ANATOMICAL STUDIES IN SOME SPECIES OF BROMUS L. (POACEAE) IN IRAN

A. Ghahreman, M. Alemi, F. Attar, B. Hamzeh'ee & J. T. Columbus

Ghahreman, A., Alemi, M., Attar, F., Hamzeh'ee, B. & Columbus, J. T. 2006 08 01: Anatomical studies in some species of *Bromus* (*Poaceae*) In Iran.-*Iran. Journ. Bot. 12 (1): 1-14.* Tehran.

In this paper the leaf structure of 25 Iranian species of *Bromus* in Iran have been anatomically examined. Eighty one characters were selected for variable and constant species characters. Among them 28 characters are variable in different localities, 40 characters constant in all species (even in different localities) and 13 characters variable between species which these characters have taxonomical value and can be used for distinguishing between species. Based on the study, annual and perennial species are separated in two groups.
In this paper, in addition to providing a list of variable and constant species characters, tables showing the species distinguishing characters as well as anatomical photos of the species is presented.

Ahmad Ghahreman, Maasumeh Alemi & Farideh Attar, Central Herbarium of Tehran University, Faculty of Science, Tehran University, P. O. Box 14155-6455, Tehran, Iran. -Behnam Hamzeh'ee, Research Institue of Forests and Rangeland, P. O. Box 13185-116, Tehran, Iran. -J. Travis Columbus, Rancho Santa Ana Botanic Garden, Claremont, California, U. S. A.

Key words. Anatomy, *Bromus*, Iran.

مطالعه ساختار تشریحی بعضی از گونه های جنس Bromus L. (Poaceae) در ایران

احمد قهرمان، معصومه عالمی، فریده عطار، بهنام حمزه و تراویس کلمبوس

ساختار تشریحی برگ ۲۵ گونه از جنس *Bromus* در این مقاله مطالعه شد. ۸۱ صفت برای تعیین صفات متغیر و صفات ثابت گونه‌ای جهت مطالعه انتخاب گردید. از این تعداد، ۲۸ صفت متغیر در ارتباط با نمونه‌ها از محلهای مختلف و ۴۰ صفت ثابت در همه گونه ها مشاهده شد. ۱۳ صفت از صفات متغیر بین گونه ای با ارزش تاگزونومیکی بوده‌اند که می توان از آنها در جدا سازی گونه‌ها استفاده کرد. در ضمن باید اشاره نمود صفات مزبور موجب گروه‌بندی کلی نشده، فقط بر اساس آنها گونه های این جنس در دو گروه کلی یکساله و چند ساله قرار می‌گیرند. علاوه بر ارائه صفات متغیر و صفات ثابت، جدول نشان دهنده صفات جدا کننده گونه‌ها و همچنین عکسهای تشریحی گونه‌ها در مقاله آمده است.

Introduction

Bromus L. is a large genus of approximately 100 (Mabberley, 1997) to 150 species which are found in the temperate regions of both hemispheres (Clayton and Renvoize, 1986; Pavlick, 1995; Watson and Dallwitz, 1992). The genus comprises annual and perennial grasses with wide geographical distribution (Smith, 1970). Its center of diversity occurs in Eurasia, especially in SW Asia where it is believed to have originated (Stebbins, 1981). It grows above the arctic circle; it is also in tropical areas at mountain-subalpine altitudes. It is introduced and naturalized in other temperate areas (Sales, 1993). *Bromus* , *Boissiera* Hochst. ex Steud. and *Littledalea* Hemsl. have been placed in tribe of *Bromeae* (Clayton and Renvoize, 1986; Soreng and Davis, 1998). More recent classifications of the *Poaceae* align the *Bromeae* near the *Triticeae* and both tribes have been placed in subfamily *Pooideae* (Hsiao et al. 1999; Macfarlane and Watson 1982; Soreng and Davis 1998; Soreng et al. 2000). The genus has been divided into six sections (Smith, 1972), seven subgenera (Stebbins, 1981) or five genera (Tsvelev, 1976).

Based on Flora Iranica (Bor, 1970), the species of this genus are arranged in six sectoins. Also there are 39 species in Iran which belong to Sect. *Bromus* (15 spp.), Sect. *Genea* Dumort. (7 spp.), Sect. *Nevskiella* (V. Krecz. & Vved.) Bor (1 sp.), Sect. *Neobromus* (Shear) Hitchc. (1 sp.), Sect. *Pnigma* Dumort. (15 spp.). The Sect. *Ceratochloa* (P. Beauv.) Griseb. ex Ledeb. does not occur in Iran. The species of Sect. *Pnigma* are perennial and other sections are annual or biennial species. *Bromus frigidu*s Boiss. & Hausskn. ex Boiss. (perennial) is the only endemic species of this genus. Most perennial species of *Bromus* are distributed in alpine regions and in addition to their important role in soil conservation, have pastural and high fodder value in Iran (Mozaffarian, 1998). *Bromus* is the largest genus of *Poaceae* in Iran (Ghahreman and Attar, 1999). Anatomical studies of some species of *Bromus* have been recorded by Metcalfe 1960 (leaf and culm).

The aim of present study, covering 25 species, is a) to add more data of leaf anatomy characters for the genus and b) use of constant leaf anatomical character which can be effected in taxonomical treatments.

Materials and Methods

After naming *Bromus* specimens based on morphological characters of Flora Iranica (Bor, 1970) and Grasses of the Soviet Union (Tsvelev, 1976) and taxonomical survey of species, twenty five species of Iranian *Bromus* were studied anatomically. Fifteen species are annual and ten species are perennial. Annual species contain *B. briziformis*, *B. gedrosianus*, *B. japonicus*, *B. lanceolatus*, *B. oxyodon*, *B. racemosus*, *B. scoparius*, *B. fasciculatus*, *B. madritensis*, *B. rubens*, *B. sericeus*, *B. sterilis*, *B. tectorum*, *B. danthoniae*, *B. gracillimus*, and perennial species contain *B. benekenii*, *B. biebersteinii*, *B. cappadocicus*, *B. kopetdaghensis*, *B. ramosus*, *B. riparius*, *B. stenostachyus*, *B. tomentellus*, *B. tomentosus*, *B. variegatus*.

Fourteen species were not included because they are rare and the materials were not available. Samples were removed from herbarium specimens at TUH, TARI, IRAN and FUMH (Ferdowsi University Mashhad Herbarium). A complete list of material used including of scientific names, exact localities, collectors and herbarium names are given in Table 1. For most species, more than one specimen was selected from different three ecological and geographic localities. For constancy of section site, secondary leaf below the inflorescence was selected in all cases. Leaves were fixed in alcohol- glycerin (1:1). Hand sections were made from the middle portion of the leaf with a razor. The sections were stained by methyl green and bismarck brown. Appropriate samples were photographed by different magnifications of Olympus VANOX AHBS3 light microscope. For anatomical comparison of species, 81 characters were used based on Ellis (1976) and Metcalfe (1960), in addition to some new quantitative characters.

Results

Among selected characters, 40 characters were similar in all species (in different localities and ecological conditions of one species), these characters are not valuable for distinguishing of species. The others are variable in different species or in different localities and ecological conditions of one species.

The constant characters are as follows (The comparison of characters were based on one half of lamina):

Symmetry of two halves of the lamina; sclerenchyma is present over first and second order vascular bundles; adaxial furrows without sclerenchyma; abaxial surface without ribs and furrows; number of vascular bundle of keel is one; absence of air spaces in keel; all bundles of different orders situated in same level in the center of the lamina; third and second order bundles are hexagonal or octagonal and each vascular bundle surrounded by six or more relatively small parenchymatous cells with inner complete bundle sheath; paranchymatous cells of outer sheath of midrib are variable in size and shape; cells of the outer sheath are larger than the inner sheath cells and less than mesophyll cells; cells of outer sheath without chloroplasts; cell wall of outer sheath slightly thickened; sclerenchymatous cells of inner sheath completely surrounding the xylem and phloem; cells of inner sheath are small; phloem adjoins the inner sheath; shape of metaxylem is angular; metaxylem vessels are larger than inner sheath cells; no sclerenchyma between bundles; shape of sclerenchyma in leaf margin is pointed cap; size of cap of sclerenchyma at the margin is small; radiate chlorenchyma arranged around the vascular bundles, may be interrupted by sclerenchyma girders; not radiate vertical regular chlorenchyma occupied spaces of the vascular bundles; palisadic parenchyma arranged in adaxial and abaxial surfaces; arm cells, fusoid cells, distinctive cells, collenchymatous cells and lacunae absent in mesophyll; bulliform cells present in adaxial epidermis at the bases of furrows and between the vascular bundles; bulliform cells are inflated and larger than the epidermal cells; colourless cells absent; macro-hairs have superficial bases; epidermal cells not modified associated to the base of the hairs; prickle and papillae absent; stomata present in adaxial and abaxial epidermis, situated lower than level of epidermal cells.

Table 1. *Bromus* specimens used in the anatomical investigation. The species arranged in alphabetical order in each section.

