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Wide Scene on Halophytes

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Abstract:

This work dealt with the different types of halophytes; obligate, facultative, and habitat-indifferent halophytes with the indication of the main angiosperm families containing each category. In the same time it summarizes the most dominant halophyte species and their belonging families and their degree of adaptation to salt habitats. These genera and species, which are more than five hundred, were belonging to more than 70 Angiosperm families. These species can be further classified according to their life span into perennial herbs or shrubs and annuals and according to their ecological habitats and adaptations to salinity into: Halophytes, Hygrophytes, Phanerophytes, Xerophytes and Succulents. Genera belonging to the major angiosperm families containing the maximum number of taxa are the Chenopodiaceae and Amaranthaceae (34 taxa; 22.08%), Poaceae (21 taxa; 13.64%), Fabaceae (14 taxa; 9.09%), and Asteraceae (13 taxa; 8.44%). Meantime the main halophytic adaptations have been mentioned, with the indication to the mangrove plants which share some common characteristics based upon physiological, reproductive and morphological adaptations. Mangrove has approximately 54 species of plants belonging to about 20 genera in 16 families. This work high lighting the taxonomic revision of genus *Salsola* as one of the most important halophytic genus within the Chenopodiaceae. Hints on the pollen grains characters, anatomical features and chemical constituents of halophytes, in general, in *Salsola* specified were mentioned.

Key words: Classification of halophyte- Halophytic families- Halophytic types- Salinity- *Salsola*

Introduction:

Halophytic plants are those plants that can survive in saline environments. Plants which grow in saline habitats, in salt marshes, salt deserts, mangroves or near the sea shores are termed halophytes plants. Schimper (1903) defined the halophytes as those plants that can survive in saline habitats and in the same time can grow in normal habitats. These plants exhibit unique morphological, anatomical and physiological traits, which characterize them from other groups in the plant kingdom and by which they are able to germinate, survive and reproduce in soils with high salt concentrations. These features help them to thrive under adverse conditions and are often displayed in the morpho-anatomical changes in plants (Grigore and Toma, 2007, Hameed and Khan, 2011 , Ashraf and Harris, 2013).The halophytes prefer to live under this harsh situation to avoid plant competition as well as avoiding insect infections. Glenn and Jed Brown (1999) indicated that the majority of the glycophytes are not salt-tolerant and cannot survive under salt stress. Few plants, in comparison to all, can survive under high concentrations of salt and harsh conditions, perhaps 2% from all the Angiosperms, which called halophytes. Various halophytes (salt-tolerant plants) are found in saline depressions. In spite of being few they are subjected to many trials of classifications. According to Stocker (1933) they are categorized into three categories based on the degree of emerging under the water into:

1- Aqua-halines, which are plants completely, emerged under the salt water or at least the roots under the water with floating stem and leaves.

2- 2- Terrestro-halines which is subdivided into three groups according to the salt water they grow on it;, the hygro-halophytes which are plants that grow mainly in swamp land, the mesohalophytes which are plants that on non swamp but wet lands, and finally xerohalophytes which are plants that grow on dry salty lands.

3- The last main category is the Aero-halines, which is classified according to the degree of soil salinity on which they grow, according to Iversen (1936), into three groups. Oligo-halophytes in which the concentration of the salt in the soil water varied from 0.01 to 0.1%. Meso-halophytes in which the concentration of the salt in the soil water varied from 0.1 to 1% and Eu-halophytes in which the concentration of the salt in the soil water exceed 1%.

