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REGULAR ARTICLE

Species, types, distribution, and economic potential of halophytes in China

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Abstract According to a survey conducted from 1995 to 2004 in the eight regions with salinized soils, China contains 587 halophytes representing 242 genera and 71 families: apart from three species of ferns, all are angiosperms. Physiologically, Chinese halophytes include salt-secreting halophytes, euhalophytes, and pseudohalophytes. Ecologically, Chinese halophytes include zerohalophytes, mesohalophytes, and hydrohalophytes. Chinese halophytes represent a salt-tolerant gene pool that might be used to increase the salt tolerance of conventional crops through breeding, but also have considerable potential as salt-tolerant economic crops providing food, forage, medicine, and industrial material in salinized soils.

Keywords Halophytes · Physiological type · Ecological type · Vegetation type · Distribution · Economic use

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Introduction

Halophytes, plants that survive to reproduce in environments where the salt concentration is around 200 mM NaCl or more, constitute about 1% of the world flora (Flowers and Colmer 2008). Halophytes are receiving substantial attention from botanists and agriculturists because soil salinity is increasing in many parts of the world. These increases largely result from low quality irrigation water (water with high salt content), high evaporation-to-rainfall ratios, and, in coastal lowlands, from rising sea levels associated with global warming. As fertile soils become salinized, the yield of conventional crops decreases (Munns 2005). Between 1993 and 1995 in the Sacramento Valley of California, for example, soil salinity increased by 1 $ds \cdot m^{-1}$, and this reduced yields by an estimated 10% (see Rozema and Flowers 2008). Yield reductions are a serious problem because the world population is rapidly increasing. Social scientists expect that the world population will reach 9.3 billion by 2050 (United Nations Population information Network www.un.org/popin/data.html).

Although salinization in agricultural soils can be avoided or reduced if crops are irrigated with fresh water (water with low salt content), fresh water makes up only 1% of the water on earth. There is an equivalent supply of brackish water (1%) and a vast quantity of seawater (98%). Agriculture must compete with domestic and industrial uses for this fresh water, and high quality water is rapidly

becoming a limited and expensive resource. It is time that we therefore must find ways to grow crops without applying large volumes of fresh water (Rozema and Flowers 2008).

One way to deal with the problem of saline soils is to develop halophytic crops, i.e., crops that are adapted to a saline environment. An important step in developing halophytic crops is to document and understand those halophytes that are already growing in our natural and agricultural ecosystems. The current paper describes a series of surveys conducted from 1995 to 2004 whose objective was to study the distribution, economic potential, and types of halophytic plant species growing in China.

Materials and methods

Salinized soils are located in eight regions in China (Fig. 1) (Soil Institute of Nanjing, Chinese Academy of Science 1978; Wang and Li 1993). From the middle of June to early August and from early September to late October in every year from 1995 to 2004, samples of halophytic plants and salinized soils were collected from each of these regions. The halophytes were identified to species with the aid of the *Chinese Plant Flora* (Editorial board of the Chinese Academy of Science 1977, 1979, 1985, 1987, 1990, 1991, 1992, 1993, 1994, 1995, 1996, 1997, 1998, 1999) and the *Xinjiang plant Flora* (Editorial board of Xinjiang plants 1992, 1994, 1996, 1999) (Wu 1980; Zhao et al. 2002). The soil samples were analyzed by conventional methods (Soil Institute of Nanjing, China Academay of Science 1978). The salt concentrations (NaCl, NaCl and Na_2SO_4, or NaCl and Na_2CO_3) of the salinized soils ranged from 0.98 to 2.4% in regions 2 through 8. The salt concentrations (NaCl) ranged from 3.0 to 3.6% in the southern part of region 1, and from 0.8 to 4.2% in the northern part of region 1.

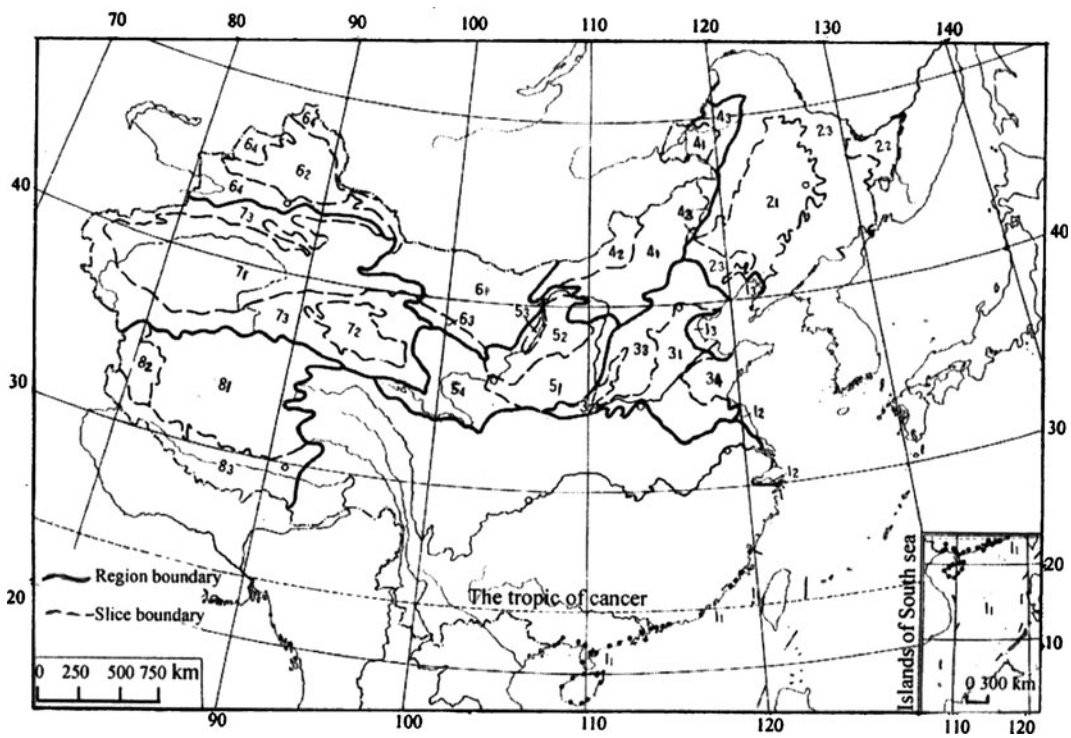

Fig. 1 The classification of the salinized soil region in China: 1. Coastal humid—semihumid salinized region; 2. Semimoist—semiarid grassland and meadow salinized region in northeastern China; 3. Semihumid and semiarid cultivated meadows salinized region on the Huang Huai Hai Plain; 4. Plateau drought–fog–desert grassland salinized region on inner Mongolia; 5. Semi-drought-semifog desert salinized region in the middle and upper reaches of the Yellow River; 6. Arid, fog-desert salinized region in Gansu, Xinjiang, and inner Mongolia; 7. The extremely arid-fog–desert salinized region in Qinghai and Xinjiang; 8. High, cold–fog–desert salinized region in Tibet (Wang and Li 1993)

