

**Suaeda iranshahrii, a new species of Suaeda subgenus Brezia (Chenopodiaceae) from the Persian Gulf coasts**

Received: 03.03.2013 / Accepted: 29.05.2013

**H. Freitag:** Prof., Plant Taxonomy, Institute of Biology, University of Kassel, 34132 Kassel, Germany

**R. Brandt:** PhD Student, Plant Taxonomy, Institute of Biology, University of Kassel, 34132 Kassel, Germany

**T. Chatrenoor:** PhD Student, Department of Plant Sciences, School of Biology, Center of Excellence in Phylogeny of Living Organisms, College of Science, University of Tehran, P.O. Box 14155-6455, Tehran, Iran

**H. Akhani:** Prof., Department of Plant Sciences, School of Biology, Center of Excellence in Phylogeny of Living Organisms, College of Science, University of Tehran, P.O. Box 14155-6455, Tehran, Iran (akhani@khayam.ut.ac.ir)

**Abstract**

*Suaeda iranshahrii* Akhani & Freitag, previous specimens cited as *S. maritima*, is described as a new species of sect. *Brezia* endemic to the coasts of the Persian Gulf; it is subdivided into the type variety distributed along the Persian side and var. *arabica* Freitag from the Arabian shore. The new species is named in honour of Dr. Musa Iranshahr, the eminent Iranian botanist to whom this Festschrift is dedicated on the occasion of his 90th birthday. The species is an important component of plant communities on tidal mudflats. Molecular, anatomical and caryological evidence pointed to *S. crassifolia* as the closest relative and putative progenitor.

**Keywords:** Amaranthaceae, anatomy, cytology, halophytes, phylogeny, SW Asian flora

**Introduction**

The genus *Suaeda* embraces a world-wide distributed group of halophytes. While the species of subgenus *Suaeda* are mostly xero-halophytic C₄-plants growing under arid conditions in the subtropics, the c. 30 species of subgenus *Brezia* Freitag & Schütze are hygro-halophytic C₃-plants of coastal and inland habitats occurring mainly in temperate zones. In the standard Floras covering the area of the Persian Gulf, e.g. Flora of Eastern Saudi Arabia (Mandaville 1990), Flora of the Arabian Peninsula (Boulos 1996), Flora Iranica (Akhani & Podlech 1997, Hedge et al. 1997), Flora of the Kingdom of Saudi Arabia (Chaudhary 1999), altogether three species of subg. *Suaeda* sect. *Salsina* are reported: *S. aegyptiaca* (Hasselq.) Zohary; *S. fruticosa* Forssk. (sometimes cited as *S. vermiculata* Forssk.); the recently described *S. baluchistanica* Akhani & Podlech. With regard to subg. *Brezia*, all the floras agree in citing *S. maritima* (L.) Dumort.

