

FOLIAR ANATOMY OF CAREX IN ARASBARAN, NW. IRAN

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Zarrinkamar, F., Jalili, A., Hamzeh'ee, B., Asri, Y., Hodgson, J. G., Thompson, K. & Shaw, S. 2002 12 30: Foliar anatomy of some *Carex* species in Arasbaran, NW. Iran. -*Iran. Journ. Bot.* 9(2): 261-270. Tehran.

The foliar anatomy of genus *Carex* (*Cyperaceae*) from the Arasbaran protected area was studied under the light microscope. The following species have been analysed: *C. distans*, *C. divisa*, *C. divulsa*, *C. halleriana*, *C. liparocarpos*, *C. nigra*, *C. pallescens*.

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Key word. Anatomy, *Carex*, *Cyperaceae*, Arasbaran, Iran.

ساختار تشریحی برخی از گونه های جنس *Carex* از منطقه ارسباران، شمال غرب ایران

فاطمه زرین کمر، عادل جلیلی، بهنام حمزه، یونس عصری، جی هودگسون، ک

تامپسون و اس شاو

ساختار تشریحی برگ در ۷ گونه از جنس *Carex* (تیره جگن) از منطقه حفاظت شده ارسباران مطالعه شد. صفات جالبی از ساختمان آناتومی برگ شامل ویژگی سلولهای اپیدرم، اندیس روزنه و مشخصات بافتهای مختلف در برش عرضی بررسی و تحلیل شد. این مطالعه اطلاعات جامعی از آناتومی برگ در این جنس ارائه می دهد.

علاوه بر آن، این بررسی گویای توانایی سازگاری جنس (*Carex*) با محیط طبیعی مرطوب و تالابی خود می باشد.

از جمله نکات جالب در آناتومی برگ این گونه مشاهده حفره های هوایی در بین مزوفیل برگ می باشد. که به گیاه امکان ذخیره سازی اکسیژن در محیط تالابی را داده تا بتواند از یک سو سبک و شناور مانده و از سوی دیگر راندمان فتوسنتز خود را متعادل نگهدارد.

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INTRODUCTION

The *Cyperaceae* family are grass-like, herbaceous plants comprising about 70 genera and 4000 species, they are commonly found in inundated or boggy conditions. Fox (2000) defines this group of the monocotyledons as being of particular significance as environmental indicators for wetland habitats.

Cyperaceae leaves are long, alternate, and mostly arise near the base, usually within a closed sheathing base, parallel veined, and strap-shaped. The flowers of this family are bisexual or unisexual, and very minute (Judd & al. 2000). They reproduce by rhizomes and seeds (Fox 2000).

Carex is one of the major genera contained within the *Cyperaceae* family; about 45 species of *Carex* are recorded in Iran, growing in diverse climatic conditions, but mostly in wetland or river basins.

This work is part of a series of anatomical studies of the main flora in the Arasbaran protected area. This area, in the northwest part of Iran, latitude 38° 41'-39° 7' N and longitude 46° 42'-46° 58' E has been studied previously (Assadi, 1987; Zarrinkamar, 2001). Altitude varies from 350 to 2840 m above sea level, mean annual temperatures are from 5 to 14° C, and annual precipitation is between 316 to 686 mm (Thompson & al. 2001). The following study presents the foliar anatomy of the genus *Carex* in this area.

MATERIAL AND METHODS

Material was fixed in FAA, and sectioned with a sliding microtome. Sections were cleared with sodium hypochlorite, dehydrated, coloured with methyl green and carmine-vest, and mounted in gelatine. In order to study stomatal density, the diafanizaion technique was employed (Stritmater, 1973), and the results observed using a light microscope. To minimise misinterpretation, the middle of the leaf lamina in relatively mature leaves was

selected for analysis, and at each site, the data recorded is an average of 15 samples of 3 plants from the same species.

The species under anatomical study are as follows.

Carex distans L. –Arasbaran, Serahie Vayghan, 1300 m, N, 10%, Hamzeh'ee & Asri.

