# Examining the Characteristics of Anatomy and Biometry of *Crataegus azarolus*

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This report discusses the biometry and microscopic features of *Crataegus azarolus* wood fibers. A *Crataegus azarolus* tree was selected and cut from the gardens of Neka city (Mazandaran province). At a breast height, 2.5 m and 3.5 m height, three 5 cm thick disks were prepared and in the transverse direction, the test samples were cut and evaluated sequentially 2 x 2 cm long by 3 cm long from the pith to the bark. The anatomical properties *of C. azarolus* wood were studied using a light microscope. Wood anatomical features of *C. azarolus* are as follows: diffuse-porous with multiple vessel grouping in the radial direction (in most cases), homogenous rays, simple perforation plates, alternate intervessel pits, and the average length of vessel elements shorter than 350 microns. There was a significant difference in the fiber length, fiber diameter, fiber lumen diameter, and fiber wall thickness, both in the transverse direction and in the longitudinal direction of the *Crataegus azarolus* tree stem. The biometric properties of the fibers increased from the pith to the bark. The average fiber length, fiber diameter, fiber lumen diameter, and cell wall thickness of the fibers were 0.78 mm, 22.53 µm, 18.6 µm, and 4.5 µm, respectively.

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## INTRODUCTION

In every facility of the wood and paper industry, wood suitable for that industry should be used. The correct use of wood reduces waste, reduces the cost of production, and increases the quality of the produced product. The correct use of wood is directly related to knowledge about it. The optimal use of wood as a raw material in wood and paper factories is related closely to the biometric structure of fibers and its anatomy. In the paper industry, investigating the biometric characteristics of wood fibers helps the paper producer.

*Crataegus azarolus* is a native tree of Iran that grows in all the coasts of the North Sea and temperate steppe areas such as western forests in Lorestan, Kurdistan, Bakhtiari and Fars. It is a deciduous tree with a maximum height of 6 m, four-cornered and sometimes thorny branches. The Hawthorn tree with the scientific name, *Crataegus azarolus* is from the family of Rosaceae. Parsapajouh and Schweingruber (2001) investigated the anatomical properties of *Crataegus azarolus*. Their research showed that this species has homogeneous wood and the diffuse-porous of wood porosity. Vessel groupings are often single or sometimes 2 or 4 of them are stuck together in the radial direction. The growth ring boundaries is barely visible due to the changes in the vessel cavities between latewood and earlywood wood. The width of the wood ray in the tangential cross-section of a uniseriate and biseriate, in the radial surface of the wood ray was heterogeneous and the vessels was simple perforations. Hassanpoortichi and Rezanezhad (2019) studied the anatomical, physical, and biometric features of *Ficus carica* wood in the longitudinal and transverse direction of the stem, and they concluded that the fiber length, fiber lumen diameter, fiber diameter, and cell wall thickness in the longitudinal axis of the stem (in three height of breast height, 1.9 m height and near the crown) decrease and in the transverse direction in all three heights, these characteristics go through an increasing trend. Oladi *et al*. (2017) investigated the physical, chemical, and anatomical characteristics of the fast-growing species of Gaz Shahi wood; this wood is suitable for the paper industry due to its high Runkle coefficient and thinness. This species has less cellulose and more lignin than other broad-leaved species. Hassanpoortichi and Rezanezhad (2020) evaluated the changes in biometric, physical, and anatomical features of mulberry wood (*Morus alba*) in the longitudinal and transverse direction of the stem. With the increase in height from the trunk to the crown of the tree, all the fiber biometric characteristics including fiber length, fiber lumen diameter, fiber diameter, and cell wall thickness decreased. Also, the biometric properties increased from the pith of the tree to the bark of the tree. Basic density and oven dry density decreased from the trunk to the crown of the tree and increased from the brain to the bark. Kord *et al*. (2010) examined the effect of the age of the *Populus deltoides* on the characteristics of the physical, chemical, and biometrical of wood; the effect of different ages of trees on fiber dimensions, physical properties, and chemical compounds of its wood was found to be significant at the 95% confidence level.

