International Journal of Horticultural Science 2005, 1, (11): 81–84.
Agroinform Publishing House, Budapest, Printed in Hungary
ISSN 1585-0404

Anatomical relations of the leaves in strawberry

Papp J., Gracza P., Szenthe A., Sárdi É. and Simon G.

Budapest Corvinus University Faculty of Horticultural Science Department of Fruit Science
H-1518. Budapest, Pf. 53., e-mail: janos.papp@uni.corvinus.hu

Summary: In the present study histology of the leaves of strawberry (*Fragaria ananassa* Duch.) variety Elsanta was the objective, which has been performed with the beginning of seedling stage, cotyledons, primary leaves and later true leaves, first cataphyll of the runner shoot as well as the bracteoles of the inflorescence. Structures of the leaf blade, the upper and lower epidermis, the petiole have been also observed. The leaf blade of cotyledons already contains a typical palisade as well as spongy parenchyma tissues, i.e. being bifacial showing a structure similar to that of the true leaf. However, the petiole displays differences from the true leaf. There are a narrow (4–5 layer) primary cortex and a tiny central cylinder. Primary leaves bear already hairs on the adaxial surface and the transporting tissue-bundles are recognised in cross sections having a "V" shape. The first true leaf composed by three leaflets is of a simple structure showing characters reminding of cotyledons and primary leaves. Leaves of intermediate size continue to grow, whereas their inner anatomy changes dramatically. In the central region of the leaflets, near to the main vein, a second palisade parenchyma appears, further on, transporting tissue bundles are branching in the petiole. Collenchyma tissues enhance the stiffness and elasticity of the petiole. Older true leaves develop thick collenchyma tissues around the transporting bundles being represented by increasing numbers. The doubled palisade parenchyma layers of the leaf blades are generally observed. The cataphylls of the runners have a more simple structure, their mesophyll is homogenous, no palisade parenchyma appears. It is evident that leaves grown at successive developmental stages are different not only in their morphological but also anatomical structure. There is a gradual change according to the developmental stage of the leaves.

Key words: straurberry, coty ledon, leaf, anatorry

Introduction

After the first morphological descriptions and pictures of strawberry by *Filarszky,* (1911), *Goebel,* (1928–32), *Troll,* (1937–1938), *Csapody,* (1969), the study of inner structures started. Roots have been explored and presented by drawings by *Muramcev* (1969), whereas *Naumann & Seip* (1989) dealt with the anatomy of root and stem. Though the transformation of the growing point from the vegetative to the reproductive stage was the objective of the paper of *Rauh & Reznik* (1953), most students described the structure of fully grown organs only.

Significant attempts summarised the knowledge related to the outer as well inner structures, physiology and growing practices of strawberry (*Mohácsy* et al., 1965; *Harmat* et al., 1973; *Szilágyi,* 1975; *Childers,* 1983; *Guttridge*, 1983; *Welch,* 1982; *Galletta & Himelrick,* 1990; *Papp & Porpáczy,* 1999; *Holb & Abonyi,* 2005).

The first integrated comparative developmental study of vegetative organs appeared in 2000 by *Papp* et al., (2000) although the existing literature offered an approach from the side of the fully grown organs. Some new meticulous details have been observed during our study, which required closer, histological examination. After the runner, developmental processes of roots, rhizomes and finally of leaves have been traced and analysed.

Material and method

Seedlings have been sampled at different stages of development, i.e. from germination up to their final growth at 5 successive dates: germinating seedling with cotyledons, primary leaves, true leaves, runners, flowering plant. Sections have been prepared instantly with a razor blade, at the same time samples have been preserved in 40% alcohol or prepared for being examined by electron microscope.

Light microscope served for the examination of hand made sections, further details are assigned to be explored by scanning electron microscope. Relevant structures have been fixed by photography or electron micrography.

