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TECHNOLOGICAL CHARACTERISTICS FROM NON-DESTRUCTIVE METHODS FOR SELECTION OF FOREST SPECIES OF GMELINA ARBOREA ROXB PLANTED IN COMPARATIVE ORIGINS TRIAL IN SEMI-DECIDUOUS DENSE FOREST, CÔTE D'IVOIRE

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Abstract: Technological wood qualities of 8 origins of *Gmelina arborea* planted in a comparative trial at Sangoué were assessed, in a semi-deciduous dense forest area in Côte d'Ivoire. The trial aimed the timber yielding. For this purpose, the choice of the non-destructive approach, preserving the tree for assessing of the quality of wood, was carried out. Results showed that the most vigorous origins relatively to diametrical growth also expressed high values of penetration depth using the Pilodyn and low densities. The latter were, strongly correlated among them, allowed the differentiating of origins in different areas of wood such as sapwood, perfect wood and heart wood. Therefore, a sample collection using the pilodyn by driving in the bark only and limited in the area near the sapwood can be sufficient for selecting forest species based on technological wood quality.

Keywords: Gmelina origins; Pilodyn penetration; Sample core; Wood infradensity.

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INTRODUCTION

The CTFT-CI (Centre Technique Forestier Tropical of Côte d'Ivoire) incorporated in 1998 to the CNRA (Centre National de Recherche Agronomique) initiated with FAO a large comparative trial programme of various tree species provenances, coordinated by DANIDA from Denmark. Seeds of thirteen provenances of *Gmelina arborea* Roxb have been provided by DANIDA to Côte d'Ivoire in 1977. These seeds were used for the setting of trials comparative of *Gmelina* spp., including that of Sangoué at the region of Oumé. This trial selected for our study, aimed to provide an efficient plant material for the production of valuable lumber. In this context, a non-destructive assessing of the wood quality by core samples and/or Pilodyn penetration was more appropriate. The non-destructive assessment of woods quality of living trees is not a new approach and several researchers have already used it on various tree species (Polge, 1966; Nepveu and Teissier, 1976; Ferrand, 1981; Castera, 1984). The advantage of this approach is to enable the reproduction of the study on the same individuals or as a function of the age if necessary. On the basis of the above, we postulate that this non-destructive approach for the assessment of wood quality could allow the selection of Gmelina trees. We intend, through this study, to use this approach for forest species selection through Gmelina provenances of a dozen years old.

EXPERIMENTAL

Plant material: The plant material for this study consisted of eight provenances of *Gmelina arborea* whose main characteristics are presented (table 1). Native of Asia, *Gmelina arborea*, was introduced in Côte d'Ivoire and the first large-scale plantations were installed at Bamoro in 1950 (FAO, 1989) before being extended to other areas. From 1970, CTFT and SODEFOR (Société de Développement des Forêts) created numerous plantations for experimental purposes in Anguédédou, Yapo, Oumé and San Pedro. Tested origins in our study were planted in a comparative trial of *Gmelina arborea*, installed at Sangoué in area of semi-deciduous dense forest. The inventories carried out for ten years of observation (Kadio, 1990a) show that the provenances that display the best characteristics such as Bamoro (9) Shikaribari (8) and Baramura (7) combine good strength and rectitude with an average cylindricity. The provenance Bilaspur (4) reveals a very high rate of mortality, probably due to its bad adaptation to the ecological area of Sangoué. Therefore, it was dropped from the study.

Experimental Design: A factorial in a randomised complete block design was used. Four blocks coded A, B, C and D containing each of all the 9 origins were used (Figure 1). The experiment was planted on 3.9 ha and had 3.75 m x 3.75 m spacings for a total of 710 seedlings per hectare. Thirty six unit plots incorporated the 9 different origins. Each unit plot counted either 7 x 11 seedlings, 6 x 11 seedlings or 7 x 9 seedlings. The trial was set up at Sangoué in semi deciduous area, in the field entirely and mechanically cleared, scraping all existing vegetation.

