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Halophytes: Classification and Potential Uses

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Introduction

Halophytes are extremely salt tolerant plants and have evolved numerous morphological, anatomical and physiological strategies to survive and proliferate under saline conditions. Flowers & Colmer defined halophytes as 'Plants that can survive and reproduce in environments where the salt concentration exceeds 200 mM of NaCl (~20 dSm^{-1}). Some of the common adaptive feature found in halophytes are salt excretory glands, hypertrophied pores, succulent leaves and stems, air spaces that carry oxygen, short life cycle, waxes and specialized roots. It is found that dicot halophytes are more tolerant (optimal growth in 100–200 mM NaCl) as compared to monocot species (optimal growth in 50–100 mM of NaCl).Less than 2% of the world plant populationcome under halophytes which are mainly distributedin arid, semi-arid inlands and high salinity wetlands near coast.Till now 2000 to 3000 halophytic plant species are identified in the world and majority of them belong to angiosperms. Details of halophytic species database can be accessed online oneHALOPH repository. Halophytes areclassified based on various criterias as depicted below (Table 1).

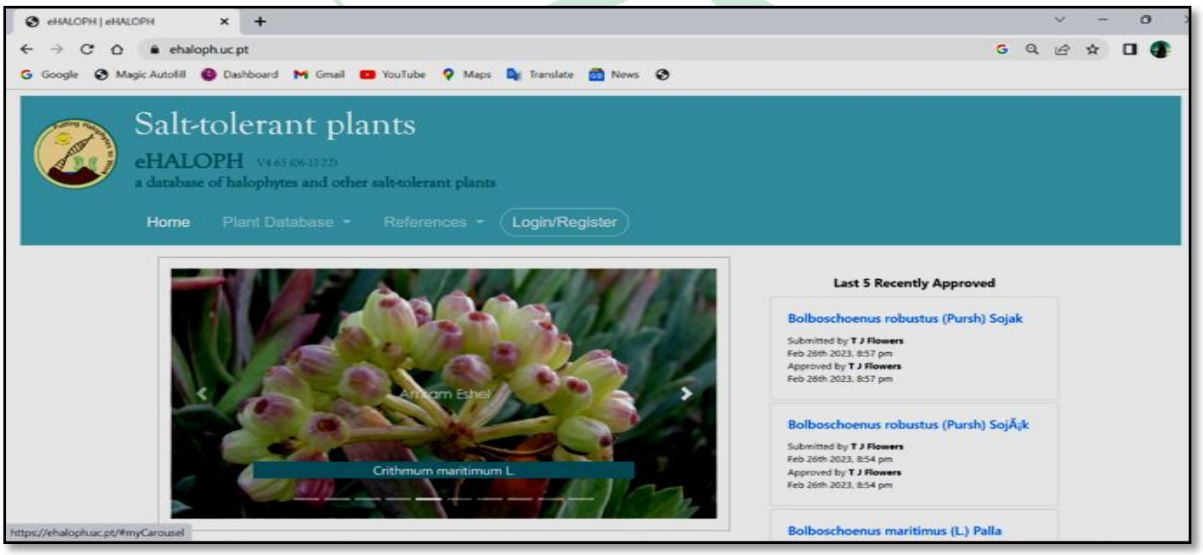

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Table 1. Classification of halophytes based on different aspects.

