

# Rating *Musanga cecropioides* and *Delonix regia* as papermaking hardwoods

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**ABSTRACT:** A series of tests were performed on two hardwood species in Nigeria to help determine their potential suitability for papermaking. Both species are clear and straight-boled and could be harvested at about eight years. Results of the screening studies are compared against *Gmelina arborea*, an established hardwood resource.

**KEYWORDS:** Anatomy, characteristics, *gmelia*, hardwoods, *musanga*, papermaking

In our part of the world, the search for suitable papermaking pulpwoods continues. The search involves screening studies of potentially useful species. The wood and pulp characteristics of candidate species are determined and compared with similar characteristics of established pulpwoods.

One such screening exercise focused

on *Musanga cecropioides* and *Delonix regia*, both of which exhibit prolific juvenile growth. These species grow in abundance, but they are not normally grown in plantations and are not presently used commercially.

This report presents results obtained from screening studies of these two species. Wood anatomy, pulping characteristics, and mechanical prop-

erties for *Musanga cecropioides* and *Delonix regia* are compared with *Gmelina arborea*, which is an established hardwood resource for production of pulp and paper (1).

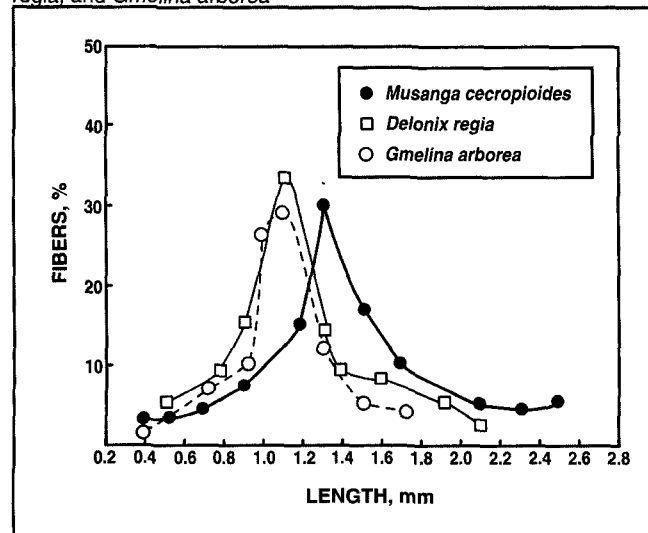
*Musanga cecropioides* is clear, straight-boled, and could be harvested in eight years in its normal rain forest habitat, where annual rainfalls are 1000 mm and more. The tree has a natural adult height of about 20 m and a girth of 3 m.

*Delonix regia* is clear and straight-boled, with a natural adult height of about 15 m and a girth of 2.5 m. The tree could be harvested as a sapling after about eight years.

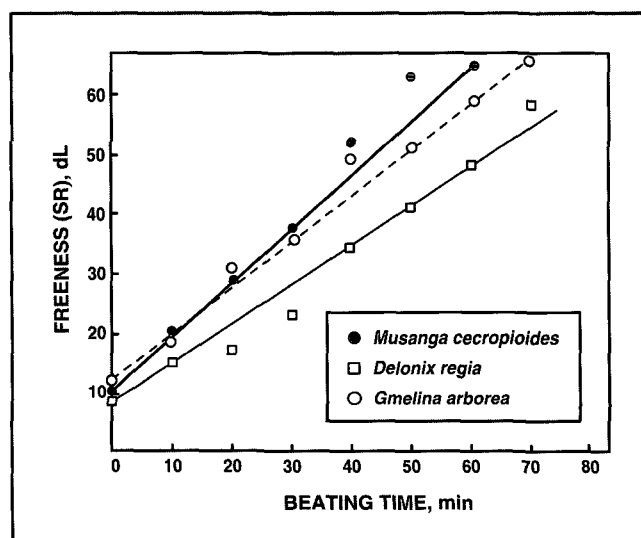
## Wood anatomy

The wood structure of *Musanga*, *Delonix* and *Gmelina* was studied from samples comprising two trees of each species felled from two different provenances, the Ondo and Oyo states

