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***Journal of Scientific and Engineering Research*, 2016, 3(3):297-302**

Research Article

ISSN: 2394-2630
CODEN(USA): JSERBR

Selection of *Terminaliaivorensis A. Chev*. Origins by Using the Pilodyn Penetration Test

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Abstract To select the best Origins of *Terminaliaivorensis*, their wood was subjected to the Pilodyn penetration test. Likewise, to predict the basic wood density from the Pilodyn penetration depth, the Pearson's linear correlations were tested. Sixteen origins of *Terminaliaivorensis*, from Côte d'Ivoire, Ghana and Cameroon, were laid out in a Randomised Complete Block Design with only one replication. This design was set up in a comparative trial in semi-deciduous dense forest. Anova was used to select the best Origins whereas the Pearson's linear correlation was carried out to search for the best relationship between the Pilodyn penetrationdepth and the basic wood density. Ordinarily, vegetative growth criteria are used to select the best origins. Nonetheless, these can be reinforced by non-destructive method of the wood quality represented by the Pilodyn penetration depth test. The results showed that the Origin 2 or 6, 7, 4, 11, 14, 2 and 9 can be selected basing only on the basic wood density or Pilodyn penetration depth. In past studies, silvicultural qualities such as the circumference at 1.3 m from the ground were used to discriminate the Origins and thus select them. A high, but negative correlation is recorded between the basic wood density and the Pilodyn penetration depth. This correlation indicates that when the Pilodyn penetration depth in wood is low, the quantity of dry matter in the tree is high.Consequently, the wood density is high. This would allow us to select on the low Pilodyn penetration depth. Thus, the Pilodyn penetration depth appears to be quick test of density appreciation for standing trees. The commercial value of forest trees depends not only on their silvicultural qualities but especially on their technological qualities. Consequently, it is important to take into account the Pilodyn penetration tests in addition to silvicultural criteria, for an efficiency selection of forest trees awaiting the multi-local and multi-annual trials.

KeywordsFramiré, basic wood density, sample core, trees selection, silvicultural qualities

Introduction

Teminaliaivorensis, also called Framiré, is a tree of the Combretaceae family. It is used in reforestation. Its hard wood is appreciated in carpentry and cabinetwork. Selection of elite trees in this botanical group uses the criterion of vegetative vigour and that of shape. These can be enhanced by relying on the wood quality criteria, easy to determine and less damageable for trees. In sucha perspective, non-destructive methods have been developed for the rapid appreciation of wood quality that can help to select forest trees. These methods include the Pilodyn penetration to a certain depth of standing trees. This presents the advantage to be reproducible. Non-destructive assessment of the wood quality on standing trees is not a new approach. Indeed, several researchers have already tried it on various forest species by sampling of drill core or penetrating to Pilodyn[1-3]. Moreover, the technological performances of some origins of *Terminaliaivorensis*, namely their resistance to the Pilodyn penetration, is stayed unknown. Such a knowledge could allow the selecting of some origins for releasing purposes. For that, we postulate that at least 1 or 2 Origin(s) might be selected on basis of its / their low basic wood density. Our study aimed to propose the non-destructive approach from the Pilodyn penetration depth for assessment of the wood quality that can contribute to select the best origins of *Terminaliaivorensis*.

Materials and methods

Plant material

The plant material consisted of 16 Origins from *Terminaliaivorensis* whose the main characteristics were reported (Table 1). This is dry forest species preferring the full light, losing its leaves each year. The distribution area corresponds to the semi-deciduous dense forest zone that spreads from the forest zone of Guinea to West of Cameroon, with frequent penetration in the evergreen area of forest in Côte d'Ivoire. Tree stumps produce vigorous shoots which quickly grow.

Table 1: Origin and geographic coordinates of 16 origins tested.

N° Local	Country	Origins	Latitudes	Longitudes	Altitudes (m)	Rainfall (mm)
1	Côte d'Ivoire	Loviguié	5° 45' N	4° 19' O	100	1500
5	Côte d'Ivoire	Yapo	4° 06' N	5° 44' O	50-100	1600
9	Côte d'Ivoire	Abengourou	6° 43' N	3° 30' O	260	1300
13	Côte d'Ivoire	Bamo	5° 56' N	4° 13' O	80	1500
15	Côte d'Ivoire	Mopri	5° 50' N	4° 50' O	80	1400
6 and 10	Ghana	PraAnum	6° 15' N	1° 15' O	150	1650
11 and 16	Ghana	Bobiri	6° 45' N	1° 15' O	150	1650
8	Ghana	Krokosua Hills	6° 30' N	2° 45' O	250-350	1650
3	Ghana	N'Dumeri	5° N	2° 15' O	150	2000
7 and 2	Ghana	Mankrang	7° 15 N	2° O	150-350	1400
14	Ghana	TanoAnhwia	5°45 N	2° 30' O	150	1650
12	Ghana	Volta River	6° N	0° O	350-500	1150
4	Cameroun	Kumba	4°32 N	9°19' EAST	350	2600

