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Leaf anatomical investigation of Cupressaceae and Taxaceae in Iran

Assiyeh Hamidipour, Tayebeh Radjabian,
David A. Charlet & Mehdi Zarrei

Summary: Anatomical and morphological investigations of seven species of Iranian representatives of gymnosperms belonging to Taxaceae and Cupressaceae are performed in this study. Transverse sections of leaves (needle-like or scales) were studied with a light microscope. Great anatomical variation exists between and within Taxaceae and Cupressaceae. Both families are easily distinguished from each other by anatomical characters. All genera and species in Cupressaceae are also distinguishable. Fiber and resin ducts are present only in Cupressaceae and not in Taxaceae. In *Cupressus sempervirens* and *Juniperus foetidissima*, stomata are present only in the upper epidermis of scale-like leaves. Stomata are present in lateral faces of needle-like leaves in *Juniperus excelsa*, *J. sabina*, *J. communis* and *J. oblonga*. In these species, stomata are present only in the abaxial epidermis where there are no fibers underneath the epidermis, a characteristic similar to that in *Taxus baccata*. *Juniperus communis* and *J. oblonga* have stomata that are distributed uniformly in the lower epidermis, except under the midrib of *J. oblonga*, which is covered with fibers instead of stomata.

Keywords: leaf anatomy, Cupressaceae, gymnosperms, Iran, systematics, Taxaceae

Gymnosperms are a relatively small group of seed plants including only 17 families, 83 genera and 730 species (Page 1990). The distribution of species in genera and families is heterogeneous, as some of the families such as Pinaceae and Cupressaceae have many genera and species (more than 100 species: Farjon (2005); Adams (2004); Schulz et al. (2005)), whereas some families (e.g. Sciadopityaceae, Stangeriaceae, Ginkgoaceae) are represented by only one species (Page 1990).

Seventeen species of gymnosperms in five genera in Iran are classified in three families: Cupressaceae (eight species), Ephedraceae (eight species), and Taxaceae (one species)(Riedl 1968; Assadi 1998; Hojjati et al. 2009). They usually occur in hard ecological conditions on high and stony mountains where soil is shallow and in warm steppes and semideserts throughout Iran. The adaptation to these severe climate conditions had great evolutionary impact on the morphology of gymnosperms in Iran. Most of the morphological traits show high degree of convergence, which obscure the species boundaries and make it difficult to distinguish species utilizing only the morphological traits. The anatomical characters are systematically and evolutionarily important (Peirce 1937; Phillips 1948; Rao & Malaviya 1965). The implication of anatomical characters in the evolution and systematics of some Iranian species of *Gagea* Salisb. has already been investigated (Zarrei et al. 2010). There is not any reference available dealing with the anatomy of gymnosperms vouchered in Iran. The aim of the present study is to investigate the systematics importance of seven species of Cupressaces and *Taxus baccata* (Taxaceae), including both native and naturalized species throughout Iran. The plasticity of the morphological and anatomical traits is then investigated and discussed.

Table 1. List of species and voucher information were used in the present study. Vouchers were preserved at IRAN.

Species	Species status in Iran	Voucher
Cupressus sempervirens L.	Native	Guilan: Between Manjil & Roudbar, mountains beside the road, 25.05.2006, *Zarrei & Hamidipour 658*
Juniperus communis L.	Native	Mazandaran: 8km to Marzan-Abad from Kojour, near the road, 36°28'37"N, 51°24'16"E, 570 m s.m., 25.11.2005, *Zarrei 677*
		Mazandaran: Nour towards Marzan-Abad, 7 km after Kadir village towards Kojour, 36°26'4o"N, 51°44'21"E, 1620 m s.m., 25.11.2005, *Zarrei 675*
Juniperus foetidissima Willd.	Native	Gorgan: Gorgan towards Chaharbagh, the pass after Touskestan, 36°40'19"N, 54°34'02"E, 1940 m s.m., 24.11.2005, *Zarrei 682*
		Ardabil: 3 km after Kaleybar towards Khoda-Afarin, shrubland near the road, 14.05.2006, *Zarrei 498*
Juniperus excelsa M.Bieb.	Native	Mazandaran: Chalus road towards Haraz road, just after Balade village, rocky mountains near the road, 36°12'08"N, 51°56'25"E, 1900 m s.m., 05.05.2006, *Zarrei 482*
		Gorgan: Gorgan towards Chaharbagh, the pass after Touskestan, 36°40'19"N, 54°34'02"E, 1940 m s.m., 24.11.2005, *Zarrei 681*
Juniperus oblonga M.Bieb.	Native	Ardabil: 3 km after Kaleybar towards Khoda-Afarin, shrubland near the road, 14.05.2006, *Zarrei 497*
		Ardabil: 3 km after Qotorsoo & Sabil hot water deviation, Sabalan slopes, 14.05.2006, *Zarrei 496*
Platycladus orientalis (L.) Franco	Naturalized	Tehran: Karaj, Azymieh, in a home garden, 1500 m s.m., 20.04.2006, *Naderi 481*
Taxus baccata L.	Native	Mazandaran: south of Babol, 5 km after Firouz-Ja towards south, just after Shour-Kesh, Ramazan-Arab field, 36°10'N, 52°38'E, 23.11.2005, *Zarrei 476*
		Gorgan: Gorgan towards Chaharbagh, foot hills, a big cutted tree near the road, 36°41'51"N, 54°35' 15"E, 1015 m s.m., 23.11.2005, *Zarrei 477*

Materials and Methods

Before commencing the anatomical investigations, the extent of morphological variation of species of gymnosperms occurring in Iran was evaluated. Several field trips were undertaken to study species in natural habitats throughout Iran. Herbarium specimens were collected throughout the known distribution range of gymnosperms in Iran and deposited in IRAN (herbarium acronyms according to Holmgren et al. 1990) and Shahed University Herbarium, Tehran (abbreviated here as SUTH). Parallel to this, all specimens deposited in IRAN, TARI and TUH were studied. Leaves and young stems of Cupressaceae (six species) and Taxaceae (*Taxus baccata* L., the sole species of this genus occurring in Iran) were sampled from the field for anatomical studies. In ideal circumstances, it would be necessary to compare plants grown under identical conditions to test the value of anatomical features. In the absence of a proper provenance test that would take many years, each species was sampled from at least two geographically distant populations (except for *Juniperus foetidissima* Willd. and *Platycladus orientalis* (L.) Franco, which were sampled from only one locality due to a restricted geographical distribution) representative of the species in Iran. Several microscope slides were studied and photographed for each species from different localities with the aid of a light microscope (model Vanox AHBS3, Olympus Company, Japan).

Table 2. Summary of anatomical variation of the studied species of gymnosperms.