Carex divisa Hudson. –Arasbaran, Toopkhaneh highland, 2250 m, N, 30% Hamzeh'ee & Asri.

Carex divulsa Stokes. –Arasbaran, between Abbasabad & Mahmoodabad highland, 2150 m, SW, 50%, Hamzeh'ee & Asri.

Carex halleriana Asso. Arasbaran, Serahie Vayghan, 1300 m, N, 10%, Hamzeh'ee & Asri.

Carex liparocarpos Gaudin. –Arasbaran, between Mahmoodabad & Makidi, 2150m, S, 60-70%, Hamzeh'ee & Asri.

Carex nigra L. –Arasbaran, Abbasabad highland, 2426 m, N, 60%, Hamzeh'ee & Asri.

Carex pallescens L. –Arasbaran, Abbasabad highland, 2426 m, N, 60%, Hamzeh'ee & Asri.

Herbarium specimens are housed at the Research Institute of Forests and Rangelands, and fixed materials are stored at the Laboratory of Vegetal Anatomy at this institute

OBSERVATIONS

Carex distans L.

Leaf surface. Epidermis: short epidermal cells with thin and sinuous walls on both surfaces (Fig. 1, E, F). *Stomata:* absent on adaxial surface; paracytic subsidiary cells mostly dome-shaped sometimes triangular on abaxial surface. The leaf had an average stomatal density of 120 per mm² on the lower surface.

T. S. Lamina. Outline: V-shaped. *Epidermis:* adaxial larger than abaxial cells (Fig. 2, A). *Bulliform cells:* regular groups present above midrib (Fig. 2, B). *Stomata:* superficial (Fig. 2, D). *Mesophyll:* chlorenchyma not radial, though tending to radial around the vascular bundles (Fig. 2, C, D). *Air-cavities:* well developed (Fig. 2, C). *Vascular bundles:* about

double, in small vascular bundles; sometimes outer bundle sheaths interrupted abaxially, larger vascular bundles incomplete adaxially and abaxially. *Sclerenchyma*: mostly small vascular bundles not accompanied by sclerenchyma, but sometimes with abaxial strands, large vascular bundles accompanied by girder adaxially and abaxially

Carex divisa Hudson

Leaf surface. Epidermis: Both abaxial and adaxial surfaces comprise short cells, with thin and sinuous walls (Fig. 1, G, and H). *Prickle-hairs*: at leaf margin (Fig.1, G). *Stomata* only on abaxial surface: with dome-shaped, sometimes triangular subsidiary cells, (Fig.1, H). The leaf had an average stomatal density of 126 per mm² on the lower surface.

T. S. Lamina. Outline: V-shaped, *Epidermis*: adaxial larger than abaxial cells (Fig. 4, E). *Bulliform cells*: present in midrib (Fig. 4, F). *Stomata*: superficial. *Mesophyll*: chlorenchyma not radial, sometimes surrounding vascular bundles. *Air-cavities*: generally well developed, decreasing in size toward leaf margins and midrib (Fig. 4, E). *Vascular bundles*: about 5-6 in each half of lamina. *Bundle sheaths*: double, outer bundle sheaths incomplete adaxially and abaxially, and consisting of large vascular bundles. *Sclerenchyma*: small vascular bundles without sclerenchyma, but large vascular bundles accompanied with girders adaxially and abaxially.

Carex divulsa Stokes

Leaf surface. Epidermis: short- cells, with thin and sinuous outline walls on both adaxial and abaxial surfaces (Fig. 1, A, B). *Stomata*: absent on adaxial surface, but with parallel-sided subsidiary cells on abaxial surface. The leaf had an average stomatal density of 143 per mm² on the lower surface.

