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COMPREHENSIVE EVALUATION OF HAWTHORN WOOD CHARACTERISTICS IN RELATION TO SOIL PHYSICOCHEMICAL PROPERTIES

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ABSTRACT

Characteristics of hawthorn wood concerning soil physicochemical properties were studied. Physical properties such as dry wood density and volumetric swelling and fiber dimension parameters like fiber length, fiber diameter, and cell wall thickness were investigated. Soil properties including clay, silt soil, sand soil, electrical conductivity, pH, nitrogen, phosphorus, potassium, and organic matter content were determined. Pearson correlation was applied to explore the relationship between soil and wood properties. The mean wood density and volumetric swelling obtained were 0.71 g.cm^{-3} and 18%, respectively. Moreover, the mean values of fiber length, fiber diameter, and cell wall thickness were 0.80 mm, 20.50 µm, and 5.78 µm, respectively. Pearson correlation analysis showed a significant and positive correlation between wood dry density, cell wall thickness and volumetric swelling with percentage of silt, while a negative relationship between fiber length and percentage of silt were found.

KEYWORDS: Soil properties, hawthorn wood, fiber dimension, density.

INTRODUCTION

Growth of tree species is impacted by environmental variables that soil parameters are one of the most important environmental variables influencing the wood characteristic. Soil as a medium for tree growth directly impacts its growth and wood formation. Different soils in forest ecosystems may be lead to varying growth of trees unrelated to their life history, but rather to their response to soil characteristics. A number of soil characteristics affect tree growth such as soil texture, structure, soil depth, and physicochemical properties (Karyati et al. 2018). Previous studies have shown that there is positive and negative correlations between soil physical and chemical properties with wood formation. Yanez-Espinosa et al. (2001) indicate that soil texture and water salinity are closely associated with the anatomical characteristics of Mexican mangrove populations. Rigatto et al. (2004) specified that there is a significant correlation between soil physicochemical properties and wood quality. Cutter et al. (2004) found that sites with favorable soil properties significantly influenced the wood density. Tufekcioglu et al. (2005) studied the influence of soil properties on hybrid poplar (*Populus* sp.) growth in Turkey and concluded that the content of clay and Mg was negatively correlated with the pH of the soil, while the range of phosphorus and sand of the soil was positively correlated with hybrid poplar growth. Maharani and Fernandes (2015) demonstrated that nitrogen, phosphorus, and potassium had a major correlation with fiber length and wood density on *Shorea leprosula* and these elements had a notable correlation with wood density on *S. parvifolia*. Soil characteristics such as nutrients and texture vary over space and time and tree growth are anticipated to vary consequently. However nutrient-rich soils can also affect tree growth. Accordingly, it is necessary to make appropriate management decisions with a deeper understanding of the potential effects of soil on wood properties in their habitats. Also, management and Understanding the relationships between tree growth and soil characteristics for reclamation practices by reforestation are essential.

In Iran, forests cover about 12 million ha (Haidari et al. 2013, Nazari et al. 2020). Zagros forests cover about five million hectares, representing 40% of Iran's forests (Sagheb-Taleb et al. 2003). The main hardwood species in this area are *Quercus* spp. (oaks), *Pistacia mutica* (wild pistachio), *Crataegus* spp. (hawthorn) and *Pyrus* spp. (pear) (Jazirehi, Rostaghi 2003). *Crategus* spp., belonging to the *Rosaceae* family and *Maloideae* sub-family including about 300 species that are grown in Europe, North Africa, West Asia, and North America. *Crataegus* species are shrubs or small trees, mainly growing up to 15 m, mostly, growth and development on mountainsides (Phipps 1998). This genus is very useful for different aims, including food, medicinal, ornamental, and as a shelter for wildlife, soil-water conservation applications and erosion control. This wood can be used for a variety of applications, including veneers production, furniture, as well as boxes, tool handles and boat parts. In addition, it is used for firewood and charcoal.

