Effect of environmental conditions on wood properties of some tree species growing in El- Jabal El- Akhdar region, Libya

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ABSTRACT: This study was conducted to investigate the impact of environmental conditions on wood formation, wood physical and anatomical properties of *Pinus halepensis* and *Juniperus Phoenicia* trees growing at different altitudes in El- Jabal El-Akhdar region, Libya. Three tree species were randomly selected at each altitude. Some wood properties were determined, such as specific gravity, tracheid length, tracheid width (diameter), tracheid cell wall thickness, ray length (height), and its number (in tangential aspect). The results showed significant differences in wood properties among the trees of pine and juniper growing at the three altitudes. Also, the specific gravity, tracheid length and tracheid diameter, in altitudes (780m and 830m) showed the highest values when compared with the trees grown at the lowest altitudes (248m and 413m).

Key words: *Juniperus Phoenicia* L.; *Pinus halepensis* Mill. , Libya, Al-Jabel Al-Akhdar, Altitude, wood physical properties

INTRODUCTION

El- Jabel El- Akhdar region(JAR) is located between longitude 32^o and 33^{o}N and 20^o to 23E.The region is about 360km long and width of about 60Km from the seashore (Fig.1)and (Table 1),(Azzawam, 1995). JAR is a forest which well-stocked growing on fertile upland soil that located in northeastern part of Libya. The area has a distinctive environmental characteristic for being a permanent evergreen forested area. It is characterized by great biological diversity with more than 50% of the total plant species of the region scattered in the entire landscape, The number of plant species in this region, area bout 1100 species of the total plant species (Omar Al-Mukhtar University, 2005).The topography of this area includes three different levels of altitude. These levels differ in their climate and microclimate. The first level- close to sea level plain lands with maritime climate, The mean average height above sea level does not exceed 200 m. The second terrace , with an average height of 460 m above sea level, represents an intermediate location between the first and the third level. The maximum height of the third terrace is about 880 m above sea level. This level is characterized by cold winter climate, but it is moderate in most of its parts during summer (Azzawam, 1995).Intensive studies have been conducted to determine the influences of climate conditions on tree growth and wood formation (Olano *et al.*

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2004; Bakhshi *et al*.2011 and Topaloglu *et al.* 2016). Most of these studies reported strong correlation among the environmental factors and wood properties. For instance, Olano *et al.* 2004 found that early wood and latewood structure were controlled by certain climate factors. In addition, Bakhshi*et al*. 2011 described the influence of the climate factors on the fiber length, fiber diameter and cell wall thickness of maple wood in Khanican forests .Their results of Pearson correlation showed that the climate condition had no effect on fiber length and fiber cell wall thickness, but had significant effect on the fiber diameter. However, it seems that various wood properties have distinct relations with the altitudes above the sea level. In this context, Topaloglu *et al*. 2016 has indicated that by increasing the altitude, the diameter of vessels narrowed and the number of vessels in 1 mm increased and the vessel length and fiber length decreased in the Oriental beech (*Fagus orientalis* Lipsky) growing in five altitude Sat Sinop, Turkey. Meanwhile, they concluded that trees growing in the third altitude (400–600 m) had the highest density, and those in first altitude (0–200 m) had the lowest values. The objectives of this current study has been to study the influence of environmental condition on wood physical and anatomical properties of *Pinus halepensis* and *Juniperus phoenicea* trees growing at different altitudes at El- Jabel El- Akhdar region, LYBIA.

MATERIALS AND METHODS

Tree species and altitudes

Nine healthy trees (3 trees of 3 altitudes) of (*Pinus halepensis* Mill and *Juniperus phoenicea L*.) were selected at different altitudes(Table 1).Pine altitudes were, 248, 413 and 830 m while juniper altitudes were, 248, 413 and 780m.At diameter at breast height(DBH), discs from each tree (five centimeters in thick) were cut.

