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THE SIGNIFICANCE OF ANATOMICAL CHARACTERS IN THE WATER ECONOMY OF SOME DESERT PLANTS

By

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ABSTRACT

The present study aims to find out the anatomical peculiarities of considerable importance in water economy.

The studied plants include eight xerophytic plants and one mesophtic for comparison. Among the xerophytic plants there are one succulent, one grass and some non-succulent species.

The most important anatomical characters from the stand point of water economy are summarized in the following:

1) Anatomical characters minimizing water expenditure such as increased cuticle thickness, presence of subepidermal layer, dense hair cover and rolling of leaves.
2) Characters increasing the efficiency of photosynthetic tissue represented by the high ratio of photosynthetic to spongy tissue.
3) Characters leading to reduction of water evaporation from the internal surface of the leaf represented by narrow intercellular spaces of the mesophyll tissue.
4) Presence of water storage tissue in some species, composed of big cells, thin walled with extremely narrow intercellular spaces.

INTRODUCTION

The anatomical characters play an important role in drought tolerance of xerophytes.

Each species has its own set of anatomical characters on which it depends in drought tolerance. In the present investigation the anatomical peculiarities of some of the common xerophytes inhabiting four desert habitats located near Cairo were studied.

MATERIAL AND METHODS

The material used in the present investigation was obtained from plants of Stachys aegyptiaca, Diplotaxis harra, Panicum turgidum, Cornulaca monacantha, Convolvulus lanatus, Artemisia monosperma, Calligonum comosum and Rumex cyprius growing naturally in different desert habitats along Cairo-Suez road, Cairo-Alexandria road, Cairo-El-Fayoum road and in the Wadi Hof. Also a material was collected from a mesophytic plant Calendula arvensis.

Sectioning for anatomical investigation was performed according to the technique used by Sass (1951) and Johansen (1940). Drawing of the studied organs was carried out by the aid of a Leitz-Camera Lucida. The magnification was given by a stage micrometer scaled to 0.1 and 0.01 mm.

RESULTS

The anatomical characters of the studied species were examined to find out the significance of these characters in drought tolerance. Emphasis was placed on the leaf anatomy since it represents the main transpiring and assimilating surface of the shoot. The internal structure of the studied species is summarised in the following:

Stachys aegyptiaca:

Leaf anatomy: The leaf is covered by clothing hairs. Walls of the hairs are stiff strongly cuticularised. The hairs are nonglandular tufted multicellular (Fig. 1). The thickness of the outer wall of the upper epidermis is about 5 u and that of the lower epidermis is about 2.5 u.

The leaf is isobilateral, the upper and lower palisade tissue of the mesophyl composed of three layers each. The spongy tissue is very reduced and composed only of about two layers. Both the palisade and spongy tissues are compact with very narrow intercellular spaces of about 7% of the cross sectional area. The ratio of palisade to spongy tissue is about 7.7:1.

It is of particular interest to notice that branches of the hairs interlock with each other forming a closed cover on the surface of the leaf increasing the protection of the leaf from air currents. Also it keeps the film of air in direct contact with the leaf in a humid state.

Diplotaxis harra:

Leaf anatomy: The leaf is covered by a thick cuticle. The thickness of the outer wall of the upper epidermis is about 5 u and that of the lower epidermis is about 4.4 u.

The mesophyll tissue is thick and composed of a compact palisade and spongy tissue with extremely narrow intercellular spaces. The percentage of intercellular spaces in the mesophyll tissue in the cross sectional area is about 4%. This phenomenon is of prime importance in water economy since the limited internal evaporating surface exposed to the air spaces results in the great reduction of water vapour accumulating behind the stomata.

The palisade layers were about three in each of the upper and lower side enclosing a reduced spongy tissue (Fig.2).

Cornulaca monacantha:

Leaf anatomy: The epidermis is covered by a very thick cuticle. The thickness of the outer epidermal wall reached about 12.5 u on the upper surface and about 7.5 u on the lower surface. Internal to the epidermis there is one layer of hypodermis in the lower side (Figs3a, 3b). The leaf is very thick of about 777 u in thickness. This implies a high ratio of volume to external surface which is of considerable importance in water economy.

The mesophyll occupies a narrow zone in the cross sectional area. It is composed of one layer of long palisade layer followed internally by one layer of chlorenchyma in each side. The main bulk of the leaf consists of large parenchyma cells with large vacuoles and thin walls. They serve for the storage of water. The intercellular spaces are narrow constituting about 6.1% of the cross sectional area. Many cells contain calcium oxalate crystals.

