Performance of a 16-year-old stand of teak (*Tectona grandis* L.F.) in the Darwin area in relation to that in other trials in the Northern Territory

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Summary

Results of periodic measures of plots in a 16- year-old stand of teak planted near Darwin, Northern Territory (NT) in 1988 and thinned to various stockings are reported. This block planting had been established 12 years before any thinning was undertaken (2000) and showed a definite response between 2000 and 2004. However, growth probably does not represent what might have been achieved on this site because of likely inbreeding of the planting stock.

Elsewhere in the NT teak is showing the best growth and form to age 4.5 years on the river levee, in neutral to alkaline pH soils near Katherine. These characteristics are reduced when planted on acidic soils in and around Darwin. The initial growth is improved greatly if drip irrigation is used in the first few dry seasons after establishment.

Introduction

Teak (*Tectona grandis* L. F., a member of the *Verbenacea* famil*y)* is a large deciduous tree, which in favourable locations develops a tall, straight, (fairly) clean cylindrical bole. As it grows older it becomes moderately fluted and buttressed (Kadambi, 1972). Teak provides a valuable, versatile, tropical timber.

Teak is widely planted throughout the tropical regions of the world, and by 1995 the area of teak plantations was 2,246,559ha. Of that, more than 1 million ha is in Indonesia, with a great deal also in nearby India, Bangladesh, Thailand, etc (Brown, 2000). Some of these countries have long-running genetic improvement programs with the species, and their costs are much lower than in Australia. Even if companies who have genetically-advanced material moved into Australia, testing of it would be needed, delaying the realisation of genetic benefits. The rapid advances that can be achieved with tissue culture technology employed in countries such as Thailand and Indonesia also allows for increased gains to be made in improvement programs.

Teak is probably the most widely cultivated high value hardwood (HVH) in the world and the decline of its natural resource in India, Myanmar, Thailand and Lao, as well as the desire to develop a valuable resource, has turned attention to its artificial cultivation in plantations.
The species has been planted in small woodlots in the Top End of the Northern Territory on a range of different soil types with varying degrees of success. It was reported that on early growth figures, teak is one of the 4 preferred species in the Top End Regional Tropical Hardwood Forestry Project (TERTHFP) (Bristow, 2003).

This paper reports on the establishment and growth of a small stand (0.54ha) of teak planted in June/July 1988, on a private property 27-km south east of Darwin. The paper also reports on the growth of other trials of teak planted on a range of different soil types in and around Darwin, Adelaide R., Douglas Daly and Katherine between 1973 and 1999.

Material and Methods

1. The Darwin planting of 1988

The stand is located on private property (Carusi) 27km south east of Darwin on a reasonably level site with laterite/clay soil. The natural vegetation before clearing in the 1970's, was dominated by *Eucalyptus tetrodonta*.

The mean annual rainfall at Darwin airport, 20 km to the NW, is 1713.9 mm, and the mean daily maximum and minimum temperatures are 31.9 C° and 23.2 C° respectively.

The teak stand is derived from seed collected from a single tree of unknown provenance growing in the backyard of a nearby residence. The seed was germinated in 8cm plastic bags and the seedlings raised until they reached an average height of 30cm.

The plot was planted by the landowner, Mr Vic Carusi, and two of his workers in June-July 1988 into auger holes 60cm in diameter x 60cm deep. A handful of fowl manure was applied around each individual tree at planting. The planting site measures 90 metres by 60 metres. Spacing was 3 metres between rows (19), and 3 metres along the row (29), with 551 trees planted over 0.54 ha. The trial was irrigated for a period of 6 hours every 6 to 8 weeks during the first two dry seasons (May to September) using 4 l/hour-dripper system. After this period no irrigation was used. Inter-rows were slashed regularly for the first four years then occasionally after this period. Form pruning was done to 3 m at age 7 years.

