

## LEAF ANATOMICAL STRUCTURE OF IRANIAN NARROW-LEAVED SPECIES OF THE GENUS *FESTUCA* L. (POACEAE, POEAE)

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Superficial similarity between narrow-leaved species of the genus *Festuca* L. was lead to using the cryptic characters such as anatomical traits for taxonomic aims. Structure and arrangement of sclerenchyma tissue and the number of veins as seen in leaf cross sections were found as being significant diagnostic features in some species aggregates in the genus *Festuca*. In total 53 selected accessions of *Festuca* species collected around the country, types and herbarium specimens housed in Natural History Museum Vienna (W), University of Vienna (WU), Botanic Garden and Botanical Museum Berlin (B), Research Institute of Forests and Rangelands (TARI), Herbarium of the University of Isfahan (HUI), Tehran University Herbarium (TUH) and Herbarium of H. Akhiani were studied. In this investigation, nearly all reported narrow-leaved species of the Iranian members of the genus *Festuca* including *F. alaica*, *F. skvortsovii*, *F. rubra*, *F. chalcophaea*, *F. sabalanica*, *F. rechingeri*, *F. akhanii*, *F. varia*, *F. transcaucasica*, *F. valesiaca*, *F. elwendiana* and *F. rupicola* which some of them are endemic were investigated and an identification key was made. The results of this study confirmed synonymy of *F. bormmulleri* and *F. ovina* subsp. *kotschyi* for *F. alaica*, also showed that there are no *F. ovina* s. str., *F. pinifolia* and *F. heterophylla* growing in the borders of Iran.

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**Key words.** Poaceae, *Poa*, anatomy, leaf cross section, tiller, Iran.

### ***Festuca* L. (Poeae, Poaceae)**

شبهات ظاهری بین گونه‌های برگ باریک جنس *Festuca* L. منجر به استفاده از صفات پنهان مانند صفات تشریحی برای اهداف تاکسونومیک شده است. ساختار و آرایش بافت اسکلرانشیمی و تعداد رگبرگ‌ها به طوری که در برش عرضی برگ قابل مشاهده است دارای قابلیت‌های تشخیصی مهمی در تعدادی از اجتماعات گونه‌ای در جنس *Festuca* هستند. تعداد ۵۳ جمعیت منتخب از گونه‌های *Festuca* شامل نمونه‌های جمع آوری شده از سرتاسر کشور، نمونه‌های تیپ و نمونه‌های هرابیومی مربوط موجود در هرباریوم‌های وین (W)، دانشگاه وین (WU)، باغ گیاه‌شناسی و هرباریوم برلین (B)، مؤسسه تحقیقات جنگلها و مراتع کشور (TARI)، دانشگاه اصفهان (HUI)، هرباریوم دانشگاه تهران (TUH) و هرباریوم آخانی مورد مطالعه قرار گرفته‌اند. در این تحقیق، تقریباً همه گونه‌های برگ-باریک گزارش شده برای ایران شامل: *F. alaica*, *F. skvortsovii*, *F. rechingeri*, *F. rubra*, *F. chalcophaea*, *F. sabalanica*, *F. akhanii*, *F. varia*, *F. transcaucasica*, *F. valesiaca*, *F. elwendiana*, *F. rupicola* که برخی از آنها بومی ایران می‌باشند مورد مطالعه قرار گرفته‌اند و یک کلید شناسایی برای آنها تهیه شده است. نتایج این مطالعه مترادف شدن دو تاکسون *F. bormmulleri* و *F. ovina* subsp. *kotschyi* را با گونه *F. alaica* تأیید می‌کند، همچنین مشخص شد که گونه *F. ovina* در مفهوم دقیق آن و نیز *F. pinifolia* و *F. heterophylla* در ایران وجود ندارند.

### **Introduction**

*Festuca* L. is a large and taxonomically complicated genus with about 450 species (Clayton *et al.* 1986).

Due to superficial similarity between the narrow-leaved species, taxonomic treatments and identifications of them are extremely difficult. In addition, the problem is

augmented for the specimens lacking or having immature inflorescence. Moreover, high polymorphism encountered in morphological features especially in *F. rubra* and *F. ovina* complexes are of the problems that caused seeking for some cryptic traits such as sclerenchyma tissue structure, as seen in a cross section of tiller leaves (Tzvelev 1975, Cope 1982, Aiken *et al.* 1995, Shu *et al.* 2006).

Application of leaf anatomical characters as taxonomic features in the genus *Festuca* originally was presented by Hackel (1882) and then followed by Saint-Yves (1927), who constructed a key and provided many black diagrams for different taxa belonging to the subgenus *Festuca* of the old world which was used by the later authors in important Floras such as Flora Europea by Markgraf-Dannenbergh in 1980. Stace *et al.* (1992) found that leaf based anatomical features such as: blade shape in cross section, number of veins and ribs and sclerenchyma tissue arrangement are of diagnostic values particularly in *F. ovina* and *F. rubra* aggregates.