Convolvulus lanatus:

Leaf anatomy: The leaf is provided with a dense cover of unicellular hairs. The epidermis is covered by a thick cuticle of about 5.4 u on the upper side and of about 5.0 u on the lower side.

The mesophyll is differentiated into palisade tissue of about three layers in each of the upper and lower side enclosing a very reduced spongy tissue of about two layers (Fig.4). The cells of both the palisade and spongy tissues are very compact with extremely narrow intercellular spaces constituting about 3% of the cross sectional area. The mesophyll tissue is traversed by laticiferous canals (Fig.4).

Artemisia monosperma:

Leaf anatomy: The leaf is fleshy and triangular in cross section. It is covered by a very thick cuticle. The thickness of the outer epidermal wall is about 12.5 u in the upper side and about 10 u in the lower side.

The mesophyll consists of about three layers of palisade tissue in each of the upper and lower side enclosing a storage tissue of relatively large cells with thin walls. The storage tissue is traversed by resin canals (Fig.9). The intercellular spaces inbetween the cells of the palisade and storage tissue are narrow not exceeding 8% of the cross sectional area.

Panicum turgidum:

Leaf anatomy: The leaf rolls under dry conditions. The cuticle is thicker on the lower side that on the upper side. On rolling, the lower side becomes outer and the upper side becomes inner. The stomata are restricted to the furrows inbetween the ridges. The ridges are supported by bundles of fibres (Fig.6).

The mesophyll consists of chlorenchyma cells which are compact. The intercellular spaces are extremely narrow. In a cross sectional area, the percentage of intercellular spaces is very low of about 2.3%.

Calligonum comosum:

Stem anatomy: The leaves of Calligonum are vestigeal. The cylindrical stem is the chief assimilating organ. The stem is covered by a very thick cuticle. The thickness of the outer epidermal wall is about 10 u. Tannin is widely distributed and accumulates in the tissues of the stem. The assimilating tissue is found directly inside the epidermis. It is represented by two layers of chlorenchyma enclosing one layer of palisade cells (Fig.7).

This well represented palisade tissue compensates for the great reduction in the leaf surface.

The pericycle consists of interrupted isolated bundles of sclerenchyma. The vascular bundles are widely separated by broad primary rays.

Rumex cyprius:

Leaf anatomy: In contrast to the above described perennials, the leaf of the ephemeral Rumex cyprius is covered by a thin cuticle. The thickness of the outer epidermal wall is about 1.3 u in the upper side and about 1.2 u in the lower side.

The mesophyll is differentiated into two upper and two lower palisade layers enclosing a spongy tissue of two layers (Fig.8). The mesophyll cells are less compact than in the studied perennials and the percentage of the intercellular spaces in the cross sectional area is about 26%. The vascular tissue is weakly developed and represented by two small vascular bundles in the midrib.

Calendula arvensis:

Leaf anatomy: Calendula arvensis being a mesophyte expresses some anatomical characters different from those exhibited by the xerophytic perennials and summarised in the following: The cuticle is thin and the thickness of the outer epidermal wall is about 1.8 u in the upper side and about 1.3 u in the lower side.

Legends for the figures:

Fig. (1) : Section in Stachys aegyptiaca leaf.

Fig. (2) : Section in Diplotaxis harra leaf.

Fig. (3a): Diagram of a section in Cornulaca monacantha leaf

Fig. (3b): Sector of a section in Cornulaca monacantha leaf.

Fig. (4) : Section in Convolvulus lanatus leaf

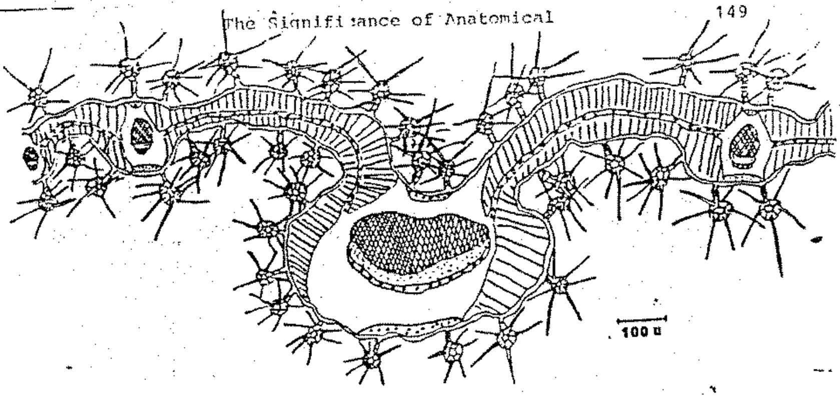
Fig. (5) : Section in Artemisia monosperma leaf.

