CHAPTER 11

HALOPHYTES OF PAKISTAN: CHARACTERISTICS, DISTRIBUTION AND POTENTIAL ECONOMIC USAGES

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Abstract. Fresh water resources are becoming increasingly limited and agricultural irrigation systems will steadily increase in salinity in the near future. The time has come to develop sustainable biological production systems that can use low quality saline water for irrigation of halophytic crops in saline lands. A large number of halophytes could be used as cash crop (forage, fodder, fuel, medicine, chemicals, ornamentals etc). Pakistan spans a distance of 1,600 kilometers from the Arabian Sea to the playas of temperate northern mountains across deserts, plains and prairies, to the playas of temperate northern mountains covering an area of 800,000 square kilometers. The varied climatic conditions have resulted in a rich diversity of halophytic flora. Compared to the total 2200 species reported worldwide, Pakistan alone has about 410 halophytes and 178 of them have not been reported before. About 274 of the total 410 halophytes reported here potentialy have economic usages.

1. INTRODUCTION

In almost all the regions of the world and particularly in arid areas soil salinity is becoming a major problem due to a variety of natural and man caused factors. In addition these arid regions, which naturally have lesser supply of fresh water, are exposed to a rapidly increasing population, which is exerting even more pressure on the supply of water. With the rapidly increasing population, scarcity of water and increasing salinization of agricultural lands is already threatening the food supply (Leith, 1994). Surface and ground water in agricultural areas is rapidly becoming brackish and saline. Furthermore, salt deserts (caused by a lack of fresh water) and saline inland basins (caused by the rising level of saline ground water as a result of leakage of drainage water) are being created. FAO data show that at least 40% of the world is affected by salinization in some form. The actual impact of this estimate is not entirely clear. However, it is known that large areas in Australia, India, Pakistan, Egypt, Central Asia, South America, Mexico and the United States (Menzel & Lieth, 1999) are faced with salinization.

There are growing indications that cultivation of crops with a high salt tolerance can be seen as an economically feasible option for utilizing saline soils

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and conserving fresh water (Glenn, 1987; Glen et al., 1998; Leith, 1994). Saline agriculture is a type of non-conventional crop (halophytes) are grown. Potential halophytic crops could be broadly grouped into three categories 1. Plants with a high salt tolerance: they grow in water with salt contents equal to or even higher than that of seawater; 2. Crops with an average salt tolerance: they grow in brackish water and 3. Crops with a moderate salt tolerance: they grow in slightly brackish water that is not suitable for conventional agriculture. Several efforts were made to compile a list of the halophytic flora of the world (Aronson, 1989; Menzel & Lieth, 1999) as well as a list of regional halophytes. However, the information regarding halophytes is still far from complete. The Flora of Pakistan is near completion and also has information about the halophytes. Currently, effort is being made to compile a list of halophytes in Pakistan, with their distribution, ecology and potential economic usages.

1.1. Physiography, salinity and climate

Pakistan has a varied physiography and climate. It stretches about 1,600 kilometers from the subtropical Arabian Sea to the temperate northern mountains covering an area of 800,000 square kilometers. The country can be divided into seven major landscape units: 1. Coast (Co), 2. Balochistan Plains (BP), 3. Indus Plains (IP), 4. Potwar Plateau (PP), 5. Deserts (Des) including Thal, Thar and Cholistan, 6. Arid and Semi-arid Mountains (ASM) including the northern Balochistan, Sulemania range, Waziristan, Kurram agency, Gilgit, and Chitral (Hindukush) and 6. Moist Mountains (MM) including the Western Himalayas, Swat, Kaghan, Kashmir, Muree and Kaghan. The Indus is a major river, which passes through Pakistan with an approximate annual water flow of 115 billion cubic meters (Ahmed & Chaudhary, 1988; Pasternak, 1990). It originates from the Tibetan plateau at an altitude of about 5500 meters and flows south to the Arabian Sea. In addition other major tributaries, the Chenab, the Jehlum, the Sutlej, the Beas, and the Ravi join the Indus at the upper Indus plain.

Pakistan is primarily arid and semiarid, except for a narrow belt in the north, with low and variable rainfall. Annual precipitation ranges from 1500 mm on the southern step of the Himalayas to less than 100 millimeters on the western Balochistan coast. About 69% of the country receives rainfall of less than 250 millimeters per year. The rain primarily falls during the monsoons (June – September). However, the southwestern Balochistan receives winter rain with a Mediterranean trend, and some northwestern areas have both winter and summer rains.

1.2. Definition of halophytes

There are numerous ways of defining halophytes. For our purpose the best definition seems to be “plants that complete their life cycle in saline habitats” (Ungar, 1991), where salt concentration of soil solution is about 5 g/l of total dissolved solids (85 mM NaCl or 7-8 dS m^{-1}, Aronson, 1989). This list is arranged alphabetically by family, and within each family, by genus and species. The nomenclature follows the "Flora of Pakistan".

1.3. Life form

Only one life form is assigned per species, even though many species show a certain amount of plasticity in this regard. Phanerophytes are further divided into a. Megaphanerophytes (MP, > 30 m tall); b. Mesophanerophytes (MSP, 8 – 30 m tall); c. Microphanerophytes (MIP, 2 – 8 m tall); d. Nano-Phanerophytes (NP, < 2 m tall); e. Epiphytic Phanerophytes (EP); f. Stem Succulent Phanerophytes (SSP); and g. Liana Phanerophytes (LP). Chamaephytes (≤ 25 cm tall) could be further sub-divided into a. Sub-Fruticose Chamaephytes (SFC, erect shoot fruit at base), b. Passive Chamaephytes (PC, erect but die down and produce horizonal buds), c. Active Chamaephytes (AC, erect shoot absent), d. Cushion Chamaephytes (CC, transition between Chamaephytes and Hemicryptophytes); Hemicryptophytes (HC) Cryptophytes which include a. Geophytes (G), and Hydrophytes (H); and b. Therophytes (TH).

1.4. Plant type

This category is based on the habitats in which the taxon is distributed. Hyphal = hydrohalophytes (present in salt marshes), Xeroh = Xerohalophyte = salt desert species, Psamm = Psammophytes (sand loving plants found on littoral or inland sand dunes), Xero = Xerohalophytes (desert species suspected as halophytes), Chasm = Chasmophytes (cliff-dwelling species), Weedy = Fugitive species, Phrea = and Fibers (8).

1.5. Economic usages

These are denoted by a numerical code as follows: Food (1), Fodder (2), Forage (3), Medicinal (4), Ornamental (5), Chemical (6), Timber and other usages of wood (7) and Fibers (8).

1.6. Halophytes in Pakistan

1.6.1. General overview

The list showed that the halophytic vegetation of Pakistan is quite diverse (Table 1) with 410 species from 58 families. The highest number of halophyte species is present in the Chenopodiaceae family (90), followed by Poaceae (68), Cyperaceae (30), Papilionaceae (29), Asteraceae (24), and Tamaricaceae (23), while other families are represented by less than 10 halophytes (Table 1, Fig. 1). Menzel and Lieth (*103*) reported that about 2,200 halophytic species were found in the literature worldwide. The halophytes of Pakistan constitute about 19% of the flora. Most of the halophytic species in Pakistan are present in the Blaochistan plains (182), whereas, others are in coastal areas (163), moist mountains (149), arid mountains (93), the Potwar plateau (76), and deserts (65) (Table 1).

The data showed that the Balochistan plains of Pakistan are more diverse in comparison with other areas. In addition among the total 410 halophytes about 140 of them could be classified as Hydrohalophytes, followed by Xerophytes (84), Xerohalophytes (77), Psammohalophytes (75), Weedy (28), Chasmophytes (4), and Phreatohytes (2). Fifty percent of halophytes from the Chenopodiaceae are found in arid environments while all halophytic members of the Cyperaceae are found in aquatic conditions (Table 2).

Life forms of these plants also showed a high degree of variation. Nano-phanerophytes (146) are the dominant life form of Pakistani halophytes, followed by Therophytes (120), Sub-fruticose Chaemephytes (64), Microphanerophytes (27), and Mesophanerophytes (20), and others are represented by less than 10 individuals (Table 1). In most of the regions Nano-phanerophytes dominated the life present in the area followed by Therophytes and Sub-fruticose Chaemephytes. Most of the halophytes present in the Northern Mountains are Hydrohalophytes, followed by Xerohalophytes, and Psammophytes, while halophytic vegetation of Balochistan is equally dominated by three types: Hydrohalophytes, Xerophytes, and Xerohalophytes (Table 1). Hydrohalophytes are the most abundant group among the coastal plants.

