

## A TAXONOMIC REVISION OF THE GENUS *SORGHUM* MOENCH (POACEAE: ANDROPOGONEAE) IN IRAN

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The taxonomic status of the genus *Sorghum* Moench in Iran was evaluated. 163 accessions were studied using 75 morphological characters. The results indicated that the genus occurs in Iran with 4 species, *S. propinquum*, *S. halepense*, *S. × drummondii*, and *S. bicolor*. *Sorghum propinquum* (Kunth) Hitchc. is reported for the first time from Iran. This species is morphologically similar to *S. halepense* (L.) Pers. but differs from it in characteristics of rhizomes, leaf mid-vein, and inflorescence. Also, images and identification key for taxa is presented.

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**Keywords:** Gramineae; Panicoideae; *Sorghum*; taxonomy; morphology; flora of Iran

مروری بر وضعیت طبقه‌بندی جنس سورگوم (Poaceae: Andropogoneae) در ایران

نگار کریمی: دانشجوی دکتری گروه زیست‌شناسی گیاهی و جانوری، دانشکده علوم و فناوری‌های زیستی، دانشگاه اصفهان، اصفهان، ایران.

حجت‌اله سعیدی: دانشیار، گروه زیست‌شناسی گیاهی و جانوری، دانشکده علوم و فناوری‌های زیستی، دانشگاه اصفهان، اصفهان، ایران. وضعیت طبقه‌بندی جنس *Sorghum* Moench در ایران ارزیابی گردید. تعداد ۱۶۳ فرد با استفاده از ۷۵ صفت ریخت‌شناختی مورد مطالعه قرار گرفتند. نتایج بیانگر حضور جنس سورگوم در ایران با ۴ گونه: *S. propinquum*، *S. halepense*، *S. × drummondii* و *S. bicolor* است. گونه *S. propinquum* (Kunth) Hitchc. برای اولین بار از ایران گزارش می‌شود. این گونه از نظر ریخت‌شناختی مشابه گونه *S. halepense* بوده اما از نظر خصوصیات ریزوم، ویژگی‌های رگبرگ میانی و خصوصیات گل‌آذین تفکیک می‌شود. هم‌چنین کلید شناسایی و تصاویر آرایه‌ها ارائه می‌شود.

### INTRODUCTION

*Sorghum* Moench is a member of the tribe Andropogoneae belonging to the subfamily Panicoideae, the family Poaceae (Kellogg 2015). The genus was first introduced by Linnaeus in 1753 under the name *Holcus* L., Linnaeus described three species of the genus; *H. sorghum* L., *H. saccharatus* L., and *H. bicolor* L. (DeWet 1978). Later, in 1794, Moench separated the genus *Sorghum* from *Holcus* and introduced all species defined by Linnaeus as a single species of *S. bicolor* (L.) Moench (Clayton 1961). The

first description that corresponds to the currently known *Sorghum* was written by Pliny in *Historia Naturalis* (House 1985). Weedy taxa of *Sorghum* were first fully studied by Piper in 1915. Piper divided the taxa into two groups of Eu-sorghums to refer to the true *Sorghum* species and Sorghastrums to refer to the complex of suspicious species (House 1985).

The most detailed taxonomic revision of the genus *Sorghum* was conducted by Snowden in 1936. He classified the genus into 31 annual taxa (containing cultivated inbred sorghums along with their wild

ancestors) and 17 perennial weedy species. Also, Snowden pointed out that all annual species could be considered as one single species. Meanwhile, to emphasize the high diversity among them and to distinguish between domesticated sorghums and their wild ancestors, it was preferred to treat each taxon as a separate species (Kalmakhan & al. 2020, Ng'uni 2011). On the basis of distinct morphological and cytological characteristics, Snowden divided the genus *Sorghum* into two sections; *Sorghum* and *Parasorghum* Snowden, in which the section *Sorghum* contained species with 20 or more chromosomes and the section *Parasorghum* included the species with 10 chromosomes.

Later on, Snowden divided the section *Sorghum* into two subsections; *Halepensis* Snowden and *Arundinacea* Snowden, each containing a number of species with high inter-specific reproductive capacity and the ability to produce fully fertile hybrids (Snowden 1955).

In parallel with Snowden, based on cytotoxic studies, Garber (1954) divided the genus *Sorghum* into five sections; *Chaetosorghum* Garber, *Stiposorghum* Garber, *Heterosorghum* Garber, *Parasorghum*, and *Sorghum* and reduced all annual taxa to one single species of *S. bicolor* (L.) Moench. In Garber's classification, the genus was introduced with 23 species (Garber 1954).

The taxonomic treatment made by Garber was accepted by many later botanists. However, Harlan and DeWet (1972) changed the groupings discussed by Garber and reduced the perennial weedy taxa to 19 species. They accepted the classification of all annual sorghums as one single species of *S. bicolor*, but based on hybridization patterns and historical selections that occurred among different members, they defined 3 subspecies; subsp. *drummondii* (Nees ex Steud.) DeWet ex Davidse, subsp. *verticilliflorum* (Steud.) DeWet ex Wiersema & J.Dahlb. and subsp. *bicolor* (L.) Moench. Subsp. *bicolor* included all cultivated domesticated sorghums, subsp. *verticilliflorum* contained a widely distributed complex of annual wild taxa and was considered the ancestor of subsp. *bicolor*, and subsp. *drummondii* included annual shatter cane type sorghums and was recognized as a hybrid resulting from hybridization between domesticated (subsp. *bicolor*) and wild (subsp. *verticilliflorum*) annual *Sorghum* species (Harlan and DeWet 1972).

DeWet (1978), based on the ability to hybridization of different types of cultivated sorghums and the fertility rate of descendants, described 5 basic cultivars for subspecies *bicolor* including; *bicolor*, *guinea*, *kaffir*,

*caudateum*, and *durra*, and 10 intermediates resulting from crossing between basic cultivars.

By the means of molecular approaches, the taxonomy of the genus has experienced detailed changes in recent years. For example, the subspecies *drummondii* is now accepted as a hybrid species resulting from hybridization between *S. bicolor* × *S. arundinaceum* (Desv.) Stapf and introduced as *S. × drummondii* (Nees ex Steud.) Millsp. & Chase (POWO 2022). *S. bicolor* subsp. *verticilliflorum* is also treated as a synonym of *S. arundinaceum* (POWO 2022).

