



## Morphological and anatomical properties of the genus *Crithopsis* (Poaceae) in Turkey

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### Abstract

*C. delileana* (Schult.) Roshev., the only member of the genus *Crithopsis* is taxonomically revised on the basis of herbarium materials, field observations, and laboratory examination. Ninety accessions belonging to 18 populations of *C. delileana* were subjected to Principal Component Analysis in order to determine the variability and the structure of its natural populations of based on morphology. The results of statistical analysis showed that the variability among the populations does not permit to distinguish any intra-specific categories. In addition to the statistical analysis, emended and updated description along with a distribution map of this species and the vegetative anatomical characters are also given.

**Key words** *Crithopsis delileana*, morphological variability, distribution, anatomy, Turkey.

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### Türkiye’de bulunan *Crithopsis* (Poaceae) cinsinin morfolojik ve anatomik özellikleri

#### Özet

*Crithopsis* cinsinin tek üyesi olan, *C. delileana* (Schult.) Roshev., herbaryum materyalleri, arazi gözlemleri ve laboratuvar incelemelerine dayanılarak taksonomik olarak revize edildi. *C. delileana*’nın 18 popülasyonuna ait 90 birey, *C. delileana* popülasyonlarının morfolojik açıdan yapısını ve çeşitliliğini belirlemek amacıyla, Temel Bileşen analizinde kullanıldı. İstatistiksel analizin sonuçları göstermiştir ki; popülasyonlar arasındaki varyasyonlar tür içi bir taksonun ayrılmasına izin vermemektedir. İstatistiksel analize ek olarak, güncellenmiş ve genişletilmiş tür tanımı aynı zamanda bu türün dağılım haritası ve vejetatif anatomik karakterleri de verilmiştir.

**Anahtar Kelimeler:** *Crithopsis delileana*, morfolojik çeşitlilik, dağılım, anatomi, Türkiye.

#### 1. Introduction

*C. delileana* (Schult.) Roshev., is the only member of the genus *Crithopsis* Jaub. & Spach (Poaceae; Triticeae). Its distribution extends from western Afghanistan and Baluchistan to Morocco (Frederiksen, 1993). Löve (1984) proposed that it carries the K genome. Sakamoto and Muramatsu (1965) were the first to report its chromosome number as  $2n = 14$ . This number was confirmed by Sakamoto (1973) and Frederiksen (1993) on the bases of the different populations collected from Syria, Iraq, Crete, Greece, and Palestine.

With respect to their common morphological feature, sharing similar spike morphology (2-3 spikelets per node), the diploid genera *Crithopsis*, *Taeniatherum* Nevski and *Psathyrostachys* Nevski, and *Hordeum* L. have been considered rather closely related (Frederiksen and Seberg, 1992; Bothmer et al., 1995).

In the Flora of Turkey, Melderis (1985) recognized one species in the genus named as *C. delileana*. According to this account, *C. delileana* was confined to South Anatolia where it was recorded from three locations.

In spite of the several studies done on the tribe Triticeae in the literature (Schwendener, 1890; Metcalfe, 1960; Watson and Dallwitz, 1992; Terrel and Peterson, 1993; Xu and Zhou, 2008), there was a limited number of studies

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based on the anatomy of the genus *Crithopsis*.

This is the sixth paper from the series: Taxonomic revision of the tribe Triticeae Dumort. in Turkey which is funded by TÜBİTAK TBAG. Former five, have been accomplished on the taxonomy, palynology and anatomy of certain genera found in tribe Triticeae in Turkey by the authors (Cabi and Doğan, 2009; Cabi et al., 2009; Özler et al., 2009; Başer et al 2009; Cabi et al., 2010). Doğan (1988, 1991, 1992, and 1997) was also carried out extensive taxonomical studies on the genera of the tribe Aveneae, Agrostideae, Phalarideae and Phleae in Turkey.

In this paper, in an attempt to revise the genus *Crithopsis* in Turkey, a detailed account of morphological, ecological and anatomical features of the genus *Crithopsis* is given.