Considering a thorough taxonomic treatment for the Iranian materials of *Festuca* is still remained to be grasped, the applicability of leaf anatomical characters to clarify the ambiguous situations in this genus is to be highlighted. Alexeev (1975, 1979) using black diagrams of leaf cross section for some *Festuca* species of Flora Iranica region, reported two new species, *F. rechingeri* E. Alexeev and *F. sabalanica* E. Alexeev, from Iran. Panahi (2004) analyzed morphological and anatomical characters of *F. ovina* complex in Iran. Also, Eslami *et al.* (2008) studied leaf anatomy in five fine-leaved species of the genus *Festuca* and presented an identification key.

This study aims to use leaf anatomical features in order to clarify the taxonomic complexities among the species belonging to the so-called "narrow-leaved" (fine-leaved) including: *F. rubra* L., *F. chalcophaea* V. Krecz. & Bobrov, *F. alaica* Drobow, *F. skvortsovii* E. B. Alexeev, *F. rechingeri* E. B. Alexeev, *F. sabalanica* E. B. Alexeev, *F. akhanii* Tzvelev, *F. varia* Haenke, *F. transcaucasica* (St.-Yves) Tzvelev, *F. valesiaca* Schleich. ex Gaudin, *F. elwendiana* Markgr.-Dann. and *F. rupicola* Heuff.

## Material and Methods

This study was performed on a total of 53 selected accessions belonging to 12 narrow-leaved *Festuca* species collected all around Iran during 2008-2011. In addition the relevant herbarium specimens deposited in the Herbarium of the University of Isfahan (HUI), Herbarium of Research Institute of Forests and Rangelands (TARI), Tehran University Herbarium (TUH), Herbarium of H. Akhani and the Iranian

materials in the Natural History Museum Vienna (W), University of Vienna (WU), Botanic Garden and Botanical Museum Berlin (B) including type specimens of: *F. sabalanica* (W44196), *F. rechingeri* (W43455), *F. bornmulleri* (Hack.) Krecz. & Bobrov (W8437), *F. ovina* subsp. *kotschyi* Hack. ex Boiss. (W 752), *F. rubra* (W 251435), *F. ovina* subsp. *asperrima* (W 1916-0011305), *F. valesiaca* (W 0008281) and *F. akhanii* (Herbarium H. Akhani10806) were included in this study (Table1).

Leaf sections were taken and prepared from the middle one third part of the fresh innovation leaves and the herbarium specimens. For the fresh materials double staining using Congo red and Green methyl and for the herbarium specimens Toluidine blue solution were used. Measurements were made using a graded ocular lens of light microscope with the magnifications of  $\times 40-400$ .

In order to construct an identification key, a total number of eleven anatomical characters were considered as followed: leaf shape in cross section, leaf-blade diameter, leaf depth, leaf-blade thickness, number of veins, number of adaxial ribs, number of adaxial groove, abaxial sclerenchyma structure (continuous/discontinuous/discrete), number of abaxial sclerenchyma strand, adaxial surface hairiness and abaxial surface hairiness (Table 2). Leaf anatomical terminology was that of Alexeev 1979 and Wilkinson and Stace 1991.

## Results, discussion and conclusion

In this study, we found that all the 11 anatomical characters studied are of taxonomic importance in the narrow leaved fescues studied. Table 2 summarizes the observations of this study. Based on the results of this study all the narrow-leaved fescues investigated exhibited only abaxial sub-epidermal sclerenchyma tissue without any trace of sub-epidermal sclerenchyma masking vein striation (free from veins). *F. varia* and *F. skvortsovii* show a continuous and uniform sub-epidermal sclerenchyma layer, however, *F. skvortsovii* in some cases forming an interrupted ring with more thickness in middle and two margins (Fig. 1, e, f; Fig. 2, a, Table 2). Notably, in the other species studied sclerenchyma tissue appeared as discrete strands in different sizes and arrangements (Fig. 1, a, b, c, d, g, h, i, j, k, l; Fig. 2, b, c, d, e, f, g). In *F. rubra* and *F. chalcophaea* the sclerenchyma strands are nearly prominent and as many as the veins (Fig. 1, a, b, g; Table 2). *F. sabalanica*, *F. rechingeri* and *F. alaica*, *F. transcaucasica*, *F. akhanii* are characterized by three isolated sclerenchyma tissue located at two leaf margins and mid rib (Fig. 1, c, d, h, i, j; Fig. 2, c, g). *F. valesiaca* group including *F. valesiaca*, *F.*

Table 1. Geographical origin of studied species of the genus *Festuca* for anatomical investigation in Iran.

