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Anatomical Characteristics of the Stem Wood of *Moringa peregrina* (Forssk.) Fiori Planted in Western Saudi Arabia

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ABSTRACT: 16-year-old *Moringa peregrina* trees, growing in a commercial plantation were sampled at breast height for wood anatomy characterization. Wood samples were collected, fixed and sectioned according to usual techniques. Qualitative and quantitative features were described. Wood anatomy is characterized by mostly solitary vessels with significantly different lumen widths, simple perforation plates and alternate bordered intervessel pits. No tyloses or organic deposits are present in the vessels. Vessels and fibers are thin-walled Fibers are short with simple pits. Rays are uniseriate and multiseriate while, axial parenchyma cells are apotracheal scanty to vasicentric. Mineral crystals are deposited in cells of rays and axial parenchyma. This work aimed to improve the knowledge about the wood of this species. The facts encountered herein are reasons for inadequacy of the wood of this species to certain utilizations such as construction and furniture making. On the other hand it can be used for the manufacturing of some other products as engineered wood material and some fence pillars.

Keywords: *Moringa peregrina,* Wood anatomy, Afforstaion, Cellular components.

I. INTRODUCTION

During the last years, *Moringa peregrina* (Forssk.) Fiori or "Yusor" trees have been attracting growing interest due to their unique properties and potential applications. Several researches were carried out in favor of introduction of Moringa into afforstaion projects [1, 2, 3, 4]. Most of those researches were concerned with silvicultural practices and medicinal or nutritional profits. On the other hand less attention was paid to the proper utilization of the wood of this tree due to the lack of information about wood structure. This article provides an overview on the wood anatomy of *Moringa peregrina* (Forssk.) Fiori, growing in the north western region of Saudi Arabia. The principle objective of this study was to characterize the wood structure of the aforementioned tree in a context of its raw material quality evaluation.

II. MATERIALS AND METHODS

The material for this study was collected from 16 years old *Moringa peregrina* (Forssk.) Fiori trees growing in a commercial plantation established in Al Bowair at Al Madina district, Saudi Arabia. Some of the basic information about the plantation could be summarized as follows (Osman and Abohassan, 2012 [4]): Location 24°56' 08.38"E 39°00' 08.87" N, Altitude 460 m and Mean Diameter (DBH) of tree main stem 20.4± 4.9cm.

A. Fiber length sample collection and processing

Five main samples for fiber length measurement were collected by increment borer at breast height from the main stems of five randomly chosen standing trees. Three subsamples measuring approximately 1 cm in the radial direction were chosen at random from each increment core. Specimens were macerated separately in labeled test tubes using a 1:1 (volume to volume) mixture of 30% hydrogen peroxide and glacial acetic acid. The test tubes were incubated at 60°C for 48 hours [5]. The resulted fiber clusters were then leached with enough amount of distilled water and vigorously shaken to make fiber suspensions. The fibers were then stained using an aqueous Safranin solution (1%) overnight and washed again with distilled water to remove excess stain [6]. For the purpose of Microscopic examination, a drop of fiber suspension was mounted in glycerol on a glass slide and covered with a glass slip just before the investigation.

B. Sampling and processing for Transverse anatomical characterization

Samples for assessing other anatomical features were obtained at random from, 1 cm thick, discs sawn at breast height from the main trunk of some harvested trees that were arbitrary chosen from the plantation. Those random samples were meant to be unbiased and representative of the plantation. From each disc, 1cm wide sub-samples were taken along several random radii. Each sub-sample was then segmented into cubes measuring 1 × 1 × 1 cm in each of the radial, tangential and longitudinal directions. Three cubes from each disc were randomly selected and labeled for wood anatomical analysis. Chosen blocks were subsequently softened by boiling in distilled water for two hours prior to sectioning. From each block, transversal, radial and tangential micro-sections 30µm thick were obtained using a rotary microtome (American optical 820). The microtome was provided with a special clamp (828 Johns Hopkins Clamp) suitable for holding solid wooden samples. The wooden cubes were subjected to live steam during cutting the sections by microtome for better processing. Sections were then dehydrated with ethanol, double stained with Safranin and Light green and permanently mounted in Canada balsam on microscopic slides according to the method used by sass [7].

