Trials of Cold-tolerant Eucalypt Species in Cooler Regions of South Central China

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Foreword

Eucalypts are of considerable economic, social and environmental importance in southern China. They are grown in plantations, as well as being used in plantings beside roads, canals, villages and homes. They provide raw materials for the pulp and paper, and solidwood industries, and poles, fuelwood and essential oils. Rates of planting have increased, but parts of the country still face an impending wood deficit as demand grows. The projected deficit is particularly acute in the provinces of the southern central region. These provinces also face other forestry and environmental problems. Large areas lie in the red soils region, where the combination of deforestation, ready soil erodibility and inappropriate land uses has led to serious environmental degradation.

The Chinese view expansion of plantation forestry as a way of addressing many of the environmental problems in the region while improving local incomes and providing needed forest products. But attempts to use native species, such as Chinese fir and Yunnan pine, have often been unsuccessful in the red soils region.

In contrast, some eucalypt species and provenances are known to display rapid growth in many of China's poor soils. But most eucalypts have been planted in China in the warmer parts of the country, not in the cooler highland areas of south central China, where the most degraded lands occur. Most eucalypt germplasm currently grown in China is adapted to warmer coastal regions and is far less suitable for these areas than specially adapted species and provenances.

ACIAR has supported collaborative forestry research between China and Australia since 1985. This report draws together the results of many trials undertaken over the past 20 years into eucalypts suited to mean annual temperatures of 15–20°C, with absolute minima down to –8°C

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Peter Core
Director
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Contents

Terms and definitions

ACIAR — Australian Centre for International Agricultural Research

ACT — Australian Capital Territory

‘asl’ — above sea level

ATSC — the Australian Tree Seed Centre (a business unit within CSIRO Forestry and Forest Products)

AusAID — Australian Agency for International Development

CAF — Chinese Academy of Forestry

CERC — China Eucalypt Research Centre, Chinese Academy of Forestry

Cold-tolerant Eucalypt Project — The project ‘Development of germplasm and production systems for cold-tolerant eucalypts for use in cool regions of southern China and Australia’ (ACIAR project FST/96/125). This project is supported in part by the Australian Centre for International Agricultural Research (ACIAR) and is a collaborative Australia–China research project being conducted over a six-year period. It commenced in January 1999.

Cooler regions — this phrase is used in this report to refer to the areas of south central China having ‘humid mesothermal’ climate with mean annual temperatures of 15–24°C, absolute minimum temperatures down to –8° to –10°C, mean minimum temperatures of the coldest month in the range –3° to 5°C and mean annual precipitation generally above 800 mm per annum.

CSIRO — Commonwealth Scientific and Industrial Research Organisation (Australia)

DBH — diameter at breast height (i.e. at 1.3 m above the ground)

Dry season length — number of consecutive months with less than 40 mm of precipitation

ig. — intergrade between two species

Landrace — a population of individuals (trees) which has, through one or more generations, become somewhat adapted to a specific environment in which it has been grown

NSW — New South Wales (Australian state)

Qld — Queensland (Australian state)

SA — South Australia (Australian state)

South central China — in this report, south central China refers to the area comprising Yunnan, Sichuan, Guizhou, Hunan, Jiangxi and Fujian provinces along with the northern part of Guangxi province.

ssp. — subspecies

SF — State Forest

Tas. — Tasmania (Australian state)

Vic. — Victoria (Australian state)

WA — Western Australia (Australian state)

Note on provenance seedlot codes appearing in this report

All provenance seedlot codes appearing in this report that begin with ‘CS’ (e.g. CS18146) were originally supplied by CSIRO Forestry and Forest Products’ Australian Tree Seed Centre.

1. Introduction

China boasts of some of the world's largest man-made forests and it is estimated to now have over 22 million ha of forest plantations. Although eucalypts make up less than 10% of this total, they are nonetheless of considerable economic, social and environmental importance in southern China. As of late 2002 the area of eucalypt plantations in China was estimated to exceed 1.5 million hectares (Qi 2003). In addition to these plantations, more than 1.8 billion other eucalypts (equivalent to about 350,000 ha) have been established as 'four-around' plantings beside roads, canals, villages and homes (Midgley and Pinyopusarerk 1996; Qi 2003).

Despite the country's significant resource of plantations of eucalypts and other species, China's southern provinces alone are expected to have an annual wood production deficit of more than 90 million m^3 by the year 2025. In 1998 China imported less than 5 million m^3 of timber (Anon. 2001). In 2000 its national net deficit in wood production was approximately 40 million m^3 and it is estimated this will increase to more than 90 million m^3 in 2010 (Sun and Bean 2001). Rapid increases in China's annual wood imports have been due to: its large annual growth in pulp and paper consumption; increased residential construction; reductions in tariffs and a more open trading system since its entry to the World Trade Organisation; and sharp reductions in timber harvesting from natural forests following policy changes in 1998. Interestingly, the furniture market in China is one of the strongest growth sectors for forest products, posting approximately 10% growth in 1999 and again in 2000 (Sun and Bean 2001). China is now home to around 30% of the world's total furniture production and it has also become the world's largest exporter of timber furniture.

Plantation resources

To address its deficits in wood production, Chinese authorities are keen to expand the forest plantation resources in cooler areas of south central provinces. In this region there are substantial areas of degraded and largely unproductive lands and many of these areas are ideally suited to forest plantation development. In addition to the national, regional and local economic benefits of developing productive forest plantation resources in this region, it is seen that such development could also provide substantial environmental benefits (Xie et al. 1991). Many of the south central provinces lie within China's 'red soils region' (see below), where the combination of deforestation, erodibility of red soil complexes and inappropriate land uses have resulted in serious sheet erosion of topsoils and, in places, deep gullying into subsoils over the last 40 years (e.g. Plate 1). Such factors have created substantial areas of largely unproductive degraded lands that now total more than 400,000 km^2 (Xie et al. 1991).

Attempts to establish large areas of productive forest plantations with native species, including Chinese fir (*Cunninghamia lanceolata*) and Masson pine (*Pinus massoniana*), in the red soils region have sometimes proved unsuccessful (Xu and Yang 1991). Also, many of the natural forest areas across the red soils region in south

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central China have become severely degraded. Consequently, a large proportion of the current fir and pine plantations provide relatively low yields of fuelwood and timber, offer little protection against soil erosion, and contribute relatively little to rural economies. Though some native species can grow well on the more fertile sites with better soils in this region, their growth can be poor on degraded lands (Tu 1991).

In contrast to the local pine species and Chinese fir, some eucalypt species are well adapted to many degraded sites in China's red soil region (Xu and Yang 1991; Brown 1994; Arnold and Luo 2003). Trials have demonstrated their ability to sustain relatively fast growth on poorer soils across a range of sites in southern China (Turnbull 1981; Bai 1994; Brown 1994; Chen 2002; Arnold and Luo 2003), and their timber is suitable for range of products including pulp, poles, fibreboards, ply and sawn timbers.

Eighty percent of China's existing eucalypt resource is concentrated at lower elevations in coastal regions of Hainan, Guangdong, and Guangxi provinces south of latitude 27°N (Chen 2002; Qi 2003). In these warmer areas the science and technology of eucalypt species/provenance selection, genetic improvement and silviculture are generally well developed. However, in the cooler regions of south central China, where the larger areas of lands available for expansion of forest plantations are located, eucalypt planting has to date been limited. Domestication of cold-tolerant eucalypts suitable for these areas is at its early stages in China. Attempts to directly transfer germplasm from China's warmer coastal areas have often met complete failure—the tropical and many of the sub-tropical eucalypts are ill adapted to the cooler inland areas of south central China. For example, in Fujian's highlands more than 2000 ha of plantations of *Eucalyptus urophylla* and *E. urophylla grandis* clones introduced from southern Guangdong were killed or severely damaged during severe winter cold (to –8°C and below) in December 1999 (Qiu Jinqing, Fujian Forestry Department, pers. comm.).

Edaphic and topographic influences on tree growth

The cooler regions of southern central China with potential for forest plantation development generally lie within the 'red soils' region. South central China's red soils are named for their characteristic red or yellow subsoil colours (Grimshaw and Smyle 1991). They are tentatively classified as red dermosols or yellow dermosols in the Australian Soil Classification System (Isbell 1996; Laffan 2002). All tend to be acidic (pH 4.5–5.5) and have low cation exchange capacity, high aluminium saturation, major nutrient and some trace element deficiencies with phosphorus (P) most often limiting, low organic matter and poor water-holding capacity. Their low available P and organic matter status are often associated with toxic levels of aluminium (see Xie et al. 1991; Baker et al. 2003; Laffan 2003; Laffan et al. 2003).

Nutrient availability is considered to be the most severely limiting soil factor affecting site productivity for eucalypt plantations in southern China. Low levels of the nutrients nitrogen (N) and P have been recorded in degraded forest plantation soils from Yunnan, Guangxi, Hunan and Fujian provinces, and it is expected that similar low levels will occur in degraded soils in other cooler areas of south central China (Baker et al. 2003; Laffan 2003). Other nutrients including potassium, magnesium and sulfur as well as various trace elements are also deficient on many sites. Red soils with high levels of free iron (red ferrosols) generally have a high P-fixation capacity and thus require repeated applications of phosphatic fertilisers. Extra applications (secondary fertilisation) of other nutrients such as nitrogen are also often required. Because of the loamy and clayey nature of the soils, nutrient retention is not considered a problem (Laffan et al. 2003).

Most of the sites considered suitable for forest plantation development on undulating and rolling slopes in the red soils region generally have well-structured soils with negligible limitations to effective root depth or ease of rooting penetration (Laffan 2002, 2003). Exceptions are where shallower soils occur over bedrock and also on some steeper slopes with very stony soils where limitations to effective rooting depth and/or root penetration would be expected.

Detailed reviews and discussions of the soils of eucalypt plantations and potential plantation sites in some of the cooler regions of south central China are provided by Laffan (2002), Laffan (2003), Laffan et al. (2003) and Baker et al. (2003).

Climatic influences

The target plantation areas of south central China are somewhat cooler than the southern coastal areas of China. This cooler climate can be broadly categorised as 'humid mesothermal' with mean annual temperatures of 15–24°C, absolute minimum temperatures down to –8° to –10°C, mean minimum temperatures of the coldest month in the range of –3° to 5°C and mean annual precipitation generally above 800 mm (Figure 1).

Figure 1. Map of China with cooler areas of south central provinces climatically suitable for eucalypt plantations shown in lighter grey. These areas are of a 'humid mesothermal' climate with mean annual temperatures of 15–24°C, absolute minimum temperatures down to –8° to –10°C, mean minimum temperature of the coldest month in the range from –3 to 5°C and mean annual precipitation above 800 mm per annum (source: Trevor Booth, CSIRO Forestry and Forest Products).

Although such conditions appear to be significantly above the lower temperature limit for many cold hardy eucalypts, some aspects of the region's climate can be problematical for their successful growth. In terms of heat sums and latitude, much of the region is seemingly subtropical (Zhao 1986). However, this can be misleading. For instance, Hunan is exceedingly hot over the summer period with maximum temperatures often exceeding 40°C and relatively high night-time temperatures (often above 27°C), but frosts can occur on 75 days or more days per year and severe cold periods (days of continuous subzero temperatures) can be encountered when masses of cold air flow in from the north and northwest. Also, inflows of cold and freezing air have on some occasions occurred following periods of relatively mild weather—conditions that can result in eucalypts being poorly prepared physiologically to cope with cold stress (Florence 1996). This was the situation in southern China in December 1991 and again in December 1999 when significant areas of eucalypt and acacia plantings in south central provinces and even in some areas of southern ones were severely damaged by cold (Yan 2001b).

Inclusion of absolute minimum temperature tolerances in species climatic descriptors of eucalypts can help to identify climatically suitable areas for them in China (see Booth et al. 1994; Yan 2001a). For many of the plantation eucalypts adapted to cooler winters, these climate descriptors/requirements are already well defined (Booth and Pryor 1991; CAB International 2000; Jovanovic and Booth 2002). Such information is useful in combination with software for species–site climate matching and with models developed for predicting frost risks and risk of cold damage to eucalypts in China (Booth et al. 1994; Yan et al. 1995; Yan 2001b). Detailed reviews and discussions of the use of computer-based climatic models for species–site matching in southern China with particular reference to plantation eucalypts are provided by Booth et al. (1994), Yan (1995, 2001a, 2001b) and Yan et al. (1995).

However, since climate and especially minimum temperatures are strongly influenced by local conditions, and species suitability is influenced by many factors other than climate, such predictions are only broad indicators of species–site suitability. Also, whilst indicating broad adaptability they do not indicate the relative productivity of species that are climatically suitable. Thus, computer software generated predictions ultimately need to be considered in conjunction with results from experimental trials in the target environment(s).

Role of this report

Through a range of Chinese–Australian collaborative projects and many other initiatives, a large number of eucalypt species, species–provenance, provenance and family trials have been established in cooler regions of south central China since the mid 1980s. Some of these trials can be clearly identified as 'species trials' as they included large numbers of species, with each represented by just one or two seedlots. Others have clearly been provenance or provenance–family trials, which included many seedlots of just one species.

The results from many of these earlier trials have the potential to collectively provide important information. However, most of them had only been assessed up till relatively early ages (generally 3–4 years or considerably less) when the collaborative project or initiative, under which they were established, terminated. For the few trials that had been assessed at later ages, available information was often obscure or poorly documented.

To enable future domestication of eucalypts for the cooler regions in China to proceed efficiently and to capitalise on investments made in earlier research, a 'Cold-tolerant Eucalypt Project' commenced in the late 1990s, with the aim of reviewing results from eucalypt trials established previously in this target area. This work commenced with the compilation of an inventory of known, existing eucalypt germplasm trials in cooler areas of Yunnan, Guangxi, Hunan and Fujian provinces. Existing results and/or data (where available) from worthwhile trials were subsequently compiled, and a range of trials was re-assessed for at least growth parameters. More recently, this has been supplemented by information and results of several trials in Sichuan and Jiangxi provinces garnered from published reports.

This report provides a compendium of the locations, basic parameters, results and key findings of a large number of eucalypt trials established in cooler regions of south central China over the past 20 years. Thus, it summarises many years of research effort, and gives a guide to the best (and worst) eucalypt species and provenances over a wide range of planting sites across the cooler regions of south central China. More detailed analyses and reports on some of these trials have already been published, while publishing of detailed reports on others are planned.

The information on these trials is presented below by the province in which they are located, along with a brief description of the environment and eucalypt domestication work in each of these provinces. Table 1 provides a complete list of these trials and Figure 2 indicates their approximate locations. Appendix 1 lists detailed information on provenance origins of all the seedlots included in these trials that were originally sourced from CSIRO (i.e. all seedlots with codes beginning with 'CS', for example, CS18146).

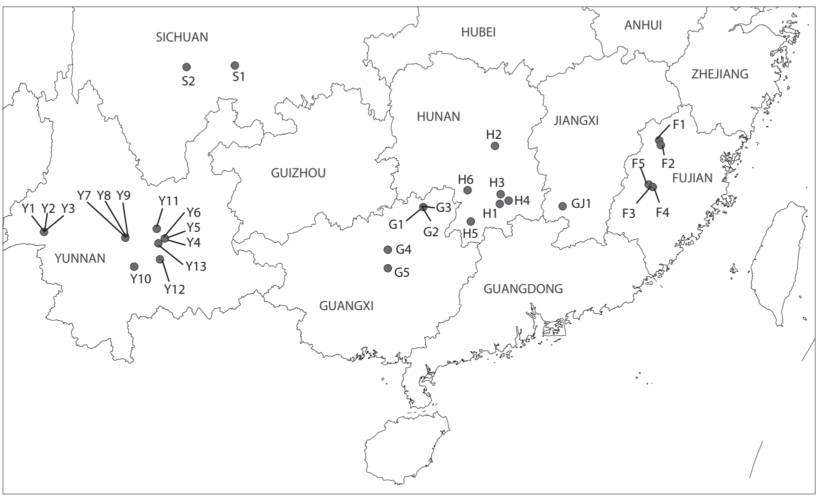

Figure 2. Map of southern China showing approximate locations of all the trials discussed.

Table 1. Locations of the eucalypt trials in cooler regions of south central China included in this report.

Trial ID	Province	Trial name	Trial type	Latitude (N)	Longitude (E)	Altitude (m asl)
Y1	Yunnan	Baoshan species trial	species	25°07'	99°10'	1665
Y2	Yunnan	Baoshan species – provenance trial I	species – provenance	25°07'	99°10'	1665
Y3	Yunnan	Baoshan species – provenance trial II	species – provenance	25°07'	99°10'	1665
Y4	Yunnan	Jindian species trial	species	25°01'	102°41'	1950
Y5	Yunnan	Jindian species – provenance trial I	species – provenance	25°01'	102°41'	1950
Y6	Yunnan	Jindian species – provenance trial II	species – provenance	25°01'	102°41'	1950
Y7	Yunnan	Chuxiong species – provenance trial I	species – provenance	25°01'	101°32'	1870
Y8	Yunnan	Chuxiong species – provenance trial II	species – provenance	25°01'	101°32'	1870
Y9	Yunnan	Chuxiong species – provenance trial III	species – provenance	25°01'	101°32'	1870
Y10	Yunnan	Yipinglang *E. globulus* provenance – family trial	provenance – family	24°14'	101°45'	1800
Y11	Yunnan	Fumin *E. smithii* provenance – family trial	provenance – family	25°14'	102°30'	1895
Y12	Yunnan	Yuxi species – provenance trial	species – provenance	24°21'	102°33'	1687
Y13	Yunnan	Haikou species – provenance trial	species – provenance	24°50'	102°34'	2000
G1	Guangxi	Guilin species – provenance trial	species – provenance	25°28'	110°28'	130
G2	Guangxi	Guilin species trial	species	25°28'	110°28'	130
G3	Guangxi	Guilin *E. dunnii* provenance trial	provenance	25°28'	110°28'	130
G4	Guangxi	Satang *E. dunnii* provenance trial	provenance	24°28'	109°24'	120
G5	Guangxi	Cha Hua Shan species – provenance trial	species – provenance	24°03'	109°24'	130
H1	Hunan	Suxian species – provenance trial	species – provenance	25°30'	112°53'	320
H2	Hunan	Hengyang species trial	species	26°54'	112°36'	107
H3	Hunan	Chengzhou species trial	species	25°45'	112°53'	246
H4	Hunan	Zixing *E. grandis* provenance – family trial	species – provenance	25°34'	113°09'	120
H5	Hunan	DaoXian eucalypt species trial	species	25°31'	111°34'	300

Table 1. (cont'd) Locations of the eucalypt trials in cooler regions of south central China included in this report.

Trial ID	Prov-ince	Trial name	Trial type	Latitude (N)	Longitude (E)	Altitude (m asl)
H6	Hunan	Shuangpai County eucalypt species trial	species	26°33'	113°16'	135
F1	Fujian	Weimin species trial	species	27°03'	117°40'	196
F2	Fujian	Pushang *E. dunnii* provenance – family trial	provenance – family	26°56'	117°46'	290
F3	Fujian	Shi Bi *E. grandis* provenance – family trial	provenance – family	25°59'	117°19'	215
F4	Fujian	Yongan species trial	species	25°56'	117°24'	270
F5	Fujian	Yongan *E. grandis* provenance – family trial	provenance – family	25°59'	117°19'	225
S1	Sichuan	Fushun *E. grandis* provenance trial	provenance	29°33'	105°04'	450
S2	Sichuan	Pingxing *E. grandis* provenance – family trial	provenance – family	29°34'	103°43'	450
GJ1	Jiangxi	Ganzhou species – provenance trial	species – provenance	25°20	114°40'	95

2. Trials in South Central China

Early work

Eucalypts were first introduced to China in about 1874 (Wang et al. 1994a) and several authors including Turnbull (1981), Bai and Gan (1993), Liu et al. (1996) and Qi (2003) have reviewed their domestication there since that time. The greatest progress with eucalypt domestication in China has occurred since 1981 (Bai 1994; Liu et al. 1996). In this time several China–Australia technical co-operation projects have facilitated substantial progress in the domestication of tropical and sub-tropical eucalypts for China's southern provinces (e.g. the Dongmen Project which operated in Guangxi from 1982 to 1989 with funding from AusAID). In the cooler regions of southern China, collaborative research into eucalypt (and acacia) species and provenance selection commenced after 1984, largely as a result of ACIAR and AusAID supported projects. Some examples are the China Eucalypt Research Centre Project (Liu et al. 1996) and the ACIAR Project FST/1996/125 'Development of germplasm and production systems for cold-tolerant eucalypts for use in cool regions of southern China and Australia' (Arnold and Luo 2003).

Two other Australian development assistance projects of great benefit to eucalypt domestication in both the warmer and cooler regions of southern and south central China are the Seeds of Australian Trees Project (funded by AusAID from 1979 to 1993 and then by ACIAR from 1993 to1999) and its successor the Domestication of Australian Trees Project (funded by ACIAR from 1999 to 2004). Since 1982 these projects have provided Chinese researchers with ready access to quality germplasm and the extensive genetic resources of a wide range of eucalypt species from Australia for inclusion in numerous trials.

Yunnan Province

Environment

Yunnan province is bounded by the Tibet Autonomous Region on the northwest, Sichuan province on the north, Myanmar (Burma) in the west, and Laos and Vietnam to the south and southeast (see Figure 2). It is the fourth largest province in China and there is substantial variation of topography and climate within this province (Britannica Online 2003a).

Yunnan consists of two distinct topographical regions, separated by the Ai-lao Mountains—a canyon region in the west and a plateau region in the east (Zhao 1986). The canyon region includes a series of high mountains ranging in altitude to more than 5500 metres above sea level (asl). The southern part of the canyon region includes much lower valleys (elevations down to 1500 m asl) which are more open and contain fertile irrigated fields (Britannica Online 2003a; Zhao 1986).

The eucalypt trials of interest in Yunnan are mostly located on the plateau area. The elevation of the plateau varies from 2100 m asl at its western end to around 1400 m asl at its eastern edge. Along its eastern edge, which adjoins the provinces of Guizhou and Guangxi, intermontane basins provide large stretches of level country suited for agriculture (Britannica Online 2003a). The Yunnan plateau is well known within China for its moderate climate. On account of its topographic conditions and latitudinal location, summers tend to be cool, whilst winters are generally considered mild. Kunming, the provincial capital at elevation 1960 m asl, is famous for its 'eternal spring'. The climate is considered sub-tropical with mean January (mid-winter) temperatures generally in the range 8–10°C and mean July (mid-summer) temperatures of 19–22°C (Britannica Online 2003a). Red soils of various ages cover most of the Yunnan plateau.

Eucalypt domestication in Yunnan

It is well over 100 years ago since eucalypts were introduced to Yunnan province (Wang et al. 1989). Indeed, in 1894 an Australian traveller noted a large 'blue gum' (most likely *E. globulus*) growing in the grounds of the French legation in Kunming (Morrison 1895).

Despite a long history of cultivation in Yunnan, eucalypts were primarily planted along roadsides and in home gardens up until the end of the 1950s (Wang et al. 1989; Qi 2003). Species involved in these plantings included *E. globulus*, *E. maidenii*, *E. camaldulensis* and *E. robusta*. Unfortunately the provenance origins of the original introductions of these species are unknown.

Larger scale planting programs began in the late 1950s–early 1960s and today the principal eucalypts grown in Yunnan are *E. globulus* and *E. maidenii*. These species have proved well adapted to many areas on the Yunnan plateau and are planted at altitudes of 1200–2400 m, though the best growth is generally found at elevations of 1500–2200 m. Both species are favoured by the moderate rainfall, dry summers with low humidities, mild winters and soils which generally have good depths even though they are often of low fertility. In recent times *E. maidenii* has become the more favoured of the two species for colder and/or drier sites in the region (Zhang Ronggui, Yunnan Academy of Forestry, pers. comm.). Most of the Yunnan *E. globulus* and *E. maidenii* plantations are managed for production of both timber and essential leaf oils, with most foliage typically being harvested on 2–3 year cycles for extraction of 1,8-cineole rich leaf oils by steam distillation. The leaf oil industry provides an important channel for cash incomes in many poor rural areas of the province (Chen 2002).

At lower elevations in southeastern Yunnan where the climate is distinctly warmer with higher rainfalls and more humid summers, a range of more subtropical to tropical eucalypts is grown. In this area there are significant areas (>10,000 ha) of *E. grandis* and hybrids of *E. grandis* and of *E. urophylla* (Chen 2002).

More than 150,000 ha of eucalypt plantations are estimated to grow in Yunnan today, with substantial additional areas of 'four-around' plantings (i.e. plantings around roads, railways, canals and villages/houses) (Chen 2002). Whilst in the south and southeast of the province planting stocks of tropical and subtropical eucalypts are generally propagated as rooted cuttings of improved clonal varieties, *E. globulus* and *E. maidenii* for planting on the Yunnan Plateau are usually propagated from seed from the local landrace.

A series of collaborative China–Australia projects supported by ACIAR, CAF, CSIRO, the Yunnan Academy of Forestry and various other organisations was particularly effective in establishing trials on the Yunnan Plateau. Early results from a number of these have been reported previously (see Wang et al. 1989, 1994b; Zang et al. 1994; Zheng et al. 1994).

Trials of cold-tolerant eucalypts in Yunnan

Baoshan eucalypt species trial (Trial ID—Y1)

Location and environment:	
Latitude: 25°07'N	Soil: red soil, heavy clay
Longitude: 99°10'E	Mean minimum temperature of coldest month: 4°C
Altitude: 1665 m asl	Absolute minimum temperature: –4°C
Mean annual rainfall: 970 mm	
Trial details:	
Trial type: species	Date planted: July 1986
Number of species: 12	Age at last assessment: 36 months
Number of seedlots: 12	Number of replicates: 5
Initial spacing: 2.0 2.0 m	Plot size: 25 trees (5 trees 5 rows)
Experimental design: randomised complete block design	

Seedlots included in the Baoshan species trial:

Seedlot	Species	Provenance
CS11711	*E. cinerea*	Gunning area, NSW
CS12655	*E. cypellocarpa*	Bonang, Vic.
CS12563	*E. dalrympleana*	Nundle SF, NSW
CS14206	*E. dendromorpha*	Mt Budawang, NSW
CS11825	*E. johnstonii*	Misery Plateau, Tas.
CS14840	*E. laevopinea*	New England, NSW
CS15057	*E. macarthurii*	ENE of Marulan, NSW
CS09751	*E. neglecta*	Buckland River, Vic.
CS14012	*E. nitens*	Brown Mt, NSW
CS10191	*E. obliqua*	East Otway Ranges, Vic.
CS10345	*E. oreades*	Bell—Mt Wilson, NSW
CS11168	*E. pulchella*	Mt Judbury, Tas.

The overall growth at this site was relatively poor with the average height growth of even the best species being less than 1.3 m per year. The relatively slow growth on this site is attributed to its poor soils. Even so, survivals were reputedly high with all species averaging over 75%. Unfortunately, monitoring and maintenance of the trial was discontinued after age 3 years. Up to that age, *E. pulchella* (CS11168) *E. dalrympleana* (CS12563), *E. nitens* (CS14012) and *E. cypellocarpa* (CS12655) had shown the best growth. The species with the poorest performance in this trial were *E. johnstonii* (CS11825) and *E. neglecta* (CS09751).

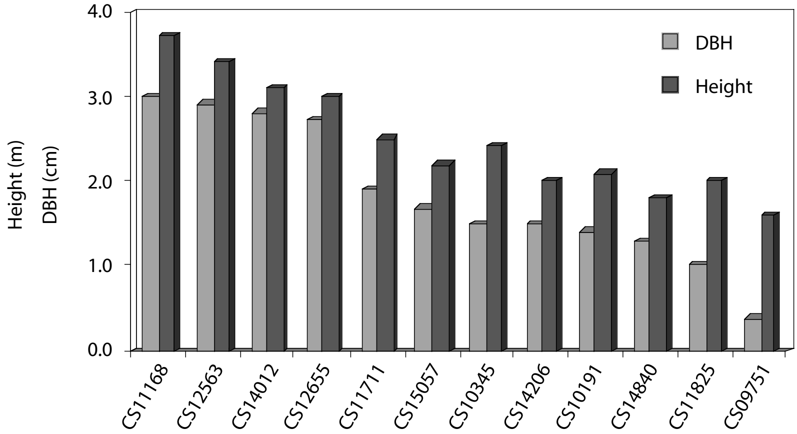

Figure 3. Growth performance, in terms of diameter at breast height over bark (DBH) and height, to age 3 years of the species in the 1986 species trial at Baoshan in Yunnan (Trial ID—Y1).

Baoshan species–provenance trial I (Trial ID—Y2)

Location and environment:	
Latitude: 25°07' N	Soil: red soil, clay loam
Longitude: 99°10' E	Mean minimum temperature of coldest month: 4°C
Altitude: 1665 m asl	Absolute minimum temperature: –4°C
Mean annual rainfall: 970 mm	
Trial details:	
Trial type: species–provenance	Date planted: July 1988
Number of species: 5	Age at last assessment: 36 months
Number of seedlots: 12	Number of replicates: 3
Initial spacing: 1.5 3.0 m	Plot size: 25 trees (5 rows 5 trees)
Experimental design: randomised complete block design	

Species and provenances included in the Baoshan species–provenance trial I:

Seedlot	**Species**	**Provenance**
CS12867	*E. denticulata*	Bonang SF, Vic.
CS09539	*E. bicostata*	Stanley, Vic.
CS09541	*E. bicostata*	NE of Mansfield, Vic.
CNEUMAID	*E. maidenii*	Yunnan landrace, China
CS12125	*E. maidenii*	Tantawanglo Mtn, NSW
CS12130	*E. maidenii*	Mt Dromedary, NSW
CS12321	*E. maidenii*	Cann Valley, Vic.
CS15918	*E. nitens*	S Captains Flat, NSW
CS17132	*E. nitens*	Tallaganda SF, NSW

Seedlot	Species	Provenance
CS14920	*E. viminalis*	Cotter Catchment, ACT
CS15017	*E. viminalis*	Silver Ck, Morwell, Vic.
CS17217	*E. viminalis*	Mickleham, Vic.

