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ORIGINAL PAPER

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Anatomy of Desert Halophytic Leaves from Qatar

Abstract: Leaf anatomy of the 10 species of the most common perennial halophytes found in Qatar were investigated, including *Aeluropus lagopoides*, *Anabasis setifera*, *Avicennia marina*, *Halopeplis perfoliata*, *Limonium axillare*, *Salsola baryosma*, *Suaeda aegyptiaca*, *Suaeda vermiculata*, *Zygophyllum qatarense* and *Zygophyllum simplex*. Most dicot halophytes have leaves of ring-shaped or oval-shaped transverse sections, coated with a layer of cuticle, with one row of epidermal cells. *Avicennia marina*, exceptionally, have multiple epidermal layers. Trichomes were minimal among species, yet, *Aeluropus lagopoides* and *Avicennia marina* had an ample amount of trichomes. Palisade tissue is rich with chloroplasts. Intercellular spaces were limited in the palisade and spongy tissues. Spongy tissue was often full of water. Salt crystals were found in the *Anabasis setifera* and *Limonium axillare*. Vascular bundles usually occupy the central parts of the succulent leaves, or are distributed across the width of the flattened non-succulent leaves. Vascular bundles are surrounded by bundle sheaths in the monocot *Aeluropus lagoides*. Twig anatomy of the green leafless *Arthrocnemum glaucum* show the presence of well developed chlorenchyma and water storing parenchyma tissues.

تشريح أوراق النباتات الصحراوية الملحية القطرية

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المستخلص: اشتملت الدراسة على تشريح أوراق عصارية لعشرة من النباتات الملحية الشائعة الانتشار في السبخات القطرية، والنباتات هي:

Aeluropus lagopoides, Anabasis setifera, Avicennia marina, Halopeplis perfoliata, Limonium axilare, Salsola baryosma, Suaeda aegyptiaca, Suaeda vermiculata, Zygophyllum qatarense and Zygophyllum simplex.

وتبين من الدراسة ان نسبة كبيرة من النباتات الملحية لها أوراق عصارية دائرية المقطع العرضي، والقليل منها مسطح. لها بشرة مكونة من طبقة واحدة من الخلايا، عدا نبات *Avicennia marina* ذو البشرة المتعددة الطبقات. أغلب النباتات مغطاة بطبقة شمعية. الخلايا الحارسة عادة موجودة بمستوى البشرة. أغلب النباتات ليس لها شعيرات، عدا النباتين. *marina* أغلب النباتات لها طبقة عمادية *Aeluropus lagopoides, Avicennia* مضغوطة الخلايا فيها الكثير من البلاستيدات الخظراء. الطبقة الاسفنجية ذات خلايا كبيرة خازنة للماء. البلورات الملحية متميزة في النباتين . *axillare* الحزم الوعائية تحتل المنطقة الوسطى *Anabasis setifera, Limonium* في الأوراق العصارية دائرية المقطع، و منتشرة في عرض الورقة إذا كانت مسطحة. والمقطع العرضي للأغصان الخضراء لنبات *glaucum* *Arthrocnemum*، والمعروف بعدم احتوائه للأوراق، فيتميز بطبقة شمعية، بشرة، طبقة عمادية غنية بالبلاستيدات الخضراء مع طبقة كبيرة خازنة للماء، و اسطوانة وعائية.

Introduction

Halophytes worldwide are commonly found in coastal areas and in salt marshes of aridlands (Chapman 1974). In the Arabian Peninsula, halophytic succulents are commonly found in lowlands along the coastal areas, and less commonly in the interior wet areas. The non-halophytic succulents are commonly found in rocky, hilly and mountainous areas in the southwestern region of Saudi Arabia, Republic of Yemen, and Oman (Abulfatih 1983, 1991, 1992, 1997, 1998;, Abulfatih and Nasher 1988; Abulfatih *et al.* 1999, Abulfatih *et al.* 2000).

In the Qatari peninsula halophytic succulents and non-succulent species are common and widespread because of the flatness and the low level of the land (Abulfatih 1998, Abulfatih *et al.* 1999; Abulfatih *et al.* 2000; Batanouny 1981).

