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PRODUCTIVITY AND WOOD PROPERTIES OF SOME EUCALYPTS AT KASUNGU FLUE CURED TOBACCO AUTHORITY, MALAWI.

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ABSTRACT

A study was conducted to assess volume production and some wood properties of the eucalypts tested at four sites at Kasungu Flue-Cured Tobacco Authority. Volume, wood basic density, moisture contents and bark thickness of the eucalypts aged 11 years varied significantly at all sites.

Eucalyptus camaldulensis and *E.tereticornis* were generally the most productive species, achieving >100 m^3 ha-1 at all sites. *E.grandis* (1532) *E. panctata* (1538) and *E.saligna* (1589) also achieved >200 m^3 ha -1 volume abeit on specific site. Wood basic density also varied significantly between the eucalypts, ranging between 300 -700 Kg m -3, the least dense wood being produced by *E.saligna*. Bark thickness and moisture content ranged between 8-21 mm and 42-63% respectively.

On the basis of growth and density, *E. camaldulensis* (1520) and *E.tereticornis* (1506 and 1521) are the overall best species for fuelwood and polewood production at Kasungu Flue Cured Tobacco Authority Estates. *E.grandis* (1532), *E.punctata* (1538), *E.saligna* (1589) and *E.torelliana* (7770) should be considered for afforestation programmed at KFCTA on specific sites only.

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INTRODUCTION

Tobacco is the main cash crop in Malawi, accounting for about 50% of the country's earnings. Tobacco production, however, largely depends on wood for curing, construction, subseqent maintenance of barns and sheds and for stakes. Malawi relies heavily on biomass energy to supply more than 90% of its primary energy requirements. With such a heavy reliance on biomass energy, the country is facing a critical wood shortage due to population growth resulting in increased energy needs as well as agricultural expansion for both food and cash crop production.

The development of the tobacco industry in Malawi has greatly contributed to the current deforestation problems in the country, mainly due to increased land clearing for tobacco growing and processing. As such, acute land shortages exist in most tobacco growing areas and wood requirements for both tobacco processing and domestic needs can no longer be met from the existing indigenous woodlands. In the absence of cheaper alternative fuels for tobacco curing, afforestation for fuelwood production is therefore recommended for all tobacco estates, utilizing mostly land of low agricultural potential.

Kasungu Flue Cured Tobacco Authority (KFCTA) is a parastatal organization responsible for training Malawian smallholder farmers in flue-cured tobacco production. As production of flue-cured tobacco relies heavily on wood, an afforestation programme was started as early as 1972 at KFCTA to meet the wood requirements. Identification of suitable species was therefore required for such a programme considering the existing site conditions set aside for afforestation programme at KFCTA. Species and provenance evaluation trials were therefore established in 1978, covering the major soil types characterizing the available sites for afforestation and *Eucalyptus camaldulensis* and *E.tereticornis* were identified as the overall best species (Ngulube, 1990).

Knowledge of wood properties of the various species and provenances tested at KFCTA is important in determining the suitability of a given wood type for a specific end-use. This report presents wood basic densities and volume production of some of the species included in the earlier trials on four major soil types.

MATERIALS AND METHODS

Sites

The KFCTA estates are located within silvicultural zone D which is characterized by an altitudinal range of 1000-1200 m.a.s.l. with a mean annual rainfall of 840-960 mm and mean annual temperatures of 19-21°C (Hardcastle,1978).

The species evaluation trials were established on four sites, each representing a different soil type: heavy, laterite, sandy and gravel soils, the commonest drainage impediment of all these being laterite, either in massive or nodular form (Ingram, 1984; Ngulube, 1990).

Field procedures

Wood samples of 11 years old eucalypts were collected from the four trial sites. The list of the species involved and details of their seed origins are presented in Table 1. At each site, five trees of each species were randomly selected and using increment bores, cores were collected at breast height for basic density determination. The cores were weighed immediately after collection for green weight values. Bark thickness were also assessed at breast height using a bark thickness gauge (two readings were taken from opposite directions). Volume was estimated by felling all trees in a plot of each species and 3m logs were cut from each tree and their mid diameter measurements taken. Huber's formula was used in calculating tree volume (F.A.O., 1980; Philip, 1983). To estimate volume per hectare, the tree stem volume was multiplied by 1320 trees, the number of trees in a hectare planted at a spacing of 2.75m x 2.75m. (Anon, 1987).

