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# COMPARISON OF VOLUME PRODUCTION, BASIC DENSITY AND STEM QUALITY BETWEEN *ACACIA MANGIUM* AND *ACACIA AURICULIFORMIS* GROWN IN ZANZIBAR

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**ALI, M.S., MALIMBWI, R.E. & IDDI, S. 1997. Comparison of volume production, basic density and stem quality between *Acacia mangium* and *Acacia auriculiformis* grown in Zanzibar.** Volume production, basic density and stem quality of 6-y-old *Acacia mangium* and *A. auriculiformis* grown in Zanzibar were compared. Twenty-one plots (11 plots for *Acacia mangium* and 10 for *A. auriculiformis*) were established and used for data collection. From each plot one to two trees free from obvious defects were selected for basic density determination. Cores were then extracted from the selected trees using an increment borer. Basic density of the cores was determined by the water displacement method. Height and diameter data were used for volume estimation. Stem quality was assessed using the scoring method, 4 being the best and 1 the worst. At age 6 y, diameter and height growth did not vary significantly ($p = 0.05$) between the two species. More than 50 $m^3$ $ha^{-1}$ volume production was achieved in both species. The average volume weighted basic density values for *A. mangium* and *A. auriculiformis* were 570 kg $m^{-3}$ and 617 kg $m^{-3}$ respectively. The basic density values for the two species differed significantly ($p = 0.05$). Stem quality was better in *A. mangium* than in *A. auriculiformis*. Based on density, *A. auriculiformis* can be recommended for fuelwood production whereas *A. mangium* should be recommended for transmission and building poles due to its good stem form.

Key words: *Acacia mangium* - *A. auriculiformis* - volume production - basic density - stem quality

**ALI, M.S., MALIMBWI, R.E. & IDDI, S. 1997. Perbandingan pengeluaran isi padu, kepadatan asas dan kualiti batang antara *Acacia mangium* dan *A. auriculiformis* yang ditanam di Zanzibar.** Pengeluaran isi padu, kepadatan asas dan kualiti batang *Acacia mangium* dan *A. auriculiformis* berumur 6 tahun yang ditanam di Zanzibar dibuat perbandingan. Dua puluh satu plot (11 plot *Acacia mangium* dan 10 plot *A. auriculiformis*) ditubuhkan dan digunakan untuk kutipan data. Satu hingga dua pokok yang bebas daripada kerosakan dipilih dari setiap plot untuk menentukan kepadatan asas. Kor diekstrak daripada pokok yang dipilih menggunakan gerumit ketambahan. Kepadatan asas kor tersebut ditentukan melalui kaedah sesaran air. Data ketinggian dan isi padu digunakan untuk menganggarkan isi padu. Kualiti batang ditaksirkan menggunakan kaedah tarahan dan didapati 4 batang terbaik dan 1 paling teruk. Pada umur 6 tahun, diameter dan pertumbuhan ketinggian tidak berubah dengan ketara ($p=0.05$) di antara kedua-dua spesies. Lebih daripada 50 $m^3$ $ha^{-1}$ pengeluaran isipadu diperoleh dalam kedua-dua spesies. Nilai ketumpatan asas purata wajaran isi padu *A. mangium* dan *A. auriculiformis* ialah masing-masing 570 kg $m^{-3}$ dan 617 kg $m^{-3}$. Nilai ketumpatan asas bagi kedua-dua spesies berbeza dengan bererti

(p = 0.05). Kualiti batang didapati lebih baik dalam *Acacia mangium* daripada *A. aurriculiformis*. Berdasarkan ketumpatan, *A. aurriculiformis* disyorkan untuk pengeluaran bahanapi manakala *Acacia mangium* disyorkan untuk tiang elektrik dan tiang bangunan kerana sesuai dengan bentuk batangnya.

## Introduction

Tree planting activities in Zanzibar started in the early 1950s during colonial rule but large scale afforestation was launched in the 1980s with the main objective of meeting the demand for various products. The main species planted are *Acacia mangium, A. auriculiformis* and *Casuarina equisetifolia* for production of fuelwood and building poles while *Pinus caribaea* is grown for the production of sawlogs. So far, a total of 8000 ha have been reserved for afforestation.

*Acacia mangium* Willd. is a leguminous tree species of the sub-family Mimosoideae. The natural distribution of *A. mangium* is concentrated in the southern hemisphere and stretches from Aru Island in the Moluccas and Irian Jaya (easternmost part of Indonesia) to river Oriomo in the western division of Papua New Guinea and Town to the northeastern part of Australia, the latitudinal limits being 0° 5'S to 19°S (Atipanumpai 1989). According to Turnbull (1986), in Australia the species is found only in Northern Queensland and has a very limited distribution in the coastal tropical lowlands.

