

TAXONOMIC REVISION OF THE GENUS *SALICORNIA* L. (CHENOPODIACEAE) IN CENTRAL AND SOUTHERN IRAN

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Abstract

Salicornia is a most complicated vascular plant group which its taxonomy and species circumscription is considered as a night-mare. This first revision of Iranian species is based on long-term field studies, co-cultivation of plants in the laboratory, ecological, cytological and molecular studies and determination of carbon isotope composition. In this paper the species of Central and Southern Iran are dealt with which will be followed by another paper on the Northern and Northwestern parts of Iran. In this paper the presence of four species, one subspecies and one putative hybrid in the area is accepted. In addition to recently described *S. persica* Akhani from Central Iran, four more new taxa and one new putative hybrid are described for science: (1) *S. iranica* Akhani spec. nov. is a diploid species widespread in central Iranian salines. This is characterized by erect habit and short opposite upper spikes; (2) *S. sinus-persica* Akhani spec. nov. is described from Southern Iran in Khuzestan, Bushehr and Hormozgan Provinces along the saline and brackish rivers running to the Persian Gulf and estuaries and coastal habitats. This is a diploid species characterized by yellowish colour and ascending to loosely prostrate and much branched habit; (3) *S. persopolitana* Akhani spec. nov. is related to *S. persica* which is described from South-Central Iranian salines around Tashk and Bakhtegan hypersaline lakes. This is a prostrate plant with leaf-like bracts, a character which is known for the first time in the genus *Salicornia*; (4) *S. persica* subsp. *rudshurensis* Akhani is a taxon found in North-Central Iran in Tehran province which differs from typical subspecies by slender spikes and obtuse central flowers; and (5) *S. x tashkensis* Akhani hybrid nov. is a putative hybrid found only in Tashk lake in South-Central Iran. The elongate and pendant fruiting spikes and absence of seeds in most flowers is distinctive in this taxon. The carbon isotope composition ($\delta^{13}\text{C}$) of most species are given and the chromosome numbers (so far investigated) are reported. The ecology, threats and biogeographical importance of the species are discussed and photographs of living plants are provided. An identification key to the known species of Iranian *Salicornia* is given.

Introduction

The Central and South West Asia are the major centres of diversification of halophytes, in general and the family Chenopodiaceae, in particular. The large expansion of saline soils and diverse climate and topography in Iran with extensive saline habitats in temperate and hot deserts provide conditions for diversification of this intriguing group. The first comprehensive account of family Chenopodiaceae in Flora Iranica (Hedge *et al.*, 1997) provides very useful and fundamental data on the arid flora of the Old World. However, this first account which arose from pre-molecular era and mostly done by scientists with less opportunity to accomplish their studies using field works and modern techniques, needs to be improved.

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The genus *Salicornia* is a cosmopolitan genus which its taxonomy correctly described by a recent overview of the genus as a night-mare (Kadereit *et al.*, 2007). Hedge (1997) and many other references on the Iranian flora mentioned the presence of only *Salicornia europaea* L. in Iran. However, subsequent intensive field studies by the author in almost all populations of *Salicornia* in Iran and Turkey and comparing with a population of *Salicornia europaea* L. in S. England and other populations in Central and Western Turkey, and molecular studies (in preparation), co-cultivation experiments, and cytological data (Ghaffari *et al.*, 2006) revealed rejection of the presence of *S. europaea* in Iran and occurrence of a remarkable diversity in Iranian *Salicornia*. In addition to a recently described endemic species *S. persica* (Akhani, 2003), there are at least five more taxa in the Central and Southern Iran need to either be described or clarified their identity.

In this paper a taxonomic revision of the genus *Salicornia* of the Central and Southern Iranian populations is given. A complete revision awaits compilation of the ongoing study in the Northern and Northwestern parts of Iran. Three new species are described which their novelties have already been announced by the author (Akhani, 2004a: 68 and 2006: 83). A key to the identification of known species and their descriptions are provided. Details on the habitat, ecology, carbon isotope composition, phytogeographical importance, cytology, threats and living pictures of all taxa are given.

Materials and Methods

The populations of Iranian *Salicornia* in Central and Southern provinces of Iran including the coastal area around Persian Gulf have been studied during various excursions in 1987, 1991, 2001, 2003, 2005 and 2008. Using field observations the variability of taxa have been studied and followed by subsequent observations during flowering and fruiting time to check whether observed differences are genetically fixed or might represent interpopulation, morphological or phonological plasticity. Some measurements have been made in the field and additional detailed measurements were made after transferring the fresh plants into laboratory. The chromosome numbers have been counted based on mitosis of the young root tips and described in Ghaffari *et al.* (2006). The carbon isotope compositions have been measured according to the methods described in Bender *et al.* (1973). The cover-abundance of associated species has been recorded according to the method of Central European School of Plant Sociology (Braun-Blanquet, 1964). The holotypes of all new taxa are kept in the herbarium of Plant Pathology Research Institute (IRAN) and all other materials including isotypes are in the Botanical Biodiversity Research Laboratory (BBRL, Hb. Akhani), School of Biology, University of Tehran.

A key to identification of Central and South Iranian *Salicornia*

It is virtually impossible to name a dried plant of *Salicornia* using any key. Therefore the following key can be only applicable for fresh plants. The colour iconography provides best tool for identification (Figs. 1, 3-7) which are available only in electronic version of the paper.

1. + Central flowers truncate, reaching to the upper spike segments, plants ascending or prostrate 2

- Central flowers obtuse, not reaching to the upper spike segments, plants usually erect, rarely ascending or prostrate..... 3
- 2. + Plants ascending-erect, leaves not distinct, a very common plant in most of salines in Esfahan, Yazd and Fars provinces *S. persica* Akhani subsp. *persica*
 - Plants completely prostrate on the ground, bracts leaf-like; presumably endemic around Tashk and Bakhtegan lakes *S. perspolitana* Akhani
- 3. + Upper inflorescence branches verticillate, (6-) 8-20 cm long 4
 - Upper inflorescence branches opposite, up to 7 cm long 5
- 4. + Plant erect, spikes pendant, few flowers produce seeds; a restricted taxon and a putative hybrid swarm restricted to the shores of Tashk lake *S. x tashkensis* Akhani
 - Plant ascending, spikes erect, all flowers usually produce seeds; plant known from river saline shores of Rud-e Shur in Central Iran *S. persica* subsp. *rudshurensis* Akhani
- 5. + Plant much branched from base, loosely and unilaterally prostrate, remaining of reduced leaves visible on lower and middle vegetative branches, young and ripe branches yellowish-green; seeds of central flowers 1.4-1.9 x 0.9-1.2 (-1.4) mm; those of the lateral flowers 0.8-1.6 x (0.6-) 0.7-1 mm; habitat on less saline soils or tidal zone in southern Iran and coasts of Persian Gulf *S. sinus-persica* Akhani
 - Plant with loose open branching; erect, never prostrate, remaining of dried cortex and reduced leaves not visible on lower and middle vegetative branches, young branches deep green, old branches reddish, seeds of central flowers 1.1-1.4 x 0.6-1.1 mm, those of the lateral flowers 0.7-0.9 mm x 0.5-0.6 mm; habitat on high saline soils of inland salines and river margin in Central Iran *S. iranica* Akhani

Enumeration of species

Salicornia iranica Akhani spec. nov. Fig. 1.

