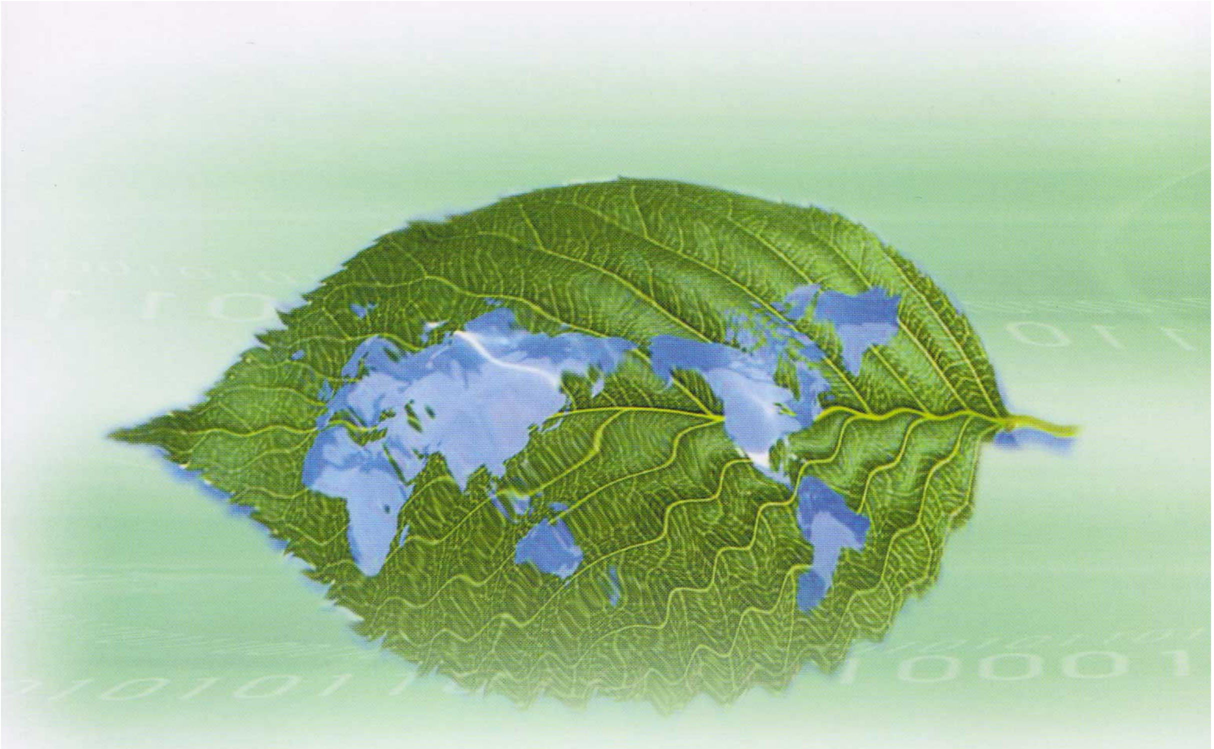

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Halophytes as Useful Tools for Rehabilitation of Degraded Lands and Soil Protection

Walter Wucherer [1], Maik Veste [1,2], Oriel Herrera Bonilla [3] & Siegmar-W. Breckle [1]

[1] University of Bielefeld, Department of Ecology, PO Box 10 01 31, 33501 Bielefeld, Germany. Corresponding email: wwucherer@web.de; sbreckle@gmx.de
[2] University of Bonn, Nees-Institute for Biodiversity of Plants, Meckenheimer Allee 170, 53115 Bonn, Germany, maik.veste@t-online.de
[3] Universidade Estadual do Ceará, Department of Biology, Av. Paranjana 1700, Campus do Itaperi, Fortaleza, Ceará, CEP; 60.740-000 Brazil.

Introduction

Worldwide salinity is often very prominent problem in degraded lands, caused by the input of sodium chloride and other salts and the lack of drainage (Breckle et al. 2001). In this environment the excesses of soluble salts in the soils have a large influence on the ecosystems and plant growth and reduce the productivity in extensive area. Halophytes may serve to improve the ecosytem production. They are model plants for the understanding of the adaptation strategies in such habitats. In this paper we present two case studies from the cold-deserts of Central Asia and the tropical semi-arid regions of north-eastern Brazil to demonstrate the use of natural halophytic vegetation in combating desertification. Aim of the presented studies were to identify suitable plants on basis of their morphological and ecospyhsiological strategies for their reestablishment on saline soils.

