SCIENTIFIC REPORT

EXECUTION PHASE NO. 2/2025

Project title:
ASSESSMENT OF THE IMPACT OF NON-THERMAL PLASMA TECHNOLOGY ON PLANT GROWTH AND DEVELOPMENT IN INDOOR FARMING

Contract no. 7BMBE／2024
Project code: PN-IV-P8-8.3-PM-RO-BE-2024-0011

Phase II/2025 (January 1 – December 31, 2025)

Phase name - Development of the experimental model of the non-thermal plasma reactor, testing to evaluate the effects of activated water on plant development in indoor agriculture, and dissemination activities.

- Objectives of the execution phase:
  - Evaluation of physical parameters for indoor agriculture and energy balance for plasma-activated water production.
  - Development of the experimental model of the NTP reactor and dimensioning of a PV system
  - Development of a protocol for irrigation with plasma-activated water.

- Scientific and technical description:

Phase results	**Degree of achievement of objectives**
Definition of environmental conditions, energy requirements, and physical-chemical parameters of activated water.	100%
Report on the possibility of integrating the activated water production system with the PV system.	100%
Protocol for irrigation with plasma-activated water in a controlled environment.	100%
Dissemination of results through international events and scientific papers.	100%

The activities carried out focused both on analyzing the environmental conditions characteristic of inland agriculture and on assessing the energy requirements necessary for the operation of the non-thermal plasma activated water production system.

In January 2025, the Romanian researcher performed a short visit to the University of Liège, Belgium, and between January and February 2025, the PhD student performed a long visit to the University of Liège, Belgium.

During the long visit to the University of Liège, Belgium, an indoor agricultural space equipped with modern climate control systems was monitored. The activity aimed to identify and characterize the main physical parameters that define the microclimate necessary for the optimal development of horticultural crops in closed spaces.

The data collected on air temperature and relative humidity provided an understanding of the specific environmental requirements for agriculture in controlled environments and offered guidelines for the integration of an activated water treatment system in accordance with the physiological needs of plants.

During the visit, the expertise of the Belgian researcher involved in the project was utilized, providing information on the interaction between microclimate parameters, crop types, and the influence of irrigation treatments.

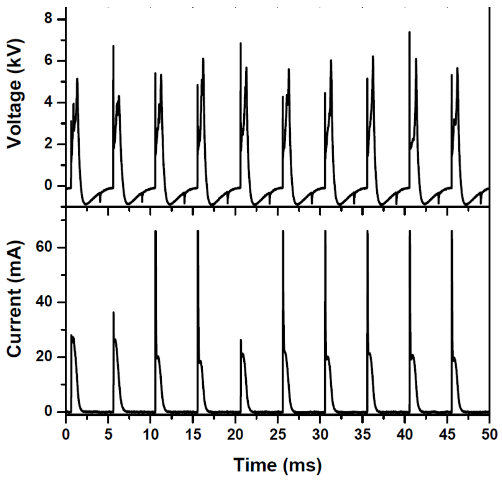
Defining the optimal environmental conditions for the use of plasma-activated water in indoor agriculture

The research activity analyzed the specific requirements of the controlled environment necessary for the efficient use of plasma-activated water (PAW) in indoor crops. The correlation between physical and microclimate parameters and the stability and efficiency of reactive species in PAW was taken into account.

The following influencing factors were identified:

- ✓ Air temperature: maintaining a temperature between 20–22°C promotes the stability of reactive species in solution (ref. https://doi.org/10.1016/j.lwt.2023.114969).

- ✓ Relative humidity: values between 60–75% have proven favorable for both maintaining PAW quality and plant development.
- ✓ Light: light intensity and spectrum indirectly influence the metabolism of plants treated with PAW. Controllable LED light sources (including UV-A/UV-B) are suitable for simulating optimal conditions for photosynthesis and adaptation to the supply of reactive species.
- ✓ Ventilation and air circulation: constant air circulation has been found to prevent excessive accumulation of ozone or other gaseous species in enclosed environments.

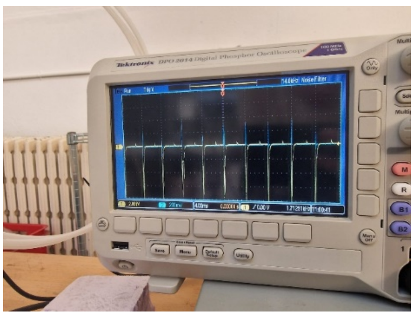


Waveforms of voltage and current of electrical discharge

Non-thermal plasma discharge

The activity was followed by a study of the energy consumption of the non-thermal plasma activated water generation system.

