SELECTION OF SPECIES FOR SOLID WOOD PRODUCTION IN SOUTHERN CHINA

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CHEN SX, WU ZH, LI ZH, XIE YJ, LI TH, ZHOU QY & ARNOLD R. 2010. Selection of species for solid wood production in southern China. Seven eucalypt species and *Acacia mangium* from a species trial in southern China were assessed for growth, stem form and wood properties at age 6 years. Differences in growth were highly significant for mean tree volume with the order *Eucalyptus urophylla* > *E. cloeziana* > *A. mangium* > *E. grandis* > *E. urophylla* × *grandis* > *E. saligna* > *E. pellita* > *E. torelliana.* There were also significant differences between species for stem form, height to first live branch and stem straightness. Positive correlations were found between height to first live branch and stem straightness. Pilodyn was used to assess variation in wood density and Fakopp was used to indirectly assess modulus of elasticity (MOE). *Eucalyptus cloeziana* had the highest wood density and MOE, while *E. grandis* had the lowest wood density and *E. torelliana,* the lowest MOE. With regard to growth, stem form and wood properties at age 6 years, the order of species for the purpose of conversion of logs into solid wood products was *E. cloeziana* > *E. urophylla* × *grandis* > *E. urophylla* > *E. pellita* > *A. mangium* > *E. grandis* > *E. saligna* > *E. torelliana.*

Keywords: Tree species selection, growth rate, wood basic density, stem form

CHEN SX, WU ZH, LI ZH, XIE YJ, LI TH, ZHOU QY & ARNOLD R. 2010. Pemilihan spesies untuk penghasilan kayu padu di selatan negara China. Tujuh spesies *Eucalyptus* dan *Acacia mangium* daripada ujian spesies di selatan negara China dinilai untuk pertumbuhan, bentuk batang dan ciri-ciri kayu. Pokok-pokok ini berusia enam tahun. Pertumbuhan berbeza secara signifikan dengan purata isi padu pokok *Eucalyptus urophylla* > *E. cloeziana* > *A. mangium* > *E. grandis* > *E. urophylla* × *grandis* > *E. saligna* > *E. pellita* > *E. torelliana.* Perbezaan yang signifikan juga dicerap pada bentuk batang, ketinggian pada aras dahan hidup pertama dan kelurusan batang. Korelasi positif dicerap antara ketinggian pada aras dahan hidup pertama dengan kelurusan batang. Pilodyn digunakan untuk menilai variasi kepadatan kayu. Fakopp pula digunakan untuk menilai modulus kekenyalan (MOE) secara tidak langsung. *Eucalyptus cloeziana* mempunyai kepadatan kayu dan MOE yang tertinggi manakala *E. grandis* mempunyai kepadatan kayu yang terendah dan *E. torelliana,* MOE terendah. Mengambil kira faktor pertumbuhan, bentuk batang dan ciri-ciri kayu pada pokok berusia enam tahun, spesies yang paling sesuai untuk ditebang bagi penghasilan produk kayu padu ialah *E. cloeziana* > *E. urophylla* × *grandis* > *E. urophylla* > *E. pellita* > *A. mangium* > *E. grandis* > *E. saligna* > *E. torelliana.*

INTRODUCTION

Eucalypts were first introduced to China in the 1890s, primarily for ornamental and amenity plantings. Nearly 50 years had passed before the earliest plantations were established in around 1935 (Qi 2002). The first large-scale eucalypt plantations were initiated in the Leizhou Peninsula in the south-west of Guangdong province in the 1950s. From there, plantations expanded into the neighbouring province of Guangxi in the 1960s (Bai & Gan 1996). While more than 300 species of eucalypts are known to have been introduced into China over the past 100 years or so, only about 20 of these have been planted extensively for wood production. Currently there are about 10 species most favoured for commercial plantation establishment (Yisheng *et al.* 2003).