Results of the examinations

The development of strawberry has been followed up by the histological structure of the leaves at different growing stages, thus cotyledons, primary leaves, true leaves, cataphylls of the runner. In each case, cross sections of the leaf blade, structure of the upper and lower (adaxial and abaxial) epidermis as well as the cross section of the petiole has been characterised.

Cotyledon

On the young seedling, the cotyledons have small, oval blades with entire margin. The adaxial (upper) surface is dark green, the abaxial (lower) is light green. On the latter, some branching veins are recognised below the short and dense hairs.

Cross section of the cotyledon shows the longitudinal, brick-shaped cells of the epidermis with a thickened outside layer of the cuticle. Below the upper (adaxial) epidermis one

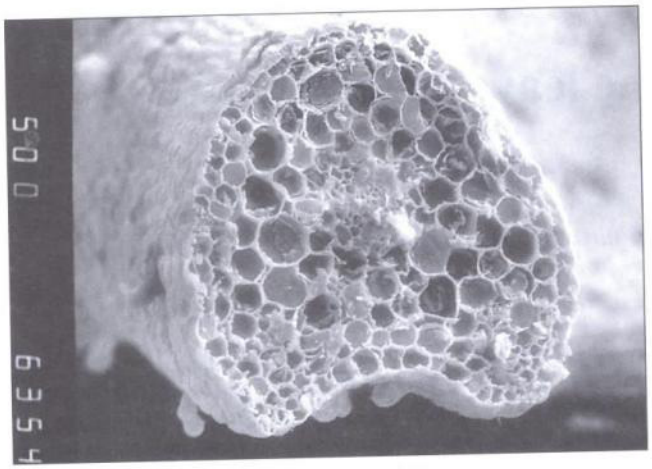

Figure 1. Cross section of the petiole of cotyledon.

layer of palisade parenchyma is recognised with many chloroplasts. Below that, a loose structure of 4–5 layers developed as spongy parenchyma with much intercellular space. There, less density of chloroplasts is observed. Elongated cells of the abaxial (lower) epidermis have a much thinner wall. The small cotyledons change their function as well as their structural characters during the germinating process, they become organs of photosynthesis instead of serving for storage, its anatomy approaches the model of true leaves with bifacial structure of the mesophyll.

The upper epidermis cells are, seeing from above, 5–6-angular covered by a fine-granulated cuticle. The lower epidermis is composed by irregularly angular cells. Their surface is densely haired. Stomata are scattered with elongated kidney-shaped guard cells.

The petiole of the cotyledon is approximately as long as the blade. Its cross section is almost round, lightly flattened. The surface is covered by a one-layer epidermis with oval-shape cells. The primary cortex is 5–6 cell-layer thick, with thin walled, almost globular cells. The central cylinder has a small diameter, with 2–3 layers of small cells surrounding the conductive tissue *(Figure 1)*.

The epidermis cells of the petiole are longitudinal, somewhat undulate. Hairs are hardly seen on the surface, but the cuticle is finely granulated.

Primary leaves

Primary leaves of strawberry are those, which succeed the cotyledons and are simple. Their pedicels are somewhat longer than those of the cotyledons, and their blade are 2–3 times larger, though much smaller than that of the true leaves. The blades are almost entire with a five serrate edge. Sometimes they have three lobes. Their adaxial surface is always darker, the abaxial one is light green. The veins are conspicuous, sunk on the upper, bulging on the lower surface. As a rule, two primary leaves used to be developed.

On the cross section of primary leaves, it is visible that the epidermal cells are long, quadrangular, their cuticle is slightly thickened. The mesophyll is divided between the palisade and spongy parenchyma. Cells of the palisade are moderately long, the spongy parenchyma consists of 3–4 cell layers with much intercellular space. The abaxial epidermis harbours slender, oval cells with thin wall and fine hairs.