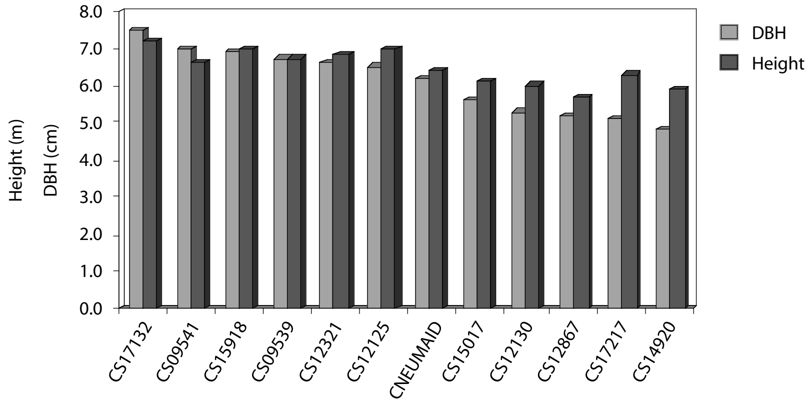

Figure 4. Growth performance, in terms of diameter at breast height over bark (DBH) and height, to age 3 years of the species–provenances in the 1988 species–provenance trial at Baoshan in Yunnan (Trial ID—Y2)

Overall growth at this Baoshan site was somewhat better with average height increments of around 2.0 m per year. Unfortunately though, monitoring and maintenance of this trial was also discontinued after about age 3 years. *E. nitens* (CS17132) showed the best growth which, along with *E. bicostata* (CS09539), *E. nitens* (CS15918), *E. bicostata* (CS09541), *E. maidenii* (CS12321) and *E. maidenii* (CS12125), was better than the growth of the local landrace of *E. maidenii* (CNEUMAID). *E. denticulata* (CS12867) and all three provenances of *E. viminalis* were inferior to the local *E. maidenii* to this early age (i.e. 3 years).

Baoshan species–provenance trial II (Trial ID—Y3)

Location and environment:	
Latitude: 25°07' N	Soil: red soil, clay loam
Longitude: 99°10' E	Mean minimum temperature of coldest month: 4°C
Altitude: 1665 m asl	Absolute minimum temperature: –4°C
Mean annual rainfall: 970 mm	
Trial details:	
Trial type: species–provenance	Date planted: July 1992
Number of species: 5	Age at last assessment: 48 months
Number of seedlots: 15	Number of replicates: 3
Initial spacing: 2.0 3.0 m	Plot size: 15 trees (5 trees 3 rows)
Experimental design: randomised complete block design	

Species and provenances included in the Baoshan species–provenance trial II:

Seedlot	Species	Provenance
CS15269	*E. bicostata*	Wee Jasper, NSW
CS17777	*E. bicostata*	10 km NW Bruthen, Vic.
CS17965	*E. bicostata*	Tumbarumba, NSW
CS16860	*E. globulus*	Blue Gum Saddle, Tas.
CS15917	*E. maidenii*	Bolaro Mt, NSW
CS17742	*E. maidenii*	Black Range via Eden, NSW
CS17769	*E. maidenii*	Yurammie SF, NSW
CS14439	*E. nitens*	Glenbog SF, NSW
CS16619	*E. nitens*	Tallaganda SF, NSW
CS16636	*E. nitens*	Majors Point Ebor, NSW
CS16750	*E. nitens*	Barkey River Rd, Mt Skene, Vic.
CS16869	*E. nitens*	Toorongo Plateau, Vic.
CS12131	*E. smithii*	Mt Dromedary, NSW
CS12559	*E. smithii*	Mt Dromedary, NSW
CS16916	*E. smithii*	12 km NE Orbost, Vic.

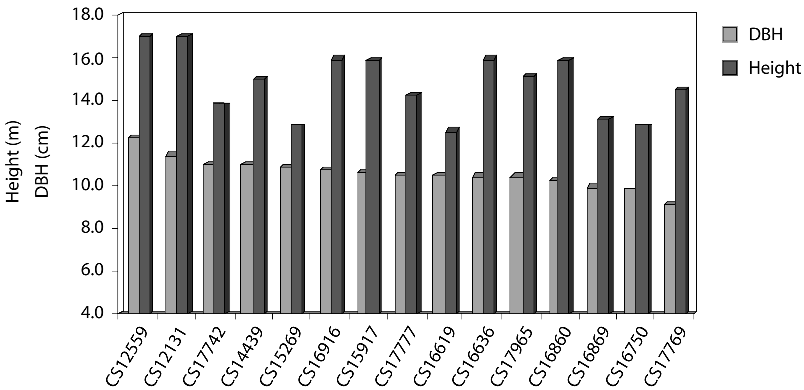

Figure 5. Growth performance, in terms of diameter at breast height over bark (DBH) and height, to age 4 years of the species–provenances in the 1992 species–provenance trial at Baoshan in Yunnan (Trial ID—Y3).

Excellent growth was obtained at this Baoshan site with height increments of all species averaging over 3.0 m per year. However, like the earlier Baoshan trials, monitoring and maintenance of this trial was also discontinued at a relatively young age (around 4 years). Two provenances of *E. smithii* (CS12559 and CS12131) had markedly better growth than the other species–provenances in the trial. Others that performed better than average included *E. nitens* (CS14439 and CS16636), *E. maidenii* (CS17742 and CS15917) and *E. smithii* (CS16916).

Jindian species trial (Trial ID—Y4)

Location and environment:	
Latitude: 25°01' N	Soil: yellow soil, clay loam to heavy clay
Longitude: 102°41' E	Mean minimum temperature of coldest month: 3°C
Altitude: 1950 m asl	Absolute minimum temperature: –8°C
Mean annual rainfall: 1010 mm	
Trial details:	
Trial type: species	Date planted: July 1986
Number of species: 16	Age at last assessment: 36 months
Number of seedlots: 16	Number of replicates: 5
Initial spacing: 2.0 2.0 m	Plot size: 9-tree-row plots
Experimental design: randomised complete block design	

Seedlots included in the Jindian species trial:

Seedlot	Species	Provenance
CS13286	*E. badjensis*	23 km from Nimmatabel, NSW
CS14214	*E. benthamii*	Wentworth Falls, NSW
CS12448	*E. camphora*	Coree Flat, ACT
CS12655	*E. cypellocarpa*	Bonang, Vic.
CS12563	*E. dalrympleana*	Nundle SF, Tamworth, NSW
CS14206	*E. dendromorpha*	Mt Budawang, NSW
CS14457	*E. fastigata*	Bombala, NSW
CNEUGLOB	*E. globulus*	Yunnan, China
CS14840	*E. laevopinea*	S New England, NSW
CS15057	*E. macarthurii*	ENE of Marulan, NSW
CNEUMAID	*E. maidenii*	Yunnan, China
CS14012	*E. nitens*	Brown Mountain, NSW
CS13606	*E. nova-anglica*	24 km SSW of Walcha, NSW
CS10191	*E. obliqua*	East Otways Ranges, Vic.
CS10345	*E. oreades*	Bell—Mt Wilson, NSW
CS11168	*E. pulchella*	Mt Judbury, Tas.

Although there was substantial growth variation between species in this trial, growth of even the best performing species averaged less than 1.8 m in height per year due to the site’s poor soil (heavy clay). The local landrace *E. globulus* (CNEUGLOB) had the greatest height and DBH at age 3 years and was approximately 20% bigger than the local landrace of *E. maidenii* (CNEUMAID) at this site. Other species that performed well at this site were *E. nova-anglica* (CS13606), *E. badjensis* (CS13286) and *E. benthamii* (CS14214). Species that had poor growth and that were markedly inferior included *E. fastigata* (CS14457), *E. oreades* (CS10345), *E. laevopinea* (CS14840) and *E. dendromorpha* (CS14206).

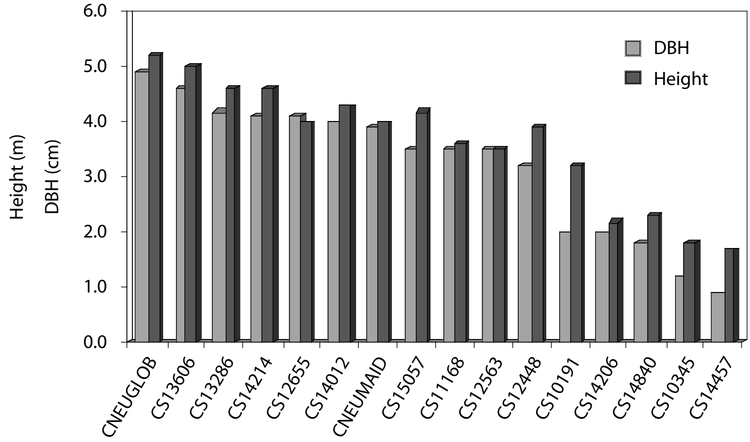

Figure 6. Growth performance, in terms of diameter at breast height over bark (DBH) and height, to age 3 years of the species–provenances in the 1986 species trial at Jindian in Yunnan (Trial ID—Y4).

Jindian species–provenance Trial I (Trial ID—Y5)

Location and environment:	
Latitude: 25°01' N	Soil: yellow soil, clay loam to clay
Longitude: 102°41' E	Mean minimum temperature of coldest month: 3°C
Altitude: 1950 m asl	Absolute minimum temperature: –8°C
Mean annual rainfall: 990 mm	
Trial details:	
Trial type: species–provenance	Date planted: July 1986
Number of species: 6	Age at last assessment: 156 months
Number of seedlots: 49	Number of replicates: 8
Initial spacing: 2.0 2.0 m	Plot size: 9-tree-row plots
Experimental design: balanced incomplete block design	

Species and provenances included in the Jindian species–provenance trial I:

Seedlot	**Species**	**Provenance**
CS12867	*E. denticulata*	Bonang SF, Vic.
CS09246	*E. bicostata*	Wee Jasper, NSW
CS09539	*E. bicostata*	Stanley, Vic.
CS09541	*E. bicostata*	NE of Mansfield, Vic.
CS11310	*E. bicostata*	Mt Lonarch, Vic.
CS11742	*E. bicostata*	5 km N of Bruthen, Vic.
CNEUGLOB	*E. globulus*	Yunnan, China
CS12742	*E. globulus*	Henty River, Tas.
CS12743	*E. globulus*	Leprena, Tas.
CS12744	*E. globulus*	Bruny Island, Tas.

Seedlot	Species	Provenance
CS12745	*E. globulus*	Channel, Tas.
CS12746	*E. globulus*	Geeveston, Tas.
CS12750	*E. globulus*	Pepper Hill, Tas.
CS12751	*E. globulus*	Taranna, Tas.
CS12752	*E. globulus*	Swansea, Tas.
CS12753	*E. globulus*	Rheban, Tas.
CS12755	*E. globulus*	Scamander, Tas.
CS12756	*E. globulus*	St Helens, Tas.
CS12757	*E. globulus*	Flinders Island, Tas.
CNEUMAID	*E. maidenii*	Yunnan, China
CS12132	*E. maidenii*	SW Nelligen Bolaro, NSW
CS12125	*E. maidenii*	Tantawanglo Mtn, NSW
CS12126	*E. maidenii*	Bimmil Hill—Nullica SF, NSW
CS12130	*E. maidenii*	Mt Dromedary, NSW
CS12321	*E. maidenii*	Cann Valley, Vic.
CS12401	*E. nitens*	Federation Range, Vic.
CS13281	*E. nitens*	ENE of Armidale, NSW
CS14437	*E. nitens*	Tallaganda SF, NSW
CS14449	*E. nitens*	Tallaganda, NSW
CS14450	*E. nitens*	Barrington Tops, NSW
CS14454	*E. nitens*	Toorong Plateau, Vic.
CS14455	*E. nitens*	Brown Mtn, NSW
CS15015	*E. nitens*	Marshalls Spur, Vic.
CS15016	*E. nitens*	Barnewell Plains, Vic.
CS11743	*E. viminalis*	40 km NNW Bruthen, Vic.
CS12554	*E. viminalis*	28 km NNW Maydena, Tas.
CS12555	*E. viminalis*	15 km NW Swanport, Tas.
CS12556	*E. viminalis*	9 km NE Mathinna, Tas.
CS12564	*E. viminalis*	Nundle SF Tamworth, NSW
CS12568	*E. viminalis*	Forest Lands SF, NSW
CS12651	*E. viminalis*	Erica, Vic.
CS12973	*E. viminalis*	Tallaganda SF, NSW
CS14198	*E. viminalis*	Cotter Flats, ACT
CS14201	*E. viminalis*	14 km SE of Bendoc, Vic.
CS14511	*E. viminalis*	Barrington Tops, NSW
CS14523	*E. viminalis*	Nullo Mt NE Rylstone, NSW
CS14525	*E. viminalis*	Warung SF Coolah, NSW
CS15017	*E. viminalis*	Silver Ck, Morwell, Vic.
CS15018	*E. viminalis*	Warburton, Vic.

Some of the earlier results from this trial have been reported by Wang et al. (1989, 1994b).

The best two lots in this trial for DBH to age 13 years were both of *E. nitens* (CS13281 and 14450). It is noteworthy that both of these provenances are from the northernmost part of *E. niten*'s natural range in Australia—an area with a climate that features summer rainfall and frequent winter frosts similar to the climate of much of the Yunnan Plateau. In contrast, performance of the more southern provenances of *E. nitens* varied substantially. *E. nitens* (CS15015) ranked fourth by DBH whilst *E. nitens* (CS14437) was among the poorest five of species–provenances in the trial. Some of the *E. viminalis* provenances (CS12554, CS12651 and CS15017) had good growth with DBHs exceeding the *E. globulus* landrace (CNEUGLOB) and heights well above average. As with *E. nitens* though, there was substantial variation among *E. viminalis* provenances at this site and two (CS15018 and CS14511) were among the poorest five in the trial.

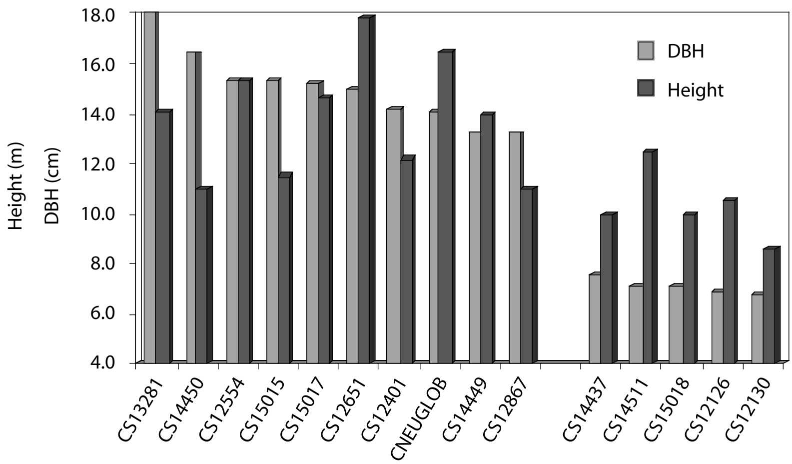

Figure 7. Growth performance, in terms of diameter at breast height over bark (DBH) and height, of the best 10 and worst five species–provenances, based on (DBH), to age 13 years in the 1986 species–provenance trial I at Jindian in Yunnan (Trial ID—Y5).

Growth of the local *E. globulus* landrace (CNEUGLOB) exceeded that of even the best of the Australian *E. globulus* provenances by more than 10% whilst growth of the local landrace of *E maidenii* (CNEUMAID) was about 5% above that of the best Australian provenance of that species. Nonetheless, growth of the *E. maidenii* landrace (CNEUMAID) was substantially inferior to both the local landrace of *E. globulus* (CNEUGLOB), as in the separate species trial nearby (see above), and also to that of many of the Australian *E. globulus* provenances.

Jindian species–provenance trial II (Trial ID—Y6)

Location and environment:	
Latitude: 25°01' N	Soil: yellow soil, clay loam to clay
Longitude: 102°41' E	Mean minimum temperature of coldest month: 3°C
Altitude: 1950 m asl	Absolute minimum temperature: –8°C
Mean annual rainfall: 990 mm	

Trial details:	
Trial type: species–provenance	Date planted: July 1986
Number of species: 7	Age at last assessment: 36 months
Number of seedlots: 11	Number of replicates: 3
Initial spacing: 2.0 2.0 m	Plot size: 9-tree-row plots
Experimental design: randomised complete block design	

Seedlots included in Jindian species–provenance trial II:

Seedlot	Species	Provenance
CS12867	*E. denticulata*	Bonang SF, Vic.
CS09539	*E. bicostata*	Stanley, Vic.
CS09541	*E. bicostata*	NE of Mansfield, Vic.
NAECGRAN	*E. grandis*	Unknown
CNEUMAID	*E. maidenii*	Yunnan, China
CS12125	*E. maidenii*	Tantawanglo Mtn, NSW
CS15918	*E. nitens*	S Captains Flat, NSW
CS17132	*E. nitens*	Tallaganda SF, NSW
CS14920	*E. viminalis*	Cotter Catchment, ACT
CS15017	*E. viminalis*	Silver Creek, Morwell, Vic.
CS17217	*E. viminalis*	Mickleham, Vic.

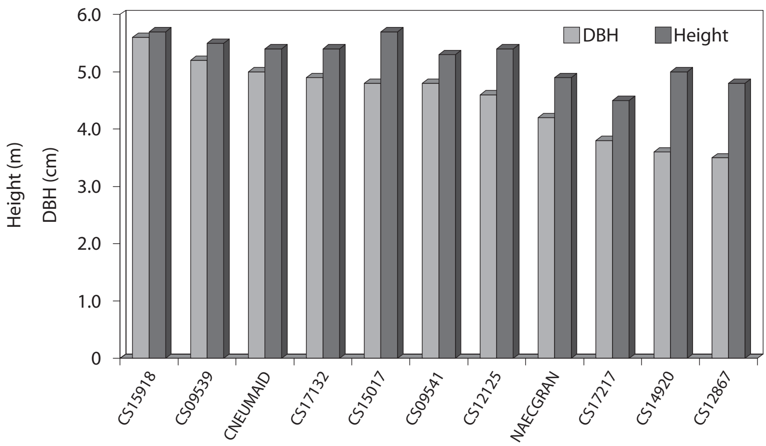

Figure 8. Growth performance, in terms of diameter at breast height over bark (DBH) and height, to age 3 years of the species–provenances in the 1986 species–provenance trial II at Jindian in Yunnan (Trial ID—Y6).

In this smaller trial, *E. nitens* (CS15918) and *E. bicostata* (CS09539) showed the best height and DBH to age 3 years. However both were only marginally better than the local land race of *E. maidenii* (CNEUMAID), which had demonstrated inferior growth in a number of separate and larger trials established around the same time (see above).

Chuxiong species–provenance trial I (Trial ID—Y7)

Location and environment:	
Latitude: 25°01'N	Soil: red soil, gravelly clay loam
Longitude: 101°32'E	Mean minimum temperature of coldest month: 6°C
Altitude: 1870 m asl	Absolute minimum temperature: –5°C
Mean annual rainfall: 830 mm	
Trial details:	
Trial type: species–provenance	Date planted: July 1988
Number of species: 6	Age at last assessment: 48 months
Number of seedlots: 10	Number of replicates: 3
Initial spacing: 2.5 2.5 m	Plot size: 25 trees (5 rows 5 trees)
Experimental design: randomised complete block design	

Seedlots included in Chuxiong species–provenance trial I:

Seedlot	**Species**	**Provenance**
CS12867	*E. denticulata*	Bonang SF, Vic.
CS09539	*E. bicostata*	Stanley, Vic.
CNEUGLOB	*E. globulus*	Yunnan, China
NAECGRAN	*E. grandis*	Unknown
CS12125	*E. maidenii*	Tantawanglo Mtn, NSW
CS15918	*E. nitens*	S Captains Flat, NSW
CS17132	*E. nitens*	Tallaganda SF, NSW
CS14920	*E. viminalis*	Cotter Catchment, ACT
CS15017	*E. viminalis*	Silver Creek, Morwell, Vic.
CS17217	*E. viminalis*	Mickleham, Vic.

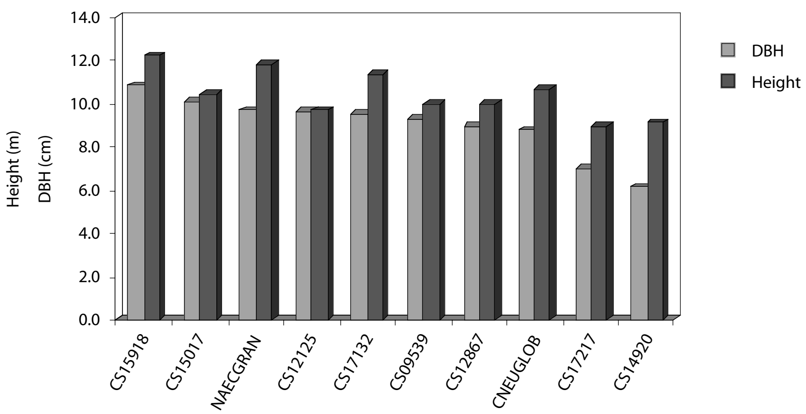

Figure 9. Growth performance, in terms of diameter at breast height over bark (DBH) and height, to age 4 years of species–provenances in the 1988 Chuxiong species–provenance trial I in Yunnan (Trial ID—Y7).

Eucalyptus nitens (CS15918) was the best in this trial for both height and DBH growth. *E. viminalis* (CS15017) and *E. grandis* (NAECGRAN) also performed well and, at least to age 4 years, proved superior for growth to the local landrace of *E. globulus* (CNEUGLOB). In contrast, two provenances of *E. viminalis* (CS14920 and CS17217) were markedly inferior to the *E. globulus* landrace.

Chuxiong species–provenance trial II (Trial ID—Y8)

Location and environment:	
Latitude: 25°01'N	Soil: red dermosol, clay loam to light clay
Longitude: 101°32'E	Mean minimum temperature of coldest month: 6°C
Altitude: 1870 m asl	Absolute minimum temperature: –5°C
Mean annual rainfall: 830 mm	
Trial details:	
Trial type: species–provenance	Date planted: July 1988
Number of species: 4	Age at last assessment: 42 months
Number of seedlots: 13	Number of replicates: 3
Initial spacing: 2.0 2.0 m	Plot size: 16 trees (4 rows 4 trees)
Experimental design: randomised complete block design	

Seedlots included in the Chuxiong species–provenance trial II:

Seedlot	**Species**	**Provenance**
CS17349	*E. dives*	Bago SF, NSW
CS15108	*E. macarthurii*	Canyonleigh, NSW
CS11864	*E. radiata*	5 km S of Nerrigundah, NSW
CS11983	*E. radiata*	E of Braidwood–Nerriga, NSW
CS17311	*E. radiata*	Mickleham, Vic.
CS17312	*E. radiata*	Riddells Ck, Vic.
CS15059	*E. smithii*	Mt Dromedary, NSW
CS15091	*E. smithii*	NW of Narooma, NSW
CS15092	*E. smithii*	Wingello, NSW
CS15542	*E. smithii*	40 km S of Eden, NSW
CS15544	*E. smithii*	20 km WNW of Braidwood, NSW
CS15545	*E. smithii*	13 km N of Orbost, Vic.
CS17131	*E. smithii*	Bodalla SF—NW Narooma, NSW

This trial comprises a range of species which, with the exception of *E. macarthurii*, are of interest for production of essential leaf oils. For growth, the best provenances were all of *E. smithii.* The single provenance of *E. macarthurii* (CS15108) had mediocre growth. All of the provenances of *E. radiata* and *E. dives* were substantially inferior for growth to age 3.5 years.

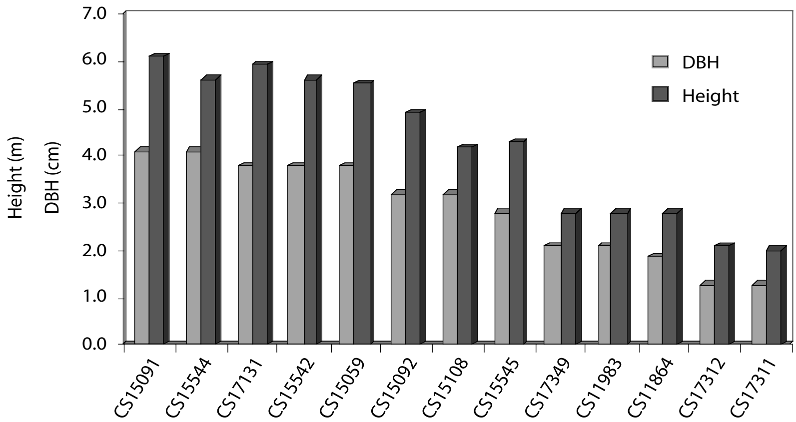

Figure 10. Growth performance, in terms of diameter at breast height over bark (DBH) and height, of species–provenances to age 3.5 years in the 1988 Chuxiong species–provenance trial II in Yunnan (Trial ID—Y8).

Chuxiong species–provenance trial III (Trial ID—Y9)

Location and environment:	
Latitude: 25°01'N	Soil: red dermosol, silty clay loam
Longitude: 101°32'E	Mean minimum temperature of coldest month: 6°C
Altitude: 1870 m asl	Absolute minimum temperature: –5°C
Mean annual rainfall: 830 mm	
Trial details:	
Trial type: species–provenance	Date planted: July 1992
Number of species: 6	Age at last assessment: 54 months
Number of seedlots: 19	Number of replicates: 3
Initial spacing: 2.5 2.5 m	Plot size: 9-tree-row plots
Experimental design: randomised complete block design	

Seedlots included in the 1992 Chuxiong species–provenance trial III:

Seedlot	Species	Provenance
CS15269	*E. bicostata*	Wee Jasper, NSW
CS17777	*E. bicostata*	10 km NW Bruthen, Vic.
CS17965	*E. bicostata*	Tumbarumba, NSW
CNEUGLOB	*E. globulus*	Yunnan, China
CS16860	*E. globulus*	Blue Gum Saddle, Tas.
CS17696	*E. globulus*	Moogara, Tas.
CNEUMAID	*E. maidenii*	Yunnan, China
CS15917	*E. maidenii*	Bolaro Mt, NSW
CS17742	*E. maidenii*	Black Range via Eden, NSW
CS17769	*E. maidenii*	Yurammie SF, NSW

Seedlot	Species	Provenance
CS14439	*E. nitens*	Glenbog SF, NSW
CS16619	*E. nitens*	Tallaganda SF, NSW
CS16636	*E. nitens*	Majors Point Ebor, NSW
CS16750	*E. nitens*	Barkey River Rd—Mt Skene, Vic.
CS16869	*E. nitens*	Toorongo Plateau, Vic.
CS12559	*E. smithii*	Mt Dromedary, NSW
CS16916	*E. smithii*	12 km NE Orbost, Vic.
CS15213	*E. viminalis*	Uriarra Forest, ACT
CS18112	*E. viminalis*	Tambo River via Swifts Ck, Vic.

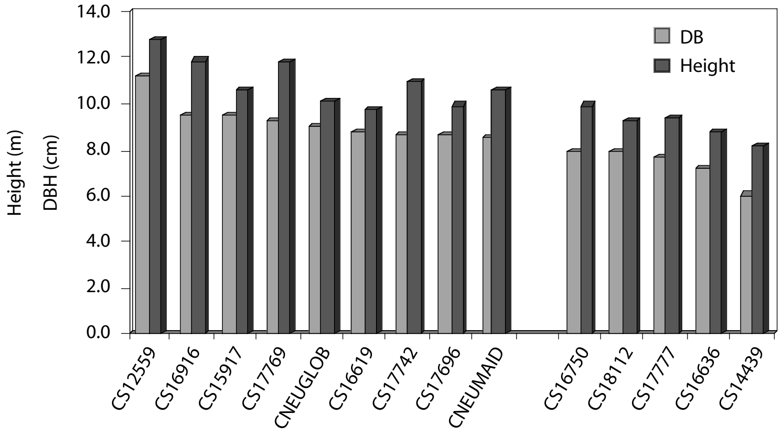

Figure 11. Growth performance, in terms of diameter at breast height over bark (DBH) and height, of the best and poorest species–provenances by DBH to age 4.5 years in the 1992 Chuxiong species–provenance trial III in Yunnan (Trial ID—Y9).

In this trial *E. smithii* (CS12559) had markedly better growth than all other species and provenances. Others reasonable performers included *E. smithii* (CS16916) and two provenances of *E. maidenii* (CS15917 and CS17769). Interestingly, all three Australian provenances of the latter species included in the trial showed better growth than the local landrace (CNEUMAID). Also, the landrace of *E. globulus* (CNEGLOB) was superior in at least DBH to the *E. maidenii* landrace, just as in most of the other trials that included these two. The poorest species and provenances in this trial were *E. nitens* (CS14439 and CS16636), *E. bicostata* (CS17777) and *E. viminalis* (CS18112).

