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Wood anatomy of timber yielding species of *Terminalia* Linn. (Combretaceae) growing in the Terai region of Uttar Pradesh, India and their taxonomic significance

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Abstract
This study dealt with the wood microstructures of four timber yielding species of *Terminalia* Linn. namely, *Terminalia arjuna* Wight & Arn. (Arjun), *T. bellerica* (Gaert.) Roxb. (Bahera), *T. chebula* Retz. (Harra) and *T. elliptica* Willd. (Asna) of the family Combretaceae which are growing in the mixed deciduous forest of Balrampur, Uttar Pradesh, India. On the basis of the structural variation of the anatomical features of vessels, parenchyma, xylem rays, fibres and intervessel pits the differentiations of microstructures among the above species is discussed in detail. The study revealed that all the *Terminalia* species have diffuse porous wood and the vessels are solitary as well as radial multiples of usually 2-4 except in *T. elliptica* Willd. which possesses the multiples of up to 8 vessels. The inter-vessel pits are vestured in all the four species with a little variation in their size. Other microstructures like xylem rays, parenchyma, and fibres have distinct variation in their distribution pattern. The crystal cells in xylem rays are varying in their size and frequency. Anatomically the genus *Terminalia* Linn is quite heterogeneous and can be differentiated at specific level.

Keywords: *Terminalia* (combretaceae), wood anatomy, systematic description, characterization and identification, vessels, xylem raya, parenchyma, terai region, U.P

Introduction

The family Combretaceae comprises trees, shrubs, and lianas of about 20 genera and 600 species distributed in tropical and subtropical regions [2]. More than 100 species belonging to 6 genera and occur in Asia. They found in diverse habitat conditions and grow mainly at low or medium altitudes up to 1200 m but rarely also extended up to 1500-1800 m altitudes. *Terrminalia* Linn. is the second largest genus among the family and well known for their economic importance due to their high-quality timber and cardiotonic and diuretic medicines. It consists of approximately 250 species of medium-to-large trees growing throughout tropical and subtropical regions of Asia, Australia, and Africa.

The wood anatomy of some combretaceous taxa is carried out [15, 29] They have made a comparative study on both trees and lianas member of this family in order to makes a wood anatomical study useful. Further, Van Vliet has studied the structure of vestures pits in the genus *Combretum* and *Terminalia* for an evaluation of their possible taxonomic and diagnostic value [26]. The relationships among the different genera of this family based on their xylem characters (Vessels, parenchyma, fibres etc) has been discussed. The general anatomy of the genus Anogeissus and *Terminalia* has been given in the book "Commercial timber of India" [19]. A comprehensive study on the wood anatomy of about 90 species belonging to 19 genera of family Combretaceae has been described in detail [29]. who has mentioned the variation of quantitative characters in vessel member length and correlated with ecological conditions of the taxa involved. He also pointed out the structural differences between lianas and erect species. The literatures on anatomy including only the photoplates of the genus *Terminalia* along with the other combretaceous taxa are also published [11, 13, 16, 18].

The anatomical study on angiospermous fossil woods has been carried out by a number of palaeobotanist in India and abroad and during the identification of fossil woods they have analyze the wood characteristics of several modern genera and species indicating their similarity with the fossil woods [1, 3, 10, 14, 20, 22, 24, 27]. Based on anatomical characteristics of fossil woods about 45 form species of the *Terminalia* Linn has been described under form genus, *Terminalioxylon* Schonfeld from all over the world [23, 28]. The structural features of the fossil woods of Kalagarh area comprising 40 species belonging to 26 genera and 14 families of Angiosperms has been analyzed in order to infer the climatic condition during Miocene period [25] based on the fact that the environmental factors influence the structure of secondary xylem of the woods [30]. In the present communication authors studied the wood anatomy of commercially important species of *Terminalia* Linn. ie. *Terminalia arjuna* Wight & Arn., *T. bellerica* (Gaert.) Roxb., *T. chebula* Retz. and *T. elliptica* Willd. of the family Combretaceae growing in the Terai region of Balarampur district in order to know the degree of heterogeneity among them.

About the study area

The study area, Balrampur is one of the districts of Devipatan division as well as the historic Awadh region of Uttar Pradesh. It occupies an area of about 3719sq km. lying all along Indo- Nepal border of Terai region. It is situated on the bank of river Rapti. Siddharth Nagar and Gonda districts are lying in the east-west and south sides respectively and Nepal is in its northern side containing Shivalik hills of the Himalaya Mountains (Fig.1). The Rapti originates in the mountains near Bhalubang in Rapti Anchal of western Nepal and after taking traverses in Bahraich District enters Balrampur District. Its banks are usually high, but the river

is continually changing its course. It only overflows its banks in rainy season. The mean daily maximum temperature at around 39°C and the mean daily minimum temperature is around 24° C. The area has a very hot summer season and in individual days maximum temperature may be as high as 48°C.