Plant adaptation to saline environments may be either salt tolerance or salt avoidance. Those which avoid the effects of high salt even though they live in a saline habitats may be referred to as facultative halophytes rather than 'true', or obligatory halophytes. Whereas those that complete their life cycle in the wet seasons can be considered from the salt avoidant plants. Halophytes have been subjected to many investigations for their ecological, physiological, anatomical, and biochemical responses toward salinity (Flowers and Colmer, 2008; Aslam *et al.*, 2011 ; Shabala, 2013 ; Ventura *et al.*, 2015). They were also explored for saline agriculture and examined as bio-energy crop (Rozema and Schat, 2013 ; Sharma *et al.*, 2016). Many experiments have been made to adapt plants to live in salt and dry habitats. Shaaban and Maher (2016) generated a callus and micropropagated plants from *Moringa oleifera* to examine their response to dryness caused by different concentrations of mannitol. Hassanein *et al.* (2019) found that the Moringa leaf extract can be used as bio-stimulant to sweet basil plants. Nowadays, dryness and loss of water which cause salinization to soil considered from the priori problem worldwide. This problem has its effect on soil productivity, microbial environment and agricultural economics as pointed by FAO (2016). In fact the fertile soil will be transferred to barren which destroy the vegetation and ecosystem as whole. Salinity stress considered as one of the major abiotic stresses limiting crop production in arid and semi-arid regions, especially with the increase in air temperature and rarity of rain fall. In this review, we deal briefly with the wild halophytes and their taxonomic categories, morphological and anatomical adaptations to salt stress. In fact Halophytes represent a complex and heterogeneous ecological group of plants, including very different species in terms of habitats, taxonomic variations and adaptive features (Grigore, 2008a, 2008b; 2012; Grigore and Toma, 2010 a, 2010b), in spite of that they all attain some common morphological and anatomical modifications to adapt salinity.

Halophyte Classifications:

O'LEARY and Glenn (1994) explained that the name 'halophyte' does not designate a member of any particular taxon or any specific geographic or physiographic area. Thus, we have to know that halophytes can be found in any part of the world whether near the sea shores or in the deserts. The word literally means 'salt plant' and is used to refer to any plant that is capable of growing and reproducing in arc as subject to high salinity during all or a substantial part of the time. Thus When we talk about wild terrestro-halines, we have to distinguish between those genera which grow and survive under the salt stress and those which escape from dryness and avoid salt stress. Iversen (1936) classified the haline habitats on the basis of their salt contents into Oligohalophytes, Mesohalophytes and Euhalophytes. Those of the first group has 0.01-0.1% NaCl, while the second group has 0.1-1.0% NaCl whereas the last group has 1.0 and more % NaCl. In between these groups, he identified other halophytes that can grow in wider salinity range and in between these three above mentioned groups. Plants that can survive in both oligohaline and mesohaline habitats are called oligo-mesohalophytes and those that can exist in all the three types of habitats are called euryhalophytes. In the past Van Eijk (1939) classified halophytes into two groups according to their distribution and responses to saline habitats; salt enduring and salt resistant. Chapman (1942) grouped the halophyte under two groups, Miohalophytes and Euhalophytes, the later is subdivided into three subgroups: mesohalophytes, mesoeuhalophytes and eneuhalophytes.

Gregore (2012) said that all the existing halophyte classifications based on arbitrary, subjective criteria despite that several classifications based on quantifiable, numerical criteria their ecological value is still in debate. This is due to the proposed salinity groups based on descriptive values and not on experimental research. He goes through the Romanian classifications with great support to Topa (1939) classification. Topa classifies the halophytes into four categories: Obligatory, preferential, supporting and accidental. This classification depended on the behavior of the plants in relation to excess salt environment. This classification considered a pivotal point in the Romanian literature on halophyte.

Bucur *et al.* classification (1957, 1960 and 1961)) is from the most important work on halophyte classification, as he investigated the salinity threshold of more than 400 halophyte species and constructs a valuable classification. He distinguished the halophytes in three main categories according to biomass results, obligatory, facultative and chalo-pholous halophytes. But when considering the bio ecological criteria he decided that plants are either halophytes or not, the halophytes are either euhalophytes or neohalophytes.