Laboratory procedures

Basic densities were determined by soaking cores in water until they were fully saturated and their volumes were measured by the displacement method. Dry weight measurements were done after cores were dried at 103°C to a constant weight. Basic density was then calculated by dividing oven weight by saturated volume.

The green moisture content percent was calculated by dividing the green weight by the saturated weight and multiplying the results by 100.

Data analysis

Both field and laboratory data were subjected to statistical analysis. Statistical Graphics Systems: Version 2.6 Computer Package was used in the analysis. Havard graphics package was used for the preparation of the graphs.

RESULTS AND DISCUSSIONS

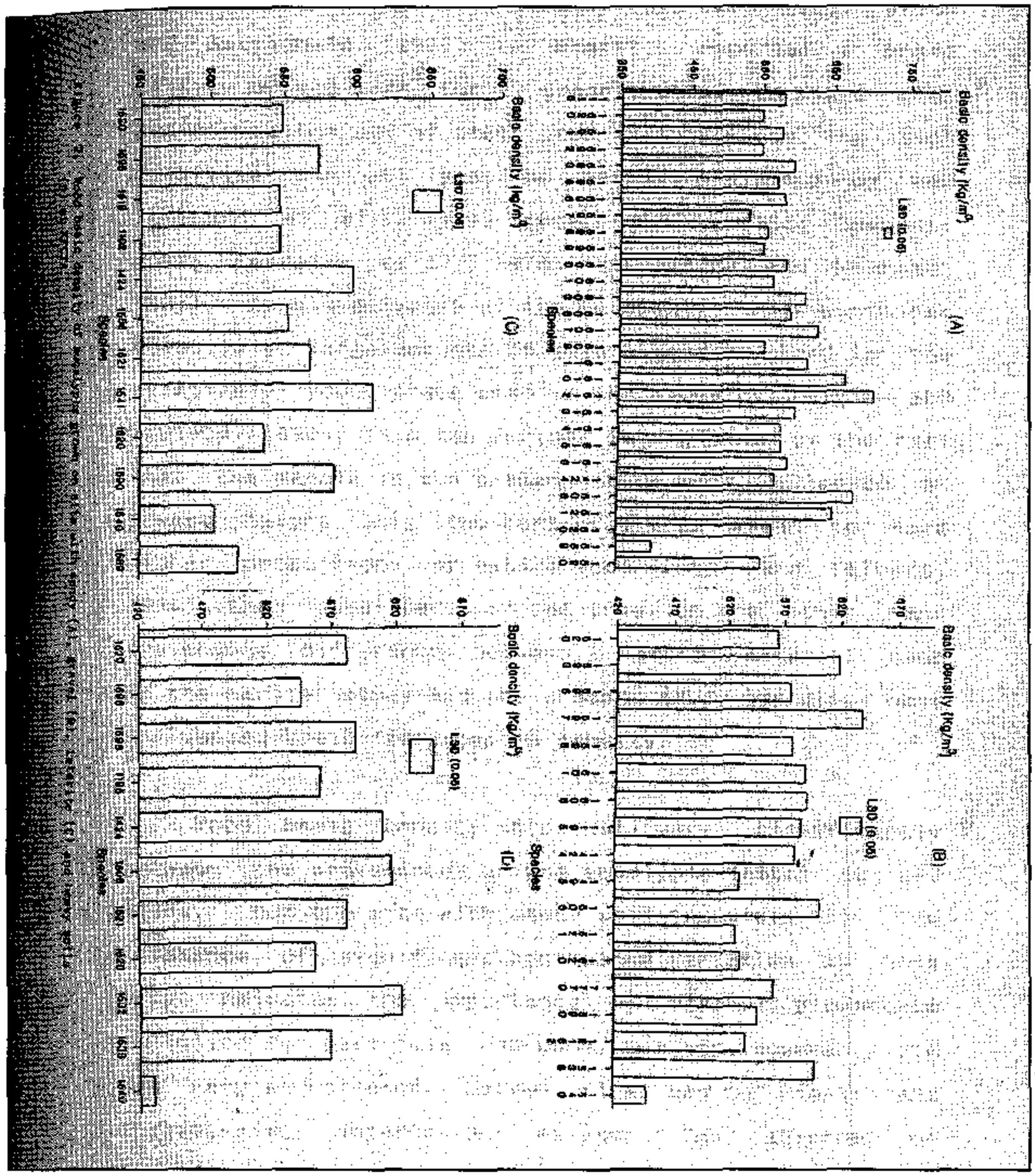
Volume production

Volume production of the eucalypts assessed in this study are presented in figure 1. Analysis of variance revealed significant differences in volume production between the eucalypts at all sites.

