The tissue structure of the vegetative organs of strawberry (*Fragaria moschata* Duch.)

Papp J.[1], Lenkefi I.[2], Gara M.[1] and Gracza P.[2]

[1]*Szent István University, Faculty of Horticulture, Dept. of Pomology, H-1118 Budapest, Villányi út 35–43.*
[2]*ELTE College of Teaching, Dept. of Biology, H-1055 Budapest, Markó u. 29–31.*

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Summary: The tissue structure of the vegetative organs of strawberry (root, rhizome, stolon, leaf) is discussed in this paper. The authors stated that the root structure described by Muromcev (1969) and Naumann-Seip (1989) develops further from the primary structure. It grows secondarily and the transport tissue becomes continuous having ring shape. In the primary cortex of the rhizome periderm like tissue differentiates, but according to the examinations up to now, it does not take over the role of the exodermis. The exodermis is phlobofän filled primary cortex tissue with 3–4 cell rows under the rhizodermis. The development of the transport tissue of the petiole is also a new recognition. In the lower third of the petiole the transport tissue consists of 3 collaterally compound vascular bundles. In the middle third there are 5 bundles because of the separation of the central bundle and in the upper third of the petiole 7 bundles can be observed because of the ramification of the outside bundles. Therefore attention must be taken also in the case of other plants at making sections. There might be confusions in the results of the examinations if the number of bundles increases in the petiole. The tissue structure might vary depending on the origin of the tissue segment.
The palisade parenchyma of the leaf blade has two layers and it is wider than the spongy parenchyma. Among the 5-6-angular cells of the upper epidermis do not develop stomata while in the lower epidermis there are a fairly lot of them.

Introduction

Researchers described first the morphological characteristics of strawberry: the features of stolons and fruits as special organ forms. The structure of stolons was described and sketched by *Dennert* (1894). In his opinion, those parts of the stolon that have long internodiums die and the shoots developing on the nodes continue to live as independent plants. In the case of plants with rosette, the growth of the internodiums is hindered resulting in rosetting leaves (*Goebel* 1928-32, *Troll* 1937-39). The hairs of the strawberry are long and soft especially on young plants (*Filarszky* 1911).

The tissue structure got into the interest of research later when changing of the structure in the grown plants was observed. The change was attributed to intensive cultivation, fertilization and irrigation. In the beginning the aim was to know the reproductive organs, such as the process of structure change when the vegetative apex goes over into reproductive phase. At this time the conical vegetative apex becomes flat and a palm-formed reproductive apex develops. The calyx and petal primordia appear along a horizontal plane (*Troll-Rauh* 1950, *Rauh-Reznik* 1953, *Zeller* 1967). A bit later the middle, undifferentiated part of the apex begins to swell developing superior pistils. In the maturing period this part is swelling further and the achenes sink into it. Abscission of the fruits from the stems was observed by *Boros* (1972).

Among the vegetative organs the tissue structure of the roots was described by *Muromcev* (1969) in detail, stating tetrarch structure. Starting from the root apex phase he describes the primary tissue structure of the roots using demonstrative vertical section. Light has an effect on the change over of the apex from vegetative phase into reproductive one (*Borthwick* 1952).

Naumann & Seip (1989) agree with the statement of Muromcev. *Papp* et al. (1999) examine the tissue structure of the vegetative organs, such as roots, stems, leaves and petioles. They state that the root thickens secondarily and in the tissue structure of the petiole there are 3 vascular bundles in the lower part, 5 bundles in the middle part and 7 bundles in the upper part of the petiole. The increase always derives from the ramification of the central bundle.

Materials and methods

In our examination the strawberry (*Fragaria moschata Duch*) variety Elsanta was observed. The first examinations were done on pot plants in green house followed by the ones on plants grown outdoors. Sections of the vegetative organs (root, rhizome, stolon, petiole, leaf blade) were prepared by razor. Excoriation of the epidermis was done oo both sides of the leaf blade with the help of nail polish. The sections were painted with toluidinblue and fixed by aqueous glycerine solution. During the microscope studies micropho-

tos were taken of the characteristic states on colour or black and white films. Sometimes, the morphological parts were also sketched. Pictures of the stolons were taken by scanning electron-microscope to make the examinations complete.

