EUCALYPTUS LONGIROSTRATA: A POTENTIAL SPECIES FOR AUSTRALIA'S TOUGHER SITES?

M. HENSON[*], H. J. SMITH and S. BOYTON

Forests NSW

PO Box J19, Coffs Harbour Jetty NSW 2450 Australia

ABSTRACT

Eucalyptus longirostrata (grey gum) has shown good potential over a range of sites in New South Wales (NSW) and Queensland, Australia and in coastal Zululand, South Africa and is reported to have acceptable pulpwood quality. Hybrids of *E. grandis* × *E. longirostrata* are also showing promise in South Africa.

Forests NSW established six progeny trials, in the Hunter Valley and northern NSW, Australia, with a total of 79 families of *E. longirostrata* in two trial series in 2004 and 2005. A third series of trials, with 74 families, is to be planted on five sites during 2007. The three trial series will contain a total of 121 families from eight provenances.

The 2004 series of trials located near Casino and Grafton (northern NSW) and Singleton (Hunter Valley) were assessed at age 31 months for growth and form traits. Survival was high on all three sites ranging from 89% (Grafton) to 95% (Singleton). Height growth was greatest at Grafton (trial mean 8.6 m) with the poorest growth recorded at Singleton (trial mean 2.4 m) reflecting the severe drought conditions at this site. Height was under moderate to high genetic control with heritabilities (h^2) for height at 31 months of 0.34, 0.49 and 0.33 at the Casino, Grafton and Singleton trials, respectively. The across site correlations for all traits measured were high, suggesting that at age 31 months there is little genetic × environment interaction across the range of site types.

Keywords: *Eucalyptus longirostrata*, low rainfall, marginal sites, Genotype by Environment interaction.

[*] Corresponding author: Michael.Henson@sf.nsw.gov.au

INTRODUCTION

Eucalyptus longirostrata (Blakely) L.A.S. Johnson & K.D. Hill (grey gum) has a natural distribution in south-eastern Queensland from Toowoomba northwards to Maryborough and extending northwest and west to Monto, the Expedition Range and the Blackdown Tableland (Brooker & Kleinig 2004). The species grows on a range sites on low hills and ridges on shallow soils derived from sandstone (Boland *et al.* 2006), within the 700–1200 mm rainfall zone, with a summer maximum rainfall. The species is tolerant of poor, shallow soils and has shown potential for growth on a range of sites in Queensland (Lee *et al.* 2003).

The taxonomy of the grey gums has been revised (Chippendale 1988). Previously a subspecies of *Eucalyptus punctata* DC., *E. longirostrata* was elevated to species in its own right, although is still grouped with *E. punctata* and *Eucalyptus propinqua* Deane & Maiden as a grey gum in the series *Lepidotae-Fimbriatae* (Brooker 2000). As a closely allied species to *Eucalyptus punctata* (Boland *et al*. 2006), the wood is expected to be of similar quality. The wood from native forests is of high density (basic density 850 kg m^{-3}), with highly durable heartwood (Class 1) and is used for heavy engineering construction, poles and sleepers (Timber Development Association (NSW) Ltd 2003; Bootle 2005). Plantation-grown wood was found in one study to have a basic density of 574–637 kg m^{-3} (Gardner e*t al.* 2007).

Gardner (2001) reported that *E. longirostrata* performed well over a range of sites in coastal Zululand, South Africa, comparing favourably with commercial clones of *E. grandis* × *E. urophylla* and *E. grandis* × *E. camaldulensis* for tree growth and wood–volume, low disease incidence, screened pulp yield and “pulp ability” factor. In the same series of trials, trees of this species were also found to have wood density suitable for wood-chip export (Gardner *et al.* 2007). The species was also found to be promising over a range of sites from high rainfall coastal regions in central and southern Queensland to the lower rainfall regions in the dry tropics in north Queensland and to the Darling Downs in the south, based on 3 to 5 year old growth data from species trials conducted throughout the state (Lee *et al*. 2003).

The Forests NSW hardwood estate has traditionally been established in higher rainfall areas, particularly on the north coast of NSW. With current alternative uses and high costs for land, the availability of sites for plantation establishment in this region is becoming rarer and less economic to plant. There is pressure to move into more marginal sites which generally have lower rainfall and poorer soils, with the aim of planting species that are suitably productive within these environments to produce a plantation which is economic to harvest. In addition, it has been recognised that there can be both economic and environmental benefits in planting trees in low rainfall and marginal agricultural sites. Planting of trees on these sites can reduce erosion, mitigate salinity, enhance biodiversity and may assist in mitigating the impacts of climate change by long term sequestration of carbon (Rural Industries Research and Development Corporation 2000).

