



King Saud University

Saudi Journal of Biological Sciences

www.ksu.edu.sa
www.sciencedirect.com



ORIGINAL ARTICLE

A re-examination of the *Salicornias* (Amaranthaceae) of Saudi Arabia and their polymorphs

Turki Ali Al-Turki^{a,*}, K. Swarupananandan^b, Anthony J. Davy^c

^a Biotechnology Center, The Herbarium and Genebank of the King Abdulaziz City for Science and Technology (KACST), Box 6086, Riyadh 11442, Saudi Arabia

^b x/21/1, Vaikuntam, Perumpadappu Lane, Mannuthy 680 651, Thrissur Dt., Kerala State, India

^c School of Biological Sciences, University of East Anglia, Norwich Research Park, Norwich NR4 7TJ, UK

Received 5 May 2015; revised 21 December 2015; accepted 27 January 2016

KEYWORDS

Salicornia persica ssp. *iranica*;
S. sinus-persica;
Geminate spikes;
Heteromorphism of basal segments

Abstract During the period from 1964 to 1999 Saudi Arabian species of *Salicornia* were wrongly treated under the European species, *S. europaea* L. Recent explorations proved that there are two separate allopatric species of *Salicornia* in Saudi Arabia, one inhabiting the inland salt-marshes of the Najd (highlands) and the other inhabiting the Arabian Gulf Coast (lowlands). Morphological, ecological and exploratory studies confirm that they are two distinct species. The two species differ in features of bark, axillary spikes, basal vegetative segment(s) of spike, fertile segments, colour of senescent plants, and flowering, fruiting and germination phenology. As both the species have been described earlier from Iran, they are now new records for Saudi Arabia. The species are, *S. persica* ssp. *iranica* (Akhani) Kadereit & Piirainen and *S. sinus-persica* Akhani. *S. sinus-persica*, of which the status was thought doubtful has been confirmed. Both the species have been described and illustrated. Each species comprises a number of polymorphs. As leaves and flowers are rudimentary, confusing species circumscriptions, a proliferation of binomials has resulted in the taxonomy of *Salicornia*. To mitigate such confusion, the full range of variability of the Saudi Arabian species has been documented.

© 2016 Production and hosting by Elsevier B.V. on behalf of King Saud University. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

* Corresponding author.

E-mail addresses: talturki@kacst.edu.sa (T.A. Al-Turki), kswarup.kfri@gmail.com (K. Swarupananandan), A.Davy@uea.ac.uk (A.J. Davy).

Peer review under responsibility of King Saud University.



Production and hosting by Elsevier

1. Introduction

The genus *Salicornia* (Amaranthaceae) was established by Linnaeus (1753). Commonly known as ‘glassworts’, the species of the genus are articulated succulent herbs with cortical palisade, opposite decussate scale-leaves, thyrsoid cymes, flowers packed in cauline depressions and the diaspore composed of 1-seeded utricle. The species inhabit saline habitats such as

<http://dx.doi.org/10.1016/j.sjbs.2016.01.040>

1319-562X © 2016 Production and hosting by Elsevier B.V. on behalf of King Saud University.

This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

Please cite this article in press as: Al-Turki, T.A. et al., A re-examination of the *Salicornias* (Amaranthaceae) of Saudi Arabia and their polymorphs. Saudi Journal of Biological Sciences (2016), <http://dx.doi.org/10.1016/j.sjbs.2016.01.040>

inland salt-marshes, saline seasonal river banks and tidal coastlines, but all tidal coasts and salines are not home to glassworts.

Taxonomic studies of the genus by Moss (1911, 1912, 1954), Duval-Jouve (1868), Scott (1977), Ball (1964) and others Ball and Tutin (1959), Ball and Brown (1970) and the recent revision of Eurasian *Salicornias* by Kadereit and her school (Kadereit et al., 2007, 2012), are notable. Scott (1977) narrowed the circumscription of the genus by restricting to annual lifeforms. However, the recent chloroplast-DNA study (Steffen et al., 2015) revealing the monophyletic lineage of the *Sarcocornia/Salicornia* pair necessitates a retreat to the earlier wider circumscription, as opined by Freitag (1989). For nomenclatural reasons, the conglomerate however would bear the name *Salicornia* L. (*s. l.*). The European *Salicornias* have been studied extensively by Ball and others (Ball, 1964; Ball and Tutin, 1959; Ball and Brown, 1970; Davy et al., 2001). The South African species have been studied by Kadereit et al. in 2007. The Iranian species were investigated by Akhani (2003, 2008) and Kadereit et al. (2012). The latter study has helped eliminate much of the taxonomic and nomenclatural confusion that existed in the Eurasian species.

Despite the above mentioned studies, the Arabian species of the genus have not received much attention. Most authors dealt with the species of *Salicornia* from Arabian Gulf States (Rechinger, 1964; Halwagy and Macksad, 1972; Al-Rawi and Daoud, 1985; Phillips, 1988; Cornes, 1989; Western, 1989; Collenette, 1985, 1999; Mandaville, 1990; Miller and Cope, 1996; Chaudhary, 1999) under *S. europaea* L. agg. (cf. Al-Turki, 1992). Al-Turki (1997) documented yet another species of *Salicornia* from the Al-Qassim Province of Saudi Arabia, but again ascribed it to the blanket species, *S. europaea* L. (Al-Turki, 1997).

Al-Turki (1992) compared *Salicornias* on the Arabian Gulf Coast (KSA; \pm msl) to several species of *Salicornia* from England. The attributes used for comparison included length and/or breadth of the following: (a) fertile segments (at top, middle and base), (b) central and lateral flowers, (c) anther, and (d) width of the scarious border – the translucent margin of the scale leaf. Multivariate analysis clearly discriminated the

European *S. europaea* L. and the Saudi Arabian populations (Fig. 1), thus necessitating a separate species status for the populations of Arabian Gulf Coast (Al-Turki, 1992). Though the novelty of the species was confirmed, it was left without a new name. The second species of *Salicornia* located in the Al-Qassim Province escaped critical evaluation and as it also differs from *S. europaea* L. remains devoid of a name.

2. Materials and methods

From 1990 onwards, several populations of *Salicornia* from the Arab Gulf Coast of Saudi Arabia were under investigation by Al-Turki (1992). Continued field explorations enabled Al-Turki to locate a different set of populations of *Salicornia* from the inland salt-marsh at Al-Auzhaziya (Al-Qassim Province; (Al-Turki, 1997). Explorations revived in 2001 enabled to locate more populations of *Salicornia* in additional inland salt-marshes of the Najd. Together, the populations belonged to two physiographic regions: (i) The Arabian Gulf Coast (lowland), and (ii) The Najd (highland). The collection localities of the populations are given in Table 1.

Though the materials collected from the two geographic zones differed in a number of distinct traits, resolving the taxonomy was not easy, mainly because of the absence of a regional revision. Hence, aiming to gain better resolution of the problem, parallel morphological, cytological, phenological, and ecological studies were conducted of the coastal and inland populations. We have also studied specimens of *Salicornia* of Arabian origin available in the herbaria of RIY, K, BM and E. In the mean time, Eurasian *Salicornias* received documentation of more species. Here, we report the results of our findings in compliance with the recent developments. All the materials cited in this paper are from Saudi Arabia, excluding a few from Kuwait and/or Bahrain.

3. Results

The two sets of populations of *Salicornia* in Saudi Arabia, *i.e.*, the coastal and inland populations, differed in a number of characters: the splitting/smooth bark, the geminate/solitary spikes, the ob-urceolatiform/doliiform fertile segments, and the reddish/yellowish colour of the senescing plants. They also differ in the October–November/November–December flowering seasons, the December/January fruiting seasons, and the December–January/February germination seasons (Table 2).

Being separated by a distance of *ca.* 750 km, their distribution never overlaps. One set of populations is restricted to the Lowlands of the Eastern coastal belt (\pm msl) and the other to the inland salt-marshes of Lower Highlands of the Najd (\pm 600–650 m msl). The morphological distinctions, allopatry and absence of intermediary populations support their distinct species status.

The two species were identified in compliance with the recent literature (Akhani, 2003, 2008; Kadereit et al., 2012) as: (1) *S. persica* Akhani. – this species is known to comprise two subspecies, of which only ssp. *iranica* (Akhani) Kadereit and Piirainen inhabits Saudi Arabia (= the inland species), and (2). *S. sinus-persica* Akhani (= the coastal species). Thus, as such Saudi Arabia is devoid of *S. europaea* L. *per se* but in its place there are two new records, *viz.*, *S. persica* ssp. *iranica* and *S. sinus-persica*.