Samples preparation

Samples were cut horizontally and outwards from pith to bark (Fig.1). A low centimeter-wide, radial cut were used to determine specific gravity (SG) and fiber length. Wood specific gravity was determined by using the maximum moisture content methods **(**Smith, 1954**).**Samples were also prepared by sawing the wood blocks which have been cut horizontally from pith to bark. Each block were divided into three equal cubes of two centimeter dimension and macerated in distilled water prior sectioning. Section of about (20-30µm) thick were obtained using the free-hand technique. Sections were stained by the safranin dye then fixed Canada balsam, and photos were taken by camera attached to a light microscope. Cross-section dimensions of individual tracheid for earlywood and latewood were measured by a calibrated slide by a length of 2mm

(Irbe *et al*,2013). Cell ray length (at tangential side), and its cell number was measured in each sample **(**Welle and Adams,1998**).**

Statistical analysis

The split-plot design experimental was implemented,. The anatomical properties were assigned to randomized complete block design, according to Steel and Torrie (1980).Statistical analysis was done by ANOVA, F- test and L.S.D procedures available within the SAS software package (SAS, 2007)

Table (1): Description of the Locations of study.

Level	Longitude	Latitude	Altitude (m)
I	32 510' 9.4"	21 39' 60.5"	248
II	32 40' 23.9"	021 33' 00.1"	413
III	32 32' 165"	21 47'466"	830
	32° 36' 435"	21° 56' 000"	780

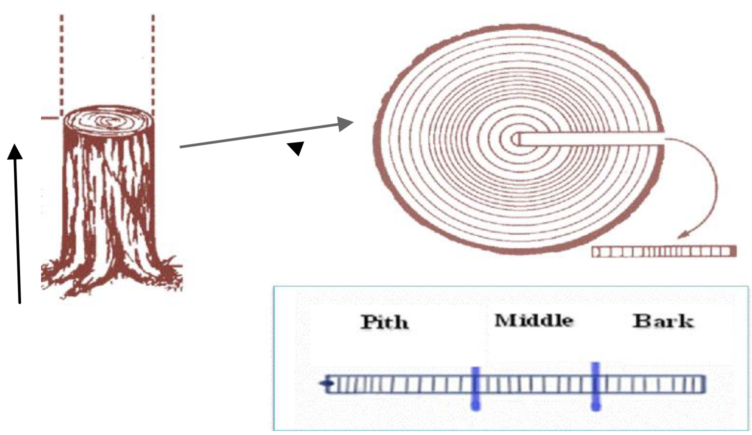


Figure (1): Flowchart of sample extraction from each stem section for the analysis of wood properties.

. RESULTS AND DISCUSSION

Specific gravity(SG)

The results of specific gravity (SG) showed significant differences between values of specific gravity for *Pinus halepensis* and *Juniperus phoenicia* from pith to bark(Tables 2 and 3). However, the recorded values for SG in both species followed the common trend distinguishes the coniferous trees, where the SG was decreased gradually from pith to sap wood then increased at the wood adjacent to bark. The last observed trend for SG values was the same for the wood of the tree growing at the three altitudes conditions.

Concerning the relation between the SG values and the altitudes, it was observed that the SG values of *P.halepensis* were increased from level I (248m) upward to level III (830m). These findings were in agreement with those described by Sheikh *et al*. (2011) and Martinez-Meier *et al.* (2011).

On the other hand , for *Juniperus phonicea*, the lowest SG value (0.399) was obtained at level II (413m), while the highest value was noted at level III (780m). Meanwhile, the SG value was higher in level I, when compared with that at level II. This could be attributed to soil properties in level I, which was characterized with a thick litter and organic matter, phosphorus and potassium contents compared to those found at level II (Table 3). These results were in agreement with those described by Khademi-Eslam*et al.* (2010).These findings can best be interpreted by the variation in temperature and precipitation in the tested altitudes. These factors are in direct relation with most wood properties, notably, wood density. Wood specific gravity responded positivity to temperature and negatively to precipitation (Xu *et al*., 2013).In conclusion, wood density is known to be affected by environmental conditions, climate in specific, cambial age of the tree *per see* ,in addition to impacts of silvicultural practices (Zobel and Sprague, 1998).Furthermore,(Zobel and Jett, 1995) reported a significant variation in wood density among tree locations and they also pointed out to partial effect of genetic traits on wood density. Furthermore, Doğu (2002) and Kiaei (2012)reported that the variation of wood density along radial position from pith to the bark was decreased in each of fixed altitude with the increase of elevation above sea level. This was attributed to the site conditions such as altitude, soil, climate condition, and the humidity of the region, i.e., the site variation had great impacts on the wood properties of the tree *in situ*.

