STUDYING THE VARIATION BETWEEN WOOD TENSION AND COMPRESSION AT DIFFERENT STEM LENGTHS AND DIAMETER LEVELS IN PHYSICAL PROPERTIES OF *MELIA AZEDARACH* L. AND *PINUS BRUTIA* TEN. LEANING STEMS

A. R. S. Almalah
Assist. Prof.
Dept. of Forestry, College of Agriculture and Forestry / University of Mosul
abdulrazakalmalah@yahoo.com

ABSTRACT

The objective of this study was to find the main differences in physical properties between tension wood of *Melia azedarach* L. and compression wood of *Pinus brutia* Ten. and comparing them to the normal wood of the standing trees. Results indicate that tension and compression wood increased swelling (length, volume and thickness) after immersion of samples in water for 2, 6 and 24 hours and volumetric shrinking percentage greater than normal wood. Also, tension wood of *Melia azedarach* L. gave greater volumetric and thickness swelling percentage than compression wood of *Pinus brutia* Ten. Results did not show clear differences between tension and compression wood in longitudinal swelling percentage. Also, results showed that the eccentric of the stem pith of both tension and compression wood of the leaning trees was the highest at the stem base, then the eccentric of the pith will decrease gradually from base to the stem top. The main average of volumetric and thickness swelling after immersion in water for 2, 6 and 24 hours of heartwood for both *Melia azedarach* L. and *Pinus brutia* Ten. was lower and insignificant compared to sapwood.

Key words: Reaction wood, leaning stem trees, wood swelling and shrinkage.

دراسة الاختلاف بين خشب الشد والضغط لمستويات طول وقطر مختلفة في بعض الصفات الفيزيائية لسيقان اشجار السبحبح والصنوبر المائلة

عبدالرزاق رؤوف سليمان الملاح
استاذ مساعد
قسم الغابات – كلية الزراعة والغابات – جامعة الموصل – موصل – العراق

المستخلص

تم قطع اربعة أشجار من مشتل قسم الغابات – جامعة الموصل، إثنتان نوع سبحبح .L *Melia azedarach* إحداهما قائمة والاخرى مائلة. وإثنتان نوع صنوبر زاويته .Ten *Pinus brutia* إحداهما قائمة والاخرى مائلة لغرض معرفة اهم الفروقات الفيزيائية بين خشب الشد في الجزء العلوي لسيقان اشجار السبحبح وخشب الضغط في الجزء السفلي لسيقان اشجار الصنوبر ومقارنتها مع الخشب الاعتيادي للأشجار القائمة. وبينت النتائج ان خشب الشد في أشجار السبحبح المائلة وخشب الضغط في أشجار الصنوبر المائلة أعطت نسبة انتفاخ بالحجم والطول والسمك بعد الغمر بالماء 2، 6، 24 ساعة ونسبة انكماش بالحجم أعلى مما في الخشب الاعتيادي. وكذلك أعطى خشب الشد نسبة انتفاخ بالحجم والسمك أعلى مما في خشب الضغط للصنوبر. ولم تظهر النتائج وجود فروقات واضحة بين خشب الشد وخشب الضغط في نسبة الإنتفاخ بالطول. كما تبين ان لامركزية اللب في سيقان الأشجار المائلة لكل من الخشب الصلد للسبحبح والرخو للصنوبر تكون اعلاها في قاعدة الساق ثم تقل لا مركزية اللب تدريجيا باتجاه قمة الساق، كما بينت النتائج ان المتوسط العام لنسبة الانتفاخ بالحجم والسمك بعد الغمر بالماء 2، 6، 24 ساعة للخشب الصميمي لاشجار السبحبح والصنوبر هي أقل قليلا مما في الخشب العصاري ولكنها لم تكن معنوية.

الكلمات المفتاحية: خشب التفاعل، سيقان الاشجار المائلة، نسبة انتفاخ وانكماش الخشب

***Received:16/11/2018, Accepted:28/2/2019**

INTRODUCTION

Forestation is a renewable natural resources and giving direct and indirect benefits to human from economic, environmental, tourism and cultural aspects (14). Many countries depend in its economy on forest such as Scandinavians countries which considered as one of the most important natural resources for human needs for wood products. Establishing the new forest stands depend on the application of modern silvicultural approach and advance technique (1), followed by studying the produced wood to estimate its utilization for different wood manufacturing. Thus, wood is considered as one of the most important products for human needs and for civilization development. Wood defects may occur in leaning tree stem which is known as reaction wood and results as a respond of unnatural growth condition such as leaning stems and branches as a results of wind effect or by stem and branch curving or by leaning tree stems on sloping ground (13). Reaction wood of hardwood leaning tree stems is called (Tension wood), it appear on the upper part of the leaning or curving tree stems grown on sloping ground (12). Tension wood can be recognized from the eccentric growth rings present on leaning trees in different grades specially on sloping ground. Also, there is a compression wood in softwood trees in the lower part of leaning tree stems, and also contain eccentric pith (13). Badia et. al. (5) explain that tension wood of *Populus* ssp. Was more light and clear in color than normal wood for newly sawn stem. Also, there were wooly fibers bumps in the sawn wood. Boyed (6) and yen et. al. (19) found that there were many factors contributing to forming tension and compression wood such as (light, gravity, plant auxin, stress and wind). One factor or more will cause the formation of tension or compression wood. Also, they found that plant hormones have a rule in tension wood formation on the upper side of *Prunus spachiana* branches. Yen et. al. (19) made a comparative study between compression and normal wood and they found that the color of compression wood was darker, and they named the portion wood at the opposite direction of compression wood (opposite wood). The compression wood have short and circular tracheid with higher microfibers angle (45˚) compared to normal wood. The secondary layer of the tracheid wall was thick with the absence of S_3 layer (secondary layer No.3). Th. Harity considered the first researcher who discover the Gelatinous layer (G-layer) in tension wood (7), which appeared as a gelatinous fibers with special unique chemical composition also called cellulosic layer. The presence of this layer in the wood signifies the presence of tension wood in most hardwood species. Tension wood have specific gravity and longitudinal shrinkage percent higher than normal wood. The increase in specific gravity (5-10%) may refer to the increase of gelatinous fiber wall thickness. Thus, it was considered that this abnormality was related to the chemical properties of the wood cell wall more than the physical properties (13). Rowell et. al. (18) clarify that the variation in the physical properties may refer to the change of fiber shape. It was assumed that the higher swelling and shrinkage percent of tension wood may refer to the swelling and shrinkage percent of the homogenous properties of the material present between the cellulosic chains such as starch and saccharides. Any change in the size of these material in cross section will lead to longitudinal shrinkage in the tension wood fiber (13). Gryc et. al. (11) indicated that compression wood swell longitudinally more compared to opposite wood, and swell less in radial and tangential direction compared to opposite wood. In normal wood Niemz (14) explain that the lowest change in wood dimension occur in the longitudinal direction of the grain (0.1-0.4%), while in the cross direction, a considerable change occur in swelling and shrinkage, with values between 3-6% in radial direction and 6-12% in tangential direction. Perstopper et. al. (17) found that longitudinal shrinkage in spruce tree wood containing compression wood in the annual ring growth was as twice as much in the opposite wood, while the shrinkage in the radial and tangential direction was about 30% higher in the opposite wood. They declare that the amount of compression wood presented in the sample test affect shrinkage percent. Ayrilimis (4) study the dimensional changes of medium density fiberboard (MDF) manufactured from black pine *Pinus nigra* Amold. Containing compression wood. They found that fiberboards containing 75% compression wood have average longitudinal swelling and shrinkage percent (0.286% and 0.247%) respectively. While fiberboards containing 10% compression wood have less average longitudinal swelling and shrinkage percent (0.148% and 0.152%) respectively. Also, the average of thickness swelling and shrinkage percent of fiberboard manufactured with 75% compression wood was 5.042% and 4.402% respectively, which was higher than thickness swelling and shrinkage for boards manufactured with 10% compression wood with average of 3.62% and 2.86% respectively. Thus, percent increase in swelling or shrinkage of compressed MDF depend on the amount of compression wood present in the boards. For as much no research was found concerning the differences between tension and compression wood in physical properties and the rarity of studies and researches in physical properties of tension and compression wood compared to normal wood, the aim of this study is to explain the variance between tension and compression wood in some physical properties (the percent of volumetric swelling, longitudinal swelling, thickness swelling, volumetric shrinkage, and moisture content loss percent) and compare these values with the normal wood in order to indicate the extent of using leaning or curved stems wood in manufacturing industries.

