Halophytes for Sustainable Biosaline Farming Systems in the Middle East

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ABSTRACT: The wide ecogeographic diversity in the Middle East is reflected in its highly diverse vegetation and plant genetic resources. The Middle East is a region of megadiversity of important food, feed, fiber, and oil crops, where most temperate-zone agricultural species originated and were first domesticated. Anthropogenic factors, in addition to the climate of this region, with its alternating pattern of winter rainfall and summer drought, resulted especially since irrigated agriculture started, in salt build-up in certain parts of the region to the extent that it accounts for 25 and 15% of the world's arid zone and its salt-affected soils, respectively. Agriculture utilizes about 70% of the fresh water in the region and it is likely to remain the major water-consuming sector in the foreseeable future. Therefore, and in view of the fact that water resources are being used to the limits of their availability, and the groundwater resources are overutilized, improving water use efficiency and substitution of reclaimed waste and saline water for irrigation is inevitable. On the other hand, it is time to utilize the invaluable reservoir of genetic diversity available in indigenous and exotic halophytic germplasm for salinity tolerance. This strategy could be the only viable, cost-effective and long-term solution to the problems of acute water shortage and increasing cost of the engineering solution to salinity. Long-term sustainability of farming systems based on these halophytes depends on the economic value of inputs and outputs, their environmental impact, the future food needs, economics, the extent to which freshwater ecosystems are withheld from further agricultural development and the development of agronomic practices appropriate for the new farming systems.

Naturally occurring saline environments in the Middle East provided necessary selection pressure for the evolution of highly salt-tolerant plants, especially for grazing. Approximately 211 halophytic species distributed over 29 plant families are recorded in the Middle East; in comparison, the world flora lists some 885 species of halophytic angiosperms distributed over 250 genera. Indigenous and exotic halophytes constitute an untapped genetic resource that can be used in developing crops under salinity. These wild plants, if domesticated, can utilize saline water and soil resources for sustainable agricultural production. Their seed, fruits, roots, tubers, or foliage can be used directly or indirectly as human food. A minimum of 50 species of seed-bearing halophytes are potential sources of grain and oil; these include halophytes with seed quality comparable to, or better than, that of wheat; and species with seed that are rich in energy, protein and fat content. Other halophytes are candidates as tuber-, vegetable- or fodder-producing crops. A number of fruit-producing halophytes can be used as rootstocks or grafts to produce economic fruit yields using saline water and soil resources. Salt-tolerant trees and shrubs constitute a rich source of energy as fuelwood, source of liquid or gaseous fuels. In addition, genetic resources have been identified among the halophytes as sources for pulp, fiber, essential oils, gums, oils, resins, bioactive derivatives, and as landscape and ornamental plants. However, the most important contribution of halophytes towards sustainable farming systems in the Middle East is their potential as fodder grasses, legumes, shrubs and trees.

INTRODUCTION

Halophytes are not a single taxonomic group, but are represented by several thousand species of forbs, grasses, shrubs and trees. There are leafless succulents and leafy shrubs; there are species found only in salt marshes and species that grow in the deserts. Halophytes are distributed from coastal areas to mountains and lowland deserts. Halophytes occupy important niches in many ecosystems. This is due to the ease with which they adapt to many diverse and generally harsh environments; xerohalophytes, in particular, are distributed in many coastal and desert regions of the world and occupy a wide range of saline to alkaline habitats.

The growing demands imposed on natural resources (land and water, in particular), especially in the Middle East, by population increases called for a reassessment of marginal and underutilized land resources. Halophytes grown on marginal lands, when properly managed, can significantly contribute towards food and feed production and environmental quality.

Many halophytes grow in natural salines or in other dry environments which are rapidly deteriorating through the process of desertification.

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Because the pattern of distribution of halophytes has remained more or less intact, it provides an immensely valuable and diverse resource to rehabilitate damaged habitats and provides forage for the region's burgeoning livestock populations.

Halophytes represent a mere 5% of the flora of the Middle East (about 150 species), however, some halophytes dominate plant communities in parts of the region. The potential economic use of most of these species, unfortunately, is not well known.

This paper presents genetic resources of halophytes in the Middle East and their potential uses. Moreover, it presents exotic genetic resources of halophytes from the Mediterranean Basin and beyond and their potential uses as food crops (grains and oil seeds), tubers and foliage, sources of leaf protein, fruits, fuel crops, fuelwood trees and shrubs, fodder crops, fiber and specialty crops, sources of bioactive derivatives (e.g., pharmaceuticals), and as landscape and ornamental plants. Finally, the long-term sustainability of farming systems based on halophytes will be addressed.

Genetic Resources of Halophytes in the Middle East Region

Halophytes represent a wide range of about 1560 species in which salt tolerance has already evolved (Aronson, 1989). Some 885 species of halophytic angiosperms are distributed over 250 genera, and the salt-tolerant species exist in about 30% of the 354 families of flowering plants (Aronson et al., 1985; Aronson, 1989). Of the 500 halophytic genera listed in Aronson's database (1989), almost 50% belong to only 20 plant families. The Gramineae and Cyperaceae have the highest percentages of halophytic genera among the Monocotyledoneae, whereas Chenopodiaceae has the highest proportion in the Dicotyledoneae.

Halophytes (Table 1) are able to osmotically adapt to acquire mineral elements, especially potassium in the presence of sodium chloride, from saline soils, while preventing the toxic effects of salt ions (Flowers et al., 1977; O'Leary, 1989).

Naturally saline environments around the Mediterranean provided necessary selection pressure for the evolution of highly salt-tolerant plants (Pasternak, 1982; Batanouny, 1993; Le Houe'rou, 1993), especially those suitable for grazing (Pasternak et al., 1983; Le Houe'rou, 1986; 1993). Halophytes of potential economic value are distributed among many plant families, of which the Chenopodiaceae (368 species) and Gramineae (136 species) have the largest number of species (Aronson, 1989). Fabaceae has 82 species, Asteraceae has 62, Plumbaginaceae has 58, Aizoaceae has 52, Cyperaceae and Papilionaceae has 46 each, Tamaricaceae has 32, Zygophyllaceae has 28, and Arecaceae and Mimosaceae has 21 species each.

Productivity of some halophytes (e.g. *Atriplex halimus*), as measured by rainfall use efficiency, RUE [kg of dry matter per hectare per year per mm of rainfall], can reach 8-10 kg, whereas RUE for typical Middle East rangelands is of the order of 2-3 kg (Sankary, 1986; Le Houe'rou, 1986). Fodder quality of these halophytes is high compared to traditional fodder plants in the Middle East; under good management, saltbush brows contains 12-15% digestible protein on a dry matter basis (Malcolm, 1969; Goodin and McKell, 1970; Goodin, 1979), and is highly valued because of its deferred production (Johnson et al., 1991; 1992; Sankary, 1986). Genetic resources of halophytes in the Middle East region, along with their life form, plant type and potential economic use are listed in Appendix I.