However, neither *E. camaldulensis* nor *E. tereticornis* provenances varied significantly at all sites except the sandy soil site (Appendix 1-4). *E. grandis* (1532), *E. punctata* (1538) *E. saligna* (1589) and *E. torelliana* (7770) were among the most productive species in this study (Fig.1).

The significant differences in volume production between the provenances of eucalypts in the present case emphasises the need for a careful provenance selection for maximum yield production. For example, volume production of *E.camaldulensis* showed a clear trend of better yield of the more extreme tropical northern Australia (<18°S latitude) than the south tropical (>18°S latitude) provenances (Fig. 1; Appendix 3). For *E.tereticornis*, the results indicate that the Northern Queensland (1521 and 1541) and Nigerian (1424 and 1506) provenances are the most productive (Fig.1, Appendix 1-4). These results largely conform with growth results reported by Ngulube, (1990) on similar trials aged 8 years.

The outstanding performance of the above provenances is possibly due to the climatic similarities of the trial sites and the tropical northern parts of Australia. The northern parts have predominantly summer rainfall while the southern parts have winter rainfall pattern and much colder winters (Pryor,1976). Experience with eucalypts in Malawi is that those from southern parts of Australia perform poorly than those from the northern parts (Clark, 1982, Nkaonja, 1979, 1985). It must be noted that species from a particular climatic pattern become adapted to that type of climate through the process of natural selection. The observations in the present study, therefore emphasises the need for proper species-site marching when introducing species to new areas. *E.tereticornis, E.camaldulensis, E.saligna* and *E.grandis* M.A.I. ranges in this study conform with those reported by Poynton (1979) on Southern Africa eucalypts. However, the M.A.I. figures reported by Ngulube (1990). The lower M.A.I. figures in Ngulube's case can probably be attributed to the use of provisional height index and yield tables which were developed by Ingram (1985) using 5-year old data. Ranasinghe and Mayhead (1991) reported positive correlation between yield and age as well as diameter growth in *E. camaldulensis*. Therefore the differences in M.A.I. figures presented in this report and in Ngulube (1990) may also be explained by age and growth differences in the two studies.



Wood basic density

Figure 2. presents the wood basic density for each site and species aged 11 years. Significant differences in wood density existed between the eucalypts at all sites (appendix 1-4). E. saligna produced the least dense wood at all sites: <500 kg/m^3 in all cases except on site with laterite soil, where density of >500 kg/m^3 was achieved. (Fig.2).

The low density figures of *E. pellita* and *E. saligna* in this study conform with earlier results reported by Chapola and Ngulube (1990). The high density figure of *E. grandis* (1532) obtained at site with heavy soil in the present case (fig 2D) does not, however, conform with earlier results (Chapola and Ngulube, 1990). *E. grandis* (1532) was the most superior species in terms of height and diameter growth at this site Ngulube, 1990). Brito and Barrichelo (1977) in Brazil, reported a basic density of 620 kg/m^3 for *E. grandis* at eleven years old, similar to the age of trees used in this study. The high densities can at least be partly explained by age (Brouard *et al*.m 1989; Bamber *et al.*, 1982; Bawagan, 1982; Ferreira *et al* ., 1979; Ranasinghe and Mayhead, 1991). At eleven years of age eucalypts trees contained relatively large amounts of mature wood compared to the relatively young trees used in the study by Chapola and Ngulube (1990). This can further be explained by the fact that the sample in the present study were collected at breast height only, the part of a tree known to have higher proportions of mature wood (Zobel and Talbert, 1984) than upper parts of the tree. On the other hand provenances between *E.grandis* material used in the earlier study and present study may also have influenced the differences in density.

Wood basic density did not vary significantly between the provenances of the eucalypts tested at all sites, but the site with sandy soil (Appendix 3). The existence of significant provenance variation at this site indicates the importance of careful provenance selection for particular end-uses. Density, however, did not vary significantly between sites and no significant species-site interaction existed. The absence of significant species-site relationship in this case gives an indication that the mean density of particular species at a specific site could generally apply to other sites with similar conditions.

