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PAPER

Agricultural Transformation: IoT Technology in the Controlled Cultivation of *Oryza Sativa* Seedlings in Greenhouse

Edwar A. Velarde Allazo(✉), Jimmy E. Vásquez Cori

Universidad Tecnológica del Perú, Arequipa, Perú

evelarde@utp.edu.pe

ABSTRACT

This paper offers a current review of the application of Internet of Things (IoT) technology for the cultivation of *Oryza sativa* (rice) in greenhouses through the incorporation of climate and soil sensors. It is not intended to cover all aspects of IoT, but rather to provide a detailed understanding of its application in this context. Through the analysis of published works, the applications developed, the approaches adopted, and the proposals of experts in the field are investigated. Therefore, real data are examined in the cultivation of *Oryza sativa* seedlings that we consolidated with Power BI, managing to compare the traditional crop with that carried out with IoT technology, highlighting the real-time monitoring of critical soil variables such as humidity, temperature, electroconductivity, pH, nitrogen, phosphorus, and potassium (NPK). Likewise, climate variables such as humidity and relative temperature. This monitoring facilitates the optimization of irrigation and fertilization, promoting efficient and sustainable agriculture. The implementation of IoT in greenhouses not only provides improvements in productivity and product quality but also boosts competitiveness and innovation in the agri-food sector.

KEYWORDS

Oryza sativa, Internet of Things (IoT), dashboard, greenhouses, sensor systems

1 INTRODUCTION

The Internet of Things (IoT) technology revolutionizes modern agriculture by providing advanced tools for monitoring and controlling various soil and environmental parameters. In the cultivation of seedlings of *Oryza sativa*, commonly known as rice, the use of IoT is presented as a truly innovative solution that improves efficiency and productivity, especially when grown in controlled greenhouses [1].

IoT integrates sensors that monitor in real time a wide variety of variables critical to rice cultivation, such as atmospheric humidity, atmospheric temperature,

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soil moisture, soil temperature, pH, electroconductivity, nitrogen, phosphorus, and potassium (NPK). These sensors continuously collect data and transmit it to a centralized platform, where it is analyzed and used to enable the right crop decisions to be made [2].

In controlled greenhouses, the implementation of IoT provides a number of benefits. Firstly, it allows optimal growing conditions to be maintained by automatically adjusting irrigation, ventilation, and heating systems according to the specific needs of the crop in real time. This not only optimizes the use of water resources such as water but also improves the quality and yield of the production of the seedlings of *Oryza sativa* [1].

Real-time monitoring of soil and weather through IoT is essential to immediately detect and correct any deviations from optimal parameters. For example, early detection of a decrease in soil moisture activates the automatic irrigation system, ensuring that plants receive the right amount of water. Similarly, climate sensors adjust ventilation levels to achieve ideal humidity and atmospheric temperature, thus preventing thermal stress on plants [3].

The application of IoT in greenhouse rice cultivation also facilitates the implementation of more sustainable farming practices. By optimizing the use of resources and reducing waste, the environmental impact is minimized. In addition, long-term data analysis makes it possible to identify patterns and trends that inform future cultivation strategies, contributing to a more resilient and efficient agriculture [4].

2 MATERIALS AND METHODS

An experimental approach based on IoT technology was chosen for the real-time monitoring of environmental variables in a controlled greenhouse where *Oryza sativa* seedlings were grown. In this context, a quantitative approach was employed to accurately measure soil and climate variables.

Currently there is a wide variety of sensors applied based on the IoT; in this context, the JXCT sensor was used to monitor soil conditions and the DHT21 sensor to record humidity and relative air temperature. Likewise, the integration is accompanied by an iCloud system that is based on an architecture oriented to the Cisco; it is widely used in various industries. The proposal proposes to incorporate a data exchange layer with the integration of the IoT gateway that, for the study, is developed by the ESP32 microcontroller and the Arduino Nano.

The combination of the ESP32 with the DHT21 sensor allows for accurate monitoring of temperature and humidity in various environments. This configuration is commonly used in IoT projects, providing fundamental data for environmental analysis and real-time condition monitoring.

