

ANATOMICAL STUDY IN SOME SPECIES OF TAMARIX IN IRAN

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The genus *Tamarix* has about 60 species growing mainly in saline areas of deserts and semi-deserts in Asia, Europe, northeastern and southwestern Africa. Thirty-five species of *Tamarix* are grown in Iran, which have been used in fields to prevent deforestation, control soil erosion or for ornamental purposes. We have limited information on anatomical features of these species. We used 15 anatomical characters for our investigation in 10 species. PCoA ordination of the studied species based on anatomical data separated some of these species from the others. We identified 5 species that were well delimited by anatomical analysis.

Key words: anatomical features, species delimitation, *Tamarix*

INTRODUCTION

The genus *Tamarix* L. has about 60 species growing mainly in saline areas of deserts and semi-deserts in Asia, Europe, Northeastern and Southwestern Africa. This genus is mainly distributed in Pakistan, Afghanistan, Iran, Turkmenistan, South Kazakhstan, western China, and the eastern Mediterranean Region (Sheidai *et al.* 2019).

Tamarix species have limited benefits for humans but are used as ornamental plants in public gardens or plantations. For example, *T. gallica* L., *T. chinensis* Lour., *T. ramosissima* Ledeb. are used as ornamental plants for the appearance of feathers and catkin-like inflorescences. Some species of *Tamarix* are good candidates for use in deforestation of dry and saline areas (halo forest) and others are used to prevent flooding (Baum 1967, Gaskin and Schaal 2002, Ijbari *et al.* 2014).

Thirty-five species of *Tamarix* are grown in Iran, which have been used in fields to prevent deforestation, control soil erosion and ornamentally (Ijbari *et al.* 2014, Sheidai *et al.* 2019).

Due to the high hybridisation and gene flow among *Tamarix* species, plants with different morphological characteristics occur in the areas of species growth, which makes it difficult to species delimitation in this genus (Baum 1978, Gaskin and Kazmer 2009, Ijbari *et al.* 2014, Mayonde *et al.* 2019, Sheidai *et al.* 2019, Sudbrock 1993).

Anatomical features are known to be valuable traits in taxonomy. Some researchers believe that the anatomical traits are better than the morphological attributes in the classification of plants (Koohdar *et al.* 2018, Sheidai and Koohdar 2018).

In general, limited literature exists on the anatomical studies on the genus *Tamarix* for example, Campbell and Strong (1964) reported the anatomical features of salt glands in *T. pentandra* Pall. and *T. ramosissima*, Wahid (2003) studied the anatomical facets in halophyte species and, Abdulfatih (2003) studied the anatomical facets in stem and leaf of *T. rosmarinus*, as well as the anatomical characters of stem and leaf in *T. tetrandra* Pall. ex Bieb was reported by Bercu (2003).

In the present study as a particular research desideratum, anatomical investigation of the genus *Tamarix* was carried out by appropriate anatomical traits to reveal species delimitation in 10 species.

MATERIAL AND METHOD

Plant material. 30 specimens of ten species, i.e. *Tamarix arceuthoides* Bge., *T. mascatensis* Bge., *T. kermanensis* Baum, *T. tetragyna* Ehrenb., *T. karkalensis* Freyn., *T. kotschyi* Bge., *T. ramosissima*, *T. aucheriana* (Decne. ex Walp.) B. R. Baum., *T. stricta* Boiss. and *T. korkowi* were randomly collected from different geographical populations for anatomical study.

Table 1
Anatomical characters studied in *Tamarix* species

No	Characters	Status
1	Stem margin	(1) smooth, (2) dentate
2	The number of epidermal layers	(1) one layer, (2) three layers
3	Epidermal layers length / stem length ratio	(1) 0.01–0.03, (2) 0.04–0.06, (3) > 0.07, (4) 0.00
4	The presence or absence of the epidermal layer	(1) presence, (2) absence
5	Parenchyma length / stem length ratio	(1) 0.05–0.14, (2) 0.15–0.26, (3) >0.273
6	Sclerenchyma length / stem length ratio	(1) 0.02–0.08, (2) 0.09–0.12, (3) >0.13
7	The presence or absence of sclerenchyma layer	(1) presence, (2) absence
8	Number of bundle vessel in stem	(1) 4.9–6.7, (2) 6.8–8.5, (3) 8.6–9, (4) 11–12
9	Type of xylem	(1) continuous, (2) discontinuous
10	Type of phloem	(1) continuous, (2) discontinuous
11	Leaf cross-border	(1) smooth, (2) dentate
12	The amount of surrounds stems with leaf	(1) whole stem, (2) 3/4, (3) (1/2), (4) 1/2
13	Length of palisade parenchyma	(1) 0.15–0.25, (2) 0.26–0.32, (3) 0.34–0.45, (4) 0.46–0.55, (5) > 0.56
14	Number of bundle vessel in leaf	(1) 5–10, (2) 11–15, (3) 16–20, (4) 20–25, 26
15	Epidermal layers length / leaf length ratio	(1) 0.03–0.06, (2) 0.07–0.12, (3) 0.12–0.19, 0.20