It has been reported that growth rate is related to wood basic density in most species (Gerischer and de Villiers 1963; Howe, 1970; Yao, 1970; Wood and Siemon, 1981). Proportions of latewood in growth rings and sapwood as well as heartwood also influenced wood basic density (Wilkes, 1984). However, no significant relationship between density and growth was observed with the eucalypts studied in the present case. There results conform with other reports on eucalypts elsewhere (Wilkes, 1984).

Bradstock (1981) suggested that site characteristics have some influence on density, and he ascribed this to the individual variations in the history, of each site. Ingram (1983) observed wide soil variations between sites and within sites in gravel and sandy soils. This could be the possible explanation for variation in wood density between sites as observed in *E. tereticornis* (1521) and (1506) (Fig. 2). Tree growing under extremely harsh condition produces starvation wood, which affect basic wood density (Gashumba and Klem, 1982).

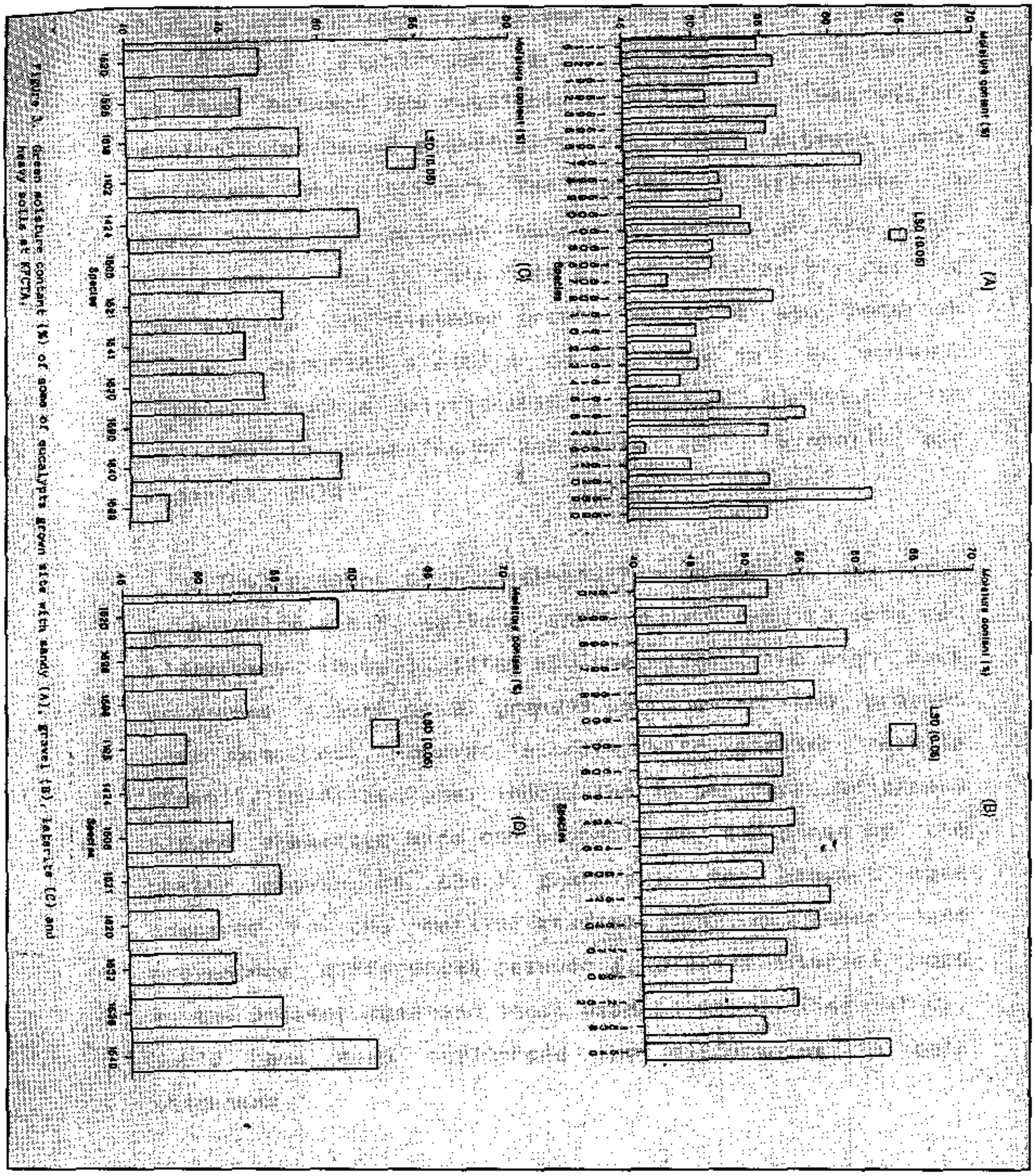


Figure 3. Green moisture content (%) of some of eucalypts grown site with sandy (A), gravel (B), laterite (C) and heavy soils at KPCTA.

