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Variation in Vessel Element Size and Tissue Proportion in Three Iraqi Oaks

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Abstract. The percentage of wood elements and the variation of vessel element dimensions were studied in the wood of three oak species (*Quercus aegilops, Q. infectoria,* and *Q. libani*) growing in the native forests of Iraq.

The volume percentages of wood vessels in these three sepecies were 22.3 for *Q. Libani,* 35.4 for *Q. infectoria* and 34.1 for *Q. aegilops.* The percentages of fibres were 55.8, 54.6, and 52.3 for the three species respectively. The vessel element length was 0.11 mm for the three species while the diameter ranged from 15.62-16.30 μm.

The dimensions of vessel element were not consistent in their change with height or distance from the pith, increasing in *Q. Libani* and *Q. infectoria,* while a consistent decrease in vessel element length in *Q. aegilops* was noticed.

Introduction

In Iraq, the demand for fibrous materials for lumber, fibre, and for pulp have significantly increased within the past decade. Much wood is utilized in manufacturing pulp and paper depending on wood type and quality, which in turn appreciably affect all paper properties. Among many wood properties of importance, the proportion of various wood elements is considered as a major factor which determines the suitability of wood for such uses [1-3].

The study of the source and variation in the elements of hardwood is necessary from the point of view of determining their suitability into finished products for the pulp and paper industry [3]. Vessel elements of hardwood affect the printing qualities of resulting paper. The vessel elements have a tendency to "pick-out" in the printing process. Vessels element length has been reported to increase and diameter

to decrease with increasing height in the stem [4-6]. Similarly, an increase in vessel element length and diameter from the pith outwards to the bark has been found by several workers [7-9].

The natural oak forests in northern Iraq have *Quercus aegilops* L., *Q. infectoria* Oliv., and *Q. libani.* as dominant species [10], and provide more than 50% of the timber used in the region. The three species are ring-porous [11]. The objectives of this work are: (i) to determine the percentage of wood elements by volume, and (ii) to study the variation of vessel element dimensions within and between the trees.

Materials and Methods

From the natural forest around Swaratuka in the north of Iraq at an elevation of 1100-1400 m above sea level (mean annual rainfall 920 mm, mean annual temperature 12-14°C), three trees of each oak species were selected. These were largely free from visible evidence of disease or mechanical damage. After felling, the stems were sampled at 1 m intervals beginning from 50 cm above the ground. Small blocks (size $0.5 \times 0.5 \times 1.0$ cm) were cut from the pith outwards to the bark on the northern side of stem; each block contained five growth rings.

The blocks were softened by Franklin's method [12]. Sections of 15 m thickness were cut, stained in safranin, and mounted in Canada balsam as permanent slides. Ten counts for each block (transverse sections) formed the basis of estimating the mean number of vessel elements, parenchyma (including rays), and fibre were calculated from randomly selected spots on the screen of the microscope.

For vessel element length and diameter measurements, macerated small blocks (selected as above) were prepared [12]. The separated wood elements were stained with 2% safranin and then mounted in Canada balsam according to Jane's method [13]. Twenty five measurements each were taken for late wood vessel element lenght and diameter from macerated small blocks.

Results and Discussion

The data derived from calculations of wood elements proportion including fibre, vessel, and parenchyma in the three species from blocks cut at intervals of 1m from 9 trees (3 trees of each species) are presented in Table 1 and the results of statistical analysis of late wood vessel element dimensions variation are given in the analysis of variance in Tables 2 and 3.

Wood components percentage

The average fibre percentage was lower in *Q. aegilops* (52.3) than in either *Q. infectoria* or *Q. libani* (54.6 and 55.7 respectively). The vessel percentage had an opposite trend with the fibre percentage of *libani* (22.3) compared to 34.1 for

Table 1. Percentage of wood elements in Iraqi oaks

Spp.	Fibres %	Vessels %	Parenchyma %
Q. libani	55.8	22.3	22.0
SD	1.5	1.3	1.1
Q. infectoria	54.6	35.4	10.0
SD	1.5	1.1	0.8
Q. aegilops	52.3	34.1	13.7
SD	1.5	1.0	1.4

SD = standard deviation

aegilops and 35.4 for *infectoria*. The highest parenchyma percentage was noticed with *Q. libani* (22.0) followed by that of *aegilops* (13.7) and *infectoria* (10.0). From Table 1 a kind of relation between vessel and parenchyma percentages appeared with *infectoria* and *aegilops*; both species had high percentage of vessel but low percentage of parenchyma. The high percentage of fibre and parenchyma in *libani* may be attributed to the effect of individual trees being free growing [14].