C. Microscopic examination and quantification of the wood tissue components

Slides were examined microscopically and imaged using a Carl Zeiss light microscope connected to a digital camera (Nikon Coolpix 4500) for image capture. Calibration of the microscope and camera was made by an object-oriented Micrometric slide. The image analyses were carried out using Image tool software (v 3.0) in accordance with the approach referred to Wilcox [8].

The following parameters were measured: vessel diameter, vessel wall thickness, fiber length, fiber diameter, fiber wall thickness, and ray height. On the other hand, principles of stereology were used to determine vessel, fiber, ray and parenchyma frequency in the cross section [9]. The same method was used for computing proportions of cell components of the wood tissue as well.

The data for diameter and wall thickness were collected from 25 vessel and 40 fiber measurements respectively in each cross section slide. In the meantime the lengths of 40 fibers were measured from each fiber slide. In this context, sample size throughout this study was determined according to Stein's two-stage sampling approach [10].

Statistical analyses of the aforementioned anatomical characteristics were performed using the SAS package V.8 software (SAS Institute [11].

III. RESULTS AND DISCUSSION

The Mean and standard deviation values for each parameter of the anatomical characteristics are summarized in Table 1.

Microscopic investigation has shown that the wood of the studied samples is diffuse porous with indistinct or absent growth ring boundaries. Vessels are arranged in no specific pattern, often solitary or in radial chains (2-4), and sometimes in clusters up to 4 or more vessels (Fig. 1).

