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SEM studies on morphology and function of salt glands in the genus Tamarix L. (Tamaricaceae) from Iran

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Abstract

The salt glands of halophytic plants are considered to be effective desalination devices and apparently maintain the salt balance in the leaves by the secretion of excess salts. These glands are also of particular interest since the mechanism of secretion is thought to be similar, if not identical, to the mechanism of ion transport which occurs in other parts of the plant. Thus, SEM studies were done on the morphology and function of salt glands of *Tamarix* species that grows in Iran. Salt gland in *Tamarix* is enclosed by a cuticular layer except in the two transfusionarea between the collecting cells and the lower pair of excretory cells. The cuticle is separated from the walls of the excretory cells along the outer surface creating a collecting compartment. The present study revealed that this compartment appears to be separated into two cavities (one for each of the outer excretory cells) by extension of the cuticular layer inwards to the central anticlinal wall of the gland. Many species in *Tamarix* L. are halophytes with characteristics of salt-secreting. Salt glands play an important role in regulating iron balance, maintaining osmotic presser and improving salt endurance. Based on the multiply studies on salt glands, we take a review on the structure and function of salt glands of *Tamarix* L. in the paper.

Key words : SEM, Salt glands, *Tamarix,* Tamaricaceae, Iran.

INTRODUCTION

The taxonomy of the genus *Tamarix* L. (*Tamaricaceae*) is notoriously complex[1, 3]. It is thought to contain between 54 and 90 species[2, 4], although about 200 taxa, including species, subspecies, varieties and forms, have been described since Linnaeus (1753) named the genus. *Tamarix* plants are adaptable halophytic or xerophytic trees, or shrubs, with multiple stems and slender branches. Young branches are reddish brown and clearly marked in dormancy with light-coloured leaf scars. The leaves are of two sizes, whorled, overlapping and sessile. Scale-like leaves are about 3 mm in length and cauline leaves may be 8-9 mm [5]. Leaves comprise about 50% of the photosynthetic area, the rest of phothosynthesis being carried out in cladophyll stems. Stomate density averages $5045/cm^2$[6]. The plant bears small pink bisexual flowers in catkin-like racemes. The flower has five stamens rising from a nectiferous disk, and the sepals and petals are distinct. Seeds are densely tufted at the apex, aiding wind dispersal.

Excreting halophytes have glandular cells capable of secreting excess salts from plant organs [7]. Excreting salt glands distributed in numerous unrelated plant groups and some grasses. A simple system with two-celled trichomes have evolved as collecting chambers for salts in the cordgrasses (*Spartina alterniflora, S. patens*), alkali grass (*Puccinelliaphry-ganodes*), saltgrass (*Distichliss picata*), and shoregrass (*Monantho chloelittoralis*). Also a complex type of salt glands is known in *Frankenia* (*Frankeniaceae*), *Tamarix*, (saltcedar, *Tamaricaceae*) and in several common mangroves.Salt-accumulating glands or vesiculated trichomes are more common in families Poaceae, Tamaricaceae, Chenopodiaceae and Frankeniaceae[8].

The presence of soluble salts can affect growth in several ways[9]. In the first place plants may suffer from water stress, secondly high concentrations of specific ions can be toxic and induce physiological disorders and thirdly intracellular imbalances can be caused by high salt concentration. Soil salinity is an important limiting factor for plant growth. Throughout plant evolution, plants growing in saline environments have developed specific organs, such as salt glands in recretohalopytes. Salt glands vary greatly among plants and can be divided into multicellular salt glands, bicellular salt glands and salt bladders according to their structure [10]. These glands also differ in their functions. One of the functions of salt glands is to secrete cations preferentially.

Tamarix is an important bush plant that grows widely in sandy wastelands and in saline-alkali areas of arid and semiarid regions. It has attracted attention for its specific biological and ecological characteristics as well as its important roles in ecology and the social economy[11]. As an important morphological trait for adaptation to saline environments, the salt glands of *Tamarix* have been studied since the 1950s. In early research into the salt secretion characteristics of the salt glands of *Tamarix* growing in fields and cultured artificially in phytotrons, it was discovered that Na^+ was the chief ion secreted[1214].

Accumulation of minerals affects the development of plants in various habitats; however, several groups of plants have the capability to cope with high levels of toxic metals. Such plants exhibit a variety of mechanisms that enable them to resist the toxic effects of excess minerals. One such mechanism is excretion of minerals whereby the level of minerals in the plant tissues is kept within a tolerable range. Excretion is an energy-consuming process that occurs from special salt glands. The ecological significance of such glands for the mineral regulation of plants is still subject to debate. Several investigators have pointed out the high efficiency of the salt-removal process in various plants species, whereas others suggest that salt excretion is of minor importance in certain cases [15]. The results provide evidence that the salt glands of *Tamarix* secrete with minimal selectivity a variety of different ions and that the composition of the secreted salts is related to the composition in the rhizosphere.

