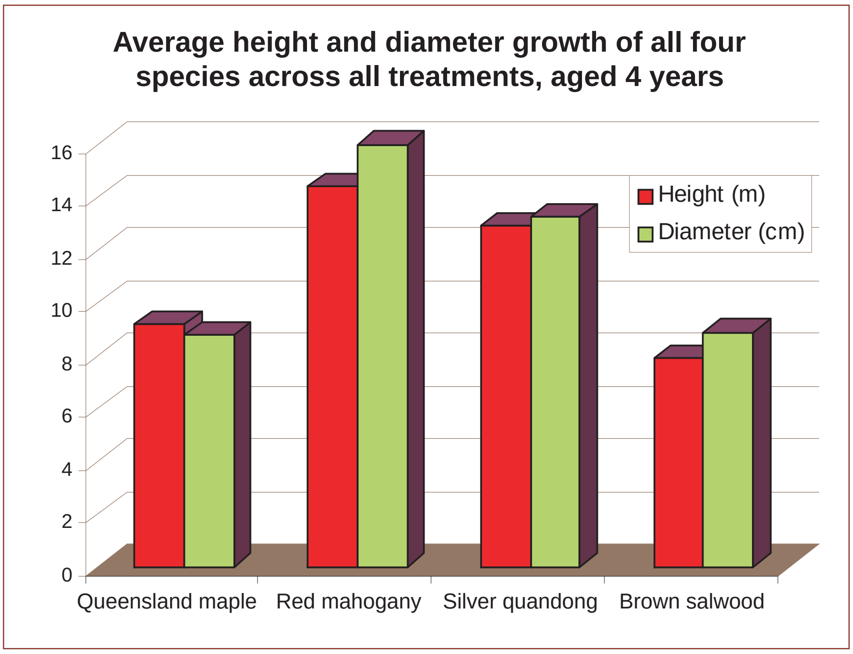


Figure 9.6 Height and diameter growth for all four species averaged across both the monoculture and mixed species treatments at age 4 years.

The relatively slow-growing Queensland maple performed better in a mixture than in a monoculture. Its average height was significantly greater when grown in mixtures with two of the other three species, than in a monoculture. The height gain was 17% when grown in a mixture with silver quandong and 43% when grown in a mixture with red mahogany. Other early results indicate, although not significantly, that the diameter of brown salwood was greater when grown in mixtures with each of the other three species. Diameter increases of up to 35% were achieved when this species was grown with red mahogany.

There were no other significant interactions between mixtures of other species, indicating at this stage that productivity is not affected, either positively, or negatively, by growing these species in mixtures. There was some indication that mixtures of the red mahogany and the silver quandong resulted in productivity decreases (compared with monocultures of each of these species), although the differences were not statistically significant. This could be caused by competition for light between these two sun-loving species. Monitoring of their growth will continue. Also at this early stage there is no measurable benefit from the nitrogen-fixing species, brown salwood, possibly because of the high level of soil fertility on the site.

9.9 What this means for the future of mixtures

These early results suggest that mixtures can result in production gains, or potentially losses, depending on the species in the mixture. For the valuable Queensland maple, planting it with any other species led to increases in early height growth, especially when planted with either silver quandong or red mahogany. For a mixed stand of this species, this could mean the yield of timber may be increased and the time taken to achieve a commercial product reduced.

Results with other species combinations are not clear at this early stage, but it is interesting to note that there was no significant growth decreases by growing more than one species in a plantation. In fact, these results point out that by adding Queensland maple to the plantation, the growth of other species is unaffected. Therefore, the value of a plantation of rapidly growing red mahogany or silver quandong timber trees could be increased by incorporating the high-value timber species Queensland maple since it would not slow their growth rates.

It should be noted that mixed species plantations will probably always be restricted to relatively small areas of the landscape and that monocultures will dominate, especially in industrial plantation areas. But many growers are expecting plantations to satisfy a broader range of demands than pure commercial production, so systems such as mixtures need further research to meet these needs. However, a point has already been reached where farmers can start to have some confidence and optimism about growing rainforest timber trees.

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11. Appendices

Appendix 1: Further reading

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Appendix 2: North Queensland commercial rainforest list and groupings (1986) prior to the cessation of logging in Wet Tropic rainforests

This table lists the commercial groups to which species were allocated prior to the cessation of logging in the rainforests of the Wet Tropics. Groups were determined by order of marketing desirability, with Group A being the most favoured (see Section 3.1).

NC = 'Non compulsory'—harvesting or otherwise of these species was determined by the millers.

Commercial group	Standard trade name	Botanical name
D	Almondbark	*Prunus turneriana*
C	Barringtonia	*Barringtonia calyptrate*
NC	Bignonia	*Deplanchea tetraphylla*
C	Black bean	*Castanospermum australe*
B	Black pine	*Prumnopitys amara*
NC	Black silky oak	*Stenocarpus reticulatus*
D	Blackwood	*Acacia melanoxylon*
D	Blush alder	*Sloanea australis*
NC	Blush satinash	*Acmena hemilampra*
C	Blush silky oak	*Opisthiolepis heterophylla*
NC	Blush touriga	*Calophyllum spp* (4 species)
NC	Blush walnut	*Beilschmiedia obtusifolia*
NC	Blushwood	*Hylandia dockrillii*
C	Bolly silkwood	*Cryptocarya oblata*
D	Bollywood	*Litsea bindoniana*
D	Bollywood	*Litsea glutinosa*
D	Bollywood	*Litsea leefeana*
D	Bollywood	*Litsea fawcettiana*
D	Bollywood	*Litsea connorsii*
C	Boonjie blush walnut	*Beilschmiedia volckii*
B	Briar silky oak	*Musgravea heterophylla*
NC	Brown cudgerie	*Canarium australasicum*
NC	Brown penda	*Xanthostemon chrysanthus*
D	Brown pine	*Podocarpus elatus*
C	Brown quandong	*Elaeocarpus coorangooloo*
C	Brown quandong	*Elaeocarpus ruminatus*
D	Brown salwood	*Acacia aulacocarpa*
D	Brown salwood	*Acacia mangium*
D	Brown silky oak	*Darlingia darlingiana*
D	Brown tulip oak	*Argyrodendron trifoliolatum*
C	Brown walnut	*Endiandra acuminata*
C	Brush mahogany	*Geissois biagiana*
D	Buff silky oak	*Sphalmium racemosum*
NC	Bumpy satinash	*Syzygium cormiflorum (ramiflorous)*
NC	Buttonwood	*Glochidion* spp
NC	Caledonian oak	*Carnarvonia araliifolia*
D	Canary beech	*Polyalthia michaelii*
NC	Candlenut	*Aleurites moluccana* (2 varieties)
D	Cassowary satinash	*Acmena graveolens*
D	Cheesewood	*Nauclea orientalis*
D	Cherry satinash	*Syzygium luehmannii*
NC	Coach walnut	*Endiandra dichrophylla*
NC	Coach walnut	*Endiandra montana*
NC	Coach walnut	*Endiandra glauca*
D	Coach walnut	*Beilschmiedia tooram*
C	Crater silky oak	*Musgravea stenostachya*
C	Cream mahogany	*Chisocheton longistipitatus*
D	Creek satinash	*Syzygium australe*
C	Damson	*Terminalia sericocarpa*
D	Endospermum	*Endospermum myrmecophilum*
NC	Eumundi quandong	*Elaeocarpus eumundi*
C	Euodia	*Melicope elleryana*
C	Fishtail silky oak	*Neorites kevediana*
NC	Grey boxwood	*Drypetes lasiogyna var australasica*
C	Grey carabeen	*Sloanea macbrydei*
NC	Grey sassafras	*Dryadodaphne novoguineensis*
C	Grey satinash	*Syzygium gustavioides*
NC	Hairy walnut	*Endiandra insignis*
NC	Hard alder	*Pullea stutzeri*