T. S. Lamina. Outline: V-shaped, *Epidermis*: adaxial larger than abaxial cells (Fig. 3, B). *Bulliform cells*: well developed in midrib (Fig. 3, C). *Stomata*: superficial (Fig. 3, D). *Mesophyll*: chlorenchyma not radial, though tending to radial around the vascular bundles (Fig.3, D). *Air-cavities*: well developed in mesophyll (Fig. 3, B). *Vascular bundles*: about 7-8 in each half of lamina. *Bundle-sheaths*: double, outer bundle sheaths incomplete in larger vascular bundles (Fig. 3, D). *Sclerenchyma*: mostly small vascular bundles without sclerenchyma, but sometimes accompanied with adaxial strands; large vascular bundles with girders adaxially and abaxially.

Carex halleriana Asso.

Leaf surface. Epidermis: short form cells, with thin and sinuous walls on both surfaces. *Prickle-hairs*: at leaf margin. *Silica-bodies*: conical, over the veins. *Stomata*: present only on abaxial surface, with dome-shaped, sometimes triangular subsidiary cells. The leaf had an average stomatal density of 136 per mm² on the lower surface.

T. S. lamina. Outline: V-shaped. *Epidermis*: adaxial larger than abaxial cells (Fig. 4, A). *Bulliform cells*: regular groups present above midrib (Fig. 4, B). *Stomata*: superficial (Fig. 4, B). *Mesophyll*: chlorenchyma not radial, well developed around air-cavities and in leaf margins (Fig. 4, A). *Air-cavities*: rectangular, many containing remnants of thin-walled translucent cells. *Vascular bundles*: about 7 in each half of lamina. *Bundle-sheaths*: outer bundle sheaths interrupted adaxially and abaxially, sometimes with extensions surrounding adaxial and abaxial sclerenchyma. *Sclerenchyma*: central vascular bundles with wide T-shaped abaxial girders and a minute adaxial girder, but other vascular bundles with adaxial and abaxial girders.

Carex liparocarpos Gaudin

Leaf surface. Epidermis: short and rectangular form with thin and sinuous walls on both surfaces (Fig. 1, C, D). *Prickle-hairs:* angular prickle at leaf margin. *Stomata:* absent on adaxial surface, abaxial dome-shaped, cells with variable triangular subsidiary cells. The leaf average stomatal density is 152 per mm² on the lower surface.

T. S. lamina. Epidermis: adaxial larger than abaxial cells but not especially inflated (Fig. 3, A). *Bulliform cells:* regular groups only above midrib (Fig. 3, A). *Stomata:* superficial. *Mesophyll:* chlorenchyma not radial (Fig. 3, F). *Air-cavities:* variable in shape, many containing remnant of thin-walled translucent cells (Fig. 3, E). *Vascular bundles:* about 5-6 small and large vascular bundles in each half of lamina. *Bundle-sheaths:* double, outer bundle sheaths incomplete abaxially in smaller vascular bundles and in larger vascular bundles interrupted adaxially and abaxially. *Sclerenchyma:* vascular bundles with abaxial girders near margins, and with adaxial and abaxial girders elsewhere.

Carex nigra L.

Leaf surface. Epidermis: short and rectangular form with thin and slightly sinuous walls on both surfaces. *Prickle-hairs:* angular prickle at leaf margin. *Stomata:* absent on adaxial epidermis, but on abaxial with triangular subsidiary cells. The leaf average stomatal density is 179 per mm² on the lower surface.

T. S. lamina. Outline: V-shaped. *Epidermis:* adaxial larger than abaxial cells. *Bulliform cells:* well developed in midrib (Fig. 2, E). *Stomata:* superficial, except above adaxial sclerenchyma and near leaf margins. *Mesophyll:* chlorenchyma not radial. *Air-cavities:* variable in size and shape. *Vascular bundles:* about 8 vascular bundles in each half of lamina. *Bundle-sheaths:* double, outer Table 1. Anatomical characters of *Carex* species.

bundle sheaths incomplete on either side. *Sclerenchyma:* most vascular bundles with wide girders at xylem and phloem poles.

Carex pallescens L

Leaf surface. Epidermis: short and rectangular form with thin and sinuous outline on both surfaces. *Macro-hairs:* short, rigid with swollen and superficial bases between the veins only on abaxial surface. *Prickle-hairs:* at leaf margin. *Stomata:* absent from adaxial epidermis, but present on abaxial, with triangular subsidiary cells. The leaf had an average stomatal density of 149 per mm² on the lower surface.