MATERIAS AND METHODS

Four trees of *Pinus brutia* Ten. (pine) and *Melia azedarach* L. (Azadirachta) trees was fallen to study compression and tension wood and compare it with normal wood. The age of the selected trees is even (20 years), the trees was fallen in December 2017 from forest nursery department in Mosul University. The fallen trees were two pine trees: one have vertical stem, the other have leaning stem, and two Azadirachta trees, one have vertical tree stem, the other have leaning tree stem with horizontal angle of 47˚ for both leaning trees. The stems of trees were straight and unaffected from any insects or diseases. The stem were sectioned into 3 equal parts, and a 3 discs of 5 cm thick were taken from each tree stem. The first disc was cut from the base of the lower stem portion (over the stump), the second disc was cut from the middle of the second stem portion (middle stem portion) and the third disc was cut from the top part of the top stem portion (Fig.1). Tension and opposite wood of Azadirachta tree stem, and compression and opposite wood of pine tree stems were determined. Also, sapwood and heart wood of both species were determined according to Donaldson et. al. (9) (Fig. 2).

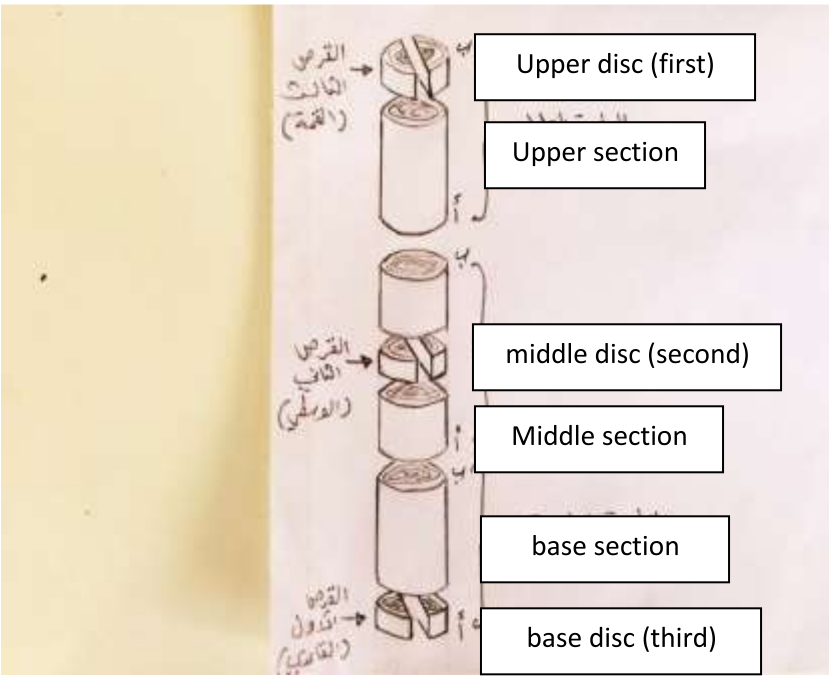

Figure 1. Three stem sections and disc sample preparation used for laboratory tests

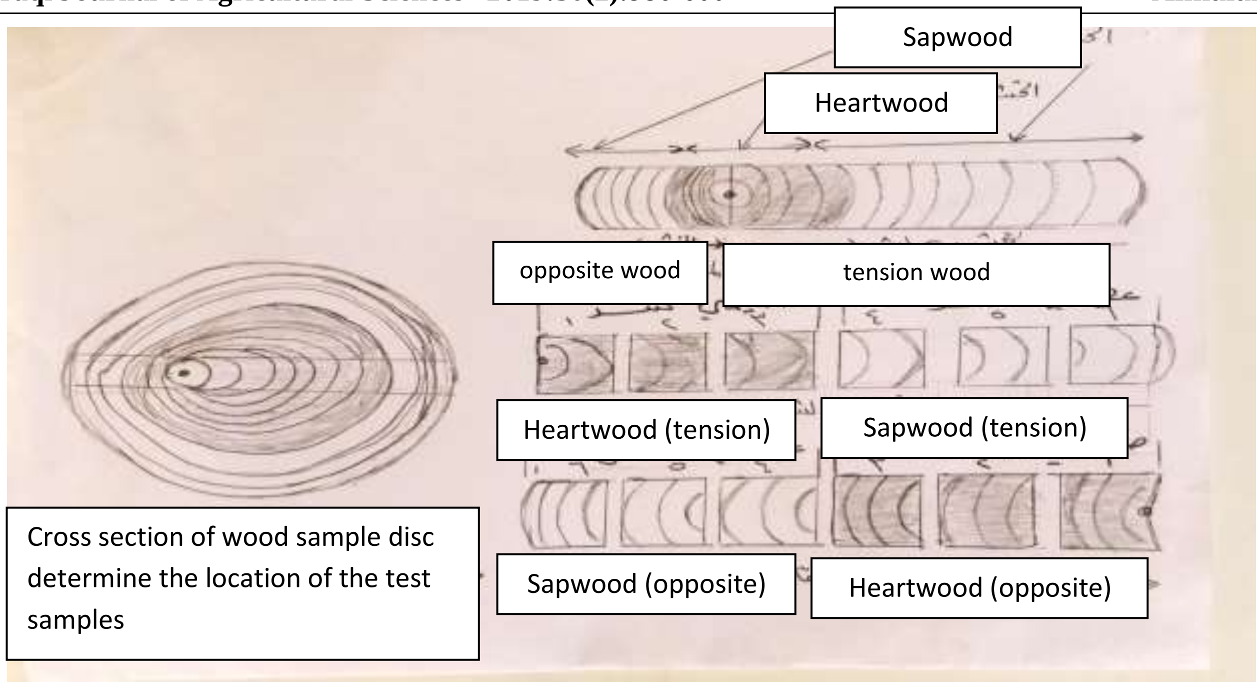

Figure 2. Physical samples test preparation (for both tension and compression wood)