The petiole is reddish with a concave channel on the adaxial side, thus the cross section seems to be a winged "V". The one-layer epidermis consists of oval cells with strong, upwards bulging veins. The primary cortex is a 3 cell-layer wide tissue, with smaller, slender cells underneath the epidermis, more round and larger towards the centre. The conductive tissue appears as "V" shaped in the cross section. In the epidermis cells of the petiole are elongated, quadrangular being equal in length without overlapping each other, thus they are hardly increasing the breaking stability of the organ.

True leaves

Strawberry seedlings develop, as a rule, composed leaves after the two primary leaves. Three leaflets are already recognised at a small size (12–15 mm).

The next true leaves are much larger and outgrow the primary leaves. Subsequently, the final size of strawberry leaves is attained, i.e. 150–220 mm length.

Leaflets of the *first small-size leaves* develop one layer of palisade parenchyma on the adaxial side with 3-4 cell-layers of spongy parenchyma. In the abaxial epidermis, sunken stomata appear *(Figure 2)*.

The adaxial epidermis are somewhat elongated regarded from above. Along the veins, club-shaped hairs with three cells appear, where one basic cell bears a shaft and a club-cell on the top *(Figure 3)*.

The abaxial epidermis of the leaflet consists of polygonal cells covered by fine hairs *(Figure 4)*.

The structure of the petiole true leaves is similar to that of the primary leaves.

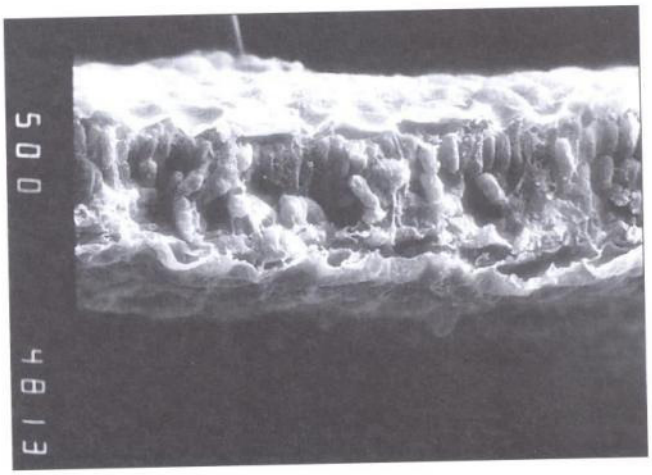

Figure 2. Cross section of the young leaf.