In general, studies on the impact of soil physicochemical properties on wood properties are limited. It is of great importance to identify the best growth conditions to produce high quality wood. To the best of our knowledge, there is no study regarding the influence of soil physical and chemical properties on the Hawthorn wood properties in Iran. The present research aims to explore and deepen the knowledge regarding the variation of oven-dry density, volumetric swelling, fiber length, fiber diameter, and cell wall thickness of Hawthorn wood in association with the soil properties.

MATERIAL AND METHODS

Study area

The study was carried out on Hawthorn trees collected from Bazoft forests Iran, which is placed between 49°59′43″N and 50°15′28″N and between 32°07′42″ E and 32°22′25″ E. The average annual rainfall and temperature are 14°C and 330 mm, respectively. Twenty seven hawthorn trees were sampled and the 5 cm disks was prepared from the trees at breast height for measurement the biometrical and physical properties.

Wood physical properties

Physical properties, namely oven-dry density and volumetric swelling, were measured from 5 cm thick disks cut down from each tree. Sample tests were prepared following ISO 13061-14 (2016). The wood sample size was 3 × 2 × 2 cm. Two hundred seventy samples were prepared from various portions of the disks. The size of samples in both green and oven-dry situations was measured with a slide caliper. An electronic balance was used to measure the oven-dry density. Dimensional changes from the green to dry conditions were considered to calculate the volumetric swelling. The physical properties were determined in accordance with the Eqs. 1 and 2:

$$D_0 = \frac{M_0}{V_0} \tag{1}$$

$$\alpha_V = \frac{V_S - V_0}{V_0} \tag{2}$$

where: D_0 - oven-dry density (g·cm^{-3}), M_0 – oven-dry mass (g), V_0 - oven-dry volume (cm^3), α_v - volumetric swelling (%), Vs - volume (cm^3).

Biometrical fiber properties

Franklin's method (1945) was applied to separate the individual wood fiber. In detail, saturation of wood samples (15 × 10 × 2 mm) in a mixture (1:1) of oxygenized water and acetic acid were performed, and then the samples were maintained inside an oven for 48 hours at 65°C ± 5°C. After maceration, the samples were washed in distilled water. Finally, they were submerged to distilled water, shacked, and fiber parameters such as fiber length, cell wall thickness, and fiber diameter were evaluated. The fiber dimensions were determined by using Leica Image Analysis System. For this test, it was necessary to measure 20 fiber dimensions per sub-samples.

Soil study

To calculate soil properties, four soil samples were obtained at a 0-20 cm soil depth under the canopy of each tree and mixed. Physicochemical properties of soil were measured, including the percentage of clay, silt, and sand, electrical conductivity (EC), soil reaction (pH), total nitrogen (N), available phosphorus (P), available potassium (K), and percentage of organic matter. Soil treatments were air-dried, then passed through a 2 mm sieve. Analysis of soil samples was carried out at the laboratory of Agricultural and Natural Resources Research Center of Isfahan Province, Isfahan, Iran. Percentage of clay, silt, and sand were calculated by the hydrometer method that this method measures the density of the colloidal solution of soil in water, as shown in Tab. 3 (Bouyoucos 1962). The pH and EC were determined using a pH/EC meter. There pH/EC meters should be calibrated before use and are calibrated using special solutions. The total nitrogen was calculated using the Kjeldahl method and this method generally used for this determination are acceptable (Zarinkafsh 1993). Phosphorus content was calculated by the Olsen method because this method has known as the finest and cheapest method appropriate for different soils (Nelson and Sommers 1996). Available potassium was measured by flame photometry and this method was desirable to chemical methods especially when potassium was to be measured in soil samples (Zarinkafsh 1993). Organic matter content was estimated as in Walkley and Black (1934).

