Plant Electrophysiology

Methods and Cell Electrophysiology

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1. Auflage 2012. Buch. XII, 359 S. Hardcover
ISBN 978 3 642 29118 0
Format (B x L): 15,5 x 23,5 cm
Gewicht: 725 g

Weitere Fachgebiete > Chemie, Biowissenschaften, Agrarwissenschaften > Botanik > Pflanzenphysiologie, Photosynthese

Preface

Plant electrophysiology is the study of the electrochemical phenomena associated with biological cells and tissues in plants. It involves measurements of electrical potentials and currents on a wide variety of scales from single ion channels to whole plant tissues. Electrical properties of plant cells mostly derive from the electrochemical properties of their membranes. Electrophysiological study of plants includes measurements of the electrical activity of the phloem, xylem, plasmodesmata, stomata, and particularly the electrical signals, propagation along the plasma membrane. Action potentials are characteristic responses of excitation that can be induced by stimuli such as: applied pressure, chemical substances, thermal stimuli, electrical or magnetic stimuli, and mechanical stimuli.

There are two major divisions of electrophysiology: intracellular recording and extracellular recording.

The electrical phenomena in plants have attracted researchers since the eighteenth century and have been discussed in a variety of books (Baluška et al. 2006; Bertholon 1783; Bose 1907, 1913, 1918, 1926, 1928; Lemström 1902; Ksenzhek and Volkov 1998; Volkov 2006; Volta 1816). The identification and characterization of bioelectrochemical mechanisms for electrical signal transduction in plants would mark a significant step forward in understanding this underexplored area of plant physiology. Although plant mechanical and chemical sensing and corresponding responses are well known, membrane electrical potential changes in plant cells and the possible involvement of electrophysiology in transduction mediation of these sense-response patterns represent a new dimension of plant tissue and whole organism integrative communication. Plants continually gather information about their environment. Environmental changes elicit various biological responses. The cells, tissues, and organs of plants possess the ability to become excited under the influence of certain environmental factors. Plants synchronize their normal biological functions with their responses to the environment. The synchronization of internal functions, based on external events, is linked with the phenomenon of excitability in plant cells. The conduction of bioelectrochemical excitation is a fundamental property of living organisms.

Electrical impulses may arise as a result of stimulation. Once initiated, these impulses can propagate to adjacent excitable cells. The change in transmembrane potential can create a wave of depolarization which can affect the adjoining resting membrane. Action potentials in higher plants are the information carriers in intracellular and intercellular communication during environmental changes.

The conduction of bioelectrochemical excitation is a rapid method of long distance signal transmission between plant tissues and organs. Plants promptly respond to changes in luminous intensity, osmotic pressure, temperature, cutting, mechanical stimulation, water availability, wounding, and chemical compounds such as herbicides, plant growth stimulants, salts, and water potential. Once initiated, electrical impulses can propagate to adjacent excitable cells. The bioelectrochemical system in plants not only regulates stress responses, but photosynthetic processes as well. The generation of electrical gradients is a fundamental aspect of signal transduction.

The first volume entitled "Plant Electrophysiology—Methods and Cell Electrophysiology" consists of a historical introduction to plant electrophysiology and two parts. The first part introduces the different methods in plant electrophysiology. The chapters present methods of measuring the membrane potentials, ion fluxes, trans-membrane ion gradients, ion-selective microelectrode measurements, patch-clamp technique, multi-electrode array, electrochemical impedance spectroscopy, data acquisition, and electrostimulation methods. The second part deals with plant cell electrophysiology. It includes chapters on pH banding in Characean cells, effects of membrane excitation and cytoplasmic streaming on photosynthesis in Chara, functional characterization of plant ion channels, and mechanism of passive permeation of ions and molecules through plant membranes.

The second volume entitled "Plant Electrophysiology—Signaling and Responses" presents experimental results and theoretical interpretation of whole plant electrophysiology. The first three chapters describe electrophysiology of the Venus flytrap, including mechanisms of the trap closing and opening, morphing structures, and the effects of electrical signal transduction on photosynthesis and respiration. The Venus flytrap is a marvelous plant that has intrigued scientists since the times of Charles Darwin. This carnivorous plant is capable of very fast movements to catch insects. The mechanism of this movement has been debated for a long time. The Chap. 4 describes the electrophysiology of the Telegraph plant. The role of ion channels in plant nyctinastic movement is discussed in Chap. 5. Electrophysiology of plant-insect interactions can be found in Chap. 6. Plants can sense mechanical, electrical and electromagnetic stimuli, gravity, temperature, direction of light, insect attack, chemicals and pollutants, pathogens, water balance, etc. Chapter 7 shows how plants sense different environmental stresses and stimuli and how phytoactuators respond to them. This field has both theoretical and practical significance because these phytosensors and phytoactuators employ new principles of stimuli reception and signal transduction and play a very important role in the life of plants. Chapters 8 and 9 analyze generation and transmission of electrical signals in plants. Chapter 10 explores bioelectrochemical aspects of the plant-lunisolar gravitational relationship. The authors of Chap. 11

describe the higher plant as a hydraulic-electrochemical signal transducer. Chapter 12 discusses properties of auxin-secreting plant synapses. The coordination of cellular physiology, organ development, life cycle phases and symbiotic interaction, as well as the triggering of a response to changes in the environment in plants depends on the exchange of molecules that function as messengers. Chapter 13 presents an overview of the coupling between ligands binding to a receptor protein and subsequent ion flux changes. Chapter 14 summarizes data on physiological techniques and basic concepts for investigation of Ca^{2+}-permeable cation channels in plant root cells.

All chapters are comprehensively referenced throughout.

Green plants are a unique canvas for studying signal transduction. Plant electrophysiology is the foundation of discovering and improving biosensors for monitoring the environment; detecting effects of pollutants, pesticides, and defoliants; monitoring climate changes; plant–insect interactions; agriculture; and directing and fast controlling of conditions influencing the harvest.

We thank the authors for the time they spent on this project and for teaching us about their work. I would like to thank our Acquisition Editor, Dr. Cristina Eckey, and our Production Editor, Dr. Ursula Gramm, for their friendly and courteous assistance.

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