

Wood characterization of *Gnidia glauca* (Fresen.) gilg (Thymelaeaceae) and its possible utilization as material for pulp production in Northwest Cameroon

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Abstract

Over the centuries, paper has been made from a wide variety of materials. Today fiber comes mainly from two sources: wood and recycled paper products. *Gnidia glauca* bark was used in neighbouring Oku for local paper production. The properties of wood and bark of *Gnidia glauca* have been less explored in the literature. Therefore, in this study, the anatomical properties were investigated to evaluate the potential utilization of this species especially in pulp and paper production. Sections (transversal, tangential and radial) with a thickness of about 15-30µm were obtained from eight samples and contain phloem, cambial zone and secondary xylem. The sections were stained with 0.1% safranin O. to determine the fiber length and vessel element, we used maceration. Densities of vessels, cambial zone thickness, fiber wall thickness, fiber length were measured in bright-field microscopy images using AnalySIS Pro 3.2 software.

The results show that our species contain short wood fiber (1.32 mm in average) while the fiber bark are longer. *Gnidia* wood fibers are the longest among *Ailanthus altissima* trunk fiber, wheat straw, canola stalks, cotton stalks and Aspen. Fiber diameter of bark is about twice of those of common papermaking and lumen width is the smallest. Cell wall thickness of *Gnidia glauca* fiber bark is thicker than those of *Gnidia* wood and non-wood fibers; consequently, the Runkel ratio is highest (7.35). The flexibility coefficient of *Gnidia glauca* xylem fibers is 54.51, so it is included in the elastic fibers group while phloem fibers is 12.15 and it is included in the highly rigid fiber. The results of anatomical study of *Gnidia glauca* show that its xylem fiber dimensions are in the normal range for hardwood and are suitable for paper manufacturing.

Keywords: *Gnidia glauca*, bark, fiber, paper, Cameroon.

Résumé

Depuis des siècles, le papier est fabriqué à partir d'une grande variété de matériaux. Aujourd'hui la fibre provient principalement de deux sources: le bois et les produits issus du papier recyclé. L'écorce de *Gnidia glauca* a été utilisée autour de la région du mont Oku pour la production locale de papier. Les propriétés du bois et de l'écorce de *Gnidia glauca* ont été très peu abordées dans la littérature. Par conséquent, dans cette étude, les propriétés anatomiques ont été étudiées afin d'évaluer l'utilisation potentielle de cette espèce comme pâte à papier. Les coupes (transversales, tangentielles et radiales) ayant une épaisseur d'environ 15-30 µm ont été obtenues à partir de huit échantillons et contenaient le phloème, la zone cambiale et le xylème secondaire. Les coupes ont été colorées avec de la safranine O. à 0,1%. Afin de déterminer la longueur des fibres et des éléments de vaisseau, nous avons utilisé la macération. La densité des vaisseaux, l'épaisseur de la zone cambiale, l'épaisseur de

la paroi des fibres et la longueur des fibres ont été mesurées à l'aide d'un microscope électronique en utilisant le logiciel AnalySIS Pro 3.2. Les résultats montrent que cette espèce contient des fibres ligneuses courtes (1,32 mm en moyenne) tandis que les fibres continues dans l'écorce sont plus longues. Les fibres de bois de *Gnidia* sont les plus longues parmi les fibres de l'écorce d'*Ailanthus altissima*, de la paille de blé, des tiges de colza, des tiges de coton et de peuplier. Le diamètre des fibres d'écorce est environ le double de celui utilisé habituellement pour la fabrication du papier et l'épaisseur de la lumière de ces fibres est la plus faible. L'épaisseur de la paroi cellulaire des fibres de l'écorce de *Gnidia glauca* est plus grande que celle des fibres de bois de cette espèce et des fibres non ligneuses en général. Le rapport Runkel est par conséquent, le plus élevé (7,35). Le coefficient de flexibilité des fibres de xylème de *Gnidia glauca* est de 54,51, elles sont donc incluses dans le groupe des

fibres élastiques, tandis que les fibres du liber ayant une valeur de 12,15 sont incluses dans la catégorie des fibres très rigides. Les résultats de l'étude anatomique de *Gnidia glauca*

montrent que les dimensions de fibres de xylème sont dans la fourchette normale pour les bois feuillus et conviennent parfaitement pour la fabrication de la pâte à papier.