Analysis study

In this study, the influence of soil physicochemical properties was studied on the wood characteristics. Pearson correlation was carried out for determining the association between soil properties and wood properties by IBM SPSS statistics 25.0.

RESULTS AND DISCUSSION

Physical properties

The results of oven-dry density and volumetric swelling of hawthorn wood are illustrated in Tab. 1. The density is one of the most important properties for wood baaed materials. According to (Zobel and Van Buijtenen 1895), wood density is an important qualitative parameter for different utilizations, because it is associated with a lot of other wood properties. As can be seen, the density of the hawthorn wood is 0.71 $g \cdot cm^{-3}$, which is lower than that of Oneseed hawthorn (0.785 $g \cdot cm^{-3}$) and Pear hawthorn (0.775 $g \cdot cm^{-3}$) (www.wood-database.com). Wood density classification is grouped according to Wong (2002): light (<0.5 $g \cdot cm^{-3}$), moderately dense (between 0.5 - 0.8 $g \cdot cm^{-3}$), including hawthorn wood, heavy (between 0.8 - 1.0 $g \cdot cm^{-3}$), very dense >1.0 $g \cdot cm^{-3}$).

Tab. 1: The average physical properties of hawthorn wood.

Wood properties	Mean	Standard deviation
Density ($g \cdot cm^{-3}$)	0.71	0.06
Volumetric swelling (%)	18.14	1.59

Moreover, the density is lower than that reported for Persian ironwood (0.820 $g.cm^{-3}$, Enayati 2010), hornbeam (0.800 $g \cdot cm^{-3}$, Khalkhali 2013) and Persian oak (0.990 $g \cdot cm^{-3}$, Saedi et al. 2017). On the other hand, the volumetric swelling of hawthorn wood (18%) is higher than that of Oneseed hawthorn (14%) (www.wood-database.com). It could be related to the growth conditions and environmental factors. According to the obtained results, hawthorn wood can be classified into high-volumetric swelling species.

Biometrical fiber properties

Wood fibers play a critical role in identifying the wood structure and final application of wooden materials (Gryc and Vavrčík 2005, Nazari et al. 2021, Dong et al. 2021). The mean values of the parameter fiber lengths for hawthorn wood are given in Tab. 2.

Tab. 2: The average biometric properties of hawthorn wood.

Fiber properties	Mean	Standard deviation
Fiber length (mm)	0.80	0.04
Fiber diameter (µm)	20.50	0.04
Cell wall thickness (µm)	5.78	0.04

The classification of the International Association of Wood Anatomists splits fibers into three groups (IAWA 1989): short fibers with a length less 900 µm, including Hawthorn wood with an average fiber length of 800 microns; fibers of medium length between 900-1900 µm fibers longer than 1900 µm.

The average fiber length of Hawthorn wood is lower than that reported for most hardwoods (Khalkhali 2013). Among Iranian wood species cell wall thickness is equal to *Populus* species (5 µm, Efhamisisi et al. 2009) and lower than that of Persian oak and wild service wood (9 µm, Saedi et al. 2017, Bahmani et al. 2020).

Physicochemical properties of soil

Tab. 3 shows the overall statistical data for the five soil physical properties and four soil chemical properties. The average contents of sand, silt and clay were 22.12%, 43.78%, and 34.17%, respectively. Soil texture analysis showed that soils in this region were predominantly composed of silt, with lower clay and sand contents. All soils were neutral, and the pH values did not vary in an obvious pattern.

Tab. 3: Soil physical and chemical properties.