A. Based on ecology: (Sengbusch, 2003)	**B. Based on mechanism of tolerance:** (Walter, 1961)	**C. Based on Habitat:** (Youssef, 2009)	**D. Based on salt tolerance:** (Chapman, 1942)
(i) Obligate halophytes: Grow only in salty habitats, satisfactory growth under high saline condition. Mainly Chenopodiceaefamily plants.*e.g. Salicornia bigelovii*	**(i) Salt excluding:** The root system possesses an ultrafiltration mechanism to exclude salts. Example: Mangrove vegetation. *Rhizophora mucronata*, *Ceriopscandolleana*, *Bruguieragymnorrhiza* and *Kandeliacandel*.	**(i) Hydro-halophytes:** Halophytic plants grow in aquatic conditions. Example: mangroves and salt marsh species along costal lines.	**(i)Mio-halophytes:** Plants that grow in the habitats of low salinity levels (below 0.5% NaCl).
(ii)Facultative halophytes: Can grow on salty soils, but satisfactory growth under salt-free or low-salt condition. Example: Most Poaceae, Cyperaceae, & Brassicaceae species	**(ii) Salt excreting:** Regulate internal salt levels through secreting salts from salt glands. Example: *Avicennia spp.*, *Aegiceroscorniculatum*, and *Acanthus ilicifolius*.	**(ii) Xero-halophytes:** Grow in environment of low soil moisture content, saline soil. Example: Most plant varieties in desert areas	**(ii) Eu-halophytes:** Plants that grow in highly saline habitats. Further sub-divided into thefollowing groups: **(a)Mesohalophytes-** Plants that can tolerate salinity range of 0.5 to 1%.
(iii) Habitat-indifferent halophytes: Plants that are	**(iii) Salt accumulating** Accumulate high concentration of salt in their cells and tissues		**(b)Mesoeuhalophytes-** Plants that can tolerate salinity range of

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insensitive to habitat. Normally grow on salt-free soils but can grow in salty soils. Example: *Chenopodium glaucum, Myosurusminimus,* and *Potentillaanserina*.	as salt storage away from the growing cells. Example: *Sonneratiaspp.*, *Limnitzeraracemosa, Excoecariaagallocha, Salvadora persica, Sesuviumportulacastrum, Suaedanudiflora,* and *Pentatropissianshoides*.		5% and higher. **(c)Eneuhalophytes** - Plants that can tolerate salinity range of 1% and above.

Potential uses of halophytes:

Due to numerous factors, saline area in the world is increasing rapidly and currently there is urgent need to slow down the salinization process of fertile land and to bring the already salinized land under cultivation. Halophytes are able to provide satisfactory yield under different degrees of salinity and can be used for several domestic as well as commercial purposes. Here are some potential uses of halophytes that can be exploited under saline conditions:

1. As Bioenergy crops

Some halophytes can store high concentrations of oil in their seeds (>20%) which are invaluable sources of biofuel.Various studies showed that the fatty acid methyl ester composition of oils extracted from halophytes is comparable to other crop derivedoilsused for production of biodiesel. Halophytes can be irrigated with seawater without compromising their biomass, seed yield and oil content. Due to their huge potential, several halophytic species have been screened and breds for saline areas for large-scale biofuel production. The salt excluder type of halophytes aregenerally better choice for biofuels, because accumulator type of halophytes largely produce non-combustible biomass. Some of halophytes are listed below (Table 2) which used for oil extraction from their seed.

Table 2: List of Halophyte species primarily used for oil extraction from seeds(Sharma *et al.*, 2016).

Name of the Plant	Oil content (%)	Name of the Plant	Oil content (%)

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Suaeda spp.	22-30	*Crithmummaritimum*	45
Allenrolfeaoccidentialis	14	*Helianthus annuus*	35–52
Atriplex heterosperma	15.8	*Descurainaiasophia*	44.17
Halogeton glomeratus	24.7	*Cressacretica*	22.3
Atriplex rosea	12.9	*Ricinus communis*	47–55
Kochia scoparia	9.7	*Kosteletzkya virginica*	22-30
Arthrocnemummacrostachyum	25	*Kosteletzkyapentacarpos*	18–22
Salicornia bigelovii	30	*Alhagimaurorum*	21.9
Sarcobatusvermiculatus	17.5	*Halopyrummucronatum*	22.7
Haloxylonstocksii	22.7		

2. Phytoremediation

Halophytes have vast potential to rehabilitate the salt-affected soils and phytoremediation of polluted soils.Salt accumulating type of halophytes play a major role in phytoremediation as they uptake salts from soil and accumulate it in their tissues. Further, proper disposal of their biomass is important to remove salts from soil. Phytoremediation capacity is mainly species-dependent,with significant variation in the quantity of salt accumulated in the biomass. Various studies suggested that following plant having great potential for phytoremediation (Table 3).