- ✓ The laboratory equipment used for water treatment was analyzed, with monitoring of electrical parameters (voltage, current, frequency).
- ✓ Experiments were carried out for different water flows in order to determine the relationship between the exposure time to non-thermal plasma and the quality parameters of the treated water.
- ✓ Based on these measurements, the energy requirement was determined.

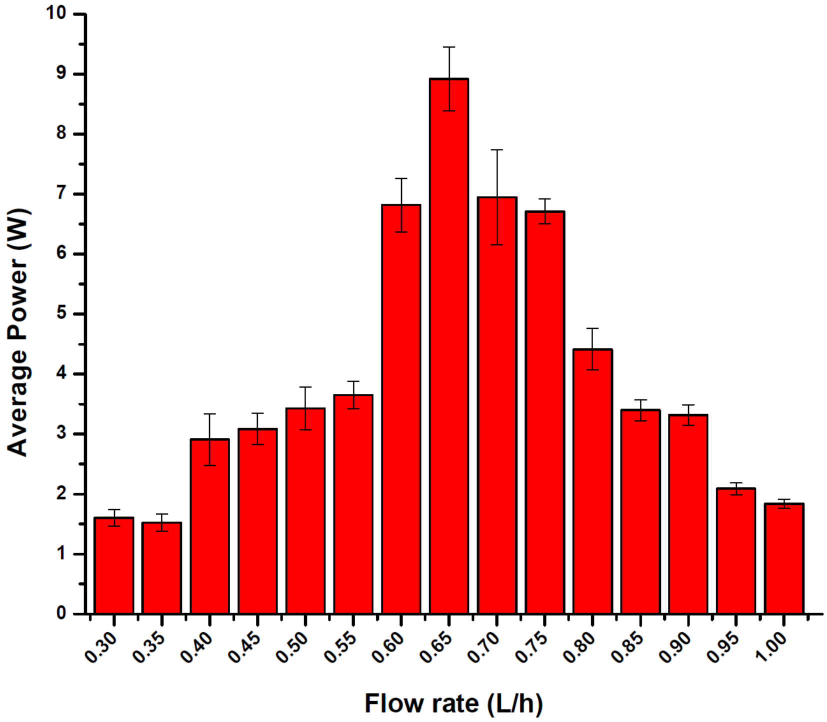


Assessment of the energy efficiency of the plasma-activated water production system (energy balance)

As part of the activity, the evolution of the average power consumed by the non-thermal plasma system was analyzed as a function of the circulating water flow rate. Experimental determinations were performed for several operating modes, monitoring both electrical parameters (voltage, current) and hydraulic parameters (flow rate, pressure).

It was found that variations in water flow rate cause changes in the overall efficiency of energy transfer to water. This information allowed for a preliminary assessment of the ratio between the electrical energy consumed and the concentrations of reactive species obtained, an essential parameter in calculating the energy efficiency of the process.

The following figure shows how the average power changes depending on the water flow rate.



Relationship between average power and water flow.

Study of energy requirements for the NTP reactor and PV system sizing, as well as analysis of the possibility of PV–NTP integration

The activity analyzed the dependence of the energy consumption of the non-thermal plasma (NTP) reactor on the water flow rate, with electrical and hydraulic measurements being performed in various operating modes. The evolution of average power as a function of flow rate allowed the identification of the optimal operating range (0.60–0.70 L/h), where the discharge has the best energy efficiency, with power values between 6.7 and 9 W. These results are essential for estimating the energy requirements of the reactive species generation process (NO_3^-, H_2O_2, etc.) and for evaluating the overall performance of the plasma–liquid interaction.

Based on the minimum calculated power requirement (≈46 Wp) and taking into account actual losses, irradiation variability, and the need to ensure stable operation of the NTP reactor, a 100 Wp photovoltaic module was selected, which provides a safety margin for system operation.

Analysis of the effect of activated water on plants and establishment of a protocol for irrigating plants with activated water in a controlled environment.

The effect of plasma-activated water (PAW) application on the growth and development of Lactuca sativa L. (S. Anna variety) lettuce, a crop valued for its nutritional value and rapid growth rate but sensitive to abiotic stress and irrigation management, was investigated. Lettuce was used as a model plant to evaluate the potential of PAW in stimulating germination, leaf development, and nutrient accumulation. PAW was obtained using a non-thermal plasma reactor, in which the mixture of water and carrier gas is treated directly in the reaction chamber. To analyze the influence of generation conditions on chemical composition, two variants of PAW (PAW I and PAW II) were produced and applied immediately after production to maintain the efficiency of reactive species.