Species	Voucher specimen (s)
Sect. *Bromus*	
B. brizifomis Fisch. & C. A. Mey.	Khorassan: Maraveh tappeh, 819 m, Moazzeni, 35988 -TUH Azerbaijan: Oskulu,1600-1900 m, Ghahreman, Attar & Hamzeh'ee, 35640-TUH Mazandaran: Pol-e Sefid, 664 m, Attar & Alemi, 35071-TUH
B. gedrosianus Penzes	Hormozgan: Rudan, 150 m, Khatamsaz & Zaeifi, 73161-TARI Sistan and Baluchestan: Khash, 300 m, Runemark, Assadi & Sardabi, 22422-TARI Tehran: Cyahkuh, 820 m, Babakhanlou, Amin, Dini & Bazargan, 17846-TARI
B. japonicus Thunb.	Lorestan: Khorram abad, 1100 m, Veiskarami, 23538- TUH Sistan: Zabol, 500 m, Valizadeh & Maasoumi, 1230-TUH Azerbaijan: Asheghlu,210 m, Ghahreman, Attar & Hamzeh'ee, 35464-TUH
B. lanceolatus Roth	Kurdestan : 2 km Marevan, 1330 m, Fattahi & Khaledian, 623-TARI Hamadan: 8 km SW Hamadan, 2100 m, Pabot, 27526-TARI Kurdestan: Sanandaj, 1540 m, Fattahi & Khaledian, 1192-TARI
B. oxyodon Schrenk	Khorassan: Neyshabour, 1700-1800 m, Rafeii & Zangooii, 26928-FUMH
B. racemosus L.	Mazandaran: Tunekabon, 1250 m, Ghahreman & Mozaffarian, 9793-TUH Gilan: Deilaman, 1600 m, American- Iranian Botanical Delegation, 34830-TUH
B. scoparius L.	Lorestan: Khorram abad, 1100 m, Veiskarami, 23537-TUH Azerbaijan: Salmas-Ghara-So, 1385 m, Ghahreman, Aghustin & Shaikhaleslami, 13124-TUH Azerbaijan: Kaleybar, 700 m, Ghahreman, Attar & Hamzeh'ee, 35496-TUH
Sect. *Genea* Dumort.	
B. fasciculatus Presl	Khuzestan: Andimeshk, 580 m, Gheissari, 1290-TARI Lorestan: Khorram abad, 1100 m, Veiskarami, 23534-TUH
B. madritensis L.	Fars: Jahrom, 1000 m, Foroughian, 5029-TARI Kermanshah: Kuh- e Pyry, 1320-1520 m, Hamzeh'ee & Lashkarbolouki, 423-TARI Guilan: Bandar-e Anzali, -20 m, Mozaffarian, 6783-TUH
B. rubens L.	Hormozgan: Bandar- e Khamir, 10 m, Mozaffarian, 63662-TARI
B. sericeus Drobov	Tehran: Chitgar, 1320 m, Attar, 15363- TUH Qazvin: Taleghan, 1000 m, Alemi, 35956-TUH Yazd: Marvast, 1700 m, Mirjalili, 20734-TUH
B. sterilis L.	Lorestan: Khorram abad, 1100 m, Veiskarami, 23535-TUH Mazandaran: Lake of Shoormast, 890 m, Attar & Alemi, 35133-TUH Qazvin: Taleghan, 1000 m, Alemi, 35958-TUH
B. tectorum L.	Mazandaran: Gaduk, 2110 m, Attar & Alemi, 35094-TUH Azerbaijan: Makidi, 1700 m, Ghahreman, Attar & Hamzeh'ee, 35511-TUH Fars: Shiraz, 1530 m, Parsa, 13120-TUH
Sect. *Neobromus* (Shear) Hitchc.	
B. danthoniae Trin.	Kuhgiloy-e and Boyer-Ahmad: Sisakht, 1700-2200 m, Ghahreman & Mozaffarian, 18260-TUH Tehran: Shahrak-e Motahari, 1320 m, Attar, 15354-TUH Bushehr: Bushehr, 4 m, Mobayen, Arefi & Yazdanpanah, 13112-TUH
Sect. *Nevskiella* (V. Krecz. & Vved.) Bor	
B. gracillimus Bge.	Tehran: Damavand, 2150 m, American- Iranian Botanical Delegation, 34044-TUH Tehran: Tar lake, 2650 m, American- Iranian Botanical Delegation, 34066-TUH
Sect. *Pnigma* Dumort.	
B. benekenii (Lange) Trimen	Azerbaijan: Kaleybar, 1500 m, Ghahreman, Aghustin & Shaikhaleslami, 17526-TUH Mazandaran: Tonekabon, 1250 m, Ghahreman & Mozaffarian, 9791-TUH Gilan: Assalem, 1100 m, Wendelbo & Assadi, 18378-TARI
B. biebersteinii Roemer & Schultes	Kuhgiloy-e and Boyer-Ahmad: Sisakht, 2800 m, Ghahreman, Attar & Mahdigholi, 25366-TUH Hamadan: Nahavand, 2500-3400 m, Assadi, 75134-TARI

Table 1. (continuted)

Species	Voucher specimen (s)
B. cappadocicus Boiss. & Bal.	Semnan: Shahmirzad, 2350-2500 m, 19650-IRAN
B. kopetdaghensis Drobov	Tehran: Shemshak, 2400-3400 m, Mozaffarian, 6749-TUH Azerbayjan: Kaleybar, 915 m, Moazzeni, 35985-TUH Esfahan: Fereidoon shahr, 1900 m, Janighorbani, 5782-TUH
B. ramosus Hudson	Mazandaran: Kheyrud kenar forest, 500-700 m, Assadi, 33791-TARI
B. riparius Rehman	Tehran: Gaduk, 1930 m, Ghahreman, Aghustin & Shaikhaleslami, 13115-TUH Hamadan: Hamadan, 1600-1900 m, Mozaffarian, 64524-TUH Mazandaran: Pol-e Zanguleh, 3350 m, Nazarian, 33130-TUH
B. stenostachyus Boiss.	Mazandaran: Haraz-road, 2350 m, Assadi & Mozaffarian, 33010-TARI Mazandaran: Amol, 1000 m, Assadi, 73349-TARI
B. tomentellus Boiss.	Azerbaijan: Kalaleh, 730 m, Ghahreman, Attar & Hamzeh'ee, 35381-TUH Tehran: Sorkheh hesar, 1500-2000 m, Mozaffarian, 6280-TUH Esfahan: Karkas Mts., 2400 m, American- Iranian Botanical Delegation, 33616-TUH
B. tomentosus Trin.	Mazandaran: Siah-Bisheh Mountains, 1700 m, Attar & Alemi, 35972-TUH Tehran: Kandavan, 2780 m, Foroughi, 1905-TARI Tehran: Gachsar, 2280 m, Foroughi, 509-TARI
B. variegatus M. B.	Ardabil: Sardabeh, 2107 m, Ghahreman, Attar & Hamzeh'ee, 35310-TUH Azerbaijan: Arasbaran protected area, 2500 m, Assadi & Sardabi, 23880-TARI Azerbaijan: Haris, 2500-2535 m, Olfat, 450-TARI

The variable characters *were* observed in two groups:

1. The characters are variable in different localities of each species. These characters are changing in different ecological conditions. Therefore, these characters which have no value for separating of species are as follows (Table 2):

2. The characters are constant between different localities of each species and variable among the species. Such characters are suitable for distinguishing of species as following (Table 3):

Shape of adaxial ribs:

rounded: in annual taxa (Fig.1, 2, A-F; Fig.3, A-C), truncate and rounded: in perennial taxa (Fig.3, D, E; Fig.4, A-E; Fig.5, A-C).

Distribution of adaxial ribs:

ribs present over all vascular bundles except marginal vascular bundles in annual species: *B. racemosus* (Fig.1, F), *B. sterilis* (Fig.2, F), *B. danthoniae* (Fig.3, B), and in perennial species: *B. benekenii* (Fig.3, E); ribs present over all vascular bundles: in other annual species: *B. brizifomis* (Fig.1, A), *B. gedrosianus* (Fig.1, B), *B. japonicus* (Fig.1, C), *B. lanceolatus* (Fig.1, D), *B. oxyodon* (Fig.1, E), *B. scoparius* (Fig.2, A), *B. fasciculatus* (Fig.2, B), *B. madritensis* (Fig.2, C), *B. rubens* (Fig.2, D), *B. sericeus* (Fig.2, E), *B. tectorum* (Fig.3, A), *B. gracillimus* (Fig.3, C) in perennial species such as: *B. kopetdaghensis* (Fig.4, B), *B. ramosus* (Fig.4, C), *B. stenostchyus* (Fig.4, E), *B. variegatus* (Fig.5, C), ribs present over some vascular bundles: in other perennials: *B. biebersteinii* (Fig.3, D), *B. cappadocicus* (Fig.4, A), *B. riparius* (Fig.4, D), *B. tomentellus* (Fig.5, A), *B.tomentosus* (Fig.5, B).

