

HALOPHYTIC VEGETATION OF IRAN: TOWARDS A SYNTAXONOMICAL CLASSIFICATION

H. AKHANI

*University of Tehran, Department of Biology, Faculty of Science, P. O. Box 14155-6455,
Tehran, Iran. e-mail: akhani@khayam.ut.ac.ir*

ABSTRACT - Iran with its diverse climatic conditions and geologic and land use history support large areas of saline habitats and diverse halophytic flora. The halophytic diversity is not only enriched by the evolving of a large number of autochthonous Irano-Turanian elements, but also many of the halophytes of other phytocoria like Saharo-Arabian, Mediterranean and even Euro-Siberian elements are represented in Iran. Therefore most of the higher syntaxa of Euro-Mediterranean and Afro-Asian-at least partly-occur in Iran. Prior to a consolidated syntaxonomical system for the halophytic vegetation of Iran, major halophytic vegetation units of Iran are summarized and shown along salinity and moisture gradients. These include: (1): Mangrove communities (**Avicennio-Sonneratietaea**), (2): Submerged aquatic plant communities (**Ruppiaetaeae maritimae**), (3): Annual obligatory hygro-halophytic communities on sea, lake and river marshes dominated by stem or leaf succulent C₃ chenopods (**Thero-Salicornietaea**), (4) Semi-woody or perennial halophytic communities on muddy or coastal salt flats dominated by stem succulent C₃ chenopods (**Salicornietaea fruticosae**), (5): Hydrophilous euryhalophytic rush communities: **Phragmitetaea australis**, (6): Halophytic grassland and herbaceous perennial sedge communities belonging to genera *Puccinellia* and *Juncus* (**Juncetaea maritimi**), (7): Salt marsh and riverine bruchwood communities dominated by salt-excreting halophytes (**Tamaricetaea ramosissimae**, prov.), (8): Annual halophytic communities dominated by C₄ chenopods in temporary moist and inundated, or disturbed salty soils (**Climacopteretea crassae**, prov.), (9): Halophytic shrubby, semi-woody or hemicryptophytic communities on salty and dry soils dominated by leaf or stem succulent C₄ chenopods (**Haloxylo-Salsoletaea tomentosae**, prov.), (10): Halophytic shrub communities on salty and sandy coastal or margin of sabkhas with high water table dominated by *Nitraria schoberi* and *Reaumuria fruticosa*, (11). Psamo-halophytic shrub communities along sandy coasts of Persian Gulf and Oman sea (**Sphaerocomion aucheri** and communities of *Zygophyllum qatarense* and *Heliotropium bacciferum* and (12): Unclassified halophytic communities: Herbaceous perennial and hemicryptophyte halophytic communities of secondary origin.

KEY WORDS - Halophytes of Iran, sabkha ecosystem, Irano-Turanian area, syntaxonomy, Chenopodiaceae.

INTRODUCTION

Salty and sabkha ecosystems are expanded in most parts of Iran, except forested zone of the Northern slopes of Alborz and high mountains of West Iran. Large salty habitats are found in the central Iranian great deserts "Dashte Kavir" and "Kavire Lut", the salt flats and salt marshes around Orumieh lake in the NW Iran, areas along the SE of the Caspian sea, Khuzestan plain in the SW Iran and large parts of the coastal and near-coastal parts along the Persian Gulf and Oman sea (FIGURE 1). The salty rivers in Iran are other major salty habitats which with their periodical or permanent water support diverse halophytic vegetation. The halophytic habitats in Iran are located in low and medium altitudes. Several factors are responsible for formation and origination of saline habitats in Iran including recycled increasing of soil salinity because of low rainfall and high evaporation, transport of salt from surrounding areas by wind, rainfall, river flow, spray of salt in the littoral and marsh zones, geologic origin and anthropogenic and agricultural activities (Akhani 2004a).

The halophytic and salt tolerant flora of Iran is very diverse comparing to many other countries. A total number of 365 species within 151 genera and 44 families of vascular plants are known in Iran as true halophyte or species capable to grow successfully on salty soils (Akhani, 2004a). The halophytic vegetation of Iran is better known than many other vegetation types in the country because firstly the halophytic vegetation are poor in species compared with many other species-rich vegetation types and secondly the halophytes attract many scientists, particularly from taxonomic, ecological, physiological and agricultural aspects. Most of publications on the Iranian halophytic vegetation are regional studies: Kavire Meyghan, Arak (Akhani, 1989), Orumieh salt lake, Azerbaijan (Atri *et al.*, 1995, Asri & Ghorbanli, 1997), Garmsar sabkha (Ghorbanli *et al.*, 1997), Touran Protected Area (Breckle, 1981, 1983, 1986), Kavir and Touran Protected Areas (Asri, 2003), Khuzestan (Alaie, 2001), Heuze Soltan, between Tehran and Qom (Ghorbanli & Lambinon, 1978); Maharlu Lake, Fars (Carle & Frey, 1977; Frey & Kürschner, 1983), Kavire Lut (Léonard, 1991/1992), mangroves and littoral halophytes along the Persian Gulf (Frey *et al.*, 1985, 1986) and Golestan National Park (Akhani, 1998). Some general information on the major vegetation units of Iran including halophytes are given by Frey & Probst (1986), Zohary (1973) and Akhani & Ghorbanli (1993).

This and another simultaneously accepted paper (Akhani, 2004a) report long-term taxonomical and ecological studies of the author in almost all kinds of salty and sabkha ecosystems of Iran. Information on the geographical, climatical, geological and soil characteristics of Iranian salines with biodiversity of halophytes are given in the cited paper. Here the major halophytic plant communities are introduced.



