An ecological overview of halophytes from Pakistan

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INTRODUCTION

In recent years there has been increasing recognition that the scarcity of fresh water and the salinification of agricultural areas are becoming much more global problems. Both trends represent a threat to the world's food supply. Currently the domestic, industrial and agricultural use of fresh and ground water is increasing so quickly that fresh water shortage can be expected all over the world. This is already the case in several different places. Surface and ground water in agricultural areas in many places in the world are rapidly becoming increasingly brackish and saline, particularly in arid tropical and subtropical areas. Furthermore, salt deserts (caused by a lack of fresh water) and saline inland basins (caused by the level of saline ground water rising as a result of leakage of drainage water) are being created. FAO data show that at least 40% of the world is affected by salinification in some form [10]. The actual impact of this estimate in not entirely clear. However, it is known that large areas in Australia, India, Pakistan, Egypt, Central Asia, South America, Mexico and the United States [34] are faced with salinification to greater or lesser extent.

At the same time there are growing indications that cultivation of crops with a high-salt tolerance can be seen as interesting option for utilizing saline soils and conserving fresh water (59, 60, 97). Saline agriculture is a type of agriculture on the saline soil in which crops (halophytes) that can withstand a higher salt content than normal agricultural crops 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 sea water; (2) crops with average salt tolerance: they grow in brackish water; and (3) crops with moderate salt tolerance: they grow in slightly brackish water that is not suitable for conventional agriculture.

Some halophytes stand out because of their spectacular growth and production in saline conditions. Nevertheless, the number of examples where halophytes are actually employed for a particular practical purpose is extremely low, although it is demonstrated that there are many potential halophytic crops. There could be several reasons for this limited utilization: (1) So far, there was virtually no urgency yet anywhere because agricultural crops met the needs. (2) Essentially all halophytes are species that occur naturally. There has been no selection or improvements of halophytes with a view of practical applications. (3) It is not unthinkable that as soon as real research efforts are started, halophytes with unique properties can be found. (4) Little information is available about the diversity of halophytes in the most areas of the world. (5) Saline agriculture is a new technology and it requires effort, and special skills to make it successful.

There are several efforts made to compile the halophytic flora of the world [4, 5, 107] as well list of regional halophytes. However, still the information regarding halophyte is far from completion. Although flora of Pakistan is near completion and it has information about the halophytes buried in somewhere. Current effort is made to compile a list of halophytes distributed in Pakistan with some relevant details.

PHYSIOGRAPHY, SALINITY AND CLIMATE

Pakistan has varied physiography and climate. It stretches about 1,600 km from the subtropical Arabian Sea to temperate northern mountains covering an area of 800,000 km^2. The country could be divided into seven major landscape units: (1) The northern

H. Lieth (ed.), Cash Crop Halophytes: Recent Studies, 167–187.

mountains, (2) the Hindu Kush and the western mountains, (3) the potwar plateau and salt range, (4) the Balochistan plateau, (5) the Indus plain, (6) Cholistan and Thal desert and (7) coastal areas. Indus is a major river, which passes through Pakistan with an approximate annual flow of 115 billion cubic meters [3, 120]. It originates on the Tibetan plateau at an altitude of about 5,500 m 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 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 1,500 mm on the southern step of Himalayas to less than 100 mm in the Western Balochistan coast. About 69% of the country receives rainfall less than 250 mm of the rain per year. The rain primarily falls during the monsoons (June–September), however, Southwestern Balochistan receives winter rain under mediteranean trend and some northwestern areas have both winter and summer rains.

TECHNICAL INFORMATION

There are numerous ways of defining halophytes. For our purpose best definition seems to be "plants that complete their life cycle in saline habitats" [178], where salt concentration of soil solution is about 5 g/l total dissolved solids (85 mM NaCl or 7–8 dS m^{-1}, 11). This list is organized alphabetically by botanical family, and within each family, by genus and species. Generic and familial taxonomy follows "Flora of Pakistan" [4]. However, the flora being continuously updated and revised, these names could be changed later.

Distribution

We have followed the distribution of halophytic species based on general landscape of Pakistan but has added one more category of plants which are cosmopolitan in distribution. They are as follows: (1) The northern mountains (NM), (2) the Hindu Kush and the western mountains (HK), (3) the potwar plateau and salt range (PP), (4) the Balochistan plateau (BP), (5) the Indus plain (IP), (6) Cholistan and Thal desert (CT), (7) coastal areas (CO) and Cosmopolitan (CM).

Life Form

Only one life form is given per species, even though many species show a certain amount of plasticity in this regard. A = annual, AQ = aquatic, CH = chamaephyte (small shrub, under 0.5 m average height), CHN = nano-chamaephyte (dwarf shrub, under 0.25 m average height), H = hemicryptophyte, HP = herbaceous perennial, PG = perennial grass, SH = shrub, T2 = tree, average height 2 m, T4 = tree, average height 4 m, and $T(x)$ = tree, average height (x) m.

Plant Type

This category bases on the habitats in which the taxon is distributed. Hyphal = hydrohalophytes (present in salt marshes), Xeorh = 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 = phreatophytes.

Max dS m^{-1}: This heading gives the maximum reported salinity tolerance of a taxon as cited in the references.

GENERAL OVERVIEW

The list showed that halophytic vegetation of Pakistan is quite diverse (Table 1) with 380 species with varied level of salt tolerance. Menzel and Lieth [107] reported that about 2,200 halophytic species were found in the literature worldwide. The halophytes of Pakistan constitute about 18% of this halophytic flora. Most of the halophytic species in Pakistan are present in the playas of northern mountains [95], whereas, others are in Indus plains [78], coastal areas [77], Hindu kush and the western mountains [34], the Potwar plateau [33], Cholistan and Thal desert [20] and 37 halophytes are cosmopolitan in distribution (Figure 1). The data showed that mountainous areas of Pakistan are more diverse in comparison of flat plains. The halophytes of Pakistan represent 58 families. The highest number of halophytes is present in the family Chenopodiaceae [87], followed by Poaceae [72], Cyperaceae [27], Papilionaceae [23], Tamaricaceae [16], Asteraceae [11] and Verbenaceae [10] while other families are represented by less than 10 halophytes (Tables 1 and 2).

Table 1. Alphabetical listing of halophytes from Pakistan

Genus, species and author	Distribution	Plant type	Life form	Max dS/m	Ref.
Aizoaceae					
Aizoon canariense L.	CO	Xero	A		18
Mesembryanthemum crystallinum L.	IP	Xero	A	56	40
Sesuvium sesuvioides (Fenzl.) Verdc.	CO, IP	Psamm.	HP		122
Trianthema portulacastrum L.	NM, IP	Xero	A		37, 55
Trianthema triquetra Rottl.ex Willd.	CO, IP	Xero	A		37, 55
Amaranthaceae					
Aerva javanica (Brum. f.) Juss. ex J.A. Schultes	CO, IP	Xero	SH		135
Asclepediaceae					
Calotropis gigantea (L.) Aiton	Cosm.	Xero	T2	8	117, 21
Calotropis procera (Ait.) Ait.	HK, NM, BP, IP	Xero	T2	8	117, 7
Cynanchum acutum L.	NM	Xero	V		135
Leptadenia pyrotechnica (Forssk.) Dene.	CO, CT	Xero	SH		91
Pentatropis spiralis (Forssk.) Dene.	CT, IP	Xero	HP		50, 100
Pergularia tomentosa L.	CO, CT	Xero	V		100
Asteraceae					
Achillea millefolium L.	NM	Psamm.	CH		134
Artemisia brevifolia Wall. ex DC	NM	Psamm.	CH		4
Artemisia maritima L.	NM	Psamm.	CH		97
Artemisia scoparia Waldst. & Kit.	NM, IP	Psamm.	CH		66
Inula brittanica L.	NM	Psamm.	HP		66
Lactuca tatarica (L.) C. A. May	NM	Psamm.	HP		66
Launea sarmantosa (Willd.) Alsoton	CO	Psamm.	HP		66
Pulicaria hookeri Jafri	CO	Psamm.	HP		66
Sonchus maritimus L.	BP, IP	Xero	HP		121
Sonchus tenerrimus L.	CO	Xero	HP		121
Xanthium sibiricum Patrin.	BP	Xero	HP		66
Avicenniaceae					
Avicennia marina (Forssk.) Vierh	CO	Hyphal	T8	58	13, 73
Boraginaceae					
Heliotropium aucheri DC	BP	Weedy	HP		110
Heliotropium bacciferum Forssk.	CO	Xero	HP		110
Heliotropium currassavicum L.	CO, IP	Weedy	HP		15, 49
Brassicaceae					
Conringia persica Boiss.	BP	Psamm.	A		4
Dilophia salsa Thompson	NM	Hyphal	CH		4
Lepidium cartilagineum (J. May) Thell.	BP	Hyphal	A		110, 137
Lepidium pinnatifidum Ledeb.	PP, NM	Hyphal	AP		137
Lepidium latifolium L.	NM	Hyphal	A		38, 97
Lobularia maritima (L.) Desv.	IP	Psamm.	A		137
Raphanus raphanistrum L.	HK, PP, BP	Psamm.	A		137
Caryophyllaceae					
Cerastium glomeratum Thuill.	NM	Weedy	HP		47
Spergularia diandra (Guss.) Heldr & Sart.	BP, NM	Weedy	HP		121, 142
Spergularia marina (L.) Griesb.	IP	Weedy	HP	50	97, 110
Spergularia media (L.) Presl.	BP	Weedy	A	50	97, 110
Caesalpiniaceae					
Caesalpinea bonduc (L.) Roxburgh.	IP	Hyphal	SH	107	39, 108
Chenopodiaceae					
Aellenia acutifolia (Moq.) Jafri	BP	Xerohal.	SH		4
Aellenia auricula (Moq.) Ulbr.	BP	Xerohal.	SH		110
Agathophora alopecuroides (Dellie.) Fenzl ex Bunge	BP	Xerohal.	SH		110

