THE ANATOMY OF CAUDEX AND ROOT OF *ERIOCAULON SEPTANGULARE*

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Introduction.

Eriocaulon is an extensive genus being found in swampy or waste tract of land in the tropical and subtropical regions of the globe. They are small usually perennial herbs with a dense tuft of linear grass-like radical leaves, above which rise one or more slender scapes bearing the terminal heads. The general appearance of Eriocaulon resembles that of Isoetes, but the arrangement of the floral parts shows greater affinity to Compositae.

In the following lines are embodied the results of an anatomical study of the caudex and root of *Ericcaulon septangulare*. Two lots of specimens, one collected by Professor R. Ruggles Gates growing submerged in a lake near Halifax, Nova Scotia, and one of the Irish species, kindly sent by Professor Dixon were used as material for examination. As neither of these specimens showed any marked variation in their structure no separate treatments are given in the paper. Microtome sections of 12μ were made and stained in Delafield's Haematoxylin.

Caudex.

The underground stem of *Eriocaulon septangulare* is a thick caudex of one to four inches in length. The ascending caudex is densely covered by new and old leaf-bases and the internodes are visible only with a hand lens. At the axil of leaves there are frequently long thin white hairs which are developed from the epidermis of the caudex. The hairs are multicellular, the cells being arranged in a single row except the basal ones which are short.

A transverse section of the caudex shows that the epidermal cells are very much enlarged, nearly twice as large as those of the exodermis, and a thick layer of collenchyma is observed in between the exodermis and epidermis (Fig. 1). The cortex is characterized by many armed bladder-shaped cells, with inter-cellular spaces in between the arms (Fig. 2). The arms of the outer layer of cells are longer than those of the immediate inner ones, but the innermost cells of the cortex are often devoid of any arms. Scattered in the cortex are found numerous mestome bundles which are leptomatic strands surrounded by a thick-walled endodermis (Fig. 3a). These mestome bundles are smaller than those embedded in the stele. Theo Holm [1] observed both collateral and bi-collateral bundles in the fundamental tissues of *Eriocaulon decangulare*. In *Paepalanthus polyanthus*, Poulsen* finds a peculiar bi-collateral mestome bundle which is marked by an inner xylem part, surrounded by phloem the latter being enclosed by a wide bolt-like outer xylem. But in the rhizome of *Actinocephalus polyanthus*, he has noted a very unusual type of mestome bundle, which is perileptomatic in the cortex and perinadromatic in the fundamental tissue. The mestome bundle of *E. septangulare* might be considerad as a very simple type of conducting strand. In the haulm of *Juncus glancus*, Haberlandt [2] describes a similar type of mestome bundle in the composite peripheral girders. Inside the fibrous sheaths of the inner flanges of the girders are embedded large-sized mestome which are free from any mechanical tissue The mestome bundles which occur in the fundamental tissue are also leptomatic strands but are surrounded by parenchymatous cells (Fig. 3b). The lateral roots which originate from the pericydic region of the caudex take a zig-zag course in the cortex before they emerge through the epidermis. Fig. 4 is a longitudinal section of the caudex showing the general appearance of the root as it enters the cortex and Fig 5 is a part of the longitudinal section of the caudex with a root shaved off longitudinally.

The endodermis is easily distinguished by the peculiarly collapsed nature of the cell walls. The cells in a transverse section appear to be linked to each other by their shorter and radial walls (Fig. 6). The cell walls are not thickened, nor do they show any characteristic Casparian stripe. Inside the endodermis there is a single layer of pericycle, the cells are larger than the other layers within. Fig. 7 is a part of the transverse section through the stele showing a type of large mestome bundle, surrounded by parenchymatous cells.

Root.

The caudex gives off numerous string-like white adventitious roots which are 1 to 2 mm. thick and 10 to 50 mm. long. The majority of roots have a uniform thickness of 1.5 mm., while a few are decidedly thinner but longer. Root hairs and branches are found in both sets of roots The peculiar transverse ridges of the roots at definite intervals might at first be taken for the wrinkles of the contractile roots. But a closer examination under a high power lens show that the transverse septa of the cortex are arranged in columns at equidistant intervals (Fig. 13).

