# Radial variation in some physical and anatomical wood properties of *Platanus orientalis* L. from different sites in Duhok province

Hilbeen Ibrahim Abdullah1 and Hishyar Hazim Suliman2

1,2Forest Department / College of Agricultural Engineering Sciences / University of Duhok

* Corresponding author: hilbeen.abdullah@uod.ac

Abstract

*Platanus orientalis* L. (Oriental plane) is a socio-ecologically important tree species that provides valuable ecosystem services across diverse climatic zones, including the Kurdistan Region of Iraq. This study investigated radial variations in selected physical and anatomical wood properties to support optimal utilization and improve understanding of intra-tree variability. Nine trees were sampled from three ecologically distinct sites in Duhok province. Tree characteristics varied in age at diameter at breast height (DBH; 20–25 years), height (10.60–16.50 m), crown width (4.82–10.40 m), and DBH (20.25–26.50 cm). Wood discs were collected at DBH, and radial measurements were taken from pith to bark. Significant differences ($p < 0.05$ to $p < 0.001$) were observed in both physical and anatomical traits. Physical properties included growth ring width (GRW: 1.30–11.85 mm), earlywood width (EWW: 0.30–8.02 mm), latewood width (LWW: 0.53–7.70 mm), specific gravity (SG: 0.455–0.710), volumetric shrinkage (VS: 1.69–10.36%), and saturated volumetric shrinkage (VSW: 1.90–11.56%). Anatomical traits varied in fiber length (FL: 0.287–2.80 mm), fiber width (FW: 4.88–39.80 μm), lumen diameter (FLU: 3.34–24.17 μm), double cell wall thickness (DCWT: 3.82–26.83 μm), vessel element length (VEL: 0.104–0.941 mm), and vessel element diameter (VED: 26.89–222.27 μm).GRW decreased from pith to bark, while FL, FW, and VED increased. VS and VSW rose from the pith before slightly declining near the bark. Variations were significantly influenced by site, tree, radial position, and site × tree interactions. Understanding these patterns is crucial for selecting quality trees and enhancing sustainable wood utilization.

Key word: *Platanus orientalis* L. physical, anatomical wood properties, radial variation

ISSN 2072-3857

Introduction

Wood is a versatile and widely used natural material, valued for its mechanical strength, aesthetic appeal, and renewable nature. However, wood exhibits significant variations in its anatomical, physical, and chemical properties, which can influence its suitability for specific applications. It is remained an important substance throughout history because of its unique properties and has been used as a most versatile constructional material for thousands of years [51]. According to [41] the variations in the properties of the wood raw material supply affect the quality of the end-products produced by wood properties, which in turn affects their profitability. The biological nature of wood makes it a highly variable material [46,70]. The wood formation and properties within trees vary with both time of growth and tree age [6,7].

For a given species, wood properties show genetic, intra-tree, inter-tree, and inter-site variation [23,69]. The wide variability in wood characteristics makes it difficult to evaluate wood performance precisely. Understanding the variability of wood features (i.e., density and growth) of a species not only allows the comprehension of wood development conditions but also enables the improvement of wood quality, processing and use [23,33]. [5] found the complete knowledge of geographic variation within a species is essential for developing effective tree improvement programmes.

Among wood properties, wood density is considered the most important due to its correlation with other physical properties such as mechanical strength and workability [31,38]. [37] evidenced that wood density is extremely variable among species, sites, and between and within tree. Wood is desirable, for wooden structures that require wood density uniformity, wood density is a wood quality indictor related to numerous morphological, physiological, mechanical, and ecological properties [7]. Radial variation is a term used to describe changes in wood properties along the radius or annual rings. It plays a crucial role in understanding the variability of wood properties during tree growth and essential for distinguishing between juvenile and mature wood [35]. Therefore, is a better understanding of wood variability within a tree species would be useful for both wood quality and efficient wood use.

*Platanus orientalis* L. commonly known as Oriental plane or Eastern chenar belongs to Platanaceae family. It is native to southeast Europe and southwest Asia [61]. Oriental plane tree which have been included only one genus with (6-10) species of tall trees [29]. Is a large monoecious tree with a spreading crown and growing up to height with 30 m. This species is a native and common species in Kurdistan region-north of Iraq, it found naturally along river valleys, streams, in moist mountain valleys, in altitude vary 600-1200 m. and absent from the rolling foothill region [53].

*P. orientalis* It is considered a great importance for provision socio-ecological and various ecosystem services in world. Accordingly, to [64,17] it is vital element of riparian ecosystems, supporting the conservation of soil and water and maintaining biodiversity and ecological integrity. With its resistance to diseases and tolerance to air pollution and different mechanical disturbances, it is also an integral part of cultural life. Hence, the decrease in the distribution area of *P. orientalis* would result in the degradation of many ecosystem services (i.e., flood and erosion control, carbon sequestration, aesthetic, and cultural values). In additions it’s very important to improve

microclimate and environmental conditions. Also, the Oriental Plane its widely used in landscape design in our country (urban open green spaces – parks-arboretum, water fronts, industrial areas, shade bearer, street tree) and has numerous examples protected as natural monumental trees [68]. Moreover, is a medicinal tree, the leaves and barks used in folklore and traditional medicine as a pain, inflammation reliever, diarrhoea, dysentery, hernias and toothache [24,12].
The timber, often called lacewood, its locally and universal desirable used in many industries and carpentry wood working for small boxes, trays, and similar articles which are lacquered and painted; also used for cabinet –making, furniture, veneers, carving, coach-building and general turnery and for wood pulp; suitable for boot lasts [21,19]. Since knowledge of variations wood properties and wood quality very important in recent years. Therefore, this study aimed to analyze the radial variation from the pith to the bark of some physical and anatomically of wood properties within, between trees, and site as a contribution to the technological knowledge of the wood in this species.

## Materials and Methods

### 1. Site determination and tree selection:

For this study, three natural sites of *P. orientalis* were selected representing various physiographic regions or location in Dohuk province / Kurdistan region of Iraq. (Table 1 and Figure 1). These included those originating from Chamanke, Sarsink and Deraluk. Three matured trees from each sites with tree diameter (20-25 cm), which they normal and healthy in terms of trunk and crown formation, displayed natural wood color, had fibers parallel to each other that did not show curling, and finally, that they were not suffering from insect or fungal damage. Care was taken to ensure that the trees were representative of the region.

ISSN 2072-3857

Table 1 . Site and physiographic data of location surveyed

| Location | Longitude (N) | Latitude (E) | Altitude (m) | Slope (%) | Aspect | Stand Density (Tree/100m$^2$) |
|---|---|---|---|---|---|---|
| Sarsink | 43°16’ 58.30480″ | 37°1′ 28.25320″ | 1070 | 18-22 | N | 85 trees/100m$^2$ |
| Chamanke | 43°24′ 53.66950″ | 36°56′ 52.00220″ | 920 | 15-18 | N-E | 90 trees/100 m$^2$ |
| Deraluk | 43°40′ 32.05170″ | 37°2′ 27.82640″ | 597 | 10_15 | E | 95 trees/100m$^2$ |

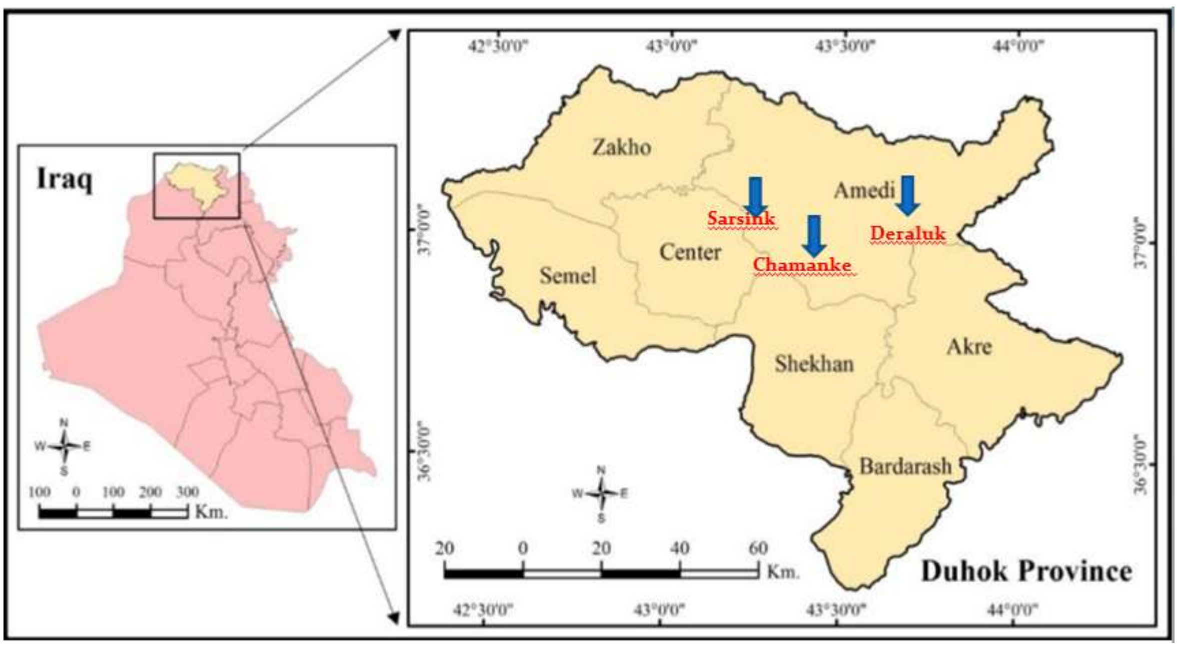


Figure (1). Map of Dukok province of Kurdistan region-Iraq, showing the tree different sites of the study.