Table 1 The taxonomy, life form, and distribution of halophytes in China

Families, genus and species	Life form	Distribution	Families, genus and species	Life form	Distribution
Acrostichaceae			*Kaliduim schrenkianum* Bge.ex Ung. –Sternb.	SH	24
Acrostichum aureum L.	PS	1, 4,7	*Kaliduim casoucyn* (L.) Ung.-Sternb.	SH	24
Acrostichum speciosum Willd	PS	7	*Kaliduim gracile Fenzl.*	SH	30
Dryopteridaceae			*Halostachys caspica* (Bieb.) C. A. Mey.	SH	30
Cyrtomium falcatum (L. f.) Presl	PG	3, 4, 27	*Atriplex hastate* L.	A	30
Salicaceae			*Atriplex oblongifolia* Waldst.	A	30
Populus euphratica Oliv.	T	30	*Atriplex cana*. C. A. Mey.	SH	30
Populus pruinosa Schrenk	T	24	*Atriplex micrantha* C. A. Mey.	A	24
Betulaceae			*Atriplex gemelinii* C. A. Mey	A	24
Betula halophila Ching et P. C. Li	T	24	*Atriplex aucheri* Moq.	P	25
Olacaceae			*Atriplex verrucifera* Bieb.	SH	24
Ximenia americana L.	SH	7	*Atriplex repens* Roth	SH	25
Polygonaceae			*Atriplex patens* (Litv.) Iljin	A	28, 29, 30
Calligonum roborovskii A. Los.	SH	24, 30	*Atriplex sibirica* L.	A	24
Polygonum glareosum Schischk.	SH	24	*Atriplex fera* (L.) Bge.	A	11
Polygonum fusco-ochreatum Kom.	A	12, 16	*Atriplex centralasiatica* Iljin	A	11
Polygonum pulvinatum Kom	A	30	*Atriplex centralasiatica. var. sagittiformis* Aellen	A	30
Polygonum corrigioloides. Jaub. et Spach	A	24	*Atriplex triangularis* Wilid	A	from U.S.A
Polygonum humifusum Pall.	A	8, 17, 18	*Atriplex canesens* (Pursh) NuH	P	from U.S.A
Polygonum patulum M. B. Fl.	A	24	*Atriplex maximowicziana* Makino.	PG	2
Polygonum junceum Leadeb.	A	24	*Atriplex tatarica* L.	A	29
Polygonum argyrocoleum Steud. ex G. Kunze	A	24	*Atriplex gmelinii* C. A. *Mey*	A	24
Polygonum sibiricum Laxm.	PG	15, 17, 22	*Atriplex aucheri Mog*	A	25
Polygonum sibiricum var. thomspnii Meisn. ex. Stew	PG	17, 24	*Ceratocarpus arenarius* L.	A	30
Polygonum aviculare L.	A	17, 24	*Panderia turkestanica* Iljin	A	30
Rumex marschallianus Rchb.	A	10, 17	*Camphorosma monspeliaca* L. subsp. lessingii (LItv.) aellen	SH	30
Rumex maritimus L.	A	28, 29	*Corispermum puberulum* Iljin	A	28, 29
Rumex ucranicus Fisch. ex Spreng	A	24, 30	*Corispermum stenolepis* Kitag.	A	28, 29
Chenopodiaceae			*Corispermum declinatum* Steph. var. *tylocarpum* (Hance.) Tsien et C. G. Ma	A	28, 29, 30
Salicornia europaea L.	A	28, 29, 30	*Chenopodium iljinii* Golosk.	A	30
Salicornia bigelovii Torr.	A	From USA	*Chenopodium chenopodioides* (L) Aellen	A	30
Ceratoides ewersmanniana (Stschegl. ex Losinsk.) Botsch. et Ikonn.	SH	1	*Chenopodium acuminatum* Willd	A	28, 30
Halopeplis pygmaea (Pall.) ex Ung. –Sternb.	A	24	*Chenopodium botrys* L.	A	17, 24
Kalidium foliatum (Pall.) Moq.	SH	28, 29, 30	*Chenopodium rubrum* L.	A	29, 30
Kaliduim cuspidatum (Ung. -Sternb.) Grub.	SH	30	*Chenopodium glaucum* L.	A	31
Chenopodium urbicum L. ssp. *sinicum* Kung et G. L. Chu	A	28, 29, 30	*Anabasis truncata* (Schrenk) Bge.	S-S	30
Kochia melanoptera Bge	A	30	*Girgensohnia oppositiflora* (Pall) Fenzl.	A	30
Kochia macroptera Iljin	A	30	*Halogeton glomeratus* (Bicb) C. A. Mey.	A	30
Kochia Krylovii Litv.	A	30	*Halogeton glomeratus. Var. tibeticus* (Bge) Grubov.	A	30
Kochia scoparia (L.) Schrad. var. *canescens* Moq.	A	28, 29, 30	*Halogeton arachnoideus* Miq.	A	30
Bassia dasyphylla (Fisch. et Mey.) O. Kuntze	A	28, 29, 30	*Iljinia regelii* (Bge) Korov.	SH	30

Table 1 (continued)

Families, genus and species	Life form	Distribution	Families, genus and species	Life form	Distribution
Bassia sedoides (Pall.)Aschers	A	24	*Aellenia glauca* (Bieb) Aellen	SH	30
Bassia hyssopifolia (Pay.) O. Kuntze	A	30	*Sympegma regelii* Bge.	SH	30
Kirilowia eriantha Bge.	A	24	*Salsola Soda* L.	A	24
Borszczowia aralocaspica Bunge	A	24	*Salsola komarovii* Iljin	A	28
Suaeda altissima (L) Pall.	A	30	*Salsola zaidamica* Iljin	A	30
Suaeda rigida Kung et G. L. Chu.	SH	30	*Salsola tamariscina* Pall.	A	24
Suaeda arcuata Bge.	A	30	*Salsola rosacea* L.	A	24
Suaeda dendroides (C. A. Mey.) Moq	S-S	30	*Salsola chinghaiensis* A. J. Li	A	18
Suaeda microphylla (C. A. Mey.) Pall.	SH	24	*Salsola paulsenii* Litv.	A	24
Suaeda glauca (Bge.) Bge.	A	28, 29, 30	*Salsola intramongolica* H. C. Fu et Z. Y. Chu	A	17
Suaeda paradoxa Bge.	A	30	*Salsola ruthenica* Iljin	A	29, 30
Suaeda linifolia Pall.	A	24	*Salsola foliosa* (L.) Schrad.	A	24
Suaeda physophora Pall.	SH	30	*Salsola affinis* C. A. Mey.	A	24
Suaeda acuminata (C. A. Mey.) Maq.	A	30	*Salsola subcrassa* M. Pop.	A	24
Suaeda pirzewalskii Bge.	A	30	*Salsola heptapotamica* Iljin	A	24
Suaeda kossinskyi Iljin	A	24	*Salsola lanata* Pall.	A	24
Suaeda liaotungensis Kitag.	A	30	*Salsola korshinskyi* Drob.	A	24
Suaeda corniculata (C. A. Mey.) Bge.	A	30	*Salsola ferganica* Drob.	A	24
Suaeda heterophylla (Kar. et Kir.) Bge.	A	29, 30	*Salsola dschungarica* Iljin.	SH	30
Suaeda stellatiflora G. L. Chu	A	30	*Salsola abrotanoides* Bge.	SH	30
Suaeda prostrata Pall.	A	28, 30	*Salsola nitraria* Pall.	A	24
Suaeda australis (R. Br.) Moq.	SH	24	*Salsola implicate* Botsch.	A	24
Suaeda crassifolia Pall.	A	24	*Salsola sukaczevii* (Botsch) A. J. Li.	A	30
Suaeda salsa (L.) Pall.	A	28, 29, 30	*Salsola brachiata* Pall.	A	30
Horaninowia minor Schrenk.	A	30	*Salsola sinkiangensis* A. J. Li	A	24
Haloxylon persicum Bge ex Boisset Buhse	T	30	*Salsola brachiata* Pall.	A	24
Haloxylon ammodendron (C. A. Mey.) Bge.	T	30	*Petrosimonia sibirica* (Pall.) Bge.	A	24
Anabasis elatior (C. A. Mey.) Schischk.	SH	24	*Petrosimonia glaucescens* (Beg.) Iljin	A	24
Anabasis salsa (C. A. Mey.) Benth.	SH	24	*Petrosimonia squarrosa* (Schrenk) Bge.	A	24
Anabasis cretacea Pall.	SH	24	*Halimocnemis villosa* Kar. et Kir.	A	24
Anabasis aphyla L.	S-S	30	*Halimocnemis longifolia* Bge.	A	30
Anabasis eriopoda (Schrenk) Benth	S-S	30	*Halimocnemis karelinii* Moq.	A	30
Ceratoides latens (J. F. Gmel.) Reveal et Holmgren	SH	23, 25	*Glycine soja* Sieb. et Zucc.	A	28, 30, 31
Ceratoides ewersmanniana (Stschegl. ex Losinsk.) Botsch. et Ikonn.	SH	17, 24	*Canavalia lineata* (Thunb.) DC.	V	4, 27
Nanophyton erinaceum (Pall.) Bge.	SH	24	*Canavalia maritima* (Aubl.) Thou.	V	4, 27
Amaranthaceae			*Trifolum fragiferum* L.	PG	24
Allmania nodiflora (L.) R. Br.	A	9	*Melilotus dentatus* (Waldsf. et Kitag.) Pers.	A	28, 30
Trichurus monsoniae (L. F.) C. C. Townsend	PG	9	*Melilotus albus* Medik	A	32
Aizoaceae			*Halimodendron halodendron* (Pall.) Voss.	SH	30
Sesuvium portulacastrum (L.) L.	PG	4, 5, 28	*Halimodendron halodendron var. albifolorum* (Kar. et Kir.) Prjech	SH	6,17,24
Trianthema portulacastrum L.	A	4, 9	*Lathyrus maritimus* (L.) Bigel.	PG	28, 29

