Effects of Plant Extract and Wood on Anatomical Structure in Ecological Environment Interaction

Abdi Atılgan *

In this study, the impregnation of a 3% solution of a mixture of medicinal aromatic plant extract, borax, and ferula plant extract on wood of eastern spruce (*Picea orientalis* L. (Link)) and mahogany were carried out and the changes in the anatomical structure of the impregnated wood were determined. Through obtaining extracts of various medicinal aromatic plants (ferula) and dual treatment with borax, the anatomical properties of wood material were examined and the related adhesion scale was determined. The highest retention (retention) was in mahogany wood borax (1.86%), and the lowest retention was again in mahogany wood ferula extract (0.31%). Both wood types demonstrated improved outcomes in comparison to the control sample when the air-dry and fully-dry specific gravity changes were investigated. The maximum air-dried specific gravity value was found in mahogany at 3% borax and ferula + borax (0.56 g/cm^3), and the lowest at 3% ferula and borax (0.37 g/cm^3). Mahogany wood with 3% borax had the greatest full dry specific gravity value (0.54 g/cm^3), and spruce wood with 3% ferula and ferula + borax had the lowest (0.35 g/cm^3). There was no retention in the tracheid and trachea cells that perform the transmission function. Because the sapphire cells are the cells that act as storage, adhesion has occurred in these cells.

DOI: 10.15376/biores.18.2.2693-2706

Keywords: Human/environmental health; Anatomical structure; Wood; Medical aromatic plant; Protection

Contact information: Design Department, Vocational School, Afyon Kocatepe University, 03200 Afyonkarahisar, Turkey; Email: dashing0343@gmail.com

INTRODUCTION

The development of new merchandises from wood is important, and impregnation techniques to be employed should not pose a risk, taking into account the preservation of wood (biotic/abiotic) and its effects on environmental and health aspects (Kartal *et al*. 2005). The necessity of creating novel materials that contribute to human and environmental health has become apparent as a result of the pressures brought on by the threat that some impregnation materials pose to human health because of their hazardous component structures (Tomak and Yıldız 2012).

The effectiveness of the impregnation process and the level of protection are dependent on the characteristics of the impregnation material and the wood, as well as the net amount of dry impregnation material attached to the wood (retention) and the depth of penetration of impregnation material into the wood. In this situation, it is crucial to protect the wooden material (furniture, construction material, *etc*.) against a variety of consequences (biotic, abiotic-combustion-air effects, *etc*.) (Baysal *et al.* 2003). In the impregnation process, the effectiveness depends on the impregnation material, wood property, retention level (penetration), and permeability level. The anatomical structure depends on the drying/slit opening process beforehand, passage aspiration in coniferous woods and the formation of tulle in leafy trees, and storage of various foreign substances in the opening in the passage membranes. These factors make impregnation in wood difficult. It is claimed that completing the peeling procedure prior to the impregnation process reduces the amount of free water in the lumen to 20% humidity, improving the depth of the impregnation effect with drying (Örs *et al*. 2001). The biological strength of wood is significantly influenced by its moisture content. One of the frequently employed protective techniques is to impregnate wood with poisonous chemicals to prevent fungi and insects. However, the use of these compounds is restricted in terms of the environment and human health. To offer dimensional stability (stabilization) and stop biological degradation , investigations into environmentally friendly technologies have begun (Baysal 1994). The effects of the heat treatment on these anatomical features of the wood material vary according to the species and the heat treatment temperature and duration. The heat-treated wood material became more brittle in both spruce and mahogany species; as a result, it has been stated that the effects of heat treatment on the anatomical structure should also be considered (İçel *et al*. 2017).

Investigating the impacts of several wood species' anatomical structures and processing methods on surface roughness, it was discovered how these factors anatomically affect the wood's tangential surface roughness and deformations (Ulusoy 2011). The studies have shown a strong relationship between environmental conditions and differences in the sizes of wood elements. According to the findings, there is a direct correlation between environmental factors and variations in wood element sizes. Increases and decreases in the dimensions of wood elements have always been in interaction with the season, water supply, and temperature level throughout geological periods (Merev 2003). It is crucial for both industry and academia to understand how impregnation affects the technological characteristics of wood species with industrial significance. The purpose of the study is to produce a preliminary analysis of the challenges that must be overcome to identify a wood material's intended use, identify anatomical species in impregnated materials, *etc*., and to contribute to other researchers by sharing the experiences obtained.

EXPERIMENTAL

Wood Material or Plant Type Material

For this study, spruce wood harvested from Turkey was employed. Cuts were made in the radial direction in accordance with the principles of TS ISO 3129 (2021). Borax and ferula (*Ferula communis* L.) plant, both of which have been known to have antibacterial and antioxidant characteristics, were employed for impregnation.

Plant Supply and Extract Preparation

The drying procedure was completed at the laboratory until they achieved a consistent weight level of around (1 to 2 months). After drying, it was brought to powder level in grinders. The dried plant material weighed 10.26 g, and it was extracted in water at room temperature for 24 h with agitation and solvent was added at the predetermined volume levels by filtration. Then, after filtering with filter paper, water was added (distilled water) until the final volume was 5 L (Ceylan 2019).

Impregnation Process

Wood impregnation was performed following ASTM-D 1413-76 (1984). Wood sample was subjected to diffusion for 45 min and followed by a 45 min vacuum test. The test samples were then made dry to avoid any possibility of moisture affecting the impregnation material.

Drying and Air Conditioning Process

After impregnation and diffusion, the samples were maintained in an air-dry condition for some time. After that, it was positioned so they were not touching one another before being placed in the oven. The oven was set at 103 °C, and it was left there for 24 h to dry entirely. Measurements were performed once it was entirely dry (Baysal 1994).

Amount of Retention

After the impregnation process, the amount of material left over (% retention) in comparison to fully dry wood was calculated using Eq. 1 (Baysal 1994),

$$R\ (\%) = \frac{\text{Moes} - \text{Moeö}}{\text{Moeo}} \times 100 \tag{1}$$

where Moes is the full dry weight of test sample after impregnation (g) and Moeö is the full dry weight of test sample before impregnation (g).