BREEDING STRATEGY

Forests NSW is focusing on *E. longirostrata* as a species for planting on sites that are currently considered marginal for the establishment of economically viable plantations, with low mean annual rainfall (MAR 550–800 mm) and often poor quality soils. The species is being evaluated on these sites for deployment as a pure species or in hybrid combinations with other species such *Eucalyptus dunnii* Maiden or *Eucalyptus pellita* F.Muell.

Since 2004 Forests NSW has established two series of progeny trials of *E. longirostrata* across site types ranging from harsh dry sites in the Hunter Valley, with planting on mine overburden, to a relative fertile soil with MAR of 1000 mm north of Grafton. A third series of trials is being established during 2007, including trials on the problematic lowland sites of the Clarence Valley.

In 2006 Forests NSW received funding to develop elite germplasm of *Eucalyptus* species suitable for planting on marginal sites, as potential mitigation and adaptation mechanisms to climate change. This work will focus on improving the productivity and density of a range of emerging commercial species including *E. longirostrata.*

GENETIC RESOURCES

During 2004 and 2005 Forests NSW established six progeny trials of *E. longirostrata* (Figure 1) and plan to establish a further five sites in 2007. The three trial series are comprised of a total of 121 families from eight provenances (Table 1, Figure 1), representing the natural range of the species. The CSIRO Australian Tree Seed Centre Seedlot No. 20464 has been accessioned with a provenance name of "Moura", however the provenance name could be more appropriately named as Coominglah (D. Kleinig, Brisbane *pers. comm*., 2006), and it is this name that has been used in this paper.

[Insert Table 1 near here]

[Insert Figure 1 near here]

METHODS

Sites

Three progeny trials of *E. longirostrata* were established in early 2004 at sites near Grafton, Casino and Singleton (Table 2), with 20 replicates of each treatment (family) in single tree plots, in a row-column design. The MAR shown in Table 2 is the long term average rainfall at the nearest Bureau of Meteorology Climate Station, although owing to the drought conditions, the actual rainfall was less during the three year period (2004–2006) between establishment and assessment of trials. The actual rainfall for 2006 at the Singleton site was only 457 mm, but the rainfall at the Grafton and Casino sites, although lower than normal, was closer to the average (Australian Government Bureau of Meteorology 2007). The Singleton trial is established on mine overburden and on a ridge with minimal top soil. A soil survey in 2005 reported a very high A Horizon soil pH for the site with some areas having a pH of over 10.

[Insert Table 2 near here]

Silviculture

All sites had mechanical strip cultivation consisting of a single pass that ripped and mounded. Spacing in all trials was 4 m between rows and 2 m between trees within the row, giving a stocking of 1250 trees per hectare. The trials were fertilised at planting with a custom blend fertiliser of N:P:K (8:18:5) with micronutrients, at a rate of 100 g per tree. The planting stock was grown from seed in Hiko V-93 containers in the Forests NSW Grafton Nursery.

Treatments

The Grafton and Casino trials contain 47 *E. longirostrata* families from six provenances (seven CSIRO ATSC seedlots) and the third trial located near Singleton in the Hunter

Valley is comprised of 42 families. Both the Grafton and Casino trials included a commercial seedlot of *E. propinqua* as a control.

Assessments

In September and October 2006 the three trials were assessed for total tree height (HT), diameter at breast height over bark (DBH) and stem straightness. Diameter was not assessed at the Singleton site owing to the small size of the trees, which only had a mean height of 2.4 m at 30 months. Conical Individual Tree Volume was calculated from the measured HT and DBH using the equation below and a form factor of 35%.

$$\text{Volume}_{\text{(individual tree)}} = ff \times \pi \times HT \times DBH^2$$

where Volume is in m^3, ff is the form factor of 0.35, π = pi (3.14), HT is the height of the tree in m, and DBH is the diameter over bark of the tree in m.

All trees were assessed for stem straightness. This assessment is a subjective score of 1 to 6, with 1 being least straight and 6 being most straight. Stem straightness scores are independent of site and time variations, with a specific evaluation of the best and worst trees for each site being made at each assessment. The scoring system is biased to attempt to produce an approximately normal distribution, *i.e.*, 5% of all trees with a score of 1, 15% of trees with 2, 30% of trees with 3, 30% of trees with 4, 15% of trees with 5 and 5% of trees with 6.