Many studies have focused on understanding of the relationship between wood density and altitude. In particular**,** Govorcin *et al*. (2003)found that the wood density of *Fagus sylvatica*L. was decreased with increasing altitude. On the other hand, wood density has increased with increasing altitude *in Quercus pubescens* (Barij*et al.*2007),and in *Carpinus betulus*L. (Kiaei,2011and Kiaei,2012). Furthermore, Hernandez and Restrepo (1995)found that there is no change in density of the wood with increasing altitude in the wood of *Alnus acuminata*. Topaloglu*et al*. (2016) found that wood density and mechanical properties had minimum values in the first altitude (0–200 m), and maximum values in the third altitude (400-600 m)**.**

The density, as a basic physical quantity, significantly affects most of the physical and mechanical wood properties(Ondřej *et al*.2019).

Table (2): Specific gravity (SG) of wood of *Pinus halepensis* from pith to bark at different altitudes.

Altitudes (m)	Pith	middle	Bark
248	0.361	0.351	0.378
413	0.376	0.365	0.384
830	0.391	0.367	0.396
Mean	0.376^{b}	0.361^{c}	0.389^{a}

For "mean" values within the row, the values same superscript letter are not significant at the level of probability of 0.95.

Table (3): Specific gravity (SG) of wood of *Juniperus phoenicea* from pith to bark at different altitudes.

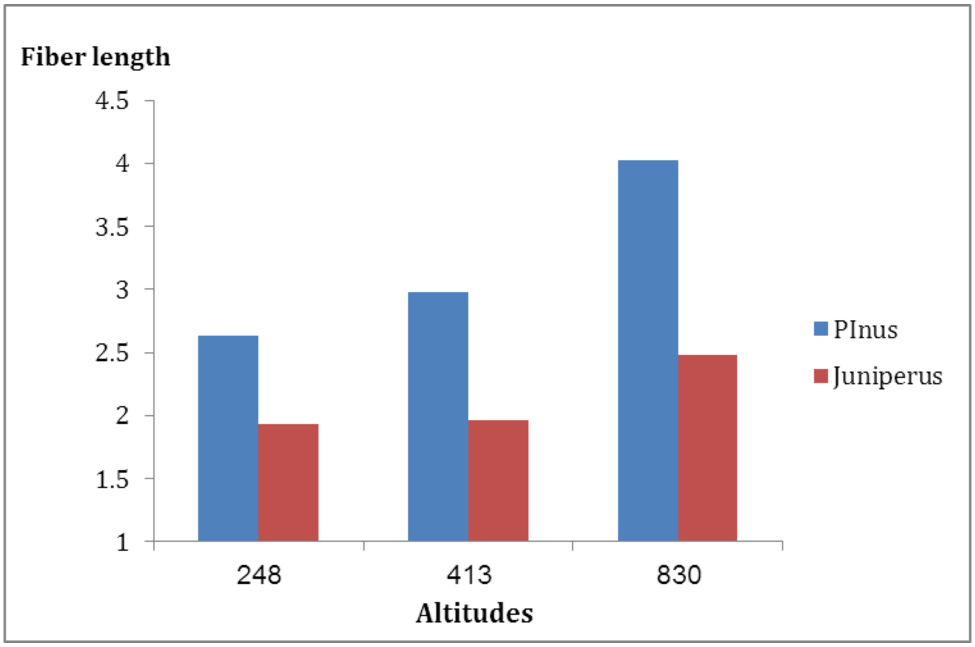
Altitudes (m)	Pith	middle	Bark
248	0.440	0.406	0.446
413	0.375	0.396	0.399
780	0.443	0.339	0.456
Mean	0.419^{b}	0.380^{b}	0.433^{a}

For "mean" values within the row, the values same superscript letter are not significant at the level of probability of 0.95.