Characters/Species	*Cupressus sempervirens*	*Platycladus orientalis*	*Juniperus*					*Taxus baccata*
			excelsa	*foetidissima*	*sabina*	*communis*	*oblonga*	
Collenchyma	6–10 layers	2–3 layers	2 layers	10–15 layers	0	2–4 layers	2–3 layers	2–4 layers
Cuticle ornaments	present	absent	absent	absent	absent	absent	absent	absent
Epidermis	elongated	elongated	oblong, semi-circular	elongated	semi-circular	elongated	elongated	semi-circular
Fibers	1 layer	1 layer	2–3 layers	1–2 layers	1 layer	1 layer	1 layer	0
Outline transverse section	rectangular	flattened	semi-circular	oblong	semi-circular	triangular	triangular	triangular
Palisade parenchyma	1 layer	1 layer	0	1 layer	0	1 layer	1 layer	1–2 layers
Phloem fiber	1–2 layers	0	3 layers	1–3 layers	1 layer	2–4 layers	0	0
Radial parenchyma	1–2 layer	1–2 layer	0	2–3 layers	0	0	0	0
Resin ducts	4	2	3	2	2	1	1	0
Scale	4	2	3	2	2	1	1	1
Secretory cell	1 layer	2 layers	4–5 layers	2–3 layers	2 layers	3 layers	3 layers	0
Transfusion tracheid	2 bundles	4 bundles	6 bundles	4 bundles	4 bundles	2 bundles	4 bundles	2 bundles

No significant differences were observed within species. Nevertheless, several samples for each species were taken from wild plants with contrasting ecological/edaphic circumstances in order to provide an indication of the potential phenotypic plasticity. The observations reported below were recorded from the best specimen/slide preparation for each organ in each species.

Comparative anatomy of the leaves (both scale-like and needle-like leaves) were investigated in this study. The stem was also analysed in species with scale-like leaves. The sampled species plus voucher information are listed in Table 1. All vouchers are deposited in IRAN and Shahed University Herbarium (SUTH). Several leaves from each specimen were then fixed in FAA solution (alcohol-formaldehyde-acetic acid). At least two samples of leaves from each species were manually transverse sectioned at the midpoint of lamina. The transverse section of scales is all in the same position, so the comparison is logical. All samples were stained using methyl blue and acetocarmine according to the method described by Gerlach (1977). Line drawings are prepared to show the extent of variation of anatomical characters.

Results

The results of the anatomical investigation are presented in Table 2. The prevailing ecological and edaphic conditions were found to have only a limited influence on the expression of the anatomical characters described below. Only within species constant anatomical characters are presented and discussed.

All species studied in this investigation possess evergreen leaves. These leaves remain on the stem for longer than one season. They all possess sunken stomata in the leaf tissues that superficially appear the same, but their location is subtly and consistently different dependent on the species. Transfusion tracheids occur in all leaves.

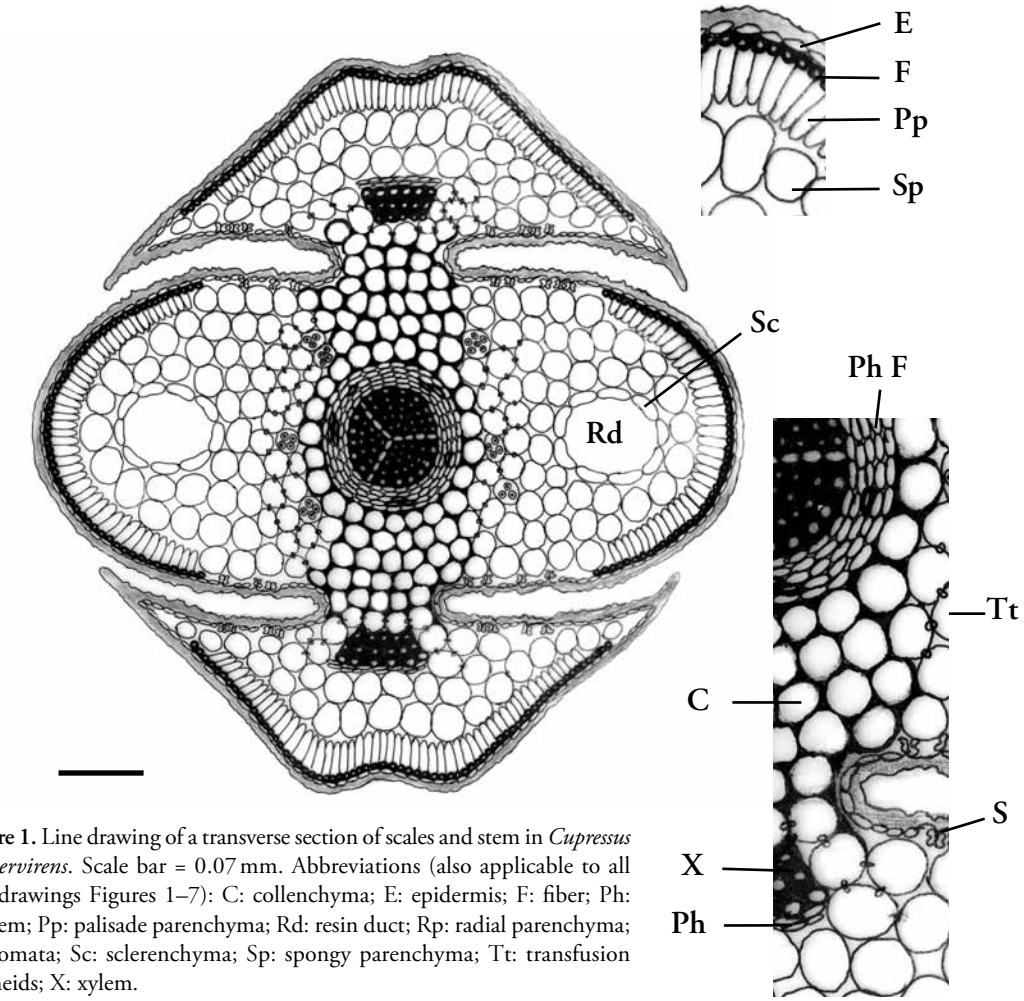

Figure 1. Line drawing of a transverse section of scales and stem in *Cupressus sempervirens*. Scale bar = 0.07 mm. Abbreviations (also applicable to all line drawings Figures 1–7): C: collenchyma; E: epidermis; F: fiber; Ph: phloem; Pp: palisade parenchyma; Rd: resin duct; Rp: radial parenchyma; S: stomata; Sc: sclerenchyma; Sp: spongy parenchyma; Tt: transfusion tracheids; X: xylem.

Anatomical characters in leaves that are useful for distinguishing between the two families are included in this study. These characters are also able to distinguish closely related species of *Juniperus*.

Description of anatomical characters

Cupressus sempervirens L.

The transverse section of the stem including leaves (called scales here) is composed of two main scales and two lateral scales (Fig. 1). Both of these scales are in opposite directions and both are connected to the main stem. The transverse section of the main leaf passes through the middle of blade whereas the section is taken at the base of the blade in lateral scales. As a result, the different anatomical characters described here represent the different areas of the blade. However, they were named with two different terms in order to describe the anatomical differences between middle and base of blade. Therefore, a combination of both scale characters is the result of only one section (Fig. 1).

