

Anatomical features of cross-sections of the genus *Equisetum* members

D.S. Feoktistov, I.I. Gureeva

National research Tomsk State University

Lenina av. 36, 634050, Tomsk, Russia. E-mail: feoktistovdmityriy@gmail.com

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The anatomical structure of cross-sections of internodes of stems and branches of 9 species and 5 interspecific hybrids of the subgenus *Equisetum* and *Hippochaete* (*Equisetum*, Equisetaceae) was studied: *E. arvense* L., *E. fluviatile* L., *E. palustre* L., *E. pratense* Ehrh., *E. sylvaticum* L., *E. × mildeanum* Rothm. (*E. pratense* × *E. sylvaticum*), *E. × sergijevskianum* CN Page et Gureeva (*E. pratense* × *E. palustre*), *E. × lofotense* Lubienski (*E. arvense* × *E. sylvaticum*), *E. hyemale* L., *E. ramosissimum* Desf., *E. scirpoides* Michx., *E. variegatum* Schlecht. ex F. Weber et D. Mohr., *E. × moorei* Newman (*E. hyemale* × *E. ramosissimum*), *E. × trachyodon* (A. Braun) W. D. J. Koch (*E. hyemale* × *E. variegatum*). The species-specific anatomical features of the species of the subgenus *Equisetum* are as follows: the shape of the ridge on the cross-section (in profile) and the presence of silica spines, the size of the vallicular cavities, the position and size of the mechanical tissue under the ridges. For species from the subgenus *Hippochaete*, the number of ridges and the shape of the ridge on the cross-section, the outline of the mechanical tissue, the presence of siliceous tubercles are important. For all species, the diagnostic feature is the size and position of the mechanical tissue in the cut, as well as the position and number of layers of the endoderm. The size of the central cavity cannot be used as a diagnostic feature. In this case, it is better to use the relative dimensions of the vallicular cavities to the central cavity. The article gives detailed descriptions of cross-sections.

Keywords: *Equisetum*; anatomical structure; Siberia; light microscopy

Introduction

Horsetails (Equisetaceae Rich. ex DC.) are one of the oldest groups of vascular plants. Despite the small size of the family and a limited number of morphological characters, most species of horsetails are characterized by very high morphological variability. There are a lot of horsetails specimens with intermediate morphological features between pairs of species. Such specimens are highly debatable because some researchers were describing them as varieties, and others were describing them as hybrids. This led to the appearance of considerable interest in this group of vascular plants in botanical community (Des-Marais, Smith, Britton, & Pryer, 2003; Feoktistov & Gureeva, 2016a, 2016b, Guillon, 2004, 2007, Hauke, 1963, 1969, 1978, 1993, Milde, 1865, 1863; Page, 1997; Page & Gureeva, 2013; Page, McHaffie, & Butler, 2007; Schaffner, 1930).

The greatest variety of horsetails falls precisely on the temperate zone, so the research of features that allow reliable determination of the taxonomic attribution of plants from Equisetaceae in the territory of Siberia and the Urals, which belongs to this zone, is very important.

Since the morphological features are too polymorphic for a reliable differentiating of species from one another, it is better to use ultrastructural and anatomical features, because they have less variability. According to the most accepted classification at the present moment (Hauke, 1963), horsetails are represented by single genus *Equisetum* L. with two subgenera (*Equisetum* and *Hippochaete* Milde). Looking at the anatomical structure of the cross-section of the horsetail stem, one can not only determine which of the two subgenera the sample belongs to but also distinguish the samples at the species level. Therefore, the aim of this research was to study the anatomical structure of the cross-section of horsetail that inhabits Western Siberia and the Urals to reveal the diagnostic value of the features.

Materials and methods

Field studies with the collection of herbarium material were carried out by a routing method. During the expeditions of 2012–2017 we collected materials from various habitats, high-altitude belts of the Urals, zones, and subzones of Siberia. The material was collected in the Chelyabinsk, Kurgan, Tyumen, and Tomsk regions, in the Republic of Khakassia and Khanty-Mansiysk Autonomous Region. During the expeditions, we collected 9 species and 5 hybrids that inhabit the study area. Four species from subgenus *Equisetum*: *E. arvense* L., *E. fluviatile* L., *E. palustre* L., *E. pratense* Ehrh., *E. sylvaticum* L. 3 hybrids from the same subgenus: *E. × mildeanum* Rothm. (*E. pratense* × *E. sylvaticum*) which was cited by the authors for the Omsk region (Feoktistov &

Gureeva, 2014), *E. × sergijevskianum* C.N. Page et Gureeva (*E. pratense* × *E. palustre*) first described from the Tomsk region (Page & Gureeva, 2009, 2013), and *E. × lofotense* Lubienski (*E. arvense* × *E. sylvaticum*) which was originally described from Norway (Lubienski, 2010) and found by us in several locations in the Omsk and Tomsk regions (Feoktistov, Gureeva & Mochalov, 2016). The following species were studied from the subgenus *Hippochaete*: *E. hyemale* L., *E. ramosissimum* Desf., *E. scirpoides* Michx., *E. variegatum* Schlecht. ex F. Weber et D. Mohr. Also, we studied two hybrids between them: *E. × moorei* Newman (*E. hyemale* × *E. ramosissimum*), *E. × trachyodon* (A. Braun) W. D. J. Koch (*E. hyemale* × *E. variegatum*) (Page, Gureeva, Mochalov, 2009).