The species belonging to subg. *Brezia* sect. *Brezia* was only relatively recently reported by Mandaville (1990) who named a couple of collections from the coast of Saudi Arabia *S. maritima*. That name was adopted for other Floras of the Arabian Peninsula, where a few more localities were added, as well as to the *Suaeda* species occurring in coastal plant communities in Bahrain (Abbas 2002) and in a floral checklist of Qatar (Böer & Al Hajiri 2002) and the Emirates (Jongbloed et al. 2000) but not in the later comprehensive field guide (Jongbloed et al. 2003). Two collections from Bandar-e Mahshahr and Bandar-e Mogham at the Iranian coast were also identified as *S. maritima* by Akhani & Podlech (1997).
Afterwards, in an integrated molecular and morphological study, Schütze et al. (2003) reported that *S. maritima* is restricted to the Atlantic and N Mediterranean coasts of Europe and replaced further east by the closely related *S. salsa* (L.) Pall. and the more distantly related *S. crassifolia* Pall. In a deeper study that included material from Qatar, Schütze (2012) showed that in their nuclear (ITS) and chloroplast sequences (*atpB-rbcL/psbB-psbH*), the *Brezia* populations from the Arabian shores of the Persian Gulf differ significantly both from *S. maritima* and *S. salsa* and are more closely related to *S. crassifolia* Pall. from C Asia and *S. crassifolia* and *S. heteroptera* which are distributed from central to east Asia. The plants from Qatar sequenced by Schütze, which also in leaf anatomy approach to *S. crassifolia*, were provisionally named “*S. arabica*” by H. Freitag. Almost at the same time, H. Akhani carried out extensive field studies along the Iranian side of Persian Gulf to clarify the same question by sequencing ITS nuclear marker, doing anatomical, cytological, pollen morphological, co-cultivation and ecological studies. Re-assessing his former interpretation, he used the name *S. aff. maritima* in recent publications (Akhani 2011, Akhani & Deil 2012, Dehghani & Akhani 2009) replacing the name of *S. maritima* in the Flora Iranica (Akhani & Podlech 1997). After personal contact, we realised that both of us were going to describe the same species: one from Iranian and the other from Arabian side of the Persian Gulf. Consequently, after a work session in Kassel, we combined our data. New ITS and chloroplast sequences were generated and compared with other *Brezia* species in Kassel by R. Brandt in addition to published sequences by Schütze et al. (2003) and unpublished sequences by H. Akhani. Although, we both intended to publish formally our new species with different epithets, we agreed on the name *S. iranshahrii* to commemorate this species in honour of the eminent Iranian botanist Dr. Musa Iranshahr on the occasion of his 90th birthday. Though the first author drafted the descriptions for the Arabian populations and the corresponding one dealt with the specimens collected along the Iranian coast of the Persian Gulf, both of us are equally responsible for the manuscript.

*Suaeda iranshahrii* Akhani & Freitag, sp. nov. (Figs 1–7).

**Type:** S Iran: Khuzestan prov., Mahshahr, Petrochemical Complex, margin of Khore Musa, Pole Sazandegi (bridge), 30°29’4” N, 49°06’00” E, sea level, tidal zone, 21.01.2008, H. Akhani 19140 (Holotype: IRAN; Isotypes: KAS, Herb. H. Akhani). GenBank acc. nos. KC763842 (ITS), KC763846 (*rpl32-trnL*).

- **Diagnosis**
  Differing from *Suaeda maritima* and *S. salsa* in the more succulent, semi-terete to terete leaves, much shorter internodes, smaller sized flowers, fruiting perianths and seeds, by being diploid and by strongly different chloroplast sequences (*rpl32-trnL*); similar in sequences to *S. crassifolia* and *S. heteroptera*, but from those it is distinguished by the more delicate appearance, a later fruiting period, often biennial habit and by the absence of regular lens-shaped seeds with hard blackish testa; differing from all other taxa in its distribution (endemic to the coasts around the Persian Gulf).