Mots clés : *Gnidia glauca*, écorce, fibre, papier, Cameroun.

1. Introduction

Over the centuries, paper has been made from a wide variety of materials such as cotton, wheat straw, sugar cane waste, flax, bamboo, wood, linen rags and hemp. Regardless of the source, we need fiber to make paper. Today fiber comes mainly from two sources: wood and recycled paper products.

Although wood is the major source of fiber supply for papermaking, the decline of forest resource in many areas of the world imposes the use of non-woods fibers as important alternative fibrous source for papermaking industries. In fact, in order to meet the future demand and to overcome the wood shortage, studies have been conducted to utilize new or alternative resources in the forest industries as raw material components for pulp and paper production in several countries (Copur et al., 2007). Global production of virgin pulp for paper and paperboard was 187.6 million metric tons in 2005, from which 17.4 million metric tons made from non-wood fibers (Bowyer et al., 2007). A number of non-wood fibers are commonly used in many countries for papermaking.

Bark is a complex tissue-system comprising of an outer zone of periderm or rhytidome and inner zone of secondary phloem. The economic utility of the bark may not be as much as that of the wood. However, the barks have their own share in medicine and industry (Gregory and Root, 1961 quoted in Natarajan et al., 2011). The bark tissues, as any other component of the plant organs, are vulnerable to environmental stress. Ecological wood anatomy has gained some momentum in the recent years (Carlquist, 1980 ; Bass et al., 1983). However, ecological perspectives of barks have been ignored (Natarajan et al., 2011).

Gnidia glauca, which belongs to the family Thymelaeaceae, is a small bushy tree growing to about 6m but can reach 15 to 24 m in height. In North-west region of Cameroon, *Gnidia glauca* bark is used as medicinal, strong mat for drying coffee and suitable for paper. In fact, it is used in neighboring Oku for local paper production. During our investigations in the Kilum-Ijim forest, we made some remarks that very often the bark is removed over almost the entire circumference of the stem, especially when the bark is thick and can be easily detached from the wood, regardless of whether it is a young or an old mature tree (Momo, 2009). This practice can lead to a high mortality of trees, because economic pressure, inadequate legislation concerning sustained non-timber resource exploitation, as well as the lack of sufficient knowledge about the resources themselves are the most important causes of resource depletion.

The properties of wood and bark of *Gnidia glauca* have never been explored in the literature. Therefore, in this study, the morphological properties were investigated to evaluate the potential utilization of this species especially in pulp and paper production.

2. Materiel and Methods

2.1. Study site

The study was carried out on the Mount Oku, a mountain area of the Bamenda Highland located in north-west Cameroon (6°12'N and 10°32'E). This site hosts the Kilum-Ijim forest, which is the largest remaining tract of the Central African cloud forest, a biodiversity hotspot threatened by contemporary land-use changes. Peaking at 3 011 m, the Mount Oku is the second highest peak in mainland West Africa

Table 1 : Description of individuals of *Gnidia glauca* (tw64018, tw64020, tw64021, tw64022, tw64023, tw64025, tw64026, tw64033 are samples that are accessible to Tervuren xylarium)

Variables	tw64018	tw64020	tw64021	tw64022	tw64023	tw64025	tw64026	tw64033
Elevation (m)	2185	2410	2401	2344	2388	2093	1963	2432
GPS	06°13'614"N 10°33'708"E	06°13'210"N 010°26'638"E	06°13'130"N 010°26'695"E	06°13'199"N 010°26'931"E	06°13'171"N 010°26'812"E	06°09'339"N 10°26'930"E	06°08'976"N 010°26'290"E	06°11'182"N 010°27'915"E
Height (m)	10	12	11,5	7	11	10	10	10
DBH (cm)	39,8	46,17	35,03	25,47	71,33	41,4	43,31	36,3
Date of collect	09/10/2012	05/11/2012	05/11/2012	05/11/2012	02/11/2012	09/11/2012	09/11/2012	03/11/2012