Bark Thickness

Bark thickness assessment results are presented in Fig. 4. Significant variations in bark thickness existed between the eucalypts at all sites. Regression analysis indicated significant relationship between bark thickness and diameters. The significant differences in bark thickness between eucalypts tested on the four different sites in this case are partly due to differences in diameter growth. Nicholls and Pederick (1979), reported a similar relationship in E. nitens. However, such a relationship is known to diminish with age to shedding of the dead bark (Nicholls and Pederick, 1979).

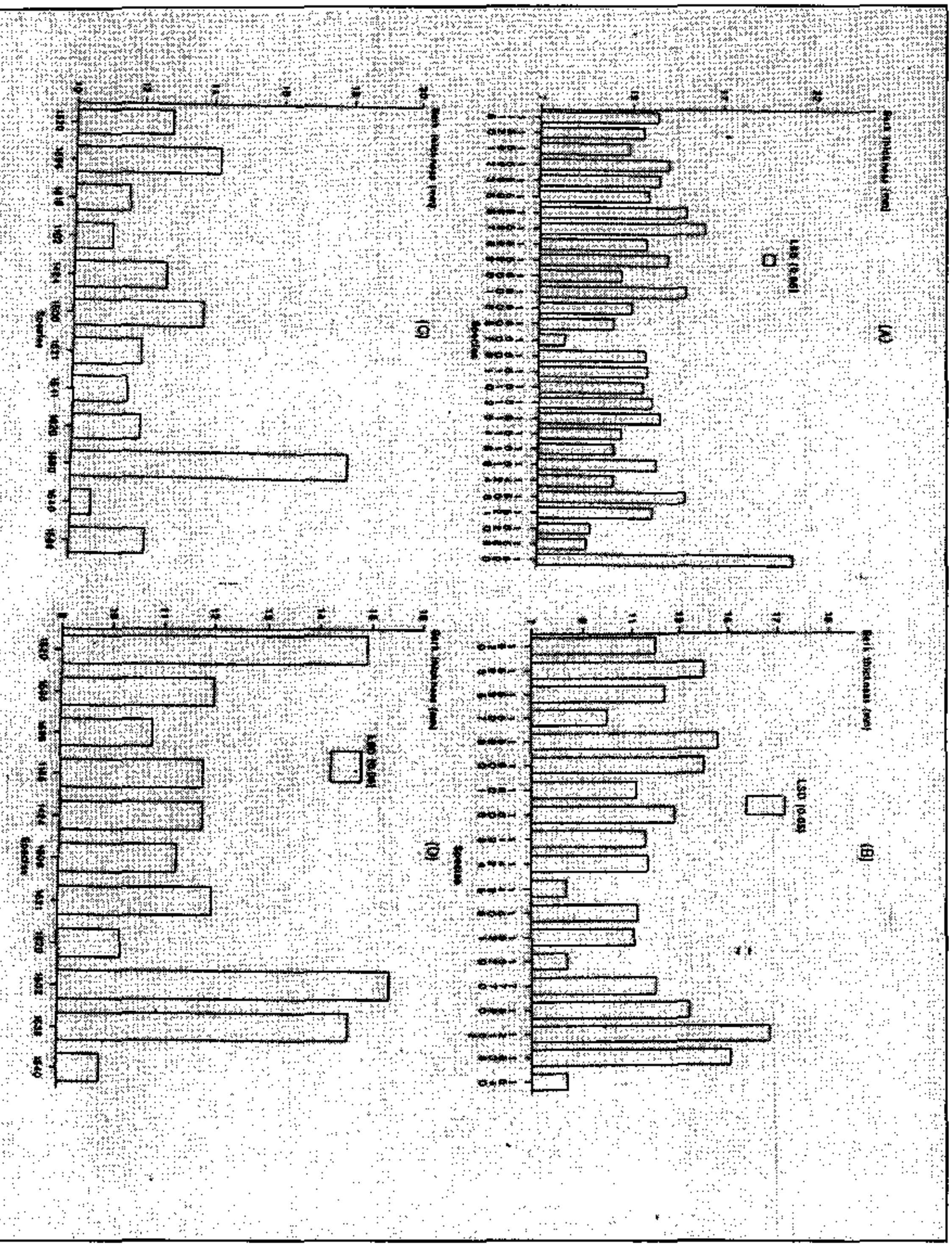


Figure 4. Bark thickness of eucalypts grown on site sandy (A), gravel (B), laterite (C) and heavy soils (D) at KTCPA.