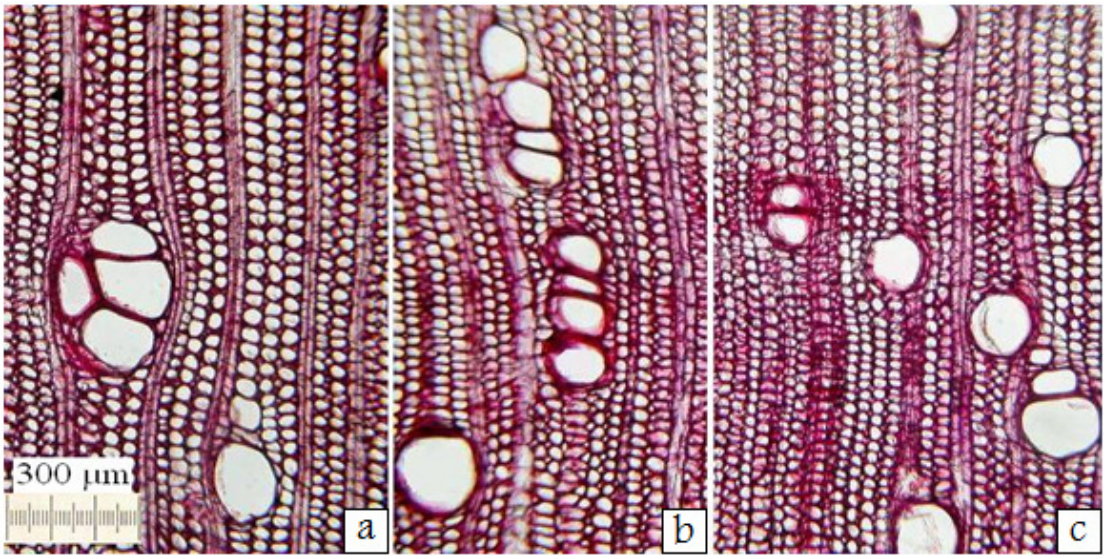


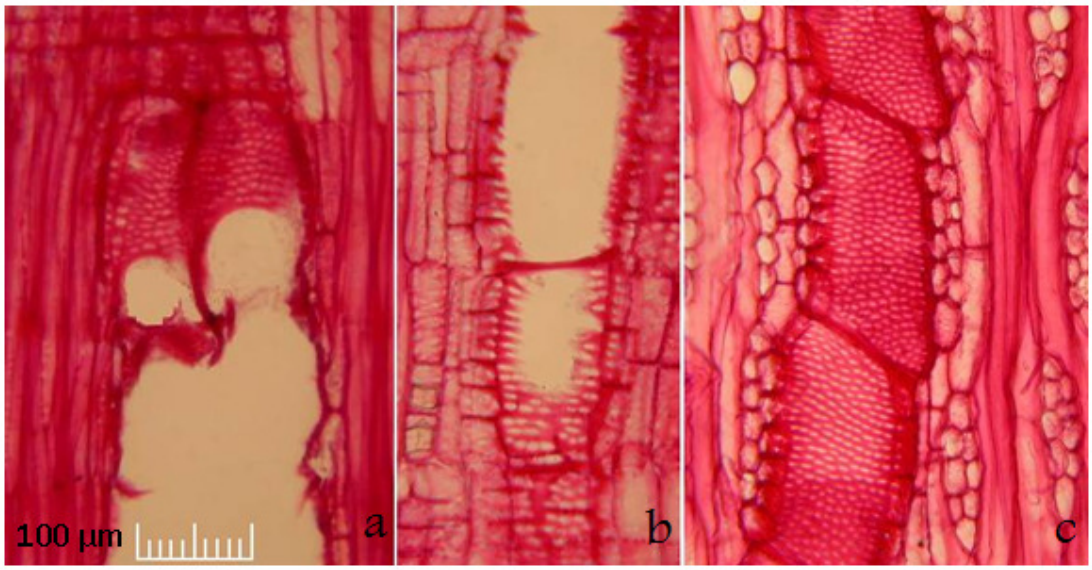
Fig. 1. Pore arrangement in cross-section: (a) Cluster of four vessels. (b) Radial chain of four vessels. (C) Solitary or in radial chain of 2-3 vessels.

Table 1: Quantitative measurements and some anatomical characteristics of cellular components of the wooden tissue of *Moringa peregrina* (Forssk.) Fiori trees from Al Boer farm in Medina.

Variable		Mean	Standard deviation
Vessel diameter (µm)		131.0	38.0±0
Vessels wall thickness (µm)		8.0	0.8±0
Fiber length (mm)		0.70	0.13±
Fiber diameter (µm)		35.0	4.0±
Fiber wall thickness (µm)		3.0	0.6±
Ray height in the tangential section (µm)		209.0	95±
Number of vessels mm^{-2} of cross section		5.0*	± 1.00
Number of fibers mm^{-2} cross section		510.0	16±
Number of rays mm^{-2} of tangential section		10.0	2±
Ratio in cross	Vessels	8.4	0.4±0
	Fibers	59.3	5.8±
	Rays	19.8	3.3±
	Axial parenchyma	12.5**	±4.1

*All cell numbers and percentages were re-converted to the actual values after square root transformation of the original data for the purpose of statistical analysis (Steel and Torrie, 2000).
**calculated by subtracting the sum of other components percentages from 100%.

The vessel walls are relatively thin (8.0µm). Vessels cross sections are likely circular to oval with variable diameters of 131.0µm on the average. Number of vessels per unit area (mm^2) is 5 on the average, counting of up to 8.4% of the total cellular components (Table 1). Perforation plates are simple. Intervessel pits are bordered alternate, of uniform size in adjacent elements, meanwhile, vessel-parenchyma pits are apparently simple (Fig. 2). Helical thickenings and Tyloses are absent. Fibers are fusiform non-septate but vary in form and length (Figs 3 & 4). Some are simple libriform fibers; others are characterized with apical extensions at both ends. End biforking is present in some fibers in one or both ends, and in rare instances with multiple forking. This phenomenon was observed also in some other species [12]. Fibers average diameter is 35.0µm and their walls are very thin (3.0µm). Pits are simple and often confined to radial walls. The number of fibers in the unit area is 510±16 and the fiber proportion accounts for an average of 59.3% of the total cellular components of the wood tissue (Table 1).