Vessel element length

The average late wood vessel element length of the three species was 0.11 mm while the range of the length ranged from 0.102-0.126 mm. Ranges of 0.092-0.122 mm and 0.096-0.133 mm were recorded for *infectoria* and *libani* respectively. The range included the length of vessel element from tree base upward and from the pith outwards.

The analysis of variance (Table 2) shows that in the case of *aegilops* no statistical difference occurred between trees, heights, tree and height combination, growth ring count from the pith outwards and the combination of tree and R.C.. There was a consistent decrease in the vessel element length with tree height increase (Fig. 1).

In the case of *infectoria* a reduction in vessel element length in combination with tree and height was significant at 1% level (Table 2); a reduction with the growth ring count from the pith outwards was significant at 5% level only. the decrease in the vessel element length from tree base upwards was not consistent with increasing tree height (Fig. 1).

The vessel element length variation of *libani* trees was highly significant, and the effect of tree height was clear. The effects of trees and growth ring count from the pith outwards were also highly significant while the effect of interaction between tree and growth ring count from pith outwards was only significant at 5% level. A consistent decrease in vessel element length was observed after three meters height (Fig. 1).

Table 2. Analysis of variance for vessel element length in the three *Quercus* spp.

Source of variation	*Q. aegilops*		*Q. infectoria*		*Q. libani*	
	D.F.	M.S.	D.F.	M.S.	D.F.	M.S.
Total reduction	18	0.0147 **	21	0.0173 **	21	0.0198 **
Tree	2	0.0009	2	0.0013	2	0.0016
Height	5	0.0018	6	0.0007	6	0.0083 **
Tree X Height	10	0.0016	12	0.0012 **	12	0.0006
Error	733	0.0004	1003	0.0005	855	0.0006
Total reduction	21	0.0029 **	18	0.0033	21	0.0031 **
Tree	2	0.0007	2	0.0044	2	0.0028 **
R.C.	6	0.0010	5	0.0040 *	6	0.0028 **
Tree X R.C.	12	0.0013	10	0.0030	12	0.0009 *
Error	429	0.0012	432	0.0017	480	0.0005

* Significant at $P<0.05$
** Significant at $P<0.01$
R.C. = Ring count from the pith outwards.

Table 3. Analysis of variance for vessel element diameter in the three *Quercus* spp.

Source of variation	*Q. aegilops*		*Q. infectoria*		*Q. libani*	
D.F.	D.F.	M.S.	D.F.	M.S.	D.F.	M.S.
Total reduction	18	28.8254 **	21	29.2879 **	21	15.4517 **
Tree	2	29.5223 **	2	8.0717	2	27.5702 **
Height	5	13.5060	6	2.3783	6	16.8570 **
Tree X Hfeight	10	15.2300 **	12	18.8972 **	12	8.7398
Error	733	6.2017	1003	5.3791	855	5.9002
Total reduction	21	100.4561 **	18	118.0242 **	21	50.5319 **
Tree	2	2.5186	2	32.5960 *	2	34.7764 **
R.C.	6	18.8334 *	5	23.2662 *	6	38.5741 **
Tree X R.C.	12	9.6596	10	33.3582 **	12	12.9887 **
Error	429	8.3745	432	9.6726	480	5.8255

* Significant at $P<0.05$
** Significant at $P<0.01$
R.C. = Ring count from the pith outwards.

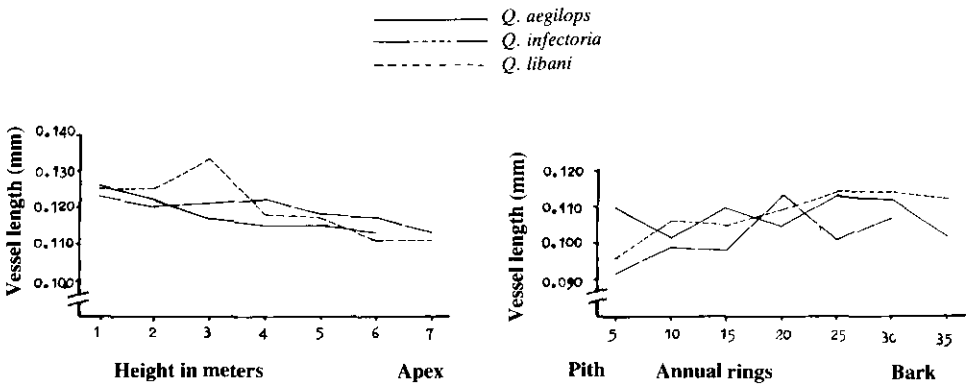

Fig. 1. Relationship of vessel length (mm) and coded tree height and rings classes of Iraqi oak species.