1. Fiber length distribution in wood of *Musanga cecropioides*, *Delonix regia*, and *Gmelina arborea*



2. Pulp freeness (Schopper-Riegler) as a function of beating time



of Nigeria. Wood blocks of each specimen were taken from the butt, the breast height, and the bole apex just below the crown. Samples from the wood blocks were macerated with Schultze's solution (2% KNO<sub>3</sub> in HNO<sub>3</sub>) as described by Bradbury (2). The macerate was used for measurements of cell dimension and derivation of Runkel ratio and flexibility coefficient. Average cell dimensions and derived ratios are presented in Table I. Fiber length distribution for the three wood species is presented in Fig. 1.

Other portions of the wood blocks were microtomed and stained in safranin "O" and fast green. The stained sections were permanently mounted for microscopic description and computation of tissue proportions using a method described by Maeglin and Quirk (3). Average tissue proportions and derived ratios are presented in Table II.

## Wood density

Wood density for each species was determined by measuring the specific gravity using a method based on Archimedes' principle and described by Browning (4). Table III lists wood specific gravity along with pulp yield and ash content for the three woods. Ash content was determined by incinerating wood dusts at 550°C and measuring the inorganic ash deposits that remained after the carboniferous matter had volatilized.

## Pulping, refining, and formation of handsheets

Wood chips of the three species were cooked separately by the kraft method in a laboratory digester under identical conditions using a cooking liquor recipe provided by Higham (5). Pulping conditions are presented in Table IV.

Pulps were refined in a Valley beater, and pulp freeness (Schopper-Riegler) was monitored at 10-min intervals, at which time handsheets were formed. These handsheets were used in subsequent tests of strength prop-