***Table 1**. Alphabetical listing of halophytes of Pakistan. (Those with an asterisk (*) are included for the first time in any halophyte list.*

Genus, Species and Author	*Distribution*	*Plant Type*	*Life form*	*Economic Uses*	*Ref.*
Aizoaceae					
Aizoon canariense L.	CO	Xero	Th	1	19
Mesembryanthemum crystillinum L.	IP	Xeroh	Th	5,8	
Sessuvium sessuvioides (Fenzl.) Verdc.	CO, IP	Psamm.	HP	5,8	125
Trianthema portulacastrum L.	COS	Xeroh	Th	1,2,4,5	33,46
Trianthema triquetra Rottl.ex Willd. (*)	CO, IP,PP,BP	Xeroh	Th	2	111
**Zaleya pentandara* (L.) Jeffrey	COS	Xeroh	H	2,4	111
Amaranthaceae					
**Aerva javanica* (Brum. f.) Juss. ex J.A. Schultes var *javanica*	CO, IP, PP	Xero	NP	8	139
**Aerva javanica* (Brum. f.) Juss. ex J.A. Schultes var. bovei Webb.	CO, ASM, PP	Xero	NP	8	*139*
Asclepediaceae					
Calotropis procera (Ait.) Ait.	ASM, MM, BP, IP	Xero	NP	4,5,6,8	15,117
Cynanchum acutum L.	MM,	Psam.	V	-	138
**Glossonema varians* (Stocks.) Hook. f.	CO, BP, ASM	Xero,	CH	1	9
**Leptadenia pyrotechnica* (Forssk.) Dcne.	CO, BP, Des	Xero	NP	4	9
*Oxystelma esculentum *(Linn. f.) R. Brown*	IP	*Xero.*	*V*	*1,4*	*9*
Pentatropis nivalis(J.F. Gmel.) D.V. Field & J.R.I. Wood	PP, BP, IP,	Xero	V	1,4	43,98
**Pergularia damia* (Forssk.) Chiov	MM, PP, IP	Xero	V	-	9
Pergularia tomentosa L.	CO, BP	Xero	V		98

Asteraceae

Achillea millefolium L.	MM	Psamm.	NP	4	137
Artemisia scoparia Waldst. & Kit.	MM, IP, PP, BP	Psamm.	NP	2,4	63
**Cymbolena griffithii* (A.Gray) Wagenitz	ASM, MM, BP	Xero	Weedy	-	123
**Grangia* madrasspotensis (L.) Poir.	BP, Des	Hyphal.	AC	-	123
**Handelia tricophylla* (Schrenk.) Heimerl	MM	Psamm.	NP	-	54
Inula brittanica L.	MM	Hyphal.	SFC	4	54
**Iphiona aucherii* (Boiss.) Anderb.	BP	Xero.			123
Lactuca tatarica (L.) C. A. May	MM	Psamm.	SFC	-	54
******Launea procumbens* (Roxb.) Ramayya & Rajagopal	ASM, MM, BP, CO	Xerohal.	SFC	-	123
**Launea sarmantosa* (Willd.) Alsoton	CO	Psamm.	SFC	-	54
**Microcephala lamellate* (Bunge) Pobed.	ASM, BP	Psamm.	TH	4	54
**Pluchia arguta* Boiss. Subsp. *Arguta*	BP, CO	Xerohal.	NP	-	123
**Pluchia arguta* Boiss. Subsp. *glabra*	COSM	Xerohal.	NP	-	123
**Pulicaria boisseri* Hook. f.	BP, CO	Xerohal.	NP	-	123
**Pulicaria carnosa* (Boiss.) Burkill	ASM, BP, CO	Xerohal.	NP	-	123
**Pulicaria gnaphalodes* (Vent.) Boiss.	BP	Xerohal	NP	-	123
******Pulicaria undulata* (L.) C.A.Meyer	PP, IP, BP, Des	Weedy	NP	-	123
**Pseudognaphalium leuto-album* (L.) O.M.Hilliard	MM, ASM, BP, PP	Hyphal	Th	-	123
**Seriphidium brevifolium* (Wall. ex DC) Ling & Y.R. Ling	MM	Psamm.	NP	2,4	54
**Seriphidium quettense* (Podlech) Ling	BP	Psamm.	NP	2,4,7	54
**Sonchus asper* (L.) Hill	Cosm.	Hyphal.	SFC	-	54
Sonchus maritimus L.	ASM, IP	Hyphal	SFC	-	123
**Sonchus tenerrimus* L.	CO	Hyphal	SFC	-	54
Xanthium sibiricum Patrin.	ASM, BP	Xero	HP	-	63

Avicenniaceae

Avicennia marina (Forssk.) Vierh	CO	Hyphal	MP	1,2,4	17,76

Boraginaceae

Heliotropium aucheri DC	BP	Weedy	SFC	-	106
Heliotropium bacciferum Forssk.	CO	Xero	SFC	-	106
Heliotropium currassvicum L.	CO, IP	Weedy	NP	-	106
**Heliotropium remotiflorum* Rech.f. & Riedl.	CO,BP	Xero	NP	-	106
**Sericostema pauciflorum* Stocks ex Wight	CO	Psamm.	NP	-	106

Brassicaceae

**Conringia persica* Boiss.	BP	Psamm.	TH	-	64
**Coronopus didymus* (L.) Smith	IP, BP, CO	Xerohal.	TH	-	64
**Dilophia salsa* Thompson	MM	Hyphal	CC	-	64
Lepidium cartilagineum (J. May) Thell.	BP	Hyphal	NP	-	106
Lepidium latifolium L.	MM	Hyphal	NP	-	35,96
Lobularia maritima (L.) Desv.	IP	Psamm.	NP	2	141
Raphanus raphanistrum L.	ASM, PP, BP	Psamm.	TH	2,5	141

Caryophyllaceae

Cerastium glomeratum Thuill.	MM, PP	Weedy	TH	-	42
**Polycarpia spicata* Wight & Arn.	BP, CO, Des	Psamm.	TH	-	55
Spergularia diandra (Guss.) Heldr & Sart.	BP, MM, IP	Weedy	TH	-	126, 146
Spergularia marina (L.) Griesb.	IP, BP, CO	Weedy	TH	-	63, 106
Spergularia media (L.) Presl.	BP	Hyphal	NP	-	63, 106

Caesalpiniaceae

Caesalpinea bonduc (L.) Roxburgh.	IP, CO	Hyphal	NP	2,4	36,107
******Cassia italica* (Mill.) F.W. Andr.	PP, CO, PP	Xero.	NP	4	7

Chenopodiaceae

**Agathophora alopecuroides* (Dellie.) Fenzl ex Bunge	BP	Xerohal.	NP	-	48

Anabasis haussknechtii Bunge ex Boiss.	BP, IP	Xerohal.	NP	-	106
**Anabasis lachnantha* Allan & Rech.	BP, CO	Xerohal.	NP	-	48
Anabasis setifera Moq.	ASM, BP, CO	Xerohal.	NP	-	93, 106
Arthrocnemum indicum (Willd.) Moq.	CO	Hyphal	NP	2	45,106
Arthrocnemum macrostachyum (Moric.) C. Koch	CO	Hyphal	NP		19,117
Atriplex canescens James	BP	Xerohal.	NP	2	109,114
Atriplex dimorphostegia Kar. & Kir.	BP	Psamm.	TH	3	11,114
Atriplex griffithii Moq.	ASM	Xerohal.	NP	2	11,114
Atriplex halimus L.	Des	Xerohal.	MIP	1,2	108,114
Atriplex hortensis L.	MM	Xero	TH	1	1508 114
**Atriplex lasiantha* Boiss.	MM, IP, BP	Xero	TH	-	48
Atriplex leucoclada Boiss.	CO, IP	Xero	NP	2	19,122
**Atriplex pamirica* Iljin	MM, IP	Xerohal.	TH	-	48
**Atriplex schugnanica* Iljin	MM	Xerohal	TH	-	48
Atriplex stocksii Boiss.	CO	Xerohal.	NP	-	89,108
Atriplex tatarica L.	MM	Xero	TH	2	63,141
Bassia dasyphylla (Fisch. & Mey.) O. Kuntze	MM	Xero	TH	-	63,141
Bassia eriophora (Schrad.) Ascher	BP	Xero	TH	-	48
Bassia hyssopifolia (Pall.) O. Kuntze	MM	Weedy	TH	-	63,107
Beta vulgaris ssp *maritma* (L.) Arcangeli	BP, IP	Weedy	NP	2	95,122
Bienertia cycloptera (Bunge ex Trautv.) Bunge ex Boiss.	CO	Xerohal.	TH	2	18,106
Camphorosma monspelictum L.	ASM, BP, IP	Xero	NP	2,4	63,106
Ceratocarpus arenarius L.	ASM, BP	Psamm.	TH	-	63
Chenopodium album L.	Cosm.	Weedy	TH	-	63
Chenopodium ambrosoides L.	MM, IP	Weedy	TH	4	101, 108
**Chenopodium botrys* L.	ASM, MM, BP	Weedy	TH	-	48
Chenopodium ficifolium ssp *blomianum* (Aellen) Aellen	ASM, MM, IP	Weedy	TH	-	48
Chenopodium glaucum L.	MM, BP	Weedy	TH	-	63,103
Chenopodium murale L.	Cosm.	Weedy	TH	-	48
**Coriospermum korovinii* Iljin	MM	Xero	TH	-	48
**Coriospermum tibeticum* Iljin	MM	Xero	TH	-	48
**Cornulaca aucherii* Moq.	ASM	Xerohal	TH	-	48
Cornulaca monacantha Del.	ASM, CO, BP	Xerohal.	NP	-	92,106
Gamanthus gamocarpus (Moq.) Bunge	BP	Xerohal.	TH	-	106
Girgensohnia oppositiflora (Pall.) Fenzl	ASM	Xero	TH	-	94,141
**Halimocnemis occulta* (Bunge) Hedge	BP	Xerohal.	TH	-	48
**Halocharis clavata* Bunge	BP	Xerohal.	TH	-	48
Halocharis hispida (Schrenk ex C. A. Mey) Bunge	ASM, BP	Xerohal.	TH	3	135
Halocharis sulphurea (Moq.) Moq.	ASM, BP	Xerohal.	TH	-	106
Halocharis violacea Bunge	BP	Xerohal.	TH	-	106
Halocnemum strobilaceum (Pall.) M. Bieb.	CO, BP	Xerohal	NP	2,5	94
Halogeton glomeratus (M. B.) C. A. Mey	MM	Xerohal.	TH	4	63,94
**Halogeton tibeticus* Bunge	MM	Xerohal.	TH	-	48
Halopeplis perfoliata (Forssk.) Bunge ex Schweinf.	CO	Hyphal	NP	-	94
Halostachys belangerana (Moq.) Botsch.	CO	Hyphal	NP	-	133,137
Halothamnus auriculus (Mey.) Botch. ssp *acutifolius*	BP	Xerohal	NP	-	133,137
Halothamnus subaphyllus (Mey.) Botsch . ssp *chariffi*	ASM	Xerohal.	NP	-	133,137
**Halothamnus iranicus Botsch.*	BP	Xerohal.	NP	-	48
**Haloxylon griffithii* (Moq.) Boiss. ssp *griffithii*	ASM, MM, BP	Xerohal.	NP	1	48
**Haloxylon griffithii* (Moq.) Boiss.ssp *wakhanica* (Paulsen) Hedge	MM	Xero	NP	1	48
Haloxylon persicum Bunge ex Boiss	ASM	Psamm.	NP	3,8	21,26
Haloxylon salicornicum (Moq.)					