The genus *Sorghum* has only been reported by section *Sorghum* in Iran and neighboring countries and there is no report of the representative of other sections in this region (Bor 1970, Davis 1970). Due to the natural distribution range of *S. halepense* (L.) Pers. from the Mediterranean region to Southeast Asia, this species occurs widely as a weed in different regions of Iran and neighboring countries (Peerzada & al. 2017, Karimi & Saeidi 2016).

Based on FAO report (2021), various cultivars of *S. bicolor* have also been introduced to Iran, mostly from China and Australia, and cultivated in different areas (Al-Modarres & al. 2008).

Parsa reported three species, *S. halepense*, *S. bicolor*, and *S. cernuum* (Ard.) Host from Iran (Parsa 1950). In Flora Iranica (Bor 1970) three species, *S. bicolor*, *S. halepense*, and *S. sudanense* Snowden, and the possible presence of *S. miliaceum* (Roxb.) Snowden as a cultivated annual species have been reported from Iran.

In this research, we updated the taxonomic status of the genus and revised the taxonomy of the genus in Iran using wide sampling.

## MATERIAL AND METHODS

A total of 163 accessions including weedy taxa and cultivated sorghum specimens collected from all of the geographical distribution range of the genus in Iran were studied; among them, there were plant materials collected from the experimental field of the Agricultural and Natural Resources Research Center of Khorasan Razavi and seed samples received from Seed and Plant Breeding Research Institute of Karaj, and Agricultural and Natural Resources Research and Training Center of Yazd. The seed accessions were planted in the field and harvested in the appropriate season and were identified. The taxonomical concept proposed by POWO (2022) was used for interpretations, and the descriptions were prepared based on the characters of the examined specimens. Accordingly, the identified specimens belonged to four

species, and the herbarium voucher specimens are deposited in the Herbarium of the University of Isfahan (HUI). Plant specimens were morphologically identified using related literature i.e., (Nevski 1934,

Bor 1970, Tsvelev 1976, DeWet 1978, Jacobs 2007). Selected specimens of the studied species with their collection data and herbarium number are provided in Table 1.

Table 1. Selected specimens of the studied species of the genus *Sorghum* in Iran with their collection data and herbarium numbers.

No.	Species	Locality	Geographical coordinates	Collector	Herbarium Code
1	<i>S. propinquum</i>	Mazandaran, Noshahr, Chaloos Road	36°39' N. 51°30' E. Alt. -8 m	Saeidi and Karimi	HUI-19718
2	<i>S. propinquum</i>	Mazandaran, Nashtarood towards Tonekabon	36°45' N. 51°00' E. Alt. 23 m	Saeidi and Karimi	HUI-19719
3	<i>S. propinquum</i>	Mazandaran, Tonekabon towards Ramsar	36°47' N. 50°54' E. Alt. -20 m	Saeidi and Karimi	HUI-19720
4	<i>S. propinquum</i>	Gilan, Lahijan, entrance of city	37°12' N. 50°00' E. Alt. -10 m	Saeidi and Karimi	HUI-19721
5	<i>S. propinquum</i>	Gilan, Sangar towards Roodbar	37°09' N. 49°41' E. Alt. 36 m	Saeidi and Karimi	HUI-19723
6	<i>S. propinquum</i>	Gilan, Rasht towards Sangar	36°56' N. 49°32' E. Alt. 129 m	Saeidi and Karimi	HUI-19724
7	<i>S. halepense</i>	Markazi, Saveh towards Salafchegan	34°45' N. 50°23' E. Alt. 1175 m	Saeidi and Karimi	HUI-19725
8	<i>S. halepense</i>	West Azerbaijan, Oromia towards Band	37°30' N. 45°01' E. Alt. 1409 m	Karimi	HUI-19751
9	<i>S. halepense</i>	West Azerbaijan, Piranshahr towards Tamarchin	36°45' N. 45°08' E. Alt. 1530 m	Karimi	HUI-19753
10	<i>S. halepense</i>	Lorestan, Khoramabad towards Alashtar	33°38' N. 48°17' E. Alt. 1339 m	Karimi	HUI-19765
11	<i>S. halepense</i>	Lorestan, 25 km Doruod, Hajiabad village	33°43' N. 48°52' E. Alt. 1521 m	Karimi	HUI-19736
12	<i>S. halepense</i>	Chaharmahal Va Bakhtiari, 5 km Lordegan, Armand	31°45' N. 50°49' E. Alt. 1292 m	Karimi	HUI-19727
13	<i>S. halepense</i>	Illam, Dareshahr, Seifaldin village	33°35' N. 46°23' E. Alt. 1323 m	Karimi	HUI-19739

Table 1. Continued.

No.	Species	Locality	Geographical coordinates	Collector	Herbarium Code
14	<i>S. × drummondii</i>	Center of Agricultural and Natural Resources Research and Education of Khorasan-Razavi	-	-	HUI-19712
15	<i>S. × drummondii</i>	Seed and Plant Improvement Institutes of Karaj	-	-	HUI-19711
16	<i>S. × drummondii</i>	Agricultural and Natural Resources Research and Training Center of Yazd	-	-	HUI-19717
17	<i>S. bicolor</i>	Lorestan, Khoramabad towards Alashtar	33°38' N. 48°17' E. Alt. 1339 m	Karimi	HUI-19765
18	<i>S. bicolor</i>	Illam, Dareshahr, Seifaldin village	33°35' N. 46°23' E. Alt. 1323 m	Karimi	HUI-19739
19	<i>S. bicolor</i>	Mazandaran, Behshahr towards Sari	36°36' N. 53°13' E. Alt. 45 m	Saeidi and Karimi	HUI-19769
20	<i>S. bicolor</i>	Mazandaran, Babol	36°32' N. 52°39' E. Alt. 15 m	Saeidi and Karimi	HUI-19770
21	<i>S. bicolor</i>	Chaharmahal Va Bakhtiari, Farokhshar	32°15' N. 50°58' E. Alt. 1024 m	Karimi	HUI-19768

## RESULTS

The annual and perennial taxa were easily recognized based on the presence/absence of rhizomes. Inflorescence shape, size, and density were among the diagnostic characteristics to distinguish different species. Different types of racemes including pyramid, ovate, and curved were observed (Fig. 1). The features of glumes were also of diagnostic importance. The

glumes showed discriminative variations in size, color, number of veins on the abaxial side, apex form, texture, and presence or absence of hair on the abaxial side of the glumes (Fig. 2). Seed characteristics including size, weight, and color were other diagnostic characteristics to distinguish species. The ratio of the length of the lower glume to the upper glume was another distinctive characteristic studied (Fig. 3).