- **Description**
  Annual or, more rarely biennial, (10)20–40(80) cm high and up to 50 cm wide, erect or sometimes prostrate in the lower parts, stems usually branched from the base with spreading to ascending branches of 1st and 2nd order; living plants bluish green or green, turning pinkish red to deep red and drying brownish. Shoots densely leafy, with usually 2–2.5 mm long internodes, leaves below the inflorescences soon dying back, turning whitish and shed. Stem at base up to 5 mm and in biennial plants up to 15 mm thick, branches in lower part light grey to brownish, rough from prominent leaf abscessions, younger stems glabrous, striate, green-lined, becoming woody at base. Leaves 10–30(35) mm long, 0.75–2(2.5) mm wide (in dry condition), decreasing in size towards the inflorescence and the base, ascending to spreading, strongly succulent, semi-terete to almost terete, linear in outline, apex ± obtuse, at base slightly
attenuated and at the adaxial side with a bulge that later becomes the abscission zone. Inflorescences weakly separated, delicate due to gradually shorter bracts and additional branches of 3rd order. Bracts leaf-like, longer than internodes, (10)8–4(3) mm long, ascending or spreading to slightly incurved or recurved, surpassing the axillary flower/fruit clusters, somewhat sheathing at base. Bracteoles 0.3–0.9 mm long, membranous, circular to ovate, obtuse to acutish, entire or slightly crenate to dentate. Flowers (1)3–5(7) per glomerule, bisexual or partly female, flat, almost circular, 1.0–2.5 mm diameter (when dry). Tepals usually 5, subequal or the outermost one slightly larger, incurved, fused for about 3/5, the apical lobes rounded, obtuse, with thin hyaline margins. Stamens usually 5, filaments 0.3–0.8(1) mm long, incurved, thread-like, inserted on lower part of tepals; anthers 0.4–0.5 mm long, wide and thick, divided for about 1/3–1/2. Ovary superior, depressed, the 2 stigmas 0.15–0.6 mm long, erect, with very short papillae, parallel or slightly diverging from a 0.1–0.3 mm long cylindrical style. Fruiting perianth 1.5–2.5(3) mm in diameter, otherwise almost unchanged, tightly enclosing the fruit. Seeds (1.2)1.4–2(2.3) mm in diameter, disc-shaped, with thin, light-brown testa; lens-shaped seeds with thick, blackish testa very rare (only sparsely in two collections from Iran), 0.9–1.1 mm wide, 0.5–0.6 mm thick, shiny, but finely reticulate by slightly bulging outer periclinal cell walls.

- Flowering and fruiting times: V–IX and VI–II, widely overlapping; seed maturity reached in October/November, germination commences in January/February.

- Leaf anatomy (Fig. 4E, F)

The succulent leaves are isobilateral with two to three peripheral layers of C3 chlorenchyma followed up adaxially by aqueous tissue consisting of 1–2 layers of very large thin-walled cells without chloroplasts. The vascular system is clearly displaced towards the abaxial side, with the central bundle located below the centre of the leaf and many small lateral vascular bundles attached to the adaxial chlorenchyma. The epidermis cells among the two samples differ considerably in shape, probably due to different environmental conditions in the field or phenology. Further studies are a desideratum.

- Chromosome numbers

In gametophytic chromosome complements (cult. from Akhani 19137, Mahshahr area in Iran), n=9 corresponding to 2n=18 (diploid) was counted, while in metaphase plates from root tips of seeds from Qatar (coll. by B. Böer) 2n=18 was found (M. Lomonosova, pers. comm.).

- Pollen morphology

The pollen morphology of the new species was described as S. aff. maritima in Dehghani & Akhani (2009) based on the samples Akhani 7967 and Mozaffarian 58687 from S Iran. The pollen grains are pantoporate and similar to other known species of the genus. The average pollen diameter is 21.76 and the average pore number is 92.81. The pollen diameter is similar to other species of sect. Brezia in SW Asia but differs markedly from S. maritima (samples from S England) by its smaller size.

- Molecular characters

Two samples each from the Arabian and the Iranian coast fully agree in their nuclear ITS and chloroplast rpl32-trnL sequences. In both phylogenetic trees (Fig. 5A, B), they form separate subclades, however with somewhat differing sister subclades and individual sister species. In the ITS tree, the unsupported S. iranshahrii subclade arises from a polytomy beside of three well supported other subclades containing S. heteroptera, S. crassifolia, S. maritima/salsa and branches leading to individual samples of S. crassifolia and S. salsa. In the cp tree, the S. iranshahrii subclade is also positioned on a polytomy but with moderate support and likewise joined by S. crassifolia and S. heteroptera subclades beside a few branches representing individual samples of those species. Most clearly, like all lineages arising from the polytomy except for one S. salsa sample, S. iranshahrii is separated from S. maritima and S. salsa by a deep split.

