DISTRIBUTION, BIOLOGY, GENETICS, AND IMPROVEMENT PROGRAMS FOR *EUCALYPTUS GLOBULUS* AND *E. NITENS* AROUND THE WORLD

W. N. Tibbits[1], D. B. Boomsma[2] and S. Jarvis[1]

Abstract:- The distribution of natural forests and plantations of *E. globulus* and *E. nitens* is outlined. The total global area of plantations of *E. globulus* was about 1,700,000 ha at the end of 1995, whilst that for *E. nitens* stood at about 150,000 ha. In the period 1991 to 1995, about 350,000 and 100,000 ha of new plantations of *E. globulus* and *E. nitens* respectively were established, largely in Portugal, Spain, Chile, Australia and Uruguay. Based on proposed planting rates, the period 1995 to 1999 may see a further increase of new plantations of about 180,000 and 70,000 ha. The main end-use of plantations is for the pulp and paper industry. When compared on the same sites in Australia, *E. globulus* has on average the higher basic density and slightly higher pulp yield. Biological aspects such as site preferences, growth rates, pests, and diseases, and establishment and management prescriptions are discussed. Information is summarised on genetic control of important traits, and tree improvement programs around the world.

Key Words: *E. globulus, E. nitens,* Plantation, Breeding, Wood quality.

DISTRIBUTION

Natural Distribution. *E. globulus* forms a species complex (Jordan *et al.* 1994), with four apparent populations, currently ascribed to four ssp. (ssp.), *E. globulus* Labill ssp. *globulus*, *E. globulus* Labill ssp. *bicostata* (Maiden, Blakely & J. Simm.) Kirkpatr., *E. globulus* Labill ssp. *pseudoglobulus* (Naudin ex. Maiden) Kirkpatr., and *E. globulus* Labill ssp. *maidenii* (F. Muell.) Kirkpatr. These four recognised taxa are largely differentiated on reproductive traits, with *globulus* having umbels of single fruits, *bicostata* and *pseudoglobulus* having three fruits per umbel and *maidenii* having up to seven fruits per umbel. Each taxa has core populations that are geographically separated. However, *globulus* integrades between *bicostata* and *pseudoglobulus*, which themselves dispay a continuum between each other. This paper deals with *E. globulus* ssp. *globulus* (referred to *E. globulus* from here on).

E. globulus, Tasmanian Blue Gum, was one of the first Eucalypts to be formally described and also cultivated as an exotic (Eldridge *et al.* 1992). It occurs along the coast and up to 60 km inland in Tasmania and Victoria, over a latitude range of 38° 30' to 43°30'S and an altitudinal range of sea level to about 600 m (Figure 1).

'North Eucalypt Technologies, P.O. Box 63 Ridgley, Tasmania 7321.
'Southern Tree Breeding Association, P.O. Box 1811 Mt Gambier , S.A. 5290

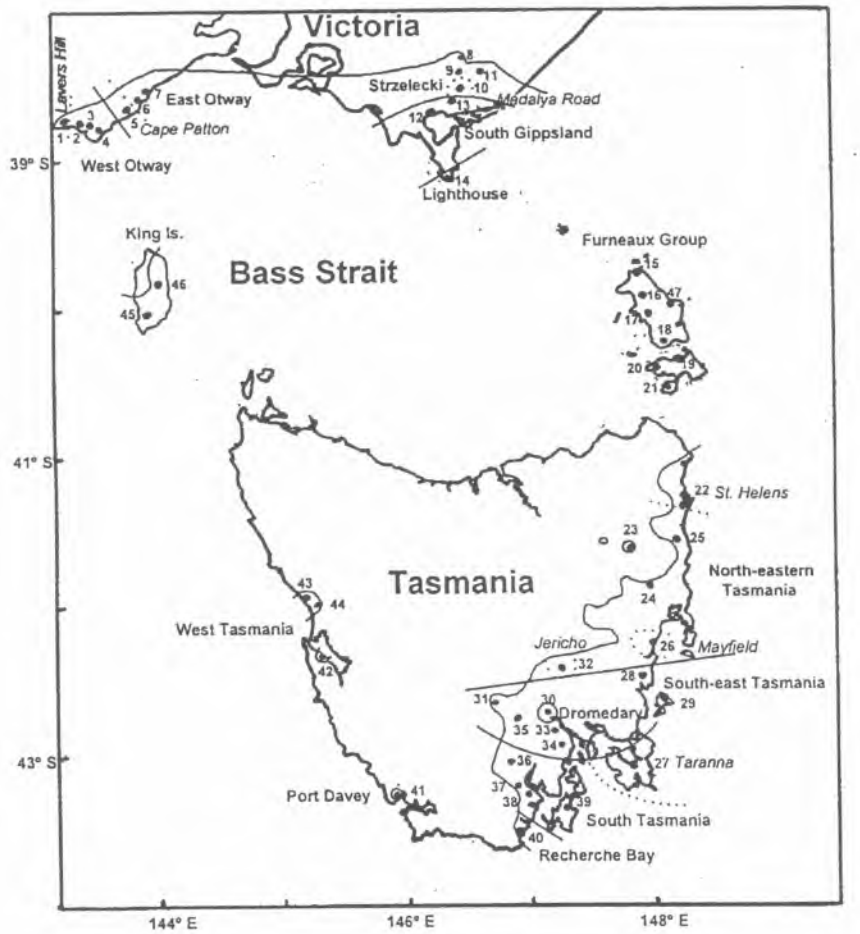


Figure 1. Natural distribution of *E. globulus* (after Dutkowski unpublished).