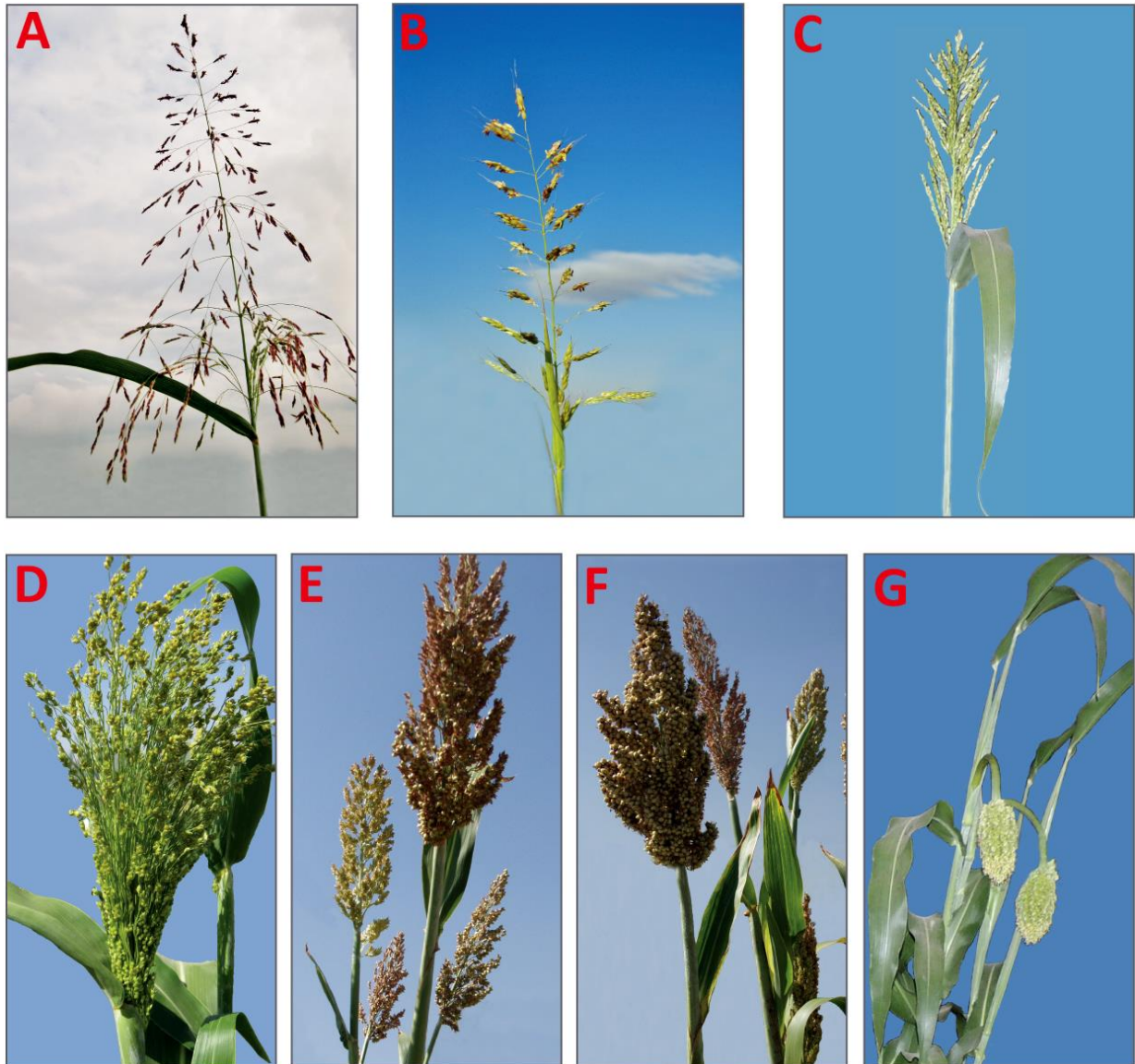


Fig. 1. Inflorescence in *Sorghum*. A, *S. propinquum*; B, *S. halepense*; C, *S. x drummondii*; D-E-F-G, *S. bicolor* (photos prepared by authors).