*Acacia mangium* is a tropical lowland tree species of moderate size, principally occurring from just above mean sea level to about 480 m elevation. The mean maximum temperature within its natural range is 31-34 °C and the mean minimum temperature is 12-16 °C. The species favours high rainfall, varying from 1000 mm to more than 4500 mm (Atipanumpai 1989). The species is commonly found along fringes of the mangrove forests where it is sometimes associated with *Rhizophora* spp. and *Melaleuca* spp. Under natural conditions, *A. mangium* grows satisfactorily on eroded, rocky to gravelly, thin mineral soils but sometimes also on acidic and clay soils. Turnbull (1986) reports that *A. mangium* tolerates acidic soils of low fertility and has yielded wood volumes of over 30 $m^3$ $ha^{-1}$ $y^{-1}$ in such soils. Table 1 shows growth of the species at different locations.

According to Atipanumpai (1989), *A. mangium* has narrow sapwood which is straw to creamy white in colour. The heartwood is medium brown, dense, strong and durable. The grain is straight on the tangential face and slightly interlocked on the radial face. The texture is medium and Turnbull (1986) and Atipanumpai (1989) report basic densities of 420 kg $m^{-3}$ and 583 kg $m^{-1}$ respectively at age 9 y. *Acacia mangium* timber can be sawn easily and polishes well. It is suitable for light duty construction such as framing and weather boarding. The wood also makes attractive furniture, cabinets, door frames and sliced veneer. Other uses include fuelwood, particleboard manufacture and pulp and paper (Turnbull 1986).

**Table 1.** Growth of *A. mangium* at different locations

| Location | Age (y) | Spacing (m) | Height (m) | DBH (cm) | MAI ($m^3 ha^{-1}$) |
|---|---|---|---|---|---|
| Sabah | 4 | 3 × 3 | 17.3 | 14.9 | - |
| Sabah | 10 | 2.4 × 2.4 | 23.0 | 20.0 | 44.0 |
| Sarawak | 3.5 | 3 × 3 | 15.5 | - | - |
| Kalimantan | 3.8 | 3 × 3 | 15.6 | 11.6 | 33.5 |
| Sumatra | 1.8 | 1 × 1 | 6.6 | 5.0 | 46.2 |
| Wanagama | 2.5 | 4 × 4 | 5.1 | 2.0 | - |
| Thailand | 2 | 2 × 2 | 5.2 | 5.2 | - |
| Taiwan | 4 | - | 8.8 | 9.4 | 23.4 |
| W. Bengal | 1 | 5 × 5 | 3.0 | 2.7 | - |
| Papua New Guinea | 2.5 | - | 8.4 | - | - |

Source: Atipanumpai (1989).

*Acacia auriculiformis* A. Cunn. *ex* Benth. is also a leguminous tree species. It is a native of the savannah of Papua New Guinea, Indonesia, islands of the Torres Strait and the northern areas of Australia. The species can grow in humid tropical conditions and thrives where mean annual temperatures range from 26 to 30 °C. The species grows well at an altitude of up to 600 m.

*Acacia auriculiformis* wood is reported to have an average basic density of 500 kg $m^{-3}$ (Turnbull 1986). The wood is well suited for fuelwood with a calorific value of 4800-4900 kcal $kg^{-1}$. The wood also yields excellent charcoal that glows well and burns without smoke or sparks (National Academy of Sciences 1980).

The production of *A. auriculiformis* is reported to be 17-20 $m^3 ha^{-1} y^{-1}$ on good sites in Malaysia and Indonesia at a rotation age of 12 y, and that even on poor soils, the production reaches 10 $m^3 ha^{-1} y^{-1}$ in moist conditions. In semi-arid West Bengal on shallow soils, yield is reported to be only 5 $m^3 ha^{-1}$ at 15 y (National Academy of Sciences 1980).

There have been no formal assessments of the performance of *A. mangium* and *A. auriculiformis* planted in Zanzibar. This study was therefore carried out to assess the performance of the two acacias with reference to volume production, wood basic density and stem quality six years after planting.

## Materials and methods

### *Description of study area*

Data were collected from the Chaani plantation located about 20 km north of Zanzibar municipality (5° 51' - 6° 00'S, 39° 10' - 39° 20'E). The topography of the area is undulating with an altitude ranging from 50 to 80 m.a.s.l. The temperature varies annually but the absolute maximum and minimum are 35 °C and 19.9 °C respectively. The area experiences two rainy seasons: long rainy season lasting from mid-March to mid-May and short rainy season lasting from

October to the end of December. The mean annual rainfall ranges between 1500 and 2100 mm. The soil of the area is classified as sandy loam with humus.

