World Applied Sciences Journal 20 (8): 1114-1122, 2012
ISSN 1818-4952

DOI: 10.5829/idosi.wasj.2012.20.08.1748

Wood Features of Saxaul (*Haloxylon* spp.) From Central Iran

Nooshin Toghraie

Botany Research Department, Research Inst. of Forests and Rangelands (RIFR)

Abstract: Wood properties of Saxaul in central Iran were investigated. Arranging tests according to common laboratory techniques showed that the wood is so heavy, so brittle, with short fibers, huge amounts of crystals. Wood structure consists of included phloem (anomalous growth) with successive cambia. Vulnerability and mesomorphy ratios were low showing a tree very resistant to drought (not shown here). The results showed that there were significant differences between wood properties of two species except for growth periodicity and heartwood lumen diameter. Besides there were significant differences between wood properties of three different trees planting density. Fiber length differs at tree planting densities wholly and the trees produce longer fibers in areas with 1000 tree per hectare. In the present study, stress has been given to some wood properties of this wood, in order to find out some possible industrial utilization of this seemingly useless wood.

Key words: Zard tagh · Ciah tagh · Wood anatomy · Wood properties

INTRODUCTION

The extent of real desert or hyper arid land in Iran according to Khalili's studies [1],in the country's water master plan is around 57.4 Mil Hectare or 35.5%. This area is a part of 137.2 million hectare dry lands and sand dune regions in Iran, i.e. hyper arid lands, arid lands and semi arid lands, are known to be completely desert. Stretching for more than a thousand kilometers in length, the arid deserts of the central Iran plateau are covered mostly by gravel and shifting sands [2]. Arid and desert zones represent ca. 84.2% of the country's area [3]. Fortunately, once stabilized, they are capable of providing a good protection for the communities, living in their vicinity.

Since 1950s several national projects of sand dune fixation have been underway in the country and their achievements in combating desertification are widely recognized [4].

From the beginning of the sand dune stabilization programmed in Iran, till 1992, an area about 985378 hectare, has been covered with xerophytes seedlings and so far, more than 224155 hectare broadcast seedlings by hand or aircraft. As part of the green belt development programs, saxaul was successfully planted over scattered areas around Iran's central desert to protect villages, roads and railways, as well as for fuel and fodder production [5-7].

Nowadays an area of more than 2 million hectares of country is covered by saxaul [8], which is the main species successfully used in sand dune stabilization programs throughout the arid zones of country.

Taking into consideration the importance of area covered by saxaul in our country and keeping in mind the extensive area of Iranian Control Desert which is practically under cultivation of above mentioned species, any research carried out on this subject could be considered as a high value research from silviculture, natural resources and life environment point of view. The aim of this study is to obtain some more data about the growth, wood structure and anatomical and physical properties of saxaul wood.

MATERIALS AND METHODS

Ten trees of saxaul species were cut down from Kashan region, 220 km. southern Tehran (Figure 1). Mean annual precipitation is 140 mm and Max. and Min. temperature are respectively 38° C and-0.1° C. The aridity index of De Martonne is 1.4, demonstrating typical desert climate. Haloxylon aphyllum (Ciah Tagh) No. 1-5 and Haloxylon persicum (Zard Tagh) No. 6-10.

Corresponding Author: Nooshin Toghraie, Botany Research department,
Research inst. of Forests and Rangelands (RIFR), P.O.Box 13185-116, Tehran, Iran.
Tel: +982144580285, Fax: +982144580223.

Fig. 1: Map showing the position of the study area, Kashan

Table 1: Annual growth in tree samples

tree no.	1	2	3	4	5	6	7	8	9	10
diam. growth mm.	4.0	4.6	4.7	4.1	3.9*	4.3	5.9**	5.4	5.3	4.9

* Ciah Tagh, 6 year, 1000 tree per hectare

** Zard Tagh, 7 year, 500 tree per hectare

The age of samples was between 6 and 15 years. The sampling areas were of tree planting density 500, 800 and 1000 per hectare. A disk of 2 cm. thick has been sawn from each stem of each sample tree. Test pieces for anatomical surveys and physical tests prepared from these disks later.