We carried out studies of the anatomical structure of stem internodes cross-sections. Cross-sections were made with a use of a rotary microtome "Microm HM325". Preliminarily, small pieces of stems selected from herbarium specimen were boiled for 3–5 minutes in a test tube, then placed on the freezing table of the microtome "Microm KS34", frozen at –15 °C to form a "cushion" of ice. After that, the sample was placed in the rotary microtome for making cross-sections. Sections were performed in the middle part of the internode. For each sample, 10–15 cross-sections were made. The study and photographing of the cross-sections were carried out using a Zeiss lab 1.3 microscopes with an increase of 50× and 100× and an AxioCam ERC 5S camera. The cross-sections were not stained since all elements of the anatomical structure are clearly visible without staining.

Results

At different times the anatomy of horsetails was studied by numerous scientists. This indicates the effectiveness of using these characteristics for taxonomy (Filin, 1978; Brune, Thiv., & Haas, 2008; Nátherová, Kresánek, & Pobiecká, 1976; Page, 1972, 1973). One of the most important features of the anatomical structure of the stem of horsetails is the mechanical tissue. The mechanical tissue lies directly underneath the epidermis and provides mechanical strength for the shoot. Under the ridges it is multilayered, and in the groove area, it consists of only 1–2 layers. There are no mechanical tissues under the stomata. The mechanical tissue in the horsetails has been described by some authors as the collenchyma (Brown, 1976; Hauke, 1963), while other authors call it sclerenchyma (Johnson, 1937; Ogura, 1972). In order to avoid confusion, some authors preferred more neutral terms, such as hypodermis (Brown, 1976), hypodermal sterom (Gierlinger, Sapei, & Paris, 2008; Sapei et al., 2007) or reinforcing tissue (Spatz, Köhler, & Speck, 1998). In the present article, we use term mechanical tissue. According to R.L. Hauke (1963), a mechanical tissue is divided into two main types by its position on the cross-section: the vallecular collenchyma located under the grooves, and the carinal collenchyma located under the ridges. Behind the mechanical tissue in the direction to the center lies the parts of the chlorenchyma. The inner cortex consists of thin-walled cells of the main parenchyma, in which the vallecular cavities are located under the grooves. These channels pass along the entire length of the internodes and form a system of aeration. In the upper interstices of the stems, they are usually absent. The cortex is separated from the stele by an endodermis that forms a continuous ring or is located around each vascular bundle (Filin, 1978). The location of the endodermis varies in different species and is sometimes a species-specific trait.

The vascular system of horsetails is represented by siphonostele (Filin, 1978), the vascular bundles are located opposite the ridges, alternating with the vallecular canals located under the grooves, and surround a more or less pronounced central cavity. Each vascular bundle is conjoint, collateral, closed, and consists of xylem, phloem and some parenchyma. In each vascular bundle is present a water-containing cavity or canal called carinal canal. The number of vascular bundles and the number of vallecular canals corresponds to the number of ridges and grooves.

Below we provide a comparative description of the anatomical features of cross-sections of species and hybrids of the genus *Equisetum* that inhabit the Urals and Siberia territory. A total of 14 taxa were analyzed. The description of the cross-section of *E. × lofotense* is given for the first time. Sections were performed in the middle and upper parts of the stem. To obtain the results that can be used for determination of herbarium specimens and medicinal raw materials, herbarium specimens were used for this study.

Subgenus *Equisetum*

Equisetum arvense (Figure 1, A–C). Ridges in the number of 5–9 (18), well-defined, because of which the cross-section is angular in the outline. The mechanical tissue is well developed and is located in the region of the ridges and grooves under the epidermis. Chlorenchyma forms a continuous ring (a chlorenchyma of a continuous type). Large vallecular canals are located close to the grooves. Vallecular canals are in the number of ridges. The stela is surrounded by a ring of a single-layer, slightly noticeable endodermis. Vascular bundles in the number of ridges, opposite the ridges, carinal canals are very narrow. The central cavity is rather narrow, about 1/5–1/4 of the stem diameter. Branches do not have a central cavity with 3–4 (usually 4) very convex ridges, separated by deep V-shaped grooves. Chlorenchyma in branches is wide and reaches the vascular bundles. *E. fluviatile* (Figure 1, D–F). Ridges in the number of 9–21 (30), poorly-defined; the cross-section is wavy in the outline. The mechanical tissue is poorly developed, consists of several layers of cells located under the ridges. Chlorenchyma interrupted, multi-row, located under the furrows. Under the grooves, there are vallecular canals in the number of grooves. Vascular bundles are with large carinal canals, each vascular bundle is surrounded by an individual endoderm. The central cavity is very large, occupying from 3/4 to 9/10 of the diameter of the stem. Branches have a relatively wide central cavity and 3–6 well-defined ridges, separated by shallow grooves. Chlorenchyma in the branches is wide and reaches the vascular bundles.