Vessel element diameter

Q. libani showed the least latewood vessel diameter; it ranged between 14.71-16.51 μm with a mean of 15.62 μm. *Q. aegilpos* on the other hand showed the largest mean diameter (16.30 μm); it ranged from 15.25-17.44 μm. Vessel diameter of *infectoria* was intermediate between both.

In the case of *Q. aegilops* the effect of trees and the combination of tree with tree height on the vessel element diameter was highly significant, that of growth ring count from the pith outwards to the bark was significant at 5% level only (Table 3). There was no consistent change in the diameter of vessel element with increasing tree height or distance form the pith. The effect of interactions between tree on one hand and both height and growth ring count on the other hand on vessel element diameter were highly significant in the case of *infectoria,* while the effects of trees and growth ring distance from the pith were significant at 5% level only (Table 3). The diameter of vessel element tended to increase with increase of annual rings until age 25 years then decreased (Fig. 2).

In the case of *libani* there was a highly significant effect of trees, tree height, growth ring distance from the pith, and the combination of tree and growth ring count from the pith outwards on vessel element diameter (Table 3). No consistent change in vessel element diameter was observed with increasing of the tree height or distance from the pith (Fig. 2).

These trends of variation may be due to the effect of the year of the formation, since the newly formed vessel element had larger diameters than the old elements, which may be affected by the presence of higher concentrations of auxins [15]. The increasing amount of auxins year after year due to the increase of the number of branches and leaves, propably explains the differences in the vessel element dimensions from the pith outwards to the bark.

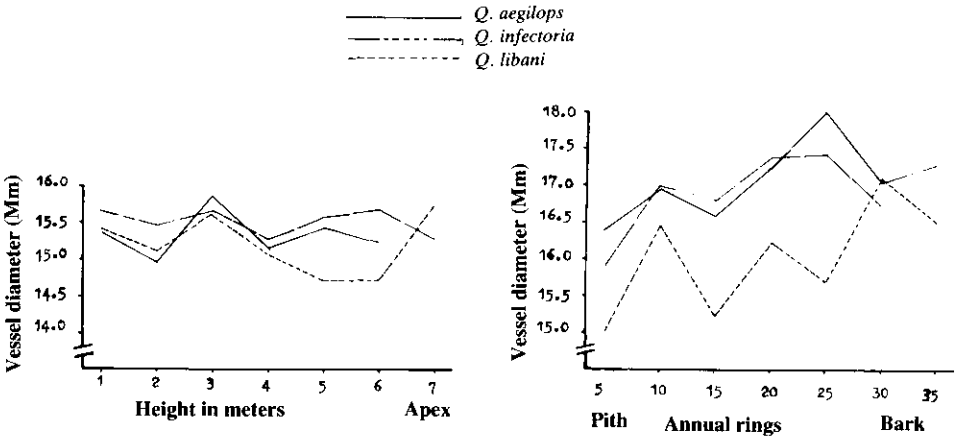

Fig. 2. Relationship of vessel diameter (μm) and coded tree height and ringe classes of Irqi oak species.

Conclusions

The present study shows that the fibre percentage of the three species ranged from 52.3-55.7. *Q. libani* had the highest percentage of fibre (55.7), parenchyma (22.0) and the lowest percentage of vessel 22.3. This situation makes *Q. libani* favoured for pulping, followed by *Q. infectoria* and finally by *Q. aegilops*. The inconsistent change of vessel element dimensions of *Q. libani* and *Q. infectoria* makes them good candidates for such purpose. A further step towards arriving to the right conclusion is to make pulp and characterize its properties.

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تباين أبعاد أوعية الخشب وتقدير نسبة مكونات الخشب في أنواع البلوط في العراق

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ملخص البحث. تمت دراسة نسبة مكونات الخشب وتباين أبعاد أوعية الخشب في خشب الأنواع الثلاثة من البلوط *Quercus libani, Q. infactoria* و *Q. aegilops* النامية في الغابات الطبيعية في العراق. وكانت نسبة أوعية الخشب الحجمية ٢٢,٣ ، ٣٥,٤ و ٣٤,١٪ للأنواع الثلاثة السابقة على التوالي. وكانت نسبة الألياف في الأنواع الثلاثة على التوالي ٥٥,٨ ، ٥٤,٦ ، ٥٢,٣٪ وكان معدل طول عناصر الأوعية للأنواع الثلاثة بواقع ٠,١١ ملمتر بينما تراوح القطر بين ١٥,٦٢ - ١٦,٣٠ مايكرون.

ولم يكن تغير أبعاد الأوعية ثابتا مع زيادة الارتفاع أو البعد عن نخاع الشجرة في النوعين *infactoria, libani* بينما كان هناك نقص واضح في طول عناصر الأوعية في النوع *aegilops* مع زيادة ارتفاع الشجرة وزيادة البعد عن النخاع.