Table 1: Nine origins of *Gmelina arborea*, their geographical coordinates and rainfall planted at Sangoué

S.No.	No. FAO*	Origins	Latitudes	Longitudes	Altitudes	Rainfall (mm)
1.	4002	Muag Leck (Thailand)	14° 37' N	101° 07' E	250	1200
2.	4006	Mahilong, Bihar (India)	23° 30' N	85° 30' E	600	1442
3.	4008	Ghotil, Maharaachtra (India)	17° 14' N	73° 57' E	1000	850
4.	4011	Bilaspur (India)	22° 23' N	82° 00 E	-	1500
5.	4016	Kundrukutu, Bihar (India)	20° 30' N	85° 20' E	600	1400
6.	4024	Thithimathi, Karnataka (India)	12° 12' N	76° 05' E	850	1400
7.	4027	Baramura, Tripura (India)	23° 46' N	91° 34' E	120	2200
8.	4028	Shikaribari, Tripura (India)	24° 13' N	92° 07' E	200	2300
9.	4035	Bamoro (Côte d'Ivoire)	7° 50' N	5° 04' W	330	1110

No. FAO*: Number given by Food and Agriculture Organization.

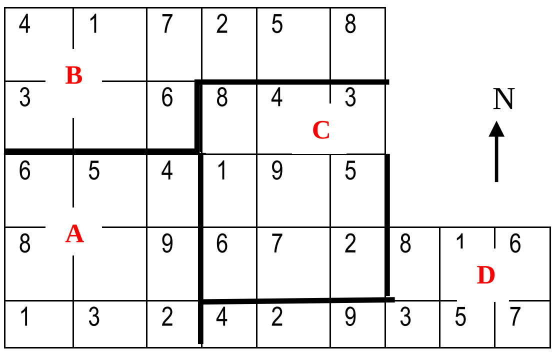

Figure 1: Experimental design used to compare effects of the tested factors: A, B, C and D, are blocks used. Numbers from 1 to 9 are treatments. These are the origins: 1 Muag Leck (Thailand), 2 Mahilong, Bihar (India), 3 Ghotil,Maharaachtra (India), 4 Bilaspur (India), 5 Kundrukutu, Bihar (India), 6 Thithimathi, Karnataka (India), 7 Baramura, Tripura (India), 8 Shikaribari, Tripura (India), 9 Bamoro (Côte d'Ivoire).

Trees selection: Fifty five trees + or better tree previously selected and written with paint at the age of 8, by plant breeders, were kept as reference for the trees selection. The selection criteria of breeders were defined, to capitalize better the intra-origin variability by retaining individuals expressing selectable characters (Kadio, 1990b and 1992). These criteria are based on the shape. Thus, selected individuals are called trees + (Figure 2). In addition, we chose well conformed individuals among neighbors of these trees +. Hundred and fifty one individuals including trees + were selected. Some unit plots did not contain trees +, namely plots C1, D1, D2 and D3 (Figure 1). Nonetheless, we selected there well conformed individuals to balance the experimental design, thus to respect the conditions for performing of the ANOVA.

Work and Measurements in the Field: On each of selected trees, the circumference at 1.30 m from the ground was recorded using a tape measure. Measurements of the penetration depth using Pilodyn 6 joules were carried out in bark at 1.30 m from the ground, in an East-West direction, in order to harmonize the insertion side for all trees (Figure 3). A core sample was finally extracted at 1.30 m above the ground in the East-West direction using a well sharpened borer of Pressler of 5 mm. Immediately after sampling, the cores were numbered and the heart side marked, before storing in plastic tubes to avoid drying.

Figure 2. Trees + of *Gmelina arborea* in the comparative trial at Sangoué, Côte d'Ivoire

Figure 3: The wood tester pilodyn of a capacity of 6 joules used for the experimentation

Work and Measurements at the Laboratory: The cores were cut at the laboratory in lengths derived from the theoretical or real diameter of the origin tree. The maximum length of the core corresponded to half of the tree diameter. If the heart is visible on the core, the length is true and corresponded to the distance bark–pith (Figure 4 a and b). If the heart is not visible (Figure 4 c), the length is theoretical and is determined on basis of tree circumference.