E. palustre (Figure 1, G–J). Ridges in the number of 3–8, well-defined, triangular in cross-section, rounded at apex. The mechanical tissue is poorly developed. Chlorenchyma is presented by few rows and located under the ridges. The vallecular cavities are large, in the number of grooves, only slightly less in the diameter compared to the central cavity. Endodermis lies in a solid ring, surrounding the stela. Vascular bundles have a narrow carinal canal. The central cavity is rather narrow, occupying 1/5–1/4 of the stem. Branches do not have a central cavity, but with vallecular cavities in the number of grooves, ridges in the number of 3–6. Chlorenchyma of branches is multi-layered, occupying the entire space to the vallecular cavity.

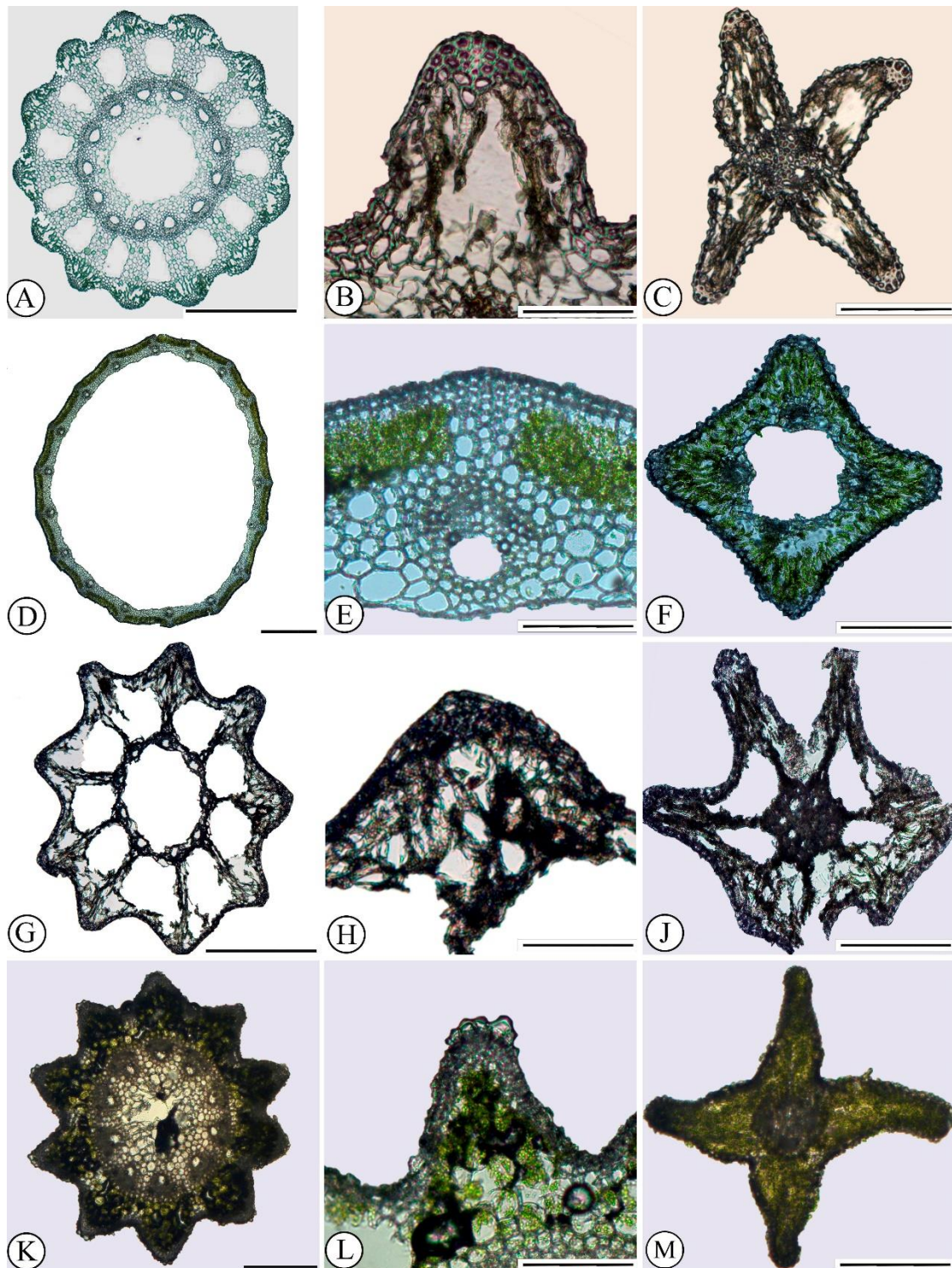


Figure 1. Cross-sections of stems and branches of subgenus *Equisetum* species:

A–C – *E. arvense*; D–F – *E. fluviatile*; G–J – *E. palustre*; K–M – *E. pratense*. 1st column – general view; 2nd column – ridge; 3 – branch. Scale bar: 1 column – 0.5 mm, 2 and 3 columns – 0.3 mm.