Table 3: Most promising Halophytic plant species for phytoremediation

Arthrocnemum indicum	*Suaedafruticosa*
Atriplex lentiformis	*Suaeda maritima*
Echinochloastagnina	*Suaeda salsa*
Juncus rigidus	*Xanthium strumarium*
Juncus acutus	*Leptochloafusca*
Parkinsonia aculeata	*Sesuviumportulacastrum*
Portulaca oleracea	*Prosopis julifera*

3. Halophilic PGPRs (Plant Growth Promoting Rhizobacterias)

Halophytic plants have evolved various strategies for survival in saline environments. The rhizosphere of halophytic plants serves as a reservoir of various types of salt-tolerant rhizobacteria called as halotolerant bacteria which enhance the growth of crops under salinity stress.Use of these bacteria'scould be explored for making favourable soil environment for

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cultivation of non-tolerant crops. It can increase the choice of crops for cultivation under saline soils.The liquid formulations of various salt tolerant biofertilizers have been developed byICAR-CSSRI, RRS, Lucknow and commercially sold as Halo-PSB, Halo-Azo, Halo-mix and Halo-Zinc(tested to suit soils with pH in the range of 7.5 to 9.7).

4. Vegetables and fruits

Edible halophytes might be explored for vegetable and fruit purpose for saline areas. Numerous halophytes are already being cultivated as vegetables and fruits locally across the salt affected areas of the world. In India there is extensive traditional use of halophytes as vegetable and fruits (Table 4). Desirable traits such as size and quality of these potential crops can be improved by development of new varieties.The coastal salt marsh succulent *Salicornia spp*is extremely salt-tolerant and a multipurpose use halophyte. Central Salt and Marine Chemicals Research Institute, Bhavnagar, Gujarat, developed a process to yield culinary vegetable salt from it and it is sold under the brand name "Saloni".Arid halophyte *Haloxylonsalicornicum*isconsidered as a famine food of Rajasthan. Ash extract of *Haloxylonrecurvum*is added as a special ingredient for unique taste of Bikaneri papad of western Rajasthan.

Table 4: Halophytic plant species used for vegetable and fruit purpose.

Halophytes used for vegetable purpose	Halophytes used for Fruit purpose
Sesuviumportulacstrum, Chenopodium album, Beta maritima, Atriplex triangularis,Suaeda spp.,Sesuviumportulacastrum, Portulaca oleracea, Crithmum maritima, Amaranthus spp., Prosopis cineraria	*Phoenix dactylifera, Carissa carandas, Capparis decidua,Morindacitrifolia, Pandanus spp.,Artocarpus heterophyllus, Annona squamosa, A. glabra, Musa spp., Ardisia spp.*

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5. Grain and Oilseeds:

About 50 species of seed producing halophytes are potential sources of edible oil and proteins. The best part of their use for grains or oilseed is that they generally do not accumulate salts in their seeds. This quality enhances their potential for immediate use as food without additional treatment. Production of vegetable oil from seed-bearing halophytes is also encouraging. *Salicornia europaea* is high-quality edible oil yielding halophyte with great economic value. The suitability of coconut *(Cocos nucifera)* oil for consumption and hair oil is well established in India.A number of salt-tolerant cereal grasses (*Pennisetum typhoides, Chenopodiumquinoa, Distichlis, Sporobolus, Uniola, Zizania, Kosteletzkya virginica and Zosteramarina*) are well known to produce small high-protein seeds with high nutritive valueas compared to wheat or rice.