Preparation Method

Three preparation samples were collected from the tip of each test sample of each tree species to obtain general anatomical measurements. To soften the wood samples from which anatomical sections will be taken and to remove the air in their tissues, they were boiled in distilled water until completely collapsed. The samples were then maintained in a 1:1:1 mixture of distilled water, alcohol, and glycerin until sections were taken. Additionally, to counteract the effects of fungi, a small quantity of crystalline acid (phenol) was added to this mixture. On the "Reichert" Guided Microtome (Microtome Blade Stainless Steel S35, Afyonkarahisar, Turkey), sectioning operations from the samples were performed. From each sample, longitudinal radial (radial) and longitudinal tangential sections of 15 to 20 m were taken. Before they were made into continuous preparations, they were cleaned in sodium hypochlorite for 15 to 20 min and then they were rinsed with distilled water. After washing with distilled water, it was washed with acetic acid for 1 to 2 min to neutralize the medium, it was then stained with saffron. After staining, the sections were thoroughly cleaned with distilled water before passing through 50%, 75%, and 95% alcohol, respectively. Longitudinal radial and longitudinal tangential sections were converted into continuous preparation first with "basic fuchsin" and then with "glycerin-gelatin" (Bozkurt 1992; Merev 1998).

RESULTS AND DISCUSSION

Solution Properties

Table 1 presents the solution characteristics for the plant extract and borax solution that were made at 3% concentration and utilized in the impregnation.

Table 1. Solution Properties

Solution (%)	Impregnation Material	Solvent Material	Temperature (°C)	pH		Density	
				BI	AI	BI	AI
3%	Ferula	Distilled water	22 °C	7.14	7.14	0.965	0.965
	Borax			9.53	9.53	1.011	1.011
	Ferula + Borax			8.75	8.75	0.990	0.990

BI: Before impregnation **AI:** After impregnation

There was no important change in pH or density, which may have been caused by the type of wood, anatomical structure, plant extract or concentration, or impregnation time or technique.

Retention

The % retention values are given in Table 2.

Table 2. Percentage Retention and Duncan Test Results

Wood	Plant Extract/ Borax	Concentration (%)	Vacuum/Diffusion Time (min)	Retention (%)	HG
Spruce wood	Ferula	3%	45 min	0.38	E
	Borax			1.31	C
	Ferula+Borax			1.03	D
Mahogany wood	Ferula			0.21	F
	Borax			1.86	A
	Ferula+Borax			1.70	B

HG: Homogeneous Groups

The highest retention was determined in mahogany borax (1.86%), the lowest in spruce wood ferula plant extract (0.21%).

Air/Full Dry Specific Gravity Changes

Air/full dry specific gravity values of wood samples are given in Table 3 and the graph indicating the change are shown in Figs. 1 and 2.

Table 3. Air Dry / Full Dry Specific Gravity (g/cm^3)

Wood	Plant Extract/Borax	Concentration (%)	Vacuum/ Diffusion Time (min)	Air Dry Density		Full Dry Density	
Spruce	**Control**	3%	45 min	**Mean**	**Hg**	**Mean**	**Hg**
	Ferula			0.36	H	0.34	I
	Borax			0.37	G	0.35	H
	Ferula + Borax			0.37	G	0.35	H
Mahogany	**Control**			0.38	F	0.37	F
	Ferula			0.53	D	0.50	E
	Borax			0.55	C	0.53	D
	Ferula + Borax			0.56	B	0.54	C

Both types of wood produced better results than the control sample when the air-dry and fully-dry specific gravity changes were investigated. The maximum air-dried specific gravity value was found in mahogany wood at 3% borax and ferula + borax (0.56 g/cm^3), and the lowest at 3% ferula and borax (0.37 g/cm^3). Mahogany wood with 3%

borax had the highest fully-dry specific gravity value (0.54 g/cm^3), and spruce wood with 3% ferula and ferula + borax had the lowest (0.35 g/cm^3).

Anatomical Changes in Eastern Spruce Wood

Through comparison with the control sample, the transverse, tangential, and radial adhesions in oriental spruce wood soaked with 3% ferula plant extract, borax, and ferula + borax mixture were examined. In this evaluation, the cross-sectional images are displayed in Figs. 1a (control), 1b (with ferula), 1c (borax), and 1d (ferula + borax).