This research reports the changes in the anatomical and biometrical properties of *Crataegus azarolus* wood in longitudinal and transverse directions. The morphology of its wood fibers was examined.

## EXPERIMENTAL

For specific assessment of biometrical and anatomical properties, three healthy pomegranate trees from Behshahr city (geographic coordinates 53º and 20 min east longitude and 36º and 40 min north latitude and 50 m above sea level) located in Mazandaran province was chosen and cut. The height, age, and diameter of these trees were 6 m, 20 years, and 20 cm, respectively. At breast height, a 2.5 and 3.5 m disk with a thickness of 5 cm was prepared and in the form of a cross and in a row, test cubic samples with dimensions of 2 × 2 × 3 cm was cut from the pith to the bark. To prevent moving the cubic samples, coding was done on them (Fig. 1). The wood industry laboratory of Shahid Hashminejad Technical faculty of Sari was used to conduct biometrical tests.

### Preparation of Microscopic Sections

Wood samples with dimensions of 2 × 2 × 3 cm were prepared. To soften the wood texture, the samples were placed in a solution of distilled water and glycerin. Using a sliding microtome (GSL1, WSL, Switzerland) very thin layers (10 µm) were taken from the three surfaces of the wood. To color the thin layers, two solutions of Astra blue and Safranin with a concentration of 0.5% were placed for 3 to 5 min, and in the next step, the layers were washed with different percentages of alcohol (50%, 95% and 96%). The thin layers of wood were mounted on slides, and an optical microscope was used to examine the anatomy of the sample (9 slides).

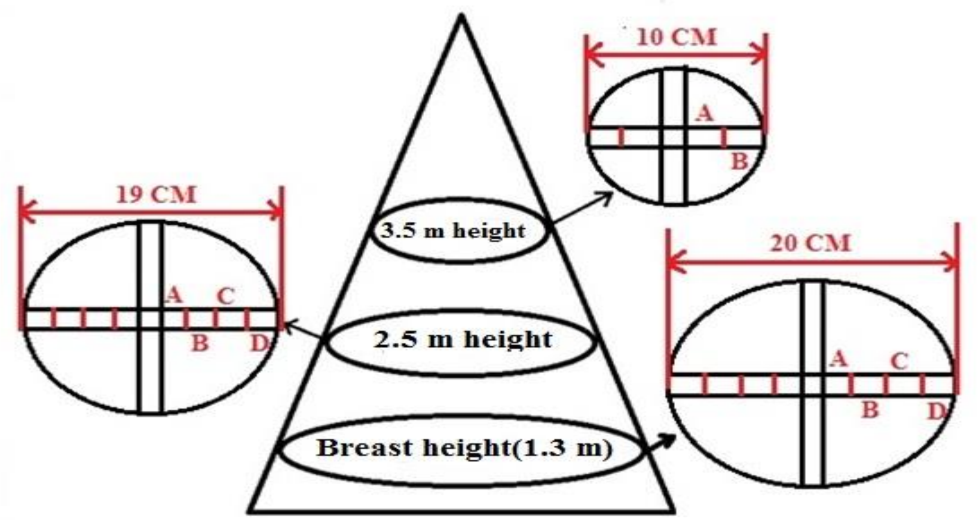


**Fig. 1.** The cutting pattern and number of test samples at three height levels

### Preparation and Measurement of Biometric Properties of Fibers

Samples were prepared at three heights of the tree; thin slices with dimensions of 1 × 0.2 × 0.2 cm square were prepared. The slices were placed inside a test tube, and acetic acid and hydrogen peroxide solution with a concentration of 100% in a ratio of 50:50 was poured on the samples with a graduated pipette twice the length of the slice. The test tubes were placed in oven at 70 °C for 24 h, and after whitening, the wooden samples inside the test tube were washed with distilled water and stained with safranin (Franklin 1945). After separation, the wood fibers were fixed on the slide, and from each slide at least 40 fibers were randomly measured from length, diameter of fibers, diameter of cell cavity, and the thickness of the cell wall using an optical microscope with a graduated eyepiece (Fiber length with 10x magnification and for cell cavity and cell wall diameter with 40x magnification).