2. Wood Sample preparation:-

For study the radial variation of some physical and anatomical wood properties, discs of approximately 15 cm thickness were it allowed to cut from the trunk at DBH of each felled tree for measuring following wood characteristics:-

A- Morphological Properties of Wood:-

1. Tree Height: Tree height was determined using Haga altimeter
2. Diameter at Breast Height (DBH): The diameter of the trees was measured using a tree caliper. The north direction of all trees was also indicated.
3. Bark Thickness: Bark thickness were measured by Verner calipper digital and the average of two perpendicular measurements to the nearest 1 mm was taken for this purpose, and bark percent were measure after the procurement of logs from the site. Bark thickness were measured with the help of measuring scale and bark percentage and calculate as the difference between total disk area and disk area without bark [25].
4. Free stem length (m).
5. Crown width and length were measured for all trees . Crown width was measured along two perpendicular axes using a measuring tape, and the average value was taken. Crown length was calculated using a Haga altimeter by subtracting the height of the lowest living branch from the total tree height.
6. Growth Increment and age: Discs were treated with sand paper in order to obtain a more conspicuous view for annual rings. The growth ring width (GRW), earlywood (EWW), latewood width (LWW), earlywood percentage (EW%), and latewood percentage (EW%) were measured using an electronic or verner caliper (0.01 mm of resolution) in each disc. Growth rings

ISSN 2072-3857

were counted in each disk and took every other ring from pith toward bark from each tree to measure the age of trees at DBH.

B. Physical properties:-

To evaluate the physical properties, the wood parameters were determined by using standard sized test specimens i.e. (2x2x3) cm from pith to bark, according to American Society for Testing and Materials (2003) to study: -

1- Specific gravity (SG) Were determined according to the method described by ISO 4471, 1982, from pith to bark, by using the following equation:

$$SG = M_0/V_0.$$

Where the ($M_0$) is the oven-dry weight of the samples and ($V_0$) is the dry volume of the samples.

2-Volumetric shrinkage (VSH) and volumetric swelling (VSW): Were estimated according to the method described by to (ISO 13061-15:2017 and ISO 13061-16:2017) in succession by the Following equation:

$$VSH= (Vs – V0) / Vs(\%)$$

Where Vs is saturated volume and V0 is oven-dry volume. While the volumetric swelling (αv) were determined by the following equation: VSW= (Vs – V0) / V0 (%).

(Vs) is saturated volume and (V0) is oven-dry volume.

C. Anatomical characteristics of wood

Wood pieces from each five-growth ring from the pith to bark were used to measure wood cells' dimensions by using the maceration method (20). The strips piece of the wood was cut and putted into the test tube. The equal amount of glacial acetic acid ($CH_3COOH$) and hydrogen peroxide ($H_2O_2$) in ratio 1:1 was added to the test tube. The small pieces of stem are put in the oven at 70 ˚C for 24 hrs. The macerate samples later were washed by distilled water to remove the remaining solution, in order to obtain better images on the microscope, the fibers and vessels elements were stained with safranin (1%) and preserved. After that, the following characteristics are studies by using the Olympus microscope of eye piece 10X and objectives 10X and 40X. The 15 readings for each treatment are taken in addition to the average by using a gaged lens. Fiber length (FL), Fiber diameter (FD), Cell wall thickness of fiber (CWT), Vessel element length (VEL), and Vessel element diameter (VED)

Statistical analysis

For the analysis data of physical and anatomical properties in radial variation, analysis of variance (ANOVA) was performed using SAS programs and Statgraphics plus software, for each parameter. Also, descriptive statistical analysis was conducted to determine the maximum and minimum values, means, standard deviations, and coefficient of variation (%) for study the variation for wood properties that were measured.

Results and discussion: -

Wood plays a crucial role in the world because it is an environmentally sustainable material and a renewable resource. Moreover, its properties play an important role in the end uses, due to their effects on the workability and strength of wood. Tables (2) include descriptive statistics for the mean, range, standard deviation and coefficient of variation of the studied wood properties, which show wide variation between sites, trees and within trees. These differences in wood properties from the core to the bark or radial variation are a result of the difference and influence of the cambium age, the tree growth environment and genetic factors among the trees. This variation appears between the trees in wood characters is very important for the selection, breeding programs, and end uses of this species.

ISSN 2072-3857

Table 2. Descriptive statistics for physical wood characters studied of (9) trees in (3) sites of *P. orientalis* trees

| Character | Mean | Max. | Min. | Standard Deviation (ST.D.) | Coefficient of Variation (C.V.%) |
|---|---|---|---|---|---|
| Growth ring width (mm) | 4.702 | 11.850 | 1.300 | 1.865 | 39.666 |
| Early wood width (mm) | 2.522 | 8.020 | 0.300 | 1.195 | 47.362 |
| Latewood width (mm) | 2.173 | 7.700 | 0.530 | 1.141 | 52.513 |
| Early wood width (%) | 53.543 | 80.780 | 20.729 | 12.714 | 23.745 |
| Latewood width (%) | 46.457 | 79.271 | 19.220 | 12.714 | 27.366 |
| Specific gravity | 0.601 | 0.455 | 0.710 | 0.455 | 10.390 |
| Volumetric shrinkage (%) | 4.147 | 1.694 | 10.367 | 1.532 | 40.835 |
| Volumetric swelling (%) | 4.368 | 1.904 | 11.565 | 1.556 | 43.589 |

1-Physical properties:-

**A.** Growth rate:

Table (2 and 3) and figures (2 and 3) summaries the results of the variation of GRW, EWW, LWW, EW%, and LW% between sites, tree to tree, and within trees in radial position indicated there ware high significant variations. The mean value of GRW varies from 11.85 to 1.30 mm, with an overall mean of 4.70 mm. While the mean value of EWW varies from 8.02 to 0.30 mm, with an overall mean of 2.52 mm, while the mean value of LWW varied from 7.70 to 0.53 mm with an overall mean of 2.17 mm, moreover, the EW% ranged from 80.78% to 20.72% with overall mean 53.54%, the maximum and minimum percentage of LW was 79.27% and 19.22% respectively, with overall mean 46.45%. These measurements of mean ring widths of this species indicate are a medium rate growth. Contrary to [58], found value rate of growth was (6.133 mm) for the same species of Platanus trees in Duhok province. The maximum ranges of GRW, EWW, and LWW were observed in Deraluk sites (Table 3). This may be caused by the occurrence of different patchy habitats throughout the site. More variability in ring features is encountered within Chamanke, Sarsing, and then Deraluk sites. High variability in GRW, EW%, and LW% in radial may cause production of heterogeneous wood in terms of lumbers, also effects on final productions, value and end users of the wood. The variation in growth rate returns to the variation of the temperature degree and growth season length between different sites, and this consider important factors to determine the time available to trees for the completion of growth, maturation of tissues and the setting of buds which differ between trees in different altitudes.

Further, results in analysis of variance (Table 4) reveals that there were statistical significant differences in the width of the growth ring and spring and autumn wood between sites, as well as between trees within a site and within a single tree and interaction between them. Moreover, an analysis of variance component also in (Table 4) reveals that sites and interaction between sites and trees variation account for most of the total variation in growth ring properties.

Investigation of the pattern of mean GRW, EWW, LWW, EW%, and LW% in radial variation at DBH from the pith to the bark (Figure 3 a and b) proves there were high variability in growth rate, the wider ring growth within the pith area, more than elsewhere, but slightly decreased to attain or less constant width, then decreased near the bark. This demonstrates there were variations and interactions in the growth of trees between the different sites. This variation in ring growth width between different sites may be due to the variations in age of trees, competition between trees in the forest, environmental and site factors. According to [57] how investigated that the growing ring width is highly variable as it is controlled by a variety factor such as locations environment fluctuations, competition for resources of nutrients or sunlight, number and age of the trees used

ISSN 2072-3857

in his study. This information on growth ring width variation is important in forest tree management and wood utilization, since it can facilitate tree growth and quality of wood.