E. sylvaticum (Figure 2, A–C). Ridges are well-defined, wide, trapezoidal in cross-section, 8–16 in number, with well noticeable spikes located in 2 rows. The mechanical tissue is well developed, under the ridges is multi-layered, in outline it has back-triangular shape. Chlorenchyma is located only under the ridges, to the center, it turns into the parenchyma. The vallecular canals are narrow, in the number of grooves, opposite the furrows. Endodermis lies in a solid ring, surrounds the stela. Vascular bundles in the number of ridges, opposite the ridges, carinal channels are narrow. The central cavity is narrow, 1/4–1/3 of the stem diameter. Branches do not a central cavity with 3–5 distinct ridges, separated by wide, shallow grooves. Chlorenchyma of the branches is narrow, located under the ridges and reaches the vascular bundles.

E. × lofotense (Figure 2, D–F). Ridges are well defined, in the number of 8–14, semicircular and flattened at the apex, with well-noticeable spikes located in 2 rows (the feature of *E. sylvaticum*). The mechanical tissue is well developed, under the ridges is multi-layered, in outline it has back-triangular shape. Chlorenchyma is interrupted and located only under the ridges (a feature of *E. sylvaticum*); it turns into the parenchyma near the center of the stem. Small vallecular canals are located under the grooves. The vallecular canals are narrow, in the number of grooves, opposite them. Endodermis lies in a solid ring, surrounds the stela. Vascular bundles in the number of ridges, opposite them, carinal canals are narrow. The central cavity is rather narrow,

occupying up to 1/5–1/6 of the diameter of the stem (the feature of *E. arvense*). Branches without central cavity with 3–5 convex ridges. Chlorenchyma of branches is multi-layered, reaches the vascular bundles. The anatomical features of the hybrid combine the characteristics of the parental species and can be used as additional features for the identification of this hybrid. *E. × mildeanum* (Figure 2, G–J). Ridges in the number of 9–16 (the feature of *E. pratense*), well defined and rounded at the apex, with well-noticeable spikes located in 2 rows (the feature of *E. sylvaticum*). The mechanical tissue is well developed, under the ridges is multi-layered, trapezoidal in shape. Chlorenchyma is located only under the ridges, to the center, it turns into the parenchyma (the feature of *E. sylvaticum*). The vallecular canals are narrow, in the number of grooves, opposite them. Endodermis lies in a solid ring, surrounds the stela. Vascular bundles in the number of ridges, opposite the ridges, carinal canals are narrow. The central cavity is rather narrow, amounting to 1/4 of the diameter of the stem. Branches do not have a central cavity, but with 3–6 very convex triangular ridges with a flattened tip and 2 rows of tubercles, separated by wide V-shaped grooves. Chlorenchyma is a continuous in the branches and reaches the vascular bundles. In general, the anatomical structure of the hybrid is more similar with *E. sylvaticum* than with *E. pratense*.