## RESULTS AND DISCUSSION

### Anatomical Properties

The anatomical features of *Crataegus azarolus* wood are shown in Table 1 and Figs. 2 through 5.

### Biometrical Properties

Changes in longitudinal and transverse direction of tree stem on biometrical properties (fiber length, fiber diameter, fiber lumen diameter, and fiber wall thickness) were significant at the 95% and 99% level. Moving from the bottom of the tree stem to the crown of the tree, the average length of the fibers decreased so that the longest length of the fibers at the breast height in sample D (close to the bark) was 0.78 mm on average and the shortest length of the fibers at a height of 3.5 m in the area of the pith (A) was equal to

0.51 mm. The average fiber length decreased from the bark (sample D) to the pith (sample A) at three tree heights (Fig. 5A).

**Table 1.** Microscopic Features near the Bark Zone of *Crataegus azarolus* According to the IAWA List of Hardwoods (Wheeler *et al*. 1989)

| Feature | Number of Features | Description (Mature Wood) |
|---|---|---|
| Growth Rings | 1 | Growth ring boundaries distinct |
| Porosity | 5 | Wood diffuse-porous |
| Vessel Arrangement | 8 | Vessels in dendritic pattern |
| Vessel Groupings | 9 | Vessels exclusively solitary (90% or more) |
| Perforation Plates | 13 | Simple perforation plates |
| Intervessel pits: Arrangement and Size | 22 | Intervessel pits alternate |
| | 23 | Shape of alternate pits polygonal |
| | 24 | Minute – ≤ 4 μm |
| | 25 | Small (4 to 7 μm) |
| Vessel-ray Pitting | 30 | Vessel–ray pits with distinct borders; similar to intervessel pits in size and shape throughout the ray cell |
| Mean Tangential Diameter of Vessel Lumina | 40 | ≤ 50μm |
| Vessel per mm$^2$ | 50 | ≥ 100 |
| Mean Vessel Element Length | 52 | ≤ 350 μm |
| | 53 | 350–800 μm |
| Ground Tissue Fibers | 62 | Fiber with simple to minutely bordered pits |
| | 63 | Fibre pits common in both radial and tangential walls |
| Septate fibers and parenchyma-like fiber bands | 66 | Non-septate fiber present |
| Fiber wall thickness | 69 | Fibers thin to thick walled |
| Mean fiber length | 71 | ≤ 900 μm |
| Axial parenchyma | 76 | Axial parenchyma diffuse |
| | 77 | Axial parenchyma diffuse-in-aggregates |
| Paratracheal axial parenchyma | 78 | Axial parenchyma scanty paratracheal |
| Axial parenchyma cell type/strand length | 91 | Two cells per parenchyma strand |
| | 92 | Four (3‑ 4) cells per parenchyma strand |
| Ray width | 97 | Ray width 1 to 3 cells |
| Rays: cellular composition | 104 | All ray cells procumbent |
| Rays per mm | 116 | ≥ 12 / mm |
| Prismatic crystals | 136 | Prismatic crystals present |
| | 142 | Prismatic crystals in chambered axial parenchyma cells |
| Other diagnostic crystal features | 156 | Crystals in enlarged cells |