In November and December 2000 a Master Tree Grower course (MTG) was held in Darwin and Katherine and this small stand was used to demonstrate some mensuration work and to determine what management options were available to Mr Carusi. The stand was marked for thinning to 556 spha in early December 2000. Thinning was undertaken in that month leaving a small, central control plot unthinned (Reid and Stephen, 2001)

2. Other Trials

a). Humpty Doo. The oldest teak planting in the Top End of the Northern Territory is a small provenance screening trial consisting of 9 provenances, with seed supplied by Danida Forest Seed Centre, Denmark (see Figure 3). This trial was established on a dark brown sandy clay with a high water table at Humpty Doo, 57 km SE of Darwin, in January 1973, (Cracium, 1973). Plots consisted of five rows of five trees at 3m x 2m spacing. Approximately 100 grams of NPK fertiliser was applied per tree at planting. Due to poor germination, of the 9 provenances included, only 4 were replicated (2-3 replicates). This trial was not irrigated.

b). Douglas/Daly. Another teak planting was established in the wet season of 1998/99 at the Research station Douglas/Daly in a Sabi grass pasture, 180 km south of Darwin, on the well drained sandy soil (Blain) with plants from bulk seed collected from the above Humpty Doo trial (see Figure 4).

Three different treatments for the planting stock used at Douglas/Daly were-
Seedlings in 1 litre bags
Seedlings in Lannen 35 side slot tray
Stumped stock

Each treatment was planted in blocks of five rows x five trees with a spacing of 3m x 2m and replicated 3 times. An application of NPK fertiliser with trace was applied at a rate of 200grams/ tree at planting. No irrigation was used in this trial.

c). NHT Trials. In the Top End Regional Tropical Harwood Forestry Project (TERTHFP), a Natural Heritage Trust (NHT) funded project, species trials were established in the wet season 1999/2000 (Reilly et *al*., 2004). Teak was one of the main species planted in these trials (see Figures 5 and 6).

Teak was planted on 10 sites (only 6 measured in 2004), across a range of different soils and climatic conditions, from Katherine to Darwin (Reilly et *al*., 2004).

Each planting site was laid out in a randomised complete block (RCB) design, with teak being one of six species. The species were planted in plots of seven rows by seven trees and replicated four times. The spacing used was 3m x 3m. Fertiliser application varied but generally 50grams of NPK/ tree was used. The trials were irrigated by drippers for the first 2 dry seasons.

Measures and observations

1. The Planting of 1988 (Carusi)

In June 1995, the diameter at breast height over bark (DBHOB) of 336 interior trees was measured, and the heights of a random sample of 35 trees was recorded. In 2002, three adjacent permanent plots were established, so as the on- going growth could be monitored. Two plots were in the thinned portion and one in the unthinned portion. Stocking and areas were 487 stems per hectare (sph), and plot size was 0.039ha and 621sph in a plot area of 0.037ha in the thinned portions of the stand, and 1094sph in a plot area of 0.032ha in the unthinned portion (see Table 1).
These three plots were measured in December 2002 and July 2004. Measurements of DBHOB of all trees and heights of 3 tallest trees per plot so as to calculate average predominant height (APH) were recorded. The results are shown in Table 1.

In 1995 the plantation had a good appearance, but clean commercial parts of the boles were too short (Neitzel et *al*., 1995).

2. Other Trials

In the other trials observations were made as noted below and the following measurements were taken.

a). Humpty Doo. In August 1978, age 5.5 years, all trees were measured for height, diameter and survival. A wild fire passed through the experiment in the same month. Damage to the trees varied from nil to total crown scorch with some plots, where litter was particularly heavy. However most trees recovered from the fire.

