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Research Article

Study of Chemical and Anatomical Properties of *Jurinea consanguinea* DC. (Compositae Giseke) In terms of Potential Applications: Insights into Root, Root Collar, and Stem Structure

Avni YILDIZBAŞ*[1], Barbaros YAMAN[2], Abdullah İSTEK[3], Esra PULAT[4], İsmail ÖZLÜSOYLU[5]

[1,3,5]Bartın University, Faculty of Forestry, Department of Forestry Industry Engineering, Bartın, TÜRKİYE
[2,4]Bartın University, Faculty of Forestry, Department of Forest Engineering, Bartın, TÜRKİYE
*Corresponding Author: avniyildizbas@gmail.com

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Abstract

Aim of study: This study aims to investigate the anatomical and fiber morphological characteristics of *Jurinea consanguinea* in the root, root collar, and stem, while also evaluating stem chemical composition.

Area of study: The study area was in Coburlar Village, Zonguldak, Türkiye.

Material and method: Chemical composition of the stem was determined according to standard TAPPI protocols. To analyze the morphological properties of fibers and vessel elements, plant parts were macerated according to the sodium chloride ($NaClO_2$) method. Anatomical sections were taken with the GSL-1 microtome. The RStudio program was used for the statistical analysis.

Main results: It was determined that the chemical composition of *J. consanguinea* stem was holocellulose at 67.17%, α-cellulose at 31.13%, lignin at 12.54%, and ethanol solubility at 18.2%. Root, root collar, and stem fiber lengths were found to be 305.7 µm, 278.31 µm, and 1322 µm, respectively. Secretory ducts were observed in the root and root collar's barks.

Research highlights: In this study, the root, root collar, and stem anatomy of *J. consanguinea*, and the stem chemical composition were examined for the first time and introduced into the literature.

Keywords: *Jurinea consanguinea*, Compositae, Anatomy, Plant Fibers, Secretory Ducts

Potansiyel Uygulamalar Açısından *Jurinea consanguinea* DC. (Compositae Giseke) Kimyasal ve Anatomik Özelliklerinin İncelenmesi: Kök, Kök Boğazı ve Gövde Yapısına İlişkin İncelemeler

Öz

Çalışmanın amacı: Bu çalışmanın amacı, *Jurinea consanguinea*'nın kök, kök boğazı ve gövde dâhil olmak üzere çeşitli bitki kısımlarında anatomik ve lif morfolojik özelliklerini kapsamlı bir şekilde araştırmak ve aynı zamanda gövde kimyasal bileşimini analiz etmektir.

Çalışma alanı: Çalışma alanı Coburlar Köyü, Zonguldak, Türkiye'de yer almaktadır.

Materyal ve yöntem: *J. consanguinea*'nın gövdesinin ana kimyasal analizi için standart TAPPI yöntemleri kullanılmıştır. Liflerin ve su iletim elemanlarının morfolojik özelliklerini analiz etmek için bitki kısımları sodyum klorit ($NaClO_2$) yöntemine göre masere edilmiştir. Anatomik kesitler GSL-1 mikrotomu ile alınmıştır. İstatistiksel analizler için RStudio programı kullanılmıştır.

Temel sonuçlar: *J. consanguinea* gövde kimyasal yapısında, holoselüloz oranının %67.17, α-selüloz oranının %31.13, lignin oranının %12.54 ve etanol çözünürlüğünün %18.2 olduğu belirlenmiştir. Kök, kök boğazı ve gövde lif uzunlukları sırasıyla 305.7 µm, 278.31 µm ve 1322 µm olarak bulunmuştur. Kök ve kök boğazının kabuklarında salgı kanalları gözlenmiştir.

Araştırma vurguları: Bu çalışmada, *J. consanguinea*'nın kök, kök boğazı ve gövde anatomisi ile gövde kimyasal bileşimi ilk kez incelenerek literatüre kazandırılmıştır.

Anahtar Kelimeler: *Jurinea consanguinea*, Compositae, Anatomi, Bitki Lifleri, Salgı Kanalları

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Introduction

Jurinea Cass. (Asteraceae: Cardueae) is represented in Türkiye's Mediterranean and Irano-Turanian phytogeographic regions with 19 species, 8 of which are endemic to Türkiye. As a result of field studies conducted in the Erzincan region in 2012, a new species was discovered; this increased the number of species distributed in Türkiye to 20 (Dogan et al., 2010; Dogan et al., 2014). *J. consanguinea* DC. (Fig. 1), a perennial herbaceous plant of these species was described by de Candolle in 1838, based on the material collected by Pierre Martin Rémi Aucher-Eloy in "Olympo Bithynico," a 2543 m high mountain located in Bursa province and known today as Uludag (Candolle, 1838; Altinordu and Crespo, 2016). *J. consanguinea* has an erect stem of 30-50 cm. The stem is sparsely arachnoid hairy and 1–3 mm wide at the base. It usually has a single stem but rarely branches and is woolly hairy at the bottom. Basal leaves are generally pinnatisect or rarely entire. Stem leaves are linear-lanceolate. The flowers are lilac and purplish-reddish (Öztürk, 2009). The achene is brown and narrowly oval. Pappus is straw-yellow and barbellate. The achene surface pattern is wavy (Bona, 2020). This species is distributed in Türkiye, Bulgaria, Greece, and Transcaucasia (Altinordu and Crespo, 2016; Bancheva and Tashev, 2020). In Türkiye, while it is widespread in the west of the Anatolian diagonal, it has a very restricted distribution in the diagonal and the eastern parts. It is generally a transitional taxon with pinnatisect leaves, but some specimens have been observed to have entire leaves. It has been observed that this species, which has diverse habitats, is adapted to the geographic, topographical, and climatological factors determined by the Anatolian Diagonal (Dogan et al., 2009).