Results

Roots. The young roots are of white or light beige colour, they are 30–50 mm in length and 1 mm in diameter. One cell layer of rhizodemis covers their surface with hairy zone towards the root tip. The primary cortex compared to the stele is wider than the average, it consists of 8-11 cell rows. The cells of the cortex are a little smaller near the rhizodermis then they get bigger and close to the stele they are smaller again. Storage of solid materials cannot be observed. The cortex border touching the stele is *Caspary spotted*. There is a one cell layer pericambium around the stele. The cell walls are thin and can be distinguished from the neighbouring cells well. In the base tissue, consisting of parenchyma cells that are getting bigger towards inside, 4 simple xylem bundles and 4 simple phloem bundles are found.

The elongated triangle shape xylem bundles comprise 7–8 protoxylem units (tracheids) with narrow cavities. Inside there is only one bigger metaxylem unit, a trachea. The phloem bundles contain 8–9 sieve tubes with companion cells around. The developing root becomes 1.5 mm in diameter wherein the wavy cambium shaping up from the pericambium develops tracheas with thick cell walls and wider cavities, tracheids with narrow cavities and xylem parenchyma cells with thin cell walls. Towards outside sieve tube, companion cell and phloem parenchyma are found surrounding the cambium (disappearing till the end of development) and the continuous xylem in 4–5 cell rows. The outer 2–3 cell rows of the primary cortex are filled with phlobofän materials serving as protecting surface tissue of greyish black colour *(Fig. 1)*.

During root thickening both the primary cortex and the stele become a little wider. These two layers are visibly separated by the still existing endodermis. The endodermis usually disappears so the cortex and the phloem get in direct contact. This is a new statement *(Fig. 2)*.

Rhizome. The primary vertical rhizome of strawberry develops in the following way. In the case of seed propagation both the main and the lateral roots of the germinating plant grow slowly, while the roots of stem origin appearing on the hypocotyl develop more intensively. In the meantime the hypocotyl gets thicker resulting in the development of vertical rhizome. On the shoot apex leaves come into existence and in the middle of the season the vegetative apex goes over into reproductive phase, the differentiation of flowers takes place. At the same time in the axils of leaves vegetative shoot tips initiate resulting in stolons of 20–50 cm in length, growing horizontally.

The secondary rhizome of strawberry develops from those parts of the stolon where a leaf is emerging with a shoot tip in the axil of the leaf. First of all a few roots of stem origin develop on the lower side having putting effect on the just forming rhizome. Then the roots developing further as fibrous roots pull the rhizome into vertical position. in the meantime the rhizome coming into existence in this way thickens and the bud differentiated in the axil of the leaf also begins to develop, producing rosetting leaves.

The thickening and slightly swelling apex of the rhizome becomes again differentiated: leaves and stolons appear on it. In the axils of leaves meristematic isles remain developing buds and rosetting shoots in the following year. So it is called vegeto-reproductive apex.

The rhizomes are covered with a layer of epidermis. The cells of the primary cortex under the leaf base are parenchymatic cells. Between the leaves the cells are smaller and can be painted better.

Towards inside the cells of the cortex are bigger. The transport tissue has continuous ring shape. The xylem is 23–25 cell rows wide. It is fairly homogenous. It contains a few tracheas but mostly tracheids and parenchyma cells divided by pith rays of one cell row. The walls of the cells are woody.

The cambium is 2–3 cell rows wide. The phloem is fairly wide, comprising 12–14 cell rows. There are pith rays in it. The phloem contains sieve tubes, companion cells and phloem parenchyma. Towards outside in the primary cortex special tissue structure is found consisting of 4–6 layers of 5–8 cell rows each. The cells are organized in radial and tangential rows resembling cork tissue. Detailed tissue studies are still necessary to follow the development of this tissue from the early developing phase of the rhizome *(Fig. 3, 4)*.