In September 1982, age 9.5 years, all trees were measured for DBHOB. The site was measured in March 1991, age 18 years, and again in January 1993, age 20 years, for DBHOB (all trees) and predominant height. The diameter figures were then converted to basal area/ha (see Figure 3). The stand was healthy in 1991 with some trees over 21 metres in height, however when measured in 1993 the stand was showing signs of stress.

b). Douglas/Daly. All trees were measured for height in August 1999, December 1999, August 2000, and March 2001. In March 2002, age 4.3 years, both height and diameter were measured (see Figure 4).

c). NHT Trials. The net plots (25 trees) were measured for DBHOB and height in 2002, age 2.5 years, and 2004, age 4.5 years (Figure 5 and 6).

Results

1. The planting of 1988

Growth of the earlier and later measures is reported in Table 1 and presented graphically in Figures 1 and 2.

In 1995, when this teak stand was 7 years old, the average diameter of 336 measure trees was 10.3 cm. The mean height of 35 sample trees was 8.4 metres. Mean diameter and average predominant

height measurements taken at age 12 years in two 0.03ha plots were 13.4 cm, and 12.5 metres respectively (Figures 1 & 2).

Figures 1 and 2 also show results of the growth response of teak to thinning at age 12, when measured 2 and 4 years later. Data for age 14 and 16 years in Figure 1 shows the mean of the 2 thinned plots has a diameter increment of 0.4 cm (f-d) over the 2-year period. However the control plot has only a diameter increment of 0.1 cm (e-c) over the same period. In the average predominant height graph (Figure 2), the average of the thinned plots has an increment of 1.1 metres (f-d) over the 2-year period, but the control plot has a larger increment of 2.1 metres (f-c).

Results of the measures in 2002 and 2004 are given in Table 1. In the 2002 and 2004 measurements, basal area/ha and the mean diameter increments over the two years of measurements are showing a response, 42 months after thinning (2000), with the heavier thinned plot (thinned to 487 stems per hectare) showing the largest gain (0.7m^2/ha).

2. Other trials

a). Humpty Doo. In the trial at Humpty Doo, a provenance of teak from Kerala in India had a basal area of 24.08 m^2/ha at age 9.6 and at age 20 this stand had increased its basal area to 40.43 m^2 /ha (see Figure 3) (Robertson, 2003). However, soon after the 20- year old measurement, individual trees started showing signs of stress and eventually death of some trees occurred.

b). Douglas/Daly. The best treatment (seedlings in 1 litre bags) at the Douglas/Daly trial after 52 months averaged just over 4 metres in height (Figure 4) and 97% survival (data not shown).

c). NHT Trials. In the recent NHT trials, the best site at 52 months was at Katherine, planted on river levee soil. The average diameter of teak on this good site was 9.9 cm and the average height 8.2 metres (Figure 5 & 6). This is over twice the height of the Douglas/Daly non-irrigated site at the same age, reported in Figure 4..

Observations on insect attack across all trials.

There has been the occasional attack by the giant termite (*Mastotermes darwinensis*) in the Darwin planting of 1988, and a baiting program had to be carried out on a few occasions up to the age of about 5 years. This termite is a voracious wood-eater and attacks a wide range of species of timber as well as living trees. It does not build a recognisable above ground nest structure, but lives in large social colonies either in hollow trees or in the soil. It is a subterranean termite and requires contact with the soil as an assured and regular source of moisture. No termites have been sited at the Humpty Doo site. The Douglas/Daly trial had some termite damage at an early age and some of the NHT plantings were slightly affected.

Observations over the years generally show teak is susceptible to various kinds of pests and diseases, but attacks by defoliators and skeletonisers are the most severe. Damage usually occurs in the wetter months of January and February. Chemical control, except in nurseries or young plantations, is not practical. The main strategy to control these pests must be on limiting food supply (controlling undergrowth in stand) and fostering parasites and predators. Unless alternative plants (undergrowth in the stand) are available, lavae of both the important defoliators starve during the period when teak is leafless (Beeson, 1938).