It has been determined that *J. kilea* Azn., *J. consanguinea*, and *J. mollis* (L.) Reichb. species show similar anatomical features, consisting of the epidermis in the outermost of the stem, parenchyma and sclerenchyma cells in the cortex part and parenchymatic cells in the pith (Saday, 2005). *J. consanguinea* has a 12 µm thick single-layer epidermis, 2-3 layers on the ridge on the stem, and a 17 µm thick cortical parenchyma with 1-2 layers on the sulci (Yılmaz, 2009). Morphologically, *J. mollis*, similar to *J. consanguinea*, has endodermal resin ducts in its root (Fritz and Saukel, 2011). *J. consanguinea* has prismatic-shaped calcium oxalate crystals only in the ovary cells (Kartal, 2016).

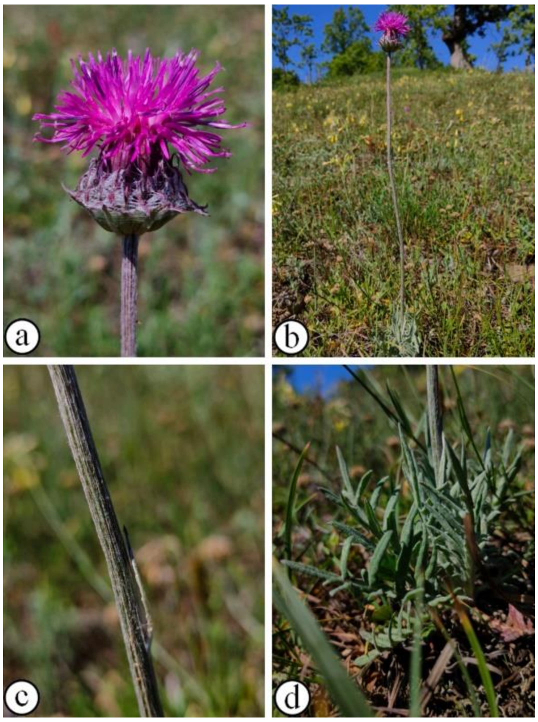


Figure 1. *J. consanguinea*. a) Flower; b) Habit; c) Stem and stem leaf; d) Basal leaves

Plant fibers are used in many application areas such as aviation, space, automobile, sports, household appliances, buildings, and construction due to their low cost, biodegradable structure, abundance, and good physical and mechanical properties (Latif et al., 2019). In addition, they have many uses, such as textiles, rope, paper and packaging, furniture, chipboards, insulation boards, food and animal feed, cosmetics, and pharmaceutical industries (Sanjay et al., 2016; Sathish et al., 2021). Plant fibers are called lignocellulosic materials, as their cell walls are mainly composed of cellulose and hemicelluloses, which are sugar-based polymers combined with lignin and pectin (Bledzki and Gassan, 1999; Chen and Chen, 2015). Lignocellulosic materials are included in wood and non-wood (Gülsoy and Şimşir, 2018). Non-wood lignocellulosic materials are divided into five classes according to the parts they are found in the plant: grass fibers, bast fibers, leaf fibers, fruit fibers, and seed fibers (Saijonkari-Pahkala, 2001; Kamarian and Song, 2022). The fiber properties of some lignocellulosic materials belonging to the Asteraceae family, such as *Centaurea solstitialis* L. (Keskin et al., 2020), *Chrysanthemum morifolium* Ramat. (Dalmis et al., 2020), *Cynara cardunculus* L. (Gominho et al., 2001; Gominho et al., 2009), *Chromolaena odorata* (L.) R.M. King & H. Rob. and *Mikania micrantha* Kunth (Vijayan and Joy, 2018) were investigated.

There are studies on the fiber properties of some Asteraceae taxa and the stem anatomy of *J. consanguinea*, but as far as we know, there is currently no literature that can provide information on the anatomical features of the root and root collar, as well as the fiber morphological features of the root, root collar and stem of *J. consanguinea*. Also, there isn't any investigation about stem cell wall chemical composition in the literature. In order to fill the gap in the literature, the anatomical and fiber morphological features of the *J. consanguinea* root, root collar, and stem, as well as the chemical composition of the stem, were investigated in this study.

Materials and Methods

Plant Material and Sample Preparation

J. consanguinea was collected in June from Coburlar village, Zonguldak, Türkiye. The plant identification was made by the systematic botany expert, Professor Dr. Zafer KAYA, when he was alive. The basal leaves, stem leaves, and flowers of the plant have been removed. 3-5 cm long pieces were cut from the root, root collar and stem. The stem portions were air-dried. The dried stem portions were ground to 0.75 mesh in a laboratory Wiley mill and then sifted through a vibrating sieve into 40 mesh (425 µm), 60 mesh (250 µm), and 80 mesh (180 µm). The portions that passed through a 40-mesh sieve and remained on the 60-mesh sieve were stored under dry conditions for later use in the experiment.

Chemical Components

Standard methods were used for the main chemical analyses of the *J. consanguinea* stem. Holocellulose (Wise and Karl, 1962), α-cellulose (Han and Rowell, 1997), klason lignin (TAPPI T 222), ethanol extraction (TAPPI T 204), hot and cold water solubility (TAPPI T 207) and 1% NaOH solubility (TAPPI T 212) were performed according to the relevant standards. The hemicellulose was determined from the difference between holocellulose and α-cellulose. Three replicates were performed for each experiment, and mean data were used.