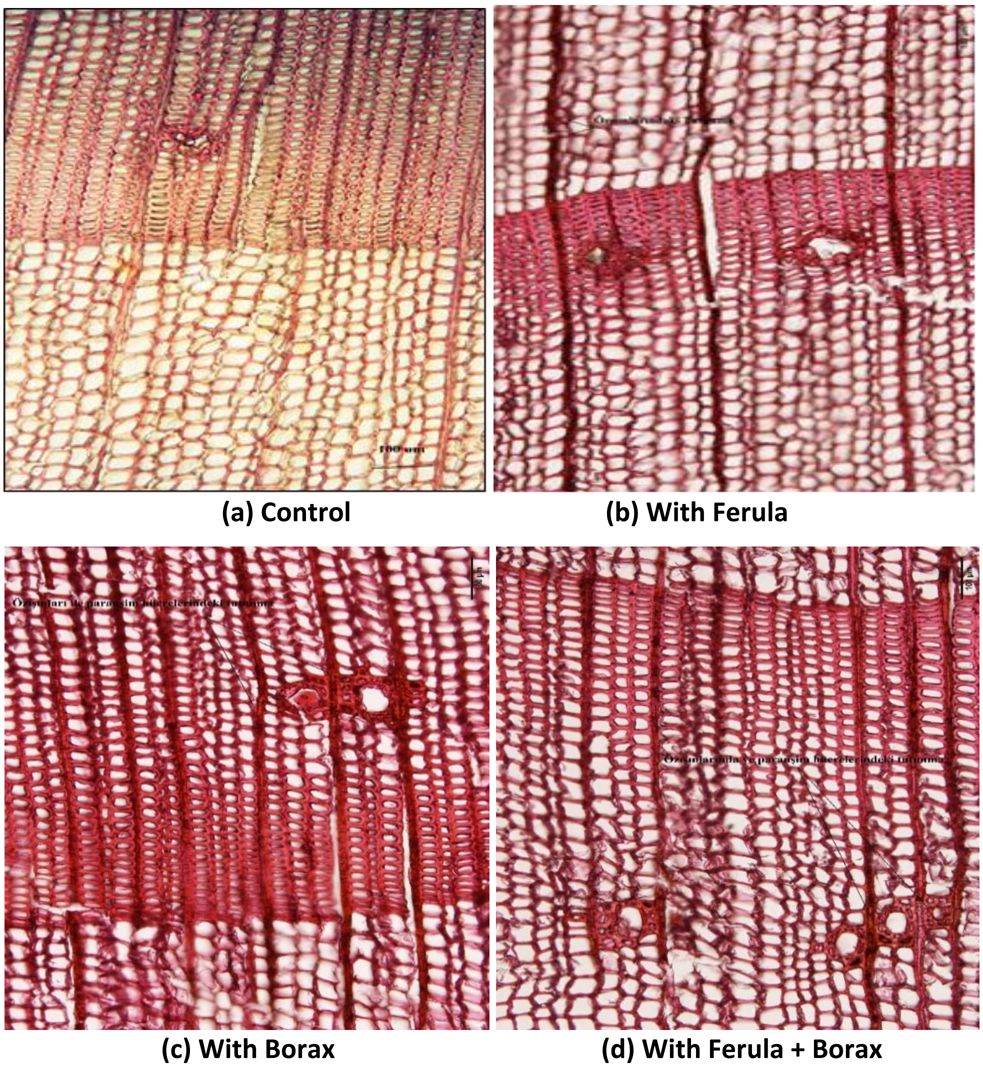
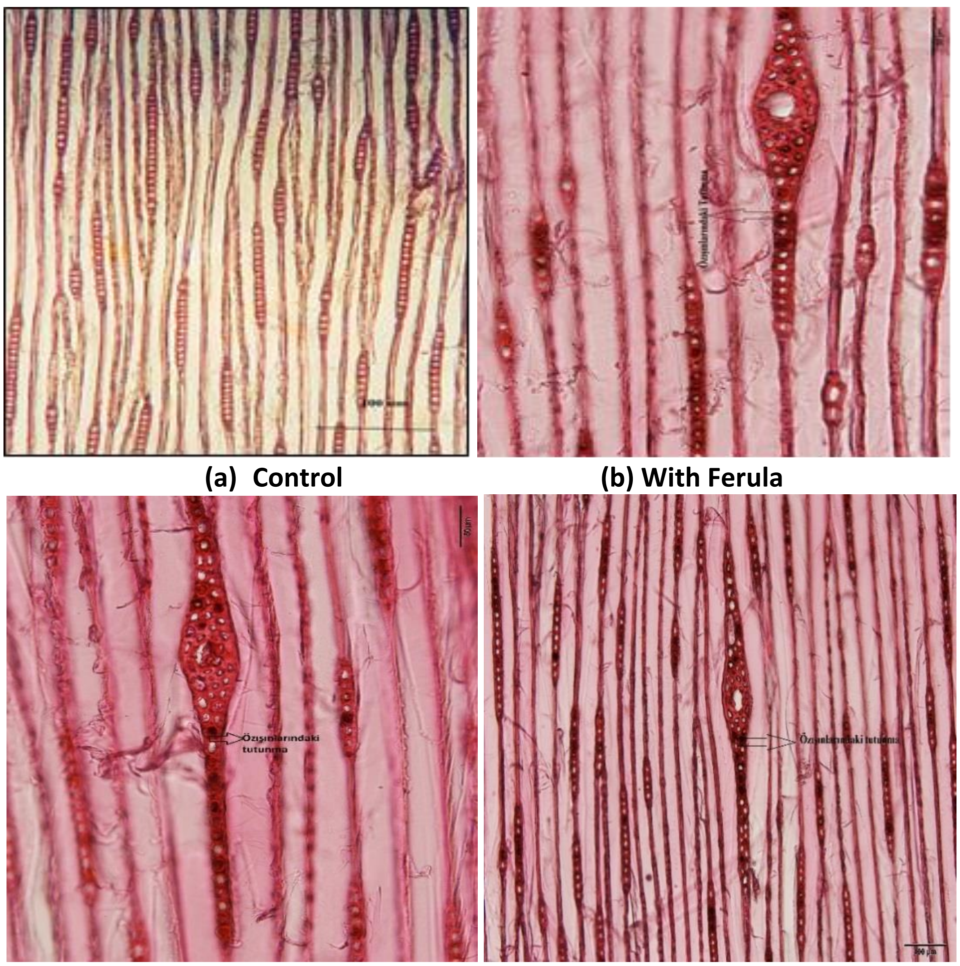


Fig. 1. The appearance of retention in cross-sections of impregnated eastern spruce wood

When examining the cross-section, compared to the control (a) sample, it was observed that there was adhesion in the self-rays and resin channels in ferula (b) and only the self-rays in the borax (c), and the ferula + borax (d) rays. It was determined that the adhesion was very intense in ferula (b) and borax (c), and it observably decreased after the mixture of spruce plant extract and borax (d) impregnations. Self-rays, which are parenchymal cells that function as storage in coniferous trees, facilitate radial food exchange (Bozkurt *et al*. 2000). It can be concluded that the various impregnation agents employed in the impregnation procedure have distinct effects on the wood cells, and that the plant extract lessens the impact of the borax agent. The impregnation process is affected by variables such as the characteristics of the wood material, the impregnation method, the liquid flow pathways, the passage aspiration, *etc*. (Bozkurt *et al*. 1993). According to a study, there were inconsistencies in the intercellular transitions compared to the control group because the epithelial cells surrounding the resin were impacted by the impregnation procedures. According to reports, the system and manner of impregnation have an impact in this regard (Akbaş 2011). In a study, it was found that adhesion only occurs in the self-rays and resin channels, that it is strong in the 1% washing and borax mixture, and it observably decreases after the mixture of the plant extract and borax impregnations (Ulusoy and Peker 2022). The state of adhesion in the tangential section was compared with the control sample. The views of this comparison are shown below (Figs. 2a-control, 2b-with ferula, 2c- borax, and 3d-with ferula + borax).



