Connecting People to Plants

ELECTRICAL SIGNALS IN PLANTS

A PHYTL SIGNS PRIMER

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OBJECTIVE

Although the phenomenon of electrical signaling in plants is well established in science, most people are unaware of it. This primer is intended to provide the reader with the background to basic knowledge in this area.

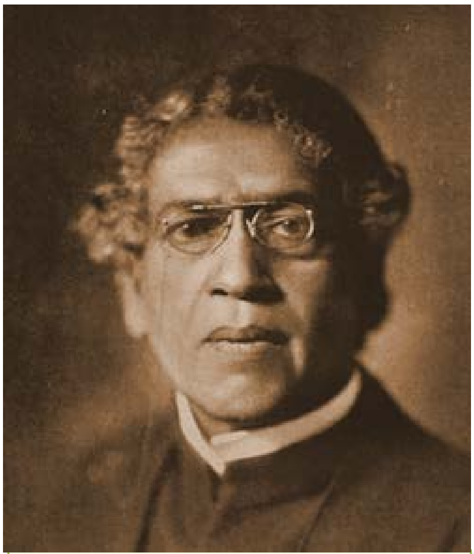
INTRODUCTION TO ELECTRICAL SIGNALS IN PLANTS

Key Insights:

- **Electrical signals, which are emitted by all higher plants, have been researched for more than 100 years**
- **Current research is almost always conducted inside a Faraday cage to ensure the signal to noise ratio is high**
- **Vivent's Phytl Signs range of instruments uses modern electronics coupled with smart signal processing to create the possibility of research *in-situ***
- **Understanding electrical signaling may lead to advances in optimization of environmental conditions as well as providing early warning of stress, disease or pest attack in plants.**

In 1873, following correspondence with Charles Darwin, electrical signals in plants were discovered by British scientist John Burdon-Sanderson[1] using a Venus Flytrap (Dionaea muscipula). The remarkable Indian scientist Jagadish Chandra Bose built on this work at the start of the twentieth century showing that plants generated electrical impulses in response to stimuli similar to those of nerves in animals[2]. This response is known as "excitability" in plants and animals.

By the 1970s it was accepted that all higher plants may be utilizing electrical signals to regulate a wide variety of physiological functions.[3] These functions may include signaling the change from photosynthesis to respiration or prompting movement in relation to light levels[4] (think of sunflowers turning towards the sun) or the emission of volatile chemicals like jasmonates in response to damage[5] such as an insect attack (rub a tomato or geranium leaf; the distinctive scent is the release of jasmonic acid which acts as a deterrent to insects).



Sir Jagadish Chandra Bose
(1858-1937)
A Bengali polymath, educated at Cambridge, who made substantial contributions to botany where he demonstrated that plants generate electrical signals in response to, for instance, wounding.
He was also key to the development of radio, being the first to use semiconductor crystals to detect radio waves. He also pioneered microwave optics and is credited as being the father of Bengali science fiction. A remarkable man!

It has been hypothesized that plants have developed pathways for electrical signal transmission because of the need to **respond rapidly** to external stimuli, for example environmental stress factors[6] like insect attacks, lack of light or drought. In 2005 Lautner et al showed that different environmental stimuli evoke specific responses in living cells that are capable of transmitting electric signals within the responding region.[7]

Both defense and development biologists continue to carry out research on the mechanisms plants use to transmit electrical signals. Researchers typically focus on either intracellular (within a single cell) or extracellular measurements. A standard protocol for experiments of this kind has been developed in Prof. E.E. Farmer's laboratory at the University of Lausanne and published in *Nature*[8]

Extracellular measurements assess the total bioelectrical activity in a large group of cells. The equivalent of these measurements in human beings are the ECG or EEG used by medical professionals.

Research into electrical plant signals may have the objective of decoding specific signals emitted by plants in response to environmental stimuli. The Phytl Signs instruments and devices are designed to make measurements and recordings of this kind far easier.

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Plants emit a variety of types of electrical signals that may be monitored using Phytl Signs instruments. The table below explains different types of electrical signals and how they might give rise to beneficial applications to users.

Signal Type	Description	Transmission	Stimuli Generating Signals	Potential Applications
LEP – Local Electrical Potential	Sub-threshold response	Locally generated, not transmitted to rest of plant	Change in environment; soil water, fertility, light, temperature, humidity	Important monitor of physiological status of plant.[9] [10]Monitor water stress, nutrient sufficiency, and temperature or light responses.
AP – Action Potential	Wide spread signal, stimuli needs to be above threshold[11]	Fast, over long distances, constant amplitude and speed	Non-damaging stimuli like cold, touch or electricity	Experiments on trap closures, regulation of leaf movement,
VP – Variation Potential	Signal that varies in shape and size with intensity of stimuli	Amplitude decreases away from stimuli site	Damaging stimuli like burning, cutting[12]	Early warning of insect attack, control of irrigation[13]

Nearly all academic research is currently done in tightly controlled laboratory conditions including vibration resistant tables inside Faraday cages. Faraday cages are solid metal or wire-mesh enclosures that shield the experiment from external electromagnetic and interference. These cages help reduce the noise picked up when recording the electrical signals from plants. When you are speaking on your mobile phone and a loud train or plane passes by, your conversation is drowned out by the environmental noise. A Faraday cage mitigates similar electro-magnetic effects.

