Joanna Szymanowska-Pułka
Department of Biophysics and Plant Morphogenesis, University of Silesia, Katowice
e-mail: jsp@us.edu.pl
Jerzy Karczewski
Department of Biophysics and Plant Morphogenesis, University of Silesia, Katowice

Analysis of the Lateral Root Morphology with the Use of the Fast Fourier Transform

During the lateral root (LR) development both the size and the form of the organ change continuously since the moment of its initiation in the pericycle of the mother root until it reaches its mature form. Subsequent stages of the LR formation with typical changes of its form and cell pattern are known [1]. However, our observations [2] prove that in the early stages, when the LR promordia push through tissues of the mother root, they show a great diversity of their surface morphology. Most of the forms are repeatable, few occur as single cases. From mechanical point of view the LR formation may be interpreted as a bucling and the observed changes in shape as local deflections on the root apex surface resulting from a pressure of the surrounding tissues of the mother root. This irregularity in form may suggest changeable mechanical properties of the cells on the surface of the LR apex. The aim of our study is to analyze atypicaly formed LRs in comparison with the apices of typical morhology as well as to estimate mechanical properties of the LR apex basing on deflections in their structures. The LR primordia forming in the Arabidopsis thaliana roots were photographed in Nomarski contrast microscopic technique in their axial sections. The outlines of the chosen LRs showing typical and atypical shapes were digitized. The coordinates were introduced as initial data to a program analyzing the shapes of the apices. The basic assumtion of our model were the following: (i) a surface of a typicaly shaped LR is a circular paraboloid [3]; (ii) trajectories of principal directions of stress form a pattern of paraboloids [3]; (iii) deflections (irregularities) on the organ surface are local and small in comparison to the apex size. The LR formation was analyzed in terms of mechanical buckling. In the model we applied the Fast Fourier Transform method a standard tool adopted to description of buckling [4, 5]. This allowed determining the deflection curves through the trigonometric series. Our results show that the outline of each LR apex of the unchanged geometry (independently on the stage of development) may be described by one parabolic curve, which in the parabolic coordinates refers the line 1.2. Thus the curves representing the outlines of atypicaly formed LRs where in the first step adjusted to that line. For each studied curve the Fourier spectrum (amplitude and phase) was calculated . On this basis we were able to classify atypicaly shaped LR apices. Then applying the Euler formula to the elastic buckling we estimated basic mechanical moduli for the studied cases. On the basis of the results the following connclusions can be drawn: (i) the Fourier Transform may be a useful tool to a shape annalisys of the living structures; (ii) mechanical moduli of a growing plant organ tissues can be estimated on the basis of the organ shape and its deformations; (iii) the mechanical properties of growing plant tissues may be regulated by biological factors like plant growth hormones as well as the cell wall achitecture. The last needs additional studies.

References

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