Typus: N. Tashk Lake near Gomban, 29°47'47"N, 53°28'41"E, 1589 m, 28.11.2001, H. Akhani 15908 (Holotypus: IRAN; isotypus Hb. H. Akhani).

Annual. Caulis 20-60 cm altus, erectus, ramosus, laetus viridescens, post anthesin rubescentis. Internodium caulinum 9-16 mm longum, internodium lateralis cauliculum 8-13 mm longum. Inflorescentia caulinum lateralibus opposita (non verticillata), inflorescentia apicalis 2.2-3.6 cm longa, 3.3-4 mm lata, segmentum sterilis basalis 5-30 mm longum; segmentulum in numero 8-18, 2-3 mm longum, scariosum marginatum (0.14-0.29 mm). Inflorescentia lateralis 15-24 mm longa, 2-3 mm lata, segmentum sterilis basalis 1-2.5 mm longum; segmentulum in numero 10-14, 1.8-3 mm longum, 2-3 mm latum. Flores centralis obtusiusculae 1.5-2 mm longae, 1.4-2 mm latae; flores lateralis 1.2-1.5 mm longae, 0.9-2 mm latae. Anthera 1-2, 0.49-0.52 mm longa. Stigma 2, 0.23-0.41 mm longa. Semina sparsa curvato pilosa, 0.4-0.15 mm longa. Semina floribus centralibus elliptica 1.1-1.4 x 0.6-1.1 mm. Semina floribus lateralibus ovoidea 0.7-0.9 x 0.5-0.6 mm.

Annual, 20-60 cm tall, erect, obliquely branched from a main stem, deep green in early flowering time, becoming red in fruiting time, internodes of main stem 9-16 mm long, internodes of lateral braches 8-13 mm long; inflorescence branches opposite (not verticillate); terminal spikes 2.2-3.6 cm long, 3.3-4 mm width; sterile basal segment 5-30 mm long; segments 8-18, 2-3 mm long, with 0.14-0.29 mm scarious margin; lateral spikes 15-24 mm long, 2-3 mm diameter, sterile basal segment 1-2.5 mm long; segments

10-14, 1.8-3 mm long, 2-3 mm width; central flowers obtuse, rhombic, not reach to the upper segment, 1.5-2 mm long, 1.4-2 mm width; lateral flowers 1.2-1.5 mm long, 0.9-2 mm wide; anthers 1-2, 0.49-0.52 mm long; stigma 2, 0.23-0.41 mm long; seeds sparsely pilose, hairs uncinata, 0.4-0.15 mm long; seeds of central flowers elliptic 1.1-1.4 x 0.6-1.1 mm, seeds of lateral flowers ovate, 0.7-0.9 x 0.5-0.6 mm.

Additional examined materials: Esfahan: Esfahan: Varzaneh, Zayand-e-rud river bed, 32°25'32"N, 52°39'5"E, 1493 m, 16.9.2001, H. Akhani & M. Ghobadnezhad 15669; Fars: N. Tashk Lake, high salty soils near Gomban, 29°48'N, 53°28'E, 1590m, 20.9.2001, H. Akhani & M. Ghobadnejhad 15721; Tehran: ca. 60 km W Tehran, Mardabad salt flats, 35°43'4"N, 50°44'24"E, 1169 m, 24.10.2004, H. Akhani 17422; *ibid.* 6.11.2003, H. Akhani 17440; *ibid.* 10.10.2003, H. Akhani 17315.

Several other specimens of this species have been collected by the author during 1987. These are kept in herbarium of Research Institute of Forests and Rangelands (TARI). In order to include these specimens a recent re-examination was necessary. Unfortunately access to material in this herbarium is hardly available for public use.

S. iranica is a typical diploid species characterized by short opposite spikes which its color changes to red earlier than other associated species (Fig. 1). It occurs commonly in most salines in Central and South-Central Iranian salines. Together with *S. persica*, it is the most common species around Tashk Lake (Table 1) and Gavkhooni wetland. Along Rude-Shur in Tehran provinces it occurs in drier habitats comparing with *S. persica* subsp. *rudshurensis* (Fig. 5). *S. iranica* is easily distinguishable from *S. persica* by opposite short spikes and its colour which change to red in fruiting time. The ongoing studies reveal that *S. iranica* is a complex of itself and further studies may lead to separating further taxa within this complex. More studies are required to be sure of the occurrence of *S. iranica* in salines of Azerbaijan and Anatolia and further into Caspian Sea and Aral Lake shores.

Cytology: 2n=18 based on four counts (Ghaffari *et al.*, 2006).

***Salicornia sinus-persica* Akhani spec. nov. Fig. 3.**

Type: ca. 15 km NW of Borazjan, Abpakhsh, along Shirin river, , on saline sandy soils under shade of *Tamarix*, 29°21'33"N, 51°5'21"E, 40m, 29.11.2001. H. Akhani 15923 (Holotypus: IRAN; isotypus: Hb. H. Akhani)

Annua vel bienna. Caulis 25-55 cm altus, post anthesin viridi-lutescens, basi racemifera, ±unilateralis prostratis, ad basin corticatis. Internodium caulinum 10-14 (-20) mm longum, internodium racemulosi 7-10 mm longum. Inflorescentia apicalis 2.4-4.6 cm longa, 2.5-4 (-4.5) mm lata; segmentulum in numero 9-18, 2.5-3.5 mm longum; segmentum sterilis basalis (1-) 2-4 mm longum. Inflorescentia lateralis 0.8-3.5 cm longa, segmentulum (3-) 6-15, (2-) 3-4 (-4.5) mm longum, segmentum sterilis basalis 1-2 mm longum. Flores centralis ovoideo-rhombiformis, apice obtusae, segmentibus brevibus, (1.5-) 1.8-2.8 mm longae, 1.8-2.2 (-2.4) mm latae, flores lateralis 1.1- 1.6 (-2) mm longae, 1-2 mm latae. Semina floribus centralibus 1.4-1.9 x 0.9-1.2 (-1.4) mm , semina floribus lateralibus 0.8-1.6 x (0.6-) 0.7-1 mm, pilosa.

