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Elymus sosnowskyi (Hackel) Melderis (Poaceae), a rare endemic species in Turkey

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Abstract: *Elymus sosnowskyi*, a rare endemic species known from East Anatolia, Turkey, was first collected by D. Sosnowsky in 1912. After that it has been collected only one other time, by F. Sorger in 1981. During the "Taxonomic revision of tribe Triticeae in Turkey" project, which was supported by TÜBİTAK, *E. sosnowskyi* was recollected from 3 populations in Oltu and Narman (A8 Erzurum, Turkey) in 2007 and 2008. The present study aimed to provide detailed diagnostic characters of this rare endemic species, including its morphological, anatomical, and palynological features. Moreover, the amended and expanded description, distribution, phenology, and ecology of this rare species are provided, along with its conservation status.

Key words: Endangered, endemic, *Elymus*, Turkey

Elymus sosnowskyi (Hackel) Melderis (Poaceae), Türkiye'den nadir bir endemik tür

Özet: *Elymus sosnowskyi*, ilk defa 1912 yılında D. Sosnowsky tarafından toplanan, Türkiye'de Doğu Anadolu bölgemizden bilinen, dar yayılışlı bir endemik türdür. İlk toplanılmasından bu yana 1981 yılında F. Sorger tarafından sadece bir kere daha toplanabilmiştir. TÜBİTAK tarafından desteklenen "Türkiye'de bulunan Triticeae Dumort oymağının revizyonu" isimli proje esnasında *E. sosnowskyi*, 2007 ve 2008 yıllarında, Oltu ve Narman (A8 Erzurum) ilçelerinden, 3 populasyondan tekrar toplanmıştır. Bu çalışma ile bu dar yayılışlı endemic türün, morfolojik, anatomik ve palinolojik özellikler bakımından detaylı diagnostik karakterlerinin verilmesi amaçlanmaktadır. Bunun yanında, bu nadir türün koruma durumu ile birlikte, genişletilmiş ve güncellenmiş tür tanımı, dağılımı, fenolojisi ve ekolojisi verilmiştir.

Anahtar sözcükler: Nesli tehlike altında olan, endemik, *Elymus*, Türkiye

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Introduction

Since Linnaeus (1753) first described the genus *Elymus* L. covering 6 original taxa, (*E. arenarius* L., *E. sibiricus, E. canadensis* L., *E. virginicus* L., *E. caput-medusae* L., and *E. sitanion* L.), numerous transfers have been made between *Elymus* and other closely related genera. The taxonomy of *Elymus* is extremely complex because of the huge morphological variation within and between species. There is also much controversy concerning its generic delimitation, which has resulted in variation in its treatment in different floras. Bor (1968, 1970) included *Elymus* species in *Agropyron* in his *Flora of Iraq* and *Iran*.

Elymus is the largest genus in the tribe Triticeae and includes about 150 taxa, most of which are caespitose, linear-spiked perennial species, which were formerly treated as *Agropyron* Gaertn. sensu lato (Tzvelev, 1973). Melderis (1978) expanded the genus *Elymus* by subsuming the genera *Roegneria* K. Koch, *Elytrigia* Desv. and *Clinelymus* (Griseb) Nevski within it.

The first revision of *Elymus* in Turkey was made by Melderis (1985) in Davis' *Flora of Turkey and the East Aegean Islands*, *Vol. 9*, in which 19 species were recognised. Since the publication of the flora, an additional species, *Elymus hoffmanni,* has been described from Turkey (Jensen & Asay, 1996). After publication of the flora and its supplements, the new grass taxa were compiled in supplements for publication (Davis et al., 1988; Güner et al., 2000). In addition to these, taxonomical and palynological studies were performed on certain genera (Doğan, 1988, 1991, 1992, 1997, 1999; Cabi & Doğan, 2009; Cabi et al., 2009; Özler et al., 2009).

Elymus sosnowskyi was originally named *Agropyron sosnowskyi* by Hackel in 1913. Later, in 1936, Nevski transferred this species to *Elytrigia*. *Elymus sosnowskyi* is closely related to *E. libanoticus*, but differs mainly by having narrowly lanceolate, acuminate subulate and 3-veined glumes. The objectives of the present study were to expand the morphological description, distribution, and habitat, to report the vegetation type, and to assess the accurate conservation status of *E. sosnowskyi*. Detailed anatomical and palynological properties of this taxon are also given.