Analyses

An Individual Tree Model in ASREML (Version 2.00a Build P) (Gilmour *et al.* 2006) was used to analyse the trial data. The following mixed model was used:

$$y = X\beta + Za + e$$

where y is a vector of phenotypic observations, β is the vector of fixed effects (Replicate and Seedlot), a is a vector of genetic effects and e is a vector of residuals. X and Z are design matrices linking phenotypic observations with fixed and random effects. Narrow sense heritability (h^2) was calculated using a coefficient of relatedness of 0.25 assuming fully out-crossed progeny.

The genetic correlations between sites and traits were estimated in ASREML using an Individual Tree Model, with Replicate and Seedlot as fixed effects.

RESULTS

Survival at 30–31 months was good at all three sites (Table 3) ranging between 89% (Grafton) and 95% (Singleton). The Grafton trial was the best performing in terms of growth with a mean trial height of 8.6 m at 31 months, mean trial DBH of 8.7cm and a mean annual increment (MAI) for volume of 9 m^3 ha^{-1}. The Casino site had intermediate growth (mean height 5.75 m and DBH 6.1 cm at 30 months). The Singleton site was the least productive with a mean height of only 2.4 m at 30 months. Although the MAR for Singleton is 724 mm (1969–1990), in 2006 the centre recorded only 457 mm of rain and less than average rainfall also occurred in 2004 and 2005. The drought was not as pronounced in the two northern sites, with the sites receiving between 80% and 90% of their average rainfall (Australian Government Bureau of Meteorology 2007). The assessment data for the three trials is summarised in Table 3.
[Insert Table 3 near here]

Provenance Performance

Significant differences (P<0.05) between seedlots (provenances) were found for height at all three sites (Table 4). The high altitude (900 m) provenance, Blackdown Tableland, had the poorest height performance in each of the three trials. All provenances of *E. longirostrata* in the Grafton and Casino trials showed superior growth performance over the bulk *E. propinqua* control. The *E. propinqua* control was not planted in the Singleton trial.

Significant differences (P<0.001) between provenances existed for individual tree volume in the Casino trial but the differences were less significant (P=0.051) in the Grafton trial. Blackdown Tableland was the worst performing *E. longirostrata* provenance for volume at the Grafton site, although Barakula provenance had the lowest mean individual tree volume in the Casino trial. In both trials where volume was assessed (Grafton and Casino), the *E. propinqua* performance was inferior to the performance of all *E. longirostrata* provenances. No significant differences (P<0.05) existed between provenances for stem straightness in the three trials and the *E. propinqua* performance was not significantly different from that of *E. longirostrata* for this trait.
[Insert Table 4 near here]

There appears to be a general trend that northern provenances have better growth performance than the more southern provenances, within the group of provenances with mid-range altitudes (300 m to 500 m). This is supported by results from two trials in Zululand, South Africa (Gardner 2007) in which *E. longirostrata* from Monto (24°49′S) had higher productivity than the more southern Gympie (26°18′S) provenance.

Genetic Parameters

Height was found to be under moderate to high genetic control at the three sites with narrow sense heritability (h^2) ranging from 0.33 in the Casino and Singleton trials to 0.49 in the Grafton trial (Table 5). Stem straightness was under moderate genetic control in all three trials with narrow sense heritability (h^2) ranging from 0.38 at Grafton to 0.45 at Singleton.

The genetic correlation between growth traits was very high (>0.93) in the Grafton and Casino trials and between growth traits and stem straightness was high (>0.66) at all three trial sites. The within site heritability, genetic correlations and phenotypic correlations at the three trial sites is shown in Table 5.

[Insert Table 5 near here]

Across Site Correlations

Across site genetic correlations for height were high (Figure 2), ranging from 0.76 (0.22) between the Casino and Singleton sites to 0.95 (0.13) between the Casino and Grafton sites. The across site correlations for DBH and volume between the Casino and Grafton trials were 0.88 (0.14) and 0.79 (0.19) respectively. For stem straightness, the across site genetic correlations were very high (Figure 2) with the lowest correlation of 0.91 (0.16) between the Casino and Singleton sites.

[Insert Figure 2 near here]

DISCUSSION

The early survival, growth and stem straightness results demonstrate that *E. longirostrata* has potential as a commercial plantation species in NSW. The species has shown particular promise on marginal sites with poor site quality and low rainfall, where other species have not performed well. The severe drought in the Singleton region over the past three years since planting (2006 rainfall 457 mm) would account for the poor productivity on this site compared to the other two sites.