Fiber Morphological Characteristics

3-5 cm long pieces cut from the root, root collar, and stem were macerated according to the sodium chloride ($NaClO_2$) method. Samples obtained after maceration were shaken with a mixer to separate fiber bundles. Then, the fiber suspension was filtered with filter paper in a Büchner funnel. The fibers remaining on the filter paper were placed in tubes, treated with glycerol, and protected (Spearin and Isenberg, 1947; İstek et al., 2009). 100 fiber lengths, 50 fiber widths, lumen width, and fiber wall thickness were measured for each of *J. consanguinea* root, root collar, and stem. The measurements were carried out using the Olympus CX21 light microscope. Additionally, fibers' morphological properties obtained from these measurements were evaluated in terms of papermaking. The indices used to determine the suitability of the fiber morphological properties for paper making are as follows (Eq., 1-5) (İstek et al., 2008).

$$Slenderness\ ratio = \frac{Fiber\ length}{Fiber\ width} \quad (1)$$

$$Flexibility\ coefficient = \frac{Lumen\ width}{Fiber\ width} \times 100 \quad (2)$$

$$Coefficient\ of\ rigidity = \frac{Fiber\ wall\ width}{Fiber\ width} \times 100 \quad (3)$$

$$Muhlstep\ ratio = \frac{((Fiber\ width^2 - Lumen\ width^2) \times 100)}{Fiber\ width^2} \quad (4)$$

$$Runkel\ ratio = \frac{Fiber\ wall\ width}{Lumen\ width} \times 2 \quad (5)$$

Anatomical Features

The transverse sections were cut at 25 µm thickness with a GSL-1 sliding microtome from the root, root collar, and stem of the plant, and placed on the slide, then stained with safranin-astra blue. The stained samples were first kept in 70% ethyl alcohol for two minutes and then in 95% ethyl alcohol for one minute to remove excess dye. Then, some glycerin was dropped on the samples and covered with a coverglass (Gärtner and Schweingruber, 2013). The transverse sections of the root, root collar, and stem were observed at the 4×, 10×, and 40× magnifications, and 50 measurements were made of their vessel element radial and tangential diameter. Also, 50 measurements of vessel element lengths were made on macerated samples. The measurements and observations were carried out using the Olympus CX21 light microscope.

Statistical Analysis

All data were calculated using the RStudio software. The mean, standard deviation, minimum, and maximum values of the vessel radial and tangential diameter, vessel element length, fiber length, fiber width, lumen width, and fiber wall thickness of the root, root collar, and stem were calculated. Root, root collar, and stem measurements were analyzed by ANOVA ($p<0.01$). Tukey's test ($p<0.01$) was performed to understand if there was a statistically significant difference among the groups.

Results and Discussion

Chemical Components

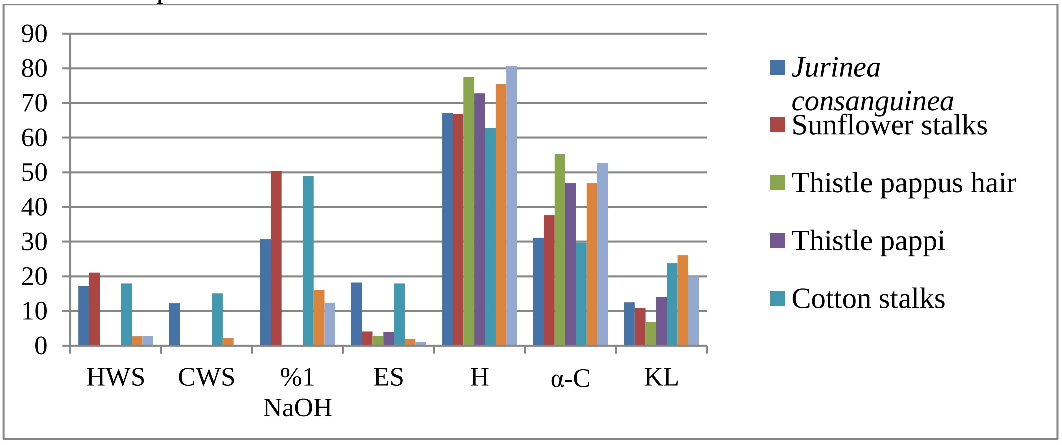
The chemical components of the *J. consanguinea* stem were determined, and the average of the data obtained is given in Table 1.

Table 1. Chemical components of the *J. consanguinea* stem (%)

Chemical components	%
Holocellulose	67.17
Hemicellulose	36.4
α-cellulose	31.13
Lignin	12.54
Ethanol solubility	18.2
Hot water solubility	17.22
Cold water solubility	12.22
%1 NaOH	30.66

In addition, the chemical composition of the *J. consanguinea* stem is shown in Figure 2 compared to some wood and non-wood lignocellulosic materials. As can be seen in Figure 2, the holocellulose content of 67.17% of the *J. consanguinea* stem is higher than that of cotton stalks and sunflower stalks and lower than that of thistle pappus hair and pappi, *Pinus brutia* Ten. and *Eucalyptus globulus* Labill.

Figure 2. Comparison of the stem chemical components of *J. consanguinea* with other lignocellulosic species



HWS: Hot water solubility; CWS: Cold water solubility; %1 NaOH: %1 Sodium hydroxide solubility; ES: Ethanol solubility; H: Holocellulose; α-C: α-cellulose; KL: Klason lignin. Sunflower stalks (López et al., 2005); Thistle pappus hair and pappi (Gominho et al., 2009); Cotton stalks (Ateş et al., 2015); *Pinus brutia* (Copur and Tozluoglu, 2008); *Eucalyptus globulus* (Jiménez et al., 2008)

Holocellulose, composed of cellulose and hemicellulose and can be extracted by chlorination by removing lignin through a delignification process, is the total water-insoluble polysaccharide fraction of lignocellulosic materials. Therefore, the extraction of holocellulose is more cost-effective and simpler than the isolation of cellulose (Basu, 2018; Long et al., 2022). Depending on the feedstock, holocellulose generally accounts for 55-80% of the plant's dry weight (Andreaus et al., 2008; Hatta, 2013). Functional materials such as holocellulose-based foams, nanopapers, and films are used in potential application areas such as packaging, environmental enhancements, light-sensitive devices, and food formulations (Long et al., 2022). Also, high holocellulose content is advantageous for the pulp and paper industry as it can produce high pulp yields after baking (Shakhes et al., 2011).