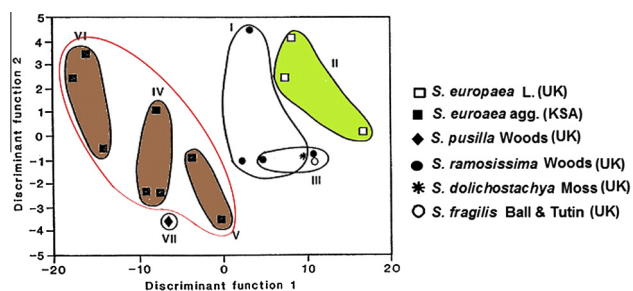


Figure 1 Discriminant analysis of species of *Salicornia* from UK and the Arabian Gulf Coast from Saudi Arabia (KSA), based on morphometric studies involving measurement of turgid vegetative segments, central and lateral flowers, anther and the scarious margin (modified from unpublished information available in Al-Turki, 1992). The green cluster corresponds to typical *S. europaea* L. (Britain) and the brown clusters forming a group represent '*Salicornia europaea* agg.' (Saudi Arabia). The analysis strongly discriminates between the two.

Table 1 Localities of collection of *Salicornia* in Saudi Arabia.

Physiographic zones	Provinces	Locations	Latitude	Longitude	Elevation
I. Eastern Lower Highlands (Najd)	Al-Qassim Prov.	1. Al-Awshaziyah	26°03'45"	44°08'29"	± 605 m
		2. Al Haqbah	26°01'05"	44°15'13"	± 609 m
		3. Abu Kushbah	25°59'29"	44°10'43"	± 601 m
		4. Al Saadia	25°47'49"	44°17'14"	± 650 m
		5. As Falah	25°07'01"	44°12'06"	± 604 m
II. Eastern Coastal Lowlands (Arabian Gulf Coast)	Eastern Prov.	6. Abu Ali Is. (Area-C)	27°18'59"	49°38'29"	± msl
		7. Abu Ali Is. (Area-B)	27°17'29"	49°29'15"	± msl
		8. Al-Khaleej Center	28°11'46"	48°37'45"	± msl
		9. Al-Amoud Center	28°11'46"	48°37'44"	± msl
		10. Abu Ali Is.	27°11'17"	49°31'36"	± msl
		11. Ras Tanura	26°40'20"	50°02'46"	± msl
		12. Al-Khoar	26°35'49"	50°03'24"	± msl
		13. Al-Zawr	26°35'35"	50°04'39"	± msl
		14. Darin	26°33'01"	50°04'43"	± msl
		15. Anak	26°30'27"	50°02'27"	± msl

Table 2 Differences between the inland and coastal species of *Salicornia* in Saudi Arabia. *

Sl. No.	Attributes	Inland species	Coastal species
1	Distribution	Restricted to inland salt-marshes (600–650 m)	Restricted to coastal inundated shores (± msl)
2	Bark	Splitting (in the lower woody portion), creamy brown	Smooth
3	Spikes	Geminate (in the upper axils of robust forms) (Figs. 5B, 8A and D)	Solitary, never geminate
4	Basal vegetative segments of spikes	Heteromorphic in geminate spikes, 3–12 mm long (Fig. 5C)	Geminate spikes absent, 2–2.5 mm long, isomorphic (Fig. 12B)
5	Fertile segments	Ob-urceolatiform (Fig. 5H)	Barrel-shaped or doliiform
6	Colour of the senescing plants	Pink-red or reddish (Fig. 6C).	Yellowish or yellowish-green (Fig. 13C, 14 E and G)
7	Flowering period	October–November	November–December
8	Fruiting period	December	January
9	Germination	December–January	February

* Summarised from various unpublished sources of the authors.

We have described the two species but no infra-specific taxa have been described. At the same time, to mitigate confusion arising from polymorphism we have described the phytomorphs, indicated by rankless names. These names are invalid in terms of ICBN, and therefore would suppress the nomenclatural noise it would otherwise generate. The term(s) 'phytomorph(s)' has been abbreviated as 'Phyt.', or 'Phyts.' in the text.

We provide below a key for the two species, descriptions, and the relevant illustrations/photographs. Descriptions and illustrations/photographs of the phytomorphs are also provided.

Key to Saudi Arabian species of *Salicornia*

- Plants of inland salt-marshes (sabkhas), never found on coastal shorelines; bark of woody base in vigorous forms brownish and splitting; unstarved well-nourished (vigorous) forms with verticillate inflorescence (geminate spikes) in upper nodes, basal vegetative segment of axillary spikes 3–12 mm long, heteromorphic (of differing lengths); fertile segments ob-urceolatiform (particularly in fruit); senescing plants pink-red *S. persica* ssp. *iranica*.

- Plants of coastal shorelines, never found in inland salt-marshes (sabkhas); bark smooth, never splitting; both unstarved and starved forms with opposite spikes (only one spike in each axil), basal vegetative segment of spike (s) 2–2.5 mm long, isomorphic, fertile segments doliiform or barrel-shaped; senescing plants turning yellowish or greenish-yellow; *S. sinus-persica*.

3.1. *Salicornia persica* ssp. *iranica*

(Akhani) Kadereit and Piirainen in Taxon 61(6): 1236. 2012 – Figs. 3–9.

Basionym: *S. iranica* Akhani in Pak. J. Bot. 40(4): 1637. 2008.

Synonym: '*S. europaea* agg.', non L., Al-Turki in Feddes Repert, 108(3/4), 259–280.

Herbs or subshrubs, –45 × –130 cm (Phyt. Gigantea), –30–70 × 30–35 cm (Phyt. Qassimensis), rarely decumbent (Phyt. Longissima), to erect little plants (Phyts. Monocaula and Parva). *Roots*: primary root –12 mm thick, lateral roots profuse, –30 cm long (Phyt. Gigantea). *Stem*: –12 mm thick

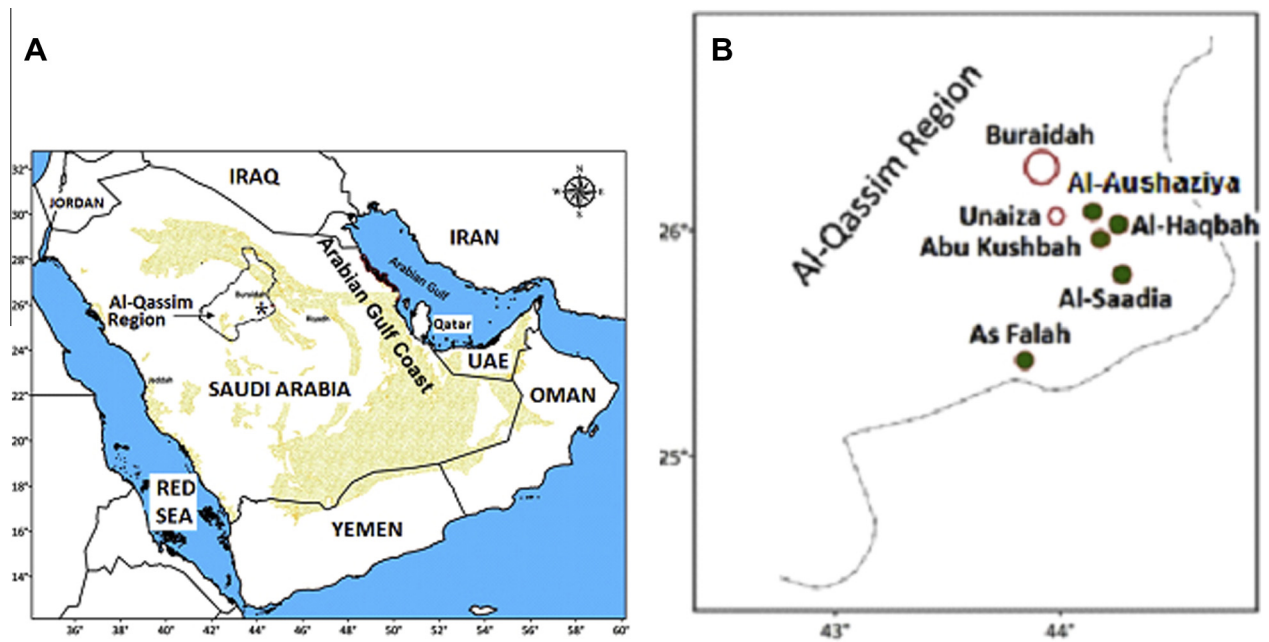


Figure 2 Distribution of *Salicornia persica* ssp. *iranica* in Saudi Arabia. (A) Map of Saudi Arabia showing the Al-Qassim region, where the species inhabits. (B) Location of the inland salt-marsh at Al-Aushazia.



Figure 3 Natural habitat of *Salicornia persica* ssp. *iranica*. (A) The inland salt-marsh at Unayza (Al-Qassim) where the species is found. (B) A rich population of *S. persica* ssp. *iranica*, adjoining the *Tamarix* stands.