Fig. (6) : Section in Panicum turgidum leaf.

Fig. (7) : Section in Calligonum comosum stem.

Fig. (8) : Section in Rumex cyprius leaf.

Fig. (9) : Section in Calendula arvensis leaf.



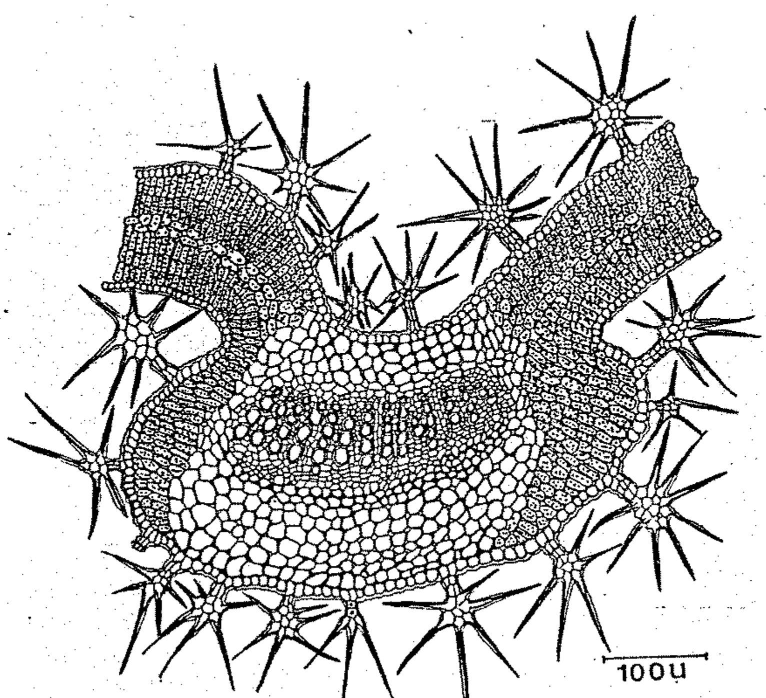


Fig. 1 . Section in Stachys aegyptiaca leaf. Diagram(above) and sector(below).