I. Average cell dimensions and associated ratios

|                               | Length,<br>mm | Diameter<br>μm | Wall<br>thickness,<br>μm | Lumen<br>width, <sup>a</sup><br>μm | Runkel<br>ratio <sup>b</sup> | Flexi-<br>bility<br>coeff. <sup>c</sup> |
|-------------------------------|---------------|----------------|--------------------------|------------------------------------|------------------------------|-----------------------------------------|
| <u>Fiber</u>                  |               |                |                          |                                    |                              |                                         |
| <i>Musanga cecropioides</i>   |               |                |                          |                                    |                              |                                         |
| Mean                          | 1.366         | 51.61          | 3.39                     | 44.83                              | 0.15                         | 0.87                                    |
| Std. error                    | 0.017         | 0.71           | 0.013                    | 0.27                               | ...                          | ...                                     |
| Range                         | 0.4-2.5       | 32-61          | 2.8-4.0                  | 26-53                              | ...                          | ...                                     |
| <i>Delonix regia</i>          |               |                |                          |                                    |                              |                                         |
| Mean                          | 1.108         | 31.34          | 4.95                     | 21.44                              | 0.46                         | 0.68                                    |
| Std. error                    | 0.014         | 0.52           | 0.021                    | 0.31                               | ...                          | ...                                     |
| Range                         | 0.5-2.1       | 26-45          | 3.9-5.1                  | 18-35                              | ...                          | ...                                     |
| <i>Gmelina arborea</i>        |               |                |                          |                                    |                              |                                         |
| Mean                          | 1.047         | 34.11          | 2.67                     | 28.77                              | 0.19                         | 0.84                                    |
| Std. error                    | 0.24          | 0.41           | 0.04                     | 0.39                               | ...                          | ...                                     |
| Range                         | 0.4-1.8       | 18-38          | 2-3.2                    | 14-32                              | ...                          | ...                                     |
| <u>Vessel</u>                 |               |                |                          |                                    |                              |                                         |
| <i>Musanga cecropioides</i>   |               |                |                          |                                    |                              |                                         |
| Mean                          | 0.288         | 201            | 4.08                     | 192.84                             | ...                          | ...                                     |
| Std. error                    | 0.061         | 1.94           | 0.01                     | 1.21                               | ...                          | ...                                     |
| Range                         | 0.190-        | 103-248        | 3.2-5.2                  | 97-238                             | ...                          | ...                                     |
|                               | 0.289         | 0.392          |                          |                                    |                              |                                         |
| <i>Delonix regia</i>          |               |                |                          |                                    |                              |                                         |
| Mean                          | 0.235         | 142            | 3.02                     | 135.96                             | ...                          | ...                                     |
| Std. error                    | 0.016         | 1.68           | 0.02                     | 1.89                               | ...                          | ...                                     |
| Range                         | 0.151-        | 130-152        | 2.6-3.2                  | 134-146                            | ...                          | ...                                     |
|                               | 0.289         |                |                          |                                    |                              |                                         |
| <i>Gmelina arborea</i>        |               |                |                          |                                    |                              |                                         |
| Mean                          | 0.221         | 115.5          | 3.1                      | 109.3                              | ...                          | ...                                     |
| Std. error                    | 0.04          | 1.59           | 0.4                      | 0.81                               | ...                          | ...                                     |
| Range                         | 0.184-        | 49-155         | 2.3-3.2                  | 43-147                             | ...                          | ...                                     |
|                               |               | 0.291          |                          |                                    |                              |                                         |
| <u>Rays (cell aggregates)</u> |               |                |                          |                                    |                              |                                         |
| <i>Musanga cecropioides</i>   |               |                |                          |                                    |                              |                                         |
| Mean                          | 0.324         | 20             | ...                      | ...                                | ...                          | ...                                     |
| Std. error                    | 0.01          | 0.42           | ...                      | ...                                | ...                          | ...                                     |
| Range                         | 0.215-        | 15-32          | ...                      | ...                                | ...                          | ...                                     |
|                               |               | 0.636          |                          |                                    |                              |                                         |
| <i>Delonix regia</i>          |               |                |                          |                                    |                              |                                         |
| Mean                          | 0.356         | 31.2           | ...                      | ...                                | ...                          | ...                                     |
| Std. error                    | 0.04          | 0.25           | ...                      | ...                                | ...                          | ...                                     |
| Range                         | 0.124-        | 9-39           | ...                      | ...                                | ...                          | ...                                     |
|                               |               | 0.543          |                          |                                    |                              |                                         |
| <i>Gmelina arborea</i>        |               |                |                          |                                    |                              |                                         |
| Mean                          | 0.408         | 69.8           | ...                      | ...                                | ...                          | ...                                     |
| Std. error                    | 0.03          | 0.61           | ...                      | ...                                | ...                          | ...                                     |
| Range                         | 0.146-        | 29-87          | ...                      | ...                                | ...                          | ...                                     |
|                               |               | 0.485          |                          |                                    |                              |                                         |

<sup>a</sup>Lumen width = diameter - (2 x wall thickness)

<sup>b</sup>Runkel ratio = (2 x wall thickness)/lumen width

<sup>c</sup>Coefficient of flexibility = lumen width/diameter

## II. Average tissue proportions by volume and associated ratios

|                             | Nonfibrous material |              |                  |        | Fiber:<br>vessel<br>ratio | Fiber:<br>nonfiber<br>ratio |
|-----------------------------|---------------------|--------------|------------------|--------|---------------------------|-----------------------------|
|                             | Fiber,<br>%         | Vessel,<br>% | Parenchyma,<br>% | Ray, % |                           |                             |
| <i>Musanga cecropioides</i> |                     |              |                  |        |                           |                             |
| Mean                        | 70.01               | 14.2         | 5.11             | 10.71  | 4.9                       | 2.3                         |
| Std. error                  | 1.21                | 0.23         | 0.81             | 0.29   | ...                       | ...                         |
| <i>Delonix regia</i>        |                     |              |                  |        |                           |                             |
| Mean                        | 71.08               | 9.3          | 12.31            | 8.2    | 7.6                       | 2.4                         |
| Std. error                  | 1.32                | 0.32         | 0.79             | 0.68   | ...                       | ...                         |
| <i>Gmelina arborea</i>      |                     |              |                  |        |                           |                             |
| Mean                        | 72.2                | 7.5          | 4.9              | 15.4   | 9.6                       | 2.6                         |
| Std. error                  | 0.92                | 0.45         | 0.61             | 0.96   | ...                       | ...                         |