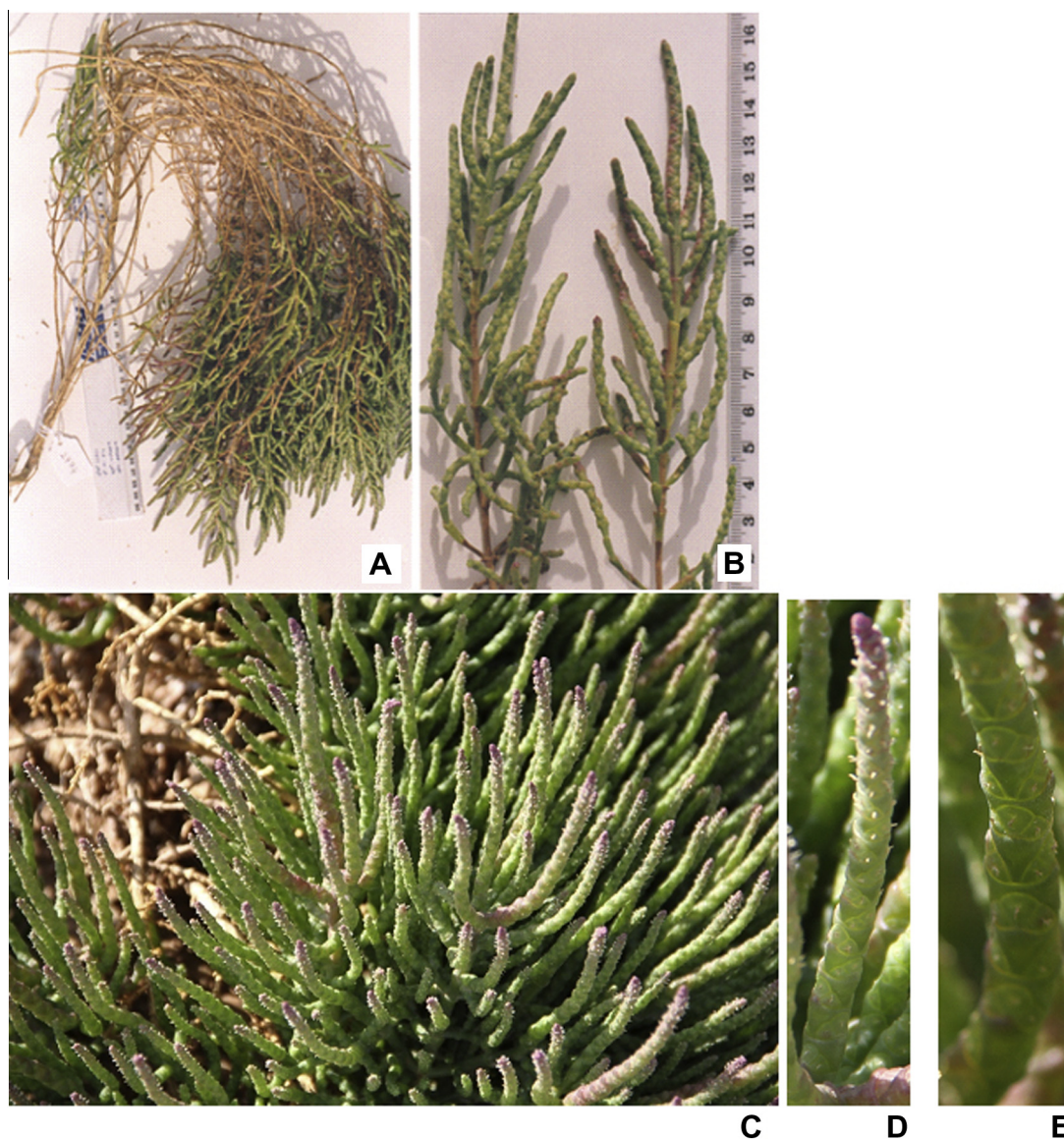


Figure 4 *Salicornia persica* ssp. *iranica*. Phyt. Qassimensis. (A) A herbarium specimen. (B) Flowering herbage. (C)–(E) Live plant. (C) Habit. (D) A spike; note the lengthy spike. (E) A close up of the spike showing the flowers.

at collar (Phyt. Gigantea), –8 mm (Phyt. Qassimensis), very thin (Phyt. Parva); wood white, with a narrow median channel extending the entire length. *Branches*: 1–4°, –30 pairs, lower ones sometimes disarticulating (Phyts. Qassimensis and Longissima), rarely restricted to upper part of the axis (Phyt. Longissima). *Spikes*: frequently geminate in upper axils (in larger phytomorphs) and appearing verticillate (Phyts. Gigantea, Longissima, Carnosa, etc; distinction from *S. sinus-persica*), –12 cm long (Phyt. Longissima), –5.5 cm (Phyt. Qassimensis), <2.5 cm long (Phyt. Brevispicata). *Fertile segments*: –44 per spike (Phyt. Longissima), –16 (Phyt. Qassimensis), –3.8 × –4.6 mm, ob-urceolatiform (particularly in fruit, distinction from *S. sinus-persica*; Fig. 7B). *Basal vegetative segments of the spikes*: 3–12 mm long, heteromorphic and of differing lengths in geminate spikes (see Fig. 5C). *Cymes*: 3-flowered. *Flowers*: central flower larger, –2 × –2 mm. *Pistil*: 3-carpellary, stigmas 3, elongate (distinction from,

S. sinus-persica), –1.5 mm long, papillate, spreading, sometimes stigmatic lobes spirally coiling after anthesis. *Senescing and fruiting segments*: generally pink-red (not yellow, distinction from *S. sino-persica*). *Diaspores*: resident in parent plant at maturity. *Seeds*: elliptic, cotyledonary and radicular arms remaining intact at maturity, hairy, hairs hooked at the tip.

Flowering: October–November. *Fruiting*: December.

Chromosomes: 2n:18 (Al-Turki et al., Unpublished information).

Diagnostic features: *S. persica* ssp. *iranica* differs from ssp. *persica* (Iran) in the rounded/obtuse apex of the central flower, whereas it is truncate in the latter. The species is easily distinguished in the ob-urceolatiform fruiting segments, the long (–1.5 mm) stigmatic lobes, the long cylindrical juvenile turgid vegetative segments, the thick stems and geminate axillary spikes in the upper axils of well-nourished phytomorphs, and the split bark (see Fig. 2).

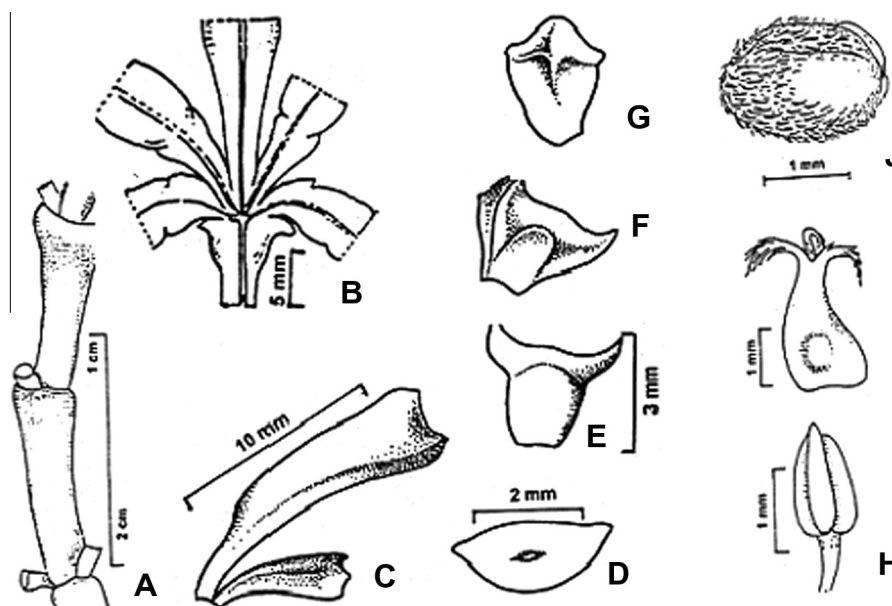


Figure 5 General features of *Salicornia persica* ssp. *iranica*. Phyt. Qassimensis. (A) Vegetative segments of the juvenile plant. (B) A longitudinal section of the geminate node with geminate (verticillate) spikes. (C) Basal vegetative segments of the geminate spikes; note the difference in the length of the basal vegetative segments of the two (geminate) spikes. (D) CS of basal vegetative segment. (E)–(G). Basal vegetative segment(s) of the smaller spike; note the difference in the length and shape of the segments. (H) A stamen. (I) Pistil. (J) A seed.