Table 1 (continued)

Families, genus and species	Life form	Distribution	Families, genus and species	Life form	Distribution
Caryophyllaceae			*Indigofera enneaphylla* L.	A	2, 4, 26
Gypsophila paniculata L.	PG	24	*Sesbania cannabina* (Retz.)Pers.	A	2, 27, 31
Gypsophila perfoliata L.	PG	24	*Sphaerophysa salsula* (Pall.) DC.	PG	29, 30, 31
Spergularia marina (L.) Griseb	A	28, 29, 30, 31	*Glycyrrhiza korshinskii* G. Grig.	PG	28, 29, 30
Ranunculaceae			*Glycyrrhiza uralensis* Fisch.	PG	28, 29, 30
Halerpestes ruthenica (Jacq.) Ovcz.	PG	28, 29, 30	*Glycyrrhiza pallidiflora* Maxim.	PG	28, 29, 30
Halerpestes sarmentosa Adams	PG	23, 28, 29, 30	*Glycyrrhiza squamulosa* Franch.	PG	28, 29, 30
Halerpestes tricuspis (Maxim.) Hand. –Mazz.	PG	20, 28, 30	*Glycyrrhiza glabra* L.	PG	28, 29, 30
Halerpestes filisecta L. Liou	PG	23	*Glycyrrhiza inflata* Bat.	PG	28, 29, 30
Hernandiaceae			*Oxytropis galbra* (Lam.)DC	PG	30
Hernandia sonora L.	T	27	*Oxytropis glabra var. tenuis* Palib	G	30
Cruciferae			*Oxytropis glareosa* Vass.	PG	30
Lepidium cordatum Willd. Ex Stev.	PG	30	*Oxytropis gorbunovii* Boriss.	PG	30
Lepidium cartilagineum (J. May) Thell	PG	30	*Oxytropis hirsutiuscula* Freyn	PG	30
Lepidium latifolium L.	PG	17, 23	*Oxytropis puberula* Boriss.	PG	30
Lepidium latifolium L. var. affine. C. A. Mey.	PG	28, 30	*Oxytropis martijanovii* Kryl.	PG	30
Dilophia salsa Thoms.	PG	23, 30	*Astragalus contortuplicatus* L.	A	3
Thellungiella salsuginea (Pall.) O. E. Schulz	A	29, 30, 31	*Astragalus chinensis* L.	PG	30
Thellungiella halophila (C. A. Mey.) O. E. Schulz	A	28, 29	*Astragalus alopecias* Pall.	PG	29, 30
Rosaceae			*Astragalus sulcatus* L.	PG	30
Potaninia mongolica Maxim	SH	17	*Astragalus adsurgens* Pall.	PG	30
Potentilla imbricata Kar. et Kir.	PG	25	*Astragalus toksunensis* S. B. Ho	PG	29, 30
Potentilla anserine L.	PG	24	*Astragalus roseus* Ledeb.	PG	30
Sibbaldia adpressa Bge.	PG	10, 23, 29	*Astragalus salsugineus* Kar. et Kir. var multijugus S. B. Ho	PG	30
Fabaceae			*Astragalus orbiculantus* Ledeb.	G	24
Sophora alopecuroides L.	SH	23, 30	*Astragalus lasiopetalus* Bge.	PG	17, 24
Smithia salsuginea Hance	A	4	*Gueldenstaedtia maritima* Maxim.	PG	24
Alhagi sparsifolia Shap. Ex Kell. Et Shap.	SH	30	*Lotus corniculatus* L.	G	30
Desmodium rubrum (Lour.) DC.	SH	4, 9	*Lotus tenuis Waldst. et* Kit. ex Willd.	G	30
Pongamia pinnata (L.) Merr.	V	2, 4, 27	*Lotus frondosus* (Freyn) Kupr.	G	30
Derris trifoliata Lour.	V	2, 4, 27	*Trigonella cancellata* Desf.	A	30
Trigonella arcuata C. A. Mey.	A	30	*Frankenia pulverulenta* L.	A	30
Medicago upulina L.	A	30	**Tamaricaceae**		
Medicago falcate var. romanica (Brandza) Hayek	PG	30	*Reaumuria songarica* (Pall.) Maxim.	SH	29, 30
Medicago falcate L. var. falcata.	PG	30	*Reaumuria kaschgarica* Rupr.	SH	30
Thermopsis lanceolata R. Br.	G	20	*Tamarix korolkovii* Rge. et Schmalh.	SH	24
Zygophyllaceae			*Tamarix taklamakanensis* M. T. Liu	SH	30
Nitraria sibirica Pall.	SH	28, 30	*Tamarix arcenthoides.* Bunge	SH	30
Nitraria tangutorum Bobr.	SH	30	*Tamarix elongata* Ledeb.	SH	30
Nitraria roborowskii Kom.	SH	24	*Tamarix laxa* Willd.	SH	30
Nitraria schoberi L. SH. Xeoh.	SH	24	*Tamarix androssowii* Litv.	SH	30
Peganum harmala L.	PG	30	*Tamarix gracilis* Willd.	SH	30
Zygophlyyum macropodum Boriss	PG	24	*Tamarix gansuensis* H. Z. Zhang	SH	30

Table 1 (continued)