Tracheid length

The pattern of tracheid length variation in this study is highly related to tree cambial age. Distinct differences monitored in the TL among the trees either *P. halepensis* or *J. Phoenicia* are owing to altitudes they growing at (Fig. 3). This observation was supported by the findings of Sadegh and kiaei (2011)and Adamopoulos *et al*., (2012).Also, the transition behavior from juvenile wood to mature one was strongly affected the TL in both tested tree species. It is noted that with the increasing of the altitude above the see level, a significant increase was observed in the TL values. The highest values for tracheid length were recorded at level III of altitudes (830m), while the precipitation records reached 600 mm and the temperature was normally low. These environmental conditions were ideal for the growth of the tested tree (*P. halepensis* and *J. Phoenicia*).

The above findings are not in harmony with those of Bakhshi*et al*. (2011), who mentioned that the environmental factors had no effect on fiber length. Also, Hosseini (2006) reported that the altitude in the range of about 500m showed no important impact on fiber length, exploitation age or juvenile wood border in Caspian forests. On the other hand, larger values that belong to high altitude, and so it can be predicted that increasing the elevation to above 500m could improve wood fiber length. Narrow ring width and variations in it from year to year should have a negative effect on fiber length variation. Similarly**,** Zoghi *et al*. (2013) **s**howed that the altitude had significant effect on fiber length, lumen width, wall thickness and biometry coefficients. Roberts *et al*.(2019) reported that the formation of earlywood was affected by temperature, while latewood anatomy showed correlation with precipitation. The correlations with climatic factors differed among the provenances, suggesting varying response to changing climate.



Figure(3):Mean of fiber length (FL) (mm) of wood of *Pinus halepensis* and *Juniperus phoenicea* growing at different altitudes.

Anatomical characteristics

As for *Pinus halepensis*, the results of ray length (RL) and its cell number indicated that there are significant impacts of altitude on RL both properties of the wood formed (Table 4). However, it was manifested that the RL was associated with the altitude, since the highest value (0.164 mm) was noted in the wood of the tree growing at level II (413m), while the lowest (0.068 mm) was observed at the level I (248m). Concerning ray cell number (CN), it is found that the highest cell number (7.700) was detected at the level II (413m) vs. the lowest (4.600) at the level I (248m). Also, there is no significant difference between the CN in of the wood of the trees growing at level II and level III. Upon these findings, it can be said that the local environments of the *P. halepensis*(Temperature, soil and moisture) or its biogeographic range (latitude, altitude) have an impacts on altitudes. The same trend was observed with *J. phoenicia* and significant differences were noted in these parameters in the tested altitudes, thus it is emphasized the effectiveness of climate conditions on RL and CN. In this regard, several literatures reported that cell number production can be strongly influenced by favorable environmental conditions, but cell size is controlled strongly by hormonal activity and phenology, while cell wall thickness is assumed to depend entirely on the availability of photosynthesis **(Irbe *et al*. 2013).** Altitude had a strong effect on all wood properties of Oriental beech except on multiseriate ray width, as altitude increased, diameters of vessels narrowed vessel number in 1 mm increased, and vessel and fiber lengths decreased.

Table (4): Mean of ray length (RL) (mm) and its cell number (CN) of wood of *Pinus halepensis* and *Juniperus Phoenicia* growing at different altitudes.

Altitude (m)	*P. halepensis*		*J. Phoenicia*	
	RL (mm)	CN	RL (mm)	CN
248	0.068[C]	4.600[b]	0.074[a]	6.700[a]
413	0.164 [a]	7.700[a]	0.072[a]	4.200[b]
780 - 830	0.108 [b]	7.400[a]	0.074[a]	3.600[b]

Means with the same superscript letter are not significantly different at 0.05 level of significance. Similar letters within the same column mean that there is no significant difference, and similar letters mean that there is no significant difference.