The main scales possess a rectangular outline in transverse section, a cuticle with ornaments, especially in scale fissures. Epidermal cells are elongated and oblong. These scales possess vascular

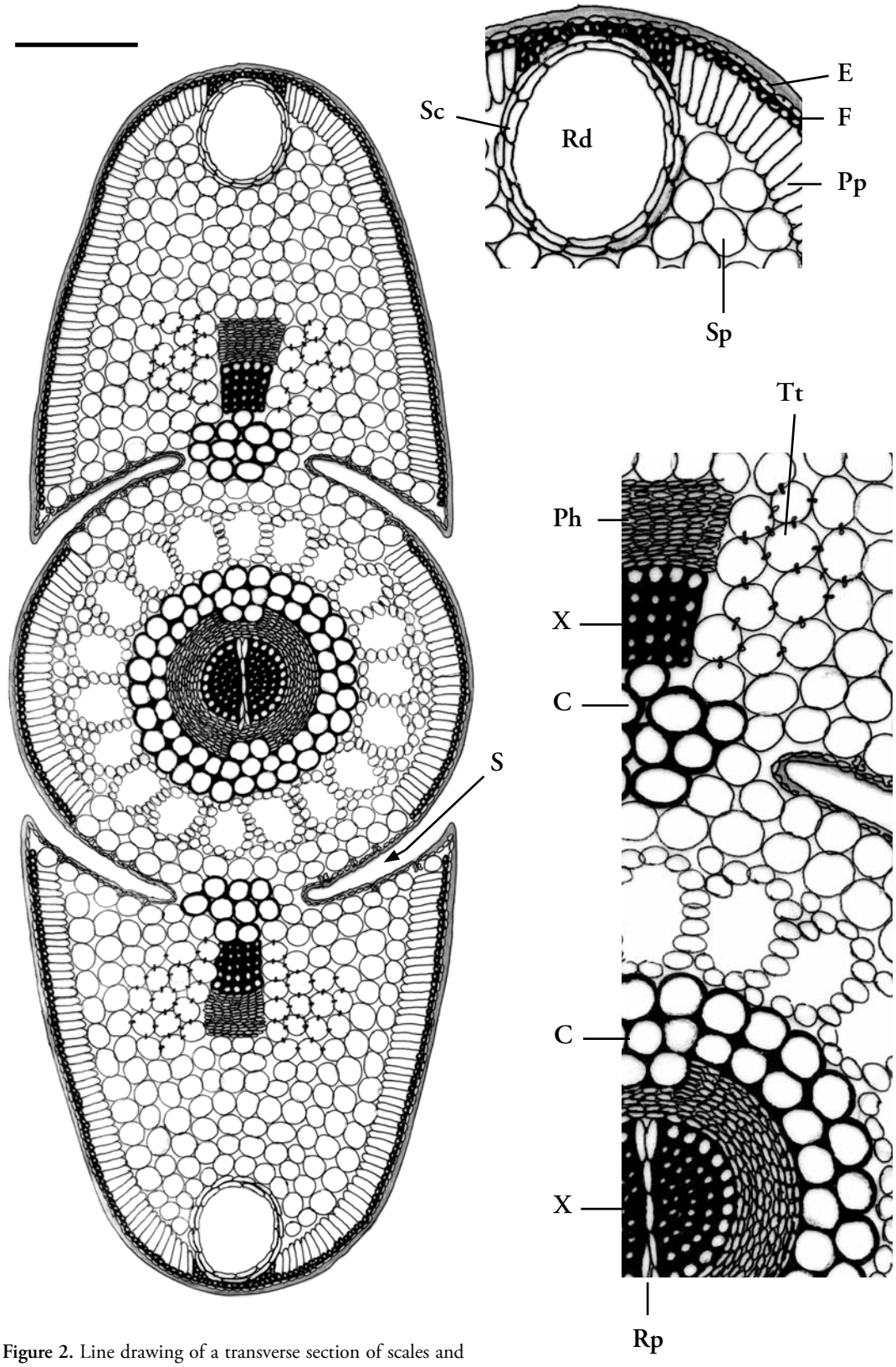

Figure 2. Line drawing of a transverse section of scales and stem in *Platycladus orientalis*. Scale bar = 0.01 mm.

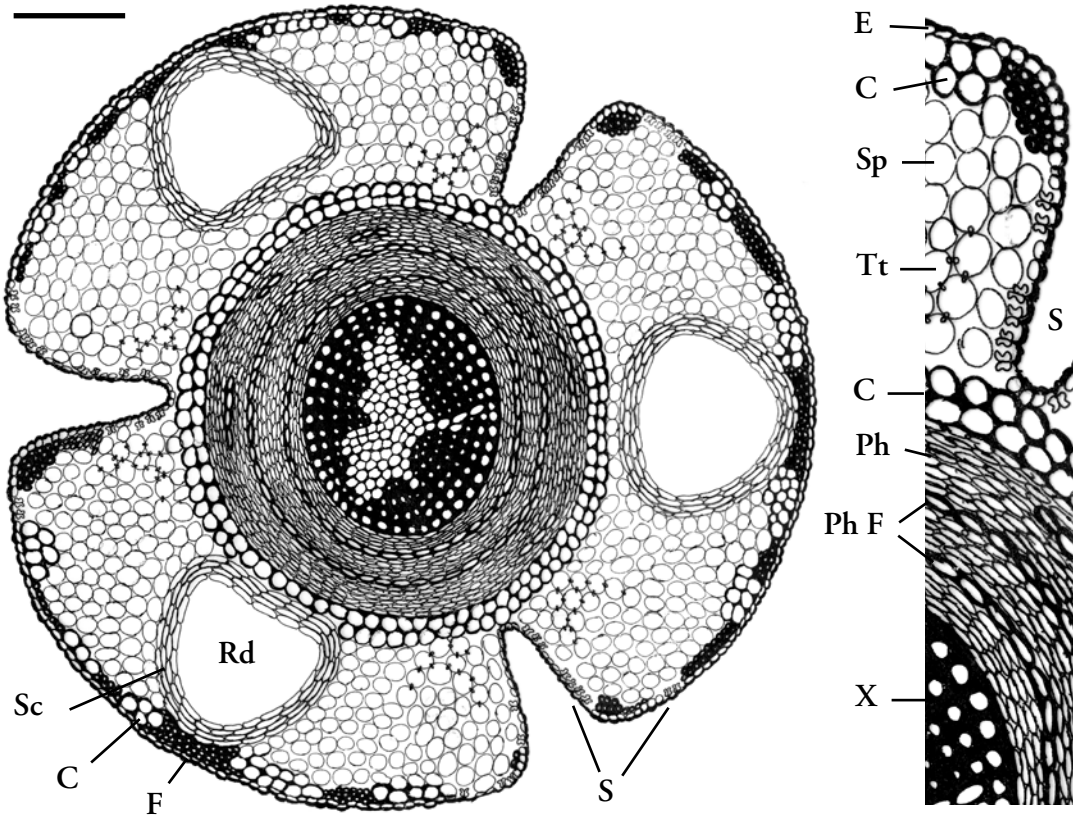

Figure 3. Line drawing of a transverse section of scales and stem in *Juniperus excelsa*. Scale bar = 0.01 mm.

bundles whereas they are absent in lateral scales. The xylem lies towards the adaxial face of the scale and the phloem is towards the abaxial face (Fig. 1).