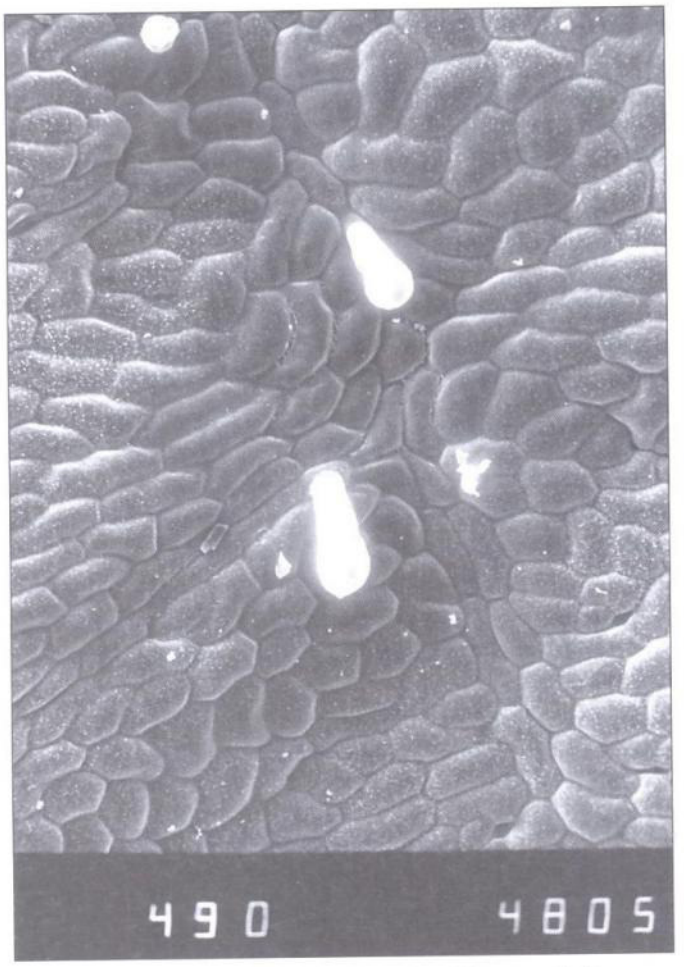

Figure 3. The upper (adaxial) epidermis, a view of the young leaf.

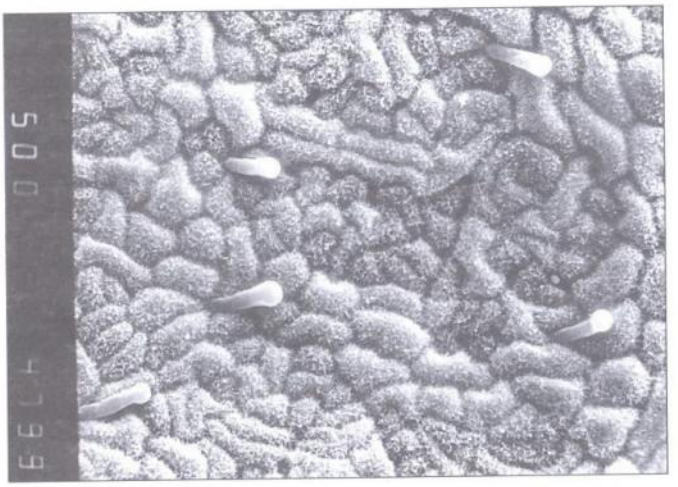

Figure 4. The lower (abaxial) epidermis, a view of the young leaf.

The leaves of intermediate size

The third and fourth true leaves attain the length of 120–130 mm, where significant changes ensue in the histological structure.

The central leaflet of the composed leaf develop already a double-row palisade along the main vein, but towards its edges the palisade is reduced to a simple cell layer. The same reduction is observed in the spongy parenchyma of the leaf. There is some difference in the tissues also between the lower and upper part of the petiole.

In the lower part of the petiole, the shape of epidermis cells are quadrangular with 1–2 cell layers of collenchyma tissue followed by a thick cortex with 14–16 parenchyma cell layers. Three collateral bundles of unequal size represent the conductive tissue: on the abaxial side one larger central bundle is flanked, laterally, by two smaller bundles. The phloem parts are located on the outer side of the collateral bundles, whereas the xylem is oriented towards the central axis of the petiole.

At the upper zone of the petiole the distribution of tissues is different. No collenchyma is developed underneath the epidermis, and the whole primary cortex is a homogenous parenchyma. The conductive tissue consists of a single bundle, crescent shaped in cross section with xylem on the adaxial side and phloem on the abaxial side.

Aged leaf

At the end of the growing season, leaves of 170–220 mm length consisting of three leaflets appear. Sometimes also five leaflets may occur.

Elongated oval shaped cells compose the adaxial epidermis of the leaflets. The palisad parenchyma has two cell layers, whereas the spongy parenchyma 4–5 cell layers. The cells of the abaxial epidermis are elongated with moderately sunken stomata *(Figure 5)*.

The adaxial epidermis cells are elongated and polygonal, and the surface of the leaf is wrinkled with a lath-like structure. The abaxial epidermis cells are elongated, near to the stomata and the hairs, polygonal.