Yipinglang E. globulus *provenance–family trial (Trial ID—Y10)*

Location and environment:	
Latitude: 24°14' N	Soil: light clay to heavy clay loam
Longitude: 101°45' E	Mean minimum temperature of coldest month: 8ºC
Altitude: 1800 m asl	Absolute minimum temperature: –5ºC
Mean annual rainfall: 900 mm	

Trial details:	
Trial type: provenance–family	Date planted: July 1990
Number of seedlots: 60	Age at last assessment: 48 months
Number of families: 309	Number of replicates: 21
Initial spacing: 1.5 3.0 m	Plot size: 2 trees
Experimental design: randomised incomplete block design	

Seedlots included in the Yipinglang E. globulus *provenance–family trial:*

Region trial code	Seedlot codes	Species	Region	No. of families included in the trial
WT	CS16075, CS16078, CS16410, CS16412, CS16422	*E. globulus*	West coast Tas.	23
ET	CS16073, CS16411, CS16472, CS16473, CS16474, CS16475,	*E. globulus*	Eastern Tas.	39
ST	CS16074, CS16080, CS16082, CS16083, CS16084, CS16086, CS16470, CS16471, CS16476, CS16477, CS16478,	*E. globulus*	Southern Tas.	44
TSO	TSO	*E. globulus*	Seed orchard Tas.	20
BSI	CS16415, CS16416, CS16417, CS16419, CS16420, CS16421, CS16424, CS16425, CS16426, CS16427, CS16428, CS16429, CS16430, CS16431, CS16433, CS16434, KI	*E. globulus*	Bass Strait Islands	47
WV	CS16223, CS16224, CS16226, CS16227, CS16240, CS16319, CS16398, CS16402, CS16405, CS16407	*E. globulus*	Western Vic.	48
EV	CS16066, CS16400	*E. globulus*	Eastern Vic.	14
WP	CS16063, CS16399	*E. globulus*	Wilson’s Promontory, Vic.	8
PSO	114648–114696	*E. globulus*	Portugal seed orchard	48
NSO	88/231	*E. globulus*	New Zealand seed orchard	1[a]
YP	YP, NJ, DL, BS, JC, HQ, HY, ES, YP,	*E. globulus*	Yunnan Province — landrace	17

[a] The seedlot from the New Zealand seed orchard was a bulked seedlot from multiple parents.

This trial was established as part of a Chinese Academy of Forestry/CSIRO collaborative project with part funding from ACIAR (ACIAR Project FST/84/57). Early age results (20 months) from this trial have been reported by Zang (1992) and Zang et al. (1994). Some later results (age 4 years) have been given by Zang et al. (1995). The results presented here on growth are taken from the latter report, and the results on frost resistance from Zang (1992).

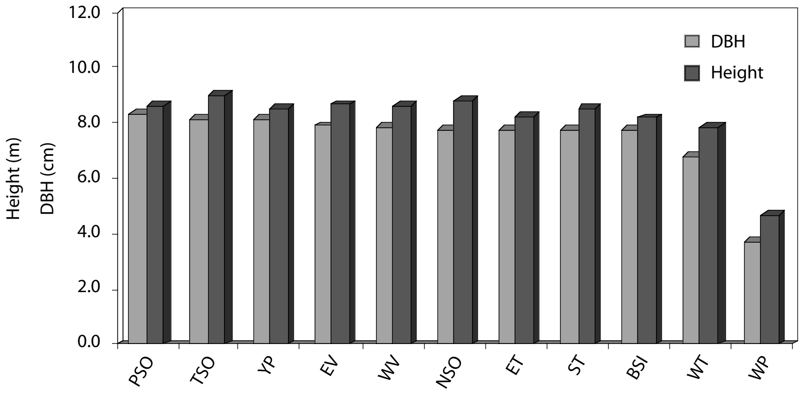

Figure 12. Region means for diameter at breast height over bark (DBH) and mean total height to age 4 years from the 1990 *E. globulus* provenance–family trial at Yipinglang in Yunnan (Trial ID—Y10).

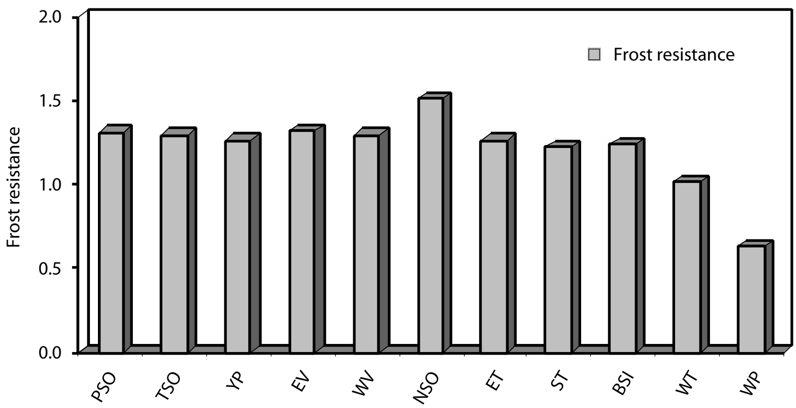

Figure 13. Region means for frost/cold resistance from the 1990 *E. globulus* provenance–family trial at Yipinglang in Yunnan (frost resistance was scored subjectively at age 1.5 years on a gradational 3 point scale, with '0' being severe damage or total necrosis, '1' being major intermediate damage and '2' for minor or no damage) (Trial ID—Y10).

The Tasmanian seed orchard material showed the best growth at Yipinglang to age 4 years and was one of the better 'regions' for frost resistance. The other two seed orchard sources, Portugal and New Zealand, showed reasonably good growth and the latter had relatively superior frost resistance. The regions of Eastern and Western Victoria and Bass Strait Islands also showed reasonably good growth and were of generally good frost resistance. While Western Tasmania had lower growth and relatively poor frost resistance, Eastern and Southern Tasmania were intermediate for both. Wilson's Promontory was markedly inferior to all other regions for both growth and frost resistance. The Yunnan landrace showed reasonably good growth but mediocre frost resistance.

E. smithii *provenance–family trial at Fumin (Trial ID—Y11)*

Location and environment:	
Latitude: 25°14'N	Soil: red dermosol, clay loam to clay
Longitude: 102°30'E	Mean minimum temperature of coldest month: 4°C
Altitude: 1895 m asl	Absolute minimum temperature: –7°C
Mean annual rainfall: 855 mm	
Trial details:	
Trial type: provenance–family	Date planted: May 1995
Number of seedlots: 7	Age at last assessment: 72 months
Number of families: 100	Number of replicates: 5
Initial spacing: 2.5 2.5 m	Plot size: 5-tree-row plots
Experimental design: randomised complete block design	

Provenances included in the Fumin E. smithii *provenance–family trial:*

Seedlot	Species	Provenance	No. of families in trial
CS18676	*E. smithii*	Wingello, NSW	12
CS18682	*E. smithii*	Wyndham, NSW	10
CS18681	*E. smithii*	Towamba, NSW	12
CS18688	*E. smithii*	Nerrigundah, NSW	12
CS18284	*E. smithii*	Tallaganda SF, NSW	19
CS17131	*E. smithii*	Bodalla SF, NSW	5
CS16916	*E. smithii*	North East Orbost, Vic.	30

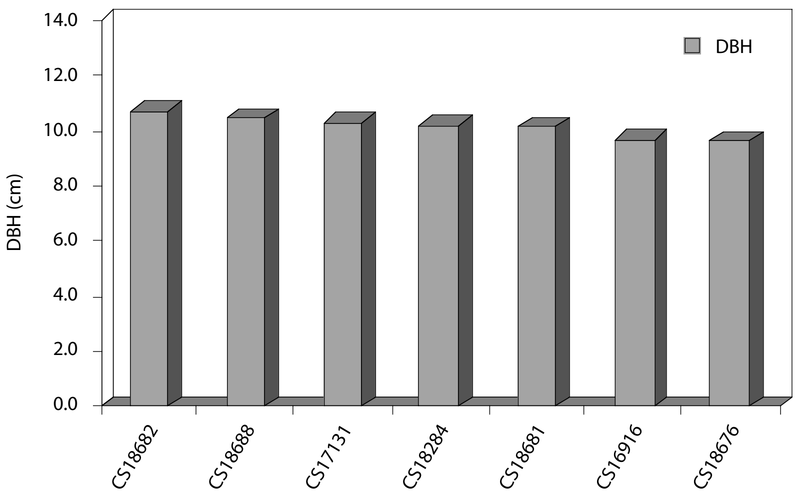

Figure 14. Provenance means for diameter at breast height over bark (DBH) to age 6 years in the 1995 *E. smithii* provenance–family trial at Fumin in Yunnan (Trial ID—Y11)

Overall growth in this *E. smithii* trial was excellent with the trial mean DBH increment being over 2 cm per year up to age 6 years. Despite this rapid growth, differences between provenances were generally small (less than 12% of the trial mean). The two best provenances by DBH, Wyndham (CS18682) and Nerrigundah (CS18688) were only marginally better than the others included in the trial.

Yuxi species–provenance trial (Trial ID—Y12)

Location and environment:	
Latitude: 24°21'N	Soil: red soil, clay loam to light clay
Longitude: 102°33'E	Mean minimum temperature of coldest month: 7°C
Altitude: 1687 m asl	Absolute minimum temperature: –6°C
Mean annual rainfall: 910 mm	
Trial details:	
Trial type: species–provenance	Date planted: July 1988
Number of species: 6	Age at last assessment: 36 months
Number of seedlots: 19	Number of replicates: 3
Initial spacing: 2.0 3.0 m	Plot size: 25-tree-plots (5 rows 5 trees)
Experimental design: randomised complete block design	

Species and provenances included in the 1988 Yuxi species–provenance trial:

Seedlot	**Species**	**Provenance**
CS12867	*E. denticulata*	Bonang SF, Vic.
CS09539	*E. bicostata*	Stanley, Vic.
NAECGRAN	*E. grandis*	Unknown
CNEUMAID	*E. maidenii*	landrace—Yunnan
CS12125	*E. maidenii*	Mt. Tantawanglo, NSW
CS12130	*E. maidenii*	Mt Dromedary, NSW
CS15918	*E. nitens*	Captains Flat, NSW
CS17132	*E. nitens*	Tallaganda SF, NSW
CS14920	*E. viminalis*	Cotter, ACT
CS17217	*E. viminalis*	Mickleham, Vic.

The mean growth of *E. maidenii* (CS12130) was superior to the other species and provenances included in this trial. *E. nitens* (CS17132) and *E. bicostata* (CS09539) ranked second and third, respectively, by growth. In contrast, the local landrace of *E. maidenii* (CNEUMAID) showed only mediocre to poor growth as did the other Australian provenance of *E. maidenii* (CS12125). The single provenance of *E. denticulata* included in this trial (CS12867) was markedly inferior to all other species and provenances.

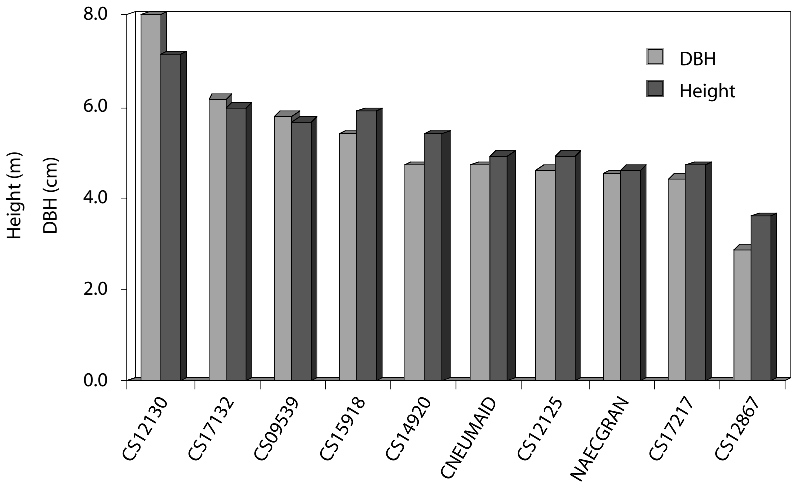

Figure 15. Growth performance, in terms of diameter at breast height over bark (DBH) and height, to age 3 years of species–provenances in the 1988 species–provenance trial at Yuxi in Yunnan (Trial ID—Y12).

Haikou eucalypt species–provenance trial (Trial ID—Y13)

Location and environment:	
Latitude: 24°50'N	Soil: red soil, clay loam to light clay
Longitude: 102°34'E	Mean minimum temperature of coldest month: 5°C
Altitude: 2000 m asl	Absolute minimum temperature: –7°C
Mean annual rainfall: 940 mm	
Trial details:	
Trial type: species–provenance	Date planted: July 1987
Number of species: 23	Age at last assessment: 156 months
Number of seedlots: 30	Number of replicates: 3
Initial spacing: 2.0 2.0 m	Plot size: 9-tree-row plots
Experimental design: randomised complete block design	

Seedlots included in the 1987 Haikou species–provenance trial:

Seedlot	Species	Provenance
CS13349	*E. amplifolia*	Paddys Land SF, NSW
CS13286	*E. badjensis*	Nimmatabel, NSW
CS14214	*E. benthamii*	Wentworth Falls, NSW
CS12448	*E. camphora*	Coree Flat, ACT
CS09755	*E. chapmaniana*	Kiewa, Vic.
CS11711	*E. cinerea*	Gunning, NSW
CS09440	*E. cypellocarpa*	Fitzroy Falls, NSW
CS12655	*E. cypellocarpa*	Bonang, Vic.
CS12914	*E. cypellocarpa*	Jeeralang, Vic.

Seedlot	Species	Provenance
CS12563	*E. dalrympleana*	Nundle SF, NSW
CS10340	*E. deanei*	Thirlmere, NSW
CS11688	*E. deanei*	Watagan Mtns, NSW
CS14521	*E. deanei*	Glen Innes, NSW
CNEUGLOB	*E. globulus*	Yunnan, China
CS11825	*E. johnstonii*	Misery Plateau, Tas.
CS14840	*E. laevopinea*	New England, NSW
CS15057	*E. macarthurii*	Marulan, NSW
CNEUMAID	*E. maidenii*	Yunnan, China
CS12159	*E. mannifera*	Yass–Dalton, NSW
CS09751	*E. neglecta*	Buckland River, Vic.
CS14012	*E. nitens*	Brown Mt, NSW
CS13606	*E. nova-anglica*	Walcha, NSW
CS12284	*E. parvula*	Badja Road, NSW
CS13831	*E. pauciflora*	Mt Coree, ACT
CS12576	*E. scoparia*	Nat. Bot. Gdns, ACT
CS15059	*E. smithii*	Mt Dromedary, NSW
CS15090	*E. smithii*	Towamba, NSW
CS15091	*E. smithii*	Narooma, NSW
CS15092	*E. smithii*	Wingello, NSW
CS14207	*E. triflora*	Morton NP, NSW

This trial was established as part of a Chinese Academy of Forestry/CSIRO/YAF collaborative project with part funding from ACIAR (ACIAR Project FST/84/57). Some of the earlier results from it were reported by Zheng et al. (1994).

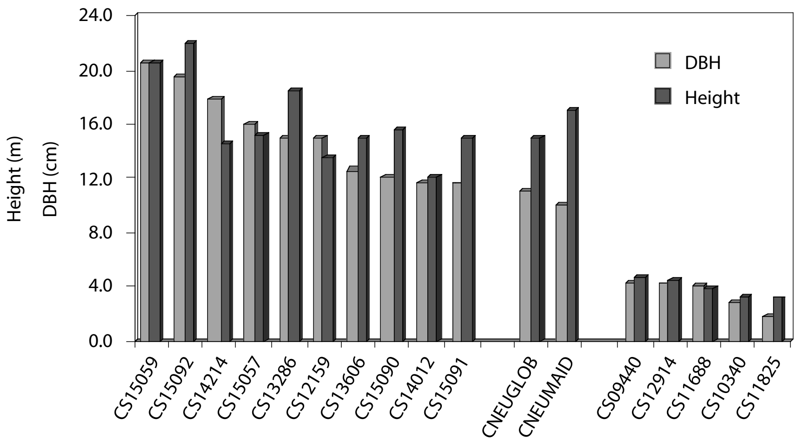

Figure 16. Growth performance, in terms of diameter at breast height over bark (DBH) and height, to age 13 years of the best and the poorest species–provenances, as judged by DBH, in the 1987 species–provenance trial at Haikou in Yunnan (Trial ID—Y13).

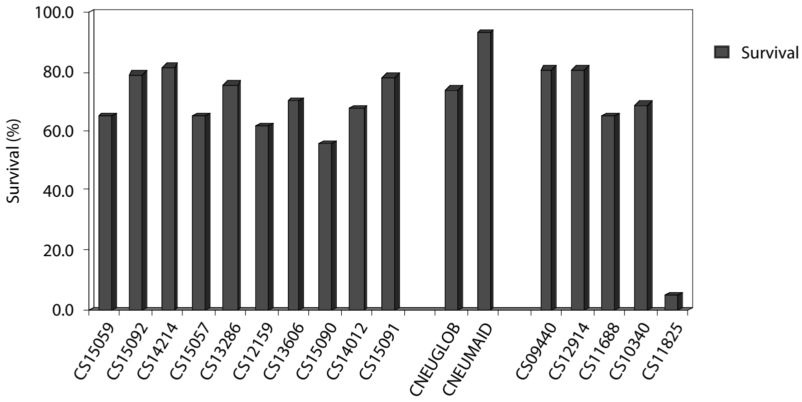

Figure 17. Provenance mean survivals, of the best and the poorest species–provenances by DBH growth, to age 4.5 years in the 1987 species–provenance trial at Haikou in Yunnan (Trial ID—Y13).

For the combination of growth and survival to age 13 years at Haikou both *E. smithii* (CS15092) and *E. benthamii* (CS14214) were outstanding. *E. smithii* (CS15059) showed excellent growth but had somewhat lower survival. Other species and provenances that ranked highly for growth (DBH) and that also had high survivals ($\geq$70%) were *E. nova-anglica* (CS13606) and *E. smithii* (CS15091). *E. macarthurii* (CS15057) showed good growth (ranked 4th by DBH) but had lower survival (65%). The best material in the trial for overall survival was the local landrace of *E. maidenii* (CNUMAID) and although it also had good height growth it was only mediocre for DBH. The local landrace of *E. globulus* (CNEUGLOB) had high survival but was only mediocre for both height and DBH.

The poorest species and provenances for growth at Haikou were *E. deanei* (CS10340 and CS11688), *E. cypellocarpa* (CS09440 and CS12914) and *E. johnstonii* (CS11825). The latter also had the poorest survival in the trial.

Guangxi Province

Environment

Guangxi (Guangxi Zhuang Autonomous Region) is bounded by Yunnan to the west, Guizhou to the north, Hunan on the northeast, Guangdong to the southeast, and by the Gulf of Tonkin and Vietnam to the south and southwest (see Figure 2). Elevations range up to 1800 m asl in the northern parts of Guangxi, and generally descend to the south and southeast to where the province meets the sea. The greater part of the province is composed of undulating to hilly country lying at heights of 500–1000 m asl. Many of the northern parts of Guangxi contain spectacular limestone ‘karst’ scenery. In general, soils in the hilly and mountainous areas of Guangxi are predominantly red soils, while most of lowlands have alluvial soils brought down by the province’s many rivers (Britannica Online 2003b; Zhao 1986).

Summers (April to October) in Guangxi are marked by hot humid conditions with mean daily maximum temperatures in July varying between 27 and 32°C. Winters are mild with occasional snow at higher elevations in the extreme north. The mean daily maximum temperatures in January generally range between 4 and 16°C (Britannica Online 2003b). The areas in the northwest tend to be drier (mean annual rainfalls down to 890 mm), while the northeastern, central, and southern areas are somewhat moister (up to 1730 mm mean annual rainfall). Most of the precipitation occurs between May and August.

Temperatures through southern and central Guangxi are warm enough to allow agricultural production throughout the year. Many tropical and sub-tropical eucalypts, including *E. urophylla*, *E. grandis* and hybrids of these two, have proved well adapted to these areas. However in the northern and northwestern areas which experience cooler winters with light frosts and, occasionally, more severe freezes, such species are not well adapted (Xiang Dongyun, Guangxi Forest Research Institute, pers. comm.; Arnold and Luo 2003). It is these cooler areas that have been a focus for the Cold-tolerant Eucalypt Project in this province.

Eucalypt domestication in Guangxi

Eucalypts were probably first introduced into Guangxi in either the late 19th or early 20th century. Early eucalypt plantings were for ornamental purposes and for roadside shade trees. It was not until about the early 1960s that they were used for larger scale forestation initiatives in Guangxi (Turnbull 1981). The species used in these earlier plantations were primarily *E. exserta* and *Corymbia citriodora* and productivities achieved in the early plantations were relatively low (<10 m^3/ha/yr) (Liu et al. 1996).

The greatest progress with eucalypt domestication in Guangxi has occurred since the early 1980s. In 1982 a major collaborative Chinese–Australian project supported by AusAID was initiated at Dongmen Forest Farm in southern Guangxi to demonstrate the use of different eucalypt species/provenances and plantation establishment and management techniques (Carter et al. 1981; Liu et al. 1996). This ‘Dongmen Project’ operated from 1982 to 1989 and it achievements included: testing of more than 38 eucalypt species and 80 provenances; establishment of productive seed production areas and seed orchards; development, testing and selection of highly productive hybrid eucalypt clonal varieties; substantial increases in the volume productivity in new plantations; development of efficient clonal vegetative propagation programs; and development of much improved silviculture for eucalypt plantations.

The work of the Dongmen Project and most of the more recent eucalypt research in Guangxi has primarily focused on species for the warmer parts of the province. It is only since the late 1990s that the focus has turned to domestication of cold-tolerant eucalypts for the cooler northern parts of the province. Fortunately though, several trials involving *E. dunnii* and other species were established in the late 1980s and early 1990s in northern Guangxi through the vision of a few key researchers.

Trials of cold-tolerant eucalypts in Guangxi

Guilin species–provenance trial (Trial ID—G1)

Location and environment:	
Latitude: 25°28'N	Soil: red soil, clay loam
Longitude: 110°28' E	Mean minimum temperature of coldest month: 4°C
Altitude: 130 m asl	Absolute minimum temperature: –8°C
Mean annual rainfall: 1515 mm	
Trial details:	
Trial type: species–provenance	Date planted: May 1984
Number of species: 7	Age at last assessment: 61 months
Number of seedlots: 11	Number of replicates: 4
Initial spacing: 2.0 3.0 m	Plot size: 25 trees (5 trees 5 trees)
Experimental design: randomised complete block design	

Seedlots included in the Guilin species–provenance trial:

Seedlot	Species	Provenance
CS13849	*E. camaldulensis* var. *obtusa*	8 km from Petford, Qld
CS13579	*E. crebra*	Gin Gin, Qld
CS13124	*E. dunnii*	Moleton, NSW
CNGLEX01	*E. exserta*	Unknown
CNGLHB01	*E. exserta* E. *saligna*	Clone—from China
CNGLHB02	*E. exserta E. saligna*	Clone—from China
CNGLGB01	*E. globulus* ssp. *globulus*	Unknown
CNGLTE27	*E. tereticornis*	Unknown
CNGLTE28	*E. tereticornis*	Unknown
CNGLTE29	*E. tereticornis*	Unknown
CNGLTE30	*E. tereticornis*	Unknown

For various reasons monitoring and maintenance of this trial was, unfortunately, discontinued after about age 5 years. Had it been possible to continue assessments for several more years then the effects of an episodic cold event (i.e. extremely damaging frosts which occurred in south central China in both December 1991 and December 1999) on adaptability of the various species included in this trial could have been assessed.

One of the clones of the hybrid *E. exersta* x *E. saligna* (CNGLHB01) along with *E. dunnii* (CS13124) showed outstanding growth to age 5 years on this site, with mean height increments of over 3 m per year. *E. globulus* (CNGLGB01) and *E. exserta* (CNGLEX01) both had relatively poor growth in this environment. Some of the *E. tereticornis* provenances sources (CNGLTE27, CNGLTE28 and CNGLTE29) showed relatively good height growth but had only mediocre diameters.

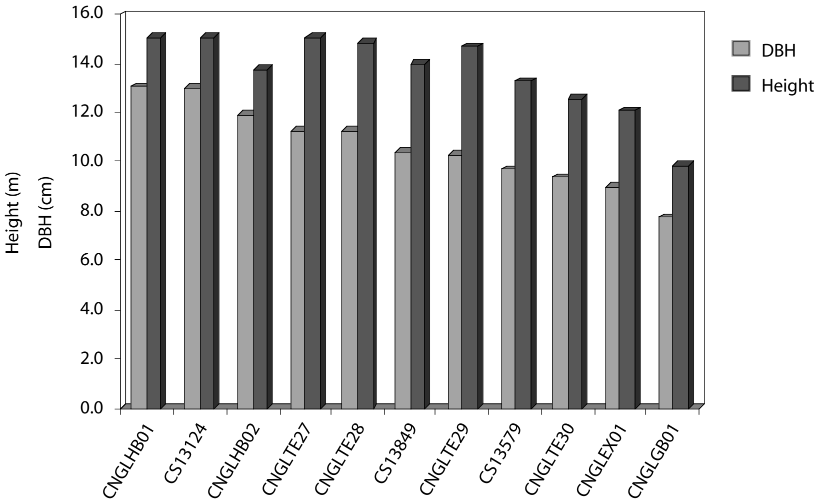

Figure 18. Growth performance, in terms of diameter at breast height over bark (DBH) and height, to approximately age 5 years of species–provenances in the 1984 species–provenance trial at Guilin in northeastern Guangxi (Trial ID—G1).

Guilin species trial (Trial ID—G2)

Location and environment:	
Latitude: 25°28' N	Soil: red soil, clay loam
Longitude: 110°28' E	Mean minimum temperature of coldest month: 4°C
Altitude: 130 m asl	Absolute minimum temperature: -8°C
Mean annual rainfall: 1515 mm	
Trial details:	
Trial type: species	Date planted: May 1987
Number of species: 6	Age at last assessment: 36 months
Number of seedlots: 6	Number of replicates: 3
Initial spacing:	Plot size: 25 trees (5 trees 5 trees)
Experimental design: randomised complete block design	

Seedlots included in the Guilin species trial:

Seedlot	**Species**	**Provenance**
CS13540	*Corymbia citriodora* ssp. *variegata*	15.4 km of Wondai, Qld
CNGLCAM1	*E. camaldulensis*	Unknown
CNGLGRA1	*E. grandis*	Unknown
CS13998	*E. pellita*	NE Coen, Qld
CNGLPRO1	*E. propinqua*	Unknown
CNGLURO1	*E. urophylla*	Unknown

As with the earlier species–provenance trial at Guilin (see above) this trial was discontinued at a relatively young age.

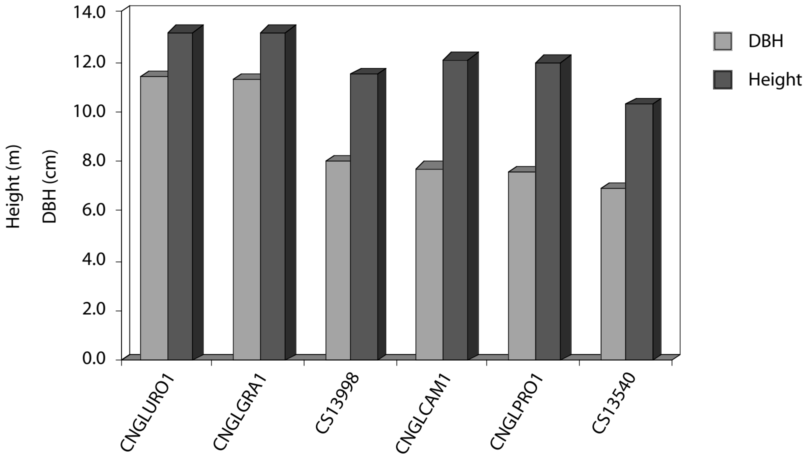

Figure 19. Growth performance, in terms of diameter at breast height over bark (DBH) and height, to age 3 years of species–provenances in the 1987 species trial at Guilin in northeastern Guangxi (Trial ID—G2).

To age 3 years in this trial both *E. urophylla* (CNGLUR01) and *E. grandis* (CNGLGRA1) showed markedly better growth than the other species. However, it is known that between the time the trial was established and when the assessment was carried out, winters in the area were relatively mild. The severe frost and cold of both December 1991 and December 1999 might have markedly affected the adaptability and subsequent growth of the species in this trial, as most were of more tropical origin.