FIGURE 1 - Distribution of saline soils in Iran. 1: saline alluvial soils, 2: solonchak and solonetz soils, 3: salt marsh soils, 4: desert soils: sierozem and solonchalk soils (After Dewan & Famouri 1964, Akhani & Ghorbanli, 1993).

PHYTOGEOGRAPHY

The halophytes of Iran belong phytogeographically to different phytochoria. According to present phytogeographical concepts of SW Asia (Zohary, 1973; Léonard 1988 in 1981-1989), only a small part along the South Caspian forests (N. Iran) belongs to Euro-Siberian region (Hyrceanian province) and the majority of the country belongs to the Irano-Turanian region. The phytogeographic position of the southern parts of Iran is discrepant. Zohary (1973) considered a small part of the SW Iran as belonging to the Saharo-Arabian region and larger parts (including West Pakistan) as belonging to the Nubo-Sindian province of Sudanian region. Léonard (1988 in 1981-1989) and White and Léonard (1991) considered the southern parts of Iran and West Pakistan as the Saharo-Sindian regional zone with some Somalia-Masai elements. However, consideration of southern Iran and adjacent Pakistan as parts of Saharo-Sindian and Sudanian regions (sensu Zohary and Léonard) could not be justifying (Akhani, 2004b), because many endemic species in these areas are either Irano-Turanian elements or have their next relatives with the Irano-Turanian elements.

The number of Euro-Siberian halophytes in Iran is not high: a few species like *Arguzia sibirica*, *Scorzonera parviflora* and *Convolvulus persicus* could be mentioned. The later species is an Euxino-Hyrceanian species. However, there are sever-

al widely distributed and linking Euro-Siberian/Mediterranean and Irano-Turanian species like *Aster tripolium*, *Cackile maritima* (recently known from Iran, Akhani, 2003a), *Glaux maritima*, *Hordeum marinum*, *Spergularia marina*, *Juncus maritimus* and *J. littoralis* (Snogerup, 1993).

The majority of Iranian halophytes (214 species or 58.6%) belongs to the Irano-Turanian region and other species belongs to following phytochoria: 2 species omni-Euro-Siberian, 16 species Saharo-Arabian, 20 species Saharo-Arabian/Irano-Turanian, 24 species Irano-Turanian/Mediterranean, 18 species Irano-Turanian/Euro-Siberian/Mediterranean, 42 species Pluri-regional or cosmopolitan species and the remaining belong to other phytochoria. Therefore the Irano-Turanian region s.l. (including the area around Persian Gulf, Makran and West Pakistan) could be considered as center of origin or center of diversity of many halophytic genera of Chenopodiaceae like *Halimocnemis*, *Halanthium*, *Piptoptera*, *Climacoptera*, *Petrosimonia*, *Gamanthus*, *Bienertia*, *Kalidium*, *Halostachys*, *Salsola* and *Suaeda*. Except the cosmopolitan genus *Suaeda* and Eurasian and African genus *Salsola*, all other encountered genera are exclusively Irano-Turanian endemics. The largest diversity both in quantity and sections in the *Salsola* can be seen in SW and Central Asia. The genus *Tamarix*, as a second important halophytic genus in Iran has a rather similar situation with *Salsola* being widely diversified in the Irano-Turanian region but a few species in the Mediterranean area, N. and South Africa (Baum, 1978).

Four distribution patterns could be distinguished in the Irano-Turanian halophytes of Iran: (1) The largest number belongs to the common Aralo-Caspian/Central Iranian species. Examples of these group are *Suaeda arcuata*, *Suaeda linifolia*, *Nitraria schoberi*, *Climacoptera turcomanica*, *Halimocnemis pilifera*, *H. mollissima*, *H. longifolia*, *Bassia eriantha*, *Gamanthus gamocarpus*, *Bienertia cycloptera*, *Petrosimonia glauca*, *Halothamnus subaphyllus*, *Haloxylon ammodendron*, *Salsola arbuscula*, *S. arbusculiformis*, *S. incanescens*. (2) The Central Iranian endemics such as *Salsola abarghuensis*, *Anabasis haussknechtii*, *A. calcarea*, *Salsola kernerii*, *Salicornia persica*, *Hypericopsis persica*, *Limonium perfoliatum*, *Halimocnemis occulta* and *Horaninowia platyptera*. (3) Endemic species in Azerbaijan or linking species between Iran, Turkey, Armenia and Azerbaijan. Examples are *Gamanthus pilosus*, *Salsola tamanschjanae*, *S. ericoides*, *S. verrucosa*, *S. persica*, *Suaeda dendroides* and *S. gracilis*. The discovery of two extremely endangered disjunct species *Asparagus lycanicus* and *Microcnemum corralloides* (Akhani, 2002; Hedge *et al.*, 1997) in West Iran and Central Anatolia are interesting phytogeographical links between these areas. (4) The fourth group are those species distributed around and along Persian Gulf area and further East into Baluchestan of Pakistan. Examples are *Salsola drummondii* (Freitag, 1991), *S. griffithii*, *Suaeda baluchestanica*, *Halothamnus iranicus*, *Halanthium purpureum*, *Salicornia* spec. nov., *Suaeda* spec. nov. (Akhani in prep.), *Tamarix kermanensis*, *Bienertia sinuspersici* (Akhani *et al.* submitted), *Limonium stocksii*, *Indigofera stricta* and *Zygophyllum qatarense* (Deil, 1999).

In the southern Iran, there are some Saharo-Arabian, Somalia-Masai and tropical species like *Avicennia marina*, *Suaeda monoica*, *Juncus socotranus* (Snogerup, 1993) or Saharo-Arabian/Mediterranean species like *Arthrocnemum macrostachyum*.