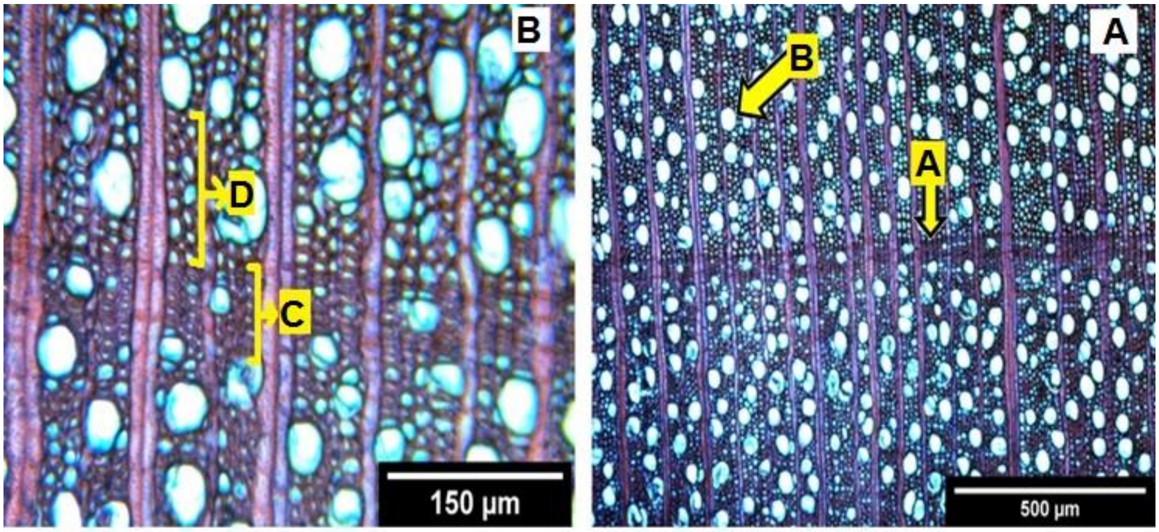


**Fig. 2.** The cross section of the *Crataegus azarolus* tree. The distinct growth ring boundary (arrow A), solitary pore (arrow B), late wood fiber (arrow C), and early wood fiber (arrow D) are illustrated.

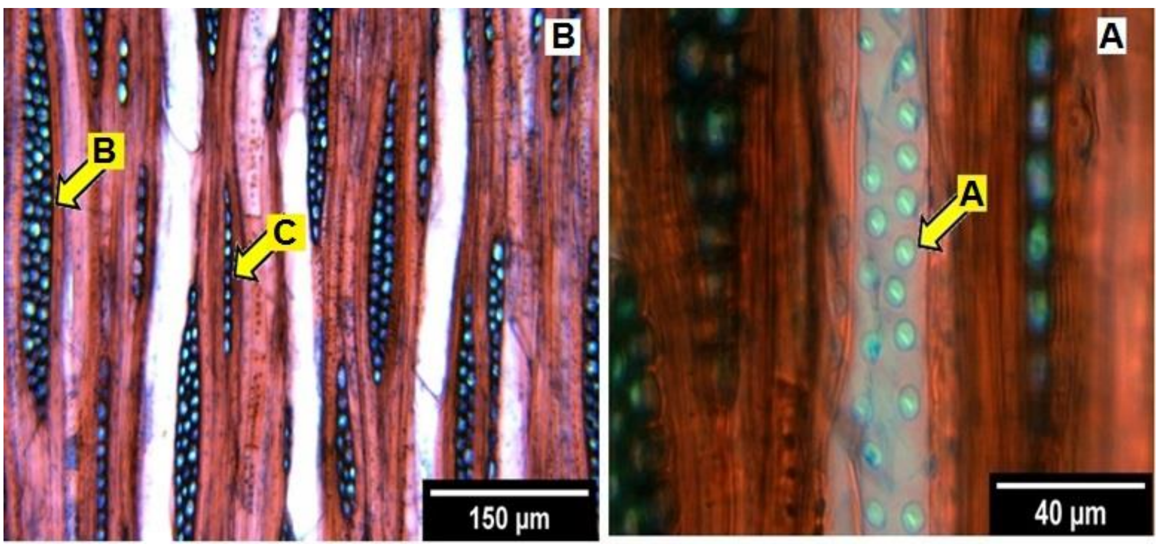


**Fig. 3.** The tangential section of the *Crataegus azarolus*. The alternative inter-vessel pits (arrow A), multiseriate rays (arrow B) and uniseriate rays (arrow c) are illustrated.