## 2. Material and methods

Since 2006, as a part of a revisional study of the tribe *Triticeae* Dumort. in Turkey, the authors have carried out extensive field studies and collected a large number of specimens of the genus *Crithopsis*. The specimens were first carefully pressed and dried using the standard techniques for field and laboratory analysis given by Davis and Heywood (1973). Morphological measurements were made on fresh and herbarium material with the use of Leica L2 Stereomicroscope and Leica Application Suite software package. During measurements largest specimen and complete spike on each specimen is chosen and measured. Measurements of the spikelets and florets were accomplished on the spikelets dissected from the middle part of spike. Each population sample constitutes minimum ten plants. The material was deposited in the Plant Systematic and Biodiversity Laboratory in the Department of Biological Sciences Middle East Technical University.

For statistical analysis, the population samples were analyzed with respect to 10 numerical characters (Table 1). Each Operational Taxonomic Unit (OTU) scored in this study, was chosen from the most complete and largest spikes on each sheath. The initial character set was established by reviewing published keys. This set was amended, after examination of material collected from the field and also herbarium specimens from major herbaria, to include additional characters that appeared to be taxonomically important and to exclude characters that were invariant among the specimens. This resulted in selection of 10 characters (Table 1) which were scored on all OTU's Inter and Intra population variability was characterized using arithmetic means, minimum and maximum values, and Principal component analysis-PCA (Sneath and Sokal, 1973) The PCA analysis was carried out with the use of the software package MVSP version 3.1 (Kovach, 1999). PCA was performed using Gower's (1971) General Similarity Index so as to generate a distance matrix. This distance matrix was used for PCA analysis with the help UPGMA algorithm. The advantage of Gower's coefficient is the allowing the presence of a mixture of all variable types and tolerates missing values as well (Mason et al., 2005).

For anatomical studies some of the freshly obtained materials were preserved in 70% ethyl alcohol solutions. After the fixation in formalin-acetic acid-alcohol (F.A.A.) solution for 48 hours, the fixative was removed by distilled water. Then the specimens were dehydrated before embedding. They were embedded into paraffin and sectioned by applying the Johansen's (1944) paraffin sectioning method. The sections were stained by Safranin and mounted by Entellan. Observations were acquired by using Euromex FE 2025 microscope and photographed by using Euromex CMEX DC.1300 camera.

Table 1. Quantitative characters used in Principal Component Analysis (PCA)

1. CLe. Culm length (cm)
2. LbLe. Leaf blade length (cm)
3. LbWi. Leaf blade width (mm)
4. SLe. Spike length (cm)
5. RhILe. Rhachis internodes length (mm)
6. LLe. Body of lemma length (mm)
7. AofLL. Awn of lemma length (mm)
8. GLe. Glume length (mm)
9. NSps. Number of spikelets at each node
10. FnSp. Florets number at each spikelet
11. GVn. Glume vein number

## 3. Results and discussion

### 3.1. Morphology

It should be noted that the populations belonging to *C. delileana* do not show any differentiation with respect to their geographical distribution. Quantitative characters used to construct scatter diagram (Figure 1) show great variation. Culm length and glume length are the most variable characters among the studied characters. The observations and measurements showed that culm length may show variability even among the representatives of the

same populations collected at different times (Figure 1).

**Principal Component Analysis.** The first two principal components accounted for 75.48%, 20.131% respectively, of the total variance. Culm, lemma and glume lengths contributed most of the first and second axis. The projection of the OTU's onto the first two components (Figure 2) revealed any strongly defined groups among the OTU's.