Hassanuzzaman *et al.*, (2014) gave valuable descriptions of halophytes and their classifications. They classified the halophytes according to the habitat conditions in which they developed and their strategies to accommodate such habitats. In 1961 Walter made new classification of the halophytes on the basis of the different mechanisms of adaptation to salty condition into (i) salt excluding, (ii) salt excreting, and (iii) salt accumulating plants. Afterwards many scientists defined and classified the halophytes in different reasonable ways. Von Sengbusch (2003), based on ecological aspect, classified halophytes into (i) obligate, (ii) facultative, and (iii) habitat-indifferent halophytes. Obligate halophytes are those plants that can grow only in salty habitats. They can flourish and gave sufficient growth and development under high saline condition. From this aspect many Chenopod plants which belonging to family Chenopodiceae fall in this category. Facultative halophytes are those plants that can tolerate themselves and live in salty soils, but their optimum growth conditions lies in a salt-free or at least low-salt condition. Accordingly most species belonging to families Poaceae, Cyperaceae, and Brassicaceae as well as a large number of dicotyledons like *Aster tripolium, Glaux maritime* and *Plantago maritima*, belong to this group. The last group; Plants that are indifferent toward their habitat; are those plants that can grow in saline habitats in nature in spite of being grown normally on salt-free soils. This group of plants can compete with species that are sensitive towards salt and are on the other hand able to live on salty soils. This group has those plants that can live in both disturbed and stable habitats. *Calotropis procera, Chenopodium glaucum, Myosurus minimus*, and *Potentilla anserina* can grow in any habitat or what we say can grow in disturbed habitats without any morphological differences. But In some species, such as *Festuca rubra, Agrostis stolonifera*, and *Juncus bufonius*, the populations living on salty soils and those on salt-free soils differ genetically and gave some morphological differences between populations. However, all of these three kinds of halophytes perform better growth compared to glycophytes (Hassanuzzaman *et al.*, 2014).

Further divisions of these group of salt tolerant plants, are hydro-halophytes and xero-halophytes. Hydrohalophytes grow in aquatic conditions or on wet soil, while xero-halophytes are those plants grow in deserts where the soil is dry with high salt contents. Steiner (1934) grouped the salt march plants in three groups, succulent, non-succulent or accumulating. Thus, most mangroves and salt marsh species along coastlines are considered hydro-halophytes. Xero-halophytes grow in habitats where the soil is mostly saline, in case of soil dryness, and cause problems with water availability for the plant. Most desert plant species lie in this group and considered xero-halophytes. Many of them try to store water by having succulent leaves and stems as in *Zygophyllum* or reduce their leaves to avoid losing water as in *Alhagi* . One can distinguish between succulent halophytes with salt bladders on the leaf epidermal surface, and those which excrete the salt by evaporation with water, where we can see the salt crystals remain on the leaf surface as in *Zygophyllum crystallinum.* In some cases plants under lower salinity levels are able to exclude the salt by either secretion through salt glands as mentioned before, or to compartmentalize ions within vacuoles. These plants possess genes which allow them to master the respective salinity under which they must function to survive. When talking about halophytes we have to distinguish between plants that can survive in high salt contents and Xerophytes. Xerophytes have different morphological features and other adaptations to dry conditions as seen in most desert plants. Some of them have very short life span and manage to live their whole live from germination to maturity, flowering and producing seeds within few weeks after an occasional rainfall. These plants, called ephemerals i.e. escaping from dryness, accordingly they finished their life cycle quickly. These ephemerals usually are small in size and can survive long droughts as seeds. Some xerophytes develop extremely deep root systems (up to 100 feet or 30 m.) to reach ground water that might be available deeper in the ground, like *Ephedra* and *Calligonum*. When talking about hydrophytes and plants emerged in water, we must mention the algae and how they can tolerate with salt stresses. Kebeish *et al.* (2014) studied the effect excess salt on the physiological and biochemical traits of Chlorella vulgaris and found that the increase in salt concentrations affect PSII efficiency and reduces the overall CO_2 assimilation rate. Fargl *et al.* (2015) compared physiological response of fresh water algae (Chlorella vulgaris) and marine algae (Chlorella salina) to different salinity levels. They found significant increase in free amino acids, proline, Na^+ , MDA contents and antioxidant enzyme activities in C. vulgaris in response to the increase in salinity.