Halophytes are those plants which grow in salt marshes or in certain types of alkaline soil that are slightly toxic (James and MacDaniels 1947). These plants, although frequently standing in water, have elaborate structural and physiological modifications that

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reduce water loss, much like those found in dry conditions (James and MacDaniels 1947, Larcher 1980). Halophytes are commonly characterized by having shallow roots as a result of the high water table, which generally exists in their habitats (Abulfatih 1975).

The extreme environmental conditions of high salinity and high temperature and solar radiation place an immense pressure on halophytic plants. Through time and natural selection, plants were adapted morphologically and anatomically to such environmental stresses. Leaf anatomy expresses various adaptive strategies to cope with such conditions, such as: a small ratio of external surface area to internal surface area of the leaf (Openheimer 1960, James and MacDaniels 1974, Esua 1977, Soliman and Khedr 1997), reduction in the size of the leaf being considered a feature correlated with the reduction of the rate of transpiration; well developed water-storing tissues (Zahran *et al.* 1993, Al-Oudat and Al-Deaji 1992), water-storage cells in the leaf consisting of large vacuoles, containing a dilute and/or mucilaginous cell sap; the lack of nitrogen compounds and/or water in the soil, often resulting in the appearance of xeromorphic characters such as the formation of thick cuticle (Fahn 1985); intense illumination, apparently resulting in the increased development of palisade tissue (Shields 1950); increased development of palisade tissues, probably resulting in an increase of photosynthesis (Fahn 1985); plants growing under the sun forming thicker cuticles than those living in shaded places (Bleckmann *et al.* 1980); epicuticular wax and resin possibly playing a role in insulation and light reflectance (Johnson 1975); hairs or scales rarely found on the surface of the succulent halophytes; in the succulent plant *Anabasis articulata* cell wall thickening seen to develop in the guard cells in the hot summer months (Fahn and Dembo, 1964); and finally, broad and short tracheid-like cells found in the mesophyll cells of some succulents, probably used to store water and/or transport water to the peripheral layers of the leaf (Fahn 1985).

The present study focuses on the leaf anatomy of the endemic halophytes of Qatar, where to my knowledge no previous research has been conducted on these species.

Materials and Methods

Leaf anatomy, or twig anatomy (of leafless plants) was conducted on the most common halophytic perennial plants found in Qatar (Table 1). The study was conducted under a light microscope using fresh materials, and dissection was made by free-hand sectioning.

Results and Discussion

Anatomy:

The present study revealed that leaf anatomy of the investigated species goes along with the general principles of the anatomy of other halophytes found in other parts of the world. Yet, it is still worthwhile to add a new piece of information to the anatomy of endemic halophytes, dealing with species which have never been reported before. Each of these species maintains distinctive anatomical features.

Leaf anatomy of the 11 species and twig anatomy of one leafless species of the most common halophytes found in Qatar were investigated (Table 1 and Figures 1-4). Plants were divided into the following categories: halophytes with succulent leaves: *Anabasis setifera, Halopeplis perfoliata, Salsola baryosma, Suaeda aegyptiaca, Suaeda vermiculata, Zygophyllum qatarense, Zygophyllum simplex and Limonium axillare*; halophytes with succulent twigs: *Arthrocnemum glaucum*; halophytes with non-succulent leaves: *Aeluropus lagopoides* and *Avicennia marina*. The study revealed the following general anatomical features:

Leaf form: Leaf transfers sections were more or less ring-shaped or oval-shaped in most investigated species. On the other hand, leaves of *limonium axillare, Aeluropus lagopoides* and *Avicennia marina* appeared flat in transverse section.

Cuticle: All investigated leaves were characterized by having a coating layer of cuticle with variable thickness.

Epidermis: All examined species have one row of epidermal cells, with the exception of *Avicennia marina* which has multiple layers of epidermis at the upper section of the leaf. Guard cells were present along the level of the epidermal cells. No obvious sunken stomata were encountered in any investigated leaves. Bulliform cells (motor cells) which control the folding and unfolding of the leaf were observed in *Aeluropus lagopoides.*

Trichomes: Trichomes are rare in succulent leaves. However, the grass *Aeluropus lagopoides* has an ample amount of trichomes on the inner leaf surface, and *Avicennia marina* has dense salt secreting

glandular trichomes on the lower epidermis.