Table 1. (Cont.)

Genus, species and author	Distribution	Plant type	Life form	Max dS/m	Ref.
Anabasis haussknechtii Bunge ex Boiss.	BP, PP	Xerohal.	SH		110
Anabasis setifera Moq.	BP	Xerohal.	CHN		94, 110
Arthrocnemum indicum (Willd.) Moq.	CO	Hyphal	CHN	90	52, 108
Arthrocnemum macrostachyum (Moric.) C. Koch	CO	Hyphal	CHN	90	75, 85
Atriplex aucheri Moq.	NM	Xero	A		4
Atriplex canescens James	BP	Xerohal.	SH	59	115, 117
Atriplex dimorphostegia Kar. & Kir.	BP	Xero	AP	56	5, 117
Atriplex griffithii Moq.	NM	Xerohal.	SH		5, 117
Atriplex halimus L.	IP	Xerohal.	SH	56	115, 117
Atriplex hortensis L.	NM	Xero	A	10	116, 117
Atriplex lasiantha Boiss.	NM, IP, BP	Xero	A		4
Atriplex leucoclada Boiss.	CO, IP	Xero	SH	79	5, 117
Atriplex pamirica Iljin	NM, IP	Xerohal.	A		4
Atriplex schugnanica Iljin	NM	Xero	A		4
Atriplex stocksii Boiss.	CO	Xerohal.	SH	36	74, 89
Atriplex tatarica L.	NM	Xero	A		66, 137
Bassia hyssopifolia (Pall.) O. Kuntze	NM	Weedy	A	58	57, 113
Beta vulgaris ssp *maritma* (L.) Arcangeli	BP, IP	Weedy	HP	20	97, 117
Bienertia cycloptera (Bunge ex Trautv.) Bunge ex Boiss.	CO	Hyphal	A		18, 110
Camphorosma monspelicata L.	BP	Xero	SH		66, 110
Ceratocarpus arenarius L.	NM, BP	Xero	A	15	66
Chenopodium album L.	NM, IP	Weedy	A		65, 66
Chenopodium ambrosoides L.	NM, IP	Weedy	A		104, 113
Chenopodium botrys L.	NM, HK	Weedy	A		4
Chenopodium ficifolium ssp *blomianum* (Aellen) Aellen	Cosm.	Weedy	A		4
Chenopodium foliosum Ascher	NM	Hyphal	A		4
Chenopodium glaucum L.	NM, BP	Weedy	CH		66, 108
Chenopodium murale L.	IP	Weedy	A	20	57, 58
Coriospermum korovinii Iljin	NM	Xero	A		66
Coriospermum tibeticum Iljin	NM	Xero	A		66
Cornulaca monocantha Del.	CO, BP	Xerohal.	A		92, 93
Gamanthus gamocarpus (Moq.) Bunge	BP	Xerohal.	A		121
Girgensohnia oppositiflora (Pall.) Fenzl	BP	Xero	A		92, 137
Halimocnemis pilifera Moq.	BP	Xerohal.	A		135
Halocharis clavata Bunge	BP	Xerohal.	A		130
Halocharis hispida (Schrenk ex C. A. Mey) Bunge	BP	Xerohal.	A		130
Halocharis lachnantha E. Korov.	BP	Xerohal.	A		130
Halocharis sulpheurea (Moq.) Moq.	BP	Xerohal.	A		110
Halocharis violacea Bunge	BP	Xerohal.	A		110
Halocnemum strobilaceum (Pall.) M. Bieb.	CO	Xero	CH		18
Halogeton glomeratus (M. B.) C. A. Mey	NM	Xerohal.	SH		66, 94
Halogeton tibeticus Bunge	NM	Xerohal.	A		66
Halopeplis perfoliata (Forssk.) Bunge ex Schweinf.	CO	Hyphal	HP	10	18, 93
Halostachys belangerana (Moq.) Botsch.	CO	Hyphal	SH		131, 137
Haloxylon griffithii (Moq.) Boiss.	NM	Xero	SH		117
Haloxylon persicum Bunge ex Boiss.	BP	Psamm.	SH		21, 28
Haloxylon salicornicum (Moq.) Bunge ex Boiss.	IP	Xero	CHN		110
Haloxylon scoparium Pomel.	IP	Psamm.	SH		25
Haloxylon stocksii (Boiss.) Benth. & Hook.	Cosm	Psamm.	SH	35	78, 87
Kochia indica Wight	NM, BP, IP	Xero	A		93, 94
Kochia iranica Litw. ex Bornm	BP	Xero	A		46, 177
Kochia prostrata (L.) Schrad.	NM, BP	Xero	A		66, 110
Kochia scoparia (L.) Schrad.	Cosm.	Xero	A		92, 130
Kochia stellaris Moq.	NM	Xero	A		93

Table 1. (Cont.)