T. S. lamina. Outline: V-shaped. *Epidermis:* adaxial larger than abaxial cells. *Bulliform cells:* only in midrib (Fig. 4, D). *Stomata:* superficial. *Mesophyll:* chlorenchyma not radial (Fig. 4, C). *Air-cavities:* well developed, mostly rectangular and variable in size (Fig. 4, C). *Vascular bundles:* about 9 vascular bundles in each half of lamina. *Bundle-sheaths:* outer bundle-sheaths incomplete. *Sclerenchyma:* most vascular bundles with T-shaped girders at xylem poles, but in midrib with abaxial girders.

DISCUSSION

As described in the observations, several common characteristics were observed between the species studied. Here, some common characters are highlighted. Study of leaf anatomy demonstrates the presence of stomata on abaxial surfaces only; stomata are paracytic, with mostly dome-shaped, subsidiary cells sometimes triangular but parallel sided in *C. divulsa*.

The cuticles are of intermediate thickness (about 4-7.5µ); adaxial surface is often thicker than abaxial surface (Table 1).

Species	Superficial view				T. S.						
	Density of stom.adx (mm ²)	Density of stom.abx (mm ²)	Length of stom.adx (μ)	Length of stom.abx (μ)	Cuticle		mesophyll	Air cavities	Bulliform cell	bundle sheath	
					adaxial (μ)	abaxial (μ)					
<i>Carex distans</i>	-	120	-	39.3	4	5	not radial	+	In midrib	2	
<i>Carex divisa</i>	-	126.33	-	33.05	4	4	not radial	+	In midrib	2	
<i>Carex divulsa</i>	-	142.76	-	35.88	7	7	not radial	+	In midrib	2	
<i>Carex halleriana</i>	-	136.26	-	33.63	7.5	5	not radial	+	In midrib	2	
<i>Carex liparocarpos</i>	-	152.07	-	32.86	6	5	not radial	+	In midrib	2	
<i>Carex nigra</i>	-	179.3	-	27.06	5	3	not radial	+	In midrib	2	
<i>Carex pallescens</i>	-	148.72	-	32	5	3	not radial	+	In midrib	2	

In epidermis cells bubble shaped bulliform cells are found on the midrib. An important adaptation for many of the *Cyperaceae* including *Carex* is the appearance of bulliform cells as part of the epidermis allowing the control of leaf rolling and unrolling at the cellular level, by turgor pressure. When water availability is limited, the bulliform cells lose water and become flaccid. Thereby the leaves are less exposed to sunlight and transpiration is reduced.

Most of the *Cyperaceae* utilise the C4 photosynthetic pathway. According to Mauseth (1988) the principal characteristic of Kranz anatomy is the radial arrangement of mesophyll around the bundle sheath; however a double bundle sheath is present in all *Carex* species and in the most of species radial mesophyll are not observed. The air-cavities

make confused their mesophyll arrangement; therefore, physiological study is needed to recognize photosynthesis pathway.

The mesophyll of these species contains air-cavities of thin-walled, translucent cells without chloroplasts. This character makes the internal atmosphere of the leaves more efficient for gas exchange during photosynthesis.

From an ecological view, the existence of these air-cavities in *Carex* leaves enables it to adapt to their variable habitats in wetland or marginal aquatic conditions.

ACKNOWLEDGMENT

This project supported by Research Institute of Forests and Rangelands (RIFR) and Darwin Initiative for survival of species (DETR, London). We would like to express our

appreciation to Azimi, Dehghan, Boostani, Kowsari and Siavash, laboratory technicians of plant anatomy.

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Fig. 1. Observations of abaxial epidermis in superficial view of the *Cyperaceae*. A, B. *Carex divulsa*. C, D. *C. liparocarpos*. E, F. *C. distans*. G, H. *C. divisa*. A, C, E, G ($\times 72$); B, D, F, H ($\times 144$).