Discussion

The 1988 teak planting south east of Darwin has shown reasonable growth considering it had very little maintenance and it is planted on an unfavourable soil type. The seed source of the Carusi stand came from a single tree with few known other teak trees in the vicinity, so it is likely the stock was rather inbred. Thus, the growth performance of the stand may be lower than possible due to likely negative effects of inbreeding. As well it was left far too late before thinning as shown by the very

narrow growth rings at age 12 years (Reid and Stephen, 2001). It was found to be in the middle of the range for teak growth in plantations in India and SE Asia (Reid and Stephen, 2001).

Growth at this site shows that a diameter increment > 1cm per annum is possible up to 10 – 12 years at approximately 1000 sph and can be continued with thinning in this stand to 16 years old. The poor growth of unthinned control plots indicate little or no increase in mean diameter after age 12 years.

In other trials, height increments of about 1 metre per year can be achieved at around five years of age regardless of thinning at a number of sites including the Blain soil at Douglas/Daly Research Farm.

The possible reason for the deaths after age 20 years in the oldest Northern Territory teak stand at Humpty Doo are competition between trees (no thinning has occurred) and the likely reduction in available moisture as the stand has matured. No termites have been sighted in this plot.

Selected provenances of teak (La Cumbre, and Rio-Lindo from Honduras,) have shown good growth on favourable soils in the Katherine region (Reilly et *al*., 2004). There are, however, very little of this deep, moist, neutral to alkaline pH soils available for forest plantations. Most of these soils are already being used for horticulture and agriculture. An alternative is to plant on the deeper dry soils and use drip irrigation. The initial growth of trees with irrigation will be boosted substantially and the extra establishment cost of up to $2,000/ha, if some infrastructure already exists (eg. water bore) on the property, will be justified (Reilly, 2001).

The current annual increment (CAI) of teak in the younger NHT Farm Forestry Program trials is 2 cm diameter and just under 2 m in height at age 4.5 years and at a stocking of about 1000 sph (Reilly et *al.*, 2004). This is twice the height growth of the teak at the unirrigated Douglas/Daly site at about the same age, and better than the older trials described here at the same age. This demonstrates the better site quality of some sites in the NHT trials. The increased growth rate on 4 of the 6 sites in younger plantings (Figures 5 and 6) may necessitate earlier thinning, as a mean diameter of 10 cm has already been reached at 4.5 years.

The presence of the giant termite (*Mastotermes darwinensis*) in the Top End of the Northern Territory has been a limiting factor in the development of plantation forestry over the years, and species susceptible to this pest have usually failed. However, teak seems to be attacked only during early stand life, i.e. up to about 5 years of age, and probably before the tree starts to produce heartwood. Healthy trees and trees growing where there is available moisture are less susceptible to attack. This is borne out in results of all trials over 5 years old, reported here.

Optimal thinning regimes for teak in Northern Territory are yet to be determined. Teak will grow reasonably well in the Top End of the Northern Territory, particularly if it is planted on the more suitable soils such as the river levee and tippera types in the Northern Territory, as demonstrated by these results, and others presented by Reilly et *al*. (2004).

Conclusions

Because it is likely the performance of the teak in the Carusi stand is constrained by a level of inbreeding in the planting stock, its growth probably does not represent what might be achieved on the site with out-crossed and improved stock. However, growth performance of the 3 permanent plots established in the stand will yield valuable information in the future, and continual management and measurement work is to be encouraged. Results of the younger trials reported are perhaps more encouraging, especially those of the Katherine River levee. However, availability of land of that quality for teak growing in the NT appears rather limited.

Acknowledgments

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Table 1. Summary of the information collected in 2002 and 2004 in the Darwin stand planted in 1988.

