EDITORIAL

Inaugural Editorial for the *Journal of Plant Electrobiology*

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Abstract

This editorial defines the core mission, academic orientation, and six interrelated thematic pillars of *Journal of Plant Electrobiology* (*JPE*), which is a peer-reviewed international journal dedicated to advancing the interdisciplinary fusion of electronics, bioenergetics, biophysics, and plant science. JPE aims to showcase innovative researches that leverage electronic principles and technologies to address fundamental and applied questions in plant biology, foster cross-disciplinary collaboration, and accelerate the translation of plant electrobiology breakthroughs into solutions for sustainable agriculture, plant stress resilience, and environmental stewardship. Against the backdrop of rapid advancements in precision sensing, computational modeling, and nanotechnology, plant electrobiology has evolved from scattered observations to a systematic discipline. The superposition of the aforementioned technologies and models transforms the "invisible" plant electrical signals into "computable and applicable" phenotypic data. This upgrades electrical signals from mere "oscilloscope curves" to "high-throughput digital phenotypes", enhancing both the precision and continuity of plant trait detection. Consequently, this advancement propels plant electrobiology into an era of systems science and in-situ precise detection. These methodological and technical advances lay the foundation for *JPE*'s thematic framework and drive the field's practical impact.

Keywords: plant electrobiology, electronic sensing, modeling and simulation, electrobiological regulation, stress detection, sustainable agriculture, methodological innovation.

1 Introduction

Plant electrobiology, an interdisciplinary field at the intersection of electronics, bioenergetics, biophysics, and plant science, focuses on deciphering the generation, transmission, and regulatory roles of electrical signals in plants, as well as developing technologies to optimize plant growth, enhance stress adaptation, and advance agricultural sustainability. Plant electrobiology primarily investigates the electronic behaviors underlying the laws of plant life activities. It is grounded in the timely and accurate acquisition of plant electrical signals, as well as the scientific and quantitative analysis of electrical signal data, while continuously promoting the expansion of its application scope, plant electrobiology's growth is fueled by continuous innovation in sensing, modeling,

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and modulation technologies.

Early research in plant electrobiology was constrained by technological limitations, remaining at the level of basic observations. The application of patch-clamp techniques, high-precision microelectrode arrays, the Gibbs free energy equation, and the Nernst equation, as well as dynamic characterization technologies for electrical information, coupled with the discovery of memristors, has driven the rapid development of plant electrobiology. This advancement has enabled the field to evolve from the initial detection of real-time electrophysiological information, such as plant physiological capacitance, resistance, and impedance, to the timely acquisition of intrinsic electrophysiological information related to dynamic parameters of plant water, nutrient, and energy metabolism, which is based on the upgrading of models and algorithms [1]. These advances have unlocked insights into plant-water metabolism, stress responses, and growth regulation, which is critical for addressing global challenges such as food insecurity and climate change resilience.

Journal of Plant Electrobiology (*JPE*) is established to serve as a dedicated platform for researchers worldwide to publish groundbreaking findings and exchange ideas. Its core mission is to propel the field forward by highlighting high-quality research across six interconnected thematic areas, spanning from basic science to real-world applications. Below, we detail these thematic pillars (Section 2) and clarify *JPE*'s publication scope and expectations for the research community (Section 3).

2 Plant Electrobiology: Bridging Electrical Signals and Life's Fundamentals

For decades, plant biology has focused on molecular mechanisms and biochemical pathways, from photosynthetic carbon fixation to hormone-mediated growth regulation. Yet a parallel dimension of plant life, governed by electrical signals and cellular circuitry, has long remained underexplored. *JPE* launches to illuminate this critical frontier, where the electrical properties of cells and tissues emerge as integral drivers of growth, adaptation, and stress response. Rooted in the intersection of plant physiology, biophysics, and electrochemistry, the journal seeks to unify chemical and electronic perspectives on plant life, revealing how electrical signals work in tandem with molecules to shape every aspect of plant function.

2.1 Cellular Circuit: Macromolecules and Cellular Structure as Intrinsic Electrical Building Blocks

At the core of plant electrobiology lies a key insight: biological macromolecules (carbohydrates, proteins, nucleic acids) and cellular structures are intrinsic electrical components, enabling them to function as natural resistors, inductors, and capacitors. Importantly, these electrical characteristics exhibit dynamic associations with the molecular conformation and biological function of the respective components.