Anatomical study. For anatomical study, embedded materials were prepared as follows: four adult plants samples were excised and immediately fixed in formalin-acetic acid-alcohol (FAA) (formalin 5%: acetic acid 5% and 50% ethanol 90%) (Jensen 1962) for 48 to 72 h, and stored at 4 °C until sectioning, then dehydrated in a graded ethanol series and embedded in 70% ethanol. After preparation of free transverse hand sections of the lamina and stem, samples were washed with distilled water and placed in 5% sodium hypochlorite solution for 20 min for clearing and rinsed with distilled water. The sections were stained with methylene blue and carmine and mounted on the slides using Canada balsam. Thin cut sections were observed under a microscope fitted with digital camera. Anatomical characters in stem and leaf are given in Table 1.

For grouping of the plant specimens, PCA and PCoA were used (Podani 2000) by using Gower distance. PAST version 2.17 (Hammer *et al.* 2012) was used for multivariate analysis.

RESULTS

The detailed descriptions of the anatomical features in the studied species are displayed in Table 2 and Fig. 1.

The stems in the cross section have a circular form. Stem margin in the cross section was smooth in *T. stricta* while in the other species it was wavy. Except *T. stricta*, which has a three-layer epidermis, the other species have one-

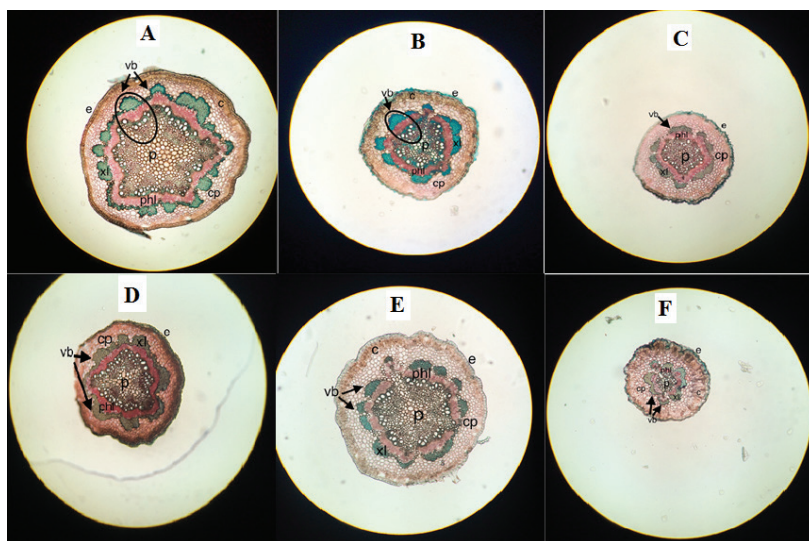


Fig. 1. Details of anatomical characteristics in *Tamarix*. a = *T. karkalensis*, b = *T. korkowi*, c = *T. kotschyi*, d = *T. mascatensis*, e = *T. ramosissima*, f = *T. kermanensis* (e = epidermis; cp = cortex parenchyma; c = collenchymas; vb = vascular bundle; phl = phloem; xl = xylem; p = pith)

Table 2
Details of anatomical characteristics in *Tamarix* species (the character, species and code numbers are in Table 1)

Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	1	1	1	1	2	1	1	2	1	1	1	1	4	12	2
1	1	1	1	1	1	1	1	2	1	1	1	1	2	11	1
1	1	1	1	1	2	1	1	2	1	1	1	1	2	16	2
1	1	1	1	1	2	1	1	2	1	1	1	1	1	8	2
2	1	1	1	1	1	1	1	2	1	2	1	2	2	16	2
2	1	1	1	1	1	1	1	4	2	1	1	3	1	5	2
2	1	1	3	1	3	2	1	1	2	1	1	1	2	14	2
2	1	1	1	1	1	1	1	3	1	2	1	3	2	10	2
3	1	1	1	1	2	1	1	3	1	2	1	2	2	15	2
3	1	1	1	1	2	1	1	3	1	2	1	2	1	9	2
3	1	1	1	1	2	2	1	1	1	2	1	2	2	15	2
3	1	1	1	1	2	1	1	3	1	2	1	2	1	17	2
4	1	1	1	1	1	1	1	2	2	1	1	1	2	20	1
4	1	1	1	1	1	1	1	2	2	1	1	1	1	21	1
4	1	1	2	1	2	2	1	1	2	1	1	1	3	9	1
4	1	1	1	1	1	3	1	1	2	1	1	1	1	8	2
5	1	1	1	1	1	1	1	3	2	1	1	4	1	6	1
5	1	1	1	1	2	1	1	3	1	2	1	4	1	14	1
5	1	1	1	1	2	1	1	2	1	2	1	4	4	5	2
5	1	1	1	1	1	1	1	3	2	1	1	3	1	15	2
6	1	1	2	1	2	1	1	2	2	2	1	2	3	18	3
6	1	1	2	1	2	1	1	1	2	1	1	3	1	12	2
6	1	1	1	1	1	1	1	4	2	1	1	4	1	10	2
6	1	1	1	1	1	1	1	3	1	1	1	4	2	26	3
7	2	3	4	2	1	0	2	2	2	1	2	1	3	15	1
7	2	3	4	2	1	0	2	1	2	1	2	1	3	20	1
7	2	3	4	2	1	0	2	2	2	1	2	1	3	16	1
7	2	3	4	2	1	0	2	2	2	1	2	1	2	16	1
8	1	1	1	1	1	1	1	2	1	1	1	2	2	11	3
8	1	1	1	1	2	2	1	1	1	1	1	2	1	12	2
8	1	1	1	1	2	1	1	2	1	2	1	2	2	16	2
8	1	1	1	1	2	1	1	1	1	2	1	2	3	13	3
9	1	1	1	1	1	1	1	3	1	1	1	1	2	13	2

Table 2 (continued)

Spe- cies	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
9	1	1	3	1	2	3	1	2	1	2	1	1	4	12	2
9	1	1	1	1	2	1	1	2	1	2	1	1	3	20	4
9	1	1	2	1	3	2	1	1	2	1	1	1	5	17	3
10	1	1	1	1	1	1	1	2	1	1	1	1	3	25	4
10	1	1	1	1	1	1	1	1	2	2	1	1	3	16	4
10	1	1	2	1	2	1	1	1	1	1	1	1	3	24	4
10	1	1	1	1	1	1	1	3	1	1	1	1	2	24	4

layer. Epidermal cells were circular in all species. The highest epiderm (41 μm) and cuticle (10 μm) thickness in stem was observed in *T. korkowi*, while *T. stricta* had the lowest value epiderm (10 μm) and cuticle (4 μm) thickness.

The shape of the pith parenchyma was stellar in all species. This parenchyma has 5 arms in *T. mascatensis* and *T. ramosissima*, but in the other species it varies between 3 to 5 arms.

Phloem vascular bundle in *T. arceuthoides*, *T. aucheriana*, *T. tetragyna*, *T. kermanensis* were continuous, while in *T. mascatensis* was discontinuous. This trait