Commercial group	Standard trade name	Botanical name
D	Hard Leichhardt	*Neonauclea glabra*
D	Hard milkwood	*Alstonia muelleriana*
D	Hard quandong	*Elaeocarpus sericopetalus*
A	Hickory ash	*Flindersia ifflaiana*
NC	Hickory boxwood	*Planchonella euphlebia*
NC	Incensewood	*Anthocarapa nitidula*
NC	Ivory mahogany	*Dysoxylum gaudichaudianum*
B	Johnstone River hardwood	*Backhousia bancroftii*
C	Kuranda satinash	*Syzygium kuranda*
D	Kwila	*Intsia bijuga*
D	Lillipilli satinash	*Acmena smithii*
NC	Macintyre's boxwood	*Xanthophyllum octandrum*
C	Magnolia	*Galbulimima belgraveana*
A	Maple silkwood	*Flindersia pimenteliana*
D	Mararie	*Pseudoweinmannia lachnocarpa*
C	Miva mahogany	*Dysoxylum muelleri*
C	Northern euodia	*Melicope vitiflora*
D	Northern quandong	*Elaeocarpus foveolatus*
D	Northern scentless rosewood	*Synoum muelleri*
A	Northern silky oak	*Cardwellia sublimis*
D	Nutmeg	*Myristica insipida*
D	Paperbark satinash	*Syzygium papyraceum*
C	Pepperwood	*Cinnamomum laubatii*
D	Pink ash	*Alphitonia petriei*
D	Pink mahogany	*Dysoxylum oppositifolium*
C	Pink myrtle	*Metrosideros queenslandica*
D	Pink satinash	*Syzygium sayeri*
NC	Pink sycamore	*Ceratopetalum virchowii*
NC	Plum boxwood	*Niemeyera prunifera*
D	Plum satinash	*Syzygium wilsonii* subsp. *cryptophlebium*
A	Queensland kauri pine	*Agathis atropurpurea*
A	Queensland kauri pine	*Agathis microstachya*
A	Queensland kauri pine	*Agathis robusta*
A	Queensland maple	*Flindersia brayleyana*
A	Queensland walnut	*Endiandra palmerstonii*
NC	Red ash	*Alphitonia whitei*
A	Red cedar	*Toona ciliata*
C	Red Eungella satinash	*Acmena resa*
C	Red penda	*Xanthostemon whitei*
B	Red silkwood	*Palaquium galactoxylum*
B	Red siris	*Paraserianthes toona*
B	Red tulip oak	*Argyrodendron peralatum*
C	Rose alder	*Caldcluvia australiensis*
C	Rose butternut	*Blepharocarya involucrigera*
D	Rose maple	*Cryptocarya onoprienkoana*
C	Rose silky oak	*Placospermum coriaceum*
C	Rose silky oak	*Darlingia ferruginea*
D	Rose walnut	*Endiandra cowleyana*
D	Rough barked satinash	*Syzygium trachyphloium*
D	Salmon bean	*Archidendron vaillantii*
C	Sassafras	*Doryphora aromatica*
B	Satin oak	*Alloxylon wickhamii*
C	Satin sycamore	*Ceratopetalum succirubrum*
NC	Scaly ash	*Ganophyllum falcatum*
C	Scented maple	*Flindersia laevicarpa*
NC	Scrub turpentine	*Canarium australianum*
NC	Scrub turpentine	*Canarium muelleri*

Commercial group	Standard trade name	Botanical name
NC	Silky celtis	*Celtis panicularа*
A	Silver ash	*Flindersia bourjotiana*
A	Silver ash	*Flindersia schottiana*
C	Silver quandong	*Elaeocarpus grandis*
A	Silver silkwood	*Flindersia acuminata*
NC	Spotted silky oak	*Buckinghamia celsissima*
C	Spur mahogany	*Dysoxylum pettigrewianum*
C	Stony backhousia	*Backhousia hughesii*
D	Tropical quandong	*Elaeocarpus largiflorens*
D	Tulip plum	*Pleiogynium timorense*
NC	Whelan's silky oak	*Macadamia whelanii*
B	White beech	*Gmelina fasciculiflora*
D	White birch	*Schizomeria whitei*
C	White carabeen	*Sloanea langii*
D	White cedar	*Melia azedarach*
B	White cheesewood	*Alstonia scholaris*
C	White Eungella satinash	*Syzygium wesa*
D	White hazelwood	*Symplocos cochinchinensis var stawellii*
D	White siris	*Ailanthus triphysa*
C	Yellow bean	*Ormosia ormondii*
D	Yellow boxwood	*Planchonella obovoidea*
D	Yellow boxwood	*Planchonella pohlmaniana*
D	Yellow euodia	*Euodia bonwickii*
D	Yellow penda	*Ristantia pachysperma*
C	Yellow satinash	*Syzygium canicortex*
C	Yellow siris	*Archidendropsis xanthoxylon*
C	Yellow walnut	*Beilschmiedia bancroftii*

Appendix 3: Guide to site-species selections for growing rainforest timber trees

These tables indicate the species that may have occurred naturally on a particular site, but they are only intended as a guide and a more thorough investigation of individual species and their suitability is required.

The Timber Species Group number refers to the tables in Appendix 4.

Alluvial or colluvial soils

Site	Altitude (m)	Rainfall (mm)	Timber Species Group number
Lowlands	0 – 40	2000 – 3200+	3
Foothills	40 – 400	1600 – 2000 2000 – 3200+	6 3
Uplands	400 – 800	1600 – 2000 2000 – 3200 3200+	6 8 12
Highlands	800+	1600 – 3200	12

Basalt soils

Site	Altitude (m)	Rainfall (mm)	Timber Species Group number
Lowlands	0 – 40	2000 – 3200+	5
Foothills	40 – 400	1600 – 2000 2000 – 3200+	2 5
Uplands	400 – 800	1600 – 2000 2000 – 3200 3200+	7 9 7
Highlands	800+	1600 – 3200	10

Other soils - including metamorphic, basic plutonic, acid volcanic and Tully granites

Site	Altitude (m)	Rainfall (mm)	Timber Species Group number
Lowlands	0 – 40	2000 – 3200+	4
Foothills	40 – 400	1600 – 2000 2000 – 3200+	6 4
Uplands	400 – 800	1600 – 2000 2000 – 3200 3200+	6 8 12
Highlands	800+	1600 – 3200+	12

Appendix 4: North Queensland commercial rainforest list and groupings (1986) prior to the cessation of logging in Wet Tropic rainforests

These Timber Species Groups are based on the species' ecological characteristics in conjunction with their timber values when they were extracted from native rainforests, prior to the 1998 World Heritage Listing of north Queensland forest (Irvine, A. K., pers. comm.). They can be used in conjunction with the tables in Appendix 3 to help with matching species to sites based on where the species occurred and its ecological requirements.

The tables are abstracted from Goosem and Tucker (1995).