The 31.13% α-cellulose content of *J. consanguinea* is higher than that of cotton stalks (29.74%) but lower than that of sunflower stalks (37.6%), thistle pappus hair (55.2%) and pappi (%46.8), *P. brutia* (46.8%) and *E. globulus* (52.79%) (Figure 2). Cellulose is an important structural component of primary cell walls in plants, algae, and some bacteria. Cellulose is a natural polymer composed of a long linear chain of glucose monomers linked by a β-(1→4) glycosidic bond (Shokri and Adibkia, 2013; Mudgil, 2017). This polymer is widely used as an additive in many industries, such as animal feed, wood and paper, fiber and clothing, cosmetics, and pharmaceuticals (Shokri and Adibkia, 2013). Cellulose is also an important part of papermaking in the pulp and paper industry, as its high cellulose content improves a paper's strength properties while ensuring better quality. Alpha cellulose, one of the three forms of cellulose, has the highest degree of polymerization and is the main component of chemically soluble pulp (Gooch, 2010; Hatta, 2013; Ferdous et al., 2021).

The 36.4% hemicellulose content of *J. consanguinea* is higher than that of sunflower stalks (29.3%) (López et al., 2005), thistle pappus hair (22.3%) and pappi (26%) (Gominho et al., 2009), cotton stalks (33.05%) (Ateş et al., 2015), *P. brutia* (28.7%) (Copur and Tozluoglu, 2008) and *E. globulus* (29.75%) (Jiménez et al., 2008). Hemicelluloses, which encompass the polysaccharides that comprise the cell walls of vegetative and storage tissues in annual and perennial plants, constitute a vast and renewable reservoir of biopolymers. A wide range of structural types are present in these compounds, which can be categorized into four main groups: xylans, mannans, mixed linkage β-glucans, and xyloglucans (Ebringerová et al., 2005). Hemicellulose, an inherent polysaccharide, is the second most prevalent renewable constituent within the framework of lignocellulosic biomass, preceded by cellulose; its annual worldwide output approximates 60 billion tons. Due to the abundant availability of this renewable polysaccharide and its remarkable physical and chemical characteristics, hemicellulose is utilized to fabricate diverse substances such as emulsifiers, films, and hydrogels. Moreover, it is utilized to synthesize valuable chemicals like xylitol, ethanol, and furfural, which are extensively used in fields encompassing food, medicine, and energy storage (Rao et al., 2023).

Derived from the Latin term lignum, meaning wood, lignin is an essential component of the secondary cell walls of plants. Lignin fills the gap between its cross-linked macromolecules and the cellulose, hemicellulose, and pectin components in the cell wall, providing mechanical strength to the cell wall (Agrawal et al., 2014). It also binds the cellulose fibers together so they can form bundles. Figure 2 shows that while the 12.54% lignin content of the *J. consanguinea* stem is higher than that of thistle pappus hair and pappi, it is lower than that of other woody and non-woody plants. Due to its unique polyphenol structure, physico-chemical properties, and abundance, lignin has many uses in the production of various sorbents, oilfield chemistry, coal industry, chemical engineering, building materials industry, agricultural applications, pharmaceuticals, and so on (Ge and Li, 2018; Huang et al., 2019). In addition, plant fibers with low lignin content result in lighter-colored, flexible, high-quality pulps (Aripin et al., 2013; Indrayanti et al., 2020).

Extractive substance contents in plants are mainly food sources (oil, fatty acids, sugars, and starch), preservatives (terpenes, resin acids, and phenols), and plant hormones (phytosterols). These extractives are divided into three main categories: soluble in organic solvents, soluble in water, and soluble in aqueous alkali (Ashori et al., 2011). For example, the antioxidant, anticholinesterase, and antibacterial properties of this plant aerial part extractives were studied in this context (Öztürk, 2009; Öztürk et al., 2011), but as a result of the literature review, it was determined that the root extractive content and potential usage areas were not investigated.

The solubility of the *J. consanguinea* stem in ethanol is 18.20% and 1% NaOH 30.66%, and the comparison with other lignocellulosic materials is given in Figure 2. The 18,20% ethanol solubility of *J. consanguinea* is much higher than that of sunflower stalks, thistle pappus hair, thistle pappi, *P. bruita*, and *E. globulus*, while slightly higher than cotton stalks (Figure 2). Steroids, glycosides, phenolic compounds, essential oils, alkaloids, triterpenoids, flavonoids, saponins, tannins, carbohydrates, and quinones are extracted with ethanol (Azwanida, 2015; Velavan, 2015; Simorangkir et al., 2018). As can be seen in Figure 2, the 30.66% sodium hydroxide solubility of *J. consanguinea* is lower than cotton stalks and sunflower stalks and higher than *P. brutia* and *E. globulus*. It is stated that catechin, prunetin, caffeic acid, sinapic acid, syringic acid, *p*-coumaric acid, *o*-coumaric acid, rosmarinic acid, ferulic acid, vanillic acid, and chlorogenic acids are dissolved with 1% NaOH (Wang et al., 2020).

The cold water solubility of *J. consanguinea* was 12.22%, and the hot water solubility was 17.22%, which was compared to some other wood and non-wood lignocellulosic materials (Figure 2). The hot water solubility of *J. consanguinea* is higher than that of cotton stalks, P. bruita, and E. globulus but lower than that of sunflower stalks. However, cold water solubility is lower than cotton stalk but higher than *P. bruita*. The water-soluble fractions of lignocellulosic materials are gum, low molecular weight phenolics, pectins, low molecular weight polysaccharides, and other polar extractives such as free amino acids and alkaloids (Anupam et al., 2016; Megra et al., 2022).