Families, genus and species	Life form	Distribution	Families, genus and species	Life form	Distribution
Zygophlyyum jaxarticum M. Pop	A	30	*Tamarix sachuensis* P. Y. Zhang et M. F. Liu	SH	30
Zygophlyyum loczyi Ranitz	A	30	*Tamarix karelinii* Bge.	SH	30
Zygophlyyum pterocarpum Bge.	A	30	*Tamarix hispida* Willd.	SH	30
Rutaceae			*Tamarix leptostachys* Bge.	SH	30
Haplophyllam perforatum Kar. et Kir.	PG	24	*Tamarix hohenackeri* Bge.	SH	28, 30
Simaroubaceae			*Tamarix chinensis* Lour	SH	28, 30
Suriana maritima L.	SH	27	*Tamarix austromongolica* Nakai	SH	28, 30
Meliaceae			*Tamarix ramosissima* Ledeb.	SH	28, 30
Xylocarpus granatum Koenig.	T	4	**Elaeagnaceae**		
Euphorbiaceae			*Elaeagnus angustifolia* L.	T	28, 29, 30
Excoecaria agallocha L.	SH	4, 27	*Elaeagnus angustifolia var. orientalis* (L.) Kuntze	T	24
Euphorbia soongarica Boiss.	A	30	*Elaeagnus songarica* (Bernh. ex Schlecht.) Schlecht.	T	24
Euphorbia atota Forst. f.	SH	4, 27	*Elaeagnus oxycarpa* Schlecht.	T	24
Sapindaceae			*Elaeagnus moorcroftii* Wall. ex. Schlecht.	T	30
Allophylus timorenlsis (DC.) Bl.	SH	9, 27	*Hippophae rhamnoides* L. subsp. turkestanica Rousi	SH	24
Dodonaea viscosa (L.) Jacq.	SH	27, 33	*Hippophae rhamnoides subsp. mongolica* Rousi	SH	30
Malvaceae			**Lythraceae**		
Althaea officinalis L.	PG	24	*Pemphis acidula* J. R. et Forst.	SH	27
Althaea rosea (Linn.) Cavan.	PG	34	*Lythrum thymifolia* L.	A	24
Hibiscus tiliaceus L.	SH	4, 27	*Lythrum virgatum* L.	PG	30
Thespesia populnea (L.) Soland. ex Corr.	T	4, 27	*Lythrum salicaria* L.	PG	30
Thespesia howii S. Y. Hu	T	7	**Cynomoriaceae**		
Kosteletzkya virginica (L.) Presl.	A	From USA	*Cynomorium songaricum* Rupr.	PP	28, 30
Sterculiaceae			**Sonneratiaceae**		
Heritiera littoralis Dryand.	T	4, 27	*Sonneratia caseolaris* (L.) Engl.	T	4, 7
Guttiferae			*Sonneratia alba* J. Smith.	SH	7
Calophyllum inophyllum L.	T	7, 27	*Sonneratia hainanensis* K. E. Chen et S. Y. Chen	T	7
Frankeninaceae			*Sonneratia avata* L.	SH	4, 26
Lecythidaceae			*Limonium wrightii* (Hance) Kuntz.	SH	27
Barringtonia racemosa (L.) Spreng.	T	7, 27	*Limonium tenellum* (Turcz.) Kuntz.	PG	30
Barringtonia asiatica (L.) Kurz.	T	27	*Limonium aureum* (L.) Hill.	PG	28, 29, 30
Rhizophoraceae			*Limonium otolepis* (Sohreuk) Kuntz.	PG	24
Rhizophora apiculata Bl.	T	4, 7	*Limonium coralloides* (Tausch.) Lincz.	PG	24
Rhizophora mucronata Poir.	T	27	*Limonium myrianthum* (Schrenk.) Kuntz.	PG	24
Rhizophora stylosa Griff.	T	4, 7, 27	*Limonium gmelinii* (Willd.) Kuntz.	PG	24
Ceriops tagal (Perr.) C. B. Rob.	SH	4, 27	*Limonium suffruticosum* (L.) Kuntz.	PG	24
Kandelia candel (L.) Druce	SH	4, 27	*Limonium roborowskii* IkM-Gal.	PG	30
Bruguiera gymnorrhiza (L.) Poir.	T	4, 27	**Loganiaceae**		
Bruguiera sexangula (Lour.) Poir.	T	7	*Mitrasacme indica* Wright	A	8
Bruguiera sexangula (Lour.) Poir. var. rhynchopetale Ko.	SH	7	**Apocynaceae**		
Bruguiera cylindrica (L.) Bl.	T	7	*Cerbera manghas* L.	T	4, 7, 27
Combretaceae			*Apocynum venetum* L.	SH	29.30.22
Lumnitzera racemosa Willd.	SH	4, 27	*Poacynum pictum* (Schrenk) Bail.	SH	30
Lumnitzera littorea (Jack.) Voigh.	SH	7	*Poacynum hendersonii* (Hook. f.) Woodson.	SH	30
Terminalia catappa L.	T	4, 27	**Asclepiadacea**e		

Table 1 (continued)

Families, genus and species	Life form	Distribution	Families, genus and species	Life form	Distribution
Onagraceae			*Gymnanthera nitida* R. Br.	V	4
Oenothera littaralis Schlect.	SH	2	*Cynanchum Chinense* R. Br	V	28.29.30
Umbelliferae			*Cynanchum insulanum* (Hance) Hemsl.	V	4.5
Sium sisaroideum DC.	PG	24	*Cynanchum sibiricum* Willd.	PV	28, 30
Sium sisarum L. PG. hydrah.	PG	24	*Cynanchum kashgaricum* Liou f.	PG	24
Cnidium salinum Turcz.	PG	29, 30	*Cynanchum cathayense* Tsiang et Zhang	PG	24
Cnidium salinum Turcz. var. rhizomaticum Y. C. Ma	PG	29, 30	*Tyyophora arenicola* Merr.	V	4.5
Cnidium japonicum Miq.	PG	22, 30	*Hoya carnosa*	V	5, 26
Glehnia littoralis F. Schmidt.	PG	28, 30, 33	*Dischidia chinensis* Champ. ex Benth.	V	4, 5
Peucedanum japonicum Thunb.	PG	2, 22, 27	**Convolvulaceae**		
Ferula krylovii Korov.	PG	24	*Calystegia soldanella* (L.) R. Br	A	28.30.27
Seseli eriocephalum (Pall.) Schk.	PG	24	*Ipomoea polymorpha* Roem. et Schult	A	4.27
Schumannia karelinii (Bge.) Korov.	PG	24	*Ipomoea pes-tigridis* L.	A	4.27
Schumannia turcomanica Kuntze	PG	30	*Ipomoea obscura* (L.) Ker-Gawl	V	4.27
Myrsinaceae			*Ipomoea pes-caprae* (L.) Sweet.	PG	4.27
Aegiceras corniculatum (L.) Blanco.	SH	2, 7	*Ipomoea stolonifera* (Cyrillo) J. F. Gmel	PG	4.27
Primulaceae			*Ipomoea gracilis* R. Br.	A	35
Lysimachia mauritiana Lam.	A	4, 22, 27	*Ipomoea tuba* (Sohlecht.) G. Don	V	4.27
Glaux maritima L.	PG	29, 30	*Stictocardia tiliaefolia* (Desr.) Hall. f.	V	4.27
Plumbaginaceae			**Boraginaceae**		
Limonium sinense (Girard) Kuntz.	PG	2, 4, 28, 30	*Coldenia procumbens* L.	A	7, 27
Limonium bicolor (Bge.) Kuntz.	PG	28, 30	*Heliotropium micranthum* (Pall.) Bge.	A	24
Limonium franchetii (Debx.) Kuntz.	PG	22, 30	*Heliotropium marifolium* Retz.	A	7
Messerschmidia sibirica L.	PG	29.30.28	*Myoporum bontioides* (Sieb. et Zucc.) A. Gray.	T	2, 4, 27
Messerschmidia argentaa (L.F.) Johmt	PG	7	**Plantaginaceae**		
Rochelia retorta (Pall.) Lipsky	A	24	*Plantago aristata* Michx.	A	22
Gastrocotyle hispida (Forsk) Bge.	A	24	*Plantago maritima* L. var. salsa (Pall.) Pilger	PG	30
Nonea caspica (Willd.) G. Don.	PG	24	*Plantago maxima* Juss. ex Jacq.	PG	24
Cynoglossum viridiforum Pall. Et Lehm.	PG	24	*Plantago cornuti* Gouen	PG	24
Mertensia asiatica (Takeda) Maobird.	PG	16	*Plantago lessingii* Fisch. et Mey.	A	24
Verbenaceae			**Rubiaceae**		
Avicennia marina (Forsk.) Vierh	SH	2.4.27	*Scyphiphora hydrophyllaceae* Gaertn. f.	SH	7
Clerodendrum inerme (L.) Gaertn	SH	2.4.27	**Goodeniaceae**		
Vitex trifolia L. var *simplicifolila* Clam	SH	28.30.4.27	*Scaevola hainanensis* Hance	SH	2, 4, 27
Premna obtusifolia R. Br.	SH	11	*Scaevola sericea* Vahl.	SH	2, 4, 27
Labiatae			**Flacourtiaceae**		
Ajuga dictyocarpa Hayata			*Scalopia chinensis*	SH	4, 11
Scutellaria strigillosa Hemsl	A	4.2.27	**Capparidaceae**		
Leucas chinensis (Retz.) R. Br.	A	4.27	*Crateva religiosa* Forst.	SH	4, 26
Leucas lavandlifolia Smith.	A	22.30	**Flagellariaceae**		
*Leucas zeylannic*a (L.) R.Br.	A	4.5	*Flagellaria indica* Linn	V	4, 11
Mentha vegans Boriss	PG	1.2.24	**Asteraceae**		
Solanaceae			*Achillea asiatica* Serg.	PG	24
Lycium ruthenicum Murr.	SH	25.30	*Tripolium vulgare* Nees.	A	28, 29, 30
Lycium dasystemum Pojark.	SH	30	*Brachyactis ciliata* Ledeb.	A	28, 29, 30

