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Research Article

Effect of Different Rainfall Levels on Wood Structure of *Acacia senegal* (L.) Willd in Clay Plain

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Abstract

The aim of this study was to examine the effect of rainfall on wood anatomical structures of Acacia senegal (L.) Willd located in the clay soil. Samples of wood were collected from sites representing three rainfall (low, medium and high) conditions throughout the gum belt of Sienar and Blue Nile States. Microscopic slides of wood samples were prepared to measure the size and percentage of wood cells. Analysis of variance was used to determine the differences between wood cells from different sites affected by rainfall. The differences in rainfall isohyets in clay soil did not significantly affect the wood anatomical structures.

Keywords: *Acacia senegal*; Anatomy; Wood; Rainfall

Introduction

Acacia senegal grows in tropical and sub-tropical, arid and semi-arid regions and is very drought resistant. Trees survive in the most adverse conditions, subject to hot winds and sandstorms on the poorest soils of rock and sand. *A. senegal* occurs naturally in areas with an annual rainfall of 100 - 200 - 400 - 800 mm with 7 - 11 dry months/year [1]. In Sudan, *A. senegal var. senegal* grows in various environments ranging from semi-desert with under 100 mm rainfall to the fringies of the moist savanna with up to 900 mm rainfall and soils ranging from sand to heavy clays. It is found in pure stands or in mixture with other species [2,3]. Wood is a product of a complex biological system, the tree, and as such it is a highly variable material. Its anatomical structure and properties vary from species to another, within the trees of the same species and even from one part of a single tree to the other. It has been shown by many investigators that property differences are closely related to structure at both macroscopic and microscopic levels. Thus, utility of a piece of wood for a specific application is dependent upon its properties which, in turn, are influenced by structure. The presently accepted practice of wood characterization is based on anatomical structure that serves as the principal method of identification [4]. Since wood anatomy and identification involve the recognition of shapes, sizes, and distribution of elements or features, it should greatly benefit from quantitative treatments of these features [5]. All woods have longitudinal and transverse elements "cells". The longitudinal elements may be vessels, various types of fibers, tracheids or parenchyma cells. The transverse tissues, or wood rays, may contain parenchyma or tracheid element or both [6].

Matrials and Methods

An experiment was carried out in the clay soil in the gum arabic belt under the different rainfall levels. Zone one in the low rainfall from (350 - 450 mm) was represented by Karkog area (13˚ 00 N 43˚ 00 'E) zone two and three were represented by Eldaly (12˚ 10' N 33˚ 35' E) and Bout (11˚ 48' N 33˚ 33' E) in moderate (500 - 600 mm) and high (700 - 900 mm) rainfall isohyets, respectively.

Nine *Acacia senegal* trees were randomly selected from each rainfall level from each of the different areas. The selected trees were marked for wood samples. The samples were taken from the mature wood. From each sample, three specimens 1×1×2 cm were prepared for sectioning. A transverse section was prepared from each sample. The cubes were softened and sectioned with sliding microtome. The sections were then stained with safranin and mounted in Canada balsam for microstructures. The transverse sections of wood samples were examined using a microscope camera setting attached to a computer. The wood softening method is described elsewhere [7]. Stereological counts were conducted following a procedure described elsewhere [8], using a 0.75 mm grid length under 4/0.1 magnification. The measurements of the microstructure involved random counts on the microscopic sections superimposed to nine squared on 16-point grid. The glass slides were fixed on microscope fitted with a camera and the cross sections were projected through the computer screen to obtain the point count (Pp), the number of points of intersection with cell boundaries per unit length of test lines (P L) and the number of objects or features in the count area of the microstructure (N A) for vessels, parenchyma, fibres and rays.

Figure 1: The Transverse sections of wood.

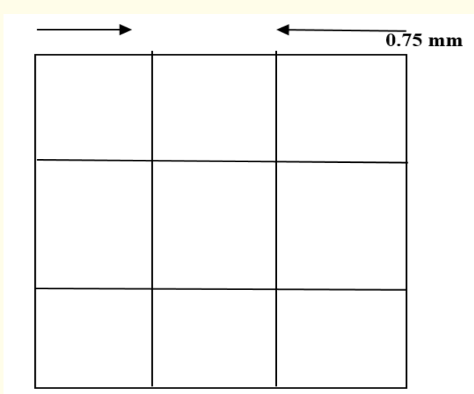

Figure 2: Nine square and sixteen-point grid.

The stereological equation relating fractional measurement in microstructure to point fraction according to [5] is as follows:

Vessel volume fraction = Pp vl + Pp vw 1

Parenchyma volume fraction = Pp pl + Pp pw 2

Fiber volume fraction = Pp fl + Pp fw 3

Ray volume fraction = Pp rl + Pp rw 4

Where l is lumen, w is wall, v is vessel, p is parenchyma, f is fiber and r is ray.