Species	Locality
<i>F. rubra</i>	Mazanderan, Lar valley, 2420 m, Wendelbo and Assadi (W 13348, TARI 13348)
<i>F. rubra</i>	Mazanderan, North slope of Kandavan, 2850 m, 7 VIII 1936, Gilli (W)
<i>F. rubra</i>	Mazanderan, North slope of Kandavan, 2600-3000 m, Rechinger (W 6777)
<i>F. rubra</i>	Kerman, Lalezar mountains, 2932 m, Hosseini and Naderi (HUI 18030)
<i>F. rubra</i>	Azerbaijan, 45 from Sarab (Sabalan), 2900 m, Moinodin (TARI 9319)
<i>F. rubra</i>	Mazanderan, Kandavan, 2600 m, Foroughi (TARI 438)
<i>F. rubra</i>	Kerman, Kuh-e-Lalezar, Zarda valley, 3000 m, Foroughi and Assadi (TARI 16315)
<i>F. rubra</i>	Tehran, km 80 Karaj Kandavan, 2500 m, Babakhanlou and Amin (TARI 11182)
<i>F. rubra</i>	Elburz mountain, 3000 m, Bornmuller (B 8436)
<i>F. chalcophaea</i>	Azerbaijan, Inter Shahpur and Rezaieyeh, Jardine (W 668-A)
<i>F. chalcophaea</i>	Kordestan, Sanandaj, Abidar forest park, 1728 m, Naderi (HUI 18026)
<i>F. chalcophaea</i>	Azerbaijan, Sahand mountains, 3393 m, Noroozi
<i>F. chalcophaea</i>	Azerbaijan, Sahand mountains, 3658 m, Noroozi
<i>F. alaiica</i>	Azerbaijan, Sabalan mountains, 3500 m, Noroozi (W 2626)
<i>F. alaiica</i>	Tehran, Tuchal, 3600-3800 m, Bornmuller (W8437, 8438)
<i>F. alaiica</i>	Fars, Kuh-e- Dinar, near Chashmeh Pias, Kotschy (W 752)
<i>F. alaiica</i>	Mazanderan, 8 km SW Reneh, 4220 m, Grant (W 16522)
<i>F. alaiica</i>	Mazanderan, Demavend, by the camping place on the southern slope, 4000 m, Wendelbo (W 1681)
<i>F. alaiica</i>	Tehran, Elburz mountain, Totschal, 3600 m, Bornmuller (W 8437)
<i>F. rechingeri</i>	Guilan-Azerbaijan, Asalem (Navrud) to Khalkhal (Herowabad), 1900-2300 m, Rechinger (W 43455)
<i>F. rechingeri</i>	Guilan-Azerbaijan, Asalem to Khalkhal, 2100 m, Hosseini (HUI 18015)
<i>F. skvortsovii</i>	Tehran, Demavand, Polur, Supra Reneh, 4000 m, Gilli (W)
<i>F. skvortsovii</i>	Mazanderan, Kojur, m. Uloj, 3200-3400 m, Rechinger (W 6491)
<i>F. skvortsovii</i>	Mazanderan, Between Haraz and Panjab, 1400 m, Wendelbo (W 695)
<i>F. skvortsovii</i>	Inter Rescht to Kaswin, near Mendschil, 300 m, Bornmuller (B 8441)
<i>F. skvortsovii</i>	Golestan, Khosh Jaila, 2100-2200 m, Hosseini (HUI 18027)
<i>F. skvortsovii</i>	Mazanderan, Gaduk, 2230 m, Hosseini (HUI 18022)
<i>F. sabalanica</i>	Azerbaijan, Sabalan mountains, 3500-3700 m, Rechiger (W 44196)
<i>F. sabalanica</i>	Azerbaijan, Sabalan mountains, 3600-3700 m, Noroozi (W 2579)
<i>F. sabalanica</i>	Azerbaijan, Sabalan, 3500 m, Rejamand (TARI 7152)
<i>F. transcaucasica</i>	Azerbaijan, Sawalan, Rasse, 20 VI 1880 (W 15)
<i>F. transcaucasica</i>	Mazanderan, Golestanak protected area, m. Varvasht, Naderin (HUI 16834)
<i>F. akhanii</i>	Golestan National Park, 2 km W. Alme towards Sharleq, 1700-1750 m, Akhani (10806)
<i>F. varia</i>	Azerbaijan, Arasbaran protected area, Abbasabad elevation, 2500 m, Hamzehee and Asri (TARI 81861)
<i>F. elwendiana</i>	Lorestan, Dorood to Khorramabad, Razan, 2050 m, Hosseini (HUI 19439)
<i>F. elwendiana</i>	Hamedan, Ganjnameh, 2000 m, Hosseini (HUI 19440)
<i>F. elwendiana</i>	Kermanshah, 20 km after Sonqor to Hamedan, 1930 m (HUI 19441)
<i>F. elwendiana</i>	Hamedan, Kaboodarahang, 2200-2800 m, Mozaffarian (TUH 64557)
<i>F. elwendiana</i>	Khorasan, Dargaz to Quchan, Tandoureh National Park, 2000 m, Hosseini (HUI 19442)
<i>F. valesiaca</i>	Khorasan, Golestan National Park, Dasht, 1200 m, Naderi and Hosseini (HUI 19437)
<i>F. valesiaca</i>	Mazanderan, Siakhkhan, Hosseini (HUI 19436)
<i>F. valesiaca</i>	Mazanderan, Demavand North slope, 2500 m, Talebi (TUH 43443)
<i>F. valesiaca</i>	Golestan National Park, 4-5 km NW Bidak, Cheshme-Derazi, 1300-1500 m, Akhani (10732)
<i>F. valesiaca</i>	Qashqai, Kohrueyeh, 25-36 km Shahreza to Semirom, 2600 m, Rechinger (W 47326)
<i>F. valesiaca</i>	Azerbaijan, Qotur river valley, W of Khvoy, 1800-2000 m, Rechinger (W 41691)
<i>F. rupicola</i>	Mazanderan, Vavsar, Shadej mountain, 2700 m, Naderi (HUI 19438)
<i>F. rupicola</i>	Semnan, Tandoureh protected area, 1400 m, Hosseini (HUI 19433)
<i>F. rupicola</i>	Guilan, Roodsar, Javaher Dasht village, Naderi and Gholizadeh (HUI 19432)
<i>F. rupicola</i>	Khorasan, Bojnourd to Shoghan, Biou neck, 1800 m, Hosseini (HUI 19431)
<i>F. rupicola</i>	Khorasan, Hezarmasjed mountains, Laein, Hosseini (HUI 19434)
<i>F. heterophylla</i>	Bulgaria, Southern coastal area of Black Sea, Cape Maslen, 50 m, Tomas Raus (W 21194)
<i>F. pinifolia</i>	Turkey, Phrygia, Sultandagh, in jugis alpinis supra Akscheher, 1900 m, Bornmuller (W 5672)
<i>F. ovina</i> s. str.	Niederosterreich, Thayatal, Frain, Walder (W 3495)

