Effect of interlocked grain on wood mechanical behaviour in *Bagassa guianensis* in French Guiana

Julie BOSSU  PhD student – CNRS  
UMR EcoFoG - *Ecologie des Forêts de Guyane*, French Guiana

Bruno CLAIR, CNRS, Kourou - *Supervisor*  
Jacques BEAUCHENE, CIRAD, Kourou  
Mériem Fournier, Agroparistech, Nancy
Presentation outline

INTRO - French guiana timber context

- Ecological context
- Economical and social context

MATERIAL - Bagassa guianensis, promising species for local forestry

- Evaluate wood quality?
- Concept of paradoxical species
- Efficient wood characteristics

RESULTS – Interlocked grain, a singular structural characteristic

- Interlocked grain
- Pattern within the tree
- Mechanical properties depending of the scale of observation

Conclusion

Outlooks
Effect of interlocked grain on wood mechanical behaviour in *Bagassa guianensis* in French Guiana

**INTRO - French Guiana timber context**

1. Ecological context
2. Local production
3. Economical and social context
**INTRO**

1. **Ecological context**

   **Favorable →** Adapted region to try new sustainable models

   **Forest cover:** 8 Millions ha

   **Area monitored by the National Forestry Agency**

   **Protected area of the Amazonian Park**

   - Well preserved region
   - High biodiversity

   **Source:** Ruth S. DeFries et al., 2006
1500 species identified
With 500 exploitable

Only 70 exploited

With only 3 species representing 70% of the mean annual production:
- « Angélique » : Dypterix odorata
- « Gonfolo rose » : Qualea rosea
- « Grignon franc » : Sextonia rubra

Small and specific production
✓ System acceptable for a small demand
INTRO

3. Economical and social context

Requires rapid adaptations

High birth rates
Population x 3 within 50 years!

Very young population
One in two people is under 25 years

Current system of production need to be adapted!

Objectives:

1. Provide the next generation
2. Avoid massive importation

Plantations!
Effect of interlocked grain on wood mechanical behaviour in *Bagassa guianensis* in French Guiana

**MATERIAL - Bagassa guianensis, promising species**

1. How to evaluate « **wood quality** » among diversity?

2. Concept of **paradoxical species**

3. Species studied: *Bagassa guianensis* (Aubl.)

4. Properties leading to such **technological performances**
   - Specific gravity variations
   - Extractives reducing shrinkage

*Julie BOSSU - PhD Student, CNRS
EcoFog, French Guiana*
MATERIAL

1. How to evaluate « wood quality » among diversity?

What are we searching for?

- Fast-growing species
- Adapted to plantations
- Quality wood for timber
- Local species

What kind of data set to represent wood quality?

Physical and mechanical database (207 species)

Growth monitoring database (352 species)

Crossing analysis

Promising species??
2. Concept of paradoxical species
MATERIAL

3. Bagassa guianensis (Aubl.)

Family: Moraceae
15 years -> Ø 25 cm
**MATERIAL**

4. Properties leading to such technological performances

- Specific gravity variations:

  “Wood density is related to tree construction costs” (Larjavaara, 2010).

### Heliophilous Pionners
- Grow fast
- Low density

### Long lived Climax
- Grow slow
- High density

Mixed ecology: « Long Lived Pioneer »

>> High growth rate and perenity of the structure
**MATERIAL**

- Extractives reducing shrinkage:

- Extreme low shrinkage in heartwood (7.28%)

- Not linked with density as established

- After extraction: secondary metabolites from heartwood formation reduce shrinkage!

- Efficient extractives content

- >> Exceptional low shrinkage and lower anisotropy
Effect of interlocked grain on wood mechanical behaviour in *Bagassa guianensis* in French Guiana

**RESULTS – Interlocked grain, a singular structural characteristic**

1. What is interlocked grain?
2. Pattern within the tree
3. Fiber scale: link with MOE
4. Ring scale: tenacity
5. Trunk scale: flexibility
RESULTS

1. What is interlocked grain?

Result of wood anatomy:

During wood production -> formation of fusiform initials cells:
- Slightly inclined to the stem axis
- Inclination can change with time

-> Grain can be straight, wavy, spiral or **interlocked**

3 things we know:
- Inclination of fusiforms -> grain angle (Bath, 1983)
- Grain inclination cycles are temporal (Krawczyszyn, 1980)
- Interlocked grain -> MOE decreases (Cabrolier, 2007; Bremaud, 2012)

3 things we don’t know:
- Signal responsible for inclination cycles?
- Adaptative advantage for the tree?
- Influence on tree mechanical behavior?
2. Pattern within the tree in B. guianensis

**RESULTS**
• For different radius: same number of grain periods
  -> confirmation of Krawczyszyn: **temporal pattern**!

• Yet « grain waves » amplitudes are **exceptional** (from -25 to 30° for mature specimens!)