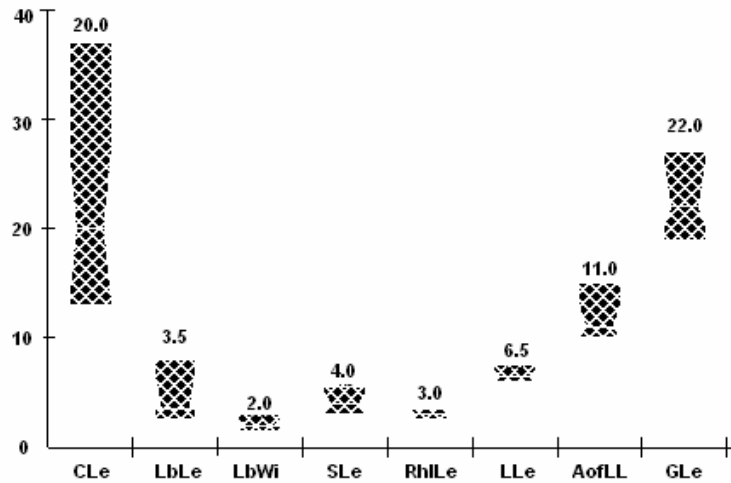


Figure 1. Box plot graph of the quantitative characters.

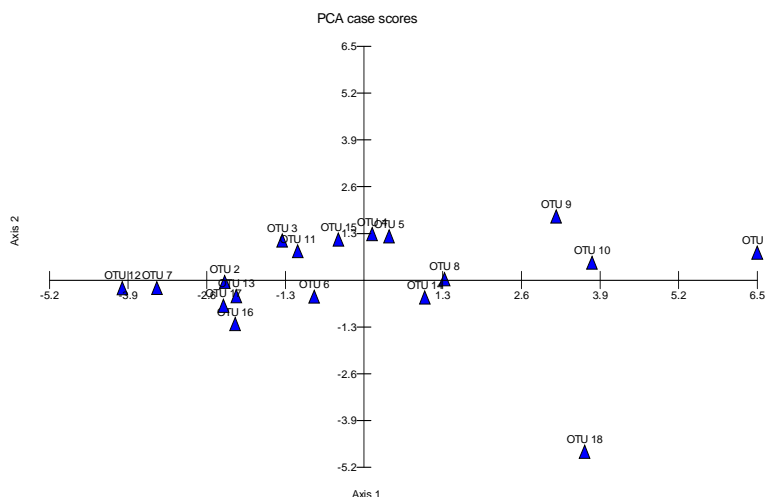


Figure 2. Principal Component Analysis (PCA)-scatter diagram of specimens from 18 populations of *C. delileana*

### **Crithopsis Jaub. & Spach**

Annual. Culms herbaceous, slightly geniculate at base then ascending or strongly decumbent. Culm nodes glabrous. Leaves linear acuminate; flat or becoming folded towards apex. Auricles present, falcate shaped. Ligule membranous. Inflorescence a dense spike consisting of fully fragile rachis segments. Rachis segments densely and rigidly pilose on margins. Spikelets in pairs at each rachis node, with 2 florets, the lower floret bisexual, the upper one rudimentary; rachilla disarticulating below florets. Spikelets distinctly longer than adjacent internodes, about > 4x length. Glumes coriaceous, strap-shaped, longer than florets, scabrid. Lemma of fertile floret oblong-lanceolate, flattened dorsally, scabrid, often slightly verrucose below, scabrid and  $\pm$  hirsute above, gradually tapering into flattened, scabrid awn. Palea two keeled, ciliate on the keels. Caryopsis adherent to palea and lemma, longitudinally grooved, dorsiventrally compressed, oblong-elliptic in outline, hairy at apex; hilum long linear. Endosperm flinty. – A monotypic genus.

The name of *Crithopsis* was originated from the Greek *krithe* (barley) and *opsis* (appearance-from the fancied resemblance of the inflorescence to the barley ear) (Bor, 1968).

**C. delileana** (Schult.) Roshev., Zlaki 319 (1937). Syn: *Elymus geniculatus* Delile, Fl. Egypt 30, t. 13 f. 1 (1812) non Curtis (1790); *E. delileanus* Schult., Syst. Veg. ed. 15, 2 Mant. 424 (1824); *Crithopsis rhachitrichus* Jaub. & Spach, Ill. Pl. Or. 4: 30, t. 321 (1851). Ic: Fl. Iraq 9: t. 77 (1968).