Table 2. Anatomical characters used for evaluation of *Festuca* species in Iran.

characters	<i>F. rubra</i>	<i>F. chalcophaea</i>	<i>F. alaica</i>	<i>F. rechingeri</i>	<i>F. skvortsovii</i>	<i>F. sabalanica</i>
shape in cross section	angular	hexagonal	elliptic	subcylindric	elliptic/circular	ovate
leaf-blade diameter (mm)	0.5–1.4	0.25–0.8	0.5–0.6	0.7–0.8	0.5–1	0.4–0.65
mean of leaf blade depth (mm)	0.9	0.48	0.33	0.55	0.48	0.36
mean of leaf-blade thickness (mm)	0.38	0.29	0.24	0.29	0.29	0.26
number of veins	5–7	5	5–7	7	7	5
number of adaxial rib	4–6	3	3 (1)	3–5	3–5	3
number of adaxial groove	4–6	4	4	4–6	4–6	4
abaxial sclerenchyma structure	discrete	discrete	discrete	discrete	continuous	discrete
number of sclerenchyma strands	5–9	7	3	3	continuous	3
adaxial surface hairiness	hairy	hairy	sparse hairs	-	hairy	sparse hairs
abaxial surface hairiness	glabrous	scabrous	glabrous	glabrous	glabrous or scabrous	scabrous

Table 2. Continued.

characters	<i>F. varia</i>	<i>F. akhanii</i>	<i>F. transcaucasica</i>	<i>F. valesiaca</i>	<i>F. elwendiana</i>	<i>F. rupicola</i>
shape in cross section	elliptic	elliptic	elliptic	elliptic	circular	ovate
leaf-blade diameter (mm)	0.5–1	0.3–0.4	0.7–1	0.4–0.65	0.4–0.75	0.6–0.9
mean of leaf-blade depth (mm)	0.55	0.23	0.58	0.31	0.2	0.4
mean of leaf-blade thickness (mm)	0.3	0.15	0.29	0.26	0.25	0.3
number of veins	7–9	3–5	7	5	5	5
number of adaxial rib	5–7	3	3–5	3	3	3
number of adaxial groove	6–8	4	4–6	4	4	4
abaxial sclerenchyma structure	continuous	discrete	discrete	discrete	interrupted	discrete
number of sclerenchyma strands	continuous	3	3	3	interrupted	3
adaxial surface hairiness	hairy	sparse hairs	hairy	hairy	hairy	sparse hairs
abaxial surface hairiness	scabrous	glabrous	glabrous	scabrous	scabrous	glabrous

*elwendiana* and *F. rupicola* mostly characterize with three stout sclerenchyma strands in middle and two margins, but some variations ranging from three or five discrete sclerenchyma strands or interrupted sclerenchyma ring have been observed (Fig. 2, b, d, e, f). *F. elwendiana* usually recognize with somewhat interrupted or unequal sclerenchyma ring; *F. valesiaca*

have 3 stout, sometimes with 2 additional smaller strands alternating, rarely confluent, whereas in *F. rupicola* sclerenchyma strands are 3 stout, rarely with 2 small strands alternating.