(Asanga, 2002). The climate is characterized by a rainy season from May to September and a dry season from October to April. Rainfalls mainly occur between July and September and vary from 1780 to 2290 mm per year. The peak is 3 050 mm per year on the summit, commonly described as cold, very cloudy and misty. In most parts of the mountain, mean temperatures vary between 13°C and 22°C. The summit is characterized by minimum (9°C) and maximum (19°C) temperatures. The dominant soils are clay (mainly Gibbsite) but altitude and climate can generate soils with high organic matter contents (humus). Before the spectacular increase of human populations and the development of agriculture in the past century (Maisels, 2001 ; Momo, 2009), it is believed the whole of the Bamenda Highlands area was forested (Cheek et al., 2000). The forest area covered 20 000 ha in 1978 but, today, it is reduced to about 9 500 ha (Momo et al., 2012). The Kilum-Ijim forest is a mountain cloud forest. In the last decades, post-agricultural forests appeared on fallow lands and are mainly characterized by heliophilous, fire-resistant trees and shrubs (*Gnidia glauca*, *Hypericum revolutum*, *Hypericum roeperianum*, *Maesa lanceolata*, *Erica mannii*) and locally include open habitat herbs (*Hyparrhenia* sp., *Sporobolus africanus*, *Pennisetum clandestinum*). Despite efforts in implying villagers and forest community managers, results are mitigated and forest stands are still cleared, converted to crop, burned, grazed by domestic animals, overhunted and overexploited for their medicinal plants (Asanga, 2002 ; Stewart, 2009).

2.2. Collection of plant material

Eight samples of *Gnidia glauca* were collected in the field. For each sample, we removed from the trunk at about 1.30 above the ground level, a block with at least 1 cm in the tangential direction, 5 cm in the radial direction (bark, phloem, cambial zone, heartwood) and 10 cm in the longitudinal direction. To be able to keep intact the cambial zone samples, we have plunged into a mixture of one- third of ethanol (at least 70%), one-third glycerin and one-third water. For each sample, we recorded the date of collection, described the site and the growth parameter of tree (table 1).

2.3. Morphology of wood

For those samples, sections (transversal, tangential and radial) with a thickness of about 15-30µm were obtained and contains phloem, cambial zone and secondary xylem. We used a sliding microtome (Shenkung Dapples, Mikrot L- serie 1117, Switzerland). The sections were stained with 0.1% safranin O (Merck KgaA, Darmstadt, Germany) solution. They were dehydrated in an ethanol

series (50% for 10 minutes, 75% for 5 minutes and 100% for 10 minutes). Afterwards the sections were mounted immediately on a slide by using Euparal (Carl Roth GmbH+Co. KG., Karlsruhe, Germany) and dried in an oven at 56°C overnight. Observations were made with an Olympus microscope cx31, equipped with a camera which permits us to obtain digital images.

2.4. Fiber morphology analysis

To determine the fiber length and vessel element, we used maceration. For each sample, we cut wood and bark separately into sticks for about 2 to 3 cm long. In fact, for fiber separation without fiber breaking, the pieces of wood and bark were treated in a mixed solution (acetic acid 100%, 500ml; hydrogen peroxide, 100ml; and distilled water, 400ml) for a period of 72 hours at 56°C. Then the samples were washed by distilled water three times and the fibers were separated by gentle shaking into individual fibers. After that, individual fibers were stained with 1% aqueous safranin O. solution, rinsed in ethanol solution at 50% and mounted on a slide by using euparal.

2.5. Measurements and analysis

Densities of vessels, cambial zone thickness, fiber wall thickness, fiber length were measured in bright-field microscopy images using AnalySIS Pro 3.2 software (Soft Imaging System GmbH, Münster, Germany). For wood density, more than 25 vessels per sample were measured. The fiber wall thickness was calculated for each measurement; at least 30 unbroken fibers were measured for length on each slide, resulting in 306 fibers measured for wood. From these data, the average fiber dimensions were calculated and the following derived indexes were determined:

- Runkel ratio = $2 \times (\text{wall thickness} / \text{lumen width})$
- Flexibility ratio = $(\text{lumen width of fiber} / \text{diameter of fiber}) \times 100$
- Slenderness ratio = $\text{length of fiber} / \text{diameter of fiber}$

All characters were described using IAWA (International Association of Wood Anatomists) List of Microscopic Features for Hardwood Identification (IAWA committee, 1989).

3. Results

3.1. Bark thickness of *Gnidia glauca*

On mount Oku, Tree and shrub layers of the secondary forests were often dominated by the barochorous species *Gnidia glauca* (figure 1) which is able to occur in a wide range of altitudinal levels and biogeographic areas.