Today, the total area of eucalypt plantations in China is estimated to be over two million hectares (Simpson 2009). The main end-product objective of this resource is wood fibre. Only a very small proportion of the current eucalypt resource in China has been established with a primary end-product objective of solid wood products (Chen 2002). However, there is now increasing interest in China in the establishment of fast-growing plantations, with species such as eucalypts, in

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order to produce higher value timbers to supply solid wood markets (Cai *et al.* 1998). In China, there is enormous demand for hardwood logs for sawing, veneer and other solid wood applications and the majority of this market currently relies on imported timbers. Based on experience and industry developments in other countries, selected eucalypt species and varieties are now seen to have good potential for sustainable plantation production of logs in China to supply such markets (Simpson 2009).

Although the knowledge and technologies for the domestication, selection and genetic improvement of eucalypts for fibre production are highly developed in China, relatively little is known about the growth, silviculture and wood quality of plantation eucalypts for production of higher value solid timber products (Jiang *et al.* 2007, Simpson 2009). Thus, there is an urgent need for more research to be carried out in China to facilitate development of profitable eucalypt plantations for sustainable production of solid wood products.

In this paper, we report the results of growth, stem form and selected wood properties of seven eucalypts and one acacia species from a species trial in southern China. We then looked at how these results could be used to rank the species according to their suitability for use in plantations for solid wood products.

MATERIALS AND METHODS

Trial site

The trial site was located in Zhangmutou Forest Farm, in Dongguang of southern Guangdong province, at a latitude of approximately 22° 53′ N, longitude of approximately 114° 01′ E and an average altitude of 250 m asl. This forest farm has a tropical climate with a mean annual temperature of 23 °C. The mean maximum temperature of the warmest month (July) is 32.2 °C. The mean minimum of the coolest month (January) is 9.2 °C and the number of frost free days per year averages 350. Mean annual rainfall is 1790 mm, with the main wet season from April till August accounting for 70% of the mean annual rainfall. August is the wettest month with mean rainfall of 292 mm and December is the driest month with a mean of only 23 mm.

The topography of the area where the trial site is located is classified as low mountainous and hilly. Soils at Zhangmutou are lateritic red, deeply weathered and derived from granite parent material. Soil depths at the trial site are variable but generally more than 150 cm, with a 5–18 cm layer of top soil, which has gravelly, clay loam texture. The soils have low pHs (mostly < 4.5), medium organic matter content and are relatively low in available phosphorous and nitrogen.

Trial establishment

Site preparation for the trial involved complete clearing of the previous vegetation (pine plantation) followed by manual strip cultivation along the contour line. This was followed by manual spot cultivation with holes of 50 × 50 × 40 cm being excavated. Base fertiliser, comprising 500 g of N:P:K (15:15:15), was then placed in the bottom of each of these planting holes before they were backfilled. Seedlings were planted in these freshly cultivated spots within seven days. Planting distance was 3 × 2 m (1667 trees ha^{-1}). All trees were given additional fertiliser of 200 g of the same compound fertiliser at three months and then 400 g one year after planting. Weed control, involving slashing of all weeds and surface cultivation of a circle of about 1 m diameter around each tree (digging out all weeds to leave a weed free circle), was carried out twice in the first year.

Genetic material and trial design

Seven *Eucalyptus* and one *Acacia* species were included in this trial. The species and their origins are given in Table 1. The trial comprised a randomised complete block design with three replicates. Each species was represented by a contiguous plot of about 60 trees, which was approximately square in shape. Within the interior of each species-plot, a plot of 30 trees (5 rows of 6 trees) was identified for measurement (these plots were placed so as to be approximately equal distance from all plot boundaries, in order to eliminate edge effects). To account for any mortality (less than 5% in all plots), measurement plots were extended to the next row on the uphill edge to acquire sufficient trees to ensure a constant number of trees (i.e. 30) within each measurement plot.