Plot no.	Area (ha)	Trees per ha (no)	Trees meas-ured (no)	DBHOB (cm) at two ages and increment			Basal area (m^2/ha) at two ages and increment			Average predominant height at two ages and increment		
				14.4 years	16.0 years	Incre ment	14.4 years	16.0 years	Incre ment	14.4 years	16.0 years	Incre ment
1	.037	621	23	16.2	16.6	0.4	13.1	13.7	0.6	14.1	15.1	1.0
2	.032	1094	35	12.6	12.7	0.1	14.2	14.5	0.3	12.2	14.3	2.1
3	.039	487	19	14.7	15.2	0.5	8.4	9.1	0.7	12.5	13.8	1.3

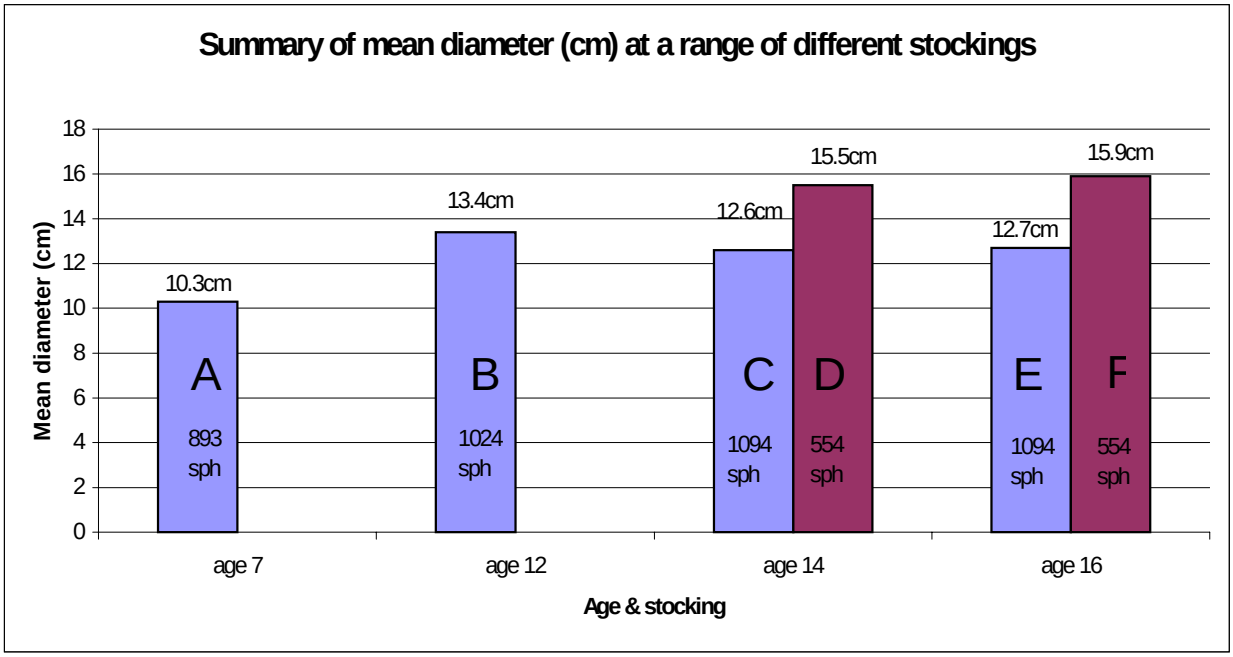

Figure 1. Summary of periodic measurements for diameter at breast height over bark in a teak stand near Darwin. NB. Age 12, December 2000, thinning treatments applied.

A 336 trees measured in June 1995 (Neitzel et *al*., 1995)
B Average of two 0.03ha plots measured December 2000 (31 and 28 trees/plot) (Reid and Stephen, 2001)
C Permanent control plot set up and measured December 2002 (35 trees)
D Average of two plots (0.037 ha & 0.039 ha) set up and measured December 2002 (23 and 19 trees)
E Permanent control plot (c) measured June 2004 (35 trees)
F Average of two plots (0.037 ha & 0.039 ha) (d) measured June 2004 (23 and 19 trees)