Timber species group 2

Common name	Botanical name
Barringtonia	*Barringtonia calyptrata*
Black bean	*Castanospermum australe*
Blush touriga	*Calophyllum* spp
Blush walnut	*Beilschmiedia obtusifolia*
Brown beech	*Litsea fawcettiana*
Bumpy satinash	*Syzygium cormiflorum (ramiflorous)*
Candlenut	*Aleurites moluccana* (2 varieties)
Cheesewood	*Nauclea orientalis*
Damson	*Terminalia sericocarpa*
Miva mahogany	*Dysoxylum muelleri*
Northern euodia	*Melicope vitiflora*
Nutmeg	*Myristica insipida*
Queensland maple	*Flindersia brayleyana*
Red cedar	*Toona ciliata*
Red silkwood	*Palaquium galactoxylum*
Silver quandong	*Elaeocarpus grandis*
White cedar	*Melia azedarach*
White cheesewood	*Alstonia scholaris*
Yellow boxwood	*Planchonella obovoidea*

Timber species group 3

Common name	Botanical name
Almondbark	*Prunus turneriana*
Barringtonia	*Barringtonia calyptrata*
Bignonia	*Deplanchea tetraphylla*
Black bean	*Castanospermum australe*
Blush satinash	*Acmena hemilampra*
Blush walnut	*Beilschmiedia obtusifolia*
Bolly silkwood	*Cryptocarya oblata*
Bollywood	*Litsea leefeana*
Brown silky oak	*Darlingia darlingiana*
Bumpy satinash	*Syzygium cormiflorum (ramiflorous)*
Candlenut	*Aleurites moluccana* (2 varieties)
Cheesewood	*Nauclea orientalis*
Damson	*Terminalia sericocarpa*
Endospermum	*Endospermum myrmecophilum*
Euodia	*Melicope elleryana*
Grey satinash	*Syzygium gustavioides*
Hard Leichhardt	*Neonauclea glabra*
Ivory mahogany	*Dysoxylum gaudichaudianum*
Kuranda satinash	*Syzygium kuranda*
Kwila	*Intsia bijuga*
Maple silkwood	*Flindersia pimenteliana*
Miva mahogany	*Dysoxylum muelleri*
Northern quandong	*Elaeocarpus foveolatus*
Northern silky oak	*Cardwellia sublimis*
Nutmeg	*Myristica insipida*
Red silkwood	*Palaquium galactoxylum*
Sassafras	*Doryphora aromatica*
Scaly ash	*Ganophyllum falcatum*
Scrub turpentine	*Canarium australianum*

Common name	Botanical name
Silver ash	*Flindersia bourjotiana*
Silver ash	*Flindersia schottiana*
Silver quandong	*Elaeocarpus grandis*
Spur mahogany	*Dysoxylum pettigrewianum*
Tulip plum	*Pleiogynium timorense*
White beech	*Gmelina fasciculiflora*
White carabeen	*Sloanea langii*
White cedar	*Melia azedarach*
White hazelwood	*Symplocos cochinchinensis* subsp *thwaitesii* (5 varieties exist)
Yellow bean	*Ormosia ormondii*
Yellow boxwood	*Planchonella obovoidea*
Yellow euodia	*Euodia bonwickii*
Yellow penda	*Ristantia pachysperma*
Yellow walnut	*Beilschmiedia bancroftii*

Timber species group 4

Common name	Botanical name
Almondbark	*Prunus turneriana*
Bignonia	*Deplanchea tetraphylla*
Black bean	*Castanospermum australe*
Blush walnut	*Beilschmiedia obtusifolia*
Bolly silkwood	*Cryptocarya oblata*
Bollywood	*Litsea bindoniana*
Bollywood	*Litsea leefeana*
Briar silky oak	*Musgravea heterophylla*
Brown penda	*Xanthostemon chrysanthus*
Brown salwood	*Acacia aulacocarpa*
Brown salwood	*Acacia mangium*
Brown silky oak	*Darlingia darlingiana*
Bumpy satinash	*Syzygium cormiflorum (ramiflorous)*
Caledonian oak	*Carnarvonia araliifolia*
Candlenut	*Aleurites moluccana* (2 varieties)
Cheesewood	*Nauclea orientalis*
Cherry satinash	*Syzygium luehmannii*
Damson	*Terminalia sericocarpa*
Endospermum	*Endospermum myrmecophilum*
Euodia	*Melicope elleryana*
Fishtail silky oak	*Neorites kevediana*
Grey satinash	*Syzygium gustavioides*
Hard Leichhardt	*Neonauclea glabra*
Hickory ash	*Flindersia ifflaiana*
Kuranda satinash	*Syzygium kuranda*
Maple silkwood	*Flindersia pimenteliana*
Miva mahogany	*Dysoxylum muelleri*
Northern quandong	*Elaeocarpus foveolatus*
Northern silky oak	*Cardwellia sublimis*
Pink satinash	*Syzygium sayeri*
Pink sycamore	*Ceratopetalum virchowii*
Queensland maple	*Flindersia brayleyana*
Silver ash	*Flindersia bourjotiana*
Red penda	*Xanthostemon whitei*
Red silkwood	*Palaquium galactoxylum*
Sassafras	*Doryphora aromatica*

Common name	Botanical name
Scaly ash	*Ganophyllum falcatum*
Scrub turpentine	*Canarium muelleri*
Silver quandong	*Elaeocarpus grandis*
Spur mahogany	*Dysoxylum pettigrewianum*
White beech	*Gmelina fasciculiflora*
White cedar	*Melia azedarach*
White hazelwood	*Symplocos cochinchinensis* subsp. *thwaitesii* (5 varieties exist)
Yellow bean	*Ormosia ormondii*
Yellow boxwood	*Planchonella obovoidea*
Yellow penda	*Ristantia pachysperma*
Yellow siris	*Archidendropsis xanthoxylon*
Yellow walnut	*Beilschmiedia bancroftii*

Timber species group 5

Common name	Botanical name
Almondbark	*Prunus turneriana*
Barringtonia	*Barringtonia calyptrata*
Black bean	*Castanospermum australe*
Blush walnut	*Beilschmiedia obtusifolia*
Bolly silkwood	*Cryptocarya oblata*
Bollywood	*Litsea fawcettiana*
Bollywood	*Litsea leefeana*
Brown penda	*Xanthostemon chrysanthus*
Brown silky oak	*Darlingia darlingiana*
Candlenut	*Aleurites moluccana* (2 varieties)
Cassowary satinash	*Acmena graveolens*
Cheesewood	*Nauclea orientalis*
Damson	*Terminalia sericocarpa*
Euodia	*Melicope elleryana*
Grey satinash	*Syzygium gustavioides*
Johnstone River hardwood	*Backhousia bancroftii*
Kuranda satinash	*Syzygium kuranda*
Maple silkwood	*Flindersia pimenteliana*
Milky pine	*Alstonia scholaris*
Northern euodia	*Melicope vitiflora*
Northern silky oak	*Cardwellia sublimis*
Nutmeg	*Myristica insipida*
Pink satinash	*Syzygium sayeri*
Queensland maple	*Flindersia brayleyana*
Red silkwood	*Palaquium galactoxylum*
Red tulip oak	*Argyrodendron peralatum*
Sassafras	*Doryphora aromatica*
Scaly ash	*Ganophyllum falcatum*
Scrub turpentine	*Canarium muelleri*
Silver ash	*Flindersia bourjotiana*
Silver quandong	*Elaeocarpus grandis*
Spur mahogany	*Dysoxylum pettigrewianum*
White beech	*Gmelina fasciculiflora*
White carabeen	*Sloanea langii*
White hazelwood	*Symplocos cochinchinensis* subsp *thwaitesii* (5 varieties exist)
Yellow boxwood	*Planchonella obovoidea*
Yellow euodia	*Euodia bonwickii*