The width of the annual growth ring decreases and changes with age; however, the change in ring width due to age, from the core to the bark, does not result in the same amount of change in the thickness and percentage of earlywood and latewood, as seen in the difference between successive growth rings, due to environmental and genetic reasons. Genetic and environmental factors may be the cause of growth ring width decrease from pith to bark conferring to [22]. On the other hand, [28] suggested that the increase in juvenile properties from the butt upwards may be due to auxin gradient theory. The annual ring width change from pith to bark is found to resemble ring width of *P. brutia* by [47] ;Valonia oak by [53]; also by [57] in *P. orientalis* L. and in *M. azedarach* L. by [1] in Dohuk province. The variation in annual ring width because it influenced by different factors, as the fluctuation in the environment [67]. Also [15] reported that the significant differences in growth rate parameters were probably caused by macro-environmental condition, for growth ring width is known to be more susceptible to fluctuation in climatic factors mainly precipitation and temperature, this climatic elements differed significantly between these isolated elevations.

Table 3. Mean± ST.D. values per site and tree for physical properties of *P. orientalis*.

| Tree No. | Wood Properties | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | GRW | EWW | LWW | EW% | LW% | SG | VSH | VSW |
| 1. | 4.66± 2.14bcd | 1.77±0.72 e | 2.89±1.67 a | 39.47±11.21 c | 60.53±11.21 a | 0.64±0.02 b | 3.88±1.07 bcd | 4.05±1.17 bcd |
| 2. | 4.71±2.03 bc | 1.98±0.80 de | 2.73±1.44 ab | 45.79±11.92 b | 54.21±11.92 b | 0.67±0.04 a | 3.71±1.11 cd | 3.87±1.19 cd |
| 3. | 4.83±2.55 bcd | 2.23±1.47 ed | 2.60±1.44 ab | 42.91±10.14 bc | 57.08±10.14 ab | 0.64±0.04 b | 4.53±1.74 bc | 4.79±1.93 bc |
| 4. | 3.91±1.39 de | 2.29±0.793 ed | 1.62±0.72 d | 58.77±8.08 a | 41.23±8.08 cd | 0.62±0.02 c | 3.62±0.47 cd | 3.75±0.50 cd |
| 5. | 5.41±1.53 ab | 3.00±0.75 b | 2.41±1.04 ab | 56.96±10.18 a | 43.04±10.18 cd | 0.64±0.02 b | 5.21±2.38 ab | 5.58±2.71 ab |
| 6. | 3.66±1.42 e | 2.12±0.95 de | 1.40±0.53 d | 59.28±8.02 a | 40.72±8.02 cd | 0.61±0.02 c | 6.42±2.20 a | 6.94±2.54 a |
| 7. | 6.19±1.66 a | 3.91±1.49 a | 2.27±0.69 bc | 62.21±10.55 a | 37.79±10.55 d | 0.48±0.02 f | 3.62±0.86 cd | 3.77±0.94 cd |
| 8. | 4.68±1.41 bid | 2.88±1.18 bc | 1.79±0.49 cd | 60.02±11.44 a | 39.98±11.44 cd | 0.54±0.02 e | 2.97±0.91 d | 3.07±0.97 d |
| 9. | 4.26±1.18 cde | 2.43±0.84 cd | 1.83±0.56 cd | 56.47±8.37 a | 43.53±8.37 c | 0.57±0.02 d | 3.36±0.72 cd | 3.48±0.77 cd |
| Sites | | | | | | | | |
| 1. | 4.73±2.22 ab | 1.99±1.05 c | 2.74±1.50 a | 42.72±11.27 b | 57.28±11.27 a | 0.65±0.04 a | 4.04±1.34 b | 4.24±1.47 b |
| 2. | 4.33±1.63 b | 2.49±0.90 b | 1.81±0.89 b | 58.34±8.76 a | 41.66±8.76 b | 0.62±0.02 b | 5.08±2.16 a | 5.42±2.47 a |
| 3. | 5.04±1.64 a | 3.07±1.34 a | 1.97±0.62 b | 59.57±10.34 a | 40.43±10.34 b | 0.53±0.04 c | 3.32±0.85 b | 3.44±0.91 b |

ISSN 2072-3857

Mean values with the same letter do not differ significant

Table 4. Analysis of variance and components of variance for growth rate of *P. orientali*

| Source of Variation | df | GRW | | EWW | | LWW | | EW% | | LW% | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | P-value | Var.% | P-value | Var.% | P-value | Var. % | P-value | Var. % | P-value | Var. % |
| Sites (S) | 2 | 0.024 | 20.12 | <.0001 | 57.75 | <.0001 | 71.63 | <.0001 | 94.26 | <.0001 | 94.26 |
| Trees (T) | 2 | 0.005 | 28.70 | 0.0016 | 15.38 | 0.149 | 7.49 | 0.6969 | 0.50 | 0.6969 | 0.50 |
| Within Tree (WT) | 24 | <.0001 | 15.20 | <.0001 | 7.27 | 0.0214 | 6.80 | 0.1129 | 1.94 | 0.1129 | 1.94 |
| S*T | 4 | <.0001 | 35.98 | <.0001 | 19.59 | 0.0073 | 14.07 | 0.054 | 3.29 | 0.054 | 3.29 |
| Error | 224 | | 100 | | 100 | | 100 | | 100 | | 100 |

Df= degree of freedom, Var = variance (%)

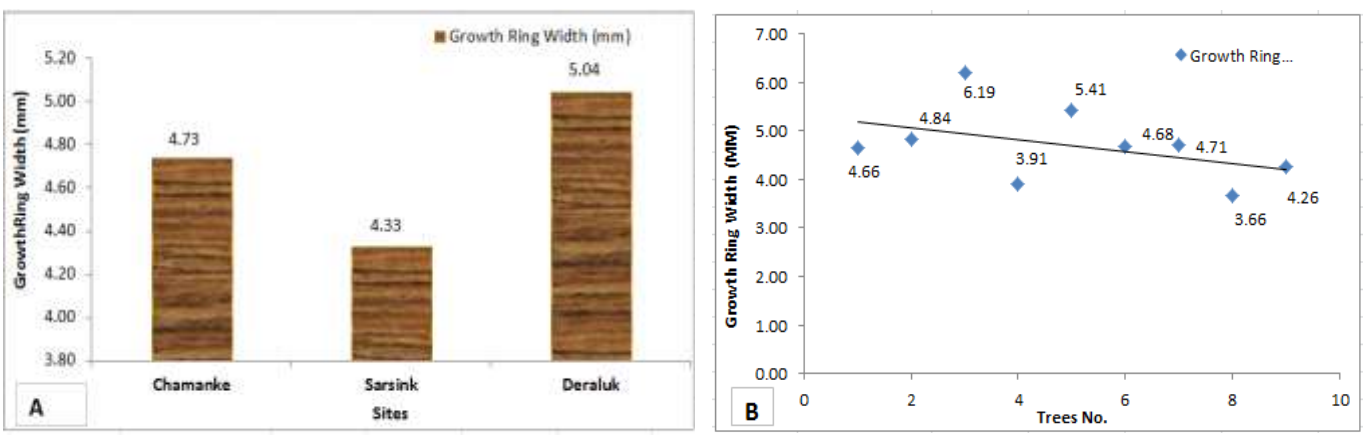


Figure (2). Show the average annual ring width (A) among sites and (B) among trees

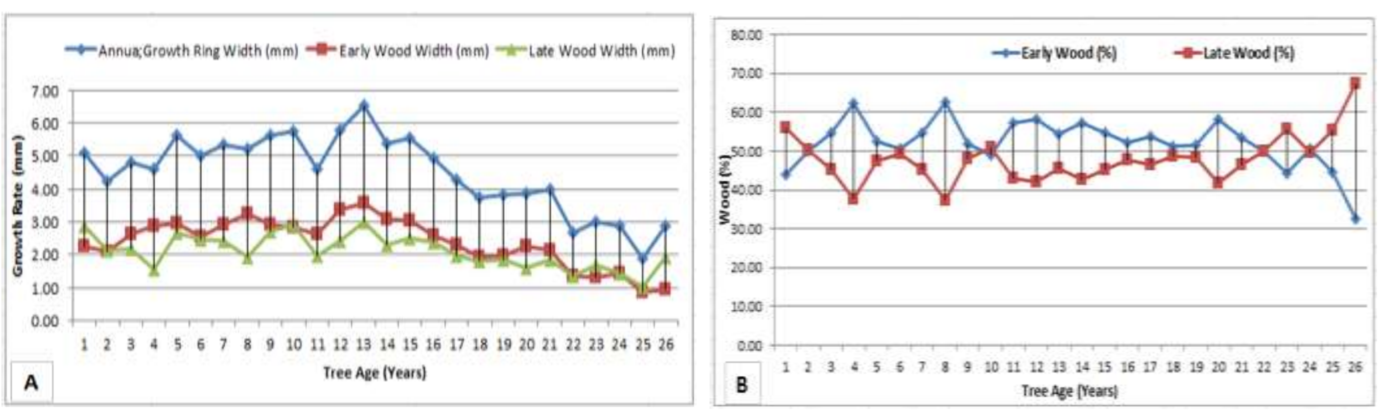


Figure (3). A- Show Annual Ring width, Earlywood width, and Latewood width variation and (B) show variation in Earlywood % and Latewood % in radial direction Changes from Pith to Bark