All biological macromolecules exhibit resistive properties. These cytosolic components modulate ion and electron flow through the cellular matrix, with their resistance directly tied to structural state and interactions with surrounding molecules. Organelles also act as resistors, while cell membranes, which are composed of phospholipid bilayers and embedded proteins, serve as natural capacitors: their dual-layer structure stores charge, with membrane potential maintained by selective ion transport, forming the basis for electrical signal generation.

Specific structural features endow macromolecules and cellular structures with inductive function. Polysaccharides' chain-like structures, proteins' helical conformations (α-helices, β-sheets), nucleic acids' helical structures (e.g., DNA double helix), and intracellular stacking structures all act as biological inductors. Within cells, ATP synthases and ATP-hydrolyzing enzymes further function as inductors: proton gradients from metabolism drive electrical currents that transiently store energy, mirroring electronic inductive circuits.

Proteins and nucleic acids can also act as capacitors due to their tertiary structures. The folding of proteins generates dielectric environments capable of storing charge. Similarly, the compact tertiary structures of nucleic acids, like folded DNA or RNA, fulfill the same function. Crucially, modifications or conformational changes can modify these properties. For instance, DNA methylation alters the dielectric characteristics of the tertiary structure, thereby influencing capacitance (and potentially affecting inductance and resistance as well). DNA unwinding, a process vital for replication and transcription, modifies its helical structural inductor, leading to a reconfiguration of its capacitive properties and a change in resistance by exposing new surfaces to ion flow. In a similar vein, conformational changes in proteins, such as those occurring during enzyme activation or signal transduction, rearrange secondary and tertiary structures, thereby reconfiguring their resistive, capacitive, and inductive characteristics. In biochemical processes, the free radical and redox reactions of biomacromolecules are closely associated with electron behavior.

Thus, a single plant cell can be viewed as a sophisticated and dynamic circuit. It comprises a network of resistors, capacitors, and inductors derived from structures and macromolecules, with their interactions encoding the physiological state. All metabolic and biochemical processes are manifestations of changes in the electrical component networks of macromolecules and cells. The energy storage and conversion processes of these electrical components manifest as the metabolic processes of cells. The proliferation and differentiation of cells indicate adaptive changes and outcomes of differentiation resulting from the interaction between the cellular electrical component's rapid regulatory network and the chemical regulatory network. Plant growth, development, adaptability, and evolution are jointly propelled by chemical and electronic energy, with life activities being shaped by both chemical and electronic behavior.

This circuitry adapts in real time to environmental cues. Under drought, membrane capacitance (a composite of lipid bilayers and embedded protein capacitors) shifts as cells adjust intracellular water holding capacity and water use rate. Studies of Broussonetia papyrifera and Morus alba confirm this link: leaf capacitance decreases under water deficit, directly correlating with reduced intracellular water use rate [2]. These findings validate that electrical parameters are not mere metabolic byproducts but precise readouts of cellular health, rooted in structure and macromolecular behavior.

2.2 Electrical Signals: The Fast Track of Plant Communication

hemical and electrical signals jointly regulate organismal growth and development. The dynamic electrical properties of cellular structures and macromolecules underpin electrical signal generation and propagation, enabling plants to respond rapidly to the environment. Unlike slow-diffusing chemical signals, electrical signals travel at speeds supporting real-time adaptation, with their genesis tied to macromolecular conformational changes and consequent shifts in cellular electrical balance. Three key signal types dominate plant communication, all rooted in structure/macromolecule-driven electrical dynamics:

- **Action Potentials (APs)**: Triggered by non-destructive stimuli (cold, touch), APs propagate without amplitude decay. Their generation relies on voltage-gated ion channels—proteins whose conformational changes (and resultant resistive/inductive/capacitive shifts) control membrane ion flux. This flow drives rapid membrane potential changes (depolarization, repolarization) that characterize APs, explaining rapid movements in Dionaea muscipula (Venus flytrap) and Mimosa pudica, where ion channel gating drives near-instantaneous turgor changes [3, 4].

- **Variation Potentials (VPs)**: Induced by wounding or pathogens, VPs spread with amplitude reduction but trigger systemic defenses. Membrane damage disrupts macromolecular electrical components, altering capacitance,inductive and resistor, leading to membrane permeability, ion leakage and propagating potential changes. In tomatoes, VPs activate proteinase inhibitor gene expression, a response rooted in early electrical signaling [5].

- **Local Potentials**: Sub-threshold responses to stimuli (light, nutrient fluctuations) modulate membrane excitability and precede APs. They arise from subtle macromolecular resistive/inductive/capacitive shifts (e.g., enzyme conformation changes, nucleic acid folding) that alter ion flow without reaching AP threshold.