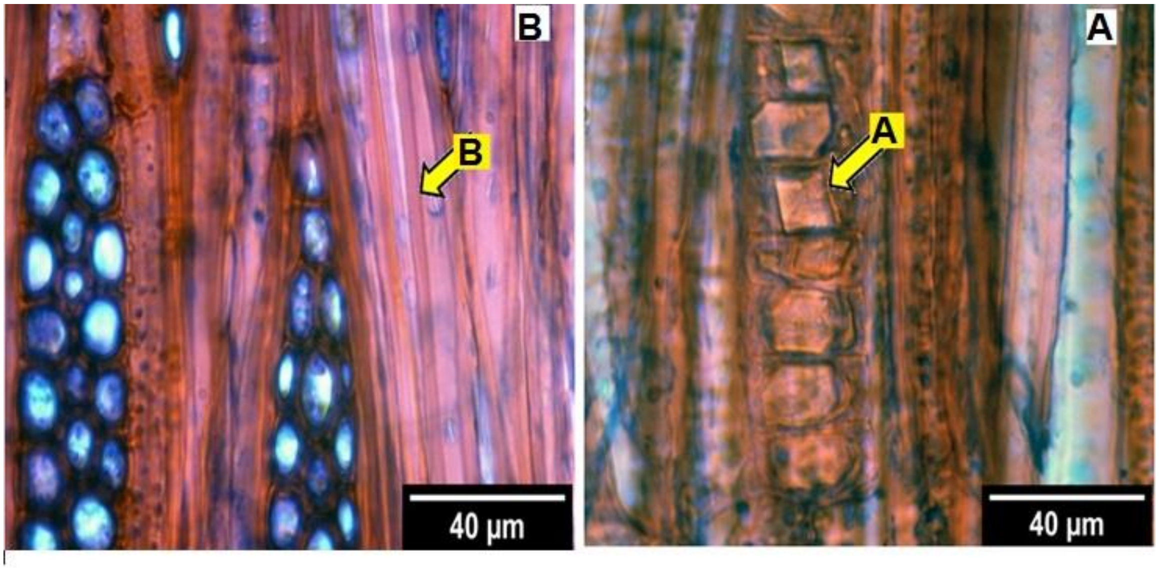


**Fig. 4.** The tangential section of the *Crataegus azarolus* tree. The Prismatic crystals (arrow A) and Non-septate fiber (arrow B) are illustrated.

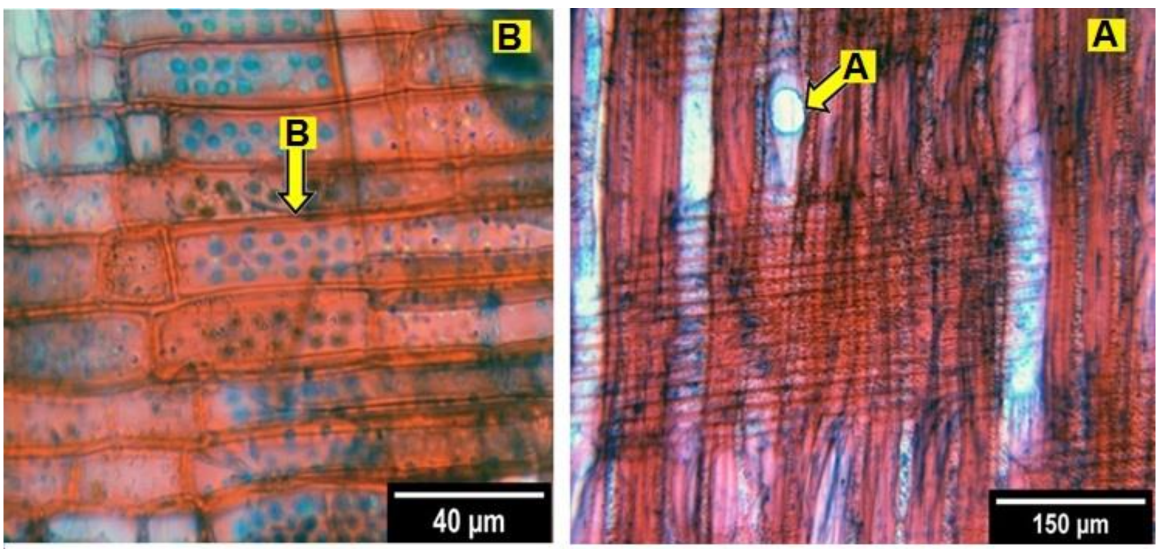


**Fig. 5.** The radial section of the *Crataegus azarolus* tree. The Simple perforation plates (arrow A), homogenous ray cells are all procumbent (arrow B).