Culms 6.5-49 cm long with 2-3 glabrous nodes, usually fasciculate, geniculate at base. Leaf blades 2.5-8 x 1.5-3 mm broad, scabrid, sparsely pilose, leaves are becoming folded towards apex. Spike to 3.5 cm (excl. awns). Glumes equaling, 17-25 mm long (incl. awns), gradually tapering into an awn, longer than the adjacent lemmas, narrow, up to 0.5 mm wide; subulate; scabrid or shortly pilose especially on nerves, 3-5 nerved. Lemmas of fertile florets 5.5-7.5 mm, with awn 6-12.5 mm long, wider than glumes (up to 1.2 mm wide), sparsely pilose. Palea as long as or slightly shorter than body of lemmas, membranous, two keeled without cleft at apex, ciliate on keels. Anthers are short up to 1 mm long. Caryopsis up to 5 mm long.

Chromosome number  $x=7$ ,  $2n=14$ . diploid. Genomic symbol **K** (Genome designations as recommended by the International Triticeae Consortium; <http://herbarium.usu.edu/Triticeae/genmsymb.htm>).

Fl. 4-5. Sandy, calcareous soils, arid steppe, 11-1003 m.

Type: [Egypt] à Alexandrie dans les champs d'orge, entre le lac Mareotis et la mer, iii 1800, *Delile* (holo. MPU).

**Examined specimens:** **S. Anatolia, C4 Mersin:**, Silifke, Mersin to Tarsus, 11 m, 36° 20.357' N 33°54.892' E, 01 May 2008, *E.Cabi* 2751 (**new record for C4 grid square**). **C6 Gaziantep:** Doğanpınar to Karkamış, Arıkdere village gravestone, 2 km to Akçaköy, 439 m, 36°49.394' N 37°50.692' E, 21 Apr 2007, *E.Cabi* 1757. **C6 Hatay:** Reyhanlı, around Cilvegözü village, 265 m, 36°14.878' N 36°37.889' E, 03 May 2008, *E.Cabi* 2805. **C6 Kilis:** Islahiye to Kilis, after Musabeyli, 478 m, 36°48.452' N 36°59.992' E, 21 Apr 2007, *E.Cabi* 1747. **C6 Adiyaman:** Besni, Çakırhöyük district, 610 m, 37°33'22" N 37°48'33" E, 20 May 2007, *E.Cabi* 2154. **C7 Urfa:** Ceylanpınar State Farm, Çevri mainroad, 478 m, 36°58.254' N 39°38.642' E, 22 May 2007, *E.Cabi* 2232. **Urfa:** Ceylanpınar State Farm, South of Horozviran, 471 m, arid environments, 36°51.904' N 39°34.410' E, 22 May 2007, *E.Cabi* 2229. **Urfa:** Urfa to Akçakale, 8 km to Büyükhana, 600 m, 37°04.618' N 38°50.550' E, 22 Apr 2007, *E.Cabi* 1790. **Urfa:** Birecik to Urfa, 20 km before to Urfa, calcareous steppes, 654 m, 37°05.093' N 38°36.606' E, 22 Apr 2007, *E.Cabi* 1785, **Urfa:** 3 km before Birecik hydroelectric power station, 379 m, 37°03.537' N 37°55.870' E, 22 Apr 2007, *E.Cabi* 1770, **Urfa:** Ceylanpınar State Farm, Güzelyat area, N of Avea base station, *E.Cabi* 1871, **Urfa:** Ceylanpınar State Farm, 8 km from Yassitepe gendarme station to Büyükyıldız, 442 m, 36°42.806' N 39°32.928' E, 23 Apr 2007, *E.Cabi* 1868, **Urfa:** Ceylanpınar State Farm, Kazıktepe sheep enterprise, 419 m, 36°48.927' N 39°51.270' E, 23 Apr 2007, *E.Cabi* 1852, **Urfa:** Ceylanpınar State Farm, Gökçayır cattle enterprise, 417 m, 36°48.927' N 39°51.270' E, 23 Apr 2007, *E.Cabi* 1845, **Urfa:** Urfa to Antep, 5 km from Urfa, 661 m, 37°03.113' N 38°14.411' E, 23 Apr 2006, *E.Cabi* 113, **Urfa:** Suruç to Birecik, 750 m, roadsides, 37°03.286' N 38°07.992' E, 29 Apr 2006, *E.Cabi* 244, **Urfa:** Ceylanpınar State Farm, Gökçayır işletmesi, 384 m, 36°49.080' N 39°57.227' E, 23 Apr 2007, *E.Cabi* 1823, **Urfa:** Viranşehir to Urfa, 66 km before Urfa, 627 m, 37°13'34" N 39°26'21" E, 22 May 2007, *E.Cabi* 2220, **C8 Mardin:** around train station, 666 m, 37° 17'10" N 40°44'06" E, 23 May 2007, *E.Cabi* 2289, **Mardin:** S. of Gercüş, 1003 m, 37°33'52" N 41°22'35" E, 23 May 2007, *E.Cabi* 2295 (**new record for C8 grid square**) (Figure 3).