In the laboratory the samples were boiled and placed in a solution with equal parts of water, glycerin and ethyl alcohol for softening. Transverse, radial and tangential sections (10-30µm thick), were taken from them using a Leica sliding microtome. Preparation of the sections from cross section, radial and tangential surface of disks was done according to common techniques applied in our lab [9, 10, 11]. These slides were studied by microscope under various magnifications to clarify the anatomical structure. We tried SEM microscopy to focus on some particular features in this wood. Wood anatomy and fiber biometry was studied according to IAWA [12].We calculated radial growth (Table 1) and periodicity of growth 30 times on cross sections and either specific gravity and fiber saturation point (FSP) within small blocks of wood according to common methods [13].

The following anatomical variables were determined: tangential and radial diameter of vessels, vessel frequency, Length of vessels, the number of vessels per vessel groups and the number of rays per mm^1, ray height, ray width, fiber length, lumen diameter and thickness of cell walls. Vulnerability ratio was calculated for every sample tree; 30 measurements or counting were performed for each variable.

Statistical analysis had been done step by step. First of all it was t-test to compare: a)two species, Haloxylon persicum (Zard Tagh) and Haloxylon aphyllum (Ciah Tagh), b) six different ages from 6 to 15 years, c) four tree planting density 500, 800, 1000 and 1500 trees per hectare. No definite results were taken by these tests, therefore factorial design with two independent factors arranged in completely randomized design was applied and related correlation coefficients were calculated where required.

RESULTS AND DISCUSSION

The following anatomical variables were determined on the whole for all status: tangential and radial diameter of vessels, 25.5 μ; vessel frequency, 40; Length of vessels, 90.5 μ; the number of vessels per vessel groups, 4.4 ; the number of rays per mm^2, 7; ray height, 205μ; ray width, 3.2 cells; fiber length, 407.7μ; lumen diameter, 3.3μ and thickness of cell walls, 5.4μ. Vulnerability ratio was 0.638 and mesomorphy ratio was 66.94. Consequently it reveals a xenomorphically wood so tolerant to water loss.

The results showed significant differences between wood properties of two species except for growth periodicity and heartwood lumen diameter (Fig. 2). Besides there were significant differences between wood properties of three different trees planting density (Fig. 2).

The maximum diametrical growth in every growth season in ten sample trees is shown in table 1. Results showed there was not any significant difference between tree growth related to species, age and tree planting density (Table 3,4,5).

Averaged growth periodicity determined 3 rings per year (Table 2) and the tree planting densities made significant differences (F=9.617). Mean results of wood properties are shown in table 3, 4 and 5, for Three independents: 1) tree density/hectare, 2) age and 3) species, respectively.

Since there is an indirect correlation between periodicity and age of trees, one can conclude that the higher the age, the lesser the annual rate of growth. Consequently as cambium activity decreases due to a reduction in articles of food, there would be a diminishing in periodicity of growth. In regions of higher tree planting density, where the usage of light and though photoperiodicity is affected, the trees race to a competition to get the moisture of the soil. When this happens, the periodicity of growth decreases which causes differentiation of longer and thicker fibers and this is a means of increasing weight in unit of volume. Besides, the porous zone of axial parenchyma extends to a lesser area due to its variable volume in this situation. Thus in every growth ring the higher density texture zones are

Table 2: Mean values of wood properties of 10 trees from different planting densities

	Properties*								
Tree no.	a*	b	c	d	e	f	g	h	i
1	10	1000	436.7	13.8	3.1	5.4	1.074	27.8	2.7
2	9	1000	430.7	15.6	4.8	5.4	1.094	29.0	2.8
3	15	800	429.9	14.6	3.2	5.7	1.052	31.2	2.3
4	8	800	368.5	14.6	3.2	5.7	1.050	29.8	2.8
5	7	500	425.0	13.5	3.0	5.3	1.056	35.2	3.4
6	7	1500	411.2	14.0	3.9	5.2	1.066	30.8	3.4
7	6	1000	407.9	13.5	3.0	5.3	1.026	37.8	3.3
8	9	1000	389.5	13.9	2.9	5.6	1.122	28.4	3.4
9	6	800	391.4	14.1	3.2	5.4	1.082	31.6	3.9
10	7	500	385.8	13.5	2.9	5.3	1.066	31.2	3.4
Mean	407.7	14.1	3.3	5.4	1.069	31.3	3.1		

