RESULTS

1- Specific gravity:

The variation of specific gravity (SG) for radial strips taken at various height levels in each species are shown in **Table 1**. The average specific gravity of *J. curcas* wood and *P. dioica* are closely near values (0.279 and 0.277, respectively), while the average specific gravity of *M. oleifera* was 0.197. The analysis of variance indicated no significant differences of specific gravity among height levels for both *J. curcas* and *M. oleifera*, while the average specific gravity for *P. dioica* is highly significant different among height levels and is decreasing from the base to top of tree (0.335 to 0.220).

The variation of specific gravity for radial strips taken at various distances from pith for the three species is presented in **Table 2**. There is a significant difference in the specific gravity of *J. curcas* and highly significant difference in *M. oleifera*. Specific gravity increased slightly from pith to bark (0.256 to 0.295) for *J. curcas* and (0.137 to 0.275) for *M. oleifera*. In *P. dioica*, the difference of specific gravity from pith to bark was not significant.

Mean values of specific gravity of normal and tension woods were compared in **Table 3**. The results of analysis of variance indicated no significant difference between normal and tension woods.

Table 1. Variation of wood specific gravity of *Jatropha curcas, Moringa oleifera* and *Phytolacca diocia* at different height levels (%) from base.

Height levels (%)	***J. curcas***	***M. oleifera***	***P. dioica***
0.0	0.291[a]	0.259[a]	0.335[c]
20	0.297[a]	0.177[a]	0.278[b]
40	0.267[a]	0.180[a]	0.281[b]
60	0.269[a]	0.200[a]	0.268[ab]
80	0.270[a]	0.169[a]	0.220[a]
Average	0.279	0.197	0.277
F. Value	1.15 [n.s]	1.19 [n.s]	9.30**

Means with the same letters are not significantly different ($P \leq 0.05$) as evaluated by One – Way ANOVA.

n.s: Not significant.

*: Significant at 0.05 probability level.

**: Highly significant at 0.01 probability level.

Table 2. Variation of wood specific gravity at different distances from pith to bark of *Jatropha curcas, Moringa oleifera* and *Phytolacca diocia*.

Position from pith	***J. curcas***	***M. oleifera***	***P. dioica***
1	0.256[a]	0.137[a]	0.299[a]
2	0.284[a]	0.179[a]	0.271[a]
3	0.295[b]	0.275[b]	0.259[a]
F. Value	4.89*	13.29**	1.89 [n.s]

For legends see Table 1.

Table 3. Variation of specific gravity in normal and tension woods of *Jatropha curcas, Moringa oleifera* and *Phytolacca diocia*.

Wood nature	***J. curcas***	***M. oleifera***	***P. dioica***
Normal	0.285[a]	0.255[a]	0.282[a]
Tension	0.284[a]	0.169[a]	0.270[a]
F. Value	1.34 [n.s]	3.62 [n.s]	0.42 [n.s]

For legends see Table 1.

2- Chemical properties:

Mean values of chemical components (cellulose, hemicelluloses and lignin contents) of wood of the selected species and the analysis of variance were recorded in **Table 4**. Analysis of variance of chemical components indicated highly significant difference among species. Cellulose contents of the wood of *J. curcas* and *P. dioica* were 46.807% and 48.885%, respectively, while it was 36.165% in *M. oleifera*. On the other hand, the hemicelluloses content in *M. oleifera* was significantly higher than those in both *J. curcas* and *P. dioica*. Lignin content in *P. dioica* was significantly lower than those of *J. curcas* and *M. oleifera*. Comparison between the chemical components of normal and tension wood was not significant **(Table 5)**.

Mean values of wood extractives and ash contents in the three studied species are presented in **Table 6**. The analysis of variance of the extractives data shows a highly significant difference among species for benzene-ethanol, hot water, 1% NaOH (soda alkali) soluble extractives, and ash content. There is non significant difference for total extractives. *P. dioica* has the greatest proportion of benzene-ethanol extractives (6.689%) and ash content (7.055%). *M. oleifera* has the greatest proportion of 1% NaOH (soda alkali) soluble extractives (29.078%).

Table 4. Variation of the main chemical components (%) of *Jatropha curcas, Moringa oleifera* and *Phytolacca diocia* woods.

Species	Cellulose	Hemicelluloses	Lignin
J. curcas	46.807[b]	38.962[a]	15.828[b]
M. oleifera	36.165[a]	50.503[b]	16.752[b]
P. dioica	48.885[b]	38.995[a]	10.885[a]
F. Value	32.76**	26.37**	6.46**

For legends see Table 1.

Table 5. Variation of the main chemical components (%) of normal and tension woods of *Jatropha curcas, Moringa oleifera* and *Phytolacca diocia*.