1. GenBank accession numbers of S. iranshahrii are added to the enumerations of specimens; the complete set of molecular data and results will be published in the forthcoming thesis of R. Brandt on the phylogeny, systematics and biogeography of Suaeda subg. Brezia.
- Distribution (Fig. 6)

Rather patchy but locally very common in the coastal lowlands around the Persian Gulf. For an earlier map of var. arabica see Boulos in Miller & Cope 1996, map 331 (p. 256). The species was known to occur widely along the Arabian coast of the Gulf, but now seems to be in serious decline because of massive development projects. Qatar probably has the best remaining stands, but coastal development remains a biodiversity conservation issue for this new species (Böer, pers. comm.). The Abu Dhabi and Ras al-Kheima localities have not been confirmed in recent years. The occurrence of S. iranshahrii in Kuwait needs confirmation. Halwagy (1972) doubtfully reported S. maritima from two localities (Fintass and Kathma). The Iranian populations in Khuzestan province are very close to Kuwait and, therefore, its presence in Kuwait is more likely.

- Habitat (Fig. 7)

On the southern and northern shores of the Persian Gulf, it is restricted to the middle and upper tidal belt of mud flats in sheltered bays, lagoons and estuaries of rivers; often dominant together with the annual Salicornia sinus-persica Akhani (Fig. 3C, see also Akhani & Deil 2012) at the outer belt of salt marshes, sometimes with Arthrocnemum macrostachyum (Moric.) K. Koch, or forming a belt between a mangrove of Avicennia marina (Forssk.) Vierh. and salt-marshes of Halocnemum strobilaceum (Pall.) M. Bieb. (Fig. 7B). For details see also Abbas (2002), Akhani (2008) and Akhani & Deil (2012). Here, the stands of S. iranshahrii var. arabica are frequently interspersed with Limonium axillare (Forssk.) Kuntze and Haloepis perfoliata (Frssk.) Bunge ex Schweinf. & Asch. The substrate can be sandy or loamy and often it is marked by crab-holes (Böer, pers. comm.).

- Two following varieties are recognized:

1. Bracts ascending, straight or slightly incurved. Bracteoles 0.3–0.5 mm long, almost circular to broadly ovate, without a petiole-like stipe. Stamens not exserted, filaments 0.3–0.4 mm long. Stigmas 0.15–0.2 mm long. Fruiting perianth 1.5–2 mm in diameter, without outgrowths. Seeds 1.2–1.6 mm in diameter. Arabian coast…………………………………… var. arabica

a. var. iranshahrii

Ic. Figs 1; 3A, C, D; 4 A–E; 7A. For published figures (as S. aff. maritima) see Akhani (2011).

Hormozgan: Bandar-e Mogham, ca. 10 m, 21.11.1985, V. Mozaffarian 58687 (TARI, Hb. Akhani); 5 km NE of Bandar Khamir, coast of Persian Gulf, 26°58’52” N,

b. var. arabica Freitag

Type: Saudi Arabia: Eastern prov., Dammam, bay to the north of the city, mud flats inundated at very high tide, repeat [of] 6196, in fruit, 26.11.1987, I.S. Collenette 6196 (Holotype: K; iso E1, RIY).

Ic. Figs 2; 3B; 4FM; 7B. For published figures (as S. maritima) see Mandaville (1990: 82, phot. 31), Chaudhary (1999: Pl. 92), Collenette 1999, p. 156. Differs from the typical variety by the characters cited in the preceding diagnostic key.

- Additional specimens examined: Saudi Arabia: Eastern prov., Abu Ali island near Jubayl, 09.1992, B. Böer 18 (KAS); North Dammam, tidal mud flat, 30.03.1987, I.S. Collenette 6196 (E, K); ditto, 29.03.1987, I.S. Collenette 6297 (E, K); ditto, 26.11.1987, I.S. Collenette 6196 (E, K); Tarut Island, 25.04.1987, T. Al-Turki 11100 (RIY, KAS), GenBank acc. nos. KC763841 (ITS), KC763845 (rpl32-trnL), ditto, 29.09.1987, I.S. Collenette 6297 (E, 12194-RIY); ditto, W coast, 26°34' N, 50°02' E, 29.09.1967, J. Mandaville 1105 (BM); ditto, Tarut Bay, 06.10.1982, J. Mandaville 7809A (E, KAS, RIY); ditto, north shore, 26.11.1987, I.S. Collenette 6414 (E, K); ditto, Abu Ali Island, B. Böer 18.09.1992 (KAS), GenBank acc. nos. FJ449814 (ITS), KC763844 (rpl32-trnL); Dareen Island, 05.05.1987, S. Chaudhari & A. Al-Juwaid 12205 (RIY), 12674 (RIY, KAS).

