Rapid population growth and climate change are crucial challenges for global food security. Agriculture 4.0, thanks to advanced technologies such as the Internet of Things, Artificial Intelligence, and robotics, offers innovative solutions for more efficient and sustainable agricultural production. In this context, this work focuses on improving Controlled Environmental Agriculture systems, with the aim of developing cultivation protocols capable of increasing productivity and reducing resource consumption.

Through an integrated, experimental, and modeling approach, a dynamic cultivation protocol specific for aeroponic systems in controlled environments has been designed. This protocol has been developed based on data collected through the Design of Experiment and supported by a hybrid model combining machine learning algorithms and a physical model. Thanks to this methodology, it has been possible to dynamically adjust key environmental parameters, such as light, temperature, and nutrients, to adapt them to the crop needs during the growth cycle.

Specifically, the hybrid model estimated the fresh weight of the crop with a mean absolute percentage error ranging from 11.20% to 13.88%. These predictions were used to develop the dynamic protocol that adjusts environmental conditions based on the stage of growth of the crop. This protocol resulted in a 25% increase in fresh weight in the third week of growth and a 32% reduction in water consumption, demonstrating the potential of integrating advanced modeling and dynamic crop management to enhance the efficiency of aeroponic systems in controlled environments.