Wood nature	Cellulose	Hemicelluloses	Lignin
Normal	43.957[a]	42.696[a]	14.120[a]
Tension	43.948[a]	42.944[a]	14.857[a]
F. Value	0.00 [n.s]	0.01 [n.s]	0.15 [n.s]

For legends see Table 1.

Table 6. Variation of extractives and ash (%) of *Jatropha curcas, Moringa oleifera* and *Phytolacca diocia* woods.

Species	Hot water extract.	Benzene - ethanol extract.	1% NaOH (soda) extract.	Total extract.	Ash
J. curcas	10.121[a]	4.064[a]	16.958[a]	57.114[a]	2.725[a]
M. oleifera	14.665[b]	3.563[a]	29.078[c]	49.872[a]	3.310[a]
P. diocia	14.317[b]	6.689[b]	24.902[b]	51.083[a]	7.055[b]
F. Value	6.79**	10.39**	66.26**	2.30 [n.s]	148.72**

For legends see Table 1.

Mean values of wood extractives and ash contents of normal and tension wood are shown in **Table 7**. There is no significant difference in benzene-ethanol extractives, hot water extractives, 1% NaOH (soda alkali) soluble extractives and ash between normal and tension wood. While, there is highly significant difference in total extractives between normal and tension wood. Hot water extractives, 1% NaOH (soda alkali) soluble extractives, total extractives and ash% of tension wood are higher than those of normal wood. Tension wood is less than normal wood in benzene- ethanol extractives. Mean values of bark extractives are presented in **Table 8**. In the current investigation, it is observed that the bark in all species contains higher extractives for all types of used solvents than the wood of the same species.

Table 7. Variation of wood extractives and ash (%) of normal and tension woods of *Jatropha curcas, Moringa oleifera* and *Phytolacca diocia*.

Wood nature	Hot water extract.	Benzene-ethanol extract.	1% NaOH (soda) extract.	Total extract.	Ash
Normal	11.816[a]	5.210[a]	22.942[a]	47.914 [a]	4.110[a]
Tension	14.253[a]	4.334[a]	24.350[a]	57.465 [b]	4.617[a]
F. Value	3.17 [n.s]	1.01 [n.s]	0.29 [n.s]	18.24**	0.27 [n.s]

For legends see Table 1.

Table 8. Variation of bark extractives (%) of *Jatropha curcas, Moringa oleifera* and *Phytolacca diocia*.

Species	Hot water extract.	Benzene–ethanol extract.	1% NaOH (soda) extract.	Total extract.
J. curcas	23.452[b]	9.034[b]	54.671[b]	68.498[c]
M. oleifera	14.695[a]	4.680[a]	37.327[a]	40.202[a]
P. diocia	24.819[b]	9.634[b]	50.436[b]	48.853 [b]
F. Value	198.88**	38.62**	41.64**	60.65**

For legends see Table 1.

3- Fiber morphology:

Fiber length data at different height levels of stem for the three selected species and the analysis of variance are presented in **Table 9**. There were no significant differences among height levels of each species. The mean values of fiber length were 0.775 mm in *J. curcas*, 0.930 mm in *M. oleifera* and 0.906 mm in *P. dioica*. The relationship between cambial age (distance from pith) and fiber length are illustrated in **Table 10**. Fiber length increased significantly with age of the studied trees especially in the case of *M. oleifera* and *P. dioica*. Fiber length increased from 0.744 to 0.807 mm in *J. curcas*, from 0.805 to 1.075 mm in *M. oleifera* and from 0.883 to 0.966 mm in *P. dioica*.

Table 11 shows the mean values and analysis of variance of fiber length for normal and tension woods of the studied species. The results indicated no significant differences between normal and tension woods.

Fiber dimensions (μm) of each species and analysis of variance are presented in **Table 12**. There are highly significant differences in wall thickness and cell lumen among the studied species. *P .dioica* has the highest wall thickness (2.180 μm) in the studied species.

Table 9. Variation of fiber length (mm) at different height levels (%) from base of *Jatropha curcas, Moringa oleifera* and *Phytolacca diocia* woods.

Height Levels (%)	*J. curcas*	*M. oleifera*	*P. diocia*	species (Overall)
0.0	0.767[a]	0.980[a]	0.874[a]	0.880[a]
20	0.782[a]	0.905[a]	0.921[a]	0.882[a]
40	0.775[a]	0.904[a]	0.921[a]	0.847[a]
60	0.777[a]	0.950[a]	0.919[a]	0.869[a]
80	0.770[a]	0.915[a]	0.957[a]	0.874[a]
# Average	0.775[a]	0.930[b]	0.906[b]	
F. Value	0.22 [n.s]	0.88 [n.s]	0.91[n.s]	0.39 [n.s]

For legends see Table 1.