Lateral scales possess a resin duct, one per each scale, each resin duct encircled by only one layer of secretory cells. Main scales do not possess resin ducts (Fig. 1).

In both scales, one layer of fiber is present under most of the epidermal cells where there are no stomata. Stomata are present only in scale fissures. Mesophyll is composed of both palisade and spongy parenchyma. Palisade tissue, which is only single-layered, is present only under the fiber layer. The spongy mesophyll is usually composed of ground tissue (Fig. 1).

The central part of stem is composed of tracheids which are encircled by phloem. The phloem is also encircled with transfusion tracheids. Transfusion tracheids are connected to two main scales to the centre of the stem. There is collenchyma around the central vascular bundle and scale fissures. One to two radial parenchyma layers between central vascular bundles are visible (Fig. 1).

Platycladus orientalis L.

The leaves in this species are morphologically similar to that found in *C. sempervirens.* The transverse section from the middle of lamina also includes the stem (Fig. 2). However, this section includes only two scales. There is great similarity between the anatomy of *C. sempervirens* and *P. orientalis*. The outline of transverse section of scales in *P. orientalis* is triangular (Fig. 2) and

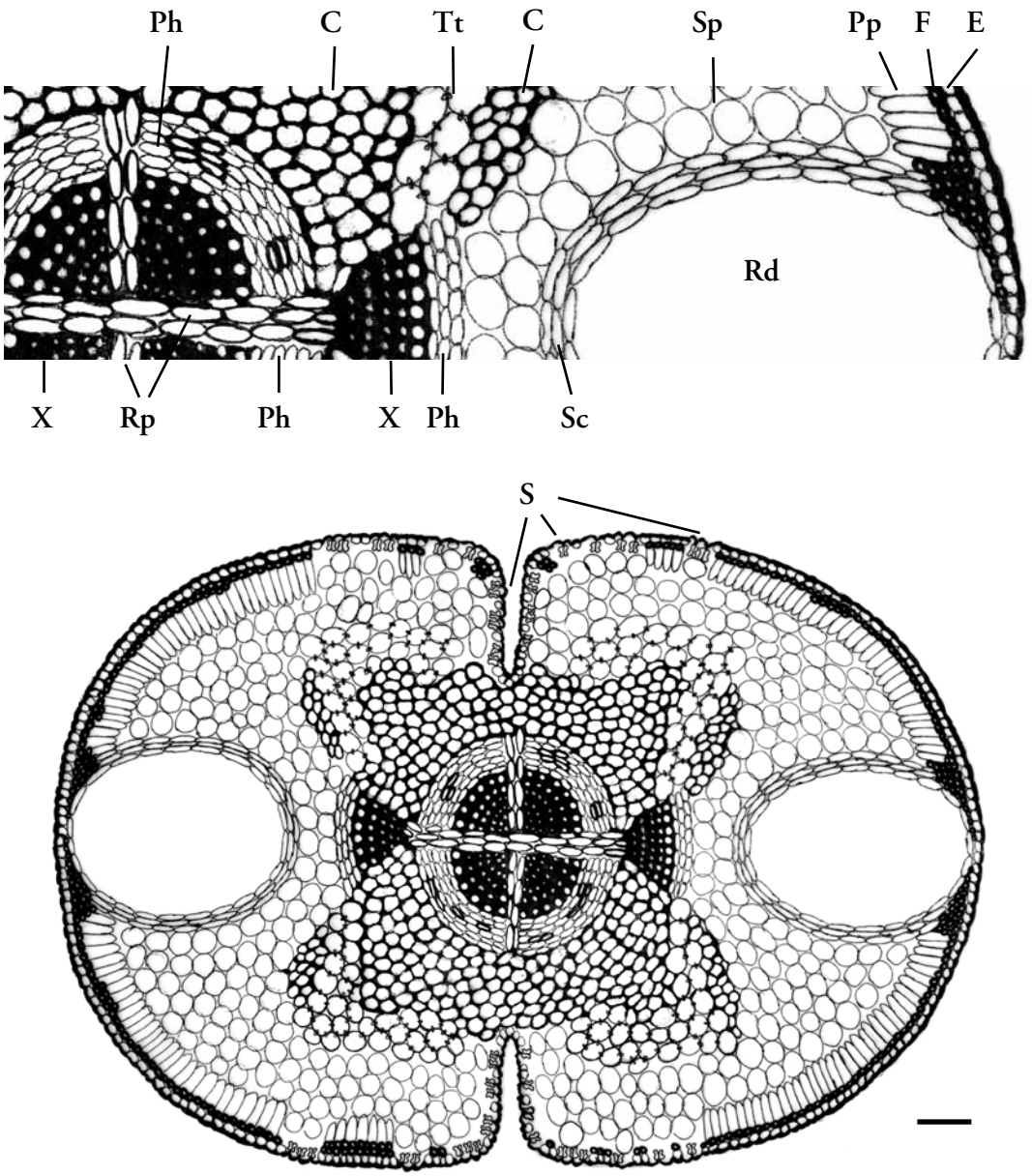

Figure 4. Line drawing of a transverse section of scales and stem in *Juniperus foetidissima*. Scale bar = 0.01 mm.

the cuticle is simple without ornaments (distinguishing it from *C. sempervirens*), and narrower than in *C. sempervirens*. Epidermal cells are elongated. There is one layer of fiber under epidermal cells in both, stem and scales where there are no stomata. The stomata occur only in fissures between the scales and stem where there is no fiber under epidermis. However, the number of fiber layers increase to two to three layers where the fiber is connected to the resin ducts. Similar to *C. sempervirens*, there is a layer of the palisade parenchyma under the fiber in both, the stem and the scales. Unlike *C. sempervirens*, each scale possesses one resin duct. The resin ducts are encircled by two layers of secretory cells. Apart from xylem, there are some transfusion tracheids present in each scale. There is no phloem fiber in the stem tissues. The stem possesses one to two radial parenchyma layers between central vascular bundles (Fig. 2).