The well known Suhelwa Wild Life Sanctuary (27° 30'1" N to 27° 55' 42" N and 81° 55' 36" E to 82° 48' 33" E) is located in this area all along the Shiwalik Hills and flourished by a dense forest of about 45000 hectares and accompanied with a number of commercial timber yielding plants. The whole forest is of deciduous type predominated by Sal (*Shorea robusta*) forest. Bankatwa, Nandmahra, Seria Naka, Jarwa, Rampur, Mansurwa, and Bhabar are well famous forest areas in this Sanctuary from where a good collection of tree plants are made. Kuwana (27.388589°N: 82.120146°E) is other big forest lies in south of Balrampur comprising a variety of timber plants. Swamp forests are also common accomplished with timber plants like *Terminalia bellerica, T. arjuna* and *Lagerstroemia parviflora* etc.

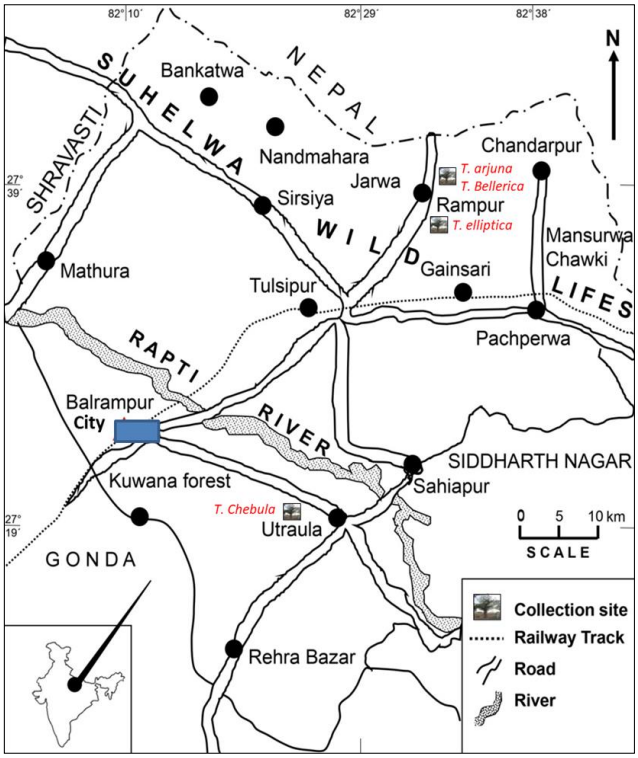

Fig 1: Map showing location of collection sites and forest areas in Balrampur district, U. P.

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Materials and methods

Material (woods) was collected from the trunk of all the four species of the genus *Terminalia* Linn. ie *Terminalia* arjuna, *T. bellerica*, *T. chebula* and *T. elliptica* growing in the different places in the terai region of Balrampur district of Uttar Pradesh (Fig. 1). The height of each tree is measured with the help of measuring tape from base as ground level to the apex of the tree and expressed in a meter. The general botanical characters have been noted. The wood sample for its anatomical study has been taken from the trunk above about 1m from the earth surface with the help of a carpenter by using mainly wood cutting machine. The wood sample is boiled with water by mixing a little amount of Glycerine until it becomes soft. The wood has been cut into thin slices along transverse (TS), tangential longitudinal (TLS) and radial longitudinal (RLS) sections were cut with the help of a sliding microtome and then prepared their slides by using different grades of ethyl alcohol for dehydration and safranin for staining. Canada balsam has been used for as a mounting substance for making permanent slides. The thin section will be examined critically under high power microscope and described their anatomical features in detail. The photography has been carried out with the help of microscopic camera attached to the high-power microscope. Authentic timber samples (wood slides) of all the four Terminalia spp were studied at the xylaria of Birbal Sahni Institute of Palaeosciences in order to anatomically compared with each other for confirmation of the identity. All the prepared slides were kept at Department of Botany, M. L. K. College, Balrampur, U. P.

Fig 2: Habit and habitat of *Terminalia* species A. *Terminalia arjuna* B. *Terminalia Chebula* C. *Terminalia bellerica* D. *Terminalia elliptica* in the Terai region of Balrampur district, U.P.

Observations

A critical study of the wood slides prepared from the woods of all the four species of *Terminalia* Linn. has been carried

out. The anatomical characters exhibited by each species are observed and described separately in details.

