SOME OF PHENOTYPIC, PHYSICAL AND ANATOMICAL WOOD PROPERTIES OF VALONIA OAK TREES IN KURDISTAN-IRAQ

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ABSTRACT

This study was aimed to investigate the morphologic, macroscopic, and microscopic description with the paper pulp quality index was determined to facilitate its increased use and to analyze the variation of wood properties. Among different morphological characteristics *Q. aegilops* registered mean height (13.63 m) and diameter (26.04 cm), while bark thickness represented from 7.2 to 15.6mm. Average bark and wood percent was noticed (8.22%) and (91.78%) of the total volume, with annual ring growth width (3.17mm) that considered a slow-growing species. The highest heartwood proportion of stem volume was 75.32% and the lowest 42.01% with a mean of 61.46%. The sapwood proportion ranged between 23.68 and 57.99% with a mean of 38.54%. While the values of anatomical properties were: The mean values of fiber length, fiber diameter, double cell wall thickness, and fiber lumen width were 1.01mm, 15.54µm, 6.288µm, and 9.25µm respectively. Moreover, the mean values of vessel length and vessel diameters were 0.54mm and 179.80µm respectively. Significant differences were found in the pulpwood quality indices for the paper samples, the means value of the runkel index was 0.86, while, slenderness index was 68.84, the coefficient of flexibility was 0.57, and the average value of the stiffness coefficient was 0.421. The fibers length more than1mm and cell well is thick accordingly are classified as good for paper. Based on its morphological and physical properties, *Q. aegilops* wood can be used in various wood manufactures. Based on the anatomical properties and pulp quality indices, this wood could be used to obtain cellulose pulp for paper production.

Key words: *Quercus aegilops*, macroscopically, microscopically properties, pulp quality index

بعض خصائص الخشب المظهرية والفيزيائية والتشريحية لأشجار بلوط فالونيا في كردستان العراق

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المستخلص

هدفت هذه الدراسة إلى التحقق من الوصف المورفولوجي و الماكروسكوبي و الميكروسكوبي مع مؤشر جودة عجينة الورق لتسهيل استخدامه المتزايد ولتحليل تباين خصائص الخشب. من بين الخصائص المورفولوجية المختلفة سجل *Q. aegilops* متوسط الارتفاع (13.63 م) والقطر (26.04 سم) ، بينما سمك اللحاء تراوح من 7.2 إلى 15.6 مم. لوحظ متوسط نسبة اللحاء والخشب بنسبة (8.22٪) و (91.78٪) من الحجم الكلي ، مع عرض حلقة النمو السنوية (3.17 مم) ويعتبر من الأنواع بطيئة النمو. أعلى نسبة للخشب القلب من حجم الساق كانت 75.32٪ وأقل نسبة 42.01٪ بمتوسط 61.46٪. تراوحت نسبة الخشب العصاري بين 23.68 و 57.99٪ بمتوسط 38.54٪. بينما كانت قيم الخواص التشريحية: القيم المتوسطة لطول الألياف وقطرها وسماكة جدار الخلية المزدوجة وعرض تجويف الألياف كانت 1.01 مم و 15.54 ميكرومتر و 6.288 ميكرومتر و 9.25 ميكرومتر على التوالي. علاوة على ذلك ، كانت القيم المتوسطة لطول الأوعية وأقطار الأوعية 0.54 مم و 179.80 ميكرومتر على التوالي. وجدت فروقات معنوية في مؤشرات جودة عجينة الورقة لعينات الخشب، حيث كانت القيمة المتوسطة لمؤشر رانكل 0.86 ، بينما مؤشر النحافة 68.84 ، ومعامل المرونة 0.57 ، ومتوسط قيمة معامل الصلابة 0.421. طول الألياف أكبر من 1 مم وعليه يصنف سمك جدارالخلية على أنها جيدة لصناعة الورق. استناداً على الخصائص المورفولوجية والفيزيائية ، يمكن استخدام خشب *Q. aegilops* في العديد من الصناعات الخشبية. و استناداً على الخصائص التشريحية ومؤشرات جودة اللب ، يمكن استخدام هذا الخشب للحصول على لب السليلوز لإنتاج الورق.