Palisade tissue: Most species have distinctive layers of elongated palisade chlorenchyma cells, having dense chloroplasts and limited intercellular spaces. Salt crystals are common in the palisade tissues of *Anabasis setifera* and *Limonium Axillare*.

Spongy tissue: Most species have distinctive spongy water-storing parenchyma tissues, with little intercellular spaces.

Vascular bundles: Vascular bundles usually occupy the central parts of the leaf when the leaf is round in transverse section. On the other hand, in flattened leaves as in *Aeluropus lagoides, Avicennia marina* and *Limonium Axillare* many vascular bundles were found across the width of leaves. Vascular bundles were surrounded by bundle sheaths of parenchyma cells in the case of the grass *Aeluropus lagoides*. Such bundle sheaths are known to play an important role in the process of photosynthesis of the C_4 plants, which live under extreme arid conditions.

Strengthening tissue: (sclerenchyma): Strengthening tissues were not encountered in the halophytic leaves.

Twig anatomy: Twig anatomy of the leafless *Arthrocnemum glaucum* reveals the presence of epidermis, chlorenchyma tissue (rich with chloroplats), parenchyma tissue, pericycle,

Table 1. Common halophytic succulent and non-succulent species from Qatar.

Species, Family	Vernacular Name	Arabic Name	Leaf * Thickness (mm)
Halophytic Succulents			
Anabasis setifera			
Chenopodiaceae	Sha"aran	شعيران	1.8
Arthrocnemum glaucum **			
Chenopodiaceae	Shinan	شنان	2.5
Halopeplis perfoliata			
Chenopodiaceae	Khraizah	خريزة	5.0
Limonium axillare			
Plumbaginaceae	Kadaf	قطف	1.2
Salsola baryosma			
Chenopodiaceae	Ikhreet	إخريط	1.2
Suaeda aegyptiaca (= *Schanginia aegyptiaca*)			
Chenopodiaceae	Julman	جلمان	2.0
Suaeda vermiculata			
Chenopodiaceae	Swaidah	سويدة	2.2
Zygophyllum qatarense			
Zygophyllaceae	Haram	هرم	3.0
Zygophyllum simplex			
Zygophyllaceae	Karmal	قرمل	2.0
Halophytic Non-Succulents			
Aeluropus lagopoides ***			
Gramineae	Ikrish	عكرش	0.8
Avicennia marina			
Aviceniaceae	Garum	قرم	1.0

* Thickness measured at the center of the leaf, ** A leafless succulent, ***Grass