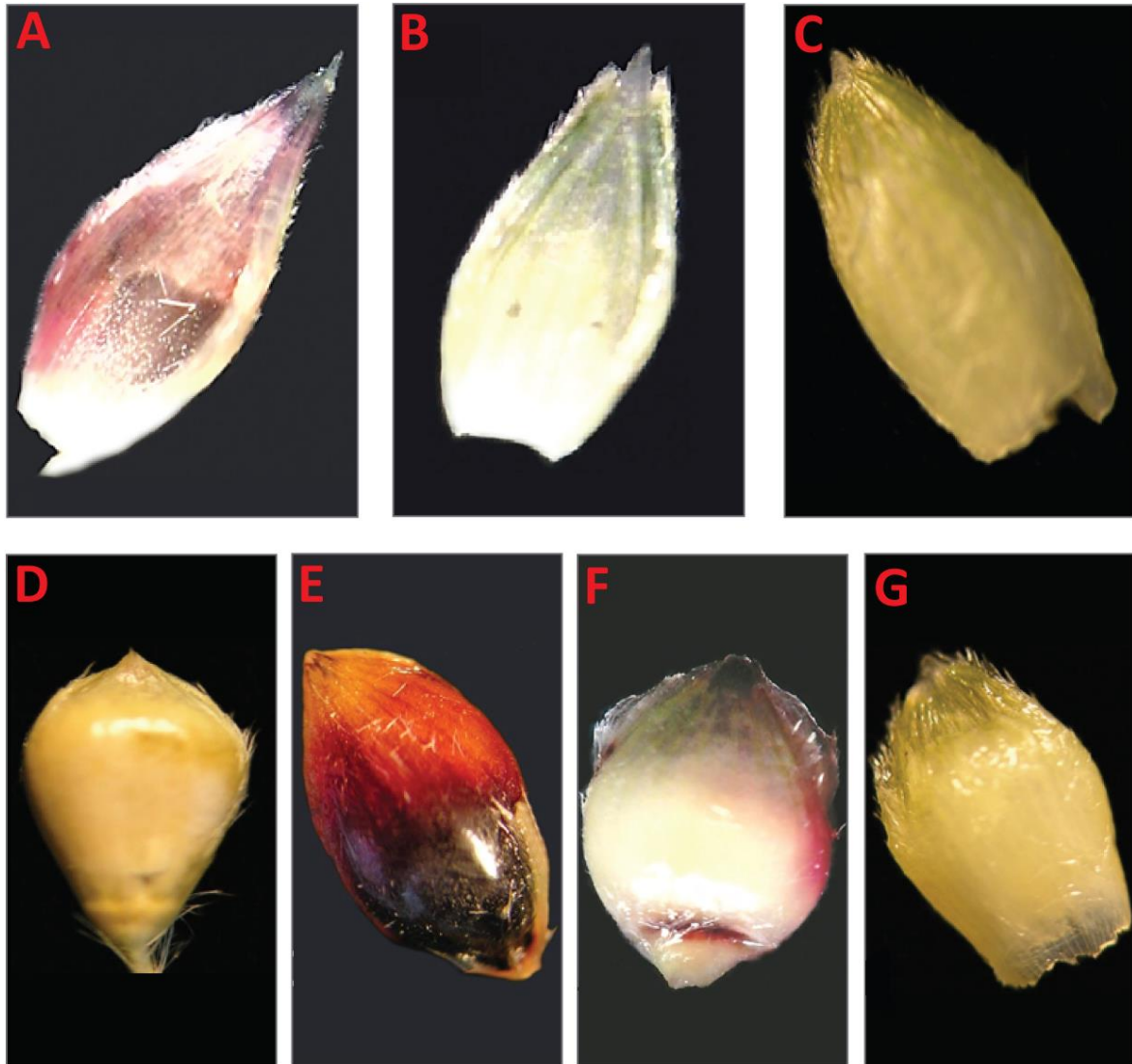


Fig. 2. Lower glumes in *Sorghum*. A, *S. propinquum*; B, *S. halepense*; C, *S. x drummondii*; D-E-F-G, *S. bicolor* (photos prepared by authors).

Among cultivated taxa studied, two main species, *S. bicolor* and *S. x drummondii* were recognized. These species were separated from each other mainly based on the presence or absence of branches on the stems and tillering. As in *S. bicolor* the stems are single and there is no tillering, while *S. x drummondii* bears on multiple branches. All weedy taxa showed morphological similarity in having stems with multiple branches. However, they were divided into two groups based on differences in the type of rhizome, length of the stem, leaf midvein prominence, shape of inflorescence, spikelet, and glumes. According to the mentioned characters, most of the accessions collected from different parts of the country showed similar

characteristics of *S. halepense*, introduced and explained in previous reports from the flora of Iran. However; the collected specimens from southwestern shores of the Caspian Sea (6 accessions), showed smaller and not creeping rhizomes, taller stems, leaves with a prominent midvein, ovate inflorescences with whorled loose branches, somewhat fragile spikelets, green to purple glumes, and lower glumes with no teeth at the apex. Morphological characters of these accessions exactly matched the characteristics of *S. propinquum* (Kunth) Hitchcock, belonging to the section *Sorghum*, and thus the species was reported as a new record for the flora of Iran.

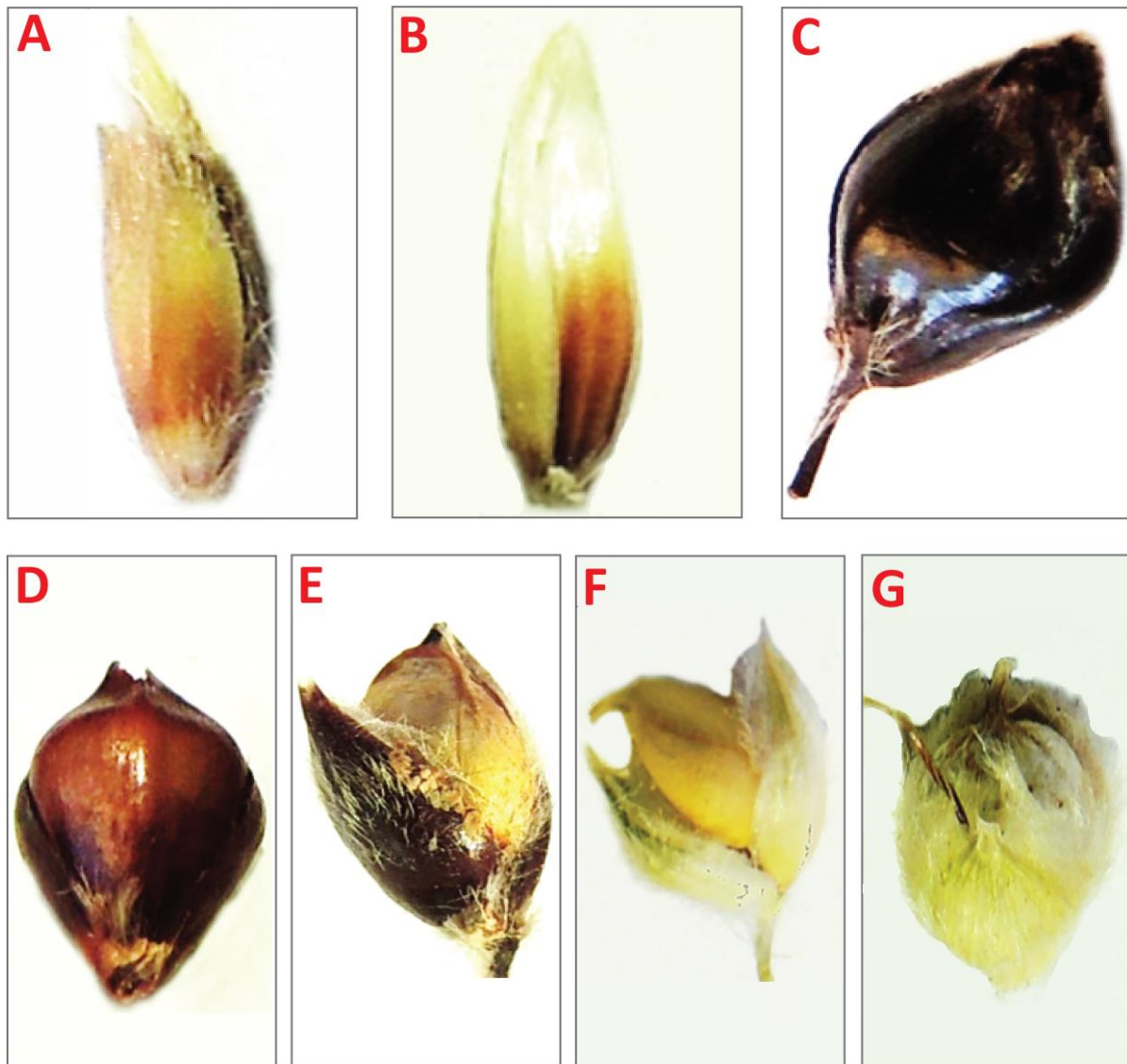


Fig. 3. Glumes and seeds at maturity in *Sorghum*. A, *S. propinquum*; B, *S. halepense*; C, *S. x drummondii*; D-E-F-G, *S. bicolor* (photos prepared by authors).