General Distribution: Crete, Cyprus, Syria, Palestine, Jordan, Egypt, Iraq, Iran, Libya.

Phytogeography: Multi regional (Holoarctic and Palearctic, Tethyan, African, Mediterranean, Saharo-Sindian, Ir.-Tur. element).

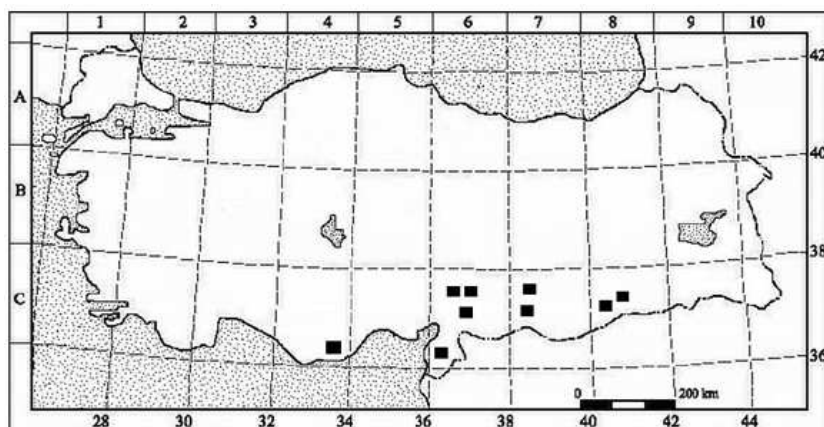


Figure 3. Updated geographic distribution of *C. delileana*

### 3.2. Ecology

The genus *Crithopsis* is a typical representative of Sakamoto's (1982) Mediterranean group in the Triticeae, comprising Mediterranean central Asiatic genera such as *Heteranthelium*, *Aegilops*. The members of this genus are confined to Mediterranean central Asiatic region with a climate of hot, dry summers and winter rainfall, changing inland to drier continental with cold winters.

In Turkey the distribution is confined to the eastern parts of South Anatolia. Its distribution range especially extends from C4 to C8 grid squares. Annual habit of this genus is an advantageous life strategy with seasonal rainfall. The seeds of this genus go into the dormancy periods to survive during the hot summers.

*C. delileana* grows on sandy arid areas, pastures, roadsides, edges of cultivated lands. Other species grow within the habitats of *C. delileana* are *Cynosurus cristatus* L., *Taeniatherum caput-medusae* (L.) Nevski, *Hordeum spontaneum* K.Koch, *H. murinum* L., *Aegilops geniculata* Roth, *Ae. crassa* Boiss., *Ae. tauschii* Coss., *Echinaria capitata* (L.) Desf., *Cynosurus echinatus* L.