The Aral Sea problem

Before 1960 the Aral Sea was the fourth largest inland lake on the globe. Inefficient water use for irrigation led to an imbalance of the regional water budget. The water supply by the two rivers Amurdarya and Syrdarya into the Aral Sea dropped from an average of about 60 km^3 (before 1960) to 4 km^3 a^{-1} (Breckle et al. 2001a). During the past years, in the 1990s, the average water input to the Aral Sea has increased again to about 14 km^3 a^{-1}. As a result of this drastic changes water level dropped by 23 m during the last 45 years and the surface area of the water body has shrunk to about one third from approx. 70.000 km^2 to 20.000km^2. The remnant water bodies today are the Small Aral Sea in the North, the Western and Eastern Great Aral Sea in the south. A new man-made desert is created on the dry seafloor: the Aralkum covering an area larger than The Netherlands. About 68% of the Aralkum surface are salt deserts with saline and alkaline soil surface, with salt crusts or puffy solonchaks, 20% are sand deserts with often newly formed barchans and other sand dune types, the remnant 12% are wetlands (Breckle & Wucherer 2005). The younger open salt flats are the main source of huge salt dust storms affecting the agricultural fields in the southern parts of the Aral Sea. To minimize wind erosion a dense vegetation cover are needed.

Halophytes on the dry sea floor of the Aral Sea

The fast increase in the salt desert area has caused a dominance of halophytes on the dry sea floor (Wucherer et al. 2001). 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 (15%) belong to the group of euhalophytes. Within the salt tolerant plants the Chenopdiaceae forms the larges group (Tab. 1). Halophytes exhibit special morphological and physiological adaptations to survive in saline ecosystems (Breckle 1990, 1995, 2002). According to their morphological and anatomical strategies the halophytes can be divided in different groups: (i) stem succulent halophytes; (ii) leaf succulent halophytes (iii) recretohalophytes and (iv) pseudohalophytes with moderate salt tolerance (BRECKLE 1990). 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*, *S. acuminata, S. microphylla, S. physophora*), *Climacoptera* species (*C. aralensis, C. ferganica, C. lanata*) and *Petrosimonia* species (*P. triandra, P. squarrosa, P. brachiata*) as typical examples. The recretohalophytes (salt-excreting species, X) are represented by *Tamarix hispida*, *Frankenia hirsuta*, *Limonium gmelinii,* and the grass *Aeluropus littoralis*, all with salt glands, and *Atriplex* species with bladder hair. Examples from the large group of pseudohalophytes with moderate salt tolerance are *Bassia hyssopifolia, Artemisia scopaeformis*, *Euclidium syriacum, Kochia stellaris* etc.. This group is very heterogeneous, 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 are the slight pseudohalophytes (P_S), which are intermediate to the non-halophytes (N), these are not treated here.

A remarkable sequence of these different halophytes types along salinity gradients can be found in several studies at different salt lakes (Breckle 2000). Halophytic stem succulents are always characteristic for soils with the highest salinity levels. With decreasing of soil salinity a clear zonation of halophyte types can be observed.

Ecophysiologcial adaptations

Accumulation pattern of inorganic solutes are charactersitic for certain taxa, which represent different physiotypes (Breckle 1990, 1995, Albert et al. 2000). For the identification of the suitable plants for planting on saline soils ecophysiological characteristics of ions pattern are needed. For the halophytes from the Aral Sea first results are shown in Table 1, giving an impression of the main cations and anions content in stems and leaves (Cl, Na, K, Ca, Mg) of selected plant species. Leaf- and stem succulents, like species from the genera *Suaeda, Salicornia* and *Halocnemum,* accumulate considerably more Na and Cl in comparison with other species (Tab. 1). The ionic content (Na and Cl) of *Climacoptera* species and of *Ofaiston monandrum* is lower 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.

Table 1. Ions pattern (mol kg^{-1} dw) of several halophytes and non-halophytes from the dry seafloor of the Aral Sea (after Breckle et al. 2001).