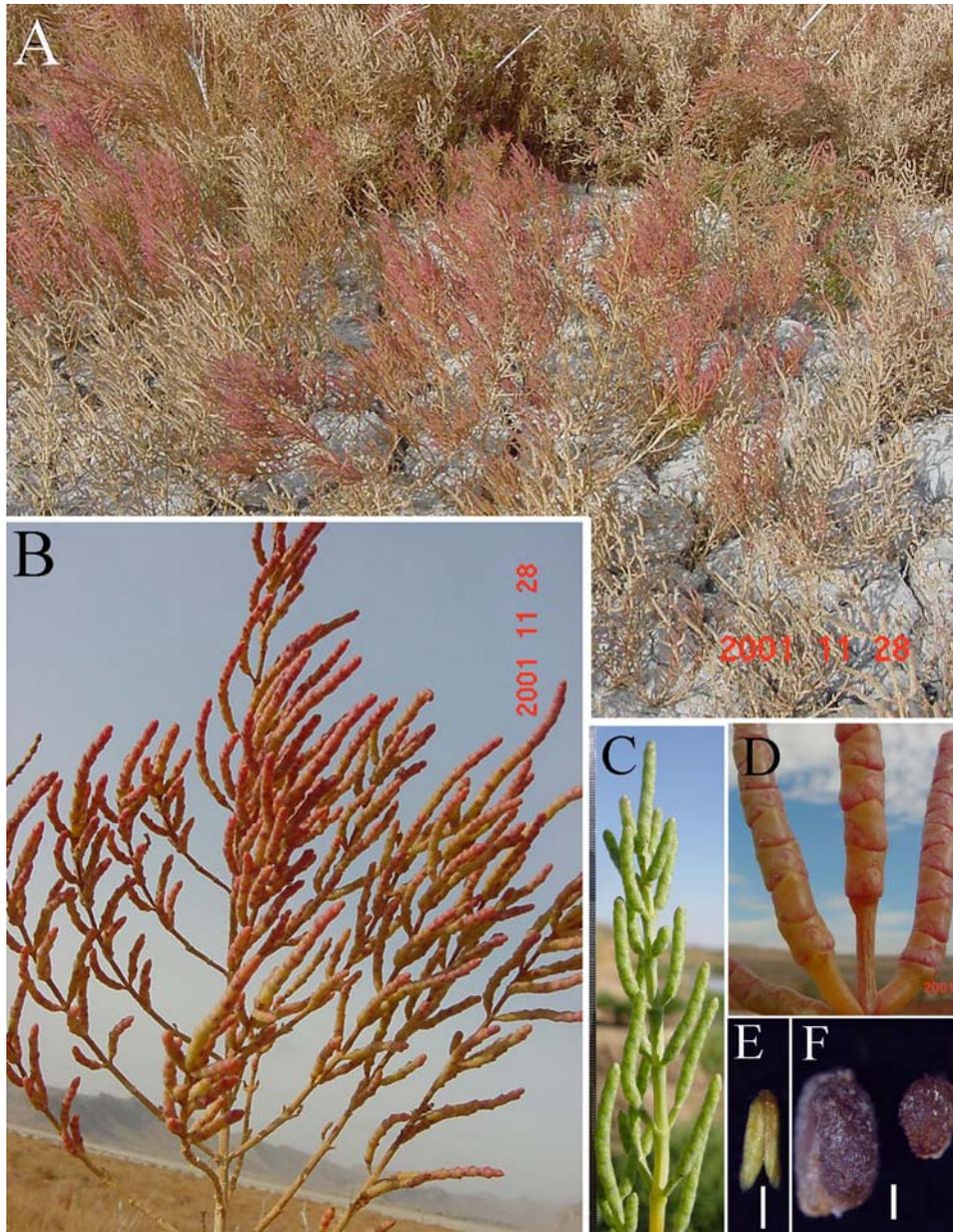


Fig. 1: *Salicornia iranica* Akhani. A-B: Habit and branching in type locality, Tashk lake, C: early fruiting inflorescence branches, Rude Shur, 60 km W Tehran; D: fruiting spikes; E: anther (scale bar 0.2 mm); F: seeds of central (left) and lateral (right) flower (scale bars 0.3 mm)

Annual, rarely biennial, 25-55 cm tall, young and ripe branches yellowish-green, loosely much branched from base, \pm unilaterally prostrate, dried cortex and reduced leaves remain on lower and middle parts of vegetative branches, internodes of main stems 10-14 (-20) mm long, internodes of lateral branches 7-10 mm long; terminal spikes 2.4-4.6 cm long, 2.5-4 (-4.5) mm thickness, segments 9-18, length of segments 2.5-3.5 mm, sterile basal segment (1-) 2-4 mm; lateral spikes 0.8-3.5 cm long, segments (3-) 6-15, (2-) 3-4 (-4.5) mm long, sterile basal segment 1-2 mm long; central flowers ovate-rhombic, apex obtuse, not reach to upper segment, (1.5-) 1.8-2.8 mm length, 1.8-2.2 (-2.4) mm width; lateral flowers 1.1- 1.6 (-2) mm long, 1-2 mm width; seeds pilose, those of the central flowers 1.4-1.9 x 0.9-1.2 (-1.4) mm; those of the lateral flowers 0.8-1.6 x (0.6-) 0.7-1 mm.

Additional examined specimens: Bushehr: 16 km N Borazjan towards Konartakhteh, margin of a salty stream, 29°24'5"N, 51°16'25"E, 93m, 30.11.2001, Akhani 15949; 17 km W Kebkan towards Bardkhoon, *Tamarix* stand along Mond river, 28°8'58"N,

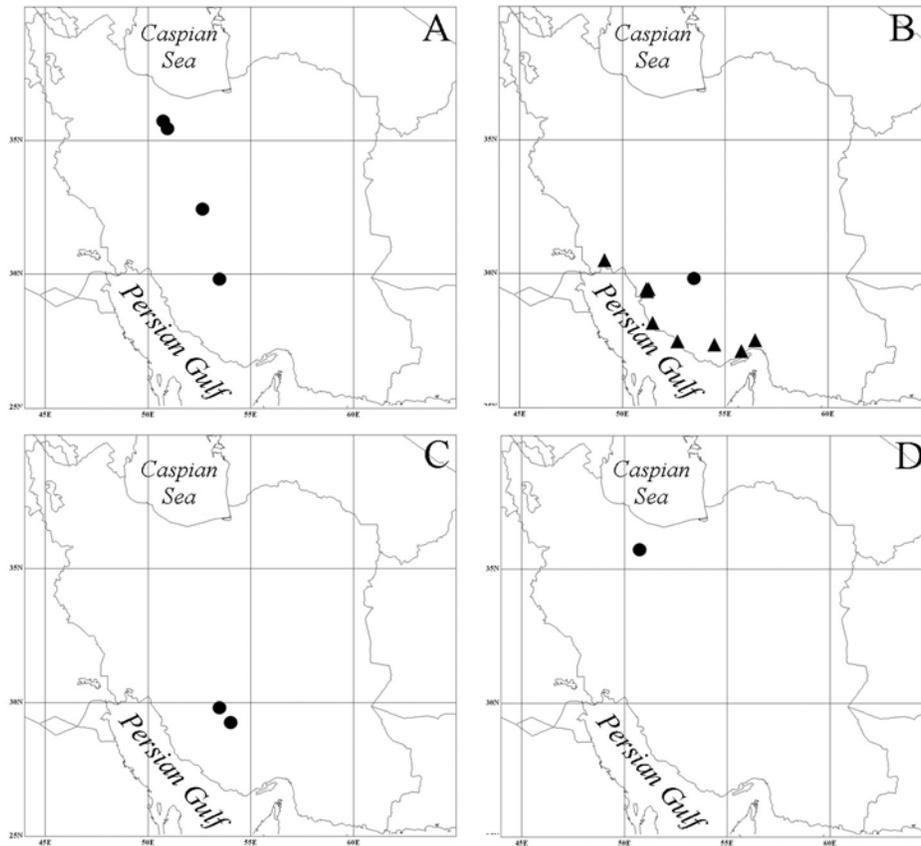


Fig. 2: Distribution of new Iranian *Salicornia* A. *S. iranica*; B. *S. sinus-persica* (triangle), *S. x tashkensis* (dot); C. *S. perspolitana*; D. *S. persica* subsp. *rudshurensis*

Table 2: Associated species with *Salicornia sinus-persica* based on 6 phytosociological relevés: Locality of recording data of relevés: 467 & 468: Bushehr: near Shahpur river, 29°21'33"N, 51°05'21"E, 29.11.2001; 474: Busher, after Dalaki, 16 km to Borazjan, 29°24'05"N, 51°16'22"E, 30.11.2001; 478 & 479: Hormozgan: N. Bandar Abbas, near Abegarme Khorgoo, 27°29'56"N, 56°27'39"E, 18.12.2001; 495: Hormozgan: Between Bandar Abbas and Bandare Khamir, along Kol river, 27°4'5"N, 55°47' 12"E, 20.12.2001.