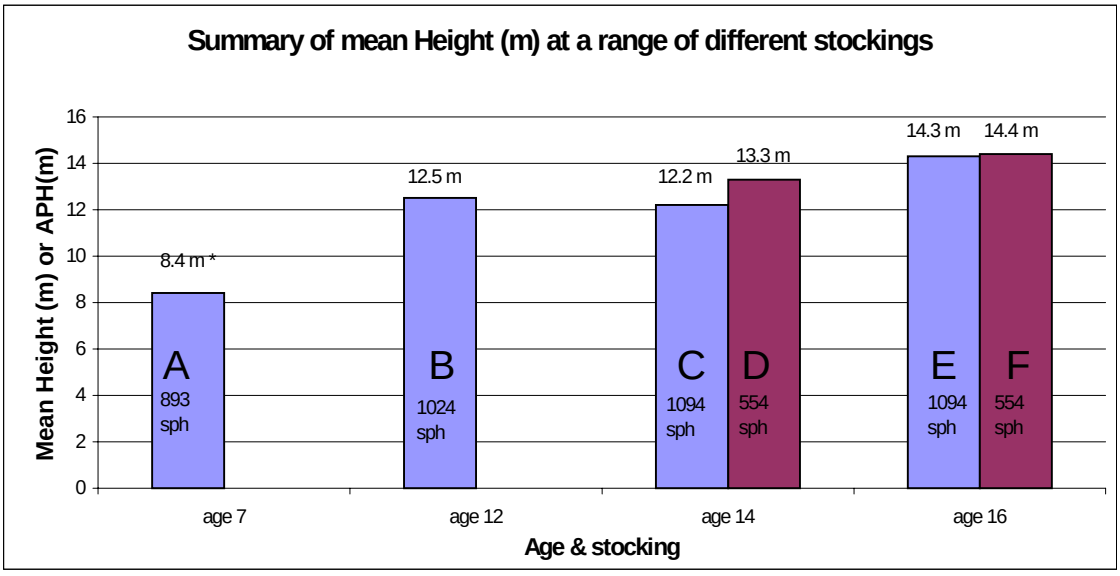

Figure 2. Summary of periodic measurements for height and average predominant height (APH) in a teak stand near Darwin. NB. Age 12, December 2000, thinning treatments applied.

A Mean height of 35 random sample trees measured June 1995 (Neitzel et *al*., 1995).
B APH of two 0.03 ha plots (Reid and Stephen, 2001).
C APH of control plot set up and measured December 2002.
D APH of two thinned plots set up and measured December 2002.
E APH of control plot (c) measured June 2004.
F APH of two thinned plots (d) measured June 2004.