For an anatomical study, both the transverse as well as longitudinal sections were made through different parts of thick as well as slender roots. A transverse section of the younger portion of the root shows 8 layers of parenchymatous cells (Fig. 8), but in a similar section through the older portion, the cortical cells have enlarged to an abnormal extent as to give the appearance of big chambers (Fig. 9), the air cavities being narrow slits in between the cells. The innermost cortical layer, the cells of which are much smaller than those of the outer layers, abuts on the endodermis. The endodermis is distinguished by the characteristic oblong-shaped cells, but no Casparian stripe or special thickening of cell walls was observed. In the cortex of the older portion of the root, peculiarly arranged horizontal diaphragms often occur in the lacunae of the air spaces (Fig 10). These diaphragms with their profusely branched trabeculæ are adapted for stiffening purposes in the case of organs which are pervaded by wide air spaces. In certain species of Scirpus the richly branched cellular trabeculae that intersect the air passages collectively form an elegant system of internal buttresses and afford an efficient strengthening effect to the plant. Fig. 11 is a transverse section through the stele showing that the central cylinder occupies proportionately a smaller space than the cortex. The pericycle is thin-walled and consists of a single layer of cells which is often interrupted by protoxylem strands in Nova Scotia specimens. These protoxylem strands are reduced to single vessels; 3 to 5 such vessels have been observed in transverse sections of the root. In the Nova Scotia specimens the pericycle is continuous, but the protoxylem strands were scattered within the stele. In one section 8 protoxylem strands with a single vessel in each have been counted. But the alternate phloem patches were not visible in most of these cases. Intercellular spaces were seen in the stele, only between the endodermis and pericycle. In both the species that have been studied there was only one central canal cell in some specimens.

A longitudinal section of the tip of a root shows a small cap consisting of 16 cells (Fig. 12). The dermatogen, periblem and plerome are distinguishable. (The little air spaces entrapped between the layers of cells are due to fixation). The cells nearer the tip do not show any marked differentiation from the cells in the common monocotyledonous root-tips. But a transverse row of cells farther away from the tip, at definite intervals assume a diminished size, and these ultimately become the transverse septa as shown in the longitudinal section through the root (Fig. 13). The puzzling question is how the alternate cells are widened to form big chambers in the upper region. The branches of roots showed a simple structure. In a transverse section, the piliferous layer and one or two layers of cortex, and a smaller cylinder with the central canal cell, are recognized.

Conclusions.

In considering the structural peculiarities of *E. septangulare* one has to bear in mind the several allied natural orders such as Juncaceae, Cyperaceae, and Gramineae. According to Van Tieghem,[3] the structure of pericycle in Eriocaulon bears the same relationship as that of Cyperaceae and Gramineae. In some species of Gramineae he has observed that all the protoxylem vessels are within the pericycle, while in others they are in direct contact with the endodermis. V. A. Poulsen remarks that the presence of collenchymatous tissue is rare among monocotyledons. But Theo Holm observed it in Commelinaceae, Smilaceae and Dioscoreaceae. In Eriocaulaceae, collenchyma occurs as prominent ridges in the stem: it replaces the stereome in the leaves and it surrounds the mestome bundles as a closed sheath.

Summary.

1. The caudex is a hairy structure about 1 to 1 inches long. Its cortex consists of bladder-like, many-armed cells, the outer zones of cells having larger arms than those immediately within. The collenchymatous tissue is observed in the cortex. The mestome bundles are surrounded by a parenchymatous sheath in the stele, but those of the cortex, by a thick-walled endodermis. The endodermis is of a peculiarly collapsed nature, and could be easily distinguished from the other layers of cells.

2. The anatomical preparations of the root of *Eriocaulon septangulare* show a wide cortex characterised by chamber-like cells, separated by irregular air cavities. The air cavities are frequently interrupted by horizontally placed diaphragms, with their numerous trabeculae. The pericycle is sometimes interrupted by 4 to 5 protoxylem groups which are reduced to simple vessels. The corresponding bundles were observed concentrically arranged in some sections.

3. In comparing the anatomy of the Caudex and Root of *E. septangulare* with that of *E. decangulare*, as described by Theo Holm,[1] and *E. helichrysoides* as described by V. A. Poulsen,[4] there seem to be certain peculiarities in common which may be characteristic of the order. The multicellular hairs, collenchymatous tissue and the bladder-shaped cells with its numerous trabeculae in the caudex and the aerenchyma with its diaphragms, the concentric

arrangements of xylem and phloem and the wide chamber-like cortical cells may be fairly taken as the characteristic features of the order Eriocaulaceae.