(a) Control **(b) With Ferula**

(c) with Borax **(d) With Ferula + Borax**

Fig. 2. The appearance of retentiion in tangential sections of ımpregnated eastern spruce wood

When examining the tangential section, compared to the control (a) sample, it was observed that only the self-rays were adhered to in ferula (b), borax (c), and ferula + boraxed (d). It was determined that the retention was very intense in ferula (b) and borax (c), and it observably decreased after the mixture of the spruce plant extract and the borax

(d) impregnation material. The core ray parenchyma cells are the cells that serve as storage, and they store the side components other than the main components in the chemical structure of the wood. It is possible that the self-rays storage function caused them to absorb these compounds more quickly as a result of the impregnation ingredient sticking to them. They are cells whose rays cause the physical properties of wood to change. The ability of wood to split increases along self-rays on tangential surfaces. The retention property of wood can be positively impacted by retention in self-rays (Bozkurt *et al.* 2000). The state of retention in the radial section was compared with the control sample and their appearances are shown below (Fig.-3a: Control, 3b: with Ferula, 3c: Borax and 3d: with Ferula + Borax).

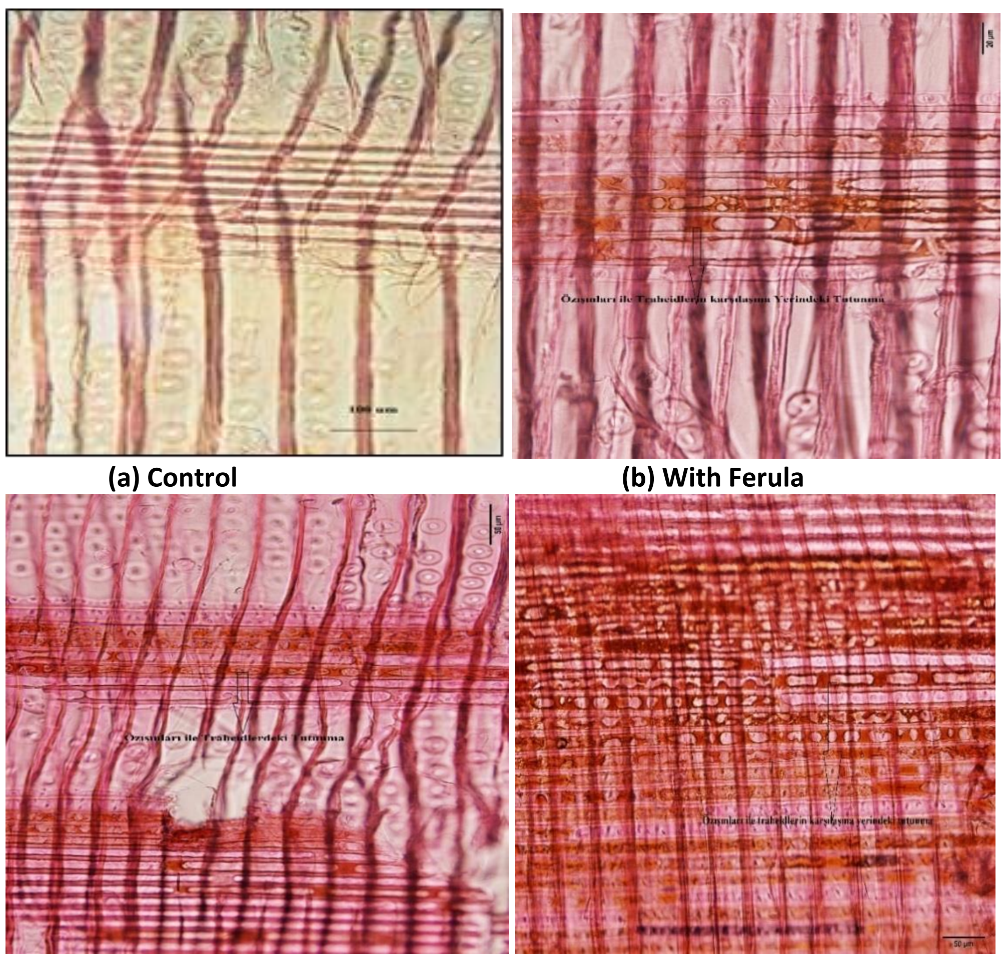


Fig. 3. Appearance of retention in radial section of ımpregnated eastern spruce wood

When examining the radial section, compared to the control (a) sample, it was observed that there was intense retention in ferula (b) and borax (c) and very intense in ferula + borax (d) at the meeting points of the self-rays and tracheid. It was determined that the retention was observably higher in borax (c) and compost plant extract and borax (d). Core ray parenchyma cells are found in radially located self-rays in coniferous woods. They store nutrients and provide transmission along their rays. The saphenous parenchyma cells are thin-walled and have simple passages. Compared to the longitudinal tracheid, they are relatively tiny cells. Nodular thickening of the walls, which is a important wall thickening, is seen close to the channels that allow conduction between the parenchyma cells. The junctional channels that allow nutrients to go from one cell to the next are generated when the longitudinal tracheid and the core ray parenchyma cells meet (Bozkurt and Erdin 2000). It has been determined that at the meeting places of self-rays and tracheid, there is intense retention in 1% ferula, non-intense in borax, intense adsorption in ferula + borax and it is observably higher in spruce and borax with mixed plant extract (Ulusoy and Peker 2022). The retention in the radial segment was largely found outside the junction tunnels. It might be argued that these wall thickenings are the possible cause of the retention that is present outside of the meeting space passages.