In order to conform our studies with other studies in Iran, other SW Asian countries and the Euro-Mediterranean area, the Braun-Blanquet approach of plant sociology have been applied (Braun-Blanquet, 1964). The samples were taken either along transects to cover edaphic and moisture gradients or randomly in homogeneous plant communities. Based on analysis of a large number of relevés (500), a detailed phytosociological study is in preparation. The problem to provide a syntaxonomical system for the halophytic communities is that many of communities are mono-or oligo-dominant communities which putting them in a hierarchical system sensu Braun-Blanquet and using multivariate analysis with a large data set belonging to higher categories would give a false result. In many cases it is not possible to delimit a community, because of many transitions and stadial stages. Many halophytic habitats are subject to annual changes resulted from change in the water and salinity supply in the area. It happens very often that several species (with various ecological niche) grow together because each profit a particular microhabitat in site. One can use high water table by long roots, the another may profit high salinity at soil surface, the other may occupy disturbed parts of the habitats and finally fluctuation of annual rainfall causes different species combination in the same place. Usually long spacing in desert vegetation permits such combination of intermixed communities which make proper sampling and classification of such communities difficult. Therefore every person may provide his subjective system which other one from a different place and data set may obtain a different result. Even in the association level, it is possible to describe so many associations. In an ongoing study by the author on annual halophytic communities near Karaj (Mardabad), I found that it is possible to introduce so many associations which are much higher than the number of species occur in a small habitat. One example is introducing of 39 associations and subassociations only based on 130 relevés by Asri & Ghorbanli (1997) from the Orumieh Salt Lake.

In the following our first classification of major halophytic communities (Akhani & Ghorbanli, 1993) is completely revised and as far as possible put in the phytosociological classes. The correlation of these communities along salinity and moisture gradients is shown in FIGURE 2. Most of these classes have already been known in the Euro-Mediterranean and Afro-Asian areas. In some cases only provisional classes (not validated according to International Code of Phytosociological Nomenclature) (Weber *et al.*, 2000) are used for making any criticism and discussion possible. A selection of 42 relevés is given in TABLE 1, from various places of Iran. The author believes that it is better to nominate formally the phytosociological units, after detailed ecological and sociological investigations have been done.

rivers (Rude Shur, 50 km W Tehran, FIGURE 4), streams around inland salines such as Kavire Meyghan (Akhani, 1989), Orumieh Lake (Asri & Ghorbanli, 1997), springs run to Maharlou Salt lake (Carle & Frey, 1977), and natural ponds such as Khuzestan and as a continuous belt at the shores of Miankaleh Bay and Gomishan wetland, the Southeasternmost part of Caspian Sea. In some places, *Zannichellia palustris* have also been seen in the brackish water. But it seems that this species could not grow in true saline water.

From the warm waters of Persian Gulf coasts there are only a few botanical records on the occurrence of *Halophila ovalis*, *Halodule wrightii* and *Thalassodendron ciliatum*, and from the Caspian coast *Zostera noltii* (Dandy, 1971). We have no more details on associated species and extent of communities of these species. *Zostera noltii* is known as character species of *Zosteretea marinae* of the Euro-Mediterranean communities (Natura-2000, 2003). In some lagoons of the Caspian Sea coasts, communities of *Callitriche* spp. have been observed, which need to be investigated phytosociologically and ecologically. Furthermore, the introduced and highly invasive fern *Azolla filiculoides* which become one of the most ecological problems in the North Caspian wetlands, occurs in many lagoon habitats and even frequently have been found in sea water along the coasts. More studies is required to show whether this species can tolerate high salinity of sea or only dispersed by the river flows or tidal connections with the wetlands.

(3): Annual obligatory hygro-halophytic communities on sea, lake and river marshes dominated by stem or leaf succulent C₃ chenopods: **Thero-Salicornietea**.
Selected relevés: TABLE 1, 168, 275, 424, 520.

The C₃ annual Chenopods of the genera *Salicornia*, *Haloepelis* (*H. pygmaea*) and *Suaeda* sect. *Brezia* occur in most saline habitats in Iran particularly on the shores of hypersaline lakes, salty rivers and rarely in littoral marshes (FIGURE 5). The most important ecological conditions for developing such communities are occurrence of high salinity and permanent high moisture which are in subject of periodical inundation. The reason for developing of such annual communities is that the dynamic habitat can not support long-lived perennials. According to soil measurements the EC of soils are between 48 to 200 dS/m (or even more!). The specific status of both *Salicornia* and annual *Suaeda* of sect. *Brezia* is one of the most complicated taxonomic struggle in our area. Based on unpublished data of the author there are some undescribed *Salicornia* species in Iran, one of them is just published (Akhani 2003b) and description of two further is in preparation.

(4) Semi-woody or perennial halophytic communities on muddy or coastal salt flats dominated by stem succulent C₃ chenopods: **Salicornietea fruticosae** [Syn.: *Halocnemetea strobilacei irano-anatolica* Zohary 1973]
Selected relevés: TABLE 1: 267, 401.

This Irano-Turanian, Mediterranean and Saharo-Arabian class of vegetation occurs on hypersaline muddy flat ground with clay soils which the upper soil surface is moist during the spring but may become dry during the summer. But a permanent high underground water level (ca. 1-2 m depth) is present. These commu-

nities develop usually as vast areas around inland saline depressions and coastal areas. The soil salinity seems to be similar with *Thero-Salicornietea* (EC ranging from 15 to more than 200 dS/m). *Halocnemum strobilaceum* is the most distinctive halophytic species which its communities can be seen almost in all inland and littoral salines from sea level to an altitude of 1822 m (in a montane saline in Alborz Mountains). In most parts of its range, *Halocnemum* is a monodominant species (FIGURE 6). The associated species occur in transitional zone with neighboring vegetation units and in successional communities towards or losing its climax. Based on a soil profile in one of its communities in Kavire Meyghan, it was observed that the soil salinity will not decrease even in 130 cm depth.