Experimental design

Each of 16 origins was used as a variant of factorOrigin in a Randomised Complete Block Design with one replication. Treatment was defined as each of levels of factor Origin. Four blocks noted A, B, C, D, with each 16 experimental plots, in which the 16 treatments were allocated (Figure 1). In all, 64 unit plots with 100 plants per origin and per unit plot were used. Regarding the origin 14 from Ghana, by reason of unavaibility of the seedlings, its counts in unit plots were reduced in half, that is to say 50 [4]. Origins were planted on 22 ha. Seedlings were spaced 3.33 m on rows and 8 m between rows. The trial was installed under poisoned forest with seedlings grown in nursery. To develop hole for planting seelings, trees whose diameter was over 20 cm were felled.

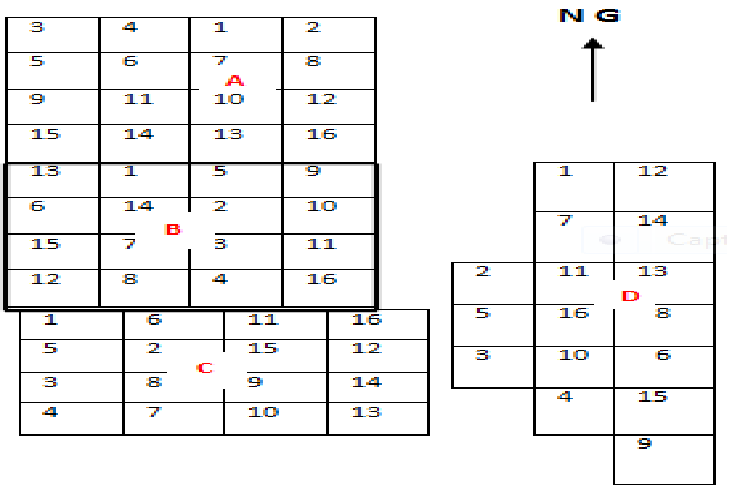

Figure 1: Experimental design of the comparative Origins trial of Terminaliaivorensis set up at Mopri, Côte d'Ivoire.

Key of origins : 1: Côte d'Ivoire (Loviguié); 2: Ghana (Mankrang); 3: Ghana (N'Dumeri); 4: Cameroun (Kumba Town); 5: Côte d'Ivoire (Yaposud); 6: Ghana (PraAnum); 7: Ghana (Mankrang); 8: Ghana (Krokosua);

9: Côte d'Ivoire (Abengourou); 10: Ghana (PraAnum); 11: Ghana (Bobiri); 12: Ghana (Volta River reserve); 13: Côte d'Ivoire (Bamo); 14: Ghana (TanoAnwhia); 15: Côte d'Ivoire (Mopri); 16: Ghana (Bobiri).

Trees choice, measurements and sampling on trees

For all the 4 blocks, 64 squared patches measuring 4 acres were laid out at the centre of each unit plot to avoid edge effects. These 4 acres allowed the sampling from 2 to 6 trees per unit plot by considering different mortalities from plot to plot. Two hundred and ninety six (296) trees from 16 origins distributed in the 4 blocks were thus selected. On each tree selected, the circumference at 1.30 m from the ground were recorded using a tape measure. Measurements of the Pilodyn 6 joule-penetration depth have subsequently been carried out on bark at 1.30 m from the ground (Figure 2). This, in the East-West direction, to harmonise the side of penetration for all trees. Finally, a core sampling was taken at 1.30 m from the ground in the East - West direction using a Pressler borer of 5 mm well sharpened.

Figure 2: The pilodyn 6 joules (wood tester) used for experimentation.

Determination of the basic wood density

The obtained core sampling (296) were subdivided into three parts : A (sapwood), B (perfect wood), C (heart area) thus giving 890 sub-cores whose each was subjected to the determination of wood basic density via the method of full saturation (Polge, 1966). For this study, only average basic density per tree was taken into account to compare the origins. Likewise, the link between the wood basic density and the Pilodyn penetration depth was established by means of the Pearson's linear correlation. These basic densities (ID) were obtained from the following relationship of Keylwerth (1954) [5] and Polge (1966) [1]:

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

Ms = Weight of the sub - core to the saturated state

M_0 = Weight of the sub - core to the anhydrous state

Statistical analysis

Collected data were subjected to 2-way analysis of variance and the Pearson's linear correlation by using the SPSS and XLSTAT softwares version 16 and 2007, respectively. The 2 factors taken into account were Block and Origin. Means were separate according to Newman - Keuls test at 5% likelihood.