*Cs= Cross section Rs = Radial section Ts=Tangential section

Fig. 2. Vessel sculpturing:(a) Simple perforation plates between vessels (Rs). (b) Pitting on the walls between vessel and parenchyma cells (Rs). (C) Alternate pitting on intervessel walls (Rs).

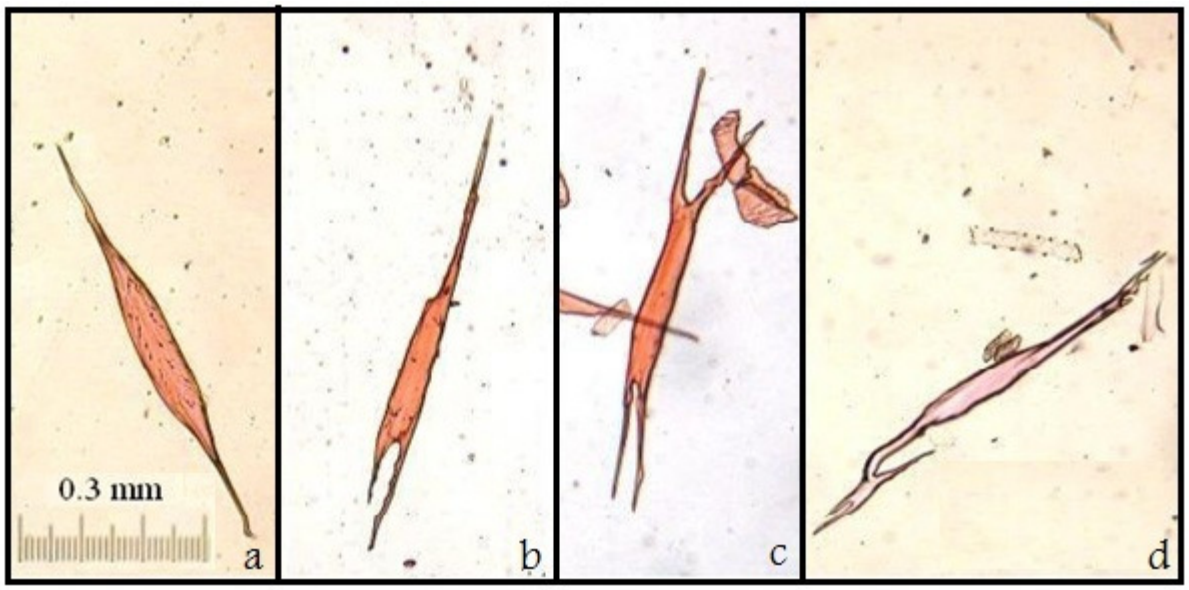


Fig. 3. Libriform fibers: (a) normal fiber with simple pitting, (b) fiber with double- forking in one end c) fiber with double- forking in both ends, (E) fiber with multiple forking.