Bunge ex Boiss.	IP, BP	Xerohal	NP	-	106
**Haloxylon stocksii* (Boiss.) Benth. & Hook.	Cosm.	Xerohal.	NP	1,2	48,87
Kochia indica Wight	MM, PP, BP, IP	Xero	TH	5	93,101
Kochia iranica Litw. ex Bornm	ASM, MM, BP	Xero	TH	5,8	135
Kochia prostrata (L.) Schrad.	ASM, MM	Xero	NP	-	63,106
Kochia scoparia (L.) Schrad.	Cosm.	Xero	TH	-	92,132
**Kochia stellaris* Moq.	MM	Xero	TH	-	48
**Krascheninnikovia ceratoides* (L.)					
Guldenst.	MM	Xerohal.	NP	-	48
Panderia pilosa Fisch. & C.A.Mey.	CO, IP, BP	hyphal	TH	-	106,146
Salicornia bigellovi Torr.	CO	hyphal	TH	1	106
Salicornia brachiata Roxb.	CO	hyphal	TH	1	68
Salsola arbuscula Pall.	BP	Xerohal.	NP	-	63, 106
Salsola chorassanica Botsch	BP	Xerohal.	TH	-	104
Salsola collina Pall.	MM	Hyphal	TH	-	63
**Salsola crassa* ssp *turcomanica* Pall.	BP	Xerohal.	TH	-	48
**Salsola cyclophylla* Baker	BP, CO	Xerohal	NP	-	48
Salsola drummondii Ulbr.	ASM, BP, IP, CO	Hyphal	NP	-	106
**Salsola griffithii* (Bunge) Freitag & Akhani	ASM, BP, CO	Psamm.	NP	-	48
Salsola imbricata Forssk. *var. imbricata*	Cosm.	Xerohal.	NP	-	48
**Salsola imbricata* Forssk. *var. hirtitepala*	BP, CO	Xerohal.	NP	-	48
Salsola incanescens C.A. Mey	BP	Xerohal.	TH	-	106
**Salsola makranica* Freitag	BP, CO	Xerohal.	NP	-	48
Sal*sola nitraria* Pall.	BP	Xerohal.	TH	-	104
Salsola orientalis S.G. Gmeln	BP	Xerohal.	NP	-	106
**Salsola paulsenii* ssp *praecox* (Litw.) Rilke	BP	Psamm.	TH	-	48
Salsola richteri (Moq.) Karel.	BP	Psamm.	MIP	-	26
Salsola sclerantha C.A. Mey	BP	Psamm.	TH	-	106
Salsola tomentosa (Moq.) Spach	ASM	Xerohal.	NP	-	106
Salsola tragus L.	ASM, MM, BP	Xerohal.	TH	2	48
Seidlitzia florida (M. Bieb.) Boiss.	BP	Xerohal.	TH	2	106
Suaeda acuminata (C. A. Mey) Moq.	MM	Xerohal.	TH	-	1
Suaeda aegyptiaca (Hasselq.) Zohary	ASM, BP, CO	Hyphal	TH	-	19
Suaeda arcuata Bunge	BP	Weedy	TH	-	48
Suaeda fruticosa (L.) Forssk.	Cosm.	Xerohal.	NP	1,2,6	79,88
Suaeda heterophylla (Kar. & Kir.) Bunge	MM	Hyphal	TH	-	48
Suaeda monoica Forssk.	BP, IP	Hyphal	MIP	-	93,108
**Suaeda olufsenii* Paulsen	MM	Hyphal	TH	-	48
Convolvulaceae					
Cressa cretica L.	Cosm.	Hyphal	SFC	2,4	72
Evolvulus alsinoides L.	Cosm.	Hyphal	AC	4	18
Ipomoea alba L.	Cosm.	Psamm.	EP	4	136
**Ipomoea carnea* L. ssp. *fistulosa*	PP, IP, DES	Psamm.	MIP	-	16
Ipomoea pes-caprae (L.) R. Br.	CO	Psamm.	AC	5	136
Cynomoriaceae					
**Cynamorium coccinium L.*	BP	Psamm.	AC	1,4	127
Cyperaceae					
Blysmus rufus (Huds.) Link.	MM	Hyphal	NP	-	96
Bolboschoenus affinis (Roth.) Drobov	PP, CO, IP	Hyphal	NP	2	135
**Bolboschoenus glaucus*	Cosm.	Hyphal	SFC	2	189
Carex divisa Hudson	BP, MM	Hyphal	NP	2	35,44
Carex songorica Kar. & Kir	MM	Hyphal	NP	-	115
Carex stenophylla ssp. S*tenophyllous*					
(V. Krecz.) Egor	MM, BP, CO	Hyphal	NP	-	117
**Cyperus arenarius* Retz.	CO, IP	Hyphal	HP	-	90
**Cyperus alopecuroides* Rottb.	CO, IP, Des	Hyphal	NP	-	90
**Cyperus atkinsonii* C.B. Clarke	MM, IP, BP, CO	Hyphal	NP	-	90
**Cyperus aucheri* Jaub. & Spach	BP	Hyphal	PC	-	90
**Cyperus bulbosus* Vahl	CO, IP, BP, Des	Hyphal	NP	-	90