E. dunnii *provenance trials—Guilin (Trial ID—G3) and Satang (Trial ID—G4)*

Location and environment (Guilin, Trial ID—G3):	
Latitude: 25°28'N	Soil: red soil, clay loam to medium clay
Longitude: 110°28'E	Mean minimum temperature of coldest month: 4°C
Altitude: 130 m asl	Absolute minimum temperature: –8°C
Mean annual rainfall: 1515 mm	

Location and environment: (Satang, Trial ID—G4):	
Latitude: 24°28' N	Soil: red soil, clay loam
Longitude: 109°24' E	Mean minimum temperature of coldest month: 5°C
Altitude: 120 m asl	Absolute minimum temperature: –6°C
Mean annual rainfall: 1400 mm	

Trial details: both sites (G3 and G4)	
Trial type: provenance	Date planted: July 1991
Number of species: 1	Age at last assessment: 102 months
Number of seedlots: 5	Number of replicates: 4
Initial spacing: 2.0 3.0 m	Plot size: 25 trees (5 rows 5 trees)
Experimental design: randomised complete block design	

Seedlots included in both trials:

Seedlot	Species	Provenance
CS13329	*E. dunnii*	Kyogle, NSW
CS15956	*E. dunnii*	Dead Horse Track, NSW
CS16894	*E. dunnii*	Teviot Falls SF, NSW
CS17555	*E. dunnii*	Moleton, Kangaroo SF, NSW
CS17733	*E. dunnii*	Spicers Gap, Qld

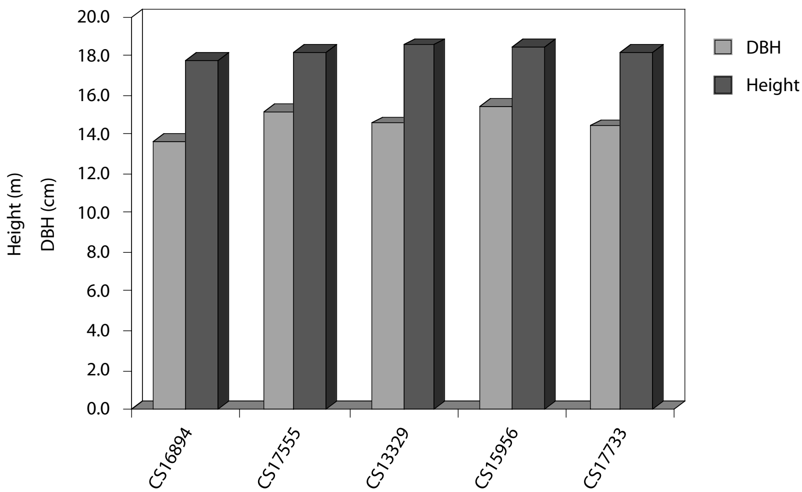

Figure 20. Growth performance, in terms of diameter at breast height over bark (DBH) and height, to approximately age 8.5 years of provenances in the *E. dunnii* provenance trial at Guilin in northeastern Guangxi (Trial ID—G3).

Early results from both these trials have been reported by Wang et al. (1999). Survivals in both trials were very high (≥87%) and there were no significant differences in survival between provenances (data not shown). Overall *E. dunnii* grew very well at both trial localities with average height increments in excess of 2.1 m per year up to age 8.5 years. Even though differences were observed between provenances for growth at both sites, the magnitude of these differences for height and DBH were small (differences less than 10% of the average of the best provenance). No one provenance showed absolute superiority for growth and, due to the small magnitude of differences, changes in performance of the provenances between the trial sites are relatively unimportant.

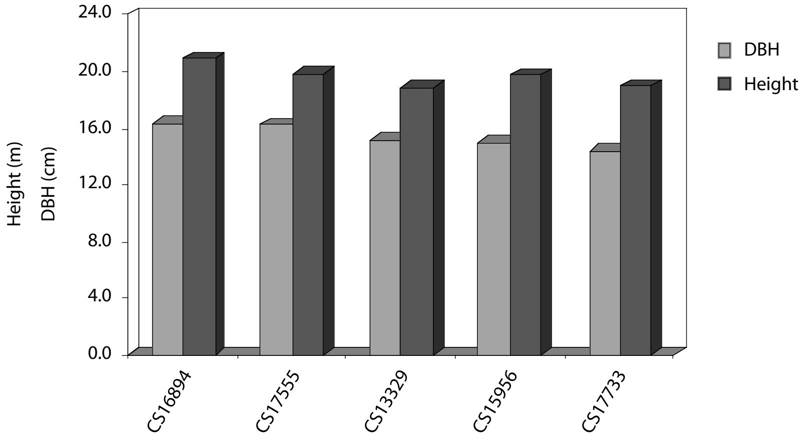

Figure 21. Growth performance, in terms of diameter at breast height over bark (DBH) and height, to approximately age 8.5 years of provenances in the *E. dunnii* provenance trial at Satang in northeastern Guangxi (Trial ID—G4).

Cha Hua Shan species–provenance trial (Trial ID—G5)

Location and environment:	
Latitude: 24°03’ N	Soil: red soil, clay loam to light clay
Longitude: 109°24’ E	Mean minimum temperature of coldest month: 6°C
Altitude: 130 m asl	Absolute minimum temperature: –3°C
Mean annual rainfall: 1600 mm	
Trial details:	
Trial type: species–provenance	Date planted: June 1994
Number of species: 9	Age at last assessment: 39 months
Number of seedlots: 23	Number of replicates: 4
Initial spacing: 1.5 4.0 m	Plot size: 90 trees (6 rows 15 trees)
Experimental design: randomised complete block design	

Seedlots included in the Cha Hua Shan species–provenance trial:

Seedlot code	**Species**	**Provenance**
CS14236	*E. cloeziana*	Herberton, Qld
CS14427	*E. cloeziana*	Blackdown Tableland, Qld
CS17008	*E. cloeziana*	Woondum SF, Qld
CS17733	*E. dunnii*	Spicers Gap, Qld
CS18231	*E. dunnii*	Koreelah SF, NSW

Seedlot code	Species	Provenance
CS18264	*E. dunnii*	Yabbra Plains Rd, NSW
CS18146	*E. grandis*	Coffs Harbour SSO, NSW
BRGD UR1	*E. grandis* *urophylla*	Brazil clone from Dongmen, China
CS18197	*E. pellita*	Kiriwo, PNG
CS18198	*E. pellita*	Kiriwo, PNG
CS18199	*E. pellita*	Serisa, PNG
CS18115	*E. saligna*	Mt Scanzi, Qld
CS18162	*E. saligna*	Bellthorpe SF, Qld
CS18229	*E. saligna*	Blackdown Tableland, Qld
CS16620	*E. saligna* ig. *botryoides*[a]	Yadboro SF, NSW
CS16349	*E. tereticornis*	Atherton Wongabel Qld
CS17430	*E. tereticornis*	Loch Sport, Vic.
CS17761	*E. tereticornis*	Spicers Gap SF, Qld
CS18315	*E. tereticornis*	Kennedy R, Lakefield NP, Qld
CS14534	*E. urophylla*	Mt Egon, Indonesia
CS17831	*E. urophylla*	Ilwaki, Wetar Island, Indonesia
CS17832	*E. urophylla*	Arnau, Wetar Island, Indonesia
CS17836	*E. urophylla*	Uhak, Wetar Island, Indonesia

[a] This provenance is from a population that is considered to be an intergrade between *E. saligna* and *E. botryoides.*

Chua Hua Shan is located at the approximate border of what is generally considered the northern limit for growing frost sensitive forest tree species in Guangxi provenance (Xiang Dongyun, Guangxi Forest Research Institute, pers. comm.). This trial was established to test the adaptability of both cold-tolerant and more tropical species to this zone.

The best performing material for growth at this site included: the tropical varieties *E. urophylla* (CS17831 and CS17836) and a hybrid Brazilian clone *E. grandis* *urophylla* (BRGD UR1); a subtropical provenance of *E. grandis* (CS18146); and the more temperate *E. saligna* ig. *botryoides* (CS16620). It is particularly noteworthy that the Brazilian clone was no better than the best of the unimproved *E. urophylla* seedling material (CS17831 and CS17836). It is likely that the environment in Brazil where the hybrid clone had originally been selected and tested differs significantly from that of northeastern Guangxi.

At this site *E. tereticornis* (CS16349), *E. saligna* (CS18162), *E. pellita* (18197), *E. cloeziana* (CS14427) and *E. dunnii* (CS17733) were all markedly inferior. However, the other two *E. dunnii* provenances in the trial (CS18231 and CS18264) were substantially better than the latter with at least 30% greater mean DBHs and heights. Interestingly, *E. dunnii* provenances from the Spicers Gap State Forest Qld have also proved to be inferior in growth to other *E. dunnii* provenances in some trials in Australia (see Johnson and Arnold 2000; Arnold et al. 2004).

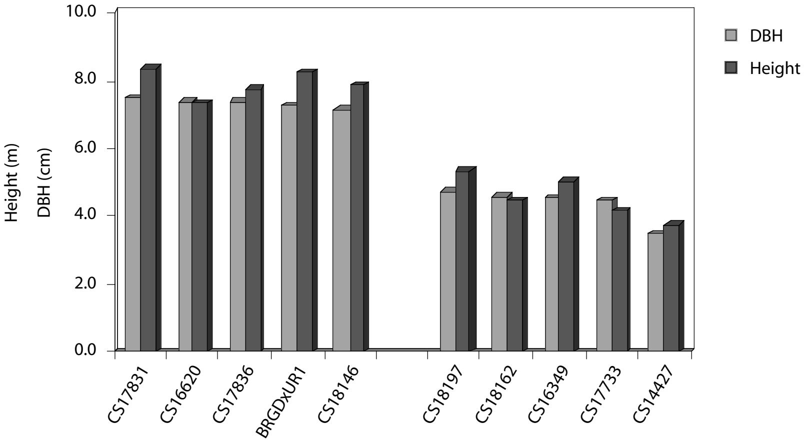

Figure 22. Growth performance, in terms of diameter at breast height over bark (DBH) and height, of the five best and five worst species–provenances, based on DBH, to age 3.25 years in the 1994 species–provenance trial at Cha Hua Shan in Guangxi (Trial ID—G5).

Hunan Province

Environment

Hunan, situated just to the south of the Yangtze River, is bounded by the provinces of Hubei to the north, Jiangxi to the east, Guangdong to the south, Guangxi to the southwest, and by the provinces of Guizhou and Sichuan to the west (see Figure 2). Topographically, the province comprises a basin that is bordered by uplands in its west, south and east but is open to the north. The altitude steadily decreases from the south, northward to the plain of Dongting Lake in the extreme north of the province. Dongting Lake is contiguous with the floodplain of the Yangtze River. Three quarters of Hunan lies at elevations below 500 m asl (Britannica Online 2003c, Zhao 1986).

In the hilly regions of central and southern Hunan, the soils are predominantly red soils with high clay content and strongly acidic, rich in alumina and iron, and poor in organic material (Britannica Online 2003c). On the northern plains, however, soils are predominantly alluvial and more fertile, originating from silt out of the Yangtze River and its tributaries. These soils are generally less acidic and well suited to wide variety of crops.

Northern Hunan generally experiences more extreme weather than the south. In winter, occasional waves of freezing air from Mongolia and Siberia sweep southward. The average minimum winter temperature is 6^{o}C. In the north there are an average of 100 frosts a year with minimum temperatures for January down to –10°C, while in the south the average number of frosts is about 60 (Turnbull 1981; Zhao 1986). Summers are long and humid, the average maximum summer temperature being more than 30°C. Maximum precipitation occurs between spring and summer. Rainfall generally decreases from south to the north, with central Hunan receiving around 1400 mm per annum (Britannica Online 2003c). The extreme contrasts that characterise Hunan’s climate (i.e. frequent winter frost with occasional advective freezes, high summer temperatures and summer rainfall combined with high humidities and, sometimes, a late summer drought) can be particularly testing to the adaptability of exotic species such as eucalypts (Arnold and Luo 2003).

Eucalypt domestication in Hunan

It is believed eucalypts were introduced into Hunan in 1926 (Lin et al. 2003). However, it was not until the 1950s and 1960s that the province undertook extensive eucalypt planting programs. Forestry, railway and road departments carried out most of the early plantings along railways, roads and other corridors. These plantings used a wide range of species and seed sources but primarily *C. citriodora* and *E. exserta*, which thrived in the warmer coastal areas of more southern provinces. Such species were poorly adapted to Hunan’s testing environment and there were widespread failures (Turnbull 1981). However, investigations in 1986 revealed that some eucalypts from the early plantings had managed to survive and prosper. Most common amongst the surviving species were *E. camaldulensis*, *E. robusta* and *E. botryoides*. Of these, the most productive and best adapted proved to be *E. camaldulensis* with some of the 40-year-old trees averaging over 25 m in height and up to 63 cm in diameter at breast height (Lin et al. 2003).

Since the mid 1990s, Hunan Forest Department has developed a more scientifically based domestication and testing program for eucalypts and has established many trials throughout the central and southern parts of the province.

Trials of cold-tolerant eucalypts in Hunan

Suxian species–provenance trial (Trial ID—H1)

Location and environment:	
Latitude: 25°30' N	Soil: red soil, clay loam to medium clay
Longitude: 112°53' E	Mean minimum temperature of coldest month: 0°C
Altitude: 320 m asl	Absolute minimum temperature: –10°C
Mean annual rainfall: 1550 mm	
Trial details:	
Trial type: species–provenance	Date planted: May 1997
Number of species: 3	Age at last assessment: 37 months
Number of seedlots: 7	Number of replicates: 3
Initial spacing: 3.5 2.5	Plot size: 25 trees (5 rows 5 trees)
Experimental design: randomised complete block design	

Seedlots included in this trial:

Seedlot code	Species	Provenance
CS15956	*E. dunnii*	Dead Horse Track, NSW
CS17555	*E. dunnii*	Moleton, Kangaroo SF, NSW
CS17733	*E. dunnii*	Spicers Gap, Qld
CS18231	*E. dunnii*	Koreelah SF, NSW

Seedlot code	Species	Provenance
CS18264	*E. dunnii*	Yabbra Plains Rd, NSW
CS16620	*E. saligna* ig. *botryoides*[a]	Yadboro SF, NSW
CS17430	*E. tereticornis*	Loch Sport, Vic.

[a] This provenance is from a population that is considered to be an intergrade between *E. saligna* and *E. botryoides.*

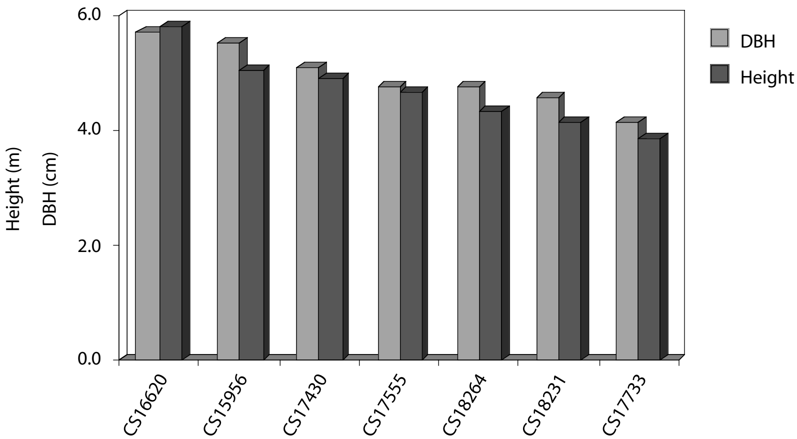

Figure 23. Growth performance, in terms of diameter at breast height over bark (DBH) and height, to age 3 years of species–provenances in the 1997 species–provenance trial at Suxian in Hunan (Trial ID—H1).

At this site in southern Hunan, *E. saligna* ig. *botryoides* and *E. dunnii* (CS15956) showed superior growth. *E. tereticornis* (CS17430), which came from the southern most part of the species' natural distribution, also showed reasonable growth. The poorest for growth in this small trial was the *E. dunnii* provenance from Spicer's Gap, Qld (CS17733).

Hengyang species trial (Trial ID—H2)

Location and environment:	
Latitude: 26°54'N	Soil: red soil, clay loam to medium clay
Longitude: 112°36'E	Mean minimum temperature of coldest month: 3°C
Altitude: 107 m asl	Absolute minimum temperature: –10°C
Mean annual rainfall: 1340 mm	
Trial details:	
Trial type: Species	Date planted: May 1991
Number of species: 4	Age at last assessment: 102 months
Number of seedlots: 4	Number of replicates: 3
Initial spacing: 2.0 3.0 m	Plot size: 25 trees (plot shape varied)
Experimental design: randomised complete block design	

Seedlots included in this trial:

Seedlot	Species	Provenance
CS15031	*E. camaldulensis*	Lake Agnes, Vic.
Local	*E. camaldulensis*	Landrace—collected off 'four around' plantings in Hengyang
Jiangxi	*E. camaldulensis*	Landrace—collected off 'four around' plantings in Guixi, Jiangxi Province
CS14113	*E. dunnii*	NNW of Urbenville, NSW
CS11319	*E. grandis*	Bulahdelah, NSW
CS14534	*E. urophylla*	Mt Egon, Flores, Indonesia
CS15213	*E. viminalis*	Uriarra Forest, ACT

In the first winter after this trial was planted there was some severe cold weather experienced in central Hunan (and indeed in much of south central China), and in December 1991 temperatures in Hengyang dropped to –6ºC. All the trees in the trial were reputedly badly damaged, though not killed, and they were subsequently topped to induce basal coppice sprouting. This coppice was thinned the following summer to the single most vigorous shoot.

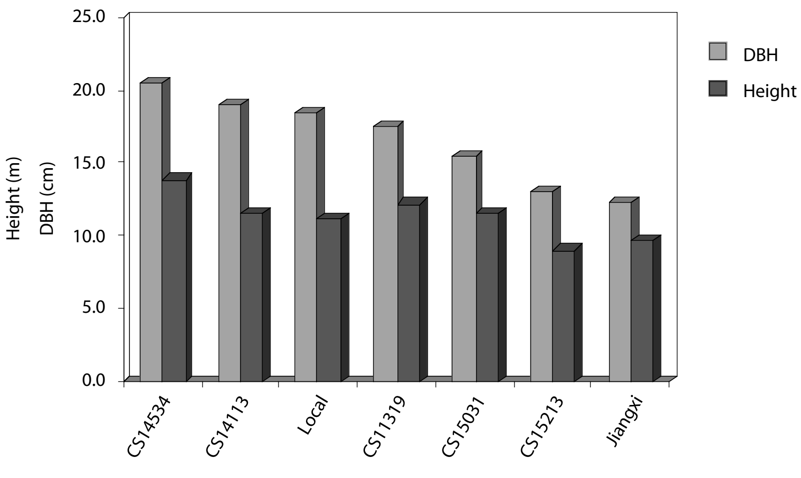

Figure 24. Growth performance, in terms of diameter at breast height over bark (DBH) and height, to age 8.5 years of species–provenances in the 1991 species trial at Hengyang in Hunan (Trial ID—H2).

Despite the initial setback in this trial from cold/frost in December 1991, the tropical *E. urophylla* (CS14534) grew very well and outperformed the other species–provenances. Along with *E. urophylla*, *E. dunnii* (CS14113) and the local landrace of *E. camaldulensis* also performed well. In contrast, the *E. camaldulensis* obtained from Jiangxi showed relatively poor growth in this environment, as did *E. viminalis* (CS15213).

In December 1999 a flow of cold air from Siberia extended southwards over much of south central China and temperatures in the Hengyang area fell to around –5°C. Surprisingly, several months later there were few visible signs of any damage on the trees in this trial. This may have been due in part to the fact that the severity of the cold experienced was more acute in the south of Hunan (temperatures as low as –9°C) than in the central and northern parts. However, during January 2003 there were a number of periods of unusually cold weather including snow and sleet, with the minimum temperature dropping as low as –7°C in Hengyang on one occasion. Visual scrutiny of the Hengyang trial several months later revealed that all the *E. urophylla* (CS14534) had been killed and some of the *E. grandis* (CS11319) badly damaged. In contrast, the other species–provenances in this trial showed little or no sign of any cold damage.

Chengzhou species-provenance trial (Trial ID—H3)

Location and environment:	
Latitude: 25°45'N	Soil: red soil, clay loam to medium clay
Longitude: 112°53'E	Mean minimum temperature of coldest month: 3°C
Altitude: 246 m asl	Absolute minimum temperature: –8°C (1999)
Mean annual rainfall: 1470 mm	
Trial details:	
Trial type: species–provenance	Date planted: June 1997
Number of species: 7	Age at last assessment: 33 months
Number of seedlots: 14	Number of replicates: 4
Initial spacing: 2.0 2.0	Plot size: 64 trees (8 rows 8 trees)
Experimental design: randomised complete block design	

Seedlots included in the Chengzhou species-provenance trial:

Seedlot code	Species	Provenance
CS17774	*E. badjensis*	Glenbog SF, NSW
CS15956	*E. dunnii*	Dead Horse Track, NSW
CS17555	*E. dunnii*	Moleton/Kangaroo SF, NSW
CS17733	*E. dunnii*	Spicers Gap, Qld
CS18231	*E. dunnii*	Koreelah SF, NSW
CS18264	*E. dunnii*	Yabbra Plains Rd, NSW
CS15921	*E. grandis*	Kempsey, Tan Ban SF, NSW
CS18146	*E. grandis*	Coffs Harbour Seed Orchard, NSW
CS13971	*E. microcorys*	NNE of Kendall, NSW
CS16620	*E. saligna* ig. *botryoides*[a]	Yadboro SF, NSW
CS16349	*E. tereticornis*	Atherton–Wongabel, Qld
CS17761	*E. tereticornis*	Spicers Gap SF, Qld
CS17430	*E. tereticornis*	Loch Sport, Vic.
Sichuan1	*E. camaldulensis*	landrace from Sichuan Province

[a] This provenance is from a population that is considered to be an intergrade between *E. saligna* and *E. botryoides.*

In December 1999, when this trial was approximately 30 months old, Hunan experienced a severe cold event (minimum temperature in the area dropped to about –8°C). The impact of this event was particularly bad as the weather in the preceding weeks had been unseasonably warm. Three months after the event an assessment was made of the trial for both growth (diameter at breast height and total height for all remaining trees) and cold damage. Frost/cold damage was assessed visually using a simple four-point scale—scores of ‘1’ were assigned to heavily damaged and/or dead trees; scores of ‘2’ to moderate to heavily damaged trees showing significant resprouting/recovery; scores of ‘3’ to lightly damaged trees; a score of ‘4’ to very lightly damaged or undamaged trees.

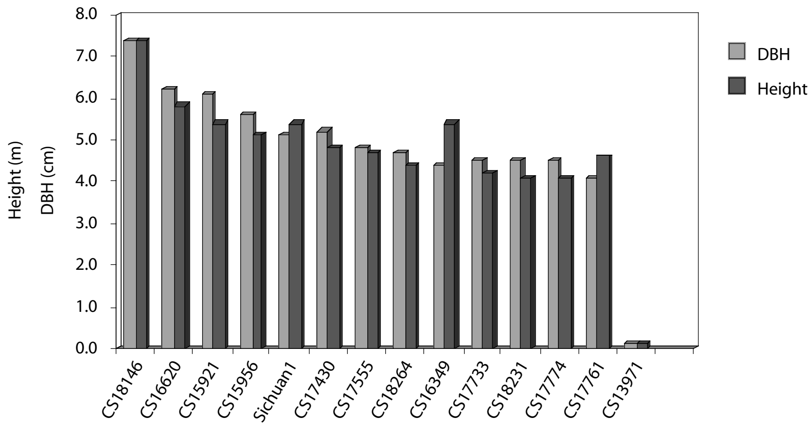

Figure 25. Growth performance, in terms of diameter at breast height over bark (DBH) and height, to age 2.75 years of species–provenances in the 1997 Chengzhou species–provenance trial in Hunan (Trial ID—H3).

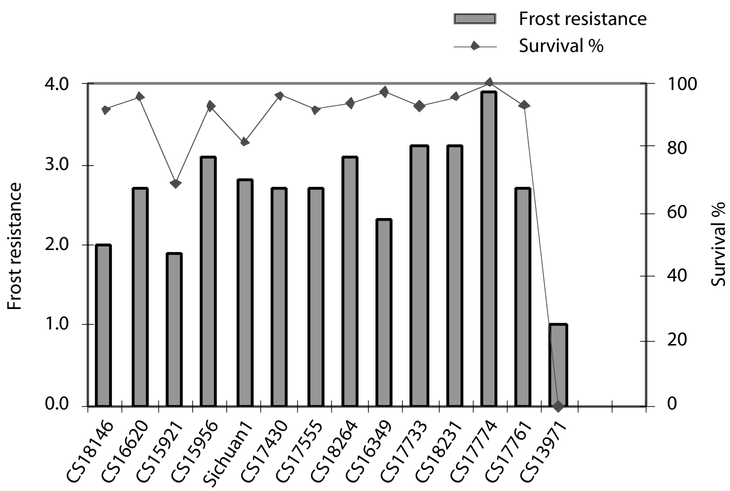

Figure 26. Frost/cold resistance and survival of species–provenances at age 2.75 years in the 1997 Chengzhou species–provenance trial in Hunan (frost resistance was scored subjectively on a gradational 4-point scale with ‘4’ for minor or no damage, and progressing down to ‘1’ being major frost/cold damage or total necrosis) (Trial ID—H3).

For the combination of growth and cold tolerance, *E. saligna* ig. *botryoides* (CS16620), *E. dunnii* (CS15965), *E. tereticornis* (CS17430) and *E. tereticornis* (CS16439) performed best in this trial. Despite the excellent cold tolerance of *E. badjensis* (CS17774), its growth was relatively poor. The best growth in the trial was by the seed orchard material of *E. grandis* (CS18146) and, despite its apparently poor cold tolerance, the locally sourced *E. camaldulensis* (Sichuan1) also grew very well. All trees of *E. microcorys* (CS13971) were killed and the locally sourced material of *E. camaldulensis*, whose original Australian origin(s) is uncertain, proved to have relatively poor cold tolerance.

Zixing E. grandis *provenance–family trial (Trial ID—H4)*

Location and environment:	
Latitude: 25°34'N	Soil: red soil, clay loam to medium clay
Longitude: 113°09'E	Mean minimum temperature of coldest month: 5°C
Altitude: 120 m asl	Absolute minimum temperature: –8°C (estimated)
Mean annual rainfall: 1538 mm	
Trial details:	
Trial type: provenance–family	Date planted: May 1998
Number of seedlots: 10	Age at last assessment: 18 months
Number of families: 80	Number of replicates: 4
Initial spacing: 2.0 2.0 m	Plot size: 6-tree-row plots
Experimental design: balanced incomplete block design	

Seedlots included in the Zixing E. grandis *trial:*

Seedlot code	Species	Provenance
CS17562	*E. grandis*	30km SW Cairns, Qld
CS17709	*E. grandis*	Windsor Tableland, Qld
CS17713	*E. grandis*	Piccaninny Ck, Qld
CS17857	*E. grandis*	10km Sth. of Ravenshoe, Qld
CS18180	*E. grandis*	Baldy State Forest, Qld
CS18569	*E. grandis*	Wongabel SF, Qld
CS18590	*E. grandis*	SSW Atherton, Qld
CS18591	*E. grandis*	Mt Spec near Paluma, NSW
CS18594	*E. grandis*	Tinaroo Ck Rd, Qld
CS18595	*E. grandis*	East of Wondecla, Qld

This well designed trial contains a good range of *E. grandis* material known to have better potential for cold tolerance. Of the 12 provenances represented, 11 are from inland locations with altitudes of 925 m asl, or higher. For frost resistance in *E. grandis* it is known that provenances from high altitudes tend be the best (Eldridge et al. 1993). This trial has only been assessed once since establishment, at age 1.5 years, and at the time of writing resources were being sought to complete a detailed up-to-date assessment.

Overall growth in this trial to age 1.5 years was outstanding, with a trial mean height increment of 3.5 m per year. Given the early age of the assessment and the relatively small magnitude of the differences between the tallest and the shortest provenances (differences less than 10% of the mean height of the best provenance), nothing conclusive can be drawn from the results.

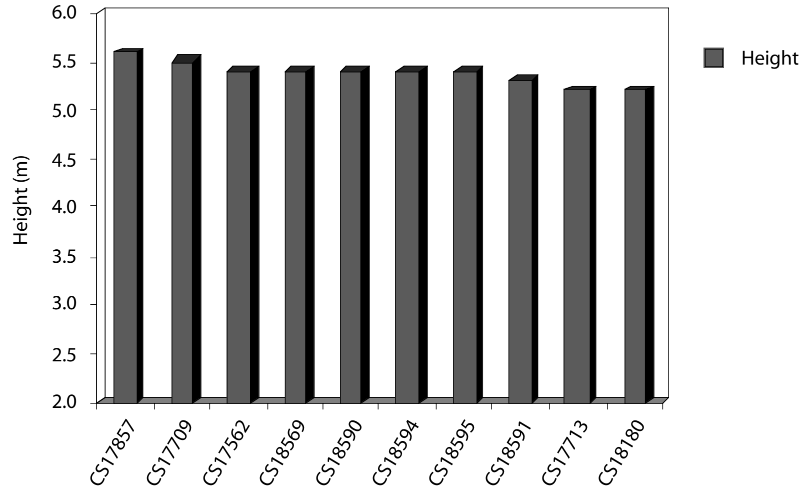

Figure 27. Growth performance in height of provenances to age 1.5 years in the 1998 *E. grandis* provenance–family trial at Zixing in Hunan (Trial ID—H4).

DaoXian eucalypt species trial (Trial ID—H5)

Location and environment:	
Latitude: 25°31' N	Soil: red soil, clay loam to heavy clay
Longitude: 111°34’ E	Mean minimum temperature of coldest month: 4°C
Altitude: 300 m asl	Absolute minimum temperature: –7°C
Mean annual rainfall: 1600 mm	
Trial details:	
Trial type: species	Date planted: May 1996
Number of species: 6	Age at last assessment: 66 months
Number of provenances: 6	Number of replicates: 3
Initial spacing: 2.0 2.0	Plot size: 10-tree-row plots
Experimental design: randomised complete block design	

Seedlots included in the DaoXian species trial:

Seedlot code	**Species**	**Provenance**
CS17733	*E. dunnii*	Spicers Gap, Qld
Landrace	*E. globulus*	landrace from Yunnan, China
CS18146	*E. grandis*	Coffs Harbour seed orchard, NSW

Seedlot code	Species	Provenance
uncertain	*E. nitens*	Blue Range Road, Vic.
CS16620	*E. saligna* ig. *botryoides*[a]	Yadboro State Forest, NSW

[a] This provenance is from a population that is considered to be an intergrade between *E. saligna* and *E. botryoides.*

In 1998, this trial encountered a severe drought lasting approximately 5 months from June to November (summer–autumn). Then, the following year in December, this trial experienced severe cold with temperatures in the area falling rapidly to –7.0°C. When the trial was approximately 6 years old in August 2002, the remaining trees were assessed for diameter at breast height and total height. Results from this trial have been reported by Lin et al. (2003).