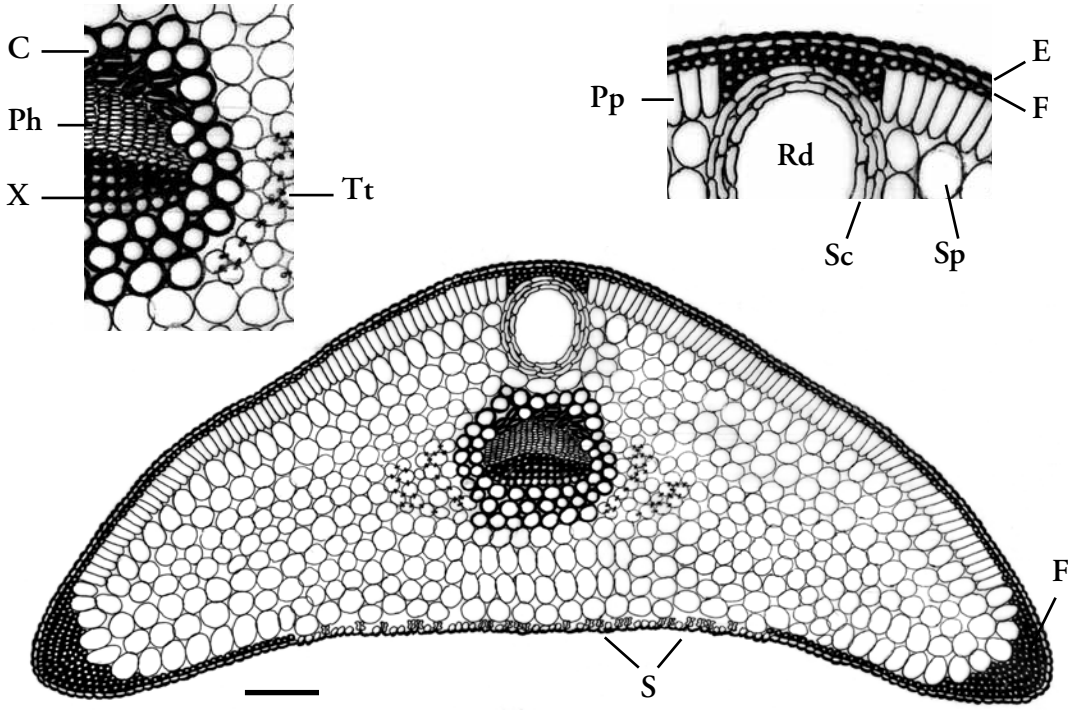

Figure 5. Line drawing of a transverse section of a leaf in *Juniperus oblonga*. Scale bar = 0.03 mm.

Juniperus excelsa M. Bieb.

The transverse section in this species includes the stem and three scales (Fig. 3). The outline of the transverse section of each scale is oblong to semi-circular. Cuticular ornaments are not present in this species. Unlike *C. sempervirens*, the fiber, which occurs under the epidermis, is not continuous but rather patched. There are two to three layers of fiber in each patch. There are stomata and large air spaces where there are no fibers. Moreover, there are some patches of collenchymatous tissues in some areas under the epidermis. There are no fibers or stomata in this area. The ground tissues are completely composed of spongy parenchyma. There is no trace of palisade parenchyma in the mesophyll. Each scale possesses one large, triangular resin duct (25–35% of scale volume). Secretory cells around each duct form three to four co-centric layers. Transfusion tracheids are also present. The transverse section in this species is from nearly ⅓ of the blade from the base, so there is no vascular bundle present in the scales, instead a very large central vascular system is present in the centre of stem. The stem vascular bundle is enclosed by two layers of collenchymatous cells compactly arranged. Three layers of phloem fibers are available in the phloem layers. Xylem occupies about 30% of volume in the centre of stem (Fig. 3).

Juniperus foetidissima Willd.

The transverse section in *J. foetidissima* includes the stem and two scales which are opposite (Fig. 4). The overall outline of the transverse section is oblong whereas each scale possesses a semi-circular outline. The cuticle in this species is thicker than in *J. excelsa*. One to two layers of fibers are present under the epidermal cells throughout abaxial surface of scales. The fiber layer becomes thicker (up to three layers) where the fibers are connected to the resin duct. Palisade parenchyma is single-layered and present only beneath the fiber cells. A resin duct occurs in each

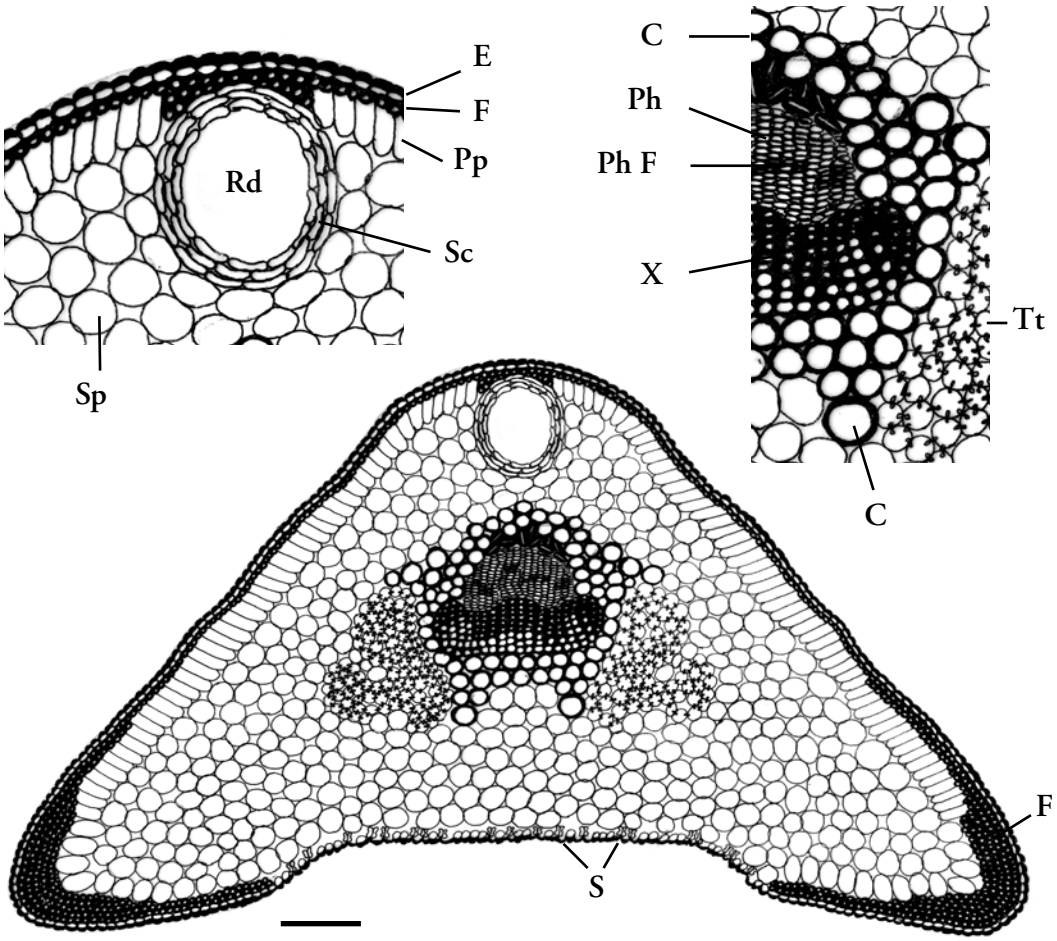

Figure 6. Line drawing of a transverse section of a leaf in *Juniperus communis*. Scale bar = 0.03 mm.

scale and occupies 20–30% of total scale volume. The secretory cells form two to three layers. Each scale possesses its own vascular bundle composed of phloem and xylem. Several bundles of transfusion tracheids and also collenchymatous tissues surround the stem vascular bundle. Radial parenchyma form two to three layers. The sunken stomata occur only in edges of the scales (Fig. 4).

Juniperus oblonga M. Bieb.