* a-tree age b-tree planting density per hectare c-fiber length (μ) d-fiber diameter (μ) e-lumen diameter (μ) f-cell wall thickness (μ) g-specific gravity h-FSP (%) i-periodicity

Table 3: Average of measured parameters in different levels of Tree planting density per hectare

		Tree planting	Density per	Hectare	
Properties	500	800	1000	1500	S.L.*
Sp. Gravity	1.061	1.061	1.079	1.066	ns.
FSP %	32.2	30.87	30.75	30.8	ns.
Periodicity	3.425	2.978	3.086	3.435	-
Growth increment mm	4.4	4.7	4.98	4.3	ns.
Sapwood fiber length μ	395.86	377.63	412.05	420.8	-
Heartwood fiber length μ	409.29	386.06	421.21	401.6	-
Sapwood lumen diam.μ	2.98	3.16	3.46	4.13	-
Heartwood lumen diam.μ	2.81	3.22	3.41	3.74	-
Sapwood wall thick.μ	5.27	5.55	5.31	5.11	ns.
Heartwood wall thick.μ	5.27	5.62	5.48	5.24	ns.

* Significant level is derived from T-test

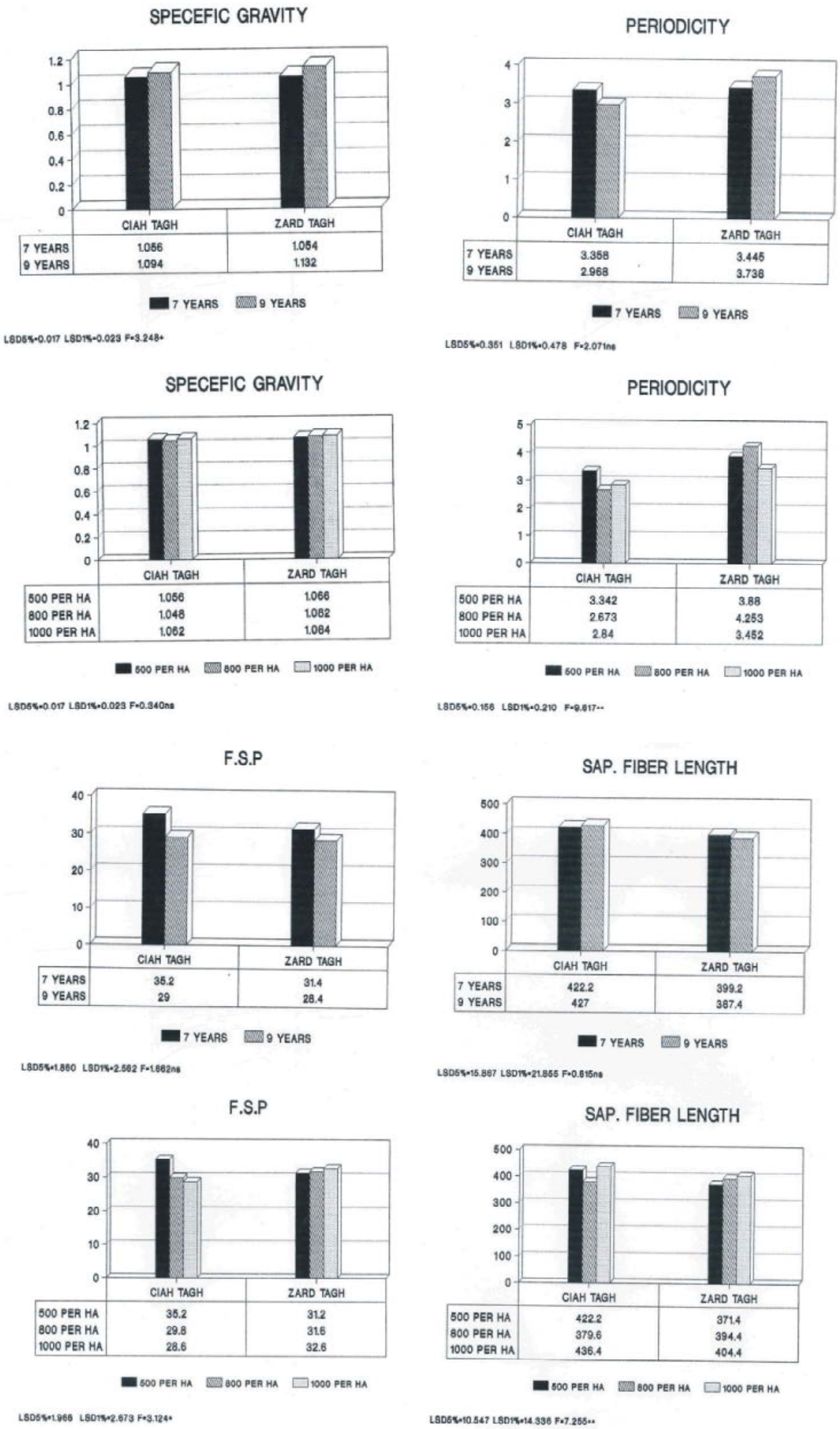

Fig. 2: Continued

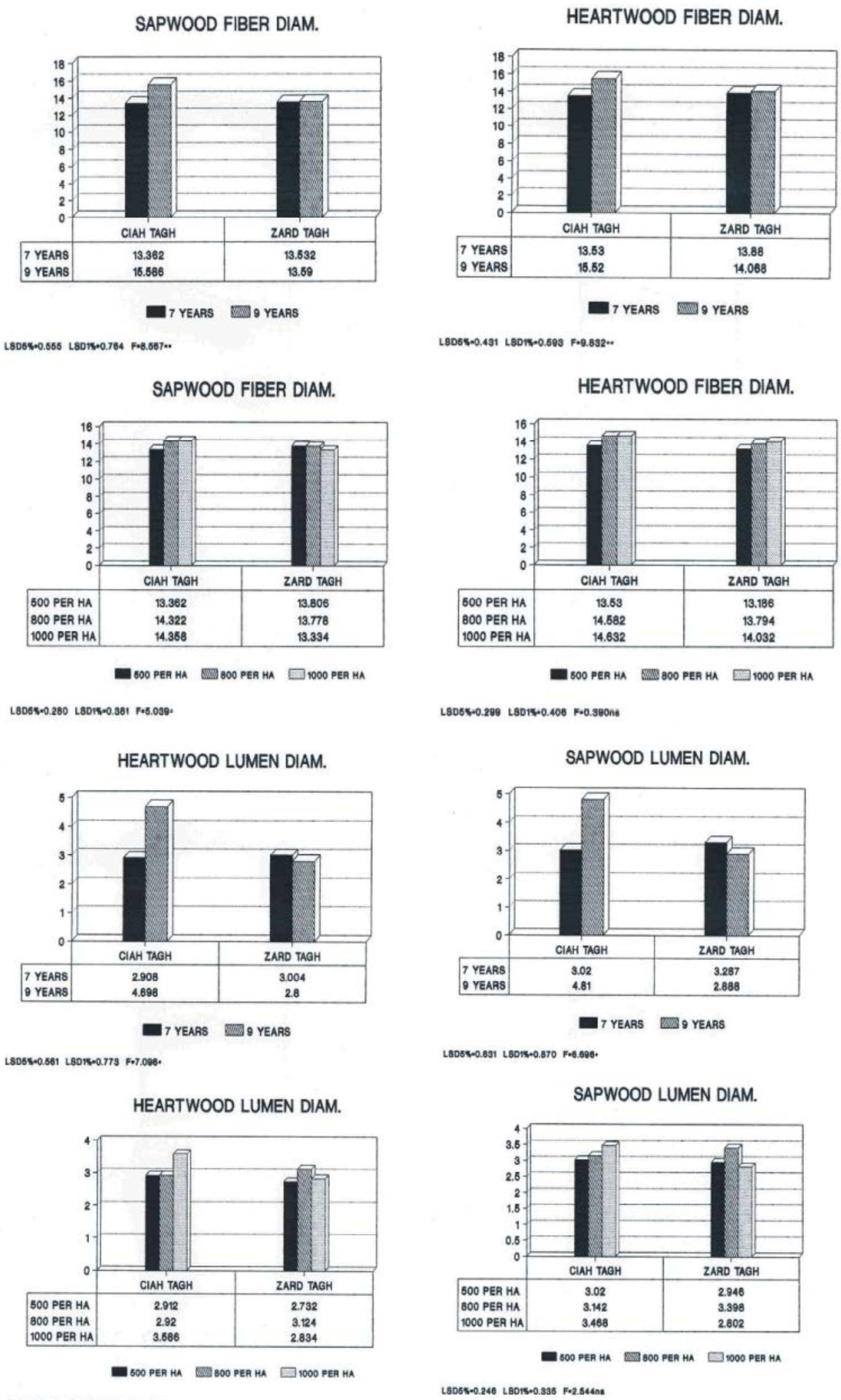

Fig. 2: ANOVA of effects of tree density/ hectare and age on measured parameters

Table 4: Average of measured parameters in different levels of Tree age

Properties	Age 6	7	8	9	10	15	S.L.*
