Halophytes on the Dry Sea Floor of the Aral Sea

in: "Sustainable Land-Use in deserts", by Breckle,S.-W., Veste,M. & Wucherer,W. (eds.) 2001, Springer/Heidelberg. p. 139-146

Siegmar–W. Breckle, Anja Scheffer and Walter Wucherer

Keywords. Halophyte types, ion pattern, salt desertification, dry sea floor

Abstract. Within a relatively short period, less than a half century, the area of salt deserts in Central Asia has grown by about 60 000 km². The process of salt desertification is tremendously active in the region of the former Aral Sea. The coastal plain and the dry sea floor of the Aral Sea are an evident model for studying salt desertification. The vast occurrence of salinization processes is the main reason for a very diverse halophytic flora on the dry sea floor. In comparison to other ecophysiological life forms, halophytes thrive on saline soils and are able to grow even on rather strongly salinized substrates. Investigation of the adaptive mechanisms of the various halophyte types is essential for an adequate species composition for phytomelioration of these saline soils. Phytomelioration by artificial planting on the dry sea floor for more rapid closure of the vegetation cover is a great need to minimize the widespread negative effects of salt desertification.

Introduction

Saline soils and halophytic vegetation are a common feature and part of the habitat pattern in deserts and steppes. The percentage of saline ecosystems in a distinct area is increasing with aridity. In Central Asia about 90% of the area are arid, semiarid or at least subhumid. Solonchak soils and halophyte plant communties are most typical for the Caspian Basin, the Aral Sea and the Balkhash Basin. In the Aral Sea Basin, within the short time of about 40 years, the development of a huge, new salt desert has taken and is still taking place, caused by the drying of the Aral Sea. This process is comparable in size with the Great Iranian Salt desert and is even larger than the Great Salt Desert in Utah. The area of saline soils on the dry sea floor amounts to about 38 000 km². Additional areas with saline soils are found within the irrigation zones. These secondary salinized soils have an area of about 22 000 km² (Glazovskii and Orlovskii 1996). This means that in a relatively short time period, within less than a half century, the area of salt deserts in Central Asia has grown by about 60 000 km². The process of salt desertification is tremendously active in the region of the former Aral Sea. The coastal plain and the dry sea floor of the Aral Sea are an evident model for studying salt desertification. The dry sea floor is covered with a mixture of shells, clay, loam, sand and salt. Only the older sandy soils are almost free of salt.

Since the middle of the 1980s, open salt deserts have formed on a large scale. The fast increase in the salt desert area and the rapid change have caused an absolute dominance of halophytes. Other life forms are more and more lacking. In comparison to other ecophysiological life forms, halophytes thrive on saline soils and are able to grow even on rather strongly salinized substrates. The formation of vegetation types on the solonchak soils of the newly formed sea floor stands can only be understood by studying the ecological characteristics of the relevant halophyte species. During the 1998–1999 expeditions on the coast of the Aral Sea, hundreds of plant and soil samples were collected and analyzed.

Halophyte Flora

The vast occurrence of salinization processes is the main reason for a very diverse halophytic flora on the dry sea floor. From the 266 species hitherto known, 200 species (75.2%) occur on solonchaks or other saline soil types of the dry sea floor. The remaining species may be influenced episodically or periodically by salt after germination or during other life phases. This results in a rich halophytic flora of the dry sea floor which, on the one hand, is affected by salinity to various degrees and, on the other has evolved adaptations for survival on those saline stands. From the halophytes 45 species (22.5%) belong to the group of euhalophytes (Fig. 1).

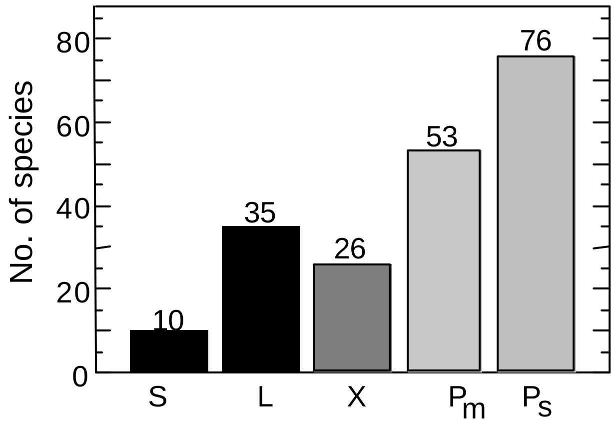

Fig.1. Spectrum of halophyte types on the dry sea floor of the Aral Sea. *S* stem succulent halophytes; *L* leaf succulent halophytes; *X* recretohalophytes; *Pm* pseudohalophytes with moderate salt tolerance; *Ps* pseudohalophytes with slight salt tolerance

Within the euhalophytes the group of the stem-succulent euhalophytes (S) with *Salicornia europaea* (s.l.), *Halocnemum strobilaceum*, *Halostachys caspica* and *Ofaiston monandrum* comprise annuals and perennials as well as the group of leaf-succulent euhalophytes (L) with several *Suaeda* species (*S. crassifolia*, Fig. 2; *S. acuminata*, *S. microphylla, S. physophora*), *Climacoptera* species (*C. aralensis*, Fig. 3; *C. ferganica, C. lanata*) and *Petrosimonia* species (*P. triandra, P. squarrosa, P. brachiata*) as typical examples.