This study showed that the outline of leaf cross section in combination with other anatomical traits can be used as an anatomical marker among the species

examined. In both *F. chalcophaea* and *F. rubra* the outline is angular although, in the former it is constantly hexagonal and in the latter differently angular (Fig. 1, a, b, g). Frequently other outlines observed among the remaining are as: ovate, compress-cylindrical, cylindrical and circular (see Table 2).

Number of veins showed to be important diagnostic specific feature in some species of this group of fescues; it varied from 3 to 9 and often 5 was the normal number (Fig. 1; Fig. 2; Table 2).

Despite some intra specific variability, however this study showed that certain leaf anatomical characters proved to be of taxonomical values. Outline of leaf as seen in our cross sections combined with the number and thickness of sclerenchyma strands can be valuable characters to separating a main group of the subgenus *Festuca* i.e. *Festuca rubra* aggregate including *F. rubra* and *F. chalcophaea* which show angular shape with nearly same size and thin strands in angles from *F. ovina* aggregate having ovate, elliptical or cylindrical shape with continuous or interrupted sclerenchyma tissue.

Taxonomical confusions caused by high morphological similarities e. g., *F. alaica* and *F. sabalanica* were resolved using the leaf structural data created in this study (see the constructed anatomical key and also Table 2). Furthermore, based on the result of this study we were able to identify the specimen W 2579 as *F. sabalanica* which had already been determined as *F. alaica*. Moreover, we confirm the synonymy of *F. ovina* subsp. *kotschyi* and *F. bornmulleri* under *F. alaica* which was accepted by Tzvelev (1976).

Bor (1970) designated *F. ovina* to enormous specimens collected from Iran and many other workers in different areas followed him (Panahi, 2004; Safikhany *et al.*, 2004; Naderi *et al.*, 2012). Noticeably, our study on the materials of *F. ovina* s. str. obtained from Wien (W 3495) led us to this notion that none of the Iranian *Festuca* specimens identified as *F. ovina* so far, belong to this species; this notion is in accordance with Alexeev (1979) and his comments on the specimens in W herbarium. As an approve evidence we provided and presented a sectional profile of *F. ovina* s. str. (W 3495) (see Fig. 1, k).

*F. heterophylla*, a close species of *F. rubra*, is known as Euro-Siberian element that having some specific anatomical characters of basal innovation leaves: 4 angular in section, 3 veins, 5 sclerenchyma strands and 1 adaxial rib (Fig. 1, l). Comparing the resultant anatomical data between *F. rubra* subsp. *rubra* (W 13348) and *F. heterophylla* Lam. (W 2006-21194; Fig. 1, l), also, leaf sections prepared from all

specimens identified as *F. heterophylla* from which TARI 13348, TARI 9319, TARI 438, TARI 16315 showed that there are no *F. heterophylla* occurring in Iran and all studied species belong to *F. rubra*.

*F. pinifolia*, other controversially reported species by Bor 1970, show stout sub-epidermal sclerenchyma ring along with 3 adaxial hairiness ribs as seen in specimens: W 1683, WU 146, WU 1683, WU 5672 (Fig. 2, h). Our anatomical study approved that 3 specimens (TARI 7152!, W 1120! and W 2945!) was considered as records of *F. pinifolia* (Hack. ex Boiss.) Bornm. for Iran belonging to *F. sabalanica*, *F. valesiaca* and *F. rupicola* respectively (Bor, 1970; Alexeev, 1975).

Finally, it should be mentioned that despite being useful however, anatomical characters like any other data have their own peculiarities and cautions should be taken in their use. In this special case, that is *Festuca*, it is very important to use tiller innovation leaves and examining adequate number of sections.