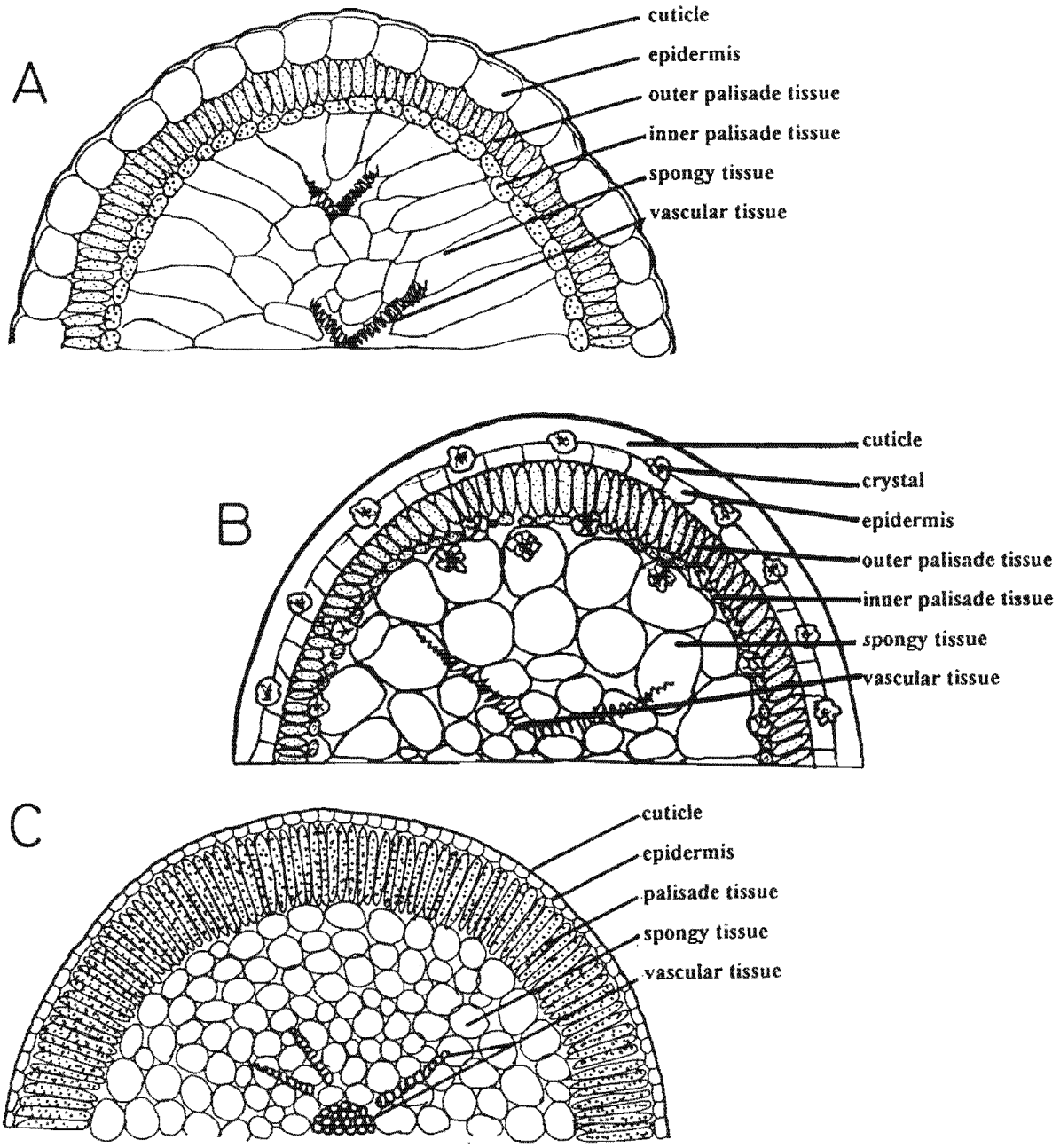

Figure 1. Transverse sections in leaves of (A) *Zygophyllum simplex*, Zygophyllaceae; (B) *Anabasis setifera*, Chenopodiaceae; (C) *Zygophyllum qatarense*, Zygophyllaceae. Leaf thickness in sequential order: 2.0 mm, 1.8 mm, 3.0 mm.