## DISCUSSION

The results of this study showed that the characteristics of rhizomes, inflorescence shape, glume shape, and size are suitable traits to distinguish weedy species in the genus. The stem tillering, shape, size, weight, and color of grains are also useful characters to separate the cultivated taxa.

### Taxonomic treatment

The results showed that the genus *Sorghum* occurs in Iran with section *Sorghum*, including 3 species; *S. bicolor*, *S. halepense*, *S. propinquum*, and a hybrid, *S. x drummondii*. Among them *S. halepense* and *S. propinquum* are perennial weedy species, *S. x*

*drummondii* is an annual weedy hybrid species and *S. bicolor* is annual cultivated species. A taxonomic treatment of the genus *Sorghum* in Iran, including the updated descriptions of taxa, and an identification key are provided.

*S. propinquum* (Kunth) Hitchc., Lingnan Science Journal. 7: 249 (1931). (Fig. 4)

*Syn: Andropogon affinis* J.Presl, C.B.Presl, Reliq. Haenk. 1: 343 (1830); *Andropogon propinquus* Kunth, Enum. Pl. 1: 502 (1833); *Andropogon sorghum* var. *propinquus* (Kunth) Hack., A.L.P.de Candolle & A.C.P.de Candolle, Monogr. Phan. 6: 503 (1889)



Fig. 4. The image of the herbarium specimen of *S. prorepens* (Herbarium Code: HUI-19721, photos prepared by authors).



Plant perennial. Rhizomes elongated. Culms erect, 200-300 cm high; culm-nodes pubescent; ligule an e-ciliate membrane. Leaf-blades 30-100 cm long, 10-50 mm wide. Inflorescence a panicle with branches tipped by a raceme, open, ovate, loose, 20-60 cm long, primary branches moderately divided; inflorescence branches flexuous and whorled; rachis fragile at the nodes, ciliate on margins; internodes filiform, transverse at tip, cupuliform. Racemes bearing 1-3 spikelets. Spikelets appressed, acute, 3.8-5 mm long, deciduous with accessory branch structures, clustered in pair, 1 fertile, 1 sterile; fertile spikelet sessile, with 2 florets, lower sterile, upper fertile; sterile spikelet pedicelled, with 2 florets, both male or infertile; pedicel pubescent, obtuse at base, with white hairs. Fertile florets bisexual, 3-6 mm long, with well-developed palea, ovate. Sterile florets with no significant palea, 3-5 mm long, bearing reduced lemmas, male or infertile. Glumes unequal, longer than florets, firmer than fertile lemma, with no distinct veins; lower glume ovate, coriaceous, green to purple, without keels or keel-less at the apex; upper glume ovate, coriaceous, without keels, acute at the apex. Lemma ciliate at the margin, dentate at the apex, 2-fid. Palea absent or minute. Lodicules 2, oblong, fleshy, ciliate, hairy across the apex. Anthers 3. Stigmas 2, laterally exerted. Caryopsis with adherent pericarp.

**Distribution:** the global distribution of this species is in the east and southeast Asia, and Central Pacific. The native range of the species includes; China, India, Indo-China, and Malesia. Here we reported this species from the north of Iran along the Caspian Sea shore. As this area is ecologically similar to the southeastern regions of Asia, and as the species is found in a limited area, it can be concluded that *S. propinquum* is probably introduced to this area through human activities.

**Specimens examined:** Mazandaran: Noshahr, Chaloo Road, -8 m, 36°39' N. 51°30' E., Saeidi and Karimi, HUI-19718; Nashtarood towards Tonekabon, 23 m, 36°45' N. 51°00' E., Saeidi and Karimi, HUI-19719; Tonekabon towards Ramsar, -20 m, 36°47' N. 50°54' E., Saeidi and Karimi, HUI-19720. Gilan: Lahijan, the entrance of the city, -10 m, 37°12' N. 50°00' E., Saeidi and Karimi, HUI-19721; Sangar towards Roodbar, 36 m, 37°09' N. 49°41' E., Saeidi and Karimi, HUI-19723; Rasht towards Sangar, 129 m, 36°56' N. 49°32' E., Saeidi and Karimi, HUI-19724.

*S. halepense* (L.) Pers., Synopsis plantarum (Persoon). 1: 221 (1805). (Fig. 5)

**Syn:** *Holcus halepensis* L., Sp. Pl.: 1047 (1753); *Andropogon halepensis* (L.) Brot., Fl. Lusit. 1: 89 (1804); *Sorghum miliaceum* (Roxb.) Snowden, J. Linn. Soc., Bot. 55: 205 (1955)

Plant perennial; caespitose. Rhizomes elongated, and scaly. Culms erect, geniculate ascending or decumbent, 50-300 cm high; culm nodes pubescent.

Leaves cauline, leaf blades linear, 20-90 cm long, 5-40 mm wide; leaf blade scabrous at margins, smooth on the surface; ligule a ciliate membrane. Inflorescence a panicle with branches tipped by a raceme, open, lanceolate, or pyramidal, 10-55 cm long, 3-25 cm wide, primary branches alternate at most nodes, moderately divided. Racemes 1.2-2.5 cm long, bearing 1-5 spikelets; rachis fragile at nodes, ciliate on margins; rachis internodes filiform, transverse at the tip, cupuliform. Spikelets appressed, acute, 3-5 mm long, clustered in pairs, 1 fertile, 1 sterile; fertile spikelet sessile, ovate, with 2 florets, lower sterile, upper fertile; sterile spikelet pedicelled, lanceolate, with 2 florets, both male or infertile; pedicel filiform, ciliate. Fertile florets bisexual, with well-developed ovate palea. Sterile florets with no significant palea, bearing reduced lemmas, male or infertile. Fertile florets bisexual, 3-4 mm long, with well-developed ovate palea. Sterile florets barren, with no significant palea, 4-6 mm long, bearing reduced lemmas, male or infertile. Glumes dissimilar, longer than florets, firmer than fertile lemma, with 3 to 5 distinct veins; lower glume elliptic, wide, length equal to spikelet, coriaceous, yellowish-green, or pallid, or dark brown, 2-keeled above, surface glabrous or pubescent, dentate at the apex, 3-fid; upper glume ovate, coriaceous, without keels, surface glabrous or pubescent. Lemma elliptic, 2 mm long, shorter than spikelet, hyaline, 2-veined, ciliate on margins, hyaline, entire or dentate at the apex, if dentate 2-fid, awnless or 1-awned; awn geniculate, 10-16 mm long, with twisted column; column pubescent, hairy on the spiral. Palea present, and minute. Lodicules 2, oblong, ciliate. Anthers 3. Stigmas 2. Caryopsis with adherent pericarp.