Shape of adaxial furrows:

wide and open furrows i.e. obtuse angle formed by furrow sides at base: in annual taxa and *B. benekenii* (Fig.3, E), *B. ramosus* (Fig.4, C), *B. stenostachyus* (Fig.4, E), *B. variegatus* (Fig.5, C) from perennial group; wide and open furrows and narrow furrows i.e. sides of furrow almost vertical, cleft like: in most perennials: *B. biebersteinii* (Fig.3, D), *B. cappadocicus* (Fig.4, A), *B. kopetdaghensis* (Fig.4, B), *B. riparius* (Fig.4, D), *B. tomentellus* (Fig.5, A), *B.tomentosus* (Fig.5, B).

Distribution of adaxial furrows:

furrows present between all vascular bundles except marginal vascular bundles: *B. danthoniae* (Fig.3, B), furrows present between all vascular bundles: in most annual taxa: *B. brizifomis* (Fig.1, A), *B. gedrosianus* (Fig.1, B), *B. japonicus* (Fig.1, C), *B. lanceolatus* (Fig.1, D), *B. oxyodon* (Fig.1, E), *B. racemosus* (Fig.1, F), *B. scoparius* (Fig.2, A), *B. fasciculatus* (Fig.2, B), *B. madritensis* (Fig.2, C), *B. rubens* (Fig.2, D), *B. sericeus* (Fig.2, E), *B. sterilis* (Fig.2, F), *B. tectorum* (Fig.3, A), *B. gracillimus* (Fig.3, C) and in perennials: *B. benekenii* (Fig.3, E), *B. kopetdaghensis* (Fig.4, B), *B. ramosus* (Fig.4, C), *B. stenostachyus* (Fig.4, E), *B. variegatus* (Fig.5, C), ribs present over some vascular bundles: in other perennials: *B. biebersteinii* (Fig.3, D), *B. cappadocicus* (Fig.4, A), *B. riparius* (Fig.4, D), *B. tomentellus* (Fig.5, A), *B.tomentosus* (Fig.5, B).

Shape of keel:

not really distinct in following species: *B. briziformis* (Fig.5, D), *B. japonicus* (Fig.5, F), *B. oxyodon* (Fig.6, B), *B. racemosus* (Fig.6, C), *B. benekenii* (Fig.8, A), *B. tomentellus* (Fig.9, B), V- shaped with flattened adaxial side as following species: *B. sterilis* (Fig.7, C), *B. ramosus* (Fig.8, E), *B. tomentosus* (Fig.9, C), V- shaped

Table 2. Variable anatomical characters in different localities of each species.

Characters	Variations
Shape of lamina in transverse section	V- shaped between 45˚ and 90˚, V- shaped between 90˚ and 180˚**,** V- shape 180˚**,** U- shaped, inrolled**,** heart- shaped
Width of one half lamina	0.7-4.75 mm
Thickness	0.1-0.27 mm
Size of adaxial rib	= thickness of lamina
Number of adaxial ribs	2-14
Depth of adaxial furrow	0.04-0.14 mm
Number of adaxial furrows	2-13
Thickness of keel	0.11-0.42 mm
Length of midrid	0.05- 0.15 mm
Width of midrid	0.06-0.15 mm
Distance of midrid from adaxial surface	0.02-0.18 mm
Distance of midrid from abaxial surface	0.03-0.17 mm
Number of vascular bundles	3-15
Arrangement of different orders of vascular bundles	are very variable
Shape of midrib	vertical elliptic, circular,ovate
Number of protoxylem	1-2
Number of lysigenous cavity	0-1
Size of metaxylem	equal, smaller or larger than the outer sheath cells
Number of outer sheath cells	7-17
Radial wall of outer sheath cells	entire or dentate
Outer bundle sheath of secondary order bundle	is complete or interrupted by sclerenchyma or chlorenchyma
Outer bundle sheath of third order bundle	is complete or interrupted by chlorenchyma
Adaxial and abaxial strand and girder	present or absent
Number of bulliform cells	3-6
Shape of macro-hairs	hairs thickened and stiff or hairs very thin and slender
Distribution of macro-hairs	not seen or present in adaxial or present in adaxial and abaxial epidermis
Density of macro-hairs	low, medium or high
Thickness of cuticle	very thin or slightly thickened

with rounded adaxial side as following taxa: *B. lanceolatus* (Fig.6, A), *B. scoparius* (Fig.6, D), *B. fasciculatus* (Fig.6, E), *B. madritensis* (Fig.6, F), *B. sericeus* (Fig.7, B), *B. tectorum* (Fig.7, D), *B. gracillimus* (Fig.7, F), *B. cappadocicus* (Fig.8, C), *B. stenostachyus* (Fig.9, A), U- shaped with rounded adaxial side: *B. riparius* (Fig.8, F), rounded with flattened adaxial side: *B. biebersteinii* (Fig.8, B), *B. kopetdaghensis* (Fig.8, D), *B. variegatus* (Fig.9, D), rounded with rounded adaxial side as following species: *B. gedrosianus* (Fig.5, E), *B. rubens* (Fig.7, A), *B. danthoniae* (Fig.7, E).

Adaxial sclerenchyma of the keel:

minute strand consisting of only a few subepidermal fibres: only in *B. sericeus* (Fig.7, B), *B. gracillimus* (Fig.7, F), small narrow girder longer than wide: in such species as *B. briziformis* (Fig.5, D), *B. gedrosianus* (Fig.5, E), *B. lanceolatus* (Fig.6, A), *B. oxyodon* (Fig.6, B), *B. scoparius* (Fig.6, D), *B. fasciculatus* (Fig.6, E), *B. madritensis* (Fig.6, F), *B. rubens* (Fig.7, A), *B. sterilis* (Fig.7, C), *B. cappadocicus* (Fig.8, C), *B. kopetdaghensis* (Fig.8, D), *B. riparius* (Fig.8, F), *B. tomentellus* (Fig.9, B), *B. variegatus* (Fig.9, D), small girder as long as wide: *B. japonicus* (Fig.5, F), *B. biebersteinii* (Fig.8, B), *B. stenostachyus* (Fig.9, A), small girder narrowing towards bundle: *B. racemosus* (Fig.6, C), small girder, small thin subepidermal strip: *B. benekenii* (Fig.8, A), well-developed girder, relatively narrow and long girder, narrower than the vascular bundle: *B. tectorum* (Fig.7, D), *B. ramosus* (Fig.8, E), well-developed girder, wide and long as wide as the vascular bundle: *B. danthoniae* (Fig.7, E), *B. tomentosus* (Fig.9, C).

Abaxial sclerenchyma of the keel:

minute strand consisting of only a few subepidermal fibres: *B. gracillimus* (Fig.7, F), small strand as long as wide: *B. gedrosianus* (Fig.5, E), small strand and shallow, forming a strip, only 2-4 fibres deep subepidermal: *B. sericeus* (Fig.7, B), small girder as long as wide: *B. briziformis* (Fig.5, D), *B. oxyodon* (Fig.6, B), *B. racemosus* (Fig.6, C), *B. fasciculatus* (Fig.6, E), *B. benekenii* (Fig.8, A), *B. stenostachyus* (Fig.9, A), *B. tomentellus* (Fig.9, B), small girder narrowing towards bundle: *B. japonicus* (Fig.5, F), *B. lanceolatus* (Fig.6, A), *B. scoparius* (Fig.6, D), *B. madritensis* (Fig.6, F), *B. rubens* (Fig.7, A), *B.*

kopetdaghensis (Fig.8, D), *B. variegatus* (Fig.9, D), well-developed girder, anchor shaped, stem short and sturdy, more than tri-seriate: *B. sterilis* (Fig.7, C), *B. tectorum* (Fig.7, D), *B. danthoniae* (Fig.7, E), *B. biebersteinii* (Fig.8, B), *B. cappadocicus* (Fig.8, C), *B. ramosus* (Fig.8, E), *B. tomentosus* (Fig.9, C), well-developed girder, wider than the vascular bundle, in horizontal band form: *B. riparius* (Fig.8, F).
(small girder is quantity of sclerenchyma less than 0.1 mm and well-developed girder is quantity of sclerenchyma more than 0.1 mm).

Adaxial outer sheath of midrib:
sheath incomplete due to interruption of sclerenchyma girder of one fibrous cell: *B. briziformis* (Fig.5, D), *B. japonicus* (Fig.5, F), *B. lanceolatus* (Fig.6, A), *B. racemosus* (Fig.6, C), *B. scoparius* (Fig.6, D), *B. fasciculatus* (Fig.6, E), *B. madritensis* (Fig.6, F), *B. kopetdaghensis* (Fig.8, D), sheath incomplete due to interruption of sclerenchyma girder of two fibrous cells: *B. oxyodon* (Fig.6, B), *B. rubens* (Fig.7, A), *B. sterilis* (Fig.7, C), *B. ramosus* (Fig.8, E), *B. tomentellus* (Fig.9, B), sheath incomplete due to interruption of sclerenchyma girder of three fibrous cells: *B. tectorum* (Fig.7, D), *B. danthoniae* (Fig.7, E), *B. benekenii* (Fig.8, A), *B. biebersteinii* (Fig.8, B), *B. cappadocicus* (Fig.8, C), *B. stenostachyus* (Fig.9, A), complete: *B. gedrosianus* (Fig.5, E), *B. sericeus* (Fig.7, B), *B. gracillimus* (Fig.7, F), *B. riparius* (Fig.8, F), *B. tomentosus* (Fig.9, C), *B. variegatus* (Fig.9, D).