Relevé No	467	468	474	478	479	495
Altitudes (m)	40	45	93	171	171	14
Surface (m ²)	100	50	64	100	100	100
Inclination (°)	5	30	0-2	0	0	0
Aspect	E	W	SW	-	-	-
Shrub (%)	55	80	60	10	15	20
Herb & ground (%)	10	80	90	80	80	10
Total cover	60	100	100	80	80	30
Shrub height (m)	2.5	2.5	2.5	1.5	1.5	1.5
Herb & ground height (cm)	100	100	100	80	100	40
C₃ plants						
<i>Salicornia sinus-persica</i>	1	2	3	2	1	1
Shrubs						
<i>Tamarix mascatensis</i>	.	.	.	.	.	2
<i>Tamarix aralensis</i>	.	.	3	.	.	.
<i>Tamarix kermanensis</i>	.	.	.	.	.	1
<i>Tamarix</i> spp.	4	5	.	2	2	.
<i>Halocnemum strobilaceum</i>	+	.	1	.	.	1
<i>Halostachys belangeriana</i>	.	.	.	1	1	.
Herbs, rushes and sedges						
<i>Phragmites australis</i>	1	.	.	.	.	.
<i>Pulicaria gnaphaloides</i>	1	.	.	.	.	.
<i>Launaea</i> sp.	+	+	.	.	.	.
<i>Limonium cf. meyeri</i>	.	.	1	.	.	.
<i>Juncus rigidus</i>	1	.	2	5	5	.
<i>Suaeda</i> aff. <i>maritima</i>	.	.	1	.	.	.
<i>Cressa cretica</i>	.	.	1	.	.	.
C₄ plants (all life forms)						
<i>Aeluropus littoralis</i>	.	.	3	1	1	.
<i>Aeluropus lagopoides</i>	1	1	.	.	.	1
<i>Suaeda aegyptiaca</i>	1	4	.	.	.	.
<i>Bienertia sinuspersici</i>	.	.	.	.	.	2
<i>Atriplex leuoclada</i>	1	.	.	.	.	.
<i>Cornulaca aucheri</i>	1	.	.	.	.	.
<i>Alhagi maurorum</i>	1	.	.	.	.	.
<i>Suaeda vermiculata</i>	.	1	.	.	.	.
<i>Halocharis sulphurea</i>	+	.	.	.	.	.



Fig. 3. *Salicornia sinsus-persica* Akhani. A: Community along a stream near Shirin river, type locality; B: habit; C: young plant in tidal zones of Bandare Mahshar; D: enlarged inflorescence of the Mahshar populations; E: inflorescence of type locality population; F: anther (scale bar 0.2 mm); G: seeds of central (left) and lateral (right) flowers (scale bar 0.3 mm); H: hairs on seed (scale bar 0.2 mm).

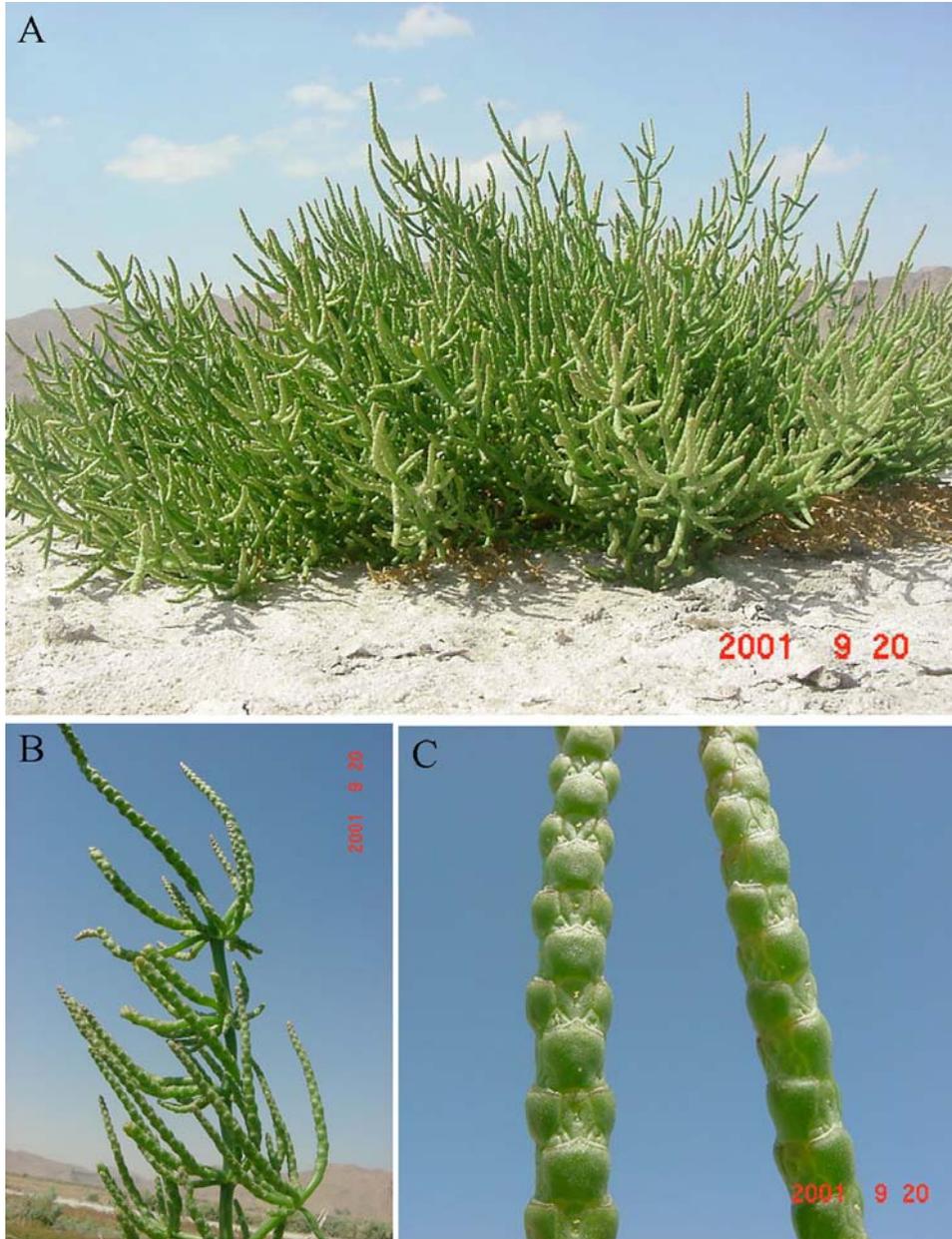


Fig. 4. *Salicornia persica* Akhani subsp. *persica*. A: Habit, B: inflorescence; C: two spikes showing truncate central flowers.