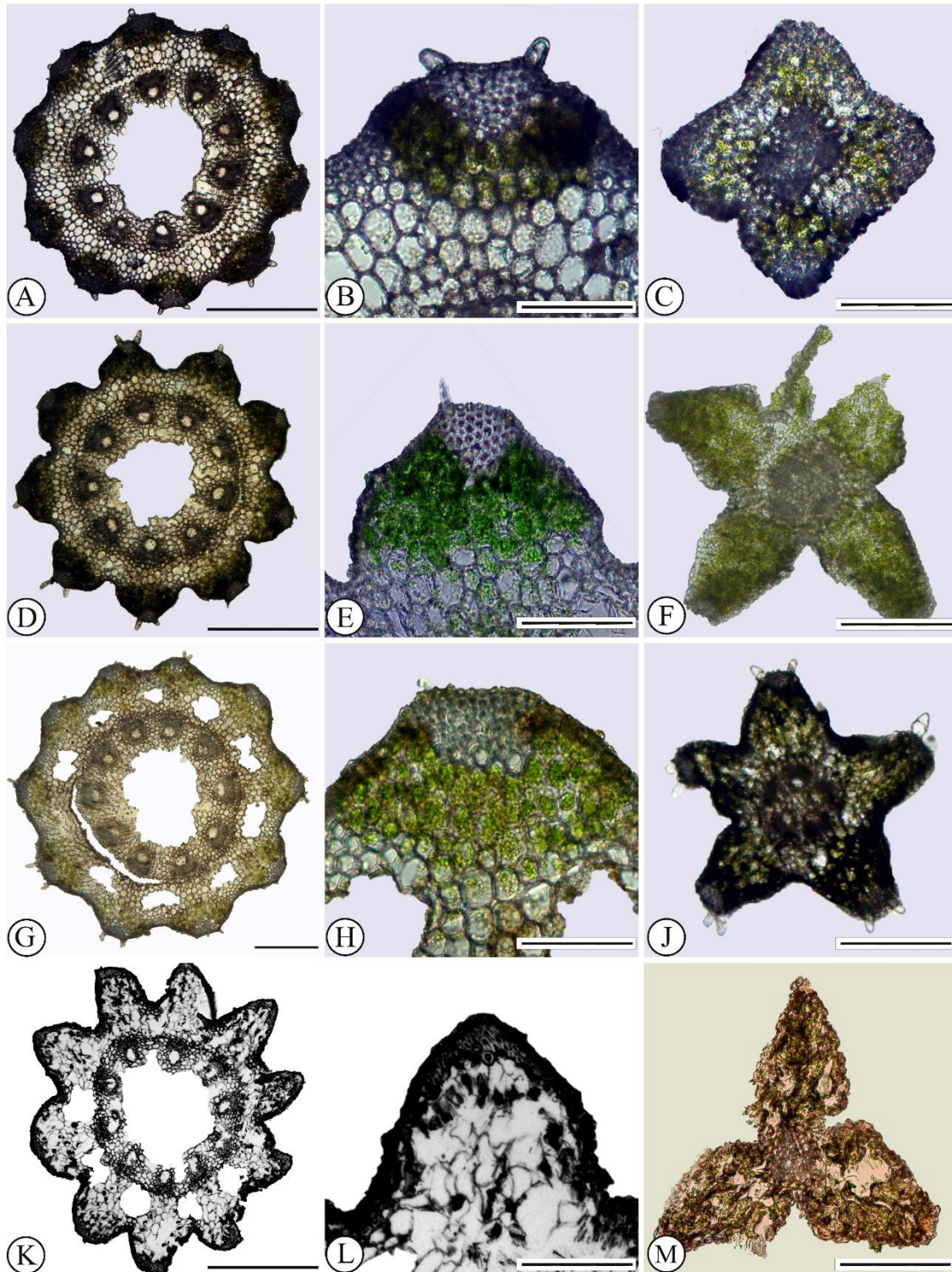


Figure 2. Cross-sections of stems and branches of subgenus *Equisetum* species and hybrids:

A–C – *E. sylvaticum*; D–F – *E. × lofotense*; G–J – *E. × mildeanum*; K–M – *E. × sergijevskianum*. 1st column – general view; 2nd column – ridge; 3 – branch. Scale bar: 1 column – 0.5 mm, 2 and 3 columns – 0.3 mm.

E. × sergijevskianum (Figure 2, K–M). Ridges in number 9–16, well defined, triangular in cross-section with a rounded tip (the feature of *E. pratense*). The mechanical tissue is poorly developed (the feature of *E. palustre*), under the ridges is two-layered. Chlorenchyma is located under the ridges, to the center, it turns into the parenchyma. Vallecular canals are narrow (the feature of *E. pratense*), opposite grooves. Endodermis lies in a solid ring, surrounds the stela. Vascular bundles in the number of ridges, opposite the ridges, carinal canals are narrow. The central cavity is rather narrow, 1/4–1/3 of the stem diameter. Branches do not have a central cavity; branches with 3–5 distinct ridges (the feature of *E. pratense*), separated by wide grooves. Chlorenchyma of the branches is multi-layered, located under the ridges and reaches the vascular bundles. Hybrid shows a combination of anatomical features of both parental species. Anatomical features can be used as additional features for identification of this hybrid.

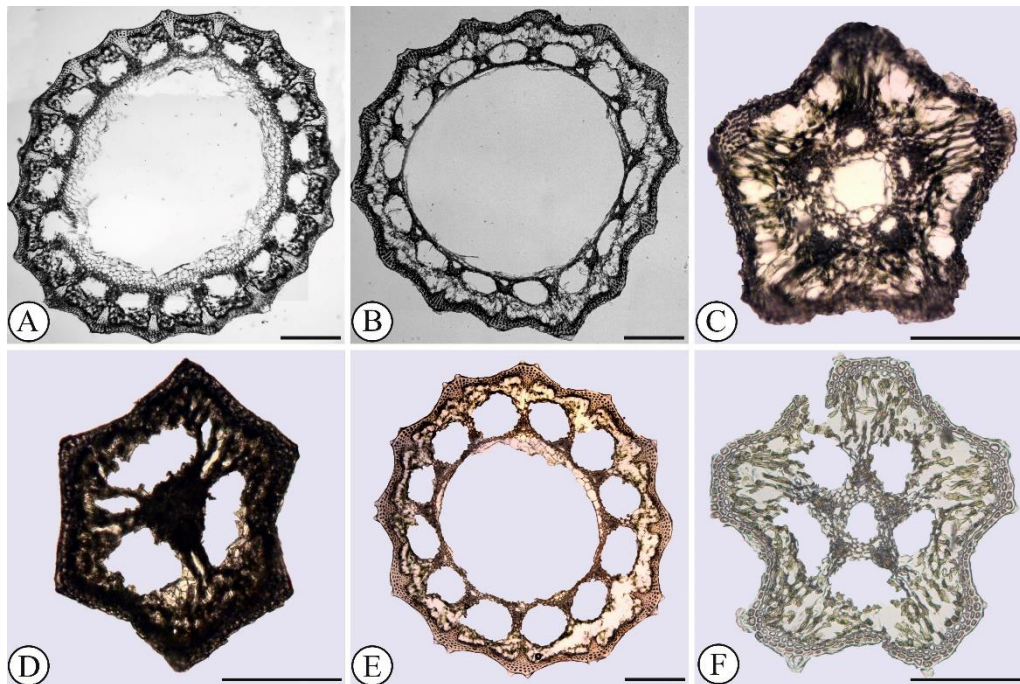


Figure 3. Cross-sections of stems and branches of subgenus *Hippochaete* species and hybrids:

A – *E. hyemale*, B – *E. × moorei*, C – *E. rammosissimum*, D – *E. scirpoides*, E – *E. × trachyodon*, F – *E. variegatum*. Scale bar 0.5 mm.

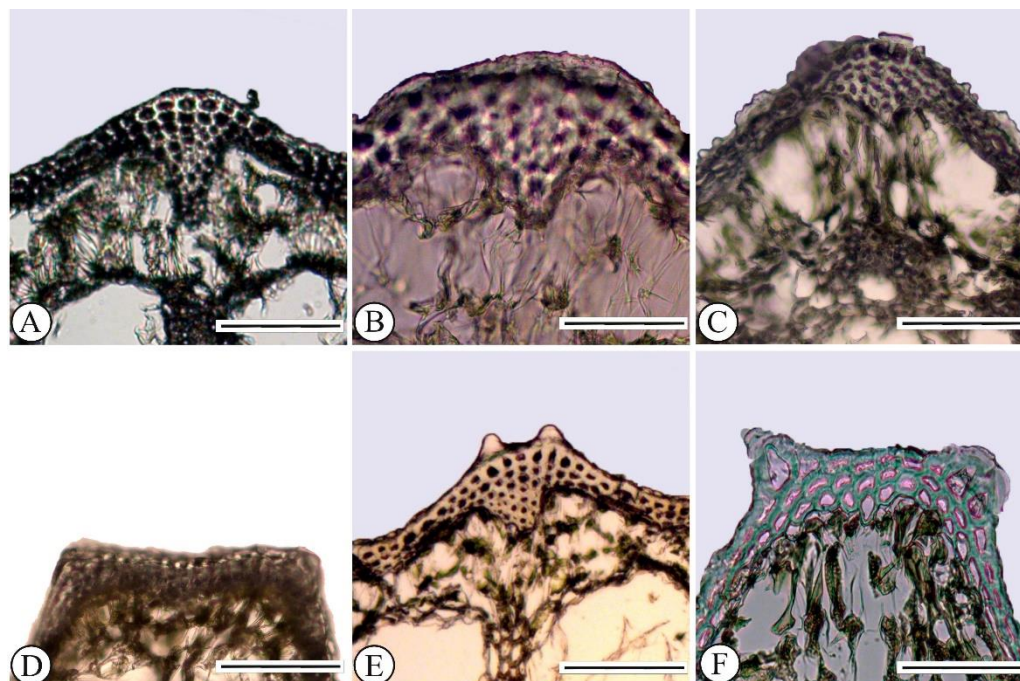


Figure 4. Cross-sections of the stem ridges of the subgenus *Hippochaete* species and hybrids:

A – *E. hyemale*, B – *E. × moorei*, C – *E. rammosissimum*, D – *E. scirpoides*, E – *E. × trachyodon*, F – *E. variegatum*. Scale bar 0.3 mm.

Subgenus *Hippochaete*

Equisetum hyemale (Figs 3, 4A). Ridges poorly defined, in the number of 10–30. The mechanical tissue is well developed, multi-layered under the ridges, back-triangular in shape, almost reaching the vascular bundles, two-rowed in grooves. Chlorenchyma is interrupted and lies between the grooves and the vallecular canal. Vallecular cavities are large, stretched, in the number of grooves, opposite them. The central cavity is large, 2/3 the diameter of the stem and more. The endodermis is two-layered, surrounds each vascular bundle.

E. ramosissimum (Figs 3, 4C). The ridges are well-defined, in the number of 5–21 depending on the diameter of the stem; the cross-section is wide-triangular. The mechanical tissue is located mainly under the ridges, multi-layered, wide-triangular in the outline, does not reach the vascular bundles. Chlorenchyma cells are arranged in several rows by a solid ring. Vallecular cavities in the number of grooves vary in size. The central cavity varies in size, ranging from 1/5 (in thin stems) to 2/3 (in thick stems) of stem diameter.

E. scirpoides (Figs 3, 4D). Stems are always with 3 ridges. Ridges are broad, flat at the apex or slightly concave, with two corners, almost as wide as the grooves. Cross-section looks like it has six ridges (pseudo-six-ridge stem). The mechanical tissue is double-rowed under the ridges and single-rowed under the grooves. Chlorenchyma is continuous and forms a solid ring. The vallecular cavities are large, in the number of 3, stretched correspondingly to wide grooves. The central cavity is absent.