الكلمات المفتاحية: *Quercus aegilops* L. : الخصائص الماكروسكوبية والميكروسكوبية، مؤشر جودة العجينة الورقية

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INTRODUCTION

Valonia oak (*Quercus aegilops* L.), is considered one of the most important, widespread, and native tree species in the Kurdistan Region of Iraq. It covers as much as 70 % of the total Oak area which constitutes about 90% of the region's forest (41). The species has large ecological adaptability landscape and socioeconomic importance, in which is the most important source of wood that is hard, heavy, dense, strong and resistant to pressure and fungi diseases. Its wood used for construction, furniture, mine timbers, plywood, pulp chips and production of coal (45, 33). Also, it plays a vital role for preserving soil and water, providing shelter and food for hundreds of animal and plants species thus contributing to the enhancement of the biodiversity and wildlife of the region. Kurdish farmer's make the shank of plough from its branches, Different parts of oak are used in folk medicine (42). This species tends to develop a decurrent growth pattern, therefore, its wood is distributed over tree trunk and tree branches, and is utilized for different purposes (50). Oaks are valuable timber species is highly considered for indoor joinery and furniture due to its mechanical properties and aesthetical value. Size and absence of defects such as knots or grain direction are also important aspects for acceptance of oak timber for higher value products (16, 27). The wood of oak is very resistant to insect and fungal attack because of its content high amount of tannin. Moreover, has very interesting grain markings, mainly when quarter sawn. It is known that dimensional and physical characteristics of wood within trees are variable. This variation which are present can be related to radial or axial position of the wood sample either within an individual growth increment or over a series of growth increments within the tree, the suitability or quality of wood for a particular purpose is determined by the variability of one or more of these characteristics which affect its structure and hence its physical properties (34). This variation can result also from population-level differences within a site and from site-to-site differences in wood (19, 21), but a main portion of the variability is often within the trees themselves (54). Since knowledge of wood properties of Valonia oak is limited in Kurdistan region therefore, this study aimed to perform the macroscopic and microscopic anatomical description of *Q. aegilops* wood to facilitate its increased use and to analyze the variation of wood properties between and within trees, site-to-site differences to characterize their radial variation, and identify the demarcation strength between heartwood and sapwood for different characteristics, as a contribution to the technological knowledge of the wood in this species.

MATERIALS AND METHODS

Ten of Valonia Oak trees free from wood defects in Mangish district, Duhok province (latitude 37^0 03' 03.9" N, longitude 043^0 04' 05.4" E and altitude 1033m) were chosen and harvested for this study (Fig 1). The average rainfall is 646.5 mm. The test trunk samples used for establishing the physical and anatomical properties were taken from the breast height

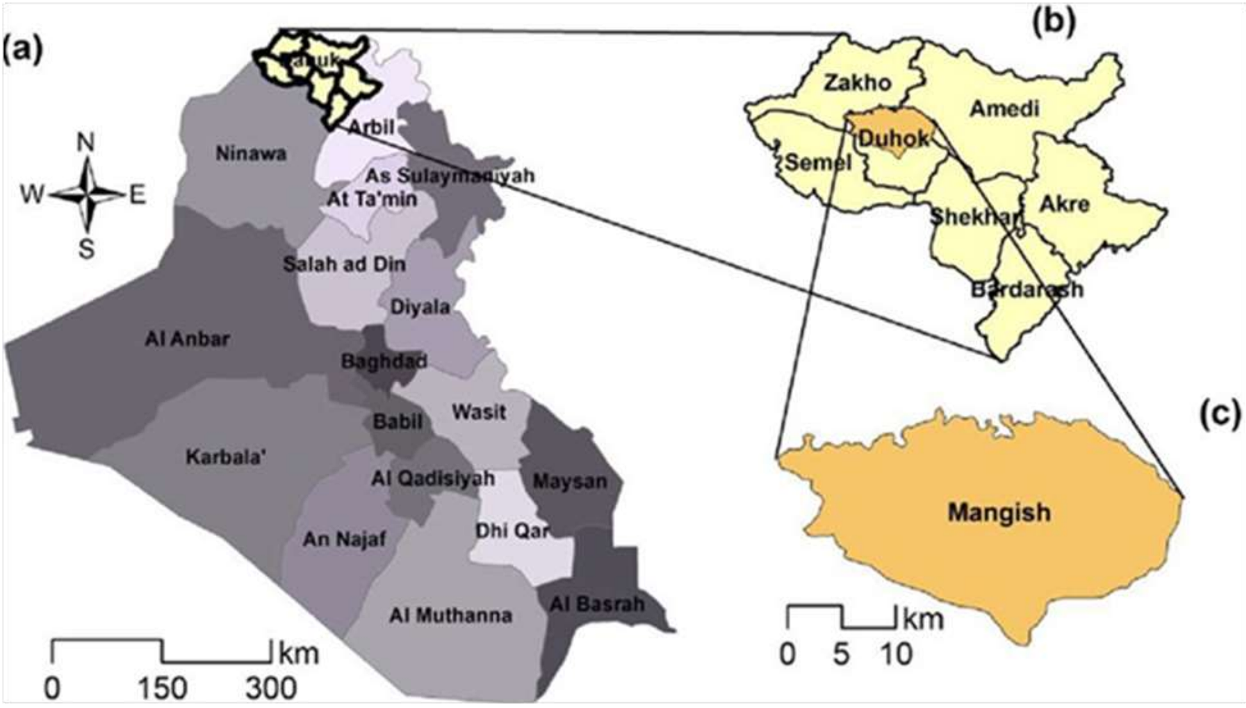

Fig 1. Map of Dohuk province showing region surveyed.