Table 1 (continued)

Families, genus and species	Life form	Distribution	Families, genus and species	Life form	Distribution
Lycium chinense Mill.	SH	28.30.33	*Pluchea pteropoda* Hemsl.	SH	27
Lycium barbarum L.	SH	30.10	*Pluchea indica* (L.) Less.	SH	27
Scrophulariaceae			*Karelinia caspia* (Pall.) Less.	PG	24
Linaria japonica Miq.	PG	16	*Helichrysum arenarium* (L.) Moench.	PG	24
Dodartia orientalis L.	PG	24	*Inula caspica* Bl.	A	24
Castilleja pallida (L.) Kunth	PG	12	*Inula caspica var. scaberrima* Trautv.	PG	24
Odontites serotina (Lam.) Dum.	A	28, 29, 30	*Inula britanica* L.	PG	24
Bignoniaceae			*Inula salsoloides* (Turcz.) Ostenf.	SH	30
Dolichandrone spathaceae (L. f.) K. Schum.	T	7	*Dendranthema indicum* (DC) Des Moul	PG	28, 29, 30
Orobanchaceae			*Pyrethrum krylovianum* Krasch.	PG	24
Cistanche salsa (C. A. Mey.) G. Beck	PPY	30	*Artemisia obtusiloba* Ledeb.	PG	1,2,24
Cistanche fissa (C. A. Mey.) G. Beck	PPY	24	*Artemisia halodendron* Turcz. ex. Bess.	SH	28,29,30
Orobanche amonena C. A. Mey.	PPP	24	*Artemisia anethifolia* Web. ex Stechm.	A	28, 29, 30
Acanthaceae			*Artemisia anethoides* Mattf.	A	28, 29, 30
Acanthus ilicifolius L.	SH	2, 4, 27	*Artemisia fauriei* Nakai	PG	10 ,22
Acanthus ebracteatus Vahl.	SH	2, 4, 27	*Artemisia adamsii* Bess.	PG	30
Acanthus xiamenensis	SH	4, 25	*Artemisia dalai-lamae* Krasch.	SH	30
Myoporaceae			*Artemisia fukudo* Makino	PS	27
Artemisia littoricola Kitam.	PS	12, 17	*Saussurea salsa* (Pall.) Spreng. var. integrifolia H. C. Fu et D. S. Wen.	PG	18
Seriphidium heptapotamicum (Poljak) Linget Y. R. Ling.	PG	24	*Saussurea thoroldii* Hemsl.	PG	30
Seriphidium amoenum (Poljak.) Poljak.			*Saussurea grubovii* Lipsch	PG	24
Seriphidium schrenkianum (Ledeb.) Poljak.	PG	24	*Saussurea alata* DC.	PG	24
Seriphidium brevifolium (Wall. ex DC.) Ling et Y. R. Ling	SH	25	*Saussurea famintzinizna* Krassn.	PG	30
Seriphidium gracilescens (Krasch. et Iljin) Poljak.	SH	24	*Saussurea lacostei* Danguy	PG	24
Seriphidium ferganense (Krasch. ex Poljak) Poljak.	PG	30	*Saussurea turgaiansis* B. Fedtsch.	PG	24
Seriphidium nitrosum (Web. ex Stechm.) Poljak.	PS	24	*Saussurea arejingensis* K. M. Shen.	PG	24
Seriphidium santolinum (Schrenk) Poljak.	PG	17, 24	*Saussurea pesudoalpina* N. D. Simps.	PG	30
Seriphidium nitrosum var. gobicum (Krasch. ex Poljak) Y. R. Ling	PG	24	*Scorzonera mongolica* Maxim.	PG	28, 30
Seriphidium terrae-albase (Krasch) Poljak.	PG	17, 24	*Scorzonera parviflora* Jacq.	PG	24
Seriphidium semiaridum (Krasch. et Lavr.) Ling et Y. R. Ling	PG	24	*Scorzonera pusilla* Pall.	PG	24
Ligularia macrophylla (Ledeb.) DC.	PG	24	*Scorzonera ensifoila* Lipsch	PG	30
Ligularia thyrsoidea (Ledeb.) DC.	PG	24	*Scorzonera tuberosa* Pall.	PG	30
Senecio jacobaea L.	PG	28, 30	*Scorzonera circumflexa* Krasch. en. Lipsch.	PG	30
Senecio dubitabilis C. Jeffery et Y. L. Chen	A	30	*Scorzonera iliensis* Krasch.	PG	24
Acroptilon repens (L.) DC.	PG	28, 30	*Scorzonera austriaca* Willd.	PG	24
Cirsium lanatum (Roxb. ex Willd.) Spreng	A	30	*Hexinia polydichotoma* (Ostenf.) H. L. Yang	PG	30
Cirsim setosum (Willd.) MB.	PG	30	*Taraxancum bicorne* Dahlst.	PG	24
Cirsim fangii Petrak	PG	30	*Taraxancum bessarabicum* (Hornem.) Hand. -Mazz.	PG	24
Cirscium alatum (S. G. Gmel.) Bobr.	PG	24	*Taraxancum sinicum* Kitag.	PG	28, 30
Serratula dissecta Ledeb.	PG	30	*Taraxancum dissectum* (Ledeb.) Ledeb.	PG	30
Chartolepis intermedia Boiss	PG	30	*Taraxancum monochiamydeum* Hand.	PG	24

Table 1 (continued)