For each sample, bark thickness was measured by using FIJI software. Results are shown on table 2. It appears

**Table 2: result of the mean bark thickness**

Samples	Tree diameter (cm)	Bark thickness mean (cm)
Tw-64020	21,33	1,41
Tw-64023	25,47	0,90
Tw-64018	26,11	1,06
Tw-64022	35,03	1,30
Tw-64033	36,3	1,05
Tw-64025	41,4	1,25
Tw-64026	43,31	1,12
Tw-64021	46,17	1,07

Figure 1 : *Gnidia glauca* debarked ; (A) base of trunk completely debarked ; (B) tree partially debarked without regeneration of bark

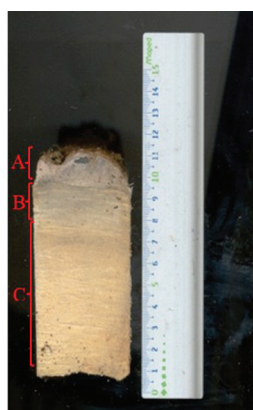


Figure 2 : Measurement of bark thickness A: bark, B: sapwood, C: heartwood

that bark thickness vary between 0.9 to 1.41 cm. This thickness is independent of tree diameter. In order to understand the non-regeneration of bark observed in the field, we calculated the area occupied by each element at 1mm apart the cambial zone. In the xylem area, vessels occupied 13.2%, ray 18.6%, parenchyma 13.9% and fiber 54.3%. Whereas in the phloem area, ray occupied 21.9%, fiber 21.3% and conducting phloem zone which consists of phloem tube and parenchyma occupied 56.8% of the area (table 3).

3.2. General microscopic structure

The general structure of cross section of *Gnidia glauca* from bark to secondary xylem is displayed in figure 3A. Phloem (bark), cambium and xylem are shown together. The cambial zone is distinguishable between phloem and xylem. The measurable characters are shown in table 3.

These anatomical features are observed: 2: growth

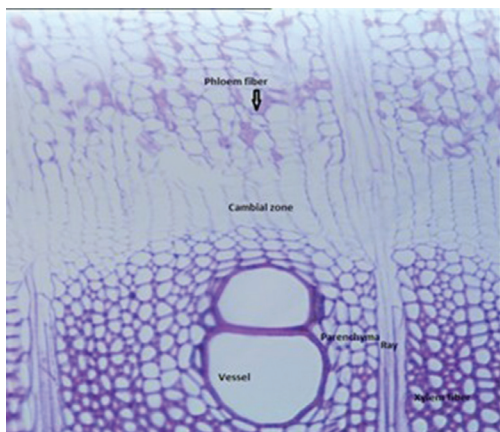
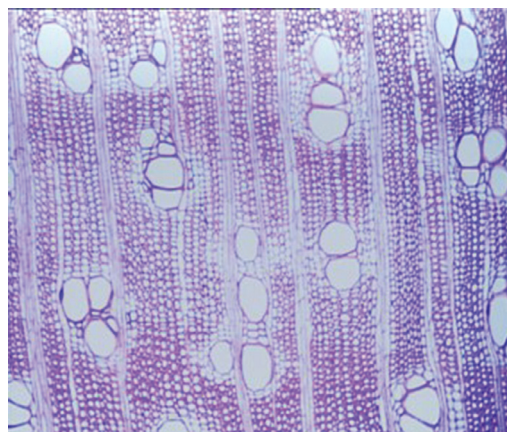
ring boundaries indistinct or absent (figure 3B); 3: wood diffuse-porous (figure 3B); 11: vessels clusters common (figure 3B, 3C); 12: absent, solitary vessel outline is circular; 13: simple perforation plates; 23: shape of alternate pits polygonal; 24: intervessel pit size minute (figure 4D); 42: mean tangential diameter of vessel lumina is 100-200µm (table 3); 46, 47, 48: vessels per square millimetre (table 3); 52: mean vessel element length $\leq 350 \mu\text{m}$ (table 3); 66: nonseptate fibers present; 69: fibers thin to thick-walled (figure 3C); 72, 73: main fiber lengths is varying between 900-1600 µm and $\geq 1600 \mu\text{m}$ (figure 5A, table 4); 81: paratracheal axial parenchyma lozenge-aliform (figure 3B); 85: axial parenchyma band more than three cells wide (figure 3B); 92: four (3-4) cells per parenchyma strand (figure 4D); 97, 98: ray width 1 to 3 cells and larger rays commonly 4- to 10-seriate (figure 4C); 104: present, all ray cells procumbent (figure 4F); 110: sheath cells (figure 4C); 115: rays per millimeter 4-12/mm.