**B.** Specific Gravity (SG):

One of the most important properties of lignocellulosic wood materials is density due to it is effect on strength, performance and the general quality of final wood products.. Therefore, wood density is fundamental criterion to define the wood technological quality and one of the first to be studied when assessing the potential value of a timber species [18]. The descriptive statistics given in Table (3 and 4) results on oven-dry SG of *P. orientalis* wood indicate a small amount of variability exhibited by SG between within tree, trees and sites. Overall mean value SG was 0.601 it is as classified and considered a moderately heavy wood, with range varies from 0.455 to 0.71 with ST.D. = 0.062 and C.V= 10.39%). The average mean values of the SG of this species were close to what was found by [54,59,27,3]. So, the SG of wood can be quite variable depending on many factors, including the geographic

ISSN 2072-3857

location of trees and moisture content, which varies by species, diameter of tree, age, and stem position. The wood density is not a simple characteristic. It is affected by the cell wall, cell width, the earlywood to latewood ratio, and the chemical content of the wood [9].While, [58] concluded that the tree influenced by different growth conditions, climate, tree developmental stage, and silvicultural treatments, wood density one of the most important and first assessed species-species parameter of wood quality.

According to analysis of variance (ANOVA Table 5) found there are significant differences observed between sites, trees, and within trees from pith to bark and the interaction between them at probability more from 1%. The significant differences observed between trees show the possibility of selection and improvement for increased wood quality.

Differences between sites are found to account for most of the total variation of 82.26%, while differences between trees account for 5.79% and within tree account to 1.56% of the total variation in Table (5) of variance components. Significant between tree variations of wood properties were attributed to genetic and micro-environmental factors. Contrary to [39] what he found that the site was not a significant source of variation of wood density and it was the tree-to-tree variation within a site the most important source of variation, explaining 30% of the total variation. Also, they reported the variation within each site was large for all cases.

Test of means of sites using Duncan's test (Table 3 and Figure 4a and b) reveals that higher value of SG recorded in Chamanke site which differ significant with other sites. For radial pattern of wood density variation from pith to periphery or bark. The results showed there were small variation of SG from the pith to bark, which increased slight and gradual from the pith and then decreases towards the bark (Figure 4c). Conflicting information are available in wood density. These results are consistent with [10], who demonstrated that basic density decreased with distance from the periphery to about 75% radius, and then showed a slight increase towards the pith. [66,15] reported linear increase in wood density from pith to bark. While, [31] found an average decrease of wood density in the first 20 to 30 years with a subsequent stabilization and observed very less variation in density of wood from pith to bark. Although [28] indicated that the wood density and mechanical properties increased from pith to bark, they however decreased from base to top at any particular height. In the other hand, [57] observed that the wood density gradually increased in heartwood from pith but decreased towards the bark in the sapwood in his study in In *M. usitata* and concluded that the increase in wood density may be due to more accumulation of extractives in heart wood. Moreover, [48], also discovered that the species *Drypetes* sp. exhibits higher density near the pith, which gradually decreases as it approaches the bark. The density varied considerably over the radial profile, increasing with cambial age [26], although [2] reported higher density for heartwood than for sapwood. Understanding how density varies in the radial direction of tropical species is crucial, as density ranks among the most significant physical properties of wood and influences various other technology, wood characterless [46].

ISSN 2072-3857

Table 5. Analysis of variance and components of variance for some physical wood properties of *P. orientalis* trees

| Source of Variation | df | SG | | VSH | | VSW | |
|---|---|---|---|---|---|---|---|
| | | P-value | Var.% | P-value | Var.% | P-value | Var. % |
| Sites (S) | 2 | <.0001 | 82.26 | <.0001 | 44.64 | <.0001 | 44.44 |
| Trees (T) | 2 | <.0001 | 5.79 | 0.0181 | 17.51 | 0.0166 | 17.69 |
| Within Tree (WT) | 2 | 0.0015 | 1.56 | 0.3113 | 4.82 | 0.3422 | 4.36 |
| S*T | 4 | <.0001 | 5.54 | 0.021 | 12.78 | 0.0193 | 12.87 |
| S*WT | 4 | 0.3638 | 0.23 | 0.8247 | 1.52 | 0.8444 | 1.39 |
| T*WT | 4 | <.0001 | 3.24 | 0.1164 | 7.86 | 0.1121 | 7.86 |
| S*T*WT | 8 | <.0001 | 1.13 | 0.3628 | 4.54 | 0.3084 | 4.84 |
| Replication | 2 | 0.290 | 0.27 | 0.2169 | 6.35 | 0.2027 | 6.56 |
| Error | 80 | | 100 | | 100 | | 100 |

Df= degree of freedom, Var = variance (%)

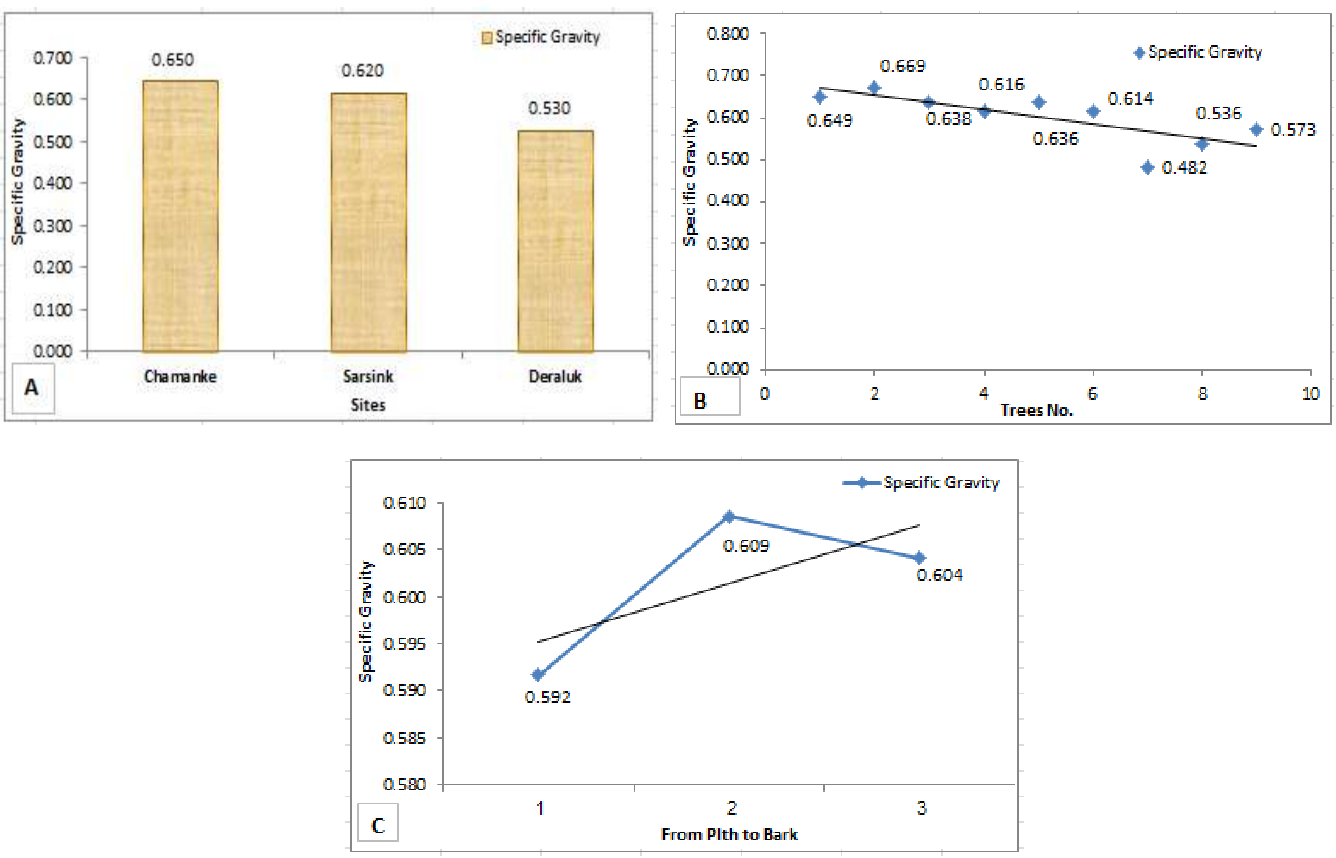


Figure (4). Show variation of specific gravity (A) among sites, (B) among trees, and (C) within trees from pith to bark.