Distribution: This subspecies is known from Iran and Saudi Arabia. It is probable that a few of the specimens from Iraq also belong here. In Iran it is recorded from 1100 to 1600 m msl (Akhani, 2008), whereas in Saudi Arabia, it is restricted to inland salt-marshes of the Lower Highlands of the Najd between 600 and 650 m and never extends to the coastal shorelines. This altitudinal difference of the species in the two countries requires further studies. The highlands of Saudi Arabia beyond 650 m msl need to be explored for inland salt-marshes and *S. persica* ssp. *iranica*. In the Al-Qassim Province, not all the inland salt-marshes are inhabited by *S. persica* ssp. *iranica*.

Soil: The soil of Al-Qassim region (Najd, the natural habitat of *S. persica* ssp. *iranica*) is mainly derived from sedimentary parent materials. Unlike in the Arabian Gulf Coast (the habitat of *S. sinus persica*), practically, sand derived from marine molluscan shells of recent origin is absent here. Compared to the Arabian Gulf Coast, the percentage of calcium carbonate in the soil is also quite low, ranging between 3.8 and 14 (Al-Jaloud et al., 2013).

Taxonomic notes: Akhani first described *S. persica* in 2003. Subsequently, Kadereit et al. (2012) amalgamated the two species, *S. persica* Akhani and *S. iranica* Akhani and treated them as two subspecies under the former, viz., ssp. *persica* and ssp. *iranica* (Akhani) Kadereit and Piirainen. The ssp. *persica* (Iran) is a tetraploid with $2n = 36$ chromosomes and verticillate inflorescences (cf. Akhani, 2003), i.e., with accessory (more than 1) spikes (i.e., geminate spikes) in the upper scale-leaf axils. In his description of *S. iranica* (= ssp. *iranica*) Akhani (2003) mentions that “inflorescence branches opposite (not verticillate)”. Nevertheless, contrary to his statement, the photograph of the infructescence of the species (Fig. 1D in Akhani, 2003) clearly shows that geminate spikes exist in the species. This implies that the transformation from opposite spikes (i.e., solitary spike in each scale leaf-axil) to verticillate

inflorescence (= geminate spikes) is a morphological continuum and an intermediary state actually exists. Saudi Arabian materials are all with opposite spikes, but verticillate state exists in the upper nodes of most of the well-nourished bushy phytomorphs. The plants are also diploid ($2n = 18$).

In Saudi Arabia, *S. persica* ssp. *iranica* has a number of phytomorphs found in specific micro-niches. The phytomorphs are described below.

Specimens: All specimens of the species in Saudi Arabia come from the inland salt-marshes of the Al-Qassim Province.

a. **Phyt. Qassimensis** (Figs. 4 and 5): Erect herbs, 33–47(–50–70) × 30–35 cm, branching 3–4°, the terminal spikes are 3.5–5(–9) cm long and fertile segments 8–16 per spike.

Specimens: SAUDI ARABIA: Al-Qassim Prov.: Al-Awshaziyah sabkha, Al-Turki and Ghafoor 1097, 1098, 1099, 1100, 2057, 2073 (KACST), Al-Turki and Swarupanandan 2774 A, B and C, 2776, 2793, 3941 (KACST).

b. **Phyt. Gigantea** (Fig. 6): Large size (60–130 × 40–45 cm) of the plant, 3–4° branching, 18–27 pairs of primary branches, basal primary branches reaching a length of ~65 cm long, and growing longer than the main stem are characteristic of this phytomorph. The terminal spikes are 4–7 cm long.

Specimens: SAUDI ARABIA: Al-Qassim Prov.: Al-Awshaziyah, 26°5'N, 44°08'E, Al-Turki and Swarupanandan 3938, 3940 (KACST).

c. **Phyt. Brevispicata** (Fig. 7): This is similar to Phyt. Qassimensis but can be distinguished in the shorter spikes. The terminal spikes are 1.8–2.4 cm long and lateral spikes 0.8–1.2 cm long; there are only 5–7 fertile segments in the terminal spike and only 2–3 segments in lateral spikes.

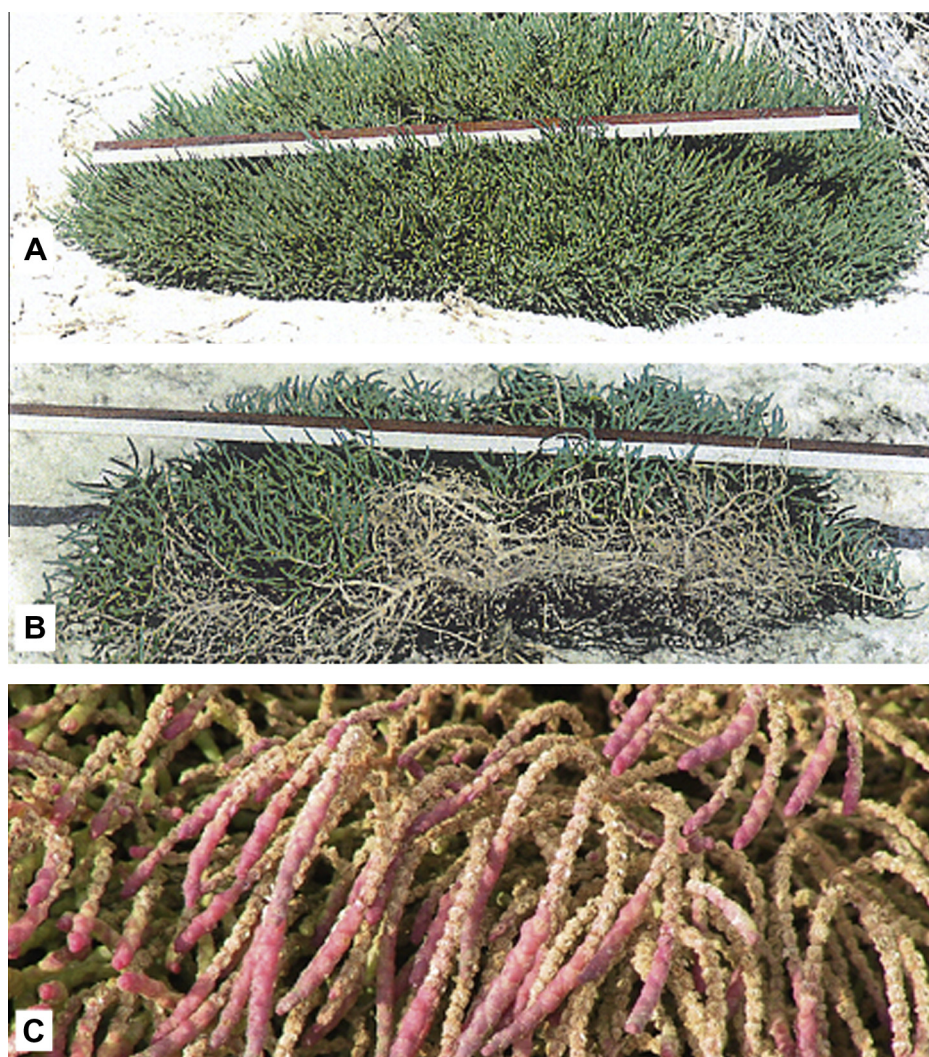


Figure 6 *Salicornia persica* ssp. *iranica*. Phyt. Gigantea. (A) A plant. (B) Vertical section of the bush (plant) showing structural details. (C) Close up of the fruiting herbage.

Specimens: SAUDI ARABIA: Al-Qassim Prov.: Al-Awshaziyah sabkha, 24°42'N, 46°38'E, *Al-Turki and Ghafoor* 2072 (KACST); *Al-Turki and Swarupanandan* 2773, 2775, 2793, 3946 (KACST).

- d. **Phyt. Carnosa** (Fig. 8A): The fertile segments of this phytomorph are much succulent and the proportion of geminate spikes in the upper axils of the inflorescence are also high; the spikes are very short. The plants are erect but stunted with only 2° branching, lateral branches are shorter than the main axis and basal primary branches almost prostrate. Basal vegetative segment of the spike is very short and fertile segments are carnose, broader than long, more or less bulliform.

Specimens: SAUDI ARABIA: Al-Qassim Prov.: Al-Awshaziyah sabkha, 24°42'N, 46°38'E, *Al-Turki and Swarupanandan* 2776 B, 2794 B (KACST).

- e. **Phyt. Longissima** (Fig. 8 B–D). This is a hydrophyte with unusually long (–130 cm) flexible stem, primary branches restricted towards the upper part, and the exceptionally long spikes with many fertile segments (–44). Branching is only 2°, spike-bearing branches

are only 5–8 pairs and restricted to the upper region. Terminal spikes are 8–12 cm long, lateral ones 4–8 cm long, geminate spikes many. Basal vegetative segment of the spike –14 mm long, curved down.

Specimens: SAUDI ARABIA: Al-Qassim Prov.: Al-Awshaziyah, 26°4.957'N, 44°8.171' E, immersed in sabkha water, *Al-Turki, Swarupanandan and Omer* 3979 A and B (KACST).