Sp. Gravity	1.054	1.063	1.05	1.108	1.074	1.052	-
FSP %	34.7	32.4	29.8	28.7	27.8	31.2	-
Periodicity	3.531	3.423	2.802	3.095	2.7	2.336	-
Growth increment mm	5.6	4.37	4.1	5	4	4.7	-
Sapwood fiber length µ	394.8	406.25	364	407.2	434.4	371.8	-
Heartwood fiber length µ	401.2	406.08	373	413	439	395.6	-
Sapwood lumen diam.µ	3.2	3.46	4.08	3.1	2.92	2.97	ns.
Heartwood lumen diam.µ	3.4	3.2	3.21	3.75	3.12	3.29	ns.
Sapwood wall thick.µ	5.33	5.2	5.6	5.37	5.24	5.67	ns.
Heartwood wall thick.µ	5.34	5.26	5.84	5.54	5.46	5.73	ns.

* Significant level is derived from T-test

Table 5: Average of measured parameters in different species

Properties	Species H. aphyllum	H. persicum	S.L.*
Sp. Gravity	1.065	1.072	ns.
FSP %	30.6	31.96	ns.
Periodicity	2.857	3.482	**
Growth increment mm	4.26	5.16	ns.
Sapwood fiber length µ	402.3	395.5	ns.
Heartwood fiber length µ	412.74	398.33	ns.
Sapwood lumen diam.µ	3.43	3.29	ns.
Heartwood lumen diam.µ	3.49	3.08	**
Sapwood wall thick.µ	5.42	5.31	ns.
Heartwood wall thick.µ	5.58	5.36	ns.

* Significant level is derived from T-test

bigger in volume and areas with fine texture, occupy lesser volume. Speaking in general as the tree density per hectare, increases the periodicity decreases and the specific gravity of wood increases. Like the other woody species the longer the fibers, the higher the specific gravity [14].

The mean specific gravity was calculated 1.069. In spite of not being significant the tree planting density, an increase in tree planting density caused specific gravity to grow in quantity (Table 2).The mean fiber saturation point (FSP) was 31.28%. For further details refer to table 2.

As shown in table 2 fiber length of saxaul is considered short [15]. The fibers produced at the early ages were longer than those produced later. There was no difference in length of fibers located in heartwood or sapwood zone but tree planting density caused a significant difference between their lengths (F=7.255). The longest fibers were produced at 1000 trees per hectare density and the shortest ones at 800 trees per hectare density. There was a strong correlation between fiber length and tree age and also a negative correlation between fiber length and lignin content percentage. All the results are specified in the form of charts from ANOVA in figure 2.