Fiber Morphological Characteristics

The dimensions of the root, root collar, and stem fibers of *J. consanguinea* are summarized in Table 2.

Table 2. Dimensions of the root, root collar, and stem fibers of *J. consanguinea*

	Root				Root collar				Stem			
	Mean	Sd	Min	Max	Mean	Sd	Min	Max	Mean	Sd	Min	Max
Fiber length	305.7^{a}	92.9	160	600	278.31^{a}	77.15	110	430	1322^{b}	421.09	700	2510
Fiber width	16.60^{a}	3.42	10	25	17.91^{a}	4.37	7.50	28.75	11.53^{b}	2.95	7.50	20
Fiber lumen width	8.10^{a}	3	2.5	17.5	7.44^{a}	3.37	2.5	15	4.55^{b}	1.73	2.5	10
Fiber wall thickness	4.25^{a}	1.43	2.5	7.5	5.24^{b}	1.93	1.25	10	3.49^{a}	0.95	1.88	5

Sd: standard deviation; Min: Minimum; Max: Maximum; Measurements are given in µm; a and b are statistically different ($p<0.01$).

Also, the morphological properties of the fibers were evaluated in terms of papermaking. The findings obtained from as a result of this evaluation were given in Table 3.

Table 3. The values derived from fiber morphological measurements.

	Slenderness ratio	Flexibility coefficient	The coefficient of rigidity	Muhlstep ratio	Runkel ratio
Root	18.42	48.79	25.60	76.19	1.04
Root collar	15.53	41.54	29.25	82.74	1.41
Stem	114.65	39.46	30.26	84.42	1.53

The high slenderness ratio of the stem fibers shows that papers with good durability, tensile, tearing, bursting, and folding resistance can be obtained. Since the slenderness ratio of the root collar and root fibers is low, the papers obtained from these fibers will have the opposite properties of those obtained from the stem fibers. Since they are classified as hard fibers according to their flexibility coefficient, it will be more appropriate to use stem, root collar, and root fibers in producing fiber plate, fiberboard, and cardboard. The papers obtained from the stem, root collar, and root fibers will have high tear resistance and folding strength as they have a high coefficient of rigidity. A high muhlstep ratio will make it difficult for the fibers to flatten; thus, the contact area will be low, and papers with low resistance properties will be obtained. Since the runkel ratio is higher than 1, this plant's fibers are unsuitable for papermaking (Ferdous et al., 2021; Bektaş, 2018; Syed et al., 2016; Ververis et al., 2004; Afrifah et al., 2021; Akgül and Tozluoğlu, 2009; Yaman and Gencer, 2005; Akgül and Akça, 2020; Gürboy, 2007; Bostancı, 1987; Kiaei et al., 2014; Saikia et al., 1997; Tofanica et al., 2011; Yiğit et., 2021).

According to the results of the ANOVA test, root, root collar, and stem fiber dimensions (fiber length, fiber width, lumen width, and wall thickness) were found to be significant at the $p<0.01$ test level. Tukey's test performed at the $p<0.01$ level showed a significant difference among the three groups (stem, root, and root collar). The statistical comparison of the dimensions of the root, root collar, and stem fibers of *J. consanguinea* is shown in Table 2. As shown in Table 2, stem fibers were found to have a thin cell wall and narrow lumen and were much longer than root and root collar fibers ($p<0.01$). The fiber and lumen width of the stem were narrower than that of the root and root collar ($p<0.01$). The wall thickness of the root collar fibers was broader than that of the root and stem ($p<0.01$). General views of the stem, root collar, and root fibers of *J. consanguinea* are given in Figure 3.