This species is now regarded as a synonym of *Juniperus communis* L. var. *saxatilis* Pall. (Farjon 2005). However, since *J. oblonga* can be clearly separated from *J. communis*, and to avoid further confusion demonstrated in the '*Flora of Iran*' (Assadi 1998), the former species is accepted for further discussion in this manuscript. Epidermal cells are elongated and without ornaments on the cuticle. One fiber layer is present beneath epidermal cells (Fig. 5). The fiber layers are two to three-layered around resin ducts and up to five-layered in the corners. There is only one palisade parenchyma layer present under fibers only in the upper epidermis. There is one resin duct enclosed by three layers of secretory cells. There are two to three collenchyma layers around vascular bundles. Transfusion tracheids consist of four bundles which are concurrent around the vascular bundles. The spongy parenchyma is located between tracheids. It has no phloem

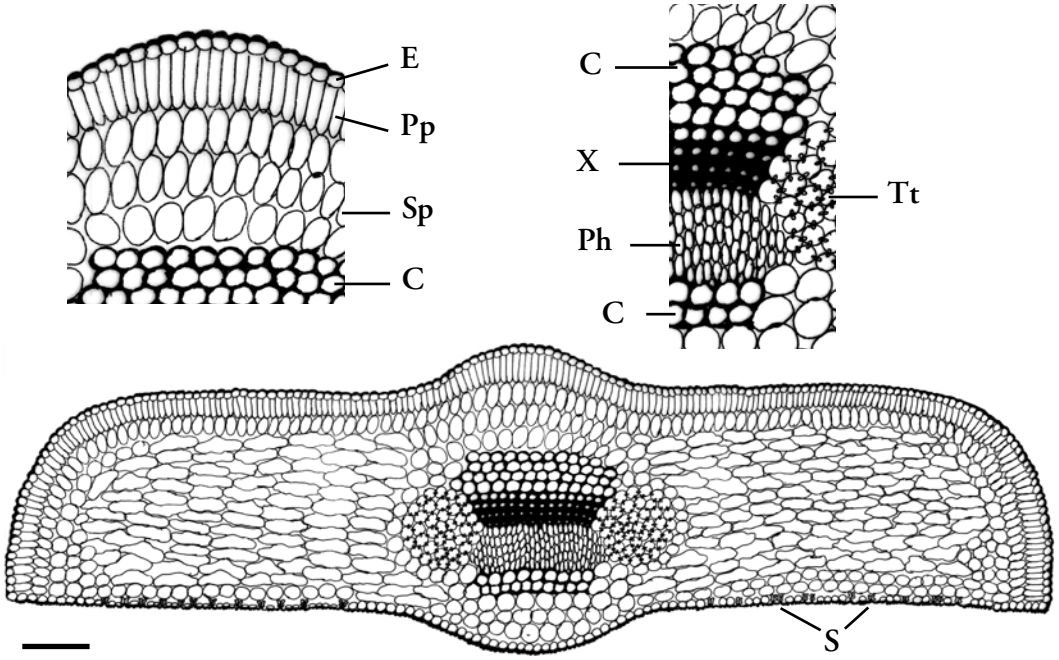

Figure 7. Line drawing of a transverse section of a leaf in *Taxus baccata*. Scale bar = 0.01 mm.

fibers but it has two fiber layers above phloem bundles. There are sunken stomata in the lower epidermis where the fibers are absent (Fig. 5).

Juniperus communis L.

Epidermal cells are elongated with only one layer of fiber cells present under epidermal cells. Two to three layers are around resin ducts and three to four layers are in the corners. There is one palisade parenchymatous layer under fibers only in the upper epidermis. The palisade layer has one resin duct with three secretory cell layers around it. There are several collenchyma layers around the vascular bundle. There are two fiber layers above phloem bundles. Two bundles of transfusion tracheids are around the vascular bundles (Fig. 6).

Juniperus sabina L.

The outline of the transverse section is semi-circular. The cuticle is thickened and without any ornament. There is a fiber layer around the resin ducts in bilateral form. Resin ducts possess two secretory cell layers. Palisade parenchyma is not clear but spongy parenchyma is clearly present and possesses phloem fibers. Transfusion tracheids are four bundles, each of which has two to three layers near the scale fissures. Spongy parenchyma are large and located between resin ducts and vascular bundles.

Taxus baccata L.

The leaves are needle-like in this species. There are no fibers present in tissues and no resin ducts could be traced. The abaxial leaf surface possesses a thicker cuticle than the adaxial surface. The palisade parenchyma (one to two layers) is only present beneath abaxial epidermis.

There are many small transfusion tracheids around vascular bundles. The leaf possesses only one vascular bundle (Fig. 7).

Discussion

These results are a preliminary survey of anatomical variation in Iranian representatives of Taxaceae and Cupressaceae. Only wild individuals of native species are included in this survey. The results are limited by the small number of samples in each species and only indicative of possible patterns. In particular, there are limited data about the degree of phenotypic plasticity, if any, in these anatomical characters in relation to growth conditions. Nevertheless, all species of both Taxaceae and Cupressaceae are studied. With this limitation in mind and with caution the following can be discussed.

Does anatomy help to separate closely related and difficult determinable species?

The eight species studied here have distinct anatomical features and can be divided into two groups. The first group possesses needle-like leaves that occur in three species, i.e. *T. baccata*, *J. communis* and *J. oblonga*. The second group consisting of five species possesses scale-like leaves, i.e. *C. sempervirens*, *P. orientalis*, *J. excelsa, J. sabina* and *J. foetidissima*. There are great anatomical differences between Taxaceae and Cupressaceae.

There are no fibers and resin ducts in the leaves and stems of *T. baccata* whereas all taxa in Cupressaceae possess resin ducts and fibers either in the stem or in leaves. There are definite anatomical diagnostic characters for separation of genera in Cupresseaceae. *Cupressus* (*C. sempervirens*) possesses resin ducts (in lateral scales) that have only one layer of secretory cells around each resin duct whereas *Platycladus* and *Juniperus* possess resin ducts that have more than one layer of secretory cells. Moreover, the fiber is only single-layered in *Cupressus* whereas it is more than single-layered in the other two genera of this family. Anatomical diagnostic characters of *Platycladus* and *Juniperus* are narrow. For example, the number of secretory cell layers around resin ducts is one of the anatomical diagnostic characters: two layers in *P. orientalis* and three to five layers in different species of *Juniperus*. There are some anatomical differences between very closely related species of *Juniperus*. The outline of transverse section, number of secretory cells and type of mesophyll are taxonomically valuable in this genus. For example, palisade parenchyma is absent in *J. excelsa* and *J. sabina* whereas it is present in all other *Juniperus* species in Iran.

Anatomy plays an important role in the taxonomy of gymnosperms. Anatomical traits are a valuable source of information dealing with the taxonomy of *Juniperus*, even in closely related species.