The trend of changes in the fiber diameter in the transverse direction of the tree from sample D (closer to the bark) to sample A (closer to the pith) was descending at three heights. The highest average diameter of the fibers at the breast height in sample D was equal to 22.5 μm, and the lowest total diameter of the fibers at the height of 3.5 m in sample A was equal to 16.3 μm (Fig. 5B).

The diameter of the fibers was different in three heights of the tree, so that it decreased from at the breast height to the crown of the tree (Fig. 5B). The increase in the height of the tree from the height of at the breast height to the top of the tree (height 3.5 m), the average thickness of the cell wall of the fiber decreased, so that the highest average thickness of the cell wall at the breast height in the area of the bark (sample D) was equal to 4.5 μm and the lowest average thickness of the cell wall at a height of 3.5 m, the area of the pith (sample A) was 2.8 μm. The changes in the cell wall thickness from the bark to the pith followed a decreasing trend (Fig. 5C). From at the breast height towards the crown of the tree (height 3.5 m) the average fiber lumen diameter decreased, so that the highest average, fiber lumen diameter at the breast height in the area of the bark (sample D) was equal to 18.6 μm and the lowest average fiber lumen diameter at height of 3.5 m was 13.3 μm in the pith (Sample A). The changes in fiber lumen diameter increased from the pith to the bark (Fig. 5D).

Moving from the core of the tree stem and closer to the end rings of the wood (bark), biometrical properties such as fiber length, fiber diameter, fiber lumen diameter, and fiber wall thickness increased. These results are consistent with the studies conducted by Hassanpoortichi and Rezanezhad (2019). One of the main reasons is the age of the cambium, which has a direct relationship between the fiber dimensions (fiber length, fiber diameter, fiber lumen diameter, and fiber wall thickness) and the age of the cambium (Zobel and Van Buijtenen 1989). As the age of the tree increased and in proportion to the age of the cambium, the dimensions of the fibers increased. In the trunk area close to the pith, the fibers have a shorter length, fiber diameter, lower diameter of the cell cavity and thinner cell wall thickness compared to the wood close to the bark.