51°27'38"E, 30m, 30.11.2001, Akhani, 15957; ca. 8 km NW of Borazjan, along Dalaki River, 29°19'57"N, 51°11'00"E, 44m, 29.11.2001. Akhani 15934; ca. 15 km NW of Borazjan, near Eslamabad, 29°24'33"N, 51°9'16"E, along irrigation canal, 90m, 29.11.2001. Akhani 15932; 4 km S of Delvar, shores of Persian Gulf, near Mohamad Ameri, 20.11.1991, H. Akhani 7966 (MMTT, Hb. Akhani); 6 km SW of Kebkan, estuary of Mond river, high saline and wet soils near the margin of Persian Gulf, 21.11.1991; H. Akhani 7972, 7976 (MMTT, Hb. Akhani); ca. 30 km from Khormouj towards Kaki, Mond river margin dominated by *Tamarix*, c. 20 m, 21.11.1991, H. Akhani 7983 (MMTT, Hb. Akhani); 17 km from Borazjan towards Bandare-Genaveh, Dalaki River margin, ca. 40 m s.l., 21.11.1991, H. Akhani 7995 (MMTT, Hb. Akhani) (2n=18); Khuzestan: Bandare Mahshar, coastal area near the Mahshar Petrochemical Complex, near Pol-e Sazandegi (Bridge), 30°29'4"N, 49°6'99"E, 21.1.2008, H. Akhani, s.n. Hormozgan: Between Bastak and Lar, near Moradnow village, 27°19'13"N, 54°28'8"E, 21.8.2003, H. Akhani 17219; 3 km after Abegarme Khorgoo towards Geno, along the river in *Juncus rigidus* comm., 27°29'56"N, 56°27'39"E, 171, Akhani 15961.

Etymology: The species epithet is derived from the name of Persian Gulf which is called Sinus Persicus in Latin and Greece literature. This is an old and historical name with over 2000 years history. This epithet was first used in 1831 by Olfers who named the gamefish called "the Persian Gulf Torpedo" or "marbled electric ray" as *Torpedo sinuspersici*. This epithet is recently used for *Bienertia sinuspersici*, an enigmatic C₄ plant lacking Kranz anatomy (Akhani *et al.*, 2005).

Cytology: *S. sinus-persica* is a diploid plant (2n=18) which was reported recently under *Salicornia* spec. C. (Ghaffari *et al.*, 2006). The chromosome complement consists of six pairs of submetacentric and three pairs of metacentric chromosomes.

Distribution: *S. sinus-persica* is distributed along the northern parts of the Persian Gulf (Fig. 2B). Recently Kadereit *et al.* (2007) included in their molecular phylogeny the sequences of a specimen from Southern parts of Persian Gulf from Abu Ali Island and mentioned that this might be a related species to *S. persica* according to ETS sequences. As mentioned above, there are large differences in cytology and morphology of *Salicornia persica* (tetraploid) and *S. sinus-persica* (diploid). As I have not seen any specimen from that area, this is open for future studies whether *S. sinus-persica* may occurs outside Iran in southern parts of the Persian Gulf or indeed another related species to *S. persica* occurs there.

Ecology: *S. sinus-persica* occurs in three different types of communities. Along the Mond river margin (Bushehr) with brackish water, it occurs commonly in shaded parts of *Tamarix* thickets (Fig. 3A, Table 1, see also Alaie 2001). In coastal parts of the Persian Gulf in Khuzestan and Assalooyeh it occurs in tidal zones and associated with *Suaeda* aff. *maritima* (Sect. *Brezia*), *Halocnemum strobilaceum* and *Avicennia marina* (Fig. 3C). In Hormozgan, it occurs on brackish water in *Juncus rigidus* community (Table 1).

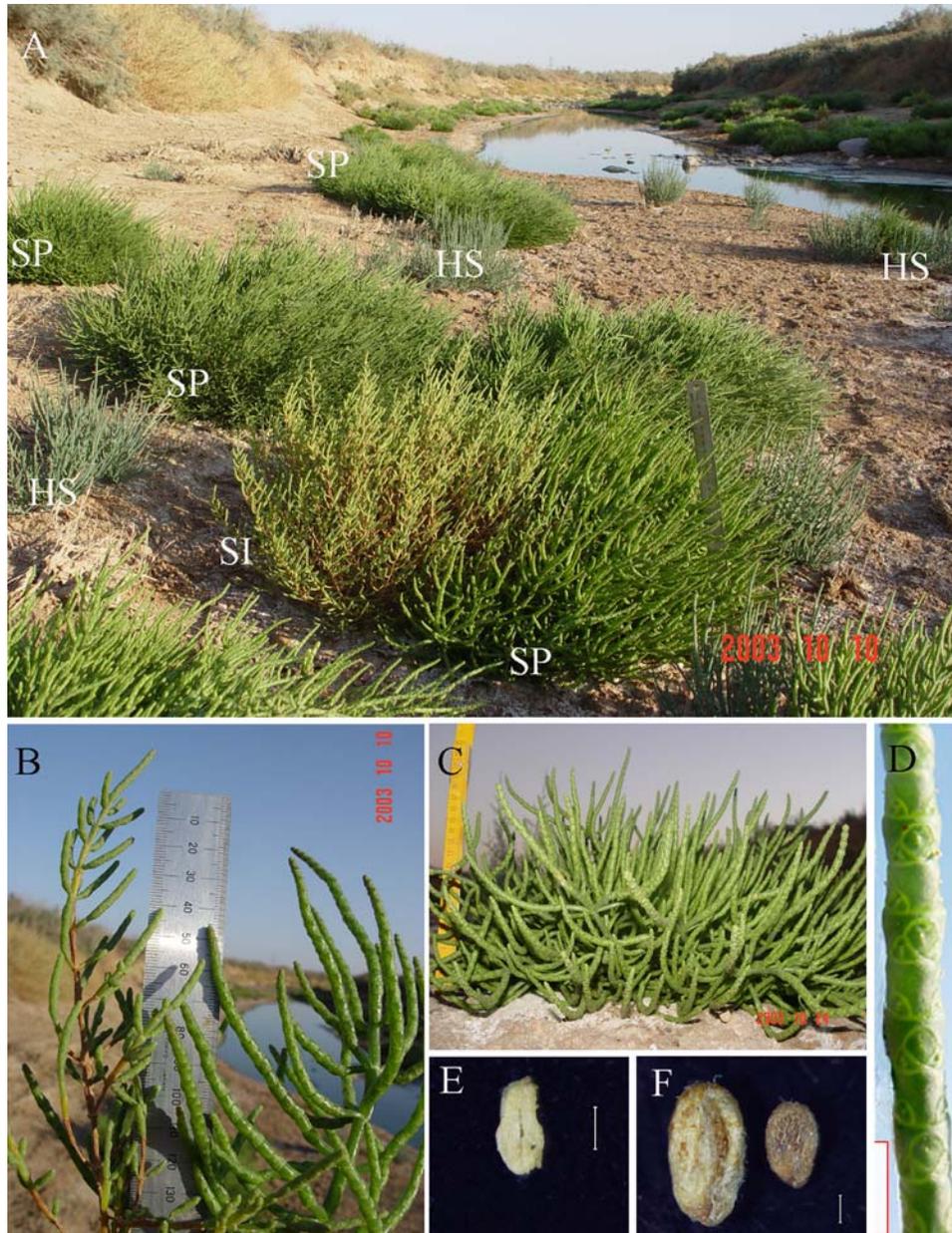


Fig. 5. *Salicornia persica* subsp. *rudshrensis* Akhani. A: Habitat along Rude Shur together with *S. iranica* (SI) and *Halocnemum strobilaceum* (HS); B: inflorescence branches of *S. iranica* at left and *S. persica* subsp. *rudshurensis* (SP) at right side; C: habit, D: close up of one spike (scale bar 1 cm); E: anther (scale bar 0.2 mm); F: seeds of central (left) and lateral (right) flowers (scale bar 0.3 mm).