## III. Ash content, wood specific gravity, and pulp yield

|                             | Ash<br>content,<br>% | Wood<br>specific<br>gravity | Pulp<br>yield<br>% |
|-----------------------------|----------------------|-----------------------------|--------------------|
| <i>Musanga cecropioides</i> | 1.973                | 0.29                        | 45.6               |
| <i>Delonix regia</i>        | 1.843                | 0.61                        | 48.4               |
| <i>Gmelina arborea</i>      | 1.301                | 0.46                        | 49.2               |

## IV. Pulping conditions

|                                |                     |
|--------------------------------|---------------------|
| Liquor-to-wood ratio           | 4.1                 |
| Active alkali, g/L             | 73.53               |
| Sulfidity, %                   | 18                  |
| Maximum temperature, °C        | 160                 |
| Pressure, kPa                  | 7 x 10 <sup>5</sup> |
| Time at maximum temperature, h | 2                   |
| Total cooking time, h          | 5.25                |

Cooking liquor: NaOH, Na<sub>2</sub>CO<sub>3</sub>, NaHS, and Na<sub>2</sub>S, as outlined by Higham (5).

## V. Summary of characteristics of *Musanga cecropioides*, *Delonix regia*, and *Gmelina arborea*

|                                   | <i>Musanga cecropioides</i> | <i>Delonix regia</i> | <i>Gmelina arborea</i> |
|-----------------------------------|-----------------------------|----------------------|------------------------|
| <b>Wood anatomy</b>               |                             |                      |                        |
| Mean fiber length, mm             | 1.37                        | 1.11                 | 1.05                   |
| Runkel ratio                      | 0.15                        | 0.46                 | 0.18                   |
| Flexibility coefficient           | 0.87                        | 0.68                 | 0.88                   |
| Fiber volume, %                   | 70.01                       | 71.08                | 72.2                   |
| Fiber:vessel ratio                | 4.9                         | 7.6                  | 9.6                    |
| Fiber:nonfiber ratio              | 2.3                         | 2.4                  | 2.6                    |
| Specific gravity                  | 0.29                        | 0.61                 | 0.46                   |
| Pulp yield, %                     | 45.6                        | 48.4                 | 49.2                   |
| Ash content, %                    | 1.973                       | 1.843                | 1.301                  |
| <b>Freeness (°SR)</b>             |                             |                      |                        |
| 30 min                            | 37                          | 23                   | 29                     |
| 40 min                            | 52                          | 34                   | 36                     |
| 60 min                            | 65                          | 48                   | 59                     |
| <b>Mechanical properties</b>      |                             |                      |                        |
| Burst strength, g/cm <sup>2</sup> | 1.56-4.62                   | 1.21-2.94            | 1.52-3.98              |
| Tear strength, g                  | 101-164                     | 88-162               | 98-165                 |
| Breaking weight, kg               | 4.91-8.89                   | 3.2-6.04             | 4.81-8.02              |
| Breaking length, m                | 1890-5108                   | 1802-3554            | 1820-5120              |

erties. **Figure 2** shows pulp freeness as a function of beating time. **Figure 3** shows the mechanical properties of the various handsheets formed when freeness was monitored at 10-min intervals. **Table V** summarizes the results obtained for the three wood species.

## Literature cited

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## 3. Mechanical properties of handsheets as a function of pulp freeness (SR).