### Key base on leaf anatomical characters for narrow-leaved species of the genus *Festuca* occurring in Iran

1. Lamina of innovation leaf of tiller angular in section; sclerenchyma in discrete and usually equal size strands 2
- Lamina of innovation leaf of tiller ovate, elliptic, cylindrical; sclerenchyma in 3-5 strands, continuous or interrupted 3
2. Hexagonal in section; 7 nearly same size sclerenchyma strands; 5 veins, 3 ribs *F. chalcophaea*
- Mostly angular in section; thin sub-vein sclerenchyma strands (sometime unequal in size) but free from veins; (5) 7-9 veins; 5-7 ribs *F. rubra*
3. Sclerenchyma in continuous or sometimes interrupted ring, adaxial surface hairy 4
- Sclerenchyma in 3-5 discrete strands, 5 - 7 veins; (1) 3-5 ribs; adaxial surface hairy or glabrous 5
4. Sclerenchyma in uniform continuous ring, (7) 9 (11) veins; *F. varia*
- Sclerenchyma in continuous or sometimes interrupted ring; the thickest at the middle and two margins; (5) 7 veins, 3-5 ribs; strikingly hairiness upper surface. *F. skvortsovii*
5. Sclerenchyma always in 3 strands at the middle and two margins, mostly sub-cylindrical or sometimes ovate in sections; 3-7 veins; 3-5 ribs 6
- Sclerenchyma in 3 strands, sometime with 2 additional strands (rarely forming an interrupted ring); mostly ovate, elliptic or circular in section; 5 veins and 3 ribs 10

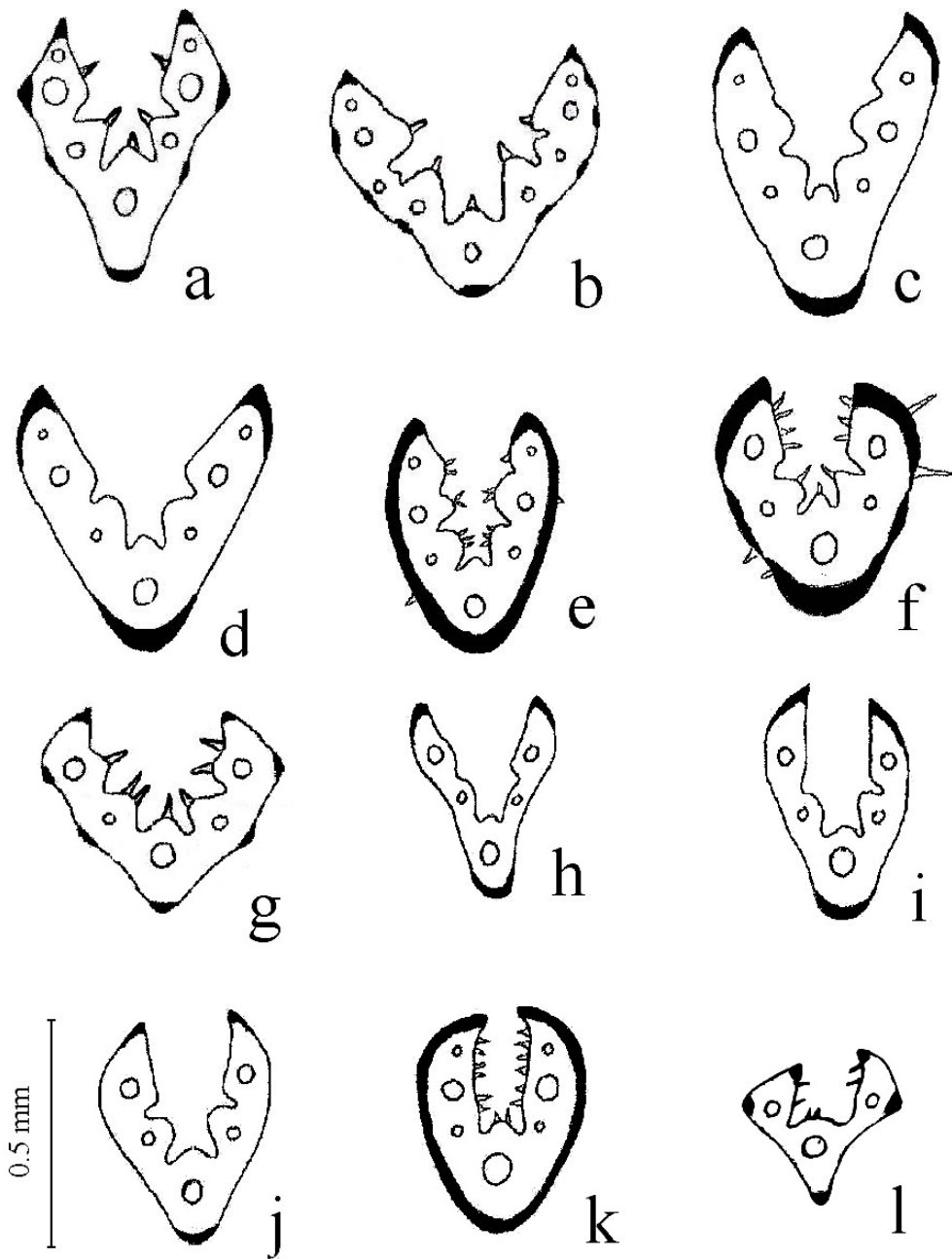


Fig. 1. Patterns of sclerenchyma tissue (black) in leaf section of *Festuca rubra* (a, b); *F. rechingeri* (c, d); *F. skvortsovii* (e, f); *F. chalcophaea* (g); *F. alaica* (h, i); *F. sabalanica* (j) *F. ovina* (k) and *F. heterophylla* (l).