Genus, species and author	Distribution	Plant type	Life form	Max dS/m	Ref.
Krascheninnikovia ceratoides (L.) Gueldena	NM, BP	Xerohal.	SH		4
Salicornia brachiata	CO	hyphal	A	40	75, 76
Salsola arbuscula Pall.	BP	Xerohal.	CH		112, 135
Salsola canescens (Moq.) Boiss.	BP	Xerohal.	CHN		130
Salsola chorassanica Botsch	BP	Xerohal.	A		110
Salsola collina Pall.	NM	Hyphal	A		66
Salsola crassa ssp *turcomanica* Pall.	BP	Xerohal.	A		134
Salsola cyclophylla Baker	BP	Hyphal	SH		134
Salsola drummondii Ulbr.	BP, IP	Hyphal	SH		66
Salsola griffithii (Bunge) Freitag & Akhani	BP	Psamm.	CH		4
Salsola imbricata Forssk.	IP, PP, BP	Xerohal.	SH		4
Salsola incanescens C.A. Mey	BP	Xerohal.	A		110
Salsola jacquemontii Moq.	NM	Xerohal.	A		4
Salsola makranica Freitag	BP	Xerohal.	CHN		4
Salsola nitraria Pall.	BP	Xerohal.	A		110
Salsola orientalis S.G. Gmeln	BP	Xerohal.	AP		27, 110
Salsola paulsenii ssp *praecox* (Litw.) Rilke	BP	Psamm.	A		66
Salsola richteri (Moq.) Karel.	BP	Psamm.	CH		27, 114
Salsola rubescens Franch	BP	Xerohal.	CH		4
Salsola sclerantha C.A. Mey	BP	Psamm.	A		27, 110
Salsola tomentosa (Moq.) Spach	BP	Xerohal.	CHN		110
Salsola tragus L.	Cosm.	Xerohal.	A		4
Seidlitzia florida (M. Bieb.) Boiss.	BP	Xerohal.	A		110
Suaeda acuminata (C. A. Mey) Moq.	NM	Xerohal.	A		66, 110
Suaeda arcuata Bunge	BP	Weedy	A		4
Suaeda aegyptiaca (Hasselq.) Zohary	BP	Hyphal	AP		18, 48
Suaeda olufsenii Paulsen	NM	Hyphal	A		18, 48
Suaeda fruticosa (L.) Forssk.	Cosm.	Xerohal.	HP	97	82, 88
Suaeda heterophylla (Kar. & Kir.) Bunge	NM	Hyphal	A		4
Suaeda monoica Forssk.	BP, IP	Hyphal	SH	56	93, 115
Cistaceae					
Helianthemum lippii (L.) Pers.	CO, BP	Xero	SH		4
Convolvulaceae					
Cressa cretica L.	IP, BP, CT, CO	Hyphal	HP	97	71, 84
Evolvulus alsinoides (L.) L.	IP, BP, CT, CO	Hyphal	HP		113
Ipomoea alba L.	Cosm.	Psamm.	HP		15
Ipomoea pes-caprae (L.) R. Br.	CO	Psamm.	HP		133
Cyperaceae					
Blysmus rufus (Huds.) Link.	NM	Hyphal	HP	16	97, 103
Bolboschoenus affinis (Roth.) Drobov	Cosm.	Hyphal	HP		130
Bolboschoenus maritimus (Roth.) Drobov	NM, PP, HK, BP	Hyphal	HP		134
Carex divisa Hudson	BP, HK, NM	Hyphal	HP		38, 50
Carex orbicularis Boott	BP, HK, NM	Hyphal	HP		66
Carex songorica Kar. & Kir	HK, NM	Hyphal	HP		118
Carex stenophylla Wahl.	BP, HK, NM	Hyphal	HP		135
Carex stenophylla ssp. *interrupta* (V. Krecz.) Egor	Cosm.	Hyphal	HP		135
Cyperus arenarius Retz.	CO, IP	Hyphal	HP		4
Cyperus conglomeratus ssp. *conglomeratus* Rottb.	CO	Hyphal	HP		18, 110
Cyperus conglomeratus ssp. *cuvulus* Rottb.	CO	Hyphal	HP		18, 110
Cyperus corymbosis Rottb.	CO	Hyphal	HP		16, 123
Cyperus laevigatus L.	IP, PP, CO, BP	Hyphal	HP		16, 51
Cyperus malaccensis Lam.	CO	Hyphal	HP		70, 111
Cyperus pachyrhizhus Nees ex Boeck	CO	Hyphal	HP		4
Cyperus rotundus L.	Cosm.	Hyphal	HP		66

Table 1. (Cont.)

Genus, species and author	Distribution	Plant type	Life form	Max dS/m	Ref.
Cyperus serotinus Rottb.	NM, PP, HK	Hyphal	HP		66
Cyperus stoloniferous Retz.	Co	Hyphal	HP		52
Eleocharis palustris (L.) Roem & Schultes	NM. IP,	Hyphal	HP		51
Eleocharis uniglumis (Link.) Schultes	NM, PP, HK, BP	Hyphal	HP	16	97
Fimbristylis cymosa R. Br.	CO	Hyphal	HP		66
Pycerus polystachyos (Rottb.) P. Beauv	CO	Hyphal	HP		66
Schoenoplectus lacustris (L.) Palla	NM	Hyphal	HP		66
Schoenoplectus littoralis (Schrad.) Palla	NM, IP	Hyphal	HP		66
Schoenoplectus triqueter (L.) Palla	NM	Hyphal	HP		66
Schoenus nigricans L.	Cosm.	Hyphal	HP		133
Scirpoides holoschoenus (L.) Sojak	NM, BP	Hyphal	HP		4
Elaegnaceae					
Elaeagnus angustifolia L.	NM, BP, IP	Hyphal	TX		66
Hippophae rhamnoides L.	NM	Hyphal	SH		66
Euphorbiaceae					
Andrachne telephioides L.	NM, PP, BP	Weedy	HP		43
Euphorbia granulata Forssk.	Cosm.	Weedy	A		117
Euphorbia serpens Kunth.	IP	Xero	A		123
Euphorbia thymifolia L.	HK, PP, BP, CT	Psamm.	AP		122
Flueggea leucopyrus Willd.	PP, IP	Xero	SH		4
Frankeniaceae					
Frankenia pulverulenta L.	BP, IP, PP	Psamm.	AP		135
Gentianaceae					
Centaurum spicatum (L.) Fritsch	IP	Xerohal.	HP		29
Goodeniaceae					
Scaevola plumieri (L.) Vahl.	CO	Psamm.	SH	60	39, 54
Scaevola taccada (gaertn.) Roxb.	CO	Psamm.	SH	10	117
Hydrocharitaceae					
Halophila ovalis R. Br.	CO	Hyphal	AQ	58	44
Iridaceae					
Iris ensata Thunb.	Cosm.	Hyphal	AQ		110
Juncaceae					
Juncus bufonius L.	IP	Hyphal	A		113
Juncus gerardii Lois.	BP	Hyphal	HP	50	97
Juncus maritimus Lam.	CO,IP	Hyphal	HP	87	97, 117
Juncus punctorius L.	BP	Hyphal	HP		4
Triglochin maritima L.	NM	Hyphal	HP	48	36
Triglochin palustris K.	NM	Hyphal	HP		113, 137
Lauraceae					
Litsea monopetala (Roxb.) Pers.	PP	Hyphal	V		135
Liliaceae					
Asparagus officinalis L.	NM	Psamm.	HP		137
Urginea indica Kunth.	NM	Psamm.	HP		117, 135
Malvaceae					
Hibiscus tiliaceous L.	CO	Psamm.	T12	58	39, 108
Thespesia populnea (L.) Sol.	CO	Hyphal	T4	58	39, 117
Thespesia populneoides (Roxb.) Kostel.	CO	Hyphal	T6	58	39, 108
Mimosaceae					
Acacia cornigera (L.) Willd.	IP	Xero	T4		15
Acacia jacquamonti Benth.	BP, IP	Xero	T6		8
Acacia leucophloea (Roxb.) Willd.	CT	Xero	T6		8

Table 1. (Cont.)

Genus, species and author	Distribution	Plant type	Life form	Max dS/m	Ref.
Acacia nilotica (L.) Delile	CO	Xero	T6		4
Acacia sphaerocephala Schl. & Chem.	IP	Xero	T2		135
Prosopis cineraria (L.) Druce	PP, IP, BP, CT	Xero	T8		18, 42
Prosopis farcta (Banks & Sol.) Macbride	HK	Weedy	CH		18, 41
Prosopis juliflora (Swartz)	DC, IP	Xero	T8		30, 53
Molluginaceae					
Glinus lotoides L.	CO, CT, IP	Psamm.	A		4
Moraceae					
Ficus microcarpa L.	CO	Hyphal	T8		4
Myrsinaceae					
Aegiceras corniculata (L.) Blanco	CO	Hyphal	T6	58	39, 49
Ardisia solanacea Roxb.	CO	Hyphal	SH		135
Najadaceae					
Najas graminea Delile	PP	Hyphal	SAQ		113
Najas marina L.	IP, NM	Hyphal	SAQ	55	2, 108
Najas minor All.	IP	Hyphal	SAQ		135
Nyctaginaceae					
Bougainvillea spectabilis Willd.	IP	Xero	V	8	20
Pisonia grandis R. Br.	CO	Psamm.	T4		1
Orobanchaceae					
Cistanche tubulosa (Schrenk) Hook	CO, IP, BP, PP	Hyphal	A		110
Palmae					
Cocos nucifera L.	CO	Hyphal	T8	58	35, 106
Hyphaene thebaica (L.) Mart.	CO	Hyphal	T8		51, 121
Livistonia chinenesis (N. J. Jacquin) R. Brown	CO	Hyphal	T8		117
Pheonix canarienses L.	CO	Hyphal	T8		5, 26
Pheonix dactylifera Linn.	CO, IP	Hyphal	T8		5, 136
Papilionaceae					
Alhaji maurorum Medic.	Cosm.	Hyphal	SH		18, 93
Amorpha fruticosa L.	IP	Xero	SH		66
Astragalus kahiricus DC.	HK,IP	Xero	CH		110
Dalbergia sissoo Roxb.	IP, BP,	Xero	T8		118
Erythrina herbacea Linn.	IP	Hyphal	SH		33
Glycyrrhiza glabra L.	NM, BP	Hyphal	CH		66
Glycyrrhiza uralensis Fisch ex DC.	HK	Hyphal	CH		135
Lespedeza juncea var serica (Thunb.) Lace & Hemsley	HK, PP, BP	Xero	HP		4
Macroptilium lathyroides (L.) Urb.	IP	Hyphal	A		4
Medicago falcate L.	NM	Chasm	PH		66
Medicago minima (L.) Grufb.	NM	Chasm	A		22, 56
Melilotus alba Desr.	NM	Chasm	A		110
Melilotus indica (L.) All.	Cosm.	Chasm	A		110, 134
Melilotus officinalis (Li.) Pall.	NM	Chasm	A		110
Oxytropis glabra DC.	NM, HK	Chasm	CHN		66
Oxytropis microphylla (Pall.) D.C.	NM	Psamm.	CH		66
Pongamia pinnata (L.) Merrill	IP	Hyphal	T20	58	39
Robinia pseudoacacia L.	PP	Hyphal	T10		66
Sophora alopecuroides L.	NM	Psamm.	SH		66
Sophora japonica L.	PP	Phre	T20		66
Sophora occidentalis L.	IP	Hyphal	SH		66
Tephrosia purpurea (L.) Pers.	IP	Hyphal	A		91, 125
Trifolium fragiferum L.	NM	Psamm.	HP	16	30, 97

Table 1. (Cont.)