The function and structure of salt glands has been reviewed [1619]. Fahn[20]classified the salt glands into two types: 1- glands eliminating salts into the vacuole of the bladder cell of the trichomes such as *Atriplex* spp.; 2- glands eliminating salts to the outside of the cells such as in *Limonium, Tamarix* and *Avicennia.* In dicotyledonous species, the salt glands are multiccellular, consisting of basal and secretary cells. The number of cells may vary from six up to forty in different genera [21].

MATERIALS AND METHODS

Specimen were collected in the field or preparation from herbaria in Iran (TARI, IAUH). Specimen were collected in the field were identified in IAUH= Islamic Azad University Avicennia Herbarium using various sources [2227]. Morphological study were carried out in 19 species of *Tamarix* presented from Iran (Table. 1). For SEM studies, we used dry sampels of leaves. The specimen were then observed under the Scanning Electron Microscope (SEM Model No. Hitachi S 530) maintaining accelerating voltage of 25 kv. The samples were viewed, studied and finally photomicrographs were taken at different magnifications. The SEM study was carried out in Collage of Basic Science, Science and Research Branch, Islamic Azad University, Tehran, Iran.

RESULTS

Tamarix L. is currently regarded as one of the species suitable to combat land degradation and mitigate climate change. This genus consists of halophytic shrubs and trees native to an area spanning from southern Europe and North Africa through the Middle East and south Asia to China and Japan. *Tamarix* plants are of particular interest for their fast growth, easy vegetative propagation and acclimatability to a wide range of contrasting environmental conditions. *Tamarix* shows various protective mechanisms allowing its survival and growth in harsh environments, including the presence of salt glands on leaves, which play an important role in regulating ionic balance and maintaining/stabilizing osmotic and turgor pressure under high salinity. Indeed, such glands may excrete the salt excess which accumulates in the tissue through transpiration

Tamarix L. is known to be a salt-tolerant plant and to excrete salts on the leaf surfaces. The excess of salts in growth media is, presumably, secreted in a major bulk. A complete analysis of the secreted materials indicated a variety of anions and cations. For instance, in *Tamarix*, Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, Cl^{-}, $SO4^{2-}$, $NO3^{-}$, $PO4^{3-}$, $HCO3^{-}$ and even Br^{-} was found to be secreted [1719]. SEM observation revealed the characteristic cylindrical shape of salt glands in *Tamarix* L. (Fig. 1), which helps distinguish the salt glands from other surface structures and analyse their distribution on the leaf surface. One of the mechanisms which help plant to cope with the excess of salt is to excrete it through salt glands onto their leaf surface. Many species in *Tamarix* L. are halophytes with characteristics of salt-secreting. Salt glands play an important role in regulating iron balance, maintaining osmotic presser and improving salt endurance [28].

It is known that the salt gland in *Tamarix* is enclosed by a

Table 1: List of taxa investigated in our analysis and herbaria where the vouchers are deposited.
TARI= Herbarium of Research Institute of Forests and Rangelands, IAUH= Islamic Azad University Avicennia Herbarium

Taxon	Origin, voucher
*T. stricta*Boiss.	Iran: Prov. Hormozgan; between Gahkom and Sarchahan, 650 m, Mozaffarian, (TARI 55920).
T. aphylla (L.) Karst.	Iran: Prov. Isfahan; between Ardestan and Zavareh, 1089 m ,Arianmanesh, (IAUH 000014837).
*T. ramosissima*Ledeb.	Iran: Prov. Isfahan; Varzaneh,1479 m , Arianmanesh, (IAUH 000014842).
*T. karakalensis*Freyn.	Iran: Prov. Kerman; Bam, 1110 m, Arianmanesh, (IAUH 000014838).
*T. aralensis*Bge.	Iran: Prov. Isfahan; 20 km Meymeh to Delijan, 2113 m ,Arianmanesh, (IAUH 000014840).
*T. mascatensis*Bge.	Iran: Prov. Fars; Kazeroon, Parishan lake, 1970 m, Arianmanesh, (IAUH 000014848).
*T. hispida*var. *karelinii*Willd.	Iran: Prov. Isfahan; Zavareh, 992 m ,Arianmanesh, (IAUH 000014836).
*T. kotschyi*Bge.	Iran: Prov. Ghom; Ghom,1029 m , Arianmanesh, (IAUH 000014847).
*T. androssowii*Litw.	Iran: Prov. Isfahan; between Naein and Ardestan, 2062 m ,Arianmanesh, (IAUH 000014844).
*T. tetragyna*Ehrenb.	Var. *meyeri* Iran: Prov. Isfahan; Isfahan,1578 m , Arianmanesh, (IAUH 000014843).
	Var. *deserti* Iran: Prov. Isfahan; Varzaneh,1481 m , Arianmanesh, (IAUH 000014841).
*T. leptopetala*Bge.	Iran: Prov. Isfahan; 75 km Esfahan to Kashan, 770 m, Arianmanesh, (IAUH 000014845).
*T. passerinoides*var. *passerinoides* Del. Ex Desv.	Iran: Prov. Isfahan; between Meymeh and Delijan, 2113 m, Arianmanesh, (IAUH 000014839).
*T. szowitsiana*Bge.	Iran: Prov. Isfahan; 83 km Esfahan to Kashan, 780 m, Arianmanesh, (IAUH 000014846).