Materials 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 *Elymus* L. First, the specimens were carefully pressed and dried using the standard techniques for field and laboratory analysis given by Davis and Heywood (1973). During one of these field trips conducted in Oltu, Erzurum (A9, *sensu* Davis 1965), an unusual population of *Elymus* was encountered. The specimens were cross-checked with the keys provided by Melderis (1985). The specimens were also compared with the specimens cited in the *Flora of Turkey* that are kept at Edinburgh (E), Kew (K), British Museum (BM), ANK, EDTU, EGE, GAZI, HUB, ISTE, and ISTF herbaria (herbarium codes from Holmgren et al., 1990). Finally, the specimens were identified as *E. sosnowskyi*. Field and herbarium surveys indicate that the species was collected only once since 1912.

The geographical location, habitat, phenological data, and relevant field observations were recorded when the specimens were collected. The following year the population was visited again to determine the conservation status of *E. sosnowskyi* (IUCN, 2001). The specimens collected by the authors are kept at Middle East Technical University (METU), Department of Biological Sciences.

Pollen slides for morphological examination by light microscopy were prepared according to Wodehouse (1935) and Erdtman (1960), and measurements were made with a Leica DM1000 microscope (Table 1). For studying pollen texture ornamentation, dry pollen grains were mounted on double-sided carbon tape affixed to aluminium stubs. Grains were coated with gold using a Hummel VII sputter coater and observations were made using a Jeol 6060 scanning electron microscope (SEM) at the Department of Biology, Gazi University. SEM images were used to describe the pollen surface texture. The descriptive terminology given by Faegri and Iverson (1975), and Punt et al. (2007) was followed.

For anatomical investigations fresh materials were collected during field excursions and stored in 70% ethyl alcohol solution. These specimens were fixed in formalin-acetic-alcohol (F.A.A.) solution for 48 h. The

Table 1. Pollen morphological parameters in the investigated taxa (μm) (mean ± SD).

Taxa	A	B	A/B	Exine	i	I	pa	pb	Pa/pb	Op	An	A
***E. sosnowskyi* (W)**	45.47 ± 2.86	42.85 ± 3.24	1.06	1.46 ± 0.17	0.49 ± 0.15	3.70 ± 0.88	6.53 ± 0.85	6.17 ± 0.63	1.06	3.46 ± 0.51	11.90 ± 1.00	2.21
***E. sosnowskyi* (E)**	44.67 ± 1.59	39.97 ± 1.99	1.12	2.00 ± 0.11			4.79 ± 0.33	4.55 ± 0.34	1.05		10.78 ± 0.99	3.45

W: Non-acetolysed pollen grains; **E**: acetolysed pollen grains; **A:** long axis of spheroidal pollen grains; **B**: short axis of spheroidal pollen grains; **A/B**: shape of pollen grains; pa: long axis of ellipsoidal porus; pb: short axis of ellipsoidal porus; **I**: thickest part of the intine; **i**: intine thickness; **Op**: operculum diameter; **An**: annulus thickness.

fixative was removed with distilled water. Next, ethyl alcohol was used for dehydration. Dehydrated specimens were embedded in paraffin and sectioned using the modified Johansen's (1944) paraffin sectioning method (Doğan, 1985). The sections were stained with safranine and mounted in Entellan. Observations were made using a Euromex FE 2025 microscope and photographed using a Euromex CMEX DC 1300 camera.

Results and discussion

Elymus sosnowskyi (Hackel) Melderis — Notes Roy. Bot. Gard. Edinburgh 42(1): 80 (1984) (Figure 1).

= *Agropyron sosnowskyi* Hackel in Monit. Jard. Bot. Tiflis 29:26 (1913)!

= *Elytrigia sosnowskyi* (Hackel) Nevski in Acta Inst. Bot. Acad. Sci. URSS ser. 1, 2:72 (1936)!

Syntypes

Turkey **A8 Erzurum:** in Prov. Kars. Distr. Olty (Oltu), in collibus siccis ad Bora-Chane, 29.v.1912, *D.Sosnowsky* 11 (BM!, TBI, W!); Turkey **A9 Erzurum:** in Prov. Kars. Distr., et in rupestribus Olty (Oltu), *D.Sosnowsky* 17 (W!).