6. Agroforestry and conservation

Cultivation of halophytic trees and shrubs for fuel, timber and soil conservation offer an opportunity to create sustainable agro-forestry systems for stabilization and rehabilitation of degraded environments. Salt and drought tolerant shrubs and trees (*Acacia, Causarina, Eucalyptus, Melaleuca, Prosopis, Tamarix, Pandanus, Hibiscus spp., Phragmites spp, Scirpus, Typha spp*and*Urochondra*) can be planted for conservation and harvested for various products likepaper-pulp, fiber, food, fuel and timber. Nitrogen fixing halophytes (*Albizia, Cassia, Cyamopsis, Luecaena, Pongamia, Sapium, Sesbania* and *Trifolium*) have been effectively utilized as cover crops, green manure, mulch and compost.The herbs like*Leptadeniapyrotechnica* (khimp),*Aeluropuslagopoides*and*Aervajavanica*are strong soil-binder used in sand dune fixation.Long term work has been conducted as BIOSAFOR project (Biosaline (Agro) Forestry) at ICAR-CSSRI to remediate the saline wastelands (Soil pH, 10-10.6 and ESP, 89-92) through cultivation of biomass for energy plantation and found that *Eucalyptus tereticornis, Acacia nilotica, Prosopis juliflora and Casuarina equisetifolia*proved helpful for reclamation and productive utilization of these lands with highest biomass production after 14 years.

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Agroforestry systems under saline Vertisols with Eucalyptus and Acacia

7. Medicinal use

Various halophytic plants are well known for their bioactive derivatives and have long been considered important ingredients for pharmaceuticals, agricultural pesticides, traditional medicines and natural cosmetics (Table 5). About 400 salt-tolerant plants have been reported to possess medicinal value based on the uses reported in literature and exploring biodiversity of saline habitats including coastal regions of India.

Table 5: Halophytic plant species used for medicinal purpose.

Halophytic species	Medicinal use
Sultan Champa *(Calophylluminophyllum)*	Anti-infammatory agent, phenyl coumarin
Balanites roxburghii	potential source of diosgenin, used for the synthesis of steroidal drugs
Sadabahar *(Catharanthus spp.)*	produces about 130 catharanthus alkaloids compounds, including vinblastine and vincristine, two drugs used to treat cancer
Apamarga *(Acheranthes aspera)*	used as herbal medicine in obstetrics and gynecology
Ageratum conyzoides	widely used against dysentery and diarrhea
Kapok *(Aervajavanica)*	Seed used to cure headaches and toothache
Shatavari *(Asparagus racemosus)*	for various reproductive and hormonal issues in women, gastric ulcers and indigestion
Punarnava(*Boerhaavia diffusa*)	acts as anticonvulsant, analgesic, laxative medication
Aak (*Calotropis procera)*	for treating skin, digestive, respiratory, circulatory

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	and neurological disorders.
Karaonda fruits	treatment of skin infections, fevers, ear-ache and syphilitic pain.
Cassia tora (Senna)	contain the organic compound anthraquinone
Cassia italica	leaves of are used as natural henna or "blonde henna"
Guggul *(Commiphorawightii)*	gum extract used in Unani and Ayurvedic medicine
Kumra (T*ridax procumbens)*	used for wound healing and as an anticoagulant, antifungal
Anant Bel *(Hemidesmus indicus)*	one of the Rasayana plants of Ayurveda
Bachnag (*Gloriosa superba)*	seed contain alkaloid Colchicine.
Shankhapushpi *(Evolvulusalsinoides)*	highly valued medicinal plant in Aayurveda.
Rudravanti *(Cressacretica)*	Anthelmintic, expectorant, aphrodisiac and aid digestion

8. Gums, Essential Oils and Resins

In India, halophytic trees and shrubs of drylands also produce important gums and resins. *Acaciasenegal*is of great economic importance for the gum Arabic or locally known as 'Kummat'in Rajasthan. The gum obtained from *Acacia nilotica* is known as Amaravati gum. Gum collected from *Acacia auriculiformis* is sold commercially. Perennial shrubs *Grindelia spp.* produce diterpene acid resins. The perennial desert shrub guayule *(Parthenium argenatum)* is a source of natural rubber. Seeds of *Cassia tora*contain various gum, tannins, resins and essential oils compounds. Halophytes like Screw pines *(Pandanus fascicularis*),*Matricaria chamomilla* and Mentha *(M. arvensis, M. piperita)*known for production of Essential oils., Lemon grass *(Cymbopogon exuosa)* cultivated as culinary and medicinal herbs because of their scent.