A- Morphological Properties of Wood

1. Tree Height: Tree height was determined using Haga altimeter

2. Diameter at Breast Height (DBH): Diameter of the trees was measured in cm with the help of tree caliper. It was measured at two axes which were at right angle to each other and mean value was taken as DBH (diameter at breast height).

3. Bark Thickness: Bark thickness was measured using Verner clipper digital and the average of two perpendicular measurements to the nearest 1 mm was taken for this purpose, and bark percent was measured after the procurement of logs from the site. Bark thickness was measured with the help of measuring scale and bark percentage and was calculated as the difference between total disk area and disk area without bark (20).

4. Wood Percentage: Wood per cent was measured according to Heena (20).

5. Sapwood and Heartwood Percentage: For the macroscopic description, a 30-cm thick slice obtained at 1.30 m above ground level was used. From the slice, the cross section of the disks was polished (sequence of sand papers. The boundary between heartwood and sapwood was separated depending on wood color, it was very clear due to their distinct color, the heartwood was brown color which sapwood white to yellow color a marked with a fine-tipped pen. The total disk area without bark, sapwood area and heartwood area and ratio were then determined using a planimeter device (to the nearest mm). Wood disk diameter without bark of Valonia Oak trees at DBH was measured first along the largest diameter and then perpendicular to it. Next, heartwood and sapwood cross-sectional area (cm^2) were calculated as geometric circle.

6. Growth Increment: Discs were treated with sand paper in order to obtain a more conspicuous view for annual rings. The discs were installed on wooden basement for imaging purpose, which were done with a high-resolution camera (Nikon Digital Camera D3100). The images of obvious wood disk were transferred to computer to be used for measuring and calibration the annual ring by using a CDendro 9.0.1. software program along with Cybis coordinate recorder. Growth rings were counted in each disk and took every other ring from pith toward bark from each tree. The early- and latewood were collected together and the average ring width was calculated by dividing the average disk radius by the number of rings, (Table 1).

Table 1. Dimensions of *Quercus aegilops* L. trees

Tree NO.	Tree Height (m)	Over Diameter of Tree at DBH (cm)	Under Diameter of Wood Disk at DBH without Bark (cm)	Bark Thickness (mm)	Annual Ring Width (mm)	Tree Age (Years)
1	8.70	21.06	19.45	8.1	4.89	26
2	10.60	21.74	20.30	7.2	4.10	27
3	11.70	22.18	20.60	7.9	4.03	33
4	7.90	23.88	21.50	11.9	3.56	33
5	16.20	24.44	22.90	7.7	5.50	25
6	18.30	25.48	22.70	13.9	2.47	71
7	11.90	27.78	25.20	12.9	4.32	38
8	13.60	28.22	26.60	8.1	2.68	57
9	17.60	31.88	28.90	14.9	2.35	85
10	19.80	33.72	30.60	15.6	2.49	79
Average	13.63	26.04	23.88	10.8	3.64	47.40
Max	19.80	33.72	30.60	15.6	5.50	85.00
Min	7.90	21.06	19.45	7.2	2.35	25.00
ST.D	4.15	4.30	3.81	3.35	1.11	23.43

B- Physical properties

To evaluate the physical properties, the wood parameters were determined by using standard sized test specimens i.e. (2x2x3) cm, according to American Society for Testing and Materials (4) to study: -

1- Moisture content (%)

Fresh weight of the samples was recorded just after they were cut from the logs. After initial weighting, the samples were oven dried first at 60C^o for few hours and then at 105±2^{o}C till constant weight. The weight of samples was recorded as oven dried weight (g). The moisture per cent of the samples was calculated by using the formula according to Akyildiz and Kol (2).

2- Specific gravity

Specific gravity was determined based on oven-dry weight and dry volume of wood specimens. Following the ASTM D 2395 (5):

3- Basic density was calculated by the gravimetric method: (18).

4- Volumetric shrinkage and **volumetric swelling** were determined according to the method described by Akyildiz and Kol (2).

5- Fiber saturation point (FSP) and maximum moisture content (MMC) were determined according to the method described by Korkut and Guller, (26) and Akyildiz and Kol, (2).

6- Percentage of the cell wall and **percentage of the porosity** were determined according to the method described by: Korkut and Guller, (26).