**Cyperus conglomeratus* ssp. *conglomeratus* Rottb.	CO, BP	Hyphal	NP	-	90
**Cyperus conglomeratus* ssp. *curvulus* Rottb.	CO, BP	Psamm.	NP	-	90
Cyperus laevigatus L.	IP, PP, CO, BP	Hyphal	NP	-	19,43
Cyperus malaccensis Lam.	CO	Hyphal	NP	-	128
**Cyperus niveus* Retz.	Cosm.	Hyphal	NP	-	90
**Cyperus pachyrhizhus* Nees ex Boeck	CO	Hyphal	NP	-	90
**Cyperus pangorei* Rottb.	CO	Hyphal	NP	-	90
Cyperus rotundus L.	Cosm.	Hyphal	NP	-	63
Cyperus stoloniferous Retz.	CO	Psamm.	NP	-	45
**Eleocharis quenqeflora* (F.X. Hartm.) O. Schwarz	MM	Hyphal	SFC	-	90
Eleocharis uniglumis (Link.) Schultes	ASM, MM	Hyphal	SFC	-	96
**Fimbristylis complanata* (Retz.) Link	CO	Hyphal	SFC	-	90
**Fimbristylis cymosa* R. Br.	CO, IP	Hyphal	SFC	-	90
**Pycerus dwarkensis* (Sahni & Naithani) Hooper	CO	Hyphal	SFC	-	90
Pycerus polystachyos (Rottb.) P. Beauv	CO	Hyphal	SFC	-	63
**Schoenoplectus lacustris* (L.) Palla ssp. *tabernamonti*	MM	Hyphal	NP	-	90
**Schoenoplectus lacustris* (L.) Palla ssp. *happolyti*	MM	Hyphal	NP	-	90
**Schoenoplectus litoralis* (Schrad.) Palla	MM	Hyphal	NP	-	90
**Schoenoplectus triqueter* (L.) Palla	MM	Hyphal	NP	-	90
Elatinaceae					
**Bergia aestivosa* Wight & Arnot	Thal, Des	Xerohal	NP	-	123
**Bergia ammanoides* Roth.	IP, CO	Hyphal	TH	-	123
Euphorbiaceae					
Andrachne telephioides L.	ASM, MM, BP	Weedy	AC	-	40
Euphorbia granulata Forssk.	Cosm.	Weedy	TH	-	117
**Euphorbia indica* Lam.	Cosm.	Weedy	TH	-	129
Euphorbia serpens Kunth.	IP, PP	Hyphal	TH	-	130
Euphorbia thymifolia L.	ASM, IP, BP, CO	Psamm.	TH	5	128
Frankeniaceae					
Frankenia pulverulenta L.	BP, IP, PP, CO	Psamm.	TH	5	117
Gentianaceae					
**Enicostema hyssopifolium* (Willd) Verdoon	CO, IP, BP	Psamm.	SFC	-110	
Goodeniaceae					
Scaevola plumieri (L.) Vahl.	CO	Psamm.	NP	5	36
Scaevola taccada (Gaertn.) Roxb.	CO	Psamm.	MIP	5	117
Hydrocharitaceae					
**Halophila ovalis* R. Br.	CO	Hyphal	TH	-	52
Juncaceae					
Juncus bufonius L.	IP	Hyphal	TH	-	63
Juncus gerardii Lois.	BP	Hyphal	NP	-	96
Juncus maritimes Lam.	CO, IP	Hyphal	NP	-	96,117
**Juncus punctorius* L.	BP	Hyphal	NP	-	67
Juncaginaceae					
Triglochin maritima L.	MM	Hyphal	NP	1,8	31
Triglochin palustris K.	MM	Hyphal	NP	3	137
Liliaceae					
**Asparagus deltae* Blatter	CO	Psamm.	NP	-	-
**Asparagus gharoansis* Blatter	Des, IP	Psamm.	NP	-	-

**Urginea indica* Kunth.	NM	Psamm.	HP	4	-
Malvaceae					
**Pavonia procumbens* (Wall. ex Wight & Arn.)Wallp.	CO	Xerohal.	SFC	-	3
**Senra incana* Cav.	CO	Xero.	NP	-	3
**Gossypium stocksii* Mast.	CO	Xero.	NP	-	3
Thespesia populneoides (Roxb.) Kostel.	CO	Hyphal.	MSP	4,8	36,105
Mimosaceae					
Acacia leucophloea (Roxb.) Willd.	Des	Xero	MSP	7	13
**Acacia nilotica* (L.) Delile ss *hemispherica*	CO	Xero	MSP	7	6
Acacia sphaerocephala Schl. & Chem.	IP	Xero	NP	-	135
**Prosopis cineraria* (L.) Druce	PP, IP, CO, Des	Xero	MSP	2,7	6
Prosopis farcta (Banks & Sol.) Macbride	IP	Weedy	MSP	2,4,7	19,38
Prosopis juliflora (Swartz) DC.	IP	Xero	MSP	2,7	19,38
Molluginaceae					
**Glinus lotoides* L.	CO, BP, IP	Psamm.	TH	1,2,4	110
Moraceae					
Ficus microcarpa L.	IP	Hyphal	MSP	5	33
Myrsinaceae					
Aegiceras corniculatus (L.) Blanco	CO	Hyphal	NP	2,6	36, 104
**Ardisia solanacea* Roxb.	CO	Hyphal	MIP	5	65
Najadaceae					
Najas graminea Delile	PP	Hyphal	NP	-	105
Najas marina L.	IP, MM	Hyphal	NP	-	105
Najas minor All.	IP	Hyphal	NP	-	135
Neuradaceae					
**Neurada procumbens* L.	ASM, BP, IP	Psamm.	TH	1,2,4	100
Nyctaginaceae					
Pisonia grandis R. Br.	CO	Psamm.	MSP	1	4
Orobanchaceae					
Cistanche tubulosa (Schrenk) Hook	Cosm.	Psamm.	TH	-	106
Palmae					
Cocos nucifera L.	CO	Hyphal	MSP	1,4	32, 102
Pheonix dactylifera L.	CO, IP	Hyphal	MP	1	131 140
**Pheonix sylvestris* (L.)Roxb.	CO	Hyphal	MSP	1	11, 24
Papilionaceae					
**Aeschynomene indica* L.	MM, Des	Hyphal	TH	-	8
Alhaji maurorum Medic.	Cosm.	Hyphal	NP	2,4,8	19,94
Astragalus fatmanses Hochsr. Ex Blatter	IP, CO	Xerohal	SFC	-	104
**Crotolaria persica* (Burn f.) Merril	CO	Xerohal.	NP	-	8
Dalbergia sissoo Roxb.	IP, BP	Xero	MSP	2,5,7	118
Erythrina herbacea L.	IP	Hyphal	NP	4	30
**Indigofera argentia* Burn f.	CO	Xerohal	NP	-	8
**Indigofera cordifolia* Heynes ex Roth.	IP, Des, CO	Xerohal	TH	-	8
**Indigofera intricata* Boiss.	CO	Xerohal	AC	-	8
**Indigofera linifolia* (L. F.) Retz.	Cosm.	Xerohal	TH	-	8
**Indigofera oblongifolia* Forsk.	CO	Xerohal	NP	-	8
**Lespedeza juncea* var *serica* (Thunb.) Lace & Hemsley	ASM, PP, BP	Xero	NP	-	8
**Lotus garcini* D.C.	CO	Psamm.	NP	-	8
**Macroptilium lathyroides* (L.) Urb.	IP	Hyphal	TH	-	8
Medicago falcata L.	MM	Chasm	NP	-	63

Melilotus alba Desr.	MM	Chasm	TH	-	104
Melilotus indica (L.) All.	Cosm.	Chasm	TH	-	104,137
Melilotus officinalis (Li.) Pall.	MM	Chasm	TH	-	104
Pongamia pinnata (L.) Merrill	IP	Hyphal	MSP	7	36
**Sesbania grandiflora* (L.) Poir	CO	Xero.	MSP	-	8
**Sesbania sesban* (L.) Merrill	IP	Xero	MSP	-	8
Sophora alopecuroides L.	MM	Psamm.	NP	-	63
**Tavernaria spartea* (Burm. f.) DC	CO	Xerohal.	NP	-	8
Tephrosia appolinea (Delile) Link	CO, BP	Xerohal.	SFC	-	8
Tephrosia purpurea (L.) Pers.	IP	Hyphal	TH	-	91, 131
**Trifolium fragiferum* L.	MM	Psamm.	AC	2	28,96
**Trifolium repens* L.	ASM, MM, BP	Psamm.	AC	2	8
**Vicia sativa* L.	Cosm.	Hyphal	TH	2	8
**Vigna trilobata* (L.) Verdc.	CO, Des	Xero	TH	-	8

Pedaliaceae

**Pedalium murex* L.	Des, CO, BP	Xerohal.	TH	1,4	1

Plantaginaceae

Plantago coronopus L.	BP	Xero	TH	-	35
Plantago depressa Willd.	MM	Hyphal	TH	-	63
Plantago lanceolata L.	MM, PP	Xero	SFC	4	105
Plantago major L.	Cosm.	Psamm.	PC	4	146

Plumbaginaceae

Limonium axillare Forssk.	MM	Hyphal	TH	5	103
**Limonium gilsei* (Hemsl.) Rech	MM	Hyphal	NP	5	22
Limonium sinuatum (L.) Miller	Cultivated	Hyphal	TH	5	117
Limonium stocksii (Boiss.) O.Ktze	CO, BP	Hyphal	NP	5	117,145
Psylliostachys spicata (Willd.) Nevski	BP	Hyphal	TH	5	106