Genetic resources of halophytes for forage production under dryland farming

Halophytes have been used as forage in arid and semiarid areas for millennia (Johnson et al., 1992; Le Houe'rou, 1993). The value of certain salt-tolerant shrubs and grass species has been recognized by their incorporation in pasture-improvement programs in many salt-affected regions throughout the world. There have been recent advances in selecting species with high biomass and protein levels in combination with their ability to survive a wide range of environmental conditions, including salinity (NAS, 1990; Ulery et al., 1998).

Halophytes suitable for forage production either as native stands or artificially established include the herbaceous species: *Elymus elongatus, Hedysarum carnosum, Cynodon dactylon* var *hirsutissimum* and var *villosum*, and *Puccinellia ciliata*, and the forage shrubs: *Atriplex halimus, Atriplex nummilaria, Atriplex canescens, Atriplex lentiformis, Atriplex semibaccata*, and *Atriplex glauca*.

The following *Atriplex* species are among the best promising experimental forage species, with RUE values 3-4 times higher than typical Middle East rangeland forages, these are: *Atriplex amnicola, A. barclayana, A. undulata, A. atacamensis, A. polycarpa, A. cinerea, A. paludosa* and *A. isatidea* (Aronson, 1989). Other desert halophytes to be considered as valuable genetic resources in the Middle East region are: *Haloxylon persicum* and *Haloxylon aphyllum*; they performed well as fodder shrubs in many countries around the Mediterranean (Nemati, 1977; Le Houe'rou and Pontanier, 1987).

Table 1. Classification of halophytes.

Euhalophytes					Pseudo-halophytes
Salt-requiring			Salt-resisting		Salt-avoiding
Obligatory	Preferential	Salt-enduring	Salt-excluding	Salt-evading	
Plants dependent on salt for their survival, e.g., *Salicornia* spp.	Plants whose growth and development are improved in the presence of salt, e.g.,*Arthrocnemum* spp., *Aster* spp., *Salicornia* spp., *Suaeda* spp.	Plants enduring a high protoplasmic salt content, e.g., *Suaeda monoica.*	Plants accumulating salts in special hairs, e.g., *Atriplex* spp. or glands e.g., *Zoysia* spp.	Plants evading salt uptake, e.g., *hisophora* spp.	Ephemerals and niche plants
			Plants secreting salts from their shoots, e.g., *Aleuropus* spp., *Limonium* spp., *Tamarix* spp. Plants transporting salts from the shoot into the root, e.g., *Salicornia* spp.	Plants evading salt transport into the leaves, e.g., *Prosopsis fracta.*	

Finally, the ornamental hedge shrub *Myoporum serratum* was identified as one of the best forage shrubs, next to *Atriplex* species, under saline conditions (Le Houe'rou and Pontanier, 1987).

The natural rangelands in Sinai region and the coastal parts of Egypt, for example, are dominated by several halophytic species. Palatable shrubs are suffering severely at present from overgrazing. The research policy has been geared towards optimum utilization of the native ranges. It was of interest to optimize the utilization of the widely distributed unpalatable and less-palatable forages in feeding livestock. The common halophytic species in Southern Sinai area varied widely in their chemical and mineral composition . They were relatively nutritious in winter season, particularly the palatable ones, i.e. *Suaeda fruticosa*, *Nitraria retusa and Salsola tetrandra.* Most halophytic shrubs in Sinai contained moderate amounts of crude protein and high levels of ash, silica and fiber constituents (Tadros, 1954; Batanouny, 1986).

Many halophytes survive saline stress by accumulating salt in their vegetative tissues. The salt level in the leaves and stems of these plants can limit their direct consumption as food, but their seeds are relatively salt-free, which may allow production of starchy grains or oilseeds (Batanouny, 1993). *Distichlis palmeri* was developed into a crop with nutritional qualities, baking characteristics, and taste of its flour compares very favorably with wheat flour (El-Shourbagy and Yensen, 1983; Yensen, 1993). *Salicornia* spp. has been experimented with in Kuwait, United Arab Emerates and Egypt as a source of vegetable oil (O'Leary, 1993). Leaf protein (Carlsson, 1975; Singh, 1985) is another product being developed from halophytes such as *Kochia scoparia, Salsola kali, Beta maritima, Salicornia* spp., *Mesembryanthemum* spp., and *Atriplex* spp.

Genetic resources of halophytes under irrigation

A large number of salt-tolerant species, besides those listed in the previous section, can be used as forage plants under irrigation (usually brackish water), however, these species exhibit large differences in salt tolerance based on a number of factors, including life cycle (short-lived vs. long-lived species) and frost tolerance (frost-susceptible vs. frost-tolerant), (Malcolm, 1969; Nobel and Shannon, 1988; Yemen, 1988; Johnson et al., 1992; Yensen and Bedell, 1993); these include: the perennial and biannual legumes: *Hedysarum carnosum, Lotus certicus, Lotus corniculatus, Tetragonolobus maritimus* and *Trifolium fragiferum*; the annual legumes: *Medicago ciliaris, Medicago intertexta, Melilotus alba, Melilotus italica, Melilotus officinalis, Trifolium resupinatum* and *Trifolium subtterraneum* subsp. *yanninicum*; a number of annual and perennial grasses and most of the fodder shrubs listed in the above section. An introduction of *Salicornia* spp. under the code name SOS-7 (Riley and Abdal, 1993) and another species, *Salicornia*

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herbacea native to the Arabian Gulf region, are promising genetic resources for the development of fodder and oil-seed crops.

More than a billion people in developing countries rely on wood for cooking and heating (NAS, 1990). In the Middle East region, the rate of deforestation for fuelwood and for agricultural expansion far exceeds the rate of reforestation (FAO, 1996). Consequently, genetic resources of halophytes for fuelwood and timber production would alleviate the problem (Le Houe'rou, 1986; Sankary, 1987; NAS, 1990).

Fuelwood and timber production in the Middle East region can be tremendously enhanced if salt-tolerant plant species can be identified, evaluated, planted and monitored on waste and degraded lands using saline or brackish water resources (NAS, 1990).

Since the 1930s the movements of nomads in the Middle East have been greatly restricted. However, until the present, nomadic pastoralism is an essential aspect of life in the Middle East (Held, 1994) with a far reaching impact on the fragile natural resources of the desert and semi-desert in the region, especially the fuel and fodder resources (Sankary, 1986; 1987; Le Hooue'rou, 1986; 1993). Desert shrubs and trees constituted, until recently, the major source for fuelwood in traditional nomadic life in the Middle East. Remaining, and introduced, genetic resources if propagated and planted along with the necessary soil conservation measures would provide the much needed fuel and help in reversing the process of desertification.

Some of the species that are promising for fuel production in saline environments are found in the genera *Prosopis, Eucalyptus, Casuarina, Rhizophora, Melaleuca, Tamarix* and *Acacia*.

The following species are among the most promising, salt-tolerant fuelwood and timber species adapted to rainfed parts of the Middle East region: *Acacia cyclops, Acacia ligulata, Acacia salinica*, several *Eucalyptus* species, several *Haloxylon* species, several *Populus* species, *Phoenix dactylifera, Phoenix canariences, Tamarix aphylla* and *Tamarix stricta*.