Abaxial outer sheath of midrib:
sheath incomplete due to interruption of sclerenchyma girder of three fibrous cells: *B. briziformis* (Fig.5, D), *B. lanceolatus* (Fig.6, A), *B. racemosus* (Fig.6, C), *B. scoparius* (Fig.6, D), *B. tectorum* (Fig.7, D), sheath incomplete due to interruption of sclerenchyma girder of more than three fibrous cells: *B. danthoniae* (Fig.7, E), *B. biebersteinii* (Fig.8, B), *B. cappadocicus* (Fig.8, C), *B. ramosus* (Fig.8, E), *B. riparius* (Fig.8, F), *B. tomentosus* (Fig.9, C), complete: *B. sericeus* (Fig.7, B), sheath incomplete due to interruption of sclerenchyma girder of one fibrous cell and chlorenchyma: *B. japonicus* (Fig.5, F), *B. madritensis* (Fig.6, F), *B. rubens* (Fig.7, A), sheath incomplete due to interruption of sclerenchyma girder of three fibrous cells and chlorenchyma: *B. oxyodon* (Fig.6, B), *B. fasciculatus* (Fig.6, E), *B. sterilis* (Fig.7, C), *B. benekenii* (Fig.8, A), *B. kopetdaghensis* (Fig.8, D), *B. stenostachyus* (Fig.9, A), *B. tomentellus* (Fig.9, B), *B. variegatus* (Fig.9, D), sheath incomplete by chlorenchyma: *B. gedrosianus* (Fig.5, E), *B. gracillimus* (Fig.7, F).

Epidermal cells at margin:
fibrous: *B. briziformis* (Fig.1, A), *B. oxyodon* (Fig.1, E), *B. scoparius* (Fig.2, A), *B. fasciculatus* (Fig.2, B), *B. rubens* (Fig.2, D), *B. sterilis* (Fig.2, F), *B. danthoniae* (Fig.3, B) and perennial taxa (Fig.3, D, E; Fig.4, A-E; Fig.5, A-C), not fibrous: *B. gedrosianus* (Fig.1, B), *B. japonicus* (Fig.1, C), *B. lanceolatus* (Fig.1, D), *B. racemosus* (Fig.1, F), *B. madritensis* (Fig.2, C), *B. sericeus* (Fig.2, E), *B. tectorum* (Fig.3, A), *B. gracillimus* (Fig.3, C).

Size of bulliform cells:
the cells occupy ¼ of the leaf thickness: *B. rubens* (Fig.2, D), *B. biebersteinii* (Fig.3, D), *B. stenostachyus* (Fig.4, E), the cells occupy less than ¼ of the leaf thickness: *B. briziformis* (Fig.1, A), *B. japonicus* (Fig.1, C), *B. lanceolatus* (Fig.1, D), *B. oxyodon* (Fig.1, E), *B. fasciculatus* (Fig.2, B), *B. madritensis* (Fig.2, C), *B. sericeus* (Fig.2, E), *B. sterilis* (Fig.2, F), *B. tectorum* (Fig.3, A), *B. danthoniae* (Fig.3, B), *B. gracillimus* (Fig.3, C), *B. cappadocicus* (Fig.4, A), *B. kopetdaghensis* (Fig.4, B), *B. riparius* (Fig.4, D), *B. tomentellus* (Fig.5, A), *B. tomentosus* (Fig.5, B), the cells occupy more than ¼ of the leaf thickness: *B. gedrosianus* (Fig.1, B), *B. racemosus* (Fig.1, F), *B. scoparius* (Fig.2, A), *B. benekenii* (Fig.3, E), *B. ramosus* (Fig.4, C), *B. variegatus* (Fig.5, C).

Thickeness of epidermal cell wall:
outer wall of each epidermal cell thickened individually and outer wall occupies less than half of the depth of the cells: in annual species (Fig.5, D-F; Fig.6, A-F; Fig.7, A-F), all walls of epidermal cells thickened: in perennial species (Fig.8, A-F; Fig.9, A-D).

Size of epidermal cells:
cells of different sizes comprise the epidermis: in annuals (Fig.5, D-F; Fig.6, A-F; Fig.7, A-F) and *B. benekenii* (Fig.8, A), *B. biebersteinii* (Fig.8, B), *B. ramosus* (Fig.8, E), *B. variegatus* (Fig.9, D), from perennials, cells of same sizes comprise the epidermis: in other perennials: *B. cappadocicus* (Fig.8, C), *B. kopetdaghensis* (Fig.8, D), *B. riparius* (Fig.8, F), *B. stenostachyus* (Fig.9, A), *B. tomentellus* (Fig.9, B), *B. tomentosus* (Fig.9, C).

Discussion

In this study 25 species of Iranian *Bromus*' leaves was anatomically examined. Of this number 15 annual species belong to 4 sections and 10 perennial species belong to one section (Table 1). Eighty one anatomical characters were selected of which 40 characters were found to be the same in all the species and the others were found to be variable. The variable characters were devided into two groups of ecologically variable characters and the species distinguishing characters. The ecologically variable characters change with change in the environmental conditions. They are, therefore, worthless for identifying the *Bromus* species (Table 2). The characters which distinguish the species they do not generally change with environmental changes and remain stable in the species in various

Table 3. Useful anatomical characters for distinguishing of species.
Adaxial rib: Sh, shape (a= rounded, b= truncate and rounded); Dis, distribution of adaxial ribs (c= ribs present over all vascular bundles, d= ribs present over all vascular bundles except vascular bundles situated in margin, e= ribs present over some vascular bundles). Adaxial furrow: Sh, shape (f= wide and open furrows i.e. obtuse angle formed by furrow sides at base, g= wide and open furrows and narrow furrows i.e. sides of furrow almost vertical, in form of cleft); Dis, distribution (h= furrows present between all vascular bundles, i= furrows present between all vascular bundles except vascular bundles situated in margin, j= furrows present between some vascular bundles). Keel structure: Sh, shape (k= not really distinct, l= V- shaped with flattened adaxial side, m= V- shaped with rounded adaxial side, n= U- shaped with rounded adaxial side, o= rounded with flattened adaxial side, p= rounded with rounded adaxial side); Ad. scl, Ab. scl, adaxial and abaxial sclerenchyma of the keel (q= minute strand consisting of only a few subepidermal fibres, r= small narrow girder longer than wide, s= small girder as long as wide, t= small girder narrowing towards bundle, u= small girder, small thin subepidermal strip, v= well-developed girder, relatively narrow and long girder, narrower than vascular bundle, w= well-developed girder, wide and long as wide as the vascular bundle, x= small strand as long as wide, y= small strand, shallow, forming a strip, only 2-4 fibres deep subepidermal, z= well-developed girder, anchor shaped, stem short and sturdy, more than tri-seriate, a'= well-developed girder, wider than the vascular bundle, horizontal band). Midrib: Ad. she, Ab. she, adaxial and abaxial outer sheath (b'= sheath incomplete due to interruption of sclerenchyma girder of one fibrous cell, c'= sheath incomplete due to interruption of sclerenchyma girder of two fibrous cells, d'= sheath incomplete due to interruption of sclerenchyma girder of three fibrous cells, e'= complete, f'= sheath incomplete due to interruption of sclerenchyma girder of more than three fibrous cells, g'= sheath incomplete due to interruption of sclerenchyma girder of one fibrous cell and chlorenchyma, h'= sheath incomplete due to interruption of sclerenchyma girder of three fibrous cells and chlorenchyma, i'= by chlorenchyma). Mar. scl, sclerenchyma in leaf margin: Mar. epi, epidermal cells at margin (j'= fibrous, k'= not fibrous). Bul. cel, Bulliform cells: Siz, size of constituent cells (l'= the cells occupy equal ¼ of the leaf thickness, m'= the cells occupy less than ¼ of the leaf thickness, n'= the cells occupy more than ¼ of the leaf thickness). Epi. cel, epidermal cells: Th, thickeness of cell wall (o'= outer tangential wall of each epidermal cell thickened individually and outer wall occupies less than half of the depth of the cells, p'= all walls of epidermal cells thickened); Siz, size of epidermal cells (q'= cells of different sizes comprise the epidermis, r'= cells of same sizes comprise the epidermis).