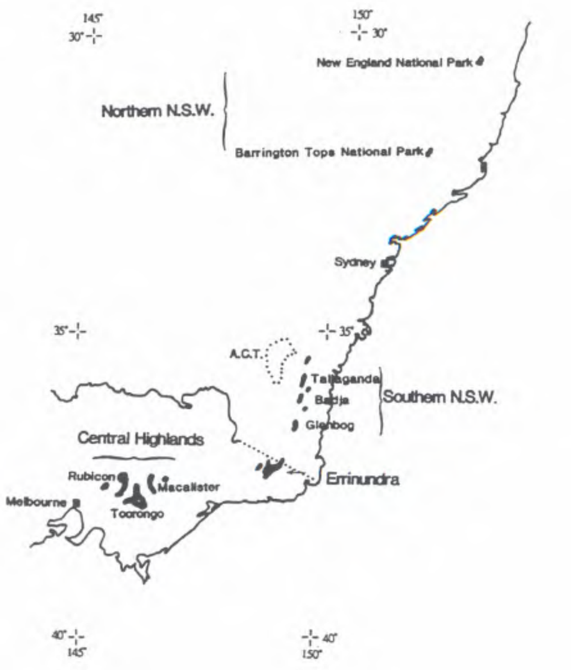


Figure 2. Natural distribution of *E. nitens* (after Tibbits and Reid 1987).

Jordan *et al.* (1994) identified 12 geographic races of *E. globulus*, with three in Victoria [(1) Otway Ranges, (2) Strezlecki Ranges, (3) South Gippsland], two on Bass Strait islands [(4) King Island, (5) Furneaux Group], the (6) central western Tasmania race, four in eastern Tasmania [(7) northeastern Tasmania, (8) eastern Tasmania, (9) Jericho, (10) southeastern Tasmania], and two small races (11) Port Davey and (12) Lighthouse, Wilson's Promontory.

Eucalyptus nitens (Deane & Maiden) Maiden, Shining Gum, is a fast-growing species with a natural distribution in small and generally isolated populations. It occurs in the mountain ranges of New South Wales (NSW) and Victoria, over a latitude range of 30° to 38°S and an altitudinal range of 600 to 1500 m (Figure 2). Pederick (1979) determined four main regions of occurrence, two in NSW (northern NSW and southern NSW) and two in Victoria (east Gippsland and the central highlands). Within the central highlands he designated three provenances, Rubicon, Toorongo and Macalister, and he designated the other regions as provenances. Pederick (1979) described two forms of *E. nitens.* The "juvenile-persistent" form was so called because of its retention of juvenile foliage after the first year of growth. The "early-adult" form did not retain its juvenile foliage for long. It came from the Errinundra provenance and parts of the Toorongo provenance, and was characterised by slower growth, finer branching and straighter stems (Pederick 1979). It has been found to have poorer cold hardiness (Tibbits and Reid 1987), different floral morphology (Tibbits 1989) and it appears to be characterised by lower pulp yields (Williams *et al.* 1995). It has subsequently been determined to be genetically distinct, and is classified by some taxonomists (Cook and Ladiges 1991) as a different species *E. denticulata.*

<u>Area Planted.</u> The area planted to *E. globulus* and *E. nitens* around the world, has been estimated from published information and responses from a questionnaire sent to organisations. Of the two species, *E. globulus* has by far the largest current total area with about 1,700,000 ha at the end of 1995 (Figure 3a). This is about an order of magnitude bigger than that for *E. nitens,* which stood at about 150,000 ha. Hence, in terms of area planted, *E. globulus* is more significant than *E. nitens.* This is apparently a consequence of a general preference for organisations to establish *E. globulus,* due to its favoured wood properties (see below), and also due to its earlier introduction as a plantation species. *E. nitens* is often planted on sites unsuitable for *E. globulus.*