Dichotomous key for Taxaceae and Cupressaceae in Iran

1. Resin ducts absent in leaf and stem tissues ..... ***Taxus baccata*** (Taxaceae)

1*. Resin ducts present in leaf and stem tissues ..... **2** (Cupressaceae)

2. Only one secretory cell layer present around each resin duct, cuticular ornaments present in scale fissures, one continuous layer of fiber present underneath the epidermical cells ..... ***Cupressus sempervirens***

2*. More than one layer of secretory cells present around the resin ducts, cuticular ornaments absent in the scale fissures, more than one layer of fiber present beneath the epidermis; if it is single-layered, then it is non-continuous **3**

3. Two secretory cell layers present around each resin duct ..... ***Platycladus orientalis***

3*. Three to five secretory cell layers present around each resin duct ..... **4** (*Juniperus*)

4. More than one continuous fiber layer especially on the leaf corners underneath the epidermis; outline of a transverse section of leaves rectangular **5**

4*. One discontinuous layer of fiber present beneath the epidermis; outline of a transverse section of leaves is triangular **6**

5. Two transfusion tracheids present, with phloem fiber, ≥ 4 layers of fiber present in each corner of leaf ..... ***J. communis***

5*. Four transfusion tracheids present, without phloem fiber, < 4 layers of fibers present in each corner of leaf ..... ***J. oblonga***

6. One layer of palisade parenchyma present beneath the fiber layer ..... ***J. foetidissima***

6*. Palisade parenchyma absent in the mesophyll of leaves **7**

7. Adjoining fiber present beneath epidermis; four to five secretory cell layers around resin ducts ..... ***J. excelsa***

7*. Adjoining fiber absent beneath epidermis; two secretory cell layers around resin ducts ..... ***J. sabina***

Geographical distribution of Taxaceae and Cupressaceae in Iran and their systematics

In order to be able to discuss possible impacts of ecological forces on anatomical characters, the geographical distribution of studied species is discussed below.

There are only three native families of gymnosperms occurring in Iran. These are Taxaceae (only one species, *T. baccata*), Cupressaceae (with eight species belonging to three genera, *C. sempervirens*, *P. orientalis* and *Juniperus* with six species) and Ephedraceae (*Ephedra* with eight species). The distribution of species within and between genera is heterogeneous. *Ephedra* and *Juniperus* include the highest number of species (eight and six, respectively), whereas *Cupressus*, *Platycladus* and *Taxus* have only one species. All other species of gymnosperms that are widely cultivated in Iranian parks are not native to Iran.

The geographical distribution of Taxaceae and Cupressaceae is also heterogeneous. Most species occur in northern and northwestern Iran, whereas southern, western and central Iran is the habitat of only one species (*J. excelsa*). The Hyrcanian forest is host to most native species like *T. baccata*, *J. sabina* and *J. communis*. Humid areas of northwestern Iran are the habitat of *J. oblonga* and *J. foetidissima*.

Taxus baccata is a widespread species in European countries. Its distribution extends from the British Isles in the north to northern Iran in the south. Despite of its wide distribution, it is an endangered species. It is not only listed in the 'Red Book of Iran' (Jalili & Jamzad 1999), but also in the Red Books of most countries. It is native to Hyrcanian forest, to the northern expositions of the Alborz Mountains (Fig. 8A) and the Arasbaran protected area (Assadi 1998). *T. baccata* is a rare species in Iran and is mostly associated with *Alnus subcordata* C. A. Mey., *Quercus castaneifolia* C. A. Mey., *Acer velutinum* Boiss. and *Buxus hyrcana* Pojark.

Cupressaceae have a wide distribution in Iran. *J. excelsa* is the most widespread taxon (Fig. 8B), whereas *J. oblonga* has a distribution restricted to northwestern Iran only (Fig. 8A).

Platycladus orientalis is also a rare species in Iran. It is probably an introduced but naturalized species. There are a few old individuals reported from northern and northeastern Iran (Assadi 1998). One of us (MZ) has also seen an individual in a village near Kakhk (Gonabad, eastern Iran, 34°06'29"N, 58°36'50"E, 1800 m s.m., Fig. 8D). There are only three known populations of this species throughout Iran with few individuals in each population. This exacerbates the immediacy of the need to develop conservational strategies. However, the individual observed in Kakhk is a sacred tree to the natives and is strongly protected from being damaged for the time being. The soil must be de-compacted, and injection of nitrogen to soil and removal of ropes and clothes from branches would help to conserve the tree. Seeds should be harvested and started in greenhouses in order to be used for reforestation efforts in areas where the species once formed forests in Iran.

Cupressus sempervirens (the only species of this genus in Iran) has a wider distribution (Fig. 8C) than *P. orientalis* (Fig. 8D). However, its distribution is now restricted to a few populations in Iran each with few more than 1000 individuals. This species occurs in areas of Iran with Mediterranean climate, mostly in Mazranabad (36°27'46"N, 51°17'13"E, 700 m s.m.) and Manjil (36°45'04"N, 49°26'42"E, 650 m s.m.). There are several old individuals of these trees in Iran, particularly in Manjil village, Abarkouh (31°07'21"N, 53°16'47"E, 1500 m s.m.) and in Dehpabid (28°35'46"N, 60°46'57"E, 1750 m s.m.; only two individuals are left and three were burnt by locals) in central Iran each with around 25 meters height. The Manjil individual is a native plant, whereas the Abarkouh individual is possibly an old cultivated tree. Both individuals are now protected as a national natural monument. They are sacred trees to native people and they are believed to be around 4500–5000 years old (Ghahreman 1994). Moreover, there are only few old individuals of this species around Iran.

The third genus of the cypress family is *Juniperus*. This genus is composed of six species with heterogeneous geographical distribution and morphological variations in Iran. The tree-like *J. excelsa* is the most widespread species extending from the whole range of Alborz and Zagros chains to the mountains in the central part of Iran (Kerman province). The extent of morphological and cryptic speciation in this species has been discussed by Hojjati et al. (2009). In contrast, *J. communis* (Fig. 8E) and *J. sabina* (Fig. 8F) have a limited distribution and are restricted to northern Iran. The first species occurs in Hyrcanian forests, whereas the latter one occurs in northwestern Iran. *J. oblonga* and *J. foetidissima* (Fig. 8D) also occur in restricted areas in northern Iran. *J. sabina* has sympatric distribution with *J. communis* (Hyrcanian forests), whereas *J. foetidissima* has sympatric distribution with *J. oblonga* (northwestern Iran). Only *J. excelsa* is tree-like, whereas all other species of *Juniperus* are either shrubby or prostrate. *J. communis* and *J. sabina* have interesting habitats. *J. communis* occurs in upper edges of Hyrcanian forests in ecotones where the forest meets the alpine flora. These habitats are mostly covered by shrubs and small trees. So, this prostrate species associates with most Hyrcanian shrub elements. *J. sabina* occurs above tree and shrub line of Hyrcanian forest where there is intensive sun light and strong wind and cold, frosty weather. It has often been observed on the passes of mountains.