Tamarix stricta is a very promising fuelwood genetic resource in the Arabian Gulf region (Bhimaya et al., 1974), it is highly adapted to this region and it outperformed the best 35 *Eucalyptus* species to which it was compared. Other promising species include *Concarpus lancifoliu*, a phreatophyte from the Red Sea shores of Somalia (Le Houe'rou, 1993), *Prosopis cineraria*, native to Oman (Felker et al., 1981), which is useful for the production of fuel and forage, and *Geoffroea decorticans*, a legume tree from the Mediterranean region of Chile in South America and already successfully established in saline soils of Tunisia (Franclet and Le Houe'rou, 1971).

Among the genetic resources adapted for timber production under conditions of moderate salinity in the Middle East are the frost-sensitive species: *Eucalyptus camaldulensis, Eucalyptus occidintalis, Eucalyptus brockwayi, Eucalyptus sargenti, Eucalyptus astringens, Casuarina equistifolia, and Casuarina cunninghamina*. On the other hand, the frost-tolerant, fast-growing poplars (*Populus alba, Populus euphratica, Populus bolleana, Populus nigra* var *thevestina*, and *Populus alba* var *erecta*) are among the best genetic resources for timber production under saline conditions in the Middle East (Zohar, 1982; Aronson, 1986; 1989).

EXOTIC HALOPHYTES AS POTENTIAL GENETIC RESOURCES FOR THE MIDDLE EAST REGION

Exotic Halophytes as Food Crops

Biosaline agriculture can provide food in many ways, especially in areas where traditional agriculture cannot be profitably practiced. Appropriate halophytes can be domesticated (NAS, 1990) and their seeds, fruits, roots, tubers, or foliage can be used directly or indirectly as food. There is ample evidence (O'Leary, 1993) that little-known seed-bearing halophytes that grow in saline environments in many parts of the world are potential candidates as germplasm resources for the development of salt-tolerant crops in the Middle East region.

Grains and Oilseeds

A unique characteristic of many seed-bearing halophytes is that their seeds are relatively salt-free, although they may have significantly high salt levels in their stems, branches and leaves. This allows consideration of a wide variety of seed-producing halophytes as new sources of grains and vegetable oils (Chandra et al., 1968; Baldwin, 1988; Risi and Galway, 1984;); some of these halophytes have been studied and even utilized as crops (O'Leary, 1993; Francois, 1994).

It is estimated (Aronson, 1989) that almost 50 species of seed-bearing halophytes are potential sources of grains and oil. The Eelgrass (*Zostera marina*) grows in the Gulf of California; its seed length and weight are comparable to those of wheat and contains 50% starch, 13% protein and about 1% fat. The perennial Palmer saltgrass (*Distichlis palmeri*) also grows in the Gulf of California and is being used as food by the natives. Although it has lower protein content as compared to wheat (8.7 vs. 13.7%), its fiber content is much higher than that of wheat (8.4 vs. 2.6%), and has comparable fat, ash and carbohydrate contents as those of wheat (Yensen, 1985). The grain crop developed from *D. palmeri* by NyPa, Inc. has a well-balanced amino acid composition and almost no antinutritional phytic acid content. Another perennial grass, Alkali Sacaton (*Sporobolus airoides*), is a candidate for domestication.

Pearl millet (*Pennisetum typhoides*) grows well on sand dunes and tolerates EC of 27-37 dS/m for irrigation (NAS, 1989). It can be grown as a food crop with seed yields of up to 1.6 tons per hectare or as a fodder crop with yields of up to 6.5 tons per hectare.

One of the staple foods of native South Americans, the annual herb Quinoa (*Chenopodium quinoa*) can tolerate moderate salinity levels and produces nutritious seed (30% of dry weight of the plant, or 2.5 tons per hectare) that has a higher protein content and an amino acid composition that is better than that of wheat (Somers, 1982; Risi and Galway, 1984).

Grain yields of the perennial Seashore mallow (*Kosteletzkya virginica*) can reach 1.5 tones per hectare using water containing 2.5% salt. Its high protein (32%) and oil (22%) content makes it an excellent candidate as a grain or oil crop.

Many *Acacia* species (*Acasia aneura, A. coriacea, A. cowleana* and *A. dictyophleba*) produce seed that are rich in nutrients with higher energy, protein, and fat content than wheat or rice (Turbull, 1986; Goodchild and McMeniman, 1987). *A. aneura* is a potential oil crop (37% fat), whereas *A. dictyophleba* is a potential grain crop with high protein content (26.8%).

Argan (*Argania spinosa*) an endemic of Southwest Morocco, has the potential, among other uses, to produce edible oil from its seed. Although not tested yet for its salt tolerance, it is a promising genetic resource for coastal areas where it can also be used as a browse (Morton and Voss, 1987).

Salicornia species, including those native to the Arabian Gulf Region (e.g., *Salicornia herbacea*) produce an edible, safflower-like seed oil (Riley and Abdal, 1993); it tolerates seawater and produces about 20 tones of plant material per hectare, a rich fodder source for sheep and goats (Charnock, 1988; Glenn et al., 1991).

Tubers and Foliage

Wild water chestnut (*Eleocharis dulcis*) produces tubers that can be cooked or pounded to meal (Glenn and O'Leary, 1985). Similarly, the roots and stems of saltwort (*Batis maritima*) can be used for food; the plant produces up to 17 tones per hectare of dry weight using seawater for irrigation; on the other hand, common Indian saltwort (*Sueda maritima*) is potentially a good source of green leaves as a vegetable besides its value for fixing seashore sand dunes (NAS, 1990).

The perennial herb Seaside purslane (*Sesuvium portulacastrum*) is an edible wild plant with potential utilization as a vegetable or as fodder (Chadha, 1972). Common purslane (*Portulaca oleracea*) has the potential to be used as a potherb and in salads and soups (Sen and Bansal, 1979). Leaves of sea fennel (*Crithmum maritimum*), besides their medicinal value, have the potential to be used as a spice or as salad ingredient (Frank, 1982). *Atriplex triangularis* produces leaves similar to those of spinach; a cultivar selected from wild germplasm produces about 21 tones of fresh leaves per hectare (Islam et al., 1987). Another species (*Atriplex hortensis*) is already cultivated in India for its spinach-like leaves.

Leaf Protein

Certain halophytes retain enough salt in their leaves to inhibit their utilization as fresh leaves or as fodder (Carlsson, 1980; Singh, 1985). One solution to this problem is to extract leaf protein from the salt-containing foliage.

A number of halophytes have been identified as sources of leaf protein; these include *Kochia scoparia, Salsola kali, Beta maritima, Salicornia* spp., *Mesembryanthemum* spp., and *Atriplex* spp. Generally, these plants have leaf protein composition (dry weight basis) as follows: true protein (50-60%), lipids (10-25%), Beta carotene (0.045-0.15%), starch (2-5%), and ash (5-10%), along with some vitamins and minerals (NAS, 1990).

Fruits

Fruit trees are among the most sensitive plants to salinity (Shannon, 1997), however, researchers were able to identify certain halophytic species that can be used either as rootstocks or as grafts to produce economic fruit yields using saline water (NAS, 1990). *Ziziphus nummularia*, a salt-tolerant species with small berries can be used as a rootstock for the salt-*sensitive Ziziphus mauritiana* that can produce large berries (O'Leary, 1985). Similarly, *Manilkara hexandra* can be used as a rootstock for grafting *M. zapota* that can produce large fruits.