Further changes are observed in the anatomy of the petiole. The lower part of the petiole harbours a collenchyma of 3–5 layers. The cortex is of significant extent, whereas the number of transporting bundles is variable. The lower part of the petiole contains three bundles, five are found about the middle part located in a half circle, whereas seven of them

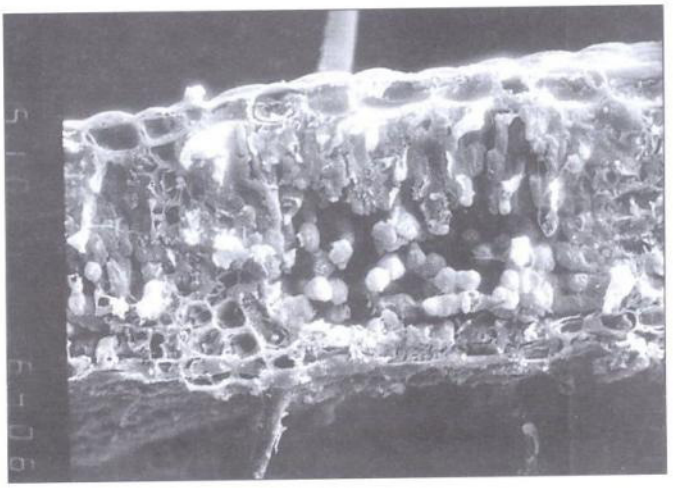

Figure 5. Cross section of an aged leaf blade.

are found in the zone where the leaflets are inserted. In the cross section of the petiole, the central bundle is always larger than the smaller, laterally associated bundles.

Stipules

The leaf basis of the strawberry leaves is outfitted by stipules. Its anatomy is more simple than that of the true leaves. Between the two epidermis of both sides, adaxial, abaxial, and a broad mesophyll with a spongy parenchyma consisting of 8–9 cell layers summarises the whole anatomy

The cataphyll of the runner

At the initiation of the runner, a small leaf rudiment is formed on the growing tip. No petiole could be distinguished and the blade embraces the shoot axis. On the growing tip, in a rosette-like circle, closely initiated leaves appear above the rudimental, scale-like structure of the mentioned "cataphyll".

The cataphylls are also simple in both morphology as well as anatomy. In cross section, as underneath the quadrangular adaxial epidermis cells, the mesophyll is rather homogenous with 7–9 cell layers *(Figure 6)*. The outer layers are composed by smaller cells with smaller intercellular space, whereas going inwards, the size of cells and the intercellular space increases. The abaxial epidermis cells are also smaller with sunken stomata.

Epidermis cells are polygonal (5–6-angular) when seen from above, iso-diametric, bulging outwards a little. The abaxial epidermis-cells are elongated and interspersed by stomata.

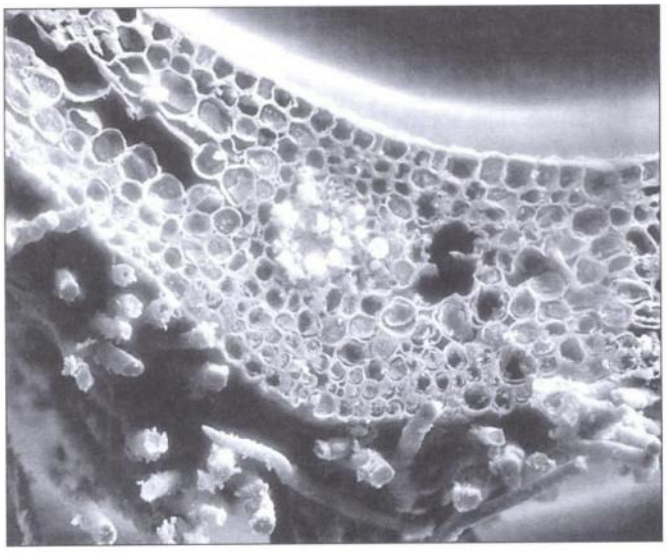

Figure 6. Cross section of a cataphyll on the runner shoot.

Acknowledgement

Research carried out with the support of the Hungarian National Scientific Research Fund (OTKA T034828).

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