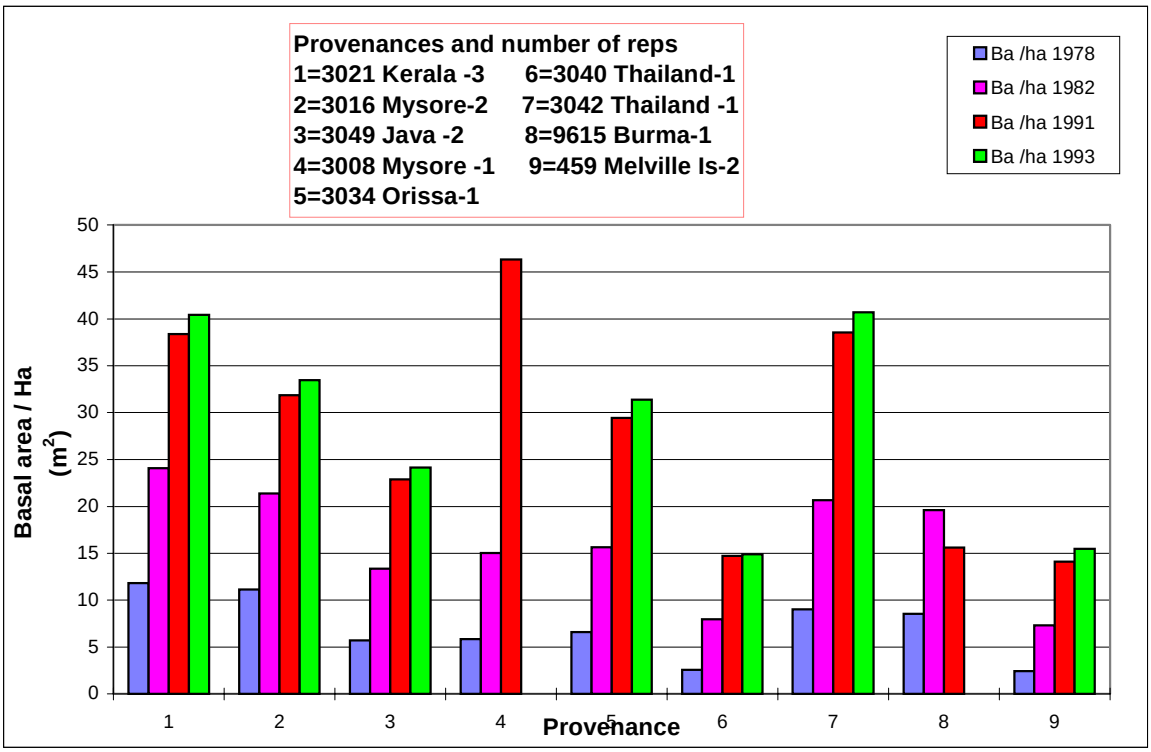

Figure 3. Basal area per ha at different ages of teak provenances in a screening trial planted at Humpty Doo in 1973. (Seed-lots no. 4 and 8 not measured in 1993 because of poor survival).