1. *Terminalia arjuna* (Roxb. ex DC) Wight & Arn. (Fig. 2A)

Terminalia arjuna (Roxb. ex DC.) Wight & Arn. is commonly known as Arjuna or Arjun tree. This plant is one of the most accepted and beneficial medicinal plant in indigenous system of medicine for the treatment of various chronic diseases. It is about 20-25m in height having buttressed trunk and form a wide canopy at the crown. It generally grows all along rivers, streams and dry water bodies, throughout sub-Himalayan tract of Uttar Pradesh, South Bihar, Chhota Nagpur, Myanmar, Madhya Pradesh, Delhi and Deccan region. The bark is smooth white and the inner surface has longitudinally striation and pinkish in colour. Leaves are green on the top and brown below, simple, sub-opposite, corioceous, oblong to elliptic with entire margin and pointed tip. Flower is white or pale yellow arranged in spikes. Fruit are ovoid to oblong with 5-7 hard angles or wings. 2.5 to 5 cm fibrous woody fruit, divided into five wings. The bark of *T. arjuna* is well known as an astringent, demulcent, expectorant, cardio tonic, styptic anti dysentery urinary astringent and has shown to be useful in fractures, ulcers, leucorrhea, diabetes, anemia, cardiopathy and cirrhosis. The wood is medium in weight to heavy mainly low resistance to decay. It is used for many purposes such as home construction, interior joinery, furniture, veneer and plywood, musical instruments, turnery and many others. It is also suitable for fuel and making charcoal.

Specimen no. - MLK/Blp-27; height 18m and diameter 2.44m.

Locality - Rampur Range (27.644045°N: 82.521131°E), Suhelwa Forest, Balrampur District, U.P.

Wood structure - *Wood* diffuse - porous. *Growth rings* inconspicuous, delimited by thick-walled fibres and smaller vessels. *Vessels mostly* small to medium occasionally large in size, solitary as well as radial multiple of 2-several (usually 2-4), 4-6 vessels per sq. mm, sometime filled with redish brown tyloses; t. d. 60-220 µm, r. d. 65-270, vessel walls 15-25 µm thick (Fig, (3A, B). Vessel's members 350-680 µm in length with usually truncate ends; perforation simple; inter-vessel pit-pairs alternate vestured, circular or oval to elliptic in shape, inter-vessel pits about 5 µm in diameter with linear to lenticular apertures (Fig. 3 C, E). *Parenchyma* both paratracheal and apotracheal; paratracheal parenchyma sparse, delimited around the vessels, vasicentric to slightly aliform, only 3-4 parenchyma cells extend outward; apotracheal parenchyma diffuse and scattered among the fibres, frequently forming the concentric bands and enclosing the adjascent vessels, parenchyma bands are 6-12 cells or 135-260 µm wide, parenchyma cells thin walled, 15-28 µm in diameter and 75-245 µm in length. *Xylem rays* fine,

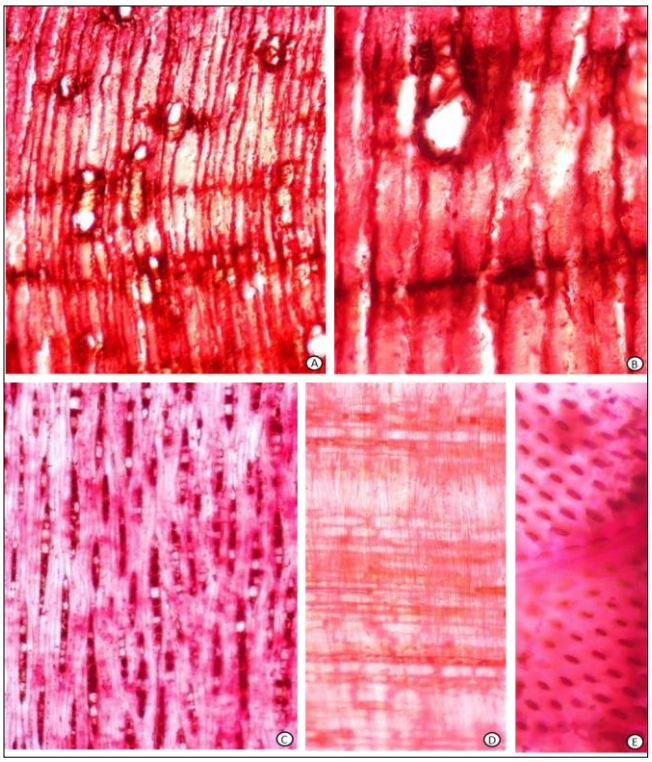

Fig 3: Wood structure of *Terminalia arjuna* A.

Transverse section showing shape size and distribution of vessels, nature of parenchyma and fibres and closely placed xylem rays x50. B. Transverse section magnified to show shape and size of parenchyma and fibre cells and thickness of vessel wall and parenchyma bands x120. C. Tangengial longitudinal section showing mostly uniseriate xylem rays with crystalliferous cells x120. D. Radial longitudinal section showing heterocellular xylem rays x120. E. vestured intervessel pits x550.

12-16 rays per mm, ray cells usually ray cells elliptic to nearly rectangular in shape, mostly uniseriate, occasionally biseriate, 20-45 µm in width and 3-22 cells or 53-590 µm in length (Fig. 3C); ray tissues heterogeneous, rays heterocellular comprising of both procumbent and white, crystalliferous upright cells; procumbent cells frequently filled with redish brown gummy substances, procumbent cells 22- 35 µm in tangential height and 25-60 µm in radial length; upright cells 30-40 µm in tangengial height and 18-20 µm in radial length (Fig. 3D). 2-3 crystalliferous cells present in each ray. *Fibres* aligned in radial rows between two consecutive xylem rays, semi-libriform to libriform, moderately thick-walled, non-septate, 325-700 µm long; pits in the fibres are not seen.