Anatomical Changes in Eastern Mahogany Wood

Transverse, tangential, and radial retentions in mahogany wood impregnated with a mixture of 3% ferula plant extract, borax, ferula+borax was evaluated by comparing it with the control sample. The cross-sectional images in this evaluation (Figs. 4a-control, 4b-with ferula, 4c-with borax, and 4d-with ferula + borax) are shown.

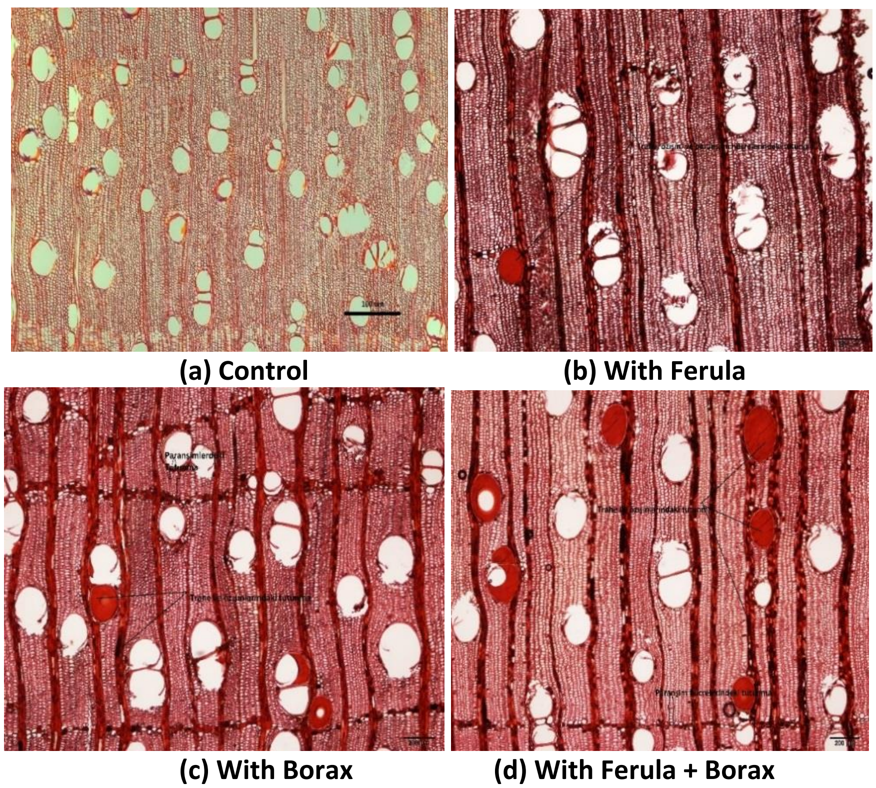


Fig. 4. Appearance of retention in cross-sections of ımpregnated mahogany wood

When examining the cross-section, compared to the control (a) sample, it was observed that very intense retention was observed in tracheas and self-rays with ferula (b), in tracheas, core rays and border parenchyma cells with the boraxed (c) and ferula + borax (d). Strand parenchyma, also known as longitudinal parenchyma, is a type of cambium cell produced by the transverse division of daughter cells that resemble spindles. They retain the original shape of the cambium cell. The membranes of the tubes connecting the trachea and parenchyma cells are incredibly thick in deciduous trees. This thick passage membrane has the capacity to shield the living parenchyma cell from the strong suction power in the nearby trachea (Bozkurt *et al*. 2000). It has been determined that the adhesion is more intense in borax (c), in the mixture of compost plant extract and borax (d) than in the mix (a). It was found that the mixture of spruce plant extract and borax had a more intense retention at 1% borax (Ulusoy and Peker 2022). These findings indicate that the impregnation substance is more effective than the plant extract in mahogany wood and it retains well. The anatomical design, solution characteristics, density, and tulle development of leafy trees may have contributed to this circumstance. The state of retention in the tangential section was compared with the control sample. The views of this comparison are shown below (Figs. 5a-control, 5b-with ferula, 5c-with borax, and 5d- with ferula + borax).