Discs taken from vertical trees were determined into two equal samples and called (first half and second half) due to the lack of reaction wood for both tree species. All discs were placed in well ventilated room for two month for drying the samples, moisture contents was measured once each two weeks until stabilization of moisture content to 5-10%. All physical characters were studied in wood technology lab at Collage of Agriculture and forestry, University of Mosul. The wood samples were divided into small portion containing 3-4 annual growth rings for each sapwood and heartwood (Fig. 2). These samples were cut into 3x3x4 cm cubic blocks and stored in the refrigerator until being used for testing. The wood samples were dried at room temperature until moisture content reached 8.43% for pine and 9.5% for Azadirachta. Then weight measurements were accomplished by using sensitive electronic balance and samples dimensions by using digital vernier. The wood samples were immersed in bowel with water by applying weight on the sample for 2 hours period. Then the weight and dimensions were measured for all samples followed by immersing them again directly in water for 4 hours and the measurements of 6 hours immersing period were taken for weight and dimensions. The same procedures above were accomplished to get the same measurements for 24 and 848 hours immersion periods. Then all samples were dried by electric oven at 105˚ C until weight loss is stopped. The measurements were used to calculate wood shrinkage percent. The following equation were used to calculate volumetric swelling percent after immersion in water for 2, 6, 24 hours periods: (3).

% Vol. swelling = [(Vol. after immersion – vol. before immersion) / Vol. before immersion)] x100

With the same equation above, swelling percent of length and thickness were measured after immersion in water for 2, 6, 24 hours.

Also, the following equation were used to calculate volumetric shrinkage percent: (3).

% Vol. shrinkage = [(Vol. before drying – vol. after drying) / Vol. before drying)] x100

The following equation were used to measure moisture loss percent: (16

% moisture loss = [(weight after immersion – weight before immersion) / weight before immersion)] x 100

Complete Randomized Design (CRD) was used to analyze research data. Three statistical analysis were used, two separated analysis for each azadirachta and pine trees to find the differences in physical characteristics between tension (or compression) wood and normal wood for each species. The following factors were included:

1- Wood type in 2 levels (reaction wood (tension or compression), normal wood).
2- 3 stem height levels (base, middle, top).

3- 2 wood location levels (heartwood, sapwood).

By adding 3 replication for each experimental units the total observations units are 2x3x2x3=36 for each kind of species. The third analysis contain 2 levels of species type factor (Azadirachta, pine) in addition to the above factors. The total observations are 2x2x3x2x3=72. The effects of these factors on the physical properties of wood were studied. Statistical analysis system program (19) were used to determine the significant differences between the means of studied physical properties by using Duncan Multiple Range Method (10).

RESULTS AND DISCUSSION

1- Effects of wood type in the studied physical characters

Duncan's analysis of means (Table 1) and Figure 3 , 4 and 5 shows generally that in tension wood of Azadirachta trees, there were significant increases in volumetric swelling percent after immersing in water for 2, 6, 24 hours (6.671, 14.650, 23.524)% respectively and in longitudinal swelling percent (1.426, 2.722, 4.112)% respectively, and in thickness swelling percent (2.901, 5.866, 9.915)% respectively, and in volumetric shrinkage percent after drying for 48 hours (14.108%) compared to normal wood in volumetric swelling percent (6.166, 8.581, 13.290)% respectively, and in longitudinal swelling percent (0.816, 1.349, 2.541)% respectively, and in thickness swelling percent (3.425, 4.177, 5.642)% respectively, and in volumetric shrinkage percent (8.197%), except volumetric and thickness swelling percent after immersion in water for 2 hours the increase was not significant. Also, there were increase in volumetric longitudinal and thickness swelling percent for each tension and normal wood by increasing immersion periods. This results was identical to the study of Yousif et. al. (21) which that thickness swelling percent and volumetric and thickness shrinkage percent and water absorption percent were higher in tension wood of *Quercus aegilops* L. leaning trees compared to normal wood of the standing trees. This increase in volumetric and thickness swelling percent and in volumetric shrinkage percent of tension wood may refer to the related to the fact that tension wood has specific gravity higher than in normal wood due to the thicker fiber cell walls of the G. layer in tension wood (7). Rowell et. al. (18) explain that alteration in the physical characteristics of wood may refer to the alteration of wood shape, since the higher swelling and shrinkage of wood is due to the highly swelling and shrinkage of the homogenous properties materials founded between cellulose chains (starch and saccharides). The reason of longitudinal swelling percent increase of tension wood compared to normal wood may related to the transverse swelling and shrinkage of homogenous properties materials which results in longitudinal swelling or shrinkage of the tension wood fibers (13). The up normal longitudinal swelling of tension wood which may refer to the reach 1.5% or more compared to normal wood which have as much as 0.01% may refer to the chemistry of the cell wall more than it's physical properties (13). Also, Table 1 show that moisture percent loss in tension wood after drying for 48 hours (21.939%) is slightly lower than normal wood (21.356%) and the differences is not significant. Also, Table 1 and Figure 3 and 4 and 5 explain that compression wood of leaning trees stems of pine gave significantly higher volumetric swelling percent after immersion in water for 2, 6 and 24 hours (7.853, 10.001, 12.455)% respectively, and for longitudinal swelling percent (2.008, 2.352, 3.019)% respectively, and for thickness swelling percent (2.932, 4.041, 4.818)% respectively compared to normal wood of standing stem pine trees for volumetric swelling percent (3.960, 6.848, 9.312)% respectively, and for longitudinal swelling percent (0.865, 1.596, 2.144)% respectively, and for thickness swelling percent (1.617, 2.405, 3.343)% respectively. Also, moisture loss percent of compression wood (43.103%) and for volumetric shrinkage percent (8.634%) was slightly higher compared to normal wood (42.561, 7.417)% respectively and was not significant. Generally, the reason of the superiority of compression wood in increasing swelling and shrinkage percent compared to normal wood may refer to the related to the increase of lignin percent and the homogenous properties materials in compression wood which lead to specific gravity increase, and hence, swelling and shrinkage percent increased. These results was similar to the finding of Gryc et. al. (11). Also, perstopper et. al. (17) declared that longitudinal shrinkage in spruce wood trees containing compression wood was as twice as much higher than opposite wood, while tangential and radial shrinkage was about 30% higher than opposite wood, and they found that compression wood quantity present in testing sample affect shrinkage percent. Ayrilms (4) found that Medium density fiberboards (MDF) containing 75% compression wood have longitudinal swelling and shrinkage percent and volumetric swelling percent and thickness shrinkage percent higher than MDF manufactured with 10% compression wood. The slight increase in moisture loss percent of compression wood compared to normal wood clarify the reason of the volumetric, longitudinal and thickness swelling percent and volumetric shrinkage percent increase of compression wood compared to normal wood. The differences in physical properties between tension wood of Azaderachta trees and compression wood of pine trees was shown in Table 1 and Figure 6, generally, for azaderachta wood there was increase in volumetric swelling percent after immersion in water for 2, 6, 24 hours (6.418, 11.615, 18.407)% respectively, and for longitudinal swelling percent (1.121, 2.035, 3.326)% respectively, and for thickness swelling percent (3.163, 5.022, 7.418)% respectively compared to compression wood of pine trees for volumetric swelling percent (5.907, 8.42, 10.883)% respectively, and for longitudinal swelling percent (1.436, 1.974, 2.582)% respectively, and for thickness swelling percent (2.274, 3.223, 4.080)% respectively. However, there were no significant differences in volumetric swelling percent after immersion in water for 2 hours, and in longitudinal swelling percent after immersion in water for 2 and 6 hours. The increase of physical characteristics for Azadirachta trees compared to pine trees may related to the increase of cellulose percent in gelatinous layer of leaning Azadirachta tree stem by which water molecules bound with the surface of crystalline cellulose layers in high percent compared to compression wood in pine tree stems which contain high lignin percent and lower percent of cellulose. In other word, the ratio of bound water in tension wood of leaning Azadirachta trees was higher than compression wood of leaning pine trees. Therefore, the free water percent in Azadirachta tree is lower compared to compression wood of pine trees. Generally, it can be concluded that compression wood of soft species is better than compression wood of hard wood species in reducing swelling and shrinkage percent. Also, Table 1 show that there were significant increase in moisture loss percent of pine trees compared to Azadirachta trees which may related to the higher percent of bound water to the surface of crystalline cellulose region in tension wood of Azadirachta trees which contain higher cellulose percent compared to compression wood of pine trees which contain higher lignin percent. Thus, the ratio of free water in compression wood of pine was higher compared to tension wood which lead to more water evaporation and increasing of moisture percent loss of pine tree after drying, knowing that free water evaporation doesn't affect wood swelling or shrinkage (11).