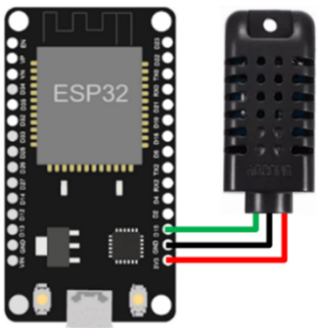

Fig. 1. DHT21 climate sensor

The combination of the JXCT sensor with Arduino Nano makes it possible to monitor detailed soil variables such as humidity, temperature, electroconductivity, pH, and nutrients such as NPK. This configuration was used in the project, such as precision agriculture and soil analysis, providing crucial information to achieve improved crop quality and yield.

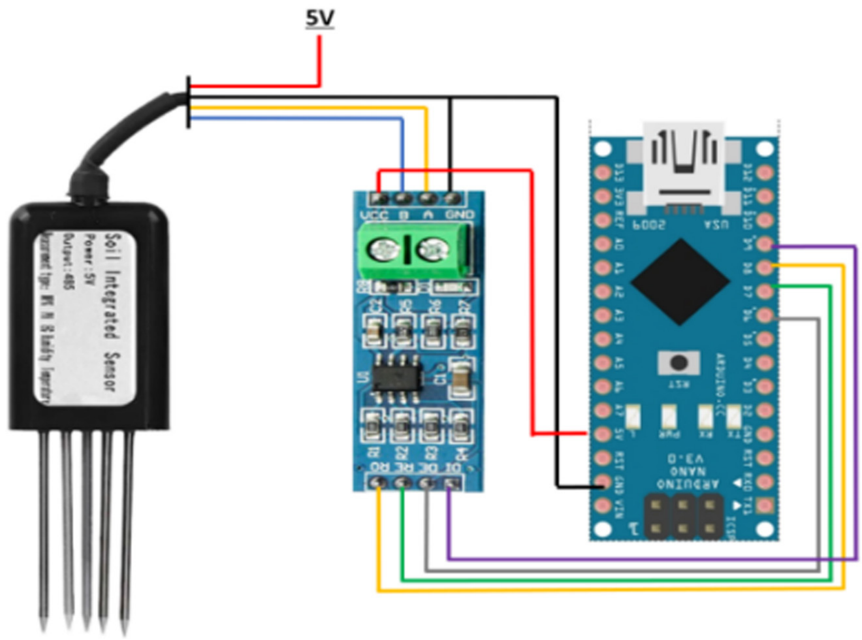

Fig. 2. JXCT soil sensor

The construction of the greenhouse was carried out following precise design standards that ensured an optimally controlled environment for the cultivation of *Oryza sativa* seedlings. Elements such as building material, natural lighting distribution, ventilation, and thermal control were considered to maintain ideal growing conditions.

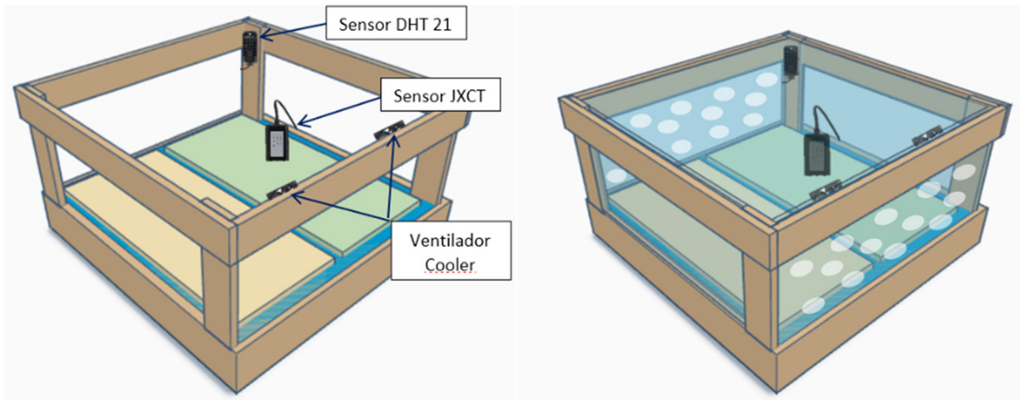

Fig. 3. Greenhouse design

The data collected by the JXCT and DHT21 sensors was transferred to a centralized platform for analysis and visualization using Power BI software. This platform includes several essential sections:. (1) Cultivation stages detail the progress of the crop in its different stages, providing information on the development of