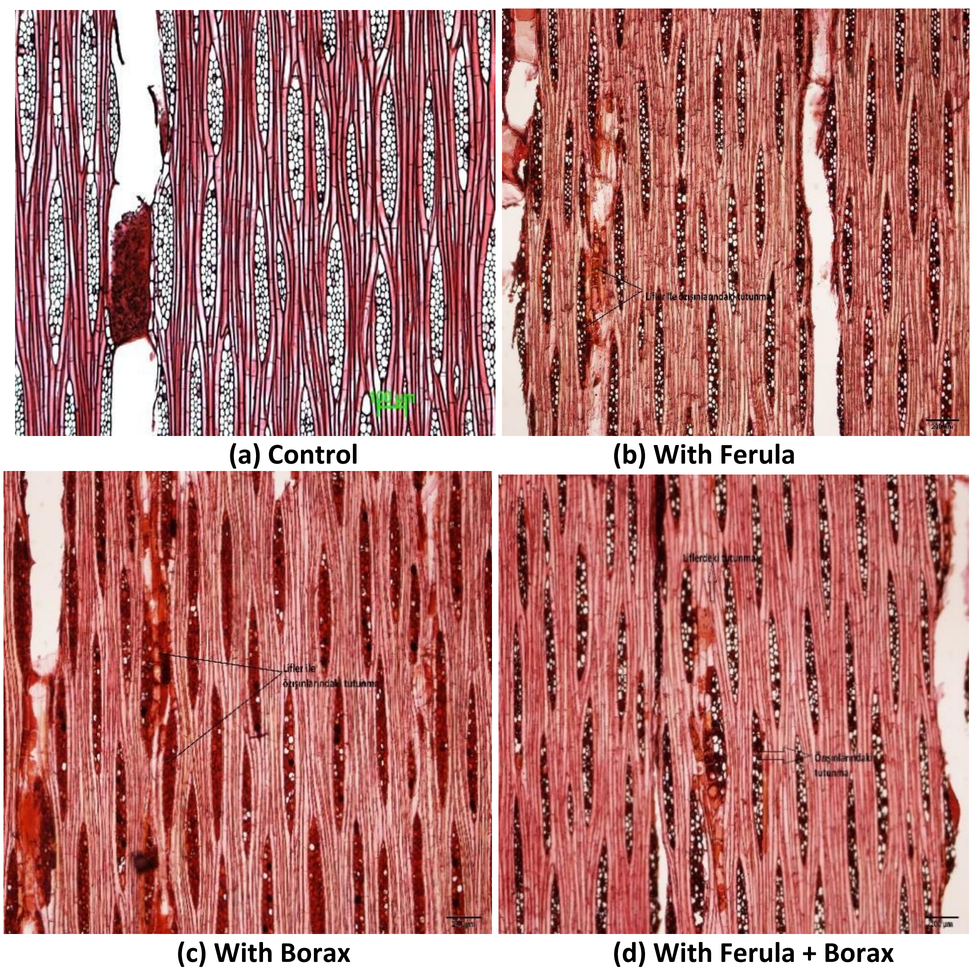
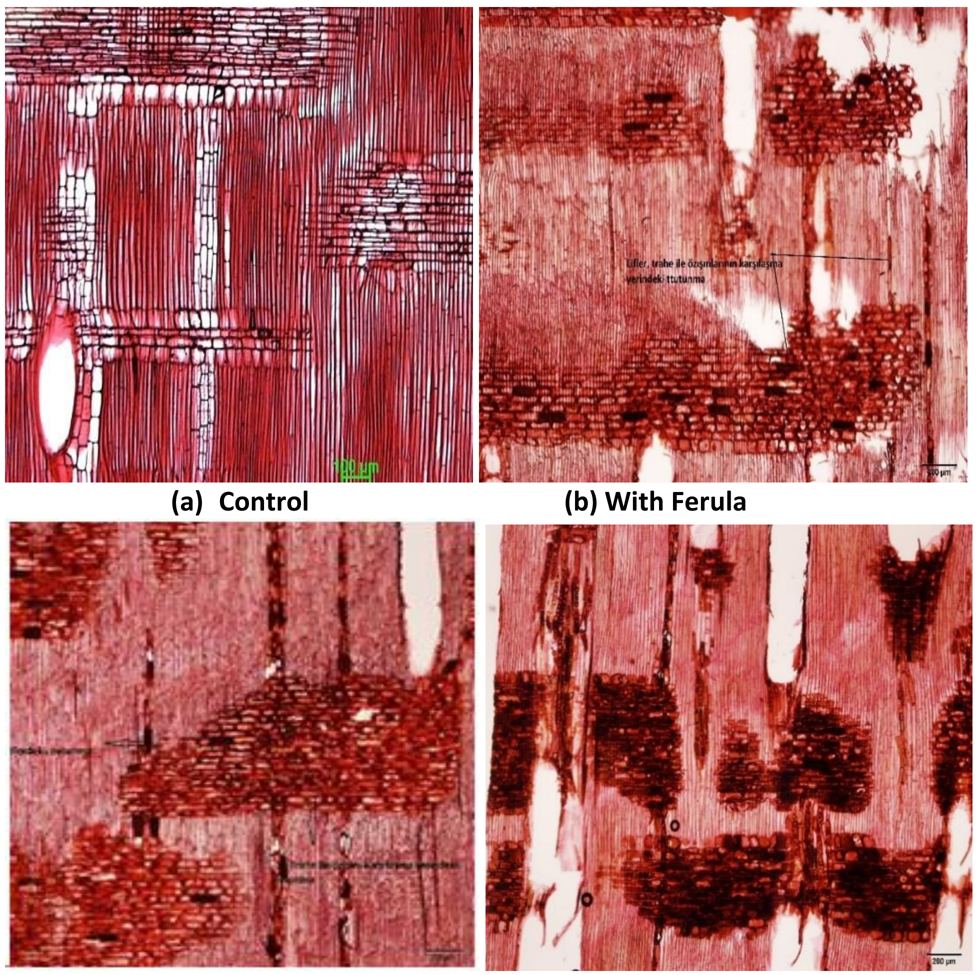


Fig. 5. Appearance of retention in tangential sections of ımpregnated mahogany wood

When examining the tangential section, compared to the control (a) sample, it was observed that there was intense retention in the core rays and fiber cells in ferula (b), ferula + borax (d), and the denser retention in the core rays and fiber cells (libriform fibers) in the borax (c). Coniferous trees do not have fiber cells, only deciduous trees do. Wood contains fiber cells that act as support. In terms of cell morphology, it is the name of a special cell type found in leafy trees. Deciduous trees have two different types of fiber cells: libriform fibers and fiber tracheids. The passages of the libriform fibers are simple. The main function of fiber cells is to provide mechanical support to trees. It has an impact on resistance, hardness, weight, and chemical composition of wood material (Bozkurt *et al.* 2000). It was observed in a previous study (Ulusoy and Peker 2022) that there was intense adhesion in the core rays and fiber cells in 1% ferula, ferula + borax, and more intense adhesion in the core rays and fiber cells (libriform fibers) in borax. It could be claimed that the impregnating substance, borax, adheres to the fiber cells more successfully. It is possible to say that the retention in the fiber cells of mahogany wood supports the support mechanism of the wood. The retention state in the radial section was compared with the control sample. The views of this comparison are shown below (Figs. 6a-control, 6b-with ferula, 6c-with borax, and 6d-with ferula + borax).