2- Effect of stem height levels on the studied physical characters

Table 2 for Duncan's analysis of means indicate generally that there were light reduction of Azadirachta wood in volumetric swelling percent after immersion in water for 6, 24 hours whenever proceeding from the stem base level to middle and top levels. The values after immersion in water for 6 hours were (12.607, 11.959, 10.280)% respectively, but without significant differences. The values after 24 hours immersion were (20.508, 18.605, 16.108)% respectively with significant differences, and in longitudinal swelling percent for the three height levels after immersion in water for 6 and 24 hours. The values after immersion 6 hours were (2.241, 2.115, 1.749)% respectively, but without significant differences. And the values after immersion in water for 24 hours (3.825, 3.188, 2.967)% respectively with significant differences, and in thickness swelling percent after immersion in water for 6 and 24 hours. The values after immersion 6 hours were (5.244, 5.033, 4.788)% respectively without significant differences, and after 24 hours immersion in water were (8.402, 6.939, 6.914)% respectively, without significant differences. While the values of immersion in water for 2 hours of the 3 height levels for volumetric (6.081, 6.449, 6.726)% respectively, longitudinal (1.223, 1.310, 0.831)% and thickness swelling percent (3.054, 3.014, 3.421)% respectively, were very close together without any significant differences, this result may be related to the shortage of time for 2 hours immersing period to absorb adequate water for noticeable swelling of the studied characters. In the same manner, there were significant gradual decrease in volumetric shrinkage percent after 48 hours drying period for the three height levels (12.778, 11.254, 9.426)% respectively. Similarly, as mentioned above, there were significant decrease of pine trees wood in volumetric swelling percent after immersion in water for 2, 6, and 24 hours from stem base level to the middle and top levels. The values after immersion in water for 2 hours were (8.262, 5.896, 3.562)% respectively, and for 6 hours immersion were (10.504, 8.880, 5.890)% respectively, and for 24 hours immersion were (12.694, 12.388, 7.569)% respectively. Similar results were obtained in longitudinal swelling percent of the three height levels of the stem after immersion for 2, 6 and 24 hours, the values after immersion for 2 hours period were (1.822, 1.414, 1.074)% respectively, and for 6 hours immersion period were (2.601, 1.930, 1.392)% respectively, and for 24 hours immersion period were (3.146, 2.895,, 1.700)% respectively. The same manner occur for thickness swelling percent of the three height levels of the stem. The values for 2 hours immersion in water were (3.587, 1.927, 3.321)% respectively, and for 6 hours immersion period were (4.342, 3.181, 2.146)% respectively, and for 24 hours immersion period were (5.011, 4.321, 2.909)% respectively. Also, a similar results were obtained for volumetric shrinkage percent after drying for 48 hours (9.222, 8.275, 6.579)% respectively.

