The importance of anatomical structure of roots for physiological processes

Monika Sobotik, Dieter Haas

Pflanzensoziologisches Institut, Kempfstraße 12, 9020 Klagenfurt, Austria
Dr. Monika Sobotik, Phone/Fax: +43 463 54461, e-mail: Monika.Sobotik@aon.at

ABSTRACT

Besides the characteristics of the species, the inner structure of the root is influenced by the place and time of origin during the growth period. From the root tip up to the base of a particular root the zones of cell division, cell elongation, formation of root hairs and those zones of the root branching by different aging processes can be distinguished. The root tip which is covered by a root cap and mucilage is protected against evaporation and water contact. From the end of the root cap the cells are exposed. The cells can elongate by water uptake or shrink by water loss. All processes of geotropic growth take place there.

Some differences are illustrated using the example of *Zea mays* plants. Seedling roots, roots emerging from several nodes of the shoot as well as lateral roots of different orders will be compared. The distances from the tip and from the base of the root are also very important. Distinctive features as root diameter, the size of the stele and of the cortex, the relation of cortex and stele, the number and width of the xylem vessels, the size of cells, special thickenings, stage of lignification as well as symptoms of maturation are observed.

KEY WORDS: root structure of *Zea mays*, root cap, seedling root, shoot root, geotropic growth

INTRODUCTION

The knowledge of anatomical structure helps us to understand the development and functions of roots in connection to the whole plant. On the example of *Zea mays* it is shown how the increase of shoot mass influences the emerging roots during the growth period.

MATERIAL AND METHODS

For the investigation of the root the seeds were either germinated in germination dishes at room temperature or they were excavated in the field. The excavation in the field was done by the dry method as described in KUTSCHERA et al. 2009. Fixation and staining see legend of the figures. Embeddings were cut with OMU 3 Leica microtome. The photos were taken using the Zeiss Axio Imager A1.

RESULTS

The root structure is not only influenced by the characteristics of the species but also by the place and time of origin during the growth period as well as by environmental conditions. The more the root elongates from the base, the higher can get the environmental influence.

The longitudinal growth of the root originates from the root tip as a result of cell division and takes place below the root cap and mucilage. The root cap and mucilage effectively protect the root tip against evaporation and water contact (Figs. 1 and 2). At the end of mucilage the cells are able to elongate by water uptake. The cells of the elongation zone will shrink if they lose water and will elongate again if water is available. Because of differences in temperature on the upper and the lower side of the root, geotropic bending takes place there. Detailed explanations have been published by KUTSCHERA 1971, 1972 and KUTSCHERA et al. 2009.

Behind the root cap and mucilage the Casparian strip which controls the water and mineral uptake and protects the root against leaching develops (Fig. 7). This is typical for all species. The elongation zone is usually followed by the root hair zone (Figs. 3 and 4). *Zea mays* was grown on a roll of filter paper (45x45 cm) standing in water (about 10 cm). It developed a root hair zone of about 11 cm (root length 20 cm), on the 3rd day after germination. At the zone where the lateral roots develop up to the base of the root many root hairs have been still alive. In the field large root hair zones can often be observed as well, especially in wormholes.

Structures of different roots of *Zea mays*: From the seedling roots (Ø 0.7–1.1 mm) to shoot roots of the 2nd and 3rd node the diameter increases extensively (Ø 3–8 mm, Figs. 5, 12 and 19). That happens by an increase of cortex cells as well as of stele cells. The diameter of the stele in Fig. 5 has 330 µm and the one in Fig. 17 has about 3000 µm. The stele has increased more than ninefold. The cortex in Fig. 5 has a width of 360 µm and the one in Fig. 17 has about 800 µm. The cortex has increased about two times. The size of the cells of the middle cortex in Fig. 5 is two or three times larger than the one in Fig. 18. The root in Fig. 5 has 7 metaxylem elements whereas the one in Fig. 17 has 50. The max. diameter of the metaxylem in Fig. 5 reaches about 50 µm, the one in Fig. 17 reaches 100–150 (180) µm. Changes of metaxylem diameters were also investigated by WEERATHAWORN et al. (1992). A seedling root from the field (Fig. 6) has a larger diameter than the lab cultured one in Fig. 5. It also has a larger stele, a lower number of metaxylem elements and a smaller cortex. Exodermis and 3 rows of the outer cortex are distinctly lignified. The same root with 30 cm distance off the base has a diameter of 1.5 mm and a distinct smaller stele, disintegrated cells of the cortex and no lignification of the outer cortex. The shoot root in Fig. 11 has 7–8 cell rows of the cortex with distinct lignification. Figs. 13 and 14 are sections from the same root. Fig. 13 and 15 are from base and Figs. 16 is 55 cm from base and in 50 cm soil depth. Fig. 14 shows similar to Figs. 6 and 8 an increase of the root diameter as well as of the cortex and a decrease of stele. The smaller the lateral roots become, the more the stele decrases, even more than the cortex.