Results

Origin and block effects on expression of the circumference at 1.30 m from the ground, the Pylodyn penetration depth and the basic wood density

Origin x Block interactions were not significant (p-value / Circ1.3 = 0.07; p-value / Pilo = 0.051; p-value / ID = 0.554; Table 1). Moreover, considering main effects, no block effect was significant. With respect to the factor Origin, relatively to the circumference at 1.30 m from the ground, 2 subsets were identified. First, composed of the origins 14, 2, 1, 12, 8, 9, 3, 16, 13, 6, 4, 15 and 11, was characterized by high circumference at 1.3 m from the ground. Second, consisting of origins 5 and 7, was marked by low circumference at 1.3 m from the ground. The gaps between the mean and each measured modalities varied from 3.11 to 19.57% (Table 2).

Regarding the Pilodyn penetration depth, 2 classes were evidenced. The first one, constituted of the origins 1, 13, 8, 15, 3 and 5, was distinguishable by strong Pilodyn penetration depth. The second one, represented by the origins 6, 7, 4, 11, 14, 2 and 9 was characterized by weak Pilodyn penetration depth. The variability around mean fluctuated from 2.30 to 6.70% (Table 2).

As far as the basic wood density is concerned, 2 clusters were identified. First, consisting of the origin 2 was characterised by high basic wood density. Second, comprising the origins 11, 14, 8, 3, 5, 13 and 1, was marked by low basic wood density. The dispersion around mean oscillated from 3.60 and 8.82% (Table 2).

Table : Origin, Block and Origin x Block interaction effects on the expression of the circumference at 1.3 m from the ground, the Pilodyn penetration depth and the basic wood density through the Anova.

		Fisher-Snedecor's statistics F*		
Source	**df***	**Circ1.3**	**Pilo**	**ID**
Origin	15	1362.171*	10.261 **	6.318**
Block	3	369.697 US	1.244 US	24.949 US
Origin x Block	45	914.265 US	1.672 US	1.766 US
Residual	1			
Total	64			

Key :Fisher-Snedecor's statistics F*: Ratio of calculated F out of the one given on the Fisher-Snedecortheorical F table. **df*:** Number of degrees of freedom. **US:** Unsignificant. ***:** Significant. ****:** Very significant.

Table 2: Classification of means of the circumference at 1.3 m from the ground, the Pylodyn penetration depth and the wood basic density as a function of origins.

Circ1.3 (m)			Pylo (mm)			ID (g/dm^3)		
Origin	**Mean**	**CV (%)***	**Origin**	**Mean**	**CV (%)***	**Origin**	**Mean**	**CV (%)***
14	122.3a	6.50	**1**	30.33a	3.9	**2**	391.7a	7.06
2	117.4a	8.97	**13**	29.21a	3.2	**16**	367.5ab	3.6
1	115.1a	7.69	**8**	28.80a	4.7	**7**	363.9ab	3.7
12	113.9a	18.02	**15**	28.69a	6.7	**9**	356.6ab	5.47
8	113.3a	3.11	**3**	28.59a	1.7	**6**	350.7ab	5.21
9	109.9a	12.89	**5**	28.54a	6.7	**4**	349.6ab	7.96
3	109.3a	8.10	**10**	27.73ab	4.4	**15**	347.7ab	6.98
16	106.7a	4.73	**16**	27.33ab	2.3	**12**	347.2ab	8.13
13	105.4a	8.99	**12**	27.18ab	5.0	**10**	346.2ab	7.5
6	105a	2.11	**6**	26.90b	4.0	**11**	342.1b	7.17
4	104a	9.91	**7**	26.88b	2.8	**14**	339.5b	8.82
15	103a	14.67	**4**	26.84b	6.4	**8**	327.7b	7.69
11	102a	12.78	**11**	26.24b	6.5	**3**	326.8b	6.3
10	98.1a	12.55	**14**	26.02b	5.1	**5**	324.8b	4.18
5	94.4b	12.79	**2**	24.35b	2.8	**13**	317.4b	3.76
7	91.1b	19.57	**9**	23.88b	4.4	**1**	316.4b	5.89

Key :Circ1.3*:circumference at 1.3 m from the ground.**Pilo*:** Pylodyn sinking depth.**ID*:** Basic wood density. **CV (%)* :**Coefficient of variation in percentage.

Relationship among the circumference at 1.3 m from the ground, the Pilodyn penetration depth and the basic wood density

Sole the Pilodyn penetration depth recorded very high but negative and significant correlation with the basic wood density (p-value <0.001; Table 3). Out of this significant correlation, no other was noted (Table 3).

Table 3: Relationship among the 3 measured variables through the Pearson's linear correlation.