9. Landscape and Ornamental Plants

Many attractive halophytes can be efficiently utilized for landscaping and ornamental purposes in saline areas. Salt-tolerant lawn and turf grasses, cut flowers, and landscape plants tend to decrease use of freshwater for more essential sensitive crops. Plants such as *Batis maritima, Conocarpus erectus, Eucalyptus sargentii, Melaleuca halmaturorum*, species of *Casuarina* and *Ficus*; and the shrubs *Mairreanasedifolia, Borrichea frutescens*

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and*Clerodendruminerme* are already being used as landscaping. Some annual flowers such as *Chrysanthemum indicum, Calandula officinalis, Matthiolaincana and Matricaria chamomilla* can be cultivated with saline water.

10. Breeding for Tolerance to Salinity

Halophytes which are known for their extreme salt tolerance can be used as a source of genes to improve presently cultivated crops into high yielding salt tolerant crops. During recent years, lot of efforts have been done to release improved salt tolerant varieties of various crops. ICAR-Central Soil Salinity Research Institute (CSSRI) worked as pioneer institute for developing salt tolerant varieties of different crops. The institute has developed salt-tolerant varieties of rice (CSR 4, CSR 10, CSR 13, CSR 23, CSR 27, Basmati CSR 30, CSR 36 and CSR 43;), wheat (KRL 1-4, KRL 19, KRL 210 and KRL 213, KRL 283), and Indian mustard (CS 52, CS 54, CS 56, CS 58 and CS 60), chickpea (Karnal chana 1) and lentil (PDL-1 and PSL-9).

11. Halophytes as forage

Halophytes have been used as forage in arid and semiarid parts of the world. They serve as the best option for sources of forage and fodderin the dry land ecosystems. Major part of commercial halophyte cultivation around the world has been covered for forage and fodder use. Fodder halophytes include grasses (*Distichlis, Hedysarum, Kochia, Paspalum, Puccinellia, Spartina, Sporobolus, and Thinopyrum*), shrubs (*Atriplex, Salsola, and Suaeda*), and trees (*Acacia, Cassia, Luecaena, and Prosopis*). Among trees species, *Acacia, Prosopis, Salvadora,Leucaena leucocephala*and *Zizyphus*are the popular traditional fodder of arid regions of India due to their high abundance and good accessibility in these areas.

Conclusion

Soil salinisation is a worldwide problem which is increasing at an alarming rate because of salt ingression, unscientific irrigation practices, poor drainage, water contamination and other environmental factors.. Salts present in the soils restrict normal crop production and at higher level it eventually transforms the fertile land in to barren. New dimensions need to be explored to bring saline areas back into some form of cultivation. Halophytes are the distinctive category of plants that can grow and thrive well in habitats with very high salt concentration where most of the other plant species don't survive. From ancient years these plants have been used for different purposes by our ancestors. Time has

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come to focus on the potential uses of halophytes and to upscale the commercial cultivation of halophytic plant species for improving the livelihood of resource poor farmers.

References

Chapman V.J. (1942) The new perspectivein the halophytes. *The Quarterly Review of Biology*,17:291-311.

Sengbusch P von (2003) Halophytes.Botanik Online, University of Hamburg.

Sharma R, Wungrampha S, Singh V,Pareek A, Sharma MK. Halophytesas bioenergy crops. Frontiers in PlantScience. 2016;7:1372.

Walter H. (1961) The adaptations of plantsto saline soils. In: Arid Zone Research.XIV. Salinity Problems in the AridZones. *Proceedings of the Teheran Symposium*;UNESCO. Paris:pp.129-134.

Youssef A.M. (2009) Salt tolerancemechanisms in some halophytes fromSaudi Arabia and Egypt. *Research Journal of Agriculture and Biological Sciences*, 5:191-206.