***Salicornia persica* Akhani in Linzer biol. Beitr. 35: 608 (2003). subsp. *persica*, Fig. 4.**

Typus: Esfahan: Varzaneh, Zayandeh Rud river bed, 32°25'32"N, 52°39'5"E, 1493 m, 16.9.2001, H. Akhani & M. Ghobadnezhad 15670 (Holotypus: IRAN; isotypus, Hb. H. Akhani).

Annual plant, glabrous; dark green in flower, but becoming purplish in fruit; up to 60 (–100) cm height, and up to 80 cm canopy diameter; with a rootstock up to 2 cm diameter; ascending in open habitats, erect in dense canopies; lower and older branches with tubercles of salt accumulated crystals; lower median internodes of main stem 2–3 cm long; upper inflorescence branches usually verticillate, with 4–6 (–8) spikes or lateral branches in each node. Terminal spikes 4–10 cm long, 3–3.5 mm diameter, with 19–35 (–40) fertile segments, at base with a sterile segment, (0.5–) 1.5–2.5 cm long; lower fertile segments 3–5.5 mm long, 3–4 mm diameter, with a scarious edge, 0.3–0.5 mm broad. Central flower in each segment reaches to upper segment, reversed pentagonal to sub-rhombic in outline, elongate, truncate, 2–2.8 mm long, 1.3–1.8 mm wide; lateral flowers triangular in outline, 1.2–1.6 mm wide at base. Anthers 0.4–0.6 mm long. Stigma 0.2–0.3 mm long, seeds elliptic; those of the central flowers larger, 1.7–1.8 x 0.8–1 mm, those of the lateral flowers 1.3–1.6 x 0.8–0.9 mm; seed surface ± smooth, sparsely with retrorse hooked hairs, 0.1–0.15 mm long.

See Akhani (2003) for details on the morphology of this species. The pollen morphology of *S. persica* is described in Akhani *et al.* (2003). For details of the ecology see notes under *S. perspolitana*.

Cytology: 2n=36 (Ghaffari *et al.*, 2006)

Distribution: Endemic in Central Iran.

***Salicornia persica* Akhani subsp. *rudshurensis* Akhani Fig. 5.**

Typus: Tehran: ca. 60 km W Tehran, Mardabad salt flats, along Rude Shur, 35°43'4"N, 50°44'24"E, 1169m, 24.10.2003, H. Akhani 17423 (Holotypus: IRAN, isotypus: Hb. H. Akhani).

Annua. Planta complicati racemosa, ascendencia. Internodium caulinum 19-26 mm longum, inflorescentia apicalis verticillata, 9-12 cm longa, 4-4.5 mm in diametro. Segmentum 21-24, 3.5-5 mm longum, basi sterili segmentulatum (14-23 mm longum). Inflorescentia lateralis 5.5-11.5 cm longa, basi sterili segmentulatum (6-17 mm longum). Flores centralis apice obtusae, 2.5-3.5 mm longum, 2.2-2.7 mm latum. Flores lateralis 1.8-2.4 mm longae, 2.1-2.5 mm latae. Semina elliptica, semina floribus centralibus 1.4-1.6 mm x 0.6-0.9 mm, semina floribus lateralibus 1.3-1.5 x 0.7-0.9 mm.

Annual, densely branched with ascending habit; internodes 19-26 mm long, upper inflorescence branches verticillate, terminal spikes 9-12 cm long, 4-4.5 mm diameter, segments 21-24, 3.5-5 mm long, basal sterile segment, 14-23 mm long; lateral spikes 5.5-11.5 cm long, basal sterile segment 6-17 mm long; central flowers obtuse at apex, not reaching the upper segment, 2.5-3.5 mm long, 2.2-2.7 mm width; lateral flowers 1.8-2.4 mm long, 2.1-2.5 mm width; seeds elliptic, those of central flowers 1.4-1.6 mm x 0.6-0.9 mm; those of lateral flowers 1.3-1.5 x 0.7-0.9 mm.

The new subsp. *rudshurensis* differs primarily from typical subspecies by the obtuse central flowers (compare Figs. 4 & 5). The range of this taxon and its variability needs to be evaluated by future studies.

***Salicornia perspolitana* Akhani spec. nov. Fig. 6.**

Typus: Fars: N Tashk lake, high salty soils near Gomban, 29°47'47"N, 53°28'41"E, 1589m, 28.11.2001. Akhani 15910 (Holotypus: IRAN; isotypus: Hb. H. Akhani).

Annua. Planta compressi prostrata (ca 60 cm in diametro), glabrata, complicati curvati racemosa. Internodium caulinum 1-3 cm longum, inflorescentia apicalis verticillata, in numero (2) 4-6 (inflorescentia terminalis excludo), apicis inflorescentia pedicellata, pedicelli 2-12 mm longi, inflorescentia lateralis pedicellata (pedicelli 2-8 mm longi). Inflorescentiae apicalis et lateralis inflorescentiae erectae vel curvatae 4-5.5 cm longae, in numero 8-19 segmentatae; segmentulum 1.8-3.2 mm longum (media 2.3 mm). Bracteae ovoideae, foliiforme, apice acutae, marginae membranaceae 0.9-1.6 mm longae (media 1.3 mm), 1-2.4 mm latae (media 1.5mm). Flores centralis 1.6-2.6 mm longae, 0.9-1.7 mm latae, rhomboideae. Flores lateralis triangularis 0.7-1.3 longae, 0.7-1.1mm latae. Anthera 0.38-0.42 mm longa, 0.27-0.28 mm lata. Semina elliptica, uncinato pilosa (pili 0.11-0.14 mm longa). Semina floribus centralibus 0.76-1.04 mm x 0.46-0.64 (media 0.89 x 0.53 mm). Semina floribus lateralibus 1.2-1.6 x 0.67-0.77 mm.

Annual, glabrous, completely prostrate on the ground, intricately and sturdy much branched from the base, forming a circular habit on the ground, with a canopy of 50-60 cm diameter, braches curved even in early growing stage; stem internodes 1-3 cm long; upper inflorescence mostly verticillate, with (2) 4-6 branches (excluding terminal spike); terminal spikes with 2-12 mm long sterile segment, lateral spikes with 2-8 mm long sterile segments. Terminal and lateral spikes erect to curved, 4-5.5 cm long, with 8-19 segments, segments 1.8-3.2 mm long, flowering spikes 2.1-2.6 mm thickness, fruiting spikes 2.5-3 mm thickness, each segment 1.8-3.3 mm long (mean 2.3 mm); bracts ovate, leaf-like, acute at apex, margin membranaceous, 0.9-1.6 mm long (mean 1.3 mm) , 1-2.4 mm broad (mean 1.5mm). Central flowers 1.6-2.6 mm long, 0.9-1.7 mm broad, rhombic, reversed pentagonal, lateral flowers triangular, 0.7-1.3 long, 0.7-1.1mm broad; anthers 0.38-0.42mm long, 0.27-0.28 mm broad. Seeds elliptic, pilose, seeds of lateral flowers 0.76-1.04 mm x 0.46-0.64 (mean 0.89 x 0.53 mm), seeds of central flowers 1.2-1.6 x 0.67-0.77 mm; hairs on seeds uncinata, 0.11-0.14 mm long.