DISCUSSION

The structure of roots is influenced by the state of the shoot and by environmental conditions in the soil. For the observation of changes the above mentioned parameters can be used. Roots of the 3rd or 4th node often do not reach the ground. So water uptake can not be their function.

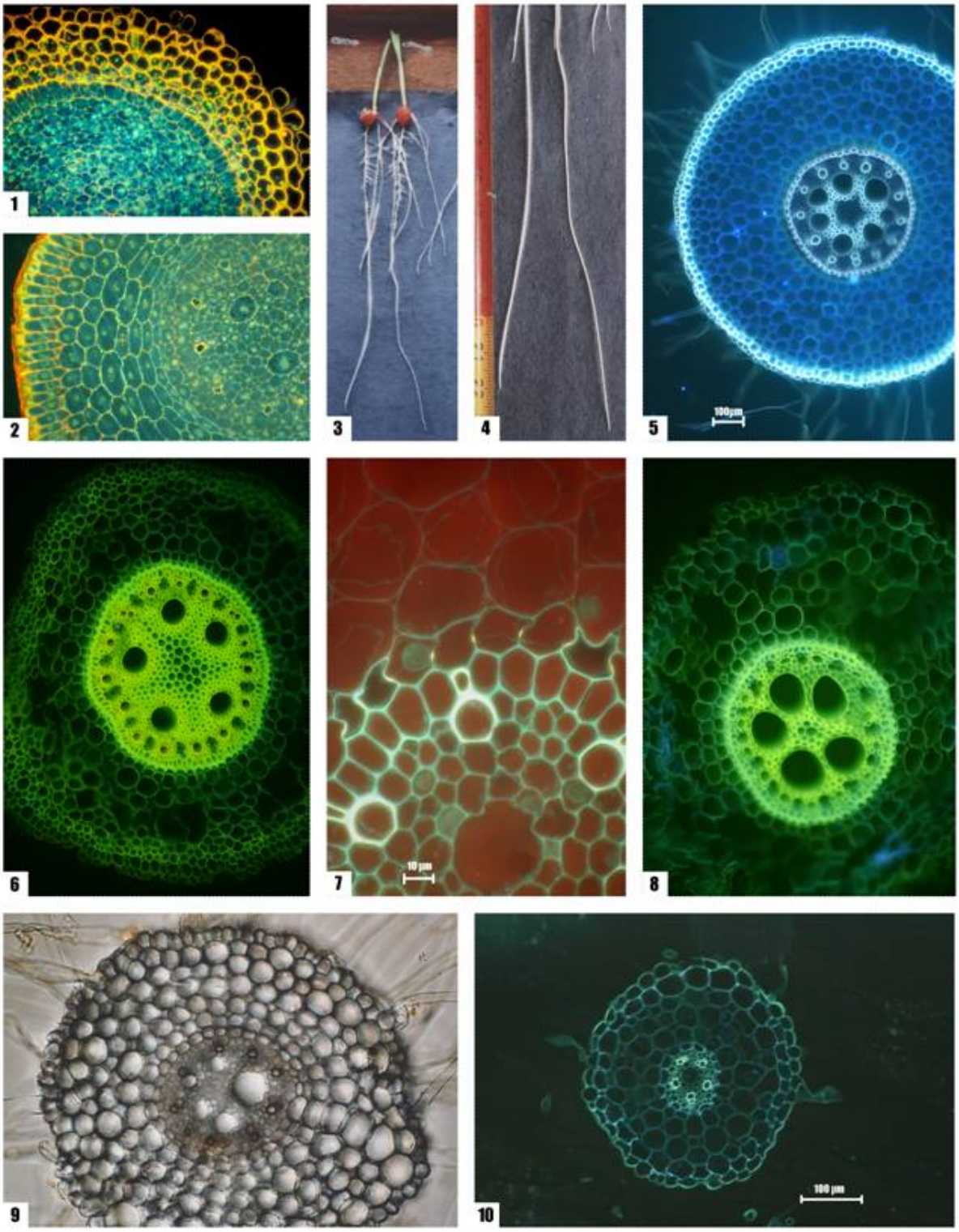
REFERENCES