Table 1 Provenance/variety origins and methods of propagation for species included in the species trial at Zhangmutou Forest Farm established in 2002

Species	Provenance/variety	Method of propagation
E. urophylla	Seed orchard seed—Dongmen Forest Farm, Guangxi, China	Seedling
E. torelliana	Unimproved natural stand seed—Kuranda, Queensland, Australia	Seedling
E. saligna	Unimproved natural stand seed—Bellthorpe State Forest, Queensland, Australia	Seedling
E. pellita	Unimproved natural stand seed—Helenvale, Queensland, Australia	Seedling
E. grandis	Unimproved natural stand seed—Windsor Tableland, Queensland, Australia	Seedling
E. cloeziana	Unimproved natural stand seed—Wilsons Pocket, Queensland, Australia	Seedling
E. urophylla × *grandis*	Clone DH32-27 (from Dongmen Forest Farm in Guangxi), China	Rooted cutting
A. mangium	Seed from seed production area, Guangdong, China	Seedling

Assessments

All trees in the interior measurement plot of each species-plot (30 tree plots) were assessed for diameter at breast height (dbh) and total height at age 6 years. Diameters were measured at a height of 1.3 m using metal measuring tapes. Heights were measured using Vertex electronic heighting instruments. Tree volume was calculated for all trees using the following equation:

$$\text{VOL} = \pi \times \left(\frac{\text{dbh}}{200}\right)^2 \times \frac{\text{HT}}{3}$$

where

VOL = canonical index of over-bark tree volume (m^3)
dbh = diameter at breast height (1.3 m) over bark (cm)
HT = total tree height (m)
π = the constant Pi = 3.141593 (6 decimal places)

Three stem form parameters were assessed for each tree: bark thickness, stem straightness, and height to the first live branch. Bark thickness was measured by removing two small squares of bark (approximately 2.5 × 2.5 cm) from each tree at breast height, one from the east side of the bole and the other from the south. The thickness of these samples were then measured directly using a metal rule. Stem straightness was assessed on a subjective 4 point scale. A score of 4 was assigned to trees with stems which (excluding the top 1–2 m of new growth) were essentially completely straight. Score 1 was used for badly kinked or otherwise deformed stems that had no potential of being merchantable for solid wood applications. Scores of 2 and 3 represented gradations of stem straightness between these extremes. Height to the first live branch was measured using Vertex electronic heighting instruments.

To evaluate wood quality, measurements were taken on each tree for wood density and wood stiffness. Both density and wood stiffness are important determinants of wood strength, which affect solid wood value. Wood density was assessed indirectly using a pilodyn instrument (6-Joule pilodyn fitted with a pin of 2 mm thickness). The pilodyn instrument drives a steel pin into the tree with a precise force. The depth to which the pin penetrates is indicated on the instrument and is inversely proportional to the density of the wood. While the pilodyn does not provide an estimate of actual wood density, it is known to be efficient for ranking groups of trees into wood density classes within sites (Hansen 2000, Ilic *et al.* 2000) and, thus, was seen to be appropriate for this study. Two pilodyn pin penetration readings were taken for each tree at breast height—one on the east side of the bole and the other on the south side, at the places where squares of bark had been removed for determination of bark thickness.

Stiffness of the outer wood of each tree was assessed by measuring acoustic velocity using a Fakopp time of flight instrument. Modulus of elasticity (MOE) was then estimated from the Fakopp reading of acoustic velocity as follows (Grabianowski *et al.* 2004):

$$MOE = \rho V^2$$

where

MOE = modulus of elasticity (MPa)
ρ = wood basic density (kg m^{-3})
V = acoustic velocity, calculated from the reading obtained from the Fakopp instrument (km s^{-1})