The genus is a typical lowland genus with just only one accession from 1000 m. The general altitudinal distribution of the genus varies from 11 m (the accession gathered from Mersin) to 1003 m (the accession gathered from Mardin, Gercüş). During the revisional study of the tribe *Triticeae* throughout the Turkey, two new records for the grid squares C4 and C8 were found.

The threat category of *C. delileana* was assessed as vulnerable (VU) in Turkish Red Data Book (Ekim *et al.* 2000). According to the recent field surveys conducted by us, although the species is distributed more than 10 locations, the populations of *C. delileana* are still vulnerable to grazing activity of the sheeps and cattle. Distribution area is affected by anthropogenic factors such as habitat degradation and overgrazing. The effects of overgrazing seems to be so high especially due to the dry and hot summers (IUCN 2001; Criteria B and C).

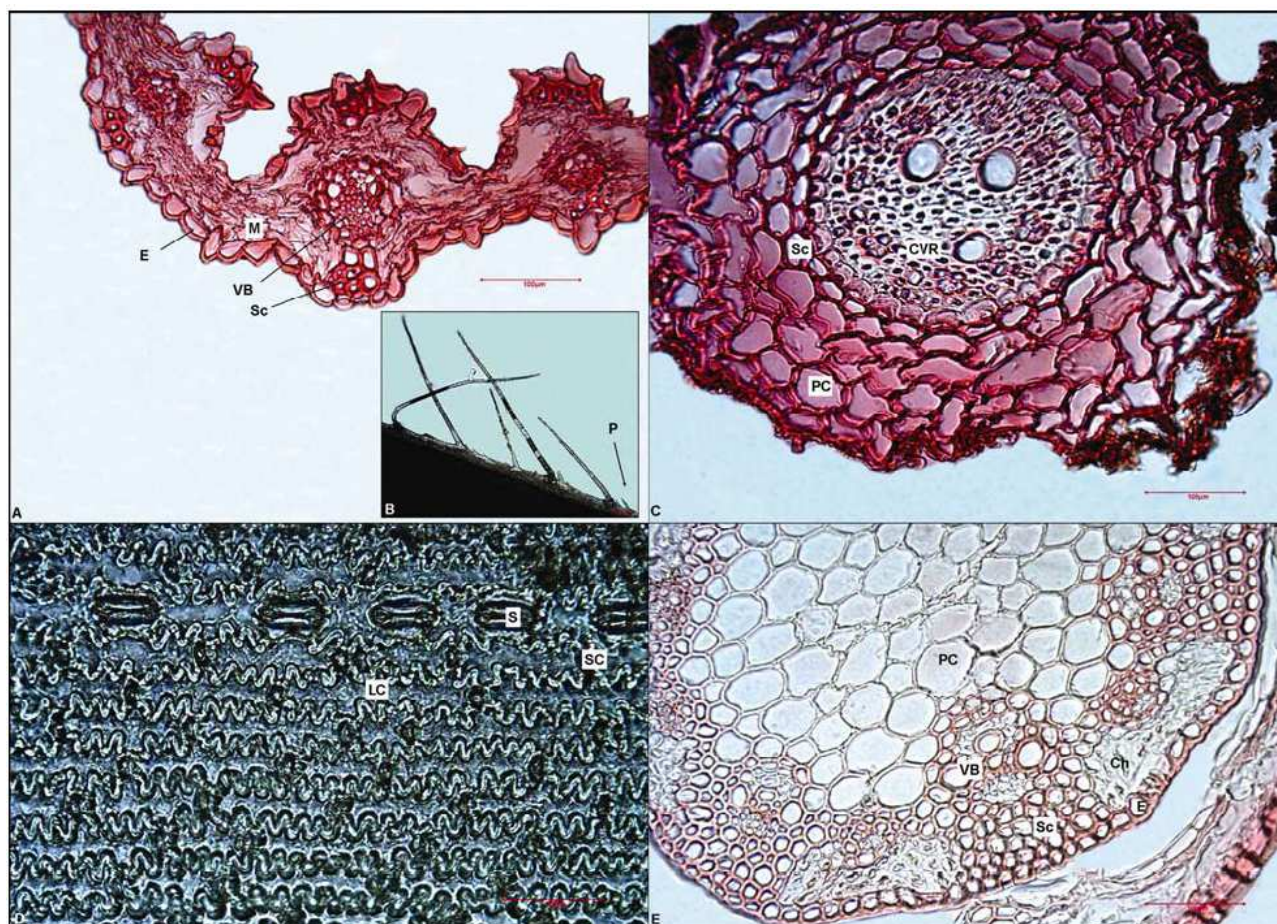


Figure 4. *C. delileana* in its native habitat

### 3.3. Vegetative Anatomy

The transverse sections of the stem, root and leaf and its surface view are shown in Fig. 5. As seen in Fig. 5A, the bulliform cells of the leaf sections are not readily distinguishable. Also the mesophyll, including irregularly shaped cells with large intercellular cavities, is not differentiated into palisade and spongy parenchyma. The arrangement of sclerenchyma around the vascular bundles seems to be in different dispositions. There are adaxial and abaxial strands but, around the differentiated central vascular bundle there are both adaxial and abaxial girders, both of which are I-shaped.

The circular vascular bundles are of nearly the same sizes except the central vascular bundle which is the largest, and there seems to be double bundle sheathes around it. The outer sheath is parenchymatic, however, the inner one, which is not completely surrounded by the outer one, is sclerenchymatic. Metcalfe (1960) indicated that stomata of the leaves of Gramineae family can be distinguished according to their subsidiary cells. From this point of view, *C. delileana* has the stomata with two parallel subsidiary cells (Fig. 5D). The leaf surfaces also include papillae, prickles and macro hairs (Fig. 5B). Long cells have clearly thick and markedly sinuous walls with only one short cell between them.