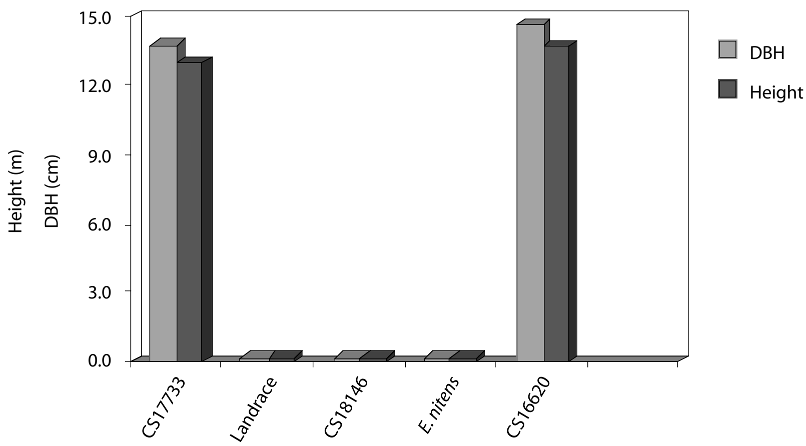

Figure 28. Growth performance, in terms of diameter at breast height over bark (DBH) and height, to age 6 years of species in the 1996 species trial at DaoXian in Hunan (Trial ID—H5).

None of the *E. globulus*, *E. grandis* or *E. nitens* survived to age 6 years. The *E. globulus* and *E. nitens* succumbed to the combination of high summer temperatures and high humidities and possibly the drought in 1998. *E. grandis* was most likely killed in the drought of 1998 and/or the cold of December 1999.

Both *E. dunnii* and *E. saligna* survived the 1998 drought and 1999 cold well with survivals of over 70% to age 6 years. Growth of both species was reasonable, with *E. saligna* ig. *botryoides* (CS16620) performing better than *E. dunnii* (CS17733). Both species had average height increments of over 2.0 m per year and DBH increments over 2.3 cm per year.

Shuangpai County eucalypt species trial (Trial ID—H6)

Location and environment:	
Latitude: 26°33' N	Soil: gravely clay loam (yellow soil)
Longitude: 113°16' E	Mean minimum temperature of coldest month: 4°C
Altitude: 135 m asl	Absolute minimum temperature: –8°C
Mean annual rainfall: 1900 mm	
Trial details:	
Trial type: species	Date planted: May 1996
Number of species: 5	Age at last assessment: 60 months
Number of seedlots: 5	Number of replicates: 3
Initial spacing: 2.0 2.0 m	Plot size: 20-tree-row plots
Experimental design: randomised complete block design	

Seedlots included in the Shuangpai species trial:

Species trial code	Seedlot code	Species	Provenance
1	n.a.	*E. dunnii*	Unknown
2	n.a.	*E. globulus*	Yunnan landrace, China
3	n.a.	*E. grandis*	Unknown
4	n.a.	*E. saligna*	Unknown
5	n.a.	*E. tereticornis*	Unknown

n.a.: not available (records could not be located)

Brief details and results from this trial have been reported by Lin et al. (2003).

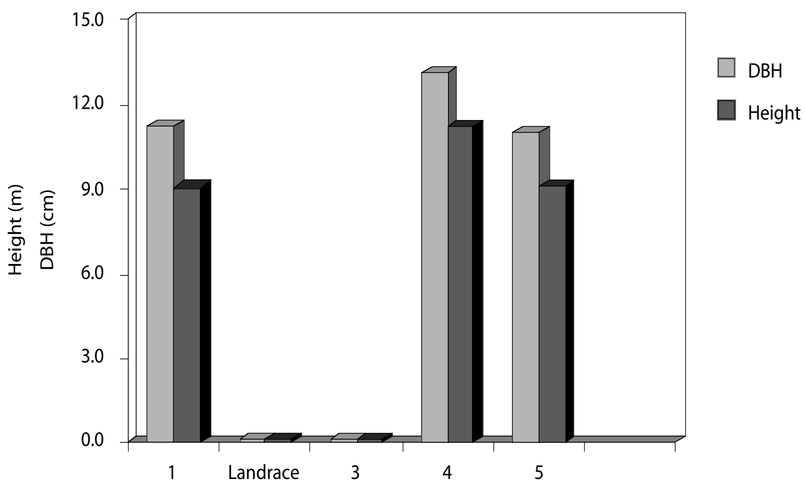

Figure 29. Growth performance, in terms of diameter at breast height over bark (DBH) and height, to age 5 years of species in the 1996 Shuangpai County species trial in Hunan (Trial ID—H6).

At the time of assessment (age 5 years) there were no trees surviving of either *E. globulus* or *E. grandis*. Results from this trial as well as other plantings in the area have indicated that *E. globulus* is not adapted to the combination of high summer temperatures and high humidities that are a feature of the climate in this part of Hunan. All the *E. grandis* is thought to have been killed in the cold of December 1999 and/or succumbed to late summer/autumn drought.

The other three species, *E. saligna, E. dunnii* and *E. tereticornis,* had survivals to age 5 years of over 80% and have proved reasonably well adapted to the local environment. *E. saligna* showed the best growth overall whilst average height and diameter for *E. dunnii* and *E. tereticornis* were about 20% less.

Fujian Province

Environment

Fujian is on the southeastern coast of China. It is bordered by the provinces of Zhejiang to the north, Jiangxi to the west, Guangdong to the southwest, the East China Sea to northeast and the Taiwan Strait to the east (see Figure 2). About 95% of Fujian is dominated by several mountain ranges of moderate elevation that run roughly parallel to the coast. The Wu-i Mountains along the province's western border, which form a natural barrier between Fujian and the interior of China, reach heights of up to 1800 metres. The general topography of Fujian slopes from the higher elevations in northwest to a small area of coastal plains in the east and south-east. At higher elevations in the mountains, well-developed grey-brown forest soils are predominant, whereas mature red soils are common at lower elevations and in the lower hill areas (Britannica Online 2003d; Zhao 1986).

Fujian lies just north of the Tropic of Cancer. The province's coastal areas have a subtropical climate with hot humid summers and mild winters. In contrast, mountainous areas in the interior and to the northwest have a more temperate climate and can become cold in winter (Britannica Online 2003d). The mean temperatures in the provincial capital, Fuzhou which is located on the coast, are about 29°C in July and about 11°C in January. Rainfall increases from the coast to the western mountains and averages 1270–2030 mm a year, most of which occurs in summer. Winters are drier.

Eucalypt domestication in Fujian

Fujian is one of the leading timber-producing provinces of southern China and has forest coverage over more than 60% of its land area (Lan et al. 2003). However, the total area of eucalypt plantations in Fujian as at the end of 2001 was less than 15,000 ha (Chen 2002)—the province's forest plantations are predominantly Chinese fir and Masson pine. It is only over the last 10 years or so that there has been significant interest in the establishment in Fujian of eucalypts as high-yielding plantation species.

More than 260 eucalypt species have reputedly been introduced to Fujian since the first were planted there in about 1894 (Lan et al. 2003). In the coastal areas of Fujian the climate is quite mild and many of the more tropical eucalypts including

E. urophylla and *E. urophylla* × *grandis* hybrids have proved well adapted and are now being planted on a larger scale. However, away from the coast where the terrain is quite mountainous, the climate is much cooler with frequent winter frosts, particularly in the northwest of the province. Since the 1980s more than 30 species of cold-tolerant eucalypts have been included in formal trials in these cooler regions of the province.

Trials of cold-tolerant eucalypts in Fujian

Weimin species trial (Trial ID—F1)

Location and environment:	
Latitude: 27°03' N	Soil: red soil, light clay
Longitude: 117°40' E	Mean minimum temperature of coldest month: 3°C
Altitude: 196 m asl	Absolute minimum temperature: –8°C
Mean annual rainfall: 1770 mm	
Trial details:	
Trial type: species	Date planted: May 1998
Number of species: 10	Age at last assessment: 31 months
Number of seedlots: 10	Number of replicates: 4
Initial spacing: 3.0 × 2.0	Plot size: 25 trees
Experimental design: randomised complete block design	

Seedlots included in the Weimin species trial:

Seedlot code	Species	Provenance
CS19555	*E. badjensis*	Glenbog, NSW
CS18788	*E. benthamii*	Kedumba Valley, NSW
CS19668	*E. dorrigoensis*	Paddys Land SF, NSW
CS17916	*E. dunnii*	Koreelah SF, NSW
CS19564	*Corymbia citriodora* ssp. *variegata*	Paddys Land SF, NSW
CS18341	*E. nitens*	Barrington Tops, NSW
CS19467	*E. nobllis*	Forest Land SF, NSW
CS17581	*E. quadrangulata*	Clouds Creek, NSW
CS18365	*E. radiata*	Oberon District, NSW
CS18676	*E. smithii*	Wingello SF, NSW

The trial at Weimin, in the inland northern part of Fujian, suffered serious damage from the cold weather experienced in south central China during December 1999 with temperatures in the area dropping to around –8°C. It was recorded that almost all trees in the trial suffered some damage from this cold and survival decreased sharply (Lan et al. 2003).

At the time of assessment there were no trees surviving of either *E. radiata* (CS18365) or *E. smithii* (CS18676). For the combination of survival and growth, *E. benthamii* (CS18788) and *E. dunnii* (CS17916) performed the best in this trial. The growth of *E. dorrigoensis* (CS19668) was similar to that of the latter but its survival was markedly lower (approximately 18%). *E. nobilis* (CS19467) had the best survival of all the species in the trial but its growth was only mediocre.

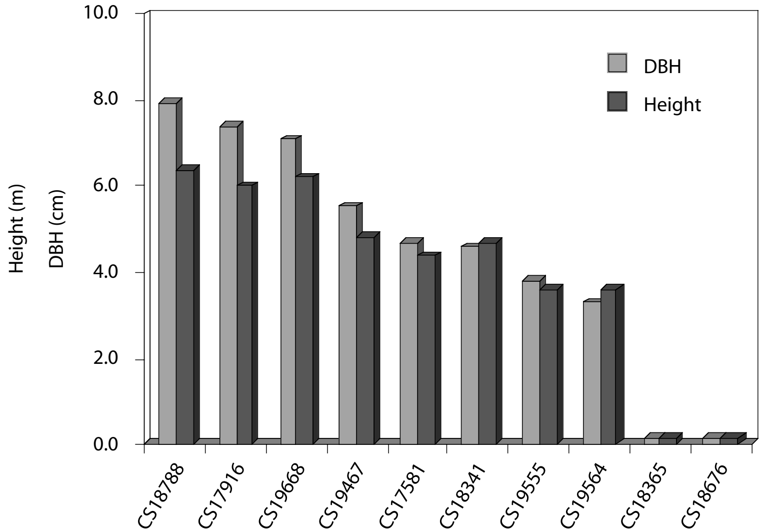

Figure 30. Growth performance, in terms of diameter at breast height over bark (DBH) and height, to age 2.5 years of species–provenances in the 1998 Weimin species trial in Fujian (Trial ID—F1).

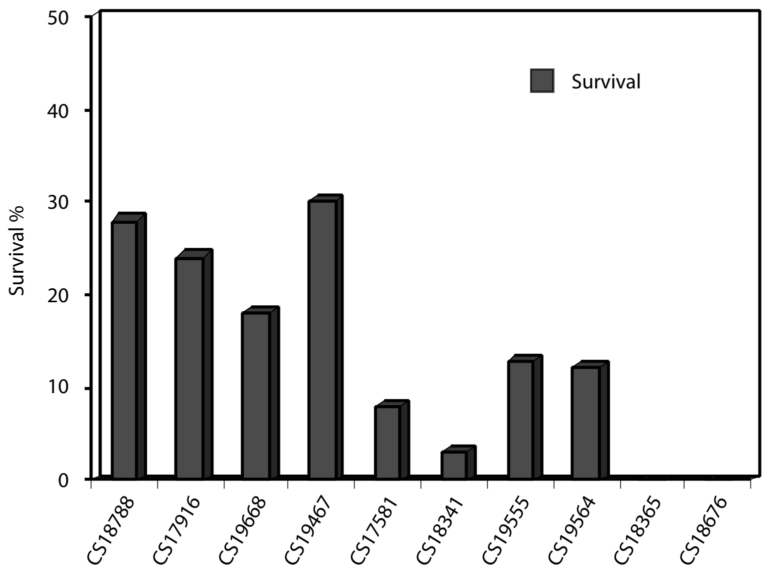

Figure 31. Performance of species–provenances in terms of average survival to age 2.5 years in the 1998 Weimin species trial in Fujian (Trial ID—F1).

Pushang E. dunnii *provenance–family trial (Trial ID—F2)*

Location and environment:	
Latitude: 26°56' N	Soil: red soil, light clay to clay loam
Longitude: 117°46' E	Mean minimum temperature of coldest month: 4°C
Altitude: 290 m asl	Absolute minimum temperature: –10°C
Mean annual rainfall: 1470 mm	
Trial details:	
Trial type: provenance–family	Date planted: May 1998
Number of seedlots: 19	Age at last assessment: 24 months
Number of families: 216	Number of replicates: 8
Initial spacing: 2.0 3.0 m	Plot size: 4 trees
Experimental design: randomised complete block design	

Seedlots included in the Pushang E. dunnii *trial:*

Provenance trial code	Seedlot codes	Species	Provenance	No. of families
1	CS16895, CS17865, CS17911	*E. dunnii*	Spicers Peak SF (western part), Qld	18
2	CS15967, CS17914	*E. dunnii*	Teviot Brook, Qld	24
3	CS17915	*E. dunnii*	Koreelah SF (lower elevation), NSW	5
4	CS17920	*E. dunnii*	Koreelah SF (higher elevation), NSW	19
5	CS17909, CS18263, CS18264	*E. dunnii*	Yabbra SF, Urbenville (higher elevation), NSW	62
6	CS17555, CS17922	*E. dunnii*	Moleton—Kangaroo SF, NSW	51
7	CS17733, CS17918	*E. dunnii*	Spicers Peak SF (eastern part), Qld	17
8	CS17800	*E. dunnii*	Moleton, NSW	16
9	CS17913	*E. dunnii*	Yabbra SF, Urbenville (lower elevation), NSW	1
10	CS17921	*E. dunnii*	Richmond Range SF, NSW	1
11	FUJN01	*E. nitens*	Unknown	1

In the cold event of December 1999 temperatures in the Pushang area reputedly stayed below 0°C continuously for 8 days with an absolute minimum of about –10°C (the coldest for 100 years). Although less than 10% of the *E. dunnii* in the trial were killed, most trees suffered varying degrees of crown dieback but soon re-sprouted. An assessment of height and cold damage was carried out approximately 6 months later. There was no apparent differentiation between provenances for cold damage. Mean heights by provenance are shown in Figure 33.

The best provenance for early growth in this trial proved to be Yabbra State Forest near Urbenville, NSW (Trial code 9). However at assessment the trees were still relatively young and differences between the mean heights of all provenances were small. Thus no single provenance or provenances could be discounted on the basis of the results from this trial. The *E. nitens* included in the trial for comparative purposes proved inferior in height growth to all of the *E. dunnii* provenances. However, as the provenance origin of the *E. nitens* is unknown and there is known to be substantial variation in this species, this result may not indicate its true potential in the Pushang environment.

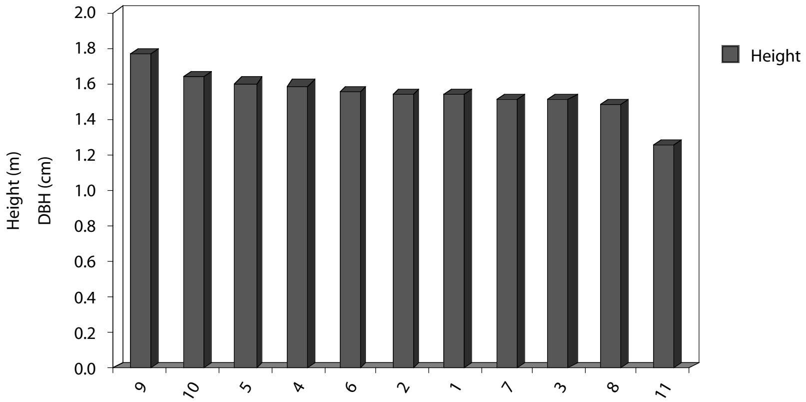

Figure 32. Growth performance, in terms of height, to age 2 years of provenances in the 1998 *E. dunnii* provenance–family trial at Pushang in Fujian (Trial ID—F2).

Shi Bi E. grandis *provenance–family trial (Trial ID—F3)*

Location and environment:	
Latitude: 25°59'N	Soil: red soil, clay loam
Longitude: 117°19'E	Mean minimum temperature of coldest month: 5°C
Altitude: 215 m asl	Absolute minimum temperature: –8°C
Mean annual rainfall: 1570 mm	
Trial details:	
Trial type: provenance–family	Date planted: May 1997
Number of seedlots: 8	Age at last assessment: 24 months
Number of families: 101	Number of replicates: 8
Initial spacing: 2.0 3.0 m	Plot size: 4 tree row plots
Experimental design: balanced incomplete block design	

Seedlots included in the Shi Bi E. grandis *trial:*

Seedlot code	Species	Provenance	No. of families in trial
CS18274	*E. grandis*	Bagawa SF, NSW	4
CS18590	*E. grandis*	SSW Atherton, Qld	10
CS18591	*E. grandis*	Mt Spec near Paluma, Qld	33
CS18592	*E. grandis*	10 km S Ravenshoe, Qld	10
CS18593	*E. grandis*	Mt Lewis, Julatten, Qld	11
CS18594	*E. grandis*	Tinaroo Ck Rd, Qld	18

Seedlot code	Species	Provenance	No. of families in trial
CS18595	*E. grandis*	East of Wondecla, Qld	15
GURG01	*E. urophylla grandis*	Hybrid clone from Guangxi	1 clone

The provenances from 10 km S of Ravenshoe (CS18592) and East of Wondecla (CS18595) had superior growth to the other provenances included in this trial to age 2 years. It is of interest that these two provenances were both from more elevated parts of the *E. grandis* natural range in north Queensland. Most of the other provenances were generally similar to each other for average growth. However, the growth of the hybrid clone (GURG01) was markedly inferior to all the *E. grandis* provenances.

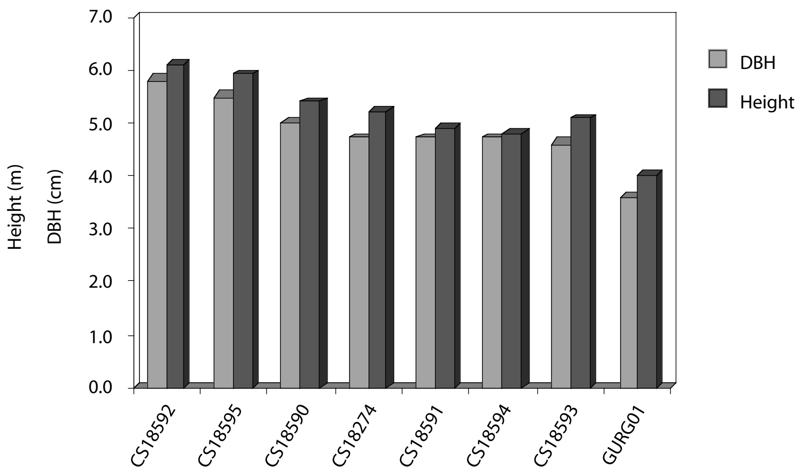

Figure 33. Growth performance, in terms of diameter at breast height over bark (DBH) and height, to age 2 years of provenances in the 1997 *E. grandis* provenance–family trial at Shi Bi in Fujian (Trial ID—F3).

Yongan species trial (Trial ID—F4)

Location and environment:	
Latitude: 25° 56'	Soil: red soil, loam to clay loam
Longitude: 117° 24' E	Mean minimum temperature of coldest month: 8.6°C
Altitude: 270 m asl	Absolute minimum temperature: –8°C
Mean annual rainfall: 1570 mm	
Trial details:	
Trial type: species	Date planted: March 1994
Number of species: 11	Age at last assessment: 60 months
Number of seedlots: 12	Number of replicates: 8
Initial spacing: 2.0 x 3.0 m	Plot size: 18 trees
Experimental design: randomised complete block design	

Seedlots included in this trial:

Species trial code	Seedlot codes	Species	Provenance
1	n.a.	*E. grandis*	Unknown
2	n.a.	*E. grandis*	Unknown
3	n.a.	*E. grandis urophylla*	Hybrid clone from Guangxi
4	n.a.	*E. saligna*	Unknown
5	n.a.	*E. urophylla*	Unknown
6	n.a.	*E. propinqua*	Unknown
7	n.a.	*E. pilularis*	Unknown
8	n.a.	*E. maidenii*	Unknown
9	n.a.	*E. triflora*	Unknown
10	n.a.	*E. camaldulensis*	Unknown
11	n.a.	*E. globulus*	Unknown
12	n.a.	*E. nitens*	Unknown

n.a.: not available (records could not be located).

Details of this trial and the results presented here came from a report published by Lan et al. (2003). Unfortunately, the last assessment of this trial took place before the cold and frosts that occurred in December 1999.

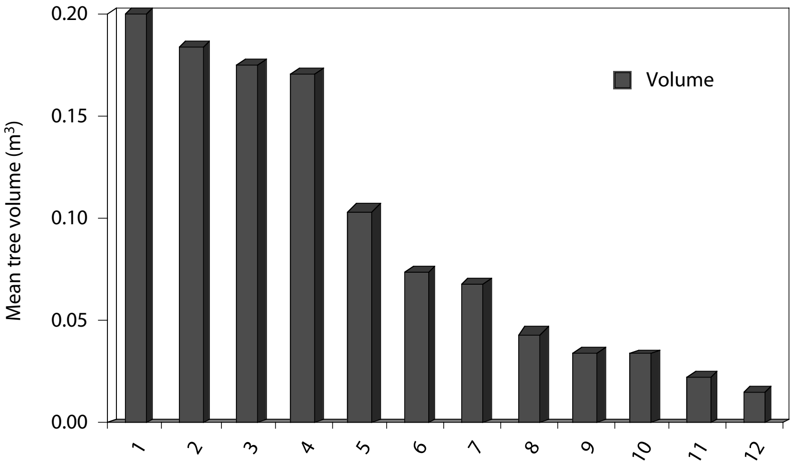

Figure 34. Growth performance, in terms of mean volume per tree, to age 5 years of species–provenances in the 1994 Yongan species trial in Fujian (Trial ID—F4).

For the combination of survival and growth at Yongan, the best species were *E. grandis* and *E. saligna*. Although the clone of the hybrid *E. grandis* x *urophylla* also grew well here, its survival was unacceptably low (approximately 50%) and may have been much lower had the trial encountered one of the periodic cold spells (such as that of December 1999) prior to the assessment. *E. maidenii*, which is favoured for its growth and cold tolerance on the Yunnan plateau, showed good survival here but its growth was relatively poor, as was that of *E. camaldulensis*, *E. globulus*, *E. nitens*

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and *E. pilularis*. Unfortunately, the provenance origins of these species are uncertain as the records have been misplaced.

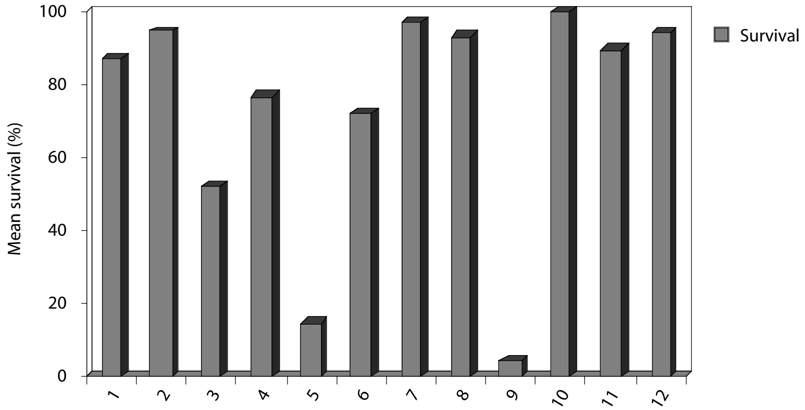

Figure 35. Mean survivals to age 5 years of the species–provenances in the 1994 Yongan species trial in Fujian (Trial ID—F4).

Yongan E. grandis *provenance–family trial (Trial ID—F5)*

Location and environment:	
Latitude: 25°59' N	Soil: red soil, silty clay loam
Longitude: 117°19' E	Mean minimum temperature of coldest month: 5°C
Altitude: 225 m asl	Absolute minimum temperature: –8°C
Mean annual rainfall: 1570 mm	
Trial details:	
Trial type: provenance–family	Date planted: May 1997
Number of seedlots: 7	Age at last assessment: 72 months
Number of familes: 202	Number of replicates: 8
Initial spacing: 2.0 3.0 m	Plot size: 4-tree-row plots
Experimental design: balanced incomplete block design	

Seedlots included in the 1997 Yongan provenance–family trial:

Seedlot code	Species	Provenance	No. of families in the trial
CS17562	*E. grandis*	30 km SW Cairns, Qld	10
CS17709	*E. grandis*	Windsor Tableland, Qld	16
CS17713	*E. grandis*	Piccaninny Ck, Qld	37
CS17857	*E. grandis*	10 km S Ravenshoe, Qld	10
CS18180	*E. grandis*	Baldy State Forest, Qld	12
CS18274	*E. grandis*	Bagawa SF, Qld	17
CS18569	*E. grandis*	Wongabel SF, Qld	10
GURG01	*E. urophylla grandis*	Hybrid clone, Guangxi	1 clone

Some results from this trial have been reported by Qiu et al. (2002) and Lan et al. (2003).

The *E. grandis* provenance from 10 km south of Ravenshoe (CS17857) had markedly better growth than most of the other provenances and, along with the provenance from SW of Cairns (CS17562), was superior to the hybrid clone (GURG01). Within most of the *E. grandis* provenances there were selected individual families that also outperformed the hybrid clone (data not shown). These results indicate that *E. grandis* selected for growth in a cooler environment such as that of Yongan, Fujian, can be markedly more productive than hybrid clones selected for a widely different plantation environment (such as that in southern Guangxi where the clone originated).

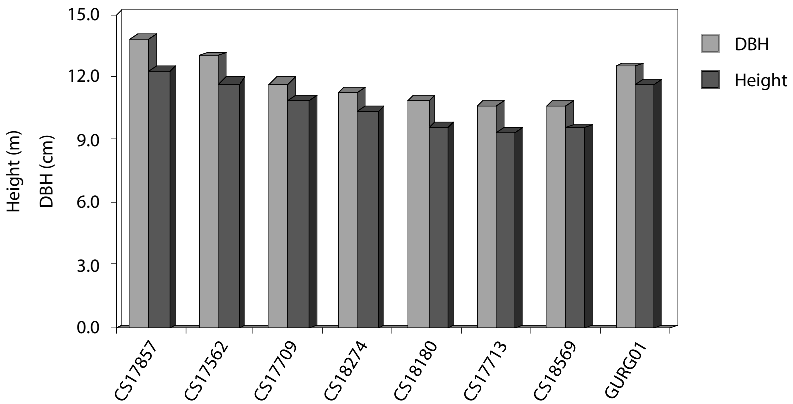

Figure 36. Growth performance, in terms of diameter at breast height over bark (DBH) and height, to age 6 years of provenances in the 1997 Yongan *E. grandis* provenance–family trial located at Yongan Forest Farm in Fujian (Trial ID—F5).

Sichuan Province

Environment

Sichuan is bordered by the provinces of Yunnan and Guizhou to the south, Chongqing to the east, Shaanxi, Gansu and Qinghai to north and Tibet Autonomous Region to the west (see Figure 2). Physically, it is surrounded by mountains—the Tsinling Mountains to the north with elevations of up to 4000 metres, Ta-pa Mountains to the northeast rising up to approximately 3000 metres, the somewhat lower Ta-lou Mountains to the south with average elevations of up to 1500–2100 metres; the Ta-hsüeh Mountains to the west along the border with Tibet which reach up to over 4000 metres in elevation and, to the east the rugged Wu Mountains with elevations of up to 2000 metres (Britannica Online 2003e). It is in the Wu Mountains that the spectacular Yangtze Gorges are located, containing the lake created by the Three Gorges Dam.

Whilst the western part of Sichuan is quite mountainous the eastern region comprises an extensive basin (the 'Sichuan Basin'). In general terms, the land in

Sichuan slopes from all directions toward the centre of the basin. The eastern basin area and some lower valleys along its western periphery are sheltered from cold polar air masses by the surrounding mountains, thus the basin's climate is markedly milder than most regions in China that lie to its east at around the same latitude (Zhao 1986). It is worth noting that there are more than 300 frost-free days in the eastern basin, and the growing season lasts nearly all year round.