Other type of communities are *Halostachys belangeriana* communities in the Central parts of Iran (Heuze-Soltan Lake and salt flats near Mobarakieh), *Kalidium caspicum* communities in Semnan and Gorgan, Azerbaijan and Khorasan provinces (sometimes intermixed with *Halocnemum strobilaceum* and *Suaeda physophora*), *Atriplex verrucifera* communities in NE, NW and Central parts of Iran and *Arthrocnemum macrostachyum* communities, a narrow zone in some mangrove communities in S. Iran.



FIGURE 3 - Mangrove forest (*Avicennia marina*), near Bandare Khamir.



FIGURE 4 - A community of *Ruppia maritima* along Rude Shur, between Tehran and Qom.



FIGURE 5 - *Salicornia* community in muddy hypersaline soils around Rude Shur, between Tehran and Saveh.

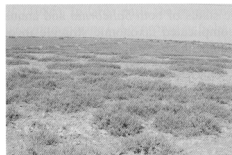


FIGURE 6 - *Halocnemum strobilaceum* community in Azerbaijan, East of Orumieh Lake.



FIGURE 7 - *Phragmites australis* community, ca. 25 km S Delijan.



FIGURE 8 - *Juncus maritimus* community, Kavire Meyghan, N. Arak.

Recently Golub *et al.* (2001a) provided a syntaxonomical overview of class *Salicornietea fruticosae*. According to their proposed system, the communities of *Halocnemum* and *Kalidium* attribute to *Kalidietalia caspici*, *Atriplex verrucifera* attribute to *Halimionetalia verruciferae* and those of *Arthrocnemum* attribute to *Salicornietalia fruticosae*.

(5): Hydrophilous euryhalophytic rush communities: **Phragmitetea australis**.
Selected relevés: TABLE 1: 400, 445, 447.

The communities of this class occur in many parts of halophytic communities which are in contact to fresh or brackish water (FIGURE 7). *Phragmites australis* as the most characteristic and widespread species show extreme variation in its morphology and occurring in extremely diverse habitats. In one extreme there are populations in fresh water and wetlands along the Caspian forests (like Anzali wetland and Miankaleh Bay) which grow as high as four meter height with broad leaves and long inflorescences. In another extreme there are small plants (sometimes subprostrate as in Kavire Meyghan) with convolute leaves which are spiny at tip. There are so many intermediates which detailed biosystematic and molecular studies are needed for study such variations and their genetic and ecologic relationship. According to Léonard (1981: in 1981-1989), the Lut populations replaced by *P. karka*, a species known from Pakistan and SE. Asia. Within this group there are several other communities dominated by *Typha*, *Bolboschoenus* and *Cyperus*.

(6): Halophytic grassland and herbaceous perennial sedge communities belonging to genera *Puccinellia* and *Juncus*: **Juncetea maritimi**
Selected relevé: TABLE 1: 19.

Communities of this group are known from many salt marshes located in the Hyrcanian province of Euro-Siberian region of Iran (South Caspian coastal zone) and many inland salt marshes in the Irano-Turanian parts of Iran and South of Iran. Similar to *Phragmitetea*, the communities of *Juncetea maritimi* develop in areas where fresh and brackish water sources run to salty habitats or are close to littoral places where the habitat is in changing situation between salty and non salty conditions. Usually along an increasing water gradient (with mentioned similar hydrologic condition), *Juncetea* follows *Phragmitetea*.

The *Juncetea maritimi* occurs in Iran both in littoral marshes and inland salines. It could be further divided into two main subgroups. The first and most extensive are the *Juncus* communities. The dominant species are tall sedge species of *Juncus* sect. *acutus*. Six species of this group grow in Iran (Snogerup 1993). In the Caspian lowlands the communities of *J. heldreichianus* subsp. *orientalis*, *J. littoralis* and *J. acutus* are more dominant. But around Orumieh salt lake and Kavire Meyghan *J. maritimus* (FIGURE 8) and in the southern parts of Iran *J. rigidus* and *J. socotranus* are represented. The second group of *Juncetea maritimi* subgroup is halophytic grassland communities dominated by *Puccinellia* species. Examples of well developed communities of *Puccinellia* have been seen in West of Orumieh Lake (cf. Asri & Ghorbanli, 1997), Kavire Meyghan and in saline areas 8 km SW of Sarab. In the relevés of this last locality (not shown) *Juncus gerardii*, *Scorzonera parviflora*, *Lotus tenuis* and *Bolboschoenus affinis* were recorded. Golub *et al.* (2003) gives arguments to consider this group of communities under the independent class *Scorzonero-Juncetea gerardii*.

(7): Salt marsh and riverine bruchwood communities dominated by salt-secreting halophytes: **Tamaricetea ramosissimae** (provisional).
Selected relevés: TABLE 1: 96, 163, 229, 404, 411, 443, 495, 517.

The *Tamarix* communities are widely represented in most parts of temporal salty or permanent rivers and around many inland salines and lakes (FIGURE 9). Sometimes these provide very dense and hardly penetrable thickets such as along Zayandeh Rud and Shurtangeh (salty valley) 60 km N of Damghan. *Tamarix* communities occur in habitats with considerable water supply where the amount of water and its salinity change during the year. The excreting of salts by salt glands in *Tamarix* increases the ground salinity as a result of shedding of leaves and falling of recreted salt. This permanent addition of salt in the soil surface eventually prevent germination of new plants, when there is no leaching. Therefore, *Tamarix* communities are well adopted along rivers or depressions where there are some kinds of washing of soil surface. Changing of water regime in a *Tamarix* community results developing of other type of vegetation units for example *Aeluropus*, *Salicornia* and *Halogetonum*.