Means with the same letters of this row are not significantly different ($P \leq 0.05$) as evaluated by One – Way ANOVA.

Table 10. Variation of fiber length (mm) at different distances from pith to bark in woods of *Jatropha curcas, Moringa oleifera* and *Phytolacca diocia*.

Position from pith	*J. curcas*	*M. oleifera*	*P. dioica*	species (Overall)
1	0.744[a]	0.805[a]	0.883[a]	0.811[a]
2	0.755[ab]	0.867[ab]	0.905[a]	0.843[a]
3	0.786[b]	0.906[b]	0.847[a]	0.847[a]
4	0.778[b]	1.000[c]	0.930[a]	0.903[ab]
5	0.807[b]	1.075[d]	0.966[a]	0.950[b]
F. Value	5.07 **	31.15 **	1.32 n.s	7.23 **

For legends see Table 1.

Table 11. Variation of fiber length (mm) of normal and tension woods of *Jatropha curcas, Moringa oleifera* and *Phytolacca diocia*.

Wood nature	*J. curcas*	*M. oleifera*	*P. dioica*	Species (Overall)
Normal	0.765[a]	0.925[a]	0.880[a]	0.856[a]
Tension	0.783[a]	0.937[a]	0.933[a]	0.884[a]
F. Value	2.43 n-s	0.15 n-s	2.23 n.s	1.96 n.s

For legends see Table 1.

Table 12. Variation of fiber wall thickness and lumen diameter (µm) of *Jatropha curcas, Moringa oleifera* and *Phytolacca diocia* woods.

Dimension	N	*J. curcas*	*M. oleifera*	*P. dioica*	F. Value
Wall thick.	25	1.280[a]	1.680[b]	2.180[c]	43.47**
Cell lumen	25	10.920[b]	15.300[c]	5.490[a]	70.62**

For legends see Table 1.

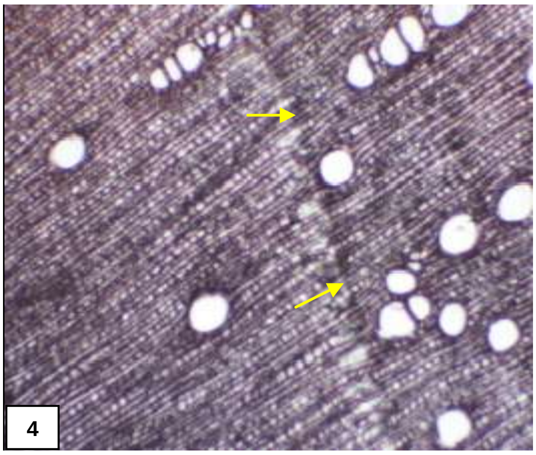
4- Anatomical features:

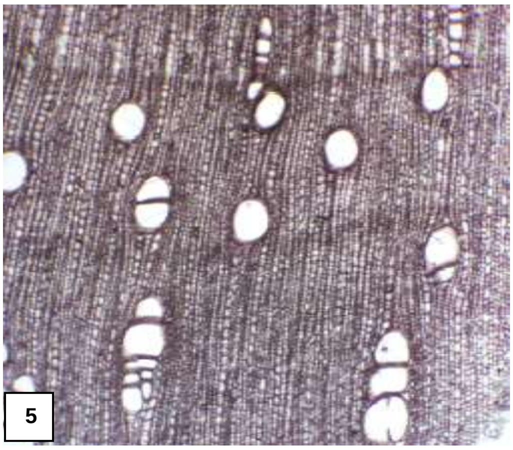
Anatomical structure study by using Light Microscope of different types of sections (transverse, radial, tangential and individual elements in macerations) for stem wood in the studied species is indicated as follows:

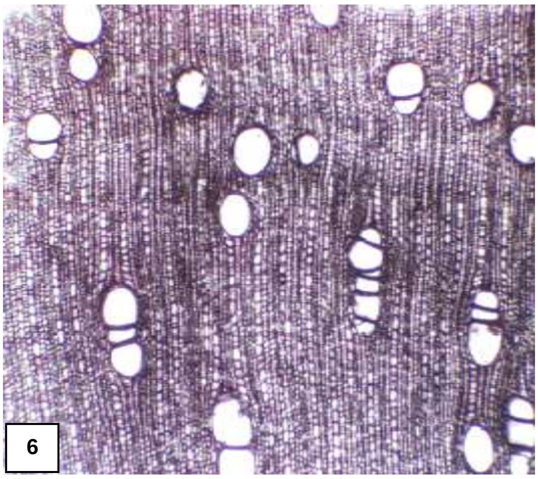
4-1- *J. curcas*:

- Growth rings are distinct by the presence of parenchyma boundary (Fig. 4).
- Wood is diffuse porous (Fig. 5). Vessel grouping is as isolated, multiples in radial rows of 2, 3, 4 and more (Fig. 4, 5, 6 and 7).
- The shapes of vessels in transverse section are circular (the most common), angular and oval (Fig. 4, 5, 6 and 7).
- Some vessels contain brown substances (Fig. 7).The tangential diameter of the vessels is ranging between 55 – 158 µm; it is classified as a medium size of vessels. On the other hand, the vessel length is ranging between 137 – 525 µm.