Table 1. Duncan analysis of means for each of Azadirachta and pine trees showing the effect of wood type in some physical properties of wood

wood properties												
after drying for 48 hrs		% thickness swelling after immersion in water for			% longitudinal swelling after immersion in water for			% volumetric swelling after immersion in water for			wood type	tree kind
% volumetric thickness	% moisture loss	24 hours	6 hours	2 hours	24 hours	6 hours	2 hours	24 hours	6 hours	2 hours		
14.108 a	21.356 a	9.195 a	5.866 a	2.901 a	4.112 a	2.722 a	1.426 a	23.524 a	14.650 a	6.671 a	tension	Azadirachta
8.197 b	21.939 a	5.642 b	4.177 b	3.425 a	2.541 b	1.349 b	0.816 b	13.290 b	8.581 b	6.166 a	normal	
8.634 a	43.103 a	4.818 a	4.041 a	2.932 a	3.019 a	2.352 a	2.008 a	12.455 a	10.001 a	7.853 a	compression	pine
7.417 a	42.561 a	3.343 b	2.405 b	1.617 b	2.144 b	1.596 b	0.865 b	9.312 b	6.848 b	3.960 b	normal	
11.152 a	21.648 b	7.418 a	5.022 a	3.163 a	3.326 a	2.035 a	1.121 b	18.407 a	11.615 a	6.148 a	Azadirachta	mean
8.026 b	42.832 a	4.080 b	3.223 b	2.274 b	2.582 b	1.974 a	1.436 a	10.883 b	8.424 b	5.907 a	pine	

Same letters in each column of each tree type means no significant differences present at 0.05 probability

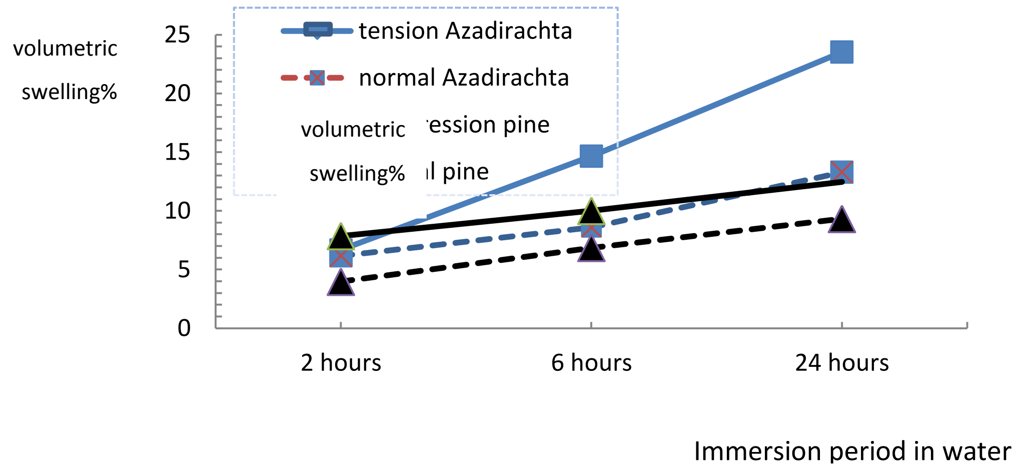

Figure 3. Effect of wood type for each Azadirachta and pine trees in volumetric swelling percent

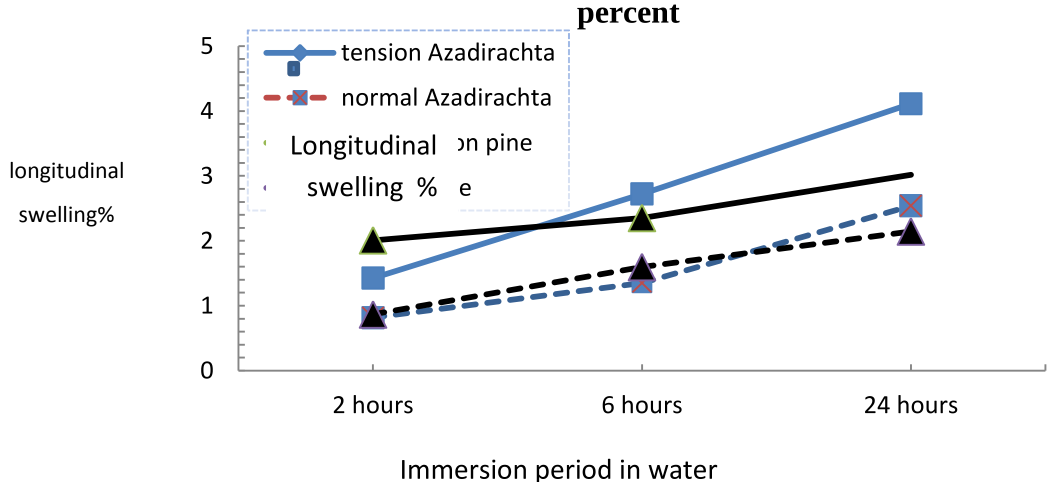

Figure 4. Effect of wood type for each Azadirachta and pine trees in longitudinal swelling percent

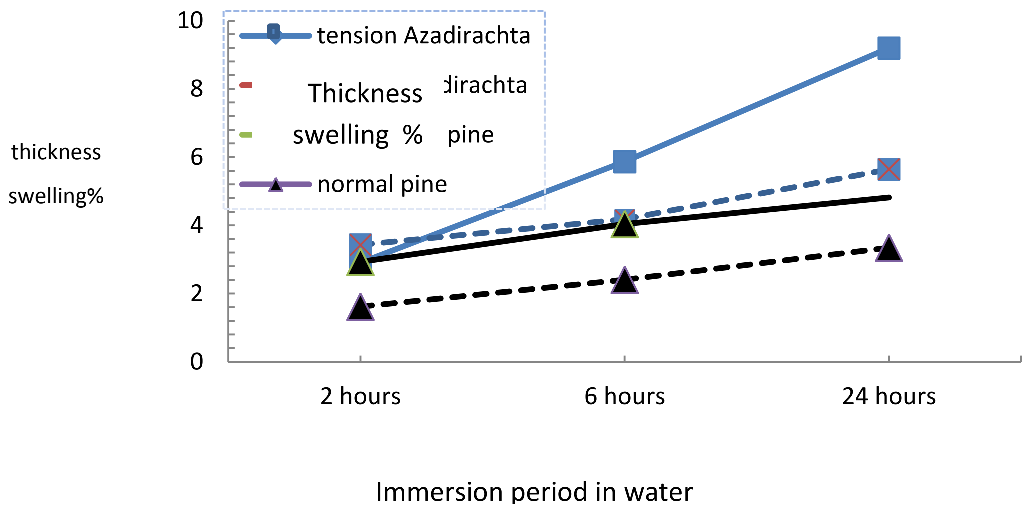

Figure 5. Effect of wood type for each Azadirachta and pine trees in thickness swelling percent