Description

Perennial caespitose herbs. Culms slender, 35-70 cm long, glabrous, slightly papillose, glaucous at nodes, generally 2 nodes on the culm. Leaf blades flat, or convolute, 6-12 cm long and 1.5-2 mm wide, stiff, glaucous, puberulous on upper surface of leaf blades, lower surface and sheaths glabrous, leaf blade apex attenuate. Inflorescence interrupted spike, single, bilateral, 10-15 cm long, bearing 9-16 fertile spikelets on each spike, rachis flattened, scabrous on margins, and minutely spinulose ciliate on angles. Spikelets packing broadside to rachis, lax. Spikelets solitary. Fertile spikelets sessile. Spikelets comprising 3-4 fertile florets with diminished florets at apex. Spikelets lanceolate, slightly compressed laterally, 10-12 mm long, breaking up at maturity, disarticulating below each fertile floret. Glumes persistent, similar, shorter than spikelet; lower glume narrowly lanceolate, 4-5 mm long, coriaceous, without keels, 3-veined, acute at apex; upper glume narrowly lanceolate, 4.5-6 mm

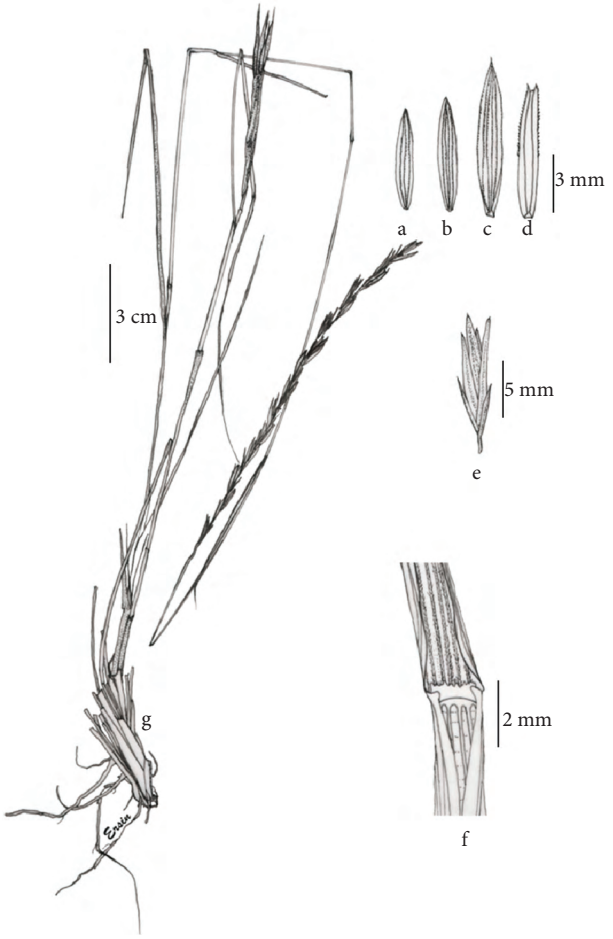

Figure 1. Line drawing of *Elymus sosnowskyi* (a) first glume, (b) second glume, (c) lemma, (d) palea, (e) spikelet, (f) ligule, and (g) mature plant (drawn by E. Karabacak).

long, coriaceous, without keels, 3-4-veined, acute-acuminate at apex. Fertile lemma elliptic, 8-9 mm long, coriaceous, keeled above, 5-veined, attenuate at apex, mucronate, mucro 0.5-1 mm; palea nearly as long as lemma, sparsely and minutely ciliate on keels in upper half; apical sterile florets resembling fertile, though underdeveloped; lodicules 2, elliptic, membranous. Anthers 3, 3.5-4 mm long. Ovary pubescent on apex. Caryopsis with adherent pericarp.