To obtain estimates of wood density values of each species for computation of MOEs, a published basic density estimate for young plantation-grown *E. grandis* wood of 455 kg m^{-3} (Downes *et al.* 1997) was assumed to be a known standard. As wood basic density is the ratio of the weight of the oven-dried sample to its green volume (Ilic *et al.* 2000), it is not moisture content dependent. For each of the eight species in the Zhangmutou trial, wood basic density was then obtained by adjusting the basic density assumed for *E. grandis* according to the mean pilodyn penetration for that species relative to that for *E. grandis* using the following equation:

$$\rho_{species} = \rho_{grandis}\left(1 + \frac{Pil_{grandis} - Pil_{species}}{Pil_{grandis}}\right)$$

where

$\rho_{species}$ = estimated density of the particular species under test (kg m^{-3})
$\rho_{grandis}$ = published basic density of *E. grandis* = 455 kg m^{-3}
$Pil_{grandis}$ = mean pilodyn penetration depth for *E. grandis*
$Pil_{species}$ = mean pilodyn penetration depth for the species under test

While these wood basic density estimates may not provide accurate values for the species growing at Zhangmutou, the relativity of the estimates to one another is considered adequate for the purposes of this study.

Data analyses

Analyses of variance were carried out on individual tree data to evaluate the significance of difference between species for the growth, stem form and wood quality traits. These analyses were carried out using the SPSS statistical software package.

RESULTS AND DISCUSSION

Growth and stem form

Analyses of variance revealed that highly significant differences ($p < 0.01$) existed between species for all growth and stem form traits assessed in this study. Species means and coefficients of variation for each of these traits are shown in Table 2.

For growth, the best species at age 6 years was *E. urophylla* with a mean dbh, height and stem volume of 16.3 cm, 15.1 m and 0.155 m^3 respectively. *Eucalyptus cloeziana* and *A. mangium* also grew very well, ranking second and third with mean stem volumes of 0.128 m^3 and 0.112 m^3 respectively. The species with the poorest overall growth was *E. torelliana* with a mean dbh, height and stem volume of 11.5 cm, 10.9 m and 0.063 m^3 respectively.

While the ranking of species by dbh followed that of stem volume, the ranking by height did not. *Acacia mangium* which ranked third by dbh and stem volume only managed fifth for height. In contrast, the hybrid *E. urophylla* × *grandis* which ranked fifth for dbh and stem volume, ranked second for height.

In terms of variation of growth within species, the least variable species as judged by coefficient of variation (CV) was *E. urophylla* × *grandis* and the most variable were *E. pellita* and *A. mangium* (Table 2). The rank of all species by variability of stem volume was *A. mangium* > *E. pellita* > *E. torelliana* > *E. grandis* > *E. saligna* > *E. cloeziana* > *E. urophylla* > *E. urophylla* × *grandis*. The relatively low variability within *E. urophylla* × *grandis* compared with the other species was as expected; it was represented by vegetatively propagated stock of a single clone while all the other species were represented by seedlings and, therefore, had potential for significant tree to tree genetic variability.

Table 2 Means and coefficients of variation (CV) for species growth and stem form traits at age 6 years in the species trial at Zhangmutou Forest Farm established in 2002

Tree species	Over-bark diameter		Height		Over-bark volume		Bark thickness		Height to 1st live branch		Stem form score		Under-bark dbh	
	Mean (cm)	CV %	Mean (m)	CV %	Mean (m^3)	CV %	Mean (cm)	CV %	Mean (m)	CV %	Mean	CV %	Mean (cm)	CV %
E. urophylla	16.3 a	8.7	15.1 a	13.7	0.1549 a	29.8	1.12 a	33.5	6.2 bcd	48.4	2.4 ab	29.2	14.1 a	10.7
E. torelliana	11.5 d	16.9	10.9 f	22.8	0.0633 e	54.8	0.49 f	33.7	4.5 e	42.2	2.0 b	43.0	10.5 d	18.5
E. saligna	12.8 cd	8.4	12.9 de	20.2	0.0874 cde	47.0	0.64 d	24.2	5.6 de	37.5	2.1 b	41.9	11.6 cde	9.6
E. pellita	12.5 cd	15.6	12.0 e	23.4	0.0806 de	56.5	0.99 b	28.9	7.5 b	26.7	2.4 ab	25.8	10.5 d	19.0
E. grandis	13.8 bc	12.7	14.0 bc	20.5	0.1088 bc	47.6	0.63 de	28.6	7.2 bc	37.5	2.3 ab	32.2	12.5 bc	14.1
E. cloeziana	15.1 ab	10.9	14.2 abc	16.3	0.1284 ab	39.5	0.80 c	23.8	6.0 bcd	43.3	2.3 ab	33.0	13.5 ab	12.4
E. urophylla × grandis	13.1 cd	5.0	14.8 ab	9.0	0.0965 cd	20.6	0.51 ef	22.5	11.8 a	12.7	2.6 a	19.2	12.1 bcd	5.6
A. mangium	14.1 bc	9.4	13.4 cd	27.2	0.1120 bc	58.1	0.54 def	29.6	4.9 de	26.5	1.4 c	39.3	13.0 abc	10.3
Least significant difference ($p < 0.05$)	1.7		1.0		0.0274		0.13		1.5		0.5		1.56	