The class name *Tamaricetea ramosissimae* is proposed here for the first time. It is equivalent to the name *Tamaricetea* and *Tamaricetea salinae* used by Asri & Ghorbanli (1997), Alaei (2001) and Asri (2003). The reference to Zohary (1973) is apparently wrong, because Zohary referred once in the introduction (p. 52) to this name and not in his description of vegetation units. A syntaxon *Tamaricion-tetragynae* as one of the alliances of *Suaedetea fruticosae deserta* was used by Zohary (1973: 462) from Dead Sea. However, most of the syntaxa used by Zohary are not validly published (Léonard, 1993). A validly name and widely used by the phytosociologist for the thermo-Mediterranean and Saharo-Arabian communities is *Nerio-Tamaricetea* (Natura-2000, 2003). The author believes that suggestion a new class encompassing *Tamarix* communities in the Irano-Turanian region is required.

(8): Annual halophytic communities dominated by C₄ chenopods in temporary moist and inundated, or disturbed salty soils: **Climacopteretea crassae** (provisional).
Selected relevés: TABLE 1: 75, 88, 128, 305, 432, 484, 514, 521.

Climacopteretea crassae is proposed here provisionally. It encompasses leaf succulent C_4 dominated annual halophytic communities which prefer moderately to high salty soils in habitats where have been influenced by natural disturbances (temporal inundation or leaching of high salty soils by flooding) or human disturbances and nitrification of habitats (wastelands, roadside). As these conditions occur usually in many parts of salty habitats, they occur as mosaic patches within or even in association with other communities such as *Salicornietea fruticosae*, *Tamaricetea*, *Thero-Salicornietea* and *Haloxyl-Salsolitea tomentosae*. An alternative decision is uniting this with previously described *Thero-Suaedetea* (or its equivalent lower level *Thero-Suaedetalia*) or *Haloxyl-Salsolitea*. Golub *et al.* (2001a), included communities assigned to this group as Alliance *Climacopteron lanatae* belonging to *Kalidietalia caspici* of *Salicornietea fruticosae*.

In Iranian halophytic communities there are certainly many associations of this group which are dominated by species like *Suaeda arcuata*, *S. altissima*, *S. aegyptiaca*, *Climacoptera spp.*, *Petrosimonia glauca*, *Halanthium rarifolium*, *Atriplex tatarica*, *Bienertia cycloptera* and *Cornulaca monacantha* (FIGURE 10). For more information on the plant communities and abiotic characteristic of these communities see Akhani *et al.* (2003).

(9): Halophytic shrubby, semi-woody or hemicryptophytic communities on salty and dry soils dominated by leaf or stem succulent C_4 chenopods: *Haloxyl-Salsolitea tomentosae* (provisional).

Selected relevés: TABLE 1: 96, 163, 229, 404, 411, 443, 495, 517.

Haloxyl-Salsolitea tomentosae is also a provisional class. This type of vegetation is characteristic of large parts of Iranian halophytic communities in the Irano-Turanian region (senu lato, including southern Iran and Pakistani Baluchestan). They are usually dominated by C_4 shrubs and subshrubs of the genera *Salsola*, *Suaeda*, *Anabasis*, *Seidlitzia* and *Haloxylon*. They are located between hygrohalophytic communities (*Salicornietea fruticosae* and *Tamaricetea ramosissimae*) and xerophytic communities (*Artemisietea sieberi*). The Irano-Turanian region is the diversity center of some genera belonging to this group. *Salsola tomentosa* is one of the most widespread xerohalophyte species in Iran which frequently mixed with *Artemisia* communities. Therefore, we can see sometime broad transition communities of the two classes *Haloxyl-Salsolitea tomentosae* and *Artemisietea sieberi*.

Four major subgroups of this class are (1), hygrohalophytic communities dominated by *Suaeda fruticosa* and *Salsola drummondii* in South Iran (*Suaedetalia fruticosae*, prov. synonym *Suaedetea fruticosae* Zohary, 1973, p.p.) (FIGURE 11), (2), leaf succulent species of the genera *Salsola*, *Halothamnus* and *Seidlitzia rosmarinus* (*Salsolietalia*, prov.), (3) extreme xerophytic mesohalophytes dominated by articulated chenopods of the genera *Anabasis* and *Hamnada* on salty and gypsum hills or disturbed habitats (*Anabasieta*, prov.). The class *Hamadetea salicornicae* Zohary (1973) in the South Iran is partly equivalent to this group; and (4), stem succulent tree and shrub communities dominated by *Haloxylon ammodendron* (on salty soils with relatively high water table) or *H. persicum* (a psammo-halophyte growing in sandy dunes with salt water underground) (*Haloxyletalia*). Léonard (1991/1992) published some relevés and described some communities assigned to

the *Haloxylon-Salsoletea tomentosae* including *Haloxylum persico-aphylli*, *Haloxylon ammodendron*, *Hammada (Haloxylon) salicornica* and *Seidlitzia rosmarinus* communities.

It seems that presence of high salt underground water is a precondition for developing of *Haloxylon ammodendron* communities. In a rare case a community of *Haloxylon ammodendron* have been developed close to species like *Juniperus excelsa* and *Acer monspessulanum* subsp. *turcomanicum* in Almeh valley in Golestan National Park (Akhani, 1998). The underground salt water in the salty marl and gypsum formation of the area make a reasonable interpretation for this vegetation rarity.

(10): Halophytic shrub communities on salty and sandy coastal or margin of sabkhas with high water table dominated by *Nitraria schoberi* and *Reaumuria fruticosa*. Selected relevé: TABLE 1: 535.