Habitat and Ecology

Elymus sosnowskyi grows on dry mountain slopes, in red soils, and on rocks. Its altitudinal range varies between 1400 and 1690 m (Figure 2). Other species growing in the area are *Ajuga chamaepitys* (L.) Schreb., *Convolvulus lineatus* L., *Dactylis glomerata* L., *Eremopyrum distans* (K.Koch) Nevski, *Euphrasia pectinata* Ten., *Galium verum* L. subsp. *verum*, *Hedysarum elegans* Boiss. & Huet, *Juniperus oxycedrus* L. subsp. *oxycedrus*, *Melica persica* Kunth, *Psathyrostachys fragilis* (Boiss.) Nevski, *Pseudorosularia sempervivoides* (Fisch.) M.Z.Gurgenidze, *Rumex acetosella* L., *Salvia huberi* Hedge, *Scutellaria orientalis* L. subsp. *sosnowskyi* (Takht.) Fed., *Teucrium polium* L., *Zingeria biebersteiniana* (Claus) P.A.Smirn., *Ziziphora clinopodioides* Lam., *Onobrychis* sp., *Potentilla* sp., *Veronica* sp., *Artemisia* sp., *Alchemilla* sp., *Euphorbia* sp., *Thymus* sp., *Alhagi* sp., *Iris* sp., *Stipa* sp., *Centaurea* sp., *Silene* sp., *Alopecurus* sp., *Anthemis* sp., and *Areneria* sp.

Phenology

Flowering occurs in May to June and fruiting from June to July.

Distribution

Elymus sosnowskyi was previously known only from 3 localities in north-eastern Turkey (Figure 3). The area in which *E. sosnowskyi* was discovered is in the Irano-Turanian phytogeographical region.

Examined Materials

A8 Erzurum: Oltu, Çamlıdere (Borahan), 40°31.037′N, 41°59.603′E, 1401 m, slopes, 22.vi.2008, *E.Cabi* 3485 [topotype]; **A8 Erzurum:** Narman to Pasinler, fairy chimney area, 40°18.050′N, 41°52.608′E, 1608 m, red soil slopes, 22.vi.2008, *E.Cabi* 3496; **A8 Erzurum:** Narman to Oltu, 21 km to Oltu, 40°24.426′N, 41°56.544′E, 1487 m, red soil slopes, 05.vii.2009, *E.Cabi* 4027; **A9 Kars:** Kuyucuk G., N.W. of Başgedikler railway station, 1800 m, *F.Sorger* 81-49-11.

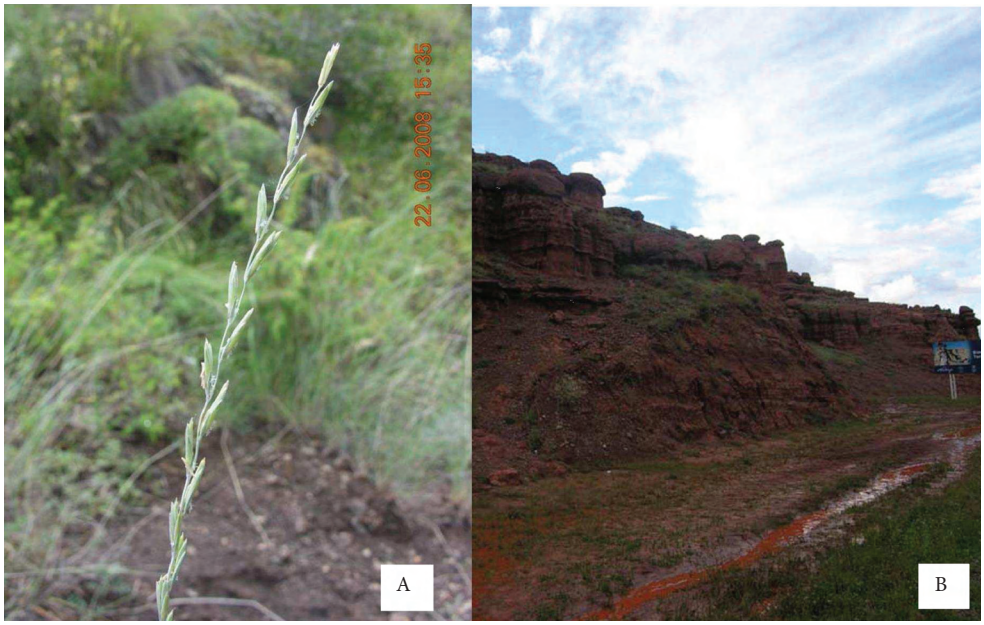

Figure 2. Spike and habitat of *Elymus sosnowskyi* in fairy chimneys locality.