2. *Terminalia bellerica* (Gaertn) Roxb. (Fig. 2B)

Terminalia bellirica (Gaertn.) Roxb. is one of the oldest medicinal plants It is a large deciduous tree *with* a straight and tall trunk reaching *up* to 40 m in height. It distributed in India, Pakistan, Nepal, Bangladesh and Sri Lanka as well as South-East Asia. Trunk is cylindrical, with horizontally spreading branches. Bark is dark brown with irregular fissures horizontally 10-20mm thick. Leaves are medium sized, 8-20 cm long and 7.5-15 cm wide, alternate or fascicled at the end of branches with long petiole, elliptic or elliptic-obovate in shape, leathery, with entire margin and acute to obtuse apex. Flowers are Greenish-yellow which grow in spikes in leaf axils, 5-15 cm long. Upper flowers on

the spike are male, and lower flowers are bisexual. Fruits are obovoid, 1.5-2.5 cm in diameter, covered with minute pale pubescence, very thick and indistinctly 5-angledand one seeded. *T. bellerica* (Gaertn.) Roxb. is used to protect the liver and treat respiratory condition including respiratory tract infection, cough and sore throat. Wood is used for furniture, boxes and durable house construction. Wood pulp is good quality for production of paper. The woods also yield a good quality fine wood and charcoal.

Specimen no. - MLK/Blp-12; Heig3ht 14m and diameter 1.07m.

Locality - Rampur Range (27.651653°N: 82.524595°E), Suhelwa Forest, Balrampur District, U.P.

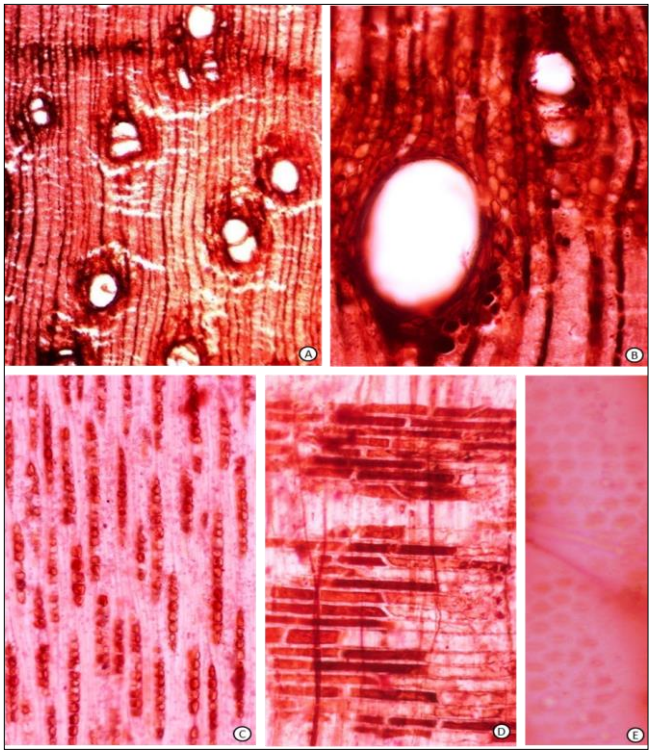

Fig 4: Wood structure of *Terminalia bellerica.* A.

Transverse section showing shape size and distribution of vessels, nature of parenchyma and fibres and closely placed xylem rays x50. B. Transverse section magnified to show shape and size of vessel, parenchyma and fibre cells and thickness of vessel wall and parenchyma bands x120. C. Tangengial longitudinal section showing mostly uniseriate, rarely biseriate xylem rays with crystalliferous cells x120. D. Radial longitudinal section showing heterocellular xylem rays x120. E. vestured intervessel pits x600.

Wood structure - *Wood* diffuse - porous. *Growth rings* sometimes delimited by thick-walled fibres and smaller vessels. *Vessels mostly* medium to large, rarely very large, occasionally small, solitary as well as radial multiple of 2-3 (usually 2), 3-5 vessels per sq. mm, sometime plugged with reddish brown tyloses; t. d. 95-230 µm, r. d. 120-330, vessel walls 25-32 µm thick (Fig, 4A, B). Vessels - members 280-830 µm in length with usually truncate ends; perforation simple; inter-vessel pit-pairs alternate, vestured, circular or oval to elliptic in shape, inter-vessel pits 4-6 µm in diameter with linear to lenticular apertures (Fig. 4 C, E). *Parenchyma* both paratracheal and apotracheal; paratracheal parenchyma usually delimited with around the vessels, vasicentric to aliform; apotracheal parenchyma sparse, diffuse and scattered among the fibres, occasionally in concentric bands which sometime enclosing the vessels, parenchyma bands 3-7 cells thick, parenchyma cells thin walled, 25-40 µm in diameter and 85-240 µm in length. *Xylem rays* fine, 13-18 rays per mm, ray cells circular to oval or elliptic in shape, mostly uniseriate, very rarely biseriate, 16-36 µm in width and 3-18 cells or 85-570 µm in length (Fig. 4C); ray tissues heterogeneous, rays heterocellular comprising of both procumbent and white, crystalliferous upright cells; procumbent cells frequently filled with redish brown gummy substances, procumbent cells 21- 45 µm in tangential height and 30-96 µm in radial length; upright cells 28-50 µm in tangential height and 16-22 µm in radial length (Fig. 4D). Crystalliferous cells frequently present in each ray. *Fibres* aligned in radial rows between two consecutive rays, semi-libriform to libriform, moderately thick-walled, septate segment 125-400 µm long; pits in the fibre segment are not seen (Fig. 4A, C).