Families, genus and species	Life form	Distribution	Families, genus and species	Life form	Distribution
Centaurea adpressa Ledeb.	PG	30	*Taraxancum kok-saghyz* Rodin.	PG	24
Saussurea runcinata DC.	PG	29, 30	*Paramicrorhychus procumbens* (Roxb.) Kirp.	PG	24
Saussurea runcinata DC. var. pinnatidentata (Lipsch) H. C. Fu et D. S. Wen	PG	30	*Youngia stenoma* (Turcz.) Ledeb.	PG	24
Saussurea laciniata Ledeb.	PG	30	*Mulgedium tataricum* (L.) DC. (Lactuca tatarica (L.) C. A. Mey)	PG	28, 30
Saussurea amara (L.) DC.	PG	28, 29, 30	*Chorisis repens* (L.) DC.	PG	34
Saussurea prostrata C. Winkl.	PG	24	**Pandanaceae**		
Saussurea robusta Ledeb.	PG	24	*Pandanus tectorius* Sol	T	2,4,27
Saussurea davurica Adam.	PG	29, 30	*Pandanus tectorius* Sol var. Sinensis Warb	T	4,27
Saussurea salsa (Pall.) Spreng.	PG	30	**Potamogetonaceae**		
Saussurea salsa (Pall.) Spreng. var. pinnatidentata H. C. Fu et D. S. Wen.	PG	29, 30	*Ruppia rostella* Koeh	SP	4,27,28,30
Zostera marina L.	SP	16,22	*Parapholis incurva* (L.) C. E. Hubb.	A	38
Zostera coulescens Miki.	SP	16	*Leymus multicaulis* (Kar.et.Kir.) Tzv el.	PG	24
Zostera asiatica Miki.	SP	16	*Leymus paboanus* (Claus) Pilger.	PG	30
Zostera caespitosa Miki.	SP	16,22	*Leymus mollis* (Trin.) Hara	PG	28
Zostera japonica Aschers	PS	22,16	*Leymus chinensis* (Trin.) Tzvel.	PG	29,30
Phyllospadix iwatensis Makino.	PS	16,22	*Leymus secalinus* (Georgi) Tzvel.	PG	27,28,29
Phyllospadix japonica Makino.	SP	7	*Leymus angustus* (Trin.) Pilger	PG	30
Posidonia australis Hook.f	SP	7	*Leymus kopetdaghensis* (Roshev.) Tzvel.	PG	17
Halodule uninervis (Forsk.) Asch.	SP	7,27	*Leymus aerginchanicus* Subsp.aerginshanicus	PG	24
Halodule pinifolia (Miki) Hartog	SP	7,27	*Leymus secalinus* Subsp. Pubescens. Tzvel.	PG	24
Syringodium isoetifolium (Asch) Dandy			*Leymus racemosus* (Lam.) Tzvel.	PG	20
Najadaceae			*Leymus angustus subsp. macroantherus* D. F. Cui	PG	24
Cymodocea rotundata Asch. et Schwainf	SP	7	*Hordeum brevisubulatum* (Trin.) Link	PG	29,30
Zannichellia palustris L.	SP	32	*Hordeum roshevitzii* Bowd.	PG	30
Zannichellia palustris L. var. *pedicellata wahlenb*	SP	32	*Hordeum bogdonii* Wilensky	PG	30
Juncaginaceae			*Puccinellia macranthera* Krecz.	PG	8,17
Triglochin maritimum L	PG	28,30	*Puccinellia tenuiflora* (Griseb.) Scribn, et Merr.	PG	28,30
Triglochin palustre L.	PG	28,30	*Puccinellia hauptiana* (Trin.) Krecz.	PG	28
Hydrocharitaceae			*Puccinellia distans* (Jacq.) Parl.	PG	28
Halophila ovalis (R. Br.) Hook.f.	PS	7	*Puccinellia micrandra* (Keng) Keng	PG	28,30
Halophila minor (Zool.) Hartog	PS	7	*Puccinellia schischkinii* (Kreez) Persson. Subsp. hackkeliana.	PG	30
Halophila beccarii Asch	PS	7,27	*Puccinellia hackkeliana* (Krecz) perssm	PG	30
Enhalus acoroides (L.f.) L. C. Rich. ex Steud.	PS	7	*Puccinellia hackkeliana* Subsp. Humilis. Tzvel.	PG	24
Thalassia hemperichii (Ehrenb.) Aschers.	PS	27	*Sclrerochloa kengiana* (Ohwi) Tzvel.	A	1,22
Poaceae			*Achnatherum splendens* (Trin.) Nevski	PG	28,30
Phragmites austialis (Cav.) Trin	PG	32	*Panicum repens* L.	PG	2,14
Aeluropus pilosus (X.L. Yang) S.L. Chen ex H.L. Yang	PG	28, 29	*Paspalum vaginatum* SW.	PG	7,27
Aeluropos sinensis (Debeaux) Tzvel.	PG	28,29,30	*Paspalum disticharm*	PG	4,7
Aeluropos pungens (M. Bieb.) C. Koch	PG	6,24	*Digitaria mollicoma* (Kunth) Henr.	PG	2,4,27
*Sporobolus vriginicus (*L.) Kunth	PG	2,4,27	*Digitaria heterantha* (Hook. f.) Merr.	PG	2,4,27
*Crypsis aculeate (*L.) Ait	A	28,30	*Digitaria bicornis* (Lam.) Roem. et.Schult.	PG	2,7
*Crypsis schoenoides (*L.) Lam.	A	17,24	*Calamagrostis epigeios* (L.) Roth	PG	30

Table 1 (continued)

Families, genus and species	Life form	Distribution	Families, genus and species	Life form	Distribution
Zoysia macrostachya Franch.	PG	1,22	*Calamagrostis pseudophragmites* (Hall. f.) Koel.	PG	24,8,26
Zoysia japonica Steud.	PG	2,27,28,30	*Chloris virgata* Sw.	A	24,8,4
Zoysia matrella (L.) Merr.	PG	4,2,27	*Cynodon arcuatus* J.S. Presl ex C.B. Preal	PG	24
Spartina anglica C. E. Hubb.	PG	Europe	*Buchloe dactyloides* (Nutt.) Engelm.	PG	30
Spartina alternifora Loisel. I.	PG	Europe	*Cenchrus calyculatus* Cav.	A	16
Lepturus repens (G. Forst.) R.Br.	PG	27	*Spinifex littoreus* (Burm. f.) Merr.	PG	2,4,27
Thuarea involuta (Forst.) R. Br. ex Roem.et Schult.	PG	4,27	*Carex kobomugi* Ohwi	PG	28,29,30
Ishaemum anteporoides (Steud.) Miq.	PG	4,22	*Carex reptabunda* (Trautv.) V. Krecz.	PG	30
Phacelurus latifolius (Setud.) Ohwi	PG	1,10,22	*Carex pumila* Thunb.	PG	22,27,30
Phacelurus latifolius var.angutifolius (Debeaux) Kitagawa.	PG	22	*Carex scabrifolia* Steud.	PG	27,30
Phacelurus latifolius var.monostachyus Keng.	PG	13,22	**Palmae**		
Cyperaceae			*Nypa fruticans* Wurmb.	SH	7
Scirpus planiculmis Fr. Schmidt.	PG	28,30,31	**Restionaceae**		
Scirpus strobilinus Roxb.	PG	30	*Leptocarpus disjunctus* Mast.	PG	5,7
Scirpus mariqueeter Tang et Wang	PG	13,8	**Commelinaceae**		
Scirpus neochinensis Tang et Wang	A	13	*Murdannia vaginata* (L.) Brueckn	PG	4,5,7
Fimbristylis sericea (Poir.) R. Br.	PG	2,4,27	**Liliaceae**		
Fimbristylis ferrugineae (L.) Vahl.	PG	2,4,27	*Asparagus persicus* Baker.	PG	30
Fimbristylis polytrichoides (Retz.) Vahl.	PG	4,7	*Allium polyrhizum* turez. ex. Regel.	PG	30
Remirea maritima Aubl.	PG	7,27	**Iridaceae**		
Cyperus fuscus L.	A.	17, 24	*Iris halophila* Pall.	PG	3,24
Cyperus iria L.	A.	17, 24	*Iris halophila* Pall. var.sogdiana Pall	PG	6,24
Cyperus stoloniferus Retz.	PG	2	*Iris lactea* Pall. var.*chinensis* (Fisch.) Koidz.	PG	23,28,29,30
Cyperus malaccensis Lam. var. brevifolius Bocklr.	PG	2,4,5	**Orchidaceae**		
Juncellus pannonicus (Jacq.) C. B. Clarke	PG	29,30,28	*Orchis latifolia* L.		
Mariscus janvanicus (Houtt.) Merr.	PG	7	*Tulip schrenkii* Regel	PG	30

The halophytic species in Table 1 were identified based on the *Flora Xinjiang Genesis* and *Chinese Plant Flora*. Halophytes in the table can survive and reproduce in around 200 mM NaCl

Life form: A-annual; F-fern; P-perennial; PG-perennial grass; PPP-parasitic perennial plant; PSG-perennial sea grass; PS-perennial shrub; SH-shrub; SG-sea grass; SP-submerged plant; V-vine

Distribution: 1. Anhui; 2. Fujian; 3. Gansu; 4. Guangdong; 5. Guangxi; 6. Guizhou; 7. Hainan; 8. Hebei; 9. Henan; 10. Hubei; 11. Hunan; 12. Heilongjiang; 13. Jiangsu; 14. Jiangxi; 15. Jilin; 16. Liaoning; 17. Neimenggu; 18. Ningxia; 19. Qinghai; 20. Shanxi; 21. Shaaxi; 22. Shandong; 23. Sichuan; 24. Xinjiang; 25. Xizang; 26. Yunnan; 27. Taiwan; 28. Northern China; 29. Northeastern China; 30. Northwestern China; 31. Eastern China; 32. The entire country; 33. Southern China; 34. Western China; 35. Xisha lands; 36. From Europe; 37. From U.S.A.; 38. Zhejiang