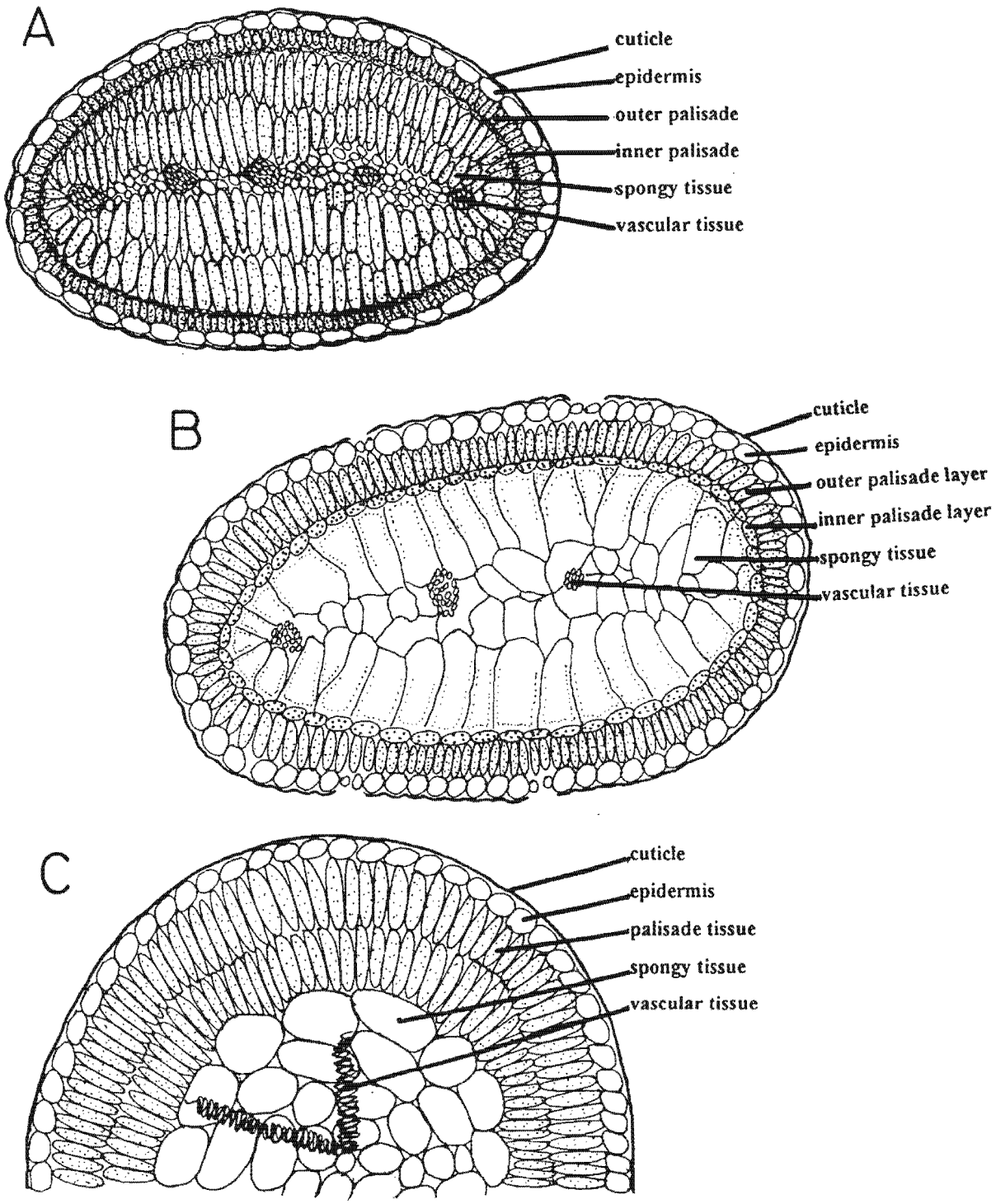

Figure 2. Transverse sections in leaves of (A) *Suaeda aegyptiaca*, Chenopodiaceae; (B) *Suaeda vermiculata*, Chenopodiaceae; (C) *Halopeplis perfoliata*, Chenopodiaceae. Leaf thickness in sequential order: 2.0 mm, 2.2 mm, 5.0 mm.