In the middle of the structure wide pith tissue is found. Cells of this tissue are sphere formed isodiametrical cells. Close to the xylem the pith cells are smaller with slightly thickened walls, towards inside they become larger.

Stolons. From the axil of the rosette leaf 2–4 stolons can develop. When they are 10–25 cm in length a leaf comes into existence on each one. Later the vegetative apex develops further, and after additional 10–15 cm a new leaf appears on it. Sometimes the apex produces one more stolon segment of 10–15 cm. The youngest part of the stolon is the thinnest but it becomes thicker later.

The stolons are covered with one layer epidermis with few hairs. The cells of the outer 3–4 cell rows of the primary cortex are alternately small and large with slightly thickened walls. In the following 9–10 rows towards inside the cells are bigger with isodiametric shape and triangle formed intercellular spaces in the corners.

The transport tissue is continuous, containing wide phloem and narrow xylem layers at first. Between the phloem and the xylem the cambium of 3- cell rows is found that is responsible for thickening of the stolon and growing of the xylem. In the beginning the cambium forms protoxylem with narrow cavities then tracheas with wider cavities in radial rows. Among them xylem parenchyma is found containing few tracheids with narrow cavities *(Fig. 5)*.

Later the oldest stolon part becomes even thicker, expansion of the transport tissue takes place. The number of