Research set up - plants inside faraday cages.
Source: PLEASED, http://pleased-fp7.eu/

A key innovation of the Phytl Signs devices is that plants can be studied outside of a Faraday cage. Modern electronics and innovative signal conditioning and processing have been used to amplify the electrical signals emitted by plants while filtering out significant amounts of ambient electro-magnetic noise.

This opens up new experimental possibilities for researchers, enables professional growers to monitor plants in situ and provides learning opportunities for plant enthusiasts, students and technophiles.

There are still substantial areas of knowledge regarding plant signaling that are not yet understood.[14] Vivent hopes that by providing tools and gathering and sharing data on a wide variety of plants in different environments that we will be able to further the understanding of the nature of information exchange within plant cells and organs and then be able to apply that knowledge to develop indicators of the physiological condition of plants.[15] We want to understand the vital signs of plants.

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So far we have produced 50 prototypes that we are testing in a wide variety of conditions to ensure we can effectively monitor and record electrical signals emitted by plants. Over the coming months we will be refining our products to meet the needs of researchers, professional growers and plant and technology enthusiasts.

If you would like more information on electrical signaling in plants or our products, if would like to see or test a prototype or if you have an opportunity in mind, such as investigating a plant pest like spider mites or boxwood blight or bringing the world of plants to life for your students please contact us. We'd be delighted to hear from you.

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1 J. Burdon-Sanderson **Note on the electrical phenomena which accompany irritation of the leaf of Dionaea muscipula**. Proc R Soc Lond, 21 (1873), pp. 495–496

2 Bose J.C. (1926) **The Nervous Mechanism of Plants**, pp. 123–134. Longmans, Green & Co., London, UK.

3 Pickard B. (1973) **Action potentials in higher plants**. Botanical Review 39, 172–201.

4 Oyarce P., Gurovich L.. **Electrical signals in avocado trees**. Responses to light and water availability conditions. Plant Signaling & Behavior, 2010; 5:34-41; PMID:20592805; http://dx.doi.org/10.4161/psb.5.1.10157

5 Koo AJ, Gao X, Jones AD, Howe GA. 2009. **A rapid wound signal activates the systemic synthesis of bioactive jasmonates in Arabidopsis**. Plant Journal 59: 974– 986.

6 Fromm J, Lautner S., **Electrical Signals and their physiological significance in plants**, Plant, Cell and Environment (2007) 30, pp. 249-257

7 Lautner S., Grams T.E.E., Matyssek R. & Fromm J. (2005) **Characteristics of electrical signals in poplar and responses in photosynthesis**. Plant Physiology 138, 2200–2209.

8 S.A.R. Mousavi, C.T. Ngueygen, E. Farmer, S. Kellenberger, **Measuring surface potential changes on leaves** Nature Protocols VOL.9 NO.8 (2014) pp 1997-2004

9 Hu JH. **Measurement and research on vegetal bioelectricity under water stress**. Dissertation, Jilin University, China, 2003.

10 H.Y. Ren, X.C. Wang, C.H. Lou, **The universal existence of electrical signals and its physiological effects in higher plants**, Acta Phytophysiol Sin, 19 (1) (1993), pp. 97–101

11 K. Trebacz, H. Dziubinska, E. Krol **Electrical signals in long-distance communication in plants**, F. Baluska, S. Mancuso, D. Volkmann (Eds.), Communication in plants – neuronal aspects of plant life, Springer-Verlag, Berlin, Heidelberg (2006), pp. 277–290

12 Stahlberg R., Cleland R.E. & Van Volkenburgh E. (2006) **Slow wave potentials – a propagating electrical signal unique to higher plants**. In Communication in Plants – Neuronal Aspects of Plant Life (eds F. Baluska, S. Mancuso & D. Volkmann), pp. 291–308. Springer-Verlag, Berlin and Heidelberg, Germany.

13 Oyarce P., Gurovich L.. **Electrical signals in avocado trees**. Responses to light and water availability conditions. Plant Signal & Behav 2010; 5:34-41; PMID:20592805; http://dx.doi.org/10.4161/psb.5.1.10157

14 Huber A., Bauerle T.,* **Long-distance plant signaling pathways in response to multiple stressors: the gap in knowledge**, Journal of Experimental Botany, Volume 67, Issue 7, pp. 2063-2079.

15 Xiaofei Yan, Zhongyi Wang, Lan Huang, Cheng Wang, Ruifeng Hou, Zhilong Xu, Xiaojun Qiao, **Research progress on electrical signals in higher plants**, Progress in Natural Science, Volume 19, Issue 12, 10 December 2009, pp 531-541

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