ICPA
17th INTERNATIONAL CONFERENCE ON PRECISION AGRICULTURE
ConBAP 2026
CONGRESSO BRASILEIRO DE AGRICULTURA DE PRECISÃO E DIGITAL
13-16 July 2026 | Porto Alegre, Brazil
ISPA
AsBraAP

TOWARDS PRECISION AGRICULTURE WITH ELECTROCHEMICAL SENSORS FOR DETECTING DOPAMINE IN PLANTS AND FRUITS

Lucas Minghini Gonçalves[1,2*], Bruno Vasconcellos Lopes[1], Betty Braga Gallo[1], Andrei Borges La Rosa[1], Diego Alberto Fruchtenicht[1], Caroline Athaides Miler[1], Paula Silveira[1], Neftalí Lenin Villarreal Carreno[1,2]

1 Center for Embedded Devices and Research in Digital Agriculture (CEDRA), São Leopoldo 93025-753, RS, Brazil

2 Federal University of Pelotas (UFPEL), Pelotas 96010-610, RS, Brazil

A paper from the Proceedings of the
17th International Conference on Precision Agriculture and 11th Brazilian Congress on Precision and Digital Agriculture
13-15 July 2026
Porto Alegre, Brazil

Abstract.

Catecholamines regulate the nervous system in animals and coordinate antioxidant responses and ionic balance in plants, where dopamine (DA) stands out as a potent growth modulator under abiotic and biotic stresses. Although DA concentrations vary across species—reaching high levels in banana peel (Musa acuminata)—its in-situ quantification is severely hindered by conventional techniques like High-Performance Liquid Chromatography (HPLC), which is costly and requires laborious sample preparation. To overcome these bottlenecks, this work proposes a low-cost, portable, and disposable electrochemical sensing platform based on laser-induced graphene (LIG) and molecularly imprinted polymers (MIP). The fabrication process involved direct laser writing on a polyimide film adhered to a polyethylene plate using a diode laser (100 mm s^{-1}, 1.8 W) to obtain LIG electrodes, followed by the deposition of an Ag/AgCl reference ink and a MIP precursor layer via drop-casting onto the working electrode. Aiming for field portability, a solid phosphate-buffered saline gel composed of glycerol/agar (3:1, v/v) was successfully employed as the electrolyte. Cyclic voltammetry assays demonstrated that the integrated PBS-Gel maintained equivalent electrochemical functionality compared to traditional liquid PBS, eliminating leakage risks and facilitating on-site handling. The architecture benefits from the synergy between the high electrical conductivity of the porous LIG and the high chemical specificity of the biomimetic MIP cavities, ensuring sensitive DA detection while mitigating matrix interferences. Future steps will focus on validating the device in banana peel extracts, consolidating this portable platform for real-time plant stress monitoring in precision agriculture.

Keywords.
Electrochemical sensors, dopamine, plants

1. Introduction

Gonçalves, L. M., Lopes, B. V., Gallo, B. B., La Rosa, A. B., Fruchtenicht, D. A., Miler, C. A., Silveira, P., & Carreno, N. L. V. (2026). Towards precision agriculture with electrochemical sensors for detecting dopamine in plants and fruits. In Proceedings of the 17th International Conference on Precision Agriculture and 11th Brazilian Congress on Precision and Digital Agriculture (unpaginated, online). Porto Alegre, Brazil: International Society of Precision Agriculture and Brazilian Congress on Precision and Digital Agriculture.

Catecholamines are essential neurotransmitters known to regulate the central nervous system of animals, while also acting as direct modulators in the plant kingdom, coordinating antioxidant responses and ionic balance regulation. Among these, dopamine (DA) stands out for its critical regulatory role in plants, acting as a potent antioxidant and growth modulator under abiotic stresses such as extreme drought and high salinity or pathogen attacks, directly assisting in free radical neutralization and cellular protection. The endogenous concentration of DA varies drastically across different species and plant tissues. For instance, while banana pulp (*Musa acuminata*) exhibits approximately 40–50 µg/g, its peel can accumulate exceptionally high levels, ranging from 80 to 560 µg/g. In contrast, significantly lower contents are observed in matrices such as avocado (4 µg/g) and orange (<1 µg/g) (Li et al., 2025). Despite its evident physiological relevance for monitoring plant health, the *in-situ* quantification of dopamine is severely hindered by conventional techniques. The use of High-Performance Liquid Chromatography (HPLC), although accurate, is costly, time-consuming, and requires laborious sample preparation, rendering field analyses unfeasible. To overcome these bottlenecks, this work proposes the development of a low-cost, portable, and disposable electrochemical sensing platform.