For the general description of stem anatomy, stereological method was used to calculate average cell diameter vertical and horizontal (D v, h), average lumen diameter (LD), the mean free path between cells (MFP), vessel shape factor (VSF), fiber density index (FDI) and double cell wall thickness (DCWT) for vessel and fiber, Rankle's ratio and fiber hardness rate. The following equations were used:

$$D_{v,h} = \frac{PL\ v,h}{2\ NA} \quad \text{..........................5}$$

$$LD = \sqrt{\frac{4 * pp\ lumem}{\pi\ Na}} \quad \text{.....................6}$$

$$MFP_{v,h} = \frac{2(1\text{-}Pp)}{P\ L\ v,h} \quad \text{..........................7}$$

$$DCWT_{v,h} = D_{v,h} - LD \quad \text{.....................8}$$

$$VSF = \frac{D\ V\ radial}{D\ V\ tangential} \quad \text{...........................9}$$

$$FDI = \frac{Pp\ w}{Pp\ l} \quad \text{....................................10}$$

$$\text{Rankle's ratio} = \frac{DCWT}{LD} \quad \text{.....................11}$$

$$\text{Fiber Hardness} = \frac{DCWT}{2\ D} \quad \text{...............12}$$

The data were analysed using the statistical analysis system (SAS), JMP programs. Analysis of variance and Duncan's Multiple Rage tests at 0.05 probability level was used to study the significance of the differences between the mean of wood parameters from different locations of the gum belt.

Results and Discussion

The results of the anatomical examination of wood showed that there were no significant differences in diameter of vessel vertical, fiber diameter vertical and mean free path of vessel vertical and horizontal (DVv, DFv, MFPv,h) in clay soil under different rainfall levels. However, the diameter of vessel horizontal (DVh) and diameter of parenchyma vertical (DPv) increased gradually with rainfall increasing. The diameter of fiber horizontal (DFh), diameter of parenchyma horizontal (DPh) had the highest values under high rainfall compared with low and medium rainfall (Table 1). The cell parameters vessel double cell wall thickness, fiber double cell wall thickness (DCWTVv, h, DCWTFv, h) and fiber lumen diameter (FLD) were similar under the three levels of rainfall in clay soil except lumen diameter of vessels (LDV) which increased with increasing rainfall (Table 2). Similarly, VSF, FDI, Rankle's ratio, fiber hardness, wood %, vessel %, parenchyma %, fiber %, ray % were not significantly different in clay soil under different rainfall levels (Table 3). These results on clay soil in different rainfall levels are not in line with the findings of other researchers working on root wood [9] who reported that there were no significant differences between vessel diameter and vessel lumen diameter in different isohyets in clay soil; also, he said that significant differences were found between isohyets in vessel shape factor. But he said that there were no significant differences between the three isohyets in double cell wall thickness of vessels, volume fraction of vessel, fiber, parenchyma and rays which are similar with the present results. [10] work on anatomy of wood in *Balanites aegyptiaca* reported that the vessel diameter was extremely variable in early wood 100 - 210 μ m; in late wood 110 - 220 μ m. Wall thickness 4 - 10 μ m, no lumen content or tyloses, diameter of axial parenchyma 10 - 40 μ m and wall thickness 1 - 3 μ m, fiber wall thickness 2.5 - 6 μ m and lumen diameter equals to 2.5 - 8 μ m.

Rainfall	DVv	DVh	DPv	DPh	DFv	DFh	MFPVv	MFPVh
Low	62.67 a	90.88 b	9.76 b	9.63 b	8.98 a	8.67 a b	1575 a	1113.56 a
Medium	91.02 a	106.02 a b	10.06 a b	9.92 b	8.84 a	7.72 b	1360 a	1018 a
High	108.93 a	126.1 a	11.7 a	11.02 a	9.52 a	9.83 a	1024.41 a	878.08 a
P	0.34	0.12	0.07	0.02	0.64	0.08	0.35	0.71
SE±	20.75	10.14	0.5	0.26	0.53	0.53	249.15	197.44

Table 1: Diameter of different cells and mean free path of vessels (in micron) of Acacia Senegal in clay soil different rainfall levels.
Means fallowed by the same letter in columns are not significantly different using DMRT at P ≥ 0.05.

Rainfall (mm)	DCWTVv	DCWTVh	DCWTFv	DCWTFh	LDV	LDF
Low	12.03 a	25.56 a	1.37 a	1.13 a	66.18 b	7.6 a
Medium	31.3 a	19.62 a	1.55 a	0.73 a	86.39 a	7.28 a
High	22.49 a	22.86 a	1.58 a	1.89 a	103.39 a	7.94 a
P	0.35	0.9	0.98	0.62	0.01	0.85
SE±	8.71	9.28	0.92	0.82	5.81	0.81

Table 2: Lumen diameter and double wall thickness of different cells (in micron) of Acacia Senegal in clay soil under different rainfall levels.
Means fallowed by the same letter in columns are not significantly different using DMRT at P ≥ 0.05.

Rainfall (mm)	V S F	FDI	F Hardness	Rankle's ratio	Wood%	Vessel %	Parenchyma %	Fiber %	Ray %
Low	0.74 a	4.16 a	0.06 a	0.37 a	58.66 a	7 a	33 a	28.33 a	31.66 a
Medium	0.83 a	4.08 a	0.05 a	0.33 a	60.66 a	7.66 a	36.33 a	29.33 a	26.66 a
High	0.85 a	3.75 a	0.35 a	0.49 a	58.66 a	13 a	32.66 a	29.66 a	24.66 a
P	0.89	0.95	0.39	0.91	0.66	0.24	0.76	0.77	0.47
SE±	0.17	0.99	0.16	0.28	1.76	2.43	3.82	1.33	3.91

Table 3: Vessel shape factor, fiber (density index, hardness) rankle's ratio and volume fraction of different cells (in micron) of Acacia senegal in clay soil under different rainfall levels.
Means fallowed by the same letter in columns are not significantly different using DMRT at P ≥ 0.05.

Conclusion

The anatomical structure and characteristic of the cells from the wood of Acacia senegal were similar in between the trees in clay soil under influence of the different rainfall levels. Hence, this species is well adapted with its environment without changes in the anatomical structures.

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