Genus, species and author	Distribution	Plant type	Life form	Max dS/m	Ref.
Plantaginaceae					
Plantago coronopus L.	BP	Xero	A	50	38
Plantago depressa Willd.	NM	Hyphal	A		86
Plantago lanceolata L.	NP, PP	Xero	HP		108
Plantago major L.	Cosm.	Psamm.	HP		137, 143
Plumbaginaceae					
Limonium gilsei (Hemsl.) Rech.	NM	Hyphal	HP		4
Limonium sinuatum (L.) Miller	Cultivated	Hyphal	HP	56	117
Limonium stocksii (Boiss.) O. Ktze	CO, BP	Hyphal	HP	50	18, 117
Psylliostachys spicata (Willd.) Nevski	BP	Hyphal	A		52, 110
Poaceae					
Aeluropus lagopoides (L.) Trin. ex Thw.	CO, RD, IP, BP	Hyphal	PG	56	18, 62
Aeluropus littoralis (Gouan) Parl.	BP	Hyphal	PG	56	18, 51
Aeluropus macrostachys Hack.	BP	Phyphal	PG		4
Agropyron cristatum (L.) Gaertn.	NM	Psamm.	PG		12
Agropyron junceum (L.) P. Beauv.	NM	Psamm.	PG		135
Agrostis stolonifera L.	NP, HK, PP,	Psamm.	HP	60	64, 124
Arundo donax L.	NP, BP, IP, PP	Weedy	PG		52, 117
Calamagrostis holciformis Jaub. & Spach.	NM	Psamm.	PG		66
Calamagrostis pseudophragmites (Hall. F.) Koeler	BP, HK, NM	Psamm.	PG		66
Cenchrus ciliaris Rich.	Cosm.	Psamm.	PG		55, 125
Chloris gayana Kunth.	NM, IP	Psamm.	PG	16	31, 55
Chloris virgata Sw.	BP	Psamm.	A		110, 128
Coelachyrum piercei (Benth.) Bor.	BP	Psamm.	PG		110
Crypsis aculeate (L.) Ait.	Cosm.	Weedy	A		66
Crypsis schoenoides (L.) Lam.	Cosm.	Weedy	A		66
Cynodon dactylon (L.) Pers.	Cosm.	Weedy	PG	17	55, 117
Dactyloctenium aegyptium (L.) P. Beauv.	Cosm.	Weedy	PG		21, 55
Dactyloctenium scindicum Boiss.	Cosm.	Xerohal.	PG		27, 73
Desmostachya bipinnata (L.) Stapf.	Cosm.	Xerohal.	PG	5.6	21, 55
Dichantheum annulatum (Forssk.) Stapf.	Cosm.	Xero	PG		128
Digitaria bicornis (Lam.) Roem & Schulte	Co	Psamm.	A		66
Digitaria longifolia (Retz.) Pers.	PP	Hyphal	PG		99
Digitaria sanguinalis (L.) Scop.	BP, HK, NM, PP	Psamm.	A		135
Diplachne fusca (L.) P. Beauv.	IP, CT	H	PG	15	18, 102
Eleusine indica (L.) Gaertn.	NM, IP, HK	Hyphal	PG		24, 51
Elymus dasytachys Trin.	Northern Area	Psamm.	PG		135
Eragrostis curvula (Schrad.) Nees.	CT, IP, BP, PP	Psamm.	PG		4
Eragrostis superba Peyr.	CO, CT	Psamm.	PG		4
Festuca pamirica Tzvelev	NM, HK	Psamm.	PG		4
Festuca rubra L.	NM, HK	Psamm.	PG	27	97, 117
Halopyrum mucronatum (L.) Stapf.	CO	Psamm.	PG	35	18, 86
Hordeum bogdanii Wilensky	BO, NM	Hyphal	PG		4
Hordeum brevisubulatum (Trin.) Link	NM, HK	Hyphal	PG		66
Hordeum marinum Huds.	NM	Hyphal	A	20	97, 101
Hordeum maritimum ssp *glaucum* (steud.) Tzvelev	BP, NM, HK, PP	Hyphal	A		4
Imperata cylindrica (L.) Raeuschel.	Cosm.	Psamm.	PG		135
Lasirus sciendicus Forssk.	Cosm.	Psamm	PG		128
Leymus secalinus (Georgi) Tzvelev	HK, NM	Psamm	PG		4
Lolium multiflorum Lam.	HK, BP	Psamm.	PG		22, 113
Lygeum spartum Loefl. ex Linn.	NM	Psamm.	PG		18, 121
Orinus thoroldii (Staps. ex Hemsl.) Bor.	NM	Hyphal	PG		66
Orthochloa compressa (Forssk.) Hilu	Cosm.	Hyphal	PG		4
Oryza coarctata Roxb.	CO	Hyphal	HP		135

Table 1. (Cont.)

Genus, species and author	Distribution	Plant type	Life form	Max dS/m	Ref.
Parapholis incurva (L.) C.E. Hubb.	BP, PP, HK	Hyphal	PG		97
Paspalidium geminatum (Forssk.) Stapf	CT	Psamm.	PG		18
Paspalum pasploides (Michex) Scribner	Cosm.	Hyphal	HP		32, 127
Pennisetum hohenackeri Hochst. ex Steud.	CT	Psamm.	PG		4
Phalaris arundinaceae L.	NM, PP	Hyphal	PG		66
Phragmites australis (Cav.) Trin. ex Steud.	NM, IP	Hyphal	PG	40.6	18, 47
Phragmites karka (Retz.) Trin. ex. Steud.	Cosm..	Hyphal	PG		108
Poa bulbosa L.	NM, BP, HK	Psamm.	PG		134
Poa pratensis L.	NM, BP, HK	Psamm.	PG		134
Polypogon monspeliensis (L.) Desf.	Cosm.	Psamm.	PG		119, 121
Puccinellia distans (Wahlb.) Parl.	NM	Hyphal	PG	27	97, 133
Puccinellia gigantia (Grossh.) Grossh.	BP	Hyphal	PG		134
Puccinellia tenuiflora (Griesb.) Scribn.	NM	Hyphal	PG		66
Sacchraum bengalense Retz.	HK, PP, IP, CT	Hyphal	PG		4
Sacchraum spontaneum L.	NM, PP, HK, IP	Hyphal	PG		66
Setaria viridis (L.) P. Beauv.	NP, BP, HK, PP	Psamm.	A		66
Spinifex littoreaus (Brum. F.) Merr.	Cosm.	Psamm.	PG		66
Sporobolus arabicus Boiss.	Cosm.	Psamm.	PG		18, 110
Sporobolus helvolus (Trin.) Dur. & Schinz.	PP, IP	Psamm.	PG		8, 52
Sporobolus piliferus (Trin.) Kunth.	IP	Psamm.	PG		4
Sporobolus tourneuxii Coss.	CT	Psamm.	PG		4
Sporobolus tremulus (Willd.) Kunth.	PP	Hyphal	A		21, 55
Sporobolus virginicus (L.) Kunth.	CO, CT	Psamm.	PG	73	18, 117
Stipa splendens Trin.	BP, HK, NM	Psamm.	PG		135
Tetrachne dregei Nees ex Boeck	BM	Psamm.	PG		110
Trikeraia hookeri (Staps.) Bor.	NM	Psamm.	PG		4
Urochloa panicoides P. Beau.	NM, HK, PP	Psamm.	PG		4
Urochondra setulosa (Trin.) C.E. Hubb	CO	Xerohal.	PG	30	62
Vulpia unilateralis (L.) Stace	NM	Psamm.	A		4
Polygonaceae					
Polygonum aviculare L.	NM	Xero	A		47, 83
Polygonum bellardii All.	NM	Xero	A		135
Polygonum delicatulum Meissn.	NM	Xero	A		4
Polygonum patulum M. Bieb.	NM	Xero	A		44
Polygonum sibiricum Laxm.	NM	Xero	A		66
Polygonum viviparum L.	NM	Xero	A		4
Rumex crispus L.	NM	Xero	A		17, 47
Portulacaceae					
Portulaca oleracea L.	Cosm.	Xero	AP		125
Portulaca pilosa L.	NM, PP	Hyphal	A		108
Primulaceae					
Anagallis arvensis L.	NM	Xero	A		47, 117
Glaux maritime L.	NM	Xero	HP	52	97, 133
Samolus valerandi L.	NM, PP, BP	Hyphal	HP		97
Punicaceae					
Punica granatum L.	NM, HK, BP	Xero	T2		4
Residaceae					
Ochradenus baccatus Del.	CO, BP	Xero	SH	58	142
Oligomeris linifolia (Vahl) Macbride	CO, IP, BP, PP	Xero	A	58	52
Rhamnaceae					
Zizyphus nummularia (Burm. f.) Wight and Arn.	NM, CO	Xero	T4		7
Rhizophoraceae					
Brugiera gymnorhiza (L.) Savigny	CO	Hyphal	T8	58	18, 108