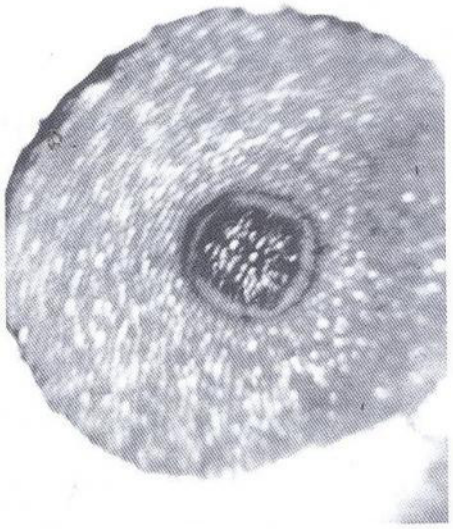

Figure 1 The structure of the young root

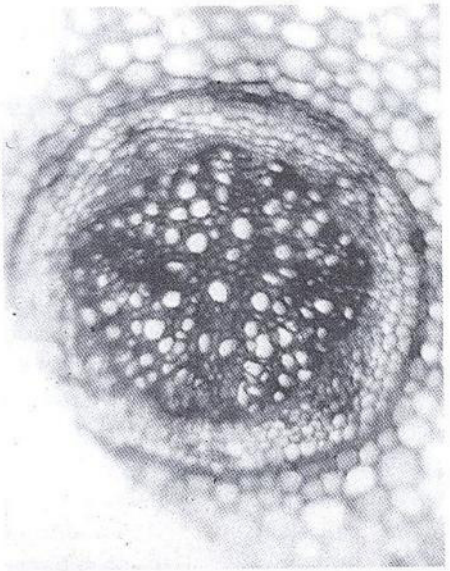

Figure 2 Old root

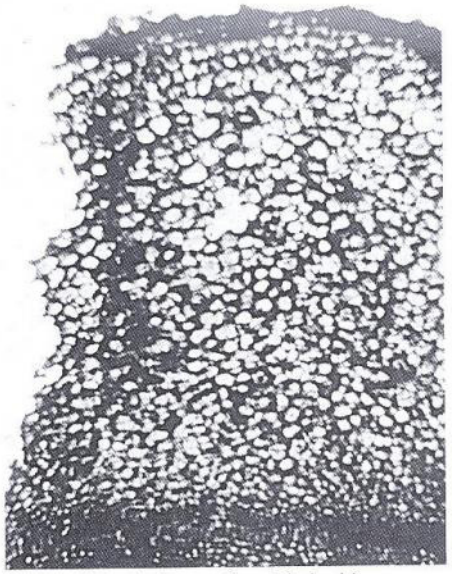

Figure 3 Teminal part of an elderly rhizome

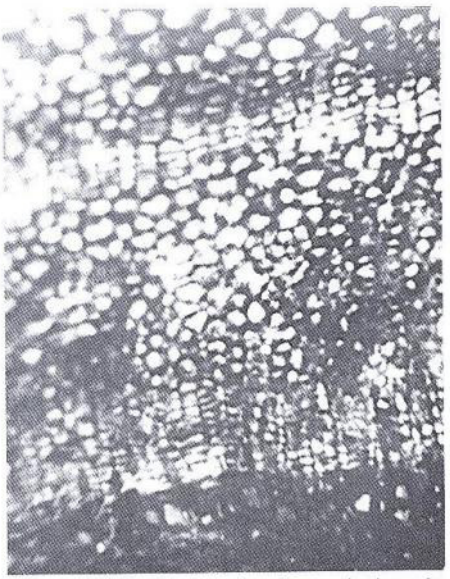

Figure 4 3–5 cell rows of meristematic tissue in the cortex

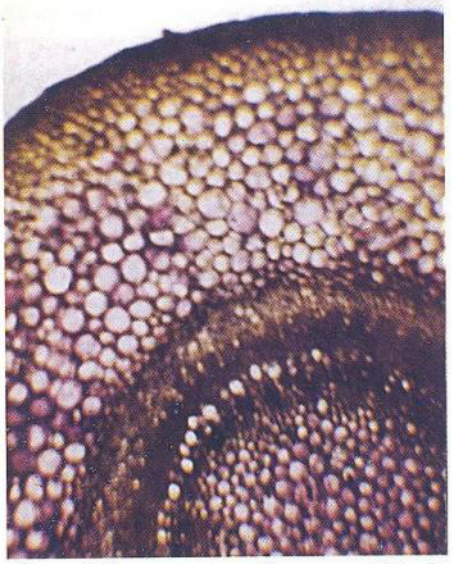

Figure 5 Tissue structure of a young stolon. In the xylem there are trachea rows

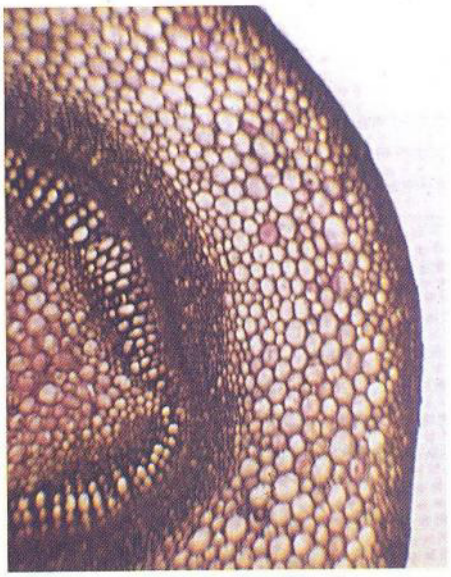

Figure 6 Cross-section of an old stolon

the tracheas increases and trachea rows develop with tracheids and xylem parenchyma cells inside. It is surprising that the walls of the phloem cells become fairly thick. During the thickening of the stolon the cells of the primary cortex become tangentially elongated. The cells of the pith tissue become also a little bigger while the intercellular spaces become larger *(Fig. 6)*.

The tissue structure of the second part of the stolon is similar to that of the first one but the xylem part of the transport tissue is thinner.

The petiole. The petiole has deltoid shape. The petiole is covered with one layer epidermis with few short hairs among the cells. The cell walls of the primary cortex are thickened hypoderm in 3–5 cell rows neighbouring the epidermis. Under this layer there are bigger cells with thin walls. Among the cells there are intercellular spaces.

The transport tissue comprises bundles. In the lower part of the petiole, there are 3 bundles. The middle one is bigger, it has sicker shape. The two smaller ones are round, developing in the direction of the two "wings" of the deltoid. The transport bundles are collaterally compound. The xylem is facing towards the inside of the petiole. The tracheas with fairly big cavities form radial rows and are divided by xylem parenchyma layers of 1–2 cell rows. Inside the xylem firming tissue is found comprising thick walled cells in 2–4 cell rows. The phloem is narrow. Its cells have small cavities. On the outer side of the phloem thick walled firming structure develops, the phloem crown *(Fig. 7)*.