3. *Terminalia* chebula retz. (Fig. 2C)

Terminalia chebula, commonly known as black or chebulic myrobalan, is a slow growing, medium to large deciduous tree reaching up to to 30 m high, with a trunk up to 1m in diameter. It is native to South Asia from Pakistan, India and Nepal east to southwest China and south to Sri Lanka, Malaysia, and Vietnam. In India it is distributed in the sub -Himalaya tract, from Ravi east ward to West Bengal and Assam. It is also common in South region like Madras and Mysore etc. Stem bark is dark brown. The leaves are alternate to sub-opposite, oblong oval, 7-8 cm x 4.5-10 cm in size with 1-3 cm long petiole, an acute tip, cordate base and entire margins. The flowers are monoecious borne in terminal spikes or short panicles and have a strong, unpleasant odour, dull and white to yellow in colour. The fruit is drupe-like, smooth ellipsoid to ovoid, 2-4.5 x 1.2-2.5 cm, blackish, with five longitudinal ridges. They are yellow to orange-brown in colour, with a single angled stone. Triphala is a important ayurvedic medicinal composition which is made of *Terminalia chebula, T. bellerica* and *Emblica officinalis* which is used for the treatment of gastrointestinal disorder. The wood is of good quality and strong and tough but no so durable. It is used as construction timber and for furniture, carts etc.

Specimen no. - MLK/Blp-61; height 20 m and diameter 1.83m.

Locality - Rajapur Bharia jungle (27.399423°N: 82.247592°E), Uttaraula Road, Balrampur District, U.P.

Wood structure - *Wood* diffuse - porous. *Growth rings* indistinct. *Vessels mostly* medium to rarely small or large sized, solitary as well as radial multiple of 2-4 (usually 2), 5-8 vessels per sq. mm, occasionally filled with reddish brown tyloses; t. d. 90-220 µm, r. d. 121-230, vessel walls 22-30 µm thick (Fig, 5A, B). Vessels - members 250-630 µm in length with usually truncate ends; perforation simple; inter-vessel pit-pairs alternate, vestured, oval to elliptic in shape, inter-vessel pits 4-6 µm in diameter with linear to lenticular apertures (Fig. 5 C, E). *Parenchyma* both paratracheal and apotracheal; paratracheal parenchyma usually delimited with 1-2 cells sheath around the vessels, vasicentric; apotracheal parenchyma diffuse and scattered among the fibres, usually in thick concentric bands which sometime also enclosing the vessels, parenchyma bands 8-12 cells or 280-448 µm thick and sometimes wavy and as

thick as fibre band, parenchyma cells thin walled, 25-36 µm in diameter and 60-110 µm in length.

Xylem rays

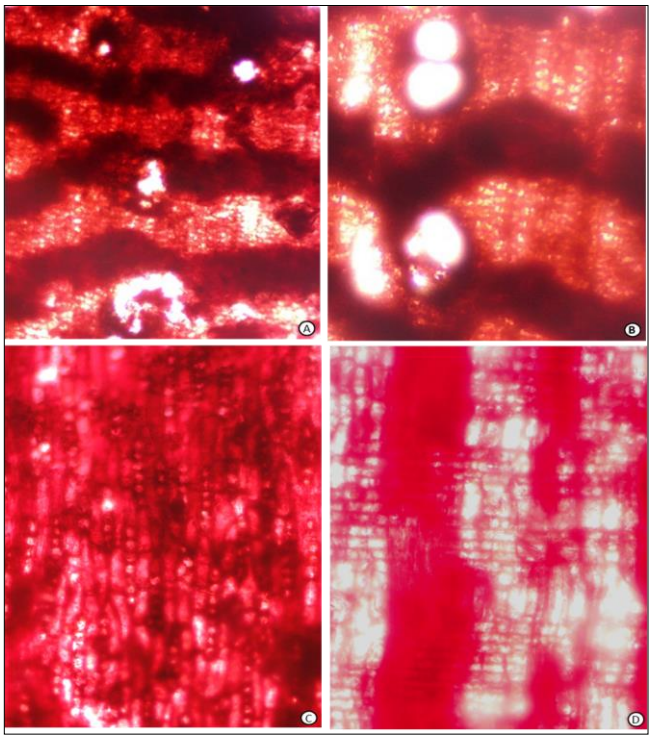

Fig 5: Wood structure of *Terminalia chebula* A.