**C.** Volumetric Shrinkage (VSH) and Volumetric Swelling (VSW)

Descriptive statistics of wood samples of *P. orientalis* in in Table (2 and 3) show there were significant variation in VS and VSW among sites, between sites, between trees, and within tree. Mean average of VSH was 4.14% varying between trees from 1.69% to 10.36%; and overall mean of VSW was 4.36% ranged from 1.90% to 11.56% and C.V. were 40.83% and 43.60% for VSH and VSW respectively. This value of VSH and VSW differs from the trees of *P. orientalis* growing in Erbil by [27] it have reached (VSH =5.44% and VSW=8.56%) and [3] how found the VSH equal to 6.42% and VSW was 6.93% in his studies on of some species of trees growing in Kirkuk. In the other side, [50], who calculated the VSH value of this species of wood and found was 11.49% from green to air dry condition and indicated that the wood is liable to shrink both in radial as well as in tangential direction.

Analysis of variance table (5) indicated there were significant differences (P< 1%) between sites and trees in this physical properties, The highest percentage of VSH and VSW percentage were recorded and occurred in wood samples from trees at the Sarsink site, while as, the lowest change in wood samples in VSH and VSW percentage occurred in from trees at the Deraluk site, as shown in Table (3). This variation in the volumetric percentage of shrinkage and swelling is due to the variation in the width of the growth rings, the proportion of earlywood and latewood, the density of wood, the proportion of wood in the cell walls, the length of the fibers, and the proportion of sapwood and heartwood, which are affected and vary from the pith to the bark and from one tree to another, and vary according to the location. [4] informed that along the radial positions, there was no significant difference of transverse shrinkage in *S. macrophylla* trees. On other hand, [42,32] reported that transverse shrinkage increased from pith to outwards in *C. odorata* and *P. euramericana*, respectively.

Also, the analysis of variance showed no significant difference was recorded in the percentage of VSH and VSW within the tree from the pith to the bark. In addition to that, Tables (5) of components of variance appeared that the Sites, trees, and the interaction between sites and trees contributed the greatest percentage to the change in these characteristics at the radial level. [67] reported that site had a highly significant effect on shrinkage properties in *E. globulus* Labill. Thus, the significant differences in transverse shrinkage between two sites in this study could be caused by the differences in growth conditions such as altitude, mean annual rainfall, and soil types between two sites.

Results of the study indicated that the mean values of VSH and VSW decreased from pith to the bark. Results consistent with the results [45] on *B. aethiopum* and [56] on *A. mangium* proved that the trend for transverse shrinkages decreased from pith towards periphery. While, [44] reported that the mean of shrinkages increased along with the sampling height from the base to the top and also increased across the radial sampling direction from the inner wood to the outer wood Their studies revealed that inner wood shrinks less than the outer wood and they all concluded that this may be due to the presence of extractives in the inner wood region which tend to inhibit normal shrinkage by bulking of the amorphous regions in the cell wall. The increase in radial shrinkage from the inner wood through the center wood to the outer wood was also reported by [43] on *T. scleroxylon.*

2- Anatomical wood properties:-

A. Fiber Dimensions (FD):-

Differences in fiber and vessel dimensions no-doubt result from environmental-genetically interaction. Descriptive statistics of range, ST.D, and C.V. % as show in Table (6) and Figure (5a and b) there were significant variability of fiber element dimensions among sites. The overall mean values of fiber length (FL), fiber width (FW), fiber lumen (FLW), and double cell wall thickness (DCWT) were observed to be 1.72 mm, 24.22 Mm, 11.51 Mm and 12.71 Mm respectively. The mean value of FL varies from 0.287 to 2,80 mm, FW from 4.88 – 39.81 Mm, FLW ranged from 3.34 to 24.17 Mm, while DCWT from 3.83– 26.84 Mm (Table-5). These values of fiber dimensions, when compared with the corresponding values, found to be higher in study by [59] in effect of altitude on wood morphology characters of *P. orientalis* in Duhok provenance.

Covariance analysis and Duncan’s test (Table 8) show there were high significant differences (P<1%) among sites, tree/site, and within tree in fiber measurements at radial variation. High significant differences between trees within sites allow to selection of individual trees for breeding programs because there were inter – taxa variation in wood properties occurs due to interactions of specific genotypes to environment or genetic differences alone [55]. The maximum values of FL, FW, and DCWT were observed in Sarsink site while the minimum dimensions in other sites. Many researchers insist that fiber dimensions are controlled primarily by change in cambial initials and pressures developed during various stages of growth.

Variance component analysis (Table 8) indicated that the sites was maximum contributes in the percentage of variability for fiber dimensions while percentage of variability caused by between trees, within tree, and interactions between these sources of variation in radial directions which were less effect. [59] found that the altitude was minimal contributes in the percentage of variability on FD, while the variability caused by between trees is more than by altitude little. Only the differences between samples within trees for fiber elements character was abundant are account to be large amount of total of variability (82.91%, 94.07% and 83.21%) for FL, FW and DCWT respectively. [40] concluded that differences in wood characteristics and branching habit are small between provenances and are affected more by site, and silvicultural treatment than by genetics.

The results also showed that the FL was a linear increased from the core to the bark of tree in radial directions, as shown in the figure (5d). These variations represent radial changes in fiber morphologies where they increased in the radial pith-bark direction and that were confirmated with the found of [57,49,11,35,48], who observed the same pattern of FL variation in plantations of hard wood species who reveals gradual increase in FL from pith to bark. In addition, the thickness of the fiber wall increased with the age of the trees, as reported in other studies [60]

B. Vessel Element Dimensions (VD):-

The morphology characteristics of vessels, including vessels element length (VEL) and vessels element diameter (VED) were expressed in microscope. The average values for these characteristics were obtained for *P. orientalis* wood in the radial positions (DBH) as shown in data in Table (6 and 7) and Figures ( 5a and d) indicated there were high variability between site, within sites ,between trees within site, and within tree in VEL and VED.

According to the results analysis of variance and Duncan's test (Table 9), statistically significant variations ($P< 0.01$) observed between the three site, nine tree, and within tree. The longer (0.59±0.09mm) and wider vessels (135.47±26.28μm) were produced by trees in Deraluk site which differs significantly with other sites in average value of VL equal to 0.59±0.09mm and VED was 135.47±26.28μm. Also the result indicated there were significant variations in radial directions in VED, which show the VED increased from the pith to bark, while found there was a fluctuation in the length of the vessels in along the radial plane of tree. [30] found in hardwoods, vessel elements in diffuse-porous wood and earlywood vessel elements in ring-porous wood have approximately the same length as the fusiform cambial cells from which they are derived, and wood fibers constitute the dominant component. As is clear in the Table (8) for the components of variance, the sites and trees contributed significantly to the percentage of variation in the vessels morphology. [7,4,65] designated that the VED gradually increased from pith to bark, but DCWT increased from pith to a peak, in the other side, [63] indicted that the various wood anatomical properties can be used to differentiate between juvenile and mature wood. Also [62] suggested the juvenile wood is formed by young cambium in which anatomical structure such as cell length and cell width change rapidly with cambial age, while mature wood is formed when length of fusiform cambial cells becomes more or less constant or increase much more slowly with cambial age.