KUTSCHERA, L., 1971: Über das geotrope Wachstum der Wurzel. Beiträge zur Biologie der Pflanze 47: 371–436. Duncker & Humbolt, Berlin.

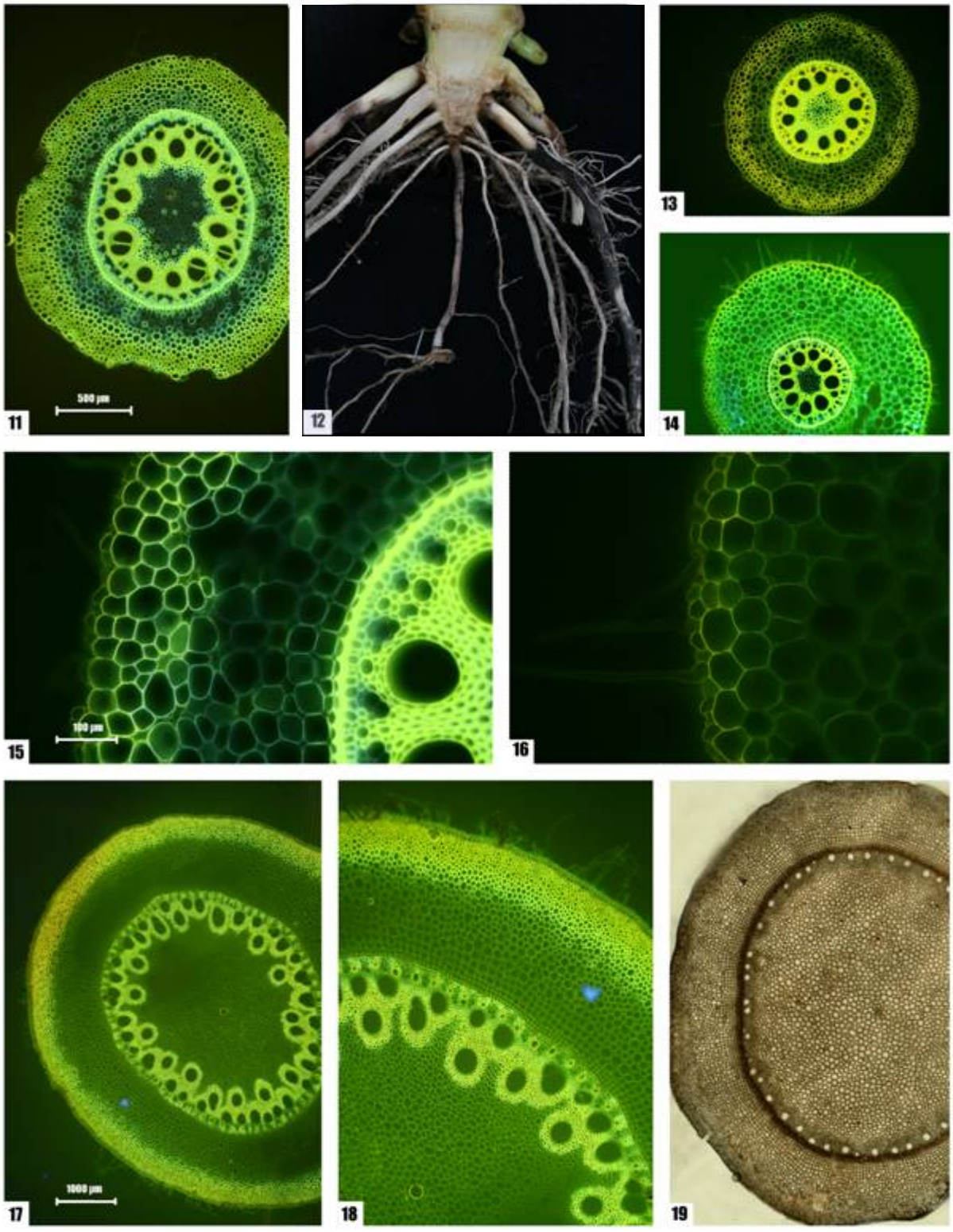
KUTSCHERA, L., 1972: Erklärung des geotropen Wachstums aus Standort und Bau der Pflanzen. Land- u. Forstw. Forschung in Österreich 5: 35–89. Österr. Agrarverlag, Wien.