In the Central and Northeastern parts of Iran, there are two types of halophytic communities which develop on salty and sandy soils (halo-psammophytes). *Nitraria schoberi* communities are well known in the sandy and salty flats East of Caspian Sea shores and inland salines of Aralo-Caspian province of Irano-Turanian region. In Iran these communities occur in inland salines mostly around salt depressions with high water table which are covered by shallow dunes. By growing of dunes, they survive by adventitious roots and sometimes form large hillocks up to one meter depth. They may also grow in vertical direction and produce very large impenetrable patches which only one plant reaches to a diameter of up to 8 m (FIGURE 12). In a soil profile in Kavire Meyghan, we found that the soil salinity at the soil surface is low (5.2 ds/m) but increase in a maximum of 35.2 ds/m in 90-100 cm depth and decrease to 12-15 ds/m from 150 to 190 cm depth. The syntaxonomical position of these communities is rather unclear. As the main distribution center of *Nitraria* communities is the Aralo-Caspian areas, we should await of more data from there to have them better classified. One alternative way would be classifying them either to *Salicornietea fruticosae* or *Tamaricetea*.

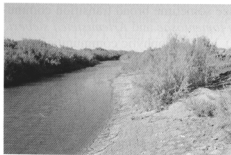


FIGURE 9 - *Tamarix* community along Kal Shur river, Touran Protected Area.



FIGURE 10 - Annual C4 halophytic communities dominated by genera *Climacoptera*, *Bienertia*, *Petrosimonia* and *Halanthium*, Mardabad near Karaj.



FIGURE 11 - *Suaeda fruticosa* community near Hasan Langi, 70 km East of Bandar Abbas.



FIGURE 12 - *Nitraria schoberi* stand, 25 km S De-lijan.



FIGURE 13 - *Zygophyllum qatarense* comm. along Persian Gulf coasts.



FIGURE 14 - *Aeluropus littoralis* comm. around Tashk Lake, Fars.

Another type of vegetation which occupies in rather similar habitats but occur in much drier climate are *Reaumuria fruticosa* communities. Although the species occurs sporadically in some salines in E parts of Iran, but as a community was observed in low sandy dunes developed on high salty soils at margin of great Kavir. The syntaxonomic status of this community is also not obvious at present.

(11): Psamo-halophytic shrub communities along sandy coasts of Persian Gulf and Oman sea: *Sphaerocomion aucheri* Deil 1999, *Zygophyllum qatarense* and *Heliotropium bacciferum* communities.

Along the Persian Gulf and Oman Sea, many coastal plant communities are developed which are dominated by various species including *Zygophyllum qatarense* (FIGURE 13) *Sphaerocoma aucheri*, *Heliotropium bacciferum*, *Halopyrum mucronatum* (this is frequently associated with *Suaeda baluchestanica*, an endemic species described from Irano-Pakistan coasts, see Hedge *et al.*, 1997), *Zygophyllum simplex*, *Panicum turgidum*, *Sporobolus arabicus* and *Cornulaca aucheri*.

(12): Unclassified halophytic communities: **Herbaceous perennial and hemicryptophyte halophytic communities of secondary origin.**

Selected relevés: TABLE 1: 144, 389.

In this group there are a number of hemicyptophyte and herbaceous perennial plant communities usually occur as secondary plant communities. Species like *Aeluropus littoralis* (FIGURE 14), *A. lagopoides*, *Salsola dendroides*, *Alhagi mauro-rum* belongs to this group. It is open for further discussion whether these elements could be classified into above mentioned classes or new classes are to be considered. In a recent study of hemicyptophyte halophytic communities in the Commonwealth of Independent States and Mongolia, the new class *Aeluropetea littoralis* is suggested by Golub *et al.* (2001b).

CONCLUDING REMARKS

1. The distribution of halophytes in Iran are not only related with the edaphic conditions, but also in larger scale they can be considered as good phytogeographical elements. Although large parts of Iranian halophytes belong to the Irano-Turanian region, but a remarkable connection with the Mediterranean and Saharo-Arabian flora is present.
2. The endemic halophytes of Southern Iran are indicators of an Irano-Turanian stock rather than supposed Saharo-Sindian and Sudanian regions.
3. The vegetation of halophytes of Iran is better known than other vegetation units. The evaluation of available data show that many of the higher syntaxa of the Euro-Mediterranean and Afro-Asian areas are represented, at least partly in Iran. *Avicennio-Sonneratietaea*, *Ruppietaea maritimae*, *Thero-Salicornietaea*, *Salicornietaea fruticosae*, *Phragmitetaea australis*, *Juncetaea maritimi* are among the known units. At least four more classes need to be added for the country including *Tamaricetaea ramosissimae*, *Haloxyl-Salsoletea tomentosae*, *Climacoptereatea crassae* and *Aeluropeteatea littoralis*.
4. *Haloxyl-Salsoletea tomentosae*, *Climacoptereatea crassae* are Irano-Turanian endemic classes of the xerohalophytic communities which are characterized by the presence of high percentage of C₄ species.

ACKNOWLEDGMENTS

Support of this research under the project title "Geobotanical studies in different parts of Iran" by the Research Council University of Tehran is acknowledged. Parts of the field studies during 2001 were carried out by a car provided by Agricultural Biotechnology Research Institute in Karaj (Dr. N.A. Khosh-Kholgh Sima and Dr. B. Ghareyazi) in the frame of a project on the genus *Salicornia*. A three months research award by DAAD (German Academic Exchange Service) during summer 2002 in Germany (Darmstadt and Freiburg) and invitations and supports by Prof. U. Deil, Prof. A. Schwabe-Kratochvil and Prof. E. Bergmeier are much appreciated.