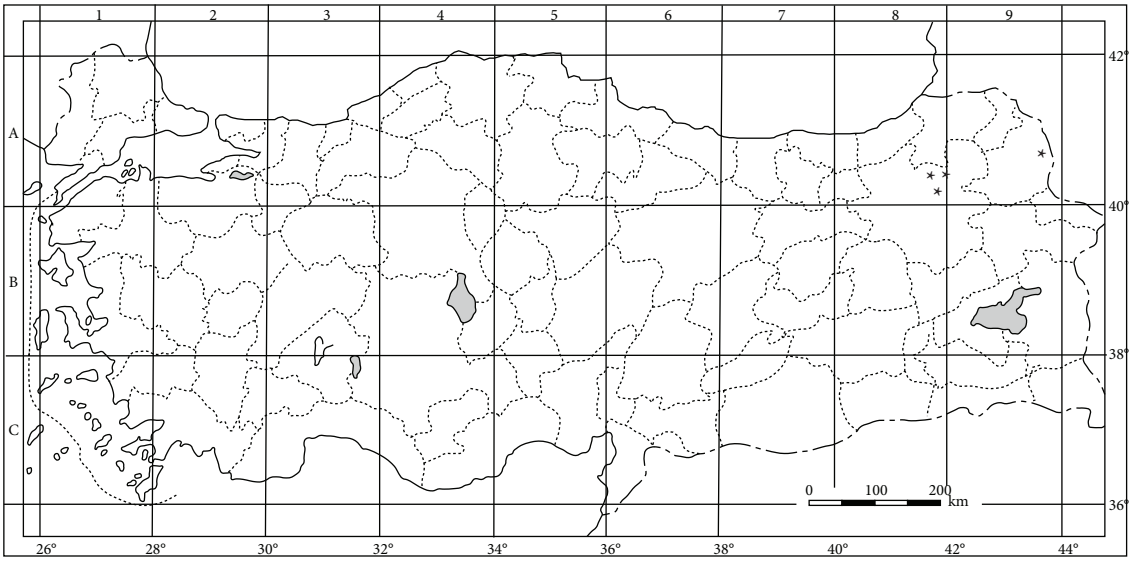

Figure 3. Distribution of *Elymus sosnowskyi* (*).

Related species

Elymus sosnowskyi is closely related to *E. libanoticus,* from which it may be distinguished by its narrowly lanceolate, acuminate-subulate, 3-veined glumes.

Recommended IUCN Threatened Category

Elymus sosnowskyi is a species endemic to north-eastern Turkey. Based on our data, its current conservation status was re-evaluated. Initially, it was assessed as Endangered (EN) in the *Turkish Red Data Book* (Ekim et al., 2000). According to the recent field surveys conducted by the research team, the species is distributed over more than 5 km^2 (criterion B2) and the mature plants number more than 500 (criterion C). As such, its conservation status has not been changed (IUCN, 2001).

Palynological features of *E. sosnowskyi*

E. sosnowskyi pollen grains are heteropolar, monoporate, and spheroidal. The pore was surrounded by an annulus and it was also covered by an operculum (Figure 4A). According to SEM investigation, the exine sculpture is scabrate with groups in *E. sosnowskyi*. There are 2-4 scabrae on each group in the investigated taxon (Figure 4B).

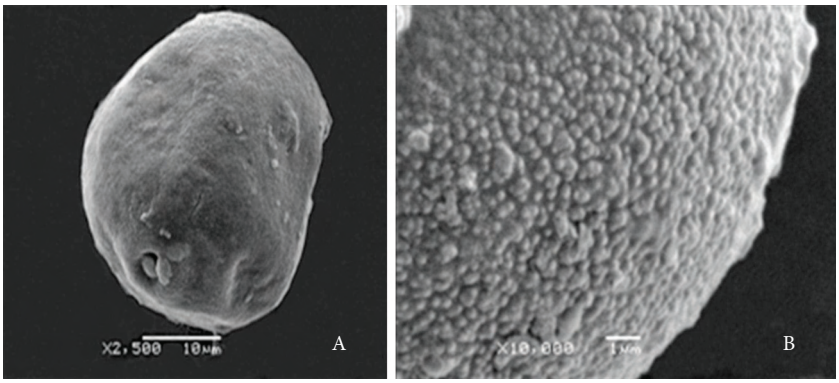

Figure 4. SEM micrograph of *E. sosnowskyi*. **A**. Slightly oblique polar view with distinct annulus **B.** Spinulose with grouped scabra.