Timber species group 6

Common name	Botanical name
Almondbark	*Prunus turneriana*
Black pine	*Prumnopitys amara*
Black silky oak	*Stenocarpus reticulatus*
Blush silky oak	*Opisthiolepis heterophylla*
Blush touriga	*Calophyllum* spp (4 species)
Blush walnut	*Beilschmiedia obtusifolia*
Bollywood	*Litsea bindoniana*
Bollywood	*Litsea connorsii*
Bollywood	*Litsea leefeana*
Brown quandong	*Elaeocarpus coorangooloo*
Brown quandong	*Elaeocarpus ruminatus*
Brown silky oak	*Darlingia darlingiana*
Caledonian oak	*Carnarvonia araliifolia*
Candlenut	*Aleurites moluccana* (2 varieties)
Cherry satinash	*Syzygium luehmannii*
Damson	*Terminalia sericocarpa*
Euodia	*Melicope elleryana*
Grey satinash	*Syzygium gustavioides*
Hard alder	*Pullea stutzeri*
Hickory ash	*Flindersia ifflaiana*
Kuranda satinash	*Syzygium kuranda*
Magnolia	*Galbulimima belgraveana*
Maple silkwood	*Flindersia pimenteliana*
Northern silky oak	*Cardwellia sublimis*
Nutmeg	*Myristica insipida*
Paperbark satinash	*Syzygium papyraceum*
Pink ash	*Alphitonia petriei*
Plum satinash	*Syzygium wilsonii* subsp *cryptophlebium*
Queensland kauri pine	*Agathis robusta*
Red ash	*Alphitonia whitei*
Red penda	*Xanthostemon whitei*
Red siris	*Paraserianthes toona*
Rose butternut	*Blepharocarya involucrigera*
Satin sycamore	*Ceratopetalum succirubrum*
Scented maple	*Flindersia laevicarpa*
Silver ash	*Flindersia bourjotiana*
Silver ash	*Flindersia schottiana*
Silver quandong	*Elaeocarpus grandis*
Spotted silky oak	*Buckinghamia celsissima*
Spur mahogany	*Dysoxylum pettigrewianum*
Tropical quandong	*Elaeocarpus largiflorens* subsp *largiflorens*
Tulip plum	*Pleiogynium timorense*
White beech	*Gmelina fasciculiflora*
White birch	*Schizomeria whitei*
White carabeen	*Sloanea langii*
White cedar	*Melia azedarach*
White hazelwood	*Symplocos cochinchinensis* subsp *thwaitesii* (5 varieties exist)
White siris	*Ailanthus triphysa*
Yellow boxwood	*Planchonella obovoidea*
Yellow euodia	*Euodia bonwickii*

Timber species group 7

Common name	Botanical name
Almondbark	*Prunus turneriana*
Blush touriga	*Calophyllum* spp (4 species)
Blushwood	*Hylandia dockrillii*
Bollywood	*Litsea bindoniana*
Bollywood	*Litsea leefeana*
Boonjie blush walnut	*Beilschmiedia volckii*
Brown silky oak	*Musgravea heterophylla*
Brown quandong	*Elaeocarpus coorangooloo*
Brown quandong	*Elaeocarpus ruminatus*
Brown salwood	*Acacia mangium*
Brown tulip oak	*Argyrodendron trifoliolatum*
Candlenut	*Aleurites moluccana* (2 varieties)
Cherry satinash	*Syzygium luehmannii*
Damson	*Terminalia sericocarpa*
Euodia	*Melicope elleryana*
Grey satinash	*Syzygium gustavioides*
Kuranda satinash	*Syzygium kuranda*
Miva mahogany	*Dysoxylum muelleri*
Northern euodia	*Melicope vitiflora*
Northern silky oak	*Cardwellia sublimis*
Nutmeg	*Myristica insipida*
Paperbark satinash	*Syzygium papyraceum*
Pink ash	*Alphitonia petriei*
Pink satinash	*Syzygium sayeri*
Plum satinash	*Syzygium wilsonii* subsp *cryptophlebium*
Queensland kauri pine	*Agathis microstachya*
Queensland maple	*Flindersia brayleyana*
Queensland walnut	*Endiandra palmerstonii*
Red ash	*Alphitonia whitei*
Red cedar	*Toona ciliata*
Red penda	*Xanthostemon whitei*
Red tulip oak	*Argyrodendron peralatum*
Rose silky oak	*Darlingia darlingiana*
Silver ash	*Flindersia bourjotiana*
Silver ash	*Flindersia schottiana*
Silver quandong	*Elaeocarpus grandis*
Spur mahogany	*Dysoxylum pettigrewianum*
White beech	*Gmelina fasciculiflora*
White cedar	*Melia azedarach*
White hazelwood	*Symplocos cochinchinensis* subsp *thwaitesii* (5 varieties exist)
Yellow boxwood	*Planchonella obovoidea*

Timber species group 8

Common name	Botanical name
Almondbark	*Prunus turneriana*
Black pine	*Prumnopitys amara*
Blush silky oak	*Opisthiolepis heterophylla*
Bolly silkwood	*Cryptocarya oblata*
Bollywood	*Litsea bindoniana*
Bollywood	*Litsea connorsii*
Bollywood	*Litsea leefeana*
Brown cudgerie	*Canarium australasicum*
Brown quandong	*Elaeocarpus ruminatus*
Brown salwood	*Acacia aulacocarpa*
Brown salwood	*Acacia mangium*
Brown silky oak	*Darlingia darlingiana*
Candlenut	*Aleurites moluccana* (2 varieties)
Cherry satinash	*Syzygium luehmannii*
Crater silky oak	*Musgravea stenostachya*
Damson	*Terminalia sericocarpa*
Fishtail silky oak	*Neorites kevediana*
Hard alder	*Pullea stutzeri*
Kuranda satinash	*Syzygium kuranda*
Magnolia	*Galbulimima belgraveana*
Maple silkwood	*Flindersia pimenteliana*
Northern quandong	*Elaeocarpus foveolatus*
Northern silky oak	*Cardwellia sublimis*
Nutmeg	*Myristica insipida*
Pink ash	*Alphitonia petriei*
Pink sycamore	*Ceratopetalum virchowii*
Plum satinash	*Syzygium wilsonii* subsp *cryptophlebium*
Queensland maple	*Flindersia brayleyana*
Queensland walnut	*Endiandra palmerstonii*
Red ash	*Alphitonia whitei*
Red penda	*Xanthostemon whitei*
Rose alder	*Caldcluvia australiensis*
Rose silky oak	*Placospermum coriaceum*
Rough-barked satinash	*Syzygium trachyphloium*
Sassafras	*Doryphora aromatica*
Scented maple	*Flindersia laevicarpa*
Silver ash	*Flindersia bourjotiana*
Silver quandong	*Elaeocarpus grandis*
Spotted silky oak	*Buckinghamia celsissima*
Spur mahogany	*Dysoxylum pettigrewianum*
Tropical quandong	*Elaeocarpus largiflorens* var *largiflorens*
Whelan's silky oak	*Macadamia whelanii*
White carabeen	*Sloanea langii*
White hazelwood	*Symplocos cochinchinensis* subsp *thwaitesii* (5 varieties exist)
Yellow euodia	*Euodia bonwickii*
Yellow satinash	*Syzygium canicortex*
Yellow siris	*Archidendropsis xanthoxylon*
Yellow walnut	*Beilschmiedia bancroftii*