A few species have been identified as being able to grow and produce an economic fruit yield when irrigated with saline water; among these are *Salvadora persica* and *S. oleoides*. These evergreen trees yield edible fruits and their seeds contain about 40% oil which can be used for making soap (Gupta and Saxena, 1968). Other potentially useful genetic resources as fruit trees include: *Lycium* spp., *Santalum acuminatum*, a small tree widely distributed across Australia's arid inlands, produces edible fruits and energy-rich kernels, and *Coccoloba uvifera*.

Exotic Halophytes as Fuel Crops

Salt-tolerant trees and shrubs, e.g., *Prosopis, Eucaliptus* and *Casuarina*, can help rehabilitate degraded lands by stabilizing the ecosystem and by providing niches and protection for other plants and animals (O'Leary, 1985; Stienen, 1985). Criteria for selecting potential genetic resources for use as fuelwood in saline environments include: a rapid rate of growth and re-growth after cutting, easy establishment under saline environments, wide adaptation and, if possible, diverse use besides the primary product (e.g., wind breaks, row-crop protection, shade for forage crops and for livestock, fences, etc.).

Fuelwood Trees and Shrubs

Among the most promising genetic resources as fuelwood under saline conditions are found in the genera *Prospois* (*P. alba, P. articulata, P. nigra, P. flexusa, P. juliflora, P. articulata, P. pallida, P. tamarugo*), *Eucaliptus* (*E. angulosa, E. camaldulensis, E. calophylla, E. erythrocorys, E. incrassata, E. halophila, E. occidentalis, E. sargentii, E. spathulata, E. kondininensis, E. largiflorens, E. neglecta, E. tereticornis*, and *E. loxophelba*), *Casuarina* (*C. equistefolia, C. obesa, C. camaldulensis, C. glauca*, and *C. cristata*) *Tamarix* (*T. aphylla, T. stricta, T. articulata, T. gallica, T. africana*, and *T. hispida*) and *Acacia* (*A. longiflora, A. saligna, A. sophorae, A. oraria, A. crassicarpa, A. stenophylla, A. redolens, A. ampliceps, A. floribunda, A. pendula, A. pycnantha, A. retinodes, A. cyclops*, and *A. xiphophylla*).

Liquid Fuels

Very few plants have been identified as potential sources of liquid fuels under saline condition, among them are: sugar beet (*Beta vulgaris*) and the nipa palm (*Nypa fruticans*).

Gaseous Fuels

Kallar grass (*Leptochloa fusca*), a fodder crop under saline conditions is a promising genetic resource for the production of biogas. The energy yield per hectare was estimated at 15×10^6 Kcal.

Exotic Halophytes as Fodder Crops

Halophytes have been used as forage in arid and semiarid parts of the world for millennia. Large numbers of salt-tolerant species have been incorporated in pasture improvement programs in many salt-affected regions throughout the world (NAS, 1990).

Grasses

Kallar grass (*Leptochloa fusca*) is a highly salt-tolerant perennial forage grass that grows well under saline and waterlogged conditions (Malik et al., 1986). Its yield potential is high (40 tones of fodder per hectare per year). However, it can become a problem weed in rice fields and in irrigation canals (Qureshi et al., 1982).

Silt grass (*Paspalum vaginatum*) is a useful pasture grass for grazing, especially in bog and seepage areas that stay wet with salty water (Korton, 1973). It is easily propagated by roots, runners, or sod.

Russian-thistle (*Salsola iberica*) is a salt-tolerant, adapted to survive under drought conditions, with high protein content (15-20%), and consumes less water than alfalfa (Foster et al., 1983). It has the potential of being used as an energy crop (NAS, 1990).

Saltgrass (*Distichlis spectata*) is a potential forage halophyte, with distinct seashore and inland ecotypes (Wrona, and Epstein, 1982). NyPa, Inc. domesticated *Distichlis* and developed a grain crop 'WildWheat Grain', a forage grass called 'NyPa Forage', a turf grass called 'NyPa Turf and a reclamation grass called 'NyPa Reclamation Saltgrass' (Yensen and Bedell, 1993).

Channel Millet (*Echinochloa turnerana*) is a productive, palatable and nutritious forage plant native to Queensland in Australia. The grain is consumed by cattle, horses, and sheep, whereas the leaves, culms and seedheads are consumed by livestock and the whole plant makes excellent hay (Shannon et al., 1981).

Cordgrass species (*Spartina* spp.) are tough, long-leaved grasses with hollow stems and rhizomes (Broome et al., 1986). *S. alterniflora* (smooth cordgrass), *S. folioso* (California cordgrass) and *S. patens* (salt meadow cordgrass) are among the most promising genetic resources for grazing and for hay. Other grasses (e.g., Rhodes grass, *Chloris gayana*, and Tall Wheat Grass, *Elytriga elongata*) are potential sources for grazing.

Shrubs

Saltbushes (*Atriplex* spp.) grow throughout the Middle East region (Franclet and Le Houerou, 1971; Goodin, 1979; Hyder, 1981; Sankary, 1986; Islam et al., 1987). They tolerate salinity in soil and water and many are perennial shrubs that remain green the year round. *Atriplex* species are especially useful as forage in arid and semiarid parts of the Middle East; *Atriplex nummularia*, for example, is a drought tolerant species and grows well with only 150-200 mm of annual rainfall. Native *A. nummularia* and *A. halimus* can produce 8 times the amount of dry matter produced by native pasture under the same conditions and they can tolerate salinities better than alfalfa. *A. halimus* proved to be hardier than *A. nummularia* or *A. canescens* under Middle East conditions (Franclet and Le Houerou, 1971). Some of the other *Atriplex* species of potential value in the Middle East region are: *A. patula, A. polycarpa, A. amnicola, A. undulata, A. lentiformis* and *A. barclayana*, the latter is an outstanding species in its salt tolerance and biomass production.

A number of *Mairiena* species that are useful for grazing have been identified in Australia (Kok et al., 1987). *Mairiena* are small to medium woody shrubs with succulent leaves and winged, wind-disseminated fruits. Some are already grown in Western Australia (e.g., *M. brevifolia*), with excellent grazing value and recovery after grazing. There is a wide variation among the species for salt tolerance, salt content, drought tolerance, leafiness and palatability. If introduced into the Middle East region, selection and breeding will be necessary to improve these characteristics as well as growth habit.

The perennial shrub *Kochia* is an excellent source of fodder for animals in Central Asia and in parts of the US and Saudi Arabia (Migahid, 1978; Mahmoud et al., 1983; Zahran, 1983), where it was recently introduced (NAS, 1990). *Kochia prostrata* (Prostrate Kochia) tolerates salinities up to 17 dS/m, with low oxalate (<2%) content. *Kochia indica* and *Kochia scoparia* have been field tested in Saudi Arabia to determine germination and vegetative yields on salt-affected land. Both species proved to be promising genetic resources as fodder shrubs.