Possible ecological impacts on anatomical characters

Native conifers of Iran have only few leaf forms, being represented by needles or shield-like coverings of small flat scales on the stems. Because Iranian native gymnosperm species occur in different ecological systems, morphological and anatomical adaptations to these habitats are

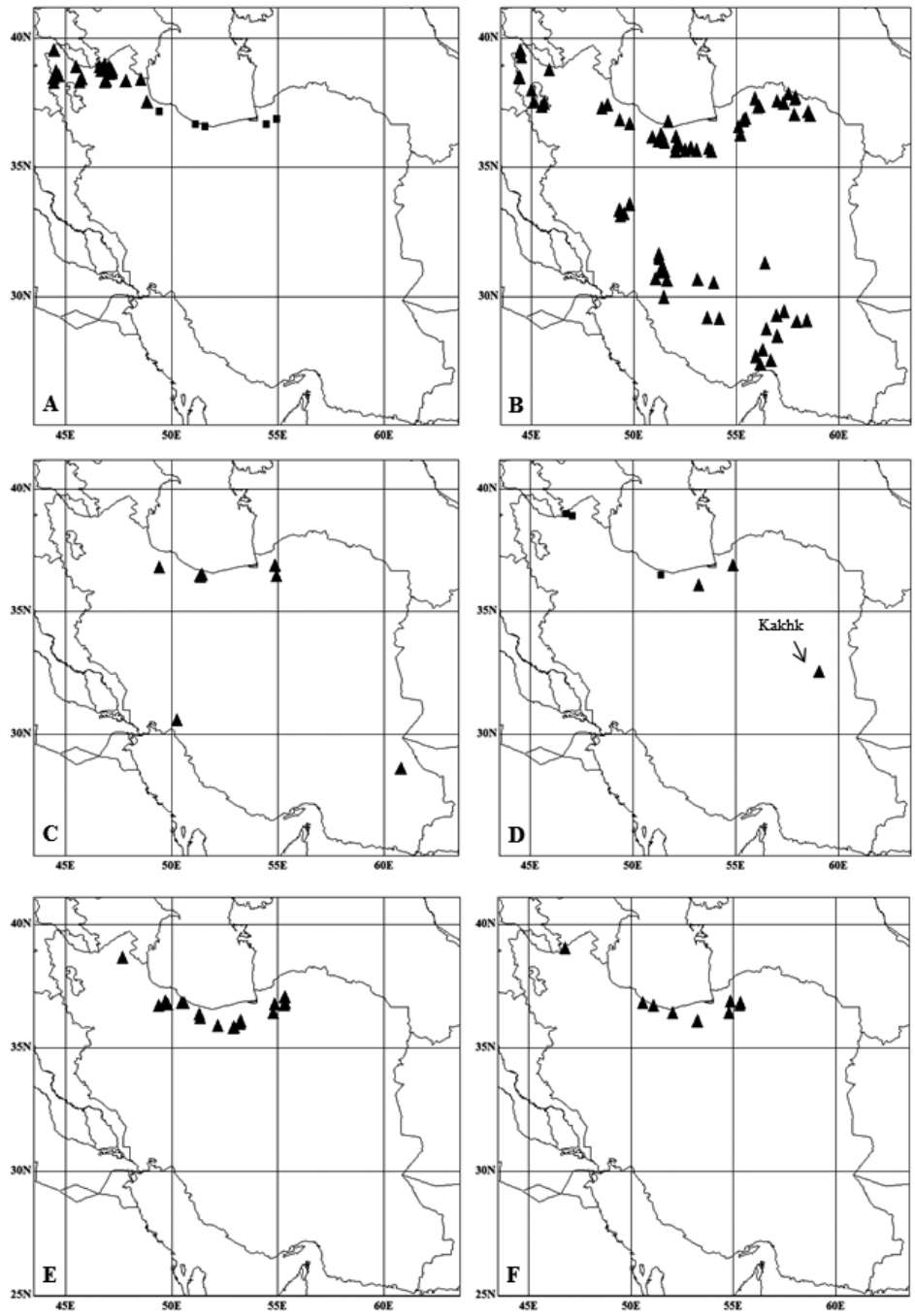

Figure 8. Distribution in Iran. A: *Taxus baccata* (■) and *Juniperus oblonga* (▲); B: *Juniperus excelsa*; C: *Cupressus sempervirens*; D: *Juniperus foetidissima* (■) and *Platycladus orientalis* (▲); E: *Juniperus communis*; F: *Juniperus sabina*.

possible. Hyrcanian forest is humid with more than 2000 mm annual precipitation in Bandare Anzali, whereas it is less than 300 mm annually in central Iran. The high annual precipitation has its own possible evolutionary effect on the anatomy and morphology. Most of Hyrcanian species possess needle-like leaves and lack the fiber layer under the epidermis. *Taxus baccata* is such an example. In contrast, species in dryer areas evolved towards adaptation to the harsh condition

of lack of water. For example, *J. excelsa* occurs in dry, stony, shallow soils from southern slopes of Alborz mountains to central Iran and also in Taftan mountains (in southeastern Iran). This species demonstrates the most extreme adaptation possible to these harsh conditions. It possesses compactly arranged scale-like leaves, with anatomically evolved traits. Several layers of fibers and collenchyma beneath the epidermis plus two layers of collenchyma covering the stem's vascular bundles are possible anatomical characters evolved towards an adaptation to the harsh, dry ecological habitats. Moreover, the anatomical study of this species was carried out on two populations from northern Iran. It is required to include samples from southern and northwestern Iran in further studies.

Examples for anatomical and morphological adaptations to different microclimates can also be quoted: *J. communis* and *J. sabina* are Hyrcanian species, but the first one demonstrates humid anatomical and morphological characters, whereas the latter species shows dry habitat characters. *J. communis* possesses needle-like leaves whereas *J. sabina* possesses the scale-like leaves. *J. oblonga* possesses more layers of fibers than *J. foetidissima* because it grows in open habitats with extensive sunlight.

Although *P. orientalis* occurs in humid areas, it demonstrates the anatomical and morphological adaptation to dry habitats by having scale-like leaves, and fibers beneath epidermis in leaves and stems.

The arrangement of the vascular tissues in the veins and the location and number of resin ducts do not depend on environmental factors.

Conclusion

Anatomical structure of leaves/scales in different species of Iranian representatives of gymnosperms has a taxonomic value and helps us to identify the plants of even closely related species. Outlines of transverse sections, presence or absences of fibers, cuticular ornaments and resin ducts have a taxonomic value. Moreover, form and type of spongy parenchyma, the number of vascular bundles and existence of sclerenchymatous tissues in vascular bundles are also important. These anatomical characters show possible ecological adaptations to various climates.

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Addresses of the authors:

Assiyeh Hamidipour
Young Researchers Club
Science and Research Branch
Islamic Azad University
Tehran
Iran
E-mail: ashamidipour@gmail.com

Dr Tayebeh Radjabian
Department of Biology
Faculty of Sciences
Shahed University
PO Box 18151-159, Tehran
Iran

Prof. Dr David A. Charlet
College of Southern Nevada
Department of Biological Sciences
700 College Drive
Henderson NV 89002
USA

Dr Mehdi Zarrei
Department of Ecology and Evolutionary Biology
University of Toronto
25 Willcocks St.
Toronto, Ontario M5S 1B1
Canada
E-mail: m.zarrei@utoronto.ca