- f. **Phyt. Monocaula**: (Fig. 9A and B): The sparingly branched erect stature with only 1° branching distinguishes this from the rest of the phytomorphs. It has only one main-axis, as the basal branches do not become leader-shoots. It resembles Phyt. Parva (see below); while Phyt. Parva has only 1–3 lateral branches, Phyt. Monocaula has –10 pairs of primary branches.

Specimens: SAUDI ARABIA: Al-Qassim Prov.: Al-Awshaziyah sabkha, 24°42' N, 46°38' E, *Al-Turki and Ghafoor* 100 (KACST).

- g. **Phyt. Repens**: (Fig. 9C): In the long aetiolated stem, smooth bark and the clustering of branches towards the upper portion, Phyt. Repens resembles Phyt.



Figure 7 *Salicornia persica* ssp. *iranica*. Phyt. Brevispicata. (A) Apical portion of the reproductive shoot showing the spikes. (B) Spike enlarged, showing the ob-urceolate segments.

Longissima, but can be distinguished from the latter in the short spikes. Phyt. Longissima is a hydrophyte, whereas Phyt. Repens is terrestrial.

Specimens: SAUDI ARABIA: Al-Qassim Prov.: 9 km north of Al-Awshaziyah, *Al-Turki and Swarupanandan* 3948 (KACST).

- h. **Phyt. Parva**: (Fig. 9D): Phyt. Parva and Repens often intergrade; however, Parva has a shorter erect stature and the spikes are shorter. The branches are not regular on the stem, are shorter than the main axis, spikes are always terminal, and lateral spikes extremely rare.

Specimens: SAUDI ARABIA: Al-Qassim Prov.: 9 km North of Al-Awshaziyah, *Al-Turki and Swarupanandan* 3947 (KACST).

3.3. *Salicornia sinus-persica*

Akhani in Pakistan J. Bot. 40:1638. 2008 – Figs. 11–14.

Syn: *S. europaea* non Linn., *sensu* Phillips, Wild Fl. Bahrain: 101, *et* plate thereof. 1988; Cornes, Wild Fl. Pl. Bahrain, 26. 1989; Mandaville, Fl. East. Saudi Arabia: 81. 1990; Miller and Cope, Fl. Arabian Penins. 1: 253, Fig. 46Ea, map # 329. 1996; Chaudhary, Fl. Saudi Arabia, 1: 172, plate 89. 1999.

Herbs: erect, 10–60 × 30 cm. *Stem*: main axis 4–5 mm thick, basal internodes 10–15(–20) mm long. *Branches*: branching of 3°, at an obtuse angle with the axis, 15–21 pairs, 2–2.5 mm thick at base, spreading, basal few branches stout and often becoming leader shoots and the plant appearing caespitose. *Vegetative segments*: 4–5 × 2–3 mm, cylindrical, tip lightly dilated, margins more or less parallel. *Leaves*: Protuberances prominent. *Terminal spike*: (2.5–3–)4–5.8 cm long, longer than the lateral spikes. *Lateral spikes*: (8–)16–14 pairs, (2–)2.5–3.5 cm. *Basal vegetative segment of spikes*: 2–2.5 mm long, isomorphic, broader at tip, narrower at base (see Fig. 12B). *Fertile segments*: (10–)16–20 in terminal spike, (4–6–)8–13 in lateral spikes, 2.3–3.5 mm long, tip 2.5–3.7 mm wide, base 2.1–2.8 mm wide, longer than broad, margins more

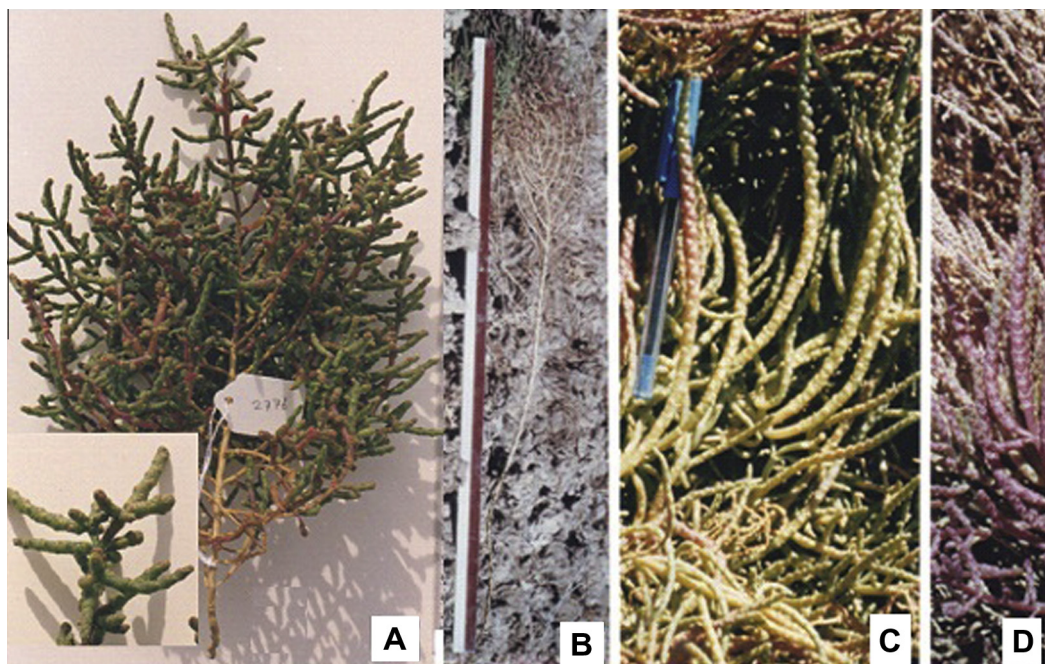


Figure 8 *Salicornia persica* ssp. *iranica*. (A) Phyt. Carnosa – note the profusion of geminate spikes. (B)–(D) Phyt. Longissima. (B) Habit. (C) Habit. (D) Apical portion of the shoot showing profusion of geminate spikes; also note the excessive length of spikes.

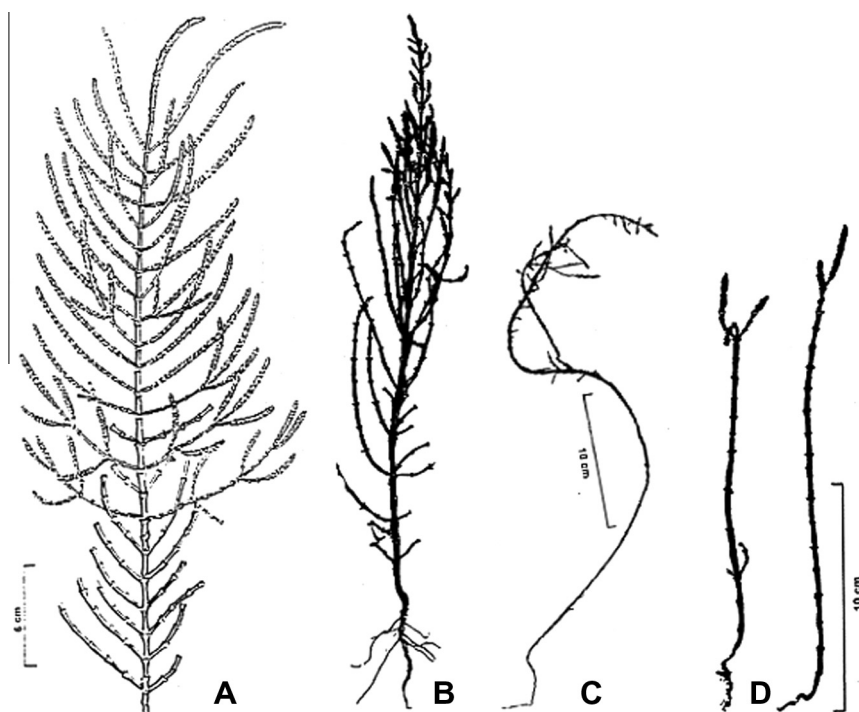


Figure 9 *Salicornia persica* ssp. *iranica*. (A) and (B) Phyt. Monocaula; note the disarticulated lower branches. (C) Phyt. Repens. (D) Phyt. Parva.