Anatomical features of *E. sosnowskyi*

Leaf anatomy

Transverse sections of leaves demonstrate that the abaxial sides of the epidermis are glabrous and the epidermal cells are arranged in parallel rows, containing stomata and long cells combined with short cells (Figure 5A). There is only 1 short cell present between 2 long cells; however the adaxial epidermis also contains hairs and bulliform cells (Figure 5B, C).

Some of the quantitative anatomical characters are given in Table 2. According to these measurements, the lower epidermal cells are bigger than the upper epidermal cells. Long cells of the abaxial side vary in length from 130.44 to 160.68 μm; however, on the adaxial side of the epidermis they vary between 70.90 and 97.64 μm. Adaxial epidermal hair length varies in the species (Figure 5D). With regard to Metcalfe (1960), in transverse leaf sections the epidermis does not seem to display a diagnostic character, while in the surface view it is important to examine the nature of the papillae or to analyse both the structure of hairs and those that are attached to the epidermis.

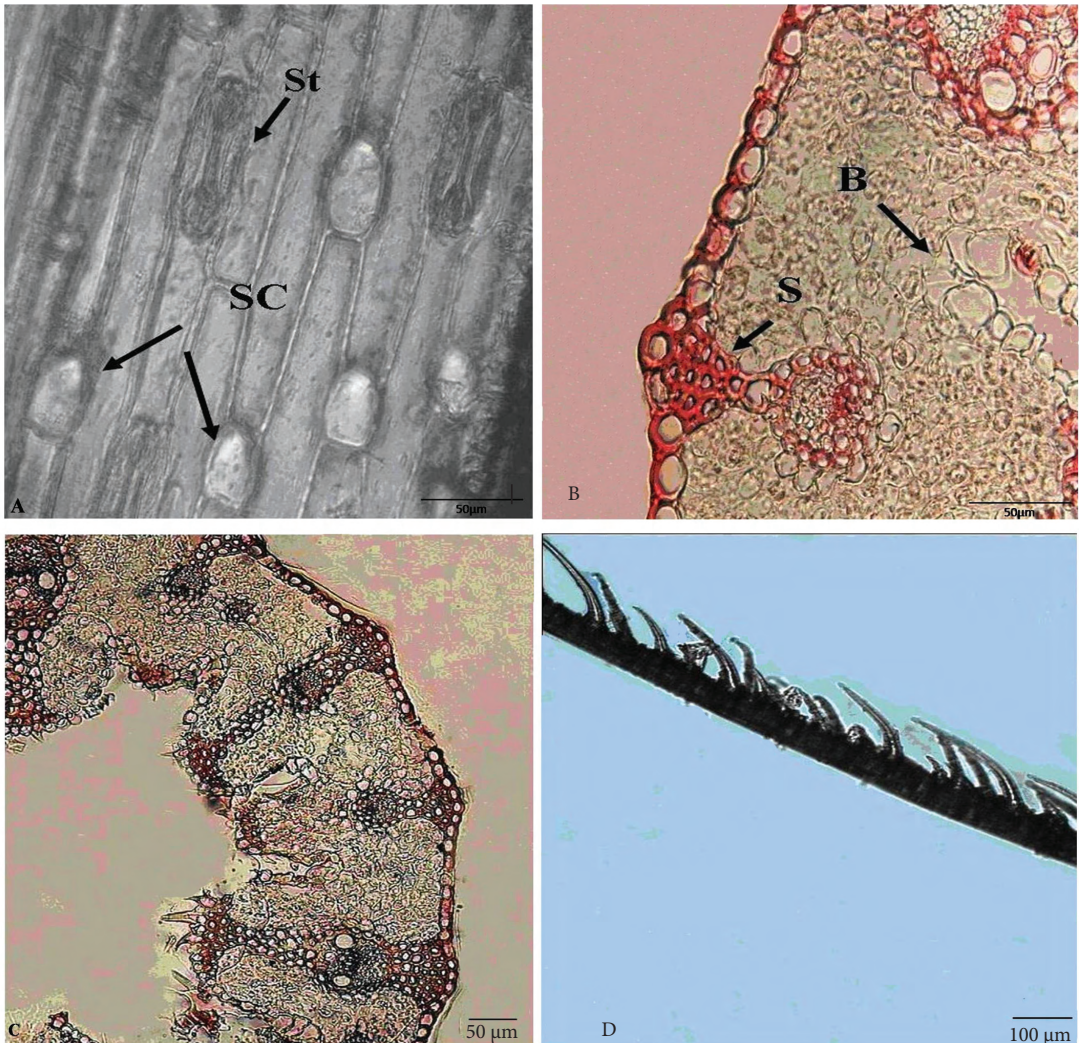

Figure 5. **A**. Lower epidermis of leaf. **B**. Transverse section of leaf (**St:** Stomata; **SC:** short Cells; **S:** sclerenchyma; **B:** bulliform cells). **C.** Transverse section of leaf. **D.** Hairs on the upper side of the leaf.

Table 2. Quantitative anatomical characters (leaf and epidermis) in the species (μm) (mean ± SD).

	Upper epidermis	Lower epidermis
Hair length (n = 10)	90 ± 20.6	no hair
Stoma width (n = 10)	10.5 ± 3.44	18.05 ± 0.05
Stomata length (n = 10)	31.5 ± 1.70	48.9 ± 0.80
Long cells width (n = 10)	10.57 ± 0.58	17.1 ± 1.43
Long cells length (n = 10)	80.45 ± 14.9	150.5 ± 11.6
Short cells width (n = 10)	14.98 ± 0.6	17.8 ± 1.11
Short cells length (n = 10)	18.55 ± 1.2	24.9 ± 2.70

E. sosnowskyi has adaxial furrows with a fan-shaped group of bulliform cells, which have thinner cell walls than the adjacent ordinary epidermal cells (Figure 5B). The epidermal cells with silica bodies are important characters in the family, as indicated by Metcalfe (1960, 1963). According to Stebbins and Kush (1961), monocotyledons are divided into the 4 major types of stomatal complexes. *E. sosnowskyi* could be included in the first type, which has a stoma with 2 subsidiary cells (Figure 5A).