Etymology: The name of *S. perspolitana* is derived from the Perspolis, the historical place and capital of the Persian Empire during Achaemenid dynasty. The Perspolis ruins are located in Fars Province, 60 km NW of the locality of this species.

Other examined materials: Fars: N. Tashk Lake, high salty soils near Gomban, 29°48'N, 53°28'E, 1590m, 20.9.2001, H. Akhani & M. Ghobadnezhad 15720; southeastern salty shores of Bakhtegan lake, 29°14'59"N, 54°1'46"E, 1568m, 25.11.2005. H. Akhani *et al.* s. n.

The new species is closely related to *S. persica* subsp. *persica*, but differs markedly by completely prostrate habit and intricate branches (Fig. 6A), much smaller spike up to 5.5 cm long, lower number of segments up to 19 and the leaf-like bracts (Fig. 6C) (compare with Fig. 4C and Akhani 2003, Fig. 2). *S. persica* subsp. *persica* has an ascending-erect habit, long spikes up to 10 cm long with 19-35 (-40) segments and

reduced bracts. Both species share similar flowers which the central one reaches to the upper segment (Figs. 4C, 6D). This species is very peculiar in habit and inflorescence form. Based on cultivation experiences the prostrate form is not depending on habitat and clearly is genetically fixed. The young stems bent in early growing stage and become prostrate in laboratory conditions. The very peculiar leafy-bracts of *S. perspolitana* in flowering stage is unique and unlike any other known *Salicornia* known to author. The extreme similarity of flowers of *S. perspolitana* with *S. persica* and their probable same ploidy level (under study) may sign of a very interesting case of sympatric evolution in flowering plants. Recently Savolainen *et al.* (2006) provided evidences of sympatric evolution in oceanic islands in two palm species.

Ecology and threats: *S. perspolitana* grows on hypersaline soils in the same habitat as *S. persica* and in association with it around Tashk and Bakhtegan saline Lakes in Fars province. In Table 1 the phytosociological records of 21 relevés in which *S. persica* occurs is shown. *S. perspolitana* was recorded in four relevés with cover abundances of 1 and 2 after Braun-Blanquet's scales (Braun-Blanquet 1964). *S. persica* is a dominant species and *Salicornia iranica* and the putative new hybrid *S. x tashkensis* and *Halopeplis pygmaea* occur from 1 to 3 cover abundances.

Conservation and threat status: In contrary to *S. persica* which is a rather common species in the area and several other salines in central Iran, *S. perspolitana* is very rare and occurs sporadically in populations of *S. persica*. The habitat of this species is severely threatened because of extensive damming along the rivers running to Bakhtegan and Tashk lakes and extensive cultivation and grazing around both lakes. Therefore we consider the threat category of *S. perspolitana* as endangered according to IUCN threat categories.

***Salicornia x tashkensis* Akhani hybrid nova (probably a hybrid between *S. persica* Akhani subsp. *persica* and *S. iranica* Akhani). Fig. 7.**

Type: N. Tashk Lake, highly salty soils near Gomban, 29° 48' N, 53° 28' E, 1590 m, 20.9.2001, H. Akhani & M. Ghobadnezhad 15722. (Holotypus IRAN, isotypus: Hb. H. Akhani)

Annua. Planta erecta 30-70 cm alta. Internodium caulinum 15-25 mm longum, internodium lateralis cauliculum 11-17 mm longum. Inflorescentia apicalis verticillata (2-8 racemifera), pendula, (6-) 8-18.5 cm longa, 3-5 mm diametro. Segmentum in numero 37-60, basi sterili segmentulatum 6-12 mm longum. Inflorescentia lateralis 6.5-15.5 cm longa, segmentum in numero 22-49, basi sterili segmentulatum 3-5 mm longum. Flores centralis 1.9-2.2 mm longae, 2.2-2.7 mm latae, obtusae. Flores lateralis 0.8-1.2 longae, 1.6-2.3 mm latae. Semina non numerosi, 1.4-1.7 x 0.9-1 mm

Annual, erect, 30-70 cm tall, main internodes 15-25 mm long, lateral internodes 11-17 mm long, upper spikes verticillate, pendant in fruiting time with 2-8 branches; terminal spikes (6-) 8-18.5 cm long, 3-5 mm diameter, 37-60 segments, sterile basal segment 6-12 mm long; lateral spikes 6.5-15.5 cm long, segments, 22-49; sterile basal segment 3-5 mm long; central flowers 1.9-2.2 mm length, 2.2-2.7 mm width, obtuse, not reaching to upper segments, lateral flowers 0.8-1.2 length and 1.6-2.3 mm width; most seeds rudimentary, few developed seeds 1.4-1.7 x 0.9-1 mm.



Fig. 6: *Salicornia perspolitana* Akhani in type locality. A: Habit, foreground (*S. perspolitana*), hinter ground (*S. persica*); B: inflorescence branching, C: flowering spike showing leaf-like bracts; D: fruiting spike, E: Seeds (Scale bar 0.3 mm).

Additional examined specimen: N. Tashk Lake, highly salty soils near Gomban, 29°48'N, 53°28'E, 1590 m, 28.11.2001, H. Akhani 15909.

This is a characteristic taxon which occurs among the populations of *S. persica*, *S. iranica* and *S. perspolitana*. The spikes are the longest among all studied plants of *Salicornia* which are pendulous during fruiting time. In later fruiting time it was observed that most plants have been dried up but the specimens of this taxon were still fresh (Fig. 7A). In spite of very long spikes, only very few perianths contain seeds. Such seeds are rather large and all effort to germinate them were unsuccessful. These are good evidences that this is a hybrid swarm which probably results from hybridization of *S. persica* and *S. iranica* as two most dominant plants in the area. The long and verticillate inflorescence branches are similar to *S. persica* but the erect habit, deep green colour and obtuse central flowers are similar to *S. iranica*. As *S. persica* is a tetraploid and *S. iranica* a diploid plant, the result of hybridization would be a triploid plant which is a sterile plant. The absence of seeds in most flowers and ingerminability of the few seeds are good evidences of the hybridization of both species. However, further molecular and cytological experiments need to confirm this hypothesis. Previously hybrids have been reported in European species of *Salicornia*. According to Davy *et al.* (2001) and Lahondère (2004) hybridization between *S. disarticulata* C. E. Moss and *S. ramosissima* Woods known from West Europe (UK, France and Belgium) under the name *S. x marschallii* D. H. Dalby. However, many authors believe that *Salicornia* species are mostly inbreeding plants which still no strong evidence for hybridization is exist (see Kadereit *et al.*, 2007). A look to the phytosociological relevés in Table 1 shows that in relevés where *S. x tashkensis* were found three other species of *Salicornia* occur as well.