KUTSCHERA, L., LICHTENEGGER, E., SOBOTIK, M., 2009: Wurzelatlas der Kulturpflanzen gemäßigter Gebiete mit Arten des Feldgemüsebaues. DLG, Frankfurt/Main, 527 pp.

WEERATHAWORN, P., SOLDATI, A., STAMP, P., 1992: Anatomy of seedling roots of tropical maize (*Zea mays* L.) Cultivars at Low Water Supply. Jour. of Experimental Botany 43: 1.015–1.021.



Figs. 1 and 2: ***Hordeum vulgare***. **– 3–6 and 8–10:** ***Zea mays***. **– 7:** ***Aegilops cylindrica***. **– 1, 2 and 5–10:** Cross sections. **– 1, 2, 6 and 8:** Field, 3.6.09. **– 3–5, 7, 9 and 10:** Laboratory. **– 1 and 2:** Tip of seedling root. Fixed with glutaraldehyde and paraformaldehyde and embedded in Spurr. **– 1:** With cells of root cap. **– 2:** Only with mucilage. **– 3 and 4:** Seedlings 3 days after germination, grown in a heating cabinet at 33 °C. **– 5–8:** Seedling roots near base. **– 5, 6, 8 and 9:** Sectioned from fresh material and cut by hand with razor blade (Dieter Haas). **– 7 and 10:** Fixed with Nawaschin and embedded in Technovit. **– 9 and 10:** Lateral root 1st order. **– 1, 2, 6, 8 and 10:** Stained with acridine orange. **– 5:** Unstained. **– 7:** Stained with Nile Red. **– 9:** Stained with Phloroglucinol-hydrochloric acid. – **1, 2, 5–8 and 10:** Fluorescence with UV animation. **– 9:** Bright field. **– 1, 2, 9 and 10:** 138x. **– 5, 6 and 8:** 69x. **– 7:** 690x.



Figs. 11–19: ***Zea mays***, Field. **– 11:** 16.6.07. **– 12:** 17.9.08. **– 13–18:** 3.6.09. **– 19:** 14.7.05. **– 11 and 13–19:** Cross sections from fresh material. **– 11 and 13:** Shoot root 1st node near base. **– 12:** Longitudinal cut of shoot base with seedling roots and shoot roots of 1st to 3rd node. **– 14:** Shoot root of same root as Fig. 13, 55 cm from base and 50 cm soil depth. **– 15:** Detail from Fig. 13. **– 16:** Detail from Fig. 14. **– 17:** Shoot root 2nd node near base. **– 18:** Detail from Fig. 17. **– 19:** Shoot root 3rd node 3 cm from base. **– 11 and 13–18:** Fluorescence with UV animation, stained with acridine orange. **– 19:** Bright field, stained with Phloroglucinol-hydrochloric acid. **– 11 and 18:** 54x. **– 13, 14, 17 and 19:** 27x. **– 15 and 16:** 220x.