Table 1. (Cont.)

Genus, species and author	Distribution	Plant type	Life form	Max dS/m	Ref.
Ceriops decandra (Griff.) Ding.	CO	Hyphal	T9	58	95
Ceriops tagal (Perr.) C.B. Robinson	CO	Hyphal	T8	58	73, 108
Rhizophora apiculata Blume, Bijdr.	CO	Hyphal	T8	58	66, 108
Rhizophora mucronata Poir.	CO	Hyphal	T8	59	18, 73
Rosaceae					
Potentilla anserina L.	NM	Hyphal	V		66
Potentilla bifurca L.	NM	Hyphal	V		66
Potentilla supine L.	NM	Hyphal	V		66
Rubiaceae					
Galium verum L.	NM	Hyphal	A		66
Ruppiaceae					
Ruppia maritima L.	Cosm.	Hyphal	AQ	58	109, 133
Salicaceae					
Populus euphratica Olivier	IP, BP, PP	Xero	T8		4
Salvadoraceae					
Salvadora oleoides Dene	CO, IP	Xero	T8		21, 63
Salvadora persica L.	CT, IP	Xero	T9	8	18, 63
Scrophulariaceae					
Euphrasia officinalis L.	NM	Xero	HP		135
Limosella aquatica L.	NM	Hyphal	HP		113
Simaroubaceae					
Suriana maritima L.	CO	Hyphal	SH	58	140
Solanaceae					
Lycium edgeworthii Dunal	IP, PP, BP	Xero	SH		4
Lycium shawii R. & S.	BP	Xero	SH		51
Solanum incanum L.	IP, PP, BP	Xero	SH	9	117
Sonneratiaceae					
Sonneratia caseolaris (L.) Engl.	CO	Hyphal	TX	58	109, 133
Tamaricaceae					
Reaumuria alternifolia (Labill) Britten	BP	Hyphal	CHN		110
Reaumuria palaestina Boiss.	BP	Hyphal	CHN		110
Reaumuria stocksii Boiss.	BP, CO	Hyphal	CHN		110
Tamarix androssowii Litw.	BP	Xero	T3		110
Tamarix aphylla (L.) Karst.	Cosm.	Phrea	T8	56	18, 19
Tamarix arceuthoides Bunge	NM	Xero	T2		110
Tamarix indica Willd.	Cosm.	Hyphal	T8		19
Tamarix karelini Bunge	BP	Xero	T2		110
Tamarix kotschyii Bumge	BP	Xero	T2		66, 110
Tamarix leptostachya Bunge	NM	Xero	T2		66, 110
Tamarix mascatensis Bunge	BP	Xero	SH		19, 110
Tamarix pakistanica Qaiser	IP, BP, CO	Phrea	T2		4
Tamarix passernioides Del.ex Desv.	BP, IP, CT	Xero	T2		18, 19
Tamarix ramosissima Ledeb.	CT	Xero	SH		18, 66
Tamarix smyrensis Bunge.	BP	Xero	T2		4
Tamarix tetragyna (Boiss.) Boiss.	BP	Xero	T2	26	18, 19
Tiliaceae					
Grewia tenax (Forssk.) Fiori	Cosm.	Xero	T2		108, 112
Typhaceae					
Typha domingensis Pers.	Cosm.	Hyphal	HP	26	17, 18
Typha latifolia L.	NM	Hyphal	HP	21	45, 133

Table 1. (Cont.)

Genus, species and author	Distribution	Plant type	Life form	Max dS/m	Ref.
Umbelliferae					
Ammi visnaga (L.) Lamk.	HK	Xero	T2		133, 137
Apium graveolens L.	Cosm.	Hyphal	AQ	16	97
Centella asiatica (L.) Urban	NM	Hyphal	HP		4
Verbenaceae					
Clerodendrum inerme (L.) Gaertn.	Cultivated	Hyphal	SH	58	66, 108
Phyla nodiflora (L.) Greene	IP	Hyphal	HP	15	117, 131
Verbena officinalis L.	NM, PP, HK	Hyphal	HP		135
Vitex trifolia L.	Cultivated	Hyphal	SH		66
Zygophyllaceae					
Fagonia bruguieri DC. Prodr.	BP	Xero	CHN		43
Fagonia indica ssp. *schweinfurthiq* Hadidi	IP, CT,	Xero	CHN		135
Nitraria retusa (Forssk.) Aschers	CO	Xero	SH	90	18, 93
Nitraria schoberi L.	BP	Xerohal.	SH	66	18, 117
Seetzenia lanata (Willd.) Bullock	IP, BP	Psamm.	HP		23, 91
Tribulus terrestris L.	Cosm.	Xero	HP		23, 91
Zygophyllum fabago L.	BP	Xerohal.	SH		66
Zygophyllum propinquum Decne	CT, IP	Xero	SH		110
Zygophyllum simplex L.	CT, IP, CO	Xerohal.	A	29	81, 142

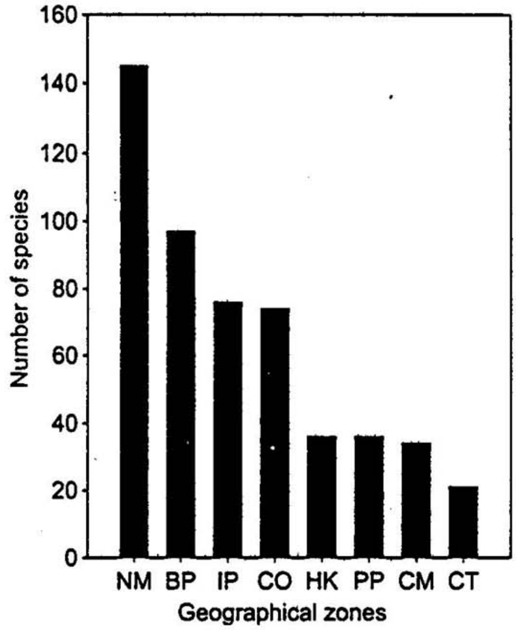

Fig. 1. Distribution of halophytic species in the major geographical zones of Pakistan.

In addition among the total 380 halophytes about 137 of them could be classified as hydrohalophytes, followed by xerophytes [91], Psammohalophytes [74], xerohalophytes [44], Chasmophytes [6], Weedy [23] and Phreatophytes [3]. Fifty percent of halophytes from Chenopodiaceae are found in arid environment while all halophytic members of Cyperaceae are found in aquatic conditions (Table 2).

Life forms of these plants also showed a high degree of variation. Annuals [98] are the dominant life forms of Pakistani halophytes, followed by Herbaceous perennials [79], perennial grass [59], shrubs [46], trees [33], Chaemaephytes [20] and others like aquatic, geophytes, hemi-cryptophytes and small trees are represented by less than 15 individuals (Table 3). The data presented in Figure 2 showed distribution of various life forms in the various geographical regions. In the northern mountains halophytic vegetation is dominated by annuals [47], herbaceous perennials [33] and perennial grasses [29]. Halophytes in Balochistan plateau are also dominated by annuals [41], herbaceous perennials [21], shrubs [20] and perennial grasses [16]. Coastal areas are dominated by herbaceous perennials and shrubs. Most of the halophytes present in the northern mountains are hydrohalophytes [46], followed by xerohalophytes [33], Psammophytes [29], while halophytic vegetation of Balochistan is equally dominated by three types like hydrohalophytes, xerophytes, and xerohalophytes (Figure 3). Hydrohalophytes are the most abundant group among the coastal plants.