- Fig. (8) and (9) show the simple perforation plate which is situated in an oblique end wall of vessels.
- Fig. (10) illustrates intervascular pits more or less in alternate arrangement.
- Diffuse longitudinal parenchyma distribution is presented in Fig. (11) and many of the parenchyma cells touch the vessels in Fig. (12), so that the scanty paratracheal type is represented here as well.
- Non storied arrangement of fibers is shown in Fig. (13) and (14). They are septate (the most common) and non septate.
- Tangential section in Fig. (13) shows that the wood rays are mostly uniseriate and in numerous rows (biseriate rays are present too).The ray height is ranging from 2 - 23 cells and 117 - 850 µm. Also, wing cells are presented in rays.
- Fig. (15) and (16) show ray parenchyma cells containing solitary crystals.
- The radial section is shown in Fig. (17), wood rays here are considered heterogeneous, consisting of upright and procumbent cells. On the other hand, most rays are irregularly arranged.







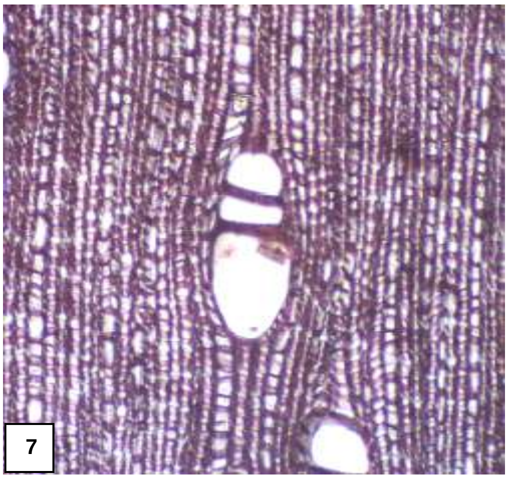


Fig. 4: Cross section showing parenchyma boundary (arrows).

Fig. 5, 6: Cross section showing vessels (distribution - shapes).

Fig. 7: Cross section showing vessels containing brown substances.