Means within a column followed by the same letter are not significantly different as judged by Fisher's Least Significant Difference (LSD) at $p < 0.05$.

Although bark thickness was measured from two directions, initial analyses showed that there were no significant differences between the two, indicating that bark distribution around the tree stems was even in each of the species. Subsequently, a single bark thickness value was derived for each tree. The bark thickness values shown in Table 2 were obtained from taking the mean of the combined values for each tree within each species. While the species with the thickest bark, *E. urophylla*, was also the species with the largest dbh and the species with the thinnest bark was that with the lowest dbh, *E. torelliana*, this trend was not present among the species ranking intermediate for either trait. For example, *E. cloeziana* and *A. mangium* which ranked second and third for dbh respectively were ranked third and sixth respectively by thickness of their bark at breast height.

Despite the existence of significant differences between species for bark thickness, the relatively small magnitude of these variations combined with the generally thin bark of all eight trial species resulted in species rankings by under-bark dbh (where under-bark dbh = over-bark dbh – 2 × bark thickness) being the same as their ranking by over-bark dbh. Thus, rank results presented here for over-bark dbh and volume were deemed appropriate for comparing this group of species for their wood production potential.

With regard to stem form traits, the best species for both height to first live branch and stem form score was *E. urophylla* × *grandis* (Table 2). In contrast, *E. torelliana* and *A. mangium* ranked poorest for both these traits. Indeed, the stem form of *A. mangium* was markedly lower than any of the eucalypt species.

The reasons for the inclusion of the trait 'height to the first live branch' in this study are the fact that it is considered an important index of tree crown structure and it has been found to vary sensitively with stem form (Shu 2008). To evaluate the relationship between these traits in this group of species, correlation analysis was carried out and it revealed that height to first live branch was significantly and positively correlated with stem form score across the eight species; the value of the correlation coefficient (r) was 0.69 (significant at $p = 0.059$) (not shown).

Wood properties

There were significant differences ($p < 0.01$) between species for pilodyn pin penetration on both the south and east sides (Table 3). However, within each species differences in the means of pilodyn pin penetrations from the two directions were small and not significant. As depth of pilodyn pin penetration is generally negatively correlated with wood density, the greater pin penetration indicates lower wood density (Ilic *et al.* 2000). For example, in 12-year-old *E. nitens* trials across three sites in Tasmania, Kube and Raymond (2002) found that basic density and pilodyn penetration had very strong negative phenotypic and genetic correlations (about -0.90). Thus, in this trial, the species with the lowest pilodyn pin penetration, *E. cloeziana*, will have the highest wood density. The ranking of the other species by decreasing wood density was *E. pellita* > *E. urophylla* × *grandis* > *E. torelliana* > *E. saligna* > *E. urophylla* > *A. mangium* > *E. grandis*.