Eucalypt domestication in Sichuan

Reports indicate that more than 100 eucalypt species have been included in various plantings in Sichuan Basin since 1900 (Li and Hu 2003). From the 40 species shown to be adapted there, those with the greatest commercial potential to date are *E. camaldulensis*, *E. maidenii* and *E. grandis*. There are now estimated to be more than 20,000 ha of short-rotation plantations of *E. grandis* and *E. maidenii* established in Sichuan (Chen 2002; Li and Hu 2003). These plantations are the most northerly commercial eucalypt plantations in China, due to the mild climate and unique environment of the Sichuan Basin.

Trials of cold-tolerant eucalypts in Sichuan

Fushun E. grandis *provenance trial (Trial ID—S1)*

Location and environment:	
Latitude: 29°33' N	Soil: silty clay loam
Longitude: 105°04' E	Mean minimum temperature of coldest month: 5°C
Altitude: 450 m asl	Absolute minimum temperature: –3°C
Mean annual rainfall: 1040 mm	
Trial details:	
Trial type: provenance	Date planted: October 1991
Number of seedlots: 14[a]	Age at last assessment: 48 months
	Number of replicates: 5
Initial spacing: 2.0 3.0 m	Plot size: 25 trees (5 rows x 5 trees)
Experimental design: randomised complete block design	

[a] One of the seedlots included in the trial was of *E. robusta*.

Seedlots included in the Fushun E. grandis *trial:*

Provenance–Seedlot code	Species	Provenance
86	*E. grandis*	Mount Lewis, Qld
CS13019	*E. grandis*	NW of Coffs Harbour, NSW
CS14393	*E. grandis*	25–36 km SE of Mareeba, Qld
CS14431	*E. grandis*	Bellthorpe SF, Qld
CS14838	*E. grandis*	WNW of Cardwell, Qld
CS15219	*E. grandis*	NE of Maleny, Qld
CS15875	*E. grandis*	Baron Pocket Maleny, Qld
CS16583	*E. grandis*	Atherton, Qld

Provenance–Seedlot code	Species	Provenance
CS17562	*E. grandis*	30 km SW of Cairns, Qld
CS17709	*E. grandis*	Windsor Tableland, Qld
CS18146	*E. grandis*	Coffs Harbour seed orchard, NSW
Brazil 01	*E. grandis*	Selected seedlot from Brazil Forest Research Institute
Brazil 02	*E. grandis*	Selected seedlot from Brazil Forest Research Institute
ROB1	*E. robusta*	landrace—collected from trees in Sichuan

Details of this trial and the results presented here have been obtained from a report published by Hu et al. (2000).

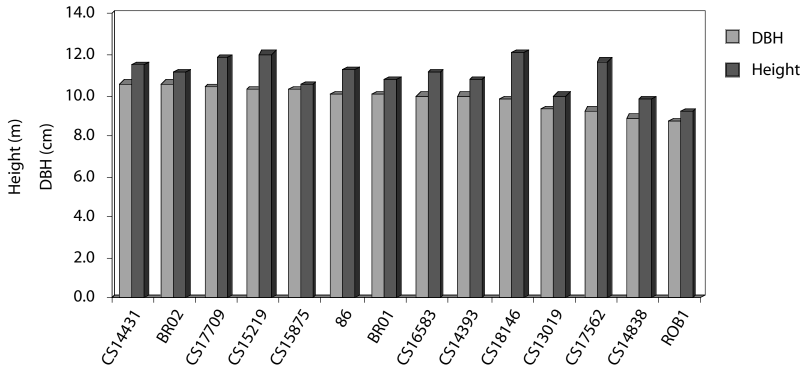

Figure 37. Growth performance, in terms of diameter at breast height over bark (DBH) and height, to age 4 years of provenances in the 1991 *E. grandis* provenance trial at Fushun County in Sichuan (Trial ID—S1).

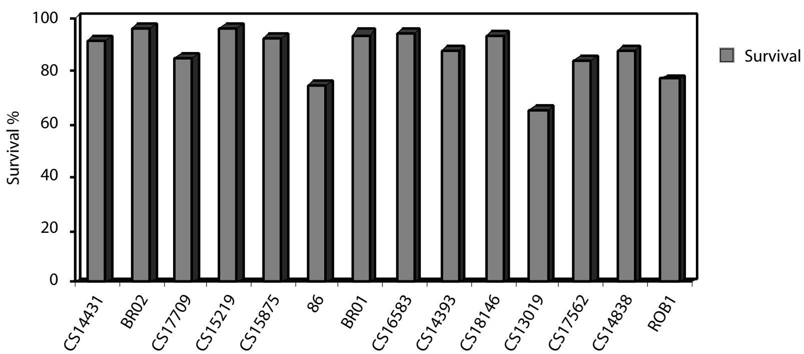

Figure 38. Provenance mean survivals to age 4 years in the 1991 *E. grandis* provenance trial at Fushun County in Sichuan (Trial ID—S1).

The best provenances for growth in this trial were CS14431, Brazil02, CS17709 and CS15219. That from the Coffs Harbour seed orchard in Australia (CS18146) showed very good height growth but only mediocre DBH. All five of these preceding provenances had good survivals (>80%). However, it is noteworthy that growth of the best natural provenances (from Australia) were just as good if not better than that of the improved seedlots imported from Brazil and Australia (i.e. Brazil01, Brazil02 and CS18146). The local landrace of *E. robusta* (ROB1) had the poorest growth in the trial and the third lowest survival rate.

Pingxing E. grandis *provenance–family trial (Trial ID—S2)*

Location and environment:	
Latitude: 29°34' N	Soil: silty clay loam
Longitude: 103°43' E	Mean minimum temperature of coldest month: 4°C
Altitude: 450 m asl	Absolute minimum temperature: –4°C
Mean annual rainfall: 1400 mm	
Trial details:	
Trial type: provenance–family	Date planted: September 1995
Number of seedlots: 27	Age at last assessment: 42 months
Number of families: 171	Number of replicates: 8
Initial spacing: 2.0 3.0 m	Plot size: 4-tree-row plots
Experimental design: randomised incomplete block design	

Seedlots included in the Pingxing E. grandis *trial:*

Provenance–Seed-lot code	Species	Provenance	Number of families included in trial
CS16892	*E. grandis*	Kin Kin, Qld	7
CS17562	*E. grandis*	30 km SW of Cairns, Qld	5
CS17563	*E. grandis*	45 km SSW of Cairns, Qld	5
CS17709	*E. grandis*	Windsor Tableland, Qld	6
CS17713	*E. grandis*	Piccaninny Creek, Qld	22
CS17857	*E. grandis*	10 km Sth. of Ravenshoe, Qld	5
CS18180	*E. grandis*	Baldy SF, Qld	4
CS18181	*E. grandis*	Coperlode Dam, Qld	4
CS18273	*E. grandis*	Wedding Bells SF, NSW	5
CS18274	*E. grandis*	Bagawa SF, NSW	4
CS18277	*E. grandis*	Bellthorpe, Qld	7
CS18569	*E. grandis*	Wongabel SF, Qld	4
CS18590	*E. grandis*	SSW of Atherton, Qld	5
CS18591	*E. grandis*	Mt Spec near Paluma, Qld	15
CS18592	*E. grandis*	10 km Sth. of Ravenshoe, Qld	4
CS18593	*E. grandis*	Mt Lewis Julatten, Qld	5
CS18594	*E. grandis*	Tinaroo Creek Rd, Qld	9
CS18595	*E. grandis*	East of Wondecla, Qld	8
CS18693	*E. grandis*	Como, Qld	4

Provenance–Seed-lot code	Species	Provenance	Number of families included in trial
CS18696	*E. grandis*	Belli, Qld	4
CS18697	*E. grandis*	Yabba, Qld	4
CS18698	*E. grandis*	Mapleton, Qld	5
CS18699	*E. grandis*	Borumba Range, Qld	4
CS18700	*E. grandis*	Connondale, Qld	9
CS18702	*E. grandis*	Bellthorpe, Qld	5
CS18703	*E. grandis*	Mt Mee, Qld	6
CS18705	*E. grandis*	Mt Lindsay, Qld	6

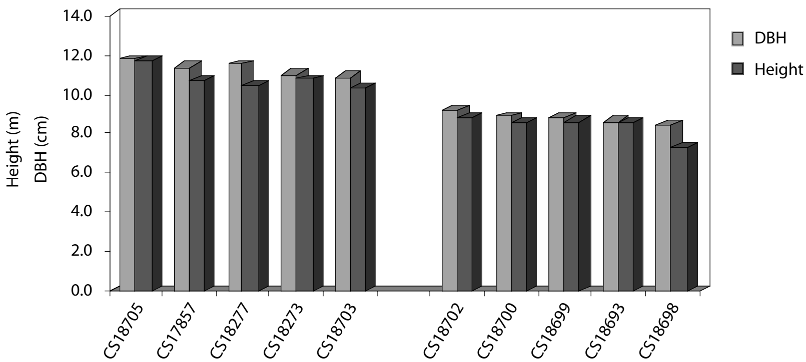

Figure 39. Growth performance, in terms of diameter at breast height over bark (DBH) and height, of the top five and the bottom five provenances by growth to age 3.5 years in the 1995 *E. grandis* provenance–family trial at Pingxing Forest Farm in Sichuan (Trial ID—S2).

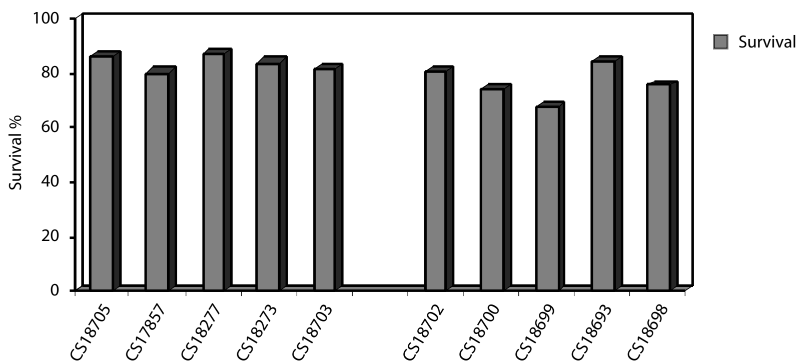

Figure 40. Provenance mean survivals of the top five and the bottom five provenances by growth to age 3.5 years in the 1995 *E. grandis* provenance–family trial at Pingxing Forest Farm in Sichuan (Trial ID—S2).

Details of this trial located at Pingxing Forest Farm near Leshan City in Sichuan province have been obtained from a report published by Hu et al. (2000).

The best five provenances for growth in this trial were from scattered locations in disparate parts of the *E. grandis* natural distribution in Australia, ranging from 30°10’S, Wedding Bells State Forest (CS18273) near Coffs Harbour NSW, up to 17°42’S, 10 km south of Ravenshoe in Queensland (CS17857). In contrast, the five provenances with the poorest growth in the trial were all from one part of the species natural range, from latitudes 26°29’ to 26°52’ S. While all of the best five provenances for growth also showed good survival (>80%), many of the poorer provenances had somewhat lower survivals (<80%).

The other provinces—Guizhou and Jiangxi

Environment

Two other south central provenances which contain areas potentially well suited for development of plantations of selected cold-tolerant eucalypts, based on species–site climatic matching, are Jiangxi and Guizhou (see Yan et al. 1995; Yan 2001b). Jiangxi is somewhat similar in topography and climate to Hunan and lies to its eastern border (Zhao 1986). To the north it is bounded by the provinces of Hubei and Anhui, to the east by Zhejiang and Fujian, and to the south by Guangdong (see Figure 2). Like Hunan, Jiangxi comprises a basin that is bordered by uplands to the west, south and east, though it is somewhat less open to the north than Hunan. Along its northeast border are the Huai-yü Mountains and the Mu-fu and Lu ranges to its northwest (Britannica Online 2003f).

Guizhou is one of China's poorest and most disadvantaged provinces. It is bounded on the north by Sichuan, on the east by Hunan, on the south by Guangxi, and on the west by Yunnan (see Figure 2). The province is part of an old eroded plateau with its altitude increasing from about 700 metres in east to about 2000 metres in the west (Zhao 1986). Complicated and extensive folding, faulting, and stream erosion of this plateau have created abrupt relief with numerous incised valleys, steep gorges and cliffs. In the limestone areas the landscape is karstic (characterised by precipitous slopes, abrupt, protuberant mountains, caverns, and subterranean streams) (Britannica Online 2003g). The province's rugged topography generally makes transport and communication somewhat more challenging than in the provinces that adjoin it, and this has inhibited development.

Eucalypt domestication in Guizhou and Jiangxi

There are numerous examples of ‘four around’ eucalypt plantings (i.e. trees planted as shelterbelts along roads and near irrigation channels, villages and individual houses) in both Guizhou and Jiangxi, and the main species surviving today are *E. camaldulensis*, *E. globulus*, *E. maidenii* and *E. robusta*. However, little work has been done to date in these provinces on the introduction, testing and further domestication of suitable plantation eucalypt species—few species trials or species–provenance trials involving eucalypts have been reported from either province. The total eucalypt plantation area in each of these two provinces is estimated to be less than 5000 ha (Chen 2002).

One eucalypt species–provenance trial that has been reported from these provinces is located near the city of Ganzhou (see below) in southern Jiangxi province. It confirms potential for selected eucalypt species in that province.

Ganzhou species–provenance trial (Trial ID—GJ1)

Location and environment:	
Latitude: 25°20' N	Soil: silty clay loam
Longitude: 114°40' E	Mean minimum temperature of coldest month: 5°C
Altitude: 95 m asl	Absolute minimum temperature: –6°C
Mean annual rainfall: 1445 mm	
Trial details:	
Trial type: species–provenance	Date planted: May 1992
Number of species: 6	Age at last assessment: 72 months
Number of seedlots: 16	Number of replicates: 4
Initial spacing: 2.0 3.0 m	Plot size: 64 tree plots
Experimental design: randomised complete block design	

Seedlots included in the Ganzhou species–provenance trial:

Seedlot code	Species	Provenance
CS15029	*E. camaldulensis*	Lake Albacutya—Nth side, Vic.
CS15272	*E. camaldulensis*	Silverton, NSW
CS17017	*E. camaldulensis*	Tullamarine Airport, Vic.
Local	*E. camaldulensis*	Landrace—collected from trees in Jiangxi
CS17555	*E. dunnii*	Moleton—Kangaroo SF, NSW
CS17733	*E. dunnii*	Spicers Gap, Qld
CS17562	*E. grandis*	30 km SW Cairns, Qld
CS17709	*E. grandis*	Windsor Tableland, Qld
CS18146	*E. grandis*	Coffs Harbour seed orchard, NSW
CS18162	*E. saligna*	Bellthorpe SF, Qld
CS16620	*E. saligna* ig. *botryoides*[a]	Yadboro SF, NSW
CS13319	*E. tereticornis*	N of Woolgoolga, NSW
CS16927	*E. tereticornis*	50 km SSE Moura, NSW
CS17430	*E. tereticornis*	Loch Sport, Vic.
CS17761	*E. tereticornis*	Spacers Gap SF, Qld
CS18112	*E. viminalis*	Tambo River via Swifts Ck, Vic.

[a] This provenance is from a population that is considered to be an intergrade between *E. saligna* and *E. botryoides.*

Details of this trial have been obtained from a report published by Chen et al. (1999). From the time this trial was established in 1992 up to the assessment in 1998 there was no untoward cold weather in the region. Notable cold events that tested the cold tolerance and adaptability of eucalypts in south central China occurred in winter 1991 and December 1999. Nonetheless, this trial is considered indicative of the potential of eucalypt species and provenances in southern Jiangxi.

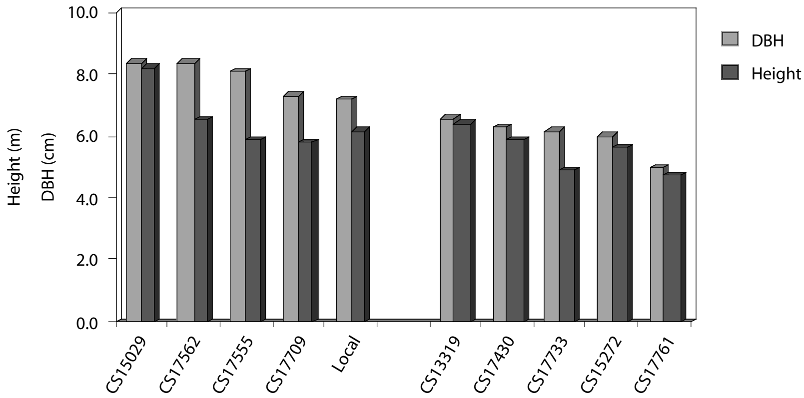

Figure 41. Growth performance, in terms of diameter at breast height over bark (DBH) and height, of the best five and the poorest five species–provenances, in terms of DBH, in the 1992 Ganzhou species–provenance trial in Jiangxi (Trial ID—GJ1).

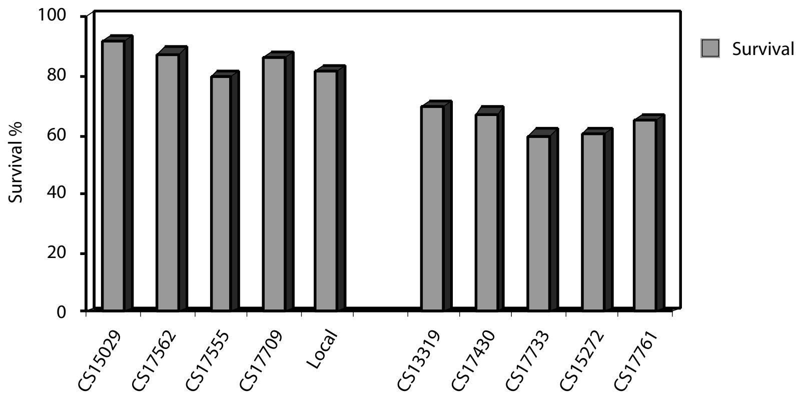

Figure 42. Mean survival to age 6 years of the best five and the poorest five species–provenances by DBH in the 1992 Ganzhou species–provenance trial in Jiangxi (Trial ID—GJ1).

For the combination of growth and survival, *E. camaldulensis* (CS15029), *E. grandis* (CS17562) and *E. dunnii* (CS17555) all performed well at Ganzhou. The local landrace of *E. camaldulensis* (CS17430) and the high elevation northern most source of *E. grandis* (CS17709) were also above average for the combination of growth and survival. The poorest species–provenances for growth and survival at this site were the Silverton provenance of *E. camaldulensis* (CS15272) and the *E. dunnii* and *E. tereticornis* sourced from Spicer's Gap (CS17733 and CS17761 respectively). However, it must be noted that the Ganzhou site is of relatively poor quality, as height increments of even the best species–provenances have averaged less than 1.5 m per year.

3. General Trends in Growth and Productivity of Selected Species

In order to examine the average growth and productivity of the better performing species across sites, data drawn from across the trials are presented graphically below by individual species. This information is presented as height and DBH against age. From each trial that data have been drawn for these analyses, the result used for the species of interest is that of its best provenance in that trial (by growth).

Given that two markedly distinct environments can be distinguished across the area where the trials are located—higher elevation (>1500 m asl) drier sites; and, lower elevation sites (<900 m asl)—these analyses of average growth are presented separately for each of these environments. The higher elevation drier sites are all located on the Yunnan Plateau, while the lower elevation sites include all trials in the other provinces. The categorisation of the trials according to these two distinct environments/site types is discussed further in Section 4.

The fitted lines on the graphs presented for each species provide an estimate of the mean productivity across ages of the species, based on the available trial results (in that environment). Given that silvicultural management regimes (including nutritional amendments) and soils have varied considerably between trials sites, such analyses can only provide approximate indications of potential productivities.

Sites on the Yunnan Plateau

E. globulus was well represented in the trials located on the Yunnan Plateau. Across the 10 trials that included this species its growth averaged 1.8 cm per year in DBH and 2.0 m per year in height up to age 13 years.

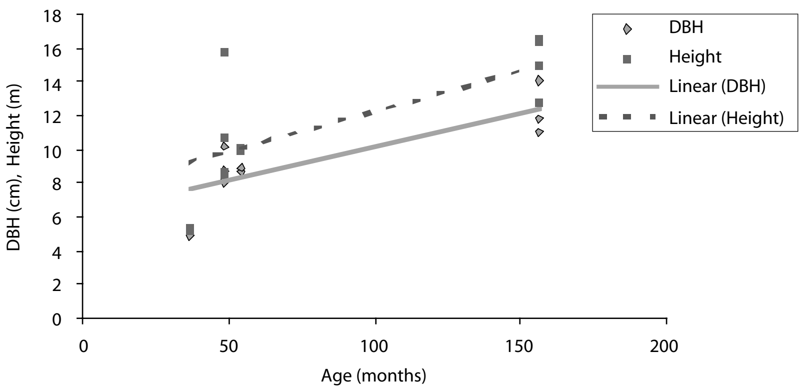

Figure 43. Growth of *E. globulus* across 10 sites on the Yunnan Plateau.

Trials of cold-tolerant eucalypt species in cooler regions of south central China
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E. maidenii was also well represented across the sites in Yunnan, with data available from 10 trials. Some of these trials were the same as for *E. globulus*, some differed. *E. maidenii* averaged 1.9 cm per year in DBH growth and 2.0 m per year in height growth up to age 13 years across the trials, a similar result to *E. globulus*.

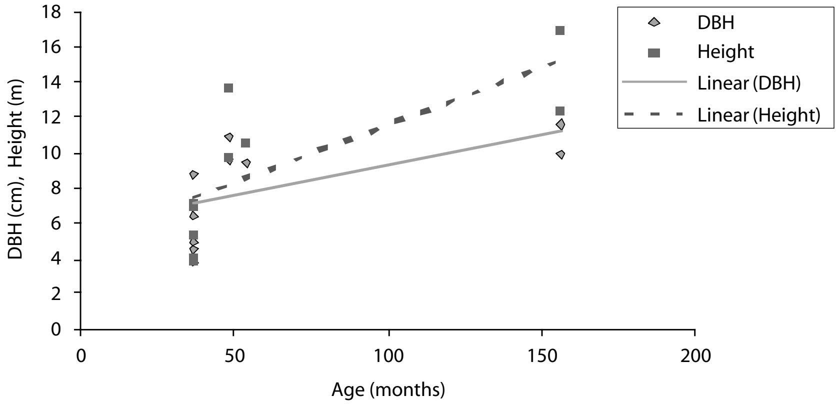

Figure 44. Growth of *E. maidenii* across 10 sites on the Yunnan Plateau.

E. nitens is a species long considered to have potential in Yunnan; it was included in many of the earlier eucalypt trials established in that province. It appeared in 10 of the trials examined here and across these sites it had an average growth of 1.7 cm per year in DBH and 1.8 m per year in height up to age 13 years.

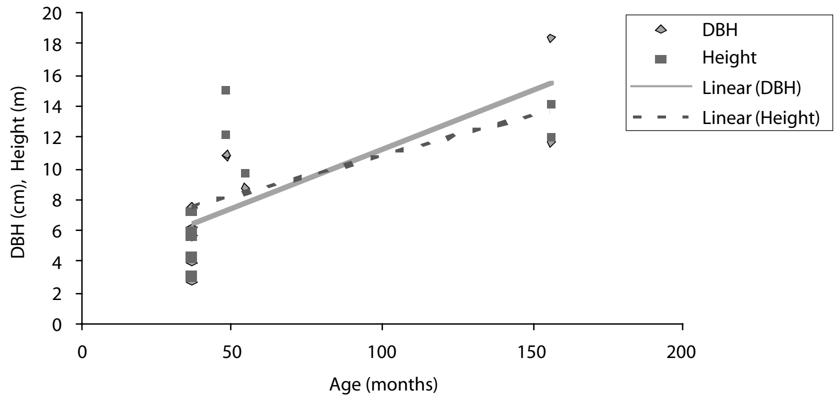

Figure 45. Growth of *E. nitens* across 10 sites on the Yunnan plateau.

E. viminalis appeared in six of the trials on the Yunnan Plateau. Across these sites it had an average growth of 1.6 cm per year in DBH and 1.7 m per year in height.

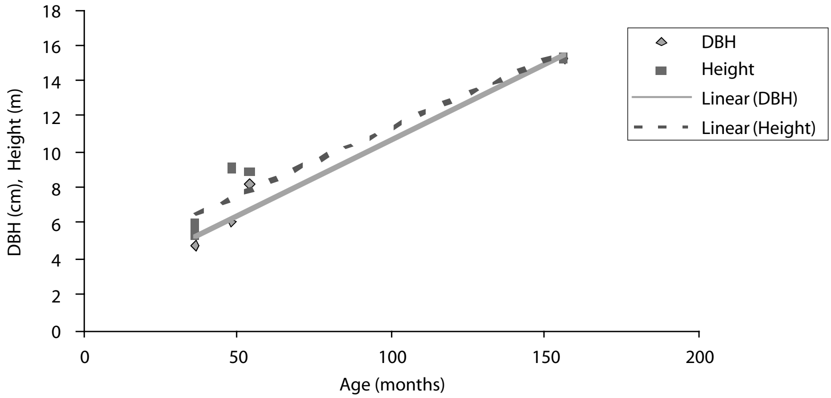

Figure 46. Growth of *E. viminalis* across six sites on the Yunnan Plateau.

E. smithii generally showed very good growth across the trials in which it appeared. It averaged 2.1 cm per year growth in DBH and 2.6 m per year growth in height. However, it was limited to only five trials; results from across more sites (e.g. 10 more) would increase the reliability of the average growth estimates for this very promising species.

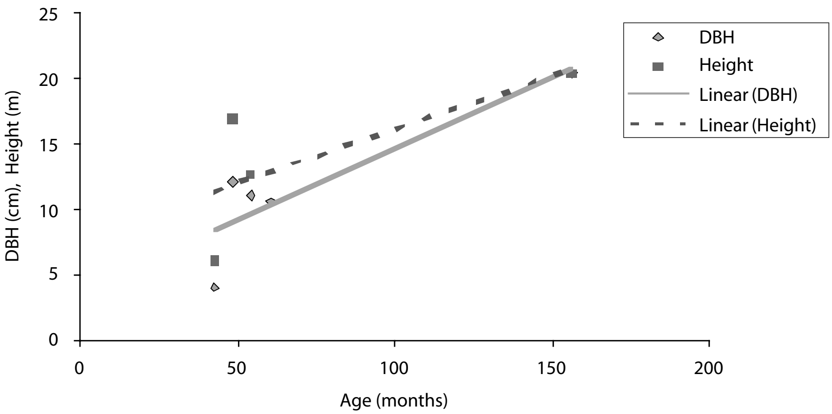

Figure 47. Growth of *E. smithii* across five sites on the Yunnan Plateau.

Lower elevation sites in south central China

Although *E. camaldulensis* is often seen in cooler regions of south central China as a component of 'four around' plantings, there has been a dearth of information about its growth rates and potential productivity in this region. Across the five trials that included this species it generally showed good growth, and it averaged 2.0 cm per year in DBH growth and 2.3 m per year in height growth.

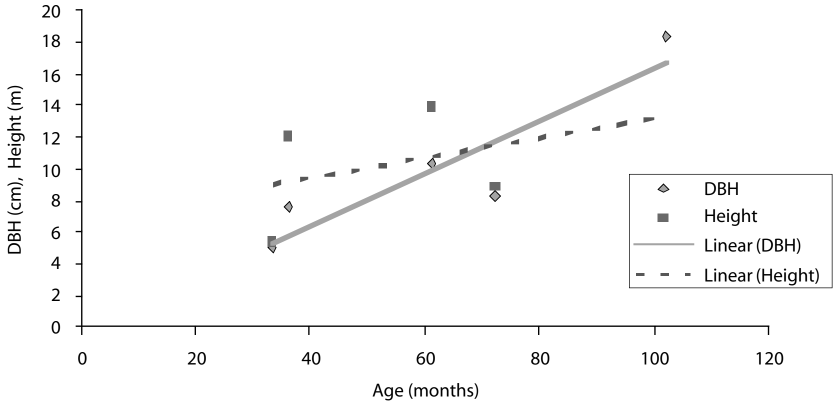

Figure 48. Growth of *E. camaldulensis* across five sites in south central China.

E. dunnii has the best representation across the eucalypt trials examined at lower elevations in cooler parts of south central China. Data were available from 12 trial sites for this species, and across these sites its growth averaged 2.1 cm per year in DBH and 2.1 m per year in height.

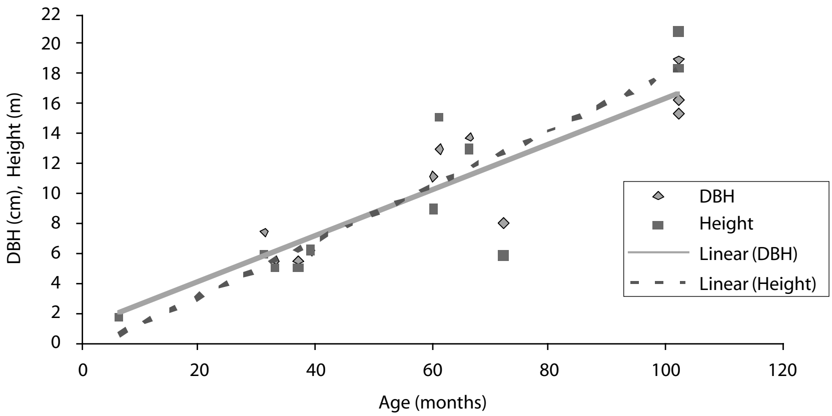

Figure 49. Growth of *E. dunnii* across 12 sites in south central China.