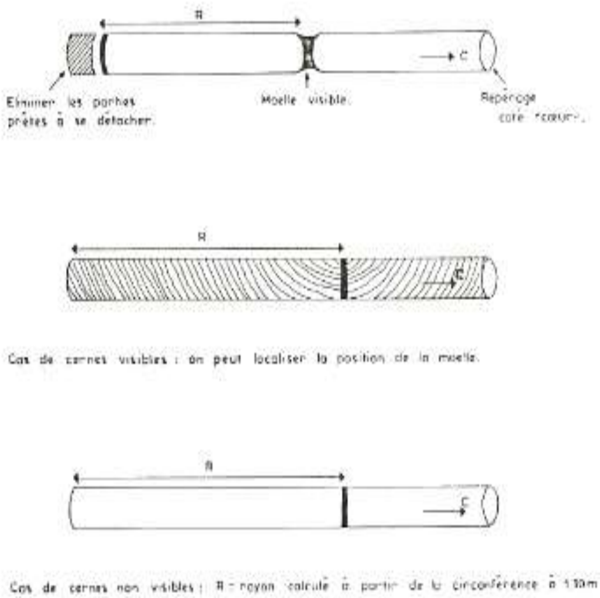

Figure 4. Location of the pith and Core length before cutting

Each core was then divided into three sub-cores of approximately equal lengths. The sub-core taken near to the sapwood was noted A, the one taken close to the heart was noted C and the one taken in the intermediate part, which is in the perfect wood, was noted B. The total number of sub-cores and their distribution per block and per origin was reported (Table 2).

Table 2. Summary of total number of sub-cores and their distribution per block and per origin

Origin	Blocks				Total
	A	B	C	D	
1	12	9	9	12	42
2	15	9	15	12	51
3	15	9	15	12	51
5	15	15	15	12	57
6	12	12	12	15	51
7	15	18	15	12	60
8	21	15	18	12	66
9	18	18	21	18	75
Total	**123**	**105**	**120**	**105**	**453**

For an easy identification, the numbering of each sub-core included the number of the mother core, the letter of the concerned block and indication of the wood area. On each sub-core, direction given to the arrows allowed the guiding relating to the tree heart. An example from of the first sub-core of block A for the origin 7 was taken on the heart side and illustrated (Figure 5).

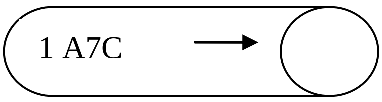

Figure 5: Numbering and orientation of the sub-cores for the study

The relatively fresh sub-cores were saturated by boiling (Keylwerth 1954; Polge, 1966) for 10 hours and then exposed for stabilisation in the cold room (22 °C, 65% humidity) for 15 days before being steamed for 48 hours at 105 °C. At each of the main processing steps (full saturation, stabilisation, deshydratation), the sub-core was weighed (10^{-2} g). As part of this study, only infradensities were taken as the physical measure in the determining of the wood quality. These infradensities (ID) or basal densities were obtained using the equation from Keylwerth (1954) and Polge (1966):

$$ID = \frac{1}{\frac{Ms}{Mo} - 0,347}$$

M_o: Sub-core weight in the anhydrous state

M_s: Sub-core weight in the saturated state

Statistical analysis: Collected data were subjected to ANOVA incorporating means comparison according to Newman-Keuls test at 5% threshold. The software STATITCF was used. Blocks and origins were used as factors.

RESULTS AND DISCUSSION

Measurements in the field: Regarding the circumference at 1.30 m from the ground, 2 statistically distinct subsets of origins were identified. First, consisted of 3, 2 and 5 origins were characterized by low circumference. Second, comprising the origin 1 was marked by high circumference. Dispersion around means varied from 2.2 to 18.9% (Table 3). As far as the Pilodyn penetration depth (mm) is concerned, 2 homogeneous subsets were noted. The first one, composed of means of the origin 3, was distinguishable by weak Pilodyn penetration depth (mm). The second one, constituted of origins 1, 7, 8, 9 and 6, was characterized by strong Pilodyn penetration depth (mm). Variability around means fluctuated from 2.0 to 6.6% (Table 3). For all the field measurements, the block effects were not significant.