ISSN 2072-3857

Table 6 . Descriptive statistics for anatomical wood characters studied of (9) trees in (3) sites of *Platanus orientalis* L.

| Character | Mean | Max. | Min. | Standard Deviation (ST.D.) | Coefficient of Variation (C.V.%) |
|---|---|---|---|---|---|
| Fiber length (mm) | 1.723 | 0.287 | 2.804 | 0.941 | 16.631 |
| Fiber width (µm) | 24.219 | 4.883 | 39.809 | 12.869 | 20.162 |
| Fiber lumen width (µm) | 11.512 | 3.343 | 24.175 | 4.855 | 29.038 |
| Double cell wall thickness of fibers (µm) | 12.707 | 3.823 | 26.837 | 2.178 | 30.090 |
| Vessel length (mm) | 0.565 | 0.104 | 0.941 | 0.344 | 18.385 |
| Vessel width (µm) | 121.790 | 26.891 | 222.265 | 40.395 | 22.080 |

Table 7. Mean± ST.D. values per site and tree for physical properties of *P orientalis* L.

| Tree No. | Wood Properties | | | | | |
|---|---|---|---|---|---|---|
| | FL | FW | FLW | DCWT | VEL | VED |
| 1. | 1.62 ± 0.19 b | 24.92±4.32 abc | 11.25±2.71 c | 13.6±7.98 bc | 0.55±0.09 ed | 119.19±20.63 cd |
| 2. | 1.72 ±0.297 b | 23.38±4.35 cde | 10.09±2.30 de | 13.29±3.09 c | 0.55±0.10 ed | 106.70±21.09 e |
| 3. | 1.71± 0.31 b | 22.51±4.00 e | 9.54±2.06 e | 12.97±3.32 c | 0.52±0.09 ef | 122.55±26.68 c |
| 4. | 1.71 ±0.30 b | 24.03±5.46 b-e | 11.19±3.58 c | 12.83±3.63 c | 0.58±0.11 cb | 113.29±23.62 de |
| 5. | 1.69 ±0.34 b | 25.61±4.97 ab | 10.76±2.59 dc | 14.84±4.14 a | 0.59±0.12 b | 121.82±26.27 c |
| 6. | 1.71±0.28 b | 25.72±5.15 a | 11.25±3.60 c | 14.46±3.72 ab | 0.50±0.08 f | 106.56±23.24 e |
| 7. | 1.82±0.25 a | 24.62±5.27 a-d | 15.17±3.46 a | 9.4±35.52 e | 0.60±0.08 b | 148.07±21.15 a |
| 8. | 1.87 ±0.23 a | 23.97±3.93 b-e | 12.53±3.28 b | 11.44±2.79 d | 0.63±0.09 a | 132.97±25.54 b |
| 9. | 1.65 ± 0.28 b | 23.19±5.44 ed | 11.81±2.84 bc | 11.39±3.99 d | 0.56±0.09 cd | 125.37±26.8 c4 |
| Sites | | | | | | |
| 1. | 1.68 ± 0.27 b | 23.60±4.32 b | 10.29±2.47 c | 13.31±3.13 b | 0.54±0.10 c | 116.15±23.86 b |
| 2. | 1.70± 0.30 b | 25.12±5.23 a | 11.07±3.28 b | 14.05±3.92 a | 0.56±0.11 b | 113.75±25.12 c |
| 3. | 1.78 ± 0.27 a | 23.93±4.94 b | 13.17±3.50 a | 10.758±3.577 c | 0.59±0.09 a | 135.47±26.28 a |

Mean values with the same letter do not differ significant

ISSN 2072-3857

Table 8. analysis of variance and components of variance for wood anatomical properties of *P. orientalis* trees

| Source of Variation | df | FL | | FW | | FLW | | DCWT | | VEL | | VED | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | P-value | Var.% | P-value | Var. % | P-value | Var. % | P-value | Var. % | P-value | Var. % | P-value | Var. % |
| Sites (S) | 2 | 0.0004 | 26.84 | 0.0013 | 28.23 | <.0001 | 62.40 | <.0001 | 70.69 | <.0001 | 31.44 | <.0001 | 61.00 |
| Trees (T) | 2 | 0.0247 | 12.73 | 0.2309 | 6.17 | <.0001 | 22.65 | 0.0004 | 9.21 | <.0001 | 48.27 | 0.0001 | 8.78 |
| Within Tree (WT) | 4 | <.0001 | 20.90 | 0.0037 | 16.52 | 0.6047 | 0.74 | 0.0002 | 6.48 | 0.0098 | 5.52 | <.0001 | 6.81 |
| S*T | 4 | <.0001 | 21.13 | 0.0022 | 17.81 | <.0001 | 7.29 | 0.0017 | 5.13 | 0.0188 | 4.89 | <.0001 | 14.15 |
| S*WT | 8 | 0.42 | 3.48 | 0.3086 | 4.96 | 0.1479 | 1.65 | 0.7639 | 0.72 | 0.8215 | 0.50 | 0.0203 | 2.24 |
| T*WT | 8 | 0.0641 | 6.35 | 0.0043 | 11.88 | 0.0023 | 3.32 | 0.0662 | 2.16 | 0.0048 | 4.58 | 0.0028 | 2.92 |
| S*T*WT | 16 | 0.1628 | 4.60 | 0.0045 | 9.24 | 0.3758 | 0.77 | 0.0001 | 3.37 | 0.0414 | 2.80 | <.0001 | 2.95 |
| Replication | 14 | 0.3019 | 3.97 | 0.245 | 5.18 | <.0001 | 1.17 | 0.0226 | 2.24 | 0.4829 | 1.59 | 0.292 | 1.15 |
| Error | 58 | | 100 | | 100 | | 100 | | 100 | | 100 | | 100 |

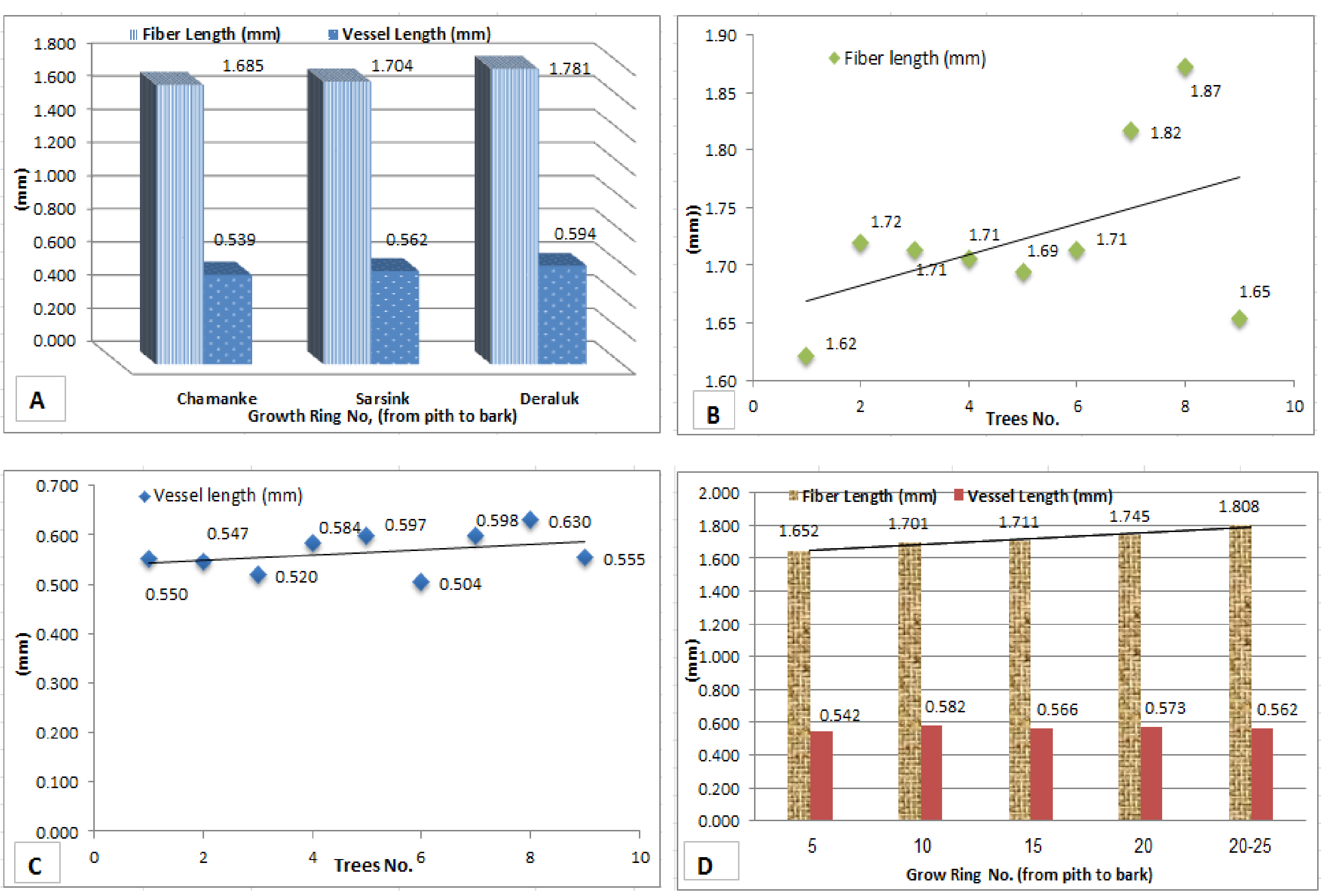


Figure (5). (A) Show average fiber length and vessel element length variation among sites, (B) average of fiber length variation among trees, (C) average of vessel length variation among trees, and (D) average fiber length and vessel length variation among tree from pith to bark.