Transverse section showing shape size and distribution of vessels, nature of parenchyma, fibres and xylem rays x50. B. Transverse section magnified to show shape and size of vessel, parenchyma and fibre cells and thickness of vessel wall and parenchyma bands x120. C. Tangengial longitudinal section showing mostly uniseriate, rarely biseriate xylem rays with sometimes crystalliferous cells x120. D. Radial longitudinal section showing heterocellular xylem rays x120.

fine, 8-10 rays per mm, ray cells oval to elliptic in shape, mostly uniseriate, rarely biseriate, 18-41 µm in width and 3-20 cells or 80-590 µm in length (Fig. 5C); ray tissues heterogeneous, rays heterocellular comprising of both procumbent and white, crystalliferous upright cells; procumbent cells sometimes filled with reddish brown gummy substances, procumbent cells 12- 27 µm in tangential height and 27-80 µm in radial length; upright cells 25-45 µm in tangential height and 18-30 µm in radial length (Fig. 5D). Crystalliferous cells present. *Fibres* aligned in radial rows between two consecutive rays, semi-libriform to libriform, moderately thick-walled, circular to polygonal in shape, non- septate, alternate with parenchyma bands of almost same thickness, 20-26 µm in diameter and 280-610 µm long; pits in the fibre are not seen (Fig. 5A, C).

4. *Terminalia elliptica* Willd. (Fig. 2D)

Terminalia elliptica Willd. commonly known as Indian Laurel is a medium-sized to fairly large deciduous tree that can reach 20-30 m of height with a trunk diameter of 1m. It is native to Southern and South East Assam, in India, Nepal, Bangladesh, Myammar, Thailand, Laos, Cambodia and Vietnam. It is a dominant species of both dry and moist deciduous forests in southern India up to 1000m.The bark is grey-black in colour, rough, deeply fissured, 15-20 mm thick and fire-resistant. The leaves are simple, opposite to sub-opposite, with 10-20 mm long petiole. The leaf blade is coriaceous, 13-20 x 5-13 cm, oblong to elliptic-ovate in shape; base oblique, apex acute, margin entire or cremulate. The flowers are bisexual, dull yellow, 2-3 mm long, without petals, and borne in terminal and maxillary paniculate spikes. The fruit is a drupe 3.5 x 5.5 cm, longitudinally 5-winged, glabrous, reddish brown in colour containing one seed. It is mainly used as valuable timber and for its ethnobotanical properties. It provides a valuable timber used for furniture, cabinet work, joinery paneling, also in boat building, rail road cross ties and musical instruments.

Specimen no. - MLK/Blp-11; height 12m and diameter 0.91m.

Locality - Jarva (27.651620°N:82.524571°E), Suhelwa Forest, Balrampur District, U.P.

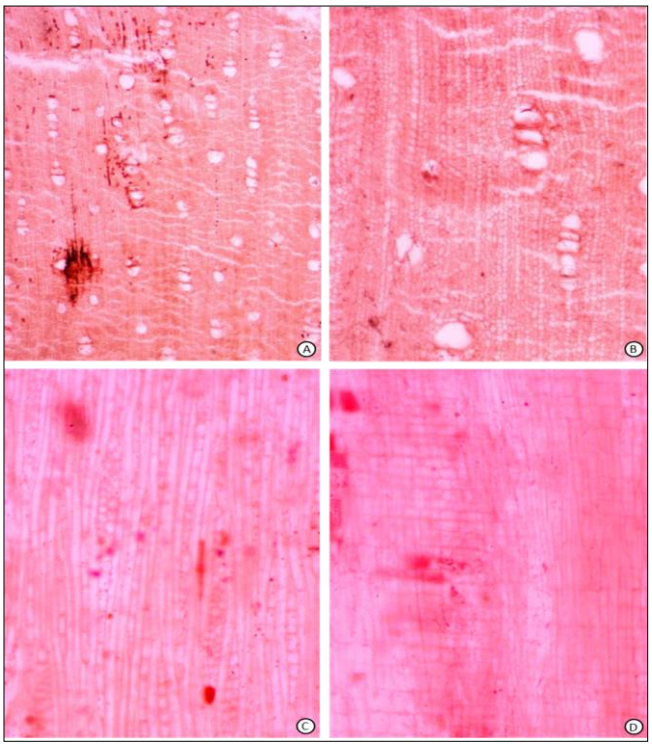

Fig 6: Wood structure of *Terminalia elliptica* A

Transverse section showing shape size and distribution of vessels, usually in radial multiples, nature of parenchyma and fibres and closely placed xylem rays x50. B. Transverse section magnified to show shape and size of vessel, vasicentric and diffuse parenchyma in usually uniseriate, interrupted band and fibre cells and thickness of vessel wall x120. C. Tangengial longitudinal section showing 1-2 seriate xylem rays without crystalliferous cells x120. D. Radial longitudinal section showing heterocellular xylem rays x120.