Measurements at the Laboratory on Core samples: Here also for Sapewood Side Infradensities (SSI), 2 significantly different subsets, namely S1 and S2, were identified. S1 comprising the origins 8, 7, 9 and 1, differed from S2 by low infradensity. S2, consisted of the origin 3, was marked by high infradensity. Gaps between each of means and measured modalities oscillated from 2.8.to 7% (Table 4). With respect to Perfect wood Side Infradensities (PSI), 2 subsets were revealed. First, composed of origins 2, 5, 9, 1, 8 and 7, differed from other subset by low PSI. Second, constituted of origin 3 differed from the first subset by high PSI. Variability around of each means was between 1.1 and 7.2 % (Table 4).

As for the heart side (HSI) and overall core infradensities (g/dm^3) as a function of origin, 2 statistically different subsets were identified. The first one, constituted of origins 5, 2, 1, 6, 8, 9 and 7, stood out from the second subset by weak heart side core infradensity. The second one, consisted of origin 3, was characterised by strong heart side core infradensity. Gaps between means and each of measured modalities varied from 2.2 to 7.6% (Table 5). No significant effect noticed from the block. The matrix of correlations (Table 6) shows strong positive correlations between basic densities from different parts of the wood (ID, IDA, IDB and IDC). On the contrary, the Pilodyn depth penetration gives strong negative correlations with these different basic densities.

Table 3. Classification of Means of Circumference of 8 Tested Origins and Pilodyn Penetration Depth (mm)

Dependent variable	Origin	Mean	CV (%)	Dependent variable	Origin	Mean	CV (%)
Circumference at 1.30 (cm) from ground	1	122a	9.6	**Pilodyn penetration depth (mm)**	1	31.30a	5.7
	9	106ab	10.5		7	30.97a	3.9
	7	104ab	5.9		8	30.37a	2.0
	6	102ab	5.0		9	30.29a	3.0
	8	101ab	18.9		6	29.89ab	3.3
	3	97b	9.6		5	28.61ab	6.6
	2	95b	8.6		2	28.50ab	2.4
	5	90b	2.2		3	27.45b	2.5

Table 4. Classification of origins as a function both sapwood and Perfect wood side Infradensities

Dependent variable	Origin	Mean	CV (%)	Dependent variable	Origin	Mean	CV (%)
SSI* **Infradensities from the sapwood side (g/dm³)**	3	443.51a	**2,8**	PSI*	3	429.9a	**1,1**
	5	433.38ab	**3,5**	**Infradensities from the perfect wood side (g/dm³)**	6	385.5ab	**4,1**
	6	411.50ab	**4,4**		2	385.44b	**7,2**
	2	403.85ab	**7,0**		5	373.33b	**7,2**
	8	396.34b	**3,5**		9	372.48b	**3,4**
	7	395.54b	**5,6**		1	371.34b	**6,4**
	9	394.63b	**4,7**		8	364.79b	**3,9**
	1	385.66b	**4,9**		7	363.8b	**7,2**

SSI* : Sapewood side infradensities. **PSI*:** Perfect wood side infradensities

Table 5. Classification of origins as a function both the heart side and overall core Infradensities

Dependent variable	Origin	Mean (mm)	CV(%)	Dependent variable	Origin	Mean (mm)	CV(%)
HSI* infradensities from the heart side (g/dm³)	3	411.23a	**3,6**	**Infradensities from the whole core (g/dm³)**	3	428.22a	**2,0**
	5	374.9ab	**2,2**		5	387.20ab	**3,7**
	2	361.55b	**7,6**		6	384.92b	**4,4**
	1	358.98b	**4,0**		2	383.55b	**7,0**
	6	357.77b	**5,2**		1	372.18b	**4,8**
	8	347.63b	**4,1**		9	371.44b	**3,1**
	9	344.02b	**4,1**		8	369.77b	**3,3**
	7	342.02b	**5,4**		7	367.12b	**5,7**