Another Australian shrub species is *Halosarica*. These shrubs are succulent, highly salt-tolerant perennial plants that occur naturally on waterlogged saltlands (NAS, 1990). The most common species are *Halosarica pergranulata, H. lepidosperma* and *H. indica* subsp. *bidens*. Although high in protein and salt-tolerant, these species contain high levels of salt.

Trees

Acacia (Goodchild and McMeniman, 1987), *Leucaena* (Kitamura, 1988) and *Prosopis* (Stienen, 1985) species are the most promising salt-tolerant tree species for the Middle East region. *Acacia* species are widely used in arid and saline environments as supplementary sources of fodder. *Acacia cyclopes, Acacia bivenosa, Acacia ampliceps, Acacia holosericea, Acacia saligna, Acacia salicina* and *Acacia victoria* are among the most promising genetic resources to be utilized in developing fodder sources in the Middle East region.

Leucaena leucocephala is a legumenous tree widely cultivated in the tropics and subtropics (Kitamura, 1988). It is both salt and drought tolerant.

Finally, Mesquite (*Prosopis* spp.) have been used as a forage in many countries (Malcolm, 1969). Among the most promising species to be utilized in the Middle East region are: *P. juliflora, P. cineraria, P. chilensis, P. glandulosa, P. pallida*, and *P. tamarugo*. The last species is a good source of wood for construction and other uses.

Exotic Halophytes as Fiber and Specialty Crops

Salt-tolerant plants are potential sources of economically important materials such as essential oils, gums, oils, resins, pulp, fiber, and bioactive compounds (NAS, 1990). Moreover, these plants can be utilized in landscaping using salt water, thereby conserving fresh water for other uses.

Essential Oils

The male flowers of the salt-tolerant screw pine (*Pandanus fascicularis*) are a source of perfume and other flavoring ingredients (Dutta et al., 1987). *Mentha* species (*Mentha piperita* and *M. arvensis*) grow on saline and alkaline soils and produce essential oils (Chandra et al., 1968). Other plants with potential utilization in saline soils for the production of essential oils include: *Matricaria chamomilla, Vetiveria zizanioides, Cymbopogon nardus, Cymbopogon winterianus, Cymbopogon martini, Tagetes minuta, Ocimum kilimandscharicum* and *Anethum graveolens*.

Gums, Oils and Resins

Salt-tolerant plant genetic resources for the production of gums, oils and resins include *Sesbania bispinosa*, an important legume and fodder crop; *S. sesban and S. speciosa*, are salt-tolerant and can be used as green manure as well (Forti, 1986; NAS, 1990). The resinous perennial shrubs: *Grindelia camporum, G. humilis, G. stricta, G. latifolia* and *G. integrifolia*, all salt tolerant and produce diterpene acid resins.

Jojoba (*Simmondsia chinensis*) is a perennial desert shrub with seed that contain a unique oil (Baldwin, 1986; NAS, 1990). It is relatively salt tolerant and it is being grown near the Dead Sea and irrigated with brackish water (Forti, 1986).

The perennial desert shrub guayule (*Parthenium argentatum*) is a source of natural rubber; it is a salt-tolerant shrub with a threshold of 7.5 dS/m (Hoffman et al., 1988).

Pulp and Fiber

A number of salt-tolerant plants are being used as sources for pulp and fiber. These include: *Phragmites australis*, a multi-purpose pulp producing plant. *Juncus rigidus* and *Juncus acutus* are potential sources of pulp for paper-making in Egypt (Zahran, 1986). *Pandanus tectorius, Stipa tenacissima, Typha domingensis, Hibiscus cannabinus, H. tiliaceus*, and *Urochondra setulosa*, are highly salt-tolerant and considered as potential sources of pulp and fiber (NAS, 1990).

Bioactive Derivatives

Valuable extracts from seed, leaves and bark of a number of halophytes have been characterized and used in the health industry (NAS, 1990). The evergreen tree, Alexandrian laurel (*Calophyllum inophyllum*) is a source of a complex phenyl coumarin that can be used as an anti-inflammatory agent. The fruits of *Balanites roxburghii* and *B. aegyptiaca* which grows naturally in the Sudan, are a potential source of diosgenin, a precursor for the synthesis of a number of steroidal drugs (Mehrotra et al., 1986).

The neem tree (*Azadirachta indica*) produces oil which can be used for soapmaking and its seed extracts are effective natural insecticides (Ahmad et al., 1986; 1989). The neem tree can grow in saline soils and withstands EC of 17 dS/m.

The salt-tolerant evergreen shrub *Adhatoda vasica* is a source of insecticides and wound-healing agents for animals (Bhargava et al., 1986); it has been used also as a source of firewood. Root extracts from the perennial herb *Anemopsis californica* are a source of a mild antispasmodic (NAS, 1990). The tropical plant *Catharanthus roseus* withstands EC of 12 dS/m and produces an alkaloid used in the treatment of leukemia and to lower blood pressure (NAS, 1990).

In addition to the potential of *Salsola* species and a source of fodder, they contain recoverable amounts of bioactive materials (Fowler, 1985). *Salsola richteri* and *S. kali* are sources of Salsolinol and Salsolidine, respectively; *S. pestifer* is a source of carotene, whereas, *S. pestifer* and *S. gemmascens* are sources of ascorbic and citric acids.

Landscape and Ornamental plants

Many attractive halophytes can be used as landscape plants, especially in areas where fresh water is unavailable for irrigation (NAS, 1990). These halophytes include trees, shrubs, succulents and semisucculents, biennial and perennial ground cover and lawn grasses. They can tolerate irrigation water with EC of 15 to almost 50 dS/m (Pasternak et al., 1986). Plants such *as Conocarpus erectus, Eucalyptus sargentii* and *Melaleuca halmaturorum*, and the shrubs *Mairreana sedifolia, Borrichea frutescens* and *Clerodendrum inerme* are already being used for landscaping (NAS, 1990).

Sustainability of halophytic farming systems

The success and long-term sustainability of any farming or cropping system based on halophytes will depend on continued efforts of selecting and breeding halophytic crops (Shannon, 1997,a;b). There is already a considerable amount of information on halophytes already being utilized or have the potential to produce valuable and economic yields. Moreover, halophyte germplasm may provide useful salt tolerant genes for genetic engineering research and the development of salt tolerant crops.

The introduction of halophytes in the farming or cropping systems will depend to a large extent upon the socio-economic needs. Opportunities exist in the Middle East, where population pressure and excessive grazing activities are causing not only the chronic shortages of human food and animal feed and fodder, but also soil erosion and related problems. Supplemental irrigation with saline water or shallow tube wells in semi-arid climates of the Middel East may prove cost effective and more sustainable than a large irrigation scheme involving mining of deep fresh water for agricultural production. Such attempts (Miyamoto et al., 1994) are already underway in a few countries of the region and around the world, and seem to hold promise.