Timber Species Group 9

Common name	Botanical name
Almondbark	*Prunus turneriana*
Black bean	*Castanospermum australe*
Black pine	*Prumnopitys amara*
Blush alder	*Sloanea australis*
Blush silky oak	*Opisthiolepis heterophylla*
Blushwood	*Hylandia dockrillii*
Bolly silkwood	*Cryptocarya oblata*
Bollywood	*Litsea fawcettiana*
Bollywood	*Litsea leefeana*
Boonjie blush walnut	*Beilschmiedia volckii*
Brown cudgerie	*Canarium australasicum*
Brown penda	*Xanthostemon chrysanthus*
Brown quandong	*Elaeocarpus ruminatus*
Brown tulip oak	*Argyrodendron trifoliolatum*
Brush mahogany	*Geissois biagiana*
Caledonian oak	*Carnarvonia araliifolia*
Candlenut	*Aleurites moluccana* (2 varieties)
Eumundi quandong	*Elaeocarpus eumundi*
Euodia	*Melicope elleryana*
Grey carabeen	*Sloanea macbrydei*
Hard alder	*Pullea stutzeri*
Johnstone River hardwood	*Backhousia bancroftii*
Kuranda satinash	*Syzygium kuranda*
Magnolia	*Galbulimima belgraveana*
Maple silkwood	*Flindersia pimenteliana*
Milky pine	*Alstonia scholaris*
Miva mahogany	*Dysoxylum muelleri*
Northern euodia	*Melicope vitiflora*
Northern quandong	*Elaeocarpus foveolatus*
Northern silky oak	*Cardwellia sublimis*
Nutmeg	*Myristica insipida*
Paperbark satinash	*Syzygium papyraceum*
Pepperwood	*Cinnamomum laubatii*
Pink ash	*Alphitonia petriei*
Plum satinash	*Syzygium wilsonii* subsp *cryptophlebium*
Queensland kauri pine	*Agathis microstachya*
Queensland maple	*Flindersia brayleyana*
Queensland walnut	*Endiandra palmerstonii*
Red ash	*Alphitonia whitei*
Red cedar	*Toona ciliata*
Red penda	*Xanthostemon whitei*
Red tulip oak	*Argyrodendron peralatum*
Rose silky oak	*Darlingia darlingiana*
Sassafras	*Doryphora aromatica*
Silver ash	*Flindersia bourjotiana*
Silver ash	*Flindersia schottiana*
Silver quandong	*Elaeocarpus grandis*
Silver silkwood	*Flindersia acuminata*
Spotted silky oak	*Buckinghamia celsissima*
Spur mahogany	*Dysoxylum pettigrewianum*
Tropical quandong	*Elaeocarpus largiflorens* subsp *largiflorens*
Whelan's silky oak	*Macadamia whelanii*
White beech	*Gmelina fasciculiflora*
White carabeen	*Sloanea langii*
White cedar	*Melia azedarach*
White hazelwood	*Symplocos cochinchinensis* subsp *thwaitesii* (5 varieties exist)
Yellow boxwood	*Planchonella obovoidea*
Yellow walnut	*Beilschmiedia bancroftii*

Timber Species Group 10

Common name	Botanical name
Almondbark	*Prunus turneriana*
Black pine	*Prumnopitys amara*
Blush alder	*Sloanea australis*
Blush silky oak	*Opisthiolepis heterophylla*
Blushwood	*Hylandia dockrillii*
Bolly silkwood	*Cryptocarya oblata*
Bollywood	*Litsea connorsii*
Bollywood	*Litsea glutinosa*
Bollywood	*Litsea leefeana*
Brown quandong	*Elaeocarpus ruminatus*
Brown silky oak	*Darlingia darlingiana*
Brown tulip oak	*Argyrodendron trifoliolatum*
Caledonian oak	*Carnarvonia araliifolia*
Candlenut	*Aleurites moluccana var rockinghamensis*
Eumundi quandong	*Elaeocarpus eumundi*
Euodia	*Melicope elleryana*
Grey carabeen	*Sloanea macbrydei*
Hairy Walnut	*Endiandra insignis*
Hard alder	*Pullea stutzeri*
Kuranda satinash	*Syzygium kuranda*
Magnolia	*Galbulimima belgraveana*
Maple silkwood	*Flindersia pimenteliana*
Miva mahogany	*Dysoxylum muelleri*
Northern euodia	*Melicope vitiflora*
Northern quandong	*Elaeocarpus foveolatus*
Northern silky oak	*Cardwellia sublimis*
Nutmeg	*Myristica insipida*
Paperbark satinash	*Syzygium papyraceum*
Pink ash	*Alphitonia petriei*
Pink satinash	*Syzygium sayeri*
Plum satinash	*Syzygium wilsonii* subsp *cryptophlebium*
Queensland kauri pine	*Agathis atropurpurea*
Queensland maple	*Flindersia brayleyana*
Queensland walnut	*Endiandra palmerstonii*
Red ash	*Alphitonia whitei*
Red cedar	*Toona ciliata*
Red tulip oak	*Argyrodendron peralatum*
Rose maple	*Cryptocarya onoprienkoana*
Rose silky oak	*Darlingia ferruginea*
Salmon bean	*Archidendron vaillantii*
Satin oak	*Alloxylon wickhamii*
Scented maple	*Flindersia laevicarpa*
Silver ash	*Flindersia schottiana*
Silver ash	*Flindersia bourjotiana*
Silver quandong	*Elaeocarpus grandis*
Spur mahogany	*Dysoxylum pettigrewianum*
Tropical quandong	*Elaeocarpus largiflorens* subsp *largiflorens*
White beech	*Gmelina fasciculiflora*
White carabeen	*Sloanea langii*
White cedar	*Melia azedarach*
White hazelwood	*Symplocos cochinchinensis* subsp *thwaitesii* (5 varieties exist)
Yellow walnut	*Beilschmiedia bancroftii*