3.3. Fiber morphology

The morphological properties of *Gnidia glauca* show that our species contain short wood fiber (1.32 mm in average) while the fiber bark are very long (personal observation, we could not separate fiber). Fiber diameter of bark is 42.52 µm in average, while in the secondary xylem, the value is 25.6 µm. Lumen width is 14.15 µm and 5.16 µm respectively in secondary xylem and in bark. Cell wall thickness was higher in bark than in wood (18.68 and 5.71 µm respectively). These values permitted to have the following indexes: Runkel ratio, slenderness ratio and flexibility ratio were respectively 0.85, 54.32 and 54.51 in secondary xylem whereas runkel ratio and flexibility ratio where 7.35 and 12.15 respectively in bark zone.

Table 3: parameters measured on various sections

	tw64018	tw64020	tw64021	tw64022	tw64023	tw64025	tw64026	tw64033
density of vessels (vessels per square millimeter)	8 - 32 (17,3)	4 - 30 (11,3)	2 - 20 (8,9)	4 - 13 (10)	3 - 22 (10,5)	6 - 27 (13,3)	2 - 20 (10)	2 - 14 (7,3)
Mean tangential diameter of vessel lumen (μm)	65,3 - 175,2 (132)	49,4 - 233,1 (150)	63,2 - 195,4 (134,7)	56,7 - 208,6 (126,8)	64,4 - 201,6 (136,2)	64,5 - 222,3 (135,2)	69,9 - 216,3 (134,7)	51,2 - 258,9 (163,8)
length of vessel elements (μm)	209,8-377,2 (283,8)	149,7-316,9 (244,3)	180,9-372,9 (282,5)	158,5-390,9 (264,7)	204,8-447,2 (318,3)	149,6-348,6 (270)	195,5-414,2 (299,1)	134,3-357,2 (254,7)
Length of fibers (μm)	891,7-2407 (1814,4)	598,3-1383,1 (1013,9)	586-1862,5 (1128,8)	889,3-1619,4 (1291,6)	1031,3-1872,1 (1463,7)	694,1-1328,2 (1093,5)	1053,3-1850,4 (1422,5)	752-1527,6 (1144,6)
Rays per mm (number per mm)	3-8 (5,7 $\pm$ 1,2)	3-7 (4,7 $\pm$ 1,1)	4-8 (5,8 $\pm$ 1,1)	3-7 (5,5 $\pm$ 1)		4-8 (5,8 $\pm$ 1)	3-7 (5,2 $\pm$ 1)	3-7 (4,8 $\pm$ 0,8)
Rays height (μm)	491,2-1103,2 (792)	454,3-1570,5 (893,2)	387,8-826,3 (573,2)	451,6-895,3 (649)		341,7-1453,1 (718,5)	405,3-930,8 (678,9)	482,1-1188,4 (748,3)
Rays width (cell number per mm)	3-6	3- 6	3- 6	4 - 8		3 - 6	3 - 6	3 - 5
Xylem vessels (%)	23,4	12,2	7,9	10,7	12,5	13,3	14,6	11,0
Xylem ray (%)	15	20,5	11,4	24,8	15,4	24,1	21,3	16,0
Xylem parenchyma (%)	18,4	9	13,8	17,0	12,6	12,0	13,2	15,5
Xylem fibers (%)	43,2	58,3	66,9	47,4	59,6	50,5	51,0	57,5
Phloem ray (%)	10,0	22,6	16,9	25,1	29,3	32,1	19,6	19,8
Phloem fibers (%)	23,1	28,6	29,5	27,7	21,5	17,0	9,8	13,0
Conducting phloem zone (%)	66,9	48,7	53,6	47,2	49,3	50,9	70,6	67,2
cambium (number of cells)	11	10	9	5	/	8	7	4