	Adaxial rib		Adaxial furrow		Keel structure			Midrib		Mar. scl	Bul. cel	Epi. cel	
Species	Sh	Dis	Sh	Dis	Sh	Ad scl	Ab scl	Ad she	Ab she	Mar epi	Siz	Th	Siz
Sect. *Bromus*													
B. brizifomis	a	c	f	h	k	r	s	b'	d'	j'	m'	o'	q'
B. gedrosianus	a	c	f	h	p	r	x	e'	i'	k'	n'	o'	q'
B. japonicus	a	c	f	h	k	s	t	b'	g'	k'	m'	o'	q'
B. lanceolatus	a	c	f	h	m	r	t	b'	d'	k'	m'	o'	q'
B. oxyodon	a	c	f	h	k	r	s	c'	h'	j'	m'	o'	q'
B. racemosus	a	d	f	h	k	t	s	b'	d'	k'	n'	o'	q'
B. scoparius	a	c	f	h	m	r	t	b'	d'	j'	n'	o'	q'
Sect. *Genea*													
B. fasciculatus	a	c	f	h	m	r	s	b'	h'	j'	m'	o'	q'
B. madritensis	a	c	f	h	m	r	t	b'	g'	k'	m'	o'	q'
B. rubens	a	c	f	h	p	r	t	c'	g'	j'	l'	o'	q'
B. sericeus	a	c	f	h	m	q	y	e'	e'	k'	m'	o'	q'
B. sterilis	a	d	f	h	l	r	z	c'	h'	j'	m'	o'	q'
B. tectorum	a	c	f	h	m	v	z	d'	d'	k'	m'	o'	q'
Sect. *Neobromus*													
B. danthoniae	a	d	f	i	p	w	z	d'	f'	j'	m'	o'	q'
Sect. *Nevskiella*													
B. gracillimus	a	c	f	h	m	q	q	e'	i'	k'	m'	o'	q'
Sect. *Pnigma*													
B. benekenii	b	d	f	h	k	u	s	d'	h'	j'	n'	p'	q'
B. biebersteinii	b	e	g	j	o	s	z	d'	f'	j'	l'	p'	q'
B. cappadocicus	b	e	g	j	m	r	z	d'	f'	j'	m'	p'	r'
B. kopetdaghensis	b	c	g	h	o	r	t	b'	h'	j'	m'	p'	r'
B. ramosus	b	c	f	h	l	v	z	c'	f'	j'	n'	p'	q'
B. riparius	b	e	g	j	n	r	a'	e'	f'	j'	m'	p'	r'
B. stenostachyus	b	c	f	h	m	s	s	d'	h'	j'	l'	p'	r'
B. tomentellus	b	e	g	j	k	r	s	c'	h'	j'	m'	p'	r'
B. tomentosus	b	e	g	j	l	w	z	e'	f'	j'	m'	p'	r'
B. variegatus	b	c	f	h	o	r	t	e'	h'	j'	n'	p'	q'

locations. These attributes are, therefore, valuable for the identification of the *Bromus* species (Table 3). On the Basis of the studies performed and the evaluation of the anatomic attributes, the annual and perennial *Broums* species can be separated, in terms of certain characters, into two general groups. These characters include shape of adaxial ribs and furrows, size of epidermal cells and thickeness of epidermal cell wall. Shape of adaxial ribs are rounded in all the annual species (Fig.1, 2, A-F; Fig.3, A-C) and are truncate and rounded in the perennials (Fig.3, D, E; Fig.4, A-E; Fig.5, A-C). Shape of adaxial furrows are wide and open furrows i.e. obtuse angle formed by furrow sides at base in all the annual species (Fig.1, 2, A-F; Fig.3, A-C) and *B. benekenii* (Fig.3, E), *B. ramosus* (Fig.4, C), *B. stenostachyus* (Fig.4, E), *B. variegatus* (Fig.5, C) from perennial group are wide and open furrows and narrow furrows i.e. sides of furrow almost vertical, in form of cleft in other perennials. Cells of different sizes comprise the epidermis in the annual species (Fig.5, D-F; Fig.6, A-F; Fig.7, A-F) and *B. benekenii* (Fig.8, A), *B. biebersteinii* (Fig.8, B), *B. ramosus* (Fig.8, E), *B. variegatus* (Fig.9, D) from perennials and cells of same sizes comprise the epidermis in other perennials. Outer tangential wall of each epidermal cell thickened individually and outer wall occupies less than half of the depth of the cells in the annual species (Fig.5, D-F; Fig.6, A-F; Fig.7, A-F) and all walls of epidermal cells thickened in the perennials (Fig.8, A-F; Fig.9, A-D).

The evaluation of the anatomical characters in the genus *Bromus* apart from separating and categorizing the perennial and the annuals, no other grouping is shown and the remaining anatomic attributes have only taxonomic value among the species. For example: *B. fasciculatus* (Fig.2, B; Fig.6, E) and *B. rubens* (Fig.2, D; Fig.7, A) which are morphologically closed together based on the cuneate spikelets and unilateral arrangmentare of spikelets may be anatomically separated on the basis of such characters as the shape of the keel, arrangement of abaxial sclerenchymatous cells in the keel, interrupted or continued outer sheath of midrib, size of bulliform cells; in the *B. japonicus* (Fig.1, C; Fig.5, F) and *B. gedrosianus* (*B. rechingeri* in Flora Iranica) (Fig.1, B; Fig.5, E) which are annual and morphologically very close by having ovate spikelets with bilateral arrangment of them, can be separated by the anatomical characters as shape of the keel, arrangement of adaxial and abaxial sclerenchymatous cells in the keel, interrupted or continued outer sheath of midrib and size of bulliform cells; other species such *B. riparius* (Fig.4, D; Fig.8, F) and *B. kopetdaghensis* (Fig.4, B; Fig.8, D) which are closed by having characters as perennial, reticulated fibrous sheath in the culm base and small awn, are anatomically separated by distribution of ribs and furrows, shape of the keel, arrangement of abaxial sclerenchymatous cells and interrupted or continued outer sheath of midrib.

The anatomical key of species

1- Shape of adaxial ribs are rounded; outer tangential wall of each epidermal cell thickened individually and outer wall occupies less than half of the depth of the cells 2

- Shape of adaxial ribs are truncate and rounded; all walls of epidermal cells thickened 16

2- Ribs present over all vascular bundles except vascular bundles situated in margin 3

- Ribs present over all vascular bundles 5

3- Furrows present between all vascular bundles except vascular bundles situated in margin *B. danthoniae* Trin.

- Furrows present between all vascular bundles 4

4- Keel is not really distinct; abaxial sclerenchyma of the keel is small girder as long as wide *B. racemosus* L.

- Keel is V- shaped with flattened adaxial side; abaxial sclerenchyma of the keel is well-developed girder, anchor shaped, stem short and sturdy, more than tri-seriate *B. sterilis* L.

5- Epidermal cells at margin are fibrous 6

- Epidermal cells at margin are not fibrous 10

6- Adaxial outer sheath of midrib is incomplete due to interruption of sclerenchyma girder of two fibrous cells 7

- Adaxial outer sheath of midrib is incomplete due to interruption of sclerenchyma girder of one fibrous cell 8

7- Abaxial sclerenchyma of the keel is small girder as long as wide *B. oxyodon* Schrenk

- Abaxial sclerenchyma of the keel is small girder narrowing towards bundle *B. rubens* L.

8- Keel is not really distinct *B. brizifomis* Fisch.& C. A. Mey.

- Keel is V- shaped with rounded adaxial side 9

9- Abaxial sclerenchyma of the keel is small girder as long as wide *B. fasciculatus* Presl

- Abaxial sclerenchyma of the keel is small girder narrowing towards bundle. *B. scoparius* L.

10- Bulliform cells occupy more than ¼ of the leaf thickness *B. gedrosianus* Penzes

- Bulliform cells occupy less than ¼ of the leaf thickness 11

11- Keel is not really distinct *B. japonicus* Thunb.

- Keel is V- shaped with rounded adaxial side 12

12-Adaxial sclerenchyma of the keel is well-developed girder, relatively narrow and long girder, narrower than vascular bundle *B. tectorum* L.

- Adaxial sclerenchyma of the keel is minute strand consisting of only a few subepidermal fibres or small narrow girder longer than wide 13

13- Adaxial sclerenchyma of the keel is minute strand consisting of only a few subepidermal fibres 14

- Adaxial sclerenchyma of the keel is small narrow girder longer than wide 15

14- Abaxial sclerenchyma of the keel is minute strand consisting of only a few subepidermal fibres; abaxial outer sheath of midrib is incomplete by chlorenchyma *B. gracillimus* Bge.

- Abaxial sclerenchyma of the keel is small strand, shallow, forming a strip, only 2-4 fibres deep subepidermal; abaxial outer sheath of midrib is complete *B. sericeus* Drobov

15- Abaxial outer sheath of midrib is sheath incomplete due to interruption of sclerenchyma girder of three fibrous cells *B. lanceolatus* Roth

- Abaxial outer sheath of midrib is sheath incomplete due to interruption of sclerenchyma girder of one fibrous cell and chlorenchyma *B. madritensis* L.