The anatomical wood features are illustrated in figure 3 by photomicrographs captured by SEM. Saxaul heartwood is dark brown in color and very distinct. It is a very heavy, brittle and hard to work timber [15]. This woody species is an example of a dicotyledonous stem which displays anomalous secondary growth , (Fig 3-995). Near the centre of the stem, you will see some primary vascular bundles embedded in lignified pith parenchyma and you will notice that there has been fairly extensive production of secondary vascular tissue. The vascular cambium is amongst the secondary phloem and secondary xylem which lie on either side of it (Fig. 3-918). The secondary xylem is composed of tracheids, fibers and narrow vessels. Interspersed with the secondary xylem one can see small pockets of phloem and what look like large-diameter metaxylem vessels. These are reminiscent of the primary bundles towards the centre of the stem.

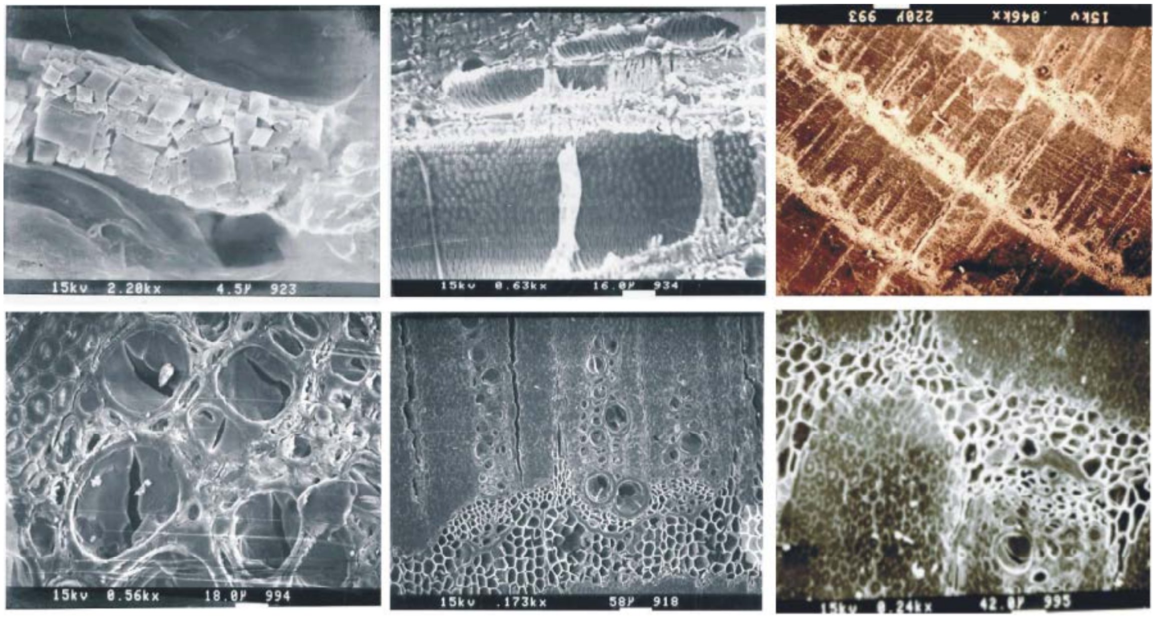

Fig. 3: Anatomical structure of saxaul wood; (923): Zard Tagh, RLS, a parenchyma cell containing numerous crystals responsible for saxaul wood brittleness. (934): Ciah Tagh, TLS, a large vessel showing simple perforation plate and alternate to opposite pits. (993): Zard Tagh, XS., successive cambia. (994): Ciah Tagh, XS., cross sections of vessels full of tyloses and adjacent fibres. (918): Ciah Tagh, XS., included phloem and related secondary xylem in a growth ring. (995): Zard Tagh: Xs., included phloem rises among parenchyma cells of conjunctive tissue.

The phloem is described as being included phloem [16, 17] which by definition is phloem tissue which lies between regions of secondary xylem and form a collection of wedges. These wedges through the phloem zone are connected with conjunctive tissue (which are in fact, axial parenchyma), though they form a complete ring, where these rings demonstrate periods of growth, i.e. growth periodicity (Fig. 3-993).