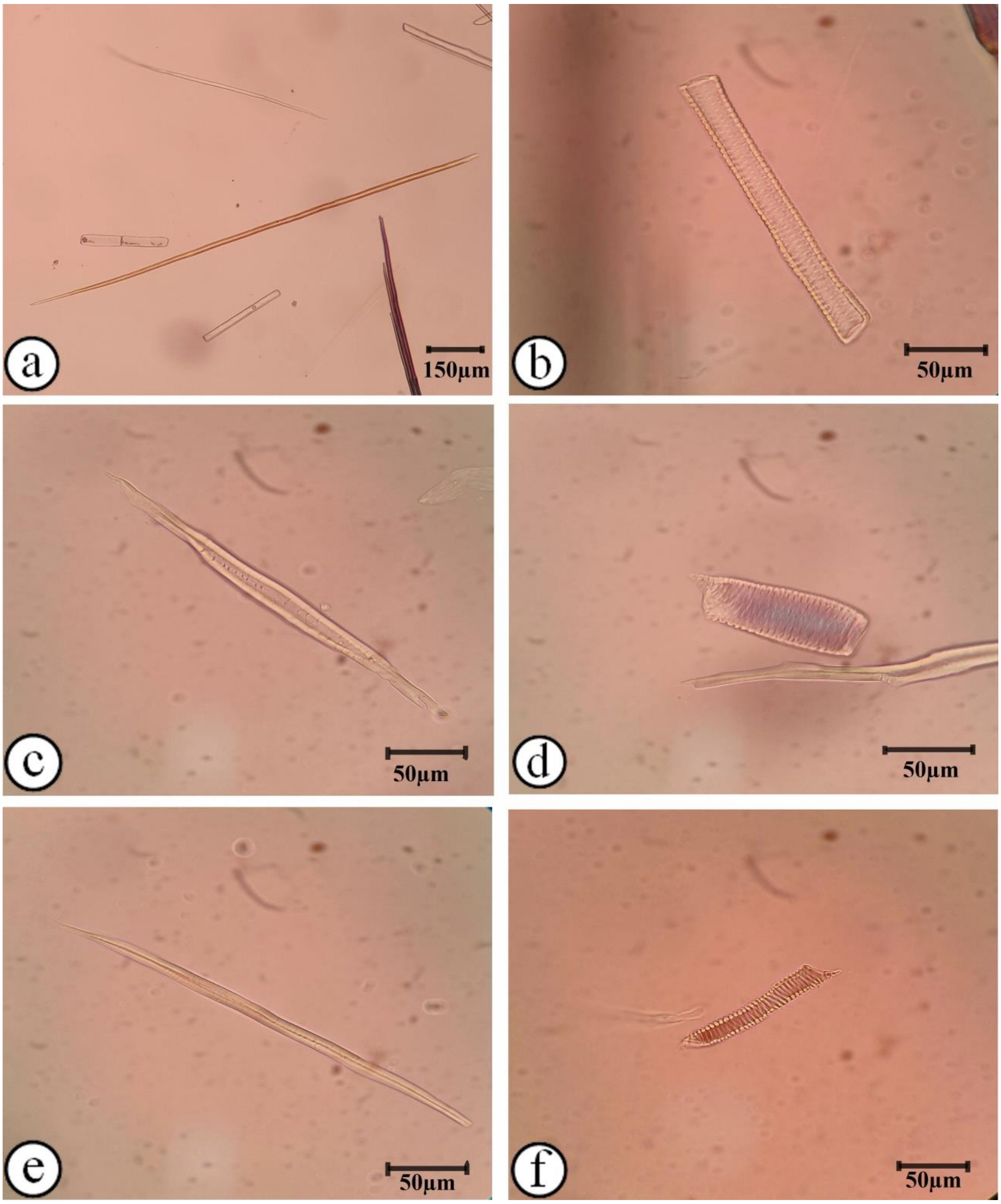


Figure 3. Root, root collar, and stem fibers and vessel elements of *J. consanguinea.* a) Stem fiber; b) Stem vessel element; c) Root collar fiber; d) Root collar vessel element; e) Root fiber; e) Root vessel element. Note: All photos were taken under a microscope using a 10× objective

The average fiber length of angiosperm trees ranges from 0.7 to 2 mm (Ilvessalo-Pfäffli, 1995; Onat et al., 2018), that of gymnosperms from 2.7 to 4.6 mm (Elmas et al., 2018), while the length of non-wood plant fibers ranges from 0.6 to 20 mm (Hurter, 1997). According to these results, the stem fibers of *J. consanguinea* are in the middle, root, and root collar fibers in the short-length group (Khakifirooz et al., 2013).

Anatomical Features

Anatomy has many inferences for plant physiology and ecology and provides an excellent tool for studying the historical sides of these disciplines, including those related to climate change (Sokoloff et al., 2021). In addition, the anatomical examination of the plant to be used as a raw material is of great importance to determine whether it is suitable for the end-use area. For example, many researchers have revealed that the properties of pulp and its products are determined by the lignocellulosic material's anatomical, morphological, and chemical properties used as raw material (Riki et al., 2019). Also, determining plant age in ecological plant anatomy allows us to reach many conclusions regarding plant ecology, climate change, ecosystem recovery, and accumulation of plant secondary metabolites (Hiebert-Giesbrecht et al., 2018).

The outermost of the *J. consanguinea* stem (Fig. 4) consists of epidermis cells in a single row in its sulci and two rows in its ridges. The cortex region consists of cortex parenchyma and angular collenchyma (Fig. 4d). Collenchyma tissue consists of unequal primary thick-walled elongated living cells with hemicellulose, cellulose, and pectic materials. It provides support, structure, mechanical strength, and flexibility to young plants' petiole, leaf veins, and stem, allowing easy bending without breaking. Collenchyma tissue is found just under the epidermis, on young stems, petioles, and under leaf veins. Collenchyma cells may or may not contain several chloroplasts and can photosynthesize and store food (Carrillo-López and Yahia, 2019). The stem has a collateral vascular bundle. The xylem and phloem of the vascular bundles are surrounded by fiber cells facing the epidermis and pith (Fig. 4a). Rarely merging of vascular bundles has been observed (Fig. 4b). Collateral vascular bundles are organized into a single ring and are of the type called eustele. Also, there are interfascicular parenchyma cells between the vascular bundles. The pith of the stem consists entirely of parenchyma cells.