I wish to express my thanks to Professor Dixon of Dublin for the Irish specimens of *E. septangulare* which he has kindly forwarded to me. This piece of work was carried out in the Botanical Laboratory of King's College, London. Under the supervision of Professor R. Ruggles Gates to whom I desire to express my sincere thanks for advice and criticism.

Literature Cited.

1. 1901, THEO HOLM.—*Eriocaulon decangulare*, An anatomical study : Botanical Gazette, 31 : 17–37. Figs. 1–5

2. G. HABERLANDT. — Physiological Plant anatomy—1914. Translated from the 4th German Edition by Montagu Drummond, pp. 170–175.

3. 1882, M. PH. VAN TIEGHAM.—Structure de la Racine et Dispos itiondes Radicells dans les Centrolepides, Eriocaulees, Joncees Mayacees et Xyridees, Journal de Botanique 1 : pp. 304–315.

4. 1888, V. A. POULSEN.—Anatomiske studier over Eriocaulaceae, Thesis, Copenhagen, pp. 44–58.

Explanation of Plates I and II.

Eriocaulon septangulare.

All figures were drawn with a camera lucida and have been reduced to in reproduction The magnification of each figure is given below Figs. 1–13. Throughout, T. S. Transverse Section ; L. S. Longitudinal Section ; P. piliferous layer ; ex. exodermis ; E. endodermis). Figs. 1–7. Caudex.

Fig. 1. Part of T. S. through the outer cortex × 280. ct. Collenchyma.

Fig. 2. Part of L. S. through the cortex showing the many armed bladder-shaped cells × 280 ; c. c. cortical cell ; p. w. partition wall ; a. s. air space.

Fig. 3. (*a*) T. S. of a mestome bundle from the cortex × 280, E. Endodermis ; c. p. cortical parenchyma ; a. s. air space,
(*b*) T. S. of a mestome bundle from the stele × 280,

Fig. 4. Part of L. S. through the inner cortex and outer stele showing the origin of a root (L. R.) from the pericyclic region × 280,

Fig. 5. Part of T. S. showing the course of a lateral root cut longitudinally × 280. The root in the figure is shaved off.

Fig. 6. Part of T. S. through the inner cortex and outer stele showing the nature of endodermis × 120. p. pericycle; E. endodermis; I. C. inner cortex; s. c. stellate cell; a. s. air space.

Fig. 7. Part of T. S through the stele showing the nature of tissues × 140. M. B. mestome buudle.

Figs. 8–13. Root.

Fig. 8. Part of T. S. through the cortex of a young root × 120. C. cortex; I. C. inner cortical layer.

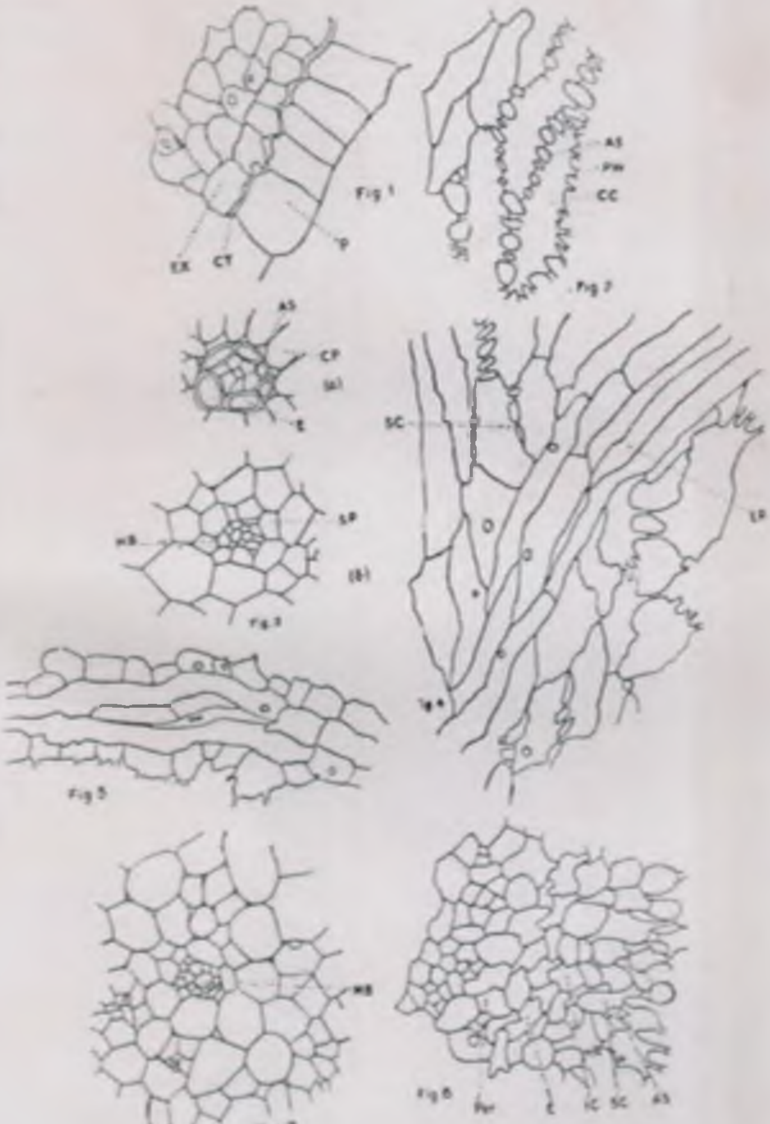
Fig. 9. Part of T. S. through an old root showing the wide cortex × 140. a. s air space. I C. inner cortical layer.