Whilst the physiological advantages of the formation of included phloem has not yet been proved, one could speculate that in this instance, the included phloem would be well-protected from predators and pests and, of course, be well-supplied with water and nutrient [18]. The included phloem is restricted to the certain families, which can be accounted as natural selection for dry areas and can last through long dry seasons [19].

The vessels are solitary or grouped in clusters consisting of 4 to 12. The maximum vessel diameter was 35 μ and they were filled up with amorphous material (Fig. 3-994). The average frequency of vessels was 40 per mm2. In tangential section, the vessels seem to have two distinct sizes, short and thick walled (Fig.3-934). Short vessels had delicate spiral thickenings.

Intervessel pits were minute (up to 2μ), round to oval, with split openings. The arrangement of Intervessel pits was alternate and simple perforation plate was the only type of perforation plate. Huge amount of crystals, mainly rhomboidal, could be found in parenchyma cells. It seems that brittleness of saxaul wood is due to presence of many crystals even in a single cell (Fig.3-923). One other reason for brittleness is the lacks of structure homogeneity and long straight fibers which overlap one another [20] which are not the fact of Haloxylon.

In XS (cross section) the radial extensions of conjunctive tissue seems to exist from short wedges to long junctions, gradually reaching the next line of conjunctive tissue. These junctions in radial surface appear as multiseriate heterogenous rays (Fig. 3-993).

In general most of Chenopodiaceae[2] are considered as rayless woods [20], because wood rays are in fact axial parenchyma junctions originally.

In tangential surface the rays are heterogeneous and multiseriate and the width of up to five cells (Fig.4). The average height of rays was 205 μ and the frequency per mm^2 was 7 (in TLS). Inside the parenchyma cells there are crystals with different sizes which most probably are of silica type because of its lack of specific geometrical structure (Fig.3-923).

[1]Recently, Amaranthaceae

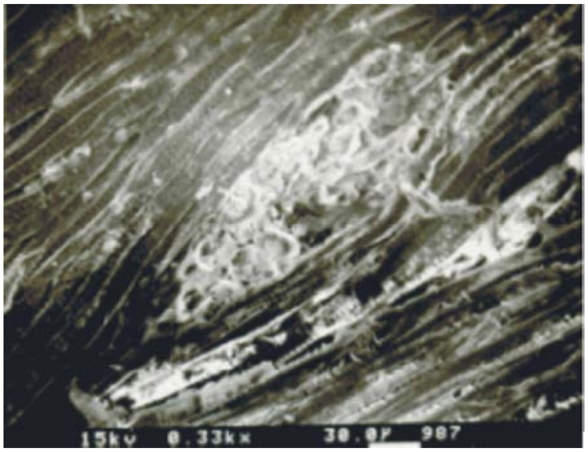

Fig. 4: Haloxylon persicum, TLS., multiseriate rays

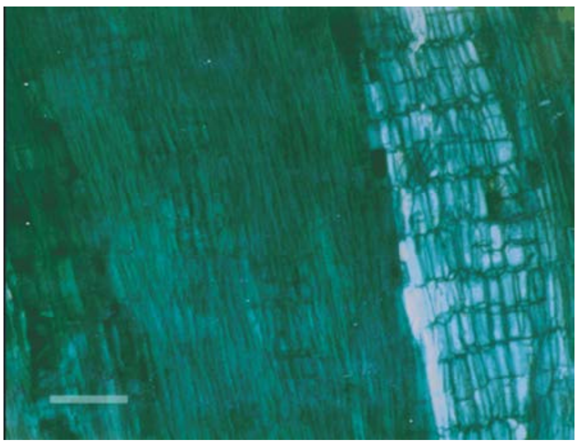

Fig. 5: Haloxylon persicum, RLS., The conjunctive tissue and phloem parenchyma cells, optical microscopy, Bar: 25 µ

The conjunctive tissue and phloem parenchyma cells appear to form fusiform storied structure which contains crystals (Fig.5). The storied type is more advanced from phyllogenetic viewpoint [21]. The existence of fusiform cells shows that divided cambium cells have not been differentiated. Generally when cambium becomes active the ratio of division process is much faster than that of differentiation. Vulnerability and mesomorphy ratio were low showing a tree very resistant to drought (not shown here).