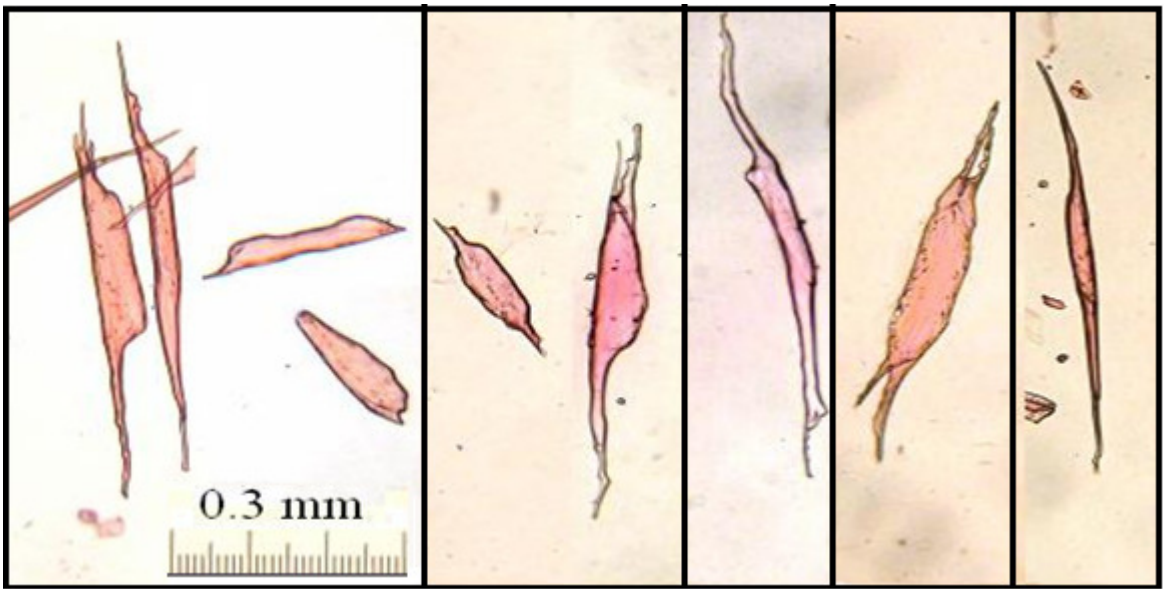


Fig. 4. Libriform fibers with varying lengths and diameters.

Intensive microscopic investigation of cross and longitudinal sections along with fiber slides revealed that vascular or vasicentric tracheids are absent. This finding is in agreement with Carlquist [13] who stated that vessel elements with simple perforation plates will tend to be associated with libriform fibers rather than tracheids. Fig. 5 illustrates the frequency distribution of fiber length. It can be seen that fiber length ranged from 0.36 to 0.99mm with an average of 0.71±0.13 mm. The information obtained herein for different variables evaluated for libriform fibersis in consistence with reports published for *Moringa peregrina* (Forssk.) Fiori. The range reported for fiber length was 0.6 - 1 mm, for fiber width was 12 - 21 µm and for cell wall thickness was 2-4 µm. Rays are exclusively multiseriate up to four cells wide at most in cross section, but they are sometimes uniseriate(us). At the radial section rays often are heterocellular composing of a core of procumbent (pr) cells while marginal rows consist of upright (up) and/or square (sq.) cells (Fig. 6).