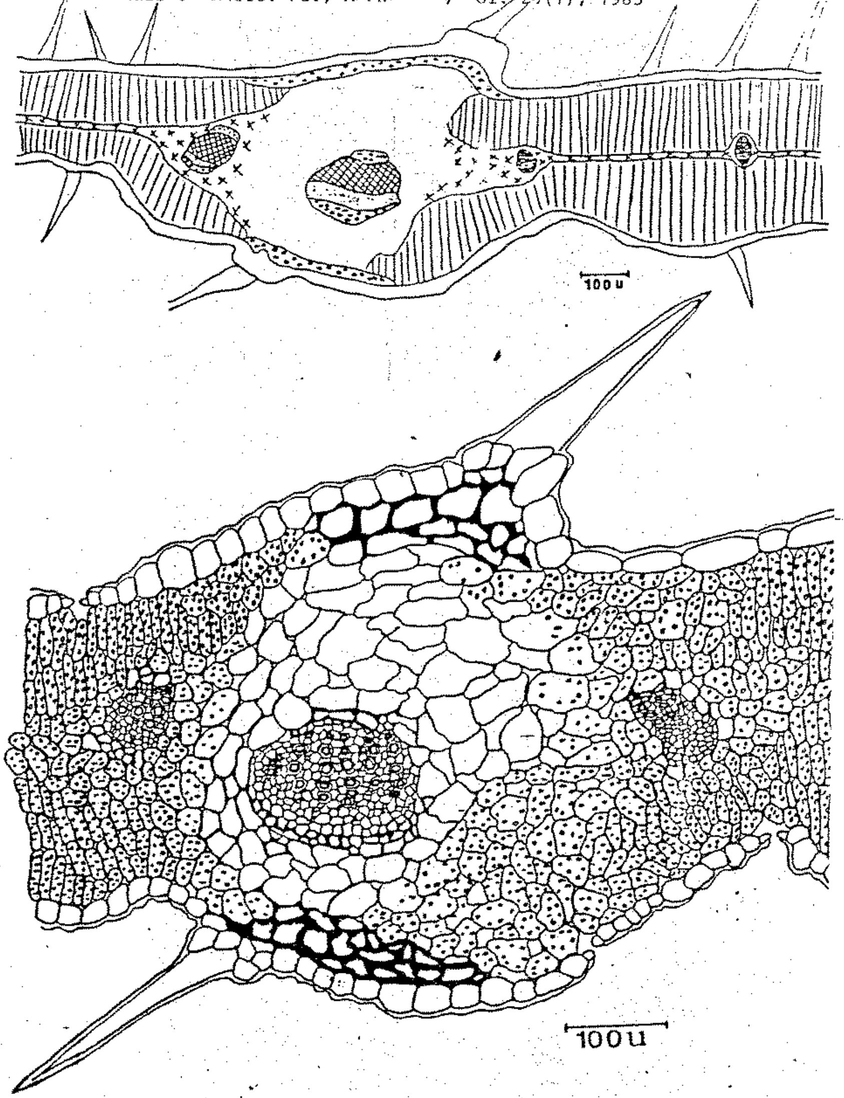


Fig. 2.. Section in <u>Diplotaxis</u> <u>harra</u> leaf.
Diagram(above) and sector(below).

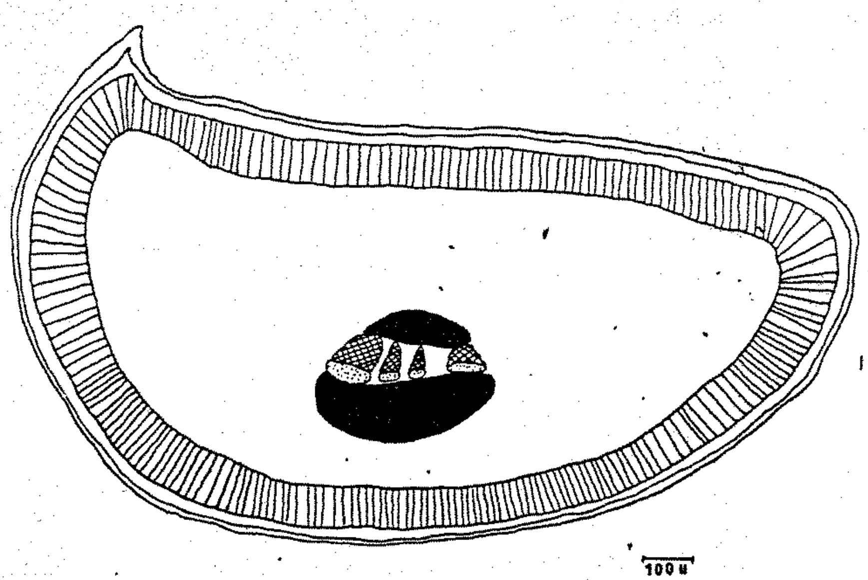


Fig. 3a . Diagram of a section in Cornulaca monacantha leaf.

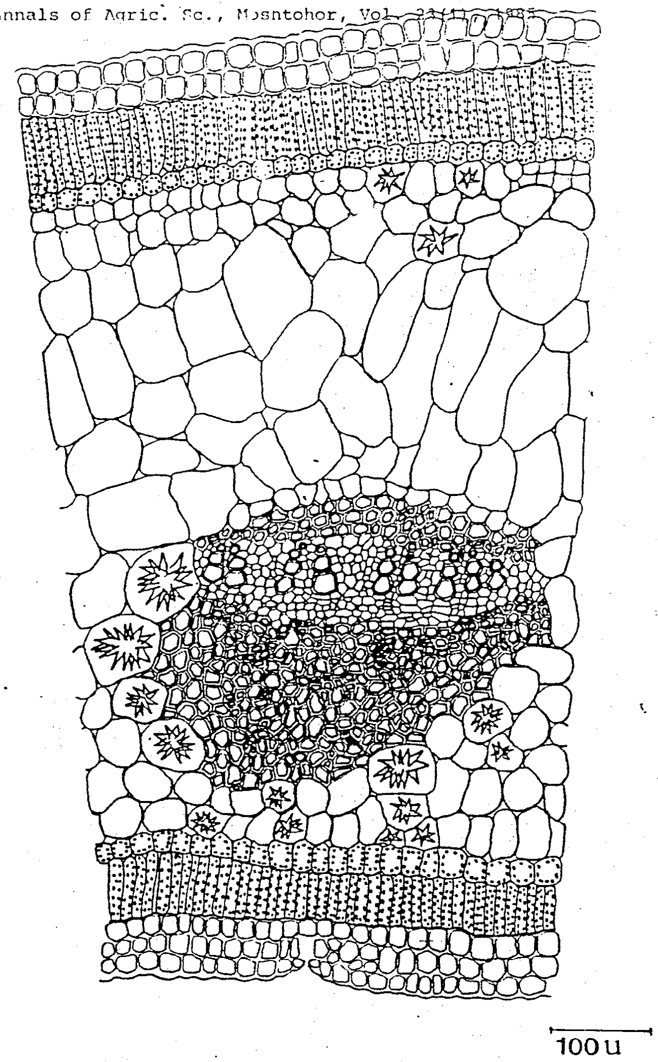
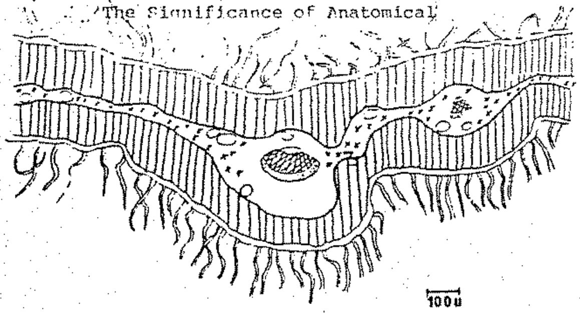