CONCLUSION

Although saxaul plantings are under development to combat desertification and for sand dune fixation, even restricted utilization after pruning should be authorized because there'd be a huge supply of wood after pruning. Wood structure of saxaul permits a few industrial and traditional utilization practices including composite pulps; particle boards; wood panels, etc.

ACKNOWLEDGEMENT

The authors wish to respect late professors Hedjazi, R. and Niloufari, P. for their whole life great attempts to establish wood research in the country.

REFERENCES

1. Khalili, A., 1982. Arid and Hyper Arid, Proceedings of Iranian Deserts and Arid.
2. Zohary, M., 1974. Geobotanical foundations of the Middle East. J. Ecol., 62: 349-350.
3. Zakeri, A. and M. Forghani, 2012. American Journal of Environmental Engineering, 2(2): 13-18.
4. Koocheki, A., 1996. The use of halophytes for forage production and combating desertification in Iran. In: R. Choukr-Allah, C.V. Malcolm and A. Hamdy (Eds), Halophytes and biosaline agriculture, Marcel Dekker, Inc., New York, pp: 263-274.
5. Soltani, A., 2011. Seed germination response of *Haloxylon persicum* (Chenopodiaceae) to different hydrothermal conditions and sand burial depths. Caspian J. Env. Sci., 9(2): 211-221.
6. Nemati, N., 1986. Pasture improvement and management in arid zones of Iran. J. Arid Environ., 11: 27-35.
7. Akhani, H., P. Trimborn and H. Ziegler, 1997. Photosynthetic pathways in Chenopodiaceae from Africa, Asia and Europe with their ecological, phytogeographical and taxonomical importance. Plant Syst. Evol., 206: 187-221.
8. Zandi Esfahan, E., M. Jafari, S.J. Khajeddin and H. Azarnivand, 2011. Study on soil salinization and its amplitude due to the planting of Haloxylon ammodendron in Segzi plain of Isfahan, Iranian journal of Range and Desert Research, 18(2).
9. Schweingruber, F.H., 1978. Microscopic wood anatomy. Swiss Fed. Inst. For. Res., Birmensdorf.
10. Toghraie, N. and H.R. Yazdani Moghadam, 1996. Wood identification key via computer, Pajouhesh va sazandegi, 9(31).
11. ISIRI 11582-1, 2009. Wood-Microscopic features for hardwood identification, specifications and test methods-Part 1: Growth rings and vessels, Institute of Standards and Industrial Research of Iran.

12. IAWA Committee, 1989. IAWA List of Microscopic Features for Hardwood identification. IAWA Bulletin n.s., 10(3): 219-332.
13. ASTM Standard. D., 143, 2009. Standard Test Methods for Small Clear Specimens of Timber, ASTM International, West Conshohocken, PA, 2009, DOI: 10.1520/C0033-03.
14. Panshin, A.J. and C. de Zeeuw, 1980. Textbook of Wood Technology, 4th Ed. McGraw-Hill, New York.
15. Esau, K., 1977. Anatomy of seed plants. Wiley and Sons, New York.
16. Fahn, A., 1979. Secretory tissues in plants. Academic Press, New York.
17. Jane, F.W., 1970. The structure of wood. Adam and Charles Black, London.
18. Wilson, K. and D.J.B. White, 1986. The anatomy of wood: its diversity and variability. Stobart and Son Ltd, London.
19. Carlquist, S., 1989. Adaptive wood anatomy of chaparral shrubs. In: S.C. Keely(ed.), The California Chaparral: 25-35. Science Series. No. 34, Narural History Museum of Los Angeles County.
20. Core, H.A., W.A. Côté and A.C. Day, 1979. Wood structure and identification. 2nd Ed.
21. Baas, P., 1982. Systematic,phylogenetic and ecological wood anatomy-history and perspectives. In: P. Baas (ed.), New perspectives in wood anatomy: 23-58. Martinus Nijhoff/ Dr. W. Junk Publ., The Hague, Boston, London.