## Conclusions

The variation in the wood properties of the same species are due different genotype and ecological conditions of sites such as altitude, precipitation, sunlight, soil, water, and nutrient. These two factors affect both the growth and development of trees [18]. As regards the within-tree variation, the radial variation was most important for all wood properties, thereby showing the importance of cambial age for the wood characteristics. The data obtained from the study revealed significant differences of physical and anatomical characteristics in the radial direction. Site, tree/site, within tree, and radial position had significant effect on the GRW, EWW, LWW, EW%, LW%, SG, VS, VSW, FL, FW, FLU, DCWT, VEL and VED which increased and decreased from pith to toward the bark with increasing of cambial age. The superiority of these wood traits makes the sources attractive for establishing plantations. Since results of ANOVA indicate high significant differences among sites for all the traits studied, the differences among trees per site are also highly significant in most cases. Also the within tree or radial directions differ significantly in most physical and anatomical wood. The site*tree interaction similarly effects on traits were also found to be significant. This means that the tree effects on the traits studied vary among site, in addition to the high percent of the total variability among site, tree and interaction between them, while, the low percent of variability within trees. Therefore, it is important the breeder could chose a site based on the performance of the trait and adaptability and then choose trees within sites for the desired trait or traits.

Reference: -


1) *[Abdulqader, A. A., Suliman, H. H., & Dawod, N. A. (2021). Some wood properties of Melia azedarach L. trees grown in Duhok province. Iraqi Journal of Agricultural Sciences, 52(3), 774-782.*

2) Aguilera, A.,&Zamora, R. (2009). Surface roughness in sapwood and heartwood of blackwood (*Acacia melanoxylon* R. Br.) machined in 90–0 direction. *European Journal of Wood and Wood Products, 67*(3), 297–301

3) Ahmad, R. M., and Al-Takay T. Q, (2022). Some wood physical properties of *Platanus orentalies* L. grown in Kirkuk. J. of Sustainable Studies. Vol.4,Issue 1

4) Anoop EV, Jijeesh CM, Sindhumathi CR, Jayasree CE (2014) Wood physical, anatomical and mechanical properties of big leaf Mahogany (*Swietenia macrophylla* Roxb) a potential exotic for south India. Res J Agric For Sci 2(8):7-13

5) Ashwath, M. N., Sathish, B. N., Dechamma, D. N. L., Devagiri, G. M., Hegde, R. K., & Hareesh, T. S. (2021). Geographic and within-tree variation for wood properties in *Acrocarpus fraxinifolius* Wight and Arn. populations. *Journal of Scientific&Industrial Research*, *80*, 1049–1055.

6) Barbour, J. (2004). Wood formation and properties. In B. Jeffery (Ed.), *Wood quality*. In *Encyclopedia of forest sciences* (pp. 1840–1846). Elsevier.

7) Bhat, K.M.; Priya, P.B.; Rugmini, P. 2001. Characterisation of juvenile wood in teak. *Wood Sci Technol* 34(6): 517-532. https://doi.org/10.1007/s002260000067

8) Bouslimi, B.; Koubaa, A.; Bergeron, Y.(2022). Regional, Site, and Tree Variations of Wood Density and Growth in *Thuja occidentalis* L. in the Quebec Forest. Forests 2022, 13, 1984. https://doi.org/10.3390/f13121984

9) CAVE, I.D. and J.C.F. Walker. (1994). Stiffness of wood in fast-grown plantation softwoods: the influence of microfibril angle. Forest Products Journal 44(5):43-48.

10) Chafe, S. C. (1986). Radial variation of collapse, volumetric shrinkage, moisture content and density in Eucalyptus regnans F. Muell. Wood Science and Technology, 20(3), 253-262.

11) Chavesta, M.; Tomazello-Filho, M.; Carneiro, M.; Nisgoski, S. 2020. Axial and radial evaluation of the basic density and fiber dimensions of Guazuma crinita Martius wood. Floresta 50(2). e1143. https://doi.org/10.5380/rf.v50i2.58356

12) Chopra, R. N., Nayar, S. L., & Chopra, I. C. (1986). *Glossary of Indian medicinal plants (Including the supplement)*. Council of Scientific and Industrial Research.

13) Chowdhury, Md., Ishiguri, Q.F., Izuka, K., Takashima, Y., Matsumoto, K., Hiraiwa, K. Ishido, M., Sanpe, H., Yokota, S., and Yoshizawa, N. (2009) . Radial variation of wood properties in Casuarina equisetifolia growing in Bangladesh. J. Wood Sci., 55 : 139-143.

14) David A.C. and Robert, B.A. (2007): Effects of size, competition and altitude on tree growth. Journal of Ecology 95:1084–1097.

15) De Castro, F.G., Williamson, B. and de Jesus, R.M. (1993). Radial variation in specific gravity of *Joannesia princeps*: The role of age and diameter. *Biotropica*, 25 : 176-182.

16) Debell, D.S., Singleton, R., Harrington, C.A. and Gartener, B.L. (2002). Wood density and fiber length in young Populus stems: relation to clone, age, growth rate and pruning. Wood Fib. Sci., 34 (4) : 529-539.

17) *Diamandis, S. Platanus orientalis a Divine Gift for Greece. 2004, pp. 52–53. Available online: http://www.dendrology.org/site/*

18) Duong, D.V. 2018. Study on within-tree variation in wood properties of Melia azedarach planted in northern Vietnam. Ph.D Thesis, Kyushu University, Japan. https://catalog.lib.kyushu-u.ac.jp


ISSN 2072-3857

19) FAO (1986): Databook on endangered tree and shrub species and provenances. FAO forestry paper, No. 77.
20) Franklin, F. L. 1946. A rapid method for softening wood for microtome sectioning. Trop Woods Yale Univ. SchFor 88:35-36p 16. Fujiwara, S., K. Sameshima, K. Kuroda, & N. Takamura, 1991. Anatomy and properties of Japanese hardwoods I. Variation of fiber dimensions and tissue proportions and their relation to basic density. IAWA journal, 12(4), 419-424
21) Gilman, E. F., & Watson, D. G. (1994). *Oriental plane tree (Fact Sheet ST-485)*. Environmental Horticulture Department, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida.
22) Gogoi BR, Sharma M, Sharma CL (2014) Ring width variations of Khasi pine (Pinus kesiya Royle ex Gordon) at breast height. Journal of the Indian Academy of Wood Science 11(1): 87-92.
23) Guller B, Isik K, Cetinay S (2012) Variations in the radial growth and wood density components in relation to cambial age in 30-year-old Pinus brutia ten. at two test sites. Trees 26:975–986
24) Hajhashemi V., Ghannadi, A. and Mousavi, S. (2011): Antinociceptive study of extracts of Platanus orientalis leaves in mice res pharmSci. 6(2): 123–128.
25) Heena. (2014). Evaluation of Willow (Salix species) Clones for Physical and Mechanical Properties of Wood. M.Sc. Thesis Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Nauni Solan -173 230 (H.P.), INDIA
26) Igartúa DV, Monteoliva S, Piter JC.(2008). Study of some physical properties of Argentinean Acacia melanoxylon. Maderas-Cienc Tecnol 2009;11(1):3–18.
27) Ismail, T. N., Saber. H. A. and Osman, S. O. (2017). Effect of different environment on physical properties of *Platanus orientalis* L. in Erbil Governorate. Eurasan Journal of Science and Engineering. Vol.3,Issue 1.September.
28) Izekor DN, Fuwape JA, Oluyege AO (2010) Effects of density on variations in the mechanical properties of plantation grown *Tectona grandis* wood. Archives of Applied Science Research 2(6): 113-120.
29) Khalid, N. (2024). Internal structure of *Platanus* (*Platanus orientalis* L.) grown in different environments in Kurdistan Region, Iraq. *Egyptian Journal of Agricultural Research*, *102*(1), Article 1431. https://doi.org/10.21608/EJAR.2023.230368.1431
30) Kitin, P., R. Funada, Y. Sano, H. Beeckman & J. Ohtani. 1999. Variations in the lengths of fusiform cambial cells and vessel elements in Kalopanax pictus. Ann. Bot. 84: 621–632.
31) Knapic S, Louzada JL, Leal S, Pereira H (2007) Radial variation of wood density components and ring width in cork oak trees. Ann For Sci 64:211–218
32) Kord B, Kialashaki A, Kord B (2010). The within-tree variation in wood density and shrinkage, and their relationship in *Populus euramericana*. Turk J Agric For 34:121-126
33) Köse N, Akkemik Ü, Dalfes HN, Özeren MS, Tolunay D (2012) Treering growth of Pinus nigra Arn. Subsp. pallasiana under different climate conditions throughout western Anatolia. Dendrochronologia 30:295–301

ISSN 2072-3857

34) Leng, C., Wang, J., Dong, L., Yi, M., Luo, H., Zhang, L., Chen, T., Xie, W., Xie, H., & Lai, M. (2024). Radial variation and early prediction of wood properties in *Pinus elliottii* Engelm. plantation. *Forests*, *15*(870). https://doi.org/10.3390/f15050870