The small vascular bundles are similar in structure but they are smaller, the xylem is bending inwards. The parenchymatic: basic tissue surrounded by the 3 vascular bundles has bigger cells that become smaller when they get to the region of the primary cortex.

Going upwards the tissue structure of the petiole changes at

Figure 7 Cross-section of the petiole with 3 bundles in the lower part of the petiole

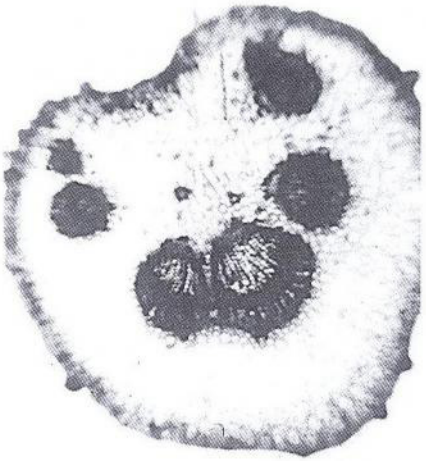

Figure 8 Cross-section of the petiole with 3 bundles in the lower part of the petiole

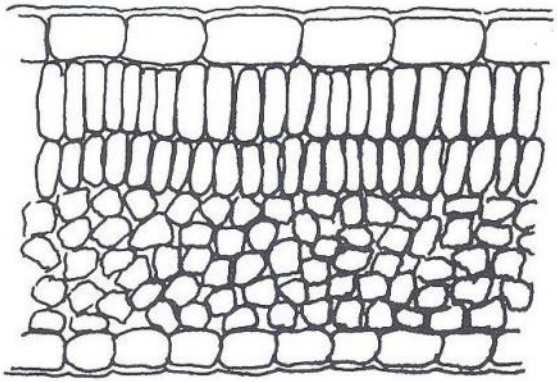

Figure 9 Cross-section of the leaf with palisade parenchyma of 2 layers

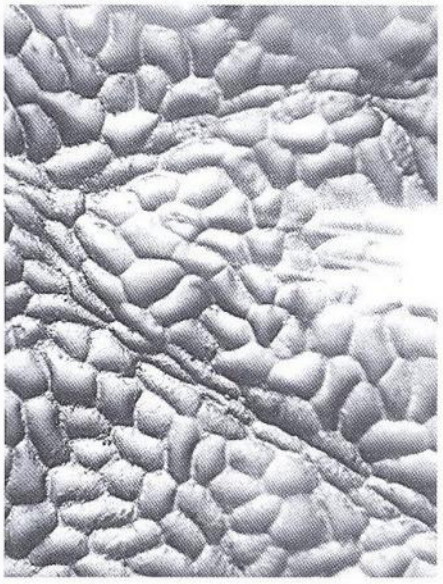

Figure 10 Upper epidermis of the leaf blade

Figure 11 Lower epidermis of the leaf blade

the border of the second and third third of the petiole, the number of bundles increases. The bundle in the middle is divided to 3 parts resulting in 5 bundles altogether. In the upper third of the petiole under the ramification layer of the 3 leaflets the outside bundles divide into two pieces resulting in 7 bundles in the end *(Fig. 8)*.

Leaf blade. The epidermis on both sides of the leaf have fairly big cells that have oval shape. In the lower epidermis the stomata are in the layer of the epidermis. Under the upper epidermis the palisade parenchyma has two cell rows. The cells are small in diameter, the cells of the inner palisade layer are even smaller. The spongy parenchyma consists of short, slightly bent cells surrounding rather big intercellular spaces. The upper epidermis contains cells with 5–6 angles, the cells of the lower epidermis have winding walls with a lot of stomata among them *(Fig. 9, 10, 11)*.

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