Species	Cl	Na	K	Mg
Stem succulent halophytes				
Halocnemum strobilaceum	3.04	3.75	0.51	0.13
Salicornia europaea	4.4	4.09	0.52	0.15
Ofaiston monandrum	1.6–2.79	1.27–3.09	0.32–0.53	0.49–0.57
Leaf succulent halophytes				
Suaeda acuminata	2.66–5.13	3.4 –5.02	0.59–0.86	0.186–0.36
Suaeda crassifolia	4.07–4.89	3.25–3.68	0.43	0.47–0.62
Climacoptera aralensis	2.14–3.22	1.77–4.14	0.52–0.91	0.13–0.2
Petrosimonia triandra	0.51	0.97	0.55	0.32
Pseudohalophytes				
Euclidium syriacum	0.31	0.13	0.5	0.095
Non-Halophytes				
Eremosparton aphyllum	0.16	0.03	0.32	0.08
Stipagrostis pennata	0.08	0.05	0.323	0.04

Chenopodiaceae accumulate high amounts of sodium and chloride even at low salinity indicating a genetically fixed ions pattern (Albert et al. 2000, Veste & Breckle 1995, 2000). However, this pattern can be modified by the soil conditions to some extent. *Suaeda acuminata* is very common in Central Asia and can be found on very contrasting saline stands. Fig. 1. shows the ions content of various location. 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.

These investigations showed that different mechanisms and strategies for the adjustment and regulation of the salt concentration in the plant tissues occurs in the halophytes from the Aral Sea regions. Different salt tolerance in the various species leads to a specific pattern of species and halophyte types along salt gradients (Breckle 1995, Breckle 2001)

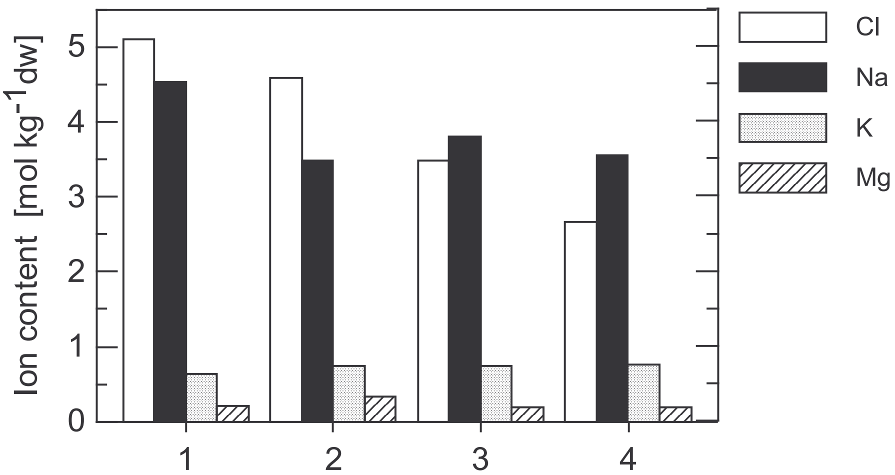

Fig. 1. The content of the main cations and chloride in the aboveground parts of *Suaeda accuminata* on different soil types of the Aralkum desert. *1* Crusty coastal solonchak; *2* marshy solonchak; *3* degraded coastal solonchak; *4* puffy coastal solonchak (after Breckle et al. 2001)

Planting experiments

The enhancement of vegetation cover by means of phytomelioration is a realistic way to reduce the salt dust output from the dry seafloor (Yair 2001, Wucherer 2001). This will support the natural spreading of plants through vegetative propagation and seed dissemination. Huge experimental plantings with plots up to 200 ha have shown, that only

very few species are suitable for this purpose: *Haloxylon aphyllum* and *Halocnemum strobilaceum*. Recent evaluation of various experimental sets reveal that special techniques to plant saplings have to be applied and have to be adjusted to the relevant soil situation (Wucherer et al. 2005, Wucherer & Breckle 2005). Plantations on sandy deserts of the Aralkum are almost always successful (more than 90%), but not necessary, since nature will cover those areas in a few years spontaneously. Plantations on saline soils are the big challenge; huge areas (about 3 million ha) would needs special techniques of soil improvement of the soil surface or by adding sand in furrows or pits. By planting small portions like islands, saxaul will spread in a few years. In this cases the successful establishment of the saxaul shrub increased.