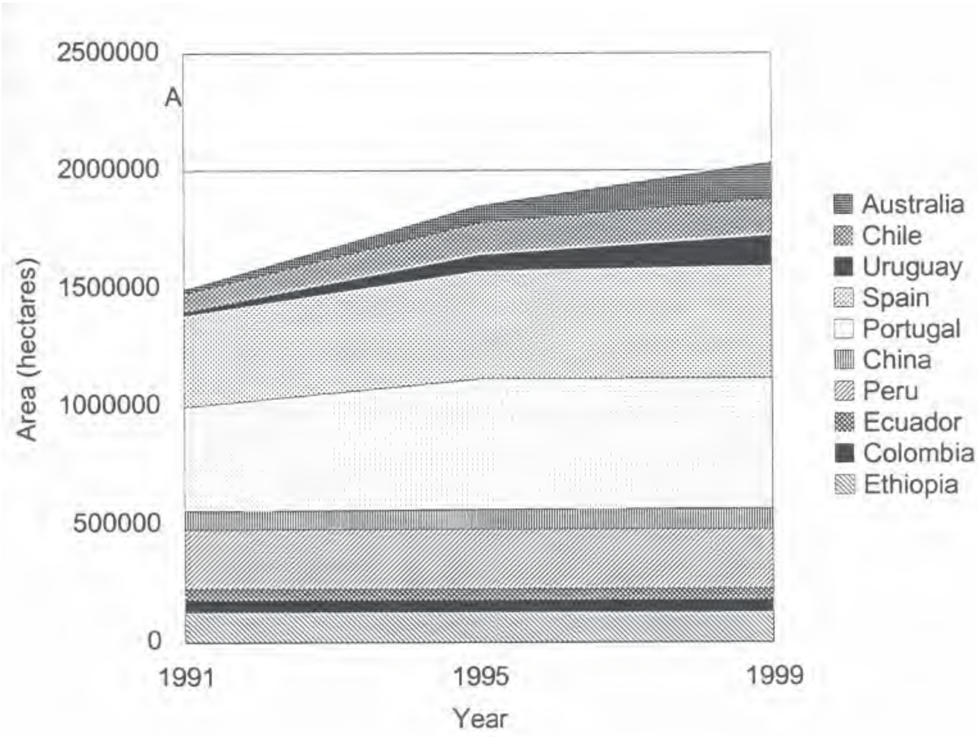
Plantation estimates for *E. globulus* in some countries like Ethiopia, Peru, Colombia and Ecuador are uncertain, and the cumulative figures for these countries reported here account for 30% of the total area (Neilson and Manners 1997). However, where more reliable estimates exist, the most significant areas are undoubtedly in Spain and Portugal, each of which has about equal areas, which together account for 60% of the total world planting of *E. globulus.* The next largest planting is in Chile. China, Australia and Uruguay have approximately equal areas. A number of organisations in Spain and Portugal (Iberia) have plantation estates of *E.* globulus at about 50,000 to 100,000 ha. However, it would appear that the majority of area in Iberia is in very small plantings of a few hectares owned by farmers. In the period 1991 to 1995, about 350,000 ha (20% increase) of new plantations were established, largely in Iberia, Chile, Australia and Uruguay. Based on information supplied by organisations on proposed planting rates, the period 1995 to 1999 may see a further increase of new plantations of about 180,000 ha (10%) to a total of 1,900,000 ha.

E. nitens is concentrated in fewer countries than *E. globulus* (Figure 3b). These are countries where reliable estimates generally exist. The most significant plantings are in Chile with 67,000 ha (45%), Australia with 46,000 ha (30%) and South Africa 26,000 ha (17%). Unlike *E. globulus*, very few of the *E. nitens* plantings are of a few hectares owned by farmers, but are larger industrial plantings. However, only a few organisations have plantation estates of *E. nitens* which exceed 15,000 ha. In the period 1991 to 1995, about 100,000 ha (160% increase) of new plantations were established, largely in these three countries. Based on information supplied by organisations on proposed planting rates, the period 1995 to 1999 may see a further, increase of new plantations of about 70,000 ha (45%) to a total of 220,000 ha.

End-use Focus. The predominant end-use of cultivated *E. globulus* is for the pulp and paper industry. For instance, in Portugal with about 550,000 ha of *E. globulus*, the average use by the pulp and paper industry in 1995 and 1996 was about 3,500,000 m3 of wood free of bark, which was used to produce about 1,100,000 tonnes of haft pulp (the majority being bleached pulp). In Spain, with a similarly large area planted, about 3,300,000 m^3 of wood is currently harvested for the pulp and paper industry (Neilson and Manners 1997). In Chile, the figure is about 1,500,000 m^3 (mostly *E. globulus)* and is forecast to rise *(E. globulus* and *E. nitens)* to something similar to that of Portugal or Spain by the year 2000 (Neilson and Manners 1997). Of the industrial growers of *E. globulus* surveyed, only in China, Argentina and Australia were other end uses indicated. The plantings in China are in Yunnan Province, some distance from any potential pulp and paper processing, and the end uses are posts, sawn timber and fuel wood. In Argentina, it is estimated that 10% of the wood is destined for posts, sawn timber and fuel. Two of 13 Australian organisations indicated that about 5 and 80% of the wood yet to be harvested would possibly end up as sawn timber. The mix of end uses of *E. nitens* is a slightly different story, since only about 4,500 ha is currently harvested annually. The majority of this is in South Africa, where 25% of the wood is used as posts and 75% for the pulp and paper industry. A similar mix of end uses in China exists as for *E. globulus.* Two of seven Australian organisations with *E. nitens* indicated that about 20 and 80% of the wood yet to be harvested would possibly end up as sawn timber, and one indicated about 15% use for veneer.

BIOLOGY

Site Parameters. Eucalypts are fairly site sensitive requiring appropriate matching of species to the climatic factors of the sites. Both *E. globulus* and *E. nitens* are species that perform well in cool temperate climates. The broad latitudinal ranges for *E. globulus* and *E. nitens* are about 30 to 40°N or S, and 35 to 45°N or S, respectively. The species are planted at more equatorial latitudes in places like China, Colombia, Ecuador and South Africa, but at much higher elevations with a temperate climate. The mean annual temperature at these sites is of the order of 11 to 16°C for both species, although in Tasmania, Australia, *E. nitens* is on some sites with a mean annual temperature as low as 8°C (Table 1).