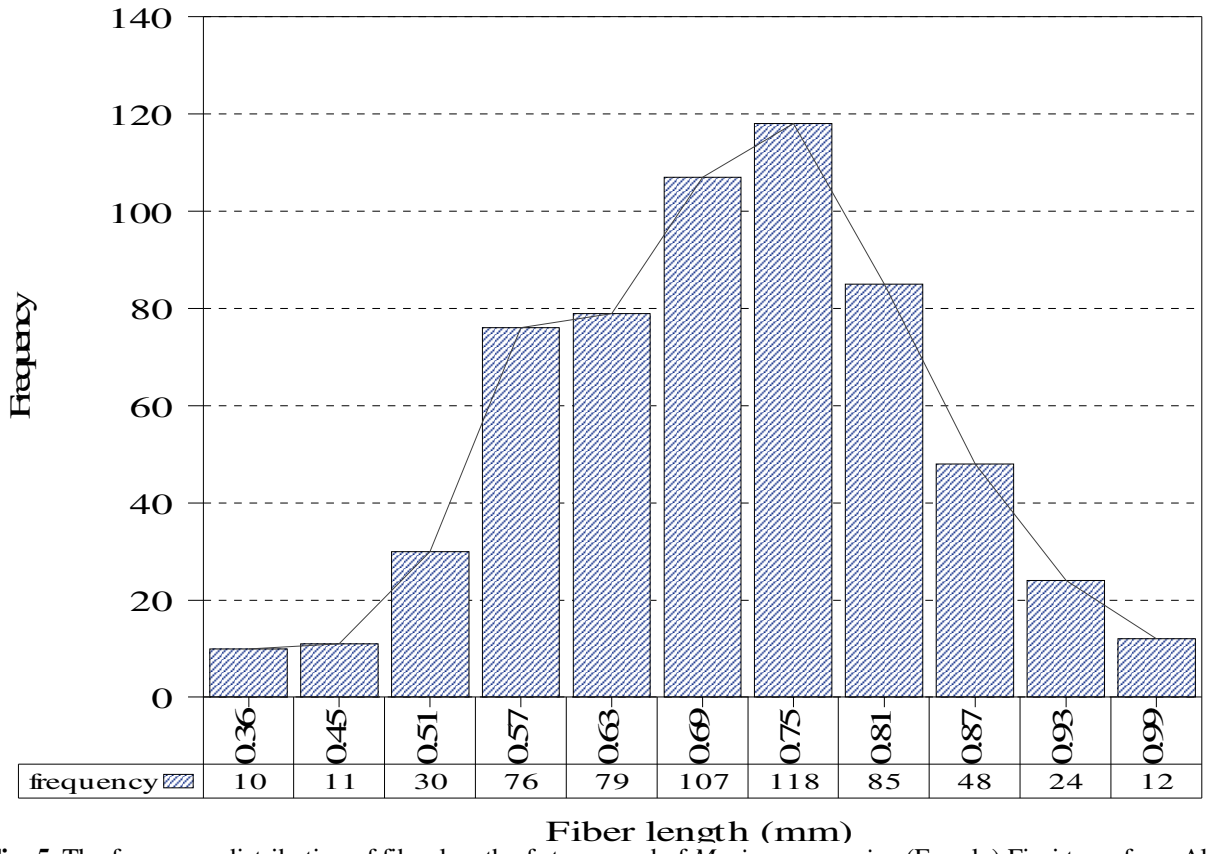
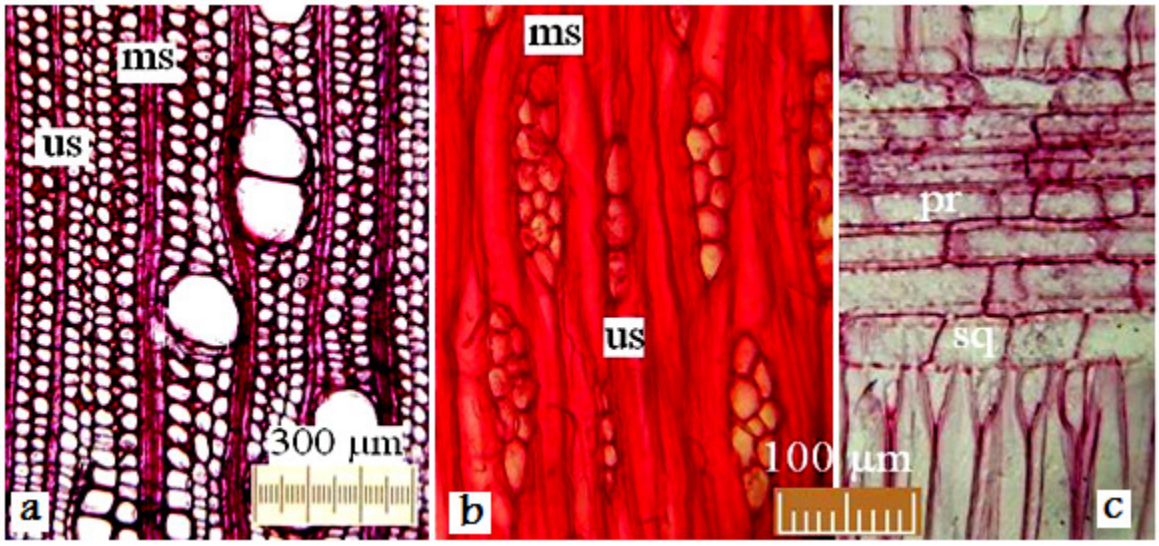