REFERENCES

- AKHANI H., 1989. (publ. 1992) - *A contribution to the vegetation and flora of Kavire-Meyghan* (NE, Arak), Iran. J. Sci. Univ. Tehran **18**: 75-84. (In Persian, English summary).
- AKHANI H., 1998 - *Plant biodiversity of Golestan National Park, Iran*. Stapfia **53**: 1-411.
- AKHANI H., 2002 - *Notes on the flora of Iran 1: Asparagus (Asparagaceae) and Nitraria (Zygophyllaceae)*. Edinburgh J. Bot. **59** (2): 295-302.
- AKHANI H., 2003a - *Notes on the flora of Iran 4. Two new records and synopsis of new data since Flora Iranica*. Candollea **58**: 369-385.
- AKHANI H., 2003b - *Salicornia persica Akhani (Chenopodiaceae), a remarkable new species from Central Iran*. Linzer Biol. Beitr. **35**: 607-612.
- AKHANI, H. 2004a - Biodiversity of halophytic and sabkha ecosystems in Iran. In: Khan, M. A., Barth, H., Kust, G. C., & Bøer, B. (eds.) Sabkha Ecosystems Vol. 3. Kluwer Academic Publishers (accepted).
- AKHANI H., 2004b - *A new spiny cushion-like Euphorbia (Euphorbiaceae) from south-west Iran, with special referre to the phytogeographic importance of local endemic species*. Bot. J. Linn. Soc. **146**:107-121.
- AKHANI H. and GHORBANLI, M., 1993 - *A contribution to the halophytic vegetation and flora of Iran*. In: LIETH, H. & AL MASOOM, A. (eds.), Towards the rational use of high salinity tolerant plants. Dordrecht: Kluwer Academic Publishers, pp. 35-44.
- AKHANI H., GHOBADNEHAD, M. and HASHEMI, S. M., 2003 - *Ecology, biogeography and pollen morphology of Bienertia cycloptera Bunge ex Boiss. (Chenopodiaceae), an enigmatic C₄ plant without Kranz anatomy*. Plant Biol. **5**: 167-178.
- AKHANI H., BAROCCA, J., KOTEVA, N., VOZNESENSKAYA E., FRANCESCHI V., EDWARDS G., GHAFFARI S.M., and ZIEGLER H., (submitted) - *Bienertia sinuspersici (Chenopodiaceae): a new species from SW Asia and discovery of a third terrestrial C₄ plant without Kranz anatomy*. Syst. Bot.
- ALAJE E., 2001 - *Salt marshes and salt deserts of SW Iran.-Pakistan* J. Bot. (1) **33**: 77-91.
- ASRI Y., 2003 - *Plant Biodiversity in Kavir Biosphere Reserve*. Research Institute of Forests and Rangelands. Tehran.
- ASRI Y. and GHORBANLI, M., 1997 - *The halophilous vegetation of the Orumieh lake salt marshes, NW Iran*. Plant Ecology **132**: 155-170.
- ATRI M., ASRI Y. and GHORBANLI M., 1995 - *Étude préliminaire de la végétation halophile du littorale ouest du lac Oromieh, Iran*. Doc. Phytosociologiques **15**: 205-210.
- BAUM B., 1978 - *The genus Tamarix*. The Israel Academy of Sciences and Humanities, Jerusalem.
- BRAUN-BLANQUET J., 1964 - *Pflanzensoziologie: Grundzüge der Vegetationskunde*. 3. neu bearb. Aufl. Wien: Springer-Verlag.
- BRECKLE S.W., 1981 - *The significane of salinity*. In: Spooner, B. & Mann, H. S. (eds.) *Dryland ecology in social perspective*. pp.277-292. Academic Press. London/New York.
- BRECKLE S. W., 1983 - *Temperate deserts and semi-deserts of Afghanistan and Iran*. In: WEST, N. (ed.), *Ecosystems of the world*, vol. 5, pp. 271-319. Amsterdam. Elsevier.
- BRECKLE S. W., 1986 - *Studies on halophytes from Iran and Afghanistan. II Ecology of halophytes along salt gradients*. Proc. Roy. Soc. Edinb. **89 B**: 203-215.
- CARLE R. and FREY W., 1977 - *Die vegetation des Maharlu-Beckens bei Shiraz (Iran) unter besonderer Berücksichtigung der Vegetation im Bereich der Süß- und Salzwasserquellen am Secufer*.-Beih. Tübinger Atlas Vorderer Orient, Reihe A, Naturwissenschaften 2, Wiesbaden.
- DANDY J. E., 1971 - *Zostracaceae*. In: Rechinger, K. H. (ed.), *Flora Iranica*, 81. Academische Druck - und Verlagsanstalt. Graz.