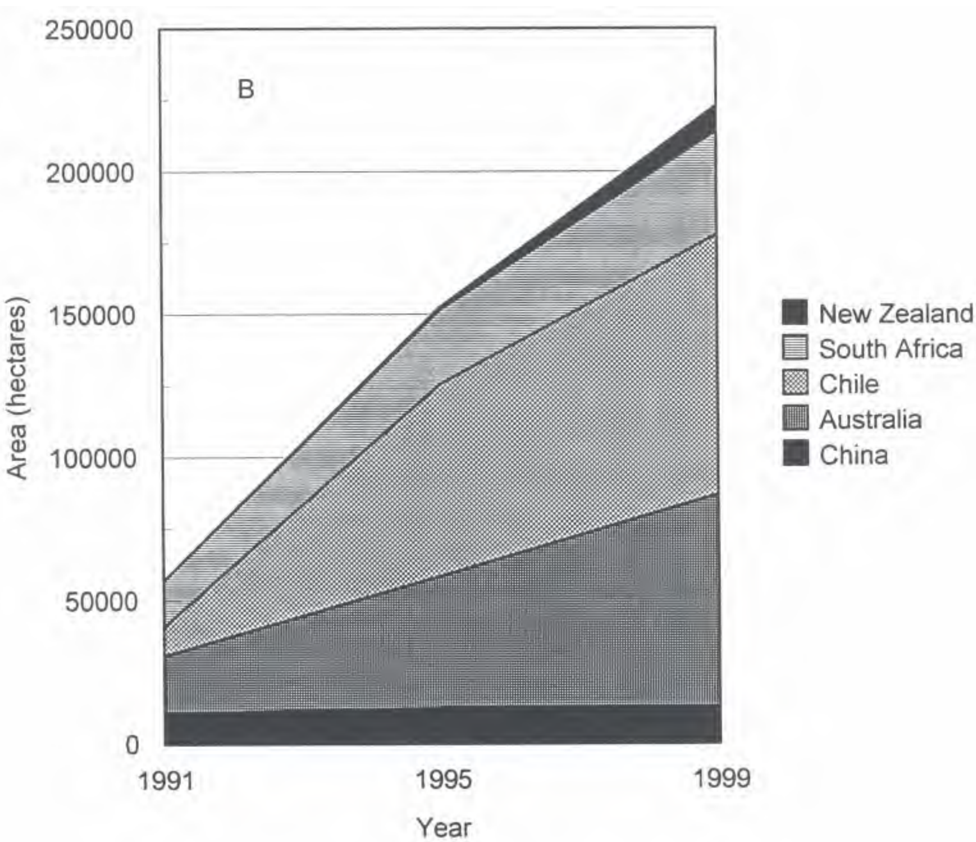


Figure 3. Areas of plantations by country and year for (A) *E. globulus* and (B) *E. nitens.*

E. globulus is generally planted on sites where mean annual rainfall ranges from a low of 500 mm to a high of 2000 mm (Table 1). Whilst *E. nitens* is planted on sites with similar rainfall parameters (Table 1), it tends to be on wetter sites. This would appear to be related to *E. nitens* being established on some higher elevation sites, due to its greater cold hardiness, and the correlated response of increased rainfall with elevation. The establishment of *E. globulus* on the drier sites would appear to support the findings of Honeysett *et al.* (1996) that *E. globulus* is more suited than *E. nitens* where moderate levels of water stress are experienced, and may use less water per unit of volume growth in the early years than *E. nitens*. In the same geographic area, *E. globulus* is generally planted on lower elevation sites than *E. nitens* (Table 1). For instance, in Chile *E. globulus* is generally planted on elevations up to 450 m, whilst *E. nitens* is established up to 800 m elevation. In Tasmania, Australia, *E. globulus* is generally planted on elevations up to 300 m, whilst *E. nitens* is established up to 700 m elevation range. This is related to the greater relative cold hardiness of *E. nitens*. In winter seedlings of *E. nitens* may be about 4°C more hardy (Tibbits *et al.* 1991).

Table 1. Ranges in climatic parameters for areas of some countries where *E. globulus* (g) and *E. nitens* (n) are planted. NZ = New Zealand.

		Parameter			
Country	Species	Rain (mm)	Latitude °)	Altitude(m)	MAT (°C)
Argentina	g	900 - 1000	37 1/2 - 39 S	0- 150	13 - 14
Australia	g	600 - 1600	32 - 43 S	0 - 700	11 - 15
Chile	g	500 - 2000	33 - 41 S	0 - 450	11 - 15
China	g	800 - 1000	24 - 30N	1500 - 2000	14
Colombia	g	1500 +	2 1/2 N	2400 - 2800	10 - 12
Portugal	g	600 +	37 - 42N	0 - 400	12 - 17
Spain	g	700 - 1800	37 - 44N	0 - 1000	12 - 17
Uruguay	g	1000 - 1200	30 - 34 S	100 - 200	15 - 16
Australia	n	650 - 2000	36 1/2 - 43 S	0 - 1100	8-15
Chile	n	800 - 2000	35 - 42 S	0 - 800	11 - 15
China		800 - 1100	24 - 30 N	1500 - 2000	14
NZ		1400 - 2100	37 1/2 - 38 S	0 - 600	14 - 16
Portugal	n	600 +	unclear	400 +	12
Spain	n	900 - 2000	43 - 44 N	400 - 1000	12
South Africa	n	800 - 1100	26 - 35 S	1300 - 1600	12 - 16