Although no relationship between bark thickness or bark roughness and suspectability of eucalypts to Phoracantha semipunctata attack existed, species with thicker bark remained suspectable to infestation for a longer period. The current debarking recommendation of eucalypts wood immediately after felling to avoid Phoracantha infestation also reduces transportation cost. However, it must also be noted that the debarking operation is somehow expensive, and in some case, may not be offset by the reduction in transportation cost.

Moreover, the necessity of this operation may largely depend on end-use requirements of the wood. For example, if the objective is fuelwood production, then debarking may not be necessary as this may reduce the total fuel output.

CONCLUSIONS AND RECOMMENDATIONS.

The results of this study provide additional useful information on the eucalypts tested at KFCTA Estates. Survival and growth parameters are generally used in selection of suitable species for various purposes. However it must be emphasised that knowledge of wood properties of the species is also important in determining the suitability of a given wood type for specific end-uses.

If high volume production, strength and high fuel value per unit volume are required, then *E. camaldulensis* (1610,1611 and 1612). *E. tereticornis* (1506, 1521 and 1541), *E. grandis* (1532) and *E. punctata* (1538) are the most suitable species for afforestation programmes at KFCTA. If on the other hand, the major objective is to maximize volume production, then *E. pellita* (1590), *E. saligna* (1589), *E. torelliana* (7770) and all *E. camaldulensis* and *E. tereticornis* provenances with >10 $m^3ha^{-1}yr^{-1}$ M.A.I. should also be considered for afforestation at KFCTA.

Although *E. camaldulensis* provenances from Fitroy River (1593), Halls Creek (1597), Peutecost River (1598), Katherine (1603) and Tennant Creek (1607) produced high wood densities if >600 kgm^{-3} (Fig.2), this is offset by the poor volume production of these provenances (Fig.1). These provenances should therefore also be considered if high strength is the major selection criteria.

Considerable variations in both bark thickness and moisture content of the eucalypts in this study also existed. Although bark is mainly considered as fuel or waste product, it may greatly influence transportation costs depending on whether barked or debarked logs are required. Moisture content on the other hand, is an important aspect in wood strength (Dinwoodie, 1981) as well as energy release (David and Eberhard, 1991). The high moisture content of *E.saligna* (1589) in this case may probably limit its use as a source of fuel and construction material.

The present recommendations largely comform with those reported by Ngulube (1990). However, *E. camaldulensis* (1520 and 1595) on sites with heavy and laterite soils respectively; and *E. tereticornis* (1195) on site with laterite soil did not rank high in most aspects in this study. These species, should therefore not be considered for afforestation under these conditions.

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Table 1. List of species provenance and respective seed source.