- DEWAN M. L. and FAMOURI J., 1964 - The soils of Iran. FAO. Rome.
- DEIL U., 1999 - Halophytenvegetation an den Küsten der Arabischen Halbinsel-kleinräumige edaphische Zonierung und großräumige klimabedingte Differenzierung. In: Brandes, D. (Hrsg.): Vegetation salzbeeinflusster Habitate im Binnenland. pp. 119-147. Universitätsbibliothek der TU Braunschweig.
- FREITAG H., 1991 - *The distribution of some prominent Chenopodiaceae in SW Asia and their phytogeographical significance*. Flora et Vegetatio Mundi **9**: 281-292.
- FREY W. and KÜRSCHNER H., 1983 - *Photosyntheseweg und Zonierung von Halophyten an Salzseen in der Türkei, in Jordanien und im Iran*. Flora **173**: 293-310.
- FREY W., KÜRSCHNER H. and PROBST W., 1986 - Persische Golfküste. Mangrove. Vegetation. Beispiele. A VI 10. Tübinger Atlas des Vorderen Orients der Universität Tübingen. (TAVO). Dr. Ludwig Reichert Verlag. Wiesbaden.
- FREY W., KÜRSCHNER H. and STICHLER W., 1985 - *Photosynthetic pathways and ecological distribution of halophytes from four littoral salt marshes (Egypt/Sinai, Saudi Arabia, Oman and Iran)*. Flora **177**: 107-130.
- FREY W. and PROBST W., 1986 - A synopsis of the vegetation of Iran. In: Kürschner, H. (ed.) Contributions to the Vegetation of Southwest Asia. Beih. TAVO, Naturwiss. **24**: 9-24.
- GHORBANLI M. and LAMBINON J., 1978 - *Premier aperçu de la zonation de la végétation halogypsophile du lac Ghom (Province de Téhéran, Iran)*. Lejeunia Rev. Bot. **92**: 1-22.
- GHORBANLI M., ASRI Y. and HAMZEHEE B., 1997 - *Végétation halophile de la bordure sud de la Sebkha Garmsar (Iran)*. Colloques Phytosociologiques **27**: 491-502.
- GOLUB V. B., RUKHLENKO I. A. and SOKOLOFF D. D., 2001a - *Survey of communities of the class Salicometalia fruticosae*. Vegetation of Russia **2**: 87-98.
- GOLUB V. B., LYSENKO T. M., RUKHLENKO I. D. and KARPOV D. N., 2001b - *Inland hemicryptophyte halophytic communities in the Commonwealth of Independent States and Mongolia*. Bull. Mosk. O. Va. Ispital'ni Priorodi Otd. Biol. **106**: 69-75 (In Russian).
- GOLUB V., KARPOV, D. and LYSENKO T., 2003 - *Moist humid salinized meadows of class Scorzonero-Juncetea gerardii Golub et al. 2001 on the territory of the Commonwealth of Independent States and Mongolia*. 46th Symposium of the International Association for Vegetation Science, June 8-14, 2003. Napoli. Italy. p.106. Abstract.
- HEDGE I. C., AKHANI H., FREITAG H., KOTHE-HEINRICH G., PODLECH D., RILKE S. and UOTILA P., 1997 - *Chenopodiaceae*. In: Rechinger, K. H. (ed.) Flora Iranica **172**. Akademische Druck - und Verlagsanstalt. Graz.
- LÉONARD J., 1981-1989 - Contribution à l'étude de la flore et de la végétation des déserts d'Iran. Fasc. 1-9. Jardin botanique national de Belgique. Meise.
- LÉONARD J., 1991/1992 - Contribution à l'étude de la flore et de la végétation des déserts d'Iran. Etude de la végétation: Analyse phytosociologique et phytocorologique des groupements végétaux. Fasc. **10** (1 & 2), Jardin Botanique National de Belgique. Meise.
- LÉONARD J., 1993 - *On the plant associations mentioned in Iran by M. Zohary*. Bull. Jard. Bot. Nat. Belg. **62**: 113-118.
- NATURA 2000, 2003 - Interpretation manual of European Union habitats. Euro 25. European Commission, DG Environment.
- RECHINGER K., (ed.). 1963 - Flora Iranica, Lfg. **1-175**. Akademische Druck - u. Verlagsanstalt. Graz.
- SABETHI H., 1976 - Forests, trees and shrubs of Iran. Ministry of Agriculture and Natural Resources. Tehran.
- SNOGERUP S., 1993 - *A revision of Juncus subgen. Juncus (Juncaceae)*. Willdenowia **23**: 23-73.
- WEBER H. E., MORAVEC J. and THEURILLAT J. P., 2000 - *International Code of Phytosociological Nomenclature*. 3rd edition. J. Veg. Sci. **11**: 739-765.

WHITE F. and LÉONARD J., 1991 - *Phytogeographical links between Africa and Southwest Asia*. *Flora et Vegetatio Mundi* **9**: 229-246.

ZOHARY M., 1973 - *Geobotanical foundations of the Middle East*. 2 vols. Gustav Fischer Verlag.

TABLE 1 - Selection of 42 phytosociological relevés in Iranian halophytic communities. The C4 species are in bold. The nomenclature follows mostly according to Rechinger (1963 ff.).

Relevé No.	Surface (m ²)	Shrub (%)	Herb & ground (%)	Total cover	Shrub height (cm)	Herb & ground height (cm)	Shrub diversity index	Number of species
534	10	0	0	0	66	0	0	1
427	10	1	0	0	80	0	0	1
168	1	1	0	0	70	70	0	2
275	4	0	25	25	0	30	0	1
520	5	0	5	5	0	15	0	1
424	2	0	50	50	0	30	0	1
401	10	10	30	40	1	35	1	2
267	10	10	50	60	0	50	0	1
400	1	0	10	10	0	1	0	1
445	4	0	10	10	0	18	0	1
447	4	0	10	10	0	40	0	1
19	1	0	0	0	90	30	0	1
443	10	10	10	10	1	15	1	1
411	50	50	50	50	3	40	3	1
229	4	0	60	60	0	30	0	1
163	16	16	80	80	1	13	1	2
96	10	70	75	75	1	70	1	1
495	10	20	30	40	1	40	1	1
404	10	20	30	40	1	40	1	1
517	10	10	10	10	0	40	0	2
521	25	0	50	50	0	40	0	1
514	10	0	12	12	0	50	0	1
88	4	0	60	60	0	50	0	1
75	4	0	85	85	0	20	0	1
432	4	0	30	30	0	60	0	1
484	25	0	60	60	0	90	0	1
128	0	0	40	40	0	25	0	1
305	25	0	30	30	0	40	0	1
259	40	0	30	30	0	80	0	1
290	10	0	30	30	0	70	0	1
490	10	0	20	20	0	60	0	1
492	10	2	10	10	0	40	0	1
439	25	0	10	10	0	25	0	1
233	25	0	30	30	0	29	0	1
116	25	0	10	10	0	39	0	1
506	40	20	20	20	1	30	1	1
332	10	0	10	10	0	40	0	1
409	10	0	55	55	0	1	0	1
473	25	0	30	30	0	50	0	1
535	10	10	30	40	0	0	0	1
389	25	0	60	60	0	90	0	1