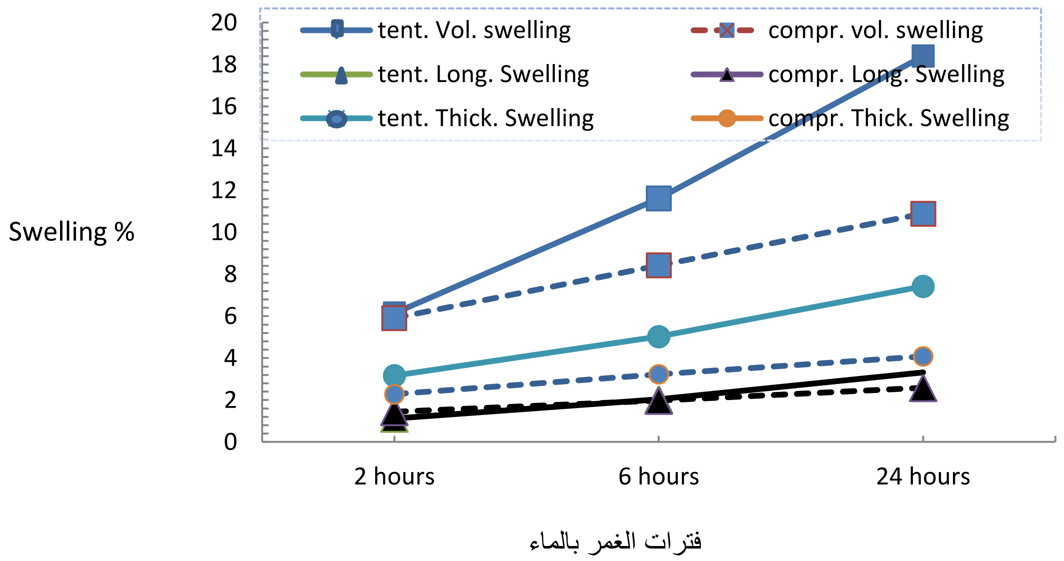

Figure 6. Differences between tension wood and compression wood in volumetric, longitudinal and thickness swelling percent after immersion in water for 2, 6, 4 hours

This results may refer to the percent increase of tension wood at the base of Azadirachta stems trees and the percent increase of compression wood of pine tree at stem base compared to the middle and top stem levels since reaction wood percent decreases gradually from base stem level to the top stem level, this will case a reduction in swelling and shrinkage percent. This fact will lead to a conclusion that the eccentric of stem pith in reaction woods of Azadirachta and pine trees were the highest at base level, then it decrease gradually at middle stem level and the lowest will be at top stem level, this results is due to gradual decrease of reaction wood from base to stem top levels, (fig. 7). These results were similar to Yousif et. al. (21) study which they explained that eccentric pith of *Quercus aegilops* L. leaning trees decreased from stem base to stem top. Also, these results were similar to the finding of Almalah and Aldosky (2) study of *pinus brutia* Den. Leaning tree stems. Table 2 also show that moisture loss percent at top level of Azadirachta stem trees was significantly higher (23.315%) compared to middle and base height levels (20.698, 20.931)% respectively which showed no significant differences between them. Also, moisture loss percent at middle and top height levels of pine trees (42.487, 45.807)% respectively, were higher significantly than base height level (40.202%). Generally, all values of moisture loss percent of pine wood for all height levels were higher compared to Azadirachta wood. The reason may refer to the same causes mentioned in the effect of wood kinds on moisture loss percent between Azadirachta and pine wood (Table 1. In addition, table (2) showed the general mean of the effect of height level of both Azadirachta and pine stems on volumetric, longitudinal and thickness swelling percent after immersion in water for 2, 6, 24 hours. The higher values of volumetric swelling percent after immersion in water for 2 hours were in the base stem levels (7.172%), then it decreased at middle level (6.173%) and the lowest was at top level (5.144%). Similarly, the same result were obtained after immersion 6 hours (11.555, 10.419, 8.085)% respectively, also, for 24

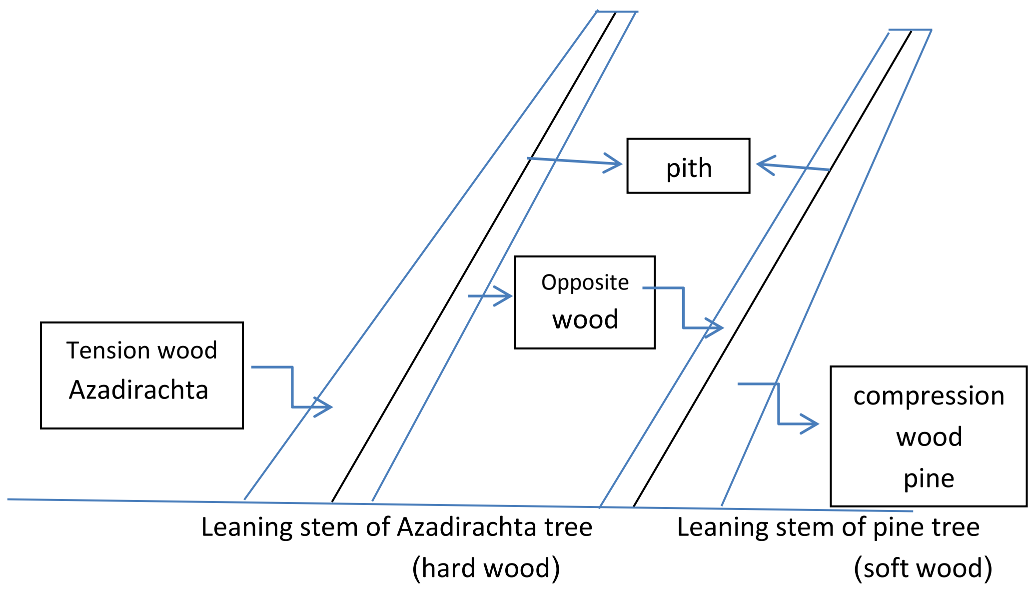

Figure 7. The eccentric pith in hardwood and softwood leaning stems

hours immersion in water (16.6021, 15.496, 11.838)% respectively. Similar results were obtained for longitudinal swelling percent after immersion in water for 2 hours (1.523, 1.362, 0.952)% respectively and after 6 hours immersion in water (2.421, 2.022, 1.571)% respectively, and after immersion in water for 24 hours (3.487, 3.042, 2.333)% respectively, also, similar results were obtained for thickness swelling percent after immersion in water for 2 hours (3.321, 2.471, 2.365)% respectively, and after 6 hours immersion in water (4.793, 4.107, 3.467)% respectively, and for 24 hours immersion in water (6.706, 5.630, 4.911)% respectively. Volumetric shrinkage percent after drying 24 hours gave similar results as mentioned above since the highest value was at base level (10.999%) then it decreased to (9.764%) at middle height level, and the lowest value was at top stem height levels (8.003%). The effects of stem height levels on moisture loss percent were similar to height levels effects on moisture loss percent of pine. The highest significant values was at top and middle height level (32.901, 33.205)% respectively, compared to base level (30.567%).