Seed No.	Species and Seed Source	Lat.	Long.	Alt. (m)
1591	E. camaldulensis, Kununura, West Aus.	15°47'	128°43'	45
1592	E. camaldulensis, Ord River, West Aus	17°29'	127°57'	300
1593	E. camaldulensis, Fitzroy River, West Aus.	18°11'	125°36'	150
1595	E. camaldulensis, Gibb River, West Aus.	16°08'	126°30'	430
1596	E. camaldulensis, Halls Creek, West Aus.	18°44'	126°52'	300
1597	E. camaldulensis, Halls Creek, West Aus.	19°34'	127°41'	300
1598	E. camaldulensis, W.Pentecost River,W.Aus.	16°26'	126°45'	370
1599	E. camaldulensis, Bartnett River, West Aus.	16°40'	125°57'	450
1600	E. camaldulensis, Lennard River, West Aus.	17°20'	124°54'	125
1601	E. camaldulensis, Leopold River, West Aus.	17°40'	126°48'	330
1603	E. camaldulensis, S.W. Katherine NT. Aus.	14°25'	132°17'	110
1606	E. camaldulensis, S.W. Katherine, Aus.	14°43'	132°03'	110
1607	E. camaldulensis, N. Tennant Creek NT. Aus.	18°38'	133°56'	360
1608	E. camaldulensis, Napperby Creek NT. Aus.	22°49'	560°36'	560
1610	E. camaldulensis, Mary River, NT. Aus.	12°48'	131°40'	120
1611	E. camaldulensis, Petford Qld., Aus.	17°20'	144°58'	460
1612	E. camaldulensis, Irvine Bank Qld., Aus.	17°24'	145°09'	680
1613	E. camaldulensis, Gilbert River, Qld., Aus.	17°10'	141°45'	30
1614	E. camaldulensis, Leichhardt River, Qld.,	19°48'	140°07'	180
1615	E. camaldulensis, N.E. Hughendon Qld., Aus.	20°42'	144°22'	370
1616	E. camaldulensis, E. Mt. Isa, Qld., Aus.	20°43'	139°33'	500
1618	E. camaldulensis, Matchbox Creek, West Aus.	-*	-	
1520	E. camaldulensis, Kimberly, West Aus.	16°57'	125°34'	340
1115	E. camaldulensis, W.A. Gibb River, Aus.	16°08'	126°30'	425
1506	E. tereticornis, Malanifatationi, Nigeria	-	-	-
1541	E. tereticornis, Mt. Poverty,N. Qld., Aus.	15°40'	145°10'	549
1521	E. tereticornis, N. Mt. Malloy N. Qld.,	16°30'	145°10'	610
1107	E. tereticornis, Dehra Dun New Forest,India	30°20'	78°55'	660
1495	E. tereticornis, Lower Shire, Masenjere,MW.	16°21	35°05'	275
1195	E. tereticornis, N. Petford, Qld., Aus.	17°17'	145°59'	457
1424	E. tereticornis, Afaka Ganimash, Nigeria	-	-	-
1620	E. tereticornis, Oro Bay, Popondetta, PNG	-	-	-
1532	E. grandis , Atherton, Qld., Aus,	16°50'	148°50'	300
1589	E. saligna ' Zomba Plateae, Malawi	15°20'	35°17'	1620
1540	E. saligna ' Gladfield, Qld., Aus.	28°00'	152°23'	1020
1538	E. punctata ' Barakula, Qld., Aus.	26°22'	150°26'	350
1590	E. pellita ' Helensvale, N. Qld.,Aus.	15°30'	145°15'	5
12162	E. pellita ' (Unknown)	-	-	-
7770	E. torelliana , Likabula, Mulanje, Malawi	15°50'	35°31'	800

* Details not available.

The species evaluation trials were established on four sites, each representing a different soil type: heavy, laterite, sandy and gravel soils, the commonest drainage impediment of all these being laterite, either in massive or nodular form (Ingram, 1984; Ngulube, 1990).

Appendix 1.

Volume production and wood characteristics of 11 year-old eucalypts tested on heavy soil site at KFCTA.

Provenance	Species	Basic Density Kgm^{-3}	Moisture Content %	Bark Thickness mm	Volume m^3ha^{-1}	M.A.I [+] $m^3ha^{-1}yr-1$
1520	E. camald.	581 a*	59 ab	14.9 ab	101.2 cd	9.2
1596	E. camald.	556 a	54 ab	12.0 abc	- **	-
1598	E. camald.	588 a	53 ab	10.8 c	92.5 d	8.4
1195	E. tereti.	560 a	49 b	11.8 abc	-	-
1424	E. tereti.	601 a	49 b	11.8 abc	100.1 cd	9.1
1506	E. tereti.	616 a	52 b	11.3 bc	96.5 cd	8.8
1521	E. tereti.	581 a	55 ab	12.0 abc	154.4 bc	14.0
1620	E. tereti.	556 a	51 a	10.2 c	101.5 cd	9.2
1532	E. grandis	623 a	52 ab	15.4 a	273.0 a	24.8
1538	E. punctata	568 a	55 ab	14.6 ab	198.5 b	18.0
1540	E. saligna	432 b	61 a	9.8 c	-	-

* Value with same following letter(s) do not differ significantly ($P<0.05$)

** Volume was not estimated due to low survival.

[+] Mean annual increment.

Appendix 2.

Volume production and wood characteristics of 11 year-old eucalypts tested on laterite soils at KFCTA site.