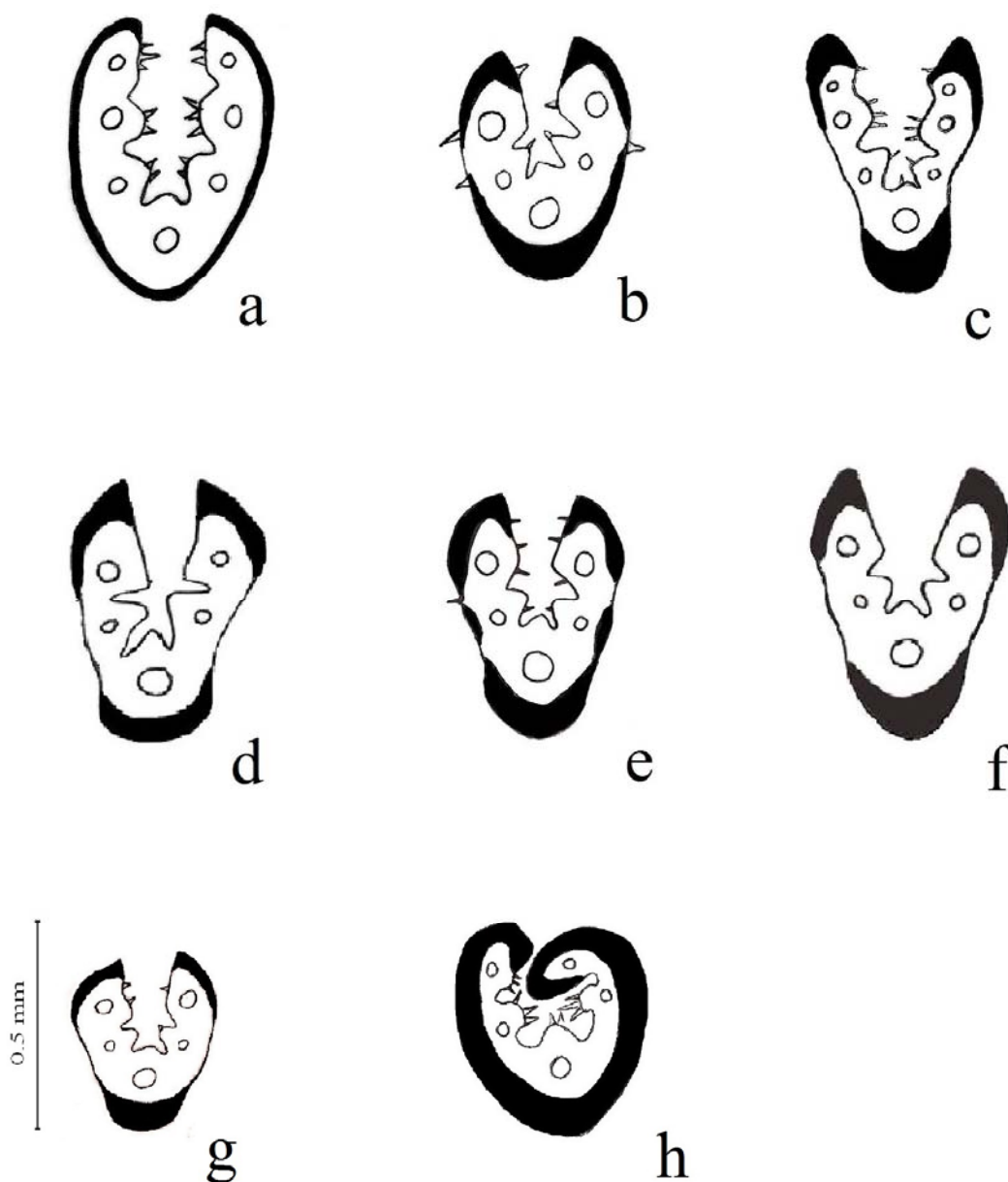


Fig. 2. Patterns of sclerenchyma tissue (black) in leaf section of *Festuca varia* (a); *F. elwendiana* (b); *F. transcaucasica* (c); *F. rupicola* (d); *F. valesiaca* (e, f); *F. akhanii* (g) and *F. pinifolia* (h).