The mean acoustic velocities by species and the estimated mean MOEs (calculated from the mean acoustic velocities and mean wood densities) for each species are shown in Table 3. In this trial, the wood of *E. cloeziana* was found to have the highest estimated average MOE (8.36 GPa) while *E. torelliana* had the lowest (4.64 GPa). The ranking of all eight species for estimated MOE was *E. cloeziana* > *E. urophylla* × *grandis* > *E. pellita* > *E. urophylla* > *E. saligna* > *E. grandis* > *A. mangium* > *E. torelliana*.

Growth and wood quality combined

The yield of merchantable timber and the quality of that timber are key factors in determining the commercial value of a forest plantation. Any enterprise that integrates growing timber (i.e. forest plantations) with processing of the timber from its own plantations (e.g. sawmilling and/or veneer production) will want to optimise both the volume yields and timber quality in order to optimise market opportunities and the financial return on investments.

One of the most critical decisions that will determine both yield and timber quality is the choice of species. To identify potentially suitable species, the first consideration must be adaptability and growth potential in the target planting environment. In choice of species, due consideration must also be given to the variety within a species—selection and genetic improvement can substantially increase growth and yield of any one species.

After volume, stem form is one of the most important external stem quality parameters that

Table 3 Mean pilodyn penetration, mean acoustic velocity, wood basic density and modulus of elasticity at age 6 years for species in the trial at Zhangmutou Forest Farm established in 2002

Species	Pilodyn penetration (mm)	Acoustic velocity (km s^{-1})	Wood basic density (kg m^{-3})	Modulus of elasticity (GPa)
E. urophylla	13.5 cd	3.625 b	468	6.15 c
E. torelliana	12.6 bc	3.055 e	498	4.64 e
E. saligna	13.2 bcd	3.351 cd	480	5.38 d
E. pellita	12.2 b	3.710 ab	511	7.03 b
E. grandis	13.9 d	3.436 c	455	5.37 d
E. cloeziana	10.4 a	3.830 a	570	8.36 a
E. urophylla × *grandis*	12.3 b	3.723 ab	509	7.05 b
A. mangium	13.6 cd	3.258 d	465	4.93 de
Least significant difference ($p < 0.05$)	1.1	0.169	na	0.59

LSD could not be obtained for wood basic density values as these were derived on a species mean basis as described in the materials and methods.
Means within a column followed by the same letter are not significantly different as judged by Fisher's Least Significant Difference (LSD) at $p < 0.05$; na = not available.

affect timber quality and value; it is often used as a criterion for grading of sawlogs and it has strong influence on lumber recovery and mechanical properties of the sawn lumber (Jiang *et al.* 2007, Tonga & Zhang 2008). Good stem form increases yield of sawn lumber (and/or veneer), while bad stem form can considerably reduce the potential for the recovery of straight sawn lumber and also reduce lumber quality due to the presence of reaction wood (Hillis & Brown 1984).

In processed timber, an important determinant of both value and utility is typically wood strength. Both wood density and MOE show strong positive correlations with this trait and thus both are often used as indirect measures of wood strength. For wood density, the pilodyn wood tester was used in this study to test resistance to penetration and subsequently indicate wood density. MOE is an important wood quality attribute which indicates stiffness and flexibility of timber. Timber with a low MOE has low stiffness and lower strength and this generally results in lower market value (Jiang *et al.* 2007). Timber which has higher stiffness has a higher MOE and this is generally correlated with higher strength and results in higher values.

In order to devise an integrated ranking of the species included in the Zhangmutou trial, a multi-trait index was devised to combine the species' means for growth, stem form and wood properties into a single quantitative measure. For this, the species means at age 6 years for each trait were standardised to have a mean of 5.0 and standard deviation of 2.0. This standardisation of species means was undertaken for the traits: volume, stem form, bark thickness, pilodyn penetration and MOE. Then, for each trait the standardised means were multiplied by an appropriate weighting factor for that trait to provide a trait score for each species. An overall index score for each species was then obtained as the sum of its scores for the five traits (Table 4). The weighting factors applied were obtained subjectively by consensus among a group of scientists from the China Eucalypt Research Centre. Volume, stem form and MOE were considered to be equally important to the yield and value of solid wood obtained, with higher values of each being desirable and hence these were each given index weightings of 1.0. Thin bark is generally considered desirable although in some locations bark itself has value as a fuel source and hence it was given an index weighting of -0.5. As pilodyn penetration is inversely proportional to the density of the wood, this trait was also given a negative index weighting (lower pilodyn penetration indicating higher wood density being desirable) but as it did not provide an estimate of actual wood density it was decided to only give it a weighting of magnitude 0.5.

