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

Turki Ali Al-Turki\(^a,\)*, K. Swarupanandan\(^b\), Anthony J. Davy\(^c\)

\(^a\) The Herbarium and Genebank of the King Abdulaziz City for Science and Technology (KACST), Box 6086, Riyadh 11442, Saudi Arabia
\(^b\) x/21/1, Vaidikantam, 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

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- *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.

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### 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 l-seeded utricle. The species inhabit saline habitats such as...
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 Salicornia/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 Mackiad, 1972; Al-Rawi and Daoud, 1985; Phillips, 1988; Cornes, 1989; Western, 1989; Collenette, 1985, 1999; Mandaville, 1990; Miller and Cope, 1996; Chaudhry, 1999) under S. europaea L. aggr. (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; ± 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-Auzhaziyah (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-ureolatiform/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 (± msl) and the other to the inland salt-marshes of Lower Highlands of the Najd (± 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 Pirainen 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 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.
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*

1. 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.*

2. 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 doliform or barrel-shaped; senescing plants turning yellowish or greenish-yellow; . . . . . . . . . . . . *S. sinu-persica.*

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

| 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-Awshaziyyah | 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 axis of robust forms)       | Solitary, never geminate                            |
| 4      | Basal vegetative segments of spikes | Heteromorphic in geminate spikes, 3–12 mm long | Geminate spikes absent isomorphic, 2–2.5 mm long, (Fig. 12B) |
| 5      | Fertile segments    | Ob-urceolatiform (Fig. 5H)                        | Barrell-shaped or doliform                           |
| 6      | Colour of the senescing plants | Pink-red or reddish (Fig. 6C). | Yellowish or yellowish-green (Fig. 13C, 14E 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.
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-Awshaziyah.

Figure 3  Natural habitat of *Salicornia persica* ssp. *iranica*. (A) The inland salt-marsh at Al-Awshaziyah (Al-Qassim) where the species is found. (B) A rich population of *S. persica* ssp. *iranica*, adjoining the *Tamarix* stands.
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, cotyledonal 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).
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 Pirainen. The ssp. *persica* (Iran) is a tetraploid with 2n = 36 chromosomes and verticillate inflorescences (cf. Akhani, 2003), ie., with accessory (more than 1) spikes (ie., 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 (ie., 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, 2057, 2073 (KACST), Al-Turki and Swarupanandan 2774 A, B and C, 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 sabkha, 26°5’N, 44°0’8’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,
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 2º 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 carnosse, broader than long, more or less bulliform. Basal vegetative segment of the spike is –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).

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 2º, 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. 9 A and B): The sparingly branched erect stature with only 1º 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.
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): *Phyts. Parva* and *Repons* 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 sinu-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 Peninsls. 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 7](image1.png) *Salicornia persica* ssp. *iranica*. Phyt. Brevispicata. (A) Apical portion of the reproductive shoot showing the spikes. (B) Spike enlarged, showing the ob-urceolate segments.

![Figure 8](image2.png) *Salicornia persica* ssp. *iranica*. (A) Phyt. Carnosa – note the profusion of geminate spikes. (B)–(D) Phyt. Longissima. (B) Habit. (D) Apical portion of the shoot showing profusion of geminate spikes; also note the excessive length of spikes.
or less parallel and often becoming barrel-shaped, never ob-
urceolatiform, scarious 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 scarious bor-
der 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. Akhani, 2008).

Soil: The soil in the natural habitat of S. sinus-persica (Arab-
ian Gulf Coast) is composed of biological calcareous and ter-
rigenous materials. The percentage of calcium carbonate in
the soil ranges from 17 to 88 percent (Basaham, 2010). The in-
tertidal sand is largely composed of calcareous material derived
from fragmented molluscan shells. This component is practi-
cally absent in the soils of the Najd (natural habitat of S. per-
sica ssp. iranica).

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

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.
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 ±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 seedling, 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 11](image-url) A population of *S. sinus-persica* on the coastal wetlands. The adjacent vegetation is *Avicennia marina* woods.

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

![Figure 13](image-url) *Salicornia sinus-persica*. Phyt. Saudiensis. (A) and (B) Habit. (C) Note the yellow colour of the fruiting herbage.
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 dolichostachyhal shape of the fertile segments.

Specimens: SAUDI ARABIA: Eastern 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 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. Saudiensis 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 near Dammam, Al-Turki and Swarupanandan 3909, 3911, 3912, 3913, 3916 (KACST); Anak, Al-Turki, Swarupanandan and Saood Omer 3900, 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. Maxima and Phyt. Pachycaula, Collenette 6190 (E). Northern Dammam: Seacoast, tidal mudflat, Collenette 6197 (E); mud flats inundated at high tides, Collenette 6305 (E); intermediary between Phyt. Maxima and Phyt. Pachycaula, 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).

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. | Germination phases | S. sinus-persica | S. persica ssp. iranica | Phenological differences between the two species |
|-----|--------------------|-----------------|-------------------------|-----------------------------------------------|
| 1   | Germination        | February        | January                 | ssp. iranica is early-germinating               |
| 2   | Seedling phase     | 1 month         | 2 months                | ssp. iranica has an extended seedling period    |
| 3   | Seedling period    | March           | February and March      | S. sinus-persica has longer vegetative phase    |
| 4   | Vegetative phase   | 7 months        | 6 months                | S. sinus-persica is early-flowering             |
| 5   | Vegetative period  | April to October| April to September      | S. persica ssp. is late-flowering              |
| 6   | Flowering period   | November and December | October and November | S. sinus-persica is late-seeding               |
| 7   | Mature seeds       | 1st half of January | 1st half of December  | S. sinus-persica is late-seeding               |
| 8   | Seed dispersal     | 2nd half of January | 2nd half of December  | S. sinus-persica is early-seeding               |

* Unpublished information from Al-Turki.

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 (±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 infraspecific taxa within the species exist. Identifying these taxa however requires further investigations.

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

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