**A****B**

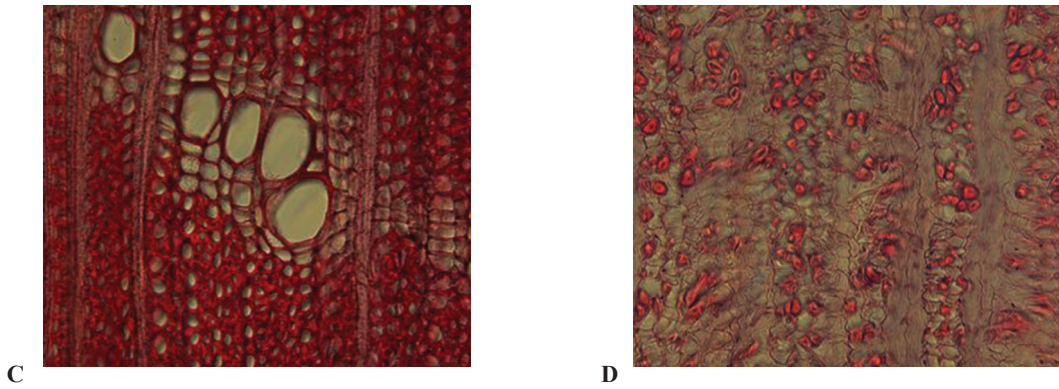


Figure 3 : An overview of transversal section A, secondary xylem, cambium and phloem are shown (100X); B, wood surface (40X); C, wood surface (100X); D, phloem surface (100X)