(a) Control **(b) With Ferula**

(c) With Borax **(d) With Ferula + Borax**

Fig. 6. Appearance of retention in radial sections of ımpregnated mahogany wood

When examining the radial section, compared to the control (a) sample, there is the same density of adhesion at the junction of the libriform fibers, the core rays, and the trachea cells in ferula (b), borax (c) samples. In contrast, more intense adhesion was observed in libriform fibers located at the meeting points of pith rays and trachea cells in ferula + borax samples (d).

In broad-leaved trees, the core rays contain various cell arrangements, cell morphologies, and foreign substances. Compared to self-rays in coniferous trees, it is wider and higher. In a study, it has been observed that libriform fibers, core rays and trachea cells meet at the same intensity in 1% ferula, borax, and ferula + borax. It can be said that the lack of important differences between the cell diameters of spring and summer wood in trachea cells in mahogany wood, their scattered tracheal structure, and the wider and higher core rays may have caused more adhesion at the meeting place of core rays and trachea. The results of the tests show that applying borax to wood to impregnate it makes it more stable; adhesion is decreased with ferula and borax mixture. It was found that the adhesion in mahogany wood was stronger in the borax and spruce mixture than in the oriental spruce wood. Mahogany wood has higher retention than other types of wood, which may be explained by the anatomical makeup of leafy trees. It is well known that one of the most crucial factors preventing the material from adhering during the impregnation process is the passage aspiration structure in eastern spruce. It is well recognized that factors, such as the anatomical makeup of the wood, its type, specific gravity, humidity, and impregnation techniques, affect where wood is used. The impregnation materials employed in the impregnation procedure in both types of wood have different effects on the wood cells; the plant extract lessens the impact of the borax substance, which may be related to the anatomical structure of the trees. Comparing the impregnation made with ferula extracts to that done with borax material, it can be concluded that the density of the wood reduces. Additionally, the impregnation material, which has better adherence, dries faster. Wood with a high density can be better impregnated; and under high temperature circumstances, its rapid moisture loss reveals a more unfavorable structure in terms of dimensional stability. It can be claimed that coniferous and leafy trees have greater retention rates. Retention has occurred in self-rays in both species of trees. There was no adhesion in the tracheid and trachea cells that perform the transmission function. The strong fluid movement in the wood within these cells was the cause of this because it prevented the impregnation ingredient from attaching to these cells. Retention has happened in the core ray cells because they are the ones used for storage.

Rapp *et al*. (2006) found that wood cell wall modification affects different mechanical properties including the wood hardness and abrasion resistance, but also its brittleness and consequently its structural integrity. Scholz *et al.* (2010) conducted studies of lateral penetration of Scots pine and beech where the main role of parenchyma rays in radial penetration is well described. Tondi *et al.* (2013) revealed the penetration mechanism within the wood of both species with the aid of a microscopic analysis. Scots pine is impregnated through the tracheids in the longitudinal direction and through parenchyma rays in the radial direction, whereas in beech, the penetration occurs almost completely through longitudinal vessels.

CONCLUSIONS

1. It was closely observed that adhesion took place in the core ray cells. Core rays parenchyma cells in coniferous woods are found in the radially positioned self-rays and facilitate the transport of nutrients in the radial direction by storing nutrients. Because the self rays have the duty of storing nutrients, it may be claimed that this aspect of the self rays may have been efficient in the uptake of the impregnation. Coniferous tree cell walls are highly prone to gate aspiration.

2. While partial retention was observed in the tracheid structure in the study, the retention level was determined to be stronger especially in mahogany wood parenchyma cells. While Ferula plant extract provided high retention in mahogany wood, it did not provide the desired penetration in spruce wood. This was because of power impregnation due to the transitional aspiration present in the spruce wood.
3. The organic preservative (impregnation-top surface) material (bioenergy) made from tea extract exhibited identical characteristics in terms of retention values and retention rates across all wood species. In terms of retention values and percent retention rates, samples impregnated with 1% plant extract from spruce and mahogany were shown to have similar characteristics (Atilgan *et al.* 2013). Although pressure, dipping, brush applications, and other techniques can be utilized, the vacuum process is particularly preferred. The rays of the parenchyma cells exist in the rays located in the radial direction in coniferous woods and provide the delivery of nutrients in the radial direction by storing the nutrients. It can be concluded that this feature may have been effective in the intake of the preservative because the retention was in the rays and the rays stored the nutrients. In coniferous trees, passage aspiration occurs especially at the cell wall. The reason for the absence of retention in tracheids may be due to passage aspiration.

ACKNOWLEDGMENT

I would like to thank Prof. Hüseyin PEKER and Assoc. Hatice ULUSOY for their contribution to this study.

REFERENCES CITED

Akbaş, S. (2011). *Kargı (Arundo donax L.) Yıllık Bitkisinden Elde Edilen Biyo-yağın Odun Koruma Maddesi Olarak Etkinliğinin Araştırılması*, [*Efficiency of Bio-Oil Obtained From Giant Reed (Arundo donax L.) as a Wood Preservative*], Master's Thesis, Karadeniz Technical University Graduate School of Science, Trabzon, Turkey.

ASTM D1413–76 (1984). "Standard methods of testing preservatives by laboratory soilblock cultures," ASTM International, West Conshohocken, PA, USA.