Results

Species of halophytes in China

Based on surveys from 1995 to 2004, China contains 587 species of halophytes (Table 1) (Li 1988, 1990; Zhao and Li 1999; Zhao et al. 2002; Xi et al. 2006); these species occur in 242 genera and 71 families and represent 10% of the angiosperm species in China. The families with the most species are the Chenopodiaceae (120 species in 29 genera) (recently some taxonomists suggest the Chenopodiaceae may be merged into the Amaranthaceae: http://www.mobot.org/MOBOT/research/APweb/), the Asteraceae (82 species in 26 genera), the Poaceae (25 genera, 55 species), and the Fabaceae (51 species in 24 genera) (some

Table 2 The salinized regions, climate trends, soil types and common halophytes in China

Region Names[a]	Limits of Region[a]	Climate trends[a]					Soil types	Common halophytes[b]
		Frost-free days	Annual accumulated temperature (≥10°)	Yearly rainfull (mm)	Yearly Evapo-ration (mm)	Evaporation to rainfull ratio		
Coastal humid - semihumid seawater soaking salinized region that are infiltrated by sea water	From Liaodong peninsula, Bohai sea, Yellow sea, East sea to Taiwan strait, South sea and Hainan island	North part: 165-225 middle part: 240 South part: 240–365	3200–4100 800–2000 8000–9500	400–700 800–2000 1200–2000	800–1800	<1–2.5	The main accumulated salt is NaCl. There is a soda component in the northern part and an acidic sulphate component in the southern part. The soil is a transgression meadow type.	South part: *Bruguiera cylindrica*, *B. gymanorrhira*, *Rhizophora apicalata*, *Acanthus ilicifoliu*, *Nypa fruticans*, *Sonneratia alba*; middle and north part: *Suaeda maritima*, *S. salsa*, *Salicornia*, *Phragmites communis*; and some submerged halophyte: *Zostera marina*, *Rupia rostellata*, *Phyllospadix japonica*
Semimoist–semiarid grassland and meadow salinized region in northeastern China	Sanjiang plain, Songnen plain and Liaohe plain	120–180	2000–3400	400–800	1600–1800	2–3	The soda content of the ground water ranges from 50% to 80%. This area mainly accumulates soda and gradually develops into meadow alkaline soils.	*Suaeda corniculata*, *Puccinellia tenuiflota*, *Aeluropus litoralis*, *Kochia sieversiana*, *Stipa baicalensis* and *Iris pallasii*, *Atriplex centralasiatica*, *Salsola collina*, *Suaeda glauca*, *Nitraria sibirica*, *Tamarix chinensis*, *Lycium chinense*
Semihumid and semiarid cultivated meadows salinized region on the Huang Huai Hai Plain	The great alluvial plain of Huang, Huai river and Hai river in Ji, Lu, Yu, Su and Wan	170–220	3400–4500	500–700	1800–2000	3–3.5	This region is characterized by seasonal salt accumulation and desalinization and also by some alkalinization, resulting in salinized meadow soils. The main salt is SO_4-Cl or Cl-SO_4	There are herbaceous plants and a few shrubs: *Aeluropus sinensis*, *Suaeda salsa*, *Nitraria angutorum*, *Phragmites australis*, *Artemsia anethifolia*, *Limonium sinense*, *Crypsis aculeatta*, *Tamarix chinensis*, *Imperata cylindrica*
Plateau drought – hemifog - desert grassland salinized region on inner Mongolia	From the east part plateau of inner Mongolia, the middle part grassland and the north part of Langshan	140–160	2000–3000	200–350	2000	5–10	Mainly alkaline soils occur in the dry steppe, and they develop into soda meadows around lakes and dry rivers. The form soil type is a dry steppe-desert steppe	*Stipa grandis*, *S. krylorii*, *S. bungeana*, *S. breviflora*, *Cleistogenes*, *C. polyphylla*, *Astragalus danhuricus*, *Festucs sulcata*, *Cleistogenes mutica*, *Artemisia xerophytica*, *Anabasis*

Table 2 (continued)

Region Names[a]	Limits of Region[a]	Climate trends[a]					Soil types	Common halophytes[b]
		Frost-free days	Annual accumulated temperature (≥10°)	Yearly rainfall (mm)	Yearly Evapo-ration (mm)	Evaporation to rainfall ratio		
	to the boundary of China and Mongolia							*brevifolia, Salsola passerine, Reaumuria soongorica, Ajania frutticulosa, Salsola pestifer, Halogeton arachoids, Artemisia frigia*
Semi-drought-semi-fog-desert salinized region in the middle and upper reaches of the Yellow River	The part area of Shanxi, Gansu, Qinghai, inner Mongolia and a part of Ningxia which are passed through by Yellow River	140–180	2500–3500	150–500	1800–2400	3–10	Salt accumulates as sulphate and carboxylates in bottom soils of the loess plateau and as soda alkalized soil and Cl-SO_4 or SO_4-Cl alkalized soil in the alluvial plain of the Yellow River	*Suaeda* spp., *Achnatherum splendens, Taraxacum* spp., *Triglochin palustre, Polggonum* spp., *Juncus* spp., *Ophiopogon* spp., *Taraxacum monglicum.* The diversity and abundance of halophytic plants are less than in above regions.
Arid, fog-desert salinized region in Gansu, Xinjiang, and inner Mongolia	Gansu, Hexi, Corridor, west part of inner Mongolia Elashan and north part of Xingjiang (Zhunger plain)	90–150, more in the basin zone	Exceed-ing 2000	100–200, or less than 100	>2000	10–20	Salt accumulation is substantial in this region because soil salinization and turtleback alkalinization occur on a large scale. relic salt accumulation	This region supports many xerohalophytes, such as *Cynolossum viridiflorum, Nonea capsica, Anabasis cretacea, Atriplex cana, Chenopodium rubrum, C. urbicum, Kalidium capsicum, Salsola affinis, S. heptapotamica, S. nitraria, S. subcrassa, Inula caspica, Scorzonera iniensis, Serratula dissecta, Cynodon dactylon, Leymus chinensis,* and *Rumex marshchallianus*, *Lycium barbarum, L. dasystemum, Tamarix androssowii*
The extremely arid – fog – desert salinized region in Qinghai and Xinjiang	Tulufan Basin, Talimu Basin, down stream of Shule river and Chaidam Basin	180–270, more in the basin zone	4000–2000	15–80	2000–3000	20–40	Soil salinization is widespread in this region. There are boronic-salt, lithic-salt, and kalisalt deposits. The form soil type is desert.	*Reaumuria songarica, Tamarix androssowii, T. gansuensis, T. hahenackoeri, T. lava. Nitraria schoberi, N. tangutorum, Kalidium capsicum, K. cuspidatum, K. foliatftum, Salsola affinis, S. arbuscula, S. brachiata, S. nifraria, Ceratoides ewersmanniana*

High, cold – fog – desert salinized region in Tibet	Tibet Plateau	180–240	Changeable	<100–300	Changeable	10–20	Saline soils are mainly distributed on the borders of lakes and in the lowland of the river valleys. The salts are mainly sulphates but there is also some soda. The form soil type is cold desert	*Saussurea* spp.. *Oxtrapis* spp., *Ceratoides lalens, Halerpestes sanmentosc, H. trcuspis, H. filisecta, Lepidium latifolium, Dilophia salsa, Sibbalida,* and *Carex* spp. Halophyte species are in the minority.