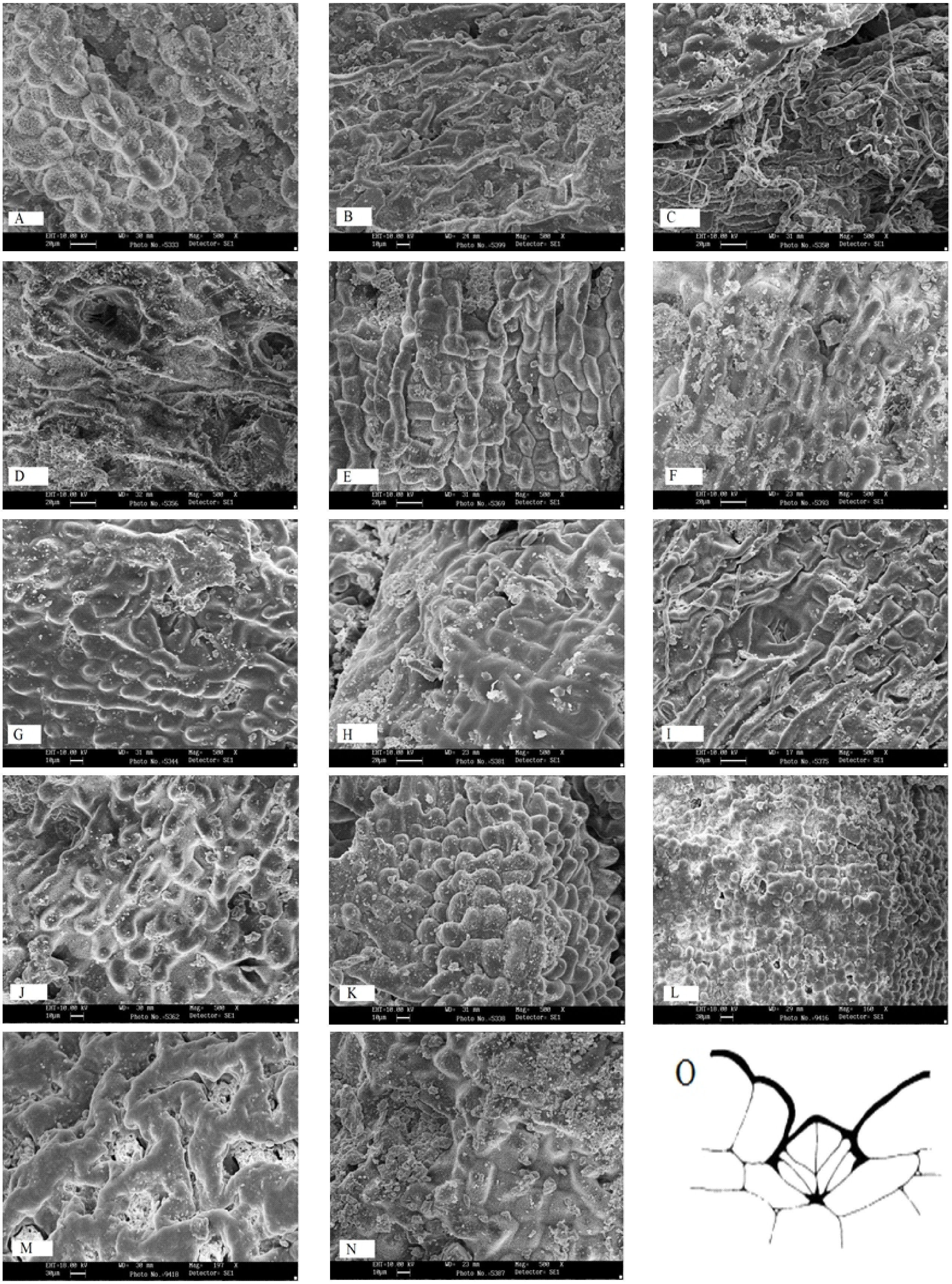

Fig 1: SEM photograph of salt glands of some members of the genus Tamarix.
A. *T. passerinoides var. passerinoides.* **B.** *T. hispidavar. karelinii.* **C.** *T. szowitsiana.* **D.** *T. karakalensis.* **E.** *T. ramosissima.* **F.** *T. tetragynavar. meyeri.* **G.** *T. aralensis.* **H.** *T. kotschyi.* **I.** *T. androssowii.* **J.** *T. Tetragynavar. deserti.* **K.** *T. leptopetala.* **L.** *T. stricta.* **M.** *T. aphylla.* **N.** *T. mascatensis.* **O.** transverse section through the salt glands of *Tamarix.*