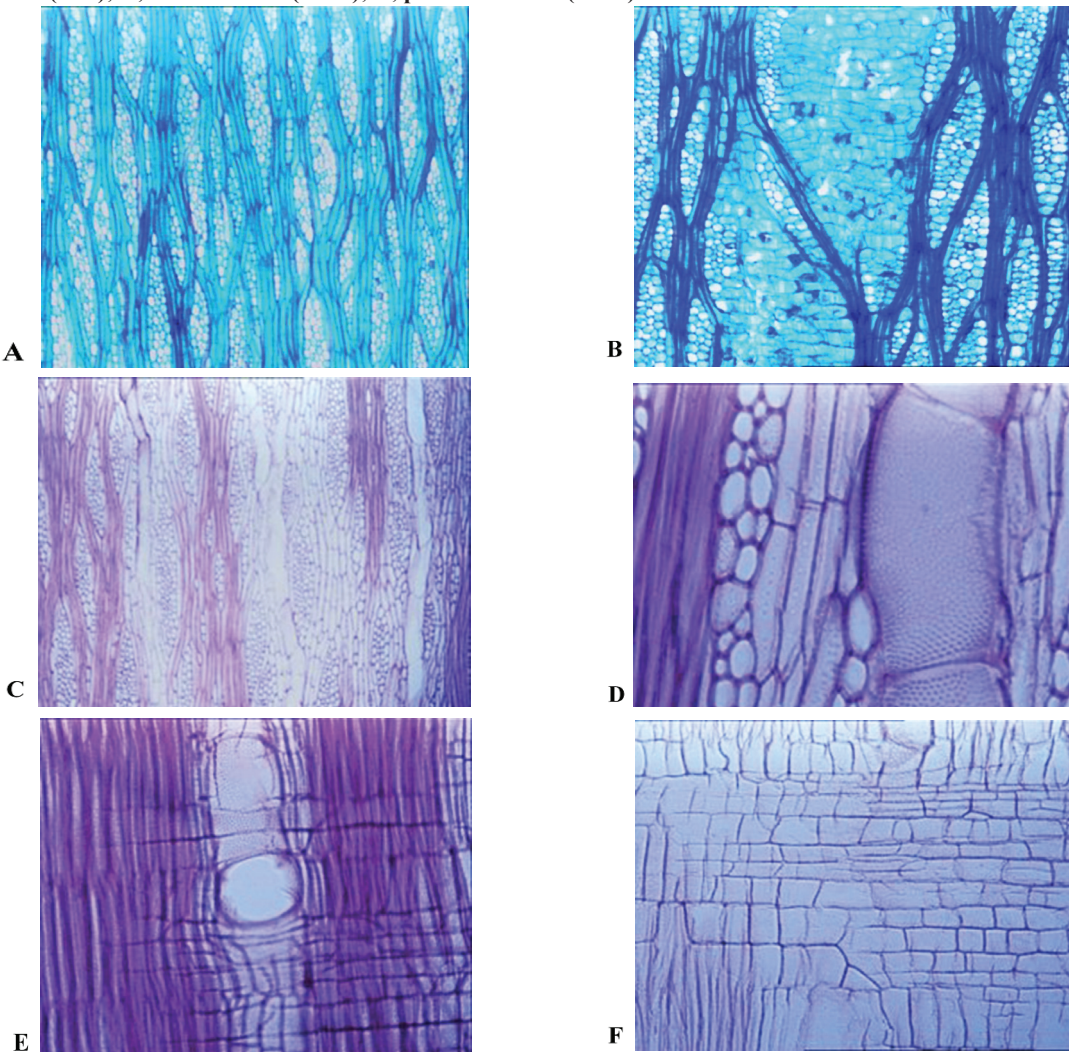


Figure 4: Tangential and radial sections (A) tangential section near cambial zone (40X); (B) tangential section in the phloem zone (40X); (C) tangential section of wood (40X); (D) tangential section showing punctuations (100X); (E) and (F) radial section (100X).

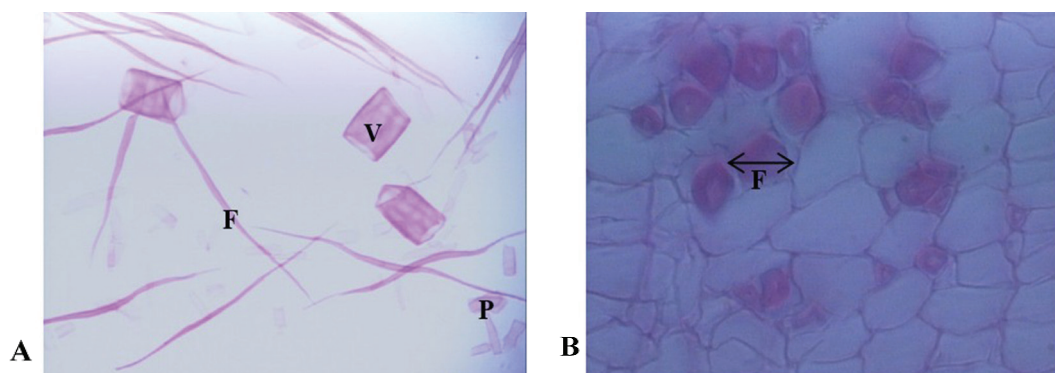


Figure 5: Fiber elements (A) result of maceration showing fibers F,; vessels elements V and parenchyma cells P (40X); (B) transversal section of phloem showing fiber (F) thickness (100X)

4. Discussion

Bark is the outer sheath of the tree. *Gnidia glauca* have persistent bark. The inner bark transports photosynthates from the crown, while the outer bark has a major protective role. The bark protects the bole from insects and damage from physical abrasion. Bark thickness will determine the duration and intensity of fire that the tree cambium can survive. Because bark thickness vary between 0.9 to 1.41 cm, montane forest in mount Oku which has been damaged in the past (often by fire) support two forest types which are the last stages in the succession back to mature forest: one is *Gnidia glauca*/*Maesa lanceolata* woodland and the other is woodland dominated by *Erica mannii* and *Gnidia glauca*. This stage is preceded by open woodland that is dominated by *Gnidia glauca* (Asanga, 2002). Barks were studied by few workers (Esau, 1969; Roth, 1981; Delvaux et al., 2009, 2010, 2013) and investigations on the barks of tropical trees are far less than those of the woods. This investigation area of structure of bark tissues will contribute valuable data usable by the forest ecologists, environmental botanists and bark- anatomists.

Phloem in general is indistinguishable even at higher magnification because the basic structure of sieve-elements does not differ from that of most parenchyma cells. The cellulose wall of the sieve element may resemble that of associated parenchyma cells but frequently it is conspicuous by its thickness and ready stain ability in dyes that stain cellulose walls (Riviere, 1953 in Esau, 1969). In the dicotyledonous plants, fibers are common in the primary phloem, specifically in the protophloem (Esau, 1969), but our observations show that fibers are scattered all around the inner bark. It appears that the low percentage of conducting phloem zone compared with the one obtained by Delvaux (2009) for tropical trees (65% -91.4%) can explain the lack of bark regeneration. The solution must be found in intrinsic factors like hormonal signal.