E. variegatum (Figs 3, 4F). Ridges are well-defined, in the number of 4–9, broad, trapezoidal in outline, slightly concave at apex, with tubercles at corners. The mechanical tissue is poorly developed, two-rowed, and sometimes three-rowed in the ridges. Chlorenchyma is continuous and forms a solid ring. Vallecular cavities are equal in size to the central cavity, in the number of grooves, they are opposed to it. The central cavity is rather narrow, 1/5–1/6 of the stem diameter, and there is no central cavity in thin stems. The endodermis is bi-layered, surrounds each vascular bundle.

E. × moorei (Figs 3, 4B). Ridges slightly protruding, in the number of 10–20, rounded at apex. The mechanical tissue is developed, especially under the ridges, back-triangular in outline, does not reach the vascular bundles. Chlorenchyma interrupted, located between the groove and the vallecular canal. Vallecular cavities stretched, in the number of the grooves, are opposed to them. The central cavity is large, 2/3 the diameter of the stem or more. The endodermis is bi-layered, surrounded by each conductive bundle. According to its anatomical features, this hybrid is more similar to *E. hyemale*.

E. × trachyodon (Figs 3, 4E). Ridges well-expressed 10–18 in number, broad-triangular in shape with a truncated apex, in corners with well-notable tubercles (the feature of *E. variegatum*). The mechanical tissue is well developed, double-rowed under the grooves, multi-layered under the ridges, wide-triangular in outline, does not reach the vascular bundles. Chlorenchyma is interrupted and located between the groove and the vallecular canal. The vallecular cavities are large, in the number of the grooves, opposing them. The central cavity is wide, 2/3–1/3 of the diameter of the stem. The endodermis is bi-layered, surrounds each vascular bundle. This hybrid demonstrates clear intermediate features between the parental species.

Conclusion

The most prominent anatomical feature distinguishing two subgenera is the feature of the endodermis: in the species and hybrids of the subgenus *Equisetum*, the endodermis lies in a continuous ring and surrounds the stela; in the taxa of the subgenus *Hippochaete*, a double-layered endodermis surrounds each vascular bundle. On this basis, *E. fluviatile* is distinguished from all species of the subgenus *Equisetum*, because endodermis in *E. fluviatile* is located around each vascular bundle.

Important anatomical features specific for the species of the *Equisetum* subgenus are the shape of the ridge on the cross-section and the presence of silica spikes, the size of the vallecular cavities, the position, and size of the mechanical tissue under the ridges. For species from the *Hippochaete* subgenus the number of ridges and the shape of the ridge on the cross-section, outline of the mechanical tissue, and presence of silica tubercles are important.

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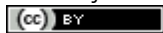
References

- Brown, J. T. (1976). Observations on the hypodermis of *Equisetum*. South African Journal of Science, 72, 303–305.
- Brune, T., Thiv, M., & Haas, K. (2008). *Equisetum* (Equisetaceae) species or hybrids? ISSR fingerprinting profiles help improve diagnoses based on morphology and anatomy. Plant Systematics and Evolution, 274(1–2), 67–81. <https://doi.org/10.1007/s00606-008-0028-9>
- Des-Marais, D. L., Smith, A. R., Britton, D. M., & Pryer, K. M. (2003). Phylogenetic Relationships and Evolution of Extant Horsetails, *Equisetum*, Based on Chloroplast DNA Sequence Data (rbc L and trn L-F). International Journal of Plant Sciences, 164(5), 737–751. <https://doi.org/10.1086/376817>
- Feoktistov, D. S., & Gureyeva, I. I. (2016a). The ultrastructure of the epidermal surface of stem and branch internodes and spores of horsetails of subgenus *Equisetum* (*Equisetum* L., *Equisetaceae*). Turczaninowia, 19(1), 47–57. <https://doi.org/10.14258/turczaninowia.19.1.6>
- Feoktistov, D. S., & Gureyeva, I. I. (2016b). The ultrastructure of the epidermal surface of stem internodes of horsetails of subgenus *Hippochaete* (*Equisetum*, *Equisetaceae*). Turczaninowia, 19(3), 59–67. <https://doi.org/10.14258/turczaninowia.19.3.2>
- Feoktistov, D. S., & Gureeva, I. I. (2014). *Equisetum × mildeanum* Rothm. (*Equisetaceae*), a horsetail hybrid new for the flora of Siberia. Systematic notes on the materials of P.N. Krylov Herbarium of Tomsk State University, (110), 38–49. (in Russian).
- Feoktistov, D. S., Gureeva, I. I. & Mochalov, A. S. (2016). New for the flora of Russia records of horsetail hybrid *Equisetum × lofotense* Lubienski. Systematic notes on the materials of P.N. Krylov Herbarium of Tomsk State University, (113), 41–50. (in Russian).
- Filin, V. R. (1978). Division Equisetophyta. Life of plants. Moscow. Prosvyaschenie, 4, 131–136. (in Russian).
- Gierlinger, N., Sapei, L., & Paris, O. (2008). Insights into the chemical composition of *Equisetum hyemale* by high-resolution Raman imaging. Planta, 227(5), 969–980. <https://doi.org/10.1007/s00425-007-0671-3>