[a] from Wang and Li 1993, and [b] from Chen et al. 1990, 1997; Desert Institute of Lanzhou in China Academy of Science 1986; Li and Wang 1990; Li and Zheng 1997; Li et al. 2001; Lin 1990, 1993; Lin and Fu 1995; Ninxia Agriculture Prospesting College 1990; Ramadan 1998; Shao et al. 2004; The Biology, Soils and Desert Institute of Xinjiang 1981; Wu 1980; Wu and Wang 1983; Xi et al. 2006; Xiong and Li 1990; Zhao and Li 1999

taxonomists divied the Fabaceae into Minosaceae, Caesalpiniaceae and Papilionaceae: http://www.mobot.org/MOBOT/research/APweb/); these four families (Chenopodiaceae, Asteraceae, Poaceae and Fabaceae) contain 52.3% of the Chinese halophytes. The species of Chinese halophytes reported in Table 1 represent 37% of the world halophytes reported by Aronson (1989) and 22% of world halophytes reported by Menzel and Lieth (1999).

Physiological and ecological types of Chinese halophytes

Physiological types

The classification of Chinese halophytes into three physiological types is based on salt uptake and storage, as described by Breckle (1995). These three types are salt-secreting halophytes (exorecretohalophytes and endorecretohalophytes), euhalophytes (i.e., salt-diluting halophytes), and pseudohalophytes (i.e., salt-excluding halophytes). The exorecretohalophytes secrete salt from epidermal salt glands of leaves and stems; in China, these include species of *Limonium*, *Tamarix*, *Spartina*, *Avicennia*, and *Frankenia*. The endorecretohalophytes discharge salt from epidermal bladders on the leaves; in China, these include species of *Atriplex*, *Chenopodium*, *Halimione* and *Mesembryanthemum*.

The euhalophytes have succulent leaves or stems. In China, the genera with succulent leaves include species of *Suaeda*, *Salsola*, *Petoroimonia*, and *Reaumria*. Those genera with succulent stems include species of *Halostachys*, *Halocnemum*, *Ralidium*, *Kalidium* and *Salicornia*.

The pseudohalophytes or salt-excluding halophytes include species of *Phragmites*, *Artemisia* and *Juncus*.

Ecological types

Chinese halophytes can be divided into three ecological types: mesohalophytes, zerohalophytes, and hydrohalophytes. Mesohalophytes normally grow in salt meadows, salt shrublands, and other semiarid habitats with moderate soil water content; mesohalophytes include species of *Atriplex*, *Limonlum*, *Aeluropus*, *Apocynum*, and *Suaeda*. Xerohalophytes grow mainly in salt deserts, i.e., in the deserts of Xinjiang, Gansu, Inner Mongolia, and inland China. Examples of zerohalophytes are *Anabasis aphylla*, as well as the species of *Haloxylon* , *Tamarix*, *Kalidium*, *Halocne-*

mum, *Halostachys*, *Suaeda*, *Glycyrrhiza*, and *Zygophyyllum*. Hydrohalophytes are divided into emergent halophytes and submerged halophytes. Emergent halophytes grow in salt marsh and coastal marsh habitats, such as mangroves; emergent halophytes include the species of *Bruguiera*, *Kandelia*, *Rhizophora*, *Acanthus*, *Lumnitzera*, *Nypa*, *Sonneratia*, *Acrostichum*, *Hibiscus*, *Triglochin*, and *Salicornia*. As the name indicates, submerged halophytes grow beneath the surface of sea water, and include *Ruppia rostellata, Zostera merina*, *Phyllospadix japonica*, *Cymodocae* spp., *Halodule* spp., and *Halophila* spp. (Hou 1982; Ramadan 1998; Zhao and Li 1999).

Distribution of Chinese halophytes

Because halophyte vegetation is azonal (i.e. intrazonal vegetation), the distribution of Chinese halophytes is closely related to the distribution of Chinese salinized soils: where there are saline soils, there are halophytes. Chinese salinized soils can be divied into eight subregions based on the similarities of soil, biology, and geographical location (Ramadan 1998; Wang and Li 1993; Wu 1980) (Fig. 1; Table 2).

Discussion

The results of this survey demonstrate that although the halophyte vegetation in China is a azonal community, the large-scale distribution is also restricted by climate, e.g., the 38 families halophytes of Xinjiang may be divided into 6 types based on their geographic distribution (Table 3). The families of world large-scale distribution are 50% of 38 families from analysis of their geographic components, The temperate zone component (include tropic zone distribution, tropic zone, temperate zone distribution and temperate zone distribution) are 42.1%, and the tropic zone, subtropic zone distribution and subtropic zone, temperate zone distribution are 7.9%. These results show that the distribution of Xinjiang halophytes and the climate zone of Xinjiang are identical, despite halophyte vegetation is an azonal vegetation, their large-scale distribution is first restricted by the area climate zone of Xingjiang. Again, higher world large-scale distribution component illustrate that the narrow ecology adapatic range families are easily suffered from the influce of Xinjiang arid climate, only the world large-scale distrinutive families of more wide adapatic range may be developed better in the adverse circumstances.

Among the 587 halophyes in China, many have economic potential. Some can provide the starch, sugar, protein, or oil materials, and these include *Acacia* spp., *Suaeda* spp., *Salicornia* spp., *Glycyrrhiza uralensis*, *Asparagus persicus*, *Pandanus tectorius*. Some of these halophytes can serve as fodder, and these include *Salsola iberica*, *Aeluropus sinenesis*, *Phacelurus latifolius*, *Achnatherum splendens*, *Atriplex* spp., *Kochia* spp., *Halostachys caspica*, and *Alhagi sparsifolia*, e.g., *Atriplex* spp. produced 12.6 to 20.9 t/ha of biomass containing 9.9% to 19.5% of protein when growing in full-strength seawater (Dong 1994; Zhao and Feng 2001). Otherwise, more than 100 species of Chinese halophytes can be used as Chinese medicines. Those halophytes include *Lycium chinense*, *Glycyrrhiza uralensis*, *Apocynum venetum*, and *Nitria tangutorum*. Some of these medicinal halophytes have been cultivated in the saline soils of northwesten China, and the plants have been marketed domestically (China Medicinal Materials Co. 1994; Zhao and Feng 2001). Except above economic materials, some halophytes also serve as fiber, tannin materials,(fibers such as *Ashmatherum splendens*, *Apocynum venetum*, *Poacynum pictum*, *Tamarix chinensis*, *Sesbania canabinia*, *Phragmites australis*, *Juncus effusus*; tannins such as *Kandelia candel*, *Ceriops tagol*, *Bruguiera gynmorrhiza*, *Rhizophora styosa*, *Rhizophora apiculata*, *Xylocarpus grantum*, and *Lumnitzera racemosa*).

Table 3 Analysis of geographic distribution of 38 families of halophytes in Xinjiang

Geographic distribution	World large-Scale distribution	Tropical zone distribution	Tropical zone, Subtropical zone distribution	Tropical zone, tempesate zone distribution	Subtropical zone, tempesate zone distribution	Tempesate zone distribution
Family	19	1	2	7	1	8
Percentage	50	2.6	5.3	18.4	2.6	21.1

From Xi et al. 2006

Some halophytes, such as *Tamarix* spp., *Alhagi sparsifolia* and *Elaeagnus omgustifolia* can also serve as wind breaks and stablize sand. As well as can survive air pollution, such as Phragmites australia (absorb NH_3), *Tamarix* spp. (tolerate SO_2, Cl_2, and HF) (Zhao and Feng 2001).

The great nature world gifted many economic potential halophytes to us. We ought to better pretect, improve and use them by mordern agrobiotechnology: (1) some bigger salt tolerant and bigger economic potential halophytes may be grown in the coastal area irrigated by sea water; (2) we may irrigated them with brackish water, or fresh water plus brackish water in the dry salinized lands. In other words, we have to deal with the changes of future climate and the increace of population in the world. So we must develop saline agriculture. Again, we also take the transgenic technology of transformation of conventional crops with different halophytes genes to increase their salt tolerance. Although it is not getting success now, we believe that this technic is bound to gain a success in near future.

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