The minimum fiber length necessary to produce acceptable paper strength properties is dependent on many factors, and fiber lengths are not unequivocally related to paper strength properties (Young, 1997). Different fiber lengths are desirable for different properties in paper. For example, longer fiber length is desirable for strength properties in paper, but they tend to bunch together and as a result do not provide good formation. Shorter fibers on the other hand provide excellent formation. In general, pulping of nonwoods is easier and cheaper compared to wood. The morphological properties of *Gnidia glauca* and their comparison with common papermaking are summarized in Table 4. The results show that our species contain short wood fiber (1.32 mm in average) while the fiber bark are longer (personal observation, we could not separate fiber). *Gnidia* wood fibers are the longest among *Ailanthus altissima* trunk fiber, wheat straw, canola stalks, cotton stalks and Aspen. Fiber diameter of bark is about twice of those of common papermaking and lumen width is the smallest. Cell wall thickness of *Gnidia glauca* fiber bark is thicker than those of *Gnidia* wood and non-wood fibers; consequently, the Runkel ratio is highest (7.35). As concern to Xu et al. (2006), the acceptable values for slenderness ratio and Runkel ratio of papermaking are more than 33 and less than 1 respectively.

According to flexibility ratio there are 4 groups of fibers (Bektas et al., 1999): 1) High elastic fibers having elasticity coefficient greater than 75. 2) Elastic fibers having elasticity ratio between 50 -75: 3) Rigid fibers having elasticity ratio between 30 -50: 4) highly rigid fibers having elasticity ratio less than 30. According to this classification, the flexibility coefficient of *Gnidia glauca* xylem fibers is 54.51, so it is included in the elastic fibers group while phloem fibers is 12.15 and it is included in the highly rigid fiber. Referring to this, we can deduce that *Gnidia glauca* barks are not suitable for papermaking instead of wood.

Table 4: the mean values of *Gnidia glauca* fibers and derived indexes compared with other papermaking fibers.

Fiber properties	<i>Gnidia glauca</i> trunk fiber	<i>Gnidia glauca</i> bark fiber	<i>Ailanthus altissima</i> trunk fiber (a)	heat straw (b)	Cotton stalks (c)	Aspen (d)	Canola stalks (e)
Length (mm)	1,32	/	0.94	0,74	0,83	0,96	1,17
Diameter (µm)	25,60	42,52	22.8	13,20	19,60	20,80	23,02
Lumen width (µm)	14,15	5,16	16.16	4,02	12,80	16,94	12,50
Cell wall thickness (µm)	5,71	18,68	3.34	4,59	3,40	1,93	5,26
Runkel ratio	0,85	7,35	0.46	2,28	0,53	0,23	0,84
Slenderness ratio	54,32	/	42.97	56,06	42,35	46,15	50,83
Flexibility ratio	54,51	12,15	70.12	30,45	65,31	81,44	54,30

(a): Samariha et al., 2011 (b): Deniz et al., 2004 (c): Ververis et al., 2004 (d) : Law and Jiang, 2001 (e) : Enayati et al., 2009

5. Conclusion

Finally *Gnidia glauca* appear to be very complex in term of bark recovery and more experiments are needed. In the xylem area, vessels occupied 13.2%, ray 18.6%, parenchyma 13.9% and fiber 54.3%. Whereas in the phloem area, ray occupied 21.9%, fiber 21.3% and conducting phloem zone which consists of phloem tube and parenchyma occupied 56.8% of the area. The low percentage of conducting phloem zone can explain the lack of bark regeneration. Runkel ratio, slenderness ratio and flexibility ratio were respectively 0.85, 54.32 and 54.51 in secondary xylem whereas runkel ratio and flexibility ratio where 7.35 and 12.15 respectively in bark zone. The results of anatomical study of *Gnidia glauca* show that its xylem fiber dimensions are in the normal range for hardwood while phloem fibers are not suitable for paper manufacturing because of the thick wall which leads to their rigidity. So, instead of destroying tree through the removal of bark, it is preferable to use the entire wood since *Gnidia glauca* regenerate very well in its natural habitat.

Acknowledgments

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