Table 3. Distribution of life form of the halophytes from Pakistan among plant families

No.	Family	Total #	A	AQ	CH	CHN	HP	PG	SH	T2	T4	T(x)	V
1	Chenopodiaceae	86	49	–	6	7	3	–	21	–	–	–	–
2	Poaceae	72	10	–	–	3	–	59	–	–	–	–	–
3	Cyperaceae	27	–	–	–	–	27	–	–	–	–	–	–
4	Papilionaceae	23	6	–	4	1	4	–	4	–	–	4	–
5	Tamaricaceae	16	–	–	3	–	–	–	2	8	1	2	–
6	Asteraceae	11	–	–	4	–	7	–	–	–	–	–	–
7	Verbenaceae	10	–	–	–	2	4	–	4	–	–	–	–
8	Mimosaceae	8	–	–	1	–	–	–	–	–	–	7	–
9	Brassicaceae	7	6	–	1	–	–	–	–	–	–	–	–
10	Polygonaceae	7	7	–	–	–	–	–	–	–	–	–	–
11	Asclepidaceae	6	–	–	–	–	1	–	1	2	–	–	2
12	Juncaceae	6	1	–	–	–	5	–	–	–	–	–	–
13	Aizoaceae	5	4	–	–	–	1	–	–	–	–	–	–
14	Euphorbiaceae	5	3	–	1	–	1	–	1	–	–	–	–
15	Palmae	5	–	–	–	–	–	–	–	–	–	5	–
16	Rhizophoraceae	5	–	–	–	–	–	–	–	–	–	5	–
17	Caryophyllaceae	4	1	–	–	–	3	–	–	–	–	–	–
18	Convolvulaceae	4	–	–	–	–	4	–	–	–	–	–	–
19	Plantaginaceae	4	2	–	–	–	2	–	–	–	–	–	–
20	Plumbaginaceae	4	1	–	–	–	3	–	–	–	–	–	–
21	Boraginaceae	3	–	–	–	–	3	–	–	–	–	–	–
22	Malvaceae	3	–	–	–	–	–	–	–	–	–	3	–
23	Najadaceae	3	–	3	–	–	–	–	–	–	–	–	–
24	Primulaceae	3	1	–	–	–	2	–	–	–	–	–	–
25	Rosaceae	3	–	–	–	–	–	–	–	–	–	–	3
26	Solanaceae	3	–	–	–	–	–	–	3	–	–	–	–
27	Umbelliferae	3	–	1	–	–	1	–	–	1	–	–	–
28	Eleagnaceae	2	–	–	–	–	–	–	1	–	–	1	–
29	Goodeniaceae	2	–	–	–	–	–	–	2	–	–	–	–
30	Liliaceae	2	–	–	–	–	2	–	–	–	–	–	–
31	Myrsinaceae	2	–	–	–	–	–	–	1	–	–	1	–
32	Nyctaginaceae	2	–	–	–	–	–	–	–	–	1	–	1
33	Portulacaceae	2	2	–	–	–	–	–	–	–	–	–	–
34	Residaceae	2	1	–	–	–	1	–	–	–	–	–	–
35	Salvadoraceae	2	–	–	–	–	–	–	–	–	–	2	–
36	Scrophulariaceae	2	–	–	–	–	2	–	–	–	–	–	–
37	Typhaceae	2	–	–	–	–	2	–	–	–	–	–	–
38	Amaranthaceae	1	–	–	–			–	1	–	–	–	–
39	Avicenniaceae	1	–	–	–		–	–	–	–	–	1	–
40	Caesalpinaceae	1	–	–	–	–	–	–	1	–	–	–	–
41	Cistaceae	1	–	–	–	–	–	–	1	–	–	–	–
42	Frankeniaceae	1	1	–	–	–	–	–	–	–	–	–	–
43	Gentianaceae	1	–	–	–	–	1	–	–	–	–	–	–
44	Hydrocharitaceae	1	–	1	–	–	–	–	–	–	–	–	–
45	Iridaceae	1	–	1	–	–	–	–	–	–	–	–	–
46	Lauraceae	1	–	–	–	–	–	–	–	–	–	–	1
47	Molluginaceae	1	1	–	–	–	–	–	–	–	–	–	–
48	Moraceae	1	–	–	–	–	–	–	–	–	–	1	–
49	Orobanchaceae	1	1	–	–	–	–	–	–	–	–	–	–
50	Punicaceae	1	–	–	–	–	–	–	–	1	–	–	–
51	Rhamnaceae	1	–	–	–	–	–	–	–	–	1	–	–
52	Rubiaceae	1	1	–	–	–	–	–	–	–	–	–	–
53	Ruppiaceae	1	–	1	–	–	–	–	–	–	–	–	–
54	Salicaceae	1	–	–	–	–	–	–	–	–	–	1	–
55	Simaroubaceae	1	–	–	–	–	–	–	1	–	–	–	–
56	Sonneratiaceae	1	–	–	–	–	–	–	–	–	–	1	–
57	Tiliaceae	1	–	–	–	–	–	–	–	1	–	–	–
58	Zygophyllaceae	1	–	–	–	–	–	–	2	–	–	–	–

Table 2. Type of halophytes distributed in various families

No.	Family	Total #	Hyphal	Xero	Psamm	Xerohal	Chasm	Weedy	Phrea
1	Chenopodiaceae	86	11	20	7	37	–	9	–
2	Poaceae	72	24	1	39	3	–	5	–
3	Cyperaceae	27	27	–	–	–	–	–	–
4	Papilionaceae	23	9	4	3	–	6	–	1
5	Tamaricaceae	16	4	10	–	–	–	–	2
6	Asteraceae	11	–	3	8	–	–	–	–
7	Verbenaceae	10	4	4	1	1	–	–	–
8	Mimosaceae	8	–	7	–	–	–	1	–
9	Brassicaceae	7	4	–	3	–	–	–	–
10	Polygonaceae	7	–	7	–	–	–	–	–
11	Asclepidaceae	6	–	6	–	–	–	–	–
12	Juncaceae	6	6	–	–	–	–	–	–
13	Aizoaceae	5	–	4	1	–	–	–	–
14	Euphorbiaceae	5	–	2	1	–	–	2	–
15	Palmae	5	5	–	–	–	–	–	–
16	Rhizophoraceae	5	5	–	–	–	–	–	–
17	Caryophyllaceae	4	–	–	–	–	–	4	–
18	Convolvulaceae	4	2	–	2	–	–	–	–
19	Plantaginaceae	4	1	2	1	–	–	–	–
20	Plumbaginaceae	4	4	–	–	–	–	–	–
21	Boraginaceae	3	–	1	–	–	–	2	–
22	Malvaceae	3	2	–	1	–	–	–	–
23	Najadaceae	3	3	–	–	–	–	–	–
24	Primulaceae	3	1	2	–	–	–	–	–
25	Rosaceae	3	3	–	–	–	–	–	–
26	Solanaceae	3	–	3	–	–	–	–	–
27	Umbelliferae	3	2	1	–	–	–	–	–
28	Zygophyllaceae	3	–	1	–	2	–	–	–
29	Eleagnaceae	2	2	–	–	–	–	–	–
30	Goodeniaceae	2	–	–	2	–	–	–	–
31	Liliaceae	2	–	–	2	–	–	–	–
32	Myrsinaceae	2	2	–	–	–	–	–	–
33	Nyctaginaceae	2	–	1	1	–	–	–	–
34	Portulacaceae	2	1	1	–	–	–	–	–
35	Residaceae	2	–	2	–	–	–	–	–
36	Salvadoraceae	2	–	2	–	–	–	–	–
37	Scrophulariaceae	2	1	1	–	–	–	–	–
38	Typhaceae	2	2	–	–	–	–	–	–
39	Amaranthaceae	1	–	1	–	–	–	–	–
40	Avicenniaceae	1	1	–	–	–	–	–	–
41	Caesalpinaceae	1	1	–	–	–	–	–	–
42	Cistaceae	1	–	1	–	–	–	–	–
43	Frankeniaceae	1	–	–	1	–	–	–	–
44	Gentianaceae	1	–	–	–	1	–	–	–
45	Hydrocharitaceae	1	1	–	–	–	–	–	–
46	Iridaceae	1	1	–	–	–	–	–	–
47	Lauraceae	1	1	–	–	–	–	–	–
48	Molluginaceae	1	–	–	1	–	–	–	–
49	Moraceae	1	1	–	–	–	–	–	–
50	Orobanchaceae	1	1	–	–	–	–	–	–
51	Punicaceae	1	–	1	–	–	–	–	–
52	Rhamnaceae	1	–	1	–	–	–	–	–
53	Rubiaceae	1	1	–	–	–	–	–	–
54	Ruppiaceae	1	1	–	–	–	–	–	–
55	Salicaceae	1	–	1	–	–	–	–	–
56	Simaroubaceae	1	1	–	–	–	–	–	–
57	Sonneratiaceae	1	1	–	–	–	–	–	–
58	Tiliaceae	1	–	1	–	–	–	–	–