Fig. 2. The leaf-succulent halophyte *Suaeda crassifolia* on the marshy solonchak of the transect Karabulak on the north coast of the Aral Sea

Fig. 3. The leaf-succulent halophyte *Climacoptera aralensis* on the coastal solonchak of the transect Bayan on the east coast of the Aral sea

Fig. 4. The accumulation form (chokolak) of *Halocnemum strobilaceum* on the coastal solonchak on the east coast of the Great Aral sea, forming nepkha hummocks

Fig. 5. The recretohalophyte *Tamarix hispida* on the degraded coastal solonchak of the dry sea floor of the Small Aral Sea

Halocnemum strobilaceum is a typical semishrub and forms a widespread vegetation cover along most parts of the east coast of the Aral Sea. Such vegetation types with *Halocnemum strobilaceum* and other perennial halophytes, with a cover percentage of 20–30% have a low salt dust output. On the dry sea floor from the 1980s and 1990s the perennial vegetation is lacking and the salt content of the substrate is much higher. Often *Halocnemum* exhibits the typical growth-form of a sand-accumulating nepkha shrub, the so called chokolaks (Fig. 4). The plant communities with *Salicornia europaea* and *Suaeda* species dominate on the marsh solonchaks close to the present coastline. The recretohalophytes (salt-excreting species, X) are represented by *Tamarix hispida* (Fig. 5), but also by *Frankenia hirsuta*, *Limonium gmelinii*, *Aeluropus littoralis*, all with salt glands, and *Atriplex* species with bladder hair .

The *Atriplex* species are grouped to the recretohalophytes, since their bladder hair recrete salts (Schirmer and Breckle 1982). Two of the Atriplex species are especially interesting. *Atriplex fominii* grows preferably on sand-covered coastal solonchaks, but also on many other localities, and exhibits a considerable morphological plasticity. *Atriplex pungens* is quite common on the dry sea floor of the northern coasts of the Aral Sea, but apparently prefers soils enriched with gypsum. Often small-scale strictly monodominant vegetation units can be found.
Five species belong to the pseudohalophytes with a slight recreto function (several Poaceae species). These are part of the large group of pseudohalophytes with moderate salt tolerance (55 species or 27.5%): examples are *Bassia hyssopifolia, Artemisia scopaeformis, Euclidium syriacum, Kochia stellaris* etc. This group is very heterogenous, concerning their ecomorphology as well as their ecophysiology. They are predominantly restricted in their distribution to the degraded coastal solonchaks of the dry sea floor. They can withstand moderate salinity in soil (moderate pseudohalophytes, P_m). The largest group (35.5%) are the slight pseudohalophytes (P_s), which are intermediate to the non-halophytes (N), these are not treated here. The latter may be glycophytic species, which can for some time tolerate a slight salinity of the topsoil. Examples of this group are, e.g. some Brassicaceae species, *Strigosella* species, and Asteraceae such as, e.g. *Tragopogon marginifolius, Acroptilon repens*. Table 1 gives a list of typical plant families with a high proportion of halophytes. Most species of Chenopodiaceae are leaf- and/or stem succulents (Table 1).

Table 1. Halophyte types within some plant families of the dry sea floor

Family	S	L	X	P_m	P_s
Chenopodiaceae	10	33	10	12	10
Brassicaceae				13	11
Asteraceae		2		8	9
Poaceae			2	9	6
Fabaceae				4	9
Tamaricaceae			7		
Limoniaceae			4		

S stem succulent halophytes; *L* leaf succulent halophytes; *X* recretohalophytes; P_m pseudohalophytes with moderate salt tolerance; P_s pseudohalophytes with slight salt tolerance

The Brassicaceae and Poaceae comprise mainly pseudohalophytes. All species of Limoniaceae are recretohalophytes.

Ion Patterns of the Several Halophyte Groups

In studies on the ecology of halophytes along salt gradients in Iran und Afghanistan (Breckle 1986) several Irano–Turanian species were discussed. A similar study is done here for the halophytes of the Aral Basin. Some preliminary results are shown in Table 2, giving an impression of the main cation and anion content in stems and leaves (Cl, Na, K, Ca, Mg) of selected plant species.