6. Mostly sub-cylindrical or sometimes ovate in sections; 7 veins; 3-5 ribs; 3 sclerenchyma strands at the middle and two margins; 7 veins; lower surface glabrous  
7 -Elliptic or ovate in section; 3-5 veins; lower surface glabrous or scabrous

7. Upper surface glabrous; 0.7-0.8 in diameter; adaxial grooves not deep  
*F. rechingeri*  
-Upper surface hairy; 0.95-1 in diameter; adaxial grooves usually deep; sclerenchyma strands stout  
*F. transcaucasica*  
8. Veins 3 (5); 0.3-0.4 mm in diameter (less than 0.5

- mm in diameter) *F. akhanii*  
 - Veins 5; more than 0.4 mm in diameter (0.4-) 0.5–0.65 9  
 9- Elliptic in section; lower surface of leaf glabrous (rarely scabrous); (1)-3 ribs *F. alaica*  
 - Ovate in section; lower surface of leaf scabrous, 3 ribs *F. sabalanica*  
 10. Lower surface glabrous, mostly with 3 discrete stout sclerenchyma strands, 0.6–0.9 mm in diameter *F. rupicola*  
 - Lower surface scabrous 11  
 11. Sclerenchyma in 3 stout, sometimes with 2 additional smaller strands alternating, rarely confluent, elliptic in section, 4–0.65 in diameter *F. valesiaca*  
 - Sclerenchyma usually with somewhat interrupted or unequal ring, usually circular in section, 0.4–0.75 in diameter *F. elwendiana*

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### References

- Aiken, S. G. & Consaul, L. L. 1995: Leaf cross sections and phytogeography: a potent combination for identifying members of *Festuca* subg. *Festuca* and *Leucopoa* (Poaceae), occurring in North America. - American Journal of Botany 82 (10): 1287-1299.
- Alexeev, E. B. 1975: Iranian and Afghan narrow-leaved fescues. -Biulleten Moskovskogo Obshchestva Ispytatelei Prirody. Otdel Biologicheskii 80 (2): 112-15.
- Alexeev, E. B. 1979: Genus *Festuca* L. Florae Iranicae et territoriorum confinium. -Novosti Sistematiki Vysshikh Rastenii 16: 7-35.
- Bor, N. L. 1970: *Festuca* L. In: Rechinger, K. H. (ed.) Flora Iranica 70: 74-87. -Akademische Druck-u. Verlagsanstalt, Graz-Austria.
- Clayton, W. D. & Renvoize, S. A. 1986: Genera Graminum, Grasses of the world. -Her Majesty Stationery Office, London, UK, 389 p.
- Cope, Th. A. 1982: Poaceae. In: Nasir, E. & Ali, S.I. (eds.), Flora of Pakistan, 143. - Islamabad.
- Eslami, N. J. , Zarinkamar, F. & Assadi, M. 2008: Taxonomic value of leaf anatomy in Iranian fine-leaved *Festuca*. -Rostaniha 9(2): 166-177.
- Hackel, E. 1882: Monographia Festucarum Europearum. -T Fischer, Kassel and Berlin: 216 p, Germany.
- Markgraf-Dannenb., I. 1980: *Festuca* L. In: Tutin, T. G. et al. (eds.) Flora Europea 5: 355 p. - Cambridge University Press, UK.
- Naderi, R., Rahiminejad, M. R., Eslami, B. & Afsharzadeh, S. 2012: Flora and vegetation of Golestanak (Elborz Mts) , Iran. -Phytologia Balcanica 18 (1): 59–68.
- Panahi, M. 2004: Numerical taxonomy on the Iranian species *Festuca ovina* L. from subgenus *Festuca*. - Pajouhesh & Sazandegi 65: 44-52.
- Safikhany, K., Rahimi Nejjad, M. R. & Kalvandi, R. 2004: Presentation of flora and life forms of plants in protected region of Khangormaz (Hamadan province). -Pajouhesh & Sazandegi 70: 70-78.
- Saint-Yves, A. 1925: Contribution 1 etude des *Festuca* (subgen. *Eu-Festuca*) de l'Amerique du Nord et du Mexique. -Candollea 2: 229 - 316.
- Shu, Y. M., Shenglian, L., Xiang, C. & Aiken, S. G. 2006: *Festuca* L. In: W Zhengyi, PH Raven, H Deyuan.(eds.). Flora of China. 22: 225–242. - Science Press, Beijing, and Missouri Botanical Garden Press, St Louis.
- Stace, C. A., Al-Bermani, A. K. K. A. & Wilkinson, M. J. 1992: The distinction between the *Festuca ovina* L. aggregate and *Festuca rubra* L. aggregate in the British Isles. -Watsonia 19: 107-112.
- Tzvelev, N. N. 1976: Grasses of the Soviet Union, Part 1. 788 p.-Nauka Publisher, Leningrad, Soviet Union.
- Wilkinson, M. J. & Stace, C. A. 1991: A new taxonomic treatment of the *Festuca ovina* L. aggregate (Poaceae) in the British Isles. -Botanical Journal of the Linnean Society 106: 347-397.