The influence of water flow and frequency on the concentration of reactive species in PAW

Experimental tests were conducted to evaluate how operating frequency and water flow rate influence the accumulation of reactive species in plasma-activated water (PAW) used for lettuce crops. The results showed that as the water flow rate increases, the concentrations of reactive species decrease, indicating a lower efficiency of the activation process. Higher values were obtained at low flow rates due to the longer interaction time between the plasma and the treated water, favoring the formation and accumulation of reactive species.

Dissemination of results

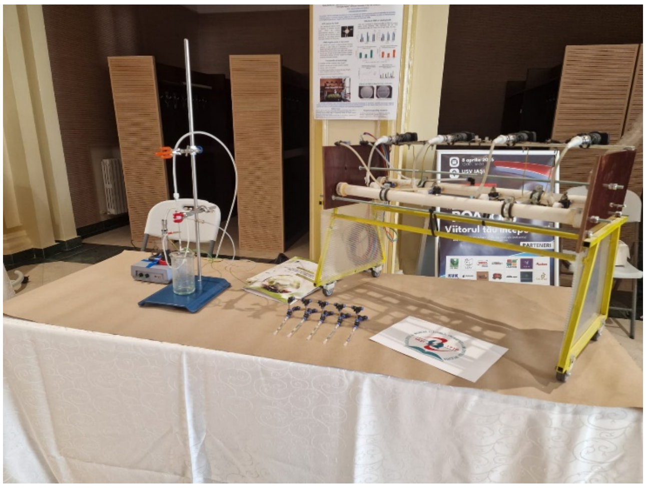
Photovoltaic Panel System with Optical Dispersion of Solar Light for Greenhouse Agricultural Applications, Beniuga Constantin Razvan, Bogdan Andrei Pingescu, Oana Cristina Beniuga, Alin Dragomir, Dragos-George Astanei and Radu Burlica *AgriEngineering 7, no. 4: 125, 2025* [DOI:https://doi.org/10.3390/agriengineering7040125](https://doi.org/10.3390/agriengineering7040125)

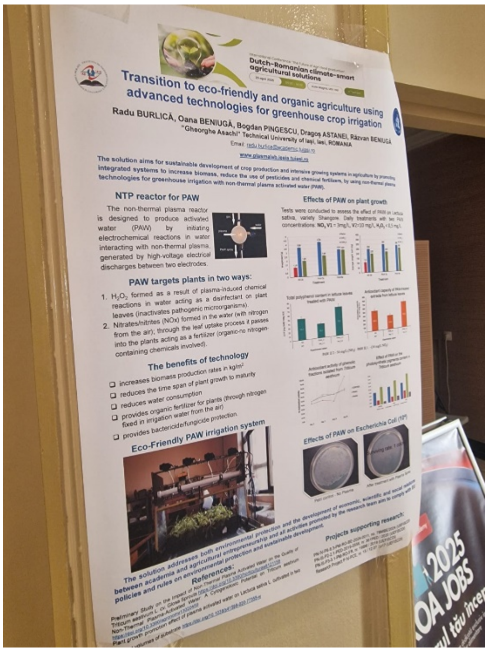
Enhancing Reactive Species Availability for Plant Growth Through Plasma-Activated Water Integration in Sustainable Farming, Oana Cristina BENIUGĂ, Bogdan-Andrei PINGESCU, Constantin Razvan BENIUGĂ, Dragoș George ASTANEI, Frédéric LEBEAU, Radu BURLICĂ,

Proc. of. 2025 15th International Conference on Electromechanical and Energy Systems (SIELMEN), Chisinau, Republic of Moldova

Participation in the 15th International Conference on Electromechanical and Energy Systems (SIELMEN), Chisinau, Republic of Moldova, October 17-19, 2025

Participation in the International Conference "The Future of Agri-food Production" – 2nd Edition (https://patronatofa.eu/international-conference-the-future-of-agri-food-production-2nd-edition/) April 29, 2025, University of Life Sciences in Iași.





Participation in "TUIASI Innovation Week" TECHNOVERS Expo, a technology and innovation exhibition, June 4, 2025, at PALAS Atrium, Iași.