The mesophyll is not differentiated into palisade and spongy parenchyma, and appears to be homogeneous (Figure 5B, C). These chlorenchyma cells occupy the entire space, except for the sclerenchyma or the vascular bundles and their surrounding sheaths. In contrast to most grasses, these mesophyll cells do not appear to radiate around the vascular bundles.

The arrangement of sclerenchyma around the vascular bundles was first shown diagrammatically in Gramineae by Vukolov (1929). In *E. sosnowskyi* there are 3 different dispositions of circumvascular sclerenchyma. These statements could be aligned as those without any girders or strands, an adaxial strand opposite a bundle, and an abaxial girder or adaxial, and abaxial girders (Figure 5C). The shapes of the girders or strands in the family were illustrated by Metcalfe (1960). Adaxial girders in *E. sosnowskyi* appear to be T-shaped and the abaxial girders seem to be I-shaped. The adaxial strands appear to be crescentiform.

The midrib is not readily distinguishable. The circular vascular bundles differ in size. There are double-type bundle sheathes; however, there is no 'girder-like extension' from the outer bundle-sheath (O.S.). There are 2 types of bundle sheath interruptions by the sclerenchyma, one of which has an outer sheath interrupted adaxially and abaxially with a complete inner sheath (I.S.), and the other has a complete inner sheath with an abaxially interrupted outer sheath. Additionally, there are double-type vascular bundle sheaths without interruption by the sclerenchyma, whose structure has a complete inner sheath; however, the outer sheath does not completely surround the inner sheath.

Small vascular bundles, without large metaxylem vessels, are not conspicuously angular in outline, whereas large vascular bundles of the basic type have a xylem in each bundle that seems to be characterised by a single, conspicuously large metaxylem vessel to the right and left of the protoxylem.

Stem anatomy

Transverse stem sections show that the vascular strands arise in a band of 2 circles-smaller bundles and larger bundles (Figure 6A). Both types of vascular bundles are connected to each other and to the glabrous epidermis with the sclerenchyma as well. Whenever there is sclerenchymatous tissue extending outwards at their attachment point, the epidermal cells tend to be smaller.