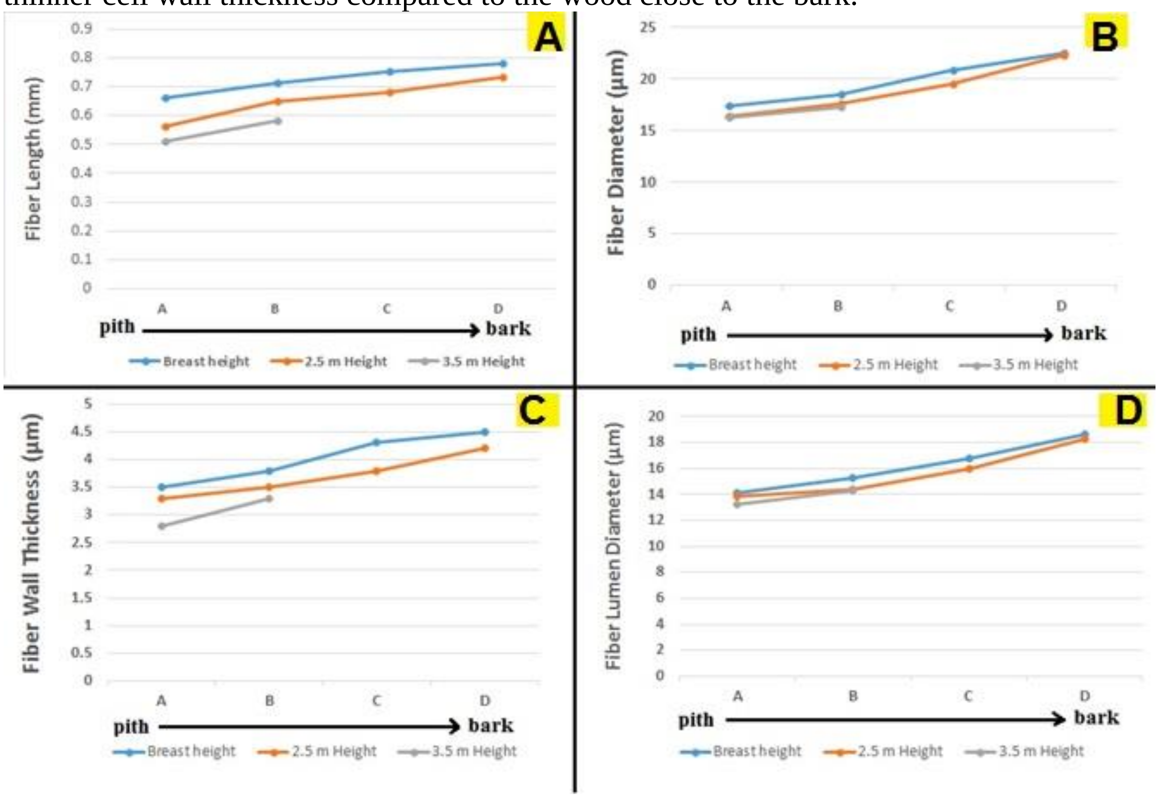


**Fig. 6.** Changes in fiber length (A), fiber diameter (B), fiber wall thickness (C) and fiber lumen diameter (D) of *Crataegus azarolus* tree in different parts of the tree stem

The cambium mother cells (primary spindles) in the mature wood region are more developed and have larger dimensions compared to the young wood, and as a result of this issue, the wood fibers of the bark area (mature wood) should consist of longer, bigger, and thicker dimensions. In the measurement of fiber length, fiber diameter, fiber lumen diameter, and fiber wall thickness in the longitudinal direction of the tree, it was apparent that as one moves from the bottom of the tree (at the breast height) to the crown of the tree, these characteristics decreased. These findings are consistent with the research done by Efhamisisi and Saraeyan (2009). The main reason for the downward trend in reducing the dimensions of the fibers in the crown of the tree compared to the trunk can be attributed to the volume of juvenile wood in the upper part of the tree (Adamopoulos and Voulgaridis 2002; Marsoem *et al*. 2002). These results are consistent with the research conducted by Zobel and Sprague (1998). According to the list of the International Association of Anatomists of the World, fiber lengths are divided into three categories: 1. Short fibers with a length less than 900 μm; 2. Medium fibers with a length of 900 to 1600 μm, and 3. Long fibers with a length of more than 1600 μm. As a result, the length of the *Crataegus azarolus* tree fiber is placed in the second category. The length of the fibers is closely related to the mechanical properties of the manufactured paper, and with this result, *Crataegus azarolus* wood is not suitable for the paper industry.

The results showed that *Crataegus azarolus* is a diffuse-porous species with distinct growth ring boundaries, simple perforation, alternative intervessel pits, and vessel–ray pits with distinct borders; similar to intervessel pits in size and shape throughout the ray cell. Vessel grouping was mainly in the radial multiples of two or three, but solitary pores were observed. Furthermore, the mean tangential diameter of the vessels was 50 µm and there were 100 vessels per mm. In the tangential section, the rays were uniseriate at 8 to 20 cells in height. In the radial section, the rays were homogeneous with procumbent ray cells (Figs. 2, 3, 4, and 5).

## CONCLUSIONS

1. All the biometric factors of *Crataegus azarolus* tree, including the fiber length, fiber diameter, fiber lumen diameter, and fiber wall thickness significantly decreased from base upward and increased from the pith to the bark.
2. The microscopic analysis showed that *Crataegus azarolus* tree is a diffuse porous hardwood with distinct growth ring boundaries, simple perforation, homogenous rays, and alternative inter-vessel pits.
3. The *Crataegus azarolus* is not suitable for the paper industry due to the biometric characteristics found. The use of this wood in the paper industry, due to the short fiber length, it can be mixed with long fiber wood to improve the quality of produced paper.

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