3- Effects of wood location in the studied physical properties

Duncan's means analysis Table 3 show that volumetric swelling percent of Azadirachta sapwood after immersion in water for 6 and 24 hours (12.651, 19.347)% respectively, were slightly higher compared to heartwood (10.579, 17.466)% respectively. Similar results was obtained for longitudinal swelling percent for sapwood after immersion in water for 6 and 24 hours (2.128, 3.331)% respectively compared to heartwood (1.942, 3.323)% respectively. Also, the same results was found for thickness swelling percent of sapwood (5.345, 7.905)% respectively compared to heartwood (4.697, 6.932)% respectively. There were no significant differences between sapwood and heartwood except for volumetric swelling percent after immersion in water for 6 hours. The reason may be related to the presence of deposits in cell cavities and cell wall of heartwood cells, as well as the presence of pit aspiration in heartwood which prevents liquid translocation across wood cell wall, this will lead to an increase in water absorption percent and increase sapwood cell swelling compared to heartwood cell swelling.These results was identical to Yousif et. al. (21) study, they explain that sapwood of *Quercus aegilops* L. has water absorption percent after immersion in water for 24 and 48 hours and moisture loss higher than heartwood. Sapwood volumetric and longitudinal swelling percent after immersion in water for 2 hours (6.818, 1.102)% respectively, were very low and un significant compared to heartwood (6.019, 1.141)% respectively. The reason may be related to immersion periods shortage which lead to un sufficient water absorption for both sapwood and heartwood. While thickness swelling percent of sapwood after immersion in water for 2 hours was significant differ (3.535%) than heartwood (2.791%). The reason may refer to the fact that thickness swelling percent in tangential direction is usually higher compared to longitudinal or radial directions (8), which lead to noticeable increase in sapwood thickness swelling percent compared to heartwood. Also, table (3) indicated that there were no significant differences in volumetric shrinkage percent between sapwood (11.038%) and heartwood (11.267) of Azadirachta wood. Also, the table show that there was slight increase in moisture loss percent of sapwood (22.072%) compared to heartwood (21.224%) but without significant differences. This may justify the reason of volumetric, longitudinal and thickness swelling percent increase after immersion in water for 6 and 24 hours as a results, more water absorption of sapwood occurs. In addition, table 3 show that sapwood of pine trees gave volumetric swelling percent after immersion in water for 2, 6, and 24 hours slightly lower (5.619, 7.902, 10.558)% respectively, compared to heartwood (6.194, 8.947, 11.209)% respectively, without significant differences between them. Similarly, longitudinal swelling percent of sapwood (1.230, 1.674, 2.272)% respectively, were slightly lower than heartwood (1.6442, 2.274, 2.891)% respectively, and the same for thickness swelling percent for sapwood (2.126, 3.032, 3.816)% respectively, compared to heartwood (2.432, 3.414, 4.345)% respectively, also, moisture loss percent and volumetric shrinkage percent of sapwood were slightly lower (42.404, 7.627)% respectively than heartwood (43.261, 8.424)% respectively. It can be noticed that most of the studied characteristics of pine sapwood and heartwood values of pine wood were lower compared to Azadirachta wood, which can be related to the possession of pine compression wood a greater lignin molecules percent which may have less bonding with water compared to Azadirachta tension wood which possess higher cellulose percent which can bond with more water molecules by hydrogen bonding with the hydroxyl group, also, pine compression wood may possess fewer percent of homogenous material which causes wood swelling and shrinkage compared to homogenous material present in Azadirachta wood. In addition, Table 3 showed the general means of studied characteristics of each sapwood and heartwood for Azadirachta and pine trees. Volumetric swelling percent after immersion in water for 2, 6, 24 hours for sapwood (6.218, 10.276, 14.952)% respectively, were slightly higher compared to heartwood (6.106, 9.763, 14.337)% respectively, with no significant differences between them. Also, thickness swelling percent for sapwood has higher values after immersion in water for 2, 6, 24 hours (2.831, 4.189, 5.860)% respectively compared to heartwood (2.607, 4.055, 5.638)% respectively. These results were in the same manner of sapwood and heartwood effects of Azadirachta wood on the studied characteristics. This results may refer to the same cases mentioned above concerning the presence of cellulose gelatinous layer and homogenous material in higher percent in tension wood of both sapwood and heartwood of Azadirachta stem trees compared to pine tree compression wood of both sapwood and heartwood which increase the general mean values of volumetric and thickness swelling percent after immersion in water for 2, 6 and 24 hours. Concerning longitudinal swelling percent, table (3) indicate that heartwood gave slightly higher percent and un significant after immersion in water for 2, 6, 24 hours (1.392, 2.108, 3.107)% respectively, compared to sapwood (1.166, 1.901, 2.801)% respectively. The reason may be related to the higher values of longitudinal swelling percent of pine heartwood after immersion in water for 6, 24 hours compared to Azadirachta heartwood (table 3) which gave a general mean of heartwood for Azadirachta and pine wood higher than sapwood. Kasir et. al. (13) explain that this phenomenon is related to the cell wall chemistry more than it's relation to cell wall physical properties. Also, table (3) show that the differences of general mean of moisture loss percent and volumetric shrinkage percent between sapwood (32.238, 9.332)% respectively and heartwood (32.243, 9.845)% respectively, were very slight with no significant differences between them. +Generally, it can be concluded that both tension wood and compression wood can get volumetric, longitudinal and thickness swelling percent and volumetric shrinkage percent higher than normal wood. Also, tension wood of Azadirachta stem give volumetric and thickness swelling percent higher than pine compression wood. But there are no clear difference between tension and compression wood in longitudinal swelling percent. Hence, soft wood containing compression wood is more preferable than hard wood containing tension wood for different wood manufacturing due to more dimensional stability of compression wood compared to tension wood of the leaning trees. Also, pith eccentric in the stem of leaning trees of both soft wood and hardwood are higher at stem base, and decreases gradually by increase stem height to the top position of the stem.

Table 2. Duncan analysis of means for each Azadirachta and pine trees showing the effect of stem height levels in some physical properties of wood

wood properties												
after drying for 48 hrs		% thickness swelling after immersion in water for			% longitudinal swelling after immersion in water for			% volumetric swelling after immersion in water for			stem height levels	tree kind
% volumetric shrinkage	% moisture loss	24 hours	6 hours	2 hours	24 hours	6 hours	2 hours	24 hours	6 hours	2 hours		
12.778 a	20.931 b	8.402 a	5.244 a	3.054 a	3.825 a	2.241 a	1.223 a	20.508 a	12.607 a	6.081 a	base	Azadirachta
11.254 ab	20.698 b	6.939 a	5.033 a	3.014 a	3.188 ab	2.115 a	1.310 a	18.605 ab	11.959 a	6.449 a	middle	
9.426 b	23.315 a	6.914 a	4.788 a	3.421 a	2.967 b	1.749 a	0.831 a	16.108 b	10.280 a	6.726 a	top	
9.222 a	40.202 b	5.011 a	4.342 a	3.587 a	3.146 a	2.601 a	1.822 a	12.694 a	10.504 a	8.262 a	base	pine
8.275 ab	45.807 a	4.321 ab	3.181 ab	1.927 b	2.895 a	1.930 ab	1.414 ab	12.388 a	8.880 a	5.896 b	middle	
6.579 b	42.487 ab	2.909 b	2.146 b	1.308 b	1.700 b	1.392 b	1.074 b	7.569 b	5.890 b	3.562 c	top	
10.999 a	30.567 b	6.706 a	4.793 a	3.321 a	3.487 a	2.421 a	1.523 a	16.601 a	11.555 a	7.172 a	base	mean for Azadirachta and pine
9.764 ab	33.253 a	5.630 ab	4.107 ab	2.471 b	3.042 a	2.022 ab	1.362 a	15.496 a	10.419 a	6.173 ab	middle	
8.003 b	32.901 ab	4.911 b	3.467 b	2.365 b	2.333 b	1.571 b	0.952 b	11.838 b	8.085 b	5.144 b	top	