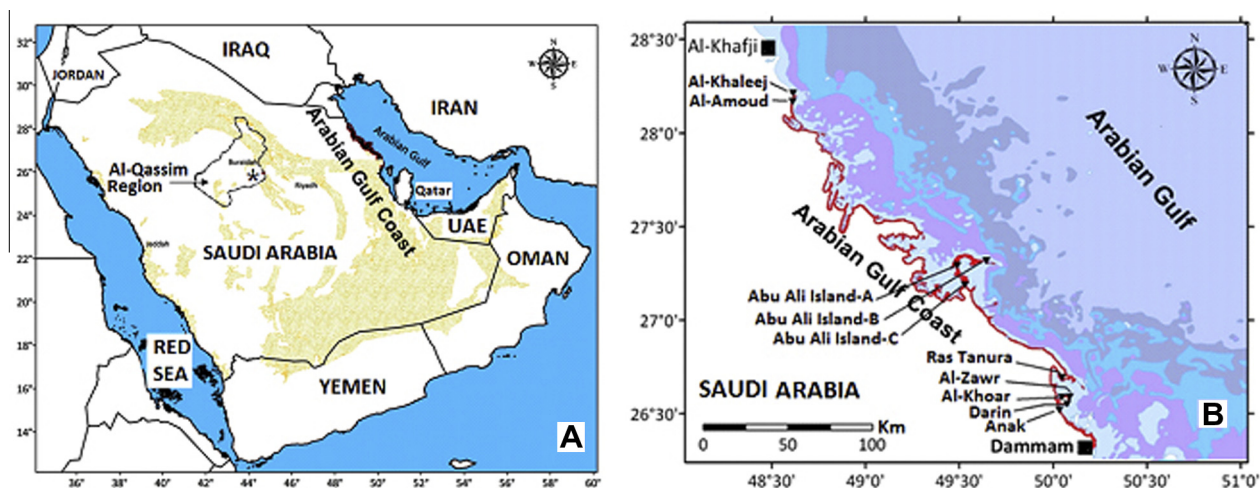


Figure 10 Distribution of *Salicornia sinus-persica* in Saudi Arabia. (A) Map showing the Arabian Gulf Coast. (B) Map of Arabian Gulf Coast showing distribution of the species.

or less parallel and often becoming barrel-shaped, never oburceoliform, scarios margin 0.15–0.2 mm wide. *Central flower*: 1.5–2 × 1.5–1.7 mm, distinctly taller than the lateral ones, narrowly ovate, tip narrowly obtuse. *Lateral flowers*: 1.1–1.5 × 1.1–1.3 mm, ovate, meeting below the scarios border of the lower scale leaf. *Stamens*: Anther 0.4–0.5 mm long. *Senile and fruiting segments*: yellowish.

Cytology: 2n: 18 (Al-Turki, Unpublished information).

Flowering: November–December. *Fruiting*: January.

Distribution: Northern part of Arabian Gulf in Kuwait, Iran, Saudi Arabia (Al Khafji to Dammam), and Bahrain. In Saudi Arabia, the species is known only from the coastlines

(± msl) (Fig. 10), but in Iran, it is recorded to ascend up to an altitude of ca. 100 m (cf. Akhiani, 2008).

Soil: The soil in the natural habitat of *S. sinus-persica* (Arabian Gulf Coast) is composed of biological calcareous and terrigenous materials. The percentage of calcium carbonate in the soil ranges from 17 to 88 percent (Basaham, 2010). The intertidal sand is largely composed of calcareous material derived from fragmented molluscan shells. This component is practically absent in the soils of the Najd (natural habitat of *S. persica* ssp. *iranica*).

Taxonomic notes: Apparently, assuming the morphological differences between *S. sinus-persica* and *S. persica* ssp. *iranica*



Figure 11 A population of *S. sinus-persica* on the coastal wetlands. The adjacent vegetation is *Avicennia marina* woods.

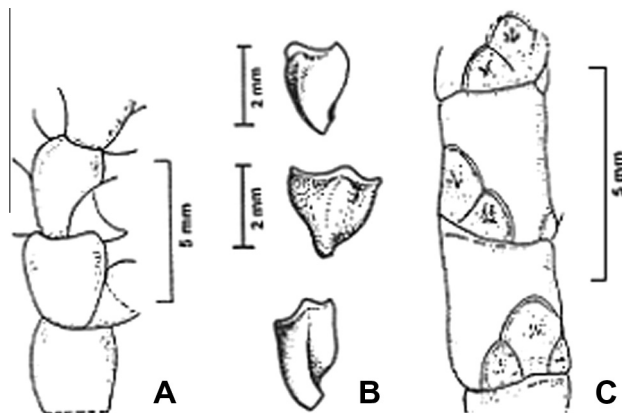


Figure 12 *Salicornia sinus-persica*. (A) Turgid vegetative segments. (B) Basal vegetative segment(s) of the spike. (C) Fertile segments of the spike.

not significant, Kadereit et al. (2012, p. 1236) treated *S. sinus-persica* as a taxon of ‘uncertain status’. However, *S. sinus-persica* occupies littoral tidal habitats at \pm msl or along saline riverbanks ascending up to ca. 100 m msl (as far as tidal inflow reaches the estuary?) (cf. Akhani, 2008) and the older herbage

turns to yellowish-green. In contrast, *S. persica* ssp. *iranica* in Iran occupies inland salt-marshes of Central highlands between 1100 and 1600 m msl (cf. Akhani, 2008, p. 1638 and 1645; i.e., away from the tidal environment) and the saline river margins there, and the older herbage turns reddish.

Another diagnostic character that distinguishes *S. sinus-persica* and *S. persica* ssp. *iranica* is the definitive absence of geminate spikes (= spikes verticillate) in the former. In the latter, the above character state exists, at least in well-nourished robust phytomorphs (For details see the note under *S. persica* ssp. *iranica*).

In addition, in Saudi Arabia, the two taxa differ in their pheno-behaviour (see Table 3). The differences are manifest in the actual timing and extent of the various phenophases, in early/late seeding, early/late germination and longer/short vegetative period.

Based on the differences in: (a) Arrangement of spikes, (b) Colour change in older herbage, (c) Pheno-behaviour, and (d) Distribution, *S. sinus-persica* is different from *S. persica* ssp. *iranica* and deserves a distinct species status.

The results of morphometric studies on the Arab Gulf populations of *Salicornia* in Saudi Arabia are interesting. Upon discriminant analysis, the populations segregate into three groups (cf. Fig. 1), indicating to the possibility of finding infra-specific taxa within *S. sinus-persica*.

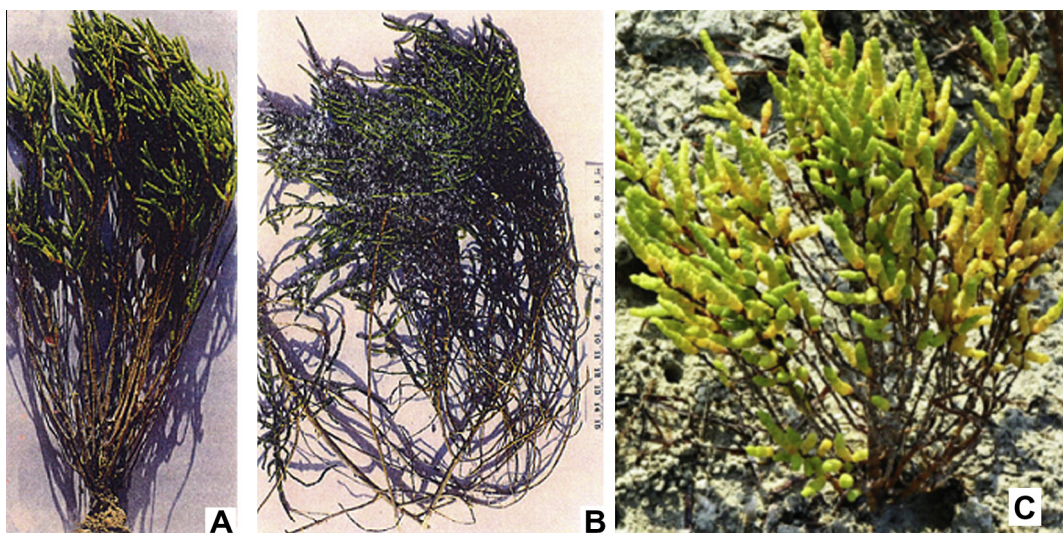


Figure 13 *Salicornia sinus-persica*. Phyt. Saudiensis. (A) and (B) Habit. (C) Note the yellow colour of the fruiting herbage.

