ON THE KINEMATICS AND DYNAMICS OF PLANT GROWTH

Wendy Kuhn Silk
Department of Land, Air, and Water Resources
University of California
Davis, CA 95616
U.S.A.

1. Introduction

If swelling is defined as water uptake leading to an increase in volume, then growth of plants must be considered an ecologically important swelling process. The irreversible expansion of plant cells is thought to involve an osmotically driven uptake of water and concomitant yielding of the cellulosic cell wall under turgor pressure. For my contribution to this symposium, I emphasize analysis of plant growth in continuum mechanical terms. I will review some experimental and theoretical work on kinematics of growth of maize roots and the underlying biophysics. Topics include description of the growth field, the water potential field which sustains the observed growth pattern, and the distributions (within the growing region) of osmotically active species and some rheological properties. This article is related to others in the symposium. I am relying on the presentation of L. Boersma for a review of the structure and water relations of the plant cell. Mechanical aspects of plant growth are addressed by J. Passioura who describes some intriguing empirical results showing plant elongation rate as a function of applied pressure. And J. Nakielski generalizes the one-dimensional growth analysis to a two-dimensional tensorial treatment using a natural coordinate system to describe apical growth.

2. Growth Kinematics

2.1. Reference frame for the velocity field in the maize root

The tip of the root of a maize plant is a radially symmetrical, tapering structure made of files of cells which are cemented in a contiguous network (Figure 1). Under adequate nutrition and constant environmental conditions (temperature, water availability, and soil impedance), the root elongates at a constant rate for many hours. Growth of the root is produced by the expansion of its component cells and accompanied by cell division. Longitudinal expansion may be analyzed in terms of the displacement of cellular particles away from the origin of a one-dimensional coordinate system (Erickson and Sax, 1956). If the root apex is chosen as origin of a moving reference frame, then a point on the organ will be characterized by
its distance from the apex, $x$. In the moving reference frame the velocity may be time invariant, in which case it is denoted by $v(x)$. The velocity field for a maize root (observed by time lapse photography of marked roots growing in vermiculite in plexiglass boxes at $29^\circ$C) is shown in Figure 2 (from Silk et al, 1986). Rate of displacement from the apex is shown to increase monotonically to a constant value at the base of the growth zone.

1. Composite micrograph of the growing part of a maize root. Cell division occurs in the meristem, which is found in the apical 2.5 mm of the root proper (above the "root cap/root junction"). Cell elongation occurs in the apical 12 mm of the root as described in the text.