Fig. 3b. Sector of a section in Cornulaca monacantha leaf.



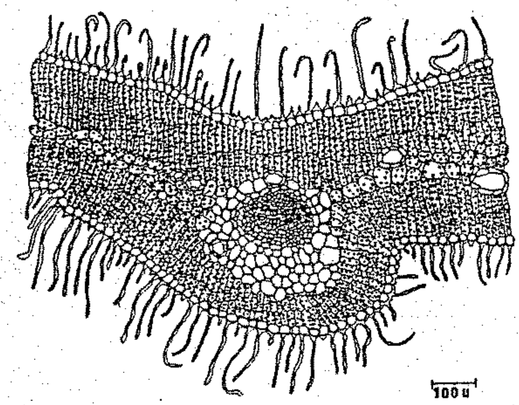


Fig. 4. Section in *Convolvulus lanatus* leaf.
Diagram(above) and sector(below).

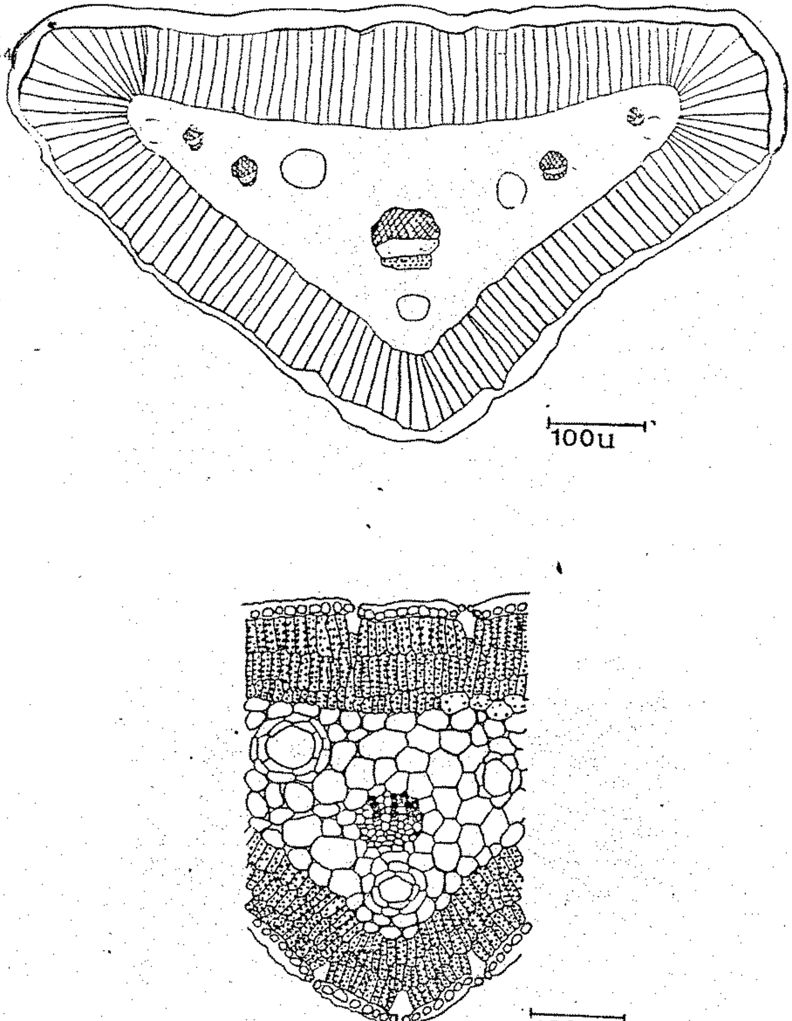


Fig. 5. Section in *Artemisia monosperma* leaf.
Diagram(above) and sector(below).