C- Anatomical properties of wood

Some matchstick sized chips were carefully cut from growth rings 16 - 20 starting from the pith to avoid juvenile wood were macerated using Franklin solution (15). Twenty measurements of **fiber length (FL), fiber diameter at the mid-point of the fiber (FD), fiber lumen width (FLW), fiber double wall thickness (FT), vessel length (VL), and vessel diameter (VD**) were recorded for each tree, and measured under 100× magnification and under 400× magnification using Olympus microscope connected to DinoXcope digital camera. For pulp wood quality indexes were calculated based on the following relationships given by Dadswell *et al*., (11) and cited by Villaseñor-Araiza and Rutiaga-Quiñones (48): **Slenderness ratio** =FL / FD, **Runkel index** = 2FT / FLW, **Stiffness coefficient = (2FT / FD)** and **Flexibility coefficient** = (FLW/FD) was studied.

Statistical analysis

Descriptive statistical analysis was conducted to determine the maximum and minimum values, means and standard deviations for all properties that measured.

RESULTS AND DISCUSSION

MORPHOLOGICAL PROPERTIES

Significant variability was found in bark thickness and bark percentages between trees and within tree. Average bark thickness at a height of 1.3 m was 10.8 mm and a ranged between (7.2 – 15.6) mm, while bark percentage averaged 8.22% with ranged of (5.74 – 10.91%). It can be shown from Table (1, 2) and Figure (2, 3) the bark thickness and its percenters increased with increasing the diameter and age of trees, the maximum value of bark thickness and percentage were found in higher tree diameters and older trees more 70 years while minimum values were found in smallest tree diameter less 30 years ages. Figure 2, appears that the linear effect of age and DBH was significant for the bark thickness. Table 3, reverse to the wood percentage were decrease with increase the diameter and age of trees, with reneged from 89.09 to 94.26% with average value 91.78%. Similarly, Viherä-Aarnio and Velling (49) they found the bark thickness was decreased with increasing seed origin latitude and increased with increasing tree DBH. Bark thickness is associated with geographic factors, as with availability of moisture, diameter and age of the tree (44). The wood structure of trees were varies by species, within each species, between trees, and even among the specimens. They can vary from the pith towards the exterior or from the base of the trunk to the crown (53 and 37).