Provenance performance and family performance within provenance for early growth and form is stable across the range of sites. The high across site correlations suggest that there is little Genetic by Environment (G x E) interaction for family performance within provenance, for either early growth traits or stem straightness across a range of different site types. Therefore superior trees selected at one site should perform well at other sites. Genetic by Environment interaction may become more significant as the trials age and the across site performance of the material should continue to be monitored.

Results from two species trials in South Africa (Gardner 2007) demonstrated that at age 7 years *E. longirostrata* was found to have excellent potential for high productivity (wet – MAR 1197 mm) sites in Zululand, on the basis of merchantable wood production and fibre production. Gardner (2007) also reported that *Corymbia henyri* (S.T. Blake) K.D. Hill & L.A.S. Johnson and *Corymbia citriodora* (Hook.) K.D. Hill & L.A.S. Johnson subsp. *citriodora* showed greater potential than *E. longirostrata* on a low rainfall site (MAR 764 mm) in the same region. Forests NSW results from early trial assessments on the lowest rainfall site, Singleton, differ from the latter findings. Progeny trials of *Corymbia* spp. (spotted gums) have been established on all sites that the *E. longirostrata* trials are planted, selecting a suitable species for each site type. On the Singleton site the adjacent trial of *Corymbia maculata* (Hook.) K.D. Hill & L.A.S. Johnson, when assessed at age 34 months, had lower survival than the *E. longirostrata* trial (80% compared with 95%) and a lower mean trial height (2.0 m compared with 2.4 m).

Although *E. longirostrata* has shown excellent early potential across a range of sites, the long-term performance and health of the species needs to be monitored. The species has been shown to be moderately frost tolerant in Queensland (Queensland Department of Primary Industries and Fisheries 2007) but may be limited in deployment on sites that experience heavy frosts.

In Australia stem borers may present a considerable constraint on the suitability of the species for high value end uses. Bootle (2005) states that the grey gums, *E. punctata* (including *E. longirostrata*) and *E. propinqua* are often marked by characteristic "grub holes". In Queensland *E. longirostrata* has been classified as having high susceptibility to the giant wood moth (*Endoxyla cinerea*) although the level of attack was less than that in *E. dunnii* and *Eucalyptus grandis* Hill ex Maiden (Lawson 2003a). The species has also been classified as having moderate susceptibility to longicorn beetles (*Phoracantha* spp.) based on results from species trials in Queensland (Lawson 2003b). In the Grafton *E. longirostrata* progeny trial 6% of the surviving trees at 31 months were reported as having borer damage, although the species of borer was not identified in this assessment. It is planned to conduct a more detailed quantitative assessment of borer damage in the trials in autumn 2007.

Carnegie (2007) reported the incidence of a range of foliar fungal pathogens on *E. longirostrata* in NSW, including *Aulographina eucalypti, Kirramyces eucalypti* and *Mycosphaerella* spp. In addition, *E. longirostrata* has recently been observed to be infected by *Quambalaria eucalypti* (Carnegie 2007), the causal fungus of a shoot blight disease of eucalypts. The fungus has also been found in north-east and south-east Queensland on *Eucalyptus grandis* Hill ex Maiden, *E. grandis* × *E. camaldulensis* and *E. dunnii* (G. Pegg, Queensland Department of Primary Industries and Fisheries Indooroopilly, *pers. comm*. 2007). This shoot blight disease has been reported on *Eucalyptus nitens* (Deane & Maiden) Maiden, *E. grandis* and *E. grandis* × *E. urophylla* hybrids in South Africa (Roux *et al.* 2006) and as a destructive pathogen of *Eucalyptus globulus* Labill. and *E. saligna* × *E. maidenii* in South America (Zauza *et al*. 2003), in both nurseries and older plantation stock.

Forests NSW has successfully crossed *E. longirostrata* with a range of species including *E. dunnii*, *E. grandis* × *E. urophylla* and *E. pellita* and it is planned to evaluate these hybrids in a range of environments in NSW and Queensland in 2007 and 2008. Hybrids between *E. longirostrata* and *E. grandis* are showing promise in South Africa (S. Verryn, CSIR South Africa, *pers. comm*. 2007).