**Figure 5.** Sections of vegetative organs of *C. delileana* **A.** Transverse section of the leaf **B.** Hairs of the upper side of the leaf **C.** Transverse section of the root **D.** Surface view of the lower side of the leaf **E.** Transverse section of the stem

**Ch:** Chlorenchyma, **C.V.R.:** Central Vascular Region, **E:** Epidermis, **L.C.:** Long cell, **M:** Mesophyll **P:** Prickle, **P.C.:** Parenchymatous cells, **S:** Stomata, **SC:** Short Cell, **Sc:** Sclerenchyma, **VB:** Vascular Bundle

Stem transverse sections show that the vascular strands arise in a band of a circle, including the smaller and the larger bundles (Fig. 5E). These vascular bundles are connected to each other with sclerenchyma. However, only the larger bundles connect to the glabrous epidermis by sclerenchymatic girders separating the near columns of assimilatory tissue, called as chlorenchyma. The inner ground tissue of the large cells has thick cell walls, getting thinner towards the centre of the stem. These are parenchymatous cells that completely cover the middle region of the stem.

Transverse sections of grass roots show the same general type of anatomy (Metcalf, 1960). Epidermis subtended by a single layer of large cells (Fig. 5.C). Beneath the ring of epidermis, there is a broad multilayered cortex, including 4-6 layers of parenchymatous cells. The inner part of the cortex is made up of a single layered of sclerenchymatous cells. The endodermis is readily distinguishable with its thick walled and U-shaped cells. The central vascular tissue marked by conspicuously large metaxylem vessels and small strands of phloem alternating with them.

### Acknowledgements

We wish to thank the curators of following herbaria ANK, GAZI, HUB, ISTE, E, K, BM, G, LE and WIR for allowing us to study their *Crithopsis* collections and the Scientific and Technical Research Council of Turkey (TUBITAK-TBAG-105 T 171) for their financial assistance.

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(Received for publication 02 September 2009; The date of publication 01 August 2010)