Growth Rates. Figure 4 presents the range and average mean annual increment (MAI) for both species, on the basis of some published information and that supplied by organisations planting the species. The more reliable estimates of MAI for *E. globulus* appear from Portugal and Spain, where large areas and volumes are harvested. In Portugal the MAI ranges from 5 to 12 and averages 9 m^3 ha^{-1} year' (Neilson and Manners 1997). Information from Portugal is largely based on under bark volumes for coppice rotations of about 10 years. Genetically improved trees scheduled to be harvested near the end of the century, are estimated by organisations such as Stora Celbi to average 16 m^3 ha-1 year' compared with 10 m^3 ha-1 year' for genetically unimproved trees. In neighbouring Spain, MAI for *E. globulus* is reported to range from 10 to 23 and average 16 m^3 ha-1 year' (Neilson and Manners 1997). Information for other countries appears to be somewhat varied in availability and reliability. In

Chile the *E. globulus* currently being harvested is reported to have a lower than expected range in MAI of 12 to 18 m^3 ha-1 year' due to poor initial management, low survival, effects of cold, and poor soils (Neilson and Manners 1997). However, five major organisations in Chile supplied information to the authors suggesting anticipated MAI averaging about 30 m^3 ha-1 year'. Similar estimates were supplied from organisations in Argentina and Uruguay. In Australia, MAI is based on sparse evidence, but all ten organisations listed their average MAI as 20 to 28 m^3 ha-1 year'. Estimated MAI for China is quite low at about 8 m^3 ha-1 year', which may be due to relatively poor soils.

There are few reliable estimates of MAI for *E. nitens* since there is little at rotation age or being harvested. However, in South Africa both organisations Sappi and Mondi report that MAI is about 13 to 14 m^3 ha-1 year'. In Tasmania, Australia, the organisation with the largest global plantation estate (30,000 ha), North Forest Products, lists its MAI at 18 m^3 ha-1 year', on the basis of extensive inventory plots and a recent commencement of harvesting of small areas. In Chile, the anticipated MAI is generally equal to *E. globulus* (30 m^3 ha-1 year'). Similar estimates were supplied from New Zealand (25 m^3 ha-1 year'). In Australia, the average MM for nine organisations was 20 m^3 ha-1 year'. As for *E. globulus,* MAI for China is quite low at about 9 m^3 ha-1 year'.

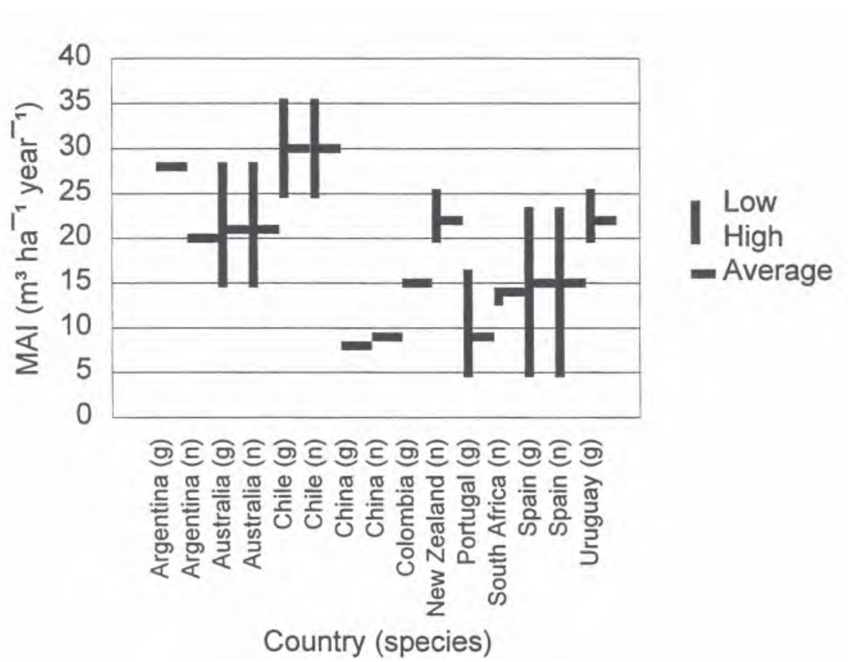


Figure 4. Mean annual increments (MAI) for *E. globulus* (g) and *E. nitens (n).*

Establishment and Management Prescriptions. Cultivation, stocking, fertiliser application, weed control, rotation length, harvesting prescriptions and fire control measures are generally much the same for either *E. globulus* or *E. nitens* for a given organisation. There are various differences amongst organisations and countries. Some are summarised in Table 2. Weed control (not shown in Table 2) is generally with a combination of chemical and mechanical measures often aimed at 100%

control for the first year or two. The effectiveness of chemical weed control can be varied (Wilkinson and Neilsen 1990). No weed control is reported used in China.

Pests and Diseases. A total of 17 types of pests and diseases were listed by organisations planting *E. globulus* and *E. nitens* (Table 2). The greatest number are reported in Australia, where the species naturally occur. Mortality due to browsing by mammals may cost about US $ 100 ha-' in lost net present value (Montague 1996).