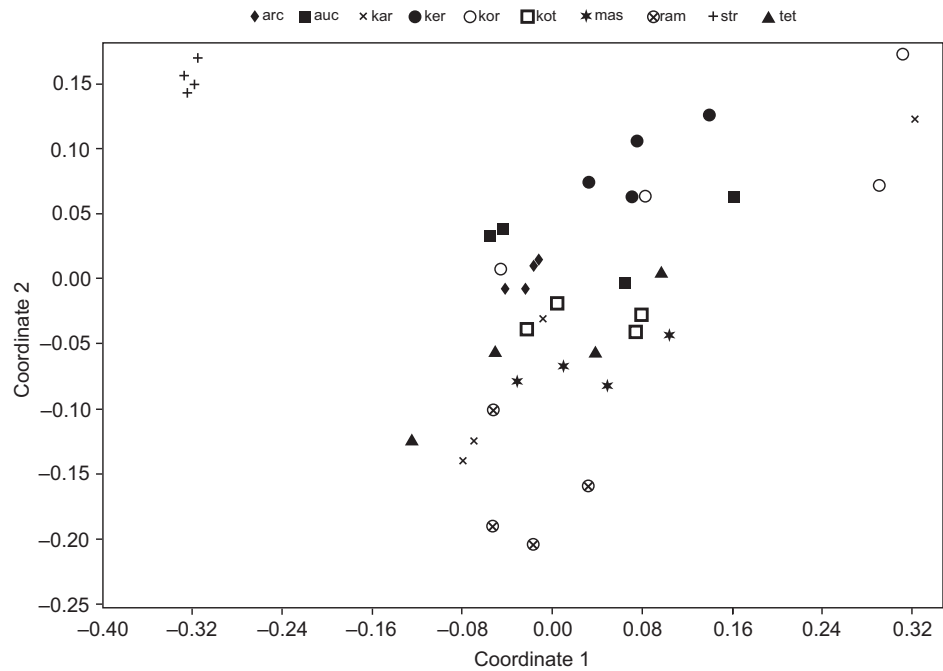


Fig. 2. PCoA plot based on the anatomical study in *Tamarix* species

was in both forms in the other species. Xylem vascular bundle in *T. arceuthoides*, *T. mascatensis*, and *T. kotschy* were discontinuous, but in *T. stricta* and *T. aucheriana* were continuous. This trait was in both forms in the other species.

In *T. kermanensis*, *T. korkowi*, *T. arceuthoides*, *T. aucheriana*, and *T. stricta*, the stems in cross section are covered with the leaves, while in the other species the leaves are covered by part of stems. Phloem vascular covered xylem vascular in all of the leaves in cross section.

PCA analysis revealed that the two first PCA axes comprised about 78% of total variance. The first component with 48% of the mean total variance, including stem cross sectional traits, number of epidermal layers, stem epidermis length to the whole stem, presence or absence of epidermis, presence or absence of sclerenchyma and cross-sectional area and the second component with 30% variance including the number of leaves on the leaves and the length of the leaf epidermis in total.

PCoA plot (Fig. 2) was drawn with ten species based on the anatomical study. These results showed only *T. stricta* was separated from the other species.

Because of the high diversity, *T. tetragyna*, *T. karkalensis*, *T. ramosissima*, *T. kotschy*, and *T. korkowi* were deleted from species delimitation analyses. Based on PCoA plot *T. arceuthoides*, *T. aucheriana*, *T. kermanensis*, *T. mascatensis*, and *T. stricta* separated from each other (Fig. 3).

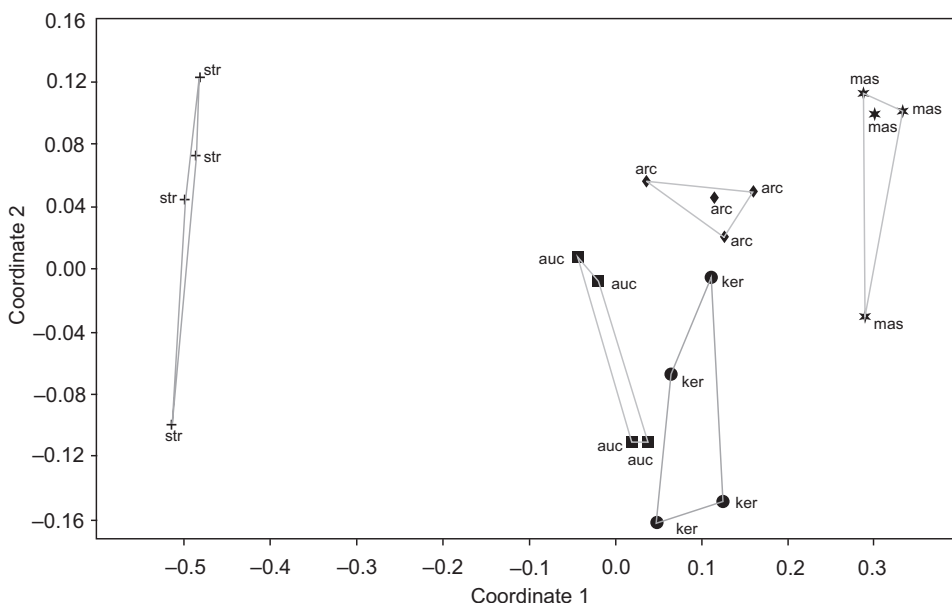


Fig. 3. PCoA plot based on anatomical traits in some *Tamarix* species. Abbreviations: arc = *T. arceuthoides*, auc = *T. aucheriana*, ker = *T. kermanensis*, mas = *T. mascatensis*, str = *T. stricta*

DISCUSSIONS

Tamarix species show a morphological overlap and diversity to cope with environmental conditions and therefore, the species delimitation is problematic (Ijbari *et al.* 2014). In this study, separation of the studied *Tamarix* species based on anatomical analysis confirmed that in spite of morphological overlap and diversity among the studied species, they can be differentiated by anatomical characters. The present study revealed taxonomic implication of leaf and stem anatomy in both *Tamarix* species delimitation. Anatomical characters, like phloem vascular bundle, xylem vascular bundle, the stems in the cross section, and number of bundle vessel in leaf and stem may be used along with morphological.

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