Preliminary results from limited vegetative propagation studies have demonstrated that *E. longirostrata* can be vegetatively propagated as rooted cuttings (Forests NSW, unpublished data). This ability to clone selected genotypes will allow genetic gains to be delivered to operational plantations in short timeframes, in comparison to some species including *Corymbia* spp., for which vegetative propagation is erratic and not economically viable. Forests NSW plans to select and develop clones of *E. longirostrata* for testing and for establishing Clonal Seed Orchards.

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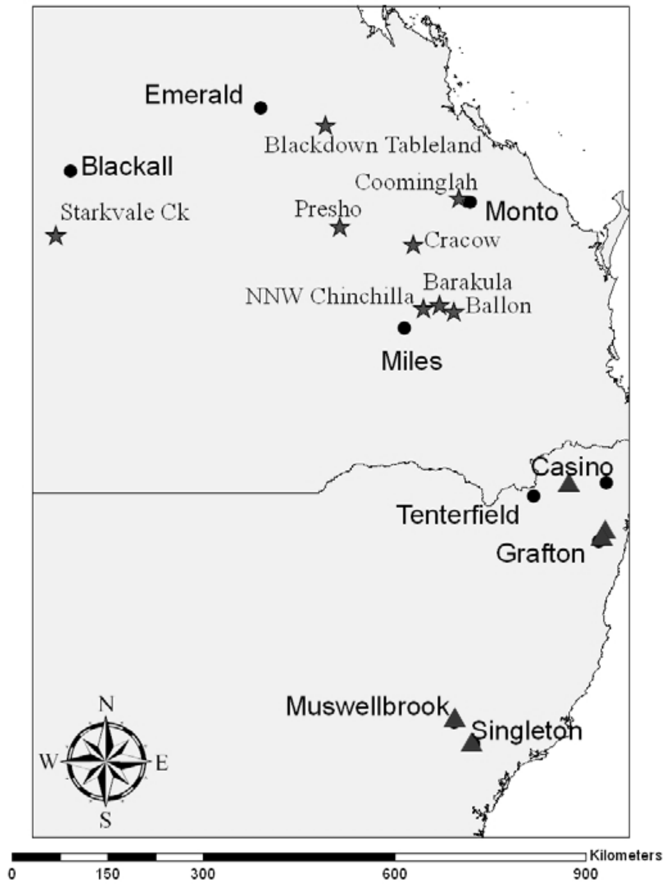
FIGURES

FIG. 1–Provenances of *Eucalyptus longirostrata* represented in the three trial series (stars) and locations of progeny trials established by Forests NSW in the 2004 and 2005 series (triangles).

FIG. 2–Across site correlations for height and stem straightness.



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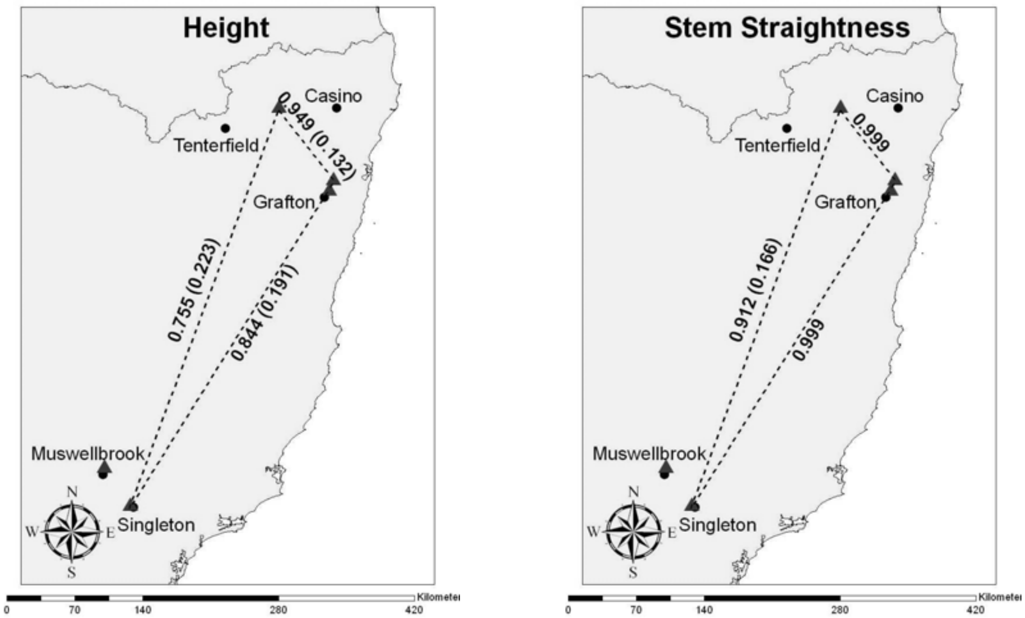

FIG. 2–Across site correlations for height and stem straightness.