Reproductive Biology and Vegetative Propagation. Trees of both species may flower early, often as young as about four years of age. However, quantity and consistency of flower crops have sometimes been a problem. Studies have shown that certain chemicals can be applied to promote flowering (Reid *et al.* 1995). Successful controlled pollination techniques exist for both species (Hardner 1996; Tibbits 1989). Generally *E. nitens* does not propagate readily using cuttings (Tibbits *et al.* 1997) or micropropagation. *E. globulus* propagates more easily, particularly with cuttings.

Table 2. Establishment and management prescriptions for organisations in some countries where *E. globulus* and *E. nitens* are planted. Pests : 1 (Autumn Gum Moth, *Mnesampela privata),* 2 (Leaf Beetles), 3 (Sawfly, *Perga* spp.), 4 *(Gonipterus scutellatus), 5 (Phoracantha semipunctata),* 6 (ants or other insects), 7 (Parrots), 8 (marsupials and other mammals); diseases : 9 *(Mycosphaerella* spp.), 10 (decay fungi), 11 *(Chilecomadia valdiviana),* 12 *(Cryphonectria cubensis),* 13 *(Septoria pulcherima),* 14 *(Botrysphaeria dothidea),* 15 *(Aulographina* spp.), 16 *(Endothia gyrosa),* 17 (Gum tree scale). NZ = New Zealand, SA = South Africa.

Country	Trees ha-'	Fertilizer (g tree-1)	Rotation (y)	Pests /Diseases
Argentina	1,333	unclear	10	none reported
Australia	800 - 1299	100-200	8-25 pulp 40 timber	1,2,3,4,5,6,7,8, 9,10,15,16,17
Chile	1111 - 1667	180-300	10-15	2,5,9,11
China	2200 - 2500	manure	15	none reported
Colombia	1111	100 + 100 NPK	7	9
NZ	1,200	60-200 urea,DAP	10-12	2,8,9,13
Portugal	1000 - 1200	250 NPK	12	5
SA	1143 or 1667	50-100 DAP	10	4,9,12,14
Spain	640 1429 1667	100 NPK	12-18	4,5
Uruguay	unclear	unclear	10	6

Wood Quality Comparisons. There is little published information on the wood quality parameters for pulping of cultivated *E. globulus* and *E. nitens.* Neilson and Manners (1997) list basic densities and kraft pulp yields for harvested *E. globulus* of generally unspecified ages in Spain, Ecuador and Chile ranging from about 560 to almost 600 kg m^{-3} and 54 to 58% respectively. The New Zealand Forest Research Institute (Anon. 1996) list a range in basic densities and kraft pulp yields for twenty 15-year-old *E. nitens* of 435 to 542 kg In^{-3} and 54 to 59% respectively. Basic density and cellulose (from NIRA methodology) at two sites in South Africa for *E. nitens* trees almost at rotation age averaged 540 kg m^{-3} and 52% respectively (ICFR 1993). Site effects can also result in highly significant variation in wood quality. Williams *et al.* (1995)

reported maximum differences in kraft pulp yield of 2.4% points for *E. globulus* and 2.5% points for *E. nitens* over three and four sites.

Direct comparisons of the two species growing well on the same site have seldom been reported. A study by Williams *et al.* (1995) found that at three Tasmanian sites from 60 to 440 m altitude, at eight years of age, kraft pulp yield was generally higher, whilst basic density and pulp productivity (basic density multiplied by pulp yield) were always higher, for *E. globulus* than *E. nitens* (average 54.2% *cf.* 52%, 503 *cf.* 459 kg m^{-3} and 272 kg m^{-3} *cf.* 239 kg m^{-3} respectively). Another study at six years of age on a single Tasmanian site found that whilst kraft pulp yields were approximately equal, basic density and pulp productivity were always higher for *E. globulus* (Tibbits *et al.* 1995). Unpublished data of North Forest Products from seven other Tasmanian sites with trees ranging in age from 5 to 17-year-old supports the generalization that *E. globulus* has about 10% higher basic density and pulp productivity (based on volume, m^{-3}), but only slightly higher kraft pulp yield. There is little information on other pulping processes and relative fibre properties of importance for paper-making. Williams *et al.* (1995) found that cold soda (not kraft) pulps of *E. globulus* had inferior unbleached brightness and light scattering properties, and similar or slightly higher relative energy requirements than *E. nitens*

Table 3. Heritability estimates for growth and wood traits in *E. globulus* (g) and *E. nitens (n)*. *r* is the coefficient of relationship assumed for open-pollinated progeny, whilst CP is for controlled-pollinated progeny. dbh = diameter at breast height, BA = basal area, vol = volume, pilo = pilodyn, BD = basic density and PY = pulp yield.