Bahrain: Sitra (h), 1964, T. Carpenter 29 (K); Tubli Bay, A.M. Alder 122 (E).

Qatar: Al Khor (Khawr), outside the town, in salt marshes. 04.04.1977, L. Boulos, 11171 (B); N of al-Khor, near al-Dhakira, 15.03.1988, A. Babikir & H. Kürschner 88-341 (B).

- Variability

The two varieties also differ somewhat in their general appearance. The plants from the Arabian coasts have a more delicate habit, not only in their reproductive parts (see above) but also by thinner leaves. However, there is much overlap. Another feature is that no flowers with exerted stamens were observed yet. Most likely that character is associated with predominant autogamy in the otherwise very homogenous populations. In contrast, the Iranian populations vary considerably in size of flowers and fruits (largest in Akhani 7970), in the scattered occurrence of regular blackish seeds (Akhani 7967, 7970) and in the length of inflorescence internodes (longest in Akhani et al. 20471).

A remarkable feature observed in both varieties is the clearly biennial habit. It seems to be more common on the Iranian side but is also documented from the type locality of var. arabica. While the type specimen with partly mature seeds was collected as late as November 26th, a preceding collection also made by Mrs Collenette at March 13th consists of young vegetative shoots carrying freshly formed leaves in continuation of last-year shoots with dead and deflexed leaves. According to Böer (pers. comm.), the regular life cycle starts in February/March, reaches flower in summer, passes into fruit while increasingly changing in colour to red and ending up with shedding of fruits/seeds and dying off in December/January when turning brown. However, some early seeds can germinate and start full vegetative growth in autumn, slow down during the short and mild winter season and resume full growth in the following year. Occasionally, flowers have been observed as early as April (Akhani & Pahlevani 20815). Interestingly, biennial plants were usually not found on the typical mudflats, but on elevated habitats with a stony substrate where they sometimes form a narrow belt (Fig. 3A, C).

- Systematic relationship

In general morphology, in particular habit and perianth structure, the new species appears to be similar to S. maritima, S. salsa, S. spicata Willd. and S. crassifolia Pall., but it differs from all of them in its
longer life cycle and the almost exclusive reproduction by ‘irregular’ disc-shaped seeds with a light-brown and thin testa. The ITS tree (Fig. 4A) rules out any affinity to the Mediterranean S. spicata and both the cp tree (Fig. 4B) and the diploid chromosome complements do not support a closer relationship to the tetraploid species S. maritima from Europe and S. salsa from Eurasia. Instead the cp tree shows S. crassifolia and S. heteroptera Kitag. as sister species to S. iranshahrii and this is corroborated by their diploid conditions. As S. heteroptera differs by distinctly unequal tepals and is geographically far distant in Siberia and Mongolia, S. crassifolia appears to be the species most closely related to S. iranshahrii. With its area extending from Central Asia to North and Central Iran and the eastern Black Sea coast (unpubl. data of HF and HA), it also spatially comes closer. Another argument in favour of S. crassifolia as being the closest relative is the identical leaf anatomy. Both species share the same "S. crassifolia-variant" of the Brezia type (Schütze 2012) which is intimately related to the high degree of succulence.