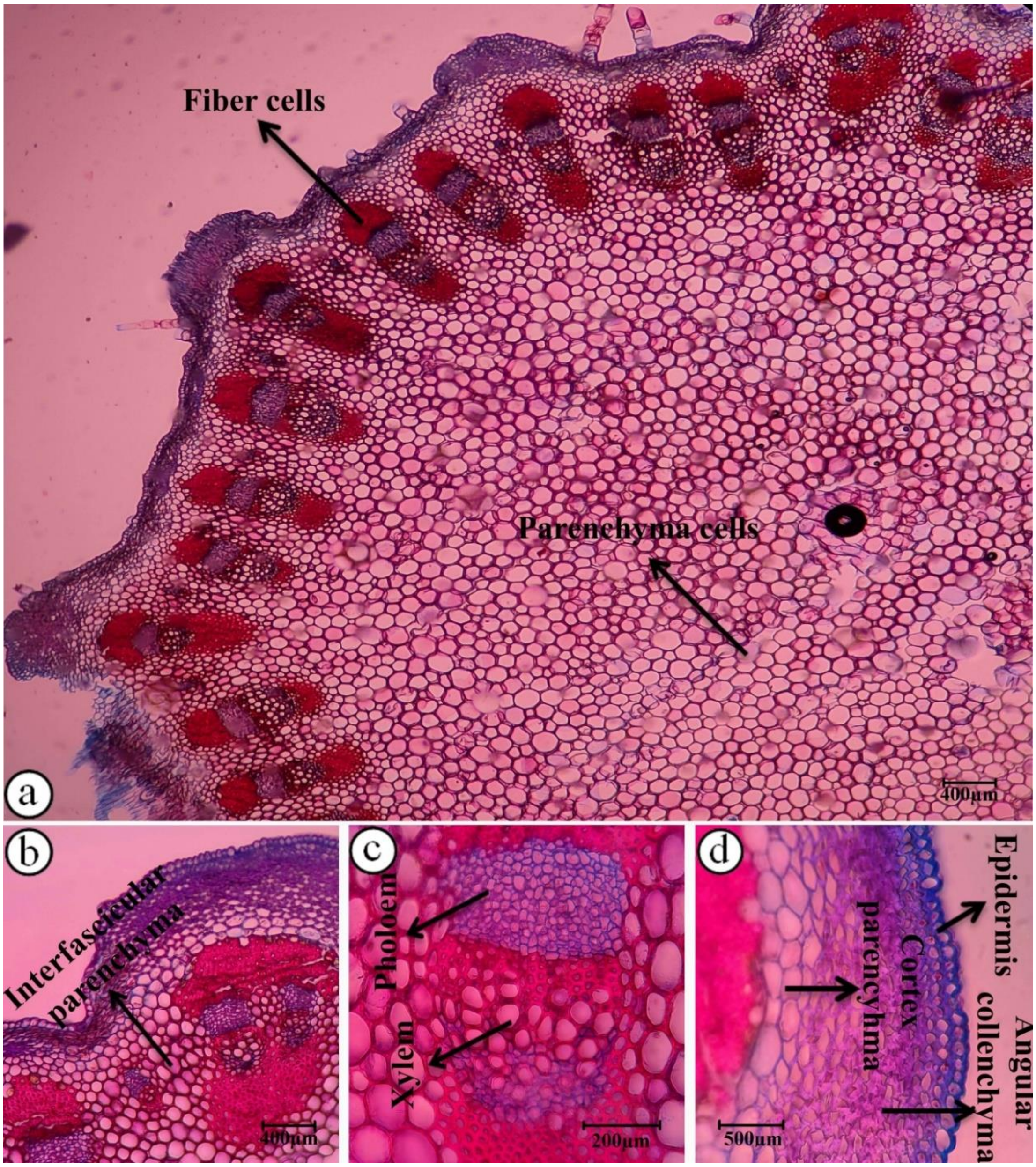


Figure 4. The transverse section of *J. consanguinea* stem. a) General view (objective: 4×); b) Vascular bundle and interfascicular parenchyma (objective: 10×); c) Pholem and xylem elements (objective: 40×); d) Epidermis and cortex (objective: 40×)

As a result of the anatomical examinations of the root collar, it was observed that there was a distinct lignification in the root collar. Although the growth ring boundaries are unclear, they can be distinguished by the dense and thick-walled fiber cells occurring in latewood. On the other hand, within some growth rings, the vessel elements were found to be present in the latewood as well. There are also rays, which consist of multiseriate, flattened parenchymal cells. When the growth ring boundaries are examined, it is estimated that *J. consanguinea* is over eight years old. Like the root collar, the root also has vessel elements, fiber cells, and multiseriate rays consisting of flattened parenchyma cells. In addition, as in *J. mollis* (Fritz and Saukel, 2011), it has been determined that *J. consanguinea* also has secretory ducts surrounded by epithelial cells in the barks of the root and root collar (Fig. 5b and 5d). The transverse sections of the root and root collar of *J. consanguinea* are given in Fig. 5.