Poaceae

Aeluropus lagopoides (L.) Trin. ex Thw.	CO, Des, IP, BP	Hyphal	SFC	3,5	59, 62
Aeluropus littoralis (Gouan) Parl.	BP	Hyphal	SFC	3	19,42
**Aeluropus macrostachys* Hack.	BP	Phyphal	SFC	3	34
Agrostis stolonifera L.	MM, PP	Psamm.	NP	3	34
**Aristida mutabilis* Trin. & Rupr	MM, ASM, IP, BP	Psamm.	NP	3	34
**Aristida adsceshoines* L.	Cosm.	Weedy	SFC	3,8	34
Arundo donax L.	MM, BP, IP, PP	Weedy	MIP	1	45, 117
Calamagrostis pseudophragmites (Hall. f.) Koel.	MM	Psamm.	NP	-	63
**Cenchrus biflorus* Roxb.	Cosm.	Psamm.	TH	3	34
Cenchrus ciliaris Rich.	Cosm.	Psamm.	NP	3,5	47
**Cenchrus pennesittiformis* Hochst. & Steud. Ex steud.	IP, CO	Psamm.	SFC	3	34
Chloris gayana Kunth	MM, IP	Psamm.	MIP	3	29
**Chloris quenqesetica* Bhide	CO, IP	Psamm.	SFC	-	34
Chloris virgata Sw.	BP	Psamm.	TH	2	104,133
**Coelachyrum piercei* (Benth.) Bor.	BP	Psamm.	SFC	-	34
Crypsis schoenoides (L.) Lam.	MM, CO, IP	Hyphal	TH	-	63
Cynodon dactylon (L.) Pers.	Cosm.	Weedy	SFC	3	117
Dactyloctenium aegyptium (L.) Willd.	Cosm.	Weedy	TH	3	21,47
**Dactyloctenium aristatum* Link	IP, CO, Des, BP	Psamm.	TH	3	34
Dactyloctenium scindicum Boiss.	Cosm.	Xerohal.	SFC	3	21
Desmostachya bipinnata (L.) Stapf	Cosm.	Xerohal.	NP	3	21,47
Dichantheum annulatum (Forssk.) Stapf	Cosm.	Xero	NP	3	133
Digitaria longiflora (Retz.) Pers.	IP	Hyphal	TH	-	34
Diplachne fusca (L.) P. Beauv.	IP	Hyphal	NP	3	34
**Echinochloa colona* (L.) Link	Cosm.	Hyphal	TH	3	34
**Echinochloa crusgalli* (L.) P. Beauv.	Cosm.	Hyphal	TH	1,3	34
Eleusine indica (L.) Gaertn.	MM, IP, CO	Hyphal	TH	3	34,43
Eragrostis curvula (Schrad.) Nees.	MM, BP, IP	Psamm.	NP	3,8	34

**Eragrostris japonica* (Thunb.) Trin.	Cosm.	Psamm.	NP	3	34
Eragrostis superba Peyr.	IP	Psamm.	NP	3	34
Festuca rubra L.	MM	Psamm.	NP	3	96,117
Halopyrum mucronatum (L.) Stapf	CO	Psamm.	SFC	3	61,86
**Hordeum bogdanii* Wilensky	BP, MM	Hyphal	NP	-	34
**Hordeum brevisubulatum* (Trin.) Link ssp. nevski*anum*	MM	Hyphal	NP	-	34
**Hordeum brevisubulatum* (Trin.) Link ssp. *turkistanicum*	MM	Hyphal	NP	-	34
**Hordeum murimim* ssp *glaucum* (steud.) Tzvelev	MM, PP	Hyphal	TH	-	34
Imperata cylindrica (L.) Raeuschel.	Cosm.	Psamm.	NP	4,8	63
Lasiurus scindicus Forssk.	Cosm.	Psamm	NP	3	133
**Leymus secalinus* (Georgi) Tzvelev	MM	Psamm.	NP	-	34
Lolium multiflorum Lam.	MM, BP	Psamm.	NP	2	19
**Orthochloa compressa* (Forssk.) Hilu	Cosm.	Hyphal	SFC	2	34
Oryza coarctata Roxb.	CO	Hyphal	NP	-	138
**Panicum antidotale* Retz.	Cosm.	Psamm.	NP	8	34
Parapholis incurva (L.) C.E. Hubb.	Des	Hyphal	SFC	-	19
Paspalidium geminatum (Forssk.) Stapf	Des	Psamm.	SFC	-	19
Paspalum paspoides (Michex) Scribner	Cosm.	Hyphal	SFC	3	132
Phalaris arundinacea L.	MM	Hyphal	NP	3	63
**Phalaris minor* Retz.	MM, IP, BP, PP	Hyphal	TH	3	34
Phragmites australis (Cav.) Trin. ex Steud.	MM, IP	Hyphal	MIP	7,8	19,42
Phragmites karka (Retz.) Trin. ex. Steud.	Cosm.	Hyphal	NP	-	105
Poa bulbosa L.	MM, BP	Psamm.	SFC	3	105
Poa pratensis L.	MM, BP	Psamm.	SFC	3	105
Polypogon monspeliensis (L.) Desf.	Cosm.	Psamm.	TH	1,5	119,126
Puccinellia distans (Wahlb.) Parl.	MM	Hyphal	SFC	-	135
Puccinellia gigantia (Grossh.) Grossh.	BP	Hyphal	NP	-	137
**Sacchraum bengalense* Retz.	PP, IP, Des	Hyphal	MIP	3,8	34
Sacchraum spontaneum L.	MM, PP, IP, Des	Hyphal	MIP	8	63
Setaria viridis (L.) P. Beauv.	ASM, MM	Psamm.	TH	-	63
**Sporobolus coromandelianus* (Retz.) Kunth	IP	Psamm.	SFC	3	48
Sporobolus helvolus (Trin.) Dur. & Schinz.	PP, IP	Psamm.	SFC	3	11, 45
Sporobolus ioclados (Nees ex Trin.) Nees	BP, CO	Psamm.	SFC	3	19,76
**Sporobolus kentrophyllus* (K.Schum.) W.D. Clayton	CO	Psamm.	SFC	3	34
**Sporobolus tourneuxii* Coss.	Des	Psamm.	SFC	3	34
Sporobolus tremulus (Willd.) Kunth.	PP	Hyphal	SFC	3	21
Sporobolus virginicus (L.) Kunth.	CO, CT	Psamm.	SFC	3	19,114
**Stipa himalaica* Rozhev.	MM	Psamm.	SFC	-	34
Stipa splendens Trin.	BP, MM	Psamm.	SFC	-	136
**Urochondra setulosa* (Trin.) C.E. Hubb.	CO	Xerohal.	SFC	3	60,61

Polygonaceae

**Bistorta vivipara* (L.) S.F. Gray	MM	Xero	SFC	-	122
**Knorringia sibirica subsp. thomsonii* Laxm.	MM	Psamm.	SFC	5,8	122
Polygonum aviculare L.	Cosm.	Xero	TH	-	42,80
**Polygonum effusum* Meisn.	MM, IP, Des	Xero	TH	-	122
Polygonum maritimum L.	MM	Xero	AC	-	122
**Polygonum plebigum* R. Br.	Cosm.	Xero	AC	-	122
**Rumex crispellus* Rich. f.	MM	Xero	SFC	-	122
**Rumex punjabensis* Vaid & Nathiani	MM	Xero	NP	-	122
**Rumex vesicarius* L.	MM	Xero	TH	1,4	122

Portulacaceae

**Portulaca quadrifida*L.	IP	Xerohal.	TH	4	49
Portulaca oleracea L.	Cosm	Xero	TH	1,4,6	129

Primulaceae

Anagallis arvensis L.	MM	Xero	TH	2	42,114

Glaux maritima L.	MM	Xero	AC	-	95,135
Samolus valerandi L.	NM, PP, BP	Hyphal	TH	-	95
Resedaceae					
Ochradenus baccatus Del.	CO, BP, IP	Xero	NP	1	204
Oligomeris linifolia (Vahl) Macbride	CO, IP, BP, PP	Xero	SFC	1,3,4	44
Rhamnaceae					
Zizyphus nummularia (Burm. f.) Wight and Arn.	MM, CO	Xero	MIP	1	11,119
Rhizophoraceae					
Ceriops tagal (Perr.) C.B. Robinson	CO	Hyphal	MSP	4	69
Rhizophora mucronata Poir.	CO	Hyphal	MSP	2	69
Rosaceae					
Potentila anserina L.	MM	Hyphal	V	-	63
Potentila bifurca L.	MM	Hyphal	V	-	63
Potentila supina L.	MM	Hyphal	V	-	63
Rubiaceae					
Galium verum L.	MM	Hyphal	TH	-	63
Ruppiaceae					
Ruppia maritima L.	CO	Hyphal	TH	-	105,135
Salicaceae					
Populus euphratica Olivier	IP, BP, PP	Xero	MSP	2,4,7	10
Salvadoraceae					
Salvadora oleoides Dne.	CO, IP	Xero	MIP	1,7	21
Salvadora persica L.	Des, IP	Xero	MIP	1,3,7	106
Scrophulariaceae					
**Bramia monniera* (L.) Penn.	IP	Hyphal	TH	-	-
Solanaceae					
**Lycium edgeworthii* Dunal	IP, PP, BP	Xero	NP	-	113
Lycium shawii R. & S.	BP	Xero	NP	-	43
Solanum incanum L.	Cosm	Xero	NP	1,4	114
**Solanum surrattense* Burm. f.	Cosm	Xerohal	AC	4	113
**Withania sominifera* (L.) Dunal	Cosm	Xero	NP	4	113
Sonneratiaceae					
Sonneratia caseolaris (L.) Engl.	CO	Hyphal	MP	4,7	114
Sterculaceae					
**Melhania denhamii* R. Br.	Des, CO, BP	Xero	SFC	4	2
Tamaricaceae					
Myricaria Sp.	MM	Hyphal	SFC	-	106
Reaumaria alternifolia (Labill) Britten	BP	Hyphal	SFC	-	106
**Reaumaria floyeri* S.Moore	CO	Hyphal	TH	-	120
Reaumaria stocksii Boiss.	BP, CO	Hyphal	TH	-	106
**Tamarix alii* Qaiser	Des	Xero	NP	-	120
Tamarix androssowii Litw.	BP	Xero	MIP	-	106
Tamarix aphylla (L.) Karst.	Cosm.	Phrea	MSP	7,8	19
Tamarix arceuthoides Bunge	MM	Hyphal	MIP	7	106
**Tamarix baluchistanica Qaiser*	ASM	*Xero*	*MIP*	-	*120 **
Tamarix dioica Roxb.	ASM	Xero	NP	-	120
Tamarix indica Willd.	Cosm.	Hyphal	MIP	-	20
**Tamarix karelini* Bunge	BP	Xero	MIP	-	120
Tamarix kotschyii Bunge	BP	Xero	MIP	-	63,106