Table 2. Type of halophytes distributed in various families

No.	Family	Total #	Hyphal	Xero	Psamm	Xerohal	Chasm	Weedy	Phrea
1	Chenopodiaceae	86	11	20	7	37	–	9	–
2	Poaceae	72	24	1	39	3	–	5	–
3	Cyperaceae	27	27	–	–	–	–	–	–
4	Papilionaceae	23	9	4	3	–	6	–	1
5	Tamaricaceae	16	4	10	–	–	–	–	2
6	Asteraceae	11	–	3	8	–	–	–	–
7	Verbenaceae	10	4	4	1	1	–	–	–
8	Mimosaceae	8	–	7	–	–	–	1	–
9	Brassicaceae	7	4	–	3	–	–	–	–
10	Polygonaceae	7	–	7	–	–	–	–	–
11	Asclepidaceae	6	–	6	–	–	–	–	–
12	Juncaceae	6	6	–	–	–	–	–	–
13	Aizoaceae	5	–	4	1	–	–	–	–
14	Euphorbiaceae	5	–	2	1	–	–	2	–
15	Palmae	5	5	–	–	–	–	–	–
16	Rhizophoraceae	5	5	–	–	–	–	–	–
17	Caryophyllaceae	4	–	–	–	–	–	4	–
18	Convolvulaceae	4	2	–	2	–	–	–	–
19	Plantaginaceae	4	1	2	1	–	–	–	–
20	Plumbaginaceae	4	4	–	–	–	–	–	–
21	Boraginaceae	3	–	1	–	–	–	2	–
22	Malvaceae	3	2	–	1	–	–	–	–
23	Najadaceae	3	3	–	–	–	–	–	–
24	Primulaceae	3	1	2	–	–	–	–	–
25	Rosaceae	3	3	–	–	–	–	–	–
26	Solanaceae	3	–	3	–	–	–	–	–
27	Umbelliferae	3	2	1	–	–	–	–	–
28	Zygophyllaceae	3	–	1	–	2	–	–	–
29	Eleagnaceae	2	2	–	–	–	–	–	–
30	Goodeniaceae	2	–	–	2	–	–	–	–
31	Liliaceae	2	–	–	2	–	–	–	–
32	Myrsinaceae	2	2	–	–	–	–	–	–
33	Nyctaginaceae	2	–	1	1	–	–	–	–
34	Portulacaceae	2	1	1	–	–	–	–	–
35	Residaceae	2	–	2	–	–	–	–	–
36	Salvadoraceae	2	–	2	–	–	–	–	–
37	Scrophulariaceae	2	1	1	–	–	–	–	–
38	Typhaceae	2	2	–	–	–	–	–	–
39	Amaranthaceae	1	–	1	–	–	–	–	–
40	Avicenniaceae	1	1	–	–	–	–	–	–
41	Caesalpinaceae	1	1	–	–	–	–	–	–
42	Cistaceae	1	–	1	–	–	–	–	–
43	Frankeniaceae	1	–	–	1	–	–	–	–
44	Gentianaceae	1	–	–	–	1	–	–	–
45	Hydrocharitaceae	1	1	–	–	–	–	–	–
46	Iridaceae	1	1	–	–	–	–	–	–
47	Lauraceae	1	1	–	–	–	–	–	–
48	Molluginaceae	1	–	–	1	–	–	–	–
49	Moraceae	1	1	–	–	–	–	–	–
50	Orobanchaceae	1	1	–	–	–	–	–	–
51	Punicaceae	1	–	1	–	–	–	–	–
52	Rhamnaceae	1	–	1	–	–	–	–	–
53	Rubiaceae	1	1	–	–	–	–	–	–
54	Ruppiaceae	1	1	–	–	–	–	–	–
55	Salicaceae	1	–	1	–	–	–	–	–
56	Simaroubaceae	1	1	–	–	–	–	–	–
57	Sonneratiaceae	1	1	–	–	–	–	–	–
58	Tiliaceae	1	–	1	–	–	–	–	–

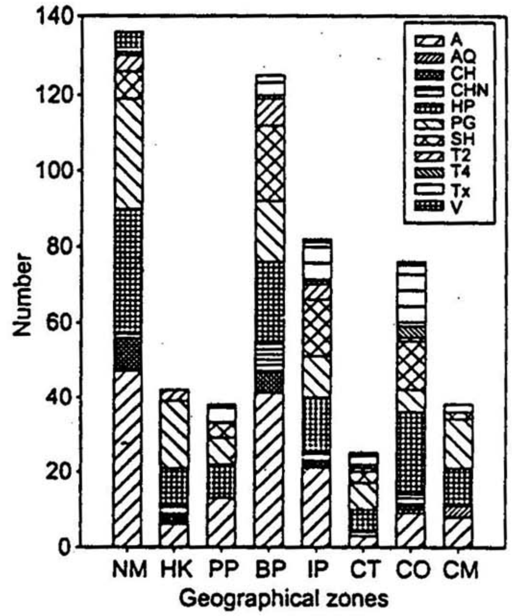

Fig. 2. Life form distribution of halophytes in major geographical regions of Pakistan.

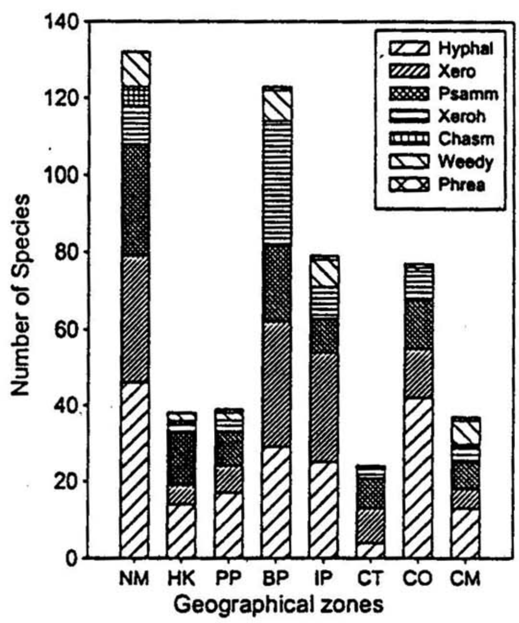

Fig. 3. Distribution of various halophyte types in major geographical regions of Pakistan.