**Distribution:** the native range of the species is the Mediterranean Sea to Central Asia and Indo-China. It is native to Lebanon, Transcaucasia, Iraq, Iran, Kazakhstan, Kirgizstan, India, and West Himalayas. However; it is introduced into different parts of the world due to its adaptability to a wide range of habitats and is considered a cosmopolitan species.

**Specimens examined:** Markazi: Saveh towards Salafchegan, 1175 m, 34°45' N. 50°23' E., Saeidi and Karimi, HUI-19725. West Azerbaijan: Oromia towards Band, 1409 m, 37°30' N. 45°01' E., Karimi, HUI-19751; Piranshahr towards Tamarchin, 1530 m, 36°45' N. 45°08' E., Karimi, HUI-19753. Lorestan: Khoramabad towards Alashtar, 1339 m, 33°38' N. 48°17' E., Karimi, HUI-19765; 25 km Doruod, Hajiabad village, 1521 m, 33°43' N. 48°52' E., Karimi, HUI-19736. Chaharmahal Va Bakhtiari: 5 km Lordegan, Armand, 1292 m, 31°45' N. 50°49' E., Karimi, HUI-19727. Illam: Dareshahr, Seifaldin village, 1323 m, 33°35' N. 46°23' E., Karimi, HUI-19739.



Fig. 5. The image of the herbarium specimen of *S. halepense* (Herbarium Code: HUI-19726, photos prepared by authors).

*S.* × *drummondii* (Nees ex Steud.) Millsp. & Chase, Publications of the Field Columbian Museum. Botanical series. 3: 21 (1903). (Fig. 6)

**Syn:** *Andropogon sorghum* var. *transiens* Hack., A.L.P.P.de Candolle & A.C.P.de Candolle, Monogr. Phan. 6: 508 (1889); *Holcus sorghum* subsp. *sudanensis* (Piper) Hitchc., Proc. Biol. Soc. Washington 29: 128 (1916); *Sorghum* × *sudanense* (Piper) Stapf., D.Oliver & auct. suc. (eds.), Fl. Trop. Afr. 9: 113 (1917); *Sorghum vulgare* var. *sudanense* (Piper) Hitchc., J. Washington Acad. Sci. 17: 147 (1927); *Sorghum bicolor* var. *drummondii* (Nees ex Steud.) Mohlenbr., Ill. Fl. Illinois, Grasses: *Panicum-Danthonia*: 192 (1973).

Plant annual. Culms solitary, erect, 150-200 cm high, 3-6 mm in diameter. Leaves cauline; ligule a ciliate membrane; leaf blades 15-20 cm long, 8-12 mm wide. Inflorescence panicle with branches tipped by a raceme, open, ovate or pyramidal, 15-30 cm long, 8-15 cm wide; branches ascending or spreading, 2-5 on each node, 5-15 cm long, flexuous, scabrous. Racemes 1.5-2.5 cm long, bearing 2-5 fertile spikelets; rachis tough, ciliate on margins, with hairs up to 0.5 mm long; rachis internodes filiform, 2.5-4 mm long, transverse at the tip, cupuliform. Spikelets appressed, acute, or ovate, 3-5 mm long, clustered in pairs, 1 fertile, 1 sterile; fertile spikelet sessile, ovate, with 2 florets, lower sterile, upper fertile; sterile spikelet pedicelled, lanceolate, with 2 florets, both male or infertile; pedicel filiform, flattened, 2-3 mm long, ciliate, with hairs up to 0.5 mm long. Sterile florets with no significant palea, bearing reduced lemmas, male or infertile. Fertile florets bisexual, 3-4 mm long, with well-developed palea, ovate. Sterile florets barren, with no significant palea, 4-6 mm long, bearing reduced lemmas, male or infertile. Glumes unequal, longer than florets, firmer than fertile lemma, shiny; lower glume elliptic, equal to spikelets in length, wide, coriaceous, much thinner above, surface glabrous or puberulous, acute at the apex, yellow or light brown, without keels or keeled near the apex, 11-15-veined; veins scabrous; upper glume elliptic, coriaceous, acute at the apex, thinner near apex, without keels or keeled near the apex, 7-veined; veins scabrous. Lemma elliptic, or ovate, 3-6 mm long, hyaline, 1-2-veined, ciliate on margins, dentate at the apex, 2-fid, 1-awned; awn geniculate, 10-16 mm long, with twisted column; column glabrous. Palea absent or minute. Lodicules 2, oblong, fleshy, ciliate, hairy across the apex. Anthers 3, 4 mm long. Stigmas 2, laterally exerted. Caryopsis with adherent pericarp, ellipsoid or obovoid, dorsally compressed, 3.5-4.5 mm long.

**Distribution:** the species is native to west tropical Africa and Sudan. Its native range includes; Chad, Egypt, Mali, Niger, and Sudan. Today it is introduced into different parts of the world through human migration and is cultivated due to its agronomic importance.

**Specimens examined:** the taxon includes the hybrids imported to the country mainly from Australia and is

known and cultivated in different parts of Iran as Speed Feed or Sudan grass. The studied accessions were received from the Center of Agricultural and Natural Resources Research and Education of Khorasan-Razavi (1 accession), the Seed and Plant Improvement Institutes of Karaj (1 accession), and the Agricultural and Natural Resources Research and Training Center of Yazd (1 accession).