Timber Species Group 12

Common name	Botanical name
Almondbark	*Prunus turneriana*
Black bean	*Castanospermum australe*
Black pine	*Prumnopitys amara*
Blackwood	*Acacia mangium*
Bolly silkwood	*Cryptocarya oblata*
Bollywood	*Litsea leefeana*
Briar silky oak	*Musgravea heterophylla*
Brown cudgerie	*Canarium australasicum*
Brown quandong	*Elaeocarpus coorangooloo*
Brown quandong	*Elaeocarpus ruminatus*
Brown silky oak	*Darlingia darlingiana*
Brush mahogany	*Geissois biagiana*
Candlenut	*Aleurites moluccana* (2 varieties)
Cherry satinash	*Syzygium luehmannii*
Crater silky oak	*Musgravea stenostachya*
Euodia	*Melicope elleryana*
Hairy walnut	*Endiandra insignis*
Hard alder	*Pullea stutzeri*
Kuranda satinash	*Syzygium kuranda*
Magnolia	*Galbulimima belgraveana*
Maple silkwood	*Flindersia pimenteliana*
Northern quandong	*Elaeocarpus foveolatus*
Northern silky oak	*Cardwellia sublimis*
Nutmeg	*Myristica insipida*
Paperbark satinash	*Syzygium papyraceum*
Pink ash	*Alphitonia petriei*
Plum satinash	*Syzygium wilsonii* subsp *cryptophlebium*
Queensland kauri pine	*Agathis atropurpurea*
Queensland maple	*Flindersia brayleyana*
Queensland walnut	*Endiandra palmerstonii*
Red ash	*Alphitonia whitei*
Red Eungella satinash	*Acmena resa*
Red penda	*Xanthostemon whitei*
Rose alder	*Caldcluvia australiensis*
Rough barked satinash	*Syzygium trachyphloium*
Salmon bean	*Archidendron vaillantii*
Satin oak	*Alloxylon wickhamii*
Scented maple	*Flindersia laevicarpa*
Silver ash	*Flindersia bourjotiana*
Silver quandong	*Elaeocarpus grandis*
Spotted silky oak	*Buckinghamia celsissima*
Tropical quandong	*Elaeocarpus largiflorens* subsp *largiflorens*
White carabeen	*Sloanea langii*
White Eungella satinash	*Syzygium wesa*
White hazelwood	*Symplocos cochinchinensis* subsp *thwaitesii* (5 varieties exist)
Yellow satinash	*Syzygium canicortex*

Appendix 5: The following information sheets are from the *Timber Species Series* produced by QFRI.

- Timber Species 5. Queensland maple (*Flindersia brayleyana*)
- Timber Species 19. Silver quandong (*Elaeocarpus grandis*)
- Timber Species 34. Red mahogany (*Eucalyptus resinifera, E. pellita*)
- Timber Species 72. Brown salwood (*Acacia aulacocarpa, A. mangium*)

TIMBER SPECIES 5

Through its R D projects, QFRI is finding solutions to plantation establishment, management and protection, wood quality and processing technologies for hardwood and softwood timbers.

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SPECIES	Queensland maple
Botanical Name	*Flindersia brayleyana*
Family Name	Rutaceae
Local Name	maple
TREE DESCRIPTION AND OCCURRENCE	A medium sized tree attaining a height of 40 m and 2.5 m in stem diameter. The trunk is usually well formed, circular in cross-section and not buttressed. The bark, which is approximately 12 mm thick, is grey to brown in colour. It has fairly distinct longitudinal fissures. In older trees these fissures are not so marked owing to a tendency to scaliness. Restricted in its distribution to northern Queensland rainforests between Townsville and the Windsor Tableland. Timber of this species is now of very limited commercial availability as the main areas which it occurs have received World Heritage listing.
WOOD APPEARANCE	**Colour.** The heartwood is pink to brownish pink while the narrow sapwood band is coloured white to pale grey. **Grain**. The grain is somewhat interlocked, often wavy or curly, and the texture medium and uniform. Some quarter sawn boards show various types of figure such as waterwave, rib and birdseye.
WOOD PROPERTIES	**Density.** 575 kgm^{-3} at 12% moisture content; approximately 1.7 m^{3} of seasoned sawn timber per tonne. **Strength Group.** (S6) unseasoned; SD6 seasoned. **Stress Grades.** F4, F5, F7, F8 (unseasoned); F7, F8, F11, F14 (seasoned), when visually stressed graded in accordance with AS 2082:2000, 'Visually stress-graded hardwoods for structural purposes.' **Shrinkage to 12% MC**. 7.2% (tangential); 2.9% (radial). **Unit Shrinkage.** 0.25% (tangential); 0.15% (radial). These values apply to timber reconditioned after seasoning. **Durability**. Class 4 - Suitable for use only in continuously dry situations under cover, well ventilated, clear of the ground and fully protected from the weather and other dampness. **Lyctid Susceptibility.** Sapwood is not susceptible to lyctid borer attack. **Preservation.** Sapwood readily accepts preservative impregnation but penetration of heartwood is negligible using currently available commercial processes.
	Seasoning. Can be satisfactorily dried using conventional air and kiln seasoning methods. **Hardness**. Firm (rated 4 on a 6 class scale) in relation to indentation and ease of working with hand tools.

	Machining. Machines and turns well to a smooth surface. **Fixing.** No difficulty has been experienced with the use of standard fittings and fastenings. **Gluing.** Can be satisfactorily bonded using standard procedures. **Finishing.** Will readily accept stain, polish and paint.
USES	**Decorative.** Furniture, plywood, shop and office fixtures, joinery, turnery, carving, inlay work, picture frames. **Others.** Light boat building (planking, decking, sawn frames, stringers, chines, gunwales), Marine plywood. Has been used for aeroplane propellers, coach, vehicle and carriage building, draughtsman's implements, gun stocks, musical instruments (piano parts, guitar necks, backs, sides and headstock. See Marton's website http://www.maton.com.au), walking sticks. Was used to some extent in general building framing in the early 1900's, and more commonly in flooring, lining mouldings and joinery, but use in such applications has been very infrequent for some decades.
IDENTIFICATION FEATURES	GENERAL CHARACTERISTICS **Sapwood.** White to pale grey. **Heartwood.** Pink to brownish-pink in colour with lustrous sheen. **Texture.** Medium and uniform, grain very variable, sometimes with interlocked fibres, wavy or curly and occasionally more disturbed producing fiddleback or birdseye. WOOD STRUCTURE **Growth Rings.** Absent **Vessels.** Small to medium in size, uniformly distributed mainly solitary but with some in short radial rows of up to four. Simple perforation plates can be seen with a lens. Deposits of extraneous material present in some vessels. **Wood Parenchyma.** Not visible under a lens. **Rays.** Visible without a lens and prominent on radial surfaces. **Ripple Marks.** Absent. **Intercellular Canals.** Present in some samples. OTHER FEATURES **Burning Splinter Test.** Burns to a full ash white-buff in colour. **"Birdseye".** Areas of dark coloured soft tissue, giving dressed surfaces a dimpled appearance, caused by attack to the living tree by an insect restricted to this species. This feature, though not particularly common in wood marketed for furniture or high value decorative uses, is a feature for distinguishing wood of *F. brayleyana* from otherwise very similar wood of *F. pimenteliana* (maple silkwood).

For more information and publications about growing, processing and pests and diseases of Queensland hardwood timbers, visit www.dpi.qld.gov.au/hardwoodsqld or call the DPI Call centre: 132 533

Further reading

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TIMBER SPECIES 19

Through its R D projects, QFRI is finding solutions to plantation establishment, management and protection, wood quality and processing technologies for hardwood and softwood timbers.

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SPECIES	Silver quandong
Botanical Names	*Elaeocarpus grandis*
Family Name	Elaeocarpaceae
Local Names	blue fig, blueberry ash, blue quandong, white quandong, cooloon

TREE DESCRIPTION AND OCCURRENCE

A tall tree attaining height of 35 m and a stem diameter up to 2 m. The stem is prominently buttressed at the base and covered with a grey, smooth, slightly wrinkled bark. The older leaves turn bright red before being shed and this is a distinctive species recognition feature in the forest.

This species occurs along the eastern coast of Australia, most commonly between Taree, New South Wales and Maryborough, Queensland. Small populations also occur on the Eungella Range and between Ingham and Cooktown. A disjunct stand occurs beside the mouth of the Daly River, Northern Territory.