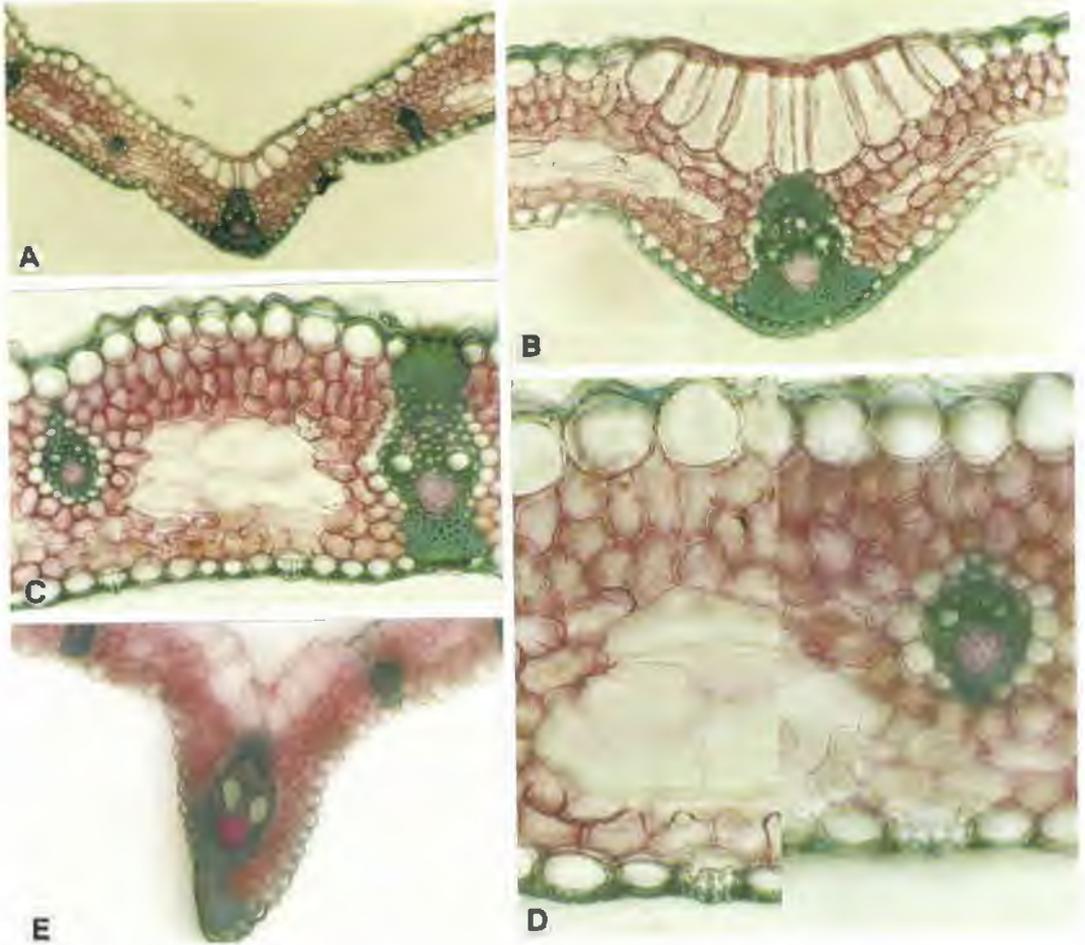


Fig. 2. Leaf of *Carex* spp. in T. S. A-D. *C. distans*; A. general aspect; B. midrib; C, D. detail of mesophyll. E. midrib of *C. nigra*. A ($\times 72$); B, C, E ($\times 144$); D ($\times 288$).



Fig. 3. Leaf of *Carex* spp. in T. S. A, E, F. *C. luparocarpos*; A. general aspect; E. midrib; F. detail of mesophyll. B-D. *C. divulsa*; B. general aspect; C. midrib; D. detail of mesophyll. A, B ($\times 29$); C ($\times 72$); D-F ($\times 144$).