The sclerenchyma and subtending epidermis also cover the assimilatory tissue, called the chlorenchyma, which forms thin and flattened layers about 6 cells wide. Vascular bundles of the outer circle are embedded in 2-layered sclerenchymas and are connected to the epidermis by sclerenchymatic

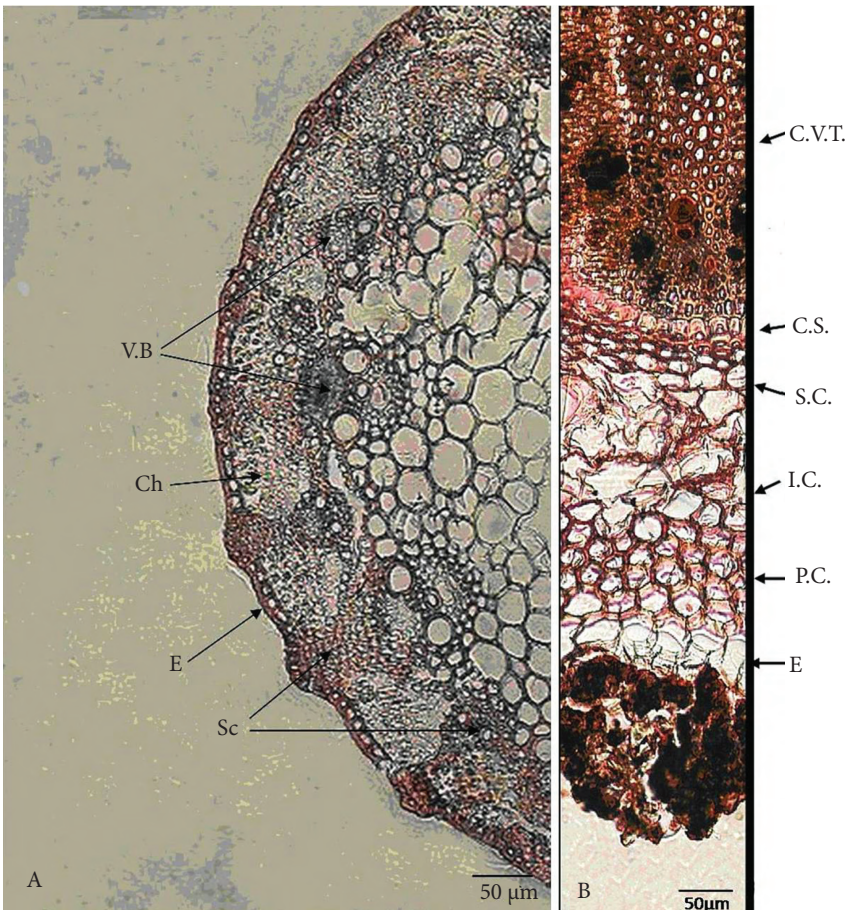

Figure 6. **A**. Transverse section of stem. **B**. Transverse section of root. **VB:** Vascular bundles; **Ch:** chlorenchyma; **E:** epidermis; **S:** sclerenchyma; **C.V.T.:** central vascular tissue; **C.S.:** Casparian strip; **P.C.:** parenchymatous cells; **I.C.:** intercellular cavity.

girders that separate the near columns of assimilatory tissue from one another.

Inner ground tissue of large and thin-walled cells seem to extend from the sclerenchyma ring to the large cavity at the centre of the stem. The ground tissue is made of parenchymatous cells. The central part of the parenchyma, the middle region, which is free of vascular tissue, is not conspicuously hollow, but breaks down in the mature internodes.

Root anatomy

Metcalfe (1960) emphasized that despite the size differences between species, transverse sections of grass roots seem to show the same general type of structure, in which the piliferous layer might become detached and the outer walls of the outermost cells become thickened. Moreover, according to Rosene (1943), hairless epidermal cells of grass roots can be capable of absorbing water. In *E. sosnowskyi* the outer surface of the root seems to be hairless.

The epidermis is subtended by 2 layers of moderately large cells (Figure 6B). The next subjacent layer, including 3-4 parenchymatous cells, has smaller ones with more thickened walls. Beneath the ring of the parenchyma there is a broad multilayered cortex. The cortex consists of radiating plates of cells (C.P.) with somewhat large radiating intercellular cavities (I.C.). The inner part of the cortex is made of 2-3-layered sclerenchymatous cells, arranged in a straight line, without intercellular spaces between them.

The Casparian strip within the endodermis and the pericycle is readily distinguishable (Figure 6B). Central vascular tissue is marked by conspicuously large metaxylem vessels and small strands of phloem alternating with them.

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