The plantation was established in 1984 and has a total area of 420 ha. The main species planted are *A. mangium, A. auriculiformis, Casuarina equisetifolia* and some *Pinus caribaea.* The spacing used is 2.0 × 2.0 m (2500 trees $ha^{-1}$). The plantation was weeded twice during the first two years. Spot weeding and slashing were done once at the age of 3-4 y. At the age of 5-6 y slashing was also done once. The plantation was due for first thinning at the age of 6 y when 100 stems should have been removed.

## *Data collection*

The data were collected from compartments 20a and 20b planted with *A. mangium* and *A. auriculiformis* respectively.

## *Volume production*

Before actual data collection for volume determination was carried out, a pilot survey was done to determine the number of plots to be measured. Twelve plots for each species were established randomly and relascope sweeps for basal area determination were made in each plot. The number of plots in the actual survey was established as follows:

$$n = \frac{CV^2 t^2}{E^2}$$

where $n$ = number of plots
$CV$ = coefficient of variation of basal area per hectare
$t$ = value derived from *t*-table at 5% probability level
$E$ = sampling error (10%)

Using this formula, 21 plots of 0.04 ha were randomly established; 11 for *A. mangium* and 10 for *A. auriculiformis.* In each plot all trees were measured for dbh and six trees representing the largest medium and smallest diameters were measured for height. The heights of the remaining trees in each plot were determined from height-diameter curves developed from the data.

## *Basic density*

A total of 30 trees (15 trees from each species) free from obvious defects were selected for wood basic density determination. In each plot (established for volume determination), 1-2 trees were selected for this purpose and cores for basic density determination were extracted at breast height of each sample tree using an increment borer. The cores were sun dried for six hours to prevent deterioration prior to laboratory analysis.

In the laboratory, each core was divided into three equal sections representing inner, middle and outer parts of the tree. The sections were then soaked in distilled water for two days in order to attain green condition. Next, the green volume of each section was determined by water displacement. After determination of green volume the sections were dried in an oven at 103 ± 2 °C to constant weight. The oven dried sections were then transferred to cool in a desiccator containing dry silica gel after which they were weighed in an analytical balance. Basic density was calculated by dividing oven dry weight by green volume.

### *Stem quality assessment*

All trees in each of the established plots were assessed for stem quality using the scoring method as follows:

| Score | Description |
|---|---|
| 4 | absolutely straight |
| 3 | slightly kinked |
| 2 | intermediately crooked |
| 1 | extremely crooked |

### *Data analysis*

The data obtained were used to calculate species means which were in turn used in statistical analysis as follows:

- For diameter and height growth, volume and basic density, significant differences between species were separated using *t*-tests.
- Radial variation of basic density was analysed using analysis of variance.
- Stem quality was compared using percentages.

## Results and discussion

### *Height and diameter growth*

At six years, the mean height was 13.9 m for *A. mangium* and 14.9 m for *A. auriculiformis* (Table 2). *Acacia auriculiformis* has slightly faster height growth than *A. mangium* but the difference is not statistically significant. The mean breast height diameter was 12.5 cm for *A. mangium* and 11.5 cm for *A. auriculiformis* (Table 2) corresponding to mean annual diameter increment of 2.1 cm and 1.9 cm for *A. mangium* and *A. auriculiformis* respectively. These differences are also not significant. Wiersum and Ramlan (1982) reported that in Java, 6-y-old *A. auriculiformis*

attained a height of 14.0 m and a diameter of 11.4 cm. On the other hand, Atipanumpai (1989) reported an average height of 7.8 m and diameter of 13.3 cm at 2.5 y for various provenances of *A. mangium* grown at Lad Krating Provenance trial site, Chachoengaso, Thailand. The height and diameter values obtained in this study for *A. auriculiformis* are close to those reported by Wiersum and Ramlan (1982) and this may indicate similar growth conditions. The growth conditions at the Lad Krating Provenance trial could be better than those in Zanzibar since the height and diameter growth of *A. mangium* appear to be higher.

## *Volume production*

At the age of 6 y the mean volume production was 64 $m^3$ $ha^{-1}$ and 59.6 $m^3$ $ha^{-1}$ for *A. mangium* and *A. auriculiformis* respectively. The corresponding annual volume production was 10.7 $m^3$ $ha^{-1}$ and 9.9 $m^3$ $ha^{-1}$ and the differences are not statistically significant (Table 2). The National Academy of Sciences (1980) reported annual wood production of *A. auriculiformis* grown in Malaysia and Indonesia of 17-20 $m^3$ $ha^{-1}$ at a rotation of 10-12 y and 5 $m^3$ $ha^{-1}$ for the species grown in West Bengal at a rotation of 15 y. The results from this study indicate that volume production of *A. auriculiformis* in Zanzibar is lower than that in Malaysia and Indonesia but higher than in West Bengal. Wiersum and Ramlan (1982) reported that *A. auriculiformis* had a mean annual increment of 18.3 $m^3$ $ha^{-1}$ at 6 y.