**S. bicolor** (L.) Moench. C., Methodus plantarum Horti Botanici et Agri Marburgensis a staminum situ describendi. (Supplementum.) (vol. 2) (1794). (Fig. 7)  
**Syn:** *Holcus bicolor* L., Mant. Pl. 2: 301 (1771); *Panicum caffrorum* Retz., Observ. Bot. 2: 7 (1781); *Milium sorghum* (L.) Cav., Descr. Pl.: 306 (1802); *Sorghum vulgare* Pers., Syn. Pl. 1: 101 (1805); *Sorghum cernuum* (Ard.) Host, Icon. Descr. Gram. Austriac. 4: 2 (1809); *Agrostis nigricans* (Ruiz & Pav.) Poir., J.B.A.M.de Lamarck, Encycl., Suppl. 1: 259 (1810); *Andropogon bicolor* (L.) Roxb., Hort. Bengal.: 21 (1814); *Sorghum ankolib* (Hack.) Stapf, D.Oliver & auct. suc. (eds.), Fl. Trop. Afr. 9: 135 (1917); *Sorghum caudatum* (Hack.) Stapf, D.Oliver & auct. suc. (eds.), Fl. Trop. Afr. 9: 131 (1917);

Plant annual. Culms erect, robust, 100-600 cm high, 30-50 mm diameter; culm nodes glabrous. Leaves cauline; ligule an e-ciliate membrane, 1-3 mm long; leaf blade broadly rounded, 30-100 cm long, 5-10 mm wide. Inflorescence panicle with branches tipped by a raceme, straight or deflexed, open or contracted, lanceolate or ovate or globose, equilateral or nodding, 4-50 cm long, 2-20 cm wide; branches appressed or spreading, not whorled, moderately divided, pubescent or villous. Racemes bearing 1-6 fertile spikelets; rachis; tough, ciliate on margins; rachis internodes filiform or linear, 0.5-5 mm long, transverse at the tip. Spikelets oblong, or ovate, dorsally compressed, 3-10 mm long, persistent (not shattering), muticous, clustered in pair, 1 fertile, 1 sterile; fertile spikelet sessile, lanceolate, with 2 florets, lower sterile, upper fertile; sterile spikelet pedicelled, lanceolate, with 2 florets, both male; pedicel filiform, flattened, 3-7 mm long. Fertile florets bisexual, 3-10 mm long, with well-developed ovate palea. Sterile florets with no significant palea, bearing reduced lemmas, male, with no significant palea, 4-6 mm long. Glumes unequal, longer than florets, firmer than fertile lemma, parallel to lemmas or gaping; lower glume ovate, equal to spikelets in length, coriaceous, pallid or red or black, 2-keeled above, surface glabrous or pilose, obtuse or acute at the apex; upper glume ovate, chartaceous or coriaceous, 1-keeled above, 5-7-veined, surface glabrous, or pubescent, ciliate on margins, entire or dentate at the apex, 2-fid. Lemma elliptic, or obovate, 1-3 mm long, shorter than spikelets, hyaline, 2-5-veined, ciliate on margins, entire or dentate at the apex, 2-fid, awnless, or 1-awned; awn geniculate, with twisted column; column pubescent, hairy on the spiral. Palea present. Lodicules 2, ciliate. Caryopsis exposed between gaping lemma and palea at maturity.



Fig. 6. The image of the herbarium specimen of *S. × drummondii* (Herbarium Code: HUI-19771, photos prepared by authors).

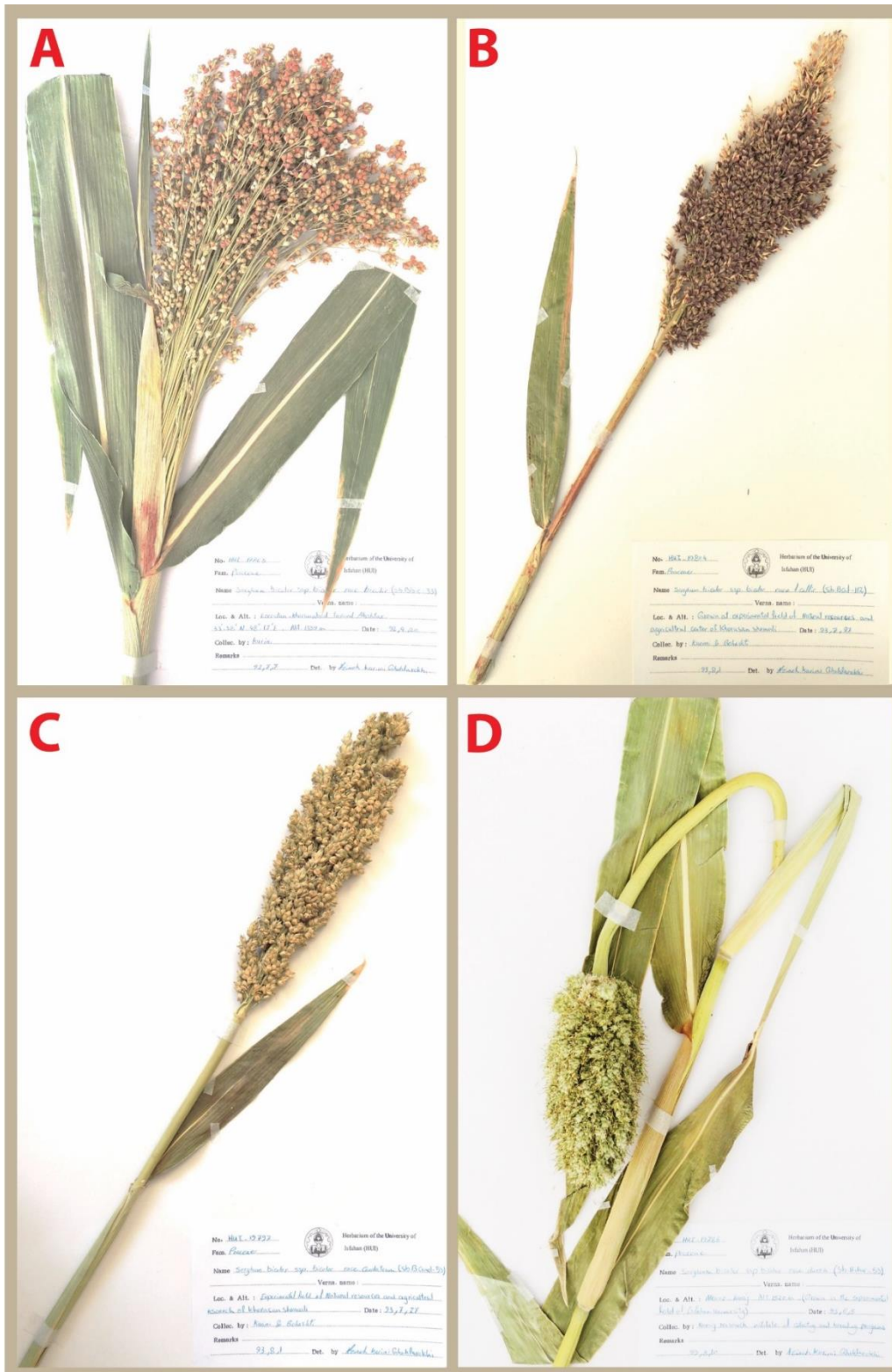


Fig. 7. The image of the herbarium specimen of *S. bicolor* (Herbarium Codes: HUI-19765, HUI-19804, HUI-19797, HUI-19788, photos prepared by authors).