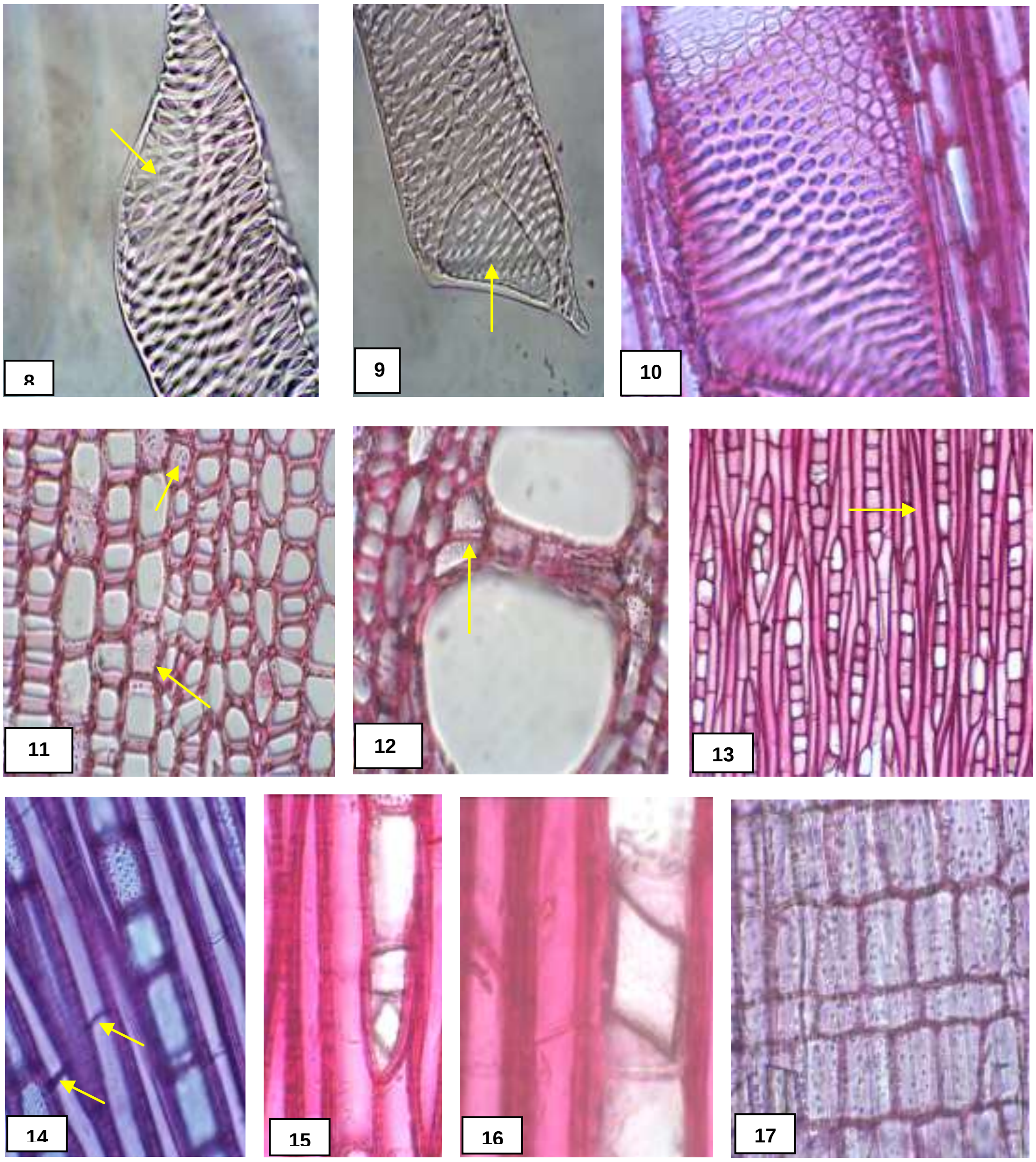


Fig. 8, 9: A macerated, tailed vessel element with simple perforation plate (arrow).

Fig. 10: Tangential section showing intervascular pits.

Fig. 11: Cross section showing diffuse parenchyma (arrows).

Fig. 12: Cross section showing scanty paratracheal parenchyma (arrow).

Fig. 13: Tangential section showing septate and non septate fibers (arrow), uniseriate and biseriate rays and wing cells.

Fig. 14: Tangential section showing septate fibers (arrows).

Fig. 15: Tangential section showing crystals in ray cells.

Fig. 16: Highly magnified tangential section showing a crystal in a ray cell.

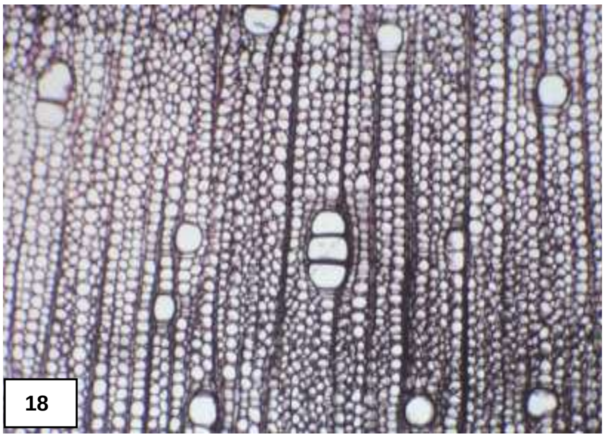
Fig. 17: Radial section showing heterogeneous ray with procumbent cells and upright cells.

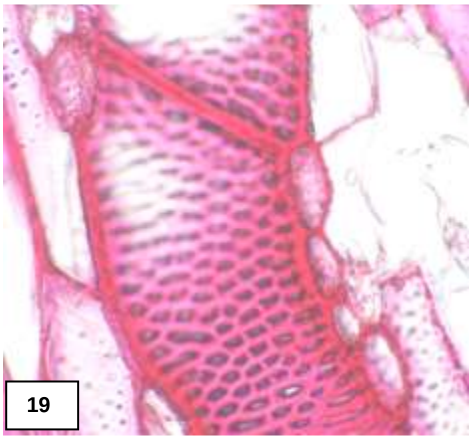
4-2- *M. oleifera*:

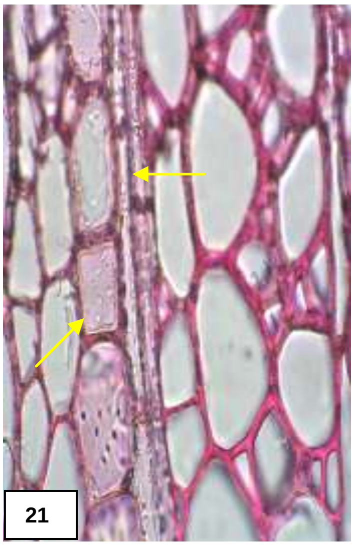
- Growth rings are indistinct and the wood is considered to be diffuse porous (Fig. 18).
- Fig. (18) shows that the shapes of vessels are oval and hemispheric. They are arranged as isolates, pairs (in radial and tangential rows) and triplets in radial rows.
- Intervascular pits are in numerous rows, with alternate and opposite arrangement (Fig. 19).
- Fig. (20) is showing that vessels have simple perforation plates. Vessel length ranges between 175 - 337.5 μm and the width ranges between 75 - 125 μm.
- Diffuse parenchyma are distributed as single cells, pairs and even in triplet strand as in Fig. (21). Paratracheal parenchyma is presented as scanty parenchyma (Fig. 22).
- Medullary rays adhering to vessels are very common. They can be two or three cells in width (Fig. 21 and 22).
- Radial section in Fig. (23) shows that libriform fibers are nearly in storied arrangement and seem to be undivided into bands. Mean length of fibers is 0.930 mm and mean wall thickness is 1.68 μm.
- Fig. (24) and (25) show simple pits on fiber wall.
- Rays are nearly in storied arrangement. They are uniseriate, biseriate and triseriate, with oval shaped cells of variable sizes (Fig. 26 and 27).
- Wing cell is present at both sides of the ray (one or two cells); oval shaped and with ovoid or somewhat tapering tips (Fig. 27). Ray height ranges between 45 - 325 μm and width ranges between 12.5 - 47.5 μm.
- Ray histology is presented in radial section (Fig. 28). Rays are

heterogeneous consisting of upright and procumbent cells.

- Cross fields are present between rays and vessels (Fig. 28).







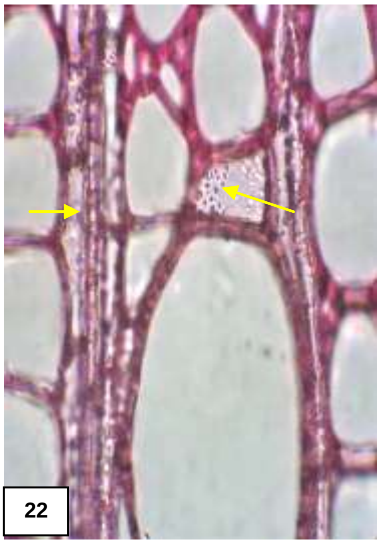


Fig. 18: Cross section showing diffuse porous wood.

Fig. 19: Radial section showing intervascular pits.

Fig. 20: A macerated vessel element with simple perforation plate (arrow).

Fig. 21: Cross section showing diffuse parenchyma (lower arrow) and medullary ray (upper arrow).

Fig. 22: Cross section showing scanty parenchyma (right arrow) and medullary ray (left arrow).