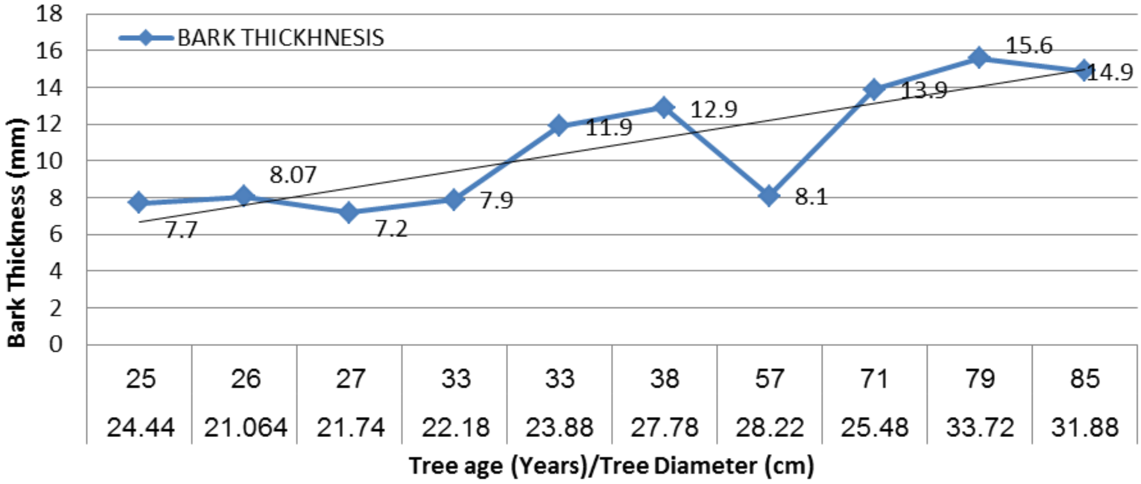

Fig 2. Relationship between bark thickness with trees diameter and age at DBH

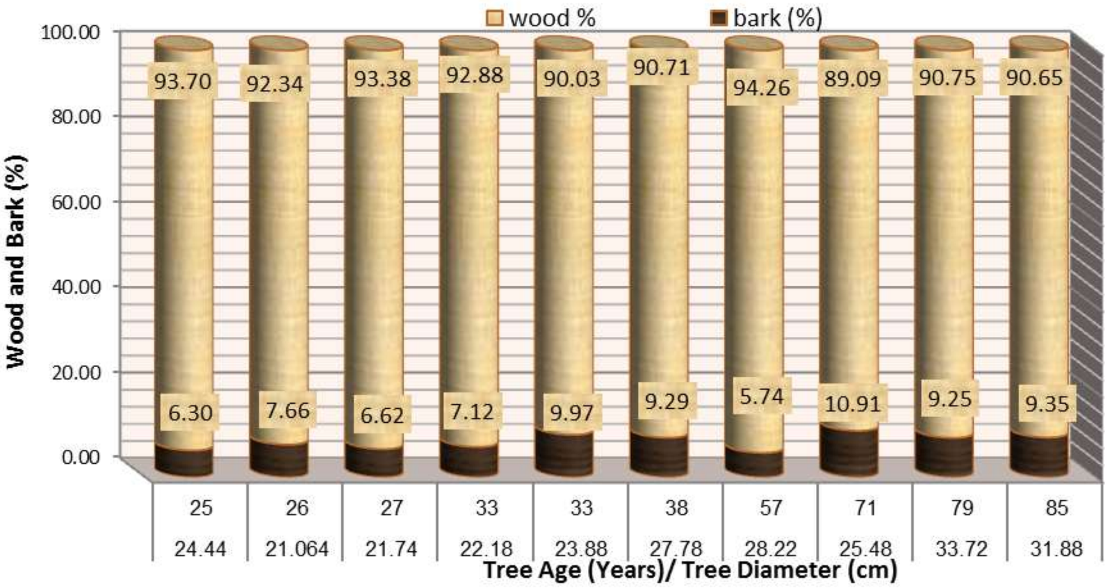

Fig 3. Relationship between bark, wood percentage with trees diameter and age at DBH

The growth rate of *Q. aegilops* trees varies from 5.50 to 2.35mm, with an overall mean of 3.64 mm per years (Table 2). Also, the results revealed that average mean annual ring width for ten trees was 3.17 with maximum ring width of 10.15mm and minimum ring width was 1.23mm (Table 3). More variability in ring features is encountered within trees and between trees. These measurements of ring width indicate a very low radial rate of growth of this species. The high variability in an average ring width may cause production of heterogeneous wood in terms of lumbers and it is influenced by different factors, as the fluctuation in the environment (54). Investigation of the pattern of mean ring width, earlywood ring, and latewood ring variation from the pith to the bark of one tree at age 26 years (Figure 4) proves that they are wider within the pith area, more than elsewhere, but slightly decreased to attain more or less constant width, then decreased apparently near the bark. The ring width change from pith to bark is found to resemble ring width of Valonia oak (42) and also by Al-Atroshy (3) in Gall oak in Dohuk province. Latewood and earlywood rings are found to be correlated strongly to the annual growth increment width, but latewood width is found to be more sensitive to the increase in width of the growth increment than the earlywood ring. Figure 5, shows there were a negative correlation between tree age and mean annual growth. Zhang and Zhong, (52) and Zhang *et al.*, (51) found the ring width declines with cambial age as well, cambial age explains more of the variation in wood density than does ring width.

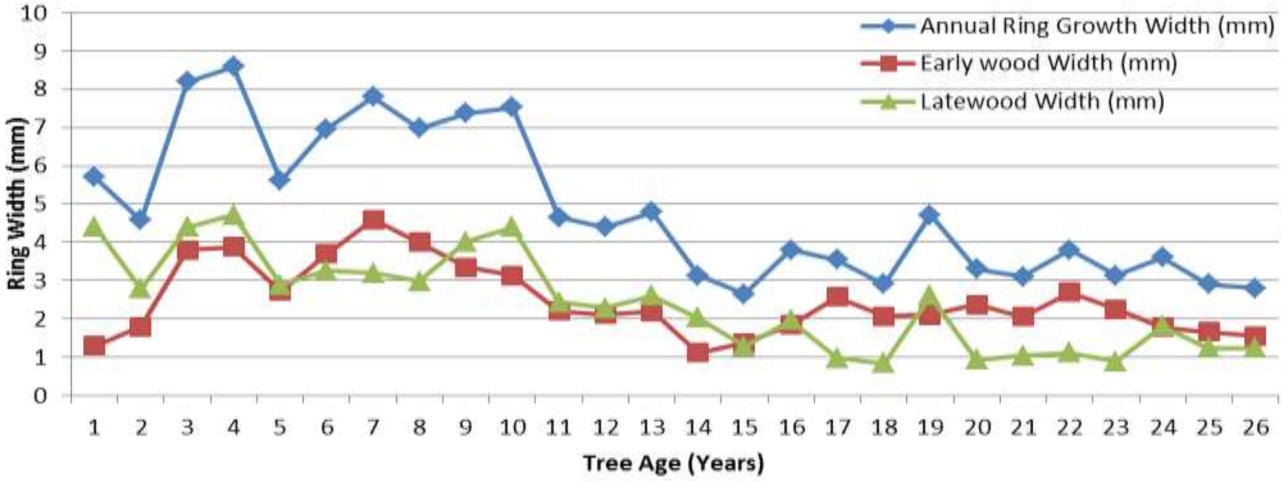

Fig 4. Annual Ring width, Earlywood and Latewood Changes from Pith to Bark *of Quercus aegilops* L. trees