Mangroves:

Mangroves are plants from facultative halophytes i.e. the salt water is not a necessary physical requirement for their growth. Most mangrove plants can grow well and flourish in fresh water, but mangrove communities are not usually found in freshwater habitats. Mangrove plant communities belong to many different taxonomical ranking. They are belonging to different angiospermous genera and families that are not always related in their phylogeny or even their taxonomy. However, they have some common physiological and morphological features based upon their physiology, reproduction and morphological adaptations that make them adapt to grow and complete their life cycle in a broad range of tidal environments, near the sea shores, in the tropical and subtropical areas of the world. By this definition, the mangrove species, occupy the interface between the land and the sea (Walsh, 1974). According to Tomlinson, 1986 there are about 54 species of plants belonging to about 20 genera in 16 families have been recognized throughout the world, as belonging to the mangroves. From the most acceptable reasons affecting the types of plants growing in this habitat is that summarized by Ahmed (1991). He gave a review article about mangrove communities and summary of Jennings and Bird (1967) in which six most important geomorphological characteristics that affect the mangrove community which are: aridity, wave energy, tidal conditions and sedimentation, mineralogy and neotectonic effects. These six items affect the establishment of mangroves. While Walsh (1974) and Chapman (1975, 1977) have described seven characteristics that may be essential requisites for mangroves on a world-wide basis. These are air temperature (within a restricted range), mud substrate, protection, salt water, tidal range, ocean currents, and shallow shores.

Major coastal marine halophytic Angiosperm:

In spite of being the halophytes few members, not exceed 2%, trials have been made to know the major angiosperm families which can adapt and survive with salinity. In fact no families are strictly halophytic plants only; these families have halophytic taxa beside the non halophytic ones. Although some have disproportionately high numbers of halophytic apecies (e.g. the Chenopodiaceae, now included in the Amaranthaceae). The new systems of classification have changed the rank of many taxa. Accordingly both halophytes and non-halophytes taxa frequently co-occur in the same genus, e.g. in *Aster*, *Chenopodium*, *Glycine*, *Plantago*, *Solanum* and *Or yza*. The most wide spread salt tolerant genera and species belonging to 70 Angiosperm families with more than five hundred species. These species can be further classified according to life span into perennial herbs or shrubs and annuals or ephemerals, and according to their ecological habitats and adaptations to salinity into: Halophytes, Hygrophytes, Phanerophytes, Xerophytes and Succulents.

As mentioned before, the halophytes represent a very small percentage of terrestrial plant species, halophytes are present in more than half the higher plant families and represent a wide diversity of plant forms and evolved in different ways of phylogenetic pathways with many origins. In China Zhao *et al.* (2011) recorded 587 halophytes representing 242 genus and 71 family apart from three species of ferns according to a survey conducted from 1995 to 2004 in eight regions with high salt content soils. The angiospermous families containing highest number of halophytic genera are the Chenopodiaceae and Amaranthaceae (34 taxa; 22.08%), Poaceae (21 taxa; 13.64%), Fabaceae (14 taxa; 9.09%), and Asteraceae (13 taxa; 8.44%). These five families represent 53.25% of the halophyte plants as mentioned by Öztürk, *et al.*, 2016. Those families have cosmopolitan distribution, and comprises of herbs or shrubs, rarely small-trees or lianas. From the widely distributed halophytic families is the Chenopodiaceae. Members of Chenopodiaceae are mostly characteristic for arid to semiarid and/or saline habitats, and they form an important component of the flora and vegetation of desert environments from the northwestern Sahara and southeastern Europe to the Himalayas and the Gobi desert, and in the arid region of Australia, South Africa, the pampas of south America and the prairies and deserts of North America. The Chenopodiaceae family is divided among eight subfamilies and 14 tribes. A great number of halophytes and xerohalophytes of the world belongs to this family (Breckle 1986; Aronson, 1989; Akhani and Ghorbanli, 1993; Le Houerou, 1993). Genera belonging to this family have fleshy nature and pinkish colour of the stem and sometimes leave. From the obligate halophytic genera in this family are *Arthrocnemon*, *Halocnemon*, *Salsola and Sweada*. The genus *Salsola* has *Salsola soda* L. species, this name derived from the Latin *Sallere* means to salt (Remann and Breckle, 1995; Idzikowska, 2005). The dominant halophytic genus *Salsola*, has six taxa. In terms of life forms, xerophytes form the largest group (44.81%), followed by hemicryptophytes (20.78%); however, in terms of ecotypes, the percentage distribution is as follows; xerophytes (25.97%), hygrohalophytes (21.43%), psammohalophytes (16.88%), xerohalophytes (16.88%), halophytes (12.34%), and ruderals (6.50%), respectively. Tribe Salsoleae, within the Chenopodiaceae, includes one-third of all known genera currently recognized in the family Chenopodiaceae (32 of 98 genus; sensu Kühn *et al.* 1993). They are mostly leaf- and stem-succulent halophytic, xerohalophytic, xerophytic, and ruderal plants with diverse traits, particularly in photosynthetic pathways and concurrent anatomical structures (Butnik *et al.*,1991& 2001; Akhani *et al*. 1997; Pyankov *et al.*, 1997, 2001 & 2002; Voznesenskaya *et al.* 1999, 2001a, 2001b; Akhani and Ghasemkhani 2007).