Atılgan, A., Ersen, N., and Peker, H. (2013). "Atık Çay Ekstraktlarından Elde Edilen Boyanın Ahşap Malzemede Renklendirme Olanaklarının Araştırılması" [Investigation of the possibility coloringon wood materials of paint obtained from waste tea extracts], *Kastamonu Unıversity Forest Faculty Journal* 13(2), 278-286. https://dergipark.org.tr/tr/pub/kastorman/issue/17230/179949

Baysal, E., Peker, H., Çolak, M. and Göktaş, O. (2003). "Çeşitli Emprenye Maddeleriyle Muamele Edilen Kayin Odununun Yoğunluğu, Eğilme Direnci ve Elastikiyet Modülü," [Density, flexural resistance and modulus of elasticity of beech wood treated with various impregnations], *Fırat Ünıversity, Journal of Science and Engineering Sciences* 15(4), 655-672. http://acikerisim.mu.edu.tr:8080/xmlui/handle/20.500.12809/7516

Baysal, E. (1994). *Çeşitli Borlu ve Wr Bileşiklerin Kızılcam Odununun Bazı Fiziksel Özelliklerine Etkisi* [*The Effect of Various Boron and Wr Compounds on Some Physical Properties of Red Glass Wood*], Master's Thesis, Karadeniz Technical

University Graduate School of Science, Trabzon, Turkey. https://tez.yok.gov.tr/UlusalTezMerkezi/tezSorguSonucYeni.jsp

Bozkurt, A. Y., and Erdin, N. (2000). "Odun Anatomisi [Wood Anatomy], İstanbul University Forest Faculty, Nilüfer Publication, Second Print, İstanbul,Turkey.

Bozkurt, A. Y. (1992). "Odun Anatomisi" [Wood Anatomy], Publications of İstanbul Ünivesity Forest Faculty Publication Number:3652, Faculty Publication Number: 415, İstanbul,Turkey.

Bozkurt, A.Y., Göker, Y., and Erdin, N. (1993). "Emprenye Tekniği" [Impregnation Technique], Istanbul University Faculty of Forestry Publications, Product Code: 5222377, İstanbul, Turkey.

Ceylan, Ş. (2019). *Possibilities of Using Irradiant Plant (Antioxidant/antibacterial) Extract in Wood Industry (Furniture/Construction), Artvin Coruh University BAP Project*, Project Code: 2017.M82.02.02, Artvin, Turkey.

İçel, B., and Şimşek, Y. (2017). "Isıl İşlem Görmüş Ladin ve Dişbudak Odunlarının Mikroskobik Görüntüleri Üzerine Değerlendirmeler" [Assessments on microscopic images of heat treated spruce and ash woods], *Süleyman Demirel University, Journal of the Institute of Science* 21(2), 414-420. DOI:10.19113/sdufbed.17217

Kartal, N., Engür, O., and Köse, Ç. (2005). "Emprenye Maddeleri Ve Emprenye Edilmiş Ağaç Malzeme İle İlgili Çevre Problemleri" [Environmental problems related to impregnated materials and impregnated wood material], *Journal of Istanbul University Faculty of Forestry* 56 (1), 17-23. https://dergipark.org.tr/tr/pub/jffiu/issue/18713/198790

Merev, N. (2003). "*Odun Anatomisi* " [*Wood Anatomy*], Karadeniz Technical University, Faculty of Forestry, General Publication No: 209, Faculty Publication No: 31, Book, Trabzon,Turkey.

Merev, N. (1998). "*Odun Anatomisi*" [Wood Anatomy] (*Wood Anatomy of Natural Angiospermae Taxa in the Eastern Black Sea Region*), Karadeniz Technıcal Unıversity Forestry of Faculty, General Publication No: 189. Faculty Publication No:27, Trabzon,Turkey.

Örs, Y., Efe, H., and Atar, M. (2001). "Sarıçam (*Pinus sylvestris Lipsky*.) Odununda Emprenye Etme ve Renk Açma İşleminin Vernik Katma Sertliğine Etkileri" [The effects of impregnation and lightening process on varnish addition hardness in scots pine (*Pinus sylvestris* Lipsky.) wood], *Gazi Universty Journal of the Graduate School of Natural and Applied Sciences* 14(2), 487-503.

Rapp, A. O., Brischke, C., and Welzbacher, C. R. (2006) "Interrelationship between the severity of heat treatments and sieve fractions after impact ball milling: A mechanical test for quality control of thermally modified wood," *Holzforschung* 60, 64–70. DOI:10.1515/HF.2006.012

Scholz, G., Krause, A., and Militz, H. (2010). "Exploratory study on the impregnation of scots pine sapwood and European beech with different hot melting waxes," *Wood Science Technology* 44, 379–388. DOI: 10.1007/s00226-010-0353-3

Tomak, E. D., and Yıldız, Ü. C. (2012). "Bitkisel Yağların Ahşap Koruyucu Bir Madde Olarak Kullanılabilirliği" [Applicability of vegetable oils as a wood preservative], *Journal of Artvin Coruh University Faculty of Forestry* 13(1), 142-157.

Tondi, G., Thevenon, M. F., Mies, B., Standfest, G., Petutschnigg, A., and Wieland, S. (2013) "Impregnation of scots pine and beech with tannin solutions: Effect of viscosity and wood anatomy in wood infiltration," *Wood Science Technology* 47, 615–626. DOI:10.1007/s00226-012-0524-5

TS ISO 3129 (2021). "Wood- Sampling methods and general requirements for physical and mechanical testing of small clear wood specimens", Turkish Standardization Institute, Ankara, Turkey.

Ulusoy, H. (2011). *Bazı Ağaç Türü Odunlarının Anatomik Yapıları ve İşleme Koşullarının Yüzey Pürüzlülüğüne Etkisi*, [*Effect On The Surface Roughness Of Some Wood Species Of Wood Anatomy And Machining Processing*], Ph.D. Dissertation, Karadeniz Technical University Graduate School of Science, Trabzon, Turkey. https://tez.yok.gov.tr/UlusalTezMerkezi/tezSorguSonucYeni.jsp

Ulusoy, H., and Peker, H. (2022). "New approach to ecological structure: Effects of medical aromatic plant extract/borax on the anatomical structure of wood and human/environmental health," *Fresenius Environmental Bulletin*, ISSN 1018-4619, Volume 31-No:01A/2022, Germany. http://acikerisim.mu.edu.tr/xmlui/bitstream/handle/20.500.12809/9825/Ulusoy.pdf?sequence=1&isAllowed=y

Article submitted: November 14, 2022; Peer review completed: January 6, 2023; Revised version received: January 30, 2023; Accepted: January 2, 2023; Published: February 9, 2023.
DOI: 10.15376/biores.18.2.2693-2706