Species	Reference	r	Trait	Age (y)	h2
g	Volker *et al.* 1990	0.4	vol	6	0.19
g	Borralho *et al.* 1992b	0.33	BA	3 8	0.15 - 0.19
g	Ipinza *et al.* 1994	0.35	dbh	4	0.13
g	Hodge *et al.* 1996	0.5	vol	2	0.10 - 0.26
g	Hodge *et al.* 1996	CP	vol	2	0.13
g	MacDonald *et al.* 1997	0.4	dbh	4	0.2
n	Whiteman *et al.* 1992	0.4	dbh	9	0.18
n	Hodge *et al.* 1996	0.5	vol	2	0.25
n	Hodge *et al.* 1996	CP	vol	2	0.15
n	Johnson 1996	0.4	dbh	5	0.14
n	Tibbits and Hodge unpubl.	0.5	BA	4 7	0.19
g	Dean *et al.* 1990	0.4	PY	8	0.57
g	Dean *et al.* 1990	0.4	BD	8	0.78
g	Borralho *et al.* 1992a	0.33	BD	8 - 9	0.65
g	MacDonald *et al.* 1997	0.4	pilo	6	0.33
n	Greaves *et al.* 1995	0.4	pilo	7	0.6
n	Tibbits and Hodge unpubl.	0.5	PY	6 - 8	0.37
n	Tibbits and Hodge unpubl.	0.5	BD	6 - 8	0.42

Hybrids. There has been considerable interest in assessment of hybrids, since they can be readily produced (Tibbits 1989). Generally speaking F_1 hybrids display intermediate characteristics to both parents (Tibbits *et al.* 1991). The hybrid between these two species is being investigated in Australia, Chile and Portugal. The only operational planing apparently taking place in by Mondi in South Africa (< 5,000 ha), using the combination of *E. nitens* and *E. grandis.* This hybrid is being tested in New Zealand. The wider use of hybrids appears limited to problems with vegetative propagation (Tibbits *et al.* 1997).

GENETICS

Genetic Parameters. In recent years various estimates of heritabilities and genetic correlations for growth, wood quality and other traits have been published. For growth traits, the heritability estimates average about 0.1 to 0.2 for both species (Table 3). However, for wood properties such as basic density, including its indirect assessment using pilodyn, and pulp yield, heritability estimates range from 0.33 to 0.65. It is beyond the scope of this paper to discuss estimates of genetic correlations. Apparently parameter estimates using progeny from native forests may be affected by varied levels of inbreeding and outcrossing. Borralho and Potts (1996) have suggested that in *E. globulus* the growth of native forest open-pollinated families was affected by the density of stand from which the seed originated and corresponding potential differences in levels of inbreeding. Hardner (1996) tested this hypothesis using isozyme markers, and found that lower breeding values were generally associated with lower rates of outcrossing. No similar work has apparently been undertaken or published for *E.* nitens. Selfing is reported to affect seed set (Hardner and Potts 1995; Tibbits 1989) and early growth (Hardner and Potts 1995; Hardner 1996) in both species. Molecular markers have been developed for *E.* globulus (Vaillancourt *et* al. 1995) and *E. nitens* (Byrne *et al.* 1994), but appear to not be in operational use.

IMPROVEMENT PROGRAMS

Commencement of Breeding Programs. Basic statistics related to breeding programs were received from Chile (6), Australia (4), Argentina (1), Portugal (2), Spain (2), New Zealand (1) and South Africa (2). In many instances the information provided in response to questionnaires was incomplete, but nevertheless it was possible to draw a general picture on current activities. The earliest programs in *E. globulus* commenced in the late 1960's (one in Portugal and one in Australia), with the majority beginning in all countries in the late 1980's and early 1990's. For *E. nitens* the earliest program began in the mid 1970's in Australia, but the bulk of programs in all countries commenced in the early 1990's. Breeding cooperatives for these species began in Chile, Australia and New Zealand around 1990.

Breeding Program Size and Generation Information on the size of breeding populations was limited to the number of families or local selections initially under test. For *E. globulus* the smallest initial population size was 145 families, with the majority of programs having 200 to 800 families under test, and four programs had more than 800 families. For *E. nitens,* the initial populations were generally smaller than for *E. globulus,* with the majority of programs having 200 to 500 families under test and only one program with near 800 families. For *E. globulus,* five of the programs (33%) are at the first generation, eight *(c.* 050%) are at the second generation and two *(c.* 15%) are moving to the third generation. For *E. nitens* seven of the programs *(c.* 50%) are at the first generation, five *(c.* 33%) **are at a second** generation and two (*c.* 25%) are into a third generation. Generation interval for both species varied from 4 to 20 years with many in the 8 to 12 years range. Nine out of the 15 *E. globulus* and eight out of the 14 *E. nitens* breeding programs, or just over half the programs, are planning to use controlled pollination (CP) mating schemes.

Table 4. Production Populations (% annual area planted) used currently, and estimate for five years time (shown [0-100] if any change). Sources are ; Prov. = selected native provenance, Race = land race, SPA = seed production area, SSO = seedling seed orchard, CSO = clonal seed orchard, CP = control pollinated seed, clone = stem cuttings. ID is organisation shown in acknowledgments. NZ =New Zealand.