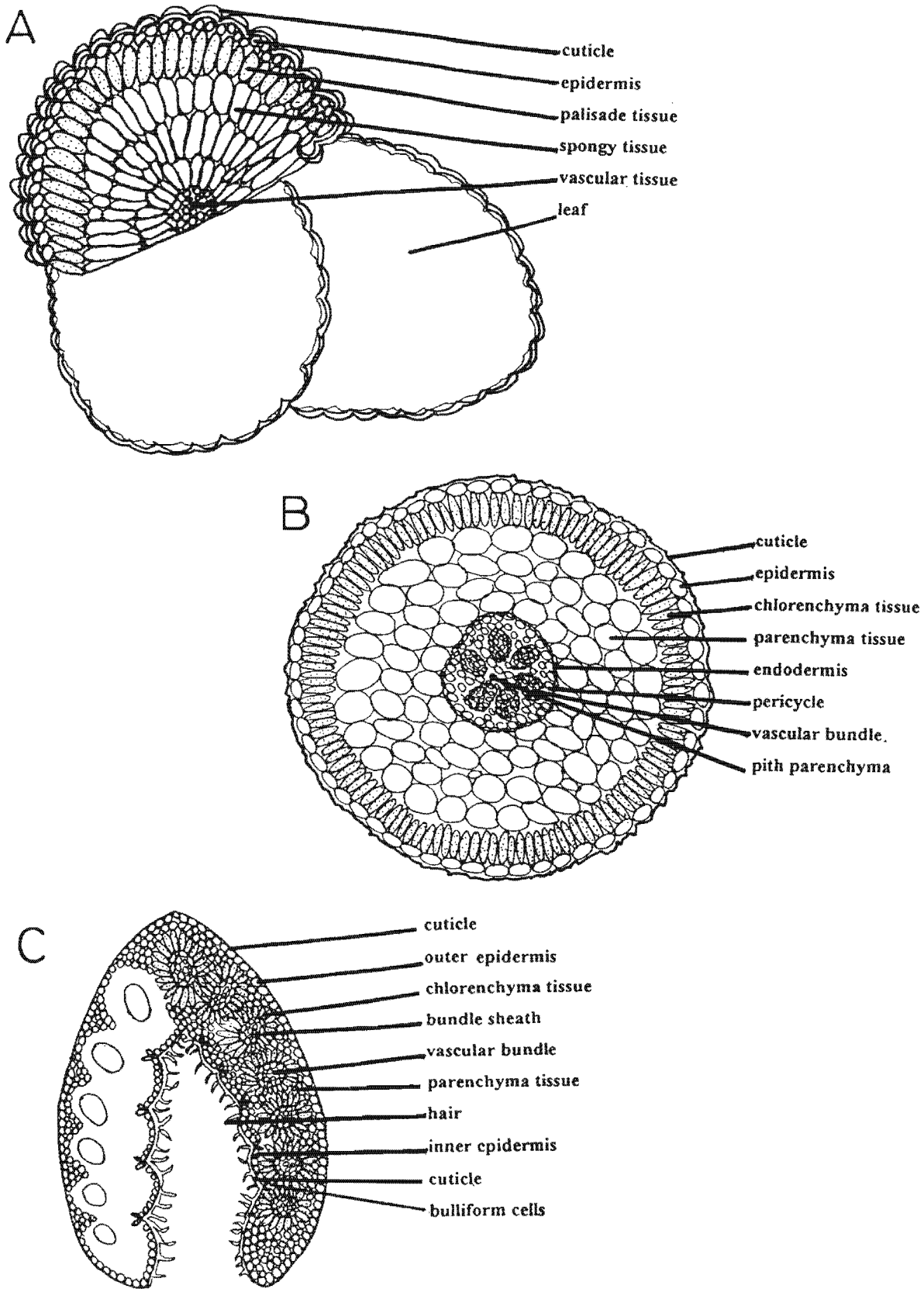

Figure 3. Transverse sections in leaves of (A) *Salsola baryosma*, Chenopodiaceae;(B) transverse section in a halophytic stem, of the leafless *Arthrocnemum glaucum*, Chenopodiaceae. (C) *Aeluropus lagopoides*, Gramineae; Leaf thickness in sequential order: 1.2 mm, 0.8 mm. Stem thickness is 2.5 mm.