Fig. 5. The frequency distribution of fiber length of stem wood of *Moringa peregrina* (Forssk.) Fiori trees from Al Bowair plantation in Medina.



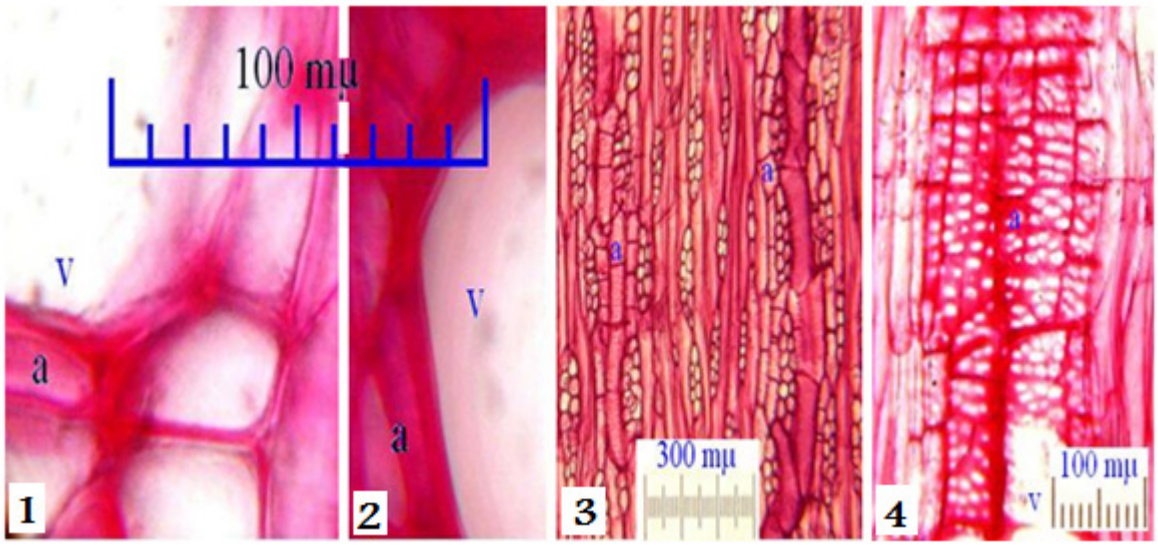
* ms= multiseriate us= uniseriate pr= procumbent up= upright sq= square

Fig. 6. (a) Wood rays (Cs), b) storied arrangement of ray Parenchyma cells (Ts) and c) heterogeneous ray consisting of a core of procumbent cells and square edge cell (Rs).

On the tangential section rays appear in storied arrangement (Fig. 6), with ray height of 209±95µm on the average. On cross-section the number of rays in the tangential millimeter is up to 10±2 on the average (Table 1). In the meantime, the proportion of rays is up to an average of 19.8±3.3% of the total cellular components ((Fig. 7).

Longitudinal axial parenchyma are partracheal scanty, or vasicentric with simple pitting on radial walls, consisting of longitudinal strands (Fig. 8). The ratio is 12.5% of the total cellular components on the average (Table 1).

Mineral inclusions are present as prismatic crystals located in upright and/or square ray cells. Sometimes they could be located in procumbent ray cells which are not chambered and number of crystals per cell is one, or more. In the mean time crystal-containing axial parenchyma cells are abundant; those cells are occasionally chambered with normal size bearing a single prismatic crystal (Fig. 8).