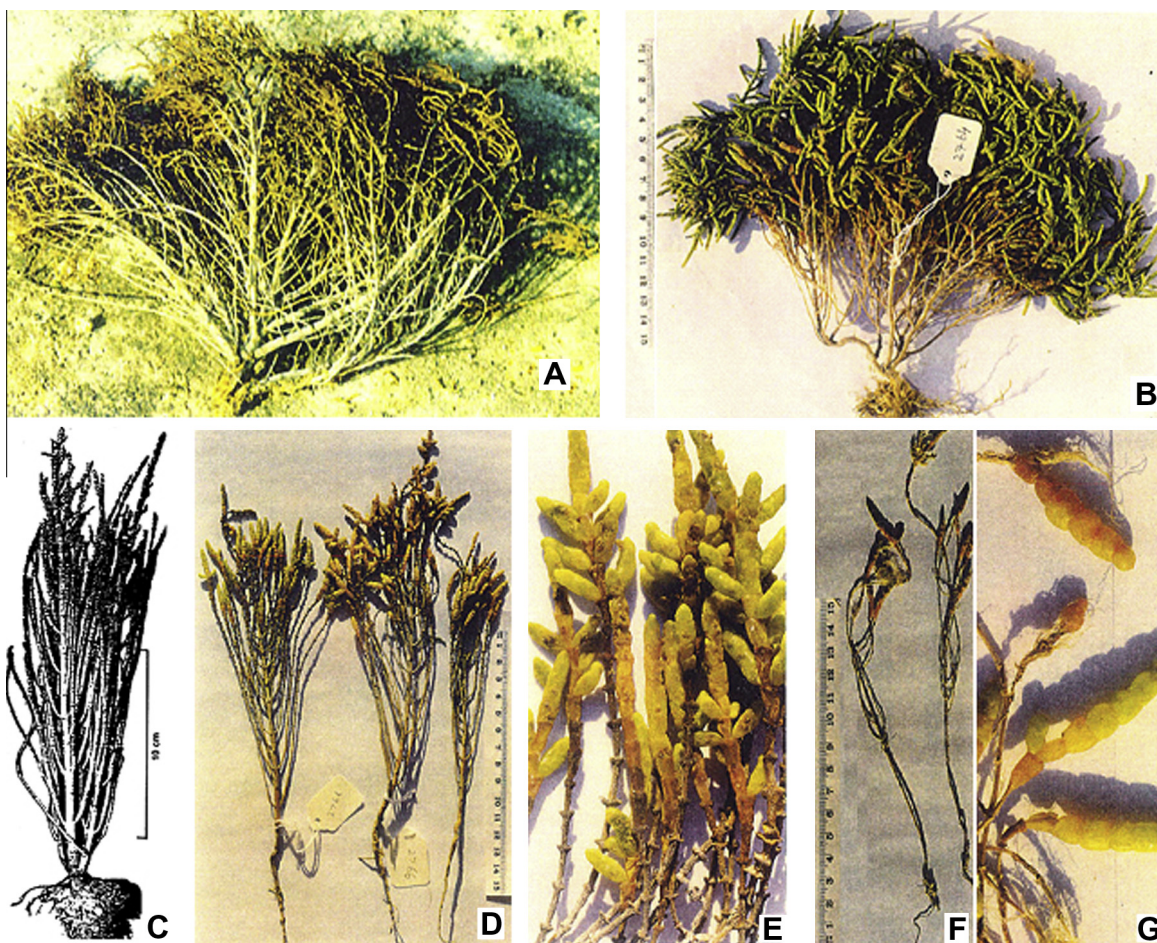


Figure 14 *Salicornia sinus-persica*. (A) Phyt. Maxima. (B) Phyt. Dolichostachyformis. (C) Phyt. Pachycaula. (D) and (E) Phyt. Monoaxia. (F) and (G). Phyt. Bulliforma.

Specimens: All the specimens cited are from the Arabian Gulf Coast of the Eastern Province of Saudi Arabia and a few from Kuwait and Bahrain. The specimens are cited under the various phytomorphs described below.

- a. **Phyt. Saudiensis** (Fig. 13): This is distinguishable from Phyt. Dolichostachyformis, in the erect stature, where the basal primary branches become leader shoots or not, but never trailing. It can be distinguished from Phyt. Monoaxia in the 2–3° branching and from Phyt. Bulliforma in the dolichostachyal shape of the fertile segments.

Specimens: SAUDI ARABIA: Al-Qassim Prov.: Al-Zawr near Dammam, *Al-Turki and Swarupanandan* 3909, 3911, 3912, 3913, 3916 (KACST); Anak, *Al-Turki, Swarupanandan and Saood Omer* 3900, *Al-Turki, Swarupanandan* 3957, 3963, 3967, 3968, 3969 (KACST). Darin N, Al-Turki and Swarupanandan 3907 (KACST); Sinabis, *Al-Turki, Swarupanandan and Saood Omer* 3925 (KACST). Tarut Is.: intermediate between Phyt. Monoaxia and Dolichostachyformis, *Collenette* 6190 (E). Northern Dammam: Seacoast, tidal mudflat, *Collenette* 6197 (E); mud flats inundated at high tides, *Collenette* 6305 (E); intermediary between Phyt. Saudiensis and Dolichostachyformis, *Collenette* 6402

(E); Western shore, tidal mud, *Mandaville* 1106 (BM); As-Saffaniya (Safaniya), tidal mud, *Mandaville* 1118 (BM); Ras Tanura, 100 km North of Dammam: *Al-Turki, Swarupanandan and Saood Omer* 3918, 3920 (KACST). KUWAIT: Salt marshes near Al-Jahra, *Boulos* L 16386 (BM); Near bridge, salt marsh, *Carpenter* 724 (K).

- b. **Phyt. Maxima** (Fig. 14A): The robustness (40–55 × 30–35 cm) of the plants, 3–4° branching, the regularly produced primary and secondary branches, and basal primary branches becoming leader shoots as the main stem distinguish it from other forms of the species.

Specimens: SAUDI ARABIA: Eastern Prov.: Al-Zawr West, 26°35.537'N, 50°03.776, E, seacoast, *Al-Turki and Swarupanandan* 3962, 3967 (KACST):

- c. **Phyt. Dolichostachyformis** (Fig. 14B): The bushy procumbent habit with an almost caespitose appearance, 3° branching, and the trailing basal primary branches becoming leader shoots as the central axis distinguish it from Phyt. Saudiensis. It differs from Phyt. Pachycaula in the thin (<0.5 mm) non-turgid portions of the branchlets and the decumbent habit.

Specimens: SAUDI ARABIA: Eastern Province: Around Dammam: Darin Is., *Al-Turki, Ghafoor and Swarupanandan* 2753, 2754, 2762 (KACST); Sinabis,

Table 3 Phenological differences between *Salicornia sinus-persica* and *S. persica* ssp. *iranica*.*

No.	Phenophases	<i>S. sinus-persica</i>	<i>S. persica</i> ssp. <i>iranica</i>	Phenological differences between the two species
1	Germination	February	January	ssp. <i>iranica</i> is early-germinating <i>S.sinus-persica</i> is late-germinating
2	Seedling phase	1 month	2 months	ssp. <i>iranica</i> has an extended seedling period
3	Seedling period	March	February and March	
4	Vegetative phase	7 months	6 months	<i>S.sinus-persica</i> has longer vegetative phase
5	Vegetative period	April to October	April to September	Ssp. <i>iranica</i> has shorter vegetative phase
6	Flowering period	November and December	October and November	Ssp. <i>iranica</i> is early-flowering <i>S. sinus-persica</i> is late-flowering
7	Mature seeds	1st half of January	1st half of December	<i>S. sinus-persica</i> is late-seeding
8	Seed dispersal	2nd half of January	2nd half of December	Ssp. <i>iranica</i> is early-seeding

* Unpublished information from Al-Turki.

Arabian Gulf Coast, *Al-Turki, Ghafoor and Swarupanandan 2754* (KACST); *Darin, Al-Turki, Ghafoor and Swarupanandan 2764* (KACST); bay north of city, msl, *Collenette 6405* (K). Ras Tanura, 100 km North of Dammam: *Al-Turki, Ghafoor and Ali 2080* (KACST); *Al-Zawr, Al-Turki and Mehmood 2760* (KACST); Ras Tanura, *Al-Zawr, Al-Turki and Mehmood 2782, 2789* (KACST), *Al-Turki, Swarupanandan and Saood Omer 3912, 3917* (KACST). Dammam North: tidal mudflats, *Collenette 6197* (K); *Collenette 6305* (K); Tarut bay, Off Al-Qatif, Mandaville JP 316 (K).

- d. **Phyt. Pachycaula** (Fig. 14C): The unusually uniformly thick (1.5–2 mm) non-turgid portion of the branchlets distinguish this from the rest.

Specimens: SAUDI ARABIA: Eastern Prov.: *Darin Is.: Al-Turki and Ghafoor 911* (KACST); Intermediate between Phyt. *Pachycaula* and *Dolichostachyformis*: *Darin Is., Al-Turki and Ghafoor 158* (KACST); *Al-Turki and Davy 2077 B* (KACST); *Darin, Al-Turki, Ghafoor and Ali 2087* (KACST). Ras Tanura: c. 100 km North of Dammam, *Al-Turki, Ghafoor and Ali 2080* (KACST).

- e. **Phyt. Monoaxia** (Fig. 14D and E): Phyt. *Monoaxia* differs from Phyt. *Bulliforma* in the erect stem and the regularly produced fastigiate primary branches in all the nodes. In Phyt. *Bulliforma*, most nodes are barren and branches are produced at random.