These signals form an integrated network translating environmental cues into physiology, with macromolecular electrical dynamics as the underlying currency. For example, heat stress in poplar induces VPs that reduce photosystem II efficiency within minutes—protecting chloroplasts—by triggering photosynthetic protein conformational changes that alter electrical properties and downstream signaling [6].

JPE prioritizes research into these transduction mechanisms, including ion channel gating (driven by protein conformation), membrane capacitance (inductive/resistive) dynamics (tied to cellular and macromolecular structure), and the role of plant memristors—recently discovered components that store electrical memory of past stimuli, potentially via persistent macromolecular conformational states.

2.3 From Lab to Field: The Applied Promise of Plant Electrobiology

Plant electrobiology is not just fundamental science, it also holds transformative potential for agriculture and ecology, with practical value stemming from the tight link between cellular/macromolecular electrical properties and plant performance. Traditional plant health assessments (biomass measurement, chlorophyll assays) are destructive or slow, but electrical parameters, which are rooted in cellular/macromolecular function, enable rapid, non-invasive monitoring.

These tools are advancing crop breeding and management. By measuring electrical signals and metabolic energy, researchers screen for stress-resistant varieties in several hours, which is faster than traditional trials.

For ecological restoration, electrical profiling matches plants to harsh environments. In mangroves, salt tolerance correlates with the dynamics of water and salt transport based on electrical signals, guiding species selection for coastal reforestation.

2.4 The Journal's Vision: Uniting Disciplines for a New Biology

JPE fills a critical gap in scientific literature, serving as a hub for research bridging biophysics, molecular biology, and plant science, centered on the electrical properties of biological macromolecules and cellular structures. We welcome contributions across four pillars:

- **Fundamental Mechanisms**: Studies of structure/macromolecule-derived electrical components (membranes, enzymes, nucleic acids, memristors) and signal generation, including how modifications/conformations alter electrical function.
- **Environmental Responses**: Research on how stressors (drought, salinity, pathogens, climate change) modulate electrical properties and drive signaling cascades.
- **Technological Innovation**: Development of sensors for real-time electrical monitoring, focused on tools capturing structure/macromolecule-linked signatures.
- **Translational Science**: Applications in breeding, precision agriculture, and ecological restoration.

The future of plant biology lies in integrating molecular and electronic perspectives—understanding how structure drives electrical function, and how electrical signals shape plant life. Just as DNA sequencing revolutionized genetics by decoding molecular information, electrical profiling will transform plant science by decoding the electrical language of macromolecules and structures. *JPE* invites authors and readers to join this journey, unlocking the electrical code of plant life to address global challenges of food security and environmental sustainability.

3 *JPE*'s Core Thematic Areas

JPE's six thematic areas address distinct yet complementary aspects of plant electrobiology, integrating technology development, mechanistic exploration, and translational application to form a holistic research framework.

3.1 Electronic Sensing of Plant Bioenergetic and Biophysical Traits

This area focuses on developing and applying advanced sensing technologies to detect plant bioenergetic and biophysical traits. Innovations include non-invasive microelectrode arrays (MEAs) for simultaneous recording of multi-tissue electrical signals, fiber-optic sensors for field-based leaf water potential monitoring, and nanoscale electrochemical sensors for intracellular $Ca2+$ and $K+$ detection. These tools enable high-precision, real-time capture of plant physiological dynamics, providing foundational data for understanding plant health and stress responses.

3.2 Modeling and Simulation of Plant Electrobiological Processes

This area emphasizes quantitative modeling to decode the mechanisms of plant electrical signal generation, propagation, and regulation. The in-depth integration of big data and knowledge graphs not only provides abundant data resources for the construction and optimization of knowledge graphs but also offers an effective knowledge framework for the analysis and application of big data. Combined with the application of automated data processing technologies, this integration can significantly enhance the efficiency of data mining and machine learning, and ultimately improve the speed, accuracy, and intelligent analysis capabilities in electrobiological data processing. These models bridge experimental observations and mechanistic understanding, guiding targeted experimental design. For instance, simulating how salt stress alters ion channel gating to predict variation potential propagation.