* a=axial parenchyma - v= vessel.

Fig. 7. Axial Parenchyma cells: (1) & (2) Paratracheal vasicentric axial parenchyma (Cs). (3) Strands of stratified axial parenchyma (TS). (4) Axial Parenchyma with simple pitting on radial walls (RS).

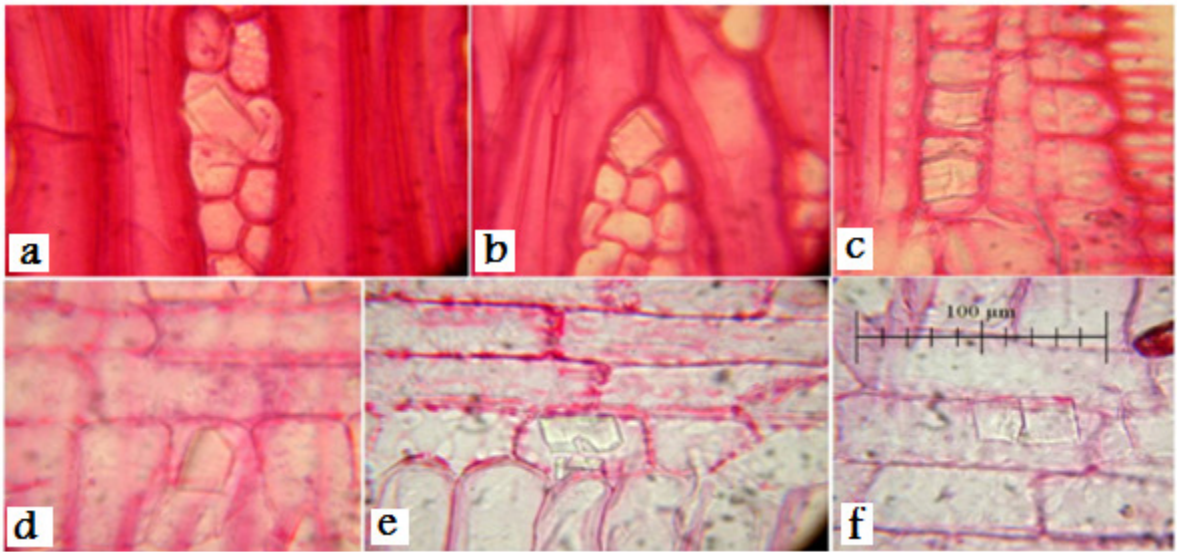


Fig. 8. Mineral inclusions (crystals) in Parenchyma cells: (a) in a cell in the middle of a ray (TS), (b) in a marginal cell in a ray (TS) (c) in a vasicentric strand axial parenchyma cell (RS), (d) in a marginal upright cell in a ray (RS), (e) and (f)) in procumbent ray cells (RS).

IV. CONCLUSION

From the above it is clear that the results obtained herein are consistent with the results obtained for the species under study in other parts of the world [14, 5]. Some differences may result due to spatial and environmental differences. Overall, these results clearly indicate an increase in the proportion of parenchyma cells (rays + coaxial parenchyma) where as their percentage is about 32.3% of the total cell volume. On the other hand fibers constitute about 59% of the woody tissue but they are generally short and thin walled, which leads to weakness in the resistance to mechanical stresses. It is evident that these anatomical traits affect the physical properties of wood, leading to lower specific gravity, and thus negatively impact both the mechanical properties and the dimension stability of the wood due to moisture content changes [16]. Consequently, all of this affects the uses of wood of *Moringa peregrina*, and limits its utilization only to some industrial purposes, such as charcoal production, fence pillars, low grade paper making, and the production of particleboard, fiberboard and some other engineered wood material. Those properties, prevents also the use of its timber in construction or in the furniture industry. Generally these conclusions should be confirmed by conducting technological investigations and mechanical tests.

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