16- Furrows present between all vascular bundles 17

- Furrows present between some vascular bundles 21

17- Shape of adaxial furrows are wide and open furrows and narrow furrows i.e. sides of furrow almost vertical, in form of cleft *B. kopetdaghensis* Drobov

- Shape of adaxial furrows are wide and open furrows i.e. obtuse angle formed by furrow sides at base 18

18- Ribs present over all vascular bundles except vascular bundles situated in margin *B. benekenii* (Lange) Trimen

- Ribs present over all vascular bundles 19

19- Abaxial outer sheath of midrib is sheath incomplete due to interruption of sclerenchyma girder of more than three fibrous cells *B. ramosus* Hudson

- Abaxial outer sheath of midrib is sheath incomplete due to interruption of sclerenchyma girder of three fibrous cells and chlorenchyma 20

20- Keel is V- shaped with rounded adaxial side; adaxial sclerenchyma of the keel is small girder as long as wide *B. stenostachyus* Boiss.

- Keel is rounded with flattened adaxial side; adaxial sclerenchyma of the keel is small narrow girder longer than wide *B. variegatus* M. B.

21- Abaxial outer sheath of midrib is sheath incomplete due to interruption of sclerenchyma girder of three fibrous cells and chlorenchyma *B. tomentellus* Boiss.

- Abaxial outer sheath of midrib is sheath incomplete due to interruption of sclerenchyma girder of more than three fibrous cells 22

22- Bulliform cells occupy equal ¼ of the leaf thickness; epidermal cells of different sizes comprise the epidermis *B. biebersteinii* Roemer & Schultes

- Bulliform cells occupy less than ¼ of the leaf thickness; epidermal cells cells of same sizes comprise the epidermis 23

23- Adaxial sclerenchyma of the keel is well-developed girder, wide and long as wide as the vascular bundle *B. tomentosus* Trin.

- Adaxial sclerenchyma of the keel is small narrow girder longer than wide 24

24- Keel is V- shaped with rounded adaxial side; abaxial sclerenchyma of the keel is well-developed girder, anchor shaped, stem short and sturdy, more than tri-seriate *B. cappadocicus* Boiss. & Bal.

- Keel is U- shaped with rounded adaxial side; abaxial sclerenchyma of the keel is well-developed girder, wider than the vascular bundle, horizontal band *B. riparius* Rehman

Acknowledgments

The authors would like to thank Dr's. Jamzad and Assadi (TARI), Mrs. Aghabeigi (IRAN) and Mr. Joharchi (Ferdowsi University Mashhad Herbarium) for loan of *Bromus* specimens. Special thanks are due to Dr. Zarre for his invaluable helps during the present study, Mr's. Mahdigholi and Okhovvat for providing microscopic sections. The second author sincerely thanks her friends, Mr's. Moazzeni and Faridi, Mrs. Sabaii and Miss Keshvari for their valuable helps.

References

Bor N. L. 1970: Bromus L. In: Rechinger K. H. (ed.), Flora Iranica. 70: 107-141. -Graz-Austria.

Clayton W. D. & Renvoize S. A. 1986: Genera graminum, grasses of the World. 389. -Her Majesty's Stationery Office, London.

Ellis R. P. 1976: A procedure for standardizing comparative leaf anatomy in the Poaceae. I. The leaf-blade as viewed in transverse section. -Bothalia. 12 (1): 65-109.

Ghahreman A. & Attar F. 1999: Biodiversity of plant species in Iran. 1: 356-371. -Tehran University publications.

Hsiao C., Jacobs S. W. L., Chatterton N. J. & Asay K. H. 1999: A molecular phylogeny of the grass family (Poaceae) based on the squences of nuclear ribosomal DNA (ITS). -Austral. J. Bot. 11: 667-688.

Mabberley D. J. 1997: The Plant-Book. 103. -Cambridge University Press.

Macfarlane T. & Watson L. 1982: The classification of Poaceae subfamily Pooideae. -Taxon. 31: 178-203.

Metcalfe C. R. 1960: Anatomy of the Monocotyledons. 1: 72-81. -Oxford University Press.

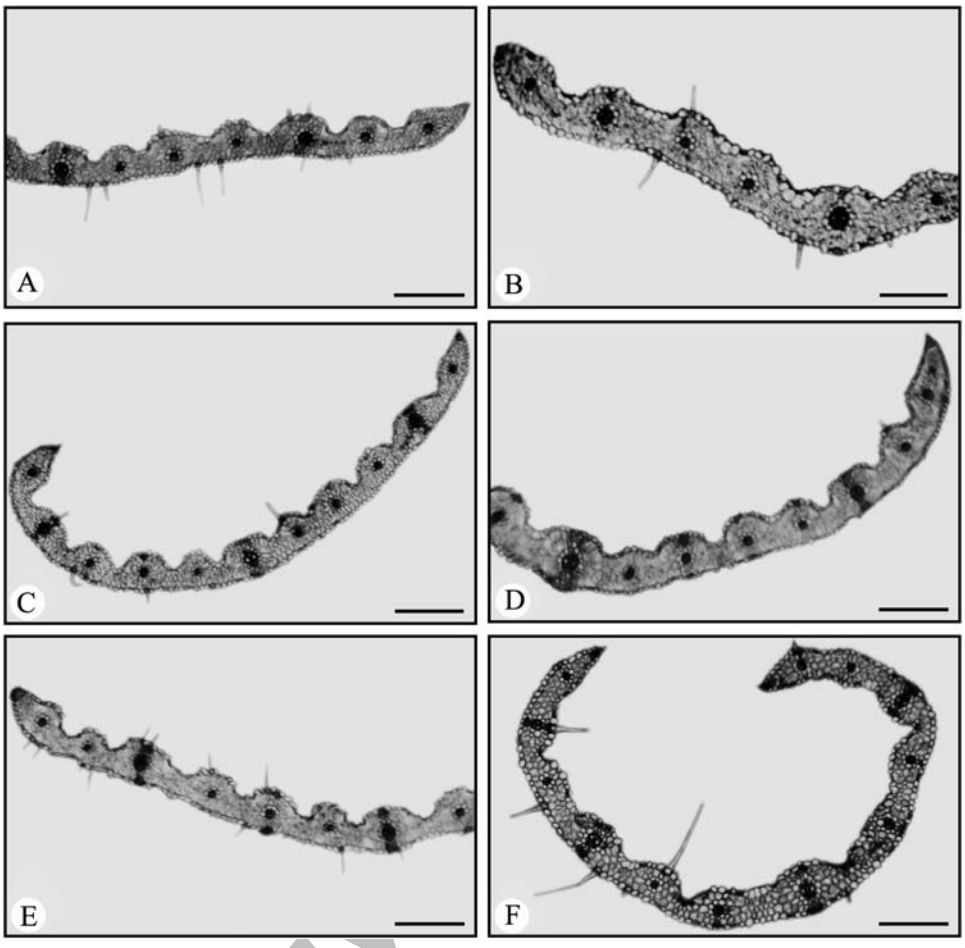

Figure 1: A-F, general aspect of leaf in *Bromus* species transverse section; A, *B. briziformis* Scale bar=200 µm; B, *B. gedrosianus* Scale bar=200 µm; C, *B. japonicus* Scale bar=300 µm; D, *B. lanceolatus* Scale bar=300 µm; E, *B. oxyodon* Scale bar=300 µm; F, *B. racemosus* Scale bar=200 µm.

Mozaffarian V. 1998: A Dictionary of Iranian Plant Names. 81-82. -Farhang Moaser Publishers.

Pavlick L. E. 1995: Bromus L. of North America. 160. -Royal British Columbia Museum, Victoria, BC.

Sales F. 1993: Taxonomy and nomenclature of *Bromus* Sect. *Genea*. -Edinburg Journal of Botany. 50 (1): 1-31.

Smith P. M. 1970: Taxonomy and nomenclature of the brome-grasses (Bromus L. s.l.). -Notes from the Royal Botanic Garden Edinburgh. 39: 361-375.

Smith P. M. 1972: Serology and species relationships in annual Bromes (Bromus L. sect. Bromus). -Annals of Botany. 36: 1-30.

Soreng R. J., Davidse G., Peterson P. M., Zuloaga F. O., Judziewicz E. J. & Filgueiras T. S. 2000: Catalogue of New World grasses (Poaceae). http://mobot.mobot.org/W3T/Search/nwgc.html.

Soreng R. J. & Davis J. I. 1998: Phylogenetics and character evolution in the grass family (Poaceae): simultaneous analysis of morphology and chloroplast DNA restriction site character sets. -The Botanical Review. 64 (1): 1-85.

Stebbins G. L. 1981: Chromosomes and evolution in the genus Bromus (Gramineae). -Botanische Jahrbuecher Fuer Systematik Pflanzengeschichte und Pflanzengeographie. 102: 359-379.

Tsvelev N. N. 1976: Grasses of the Soviet Union. part 1: 298-343. -Nauka Publishers, Leningrad (English translation published by Amerind Publishing Co., New Delhi, 1983).

Watson L. & Dallwitz M. J. 1992: The grass genera of the World. 1038. -CAB International, Wallingford, UK.