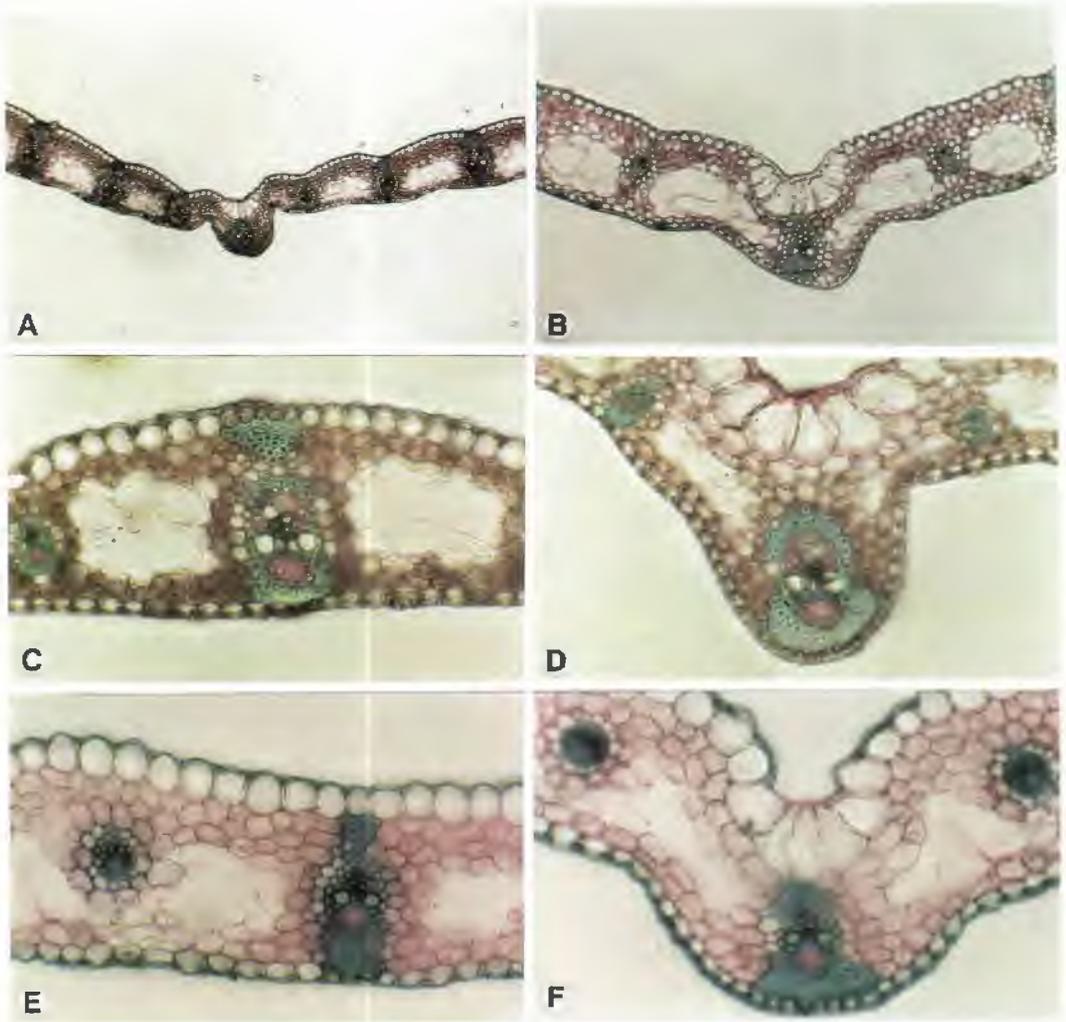


Fig. 4. Leaf of *Carex* spp. in T. S. A, B. general aspect of *C. helleriana*. C, D. *C. pallescens*; C. detail of mesophyll; D. midrib. E, F. *C. divisa*; E. detail of mesophyll; F. midrib. A ($\times 29$); B ($\times 72$); C-F ($\times 144$).