The overall solid wood production potential index scores obtained for the species (see Table 4) indicated that the best species in the Zhangmutuo environment were *E. cloeziana* and the hybrid *E. urophylla* × *grandis* (16.3 and 14.6 respectively). As judged by the total index scores, both species were markedly superior compared with the other six species; *E cloeziana* provided good growth, reasonable stem form and both high wood density (low pilodyn penetration) and high MOE, while *E. urophylla* × *grandis,* despite having only mediocre growth, did have excellent stem form, and reasonable wood density and above average MOE. The two species with the lowest index scores were *E. torelliana* and *E. saligna* (3.6 and 6.5 respectively). The former had the poorest growth, stem form and MOE, though it did have above average wood density. The latter species had only mediocre growth but below average stem form, wood density and MOE. The intermediate species, ranked by their index scores were in the order *E. urophylla* > *E. pellita* > *A. mangium* > *E. grandis*.

CONCLUSIONS

Obvious differences were found in growth, stem form and wood properties between the eight species included in the species trial in southern Guangdong. Overall, the best species proved to be *E. cloeziana* and *E. urophylla* × *grandis* — they were particularly well suited for production of logs for sawn timber products in plantation environments typified by Zhangmutou on account of their good growth, stem form and favourable wood properties. Although *A. mangium* had reasonable growth, its stem form and timber strength (as indicated by pilodyn penetration and MOE) were markedly inferior to most of the eucalypt species tested. Of the eucalypts, the poorest were *E. torelliana* and *E. saligna*; both suffered from below average growth, stem form and *E. saligna* had generally inferior wood properties.

Although the results obtained in this study clearly favoured *E. cloeziana* and *E. urophylla* × *grandis,* the study could not be regarded as conclusive of their commercial potential for plantation production of timbers suitable for solid wood products. A number of other important wood properties need further analyses

Table 4 Overall evaluation of the eight species included in trial at Zhangmutou Forest Farm, for production of logs for solid wood products

Species	Standardised score for each trait					Total index score
	Volume	Stem form	Bark thickness	Pilodyn penetration	Modulus of elasticity	
E. urophylla	8.5	4.6	6.2	6.4	5.1	11.9
E. torelliana	2.2	3.1	4.0	4.8	2.7	3.6
E. saligna	3.8	4.0	4.5	5.9	3.9	6.5
E. pellita	3.4	5.7	6.2	4.1	6.4	10.4
E. grandis	5.3	5.4	5.6	7.1	3.8	8.2
E. cloeziana	6.7	4.4	5.6	0.9	8.5	16.3
E. urophylla × *grandis*	4.5	9.4	7.2	4.3	6.5	14.6
A. mangium	5.6	3.4	0.7	6.6	3.1	8.5
Index weighting for trait	1.0	1.0	-0.5	-0.5	1.0	–

The higher the total index score the better the species is for plantation production of such products. The species standardised scores for a trait were obtained by standardising the actual species means for that trait to have a mean of 5.0 and standard deviation of 2.0. The total index score for each species was obtained by summing the products of standardised trait score by the index weighting for trait across the five traits of volume, stem form, bark thickness, pilodyn penetration and modulus of elasticity.

to confirm their potential for any particular wood processing facility such as growth stresses (which can lead to distortion upon seasoning, cracking and end splitting); brittle heart; seasoning collapse and checking; and a number of wood surface properties.

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