The introduction of halophytes into commercial agriculture has been viewd with great deal of skepticism, partly due to many difficulties encountered in cultivating traditional (glycophytes) crops with saline water and partly due to social norms and consumer prefrences (Subbarao and Johansen, 1999). However, opportunities seem to exist for halophyte cultivation in once-irrigated, but subsequently abandoned lands due to salinization of irrigation water and/ or soils, and in marginal lands with saline water resources.To carry out efficient irrigated production of halophytes (Dudal and Purnell, 1986), however, considerable efforts are needed for agronomic evaluation, in addition to selection and breeding.

Enough supplies of seed or propagule of these potential crops have to be produced and made available to farmers in order to ensure sustainability and profitability of the new farming systems (Khan and Unger, 1997). Also, it should be remembered that traditional and "halophytic" agriculture need not compete, particularly when there is careful planning to ensure ecological conservation and sustainability of production methods.

One of the main issues facing the establishment of halophytic farming systems is that of environmental impact. Large monocultures have often had negative environmental impacts and this must be avoided at all costs. However, high yields can be achieved with halophytic monocultures of selected crops, but these are often associated with high inputs of fertilizers and saline water, and may be prone to disease (Francois and Maas, 1999). Moreover, exotic species are often used as they may be more productive than indigenous species, but they are generally less well adapted to local environmental conditions, pests and diseases (Pasternak, 1987).

Proper management (Francois and Maas, 1999) can optimize nutrient and water conditions, thus avoiding wastage and the need for leaching. There are potential negative impacts of halophytic agriculture, in addition to the impact of saline water, many of which are similar to the problems of intensive agriculture, and farmers must be aware of these so that with careful management these problems can be avoided. Overall, the possible positive environmental effects far outweigh the negative effects, as long as halophytic agriculture is established on marginal or set-aside lands where saline water resources are available. More research is needed to establish sustainable methodologies, selection of appropriate species, and good management practices which are economically viable and acceptable to the halophytic farming community.

Economics is always an important consideration (Grierson, 1999), therefore, to encourage halophyte farming by individuals and private investors it will be necessary to provide grants and economic and social incentives; care also must be taken to ensure environmental sustainability.

CONCLUSIONS

Boyko (1966) was the first to draw attention to the possibility of crop production using seawater as an irrigant. In recent years, however, several researchers have promoted the use of halophytes for the seawater irrigation problem and demonstrated the potential of using halophytes to economically produce a large and diverse number of traditional and new products using saline waters, seawater and marginal land resources. The need for halophytes in saline agriculture is on the rise, as the growing population seeks to feed itself with ever-decreasing soil sources and dwindling freshwater supplies. The use of saline or sea water to irrigate various food, feed, fiber, fodder and industrial crops has been reported by several researchers; economic yields of grains, oil seeds, vegetables, fodder, fuel and fibers, and pharmaceuticals, and other products have been obtained. This biological option, based on genetic resources of indigenous and exotic halophytes, opens the way for the novel concept of using halophytes as alternative crops and making use of the vast saline or seawater resources and marginal lands in the Middle East.

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Appendix I

Genetic resources of halophytes in the Middle East region (entries from the Mediterranean isoclimatic zone are marked with *).

Family	Species	Life form	Plant type	Economic use
Aizoaceae	*Gunniopsis glabra* *	Herbacious Perennial	Hydrohalophyte	-
	G. intermedia *	Annual	Hydrohalophyte	-
	Hypertelis salsoloides	Herbacious Perennial	Xerohalophyte	-
	Mesembranthemum forskahlei	Annual	Xerohalophyte	-
Apiaceae	*Ammi visnaga*	Annual	Weedy	-
	Bupleurum semicompositum	Annual	Xerohalophyte	-
	Crithmum maritimum	Herbacious Perennial	Cahsmophyte (Cliff-dwelling)	Vegetables and Fruits:Salt -tolerant ornamental
	Dacus halophilus	Annual	Cahsmophyte (Cliff-dwelling)	Breeding stock
	Eryngium maritimum	Aquatic	Psammophil (sand-loving)	Salt -tolerant ornamental:Laxative (Mildly cathartic)
Arecaceae	*Phoenix dactylifera*	Tree 8m.	Hydrohalophyte	Fruit:Beverages:Salt - tolerant ornamental
	P. paludosa	Tree 6m.	Hydrohalophyte	-
Asteraceae	*Grindelia paludosa* *	Dwarf shrub (<0.25 m)	Hydrohalophyte	-
	G. robusta *	Dwarf shrub (<0.25 m)	Hydrohalophyte	-
	Inula crithmoides	Herbacious Perennial	Psammophil (sand-loving)	Salt -tolerant ornamental
	I. viscosa	Herbacious Perennial	Psammophil (sand-loving)	-
	Iva hayesiana *	Herbacious Perennial	Hydrohalophyte	-
	Otanthus maritimus	Dwarf shrub (<0.25 m)	Psammophil (sand-loving)	Salt -tolerant ornamental
Brassicaceae	*Crambe maritima*	Annual	Psammophil (sand-loving)	-
	Lipidium acutidens	Annual	Hydrohalophyte	-
	L. cardamines	Aquatic	Hydrohalophyte	-
	Raphanus raphiniastrum	Annual	Psammophil (sand-loving)	
Caryophyllaceae	*Arenaria graveolens*	A Annual	Psammophil (sand-loving)	-
	Cerastium glomerata	Annual	Herbaceous perennial	-
	Sagina maritima	Annual	Psammophil (sand-loving)	-
	Spergularia diandra	Herbacious Perennial	weedy	-
	S. marginata	Annual	Hydrohalophyte	-
	S. rubra	Annual	weedy	-
	Stellaria littoralis	Herbacious Perennial	Hydrohalophyte	-
Chenopodiaceae	*Arthrocenemum capensis*	Dwarf shrub (<0.25 m)	Hydrohalophyte	-
	A. fruticosum	Dwarf shrub (<0.5m.)	Hydrohalophyte	-
	A. heptiflorum	Dwarf shrub	Hydrohalophyte	-