E. grandis has demonstrated very good productivity on milder sites in south central China. Across 10 trial sites, where it proved reasonably well adapted, its growth averaged 2.6 cm per year in DBH and 2.7 m per year in height. However, it is important to note that it failed totally in several trials due to winter cold and/or late summer drought where other species such as *E. dunnii* and *E. saligna* performed relatively well (e.g. the trial at DoaXian in southern Hunan).

E. saligna had reasonable representation across the trials at lower elevations in cooler parts of south central China. Data for this species were available from eight trial sites, and across these sites it averaged 2.0 cm per year in DBH growth and 1.8 m per year in height growth. Its growth seemed unusually slow in one trial (the low outlying points at 72 months in Figure 49), which was the trial at Ganzhou in Jiangxi province

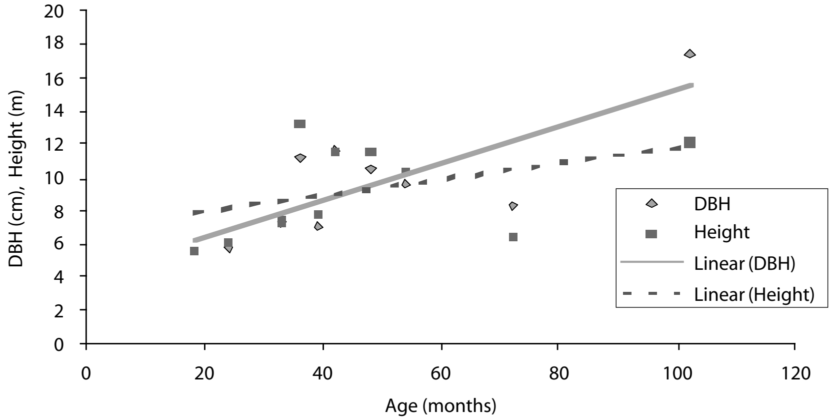

Figure 50. Growth of *E. grandis* across 10 sites in south central China.

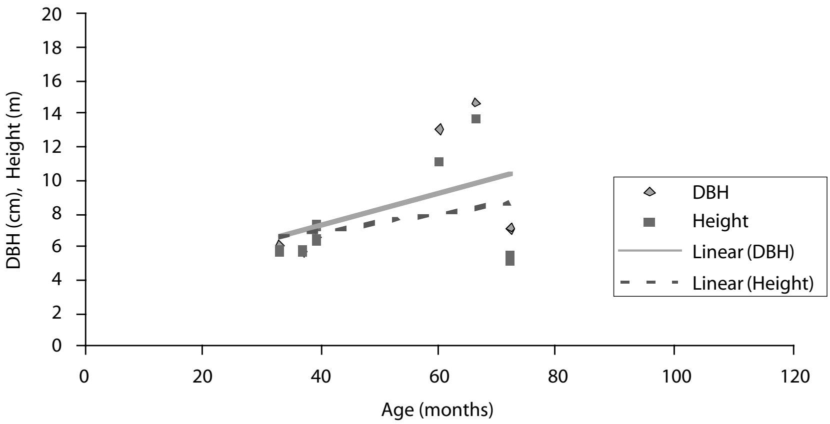

Figure 51. Growth of *E. saligna* across eight sites in south central China (note: the data presented here include the provenances from populations considered to be intergrades between *E. saligna* and *E. botryoides*).

The average growth of *E. tereticornis* across six trial sites was 1.8 cm per year in DBH and 1.9 m per year in height. As this species is known to contain substantial variation between provenances associated with the very large geographic and latitudinal range of its natural distribution (i.e. from around 7^{o} to 37^{o}S), selection and use of superior provenances/seed sources might lift its productivity significantly.

Other factors influencing productivity

Undoubtedly, growth analyses across sites that incorporated environmental factors as well as age would provide a more precise and soundly based estimation of average productivities. In addition, it would be desirable to account for variation between sites in respect to pre-planting site preparation, fertilisation and weed control practices, as these are known to have varied substantially. While incorporating such factors into productivity analyses would be worthwhile, the complexities of doing so are beyond the scope of this current study. It is worth noting, however, that in terms of rainfall many of the sites within each of the two regions were remarkably similar. On the Yunnan Plateau the maximum difference between the mean annual rainfalls of trial sites was less than 200 mm, with all sites being within the range of 830 to 1010 mm. In regards to the lower elevations, with the exception of two sites all were within a mean annual rainfall range of 1340 to 1770 mm. The two exceptions among the lower elevation sites were the trial at Fushun in Sichuan (1040 mm per year) and the one at Shuangpai in southern Hunan (1900 mm per year).

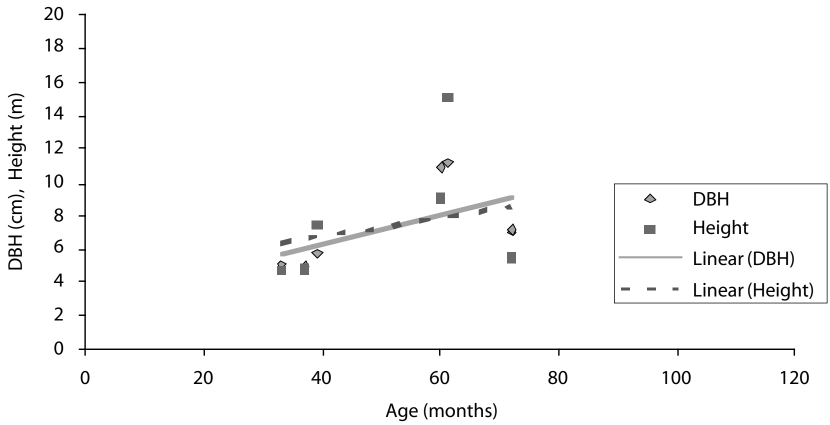

Figure 52. Growth of *E. tereticornis* across six sites in south central China.

Provenance variation within many of the individual species of interest would also be a factor having substantial impacts on the growth and productivity achieved, as mentioned above for *E. tereticornis*. Out of the species considered in the above analyses, *E. camaldulensis*, *E. globulus*, *E. maidenii*, *E. grandis*, *E. saligna* and *E. tereticornis* all have quite wide natural distributions and there is known to be substantial variability within their geographic ranges. Undoubtedly, selection and consistent use of superior provenances/seed sources and possibly even provenance–site matching might considerably lift the average growth of a species across sites, and also considerably improve mean productivity achievable in operational plantations.

Future work could be directed towards refining analyses of growth and productivity to take into account more site and management information, and also to looking at other species and more provenances-within-species.

4. Eucalypts with Potential in the Cooler Regions

There are two markedly distinct environments across the cooler region of south central China where the trials are located. The first type comprises the higher elevation drier sites and the second comprises lower elevation sites with generally higher rainfalls. The higher elevation, drier sites are located on the Yunnan Plateau at elevations above 1500 m asl and generally have mean annual precipitations of less than 1000 mm per year. The lower elevation sites are all below 500 m asl and generally have mean annual rainfalls of 1400 mm or more. The lower elevation category includes large areas in all the other provinces of interest other than Yunnan (i.e. Guangxi, Hunan, Jiangxi, Sichuan and Fujian).

Species for higher elevation drier environments

On the Yunnan Plateau, *E. globulus, E. maidenii* and *E. smithii* have all performed relatively well across sites. Interestingly, there is a long history of cultivation of both *E. globulus* and *E. maidenii* in Yunnan in both plantations and 'four around' plantings (Turnbull 1981). *E. smithii* has more recently gained favour with growers in Yunnan due to its good adaptation, growth and stem form when grown in Yunnan and also for high yields of essential leaf oils. In a number of the Yunnan trials selected provenances of *E. nitens* also showed relatively good growth. However, a key limitation for *E. nitens* relative to *E. globulus*, *E. maidenii* and *E. smithii* in Yunnan is the much lower levels of essential oils in its foliage—a factor of great importance to most eucalypt growers in that province.

Other species such as *E. viminalis* and *E. macarthurii* have performed well at one or two sites but poorly elsewhere in Yunnan. Also, there are a large number of eucalypt species that appear in only one or two trials—too few to enable confident judgment of a species adaptability and productivity. Based on the trials examined to date, several species warrant further monitoring and testing in Yunnan including *E. badgensis* and *E. macarthurii. E. badgensis* has shown very good growth and form in a number of trials in Australia (Myers 1994; CAB International 2000) and on some higher elevation summer rainfall sites subject to winter frosts in South Africa (Darrow 1996). *E. macarthurii* has proved one of the most frost tolerant of all plantation eucalypts in South Africa, where it is now favoured for frost-prone summer rainfall areas (Darrow 1996; Swain and Gardner 2003).

Species for lower elevation environments

At lower elevations in the cooler areas of south central China, the best performing species across trials are *E. camaldulensis, E. dunnii* and, for milder sites, *E. grandis*. As an alternate species on selected sites, *E. saligna* has good potential, particularly where quality sawn timber is the end product objective (see Turnbull and Pryor 1984). However, only a total of five species appeared in three or more successful trials at lower elevations across the cooler regions of south central China. As is the case in Yunnan, a wide range of other species has also been included in just one or two trials across this region. This situation highlights the need for better coordination and communication between researchers. *E. dunnii* is the species best represented across trials at lower elevations in cooler parts of south central China and it has shown good adaptation, growth, stem form and cold tolerance in many trials and plantings in northern Guangxi, Hunan and Fujian. *E. camaldulensis* has also shown good adaptation with very good cold tolerance and rapid early growth in Hunan and Fujian. *E. grandis* had the best growth of all across the trials where it was well adapted, though its lower cold tolerance was clearly a major limitation. It failed to survive significant cold events in a number of trials, particularly in Hunan province. Such results emphasise the need for careful species–site matching to optimise plantation productivities in the cooler regions of south central China.

With *E. saligna* the overall results suggest its productivity is lower than that of *E. dunnii* and *E. camaldulensis*. However, it has shown relatively good cold tolerance and good adaptation in a number of trials where *E. grandis* failed due to cold and/or drought. In several of the trials examined its growth matched or even exceeded that of *E. dunnii*. Clearly, *E. saligna* warrants wider testing.

Although it appeared in only one of the lower elevation trials (the Weimin species trial in Fujian) *E. benthamii* is a species that has attracted interest in Hunan and Fujian in recent years. It has been included in numerous small trials established quite recently (but not reported here) and there are a number of somewhat older small non-trial plantings of the species in the region. In these it has demonstrated excellent growth, very good cold tolerance and stem form. As with *E. saligna*, wider testing of *E. benthamii* also appears warranted. *E. tereticornis* also showed reasonable growth and good adaptation in a number of the trials. More thorough provenance testing of the latter species would provide more reliable information on its adaptability and true yield potential.

It also apparent that when selecting eucalypt species and provenances for south central China's cooler regions, more consideration needs to be given to pathogens, and their potential to cause epidemics. Lower elevated regions of south central China have a distinct summer rainfall pattern, and experience elsewhere has shown that in such environments epidemics of eucalypt foliar pathogens may occur (Old and Floyd 2000). This is particularly so where eucalypt species and provenances are being grown in plantation environments that have much higher rainfall and humidity than normally encountered in their natural habitats. For example, in humid regions of southern and Southeast Asia foliar fungi including *Cylindrocladium* species can sometimes cause severe defoliation of certain *E. camaldulensis* provenances during wetter seasons (Doran and Turnbull 1997).

Notes on the individual species

Climatic requirements for productive plantations of the species discussed below are given in Tables 2 and 3.

Table 2. Climatic requirements for productive plantations of selected cold tolerant eucalypts—species for the Yunnan Plateau (sources of data: CAB International 2000; Jovanovic and Booth 2002; and trial results).

Climatic parameter	*E. globulus*	*E. maidenii*	*E. smithii*	*E. nitens*
Mean annual rainfall (mm)	600–1500	750–1500	610–1930	700–2300
Rainfall regime	uniform, winter	uniform, winter	uniform, winter	uniform, summer, winter
Dry season length	0–6 months	0–6 months	0–6 months	0–5 months
Mean max. temp. hottest month	13–29°C	23–27°C	20–27°C	19–29°C
Mean min. temp. coldest month	–1–12°C	–4–2°C	–3–7°C	–3–4°C
Mean annual temperature	4–18°C	10–23°C	7–17°C	5–17°C
Absolute minimum temperature	>–8°C	>–10°C	>–6°C	>–10°C

Table 3. Climatic requirements for productive plantations of selected cold tolerant eucalypts—species for lower elevations in south central China (sources of data: CAB International 2000; Jovanovic and Booth 2002; and trial results).

Climatic parameter	*E. camaldulensis*[a]	*E. dunnii*	*E. grandis*	*E. saligna*
Mean annual rainfall (mm)	400–2000	845–1950	900–3730	700–2300
Rainfall regime	uniform, winter	uniform, summer	uniform, summer	uniform, summer, winter
Dry season length	0–7 months	0–5 months	0–5 months	0–6 months
Mean max. temp. hottest month	21–41°C	24–31°C	22–34°C	23–34°C
Mean min. temp. coldest month	0–14°C	–1–17°C	0–16°C	–1–17°C
Mean annual temperature	10–25°C	12–22°C	12–25°C	10–22°C
Absolute minimum temperature	>–10°C	>–10°C	>–8°C	>–10°C

a. The climatic requirements given for *E. camaldulensis* are based on the southern form, which should generally have the superior cold tolerance. However, no formal boundary exists between northern and southern forms of this species; rather studies suggest a gradual change over the range (Marcar et al. 1995; Jovanovic and Booth 2002).

Eucalyptus globulus and *E. maidenii*

It has been well established elsewhere that both *E. globulus* and *E. maidenii* are species primarily suited to Mediterranean type environments, which feature dry summers and cool moist winters (CAB International 2000; Jovanovic and Booth 2002). Thus, it is not surprising that these species have generally failed in Hunan and Fujian while proving well adapted to the drier upland climate of the Yunnan Plateau and some adjoining lower rainfall areas of Sichuan.

In Yunnan both species have long been favoured on account of their reasonable cold tolerance, fast growth and relatively high yields of leaf oils rich in 1,8-cineole . Numerous small oil extraction plants operate in Yunnan and leaf oil production is a prime objective for many eucalypt growers in that province. Foliage of *E. maidenii* has both higher total oil content and higher 1,8-cineole percentage in this oil than some sources/provenances of *E. globulus* (Boland et al. 1991; Chen 2002). This superiority of *E. maidenii* for leaf oil production is now recognised by some growers in Yunnan, and the species has also acquired a reputation there for better cold tolerance than *E. globulus* (Zhang et al. 2003a).

The provenance performance results observed in *E. globulus* at Yipinglang and other Yunnan trials are in general accord with results from trials in many other countries. Whilst such trials have found that no single provenance of *E. globulus* shows consistent superiority, provenances from western and eastern Victoria as well as those from southern Tasmania have generally shown better growth across a range of sites (Eldridge et al. 1993; Dutkowski and Potts 1999). At Yipinglang, however, the lots from the Portuguese and Australian seed orchards were even better than the best natural provenances. Interestingly, the Yunnan *E. globulus* landrace also showed good growth and was comparable to the best natural provenances from Australia. Growth of the Yunnan landrace of *E. globulus* also generally proved as good, or better, than that of the best natural provenances in all the Yunnan trials where it was included. By contrast, growth of the Yunnan landrace of *E. maidenii* generally proved markedly inferior to that of its natural provenance counterparts in most of the Yunnan trials.

Eucalyptus nitens

E. nitens showed promise at early ages in a number of the trials on the Yunnan Plateau (e.g. see Wang et al. 1994b). However, at later ages (>6 years or so) it often appears poorly adapted. This may in part be due to the area's long dry season (5–6 consecutive months with less than 40 mm rainfall/month), which is at the extreme of that generally tolerated by *E. nitens* (see CAB International 2000; and, Table 2).

The northern *E. nitens* provenances have generally shown better adaptation to environments featuring summer rainfall climates (CAB International 2000). In the frost-prone summer rainfall areas of South Africa, provenances from northern New South Wales have proved better adapted to their combination of frequent winter frosts and cold with high summer rainfalls, whilst also being faster growing than provenances from southern New South Wales and Victoria (Swain and Gardner 2003). In trials in summer rainfall areas in Australia, northern provenances of *E. nitens* had markedly superior resistance to foliar fungal pathogens than did the southern provinces (Carr 2004). In a number of the trials in Yunnan, particularly those where assessments had been carried out at older ages, the northern provenances performed markedly better than most of the southern ones (e.g. the province 'ENE of Armidale NSW, CS13281' in the 1986 species–provenance trial at Jindian—trial Y5). As Yunnan and other south central provinces have summer rainfall, future work there needs to focus on northern provenances of *E. nitens*.

Eucalyptus smithii

Although *E. smithii* has only been planted in Yunnan on a very limited scale to date (to the end of 2001 it is estimated there were less than 4000 ha of *E. smithii* plantations in Yunnan (Zhang et al. 2003b)), it is already highly regarded there for its good growth rate, good stem form, relatively good cold tolerance and a relatively high yield of 1,8-cineole-rich essential leaf oils (Chen 2002; Zhang et al. 2003b). Research in South Africa has also shown it to have rapid early growth, be moderately frost resistant and be relatively hardy to drought and also to snow (Swain and Gardner 2003). It is now planted on a large scale in some cooler areas of South Africa for production of both essential leaf oils and pulpwood from short-rotation plantations.

The trials studied in this project generally confirm that *E. smithii* is well adapted to many parts of the Yunnan Plateau and one of the more productive eucalypt species in that environment. By contrast, it failed completely in trials in Fujian and some demonstration plantings of the species in Hunan also reputedly failed during severe cold.

The trials of *E. smithii* in Yunnan have been inconclusive in regard to provenance variation and the better natural provenances. In the provenance–family trial at Fumin differences between provenances for growth were small, while in the trials at Chuxiong there was substantial variation between the growth of different provenances. Elsewhere, it was found that *E. smithii* provenances were fairly consistent with regard to leaf oil yield and percent of 1,8 cineole in the foliar oils (Clarke et al. 2004), though there is reputedly some variation between and within provenances in terms of factors like biomass production and frost resistance. Trials in Swaziland found that some of the better provenances of the species for growth came from Tallaganda State Forest and Narooma area in NSW. In South African trials, provenances from Larry's Mountain and Mount Dromedary areas in NSW were the best performing provenances in terms of growth performance and frost resistance (Jacovelli 2002).

Although the Yunnan trials are inconclusive in regard to selection of the better provenances for plantation establishment, they do provide a solid basis for ongoing domestication and genetic improvement of the species there (see Zhang et al. 2003b). Several of the key trials and plantations of better provenances have been thinned to develop seed production areas that can provide moderately improved seed. Simultaneously, intensive phenotypic selection and thinning has been carried out in the provenance–family trial at Fumin to develop it into a seedling seed orchard. This orchard and the seed production areas should soon be providing improved seed well adapted for planting sites on the Yunnan Plateau.

Eucalyptus camaldulensis

E. camaldulensis has shown good adaptation and growth; reasonable stem form and very good cold tolerance in a number of the trials studied and also in many separate plantings in Hunan, Sichuan and Fujian provinces. In the late 1990s selected clonal material of the species became highly sought after for plantation establishment in Hunan. It is a relatively easy species to propagate through micro-propagation and/or as rooted stem cuttings, and clones selected for cold tolerance, vigour and stem form were propagated and established on a large scale in Hunan and adjoining provinces.

Such material has proved surprisingly cold hardy in central and even northern Hunan with little damage at temperatures as low as –10°C. However, recent observations of some *E. camaldulensis* plantings in Hunan indicate that some foliar fungal pathogens, which tend to thrive in warm moist and humid weather encountered there in summer, are starting to significantly reduce growth. Unfortunately the provenance origins of the earlier 'four around' *E. camaldulensis* plantings, which have performed relatively well through cooler areas of south central China, are unknown.

Research in other countries has shown that the better provenances for plantation establishment in areas featuring Mediterranean type climates are generally those from the Lake Albacutya region in northeast Victoria, Australia (CAB International 2000). It is of interest that in the trial at Ganzhou in Jiangxi the *E. camaldulensis* provenance from Lake Albacutya (CS15029) showed markedly superior growth to both other provenances and to other species. For plantations in tropical areas the better provenances are generally those from the Petford area and also the Helenvale–Kennedy River area in north Queensland (CAB International 2000). However, the climate of Hunan and adjoining areas of south central China is neither Mediterranean nor tropical. While a range of provenances of this species has performed reasonably well in the region, it is not yet known which provenances of *E. camaldulensis* are optimal for the Hunan climate with its combination of summer rainfall and frequent winter frosts and cold.

With respect to cold tolerance of *E. camaldulensis*, research in Australia has found provenances from inland Australia are generally less affected by severe frosts—particularly when trees are in an unhardened condition—than provenances from more coastal areas (Florence 1996). Tolerance to frost and cold in an unhardened condition is a favourable trait in south central China where, periodically, there can be an advective freeze immediately following a period of relatively mild weather, as happened during December 1991 and again during December 1999.

Eucalyptus dunnii

E. dunnii has long been a species of interest in cooler regions of south central China. It has been included in many trials since at least 1984, and generally showed excellent stem form and adaptation, (including very good cold tolerance and good drought tolerance). It also had the fastest growth rate in many of the trials at lower elevations. In several of the trials in Hunan it performed well where *E. grandis* had failed totally due to cold and/or drought. Some older *E. dunnii* plantings (1991) in northern central Hunan are known to have survived several severe cold events, with temperatures as low as –11°C, with no visible damage. Thus *E. dunnii* seems to be one of the best eucalypt species for plantation establishment on lower elevation sites in south central China and particularly on sites too cold and/or too dry for *E. grandis* (see Table 3).

The trials in China along numerous trials elsewhere have generally shown that growth and form differences between provenances of *E. dunnii*, whilst often significant, are generally small in absolute magnitude. In the trials at Guilin and Satang in Guangxi province, the differences among widely-sourced provenances for DBH up to age 4 years were as low as 5% of the trial mean at any one site (Wang et al. 1999). In two trials in northern New South Wales, Australia, which included 14 different provenances representing most of the species' natural range, 3-year-old mean height of the poorest provenances was about 85% of that of the best, and differences in stem form among provenances were minor (Johnson and Arnold 2000). However, some more recent work in Australia (Arnold and Johnson 2004) as well as some of the trials in Hunan (e.g. that at Suxian) indicate that the Queensland provenances of the species often grow more slowly.

At present, the scale of *E. dunnii* plantation establishment in China is constrained by difficulties of seed production and vegetative propagation. *E. dunnii* generally does not start to flower until age 10 years or more, and even once flowering starts it can be light and irregular. In the target environments for plantations of this species in south central China, trees 14 years of age and older are yet to start flowering, and several good quality seed orchards and seed production areas established there as early as 1989 have yet to start producing seed (Arnold and Xiang 2003). In addition vegetative propagation of this species has very low success rates.

Eucalyptus grandis

On milder sites within the cooler regions of south central China, *E. grandis* has grown very well and it clearly has good potential for wider establishment on selected sites. However, careful species–site matching is especially important for *E. grandis* (see Table 3). This species was very successful in the trials in Sichuan and in some in Fujian and southern Hunan but failed totally at other sites in Hunan. It is also well known that *E. grandis* prefers moist, well drained, deep, loamy soils of alluvial or volcanic origin, and that it cannot tolerate long periods of drought nor sites on dry, stony, skeletal soils or those with relative little moisture-holding capacity (CAB International 2000). It may well have been the combination of minimum temperatures at the lower limit of tolerance for *E. grandis,* along with its inability to tolerate drought, which together led to its failure in some of the trials reported above.

Although the trial results obtained from south central China did not define the consistently superior provenances of *E. grandis*, many of the better provenances were from high elevation locations in the northern part of *E. grandis* range including the area around Ravenshoe (e.g. CS17857) and the Atherton Tableland (e.g. CS17562). The seedlot representing the Coffs Harbour seed orchard (CS18146) showed superiority over other provenances in some trials but not others. Other imported improved seedlots, namely those from Brazil and hybrid clonal varieties brought in from other provinces, showed no advantage in any of the trials over the best natural stand (unimproved) *E. grandis* provenances. This emphasises the need to test and select genetic material in the target environment where plantations are to be established—material from foreign improvement programs will not necessarily provide any advantage for growers.

There is now an intensive improvement program being pursued for *E. grandis* in Fujian, including development of both seedling seed orchards and clonal seed orchards. This program should soon be producing improved seed from trees selected specially for cold tolerance and growth in south central China. The Fujian work is complemented by the *E. grandis* provenance and provenance–family trials in Sichuan. If resources were available, the Sichuan trials would also be an excellent genetic base to support an intensive ongoing improvement program.

Eucalyptus saligna

E. saligna demonstrated good cold tolerance and adaptation in some trials where *E. grandis* had failed totally, and in some of trials its growth matched or even exceeded that of *E. dunnii*. Overall the results indicated it may have somewhat lower productivity than the latter species. However, its lower productivity may be the result of the use of sub-optimal provenances in some trials. In Australia *E. saligna* has a wide ranging natural distribution— from around 24°S in central Queensland to 36°S in southern New South Wales, from the coast up to more than 120 km inland and from sea level up to 1100 m asl. Within this geographic range there is significant variation between provenances (CAB International 2000), as demonstrated in the species–provenance trial at Cha Hua Shan in Guangxi provenance.

As with *E. camaldulensis* it is not yet known which provenances of *E. saligna* are optimal for south central China. In a number of the trials in both Guangxi and Hunan, provenances from populations considered to be intergrades between *E. saligna* and *E. botryoides* showed excellent growth (e.g. seedlot CS16620). However, in the trial in Jiangxi the same material was no better for growth and survival than a pure *E. saligna* provenance, and markedly inferior to the best *E. camaldulensis* provenance. Performance of *E. saligna* provenances in trials in various other countries have been inconsistent, with the optimal provenances varying substantially between countries and environments (CAB International 2000).

Other traits of *E. saligna* that make it an attractive plantation species in south central China are its relative ease of vegetative propagation (either through micro-propagation or as rooted stem cuttings) and its superiority over *E. grandis*, *E. globulus* and various other eucalypts for sawn timber production (Darrow 1983; Turnbull and Pryor 1984; CAB International 2000). Logs of *E. saligna* are less prone to end-splitting and it generally has a higher wood density than *E. grandis*. Its timber also tends to have a darker (red) colour than that of *E. grandis* (CAB International 2000), which would make it particular appealing timber for the Chinese furniture industry.

Species performance—the role of silviculture, soils and nutrition

Selection of superior species and provenances followed by their genetic improvement is an insufficient process to optimise the productivity and sustainability of eucalypt plantations in cooler regions of south central China. Quality silvicultural management is an absolute requisite to fully realise the combination of genetics and site potentials in eucalypt plantations established in such areas. Development of appropriate tree spacing, pruning and thinning regimes can increase the yield, quality and hence economic value of forest products obtained from eucalypt plantations (Gerrand et al. 1997; Pinkard 2002; Pinkard and Neilsen 2003). Direct adoption of silvicultural regimes employed in China’s tropical and subtropical coastal eucalypt plantations may not be appropriate in many of the cooler areas—the species, target end products, sites and market access are widely different.

Although useful research on silviculture for cold-tolerant eucalypt plantations has already been carried out in Australia and other countries, more work will be needed to optimise these systems for the context of south central China. In the longer term, the most profitable markets for logs from new eucalypt plantations in south central China are likely to be those for higher quality furniture timbers to meet burgeoning domestic demand (see Sun and Bean 2001). There is a major need to design and test spacing and stand manipulations more suited to producing such products in the environments in this region.

In addition, the successful development of large areas of sustainable eucalypt plantations in Hunan, Fujian and other cooler areas of south central China will require detailed understanding of soil types, and intensive management of nutrition, in the target plantation environments (Laffan et al. 2003). Although the ‘red soils’ that dominate south central China generally have very good physical properties for tree growth, there are major differences in other soil properties that have important implications for plantation establishment and management (Laffan 2002). Characterisation and mapping of soils for site selection and appropriate nutrition supplementation will lead to higher plantation productivities.

5. Conclusions

Trials across a wide range of sites have identified some eucalypt species and provenances well adapted for establishment of eucalypt plantations in cooler environments of south central China. Those species that have demonstrated the best potential to date include *E. globulus, E. maidenii* and *E. smithii* for sites on the Yunnan Plateau, and *E. camaldulensis*, *E. dunnii* and *E. saligna* for lower elevation sites in the region. On milder sites selected sources of *E. grandis* have proven well adapted with relatively high productivities. A range of other eucalypt species, including *E. nitens*, warrants further testing and evaluation. It is essential that any such future work is well coordinated with good communications between all researchers and practitioners involved.

Significant genetic variation in growth and adaptation has been demonstrated within some of these key eucalypt species. This provides opportunities for substantial genetic improvement in productivity through well planned and managed tree improvement programs. There is now an urgent need for mass production of superior planting stock, a key component of such improvement programs. High priority should be given to development of breeding populations and seed orchards in these regions for the key species. A shortage of local production capacity for seed of eucalypt species and provenances adapted to the cooler areas of south central China has to date been a major barrier to expansion of cold-tolerant eucalypt plantations in such areas.

It is unfortunate that monitoring and maintenance of the majority of the trials reported here terminated at relatively young ages (i.e. age 4 years or less). Older age assessments (i.e. 8 years or more) from species and species–provenance trials are needed to reliably establish the adaptability and true yield potential of the species and provenances being tested. This is particularly important in south central China where extreme cold events sometimes occur only once every 5 to 10 years or so. Testing over longer periods would also overcome limitations that can arise from changes in relative performance of species and provenances across different ages.