Timber of this species is now of limited commercial availability, although there is interest from Farm Forestry groups in establishing plantations of silver quandong.

WOOD APPEARANCE

Colour. The heartwood is generally white to cream white. In some cases it can have greyish or light brownish tones. There is no noticeable colour difference between sapwood and heartwood.

Grain. Porous and open grained. There is no pronounced figure but a characteristic of the species is its long straight vessel lines on dressed longitudinal surfaces.

WOOD PROPERTIES

Density. 495 kgm^{-3} at 12% moisture content; approximately 2 m^{3} of seasoned sawn timber per tonne.

Strength Group. S5 unseasoned; SD6 seasoned.

Stress Grades. F5, F7, F8, F11 (unseasoned), F7, F8, F11, F14 (seasoned), when visually stress graded in accordance with AS 2082:2000, 'Visually stress-graded hardwoods for structural purposes.'

Shrinkage to 12% MC. 4.3% (tangential); 1.4% (radial). These values apply to timber reconditioned after seasoning.

Unit Shrinkage. 0.24% (tangential); 0.11% (radial). These values apply to timber reconditioned after seasoning.

Durability. Class 4 – Suitable for use only in continuously dry situations under cover, well ventilated, clear of the ground and fully protected from the weather and other dampness.

Lyctid Susceptibility. Untreated sapwood susceptible to lyctid borer attack.

Preservation. Sapwood readily accepts preservative impregnation but penetration of heartwood is negligible using currently available commercial processes.

Seasoning. Can be satisfactorily dried using conventional air and kiln seasoning methods.

	Hardness. Soft (rated 5 on a 6 class scale) in relation to indentation and ease of working with hand tools. **Machining.** Machines and turns well to a smooth surface. **Fixing.** No difficulty has been experienced with the use of standard fittings and fastenings. **Gluing.** Can be satisfactorily bonded using standard procedures. **Finishing.** Seasoned timber will readily accept stain, polish and paint.
USES	**Construction.** Once commonly used in joinery, mouldings and linings and also occasionally in general house framing, but is rarely used for these applications now. **Decorative.** Plywood, furniture, shop and office fixtures, turnery, carving, inlay work, picture frames. **Others.** Boat building (light), aircraft components. Has been used for archery equipment, billiard cues, beehives, venetian blinds, broom handles, templates, pattern making, boat oars, pencils, piano parts, tennis racquets, vaulting poles.
IDENTIFICATION FEATURES	GENERAL CHARACTERISTICS **Sapwood.** Indistinguishable from heartwood. **Heartwood.** Almost white to cream-white. **Texture.** Medium to coarse; grain straight with little or no figure. WOOD STRUCTURE **Growth Rings.** Absent. **Vessels.** Medium in size, in short radial rows of 2 to 6, sometimes more. Solitary vessels and pairs tending to be oval in shape. Vessel lines distinct. **Parenchyma.** Indistinguishable under a lens. **Rays.** Of two sizes (i) fairly large and distinct under a lens (ii) fine and small, barely visible even under a 10 x lens. OTHER FEATURES **Burning Splinter Test.** Burns to a thin white greyish partial ash.

For more information and publications about growing, processing and pests and diseases of Queensland hardwood timbers, visit www.dpi.qld.gov.au/hardwoodsqld or call the DPI Call Centre: 132 533

Further reading

Ilic, J. 1991. CSIRO Atlas of Hardwoods. Crawford House Press.

Tree Talk, Inc 1994. Woods of the World Pro. CD Rom.

Boland, D.J., Brooker, M.I.H., Chippendale, G.M., Hall, N., Hyland, B.P.M., Johnston, R.D., Kleinig, D.A. and Turner, J.D. (1984) Forest Trees of Australia. CSIRO, Australia.

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TIMBER SPECIES 34

Through its ***Hardwoods Queensland*** R D & E project, QFRI is finding solutions to plantation establishment, management and protection, wood quality and processing technologies for Australian hardwood timbers.

www.dpi.qld.gov.au/hardwoodsqld

SPECIES	**Red mahogany**
Botanical names	*Eucalyptus resinifera, E. pellita*
Family name	Myrtaceae
Trade name	red mahogany
Local names	red stringybark, red messmate (*E. resinifera*); red stringybark, Daintree stringybark, large-fruited red mahogany (*E. pellita*).
TREE DESCRIPTION AND NATURAL OCCURRENCE	A medium sized tree attaining a height of 40 to 45m and 1.0 to 1.5m in stem diameter. The bark is rough and persistent to the small branches, fibrous, shallowly to coarsely fissured. It is coloured greyish to reddish-brown (*E. resinifera*) and reddish-brown to brown (*E. pellita*). *E. resinifera*: occurs from Jervis Bay in New South Wales to Coen in Queensland. *E. pellita* occurs from just north of Townsville to Iron Range on Cape York Peninsula and scattered areas from Gladstone in Queensland to southern coastal New South Wales.
PLANTATION-GROWN TIMBER	Through its Hardwoods Queensland R&D project the Queensland Forestry Research Institute is defining plantation site suitability for a number of hardwood timber species. Early results suggest that future supplies of plantation-grown *E. pellita* will be available from northern Queensland on suitable soils and where the mean annual rainfall exceeds 900 mm.

WOOD APPEARANCE		
	Colour	The heartwood ranges from red to dark red. Sapwood is distinctively paler.
	Grain	Generally medium textured with even grain. At times the grain can be interlocked producing an attractive figure.

Timber samples are available from QFRI, 80 Meiers Road, Indooroopilly, Brisbane, Qld 4068, Ph: 07 3896 9708

PROPERTIES OF MATURE, NATURAL GROWN TIMBER

*QFRI is currently assessing the wood properties of plantation-grown timber

Property	Mature, natural grown timber	Plantation-grown timber*
Air dry density	995 kgm^{-3} at 12% moisture content; approximately 1.0 cubic metres of seasoned sawn timber per tonne.	***The density of 8.5 year old plantation-grown timber is 70% that of mature, natural grown timber**
Strength Group	S2 unseasoned, SD3 seasoned (*E. resinifera*); (S2) unseasoned, (SD3) seasoned (*E. pellita*).	
Stress Grades	F11, F14, F17, F22 (unseasoned), F14, F17, F22, F27 (seasoned), when visually stress graded in accordance with AS 2082:2000, 'Visually stress-graded hardwood for structural purposes.'	
Shrinkage to 12% MC	6.3% (tangential); 3.9%(radial). These values are for *E. resinifera* only.	*8.5 year old plantation-grown *E. pellita*; 5.2% (tangential); 1.9% (radial).
Unit Shrinkage	0.34% (tangential); 0.27% (radial). *E. resinifera* reconditioned after seasoning.	*8.5 year old plantation-grown *E. pellita.* 0.28% (tangential); 0.17% (radial).
Durability	Class 2 - Highly resistant to decay when fully exposed to the weather, clear of the ground and well drained with free air circulation. Only moderately resistant to decay when used in the ground.	
Lyctid Susceptibility	Untreated sapwood susceptible to lyctid borer attack. Timber should be sapwood free or chemically treated before sale in Queensland.	