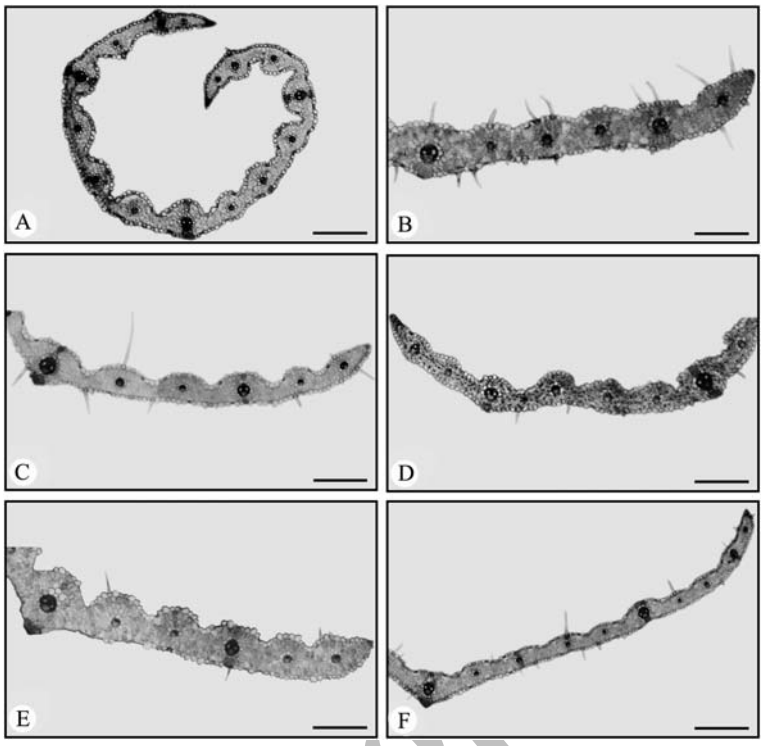

Figure 2: A-F, general aspect of leaf in *Bromus* species transverse section; A, *B. scoparius* Scale bar=200 µm; B, *B. fasciculatus* Scale bar=200 µm; C, *B. madritensis* Scale bar=200 µm; D, *B. rubens* Scale bar=200 µm; E, *B. sericeus* Scale bar=200 µm; F, *B. sterilis* Scale bar=300 µm.

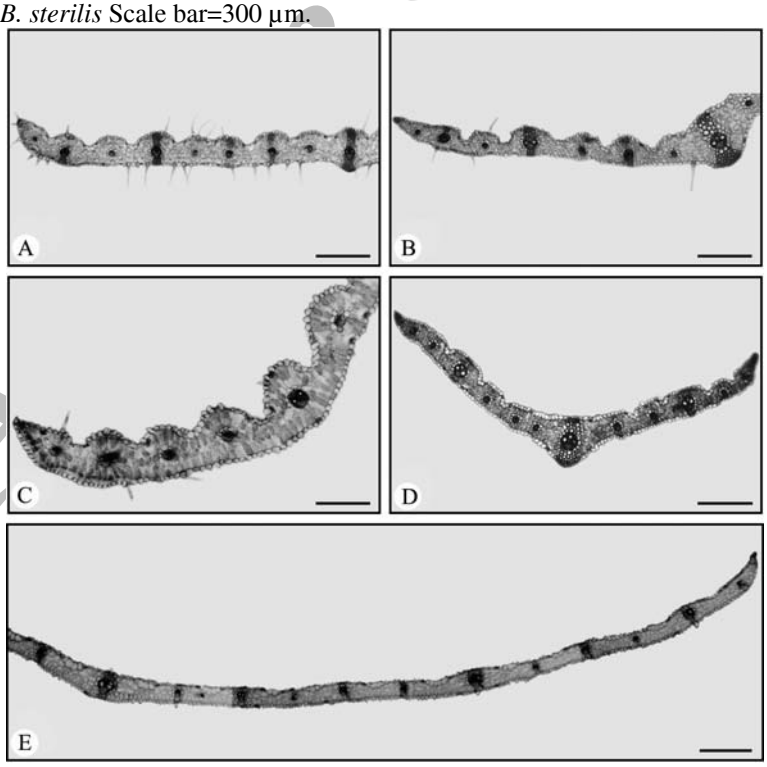

Figure 3: A-E, general aspect of leaf in *Bromus* species transverse section; A, *B. tectorum* Scale bar=300 µm; B, *B. danthoniae* Scale bar=300 µm; C, *B. gracillimus* Scale bar=100 µm; D, *B. biebersteinii* Scale bar=200 µm; E, *B. benekenii* Scale bar=200 µm.

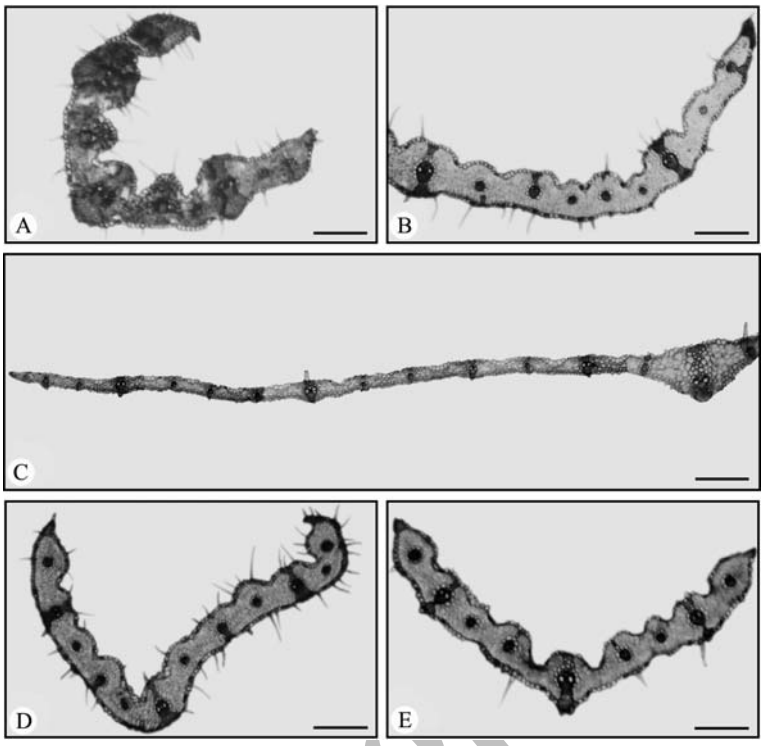

Figure 4: A-E, general aspect of leaf in *Bromus* species transverse section; A, *B. cappadocicus* Scale bar=200 µm; B, *B. kopetdaghensis* Scale bar=300 µm; C, *B. ramosus* Scale bar=300 µm; D, *B. riparius* Scale bar=200 µm; E, *B. stenostachyus* Scale bar=100 µm.

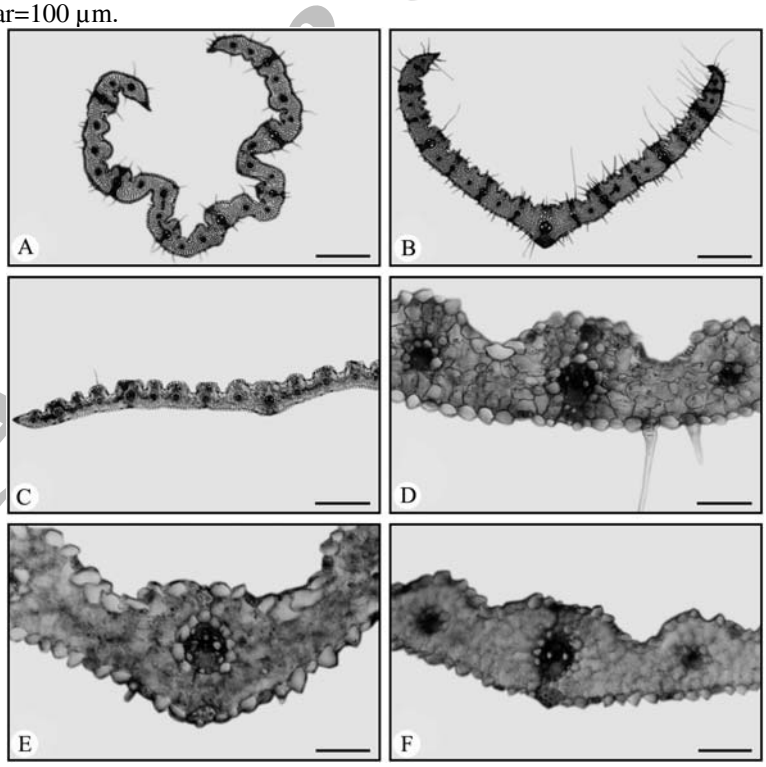

Figure 5: A-C, general aspect of leaf in *Bromus* species transverse section; A, *B. tomentellus* Scale bar=400 µm; B, *B. tomentosus* Scale bar=500 µm; C, *B. variegatus* Scale bar=400 µm; D-F, keel structure and midrib of *Bromus* species; D, *B. briziformis* Scale bar=70 µm; E, *B. gedrosianus* Scale bar=70 µm; F, *B. japonicus* Scale bar=80 µm.