		Mean	Standard deviation
Soil physical properties	Percentage of clay (%)	34.17	1.51
	Percentage of silt (%)	43.78	1.21
	Percentage of sand (%)	22.12	1.58
	Electrical conductivity (Ec)	0.85	0.15
	Soil reaction (pH)	7.73	0.01
Soil chemical properties	Total nitrogen (%)	0.21	0.09
	Available phosphorus ($mg \cdot kg^{-1}$)	9.63	4.71
	Available potassium ($mg \cdot kg^{-1}$)	485.48	79.36
	Percentage of organic matter (OM) (%)	2.42	0.48

Correlation between wood characteristics and physicochemical properties of soil

Correlation was expressed using of coefficient "r" that always takes a value between -1 and 1, with 1 or -1 indicating perfect correlation. A correlation value close to 0 indicates no association between the variables. Results showed that there is a significant and positive correlation between dry wood density (r = 0.50), cell wall thickness (r = 0.49) and volumetric swelling (r = 0.65) with the percentage of silt, while a negative relationship between fiber length and percentage of silt were found. Wood dry density (r = 0.40) and volumetric swelling (r = 0.49) had a significant positive correlation with available potassium. There is a significant and positive correlation between fiber diameter (r_{Ec} = 0.46, r_{OM} = 0.47) and volumetric swelling (r_{Ec} = 0.47, r_{OM} = 0.65) with electrical conductivity and percentage of organic matter, while a negative relationship between these wood properties with percentage of clay (r_{FD} = -0.43, r_{SV} = -0.77), respectively. Moreover, the results revealed a positive correlation between fiber diameter with percentage of sand (r = 0.46). There is a significant and positive correlation between volumetric swelling and soil reaction (r = 0.84) (Tab. 4).

Tab. 4: Pearson's correlation coefficient between wood characteristics and physicochemical properties of soil. Correlations are significant at P< 0.05 and P< 0.01.

Wood characteristics	Total nitrogen	Available phosphorus	Available potassium	Soil reaction (pH)	Percentage of sand	Percentage of clay	Percentage of silt	Percentage of organic matter	Electrical conductivity (EC)
Wood dry density	0.03	-0.35	0.40*	0.20	-0.38	-0.05	0.50**	0.08	-0.22
Fiber length	-0.24	0.23	0.14	-0.24	0.26	0.11	-0.44*	-0.01	0.14
Fiber diameter	-0.17	-0.26	0.33	0.23	0.46*	-0.42*	-0.02	-0.47*	0.46*
Cell wall thickness	0.07	0.20	-0.11	0.34	-0.18	-0.23	0.49**	-0.12	-0.01
Volumetric swelling	0.02	0.08	0.49*	0.84**	0.14	-0.77**	0.65**	-0.65**	0.47*

Note: Significant (Sig.) at the 0.05 significance level, ** significant at the 0.01 significance level.

Potassium and organic matter, as essential macronutrients, are vital for physiological processes in tree growth and development (Potchanasin et al. 2009). Fromm (2010) revealed a distinct correlation between potassium and wood properties and demonstrated that 30% of the potassium in xylem cell walls originate during uptake into the root. Larson (1994) demonstrated that the mineral elements have direct effects on vascular cambium. These elements increase cell division in the vascular cambium, and this element allows improved performance in plants. The increase in cambial activity is followed by changes in the structure, mainly by reason of pores of larger size, fibers with thinner cell walls and more significant presence of parenchyma cells. Volumetric swelling is positively correlated with potassium, organic matter, silt, Ec, and pH. Meanwhile, it is negatively correlated with clay. Moya and Perez (2008) reported that normal radial shrinkage and normal tangential shrinkage were the best correlated factors with soil properties.

CONCLUSION

Hawthorn is a valuable tree species in Iranian Zagros forests with limited availability of data on its wood properties. In this study, the properties of hawthorn wood in relation to soil properties were examined. Results illustrated that Hawthorn is moderately heavy wood with the density approximately 0.70 $g \cdot cm^{-3}$ and can be classified into high-volumetric swelling species. Fiber dimension measurement showed that hawthorn wood is classed into medium fiber length. In addition, results indicated that a significant and positive association between wood density, cell wall thickness and volumetric swelling with percentage of silt, while a negative relationship between fiber length and percentage of silt were obtained.

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