Wood structure - *Wood* diffuse - porous. *Growth rings* not seen. *Vessels small* to medium, evenly distributed, usually in radial multiple of 2-8 (usually 2-4), occasionally solitary, 15-18 vessels per sq. mm, vessels not filled with tyloses; t. d. 50-110 µm, r. d. 55-121, vessel walls 12-18 µm thick (Fig, 6 A, B). Vessels-members 268-490 µm in length with usually truncate ends; perforation simple; inter-vessel pit-pairs alternate, vestured, circular or oval to elliptic in shape, inter-vessel pits 3-6 µm in diameter with linear to lenticular

apertures (Fig. 6 C, E). *Parenchyma* both paratracheal and apotracheal; paratracheal parenchyma usually attached with the vessels, vasicentric to poorly aliform; apotracheal parenchyma sparse, diffuse and scattered among the fibres, occasionally in 1-2 seriate, short and interrupted concentric bands, parenchyma cells thin walled, 18-24 µm in diameter and 90-280 µm in length. *Xylem rays* fine, 25-30 rays per mm, closely spaced having distance of 30-80 µm, ray cells elliptic to rectangular in shape, 1-2 seriate, 14-32 µm in width and 3-25 cells or 60-580 µm in length (Fig. 6 C); ray tissues heterogeneous, rays heterocellular comprising of both procumbent and upright cells; procumbent cells 15-28µm in tangential height and 28-45 µm in radial length; upright cells 30-50 µm in tangengial height and 25-30 µm in radial length (Fig. 4D). Crystalliferous cells are not seen in the rays. *Fibres* aligned in radial rows between two consecutive rays, semi-libriform to libriform, moderately thick-walled, non- septate, 330-650 µm long; pits in the fibre are not seen.

Result and discussion

Wood anatomical studies discussing with the implications for relationship within the genus *Terminalia* Linn. of the family Combretaceae are very few. In the present communication the authors investigated the commercial timbers/woods of four species of this genus namely *Terminalia* arjuna, *T. bellerica*, *T. chebula* and *T. elliptica* obtained from the mixed deciduous forest of terai region of Uttar Pradesh and provides the characteristic and quantitative data on structural variation in the vessel size and frequency, wall thickness, vessel member length, parenchyma distribution, thickness and length of xylem rays and the nature of fibres. The wood anatomical differences among the above-mentioned species of *Terminalia* Linn. are given in Table -1 and analyzed them in order to characterize for their identification. The table shows that a few characters are constant within all species and are therefore suitable for a diagnostic value for only the generic level. Other characters such as the nature of xylem and parenchyma, vessel size and its multiplication, presence or absence of crystalliferous cells in the xylem rays, suggest a great variation within them and can be useful for differentiation at the species level. The analysis indicates that all *Terminalia* spp has diffuse porous wood having vessels solitary as well as in radial multiples of 2-4 in *T. bellerica* and *T. chebula* however in some cases it extends up to 2-9 as in *T. arjuna* and *T. elliptica.* Variation in vessel size and frequency has also been seen among them. The wood of *T. arjuna* and *T. elliptica* posses small to medium sized vessels as compared to medium to large in *T. bellerica* and mostly medium sized in *T. chebula*. The vessel frequency shows a little variation in *T. arjuna* (4-6/sq.mm), *T. bellerica* (3-5 sq mm) and T. chebula (5-8 sq.mm) but in *T. elliptica* it extends up to 15-18 vessel / mm. Inter-vessel pit pairs in all the four species are vestured type having almost same shape and size. The length of vessel segments in Terminalia spp. has not any remarkable variation. Wood of *Terminalia* possess 1-2 seriate, heterogeneous xylem rays comprising of both upright and procumbent cells. Xylem rays vary in their quantity of uniseriate and biseriate type of rays. Uniseriate rays show their greater quantity in *T. arjuna, T. bellerica and T. chebula.* The biserate rays are more common in *T. elliptica.* Although, the width and height of rays are not enabled to differentiate them but the nature of ray cells and presence of crystalliferous cells and quantity play an important role for distinguishing them at specific level. Moreover, the xylem rays in *T. elliptica* have greater frequency of about 25-30 rays /mm than *T. arjuna* (12-16/mm), *T. bellerica* (13-18/mm) and T. *chebul*a (8-10/mm). Both paratracheal and apotracheal parenchyma are found in the wood of *Terminalia* spp. but they vary in their amount and distribution pattern. Apotracheal parenchyma is in good amount generally present in concentric bands of different thickness and frequency. Parenchyma bands are thicker and common ally found in *T. arjuna* (6-12 cells) than in *T. bellerica* (5-7 cells). In *T. chebula* the parenchyma bands are also thick (8-12 cells) but found continuously alternating with the fiber's bands of about same thickness. *T. elliptica* possesses somewhat different pattern of apotracheal parenchyma showing 1-2 cells thick interrupted bands. The paratracheal parenchyma in all the Terminalia spp. are varied from vasicentric in *T. elliptica* and *T. chebula* to aliform and confluent as in *T. arjuna* and *T. bellerica*. Segmentation of fibres due to presence of septa is one of the important distinguishing features for *Terminalia* spp. Septa are found only in the fibres of *T. bellerica.* Finally, it can be concluded that ray cell arrangement and axial parenchyma types can be used together as baseline to distinguish *Terminalia* spp in in terai region of Uttar Pradesh for the purpose of timber identification.