TABLE 1–Provenances and number of families per provenance represented in each trial series.

Origin	Latitude	Longitude	Altitude	Trial Series		
				2004	2005	2007
NNW Chinchilla, Qld	26°22′S	150°27′E	330	5	5	
Coominglah, Qld	24°48′S	150°57′E	480	12	12	12
Starkvale Creek, Qld	25°20′S	145°15′E	450	10	10	
Blackdown Tableland, Qld	23°46′S	149°04′E	900	10	10	
Barakula, Qld	26°19′S	150°41′E	300	10	24	14
Ballon, Qld	26°25′S	150°53′E	362		18	18
Cracow, Qld	25°28′S	150°18′E	358			20
Presho, Qld	25°12′S	149°16′E	394			10

TABLE 2–Trial site details for 2004 series of progeny trials.

Location	Provenances	Families	Total trees	Planted	Average Soil pH	MAR
Grafton	6	47	940	Jan 04	5.5	1000 mm
Casino	6	47	940	Mar 04	6.0	1240 mm
Singleton	6	42	840	Apr 04	>10	730 mm

TABLE 3–Mean values for traits assessed at age 30/31 months for the 2004 series of progeny trials.

Trial	Age	Trait	Unit	Mean	SD	CV
Grafton	31 months	Survival		89%		
		DBH	cm	8.69	2.63	30%
		Height	m	8.60	1.82	21%
		Volume	m^3	0.0211	0.0124	59%
		Straightness	1-6 (6=straight)	3.92	1.05	27%
Casino	30 months	Survival		93%		
		DBH	cm	6.06	1.82	30%
		Height	m	5.75	1.38	24%
		Volume	m^3	0.0070	0.0045	64%
		Straightness	1-6 (6=straight)	4.04	1.07	26%
Singleton	30 months	Survival		95%		
		Height	m	2.37	0.79	33%
		Straightness	1-6 (6=straight)	3.22	1.04	32%

TABLE 4–Provenance performance at the three trial sites.

			Height (m)			Straightness (1-6)		
CSIRO No.	Provenance	Families	Grafton	Casino	Singleton	Grafton	Casino	Singleton
Significance			0.007	<0.001	0.002	0.057	0.994	0.053
20464	Coominglah (Moura)	7	9.47	6.34	2.83	3.85	4.23	3.38
19312	Coominglah SF	5	9.04	6.22	2.91	3.59	4.09	3.34
20007	Starkvale Ck	10	9.14	5.92	2.78	3.85	4.19	3.27
16008	NNW Chinchilla	5	9.04	5.82	2.55	3.79	4.13	3.21
20404	Barakula	10	9.24	5.63	2.66	4.04	4.15	3.36
20008	Blackdown Tableland	10	8.22	5.44	2.34	3.45	4.09	2.79
Control	*E. propinqua*	Bulk	8.04	4.42		3.71	4.14	

TABLE 5–Summary of genetic parameters for the three trials; within each trial Narrow Sense Heritability (h^2) is on the diagonal, Genetic Correlations are above the diagonal and Phenotypic Correlations below the diagonal. Standard Errors are shown in brackets.

	Height	DBH	Volume	Straightness
Grafton Trial				
Height	**0.485 (0.136)**	0.961 (0.023)	0.980 (0.026)	0.771 (0.105)
DBH	0.883	**0.440 (0.128)**	0.998 (0.007)	0.813 (0.098)
Volume	0.822	0.951	**0.371 (0.117)**	0.784 (0.117)
Straightness	0.588	0.565	0.485	**0.384 (0.120)**
Casino Trial				
Height	**0.335 (0.110)**	0.931 (0.035)	0.942 (0.043)	0.669 (0.137)
DBH	0.906	**0.339 (0.109)**	0.981 (0.019)	0.713 (0.127)
Volume	0.854	0.933	**0.262 (0.096)**	0.655 (0.160)
Straightness	0.580	0.546	0.440	**0.393 (0.119)**
SingletonTrial				
Height	**0.334 (0.120)**			0.809 (0.129)
Straightness	0.640			**0.447 (0.137)**