19 Electrochemistry of Plant Life

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19.1 Green plants: electrochemical interfaces

All processes of living organisms examined with suitable and sufficiently sensitive measuring techniques generate electric fields (Volkov 2000). The conduction of electrochemical excitation must be regarded as one of the most universal properties of living organisms (Bertholon 1783; Bois-Reymond 1848; Burdon-Sanderson 1873, 1888; Burdon-Sanderson and Page 1876; Bose 1914, 1925, 1926, 1927). It arose in connection with a need for the transmission of a signal about an external influence from one part of a biological system to another. The study of the nature of regulatory relations of the plant organism with the environment is a basic bioelectrochemical problem. It has a direct bearing on the tasks of controlling the growth and development of plants (Mizuguchi et al. 1994).

According to Goldsworthy (1983), bioelectrochemical signals resemble nerve impulses, and they exist in plants at all levels of evolution. The inducement of non-excitability after excitation and the summation of subthreshold irritations were developed in the vegetative and animal kingdoms in protoplasmatic structures prior to morphological differentiation of nervous tissues. These protoplasmatic structures merged into the organs of a nervous system and adjusted the interfacing of the organism with the environment.

Action potentials in plants have been studied in detail in the giant cells of *Chara* and *Nitella*. These plants possess many of the properties associated with action potentials of animal cells such as the all-or-nothing law, threshold potential, and a refractory period (Abe et al. 1980). Action potentials have been researched with detail in many species of higher plants, and these same electrophysiological properties have been found (Ksenzhek and Volkov 1998; Volkov et al. 2002c).

Action potentials are signals caused by the depolarization of the cellular membrane (Volkov and Jovanov 2002; Lautner et al. 2005). The plasma membrane allows for cells, tissues, and organs to transmit electrochemical signals over short and long distances. According to Gunar and Sinyukhin (1963), excitation waves or action potentials in higher plants are possible mechanisms for

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intercellular and intracellular communication in the presence of environment changes.

Plants respond to irritants at the site of the applied stimulus, but excitation can be dispersed throughout the entire plant (Sinyukhon and Britikov 1967; Pickard 1973; Volkov 2000). Waves of excitation travel from the top of the stem to the root and from the root to the top of the stem, but not at identical rates (Zavadzki 1980; Zavadzki et al. 1991). The speed of propagation is dependent on factors such as the chemical treatment, intensity of the irritation, mechanical wounding, previous excitations, or temperature (Volkov and Mwesigwa 2001a).

Conductive bundles of vegetative organisms support the movement of material, and they trigger the transfer of bioelectrical impulses (Sinyukhin and Gorchakov 1966, 1968, 1996). This feature motivates the harmonization of processes pertaining to the fundamental activity of vegetative organisms. Electrical impulses arise under the impact of various chemical compounds such as herbicides, plant growth stimulants, salts, and water (Volkov et al. 2001a, 2002a,b). Physical factors such as electromagnetic or gravitational fields, mechanical wounding, and temperature effects also elicit electrical impulses (Sibaoka 1962; Abe 1981; Eschrich et al. 1988; Eschrich and Fromm 1989, 1994; Fromm and Eschrich 1989; Pyatygin and Opritov 1990; Fromm 1991; Fromm and Spanswick 1993; Fromm and Bauer 1994).

Bioelectrochemical signaling is the most rapid technique of long distance signal transmission between plant tissues and organs. Plants respond quickly to changes in luminous intensity, osmotic pressure, and temperature. They also rapidly respond to cutting, mechanical stimulation, water availability, and wounding (Davies and Schuster 1981; Davies 1983; Davies et al. 1991). These responses can be discovered in distant parts of the plant directly after the stimulus occurs. Action potentials activate the membrane enzymatic systems. These systems realize biochemical reactions, accelerate the production of ethylene, increase the concentration of the proteinase inhibitor, and modify the rate of production of polysomes and proteins (Stankovich and Davies 1996).

The physiological aspect of rapid, electrochemical long-distance communication between plant tissues and organs is poorly understood (Siomons 1981). Traditionally, the translocation of phytohormones and other endogenous compounds is recognized as the principal means of signaling between stimulated and specific remote tissues in the plant where physiological responses are observed. Slow response kinetics limit the communication system utilizing the transport of chemical compounds. Many physiological responses in higher plants occur within seconds of the application of a stimulus: gravitropic responses, thigmotropic responses in *Mimosa pudica* L. and *Dionaea muscipula* Ellis, growth responses to salinity, and stomatal closure following treatment of *Salix* roots with abcisic acid.

The speed of propagation of action potentials depends upon the varying types of induced stress (Volkov et al. 2000). The speed of propagation of bioelectrical signals ranges from 0.05 cm/s to 40 m/s and it adequately sustains