35) Lima, I.L.; Ranzini, M.; Longui, E.L.; Barbosa, J.A. 2021. Wood characterization of *Tectona grandis* L. F. cultivated in Brazil: A review of the last 30 years. Research, Society and Development 10(14). e162101421549. https://doi.org/10.33448/rsd-v10i14.21549

36) Lobão, M. S.; Costa, D. P.; Almonacid, M.A.A.; Tomazello-Filho, M. 2012. Qualidade do lenho de árvores de Schizolobium parahyba Var. amazonicum, Acre, Brasil. Floresta e Ambiente 19(3): 374-384. https://doi.org/10.4322/floram.2012.044

37) Louzada JL (2003) Genetic correlations between wood density components in Pinus pinaster Ait. Ann For Sci 60:285–294

38) Louzada JL, Fonseca F (2002) The heritability of wood density components in Pinus pinaster Ait. And the implications for tree breeding. Ann For Sci 59:867–873

39) Machado, J. S., Louzada, J. L., Santos, A. J. A., Nunes, L., Anjos, O., Rodrigues, J., Simões, R. M. S.,&Pereira, H. (2014). Variation of wood density and mechanical properties of blackwood (*Acacia melanoxylon* R. Br.). *Materials&Design*, *56*, 975–980. https://doi.org/10.1016/j.matdes.2013.11.055

40) Mary T., Jos, E. and Áine, N.D. (2000): A Comparison of mechanical and physical wood properties of a range of Sitka spruce provenances. COFORD, the National Council for Forest Research and Development, who provided financial support.

41) Moore, J. and Cown, D. (2015). Wood quality variability – what is it, what are the consequences and what we can do about it? NZ Journal of Forestry, February, Vol. 59, No. 4

42) Ofori J, Brentuo B (2005) Green moisture content, basic density, shrinkage and drying characteristics of the wood of *Cedrela odorata* grown in Ghana. J Trop For Sci 17(2):211-223

43) Ogunsanwo, O. Y. 2000. Characterization of wood properties ofplantation grown Obeche (Triplochiton scleroxylon K. schum) in Omo Forest Reserve, Ogun State, Nigeria. PhD thesis, University of Ibadan, Nigeria. 272 pp.

44) Ojo, A. (2021). Variations in Physico-Mechanical Properties of Lonchocarpus sericeus (Poir), a Lesser-Used Species in West Africa. Forest Products Journal. https://doi.org/10.13073/FPJ-D-21-00004

45) Ojo, A. R. 2016. Intra-tree variation in physic-mechanical properties and natural durability of *Borassus aethiopum* Mart. woods in savanna zones of Nigeria. PhD thesis, University of Ibadan, Nigeria. 174 pp.

46) Panshin, A.; De Zeeuw, C. (1980). Textbook of wood technology. McGraw-Hill Book Company: New York, USA. 4th ed.722p.

47) Pasha, A. A. A. 1999. (The impact of geographical location in some technological properties of zawita pine wood (Pinus brutia Ten)). In Dohuk Governorate. M. Sc.thesis. Uni. of Dohuk. Iraq.

48) Portal Cahuana, L. A. ., Payeza Tuesta, G. ., Grandez Piña, E. A. ., Stenico da Silva, M. V. ., & Tomazello, M. . (2024). Radial variation of fiber morphology and wood density of the

commercial species Drypetes sp. and Myroxylon balsamum. Maderas. Ciencia Y Tecnología, 27, e1125. https://doi.org/10.22320/s0718221x/2025.11

49) Portal, L.A.; Figueiredo, J.V.; Camargo, J.H.; Vieira, G.; Oliveira, D.; Alves, L. M.; Latorraca, J. (2019). Variabilidad radial física y anatómica del leño de árboles de Amburana cearensis. Colombia Forestal 22(1): 17-26. https://doi.org/10.14483/2256201X.13083

50) Rauf, Z.M and Raza, S. J. (2012). Properties and utilization of locally grown chinar (*Platanus orientalis* L.) wood. The Pakistan Journal of Forestry. V. 62(2).

51) Rowell RM. 2013. Handbook of wood chemistry and wood composites. 2nd ed. CRC Press. Boca Raton, London, New York. 687p.

52) SAS (2005). Statictical analysis system. User's guide for personal computer. Releaze 9.1 SAS Insitituted Inc. Cary, NC`USA.

53) Shahbaz S. E. (2010). Trees and Shrubs. A field guide to the trees and shrubs of the Kurdistan Region of Iraq. Duhok University Press, pp 213

54) Shahbaz S.E. (1979): A study on some wood technological properties of *Platanus orientalis* L. growing in Ninevah forest plantation. M.Sc. Thesis, Unversity of Mosul, Iraq.

55) Shahbaz, S. Esmael and H. H. Suliman (2007). (Phenotic variation of wood quality characters in natural stands of *Quercus infectoria* Oliv. (*Fagaceae*) in Dohuk province). Journal of Dohuk University, Kurdistan 1st Conference of Biological Sciences, University of Dohuk 2-4 May, 2006, Vol. 11, No. 1, 77-91 (2008).

56) Shanavas A, Kumar BM (2006) Physical and mechanical properties of three agroforestry tree species from Kerala, India. J Trop Agric 44:23-30

57) Sharma CL, Sharma M, Carter MJ (2013) Radial variation in fibre length and wood density of *Melanorrhoea usitata* Wall. The Indian Journal of Forestry 139(6): 518-520.

58) Šilinskas, B., Varnagirytė-Kabašinskienė, I., Aleinikovas, M., Beniušienė, L., Aleinikovienė, J., & Škėma, M. (2020). Scots Pine and Norway Spruce Wood Properties at Sites with Different Stand Densities. Forests, 11(5), 587. https://doi.org/10.3390/f11050587

59) Sulaiman, H. H. (2014). Effect of Altitude on Wood Morphology Characters of *Platanus orientalis* L. in Duhok Provenance. Journal of Duhok University, Vol. 17, No. 1, (2014).

60) Trak Hizal, K., Erdin, N. (2016): Radial Variation of Annual Ring Width and Fiber Dimensions from Natural and Plantation Trees of Alder (Alnus glutinosa L. Gaertner) Wood. – Ormancılık Dergisi 12(2): 1-12

61) Tree Guide. (2020), Oriental Plane Tree. Available from: http://www.tree-guide.com/oriental-plane-tree [Last accessed on 2021 Mar 05].

62) Tsuchiya, R.; Furukawa, I. (2009a). Radial variation in the size of axial elements in relation to stem increment in *Quercus serrata*. *IAWA J* 30(1): 15-26. https://doi.org/10.1163/22941932-90000199

63) Tsuchiya, R.; Furukawa, I. (2009b). Radial variation of vessel lumen diameter in relation to stem increment in 30 hardwood species. IAWA J 30(3): 331-342. https://doi.org/10.1163/22941932-90000222

64) Tutin, T., Burges, N., Chater, A., Edmondson, J., Heywood, V., & Moore, D. (1993). Cruciferae. In *Flora*

*Europaea* (2nd ed., Vol. 1, pp. 313–416). Cambridge University Press

65) *Tutin, T.; Burges, N.; Chater, A.; Edmondson, J.; Heywood, V.; Moore, D. Cruciferae; Flora Europea Ed. 2; Cambridge University Press: Cambridge, UK, 1993; Volume 1, pp. 313–416.*

66) Van Duong, D., Schimleck, L., Tien Dinh, T., & Van Tran, C. (2020). Radial variation in cell morphology of melia azedarach planted in northern vietnam. *Maderas. Ciencia Y Tecnología*, *23,* 1–10. https://doi.org/10.4067/s0718-221x2021000100407 (Original work published January 1, 2021)

67) Wiemann, M.C. and Williamson, G.B. (1989). Radial gradient in the specific gravity of wood in some tropical and temperate trees. For. Sci,. 35: 197-210.

68) Yang JL, Fife D, Ilic J, Blackwell P (2002) Between-site and between-provenance differences in shrinkage properties of 10-year-old *Eucalyptus globulus* Labill. Aust For 65(4):220-226

69) -Zencirkıran, M. (2010). Determination of native woody landscape plants in Bursa and Uludag. *African Journal of Biotechnology*, *8*(21), 5737–5746.

70) Zhang, S. Y., Nepveu, G., & Owoundi, R. E. (1994). Intratree and intertree variation in selected wood quality characteristics of European oak (*Quercus petraea* and *Quercus robur*). *Canadian Journal of Forest Research, 24*(9), 1818–1823. https://doi.org/10.1139/x94-239

71) Zobel, B. J., & van Buijtenen, J. P. (Eds.). (1989). *Wood variation: Its causes and control* (Springer Series in Wood Science). Springer-Verlag.

ISSN 2072-3857