- Guillon, J.-M. M. (2004). Phylogeny of horsetails (*Equisetum*) based on the chloroplast *rps4* gene and adjacent noncoding sequences. *Systematic Botany*, 29(2), 251–259. <https://doi.org/10.1600/036364404774195467>
- Guillon, J.-M. M. (2007). Molecular phylogeny of horsetails (*Equisetum*) including chloroplast *atpB* sequences. *Journal of Plant Research*, 120(4), 569–574. <https://doi.org/10.1007/s10265-007-0088-x>
- Hauke, R. L. (1963). A Taxonomic Monograph of the Genus *Equisetum* Subgenus *Hippochaete*. *Beihefte Zur Nova Hedwigia*, 8, 1–123. Available from <http://kdb.kew.org/kdb/detailedresult.do?id=25673> Accessed on 25.03.2018.
- Hauke, R. L. (1969). The Natural History of *Equisetum* in Costa Rica. *Revista de Biología Tropical*, 15(2), 269–275.
- Hauke, R. L. (1978). A taxonomic monograph of *Equisetum* subgenus *Equisetum*. *Nova Hedwigia*, 385–456.
- Hauke, R. L. (1993). *Equisetaceae* Michaux ex De Candolle: horsetail family. *Flora of North America North of Mexico*, 2, 76–84.
- Johnson, M. A. (1937). *Hydathodes* in the Genus *Equisetum*. *Botanical Gazette*, 98(3), 598–608. <https://doi.org/10.1086/334662>
- Lubienski, M. (2010). A new hybrid horsetail *Equisetum* × *lofotense* (*E. arvense* × *E. sylvaticum*, *Equisetaceae*) from Norway. *Nordic Journal of Botany*, 28(5), 530–540. <https://doi.org/10.1111/j.1756-1051.2010.00806.x>
- Milde, J. (1863). *Index equisetorum omnium*. *Verh. Zool.-Bot. Ges.*, 13, 233–244.
- Milde, J. (1865). Repräsentieren die Equiseten der gegenwärtigen Schöpfungsperiode ein oder zwei Genera. *Botanische Zeitung*, 23, 297–299.
- Nátherová, L., Kresánek, J., & Pobiecká, K. (1976). Anatomical study of the domestic species of genus *Equisetum* L. *Ceskoslovenská Farmacie*, 25(1), 20–25.
- Ogura, Y. (1972). Comparative anatomy of vegetative organs of the pteridophytes (2-nd ed). Germany: Gebrüder Borntraeger.
- Page, C. N. (1972). An assessment of inter-specific relationships in *Equisetum* subgenus *Equisetum*. *New Phytologist*, 71(2), 355–369.
- Page, C. N. (1973). Two hybrids in *Equisetum* new to the British flora. *Watsonia*, 9, 229–237.
- Page, C. N. (1997). *The ferns of Britain and Ireland* (2nd ed.). Edinburgh: Cambridge University Press.
- Page, C. N., & Gureyeva, I. I. (2009) A new horsetails hybrid from Western Siberia. *Systematic notes on the materials of P.N. Krylov Herbarium of Tomsk State University*, (113), 41–50. (in Russian).
- Page, C. N., & Gureyeva, I. I. (2013). *Equisetum* × *sergijevskianum*, a hybrid horsetail from Siberia. *Fern Gazette*, 19(5), 181–190.
- Page, C. N., Gureyeva, I. I. & Mochalov, A. S. (2009) A new hybrid for the flora of Siberia: *Equisetum* × *trachyodon* A. Braun (*Equisetaceae*). *Systematic notes on the materials of P.N. Krylov Herbarium of Tomsk State University*, (113), 41–50. (in Russian)
- Page, C. N., McHaffie, H., & Butler, J. K. (2007). A new far northern hybrid horsetail from Scotland: *Equisetum* × *mchaffieae* CN Page (*Equisetum fluviatile* L. × *E. pratense* Ehrh.). *Watsonia*, 26(3), 339–346.
- Sapei, L., Gierlinger, N., Hartmann, J., Nöske, R., Strauch, P., & Paris, O. (2007). Structural and analytical studies of silica accumulations in *Equisetum hyemale*. *Analytical and Bioanalytical Chemistry*, 389(4), 1249–1257. <https://doi.org/10.1007/s00216-007-1522-6>
- Schaffner, J. H. (1930). Geographic distributions of the Species of *Equisetum* in relation to their phylogeny. *American Fern Journal*, 20(3), 89–106. <https://doi.org/10.2307/1543867>
- Spatz, H. C., Köhler, L., & Speck, T. (1998). Biomechanics and functional anatomy of hollow-stemmed sphenopsids. I. *Equisetum giganteum* (*Equisetaceae*). *American Journal of Botany*, 85(3), 305–314. <https://doi.org/10.2307/2446321>

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