Table 2. Ion pattern of several halophytes (mmol kg^{-1} dw)

Species	Locality	Cl	Na	K	Mg
Stem succulent halophytes					
Halocnemum strobilaceum	B	3042	3748	506	133
Salicornia europaea	B	4402	4094	522	152
Ofaiston monandrum	Ka	1604–2789	1272–3096	323–525	490–574
Leaf succulent halophytes					
Sueda acuminata	Ka	2659–5133	3399–5018	589–860	185–356

Sueda crassifolia	Ka	4076–4895	3254–3676	426–427	471–619
Climacoptera aralensis	Ka	2136–3216	1774–4142	517–910	130–197
Petrosimonia triandra	B	510	966	550	320
Pseudohalophytes					
Euclidium syriacum	Ka	314	127	497	95
Non-Halophytes					
Eremosparton aphyllum	B	155	33	324	78
Stipagrostis pennata	B	78	45	327	43

B Bayan; *Ka* Karabulak

It is obvious that leaf- and stem succulents, like species from the genera *Suaeda*, *Salicornia* and *Halocnemum*, accumulate considerably more Na and Cl (3000–5000 mmol kg^{-1}) in comparison with other species. The ionic content (Na and Cl) of *Climacoptera* species and of *Ofaiston monandrum* are lower (2000 –3500 mmol kg^{-1}) in comparison with species from *Salicornia* and *Suaeda*. Even lower are the values from *Petrosimonia triandra*. On the other hand, the Na and Cl accumulation of pseudohalophytes like *Euclidium syriacum* and *Stripagrostis pennata* is very low.

It is always an open question to what extent the edaphic conditions influence the ionic pattern and content in plants. The Pontic–Irano–Turanian *Suaeda acuminata* (Fig. 6) is also very common in Central Asia (Wucherer 1986). This species exhibits a wide ecological amplitude and thus can be found on very contrasting saline stands. Within the transect Karabulak on the northern coast of the Aral Sea, four localities were chosen for investigation (Fig. 7).

It is obvious that the Na and Cl content of the above ground plant organs of *Suaeda acuminata* on degraded coastal solonchaks and puffy coastal solonchaks is significantly lower. These soils contain significantly less salt in the top soil. On these stands also the Na content is higher than the Cl content in comparison with the marshy solonchaks and crusty coastal solonchaks. This example with *Suaeda* demonstrates that the ion content in halophytes growing on real solonchaks with high salinity is distinctly influenced by the edaphic conditions. Balnokin et al. (1991) studied the Na, Cl, and S content in *Salicornia europaea*, *Climacoptera aralensis* und *Petrosimonia triandra* along the transect Bayan on the east coast of the Aral Sea.

Fig. 6. The leaf-succulent halophyte *Sueda accuminata* on the coastal solonchak of the transect Bayan on the east coast of the Aral Sea

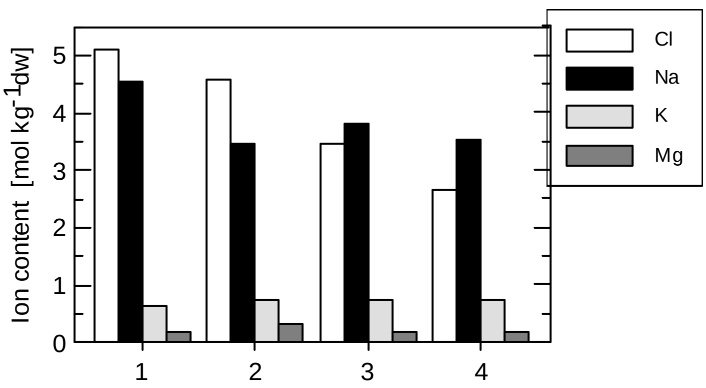

Fig. 7. The content of the main cations in the above-ground parts of *Sueda accuminata* localities from the Aralkum desert. *1* Crusty coastal solonchak; *2* marshy solonchak; *3* degraded coastal solonchak; *4* puffy coastal solonchak

It was shown that the Na and the Cl content in *Salicornia europaea* and *Climacoptera aralensis* was more or less constant in the roots, but increased in the stems and leaves with increasing soil salinity. In *Petrosimonia triandra,* the ion content remained rather constant also in the above ground organs even with varying soil salinity. This is an indication that also in the stem and leaf succulent halophytes, in the recreto- and pseudohalophytes from the dry Aral Sea floor, different mechanisms and strategies for the adjustment and regulation of the salt concentration in the plant tissues are operating (Breckle 1995) and thus a differing salt tolerance in the various species leads to a specific pattern of species and halophyte types along salt gradients.

Conclusion

Investigation of the adaptive mechanisms of the various halophyte types is essential for an adequate species composition for phytomelioration of these saline soils. The salinization of the substrate on the dry sea floor varies to a great extent, causing a wide variety of saline soil types; various solonchaks have developed: marshy solonchaks, crusty and puffy solonchaks, solonchaks slightly covered by sand, degraded coastal solonchaks, takyr solonchaks etc. Phytomelioration by artificial plantings on the dry sea floor for a more rapid closure of the vegetation cover is a great need to minimize the widespread negative effects of salt desertification in the whole area. Studying natural halophytes is thus very important for all those regions where salinity has reached such a level that desalinization techniques are much too costly. Investigations of halophytic ecosystems, of the salinity process in agrarial systems and of plant strategies for salt regulation are an urgent need in the Aral Sea region, where salt desertification has become dominant.

Acknowledgements. This research is funded by the German Federal Ministry for Education and Research (BMBF grant 0339714).

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