Variables	ID	Pilodyn (mm)	Circ 1.3
ID	**1**	**-0.523**	0.112
p-value	**0**	**< 0.0001**	0.378
Pilo (mm)	**-0.523**	**1**	-0.117
p-value	**< 0.0001**	**0**	0.357
Circ 1.3	0.112	-0.117	**1**
p-value	0.378	0.357	**0**

Key: In bold, in the table field, out of the row head and that of column, the significant correlation value reported there accompanied of its p-value.

Discussion

Performances of 16 origins from 3 countries were evidenced.In recent work, similar performances were assessed on 8 origins of *Gmelina arborea* Roxb. It showed that the most vigorous origins relatively to diametrical growth also expressed high values of pilodyn penetration depth and thus low basic densities (Ahoba *etal*., 2015). Our present works revealed that the origins 5 and 7 from Côte d'Ivoire and Ghana, respectively displayed the lowest circumference at 1.3 m from the ground. Likewise, the origins 2, 4, 6, 7, 9, 11 and 14 showed the weakest Pilodyn penetration depth.

Joint effects Origin x Block, regarding the 3 measured variables, were not significant (Table 1). Thus, the variations of 3 measured variables, individually taken, were independent of the simultaneous variations of block and those from Origin. Experiments conducted in the field in Ahoba *etal*., (2015) [3], Kouassi (1990) [6], Vauboud (1989) [7] reported unsignificant interactions among tested factors from several measured variables. Therefore, the classications of Origins will not change from block to block. Moreover, the examination of the main effect, namely the block effect, showed that the effetcs of all 4 Blocks were not significant (Table 2). Consequently, there was no heterogeneity gradient in the experimental field.

As far as the Origin effect is concerned, for the circumference at 1.3 m from the ground, the Origins 5 and 7 recorded the lowest value of this variable (Table 2). The former derives from Cote d'Ivoire while the latter from Ghana. These 2 origins are alike. The circumference at 1.3 m from the ground is negatively correlated with the basic wood density (Data not shown). In Ahoba et *al.*, (2015) [3], only the indian origins represented by numbers 2 from Mahilong and Bihar, 3 from Ghotil and Maharaachtra as well as 5 from Kundrukutu and Bihar expressed the lowest circumference at 1.3 m from the ground. Our 2 best Origins reperesented by numbers 5 and 7 have got weak cambial activity. The latter allows the ancreasing of content in dry matter in wood. Therefore, the 2 Origins might be selected for releasing purposes on condition that the multi-local and multi-annual tests are conclusive.

Regarding always the Origin effect relatively to the Pilodyn penetration depth, outputted data revealed the Origins 2, 4, 6, 7, 9, 11 and 14 recorded the lowest values of this variable (Table 2). These 7 Origins would be the most dense. Working on *Gmelina arborea*, Ahoba et *al.*, (2015) [3], the Origin 3from Ghotil and Maharaachtra in India showed the lowest values of the Pilodyn penetration depth. Our 7 Origins might also be selected for the multi-local and multi-annual trials. Thus, the Pilodyn penetration test thus appears as a rapid appreciation of density on standing trees as stated in Cown (1978), Vauboud (1989) and Farrington (1996) [7-9].

Regarding the basic wood density, the only and best Origin was the number 2. It was the only to show high basic wood density. The wood density represents technological criterion which informs on the wood workability. In Ahoba et *al.* (2015)[3], the Origin 3 of *Gmelina arborea* from Ghotil and Maharaachtra in India displayed the highest basic wood density. Our origin 2 should be selected for the multi-local and multi-annual trials before its releasing. In short, only the Origin 2 is common to classifications from the Pilodyn penetration depth and the basic wood density. Thus, in the worst case, we could select it only. In the best case, the Origins 2, 4, 6, 7, 9, 11 and 14 could be selected for the multi-local and multi-annual trials.

The Pilodyn penetration depth was the only correlated variable with the basic wood density (Table 3). The negative sign of the correlation value indicates when the value of the Pilodyn penetration depth is high, that of the basic wood density is low. We can select the best Origins by choosing those displaying the lowest values of the Pilodyn penetration depth awaiting the multi-local and multi-annual trials. Doing it, we would have chosen the Origins expressing high basic wood density. The latter is technological characteristic interesting.

Conclusion and perspectives

We hypothesised that at least 1 or 2 Origin(s) might be selected on basis of its / their high basic wood density or low pilodyn penetration depth.Effectively, in the best case, the only Origin 2 can be selected. In the worst case, the Origins 2, 4, 6, 7, 9, 11 and 14 can all be selected. The Pilodyn penetration tests, easy to implement, can help differentiate rapidly different Origins of forest species. These tests may be supplement to the traditional forestry criteria such as vegetative vigour for the selection of forest trees. Their major advantages lie in the fact that they are rapid, non-destructive and highly correlated to the density which affects numerous qualities of the plant material.

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