**Distribution:** The species originated in Africa and is native to Central Africa, South West Africa, and East Africa. The species was introduced into different regions of the world due to its importance for food and forage storage. The species has been introduced to Iran from China and is widely cultivated in different regions of the country.

**Specimens examined:** Lorestan: Khoramabad towards Alashtar, 1339 m, 33°38' N. 48°17' E., Karimi, HUI-19765. Illam: Dareshahr, Seifaldin village, 1323 m, 33°35' N. 46°23' E., Karimi, HUI-19739. Mazandaran: Behshahr towards Sari, 45 m, 36°36' N. 53°13' E., Saeidi and Karimi, HUI-19769; Babol, 15 m, 36°32' N. 52°39' E., Saeidi and Karimi, HUI-19770. Chaharmahal Va Bakhtiari: Farokhshar, 32°15' N. 50°58' E., Karimi, 1024 m, HUI-19768.

Key to taxa in Iran

1. Plants perennial, wild or weedy, rhizomatous. Rachis highly fragile and spikelets shattering..... 2
- Plants annual, cultivated, without rhizome. Rachis persistent ..... 3
2. Rhizomes short, without scales. Stem brittle and fragile. Leaf mid veins thick, significantly large. Inflorescence pyramid with provided or whorled branches; lower glumes without teeth at the apex ..... *S. propinquum*
- Rhizomes long and creeping, with scales. Stem flexible. Leaf mid veins thin. Inflorescence ovate with solitary and alternat branches; lower glumes specifically 3-toothed at the apex ..... *S. halepense*
3. Stem branched. Lemma awns long and bent. Pedicel of sterile spikelets 1-2 mm long .... *S. × drummondii*
- Stem individual. Lemma awns short and straight. Pedicel of sterile spikelets less than 1 mm long .. *S. bicolor*

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## REFERENCES

- Al-Modarres, A. Safavi, V. & Taheri, R. 2008: Sorghum. Jahad Daneshgahi Press, University of Isfahan, Isfahan, Iran. (in Farsi) 264 pp.
- Bor, NL. 1970: Gramineae in Rechinger, KH. (ed), Flora Iranica. 70: 147-244. - Graz.

- Clayton, WD. 1961: Proposal to Conserve the Generic Name *Sorghum* Moench (Gramineae) versus *Sorghum* Adans. (Gramineae). -Taxon. 10 (8): 242-243.
- Mill, R. R. 1985: *Sorghum* Moench in Davis, PH. (ed.), Flora of Turkey and the East Aegean Islands. Vol 8: 606-610.
- DeWet, JM. 1978: Special paper; systematics and evolution of *Sorghum* sect. *Sorghum* (Gramineae). -American Journal of Botany. 65 (4): 477-484.
- FAO. 2021: World cereal production in 2016 sets to 2521 million tons. FAO in the Islamic Republic of Iran, retrieved from <https://www.fao.org/iran/news/detail-events/ru/c/410341/>.
- Garber, ED. 1954: Cytotaxonomic studies in the genus *Sorghum*, the polyploid species of the subgenera *Parasorghum* and *Stiposorghum*. -Botanical Gazette. 1, 115 (4): 336-342.
- Harlan, JR. & DeWet, JM. 1972: A simplified classification of cultivated sorghum. -Crop Science. 12 (2): 172-176.
- House, L.R. 1985: A guide to sorghum breeding. International Crops Research Institute for the Semi-Arid Tropics. 238: 2-20.
- Jacobs, SW. 2007: Poaceae in Zhengyi, W. Peter, HR. & Deyuan, H. (eds). Flora of China. Missouri Botanical Garden. Vol. 22.
- Kalmakhan, M. Rosa, A. Gulzhayna, A. Aigul, A. Raikhan, K. Nurpeys, I. Rabiga, K. Elmira, A. Amina, D. & Zhaksylyk, M. 2020: Investigations of primary grain and sorghum materials in the South Kazakhstan region and development of methods for selecting their new varieties and hybrids. EurAsian Journal of BioSciences. 1, 14 (2).
- Karimi, A. & Saeidi, H. 2016: Genetic diversity of *Sorghum halepense* (L.) Pers. in Iran as revealed by IRAP markers. -Plant Genetic Resources. 14 (2): 132-141.
- Kellogg, EA. 2015: Flowering plants, Monocots: Poaceae. Springer. 416: 281-302.
- Nevski, SA. 1934: Tribe XIV. Hordeae Benth. in Komarov, V. L. (ed), Flora of the USSR. Vol. 2: 469-579.
- Ng'uni, D. 2011: Phylogenetics of the genus *Sorghum*, genetic diversity and nutritional value of its cultivated species. Swedish University of Agricultural Sciences. 63: 9-19.
- Parsa, A. 1950: Flora del Iran. Publication du Ministere del Education Museum. Histoire Naturelle De Tehran (in French). 4: 718-728.
- Peerzada, AM. Ali, HH. Hanif, Z. Bajwa, AA. Kebaso, L. Frimpong, D. Iqbal, N. Namubiru, H. Hashim, S. Rasool, G. & Manalil, S. 2017: Eco-biology, impact, and management of *Sorghum halepense* (L.) Pers. -Biological Invasions. 16: 1-9.

POWO. 2022: Plants of the World Online. Facilitated by the Royal Botanic Gardens, Kew. Published on the Internet; <https://powo.science.kew.org/taxon/urn:lsid:ipni.org:names:331290-2>. Retrieved 20 April 2022.

Snowden, JD. 1936: The cultivated races of sorghum. The cultivated races of sorghum.

Snowden, JD. 1955: The wild fodder sorghums of the section *Eu-sorghum*. Botanical Journal of the Linnean Society. 1, 55 (358): 191-260.

Tsvelev, NN. 1976: Zlaki SSSR. Cereals of the USSR. Science, Leningrad, Nauka (in Russian).