Oryza sativa seedlings from sowing to harvest. (2) The Climatological section compares the environmental conditions inside the greenhouse with the information from the weather station exposed to the outside. Variables such as humidity and ambient temperature are analyzed to evaluate the climate control of the greenhouse. (3) Overview provides a complete view of the crop, including an up-to-date picture, the amount of water used, stem height, root dimensions, leaf area, type of fertilizer used, and seedling color. These details provide a comprehensive perspective of the state and development of the plants. (4) Soil analysis presents in a graphical way the variables of the soil in relation to moisture, allowing a detailed evaluation of soil conditions and their impact on plant development.

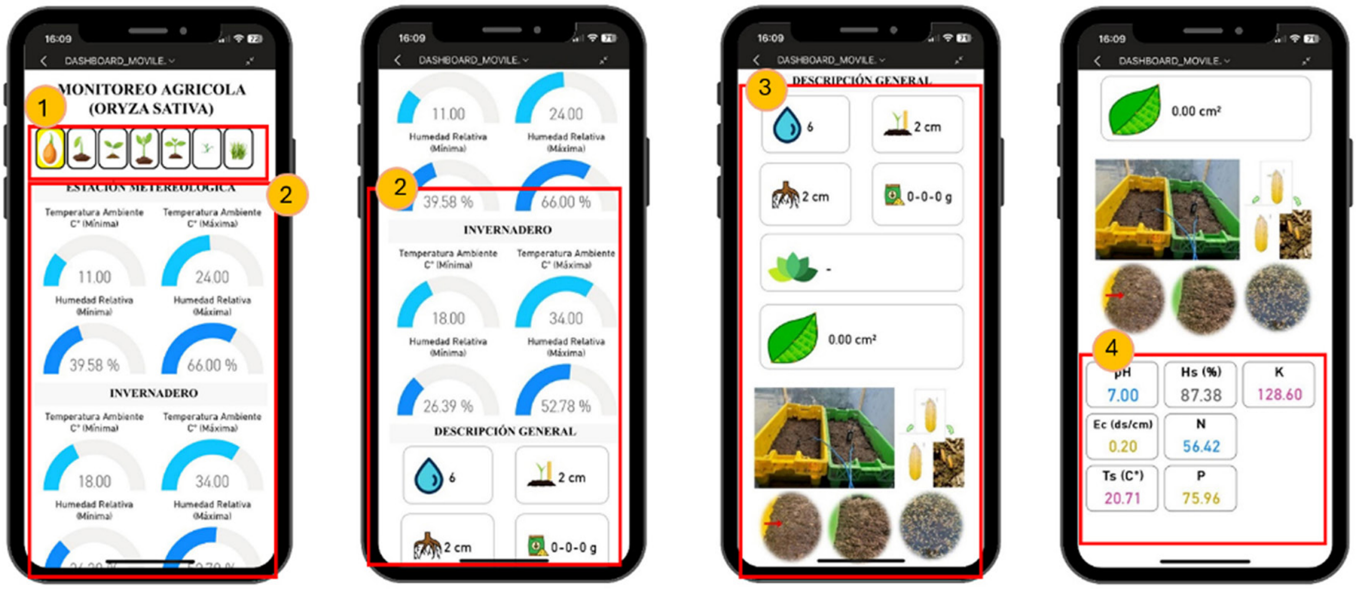

Fig. 4. Agricultural monitoring panel

The combination of these methods was tailored to the research, allowing for a clear interpretation of the motive and impact of their adoption. This provided a detailed and rigorous understanding of the environmental factors influencing the growth of *Oryza sativa* seedlings in a controlled greenhouse environment. The methodology emphasizes the relevance of IoT technology in precision agriculture and real-time data analysis. The data obtained were statistically analyzed to understand the growth of *Oryza sativa* seedlings, and quantitative and qualitative methods were compared against the specific needs of the research.

3 RESULTS

In the first stage of the experiment, IoT technology was implemented for the monitoring and control of the cultivation of *Oryza sativa* seedlings in a greenhouse. Soil and climate sensors allowed for the maintenance of adequate conditions for germination and initial development. The soil started with levels of 56.42, 75.96, and 128.60 kg/ha of NPK, which resulted in uniform germination of seedlings. Thanks to the accuracy of the real-time monitoring system, a germination yield of 93% was achieved, calculated from 58 grams of seeds sown, equivalent to 1161 seed grains, resulting in 1080 seedling units.