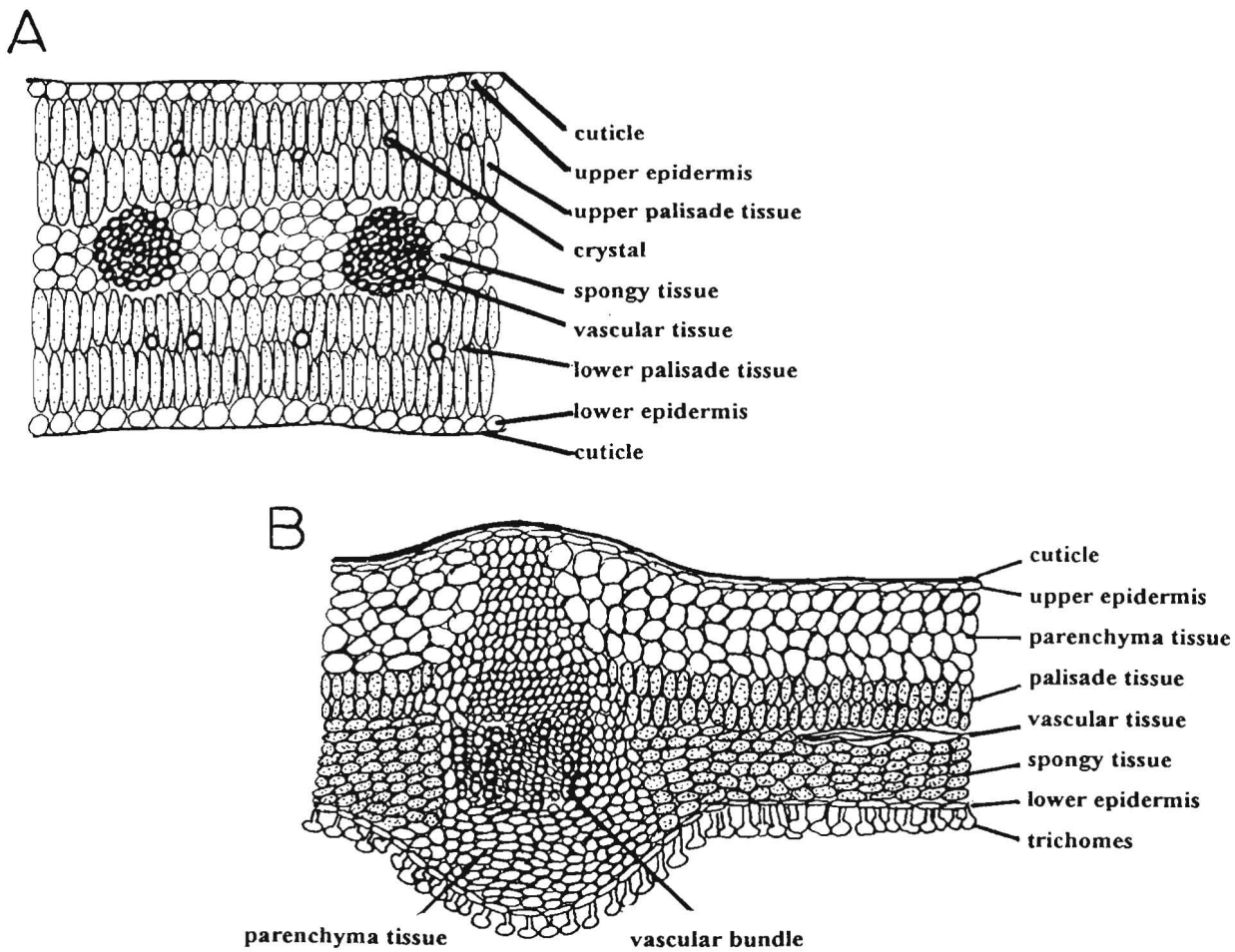

Figure 4. Transverse sections in leaves of (A) *Limonium axillare*, Plumbaginaceae; (B) *Avicennia marina*, Aviceniaceae. Leaf thickness in sequential order: 1.2 mm, 1.0 mm.

endodermis, and centric vascular bundles. A somewhat similar structure was found in *Arthocnemum fruticosum* (Saad-Eddin and Doddema 1984).

Ecological and Morphological Remarks:

Halophytes are mostly found on sandy saline soils of the coastal and inland flat areas of Qatar (Abulfatih 1998, Abulfatih *et al.* 2000, Batanouny 1981). These halophytes are characterized by the following features:

Aeluropus lagopoides: non-succulent small grass, found on saline soils with high water table (Fig. 3-C).

Anabasis setifera: A dwarf shrub, half-woody half-succulent, living on saline and brackish waters (Fig.1-B).

Arthrocnemum glaucum: A dwarf shrub, half-woody half-succulent, leafless plant, having fleshy green twigs. Commonly found at the high tide coastal marshes (Fig. 3-B).

Avicennia marina (mangrove): A woody tree, with leathery non-succulent leaves, commonly found in the eastern intertidal coastal areas of Qatar (Fig. 4-B).

Halopeplis perfoliata: A dwarf shrub, half-woody half-succulent, living on sandy saline soil (Fig. 2-C).

Limonium axillare: A dwarf shrub, half-woody half-succulent, found on saline compact soil (Fig. 4-A).

Salsola baryosma: A dwarf shrub, half-woody half-succulent, found on disturbed saline soil (Fig. 3-A).

Suaeda aegyptiaca: A dwarf shrub, half-woody half-succulent, found on saline soil (Fig. 2-A).

Suaeda vermiculata: A dwarf shrub, half-woody half-succulent, found on saline soil (Fig. 2-B).

Zygophyllum qatarense: A dwarf shrub, half-woody half-succulent, widespread in Qatar, in diverse habitats, ranging from rocky to sandy, and

living on a wide range of water salinity, from fresh water to highly saline water (Fig. 1-C).

Zygophyllum simplex: A small fragile herbaceous plant, found mostly on disturbed saline soil (Fig. 1-A).

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