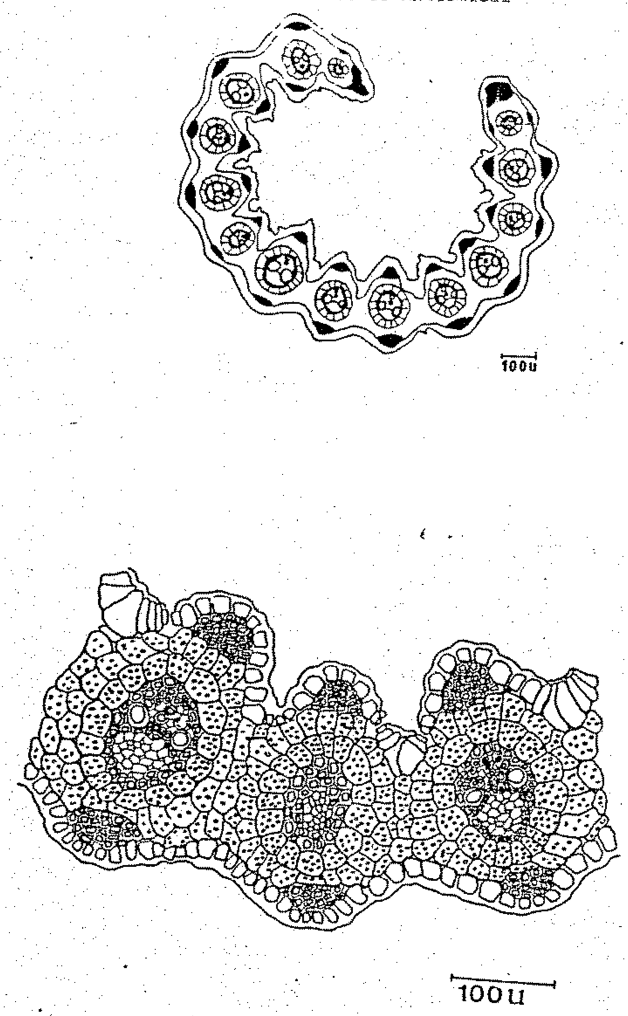


Fig. 6) Section in *Panicum turgidum* leaf. Diagram(above) and sector (below).

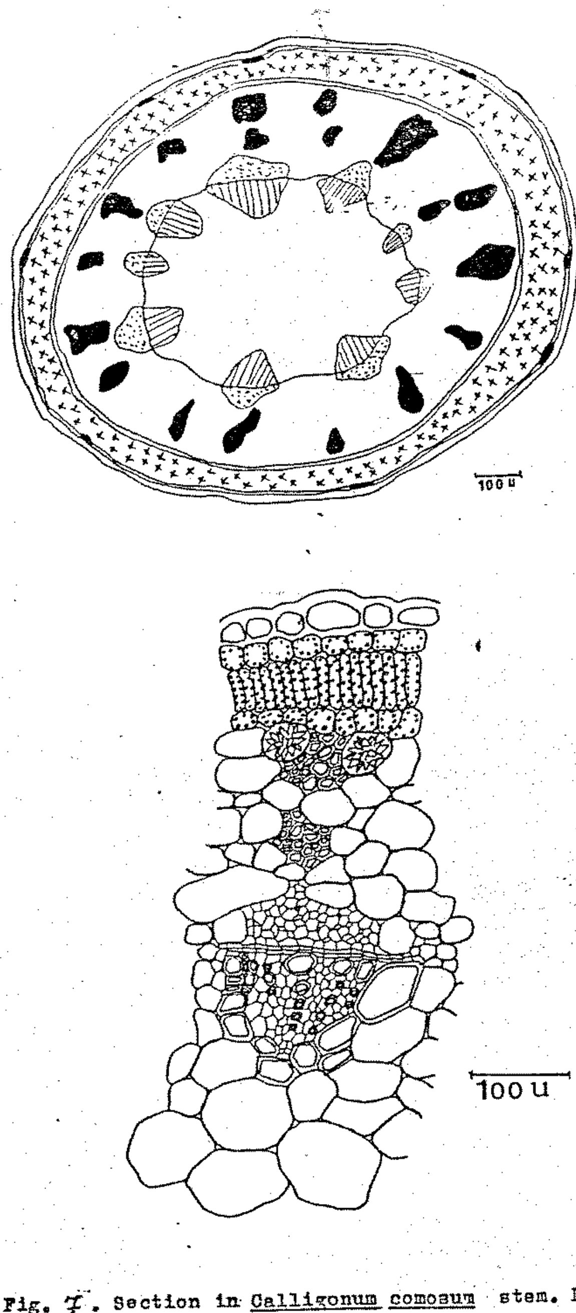
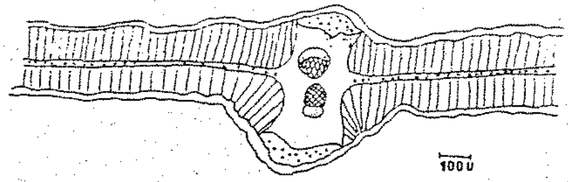


Fig. 7. Section in Calligonum comosum stem. Diagram(above and sector(below).