Rehabilitation of saline soils in NE Brazil

Meanwhile, also in tropical regions soil salinization is a severe problem in land degradation processes. The north-eastern parts of Brazil in the State of Pernambuco desertification and soil degradation results in a drastic increase in soil salinity and reduction of plant productivity. Using tropical halophytes is a possible way for land rehabilitation. In screening experiment 13 of 24 were identified as suitable plants for the rehabilitation. The investigations were carried out in two different sites of the Empresa Pernambucana de Pesquisa Agropecuária (IPA) and they are located in the semi-arid region of the State of Pernambuco in northeast Brazil. The annual rainfall is in Sâo Bento do Una 650 mm a^{-1} and in Serra Talhada 895 mm a^{-1}. Samples were collected in the rainy and dry season in a period of three years. In most of these species the total salt amounts increased over 0.8 - 1.0 mol kg^{-1} dw (Fig. 2) indicating a high salt tolerance. The highest amount of Na and Cl could be found in leaf-succulent *Sesuvium portulacastrum*, which is charactersitic for Aizoaceae. Potassium accumulation was for all species in the same range. *Sesuvium portulacastrum* (Aizoaceae) is a common halophyte growing at tropical coasts and inland saline lakes of South America. Like other Aizoaceae, *Sesuvium* accumulate high amounts of Na even at low salinity. However, differences in sodium accumulation between populations from Venezuela, Panama and Dominican Republic could be found under controlled conditions indicating intra-specific differences in the genetically fixed ions patterns (Herrera Bonilla 1997).

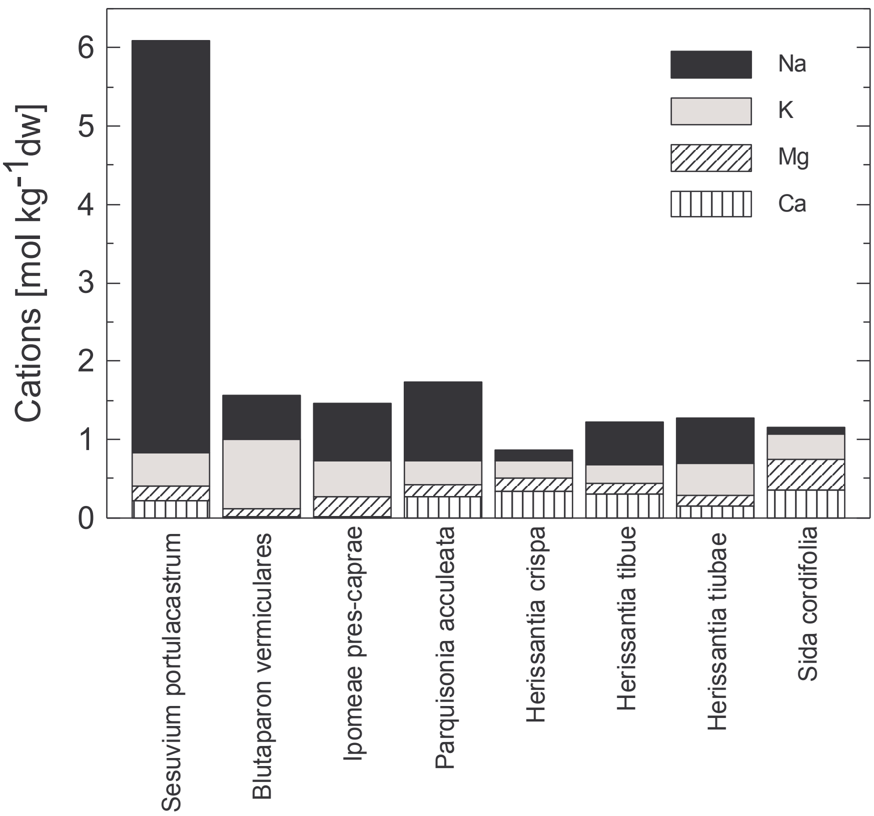

Fig. 2. Cations content in various plant species at the test site of Serra Talhada (NE Brazil)

Conclusions

Halophytes are suitable tools for rehabilitation of saline soils. The salinization of the substrate varies to a great extent, causing a wide variety of saline soil types. Therefore, investigations of the adaptive mechanisms of the various halophyte types are essential for an adequate species composition for phytomelioration of saline soils. Further informations are needed about salt tolerance of other indigenous species and populations. Phytomelioration by plantings on saline soils leads to a more rapid closure of the vegetation cover and helps to minimize the widespread negative effects of salt desertification. Studying natural halophytes and ecosystem processes are very important for all those regions where salinity has reached such a level that desalinisation techniques are much too costly.

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