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Short communication

Time-Resolved Teraohmmeter-Assisted Measurements of Plant Leaf Resistance: Kinetic Registration of Plant Leaf Resistance, Plant Leaf Resistance Oscillations and Accelerated Photoinduced Kinetics under UV-C Irradiation

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Abstract

In this paper, we propose a new rapid method for testing the physiological state of an etiolated plant and its short-wavelength (UV-C) photophysiological response. For this task we propose to use portable teraohmmeters with Faraday cages (chambers), capable of operating even in field conditions with a battery. With their help, by modifying the design of Faraday cages, it is possible to record the dynamics of growth and decay of plant impedance under various influences - from conventional dark etiolation to exposure to heat and cold in thermostated Faraday cages. In this way, the homeostasis and kinetics of plant adaptation to corresponding stimuli or environmental conditions can also be characterized. As a result of testing this installation, we recorded:

a) Fluctuations in the impedance of a fresh leaf - from self-oscillations to the onset of irreversible death processes

b) High impedance stability of a freshly picked leaf

c) Increase in sheet resistance to etiolation

d) Weak fluctuations - transient cycles of reactive decompensation with an amplitude an order of magnitude less than resistance fluctuations on the active sheet immediately after installing it on the stand drastic acceleration of impedance kinetics upon UV-C irradiation of a plant leaf in EPROM laser (254 nm; Hg line).

Introduction

Despite the fact that the first measurements of the electrical resistance of plants date back more than a century ago, the applications of impedance methods for analyzing and monitoring the state of plants in biotechnology and applied botany came into force no earlier than the last quarter of the twentieth century, which was associated with the development of simple (user-friendly and compact) measurement instruments. Already by the beginning of the 1990s some paper cycles appear devoted not only to fundamental model [1-3], but also to technical and methodological aspects of impedance measurements on plant tissues and cells, on roots and leaves [4-7]. It has been proven that impedance measurements or dielcometry / dielectric spectroscopy can be an effective means of analyzing thermal and cold damage to plant tissues [8-10]. However, instrumental aspects remain, as a rule, inaccessible to real agronomists and biotechnologists - since they require the use of precision analyzers [5], ratiometric and shigometric, including radio-frequency shigometric devices [7], often working well only with cell suspensions (performing the function of an impedance protoplast counter) with scanning across the frequency range [6]. Therefore, EIS - electr(ochemic)ical impedance spectroscopy [11-14], which is not always correctly applied and interpreted by many agricultural technicians, still has prevailing importance in characterizing the state of plant tissues and modules. Indeed, it is not entirely clear how to interpret the response of specific plants in relation to specific models (such as the Cole–Davidson function-based impedance model [15], how a biologist without a background in physics can interpret the phase angle shift under plant stress [16], etc. Therefore, it is necessary to introduce, in practice, simpler methods of kinetic/dynamic impedance analysis with reference to the topography of specific plants (which would replace the practical need for electrical impedance and radiofrequency tomography for multiphysical digital phenotyping tasks [17]).

Experimental Method

We propose to use for this purpose elementary teraohmmeters of the E6-13A type with Faraday cages (chambers), capable of operating even in field conditions with a battery [18-20]. With their help, it is possible to record the dynamics of growth and attenuation of plant impedance under various influences (from etiolation to heat and cold in thermostated Faraday cages), which also characterize the homeostasis and kinetics of plant adaptation to the stimulus. Laborant work before the start of experiment with plant leafs in the Faraday cage illustrated at the video page: https://www.youtube.com/watch?v=NHyYL5VbQJA

Results and Video Links

Particularly, we observed:

a) fluctuations in the impedance of a fresh leaf before the onset of irreversible processes (https://youtu.be/6Q4oGgnNgF0)

b) high impedance stability of a freshly picked leaf (small compensatory change: https://youtu.be/qqvEiCclayw)

c) increase in leaf resistance to etiolation (https://youtu.be/BAVwPfWVD80)

d) weak fluctuations - a transient cycle of reactive decompensation with an amplitude an order of magnitude less than resistance fluctuations on the active sheet immediately after installing it on the stand (https://youtu.be/MW_YncDBa5w)

e) acceleration of impedance kinetics upon UV irradiation of a plant leaf in the EPROM eraser (253.7 nm / ≈254 nm; Hg line [21-24]).

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