2. Methodology

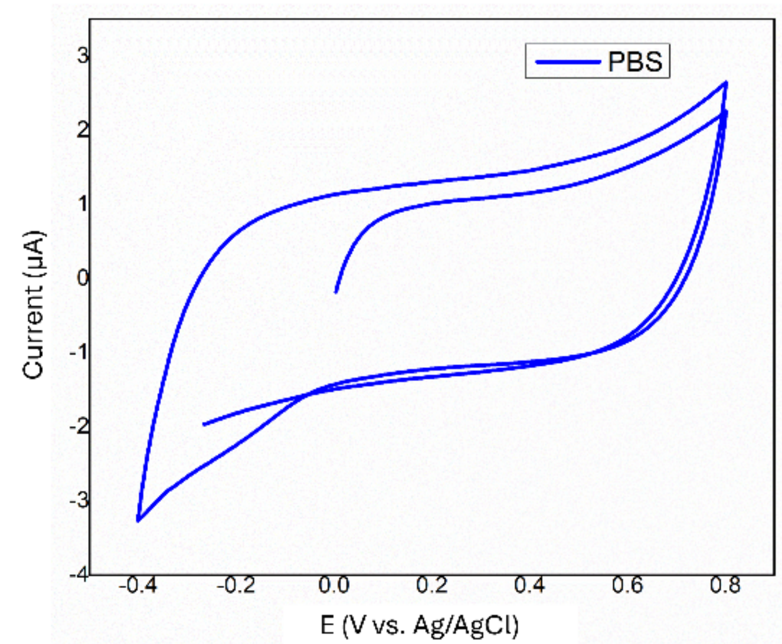
In the sensor fabrication process, three-electrode chips were developed, consisting of a working electrode, a counter-electrode, and a reference electrode made with silver chloride paint (Ag/AgCl ink, ALS product No. 011464, distributed by BAS Inc., Tokyo, Japan). To obtain the electrodes, a polyimide polymeric film adhered to a polyethylene (PE) plate was subjected to direct laser writing using an XTool diode laser engraving machine, with a scanning speed of 100 mm s^{-1} and a power of 1.8 W. The tape initially undergoes laser ablation to define the entire sensor shape; subsequently, a modification layer (MIP precursor) is deposited via drop-casting onto the laser-induced graphene (LIG) surface of the working electrode. Aiming for portability during field and controlled-environment analyses, a phosphate-buffered saline gel composed of glycerol/agar (3:1, v/v) (PBS-Gel) was employed as a solid electrolyte.

3. Results and Discussion

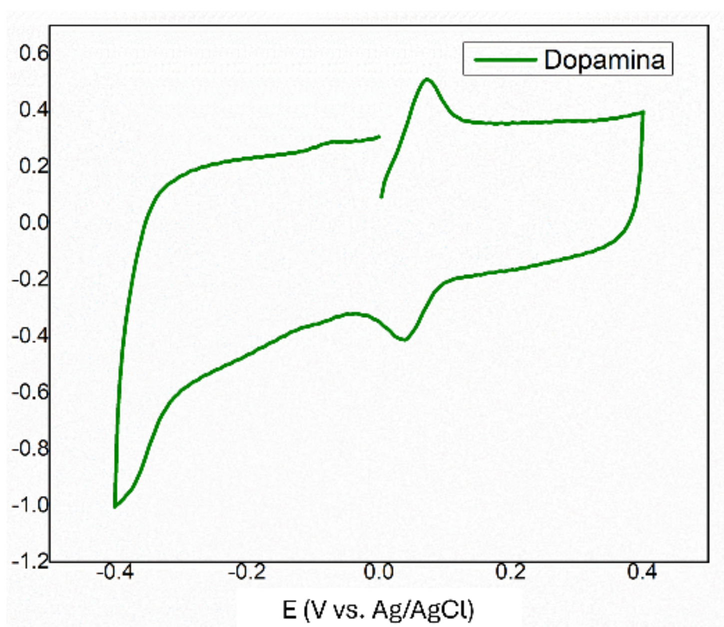
Preliminary assays demonstrated that the LIG sensor integrated with the PBS-Gel maintained similar electrochemical functionality compared to the use of traditional liquid PBS (Figure 1). This equivalence represents a significant milestone, as it validates the use of a gel electrolyte, eliminating leakage risks and facilitating device handling under out-of-laboratory conditions. The sensor architecture benefits from the synergistic effect between two primary factors, High electrical conductivity provided by the porous network of the laser-induced graphene (LIG), and High chemical specificity provided by the biomimetic cavities of the MIP, exclusively designed to recognize the target molecule. This combination results in a highly promising analytical tool for sensitive dopamine detection, mitigating the effects of common interfering compounds present in complex plant matrices.

Fig. 1 *Cyclic Voltammetrys comparing LIG-pristine in 0,1 mol L^{-1} PBS (A) and 0,1 mol L^{-1} PBS-Gel with dopamine 1 mmol L^{-1} (B).*

(A)



(B)



4. Conclusions and Future Perspectives

The LIG/MIP-based electrochemical sensor with a gel electrolyte proved to be a viable, rapid, and low-cost alternative to traditional chromatographic methods. As subsequent steps in this research, the focus will shift toward validating the device in complex real matrices, specifically for the detection and quantification of dopamine in banana peel (*Musa acuminata*) extracts. The goal is to consolidate this analytical platform as a robust, portable tool for real-time monitoring of plant stress in precision agriculture.

Acknowledgments

This work has been partially funded by the project AgroHeath supported by the Center for Embedded Devices and Research in Digital Agriculture (CEDRA) of SENAI-RS, with financial resources from the PPI IoT/Manufatura 4.0 / PPI Hardware BR of the MCTI, grant number 056/2023, signed with EMBRAPII.

References

Li, J., Wu, Q., Cheng, J., Zhu, J., Su, P., Wu, J., Fan, X., & Li, G. (2025). Mechanism of Exogenous Dopamine Regulating Shine Muscat Grape in Response to Low-Temperature Stress. *Plants*, *14*(20). https://doi.org/10.3390/plants14203225

Gonçalves, L. et al. Toward Non-Invasive Neurological Biomarker Monitoring: Dopamine Sensing in Tears with Laser-Induced Graphene Electrochemical Sensors, ACS Omega, p. 1-10, 2026. https://doi.org/10.1021/acsomega.6c03287