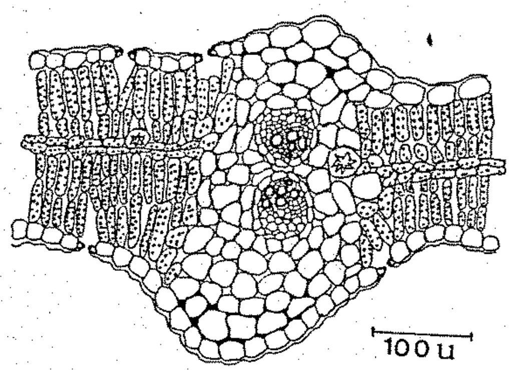


Fig. 8 . Section in *Rumex cyprius* leaf. Diagram (above) and sector(below).

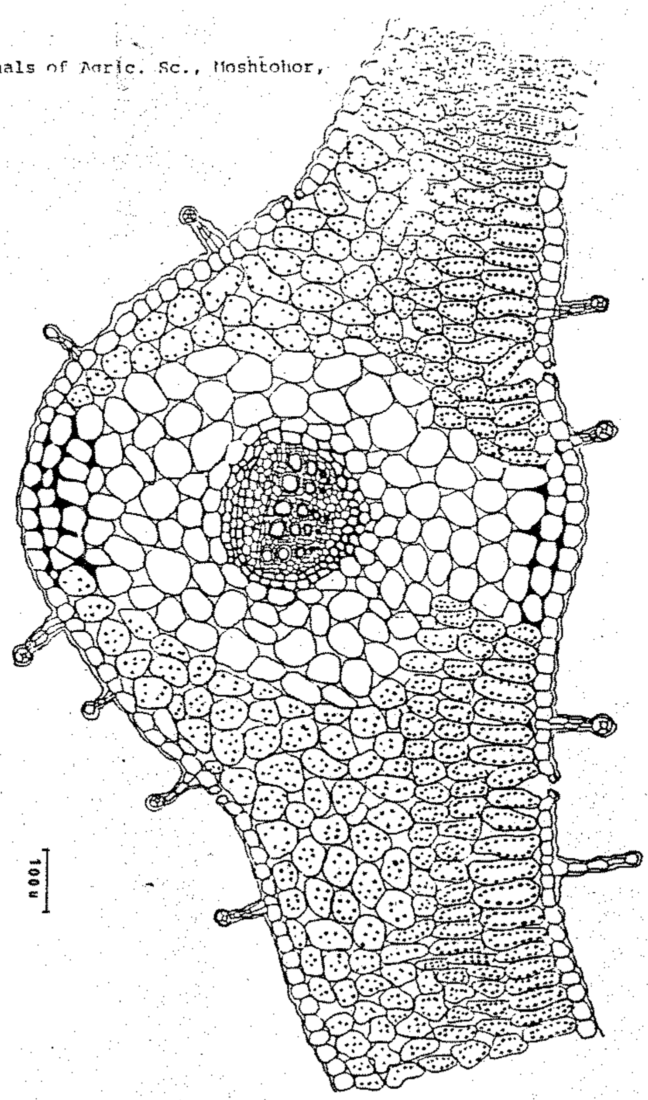


Fig. 9. Section in _Calendula arvensis_ leaf.

DISCUSSION

The xeromorphic anatomical characters exhibited by the studied perennial species can be summarised in the following:

1) Characters minimising the transpiration rate. These characters depend on:

a. Thickness of the cuticle which reduces the cuticular transpiration. Kramer (1969) reported that cutinization increased in leaves when plants subjected to water stress. Scott, Schroder and Turell (1948) showed by dissolution methods that internal surface tension (infiltration methods), also showed that internal leaf surfaces were cutinized. Stalfelt (1956) pointed out that there are differences in permeability of cutin resulting from age and hydration in addition to those resulting from difference in thickness. The difference in degree of external cutinization are well known and they probably are as characteristic to the internal leaf surface as well.

Clark and Levitt (1956) reported that xerophytes have thicker cuticle and cell walls with more lipids on the transpiring surfaces.