Carbon isotope composition

The carbon isotope composition of all known Iranian *Salicornia* species are provided in Table 3. As expected all species are clearly C₃ with a $\delta^{13}\text{C}$ ranging from a minimum negative of -23.33‰ to a maximum negative of -29.25‰ and an average of -26.34‰. Interestingly there are variations between species which may be correlated with their taxonomy and ecology. The highest negative values have been found in *S. sinus-persica* (-28.71‰) with a low variance (SD=0.39). The lowest negative values have been found in *S. x tashkensis* (-24.30‰) and one sample of *S. iranica* (-23.33‰). Evidently the carbon isotope values are not correlated with the ploidy level of species, as very high and very low negative values are found in *S. sinus-persica* and *S. iranica*, both diploid. It seems that the carbon isotope values are more correlated with habitat of species and more likely water availability. *S. sinus-persica* grows in less saline soils, in shady habitats and close to rivers with running brackish water. *S. persica* grows on high salinity and wet soils near the margin of hypersaline lakes. *S. iranica* prefers drier soils. This results are in agreement with previous studies that carbon isotope values in C₃ species are negatively correlated with water use efficiency of plants (Rytter 2005). In other word $\delta^{13}\text{C}$ may be more positive when water supply is less favourable (Wang 2003). In inland species of *Salicornia* in Central Iran where the soil salinity is much higher than the populations in South Iran reduce water supply even when the species occur in wet habitats.



Fig. 7: *Salicornia x tashkensis* Akhani. A: Habit B-C: Lateral and terminal spikes showing verticillate inflorescence branches and long spikes; D: Seed (scale bar 0.3 mm).

Table 3: Comparison of $\delta^{13}\text{C}$ of Iranian *Salicornia* species. The localities of those samples which are marked by an asterisk are given under the respective species.

Name	$\delta^{13}\text{C}$ (‰)	Voucher
<i>S. sinus-persica</i>	-28.53	Akhani, 15957*
<i>S. sinus-persica</i>	-28.33	Akhani 15949*
<i>S. sinus-persica</i>	-29.25	Akhani 15934*
<i>S. sinus-persica</i>	-28.74	Akhani 15932*
Mean & standard deviation	-28.71 ± 0.39	
<i>S. persica</i>	-24.97	Akhani & Ghobadnezhad 15670*
<i>S. persica</i>	-26.38	Esfahan, N of Ghavkhooni 17.9.2001, Akhani & Ghobadnezhad 15677
<i>S. persica</i>	-27.46	N. Tashk Lake, 20.9.2001 Akhani & Ghobadnezhad 15719
<i>S. persica</i>	-26.36	Fars: Tashk, 28.11.2001, Akhani 15907
Mean & standard deviation	-26.29 ± 1.02	
<i>S. perspolitana</i>	-25.41	Akhani 15910*
<i>S. x tashkensis</i>	-24.73	Akhani 15722*
<i>S. x tashkensis</i>	-24.30	Akhani 15909*
Mean & standard deviation	-24.51 ± 0.30	
<i>S. iranica</i>	-25.24	Akhani & Ghobadnezhad 15721*
<i>S. iranica</i>	-25.75	Tehran: Rude Shur between 13 Robot-e Karim and Saveh, 35°26'31"N, 50°57' 54"E m, 9.11.2001. Akhani 15905
<i>S. iranica</i>	-23.33	H. Akhani 15908*
Mean & standard deviation	-24.77 ± 1.27	

Phytogeographical remarks

The new species in this paper are known from the central and southern Iran (Fig. 2). As the range of species in *Salicornia* is imperfectly known, it is rather premature to evaluate their plant geographical importance. However, based on present data two species groups can be distinguished: The first are Central and South-Central Iranian species including *S. persica* subsp. *persica*, *S. persica* subsp. *rudshurensis*, *S. perspolitana*, *S. iranica* and *S. x tashkensis* and the second group consisted only of *S. sinus-persica* which is endemic around the Persian Gulf. The Central and South-Central Iran possess several endemic species of desert and arid flora with remarkable phytogeographic importance. Furthermore the area is part of the Zagros Mountains which is known as a very important plant diversity center in SW Asia (Akhani, 2004b; Noroozi *et al.*, 2008). *Frankenia persica* (synonym of *Hypericopsis persica*, cf. Olson *et al.*, 2003) was already known as a monotypic genus from the salines of Fars Province (Chrtek 1972). It is a highly salt tolerant plant which occurs in the same habitat of *S. persica* and *S. iranica* (Table 1). *Limonium reniforme* (Girard) Lincz is another halophytic local endemic of the area which erroneously its distribution was reported from Iran, Afghanistan and Middle Asia by Rechinger & Schiman-Czeika (1974), but based only unpublished data of the author it is an endemic plant in South-Central Iran. Recently (Soltani & Khosravi 2005) described *Haplophyllum bakhteganicum* Soltani & Khosravi as a new endemic species around

Bakhtegan and Tashk Lakes in addition to some other local endemics of the genus *Halpophyllum* in Southern and Central parts of Zagros (see Fig. 2 in Soltani & Khosravi, 2005). There are many more species endemic to Central Iranian deserts and salines such as *Heliotropium samoliflorum* Bunge, *H. dissitiflorum* Boiss., *H. agdense* Bunge, *H. aucheri* Moq., *H. shirazicum* Mozaffarian, *Salsola kernerii* (Wol.) Botsch, *Caroxylon abarghunense* (Assadi) Akhani, *Anabasis calcarea* (Sharif & Aellen) Bokhari & Wendelbo (Akhani 2007), *Cousinia belangeri* DC., *Astragalus glaucacanthus* Fisch., *Launaea acanthodes* (Boiss.) O. Kuntze, *Hertia angustifolia* (DC.) O. Kuntze, *Erysimum crassicaule* (Boiss.) Boiss. and *Matthiola revoluta* Bunge ex Boiss. (Rechinger, 1963-2005).

The range of *Salicornia sinus-persica* well matches with many other endemic species around Persian Gulf and Gulf of Oman. The most interesting case was recently found in *Bienertia sinuspersici* (Akhani *et al.*, 2005). As it is described recently on the phytogeographical importance of the species of the genus *Heliotropium* (Akhani 2007), most of the endemics of Persian Gulf area have an Irano-Turanian origin which provide good evidence of the consideration of this area as part of the Irano-Turanian area rather than Sudanian or Saharo-Sindian by Zohary (1973) and Léonard (1989).

Acknowledgments: This paper is in part the result of the research projects “Geobotanical Studies in Different Parts of Iran, I-IV” supported by the Research Council University of Tehran. Parts of the field studies during 2001 were possible by a car provided by the Agricultural Biotechnology Research Center, Karaj. The carbon isotope compositions have kindly been measured through the generous helps of Prof. Dr. H. Ziegler and by Dr. C. Deigele from the Bayern Academy of Science and Dipl. Eng. P. Trimborn in GSF National Research Center for Environment and Health, Munich, Germany. The translation of Latin descriptions by Dr. F. Khassanov (Tashkent) is much appreciated. A support to attend in the International Conference of Plant Scientists to Faisalabad by Islamic Development Bank is acknowledged.

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(Received for publication 21 April, 2008)