	(<0.25 m)		
*Atriplex californica**	Dwarf shrub (<0.25 m)	Psammophil (sand-loving)	Grazing
A. rosea	Annual	Xerohalophyte	Pickles:Salt and salt substitutes
*A. turcomanica**	Dwarf shrub (<0.5m.)	Xerohalophyte	-
Beta patellaris	Herbacious Perennial	Cahsmophyte (Cliff-dwelling)	-
Beta vulgaris	Herbacious Perennial	weedy	Fodder
*Cornulaca korshinskyi**	Annual	Xerohalophyte	-
*Girgensohnia oppositfolia**	Annual	Xerohalophyte	-
Halimione portulacoides	Herbacious Perennial	Hydrohalophyte	-
Halimocnemis karelinii	Annual	Xerohalophyte	-
Halimocnemis sclerosperma	Annual	Xerohalophyte	Grazing. Camel
Halocharis hispida	Annual	Xerohalophyte	Grazing. Camel
*Halocharis turcomania**	Annual	Xerohalophyte	Grazing. Camel
Halocnemum strobilaceum	Dwarf shrub (<0.5m.)	Xerohalophyte	Fodder:Salt -tolerant ornamental
Halogeton sativus	Annual	Xerohalophyte	Salt and salt substitutes
Halopeplis emplexicaulis	Herbaceous perennial	Xerohalophyte	-
*Halosarica dloeiformis**	Dwarf shrub (<0.5m.)	Hydrohalophyte	-
*Halosarica lepidosperma**	Shrub	Hydrohalophyte	Grazing
*Halosarica lylei**	Shrub	Hydrohalophyte	-
*Halotis pilosa**	Annual	Xerohalophyte	-
Haloxylon articulatum	Dwarf shrub (<0.5m.)	Xerohalophyte	-
Haloxylon persicum	Shrub	Psammophil (sand-loving)	Fuel:Grazing
Haloxylon scoparium	Shrub	Psammophil (sand-loving)	Medicinal
*Horaninowia minor**	Annual	Psammophil (sand-loving)	Fodder
*Horaninowia ulicina**	Annual	Psammophil (sand-loving)	Fodder
*Kalidium caspicum**	Dwarf shrub (<0.25 m)	Xerohalophyte	Salt and salt substitutes:Salt - tolerant ornamental
*Kalidium foliatum**	Dwarf shrub (<0.25 m)	Xerohalophyte	Salt and salt substitutes:Fodder
*Kalidium schrenkianum**	Dwarf shrub (<0.25 m)	Xerohalophyte	Salt and salt substitutes
*Kochia californica**	Dwarf shrub (<0.5m.)	Xerohalophyte	-
*Kochia iranica**	Annual	Xerohalophyte	-
*Kochia scoparia**	Annual	Xerohalophyte	Thatching:Salt -tolerant ornamental
Mariana brevifolia	Shrub	Weedy	Grazing
*Mariana carnosa**	Dwarf shrub (<0.5m.)	Hydrohalophyte	-
*Mariana diffusa**	Shrub	Xerohalophyte	-
*Mariana eriosophaera**	Dwarf shrub (<0.5m.)	Hydrohalophyte	-
*Mariana glomerifolia**	Shrub	Xerohalophyte	-
*Mariana luehmannii**	Dwarf shrub (<0.5m.)	Hydrohalophyte	-
*Mariana melanocarpa**	Shrub	Hydrohalophyte	-

	*Mariana radiata**	Shrub	Hydrohalophyte	-
	*Napophytum erinaceum**	Shrub	Xerohalophyte	-
	*Nitrophila mohavensis**	Herbaceous perennial	Hydrohalophyte	-
	*Ofaiston monandrum**	Annual	Hydrohalophyte	-
	*Panderia pilosa**	Annual	Xerohalophyte	-
	*Petrosimonia brachiata**	Annual	Xerohalophyte	Grazing.4
	*Petrosimonia crassifolia**	Annual	Hydrohalophyte	Grazing. Bovine:Grazing. Camel
	Salicornia lignosa	Shrub	Hydrohalophyte	-
	Salsola soda	Annual	Hydrohalophyte	Vegetables and Fruits: Soup and soup substitutes
	Salsola tetragona	Dwarf shrub (<0.5m.)	Xerohalophyte	-
	*Sarcocornia globosa**	Dwarf shrub (<0.25 m)	Hydrohalophyte	-
	*Seidlitzia florida**	Annual	Xerohalophyte	Fodder
	Sueda splendens	Shrub	Xerohalophyte	Grazing
	Sueda vera	Dwarf shrub (<0.25 m)	Hydrohalophyte	Oilseed:Salt -tolerant ornamental
	*Ticticornia verrucosa**	Aquatic	Hydrohalophyte	Edible seed
	*Tegicornia uniflora**	Herbacious Perennial	Hydrohalophyte	-
Convolvulaceae	*Cressa cretica*	Herbacious Perennial	Hydrohalophyte	-
	Ipomoea sagittata	Herbacious Perennial	Hydrohalophyte	-
	Ipomoea stolonifera	Herbacious Perennial	Psammophil (sand-loving)	Sand stabilization:Salt -tolerant ornamental
Cymodoceaceae	*Cymodocea nodosa*	Seagrass	Hydrohalophyte	-
	Halodule wrightii	Seagrass	Hydrohalophyte	-
Cyperaceae	*Blysmus rufus*	Herbacious Perennial	Hydrohalophyte	-
	Carex extensa	Herbacious Perennial	Hydrohalophyte	-
	Cyperus laevigatus	Herbacious Perennial	Hydrohalophyte	-
Euphorbiaceae	*Andrachne telephioides*	Herbacious Perennial	weedy	-
	Euphorbia terracina	Herbacious Perennial	Psammophil (sand-loving)	-
Frankeniaceae	*Frankenia boissieri*	Herbacious Perennial	Hydrohalophyte	-
	Frankina hirsuta	Herbacious Perennial	Psammophil (sand-loving)	-
	Frankina laevis	Herbacious Perennial	Xerohalophyte	-
	Frankina thymifolia	Herbacious Perennial	Xerohalophyte	-
Juncaceae	*Juncus capitatus*	Annual	Hydrohalophyte	-
Juncaginaceae	*Triglochin bulbosa*	Herbacious Perennial	Hydrohalophyte	-
Liliaceae	*Asparagus maritimus*	Herbacious Perennial	Psammophil (sand-loving)	-
	Asparagus stipularis	Herbacious Perennial	Xerohalophyte	-
	Urginea maritima	Geophyte	Psammophil (sand-loving)	-
Linaceae	*Linum maritimum*	Herbacious Perennial	Hydrohalophyte	-

Malvaceae	*Althaea officinalis*	Dwarf shrub (<0.5m.)	Xerohalophyte	Gums and resins
	Lavatera arborea	Shrub	Psammophil (sand-loving)	-
Mimosaceae	*Prosopis cineraria*	Tree 8m.	Xerohalophyte	Fuel:Fodder:Landuse/Shelter
	Prosopis farcta	Dwarf shrub (<0.5m.)	weedy	-
Pandanaceae	*Pandanus odoratissimus*	Tree 8m.	Hydrohalophyte	Construction timber:Fibers
Papilionaceae	*Alhagi maurorum*	Dwarf shrub (<0.5m.)	weedy	-
	Lotus creticus	Herbacious Perennial	Psammophil (sand-loving)	Sand stabilization:Salt -tolerant ornamental
	Lotus cytisoides	Herbacious Perennial	Cahsmophyte (Cliff-dwelling)	Sand stabilization:Salt -tolerant ornamental
	Lotus halophilus	Herbacious Perennial	Psammophil (sand-loving)	-
	Lotus preslii	Herbacious Perennial	Psammophil (sand-loving)	Grazing
	Lotus tenuis	Herbacious Perennial	Hydrohalophyte	-
	Medicago litoralis	Annual	Psammophil (sand-loving)	-
	Medicago marina	Herbacious Perennial	Psammophil (sand-loving)	-
	Trifolium maritimum	Herbacious Perennial	Psammophil (sand-loving)	Grazing
	Trifolium resupinatum	Herbacious Perennial	Psammophil (sand-loving)	-
	Trifolium tomentosum	Herbacious Perennial	Psammophil (sand-loving)	-
Plantaginaceae	*Plantago bigelovii*	Annual	Hydrohalophyte	-
	Plantago cornuti	Herbacious Perennial	Psammophil (sand-loving)	-
	Plantago coronopus	Annual	Xerohalophyte	-
	Plantago crassifolia	Herbacious Perennial	Hydrohalophyte	Salt -tolerant ornamental: Gums and resins
	Plantago major	Herbacious Perennial	Psammophil (sand-loving)	-
Plumbaginaceae	*Limonium articulatum*	Herbacious Perennial	Psammophil (sand-loving)	-
	Limonium auriculae-ursifolium	Herbacious Perennial	Psammophil (sand-loving)	Salt -tolerant ornamental
	*Limonium californicum**	Herbacious Perennial	Hydrohalophyte	Salt -tolerant ornamental
	*Limonium catalaunicum**	Herbacious Perennial	Cahsmophyte (Cliff-dwelling)	-
	Limonium cordatum	Herbacious Perennial	Hydrohalophyte	Salt -tolerant ornamental
	Limonium cylindrifolium	Herbacious Perennial	Xerohalophyte	Salt -tolerant ornamental
	Limonium diffusum	Herbacious Perennial	Cahsmophyte (Cliff-dwelling)	-
	Limonium duriusculum	Herbacious Perennial	Cahsmophyte (Cliff-dwelling)	Salt -tolerant ornamental
	Limonium echiodes	Herbacious Perennial	Xerohalophyte	-
	Limonium ferulacium	Herbacious Perennial	Hydrohalophyte	Salt -tolerant ornamental