It is critical to the success of eucalypt plantations in the cooler regions of south central China to ensure that selection and tree improvement of the key species are not pursued in ‘isolation’ from other factors that influence productivity. Attention must also be focused on optimising soil, nutritional and silvicultural management for eucalypt plantations to be successful in such areas—improved planting material can only perform well if given appropriately high quality silvicultural management.

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Appendix 1

Information on the provenance origins of seedlots, originally sourced from CSIRO, that were used in the trials in south central China and referred to in this report.

Seedlot	Species	Latitude (°S)	Longitude (°E)	Altitude (m asl)	Location	State/country	No. of parent trees for bulk seedlot
CS13349	*E. amplifolia*	30°04'	152°09'	880	E of Guyra	NSW	10
CS13286	*E. badjensis*	36°32'	149°15'	900	23 km from Nimmatabel	NSW	5
CS13286	*E. badjensis*	36°32'	149°15'	900	23 km from Nimmatabel	NSW	5
CS17774	*E. badjensis*	36°36'	149°26'	1050	Glenbog SF	NSW	4
CS19555	*E. badjensis*	36°29'	149°19'	1100	Glenbog	NSW	20
CS14214	*E. benthamii*	33°48'	150°24'	150	Wentworth Falls	NSW	10
CS18788	*E. benthamii*	33°49'	150°23'	140	Kedumba Valley	NSW	13
CS09246	*E. bicostata*	35°28'	148°10'	910	Wee Jasper	NSW	9
CS09539	*E. bicostata*	36°11'	146°40'	580	Stanley	Vic.	4
CS09541	*E. bicostata*	37°03'	146°20'	850	NE of Mansfield	Vic.	8
CS11310	*E. bicostata*	37°15'	143°22'	680	Mt Lonarch	Vic.	not recorded
CS11742	*E. bicostata*	37°40'	147°47'	310	5 km N of Bruthen	Vic.	2
CS15269	*E. bicostata*	35°11'	148°54'	870	Wee Jasper	NSW	8
CS17777	*E. bicostata*	37°40'	147°47'	310	10 km NW Bruthen	NSW	5
CS17965	*E. bicostata*	35°46'	148°04'	720	Tumbarumba	NSW	10
CS15029	*E. camaldulensis*	35°42'	141°57'	70	Lake Albacutya—north side	Vic.	12
CS15031	*E. camaldulensis*	35°26'	141°57'	45	Lake Agnes	Vic.	12
CS17017	*E. camaldulensis*	37°39'	144°48'	100	Tullamarine Airport	Vic.	8
CS13849	*E. camaldulensis*	17°23'	144°58'	500	8 km from Petford	Qld	21
CS15272	*E. camaldulensis*	31°53'	141°13'	210	Silverton	NSW	10
CS12448	*E. camphora*	35°17'	148°49'	1070	Coree Flat	ACT	5
CS09755	*E. chapmaniana*	36°16'	147°01'	140	Kiewa northeast	Vic.	not recorded
CS11711	*E. cinerea*	34°51'	148°54'	490	Gunning Area	NSW	40
CS14236	*E. cloeziana*	17°20'	145°00'	800	10–25 km W Herberton	Qld	25

Seedlot	Species	Latitude(S)	Longitude (E)	Altitude(m asl)	Location	State/country	No. of parent trees for bulk seedlot
CS14427	*E. cloeziana*	23°48'	149°01'	750	Blackdown Tableland	Qld	25
CS17008	*E. cloeziana*	26°14'	152°50'	300	Woondum SF	Qld	10
CS13579	*E. crebra*	25°56'	151°55'	100	Gin Gin	Qld	5
CS09440	*E. cypellocarpa*	34°39'	150°29'	650	Fitzroy Falls	NSW	not recorded
CS12655	*E. cypellocarpa*	37°2'	148°42'	860	Bonang	Vic.	1
CS12914	*E. cypellocarpa*	38°25'	146°29'	520	Jerralang Nth	Vic.	10
CS12563	*E. dalrympleana*	31°27'	151°15'	1250	Nundle SF, Tamworth	NSW	4
CS10340	*E. deanei*	34°13'	150°31'	240	SW of Thirlmere	NSW	10
CS11688	*E. deanei*	33°02'	151°25'	370	Watagan Mtns	NSW	not recorded
CS14521	*E. deanei*	29°48'	152°07'	950	Glen Innes	NSW	10
CS14206	*E. dendromorpha*	35°28'	149°59'	1130	Mt Budawang	NSW	5
CS12867	*E. denticulata*	37°12'	148°42'	800	Bonang SF	Vic.	5
CS17349	*E. dives*	35°36'	148°13'	460	Bago SF	NSW	10
CS19668	*E. dorrigoensis*	30°05'	152°08'	1000	Paddys Land SF	NSW	8
CS13124	*E. dunnii*	30°05'	153°00'	300	Kangaroo River SF, Moleton	NSW	8
CS13329	*E. dunnii*	28°24'	152°41'	400	NW of Kyogle	NSW	10
CS14113	*E. dunnii*	28°23'	152°20'	675	NNW of Urbenville	NSW	26
CS15956	*E. dunnii*	28°25'	152°20'	650	Dead Horse Track	NSW	70
CS15967	*E. dunnii*	28°15'	152°30'	450	Teviot Brook—Burnett Ck	Qld	5
CS16894	*E. dunnii*	28°13'	152°32'	350	Teviot Falls SF	Qld	4
CS16895	*E. dunnii*	28°04'	152°24'	700	Spicers Peak SF	Qld	14
CS17555	*E. dunnii*	30°05'	152°54'	420	Moleton Kangaroo SF	NSW	6
CS17733	*E. dunnii*	28°04'	152°22'	650	Spicers Gap	Qld	16

Seedlot	Species	Latitude (S)	Longitude (E)	Altitude (m asl)	Location	State/country	No. of parent trees for bulk seedlot
CS17800	*E. dunnii*	30°09'	152°53'	500	Moleton	NSW	5
CS17865	*E. dunnii*	28°04'	152°22'	650	Spicers Gap	Qld	14
CS17909	*E. dunnii*	28°35'	152°29'	550	Yabbra SF—Urbenville	NSW	12
CS17911	*E. dunnii*	28°04'	152°22'	675	Spicers Peak SF	Qld	26
CS17913	*E. dunnii*	28°41'	152°28'	330	Yabbra SF—Urbenville	NSW	3
CS17914	*E. dunnii*	28°13'	152°32'	360	Teviot Falls SF	Qld	12
CS17915	*E. dunnii*	28°16'	152°28'	625	Koreelah SF	NSW	9
CS17916	*E. dunnii*	28°19'	152°30'	710	Koreelah SF	NSW	4
CS17918	*E. dunnii*	28°04'	152°22'	650	Spicers Peak SF	Qld	4
CS17920	*E. dunnii*	28°24'	152°20'	690	Koreelah SF	NSW	23
CS17921	*E. dunnii*	28°40'	152°43'	300	Richmond Range SF	NSW	6
CS17922	*E. dunnii*	30°05'	152°54'	420	Moleton	NSW	9
CS18231	*E. dunnii*	28°18'	152°30'	575	Koreelah SF	NSW	7
CS18263	*E. dunnii*	28°35'	152°29'	580	South Yabbra	NSW	14
CS18264	*E. dunnii*	28°37'	152°29'	500	Yabbra Plains Rd	NSW	48
CS18264	*E. dunnii*	28°37'	152°29'	500	Yabbra Plains Rd	NSW	48
CS14457	*E. fastigata*	37°02'	149°21'	860	Bombala	NSW	17
CS12742	*E. globulus*	42°02'	145°15'	50	Henty River	Tas.	not recorded
CS12743	*E. globulus*	43°25'	146°55'	20	Leprena	Tas.	not recorded
CS12744	*E. globulus*	43°24'	147°19'	180	Bruny Island	Tas.	not recorded
CS12745	*E. globulus*	43°17'	147°12'	100	Channel	Tas.	not recorded
CS12746	*E. globulus*	43°10'	146°53'	200	Geeveston	Tas.	not recorded
CS12750	*E. globulus*	41°40'	147°49'	560	Pepper Hill	Tas.	not recorded
CS12751	*E. globulus*	43°05'	147°55'	120	Taranna	Tas.	not recorded

Seedlot	Species	Latitude (S)	Longitude (E)	Altitude (m asl)	Location	State/country	No. of parent trees for bulk seedlot
CS12752	*E. globulus*	42°07'	148°03'	100	Swansea	Tas.	not recorded
CS12753	*E. globulus*	42°38'	147°54'	80	Rheban	Tas.	not recorded
CS12755	*E. globulus*	41°27'	148°16'	50	Scamander	Tas.	not recorded
CS12756	*E. globulus*	41°16'	148°17'	50	St Helens	Tas.	not recorded
CS12757	*E. globulus*	39°51'	148°01'	50	Flinders Island	Tas.	not recorded
CS16063	*E. globulus*	39°08'	146°25'	60	Wilsons Promontory	Vic.	7
CS16066	*E. globulus*	38°20'	146°30'	380	19.1 km S Traralgon Post Office	Vic.	10
CS16073	*E. globulus*	41°52'	147°59'	560	45.2 km NW of Swansea	Tas.	10
CS16074	*E. globulus*	41°38'	147°51'	540	16 km WNW Fingal	Tas.	10
CS16075	*E. globulus*	43°16'	145°55'	21	Port Davey	Tas.	6
CS16078	*E. globulus*	43°30'	146°54'	40	Recherche Bay	Tas.	5
CS16080	*E. globulus*	43°04'	146°47'	260	Whale Point	Tas.	1
CS16082	*E. globulus*	42°56'	147°16'	210	SW of Hobart	Tas.	10
CS16083	*E. globulus*	43°22'	147°17'	105	South Bruny Island	Tas.	7
CS16084	*E. globulus*	42°50'	147°12'	295	W of Glenorchy	Tas.	5
CS16086	*E. globulus*	42°35'	148°03'	245	Maria Island	Tas.	7
CS16223	*E. globulus*	38°46'	143°32'	200	19 km W Apollo Bay Post Office	Vic.	6
CS16224	*E. globulus*	38°49'	143°34'	145	21.6 km SW Apollo Bay	Vic.	1
CS16226	*E. globulus*	38°48'	143°37'	130	8.0 km SW Apollo Bay	Vic.	16
CS16227	*E. globulus*	38°47'	143°37'	150	9.5 km SW Apollo Bay	Vic.	2
CS16240	*E. globulus*	38°45'	143°27'	150	Otway SF	Vic.	22
CS16319	*E. globulus*	38°19'	146°33'	220	Jeeralang North	Vic.	27
CS16398	*E. globulus*	38°38'	146°30'	20	1.5 km NW of Hedley	Vic.	9

Seedlot	Species	Latitude (S)	Longitude (E)	Altitude (m asl)	Location	State/country	No. of parent trees for bulk seedlot
CS16399	*E. globulus*	39°08'	146°25'	60	Wilsons Promontory	Vic.	9
CS16400	*E. globulus*	38°37'	146°21'	180	8.5 km N of Toora Post Office	Vic.	3
CS16402	*E. globulus*	38°39'	143°48'	250	5.4 km W Kennett River	Vic.	6
CS16405	*E. globulus*	38°36'	143°54'	200	12.1 km S Lorne Post Office	Vic.	7
CS16407	*E. globulus*	38°32'	143°56'	210	17.1 km W Lorne Post Office	Vic.	9
CS16410	*E. globulus*	41°59'	145°18'	120	Badgers Ck, Quarry Rd	Tas.	9
CS16411	*E. globulus*	41°16'	148°18'	120	Near Binalong Bay	Tas.	13
CS16412	*E. globulus*	41°56'	145°12'	10	Little Henty River	Tas.	11
CS16415	*E. globulus*	40°32'	148°08'	40	Clarke Island	Tas.	6
CS16416	*E. globulus*	40°19'	148°19'	60	NE Cape Barren Island	Tas.	5
CS16417	*E. globulus*	40°22'	148°13'	20	N Cape Barren Island	Tas.	5
CS16419	*E. globulus*	40°21'	148°07'	20	NW Cape Barren Island	Tas.	8
CS16420	*E. globulus*	40°22'	148°05'	60	NW Cape Barren Island	Tas.	6
CS16421	*E. globulus*	40°26'	148°03'	40	SW Cape Barren Island	Tas.	6
CS16422	*E. globulus*	42°20'	145°20'	20	Macquarie Harbour	Tas.	8
CS16424	*E. globulus*	40°00'	144°00'	60	King Island	Tas.	23
CS16425	*E. globulus*	40°14'	148°08'	120	S Flinders Island	Tas.	6
CS16426	*E. pseudoglobulus*	39°46'	147°52'	20	NW Flinders Island	Tas.	2
CS16427	*E. globulus*	39°45'	147°57'	40	N Flinders Island	Tas.	6
CS16428	*E. globulus*	39°51'	147°50'	20	W Flinders Island	Tas.	2
CS16429	*E. globulus*	39°55'	147°57'	40	Central Flinders Island	Tas.	7
CS16430	*E. globulus*	39°55'	148°02'	20	Central Flinders Island	Tas.	2
CS16431	*E. globulus*	40°02'	148°01'	190	Central Flinders Island	Tas.	11
CS16433	*E. globulus*	40°04'	148°04'	150	Central Flinders Island	Tas.	4
CS16434	*E. globulus*	40°16'	148°10'	12	S Flinders Island	Tas.	6

Seedlot	Species	Latitude (S)	Longitude (E)	Altitude (m asl)	Location	State/country	No. of parent trees for bulk seedlot
CS16470	*E. globulus*	42°47'	146°55'	500	Moogara	Tas.	21
CS16471	*E. globulus*	43°16'	146°59'	190	NW of Dover	Tas.	3
CS16472	*E. globulus*	42°38'	146°42'	460	Ellendale	Tas.	5
CS16473	*E. globulus*	42°43'	147°09'	300	NE New Norfolk	Tas.	4
CS16474	*E. globulus*	41°34'	148°12'	400	N of St Marys	Tas.	5
CS16475	*E. globulus*	42°25'	147°16'	500	SW of Jericho	Tas.	5
CS16476	*E. globulus*	43°12'	146°54'	250	S of Geeveston	Tas.	7
CS16477	*E. globulus*	43°08'	146°57'	200	N of Geeveston	Tas.	3
CS16478	*E. globulus*	43°04'	147°50'	20	Koonya Tasman Peninsula	Tas.	4
CS16860	*E. globulus*	43°13'	146°55'	250	Blue Gum Saddle	Tas.	6
CS17696	*E. globulus*	42°47'	146°55'	500	Moogara	Tas.	11
CS11319	*E. grandis*	32°30'	152°13'	3	Bulahdelah	NSW	not recorded
CS13019	*E. grandis*	30°13'	153°02'	135	NW of Coffs Harbour	NSW	10
CS14393	*E. grandis*	17°06'	145°33'	900	25–36 km SE Mareeba	Qld	6
CS14431	*E. grandis*	26°52'	152°42'	500	Belthorpe SF	Qld	12
CS14838	*E. grandis*	18°14'	143°00'	620	WNW Cardwell	Qld	7
CS15219	*E. grandis*	26°42'	152°53'	200	NE of Maleny	Qld	20
CS15875	*E. grandis*	26°42'	152°53'	200	Baroon Pocket—Maleny	Qld	20
CS15921	*E. grandis*	30°52'	152°51'	50	Kempsey—Tan Ban SF	NSW	6
CS16583	*E. grandis*	17°18'	145°25'	1100	Atherton	Qld	10
CS16892	*E. grandis*	26°12'	153°10'	40	Kin Kin	Qld	12
CS17562	*E. grandis*	17°13'	145°42'	700	30 km SW Cairns	Qld	10
CS17563	*E. grandis*	17°18'	145°44'	680	45 km SSW Cairns	Qld	10

Seedlot	Species	Latitude (S)	Longitude (E)	Altitude (m asl)	Location	State/country	No. of parent trees for bulk seedlot
CS17709	*E. grandis*	16°12'	145°01'	1250	Windsor Tableland	Qld	16
CS17713	*E. grandis*	16°13'	144°58'	1160	Piccaninny Ck	Qld	37
CS17857	*E. grandis*	17°42'	145°29'	925	10 km S of Ravenshoe	Qld	11
CS18146	*E. grandis*	30°08'	153°07'	100	Coffs Harbour seed orchard	NSW	8
CS18180	*E. grandis*	17°17'	145°23'	1000	Baldy State Forest	Qld	12
CS18181	*E. grandis*	16°59'	145°40'	400	Coperlode Dam	Qld	11
CS18273	*E. grandis*	30°10'	153°07'	100	Wedding Bells SF	NSW	11
CS18274	*E. grandis*	30°07'	152°54'	440	Bagawa SF	NSW	7
CS18277	*E. grandis*	26°52'	152°42'	400	Bellthorpe	Qld	16
CS18569	*E. grandis*	17°18'	145°24'	1000	Wongabel SF	Qld	5
CS18590	*E. grandis*	17°22'	145°24'	920	SSW Atherton	Qld	10
CS18591	*E. grandis*	18°52'	146°08'	925	Mt Spec Near Paluma	Qld	5
CS18592	*E. grandis*	17°42'	145°29'	925	10 km S Ravenshoe	Qld	9
CS18593	*E. grandis*	16°35'	145°16'	950	Mt Lewis Julatten	Qld	5
CS18594	*E. grandis*	17°05'	145°36'	1100	Tinaroo Ck Rd	Qld	18
CS18595	*E. grandis*	17°23'	145°28'	950	East of Wondecla	Qld	10
CS18693	*E. grandis*	26°10'	152°59'	40	Como	Qld	10
CS18696	*E. grandis*	26°29'	152°50'	100	Belli	Qld	10
CS18697	*E. grandis*	26°32'	152°24'	440	Yabba	Qld	10
CS18698	*E. grandis*	26°36'	152°52'	300	Mapleton	Qld	15
CS18699	*E. grandis*	26°35'	152°36'	500	Borumba Range	Qld	15
CS18700	*E. grandis*	26°40'	152°36'	560	Cannondale	Qld	21
CS18702	*E. grandis*	26°52'	152°45'	200	Bellthorpe	Qld	15

Seedlot	Species	Latitude (S)	Longitude (E)	Altitude (m asl)	Location	State/country	No. of parent trees for bulk seedlot
CS18703	*E. grandis*	27°08'	152°43'	200	Mt Mee	Qld	13
CS18705	*E. grandis*	28°21'	152°45'	340	Mt Lindsay	Qld	12
CS11825	*E. johnstonii*	42°30'	147°35'	760	Misery Plateau	Tas.	not recorded
CS14840	*E. laevopinea*	31°30'	151°06'	186	S New England	NSW	9
CS15057	*E. macarthurii*	34°39'	150°10'	600	ENE of Marulan	NSW	19
CS15108	*E. macarthurii*	34°36'	150°06'	600	Canyonleigh	NSW	11
CS12125	*E. maidenii*	36°48'	149°34'	381	Tantawanglo Mtn	NSW	6
CS12126	*E. maidenii*	37°07'	149°53'	360	Bimmil Hill Nullica SF	NSW	5
CS12130	*E. maidenii*	36°17'	150°03'	305	Mt Dromedary	NSW	10
CS12132	*E. maidenii*	35°41'	150°04'	335	SW Nelligen, Bolaro SF	NSW	6
CS12321	*E. maidenii*	37°18'	149°12'	290	Cann Valley	Vic.	7
CS15917	*E. maidenii*	35°40'	150°02'	360	Bolaro Mt	NSW	7
CS17742	*E. maidenii*	37°10'	149°41'	320	Black Range—via Eden	NSW	37
CS17769	*E. maidenii*	36°49'	149°45'	250	Yurammie SF	NSW	5
CS12159	*E. mannifera*	34°51'	148°54'	530	Yass—Dalton District	NSW	not recorded
CS13971	*E. microcorys*	31°34'	152°47'	40	NNE of Kendall	NSW	5
CS09751	*E. neglecta*	36°42'	146°53'	760	Buckland River	Vic.	not recorded
CS12401	*E. nitens*	37°27'	145°57'	1100	Federation Range	Vic.	3
CS13281	*E. nitens*	30°28'	152°15'	1277	ENE of Armidale	NSW	11
CS14012	*E. nitens*	36°38'	149°24'	1100	Brown Mountain	NSW	11
CS14437	*E. nitens*	35°54'	149°30'	1300	Tallaganda SF	NSW	6
CS14439	*E. nitens*	36°38'	149°24'	1050	Glenbog SF	NSW	7
CS14449	*E. nitens*	35°49'	149°31'	1200	Tallaganda	NSW	19
CS14450	*E. nitens*	32°00'	151°30'	1500	Barrington Tops	NSW	23

Seedlot	Species	Latitude (S)	Longitude (E)	Altitude (m asl)	Location	State/country	No. of parent trees for bulk seedlot
CS14454	*E. nitens*	37°47'	146°16'	900	Mt Toorong Plateau	Vic.	31
CS14455	*E. nitens*	36°38'	149°24'	1130	Brown Mtn	NSW	7
CS15015	*E. nitens*	37°50'	146°21'	1165	Marshalls Spur	Vic.	20
CS15016	*E. nitens*	37°27'	145°57'	1100	Barnewell Plains	Vic.	6
CS15918	*E. nitens*	35°59'	149°53'	1300	S Captains Flat	NSW	70
CS16619	*E. nitens*	35°48'	149°31'	1250	Tallaganda SF	NSW	17
CS16636	*E. nitens*	30°25'	152°25'	1450	Majors Point, Ebor	NSW	7
CS16750	*E. nitens*	37°27'	146°24'	1200	Barkey R. Rd—Mt Skene	Vic.	5
CS16869	*E. nitens*	37°54'	146°00'	1000	Toorongo Plateau	Vic.	16
CS17132	*E. nitens*	35°52'	149°28'	1417	Tallaganda SF	NSW	7
CS18341	*E. nitens*	31°38'	151°30'	1250	Barrington Tops	NSW	10
CS19467	*E. nobilis*	29°12'	152°07'	1250	Forest Land SF	NSW	12
CS13606	*E. nova-anglica*	31°09'	151°31'	1045	24 km SSW of Walcha	NSW	7
CS10191	*E. obliqua*	38°33'	143°29'	270	East Otways Ranges	Vic.	not recorded
CS10345	*E. oreades*	33°34'	150°20'	910	Bell-Mt Wilson	NSW	2
CS12284	*E. parvula*	36°04'	149°30'	1300	Badja R, Sth Tablelands	NSW	not recorded
CS13831	*E. pauciflora*	35°19'	148°49'	1390	Mt Coree	ACT	5
CS18197	*E. pellita*	08°25'	141°30'	45	S of Kiriwo, Western Province	PNG	50
CS18198	*E. pellita*	08°20'	141°32'	45	Kiriwo	PNG	21
CS18199	*E. pellita*	08°36'	141°26'	45	Serisa	PNG	33
CS11168	*E. pulchella*	43°00'	146°55'	360	Mt Judbury	Tas.	not recorded
CS17581	*E. quadrangulata*	30°04'	152°38'	650	Clouds Creek	NSW	5
CS11864	*E. radiata*	36°19'	149°45'	94	5 km S Nerrigundah	NSW	2
CS11983	*E. radiata*	35°24'	149°53'	820	E Braidwood—Nerriga	NSW	4

Seedlot	Species	Latitude (S)	Longitude (E)	Altitude (m asl)	Location	State/country	No. of parent trees for bulk seedlot
CS17311	*E. radiata*	37°26'	144°55'	300	Mickleham	Vic.	6
CS17312	*E. radiata*	37°27'	144°40'	350	Riddells Ck	Vic.	20
CS18365	*E. radiata*	33°42'	149°51'	1000	Oberon District	NSW	11
CS18115	*E. saligna*	34°45'	150°27'	680	Mt Scanzi	NSW	24
CS18162	*E. saligna*	26°52'	152°42'	400	Bellthorpe SF	Qld	18
CS18229	*E. saligna*	23°50'	149°05'	880	Blackdown Tableland	Qld	8
CS16620	*E. saligna* ig. *botryoides*	35°20'	150°12'	60	Yadboro SF	NSW	5
CS12576	*E. scoparia*	35°17'	149°06'	620	Nat. Botanic Gardens, Canberra	ACT	not recorded
CS12131	*E. smithii*	36°17'	150°03'	305	Mt Dromedary	NSW	6
CS12559	*E. smithii*	36°22'	149°57'	600	Mt Dromedary	NSW	not recorded
CS15059	*E. smithii*	36°18'	150°01'	305	Mt Dromedary	NSW	16
CS15090	*E. smithii*	37°05'	149°47'	220	Towamba	NSW	12
CS15091	*E. smithii*	36°00'	150°00'	450	NW of Narooma	NSW	30
CS15092	*E. smithii*	34°42'	150°10'	650	Wingello	NSW	5
CS15542	*E. smithii*	37°27'	149°51'	200	40 km S of Eden	NSW	10
CS15544	*E. smithii*	35°23'	149°37'	950	20 km WNW of Braidwood	NSW	10
CS15545	*E. smithii*	37°36'	148°30'	300	13 km N of Orbost	Vic.	9
CS16916	*E. smithii*	37°34'	148°29'	370	12 km NE Orbost	Vic.	24
CS17131	*E. smithii*	36°12'	150°04'	90	Bodalla SF—NW Narooma	NSW	5
CS18284	*E. smithii*	35°26'	149°36'	900	Tallaganda SF	NSW	40
CS18676	*E. smithii*	34°44'	150°10'	650	Wingello SF	NSW	7
CS18681	*E. smithii*	37°04'	149°45'	300	Towamba	NSW	7
CS18682	*E. smithii*	36°54'	149°43'	400	Wyndham	NSW	8

Seedlot	Species	Latitude (S)	Longitude (E)	Altitude (m asl)	Location	State/country	No. of parent trees for bulk seedlot
CS18688	*E. smithii*	36°08'	149°49'	400	Nerrigundah	NSW	9
CS17430	*E. tereticornis*	38°04'	147°35'	10	Loch Sport	Vic.	10
CS13319	*E. tereticornis*	29°55'	153°12'	30	N of Woolgoolga	NSW	6
CS16349	*E. tereticornis*	17°19'	145°28'	780	Atherton Wongabel	Qld	6
CS16927	*E. tereticornis*	25°00'	150°00'	150	50 km SSE Moura	Qld	15
CS17761	*E. tereticornis*	28°03'	152°24'	675	Spicers Gap SF	Qld	10
CS18315	*E. tereticornis*	15°05'	144°19'	32	Kennedy R, Lakefield National Park	Qld	3
CS14207	*E. triflora*	35°06'	150°09'	760	Morton National Park	NSW	5
CS14534	*E. urophylla*	08°38'	122°27'	500	Mt Egon, Flores	Indonesia	30
CS17831	*E. urophylla*	07°52'	126°27'	515	N of Ilwaki, Wetar	Indonesia	17
CS17832	*E. urophylla*	07°49'	126°10'	315	6 km N of Arnau, Wetar	Indonesia	25
CS17836	*E. urophylla*	07°39'	126°29'	350	SW of Uhak, NE Wetar	Indonesia	20
CS11743	*E. viminalis*	37°26'	147°34'	900	40 km NNW Bruthen	Vic.	7
CS12554	*E. viminalis*	42°36'	146°28'	400	28 km NNW Maydena	Tas.	5
CS12555	*E. viminalis*	42°15'	147°51'	580	15 km NW Swanport	Tas.	11
CS12556	*E. viminalis*	41°24'	147°58'	340	9 km NE Mathinna	Tas.	11
CS12564	*E. viminalis*	31°27'	151°15'	1250	Nundle SF, Tamworth	NSW	6
CS12568	*E. viminalis*	29°09'	152°06'	1100	Forest Lands SF	NSW	9
CS12651	*E. viminalis*	37°46'	146°18'	325	Erica	Vic.	3
CS12973	*E. viminalis*	35°31'	149°33'	900	Tallaganda SF	NSW	5
CS14198	*E. viminalis*	35°38'	148°50'	1100	Cotter Flats	ACT	5
CS14201	*E. viminalis*	37°15'	148°58'	850	14 km SE of Bendoc	Vic.	25
CS14511	*E. viminalis*	31°58'	151°23'	1300	Barrington Tops	NSW	25
CS14523	*E. viminalis*	32°43'	150°13'	900	Nullo Mt—NE Rylstone	NSW	26

Seedlot	Species	Latitude (S)	Longitude (E)	Altitude (m asl)	Location	State/country	No. of parent trees for bulk seedlot
CS14525	*E. viminalis*	31°45'	149°58'	1080	Warung SF, Coolah	NSW	25
CS14920	*E. viminalis*	35°38'	148°50'	1100	Cotter Catchment	ACT	19
CS15017	*E. viminalis*	38°20'	146°14'	240	Silver Ck, Morwell	Vic.	6
CS15018	*E. viminalis*	37°44'	145°45'	220	Warburton	Vic.	8
CS15213	*E. viminalis*	35°21'	148°49'	900	Uriarra Forest	ACT	15
CS15213	*E. viminalis*	35°21'	148°49'	900	Uriarra Forest	ACT	15
CS17217	*E. viminalis*	37°26'	144°55'	250	Mickleham	Vic.	30
CS18112	*E. viminalis*	37°10'	147°47'	480	Tambo River via Swifts Ck	Vic.	8
CS13540	*C. citriodora* ssp. *variegata*	26°25'	151°55'	370	15.4 km of Wondai	Qld	10
CS19564	*C. citriodora* ssp. *variegata*	30°06'	152°10'	1100	Paddys Land SF	NSW	13