Table 1: Showing the variation in Growth ring, Vessels, Parenchyma, Xylem rays and Fibres in all the selected species of the genus *Terminalia* Linn.

Wood Anatomical Characters					
Species	**Growth rings**	**Vessels**	**Parenchyma**	**Xylem rays**	**fibres**
Terminalia arjuna	Present	Small to medium, rarely large, t.d. 60-220µm, r.d. 65-270 µm, radial multiples of up to 8, usually 3-4, 4-6/sq mm, walls 15-25 µm thick, vessel members 350-680 µm long, pits about 5 µm in diameter	Paratracheal parenchyma vasicentric to slightly aliform, apotracheal parenchyma diffuse and in concentric bands of 6-12 cells thick, 15-28 µm in diameter and 75-245 µm in length.	Mostly uniseriate, occasionally biseriate, 12-16 rays /mm, 20-45 µm in width 3-22 cell or 53-590 µm long, heterogeneous, crystalliferous cells frequently present, ray cells elliptic to nearly rectangular in shape	Non-septate,325-700 µm in length
Terminalia bellerica	present	Medium to very large, t.d. 95-230µm, r.d. 120-330 µm, radial multiples of up to 9, usually 2, 3-5/sq mm, walls 25-32 µm thick, vessel members 380-830	Paratracheal parenchyma usually vasicentric to rarely aliform, apotracheal parenchyma diffuse and in concentric bands of 5-7 cells	Mostly uniseriate, very rarely biseriate, 13-18 rays /mm, 16-26 µm in width 3-18 cell or 83-575 µm long, heterogeneous, crystalliferous cells present, ray	Septate, segment125-400 µm in length

		µm long, pits about 4-6 µm in diameter	thick, 25-40 µm in diameter and 85-570 µm in length.	cells circular to oval or elliptic in shape	
Terminalia chebula	absent	Mostly medium sized, t.d. 90-220µm, r.d. 121-230µm, in radial multiples 2-4, usually 2, 5-8/sq mm, walls 22-30 µm thick, vessel members 250-630 µm long, pits 4-6 µm in diameter	Paratracheal parenchyma usually vasicentric, delimited by 1- 2 cells around the vessels, apotracheal parenchyma diffuse and in 8-12 cells of concentric bands, 25-36 µm in diameter and 60-110 µm in length	Xylem rays mostly uniseriate, 8-10 rays /mm, 18-41 µm in width, 3-20 cell or 80-590 µm long, heterogeneous, crystalliferous cells present, ray cells oval to elliptic in shape	Non-septate, 280-610 µm in length
Terminalia elliptica	Absent	Small to medium, t.d. 50-110µm, r.d. 55-121µm, usually in radial multiples 2-4, rarely up to 8, 15-18/sq mm, walls 12-18 µm thick, vessel members 268-490 µm long, pits about 3-6 µm in diameter	Paratracheal parenchyma usually vasicentric, sometime extending 2-4 cells outward, apotracheal parenchyma diffuse and in 1-2 cells of concentric bands, 18-24 µm in diameter and 95-280 µm in length.	Xylem rays 1-2 seriate, closely placed, 25-30 rays /mm, 14-32 µm in width, 3-25 cell or 60-580 µm long, heterogeneous, crystalliferous cells not present, ray cells elliptic to rectangular in shape	Non-septate, segment 330-650 µm in length

Conclusions

A detailed and comparative study has been carried out on the wood anatomy of four selected species namely, *Terminalia arjuna, T. bellerica, T. chebula* and *T. elliptica*. of the family Combretacea. This suggests that the variation in ray width and ray height within all the four species is not useful for differentiating them but the presence of abundant upright crystalliferous cells in xylem rays of *Terminalia arjuna* can be used comfortably for differentiating it from other three species. The nature and arrangement of apotracheal parenchyma as a comparatively thick continuous and wavy concentric bands distinguish from *T. arjuna*, *T. bellerica* and *T. elliptica*. the occurrence of 1-2 seriate, interrupted lines of apotracheal parenchyma in *T. elliptica* itself differentiating it from other three species which are having thick (6-12 cells) and almost continuous bands.

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