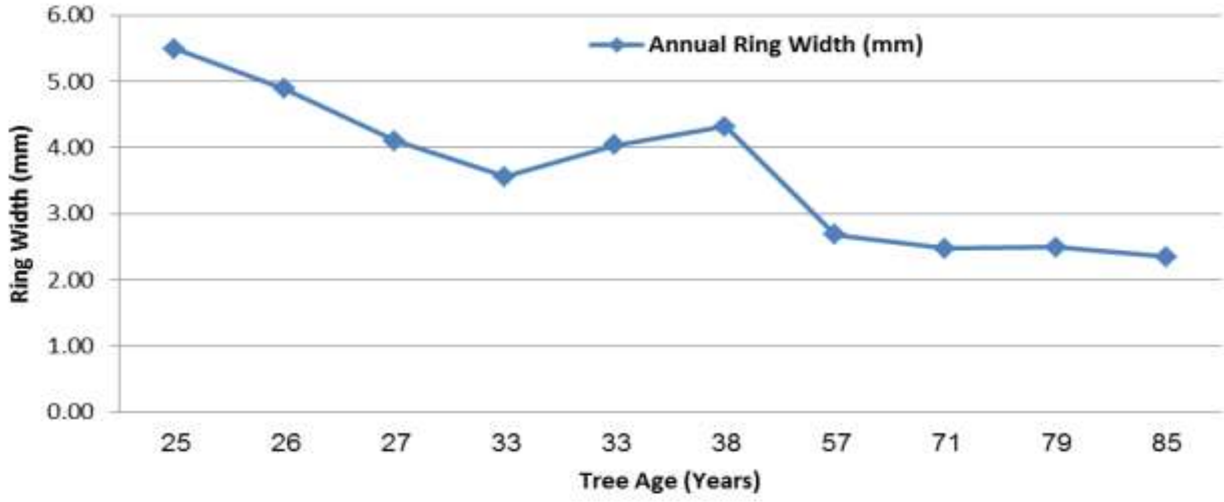

Fig 5. Relation between mean annual ring growth width with tree age.

Cross-sectional area of wood, heartwood, and sapwood at DBH varied among samples taken from various trees. All studied trees appear to be a difference in the proportions of heartwood and sapwood (Table 3), the highest heartwood proportion of total wood area at DBH was 76.32% with lowest values of 42.01% with average value of 61.46%. The proportion of sapwood ranged between 23.68 to 57.99% of the total wood area, with a mean value of 38.54%. Figure 6, showed that the heartwood percentage increased with increasing age and tree diameter, while the percentage of sapwood decreased with increasing the tree age and diameter. This result was in agreement with that reported by EL-Juhany (14) and Pérez Cordero and Kanninen (35), as well as with others reports in different species (30; 32; 29; 1; and 39).