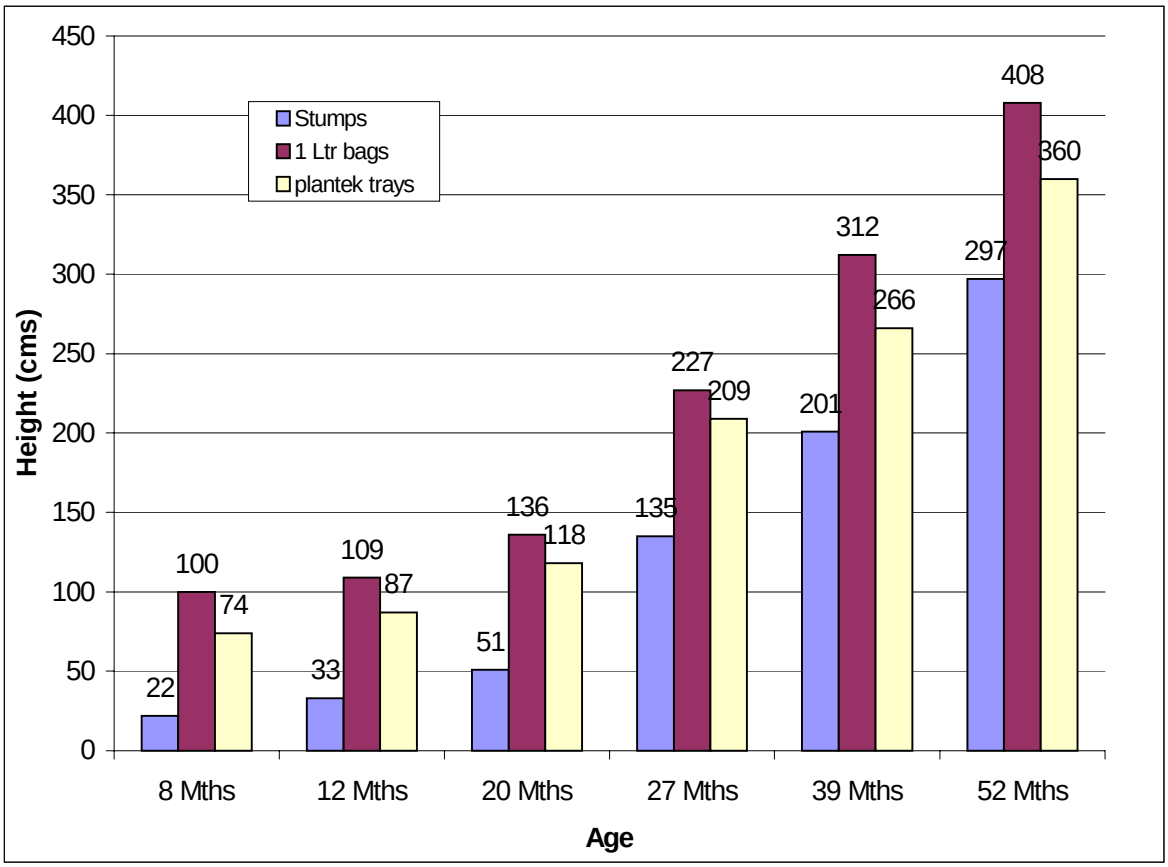

Figure 4. Height growth (cm) to age 4.3 years of teak planted at the Douglas/Daly Research Station in 1998/1999.

Figure 5. Mean diameter at breast height over bark (cms) of teak in the NHT trials, across a range of sites established 1999/00 in the NT (see Reilly et *al*., 2004 for site details).

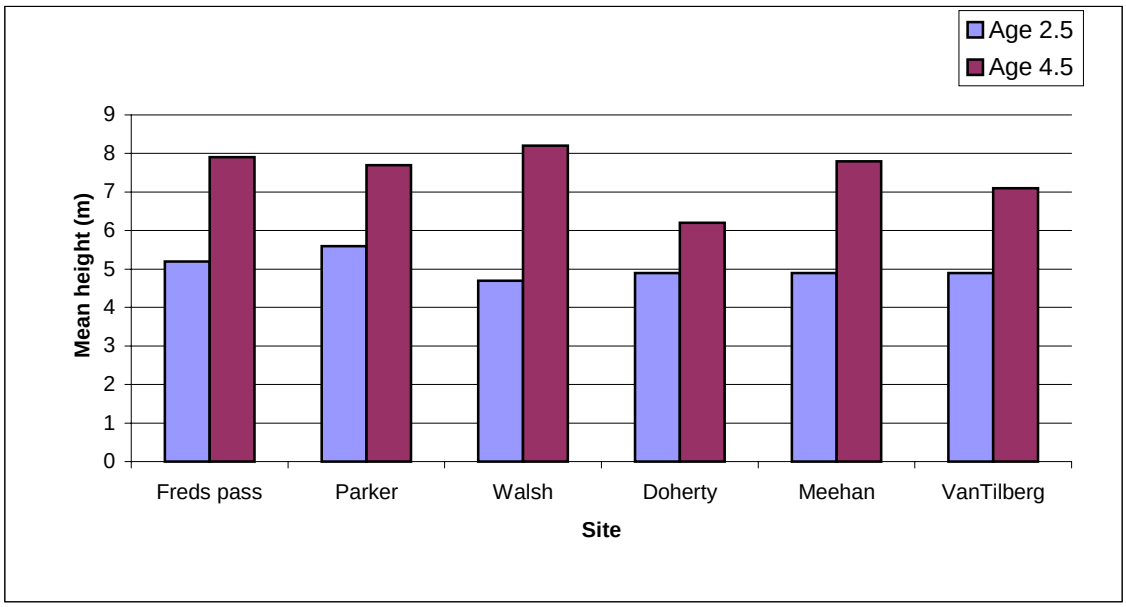

Figure 6. Mean height (m) of teak in the NHT trials, across a range of sties all sites established in 1999/00 in the NT (see Reilly et *al.*, 2004 for site details).