Tamarix leptostachya Bunge	MM	Xero	MIP	-	63,106
Tamarix mascatensis Bunge	BP	Xero	MIP	5,7	20,106 *
Tamarix pakistanica Qaiser	IP, BP, CO	Phrea	MIP	-	120
Tamarix passernioides Del.ex Desv.					
var. *macrocarpa*	BP, IP, Des	Hyphal.	NP	5,7	19,20
Tamarix ramosissima Ledeb.	MM, BP	Xero	MIP	5,7	19,63
Tamarix salina Dyer	IP, Des	Hyphal.	NP	7	120 *
Tamarix sarenensis Qaiser	Des	Hyphal.	MIP	-	120
**Tamarix sultanii* Qaiser	Des	Xero	MIP	-	120 *
Tamarix symyrenensis Bunge	ASM	Xero	MIP	-	120
Tamarix szovitsiana Bunge	BP	Xero	MIP	5,7	106
Tamarix tetragyna (Boiss.) Boiss.	BP	Xero	MIP	5,7	19,20
Tiliaceae					
**Corchorus depressus* (L.) Stocks	Cosm.	Xero	T2	4	50
Typhaceae					
Typha domingensis Pers.	Cosm.	Hyphal	NP	7,8	19,20
Typha latifolia L.	MM	Hyphal	NP	-	41 135
Umbelliferae					
Ammi visnaga (L.) Lamk.	ASM	Xero	MIP	4	135, 137
Apium graveolens L.	Cosm.	Hyphal	AQ	1	95
**Centella asiatica* (L.) Urban	MM	Hyphal	HP	4	109
Verbenaceae					
Clerodendrum inerme (L.) Gaertn.	Cosm.	Hyphal	NP	5,8	63, 105
Phyla nodiflora (L.) Greene	IP	Hyphal	NP	5	117
Verbena officinalis L.	MM, PP, ASM	Hyphal	NP	4	138
Zygophyllaceae					
Fagonia bruguieri DC. Prodr.					
Var. *rechingeri* Hadidi	BP	Xero	TH	-	42
**Fagonia indica* ssp. *schweinfurthia* Hadidi	IP	Xero	TH	-	51
Nitraria retusa (Forssk.) Aschers	CO	Xero	SFC	1,3,5	18,92
Nitraria schoberi L.	NM	Xerohal.	SFC	1,5	18,114
Seetzenia lanata (Willd.) Bullock	IP, BP	Xero	SFC	-	115
Tribulus terrestris L.	Cosm.	Xero	TH	4	63
Zygophyllum fabago L.	BP	Xerohal.	NP	-	63
Zygophyllum propinquum Decne	CT, IP	Xerohal	NP	4	106
Zygophyllum simplex L.	Des, BP, IP, CO	Xerohal.	TH	1,2,4	76,1

1.7. New record of halophytes not yet published

There are about 168 halophytes that were not present in any of the halophyte lists published before (Aronson, 1989; Menzel and Lieth, 1999). They are distributed among 37 families and most of them are from Chenopodiaceae (26), Poaceae (25), Cyperaceae (19), Asteraceae (18) and Papilionaceae (17) while other families are represented by less than 10 new halophytes (Table 1).

1.8. Adaptations

A number of different mechanisms are used by halophytes to achieve osmotic adjustment, including inorganic ion accumulation, synthesis or accumulation of organic compounds and water loss (Ungar, 1991). Classification schemes have been constructed that attempt to match morphological and physiological characters to specific halophyte habitats and growth strategies (Breckle, 1983). However, these classifications have little predictive value. Under physical or physiological stress conditions, the leaves of saline plants play an important role and develop certain xeromorphic adaptive characteristics, such as succulence, reduction in surface area, thick cuticle or a cover of waxy layers on the epidermis, hairs on stem and leaves, sunken stomata, salt glands, etc. The succulents often lack the ability to secrete salts, but thwart the rise of salt concentration through an increase of their water content, and become increasingly succulent during their development. *Arthrocnemum, Halogeton, Halopeplis, Halostachys, Haloxylon*, *Heliotropium, Salicornia, Suaeda*, *Salsola*, and *Zygophyllum* are prominent succulent halophytic genera in Pakistan. There is an abrupt reduction in surface area of leaves of some species (e.g., *Salsola imbricata*, *Trianthema triquetra*, *Suaeda fruticosa*) under conditions of extreme salt stress. *Suaeda fruticosa*, *Salsola imbricata*, *Haloxylon stocksii*, *H. salicornicum*, *Cressa cretica*, *Sporobolus ioclados*, *Urochondra setulosa*, and *Aeluropus lagopoides* are characterized by thick cuticles and a cover of waxy layers, while stems and leaves of the last five species remain covered with hairs. Only a small number of halophytes are able to excrete salts through glandular cells. Liphschitz and Waisel (1982) listed active secreting glands in *Avicennia*, *Aeluropus*, *Aegiceras*, *Limonium*, *Rhizophora*, *Ceriops*, *Tamarix* and *Reaumuria*. Salt concentration of the growth medium, light, temperature, oxygen, pressure and the presence of metabolic inhibitors are the governing factors of salt excretion. A similar function of salt recretion is ascribed to bladder trichomes of some Chenopodiaceae, e.g., *Atriplex* species. The basic role of bladders is to protect young developing shoots and leaves from toxic salt levels first in the apoplast and subsequently in the symplast.

Tolerance of salinity by halophyte seeds may be expressed either as the ability of un-germinated seeds to tolerate high salinity without losing viability or the ability of seeds to germinate at high salinities (Khan, 2003). Seeds of halophytes not only germinate at higher salinities but also remain viable for long periods of time when immersed in saline water (Ungar, 1995). Halophytes vary in their upper limits of salt tolerance and an increase in salinity usually delays their germination (Ungar, 1995). Seeds of salt marsh species like *Atriplex stocksii, Polygonum aviculare,* and *Zygophyllum simplex* show little germination above 125 mM NaCl (Khan & Rizvi, 1994; Khan & Ungar, 1997; Khan & Ungar, 1997; Ungar, 1991). However, species like *Aeluropus lagopoides*, *Haloxylon stocksii, Sporobolus ioclados, Suaeda fruticosa, Limonium stocksii*, *Triglochin maritima* and *Urochondra setulosa* were able to germinate in up to 500 mM NaCl (Khan & Ungar, 1996; Khan & Ungar, 1998; Khan & Ungar, 1999; Gulzar & Khan, 2001ab; Khan et al., 2001; Zia & Khan, 2002). A third group of species like *Arthrocnemum macrostachyum*, *Cressa cretica*, *Halogeton glomeratus*, *Kochia scoparia*, *Salicornia brachiata*, *Salicornia bigelovii*, *Salsola iberica*, and *Tamarix pentandra* could germinate at NaCl concentrations of 800 mM and higher (Khan, 1991; Ungar, 1995; Khan & Gul, 1998; Khan et al., 2000; Khan et al., 2001; Khan et al., 2002; Khan, 2003). Species like *A. stocksii*, *H. stocksii*, and *S. fruticosa* could be classified as moderately salt tolerant and *A. macrostachyum* and *C. cretica* as highly salt tolerant. Sharma and Sen (Sharma & Sen, 1989) observed an extremely fast germination in the seeds of *Haloxylon stocksii* and *H. salicornicum*, occurring within an hour. An ecophysiological adaptive role is assigned to such a phenomenon of germination, which involves the uncoiling of the young embryo out of the testa immediately after contact with water, with an unusually high rate of cell elongation soon after imbibitions. Such fast seed germination indicates an adaptive strategy taken by the plants, as water with reduced NaCl content in soil during the rainy season is available only for a short duration. An increase in salinity leads to dormancy of seeds in halophytes and glycophytes. More investigations with halophytes (Ungar, 1991) have demonstrated that seeds of several species, including *Arthrocnemum macrostachyum, Salicornia bigelovii, Salicornia brachiata, Cressa cretica, Tamarix pentandra, Salsola iberica, Halogeton glomeratus, Kochia scoparia, Aeluropus lagopoides*, *Atriplex stocksii, Haloxylon stocksii, Sporobolus arabicus, Suaeda fruticosa, Limonium stocksii*, *Triglochin maritima* and *Urochondra setulosa* remained dormant at a high salinity, and these will germinate when returned to distilled water (Joshi, 1979; Khan, 1991; Khan & Rizvi, 1994; Khan & Ungar, 1995; Khan & Ungar, 1996; Khan & Ungar, 1997; Khan & Aziz, 1998; Khan, 2001,2003; Khan & Gul, 1998; Khan et al., 1998; Khan & Ungar, 1998ab; Khan & Ungar, 1999; Khan et al., 2001ab; Khan et al., 2002; Khan & Gulzar, 2003).