• Really **homogeneous pattern** for all the individuals:

---

**Consequence on wood material:** Increase wood anisotropy in a longitudinal cut!

↓

Might alterate wood mechanical behavior
RESULTS

3. Fibers scale (mm) : link with MOE

\[ E' = \frac{48\pi^2 l^4}{m_n h^2 f_{Rn}^2} \]

where \( l = \) length; \( h = \) thickness; \( m_n = \) constant depending of the vibration node; \( f_{Rn} = \) resonance frequency.
Grain angle is a significant modeling parameter ***
\( (P_{value} < 2e-16) \)

Grain angle is confirmed to be negatively correlated to MOE.

**Fibers scale:**
Interlocked grain cut down mechanical properties

-> WOOD FLAW!
RESULTS

Microfibrils angle (MFA):

AMF variations might offset the effect of interlocked grain on MOE!

Example:
(Cabrolier, 2007)
RESULTS

Microfibrils angle (MFA):

Yet we measured slight variations in MFA:

MFA can’t offset interlocked grain effect on MOE!
RESULTS

4. Ring scale (cm) : tenacity test

Interlocked grain revent cracks propagation?

- **R/T tenacity test:**

- **Indicators of the grain angle deviation:**

\[
G_f = \text{Maximum surfacic energy before fracture} \\
\sigma_f = \text{Maximal constraint before fracture}
\]

MDA : Maximum Deviation Angle
GI : Grain Angle
RESULTS

Ring scale:
Interlocked grain improves tenacity
-> ADVANTAGE!
RESULTS

5. Simulation of interlocked grain at trunk scale: flexion behavior

Interlocked grain improves flexibility?

Artificial reconstitution of interlocked grain in the tree:

- **Objective:**
  Simulate the mechanical behavior of a material including several interlocked grain periods.

- **Multilayers samples:**
  - 5 Layers with alternate grain direction
  - 17 ranges of grain angle (2° - 40°)
  - Neutral middle layer (0°)
  - Hygroscopic conditions under control
  - Layers with same density – Same MOE
Trunk scale:
Interlocked grain reduces strength and yield point
-> DEFECT!

Experimental limits:
• Small sample dimensions
• Boundary conditions inducing shearing
• Delaminating ruptures for 2 samples with epoxy

-> Not fully adapted to simulate the real effect at trunk scale

Adaptations required?
• Phenol-resorcin resin
• 4-points flexion
• Compression tests

Caution!!
Conclusion

- Paradoxical species combine high growth rate / medium density / low shrinkage
  - Promising species for quality wood products
  - Well adapted for plantations

- Example of an optimized tradeoff between strength and cost of construction.

- Interlocked grain:
  - Strict pattern within the tree
  - Line guides for cutting process according to desirable uses
  - Advantage or inconvenient depending on the scale length
    - Negative effect on MOE on microscale
      - But positive effect on tenacity on macroscale
      - Need to be tested with larger samples to evaluate the effect on yield
      - Effect on trunk torsion? Resistance to the wind?

- Applications?
  - Necessarily advantageous for specific uses
  - Resistance to cracks -> can be used as cutting boards
  - Construction : improve the strengthening of glued laminated timber

Julie BOSSU - PhD Student, CNRS
EcoFog, French Guiana
Outlooks

• Next steps in the study of B. guianensis:
  ✓ Valorize its potential for local timber industry
  ✓ Improve knowledge about growth strategy and impact on wood properties
  ✓ Practical application of the results

• Interlocked grain VS wood mechanics:
  ✓ Link between growth strategy and interlocked grain?
  ✓ Influence of the environment?
  ✓ Applications:
    • Resistance to cracks -> can be used as cutting boards
    • Good contender to improve the stiffness of glued laminated timber
      example: wood tubes

Julie BOSSU - PhD Student, CNRS
EcoFog, French Guiana
Thanks for your attention

julie.bossu@ecofog.gf