**Table 2.** Mean values for height, DBH, volume and basic density for *A. mangium* and *A. auriculiformis*

| Parameter | Species *A. mangium* | *A. auriculiformis* | Significance |
|---|---|---|---|
| Height (m) | 13.9 (0.58) | 14.9 (0.45) | ns |
| dbh (cm) | 12.5 (0.45) | 11.5 (0.43) | ns |
| Volume ($m^3$ $ha^{-1}$) | 64.0 (8.56) | 59.6 (6.9) | ns |
| Basic density (kg $m^{-3}$) | 570 (13.9) | 617 (14.2) | ** |

( ) = standard error,
** = significantly different at 1% probability level,
ns = not significantly different.

## *Basic density and its variation*

The average weighted basic density of *A. mangium* was 570 kg $m^{-3}$ while that of *A. auriculiformis* was 617 kg $m^{-3}$ (Table 2). The basic density value of *A. mangium* obtained in this study is similar to the value of 583 kg $m^{-3}$ reported by Atipanumpai

(1989) but higher than that of 420 kg $m^{-3}$ reported by Turnbull (1986) for the species at 9 y. Ngulube *et al.* (1993) found basic density of 511-617 kg $m^{-3}$ for 1- to 2-y-old *A. auriculiformis* grown in Malawi. The upper value is similar to that obtained in this study for the species. Statistical analysis showed significant difference in the mean basic density between *A. mangium* and *A. auriculiformis*. The difference may be due to the presence of extraneous materials in *A. auriculiformis* since sections of this species when soaked to regain green condition, caused an intense colour change of the water. The difference may also be due to genetic make-up of the species as different species have different anatomical structures and physical properties (Panshin & de Zeeuw 1970).

Table 3 shows the basic density variation within species. For both species, basic density increased significantly from pith to bark. It increased from 542 kg $m^{-3}$ to 598 kg $m^{-3}$ in *A. mangium* and from 597 kg $m^{-3}$ to 638 kg $m^{-3}$ in *A. auriculiformis*. The results are in agreement with trends reported elsewhere (e.g. Gashumba & Klem 1982).

**Table 3.** Radial basic density (kg $m^{-3}$) variation for *A. mangium* and *A. auriculiformis*

| Core position | Species | | Significance |
|---|---|---|---|
| | *A. mangium* | *A. auriculiformis* | |
| Inner | 542a | 597a | * |
| Middle | 571b | 615b | * |
| Outer | 598c | 638c | * |

a,b,c denote differences between two means exceeding an LSD (least significant difference) of 17.2kg $m^{-3}$ at a probability level of 5%.

## *Stem quality*

Table 4 shows the stem quality of the two species. The table shows that *A. mangium* has better stem quality than *A. auriculiformis* since it has a higher proportion of absolutely straight stems, slightly kinked stems and intermediately crooked stems compared to *A. auriculiformis*. These results are in agreement with those reported by Atipanumpai (1989), Boland (1989), and Wiersum and Ramlan (1982). These authors reported that *A. auriculiformis* has crooked stem form.

**Table 4.** Stem quality of *A. mangium* and *A. auriculiformis* grown in Zanzibar

| Quality score | Species/percentage of stems | |
|---|---|---|
| | *A. mangium* | *A. auriculiformis* |
| 1 | 5.1 | 21.2 |
| 2 | 29.5 | 43.0 |
| 3 | 39.7 | 26.2 |
| 4 | 25.7 | 9.6 |

## Conclusion and recommendations

The study showed that at the age of 6 y *A. auriculiformis* has significantly higher basic density than *A. mangium*. Since density is positively correlated with fuel value, it would appear that *A. auriculiformis* is more suitable for fuelwood production. *Acacia mangium* appears to be more suitable for the production of poles (both building and transmission) since it has better stem quality. It is suggested that when planted for production of building poles, harvesting of *A. mangium* be done at age of 5 - 6 y when average dbh will be about 10.5-12.6 cm and mean height 11.5 - 13.8 m. When planted for production of transmission poles, harvesting could be done at age 11-12 y when mean dbh of stems would be 23 - 24 cm and mean height 25-28 m, based on the current increment rates.

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