cuticular layer except in the two transfusion area between the collecting cells and the lower pair of excretory cells. The cuticle is separated from the walls of the excretory cells along the outer surface creating a collecting compartment (Fig. 1). Multicellular salt glands in dicotyledons accumulate salt-containing water between the gland cells and the covering cuticle, and leak it via the pores [18]. The pores occur in the cuticle on the top of the glands and are detectable by SEM [20]. Glycophily is no doubt a less advanced characteristic than halophily in *Tamarix* [3]. Most of the hypodiscal species of *Tamarix* are glycophytes , while the bulk of the species are halophytes. This is in agreement with the view that non-salt-tolerant species are less specialized than salt-tolerant ones.

The salt glands of several species of *Tamarix* have been studied extensively, with the aim of determining mechanisms by which these xerophytes survive in solils with high salt concentration. Located on both leaf surfaces and young branches, the glands consist of two highly vacuolated and six less vacuolated cells, surrounded by epidermal cells with adjacent mesophyll cells. These structures are considered to provide protection of the salt glands. The salt glands are protected because they are important epidermal structures. The location and surroundings of salt glands may relate to the environment in which the plants evolved. Interspecific difference of the salt gland distribution seems to reflect the difference in the salt-excretion pathway from the vessel to the salt gland. It was noted that the secretory cells of some glands contained numerous small vacuoles distributed around the periphery of the cells. It was suggested that the vacuoles and wall projections had an important role in the secretory process.

DISCUSSION

Salt glands in *Tamarix* are compound organs consisting of eight cells composed of two inner, vacuolated, collecting cells and six outer, densely cytoplasmic, secretory cells. The secretory cells are completely enclosed by a cuticular layer except along part of the walls between the collecting cells and the inner secretory cells. Palisade parenchyma are present below the salt glands. In *Tamarix* spp. the salt glands consist of two basal collecting cell and outer six highly cytoplasmic secretory cells and the position of the gland may be a lateral register with epidermis [29].

T. aralensis and *T. ramosissima* can be identified by their sessile leaves, pentamerous flowers and hololophic androecial disks. Crins (1989) claims that their morphology is similar, and that it is difficult to recognize these two taxa as different species[30]. *T.aralensis*is distinguished from *T. ramosissima* by its caducous petals at the time of seed maturation. The morphology of salt glands, confirmed similarity between two species.

Based on morphological characteristics, *T. kotschyi* and *T. androssowii* are very similar and it is difficult to distinguish the two species. Assadi (1987) said, further researches may prove that the two types of species are the same as each others. In *T. androssowii*, bracts shorter than the pedicels and inflorescence is no dense or semi-dense. The morphology of salt glands in these two species are not closely together.

T.leptopetala and *T.mascatensis* are known synonymous by Baum (1978) while *T.leptopetala* and *T.kotschyi* are known synonymous by Qaiser (1983) but Assadi (1987) knows each of the mas independent species. *T.leptopetala* has pentamerous flowers but *T.kotschyi* has tetramerous flowers as well as *T.leptopetala* hassynlo to hololophic disk but *T.mascatensis* has synlophic disk. The morphology of salt glands in these two species are not closely together.

Two species *T. meyeri* and *T. tetragyna* are known as distinct species by Baum (1978) but Assadi (1987), for *T. tetragyna*, has identified two varieties: var. *meyeri* and var.*deserti*. In *T. tetragyna* var. *meyeri* racemes are dense with 8-10 mm broad but in *T. tetragyna* var. *deserti* racemes are not dense with 5-8 mm broad. The morphology of salt glands in these two varieties are not closely together.

CONCLUSION

The present study was carried out on thirteen species of the genus *Tamarix* L. representing the most common salt excreting halophytes in Iran. The glands of *Tamarix* are sunk in the epidermis of both leaf-sides, especially on the stems, are located in well-like cylindrical depressions. Salt glands are important for ion homeostasis regulation indicotyledons. Internal ionic equilibrium under salt stress is a comprehensive reflection of a variety of salt resistance mechanisms. The location and surroundings of salt glands may relate to the environment in which the plants evolved. Interspecific difference of the salt gland distribution seems to reflect the difference in the salt-excretion pathway from the vessel to the salt gland.

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