It can be hypothesized that S. iranshahrii originated directly from populations of S. crassifolia. That could have happened during the Pleistocene when the range of S. crassifolia was forced southwards by decreasing temperatures. In subsequent warmer interglacial phases there a part of the population might have adapted to increasing higher temperatures and a longer growing season. The establishment in a climatic zone without real winter frost might also have led to the loss of ‘regular’ seeds with a thick blackish testa because their inherent seed dormancy was no longer required. It is most likely that similar scenarios also led to the origin of other southern derivate species of northern immigrants, e.g. Bienertia sinuspersici Akhani and Salicornia sinus-persica Akhani (Akhani et al. 2005, Akhani 2008). Additionally, Bienertia also shows some parallelism in producing regular and irregular fruits; while B. sinuspersici from coastal southern Iran produces both types of seeds, the closely related sister species B. cycloptera that occurs from Central Asia to Transcaucasia in a region with very cold winters, has exclusively seeds with black testa (pers. obser. HA.).

Though, both varieties share the same ITS and rpl32-trnL sequences, the type variety from the northern shores of the Persian Gulf comes closer to S. crassifolia in morphology. That might be explained by some gene flow that happened after the divergence of the two taxa. Understanding the geographical separation of the two varieties still poses problems because the Persian Gulf is just 250–300 km wide and floating seeds might easily reach the opposite coast, in particular during storms from the north which are not uncommon during winter.

Acknowledgements

H.F. is most thankful to Dr. B. Böer from the UNESCO office in Doha for information concerning the populations along the Arabian coast, in particular about their ecology and phenology. He provided photos and technical support. The curators of B, BM, K and RIY were helpful by loan of herbarium specimens. H.A. acknowledges Petrochemical Special Economic Zone and the former director of the Environmental Office Engr. F. Nejat-Bahadori for supporting several field trips in the Southern Khuzestan and associated Islands during the research project ‘Plants of Petrochemical Special Economic Zone and adjacent ecosystems’. He is further thankful to Alexander von Humboldt Foundation for supporting his research stay in Germany during 2011–12. We acknowledge the laboratory assistance of Dr. R. Khoshravesh and of Mrs. I. Diebel for preparing anatomical cross sections. We also greatly acknowledge critical reading of the manuscript and suggestions given by I. Hedge, Edinburgh, Benno Böer, Doha and an unknown reviewer.
Fig. 1. Holotype of S. iranshahrii Akhani & Freitag var. iranshahrii: Akhani 19140 (IRAN) (Photo H. Akhani).
Fig. 2. Holotype of *S. iranshahrii* Akhani & Freitag var. *arabica* Freitag: *Collenette 6404* (K) (Photo H. Freitag).
Fig. 5. Phylogenetic trees containing an identical set of 42 accessions belonging to sect. *Brezia* and 4 from sect. *Schoberia*. The numbers above branches are bootstrap values. A. Majority rule consensus tree of 1020 most parsimonious trees derived from the nuclear rDNA ITS region. B. Majority rule consensus tree of 37465 most parsimonious trees based on the chloroplast *rpl32-trnL* region (By R. Brandt).

Fig. 6. Distribution of *Suaeda iranshahrii*: The grey circles refer to records by Jongbloed et al. (2000) from UAE and Halwagy (1972) from Kuwait. All records from the Arabian side belong to var. *arabica*, those from the Iranian coast to the typical variety.
Fig. 7. Habitats of *S. iranshahrii*: A. var. *iranshahrii*, Khure Musa tidal zone, with an outer belt of *S. iranshahrii/Salicornia sinus-persica* and an inner belt with *Halocnemum strobilaceum*, 6.3.2009, inset shows seedling plant in nature 12.3.2009, B. var. *arabica*, coast near Al Khor N of Doha, Qatar, with the common sequence of vegetation belts on lagoon habitats in the different tidal zones from *Avicennia marina* to *Suaeda iranshahrii/Salicornia sinus-persica* and *Halocnemum strobilaceum*, 11.10.2012 (A. Photo H. Akhani, B. Photo B. Böer).
References