Genus *Salsola* is a cosmopolitan group of plants which distributed and naturalized all over the world. Species belong to this genus found in most arid places of the world, along sea beaches, in grassland, wastelands, roadsides and desert communities (Krzaczek *et al.*, 2009). Plants belonging to this genus tolerate with dryness, pH fluctuation and high degree of salinity. *Salsola* has had a controversial subgeneric classification, and its monophyly has been questioned, as has the recognition of such genera as *Climacoptera* (Botschantzev 1956, 1969b; Pratov 1986), *Halothamnus* (Iljin 1936; Botschantzev 1981b), *Darniella* (Brullo 1984), *Fadenia* (Aellen and Townsend 1972), and *Xylosalsola, Nitrosalsola*, and *Newcaspia (*Tzvelev 1993). The detailed revision of most species groups of the genus *Salsola* was carried out by Botschantsev and Akhani (1989) based on the earlier works of Fenzl (1851), Ulbrich (1934) and Iljin (1936), as well as on morphological features of vegetative organs as shown in table 1

.Table 1 Historical nomenclature of Salsoleae and the genus *Salsola* and members of the Chenopodiaceae from the first trial of Lindley 1830 till Shipunov, 2014

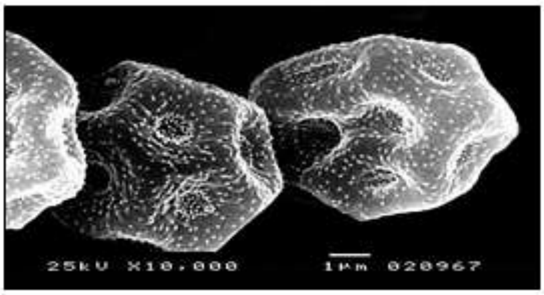
Rank / Author name	Class	Sub-class	Super Order	Order	Sub order	Family	Sub family	Genus
Lindley (1830)	**Dicotelydons**	**Exogenae**	_____	**Caryophyllales**	_____	**Amarenthaceae**	**Salsoloideae**	***Salsola***
Bentham& Hooker (1862-1883)	**Dicotelydons-monochlamideae**	**Curvembreae**	_____	**Caryophyllales**	_____	**Chenopodiaceae**	**Salsoloideae**	***Salsola***
Hutchinson (1926-1934)	**Dicotelydons**	**Archeclamydeae**	_____	**Chenopodiales**	_____	**Chenopodiaceae**	**Salsoloideae**	***Salsola***
Wettstein (1933-1935)	**Dicotelydons**	**Choripetaleae**	_____	**Centrospermae**	_____	**Chenopodiaceae**	**Salsoloideae**	***Salsola***
Melchior (1964)	**Dicotelydoneae**	**Archeclamydeae**	_____	**Centrospermae**	**Chenopodiineae**	**Chenopodiaceae**	**Salsoloideae**	***Salsola***
Goldberg (1986)	**Dicotelydoneae**	_____	_____	**Caryophyllales**	_____	**Chenopodiaceae**	**Salsoloideae**	***Salsola***
Cronquist (1981)	**Magnolopsida**	**Caryophyllidae**	_____	**Caryophyllales**	_____	**Chenopodiaceae**	**Salsoloideae**	***Salsola***
Kubitzki (1990)	**Magnolopsida**	**Magnoliidea**	**Caryophyllaneae**	**Caryophyllales**	_____	**Chenopodiaceae**	**Salsoloideae**	***Salsola***
Thorn (1992)	**Magnolopsida**	**Magnoliidea**	**Caryophyllaneae**	**Caryophyllales**	_____	**Chenopodiaceae**	**Salsoloideae**	***Salsola***
APG I (1998)	**Clade: Eudicots**			**Caryophyllales**	_____	**Amarenthaceae**	**Salsoloideae**	***Salsola***
Reveal (1999)	**Rosopsida**	**Caryophyllaneae**	_____	**Caryophyllales**	_____	**Chenopodiaceae**	**Salsoloideae**	***Salsola***
APG II (2003)	**Eudicots**	**Core eudicots**	_____	**Caryophyllales**	_____	**Amarenthaceae**	**Salsoloideae**	***Salsola***
APG III(2009)	**Eudicots**	**Core eudicots**	_____	**Caryophyllales**	_____	**Amarenthaceae**	**Salsoloideae**	***Salsola***
Reveal (2012)	**Magnoliidea**	_____	**Caryophyllaneae**	**Caryophyllales**	**Chenopodiineae**	**Chenopodiacea**	**Salsolaceae**	***Salsola***
Shipunov (2014)	**Magnolia**	**Asterideae**	**Caryophyllaneae**	**Caryophyllales**	**Chenopodiineae**	**Amarenthaceae**	**Salsoloideae**	***Salsola***