Salt tolerance of species varies with the stage of their development. Some species, such as *Suaeda fruticosa, Haloxylon stocksii, Atriplex stocksii* and *Zygophyllum simplex,* were not highly salt tolerant at germination, but showed a high salinity tolerance at the growth stage (Khan, 2003). While other species like *Arthrocnemum macrostachyum,* and *Cressa cretica* showed a higher degree of salt tolerance both at the germination and growth stages (Khan, 1991; Khan & Gul, 1998).

It has been assumed that survival of plants in saline environments depends upon the altered biochemical relations and on the quantitative ratio between toxic and protective compounds like betaine. Khan et al., (1998) while studying *Halopyrum mucronatum, Atriplex stocksii*, *Haloxylon stocksii* and *Suaeda fruticosa* found a high accumulation of betaine with a corresponding increase in salinity. The betaine is said to function as a source of solute for intracellular osmotic adjustment. Betaine accumulation occurs in the tissues of plants exposed to a saline substrate, and there is a positive correlation between betaine content and the amount of Na^+ and Cl^- in the cell sap. It is also estimated that about 200 mM L^{-1} of plant water or higher betaine concentration is needed to achieve osmotic adjustment successfully under saline conditions, and most of the Pakistani species tested have levels of betaine concentration higher than this.

Ungar (1991) described the presence of an ultrafilter in roots of mangroves of the Rhizophoraceae family, enabling only selective absorption of ions. They may retain a low internal salinity by means of salt excluding mechanisms in the roots.

In this type, sodium and chloride concentrations are higher in xylem sap and do not reach the metabolic cellular environment. Another mechanism of salt regulation in mangroves is salt excretion. In species of *Avicennia*, and *Aegiceras*, NaCl concentration in the excreted solution exceeds the NaCl concentration of seawater and this is normally 10 times that of salt exclusion types and also does not reach the metabolic environment (Joshi, 1979). The same holds true for *Aeluropus littoralis*, *Limonium latifolium*, and all species of *Tamarix* and *Reaumaria* (Ungar, 1991).

The stem and leaf succulent halophytes lack the ability to excrete salt and accumulate salt in their tissues. They are highly succulent and thwart the rising of salt concentration with a permanent increase in their water content. They become increasingly succulent in their development and are known as cumulative halophytes. Inland halophytes, such as *Haloxylon stocksii*, *H. salicornicum*, *Salsola imbricata*, *Sesuvium sesuvioides*, *Suaeda fruticosa*, *Trianthema triquetra* and *Zygophyllum simplex* are characterizes by a thickening in leaves, elongation of cells, higher elasticity of cell walls, smaller relative surface areas, a decrease in extensive growth, and a high water content per unit of surface area. Leaves in some species, such as *Suaeda fruticosa*, *Salsola imbricata* and *Trianthema triquetra,* are reduced in surface area when exposed to high salt content in the soil. Because these species lack regulatory mechanisms, salt concentration rises during the growing season, and when a certain level is reached, the plant dies. Among mangroves, species of *Avicennia, Ceriops* and *Rhizophora* absorb and accumulate excessive amounts of salts and the leaves become fleshy.

1.9. Utilization and potential of halophytes

Halophytes have their greatest potential not so much in contributing to the world's food supply but primarily in their utilization of the growing areas of saline land for a range of different goals (Figure 1). The most important opportunities relate to reforestation or replanting and ecological recovery of saline areas that have fallen into disuse, coastal development and protection, and the production of cheap biomass for renewable energy, climate improvement and CO_2 sequestration. Mangroves, besides playing roles in stabilization of coasts and beaches; food chain and life support systems; aquaculture; agriculture; and support to development of wild-life sanctuary and recreation areas; also provide tannin; thatching material; fodder; fish poison; food products; medicine and wood for building purposes, fuel, and boat and canoe making for the residents of coastal areas. There are 272 halophytes out of a total 410 reported from Pakistan and about 51 could be used for extracting medicine, 48 as forage, 47 as fodder, 38 as food, 34 as ornaments, and others as fibers, timber and other usages of wood, and various chemicals (Figure 1).

1.9.1. Food yielding halophytes

Of conventional crops, the only species with halophytic ancestors are beets (*Beta vulgaris*) and the date palm (*Phoenix dactylifera*), which can be irrigated with brackish water. The seed bearing species, which are used as food, include *Salvadora oleoides, S. persica, Trianthema portulacastrum, Oxystelma esculentum* and *Zizyphus nummularia*. The young leaves and shoots of *Salicornia bigellovi, S. brachiata, Sesuvium portulacastrum*, *Chenopodium album*, *Atriplex hortensis, Triglochin maritima, Arundo donax, Rumex vesicarius, Apium graveolens*, *Portulaca oleracea*, and *Suaeda maritima* have also been used for vegetables, salads and pickles in various parts of the country. *Suaeda fruticosa* and *Haloxylon stocksii* are used to prepare a kind of baking soda, which is used in the preparation of food. Radicles of *Rhizophora mucronata*, *Zizyphus nummularia* and *Ceriops tagal* and tender leaves of *Thespesia populnea*, *Hibiscus tiliaceus* are also used as salad.

1.9.2. Forages and fodders

There are about 95 halophytic species that could be used as either forage or fodder and most prominent among them are mangroves. The foliage of such species as *Avicennia marina*, *Aegiceras corniculata*, *Ceriops tagal*, and *Rhizophora mucronata* are used as camel and cattle feed. Among trees, species of *Acacia*, *Prosopis*, *Salvadora* and *Zizyphus* are traditional fodder of arid regions. Many species of *Alhagi, Salicornia*, *Chenopodium*, *Atriplex*, *Salsola*, *Suaeda* and *Kochia* are common fodder shrubs. Among grasses *Leptochloa fusca*, *Aeluropus lagopoides*, *Dactyloctenium sindicum*, *Cynodon dactylon*, *Paspalum vaginatum*, *Sporobolus marginatus*, *Chloris gayana*, *C. virgata*, *Echinochloa turnerana*, *E. colonum* and *Puccinellia distans* are common species found in saline and alkaline areas and used as forages. However, most of the 68 grasses found in Pakistan are browsed by animals Aronson (1985) recorded 1.26 to 2.09 Kg m^{-2} dry matter, and 15.5 to 39.5% fiber, and 10.2 to 19.5% crude protein in some species of *Atriplex*. *Kochia indica* has been field tested for domestic livestock and found to produce good fodder with fresh biomass of 8.5 kg per bush from March through August (Dagar, 1995). Kallar grass (*Leptochloa fusca*) has gained much attention as a fodder on salt affected soils (both saline and alkaline) in Pakistan (Malik et al. 1986) and yields about 46.5 t ha^{-1} of green forage when planted in extreme alkali soil (pH > 10) for 5 years.

1.9.3. Oil seeds

Production of vegetable oil from seed-bearing halophytes appears promising. Seeds of various halophytes, such as *Suaeda fruticosa, Arthrocnemum macrostachyum, Salicornia bigelovii, S. brachiata, Halogeton glomeratus, Kochia scoparia*, and *Haloxylon stocksii* possess a sufficient quantity of high quality edible oil with unsaturation ranging from 70-80 % (Weber et al., 2001). Seeds of *Salvadora oleoides* and *S. persica* contain 40-50% fat and are a good source of lauric acid. Purified fat is used for soap and candle making and is a potential substitute for coconut oil.

1.9.4. Fuel wood

More than a billion people in developing countries rely on wood for cooking and heating. Quite often fuel wood is obtained from salt tolerant trees and shrubs, which may include species of *Prosopis*, *Tamarix*, *Salsola*, *Acacia, Suaeda*, *Kochia*, *Capparis* and *Salvadora* (Dagar, 1995). In addition species like *Dalbergia sisso, Pongamia pinnata, Populus euphratica, Tamarix aphylla, T. indica, T. mascatensis, T. pakistanica, T. passernoides, T. ramosisima, T. salina, T. stricta, T. szvoitsiana*, and *T. tetragyna* could provide good quality wood. In coastal areas the mangroves are used frequently for fuel and timber, which has contributed significantly to the deforestation of these habitats. Species of *Rhizophora*, *Ceriops*, *Avicennia* and *Aegiceras* are good fuel woods and also contribute to charcoal production.