	Preservation	Sapwood readily accepts preservative impregnation but penetration of heartwood is negligible using currently available commercial processes.
	Seasoning	Can be satisfactorily dried using conventional air and kiln seasoning methods.
	Hardness	Very hard (rated 1 on a 6 class scale) in relation to indentation and ease of working with hand tools. | 12 kN (mature native) 4.9 kN (8.5 year old plantation timber)*
	Machining	Machines well.
	Fixing	No difficulty has been experienced with the use of standard fittings and fastenings.
	Gluing	As with most high density species machining and surface preparation should be done immediately before gluing.
	Finishing	Will readily accept paint, stain and polish.
	Engineering	As sawn and round timber in wharf and bridge construction, railway sleepers, cross arms, poles, piles, mining timbers.
	Construction	As sawn timber in general house framing, cladding, internal and external flooring, linings, joinery, fencing, landscaping, retaining walls.
	Decorative	Internal quality furniture, outdoor furniture, turnery.
	Others	Boat building (keel and framing components, planking), coach, vehicle and carriage building, agricultural machinery, structural plywood.
IDENTIFICATION FEATURES	GENERAL CHARACTERISTICS	
	Sapwood	Paler and distinct from heartwood.
	Heartwood	Generally deep red in colour but may be lighter in younger material.
	Texture	Uniform, coarse grain, often interlocked. An occasional tight gum vein.
	WOOD STRUCTURE	
	Growth Rings	Generally absent, but some specimens may tend to show vessels arranged in zones.
	Vessels	Medium size, solitary, distributed in a diffuse pattern. Vessel lines conspicuous on longitudinal surfaces. Contains frequent tyloses and dark-red gum deposits.
	Parenchyma	Variable in amount, not abundant; diffuse and paratracheal.
	Rays	Fine, visible only with a lens.
	OTHER FEATURES	
	Burning Splinter Test	A match size splinter burns to charcoal without ash.

For more information and publications about growing, processing and pests and diseases of Queensland hardwood timbers, visit www.dpi.qld.gov.au/hardwoodsqld or call the DPI call centre: 132 533

Further reading

Ilic, J. 1991. CSIRO Atlas of Hardwoods. Crawford House Press.

Tree Talk, Inc 1994. Woods of the world Pro. CD Rom

Boland, D.J., Brooker, M.I.H., Chippendale, G.M., Hall, N., Hyland, B.P.M., Johnston, R.D., Kleinig, D.A. and Turner, J.D. (1984) Forest Trees of Australia. CSIRO, Australia.

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TIMBER SPECIES 72

Through its R&D projects, QFRI is finding solutions to wood quality and processing technologies for hardwood and softwood timbers.

www.dpi.qld.gov.au/qfri/

SPECIES	Brown salwood
Botanical Names	*Acacia aulacocarpa, Acacia mangium*
Family Name	Leguminosae
Local Names	Black wattle, hickory wattle (both species), sally wattle (*A. mangium* only). A lesser species, *A. crassicarpa*, is also known as brown salwood.
TREE DESCRIPTION AND NATRURAL OCCURRENCE	Medium sized hardwoods with flanged buttresses at the base, attaining 30 metres in height and 1 metre diameter on favourable sites. Bark is thin, brown, hard and fissured. Occurs from northern New South Wales along the eastern coast of Queensland to Cape York, and also in the coastal areas of the Northern Territory.
WOOD APPEARANCE	**Colour.** Heartwood varies from light brown to brown, often streaked with darker markings. Sapwood creamy-white to pale brown. **Grain.** Grain variable, texture coarse but rather even.
WOOD PROPERTIES	**Density.** 690-800 kilograms per cubic metre at 12 % moisture content; approximately 1.3 cubic metres of seasoned sawn timber per tonne. **Strength Group.** *A. mangium* (S5) unseasoned; (SD5) seasoned; . *A. aulacocarpa* (S4) unseasoned; (SD4) seasoned. **Stress Grades.** *A. mangium* F5, F7, F8, F11 (unseasoned), F8, F11, F14, F17 (seasoned), *A. aulacocarpa* F7, F8, F11, F14 (unseasoned), F11, F14, F17, F22 when visually stress graded in accordance with AS2082-1979, 'Visually stress-graded hardwood for structural purposes.' **Shrinkage to 12% MC.** 4.2 % (tangential); 1.4 % (radial). These values apply to *A. aulacocarpa.* **Unit Shrinkage.** 0.36 % (tangential); 0.14 % (radial). These figures apply to timber of *A. aulacocarpa* reconditioned after seasoning. **Durability.** Class 3 - Moderately resistant to decay when fully exposed to the weather, clear of the ground and well drained with free air circulation. Not recommended for in-ground use. **Lyctid Susceptibility.** Untreated sapwood susceptible to lyctid borer attack. **Preservation.** Sapwood accepts preservative impregnation. **Seasoning.** Can be satisfactorily dried using conventional air and kiln seasoning methods. **Hardness.** Moderately hard (rated 3 on a 6 class scale) in relation to indentation and ease of working with hand tools. **Machining.** Relatively easy to work and machine. Turns well to a smooth finish. **Fixing.** No difficulties have been experienced with the use of standard fittings and fastenings. **Gluing.** Can be satisfactorily bonded using standard procedures. **Finishing.** Staining is normally not necessary. It polishes and paints well.

USES	**Construction.** Once had limited use in general house framing, flooring, linings and mouldings, but is rarely used for these applications now. **Decorative.** Plywood, furniture, shop and office fixtures, joinery, turning, walking sticks. **Others.** Fishing rods, archery bows, tool handles (axes and hammers), boat building (light).
IDENTIFICATION FEATURES	**GENERAL CHARACTERISTICS** **Sapwood.** Creamy-white, distinct from heartwood. **Heartwood.** Light-brown through to chestnut, occasionally with darker streaks. **Texture.** Medium to coarse. Straight grain. Lustrous. **WOOD STRUCTURE** **Vessels.** Medium to large, visible without lens, solitary and radial chains of up to 3, uniform distribution. A tendency for vessel size to decrease with the zone of latewood. Vessel lines visible. **Parenchyma.** Indistinct. **Rays.** Very fine, barely visible with lens. **OTHER FEATURES** **Burning Splinter Test.** A match size splinter burns to a charcoal.

For more information and publications about growing, processing and pests and diseases of Queensland hardwood timbers, visit www.dpi.qld.gov.au/hardwoodsqld or call the DPI call centre: 132 533

Further reading

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Growing Rainforest Timber Trees

A farm forestry manual for north Queensland

A report for the RIRDC / Land & Water Australia / FWPRDC / MDBC Joint Venture Agroforestry Program

by Mila Bristow
Mark Annandale and Alan Bragg

RIRDC Publication No. 03/010

This manual is one in a series which aims to provide practical guidance for people wishing to establish farm forestry projects. It outlines the steps required to successfully establish rainforest timber trees, particularly in plantation situations, in the Wet Tropics of north Queensland. It was written for land managers (including farmers) and intermediaries such as farm forestry or agribusiness advisors.

There are chapters discussing what is known about growing native rainforest species on farms, the planning issues that growers need to address and the trees' requirements for successful establishment and early plantation management.

The manual is general in nature because the environment of northern Queensland varies. However, it describes general principles that can be applied to different sites and illustrates management decisions involved using case studies based on north Queensland research. The final chapter presents a case study based on a mixed species plantation in north Queensland. This demonstrates the site specific issues that were considered, and the management options which were adopted to suit the site. There is also has a list of publications containing additional information that may be relevant to particularl situations.

Photos:
Top: *Six-month-old red cedar*
Bottom: *Thinning in a silver quandong plantation*

www.rirdc.gov.au