In Egypt the genus comprise twelve species distributed in the Mediterranean coastal region, El-Tih, Oasis, Arabic desert and Gebel Elba (Tackholm. 1974, Bolous. 1999). Only six of them are found in the Mediterranean coastal region west Alexandria till El.Dabaa. The study of Taia *et al.* (2018 a & b) studied the micro and macromorphological characters of six Mediterranean *Salsola* sp.and they found great variations between them. They continued their study in the anatomy and chemical constituents of these species to investigate the internal variations between them. The anatomical results obtained showed that *S. kali* and *S. innermis* were closely related and separated from the rest of the studied species, while *S.tetrandra* and *S.volkensii* were related as well and meanwhile in relation with the other two species; *S.tetragona* and *S.longifolia*. This study revealed that the genus *Salsola* exhibit either normal or abnormal secondary growth in their stems with great variations within the studied species. The biochemical data indicate that *Salsola kali* is highly different and support its anatomical aspects. Gallic acid the precursor of hydrolysable tannins was only found in *Salsola kali*. As the genus *Salsola* exhibits a large diversity in habitat and morphology, it could be also seen that there is a variety in the phenolic constituents. The biochemical data indicate that *Salsola kali* is highly different and support its morphological and anatomical aspects.

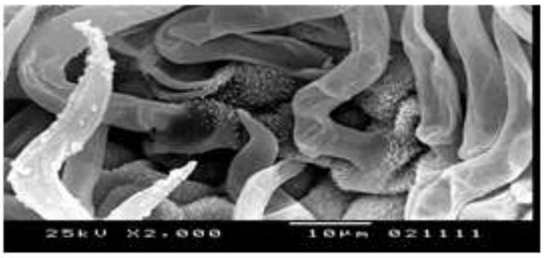
Although the number of species involved in this study is rather limited, yet the results obtained give an indication to the possibility of deducing a correlation between the presence or absence of certain flavonoid compounds and the different groups of species in the genus. This in itself may have significance in the hierarchical arrangement of the species within the genus *Salsola*.

The data obtained, so far, show that all the glycosidic patterns are flavonol-O-glycosides of quercetin. The different phenolic patterns are related to their occurrence to the family chenopodiaceae. Mineral and organic compounds analyses revealed that the studied species are under stress and their variations cannot be used in the taxonomy of the group.