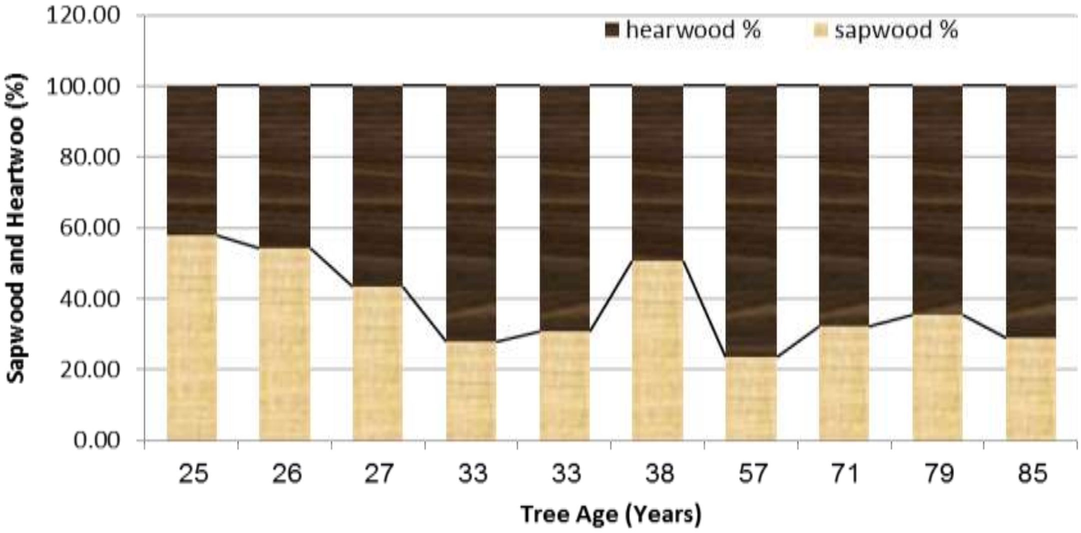

Fig 6. Relation between tree age with sapwood and heartwood percentage

Table 2. Morphological properties of *Quercus aegilops* L. trees

Tree NO.	Wood Area (cm^2)	Sapwood Area (cm^2)	Heartwood Area (cm^2)	Wood (%)	Bark (%)	Sapwood (%)	Heartwood (%)
1	61.13	33.16	27.97	92.34	7.66	54.24	45.76
2	63.80	27.66	36.14	93.38	6.62	43.35	56.65
3	64.74	19.80	44.94	92.88	7.12	30.58	69.42
4	67.57	18.86	48.71	90.03	9.97	27.91	72.09
5	71.97	41.74	30.23	93.70	6.30	57.99	42.01
6	71.34	22.94	48.40	89.09	10.91	32.16	67.84
7	79.20	40.23	38.97	90.71	9.29	50.79	49.21
8	83.60	19.80	63.80	94.26	5.74	23.68	76.32
9	90.83	26.40	64.43	90.65	9.35	29.07	70.93
10	96.17	34.26	61.91	90.75	9.25	35.62	64.38
Average	75.04	28.48	46.55	91.78	8.22	38.54	61.46
Max	96.17	41.74	64.43	94.26	10.91	57.99	76.32
Min	61.13	18.86	27.97	89.09	5.74	23.68	42.01
ST.D	11.98	8.49	13.50	1.74	1.77	12.36	11.82

Physical properties

The data on physical properties of *Q. aegilops* wood are presented in Table 3, and revealed a significant variation among trees studied. The maximum and minimum values of wood specific gravity were 0.859 and 0.746, respectively, with an overall mean of 0.811. Similar results were found by Cox *et al.*, (10); AL-Atroshy (3) and Jayawickrama *et al.*, (25). While, the basic density value ranged from 0.711 to 0.779 g/cm^3 with an average of 0.736 g/cm^3. According to Chowdhury and Ghosh (9) for classifying wood on the basis of specific gravity the wood of the present study is classified as heavy wood tree spices. The descriptive statistics given in Table 3, indicates there is a significant variation in wood density among different oak trees in the natural stands. Bastin *et al.*, (6) investigate that the wood specific gravity varies widely between and within species and also within individual trees. Moreover, due to environmental and genetic influences, wood specific gravity varies among trees of the same species. In the present study, the data related to moisture content was presented in Table 4. It appears a significant variation among Vilonia oak. The average and range value of moisture content and maximum moisture content were 39.25 (34.34 to 45.33%) and 68.58 (60.75 to 73.77%), respectively. Moreover, the mean values of volumetric shrinkage and swelling percentage were 10.43% and 11.69%. It appeares that *Q. aegilops* wood shrinks and swells less than other strong species and indicate a higher dimensional stability of the wood. Most of the physical and mechanical properties of wood such as hardness, weight, impact resistance, and shrinkage rates are directly related to density (38). While, Bowyer and Smith (7) noticed that some wood properties that are closely related to wood specific gravity are strength, dimensional stability with moisture content change, ability to retain paint, fiber yield per volume, suitability for making particleboard and related wood composite material and suitability as a raw material for making paper. On the other hand, fiber saturation point was 14.33%. The FSP according to the average is classified as low (40). Wood with a high content of extracts has a relatively low fiber saturation point (34). Which differ in values reported for *Q. convallata* Trel. (22), *Q. suber* L. (28), and *Q. macdougallii* Martínez (39). Moreover, it was noted that *Q. aegilops* has a very high proportion of the cell wall (55.24%). Therefore, it has a low ratio of porosity (44.76%). The extractives in this species are mainly located in the cell lumen and they fill empty spaces in the wood and thus decrease the porosity and thereby increase the specific gravity. Even the variable lignin deposition in the cell wall resulted in an influence the specific gravity of wood. Porosity and thickness of cell walls causes variation in the density between wood species, within a species, and between earlywood and latewood growth (13). The thickness of the walls gives it weight and the hardness necessary for use in construction (24).