Fig. 10. Part of T. S. through the cortex showing diaphragm × 280. c. c. cortical cell; a. s. air space.

Fig. 11. T. S. through the central cylinder × 140; I. C inner cortical cell: p. pericycle; c. c. central canal cell.

Fig. 12. L. S. through the tip of a root × 140. r. c. root cap; a. s. air space; Dr. dermatogen; pr. periblem; Pl. plerome.

Fig. 13. L. S. through the cortex × 140. T. S. transverse septa.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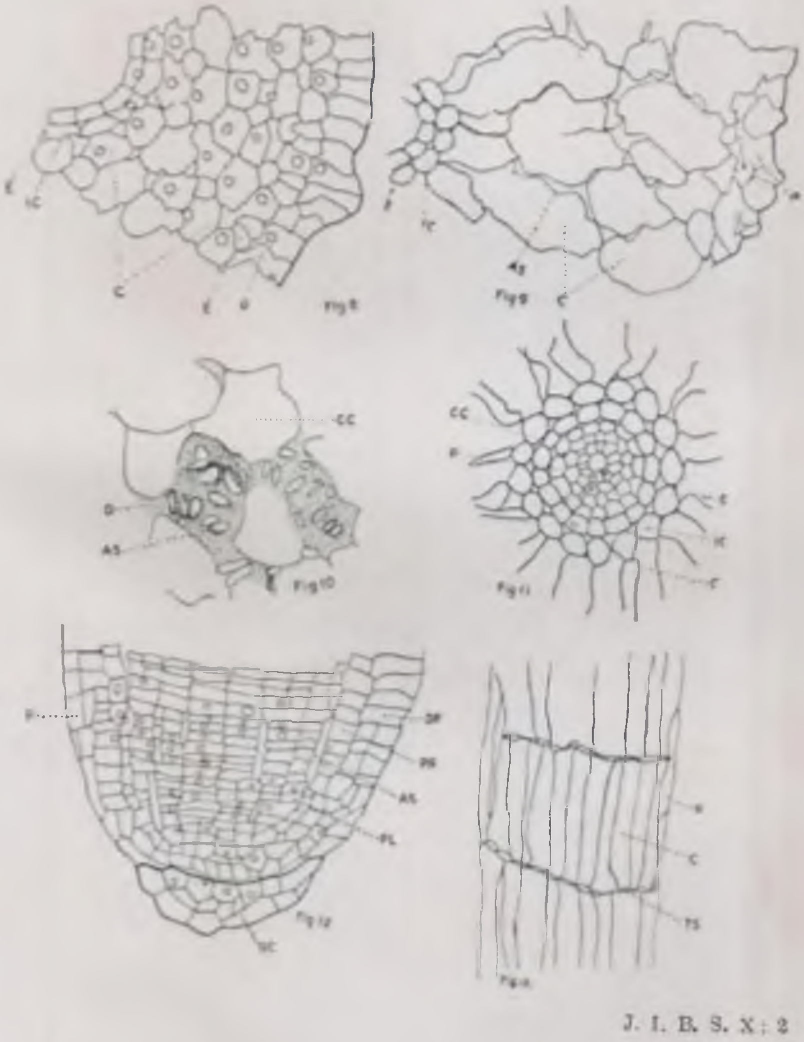
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