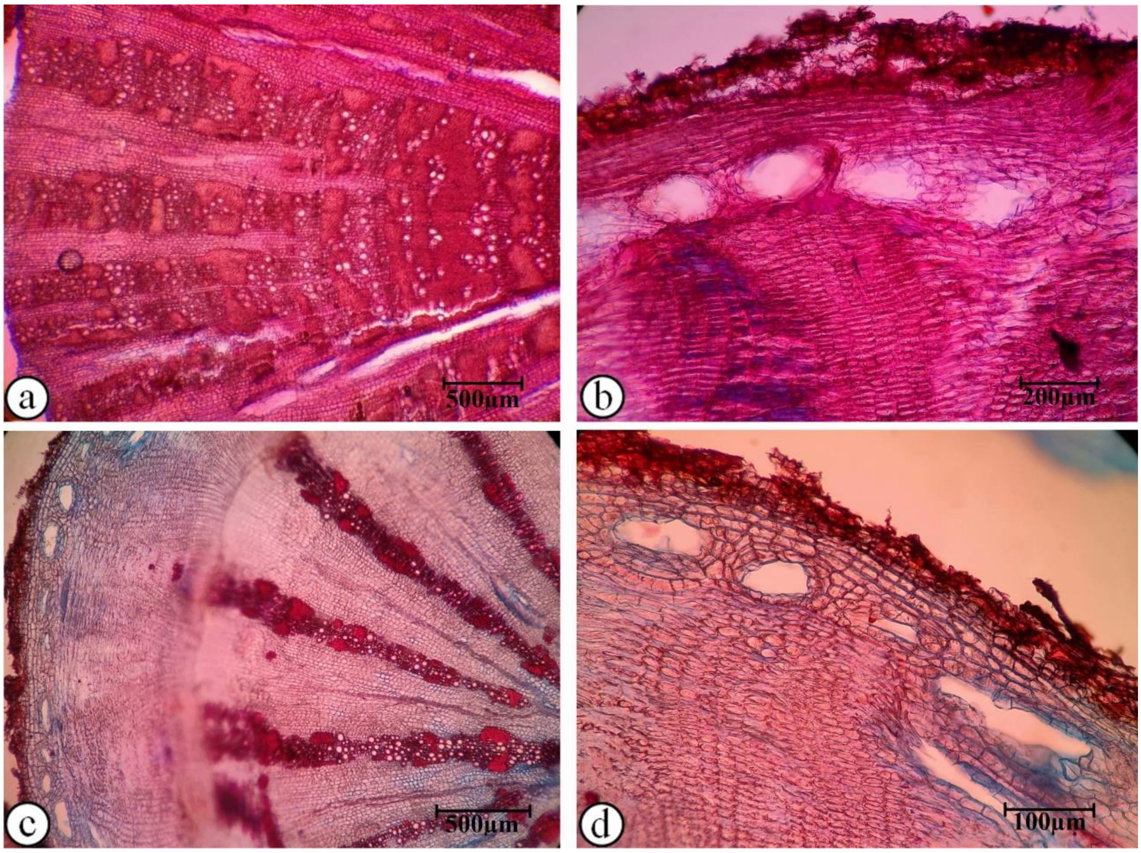


Figure 5. The transverse section *J. consanguinea* root collar and root. a) Root collar (objective: 4×); b) Root collar secretory ducts (objective: 10×); c) Root (objective: 4×); d) Root secretory ducts (objective: 10×)

The lengths and radial and tangential diameters of vessel elements in the root, root collar, and stem were measured and summarized in Table 4, and their general views are given in Fig. 3.

Table 4. VTD, VRD, and VEL values of *J. consanguinea* root, root collar, and stem

	Root				Root collar				Stem			
	Mean	Sd	Min	Max	Mean	Sd	Min	Max	Mean	Sd	Min	Max
VTD	34.6^{a}	7.17	22.5	55	40.95^{b}	9.93	20	57.5	19.27^{c}	3.6	12.5	12.5
VRD	37.1^{a}	7.99	22.5	57.5	45^{b}	12.15	20	72.5	19.23^{c}	4.38	7.5	7.5
VEL	138.6^{a}	50.64	60	370	$106{,}6^{a}$	29.16	40	180	186.6^{b}	90.27	70	480

VTD: Vessel tangential diameter; VRD: Vessel radial diameter; VEL; Vessel element length; Sd: standard deviation; Min: Minimum; Max: Maximum. Measurements are given in µm. a, b, and c are statistically different from each other ($p<0.01$)

According to the results of the ANOVA test, lengths, radial and tangential diameters of vessel elements in three groups were found to be significant at the $p<0.01$ test level. Based on Tukey's test, there was a significant difference between all three groups in terms of VTD and VRD ($p<0.01$). In addition, the stem showed a significant difference from both the root and the root collar in terms of VEL ($p<0.01$). The VTD and VRD of the root collar are broader than those of the root and stem, while those of the root are wider than those of the stem. The VEL of the stem is longer than the root and root collar. Statistical comparison of VTD, VRD, and VEL dimensions of root, root collar, and stem of *J. consanguinea* is shown in Table 4.

Conclusion

In this study, a comprehensive analysis of the chemical components, fiber morphological characteristics, and anatomical features of *J. consanguinea* has provided valuable insights into its potential applications, ecological adaptations, and structural properties. The plant's stem exhibits a relatively high content of holocellulose 67.17%, α-cellulose 31.13%, and low lignin 12.54%. These results make it promising for industrial applications like packaging and light-sensitive devices, animal feed, paper, textiles, cosmetics, sorbents, chemical engineering, and building materials. The solubility of the stem in ethanol and 1% NaOH presents opportunities for the extraction of valuable compounds, such as steroids, glycosides, phenolic compounds, and essential oils.

The fiber morphological characteristics revealed distinct differences among the root, root collar, and stem fibers of *J. consanguinea*. The stem fibers exhibited notable attributes, including thin cell walls, narrow lumens, and greater lengths, suggesting their potential as reinforcing agents in various composite materials. Also, the fibers of this plant were evaluated for papermaking according to their slenderness ratio, flexibility coefficient, coeffient of rigidity, muhlstep ratio and runkel ratio. According to the evaluation, it was concluded that these plant fibers are not very suitable for papermaking. In contrast to previous studies, the stem's outermost layer consists of a single row in sulci and two rows in ridges, with an angular collenchyma in the cortex. Since the complex cell structure of non-wood lignocellulosic materials makes the maceration process difficult, it was evaluated that the maceration period of *J. consanguinea* was long, and this situation was caused by the collenchyma cells detected in the stem. In addition, it was observed that the vascular bundles rarely merged. It has been determined that a large part of the stem consists of parenchyma cells, and the lengths of the vessel elements are longer than those of the root and root collar vessel elements. For the first time in this study, we observed the presence of lignification and growth rings in the root collar of this plant. While the fiber density in the root is low, it is higher in the root collar. It is estimated that this situation is caused by lignification.

As a result, this study contributes to our knowledge of *J. consanguinea*'s chemical, morphological, and anatomical traits, underscoring its potential for diverse applications and highlighting its ecological significance. Although it is concluded that these plant fibers are not very suitable for paper making, the index used to calculate the rigidity coefficient shows that they are more suitable for making fiber plate, fiberboard, and cardboard. While aerial parts have been studied for antioxidant and antibacterial properties, the root extract and potential uses remain unexplored. Further research in this direction could unlock the plant's full potential and contribute to sustainable solutions in various industries. The secretory ducts, vessel elements, and specific growth rings in the root and root collar further enhance our understanding of the plant's age and ecological context. In this context, investigating perennial herbaceous plants with woody roots like this plant is considered important for understanding climate change processes and age-related chemical changes in treeless areas.

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Conflict of Interest

The authors have no conflicts of interest to declare.

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