Table 3. *Descriptive statistics for physical* properties studied of *Quercus aegilops* L. wood

Properties	Mean	Maximum	Minimum	Standard Deviation (ST.D.)
Basic Density (g cm^{-3})	0.7363	0.7790	0.7114	0.0167
specific gravity	0.8115	0.8590	0.7467	0.0279
Annual Ring growth width (mm)	3.17	10.15	1.23	1.66
Moisture content (%)	39.258	45.331	34.343	2.382
Maximum moisture content (%)	68.5876	73.7725	60.7582	3.2843
Volumetric shrinkage (%)	10.43	12.21	6.48	1.32
Volumetric swelling (%)	11.6985	14.0276	8.3814	1.4589
Fiber saturation point (FSP) (%)	14.2235	17.7710	8.8721	2.0220
Cell wall (%)	55.240	57.9256	53.3192	1.2870
Porosity (%)	44.760	46.6801	42.0743	1.2870

Anatomical properties

Fiber dimensions and wood density are related to many structural, physical and chemical properties in wood. According to Hughes and Alburquerque-Sardinha (23) the sizes of fiber affects in many wood-product industrial, like pulping process, behavior in the drying process and resistance to cutting and machining. It was indicated from Table 4, there is a variation in fiber and vessel dimensions in this study between different Oak trees. The overall mean values with of fiber length, fiber diameter, double cell wall thickness, and fiber lumen width were 1.014 mm, 15.542µm, 6.288µm, and 9.254µm respectively. Moreover, the mean values of vessel length and vessel diameter were found to be 0.545 mm and 179.806 µm respectively. The dimensions of fibers and vessels are the most important characteristic for the variability of wood. Such differences in fiber dimensions, no doubt is the result from genetic and environmental interaction (G*E interaction). The structure of the wood varies between species and between individuals within species and even in the specimens. They can vary from the pith towards the exterior or from the base of the trunk to the crown (53, 37). The variation may be due to genetic, physiological or silvicultural treatments (31). However, many researchers insist that fiber dimensions are controlled primarily by changing cambial initials and pressures developed during various stages of growth (43). The fibers dimensions intervene in the physical and mechanical behavior of the wood, where the total volume and the thickness of the cell wall directly impact the density. Species with thick walls have high density (17). And there is a close relationship between the wood density and cell wall thickness and is negative relationship between wood density and vessel (36). Therefore, the greater the length the greater the resistance (12). Also, similarity it was reported that fiber length, fiber diameter and vessel dimensions for the wood of *Q. infectoria* Oliv. (3), *Q. obtusata* (8), *Q. polymorpha* (17), and *Q. macdougallii* (39). Significant differences were found in the pulp wood quality indices for paper of samples (Table 4), for the Runkel index, data ranged from 0.168 to 2.979 with mean value 0.867. While, the average value of the slenderness index was 68.841. The average value of the coefficient of flexibility was 0.578, the results close to *Q. obtusata* (0.45) (47) and *Q. macdougallii* is 0.47 (39). The mean value of the stiffness coefficient was 0.421, and the thickness of the cell wall is classified as thick. Studying the morphological characteristics of fibers should assist in understanding and interpreting the behavior of wood products (46).

Table 4. *Descriptive statistics for anatomical* properties studied of *Quercus aegilops* L. wood

Properties	Mean	Maximum	Minimum	Standard Deviation (ST.D.)
Fiber length (mm)	1.014	1.544	0.398	0.209
Fiber width (µm)	15.542	35.782	8.419	4.317
Fiber double cell wall thickness (µm)	6.288	17.976	2.004	2.276
Fiber lumen width (µm)	9.254	27.964	2.116	4.116
Vessel length (mm)	0.545	3.730	0.323	0.2515
Vessel width (µm)	179.806	326.910	84.612	47.503
Runkel index	0.867	2.979	0.168	0.562
Slenderness ratio	68.841	152.915	26.416	22.741
Flexibility coefficient	0.5787	0.8564	0.2513	0.1498
Stiffness coefficient	0.4213	0.7487	0.1436	0.1498

CONCLUSION

Investigation of morphological, physical and anatomical properties of wood is important for application of wood as a raw material. This study leads to the following conclusions:

1- This species has thick bark and the bark thickness and percentage increase with increase the age and diameter of Oak trees

2- Sapwood and heartwood percentage varied between trees and influenced by tree diameter and tree ages.

3- Basic density and specific gravity are classified as heavy, hard, dense and strong wood. superior mechanical properties could be expected. Based on its physical properties, the wood can be used in different manufactures and constructions

4- It appeared that *Q. aegilops* wood less shrinks and swells than other strong species; also content little moisture content therefore was indicating a higher dimensional stability of the wood.

5- Fiber length is a wood-quality parameter of important to pulp and paper making. The fibers (fiber length > 1mm) and cell well are thick consequently are classified as good for paper.

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