		Source						
Country	ID	Prov.	Race	SPA	SSO	CSO	CP	Clone
E. globulus								
Chile	C1			20[0]		80		[20]
	C2		100[0]			[100]		
	C3			100				
	C4	38[0]	50[0]		12[10]	[70]		[20]
Australia	A1	95[0]		[30]	[30]	[40]		
	A2	40[0]		30	30[50]	[50]		
	A3	74[0]			25[10]	1[85]		[5]
	A4	100[50]			[50]			
	A5				100[75]	[20]	[5]	
	A6	100[40]		[60]				
Portugal	P1						100	
	P2					50[20]		50[80]
Spain	S1	50[15]	20[0	[7]				30[78]
	S2	60[0]	40[0]	[50]	[50]			
E. nitens								
Chile	C1	30[0]		70[100]				
	C2	100				[100]		
	C3			100				
	C4	100[0]			[80]	[20]		
Australia	A2				100[50]	[50]		
	A5	40[0]			100[50]	[50]		
	A7				100			
NZ	NZ1				100[30]	[70]		
Portugal	P1				100			
Spain	S1	100		[50]	[50]			

Breeding Objectives, Traits, Selection Criteria and Analytical Methods. For both species, pulpwood production was the primary focus and was expressed in a number of ways by different companies. The companies in Chile had all included frost tolerance in the breeding objectives for *E. globulus* and *E. nitens.* Sappi from South Africa mentioned fibre quality in their breeding objective for *E. nitens.* Growth was assessed by all programs and measured as volume, basal area, diameter or height for *E. globulus* and *E. nitens.* Half the programs also measured wood density in both species, although it was not clear how many used direct or indirect (pilodyn) approaches. Pulp yield was reported considered or assessed in about 33% of the

E. globulus and 50% of the *E. nitens* programs. Stem straightness and disease resistance were assessed for both species in three programs and one program respectively. Frost resistance in *E.globulus* was assessed by three companies in Chile and one in Australia; for *E. nitens* five companies measured frost resistance. If parent trees were being selected in landrace stands then the age of selection was generally greater than 10 years for half the *E.globulus* breeders, and as old as 40 years for one company. Age of selection for *E. nitens* was generally younger than for *E.globulus* reflecting the younger age of *E. nitens* estates. Age of selection from progeny trials was between 4 and 10 years for both species with selection for frost resistance at less than one year for one company. All breeding efforts are using Best Linear Prediction (BLP), Best Linear Unbiased Prediction (BLUP) or Selection Indices (SI) to rank individuals. Parameters are estimated using Restricted Maximum Likelihood (REML), Gibbs Sampling or SAS procedures, including GLM and VARCOMP.

Production Populations. Table 4 shows the current (1997) and predicted (2002) sources of propagation for some companies growing *E. globulus* and *E. nitens.* Currently for *E. globulus,* there are quite clear differences between countries in the origin of seed and propagules for plantations. In Chile, landrace seed is still important followed by seed from seed production areas. In Spain, selected provenance and landrace origin seed is complemented by some clonal propagation. In Portugal, clonal seed orchards, clonal forestry and mass production of CP seed make up the sources of propagules. In Australia, selected provenance seed (from the native forest) is dominant, followed by seedling seed orchards. Currently for *E. nitens,* in Chile and Spain, again as for *E.globulus,* native provenances and seed production areas supply the seed. Australia, New Zealand and Portugal rely on seedling and clonal seed orchards. In Australia, selected provenance seed (from the native forest) is dominant, followed by seedling seed orchards.

In five years time, all organisations anticipate a shift upwards in genetic quality of propagules. For *E. globulus,* one company in Spain will rely on seedling seed orchards and seed production areas, while the other will move to clonal propagation. Portuguese companies will use clonal propagation and mass CP. Companies in Chile predict that most of their seed will come from clonal seed orchards supported by seedling seed orchards and clonal propagation. In Australia, seedling seed orchards are expected to dominate complemented by clonal seed orchards. For *Eucalyptus nitens,* there is an expectation that seed will be the source of propagules in contrast to *E.globulus.* Seedling seed orchards are expected to dominate in most countries, complemented by seed production areas.

Research Efforts and Priorities . Research priorities listed by 25 organisations (industrial companies, cooperatives and research institutions) from seven countries are listed in Table 5. This should be regarded as a broad picture, since this does not cover all major organisations, and ten of the 25 are from Australia. Nonetheless, the research area of greatest interest appears to be that of wood quality, since it was listed as a priorities in all seven countries and by 15 of the 25 organisations. There are a number of other research areas with apparently similar priority, such as cloning technology, nutrition, pests and diseases, reproductive biology, and weeds. management.

Table 5. Research priorities for organisations (Org.) in Argentina (Ar), Australia (Au), China (Ch), New Zealand (NZ), Portugal (Pt), South Africa (SA) and Spain (Sp).

Research Area	Specific Issues	Org.	Countries
Wood quality	density, pulp yield, fibre properties, mechanical pulping, sawn timber	15	Ar, Au, Ch, NZ, Pt SA, Sp
Cloning	cuttings, micropropagation, embryogenesis	8	Au, Ch, Pt
Nutrition	nutrient balance, fertilizer	6	Au, Ch, Pt
Pests and diseases	management,seed predation, decay	6	Au
Reproductive biology	floral induction, outcrossing rates, orchard management, synchrony, genetic parameters	6	Au, Ch
Weed management	control, prescriptions, cost effectiveness	6	Au, Ch
Silviculture	second rotation, spacing, coppice	5	Au, Ch
Molecular biology	marker-aided selection, genetic engineering	4	Au, Pt
Water relations	drought tolerance, hydrological balance, salinity	4	Au, Pt
Hybrids	testing,clone adaptation	3	Ch, NZ, SA
Genetic parameters	statistical tools, selection, crossing, testing, inbreeding	2	Au

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