	Limonium girardianum	Herbacious Perennial	Hydrohalophyte	Salt -tolerant ornamental
	Limonium hirsuticalyx	Herbacious Perennial	Cahsmophyte (Cliff-dwelling)	-
	Limonium meyerii	Herbacious Perennial	Hydrohalophyte	Salt -tolerant ornamental
	Limonium oleifolium	Herbacious Perennial	Hydrohalophyte	Salt -tolerant ornamental
	Limonium perezii	Herbacious Perennial	Cahsmophyte (Cliff-dwelling)	Salt -tolerant ornamental
	Limonium ramosissimum	Herbacious Perennial	Hydrohalophyte	Salt -tolerant ornamental
	Limonium sinuatum	Herbacious Perennial	Hydrohalophyte	Salt -tolerant ornamental
	Limonium vulgare	Herbacious Perennial	Hydrohalophyte	Salt -tolerant ornamental
	Limonium spicata	Annual	Xerohalophyte	Salt -tolerant ornamental
Poaceae	*Aeluropus massauensis*	Perennial grass	Hydrohalophyte	Grazing
	Agropyron acutum	Perennial grass	Psammophil (sand-loving)	Grazing:Sand stabilization
	Agropyron elongatum	Perennial grass	Psammophil (sand-loving)	Grazing
	Agropyron pungens	Perennial grass	Psammophil (sand-loving)	-
	Cynodon dactylon	Perennial grass	weedy	Grazing:Salt -tolerant ornamental
	Dactyloctenium aegyptium	Perennial grass	weedy	Edible seed
	*Dcatyloctenium etenoides**	Annual	Hydrohalophyte	-
	*Distichlis palmeri**	Perennial grass	Hydrohalophyte	Breeding stock
	*Eleusine compressa**	Perennial grass	Psammophil (sand-loving)	Grazing. Bovine
	Festuca rubra	Perennial grass	Hydrohalophyte	Fodder
	Lepturus filiformis	Perennial grass	Psammophil (sand-loving)	-
	Lepturus incurvatus	Annual	Psammophil (sand-loving)	-
	Polypogon elongatus	Perennial grass	Hydrohalophyte	Landuse
	Polypogon monspeliensis	Perennial grass	Psammophil (sand-loving)	-
	Puccinellia ciliata	Perennial grass	Hydrohalophyte	-
	Sphenopus divaricatus	Annual	Psammophil (sand-loving)	-
	Sporobolus spicatus	Perennial grass	Psammophil (sand-loving)	-
	Urochloa halopus	Perennial grass	Psammophil (sand-loving)	-
Polygonaceae	*Polygonum aphyllum*	Herbacious Perennial	Psammophil (sand-loving)	-
	Polygonum aviculare	Annual	Xerohalophyte	-
	Polygonum maritimum	Herbacious Perennial	Psammophil (sand-loving)	-
	Polygonum monspeliensis	Herbacious Perennial	Psammophil (sand-loving)	-
	Polygonum patulum	Annual	Psammophil (sand-loving)	-
Potamogetonacea e	*Cymodocea nodosa*	Seagrass	Hydrohalophyte	-
Resedacea	*Reseda hirsuta*	Herbacious Perennial	Hydrohalophyte	-
	Reseda pulverulenta	Herbacious	Hydrohalophyte	-

Tamaricaceae	*Tamarix africana*	Perennial Shrub	Hydrohalophyte	Fuel:Salt -tolerant ornamental
	*Tamarix aralensis**	Tree 4m.	Xerohalophyte	Fuel
	Tamarix arboreta	Tree 4m	Xerohalophyte	Fuel
	Tamarix boveana	Tree 2m.	Xerohalophyte	Fuel
	Tamarix canariensis	Tree 2m.	Phreatophyte	Fuel
	Tamarix dalmatica	Tree 4m.	Xerohalophyte	Fuel
	Tamarix galica	Tree 4m.	Phreatophyte	Fuel:Salt -tolerant ornamental
	Tamarix hampeana	Tree 4m.	Phreatophyte	Fuel:Salt -tolerant ornamental
	*Tamarix karakalensis**	Tree 2m.	Xerohalophyte	Fuel:Salt -tolerant ornamental
	*Tamarix komarovii**	Tree 2m.	Xerohalophyte	Fuel:Salt -tolerant ornamental
	Tamarix macrocarpa	Tree 2m.	Xerohalophyte	Fuel:Salt -tolerant ornamental
	Tamarix mannifera	Tree 2m.	Xerohalophyte	Fuel:Salt -tolerant ornamental
	*Tamarix octandra**	Shrub	Xerohalophyte	Fuel:Salt -tolerant ornamental
	Tamarix palaestina	Tree 2m.	Xerohalophyte	Fuel:Salt -tolerant ornamental
	Tamarix pycnocarpa	Shrub	Xerohalophyte	Fuel:Salt -tolerant ornamental
	Tamarix rosea	Tree 2m.	Xerohalophyte	Fuel:Salt -tolerant ornamental
	*Tamarix salina**	Tree 2m.	Phreatophyte	Fuel:Salt -tolerant ornamental
Tamaricaceae	*Tamarix szowitsiana**	Tree 2m.	Xerohalophyte	Fuel:Salt -tolerant ornamental
	Tamarix tetragyna	Tree 2m.	Xerohalophyte	Fuel:Salt -tolerant ornamental
Typhaceae	*Typha anguustata*	Herbaceous perennial	Hydrohalophyte	-
Zygophyllaceae	*Tetradiclis tenella*	Annual	Xerohalophyte	-
	Zygophyllum decumbense	Shrub	Xerohalophyte	-
	Zygophyllum quatarense	Dwarf shrub (<0.5m.)	Xerohalophyte	-