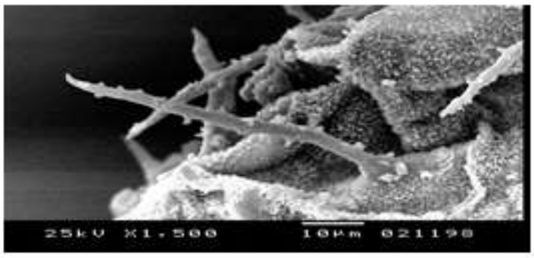
Salsola kali (X=3500µm)



Salsola tetrandra (X=3500µm)

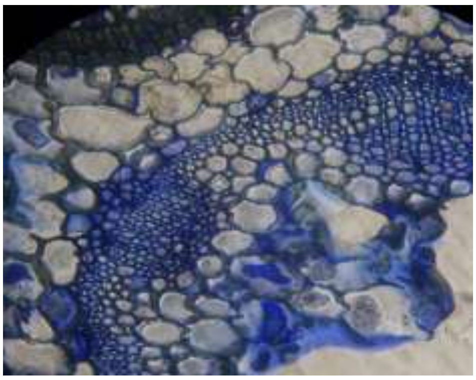


Salsola tetragona (X=500µm)

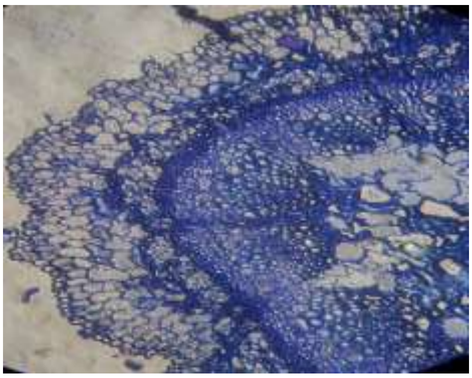


Salsola volkanesii (X=500µm)

Surface view of the leaves showing the hairs and wax deposition in *Salsola tetragona and S volkanesii*

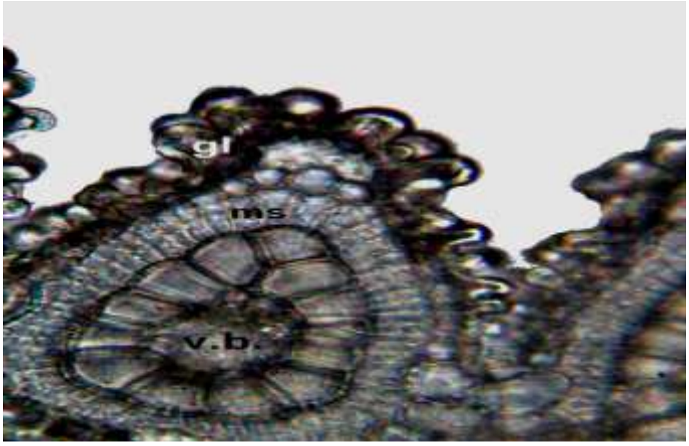


Salsola kali (X=100mm)



Salsola innermis(X=100mm)

Transverse sections in the fourth node of the stem in Skali and S. innermis showing stem secondary growth, few layers of phloem tissue



Cross section through the lamina of *Sporobolus pungens* (X 200); gl – salt gland; ms –mesophyll; v.b. – vascular bundle after Grigore *et al.* 2012

Adaptations within halophytes:

Flowers and Colmer (2015) said that ″Salt tolerance, however, occurs in relatively few current species, suggesting this trait has either been gained and lost, or that various salt-tolerant species become extinct over evolutionary time″. This statement takes us to give this group great attention to trace their phenomena and their external and internal variations. Chapman (1975) identified nine distinct geographical zones within the maritime salt marshes which are widely distributed throughout the world. Each of these zones has its own characteristic vegetation due to different climatic and edaphic conditions. These plants viz., halophytes and mangroves exhibit unique morphological and physiological characters, which characterize them from other groups of the plant kingdom and by which they are able to withstand high concentrationsof salts in the habitats.