Esau (1960) stated that thick cell walls especially in the epidermis and thick cuticles are often recorded in xerophytic plants, but generally cuticle thickness is variable.

In the ephemeral and mesophytic species the wall did not exceed 1.8 u whereas in the studied perennial species it reached a high value of about 12.5 u as is Cornulaca monacantha and Artemisia monosperma.

b. The presence of one or two layers of hypodermis below the epidermis provided with thick walls increases the protection of the internal tissues against evaporation of water. This character is well illustrated in Cornulaca monacantha leaf. Wylie (1954) reported that a xerophytic flora may also have a high proportion of representatives with leaves having hypodermis, a tissue with few or no chloroplasts.

c. The dense cover of hairs protects the surface of the leaf from air currents and keeps the atmosphere directly in contact with the stomata in a humid condition. In the case of Stachys aegyptiaca, the hair cover appears like a forest of branched hairs interlocking with each other and thus provides a firm cover over the leaf surface. Esau (1960) reported that trichomes are abundant in many xerophytes and if the same pubescent has mesophytic and xerophytic forms, the latter usually have a denser covering of hairs. Black (1954) stated that sometimes the trichomes play a role in insulating the mesophyll from excessive heat.

d. Rolling of leaves as in case of Panicum turgidum keeps the stomata distributed in the grooves of the upper surface in a closed atmosphere away from air currents.

2) Characters increasing the photosynthetic efficiency of the leaf: These are well illustrated in thick leaves with well developed palisade tissue at the expense of the spongy tissue. In some species, the ratio of multilayered palisade tissue in both the upper and lower sides to the spongy tissue reached a high value of 7.7:1 as in case of Stachys aegyptiaca. In contrast, the ratio of palisade to spongy tissue is low of about 1.7:1 in the mesophytic species Calendula arvensis. Shields (1950) and Stalfelt (1956) reported that one of the most prevalent characteristics of xerophytic leaves is the high ratio of volume to surface; that is the leaves are small and compact. This character is associated with distinct internal structural features such as thick mesophyll with the palisade tissue more strongly developed than the spongy parenchyma or present alone.

3) Characters leading to suppression of internal evaporation of water and diffusivity of water vapour inside the leaf: These characters are represented by the extremely narrow intercellular spaces inbetween the mesophyll cells. In some species, the percentage of intercellular spaces in the cross sectional area of the leaf was extremely low of about 3-4% as in case of Convolvulus lanatus and Diplotaxis harra, respectively. In the ephemeral species Rumex cyprius and the mesophytic species Calendula arvensis the percentage of intercellular spaces were 26.2% and 28.5%, respectively. Daubenmire (1974) cited that xerophytes are characterised by smaller intercellular spaces.

4) The development of a water storage tissue composed of big cells with large vacuoles. The intercellular spaces are narrow. The water storage tissue is present in the leaves of Cornulaca monacantha and Artemisia monosperma. Storage of water in the xerophytic plant is a mechanism by which the plant can maintain its turgidity.

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أهمية الصفات التشريحية فى الاقتصاد المائى لبعض النباتات الصحراوية

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شملت الدراسة تحديد الصفات التشريحية المميزة لبعض النباتات الصحراوية والتى لها صلة وثيقة بالاقتصاد المائى ومقاومة الجفاف.

ولقد أجريت الدراسة على ثمانية نباتات صحراوية بينها نبات حولى والبقية نباتات صحراوية معمرة ضمت نباتا عصريا واخر من الحشائش والبقية غير عصرية ولقد أختير نبات من النباتات الوسطية للمقارنه بالنباتات الصحراوية لابراز الصفات الجفافيه التى تتميز بها النباتات الصحراوية.

وتتلخص الصفات التشريحية الهامة التى يتميز بها النباتات الصحراوية فى الاتى:

١ ـ الصفات التى تؤدى الى تقليل فقد الماء عن طريق النتح وتشمل زيادة سمك الكيوتين وطبقة تحت البشرة والغطاء الشعرى والتفاف الاوراق.

٢ ـ الصفات التى تزيد من فاعلية البناء الضوئى وتشمل زيادة نسبة النسيج العمادى الى النسيج الاسفنجى فى الورقة.

٣ ـ الصفات التى تقلل من بخر الماء من السطح الداخلى للورقة وتتمثل فى ضيق المسافات البينية بين خلايا النسيج الوسطى للورقة.

٤ ـ وجود نسيج تخزينى للماء فى بعض النباتات يتركب من خلايا كبيرة الحجم رقيقة الجدر تتخللها مسافات بينية غاية فى الدقة.