Provenance	Speceis	Basic Density Kgm^{-3}	Moisture Content %	Bark Thickness mm	Volume m^3ha^{-1}	M.A.I + $m^3ha^{-1}yr^{-1}$
1520	E. camaldu.	548 abc *	47	12.8 ab	99.8 d	9.1
1595	E. camaldu.	573 abc	46	14.2 ab	95.5 d	8.7
1618	E. camaldu.	546 abc	49	11.6 b	- **	-
1107	E. teretic.	546 abc	49	11.1 b	136.8 dcd	12.4
1424	E. teretic.	597 ab	52	12.7 ab	113.3 d	10.3
1506	E. teretic.	552 abc	51	13.8 ab	151.3 bcd	13.8
1521	E. teretic.	567 abc	48	12.0 b	114.4 d	10.4
1541	E. teretic.	611 a	46	11.6 b	100.5 d	9.1
1620	E. teretic.	536 abc	47	12.0 b	66.4 d	6.0
1590	E. pellita	585 abc	49	18.0 a	120.6 d	11.0
1540	E. saligna	503 c	51	10.6 b	73.3 d	6.7
1589	E. saligna	519 cd	42	12.2 b	260.0 ac	23.6

* Values with same following letter(s) do not differ significantly ($P<0.05$).

** Volume was not estimated due to low survival.

\+ Mean annual increment.

Appendix 3.

Volume production and wood characteristics of 11 year-old eucalypts tested on sandy soils at KFCTA site.

Provenance	Species	Basic Density Kgm^{-3}		Moisture Content %		Bark Thickness mm		Volume m^3ha^{-1}		M.A.I + $m^3ha^{-1}yr^{-1}$
1115	E.camaldulensis	578	efg*	54.8	abcd	13.4	bcde	109.9	bcdef	9.0
1520	E.camaldulensis	546	fg	56.6	bcde	12.6	bcde	137.0	b	12.5
1591	E.camaldulensis	575	efg	54.8	bcde	11.8	bcde	56.6	def	5.1
1592	E.camaldulensis	547	fg	50.9	cde	14.0	bcd	131.1	bcd	11.9
1593	E.camaldulensis	593	g	56.2	abcd	13.5	bcde	50.6	ef	4.6
1595	E.camaldulensis	570	efg	55.5	efg	12.9	bcde	94.1	bcdef	8.9
1596	E.camaldulensis	580	defg	54.0	bc	15.0	bc	98.8	bcdef	9.0
1597	E.camaldulensis	529	g	62.2	a	16.0	b	62.1	def	5.6
1598	E.camaldulensis	555	efg	51.8	cde	12.8	bcde	103.4	bcde	9.4
1599	E.camaldulensis	550	fg	52.0	cde	14.0	bcd	105.7	bcde	9.6
1600	E.camaldulensis	582	defg	53.4	bcde	11.4	cde	99.5	bcde	9.0
1601	E.camaldulensis	564	efg	54.1	abcd	15.0	bc	112.3	bcde	10.2
1603	E.camaldulensis	610	bcdef	51.2	cde	12.0	bcde	61.6	def	5.6
1606	E.camaldulensis	588	defg	51.1	cde	11.0	cde	72.1	bcdef	6.6
1607	E.camaldulensis	626	bcde	47.9	de	9.4	e	27.3	f	2.5
1608	E.camaldulensis	552	fg	55.7	abcd	12.8	bcde	129.1	b	11.7
1611	E.camaldulensis	613	bcdef	52.5	cde	12.9	bcde	104.2	bcde	9.5
1610	E.camaldulensis	665	abc	49.9	cde	12.6	bcde	135.6	b	12.3
1612	E.camaldulensis	701	a	49.5	cde	13.1	bcde	138.1	bc	12.6
1613	E.camaldulensis	597	cdefg	50.0	cde	13.6	bcde	74.9	bcdef	6.8
1614	E.camaldulensis	579	defg	48.7	cde	11.4	cde	63.4	cde	5.7
1615	E.camaldulensis	577	efg	51.6	cde	11.0	cde	91.0	cde	8.3
1616	E.camaldulensis	587	defg	57.9	ab	13.4	bcde	-**	bcde	-
1424	E.tereticornis	569	efg	55.2	abcd	11.0	cde	91.2	bcdef	8.3
1506	E.tereticornis	679	ab	46.2	e	15.0	bc	-		-
1521	E.tereticornis	652	abcd	49.5	cde	13.2	bcde	231	a	21
1620	E.tereticornis	567	efg	55.3	abcd	9.8	de	-		-
1589	E.saligna	398	c	62.7	a	9.6	de	-		-
1590	E.pellita	551	fg	55.2	abcd	21.0	a	120.5	bcde	11.0

* Values with the same following letter(s) do not differ significantly ($P<0.05$)

** Volume was not estimated due to low survival.

\+ Mean annual increment.