Halophytes are well-adapted and thrive under high salinity by using two strategies, salt tolerance, and salt avoidance. Generally, halophytes follow three mechanisms of salt tolerance; reduction of the Na^+ influx, compartmentalization, and excretion of sodium ions (Flowers and Colmer, 2008, 2015). Adaptations involved in salt avoidance are secretion, shedding, and succulence (discussed in Waisel, 1972; Rozema, 1995; Aslam *et al*., 2011; Shabala *et al*., 2014 and Meng *et al.*, 2018). In brief, secretion is a complex mechanism, and salt-secreting structures (salt hairs or salt glands) are distributed in halophytes. Some halophytes are capable of excreting excess salt in the form of a liquid which becomes crystals in contact with air and may visible on the plant leaf surface as in *Zygophyllum cristallinum*. In some halophytes, shedding of the old leaves which are grown under high salt concentrations is another strategy to avoid the salt toxicity. Grigore *et al*. (2012) discussed the different aspects of the various adaptive structures of halophytes in an integrative way at the anatomy level.

These variations considered as intelligent behavior to survive. Accordingly, we will go first on the external variations which give them support for survival.In *Rhizophora mucronata* stilt roots are strong and well developed. In addition to normal roots stilt or prop roots develop from the aerial branches of stem for efficient anchorage in muddy or loose sandy soil. Meanwhile mangroves plants develop negatively geotropic roots known as ‘ pneumatophores’, root knees or breathing roots arising upwards in the air. Several aerial roots have been traced by Tomlinson (1986) in mangroves.

Stilt roots in mangrove species

Lenticels in the stemof mangrove species

Halophytes have adaptation mechanisms to cope with excessive amount of salt. They maintain acceptable internal salt concentration by excreting excess salts through roots or leaves or by concentrating salts in leaves that later die and drop off.

Morphological Adaptations:

Most halophytes exhibits some morphological adaptations to help them to survive under excess salt concentrations and severe dryness, in this review we have to mention some of these adaptations which we can easily observed. In contrast to desert plants, Xerophytes which often have leaf modifications to minimize the exposed surface which can lose water. Xerophytes leaves are often small in size and covered by thick cuticle or by wax and hairs. In some cases leaves are so reduced in size that the leaf function of photosynthesis is done by the stem, which become rich in chloroplasts. In *Calotropis procera* the leaves take special perpendicular arrangement to protect themselves from sun rays. In the same time halophytes have some morphological adaptations, as well, that enable them to survive in salty habitats from them are the following:-

- The leaves swollen and store water
- The leaves have many secretory glands
- Water storage structures develop in the leaves, such as excretory hairs and gall bladders
- They have long roots, which go in search of water
- The stem becomes green or pinkish in some species the stems become purple.
- Pollen grains have pantoprate apertures with sunken and covered pores.

Adaptations to oligotrophic soils:

The oligotropic soils have very low amount of nutrients. This is due to the effect of weather and high rates of leaching, these soils become very poor in nutrients. Accordingly, halophytic plants go through relationship with fungi, mycorrhizae, in their roots to help them in absorbing the trace amounts of nutrients present in the soil. These fungal mycorrhizae can be either inside the roots, endo mycorrhizae, or on the root surface, ectomycorrhizae. In endo mycorrhizae the fungus lives inside roots. In this case, the halophyte can survive even in this poor soil.

Internal adaptations:

Halophytic species have some internal, microscopic, features to enable them to adapt the salinity stress and to prevent them to lose water. From these adaptations are the following items:-

- The leaves covered with layers, or granules, of wax depositions
- They have a thick cuticle and a multiple layered epidermis
- They have sunken stomata
- The leaves and stems covered with hairs
- The phloem tissue is reduced to few layers
- The xylem tissue is represented by few vessels
- They have either normal or ubnormal secondary growth
- No secondary phloem can be noticed in most halophytic species.
- The mineral composition in their tissues are in very low concentrations

Conclusion:

This study summarizes the different types and classifications of halophytes with the recognition of the major halophytic angiosperm families and the important genera and species within each family. Also indicates to both the external and interna adaptations within them. The study concentrates on one of the widely distributed halophytic genus, *Salsola*, which means to salere i.e salt. This genus is one of the chenopod genera has the main criteria of the halophyte species. Hints on the pollen grains characters, anatomical features and chemical constituents of halophytes, in general, in *Salsola* specified were mentioned. This chapter highlights the features, taxonomic status and general adaptations of halophyte to facilitate their study and understand their ways to overcome salt stress.

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