Upon the findings obtained pertaining tracheid diameters (µm) in both earlywood (EW) and latewood (LW) of the wood of the trees growing at different altitudes, there are significant differences among the impact of the altitudes on *c*haracteristics of tracheid diameters (TD) and tracheid cell wall thickness (TWT) in *P. halepensis*(Table 5). However, it is clear that the tracheid diameter is more sensitive to climatic conditions, since the highest value was recorded at the altitude of 830 m, which were 27.26 and 10.00 µm of earlywood and latewood, respectively, while the lowest values (13.60 and 3.6 µm for the tracheid diameters) were observed at the altitude of 280 m in earlywood and latewood, respectively. The trees of different social status show diverse patterns in variation of wood rays due to specific carbon allocation patterns. Earlywood and latewood differed by size and quantity of wood rays; wood rays were more numerous in latewood. Quantity of wood rays displayed high , and well as medium frequency variation. Roberts *et al*. (2019)

Table (5): The average of tracheid diameters (µm) in both early wood (EW) and late wood (LW) of *P. halepensis* and *J. Phoenicia* growing at different altitudes.

Altitude (m)	*P. halepensis*		*J. Phoenicia*	
	EW	LW	EW	LW
280	15.60[b]	3.6[b]	21.33[a]	10.00[b]
413	25.86[a]	10.00[a]	20.73[b]	10.00[b]
780 - 830	27.26[a]	10.00[a]	25.60[c]	10.00[b]

Means with the same superscript letter are not significantly different at 0.05 level of significance.
Similar letters within the same column mean that there is no significant difference, and similar letters mean that there is no significant difference.

Based on the obtained data, it can be noted a good correlation between tracheid diameter and the climatic factors, which certainly varied with the altitude. These obtained data are consistent with those reported by Akkemik (2003), Xu *et al*. (2013), Irbe *et al*, (2013) and Xu *et al*. (2014).

Gricar *et al*. (2006)reported that tracheid size is controlled by climatic conditions during the cell enlargement phase. In addition, it has been reported that low water content decreased cell turgidity, thus affecting cell enlargement resulting in smaller, denser, and mechanically stronger tracheid (Abe *et al*., 2003 and Sperry *et al*., 2006).

CONCLUSIONS

There was significant difference in wood properties among the altitude level in pine and juniper trees. Wood properties such as: specific gravity, tracheid length, tracheid diameter, in altitude III were more than those at the other altitudes at the both tree species. . as well as When using pine and juniper wood in the forest products industry, the altitude factor should be taken into consideration. Finally, variations of anatomical and physical properties of pine and juniper wood and its relation with the altitude can be useful indicator in forest products industry.

تأثير الظروف البيئية على خصائص الخشب لبعض الأشجار النامية بمنطقة الجبل الأخضر ، ليبيا

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المستخَلص

أُجريت هذه الدراسة بمنطقة الجبل الأخضر–ليبيا بهدف التعرف على تأثير الاختلافات البيئية على تكوين الخشب وصفاته المختلفة في أشجار الصنوبر الحلبي والعرعر الفينيقي النامية على ارتفاعات مختلفة في منطقة الجبل الأخضر ، ليبيا. تم اختيار ثلاث اشجار لكل نوع عشوائياً عن كل ارتفاع. تم تحديد بعض

خصائص الخشب مثل: الثقل النوعي ، طول القصيبة ، عرض القصيبة (القطر) ، سمك جدار القصيبة ، طول الشعاع (الارتفاع) وعددها (في القطاع المماسي). أظهرت النتائج وجود فروقات معنوية في خواص الخشب بين أشجار الصنوبر والعرعر على الارتفاعات الثلاثة. أيضًا ، كانت قيم الثقل النوعي وطول القصيبة وقطرها على ارتفاعات (780 م و 830 م) أعلى مقارنة بالأشجار النامية على ارتفاعات منخفضة (248 م و 413 م).

الكلمات الدليلية: العرعر الفينيقي، الصنوبر الحلبي، الجبل الأخضر، ليبيا، الارتفاع عن سطح البحر، الخصائص الفيزيائية للخشب.

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