1.9.5. Medicinal uses

Many workers have reported the medicinal uses of halophytes while describing the economic importance of plants (Dagar, 1995). Halophytic plants are known to provide relief in the following diseases: Cold, flu & cough: (*Achillea mellifolium, Microcephala lamellate, Phylla nodiflora, Caesalpinea bonduc, Plantago lanceolata, Portulaca quadrifida, Portulaca oleracea, Solanum surratense, Withania sominifera, Tribulus terrestris, Capparis decidua, Zygophyllum simplex, Salvadora persica & S. oleoides*), vermifuge (*Artimesia scoparia, Portulaca quadrifida, Seriphidium brevifolium, S. quetenses, Cocos nucifera, Portulaca oleracea, Evolvulous alsinoides, Salsola imbricata, S. tetrandra, Zygophyllum propinqum, Z. simplex*), stomach ailments (*Juncus rigidus, Seriphidium quetenses, Thespesia populnea, Zaleya pentandra*), pain killer; (*Artimesia scoparia*, *Solanum surratense*), diuretic (*Plantago major*, *Portulaca quadrifida, P. oleracea, Withania sominifera,Tribulus terrestris, Juncus rigidus*), snake bite: (*Rumex vesicarius, Verbena officinalis, Zaleya pentandra*), gonorrhea (*Portulaca oleracea, Corchorus depressus*), sedative (*Withania somnifera*), ulcer (*Ceriops tagal, Withania sominifera*), pneumonia (*Corchorus depressus*), heart disease: (*Ammi visnaga, Tribulus terrestris, Capparis decidua, Kochia indica, Zygophyllum simplex*), skin diseases (*Centella asiatica, Salsola imbricata*), laxative (*Capparis deciduas*), eyes (*Zygophyllum simplex*); ear pain (*Artemesia scoparia*); asthma (*Evolvulous alsinoides*, *Solanum incanum*); wound healing (*Plantago lanceolata*) and stimulant (*Kochia indica*).

1.9.6. Products of economic and common use

Suaeda, *Salicornia*, *Salsola*, and *Haloxylon*: a carbonate of soda is obtained in large quantities and used for the soap and glass industry. *Calotropis procera*: parts of the seeds for pillows. The stem and leaves of *Juncus maritimus, Kochia* *scoparia, Aristida adscenscoinis, Imperata cylindrica, Phragmites australis* and *Typha domingensis* have been used since ancient times for the manufacture of mats, baskets thatching and cordage.

1.9.7. Chemicals

Most of the mangrove species are rich in tannin. Its extraction from the bark has been a major use of mangroves.

Aronson (1982, 1985, 1986, 1991) in a recent survey of over 1,600 salt-tolerant plants with economic potential, has identified 290 tree species as being tolerant of 7-8 dS m^{-1} salinity. *Tamarix stricta* has been recorded as yielding 7.2 t DM ha^{-1} yr^{-1}, with a final density of 600 trees ha^{-1} after 5 years. Various species of *Prosopis*, *Casuarina*, *Eucalyptus* and *Acacia* have been evaluated for their salinity tolerance and biomass production. *Prosopis juliflora* could yield up to 52.3 t ha^{-1} biomass in 6 years. *P. juliflora, Acacia nilotica* and *Casuarina equisetifolia* have been found to be most alkali tolerant; *Tamarix indica*, *T. articulata*, *Prosopis juliflora*, *Pithecellobium dulce*, *Parkinsonia aculeata* and *Acacia farnesiana* to be tolerant of salinity levels up to EC 25 to 35 dS m^{-1}; and *Acacia nilotica*, *A. tortilis*, *Casuarina glauca*, *C. obesa* and *Eucalyptus calmadulensis* to be tolerant of salinity levels up to 15-25 dSm^{-1}. *Aegiceras corniculata, Avicennia marina, Ceriops tagal,* and *Rhizophora mucronata* trees could be grown in areas with high salinity and low water tables. In recent years research in the evaluation of halophytes for land reclamation and landscape management has taken a new dimension.

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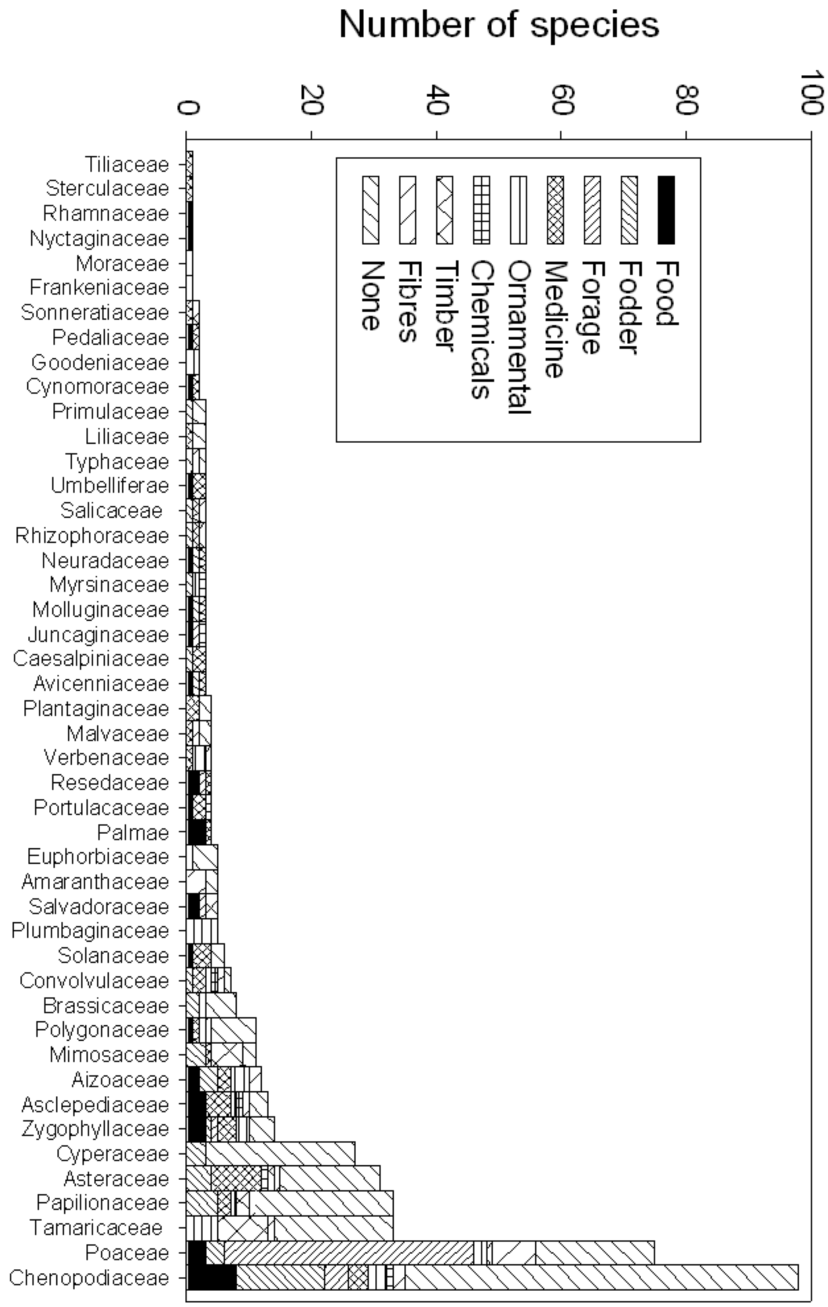

Number of species
0
20
40
60
80
100
Food
Fodder
Forage
Medicine
Ornamental
Chemicals
Timber
Fibres
None
Tiliaceae
Sterculaceae
Rhamnaceae
Nyctaginaceae
Moraceae
Frankeniaceae
Sonneratiaceae
Pedaliaceae
Goodeniaceae
Cynomoraceae
Primulaceae
Liliaceae
Typhaceae
Umbelliferae
Salicaceae
Rhizophoraceae
Neuradaceae
Myrsinaceae
Molluginaceae
Juncaginaceae
Caesalpiniaceae
Avicenniaceae
Plantaginaceae
Malvaceae
Verbenaceae
Resedaceae
Portulacaceae
Palmae
Euphorbiaceae
Amaranthaceae
Salvadoraceae
Plumbaginaceae
Solanaceae
Convolvulaceae
Brassicaceae
Polygonaceae
Mimosaceae
Aizoaceae
Asclepediaceae
Zygophyllaceae
Cyperaceae
Asteraceae
Papilionaceae
Tamaricaceae
Poaceae
Chenopodiaceae