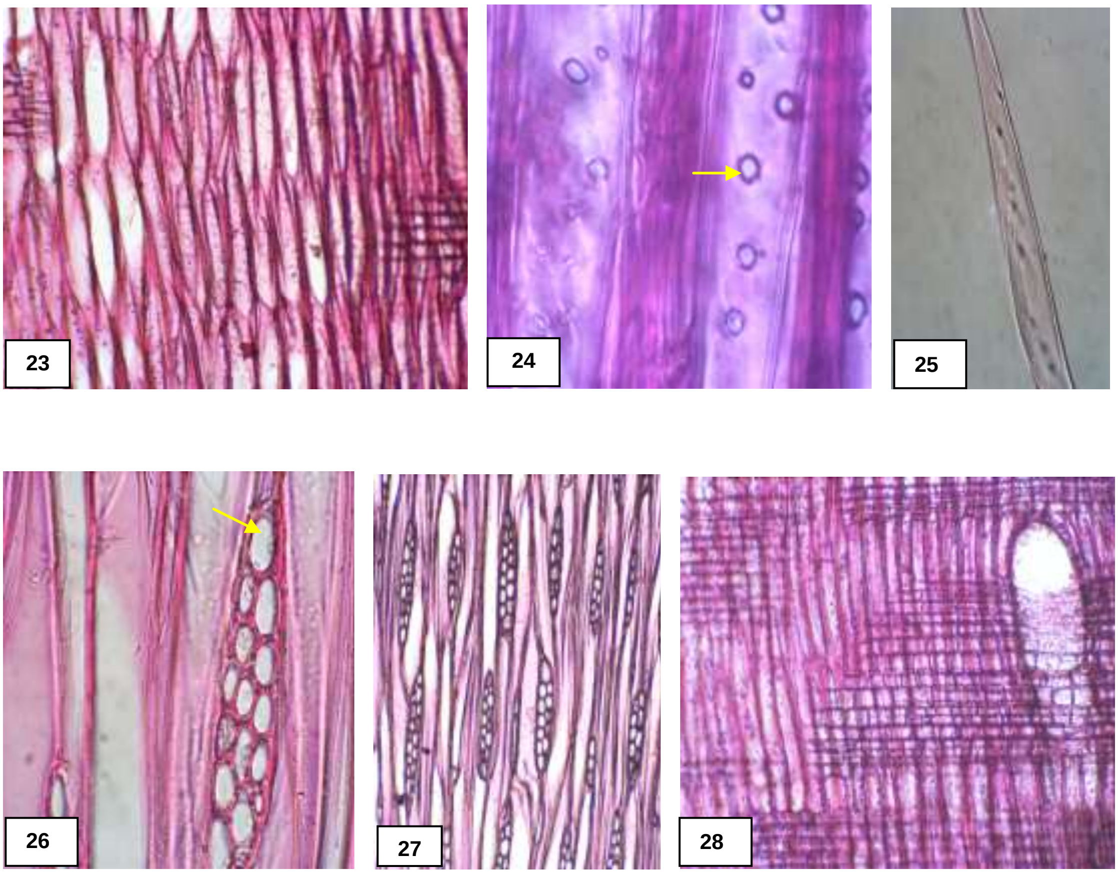


Fig. 23: Radial section showing storied arrangement of libriform fibers.

Fig. 24: Tangential section showing simple pits on fibers (arrow).

Fig. 25: A macerated fiber.

Fig. 26: Tangential section showing triseriate ray and wing cell (arrow).

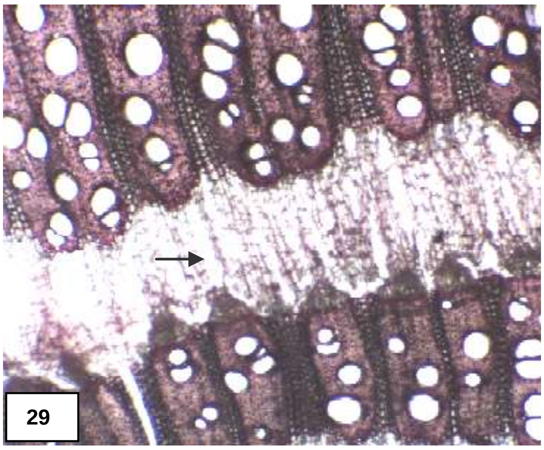
Fig. 27: Tangential section showing uni- and biseriate rays with storied arrangement of rays.

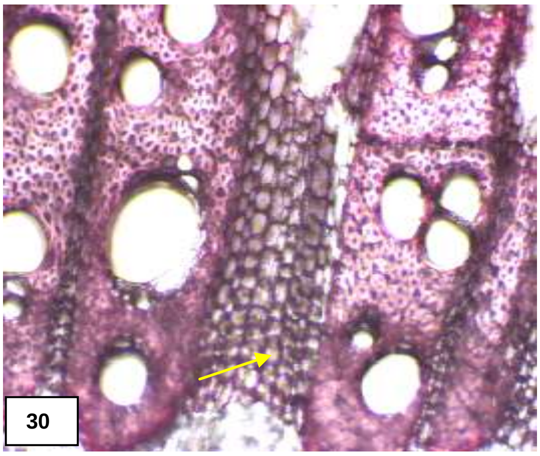
Fig. 28: Radial section showing heterogeneous ray and cross field between ray and a vessel.

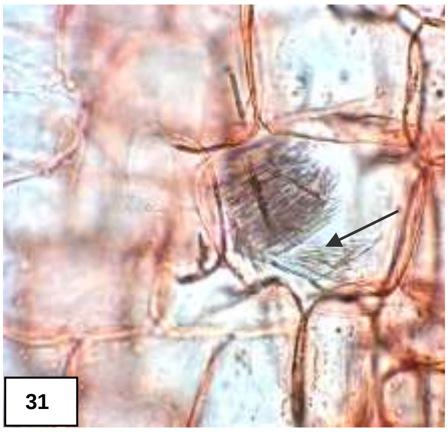
4-3- *P. dioica*:

- Fig. (29) illustrates clear successive growth rings (centric) which represent the anomalous secondary growth. Each ring consists of vascular bundles; each vascular bundle consists of phloem, cambium and xylem. Each ring is separated from the other by a zone of conjunctive tissue consisting of loose parenchymatous cells containing raphids (Fig. 29 and 31).
- Vascular bundles are separated from each other by parenchyma cells (2 - 10 cells in width); these cells are connected by the conjunctive tissue (Fig. 30).
- Fig. (29) and (30) show vessels distributions and shapes. Vessels are randomly distributed in the bundle; they are distributed as isolates (the most common), pairs and triplets. Vessels shapes can be rounded, oval, hemispheric and triangular.
- Vessels have simple perforation plates (Fig. 32 and 33).
- Fig. (33) shows the intervascular pits which are arranged as multiple rows in alternate way. Vessels length ranges between 100 - 212.5 μm, while the width ranges between 50 -150 μm.
- Paratracheal parenchyma are present as scanty (Fig. 34).
- The tangential section in Fig. (35) shows fibers which have simple rounded pits. Fibers mean length is 0.906 mm, mean wall thickness is 2.18 μm.
- Fig. (36) shows the rays which are very large and multiseriate with sheath cells (4 -10 cells in width). Wing cell is present as a single triangular cell (some times is very long) at both sides of the ray. Ray height ranges between 125 - 2075 μm and its width ranges between (45 - 250) μm.

- Rays are heterogeneous consisting of both cubic and long upright cells of variable lengths (Fig. 37).







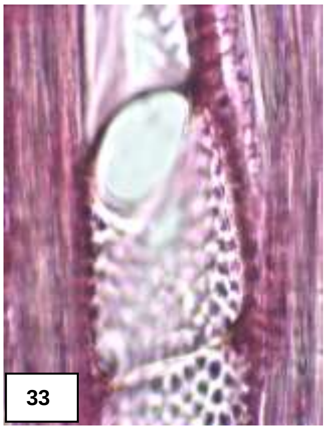


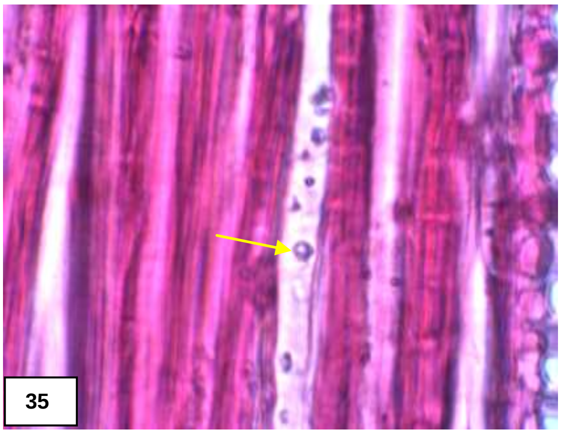
Fig. 29: Cross section showing anomalous secondary growth and conjunctive tissue (arrow).

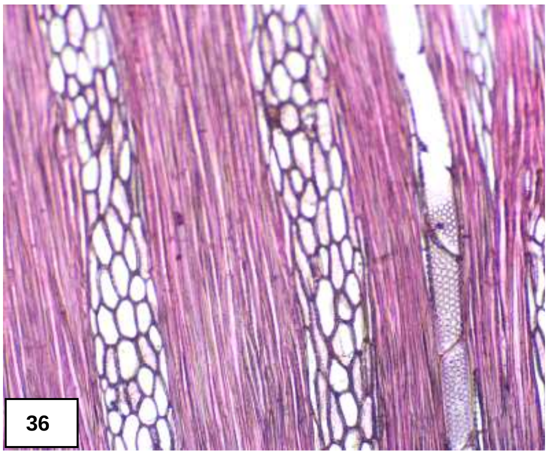
Fig. 30: Cross section showing vascular bundles separated by parenchyma cells (arrow).

Fig. 31: Cross section showing raphids in conjunctive tissue (arrow).

Fig. 32: A macerated vessel element with simple perforation plate (arrow).

Fig. 33: Tangential section showing a vessel with simple perforation plate and intervascular pits.





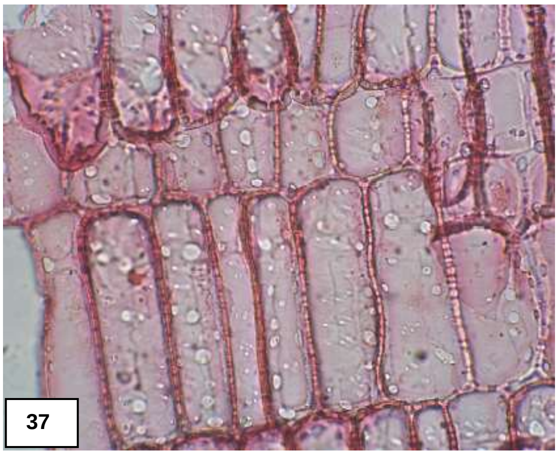


Fig. 34: Cross section showing scanty parenchyma (arrow).

Fig. 35: Tangential section showing fiber with simple pits (arrow).

Fig. 36: Tangential section showing large multiseriate rays, sheath and wing cells.

Fig. 37: Highly magnified radial section showing heterogeneous ray.