HSI*: Heart side Infradensities

As the discussion, the measurements achieved in the field, the origin 1 (Muag Leck) from Thailand expressed the best circumference at 1.3 m from ground. These results can find an explanation through the specific adaptation of this origin in Sangoué area. These diameters are similar to those of Gmelina 12 years old in dense evergreen forest zone according to Yamké (1983) and even preforest area where diameters of 32 cm are noted at 16 years old after Dupuy (1986). The average diameter (33 cm) is in the same order of magnitude than the one aged 15 in *Pinus oocarpa* in Côte d'Ivoire (Durand and Edi, 1984). They show the relative strength of vegetative growth of *Gmelina arborea*. Therefore, origin 1 should undergo multi-year and multi-local on-station tests in evergreen forest area before their releasing throughout where it can grow throughout in Côte d'Ivoire. Regarding the resistance to the Pilodyn depth penetration, origin 3 (Ghotil, Maharaachtra) from India recorded the weakest value. This result is illustrated by the equation *infradensity = 593.39– 10.39 Pil* obtained on *Gmelina arborea* aged 12 years (Kouassi, 1990) and *infradensity = 566.53– 8.12 Pil* obtained from *Terminalia ivorensis* aged 18 years (Ahoba (1990). These equations show that the pilodyn depth penetration (Pil) provides a good appreciation of wood density. These features are in contrast with those of vigorous vegetative growth provenances as Mua leck (1), Bamoro (9), Baramura (7) and Shikaribari (8). The most vigorous provenances in term of diametrical growth, also display a high penetration of pilodyn and correlatively a low density. Thus, the pilodyn penetration, quick and easy to realize, can be an interesting test for a quick selection of forest species based on wood quality. The lack of the bloc effect shows that obtained differences express the intrinsic value of origins.

Table 6: Relationship between Measured variables

	PIL	CIRC	ID	IDA	IDB	IDC
PIL	1					
CIRC	0,539	1				
ID	- 0,638	-	1			
IDA	- 0,683	- 0,364	0,925	1		
IDB	- 0,507	-	0,95	0,823	1	
IDC	- 0,614	-	0,931	0,783	0,831	1

PIL=Pilodyn depth penetration on bark; CIRC= circumference; ID = Infradensities from the whole core; IDA =Infradensities from the sapwood side; IDB = Infradensities from the perfect wood side; IDC= Infradensities from the heart side.

Concerning measurements at the laboratory on sample cores, the Sapewood Side Infradensities (SSI) showed that the origin 3 recorded the highest one. The values obtained increasing from the heart to the periphery of the tree for all the provenances. This increasing already observed in *Populus nigra*, is almost universal among forest species (Nepveu and Teissier, 1976). Our study shows that the relatively mature wood of *Gmelina arborea* showed higher density (405 g/dm^3) than the juvenile wood (362 g/dm^3). The perfect wood density (380 g/dm^3) intermediate between the heart and the sapwood confirm somehow the increase of wood density with tree's age. Gmelina matures wood offer better qualities in terms of basic density. Likewise, for the Perfect wood Side Infradensities (HSI), the same origin 3 revealed the highest value. This origin (Ghotil), is selectable on density from increment cores or deducted from pilodyn depth penetration. Similar values of density in the order of 380 g/dm^3 have already been obtained from samples core *Gmelina arborea* aged 24 years (Djah, 1991). The basic densities from different part of the wood (sapwood, perfect wood, heart) are highly correlated between them. These strong correlations point out the possibility of early selection on the basis of wood density. They also make it possible to consider selection of forest species by sampling cores limited in the sapwood area. Sampling core limited to the sapwood zone has the added benefit to be less damaging to the trees and to save time in the field.

CONCLUSION

The Pilodyn depth penetration, quick and easy to perform, provides a good assessment of the wood density and can be an interesting test for forest species selection. The most vigorous trees in diametric growth seem also at high depression in pilodyn penetration and correlatively low density. The densities from sample cores allow distinguishing subjects at the sapwood area, perfect wood, heart and even the entire core. These densities leave reflected some increase with the age of the tree. Strong correlations of densities in different areas along the radius of the wood Point out the possibility of early selection based on wood quality. They also make it possible to consider selection of forest species by sampling cores limited in the sapwood area. Sampling core limited to the sapwood zone has the added benefit to be less damaging to the trees and to save time in the field.

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