Same letters in each column of each tree type means no significant differences present at 0.05 probability

Table 3. Duncan analysis of means for each of Azadirachta and pine trees showing the effect of wood location in some physical properties of wood

wood properties												
after drying for 48 hrs		% thickness swelling after immersion in water for			% longitudinal swelling after immersion in water for			% volumetric swelling after immersion in water for			wood location	tree kind
volumetric shrinkage %	moisture loss %	24 hours	6 hours	2 hours	24 hours	6 hours	2 hours	24 hours	6 hours	2 hours		
11.267 a	21.224 a	6.932 a	4.697 a	2.791 b	3.323 a	1.942 a	1.141 a	17.466 a	10.579 b	6.019 a	heartwood	Azadirachta
11.038 a	22.072 a	7.905 a	5.345 a	3.535 a	3.331 a	2.128 a	1.102 a	19.347 a	12.651 a	6.818 a	sapwood	
8.424 a	43.261 a	4.345 a	3.414 a	2.432 a	2.891 a	2.274 a	1.642 a	11.209 a	8.947 a	6.194 a	heartwood	pine
7.627 a	42.404 a	3.816 a	3.032 a	2.126 a	2.272 a	1.674 a	1.230 a	10.558 a	7.902 a	5.619 a	sapwood	
9.845 a	32.243 a	5.638 a	4.055 a	2.607 a	3.107 a	2.108 a	1.392 a	14.337 a	9.763 a	6.106 a	heartwood	mean for Azadirachta and pine
9.332 a	32.238 a	5.860 a	4.189 a	2.831 a	2.801 a	1.901 a	1.166 a	14.952 a	10.276 a	6.218 a	sapwood	

Same letters in each column of each tree type means no significant differences present at 0.05 probability

REFERENCES

1. Abdul-Razzaq A. M. and M. A. Salman. 2018. Modern communications technologies and their role in improving agricultural extension work in Middle Iraqi Governorates. Iraqi J. Agric. Sciences. 49(5):826-839

2. Almalah, A. R. S. and H. A. Aldosky. 2009. Studying some anatomical and mechanical characteristics of compression wood for *pinus brutia* ten. Leaning trees. Mesopotamia J. of Agriculture. 37(4): 85-96

3. Anonymous. 1982. Wood-Determination of volumetric swelling . International Standard, ISo. 5859. Internal Organization for Standardization, Ref No. ISO

4. Ayrilimis, N. 2008. Effect of compression wood and dimensional stability of medium density fiberboard. Silva Fennica 42(2): 285-293

5. Badia, MA, F. Mothe and G. Nepven. 2005. Assessment of tension wood detection based on shiny appearance for three poplar cultivars. Ann For Sci. 62:43–49.

6. Boyd, J. D. 1977. Relationship between fiber morphology and shrinkage of wood. Wood Sci. Technol. 113-22

7. Clair, B., J. Ruelle and B. Thibaut. 2006. Tension wood and opposite wood in 21 tropical rainforest species. 1.Occurrence and efficiency of the G-layer . IAWA J 27(3):329-338

8. Dinwoodie, J. M. 2000. Timber: Its Nature and Behavior. University of Wales. Macmillan, London, Newyork.

9. Donaldson, L. A., J. Grace and G. M. Downs. 2004. Within tree Variation in Anatomical properties of compression wood in radiate pine. IAWA Journal, Vol.25: 253-271

10. Duncan, D. B. 1955. Multiple range and multiple F-tests. Biometrics 11: 1-42

11. Gryc, H., P. Vavrcik and P. Horacek. 2007. Variability in swelling of spruce (*Picea abies* L. Karst.) wood with the presence of compression wood. Journal of Forest Science, 53, (6): 243-252

12. Haygreen, J. G. and J. L. Bowyer. 1982. Forest Product and Wood Science an Introduction. The lowa state university. Iowa USA. Maeglin, R.R. 1970. pp. 495

13. Kasir, W. A., A. S. Saleem and A. A. Ali. 1985. Wood as Raw Material. Translated book. Ministry of higher education, Mosul University press, Iraq. pp. 325

14. Myasnikov, Al A. 2018. Zonal forest communities and forest zoning of western Siberia (Russia). Iraqi J. Agric. Sciences. 49(6):938-943

15. Niemz. P. 1993. Physic der Holzes und der Holzwerkstoffe. Leinfelden-Echterding, DRW-Verlag Weinberenner. pp. 243

16. Ozmen, N. 2007. Dimensional stabilization of fast growing forest species by acetylation. Journal of Applied Sciences. 7 (5): 710-714

17. Perstopper, M., M. Johansson, R. kliger and G. Johansson. 2001. Distortion of Norway spruce timber. Part 1. Variation of relevant wood properties. Holz als Roh-un Werkstoff, 59: 95-103

18. Rowell, R. M.; J. S. Han and J. S. Rowell. 2000. Characterization and Factors Effecting Fiber Properties. Natural Polymers and Agrofibers Composites, Sãn Carlls- Brazil-2000. E. Florin, A. L. Leão and L. H. C. Mattoso. http://www.fpI.fs. fed.us /documents/pdf 2000/ roweloob.pdf

19. SAS. 2002. Statistical Analysis System. SAS\ STAT\ Users Guide for personal Computers Release 6.12 . SAS Institute Inc, Cary, NC, USA

20. Yen, T. F., T. Yamada, E. Capanema, H. M. Change, V. Chiang and J. F. Kadla. 2005. Rapid screening of wood chemical component variation using transmittance near infrared spectroscopy. J. Agric. Food Chem. 3328-3332

21. Yousif, S. I., A. R. Almalah and S. A. Mustafa. 2018. Anatomical, Chemical And Physical Properties of *Quercus Aegilops* L. Tension Wood Trees. M.Sc. Thesis, Dept. of Forestry., Coll. of Agric. and Forestry., Mosul Univ. pp. 117.