3.3 Regulation of Plant Growth via Electrobiological Modulation

This area explores how electrical signals (e.g., membrane potential fluctuations, proton motive force) regulate plant growth and development, and develops corresponding modulation technologies. Research focuses on identifying electrical "targets" for growth optimization, i.e., proton pump activity in root hairs, and designing stimuli strategies (e.g., high-voltage pulses) to enhance nutrient uptake or photosynthetic efficiency. Integrated data frameworks (combining electrobiological, transcriptomic, and metabolic data) validate regulatory mechanisms, while field trials test the efficacy of modulation technologies in crops like wheat and tomato.

3.4 Electrobiological Technologies for Plant Stress Detection & Mitigation

This area focuses on developing tools to detect plant stress (drought, salinity, pests) at early stages and mitigate its impacts. Early detection relies on technologies such as impedance spectroscopy for rapid membrane integrity assessment and machine learning-based classification of electrical signal patterns to distinguish stress types. Mitigation strategies include electrical priming to enhance antioxidant capacity and targeted irrigation triggered by leaf capacitance feedback. These technologies align with plant stress physiology research, for example, using variation potential signatures to predict pest outbreaks, and support the development of resilient agricultural systems.

3.5 Sustainable Agriculture via Electrobiological Innovation

This area translates plant electrobiology research into practical solutions for sustainable agriculture. Key directions include field-deployable sensing systems for real-time crop water/nutrient monitoring, electrical signal-based precision irrigation to reduce water waste, and electrobiologically optimized nutrient management to improve fertilizer use efficiency. Case studies include using leaf electrobiological traits to schedule irrigation in crops and to screen drought-tolerant crop varieties. These applications balance productivity and environmental stewardship, advancing global sustainable agriculture goals.

3.6 Methodological Advances in Plant Electrobiology

This area focuses on innovating tools and protocols to support the entire plant electrobiology research pipeline. Progress includes developing ultra-sensitive nanosensors for single-cell electrical recording, refining computational models to account for plant tissue heterogeneity, and establishing standardized protocols for electrical signal data collection. Methodological breakthroughs provide critical support for the other five themes and drive the field's overall maturity.

4 Call to Action

Journal of Plant Electrobiology (*JPE*) is committed to advancing the field by publishing high-quality research across its six core thematic areas. We welcome submissions of original research articles, comprehensive reviews, methodological papers, and technical notes that align with our scope, including:

- Innovative sensing, modeling, or modulation technologies for plant electrobiology;
- Translational studies linking electrical signals to crop stress resilience or sustainable agriculture;
- Methodological breakthroughs that enhance the precision or accessibility of electrobiological research;
- Perspective articles discussing emerging trends (e.g., memristors in plants) and unmet challenges.

With the support of the global research community, *JPE* aims to become the leading platform for academic exchange in plant electrobiology, accelerating the translation of laboratory discoveries into solutions for food security, environmental sustainability, and climate resilience.

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Conflicts of Interest

The authors declare no conflicts of interest.

Ethical Approval and Consent to Participate

Not applicable.

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Yanyou Wu holds a Ph.D. in Botany, an M.S. in Plant Physiology and Biochemistry, and a B.S. in Biology. His research focuses on plant biophysics, electrobiology, and environmental adaptation. He has dedicated himself to explaining the fertility of certain intergeneric hybrids through "cell fusion - chromosome set segregation" and the extended genetic laws in his early years. He proposed a new mechanism of photosynthetic oxygen release: half of the oxygen originates from the photolysis of bicarbonate, and the other half from the photolysis of water. The release of oxygen through electrochemical energy is fundamental. He has also innovated plant electrobiological information detection technology and invented a plant life information instrument. Additionally, he created a technical method for characterizing physical information of life (including humans) based on the energy storage and conversion of cellular electrical components. He serves as the Editor-in-Chief of the *Journal of Plant Electrobiology*. (Email: wuyanyou@mail.gyig.ac.cn)

Deke Xing holds a Ph.D. in Geochemistry, M.S. in Agricultural Bioenvironment and Energy Engineering, and B.S. in Environmental Science. His research focuses on plant electrobiology, plant stress physiological ecology, and water-saving irrigation. He has successfully applied electrobiological techniques to research in plant stress physiological ecology and water-saving irrigation. By employing electrobiological techniques, he investigated the dynamic characteristics of intracellular water utilization in various plant species under stresses. Meanwhile, he developed models that correlates electrobiological parameters with the plant's net photosynthetic rate and growth status, allowing for the precise prediction of both the net photosynthetic rate and growth rate. These models have also been applied to the precision irrigation. He serves as Associate Editor of *Journal of Plant Electrobiology*. (Email: xingdeke@ujs.edu.cn)