Specimens: BAHRAIN: SW of Jufair, muddy shore, *Ronald Good 279* (BM). SAUDI ARABIA: Eastern Prov.: Al-Zawr near Dammam, *Al-Turki, Ghafoor and Ali 2083, 2084* (KACST); *Al-Turki, Ghafoor and Swarupanandan 2757* (KACST); *Al-Turki, Ghafoor and Swarupanandan 2766* (KACST); *Al-Turki and Mehmood 2786, 2788, 2792* (KACST); *Al-Turki and Swarupanandan 3909, 3914* (KACST). *Anak, Al-Turki and Swarupanandan 3958* (KACST). Tarut Is.: Southern region, mud flats, near *Avicennia* groves, *Collenette 5190* (K); Northern shore, mud flats inundated by high tides, *Collenette 6402* (K).

- f. **Phyt. Bulliforma** (Fig. 14F and G): Phyt. *Bulliforma* is a much starved form, and is distinguished from Phyt. *Monoaxia* in the sparingly branched nature and the branches not being regular in all the nodes. Phyt. *Bulliforma* and *Monoaxia* share the moniliform appearance of the spikes and the yellowish older herbage.

Specimens: SAUDI ARABIA: Eastern Prov.: Al-Zawr near Dammam: 26°35' N, 50°04' E, *Al-Turki, Ghafoor and Swarupanandan 2752* (KACST); *Al-Turki, Ghafoor and Ali 2083, 2054* (KACST); *Al-Turki, Ghafoor and Swarupanandan 2757, 2766* (KACST); *Al-Zawr, Al-Turki, and Mehmood 2786, 2792* (KACST); *Al-Turki, Swarupanandan and Saood Omer 3915* (KACST). Sinabis, *Al-Turki and Mehmood 2788* (KACST).

4. Conclusions

1. The earlier belief that Saudi Arabia has only one species of *Salicornia* has been refuted. There are two species of the genus in the country and they do not belong to the european species, *S. europaea* L.
2. In Saudi Arabia, there are two sets of populations of *Salicornia* inhabiting two non-overlapping (allopatric) geographic realms: (a) The Lower Highlands of the Najd (600–650 m msl) in inland salt-marshes (sabkhas), far away from the seacoast, and (b) The Littoral inundated Lowlands (\pm msl) of the Arab Gulf Coast. Inferred from morphological, ecological and geographic differences, they are two distinct species. In compliance with the recent resolutions on the taxonomy of the genus, they are: (i) *S. persica* ssp. *iranica*, and (ii) *S. sinus-persica*. Both the species exhibit a high degree of polymorphism. Many of these are probably edaphic forms in response to differing degrees of trophic status, salinity, and moisture content of soils.
3. As discriminant analysis of populations of *S. sinus-persica* from the Arab Gulf Coast segregates the populations into three groups (cf. Fig. 1), possibility of finding infra-specific taxa within the species exist. Identifying these taxa however requires further investigations.

Acknowledgements

The authors wish to place on record the support received from the King Abdulaziz City for Science and Technology (KACST), Saudi Arabia. Reviews on an earlier draft by Dr. PW Ball, University of Toronto, and Dr. PG Wilson, Western Australian Herbarium helped improve the MS. The authorities of the herbaria, BM, E, K and RIY permitted to examine

specimens of *Salicornia* from Saudi Arabia, Kuwait and Bahrain in their collection.

References

- Akhani, H., 2003. *Salicornia persica* Akhani (Chenopodiaceae), a remarkable new species from Central Iran. *Linzer Biol. Beitr.* 35 (1), 607–612.
- Akhani, H., 2008. Taxonomic revision of the genus *Salicornia* L. (Chenopodiaceae) in Central and Southern Iran. *Pak. J. Bot.* 40 (4), 1635–1655.
- Al-Jaloud, A.A., Al-Rabhi, M.A., Bashour, I.I., 2013. Availability and fractionation of trace elements in arid calcareous soils. *Emir. J. Food Agric.* 25 (9), 702–712.
- Al-Rawi, A., Daoud, H., 1985. In: *Flora of Kuwait*, vol. 1. Dicotyledonae. KPI Publ. Ltd., London.
- Al-Turki, T.A., 1992. Systematic and ecological studies of Suaeda and *Salicornia* from Saudi Arabia and Britain. Doctoral Thesis, Univ. East Anglia, Norwich.
- Al-Turki, T.A., 1997. A preliminary checklist of the flora of Qassim, Saudi Arabia. *Feddes Repert.* 108 (3/4), 259–280.
- Ball, P.W., 1964. A taxonomic review of *Salicornia* in Europe. *Feddes Repert.* 69, 1–8.
- Ball, P.W., Brown, K.G., 1970. A biosystematic and ecological study of *Salicornia* in the Dee Estuary. *Watsonia* 8, 27–40.
- Ball, P.W., Tutin, T.G., 1959. Notes on the annual species of *Salicornia* in Britain. *Watsonia* 4, 193–205.
- Basaham, A.S., 2010. Distribution and partitioning of heavy metals in subtidal sediments of the Arabian Gulf Coast of Saudi Arabia. *J. King Abdulaziz Univ. Earth Sci.* 21 (1), 201–222.
- Chaudhary, S.A. (Ed.), 1999. *Flora of the Kingdom of Saudi Arabia*, vol. 1. Ministry of Agriculture and Water, Riyadh.
- Collenette, S., 1985. *An Illustrated Guide to the Flowers of Saudi Arabia*. Scorpion Publ, London.
- Collenette, S., 1999. *Wild Flowers of Saudi Arabia*. National Commission for Wildlife Conservation and Development (NCWCD), King of Saudi Arabia.
- Cornes, C.D., 1989. *The Flowering Plants of Bahrain, an Illustrated Guide*. Immel Publ. Ltd., London.
- Davy, A.J., Bishop, G.F., Costa, C.S.B., 2001. Biological flora of the British Isles. *Salicornia* L. (*Salicornia pusilla* J. Woods, *S. ramossissima* J. Woods, *S. europaea* L., *S. obscura* P.W. Ball and Tutin, *S. nitens* P.W. Ball & Tutin, *S. fragilis* P.W. Ball and Tutin and *S. dolichostachya* Moss). *J. Ecol.* 89, 681–707.
- Duval-Jouve, M.J., 1868. Des *Salicornia* de l'Herault. *Bull. Soc. Bot. France* 15, 165–178.
- Freitag, H., 1989. Contributions to the chenopod flora of Egypt. *Flora* 183, 149–173.
- Halwagy, R., Macksad, A., 1972. A contribution towards a flora of the state of Kuwait and the neutral zone. *Bot. J. Lin. Soc.* 65, 61–79.
- Kadereit, G., Ball, P., Beer, S., Mucina, L., Sokoloff, D., Teege, P., Yaprak, A.E., Freitag, H., 2007. A taxonomic nightmare comes true: phylogeny and biogeography of glassworts (*Salicornia* L., Chenopodiaceae). *Taxon* 56 (4), 1143–117.
- Kadereit, G.I., Piirainen, M., Lambinon, J., Vanderpoorten, A., 2012. Cryptic taxa should have names: reflections in the glasswort genus *Salicornia* (Amaranthaceae). *Taxon* 61 (6), 1227–1239.
- Linnaeus, C., 1753. *Species plantarum*. Stockholm.
- Mandaville, J.P., 1990. *Flora of the Eastern Saudi Arabia*. Kegan Paul International, London (p. 81, *Salicornia* L.).
- Miller, A.G., Cope, T.A., 1996. In: *Flora of the Arabian Peninsula and Socotora*, vol. 1. Edinburgh Univ. Press, Edinburgh.
- Moss, C.E., 1911. Some species of *Salicornia*. *J. Bot. London* 49, 177–185.
- Moss, C.E., 1912. The genus *Salicornia* in Denmark. *J. Bot. London* 50, 94–95.
- Moss, C.E., 1954. The species of *Arthrocnemum* and *Salicornia* in Southern Africa. *J. South Afr. Bot.* 20, 1–22.
- Phillips, C.D., 1988. *Wild flowers of Bahrain*. Manama, Bahrain.
- Rechinger, K.H. (Ed.), 1964. *Flora of Lowland Iraq*. Hafner Publ, New York.
- Scott, A.J., 1977. Reinstatement and revision of *Salicorniaceae* J. Agardh (Caryophyllales). *Bot. J. Linn. Soc.* 75, 357–374.
- Steffen, S., Ball, P., Mucina, L., Kadereit, G., 2015. Phylogeny, biogeography and ecological diversification of *Sarcocornia* (Salicornioideae, Amaranthaceae). *Ann. Bot.* 115, 353–368.
- Western, A.R., 1989. *The Flora of the United Arab Emirates, an Introduction*. United Arab Emirates University, UAE.