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 [138]. Classification schemes have been constructed that attempts to match morphological and physiological characters to specific halophyte habitats and growth strategies [28]. However, all 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 like succulence, reduction in surface area, thick cuticle or a cover of waxy layers on epidermis, hairs on stem and leaves, sunken stomata and salt glands, etc. The succulents often lack the ability to secrete salts but they thwart the rise of salt concentration by an increase of their water content, and they become more and more succulent during their development. *Arthrocnemum, Halogeton, Haloxylon, Heliotropium, Salicornia, Suaeda, Salsola*, and *Zygophyllum* are prominent succulent halophytic genera. There is abrupt reduction in surface area of leaves of some species (e.g. *Salsola imbricata, Trianthema triquetra, Suaeda fruticosa*) during extreme salt stress conditions. *Suaeda fruticosa, Salsola imbricata, Haloxylon stocksii, H. salicornicum, Cressa cretica, Sporobolus arabicus, Urochondra setulosa* and *Aeluropus lagopoides* are characterized by thick cuticle and a cover of waxy layers, while stem and leaves of last five species remain covered with hairs. Only a small number of halophytes are able to excrete salts through glandular cells. Liphschitz and Waisel (98) listed active secreting glands in *Avicennia, Aeluropus, Aegiceras, Limonium, Rhizophora, Ceriops, Bruguiera, 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, for example, *Atriplex* species. The basic role of bladders is the protection of 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 loosing viability or the ability of seeds to germinate at high salinities [79]. Seeds of halophytes do not only germinate at higher salinities but also remain viable for long periods of time when immersed in saline water [80]. Halophytes vary in their upper limit of salt tolerance and increase in salinity usually delays their germination [139]. Seeds of salt marsh species like *Atriplex stocksii, A. triangularis, Hordeum jubatum, Polygonum aviculare* and *Zygophyllum simplex* show little germination above 125 mM NaCl [14, 74, 76, 89, 80], however, species like *Aeluropus lagopoides, Haloxylon stocksii, Sporobolus arabicus, Suaeda fruticosa, Limonium stocksii, Triglochin maritima* and *Urochondra setulosa* could germinate up to 500 mM NaCl [61, 62, 75, 78, 82, 83]. 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 800 mM or higher NaCl concentrations [60, 71, 76, 85, 86, 87, 88, 89, 139]. Species like *A. stocksiii 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 [129] 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 appears like uncoiling of the young embryo out of the testa immediately after contact with water with an unusually high rate of cell elongation, soon after imbibition. Such fast seed germination indicates the adaptive strategy by the plants as the availability of water with reduced NaCl content in soil during the rainy season is for a short duration. Increase in salinity leads to dormancy of seeds in halophytes and glycophytes. More investigations with halophytes [139] 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 high salinity and these will germinate when returned to distilled water [72, 77–83].

Salt tolerance of species vary with the stage of their development. Some species like *Suaeda fruticosa, Haloxylon stocksii, Atriplex stocksii* and *Zygophyllum simplex* were not very highly salt tolerant at germination but showed a high-salinity tolerance at growth stage [74, 76–90]. While other species like *Arthrocnemum macrostachyum* and *Cressa cretica* showed a higher degree of salt tolerance both at germination and growth stages [71, 72].

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. [85] while studying *Halopyrum mucronatum, Atriplex stocksii, Haloxylon stocksii* and *Suaeda fruticosa* found high accumulation of betaine with the 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} plant water or more betaine concentration is needed to successfully achieve osmotic adjustment under saline conditions and most of the Pakistani species tested have betaine concentration higher then this.

Scholander [121] described the presence of an ultrafilter in roots of mangroves of the family Rhizophoraceae, 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 [69]. The same holds true for *Aeluropus littoralis, Limonium latifolium* and *Tamarix aphylla*.

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

Avicennia, Ceriops, Rhizophora and *Sonneratia* absorb and accumulate excessive amounts of salts and the leaves become fleshy.

UTILIZATION AND POTENTIALS OF HALOPHYTES

Halophytes can play an important role in local and regional communities in the western, tropical and subtropical areas as a source of food, animal feed, chemicals, fine chemicals and other raw materials. 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. 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 system; 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, boat and canoe making for the residents of coastal areas.

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 alkali sacaton (*Sporobolus airoides*). Indian almond (*Terminalia catappa*). *Salvadora oleoides* and *S. persica* yield fruits rich in oil and fat. The young leaves and shoots *Salicornia bigellovi, S. brachiata, Sesuvium portulacastrum, Chenopodium album, Portulaca oleracea, Suaeda maritima* have also been used for vegetables, salads and pickles in various parts of the country. *Suaeda fruticosa* is used to prepare a kind of baking soda, which is used in preparation of food. Radicles of *Rhizophora, Bruguiera* and *Ceriops*; tender leaves of *Thespesia populnea, Hibiscus tiliaceus* and fruits or kernels of littoral species such as *Terminalia catappa*.

Forages

In many arid coastal areas where mangroves occur sporadically, but little additional vegetation is available, the foliage of such species as *Avicennia marina, Sonneratia alba, Ceriops tagal* and *Rhizophora mucronata* has served as camel and cattle feed. Among trees, species of *Acacia, Prosopis, Salvadora* and *Zizyphus* are traditional fodder of arid regions. Many species of *Salicornia, Chenopodium, Atriplex, Salsola, Suaeda* and *Kochia* are common fodder shrubs. Among grasses *Leptochloa fusca, Aeluropus lagopoides, Dactyloctenim 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. Aronson et al. (11) recorded 1.26–2.09 kgm^{-2} dry matter and 15.5–39.5% fiber and 10.2–19.5% crude protein in some species of *Atriplex. Kochia indica* has been field tested for domestic livestock and found the good fodder producing with fresh biomass of 8.5 kg per bush from March through August. Kallar grass (*Leptochloa fusca*) has gained much attention as a fodder on salt affected soils (both saline and alkaline) in Pakistan [102]. We could get 46.5 t ha^{-1} green forage when planted in extreme alkali soil (pH >10) for 5 years.

Oil Seeds

Production of vegetable oil from seed-bearing halophytes appears promising. Seeds of various halophytes like *Suaeda fruticosa, Arthrocnemum macrostachyum, Salicornia bigelovii, S. brachiata, Halogeton glomeratus, Suaeda moquinii Kochia scoparia* and *Haloxylon stocksii* possess sufficient quantity of high quality edible oil with unsaturation ranging from 70% to 80% (*141*). Seeds of *Salvadora oleoides* and *S. persica* contain 40–50% fat and are good source of lauric acid. Purified fat is used for soap and candle making and is a potential substitute for coconut oil.

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, Suaeda, Kochia, Capparis* and *Salvadora* (42). In coastal areas the mangroves are used frequently for fuel and timber which has contributed a lot to deforestation of these habitats. Species of *Rhizophora*, *Ceriops*, *Avicennia* and *Sonneratia*, are excellent fuel woods and also contribute to form charcoal.

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. The stem and leaves of salt-tolerant rushes (species of *Juncus* and *Spinifex*) have been used since ancient times for the manufacture of mats, baskets and cordage. Most of the mangroves species are rich in tannin contents and extraction of tannin from the bark of mangrove species had been one of the major uses of mangrove species.

Medicinal Uses

Many workers have reported the medicinal uses of halophytes while describing the economic importance of plants [42], some of these have been briefed here: *Acanthus volubilis* – leaves are used for dressing boils and wounds. *Capparis decidua* – bark is acrid, laxative, diaphoretic, anthelmintic, useful for cough, asthma and inflammations; fruits useful in cardiac troubles and biliousness. *Juncus rigidus* – it has diuretic properties and used in diarrhea. *Kochia indica* – the plant is considered cardiac and stimulant. *Salsola imbricata* – the plant is considered vermifugal; ash is applied to itches. *S. tetrandra* – it has antispasmodic and anthelmintic properties. *Salvadora persica* and *S. oleoides* – leaves are useful to relieve cough; seed oil in rheumatism and suppositories; stem and roots in toothache, leaf poultice in piles and tumors. *Thespesia populnea* – leaves are used in stomach trouble. *Zygophyllum simplex* – the plant has cardiac, antimicrobial and anthelmintic properties; leaves and seeds are applied in eye disease.

Aronson [5, 6, 9–11] 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 and *Tamarix troupii*, *T. articulata*, *Prosopis juliflora*, *Pithecellobium dulce*, *Parkinsonia aculeata* and *Acacia farnesiana* as of tolerant salinity up to EC 25–35 dS m^{-1}; and *Acacia nilotica*, *A. tortilis*, *Casuarina glauca*, *C. obesa* and *Eucalyptus calmadulensis* up to salinity of 15–25 dS m^{-1}. *Aegiceras corniculata*, *Avicennia marina*, *Ceriops tagal* and *Rhizophora mucronata* trees could be grown in the areas with high salinity and low-water table. In recent years research in evaluation of halophytes for land reclamation and landscape management has taken a new dimension.

SUMMARY

Fresh water resources is becoming increasingly limited and that agricultural irrigation systems will steadily increase in salinity in the near future. It is about time to develop sustainable biological production system which could use low-quality saline water for irrigation of halophytic crops in saline lands. Halophytes are non-conventional crops and it would take a little to make people believe that they are good for them. However, there are potentials to extract high-quality edible oil from them and this would not have any problem of acceptability. Same would be true for feed, fiber and forage crops and the role of halophytes in ecologically improving the quality of saline degraded lands. There is no doubt that saline agriculture is here to stay. It would need fine tuning in different ecological situations and modern tissue culture techniques to improve the desired quality of halophytic cash crops. Pakistan has about 380 halophytes and if detailed field and laboratory studies are carried out, I am sure that many potential crops could be found.

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