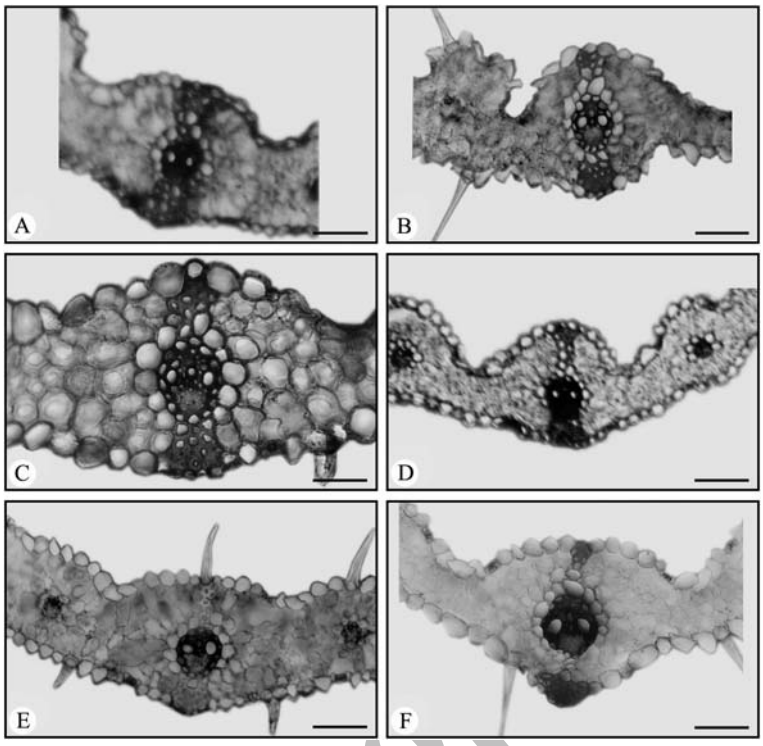

Figure 6: A-F, keel structure and midrib of *Bromus* species; A, *B. lanceolatus* Scale bar=100 µm; B, *B. oxyodon* Scale bar=80 µm; C, *B. racemosus* Scale bar=40 µm; D, *B. scoparius* Scale bar=80 µm; E, *B. fasciculatus* Scale bar=70 µm; F, *B. madritensis* Scale bar=80 µm.

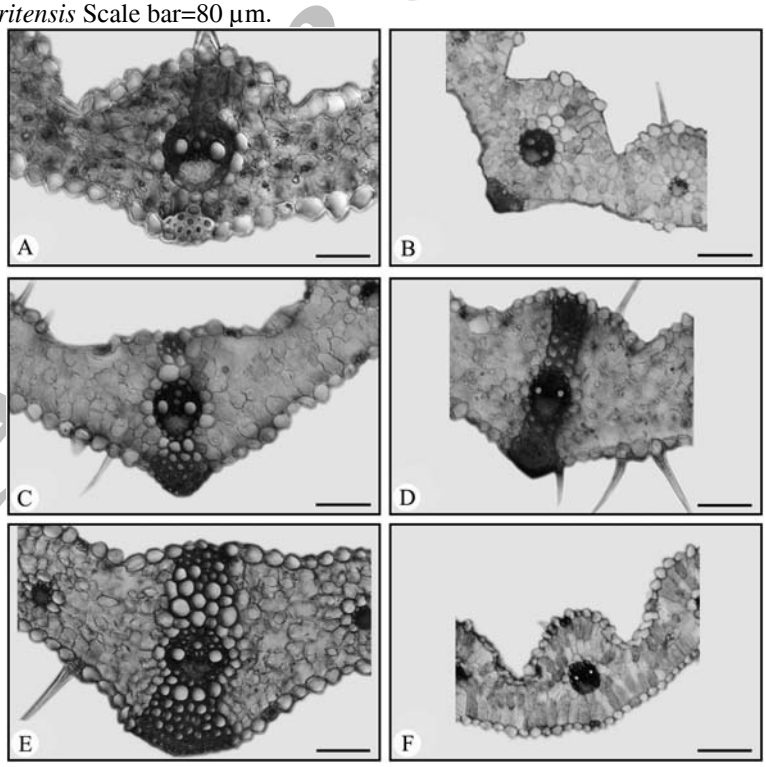

Figure 7: A-F, keel structure and midrib of *Bromus* species; A, *B. rubens* Scale bar=40 µm; B, *B. sericeus* Scale bar=100 µm; C, *B. sterilis* Scale bar=70 µm; D, *B. tectorum* Scale bar=70 µm; E, *B. danthoniae* Scale bar=80 µm; F, *B. gracillimus* Scale bar=80 µm.

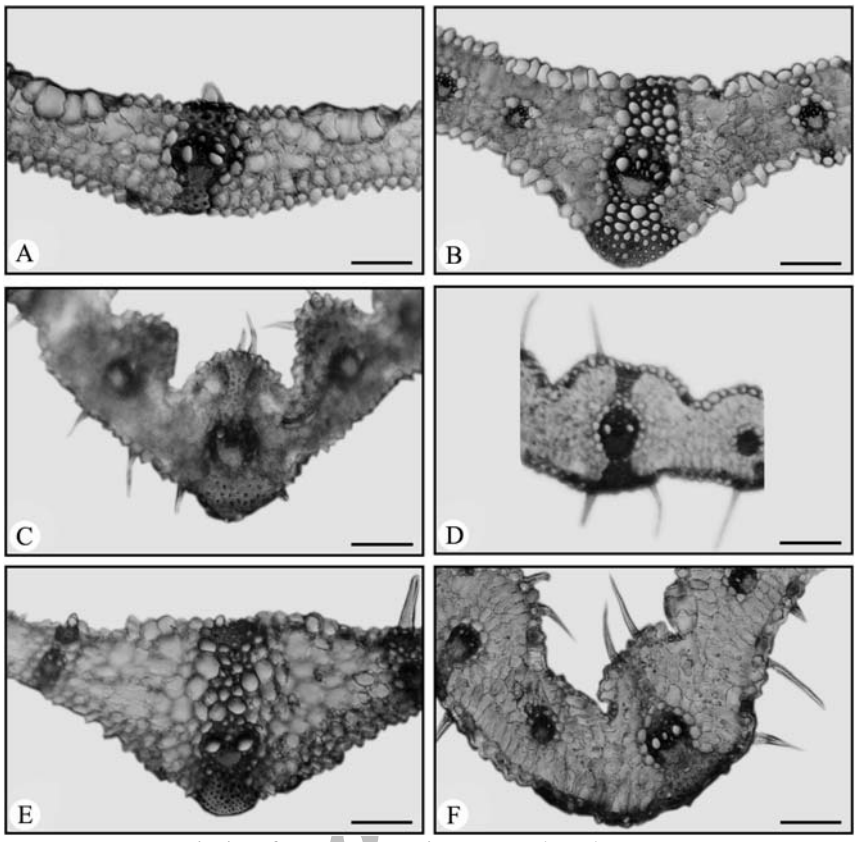

Figure 8: A-F, keel structure and midrib of *Bromus* species; A, *B. benekenii* Scale bar=70 µm; B, *B. biebersteinii* Scale bar=70 µm; C, *B. cappadocicus* Scale bar=90 µm; D, *B. kopetdaghensis* Scale bar=100 µm; E, *B. ramosus* Scale bar=100 µm; F, *B. riparius* Scale bar=70 µm.

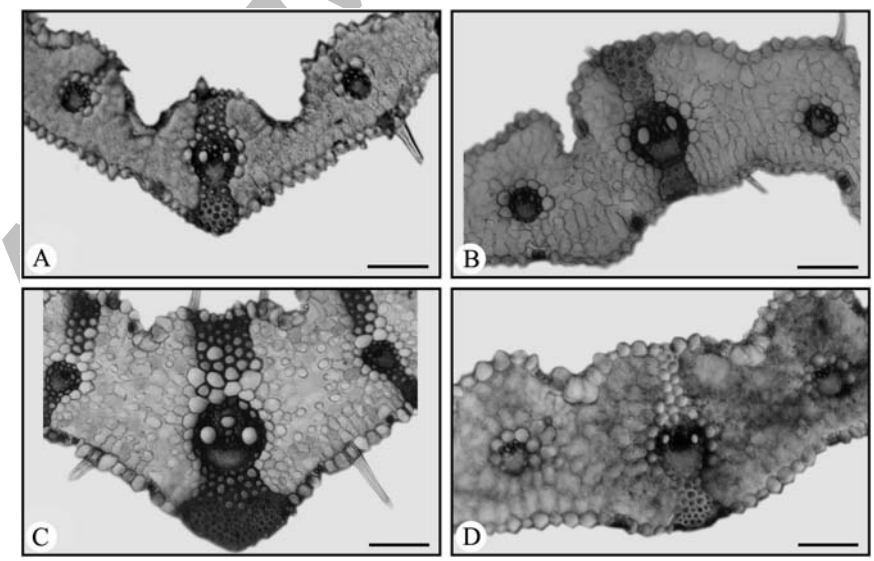

Figure 9: A-D, keel structure and midrib of *Bromus* species; A, *B. stenostachyus* Scale bar=70 µm; B, *B. tomentellus* Scale bar=70 µm; C, *B. tomentosus* Scale bar=100 µm; D, *B. variegatus* Scale bar=100 µm.