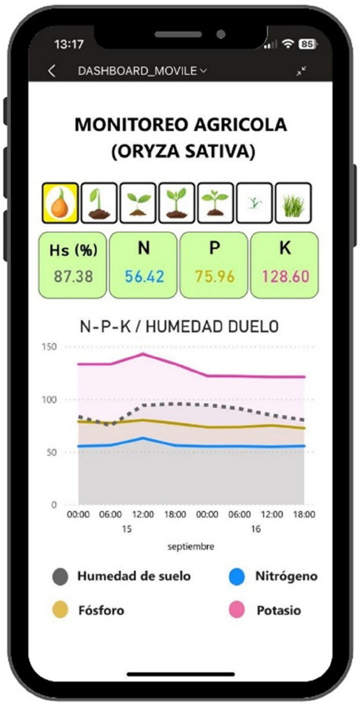

Fig. 5. Macronutrient levels (germination stage)

By monitoring humidity, six liters of water were used to keep humidity above 85%. However, cultivation with IoT technology proved to be more efficient and effective in terms of uniformity and germination yield. These results underscore the effectiveness of IoT technology in optimizing growing conditions, significantly improving the efficiency and uniformity of seedling germination compared to traditional methods.

Fig. 6. Comparison in crop growth

During the initial emergence stage of *Oryza sativa* seedlings, uniform growth was observed as the 1st, 2nd, 3rd, and 4th leaves developed. The implementation of IoT technology in the greenhouse allowed continuous monitoring of NPK macronutrient levels. A decrease in these nutrients was detected, reaching levels of 33.03 kg/ha of nitrogen, 43.80 kg/ha of phosphorus, and 77.69 kg/ha of potassium. In response to these precise data, 20-20-20 fertilizer was applied at a dose of 4-1-2 grams, which raised nutrient levels to 52.58 kg/ha nitrogen, 51.21 kg/ha phosphorus, and 89.74 kg/ha potassium in the tillering stage. In addition, a marked improvement was observed in the characteristics of plants that initially showed signs of nutritional deficiency.

Fig. 7. NPK macronutrient levels (emergency stage)

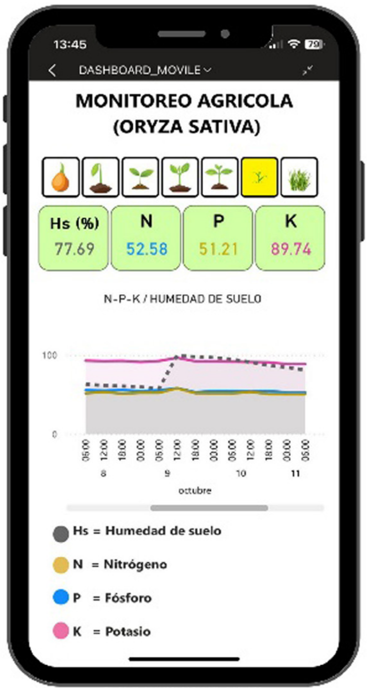

Fig. 8. NPK macronutrient levels (tiller)

Upon reaching the emergence of the 3rd leaf, concerning symptoms were observed in the plants, such as drooping leaves and yellowish discoloration. Monitoring with IoT technology revealed that the relative humidity had reached above-ideal levels, while the temperature had reached 36°C. This analysis made it possible to quickly identify the problem and activate the greenhouse ventilation system to regulate environmental conditions and prevent further deterioration of the seedlings.

Fig. 9. Climate monitoring (emergency)

During continuous monitoring, a drop in soil pH was also identified. Although levels remained above optimal, this change could have affected seedling growth. At the same time, electroconductivity levels were kept within ideal ranges, which contributed to the proper initial development of *Oryza sativa* seedlings.

Fig. 10. Monitoring of soil variables

During the maximum tillering stages, the use of IoT technology made it possible to identify and maintain optimal conditions for the cultivation of *Oryza sativa* seedlings in the greenhouse. The relative temperature remained level with an average of 31°C, which is ideal for seedling development. In addition, soil moisture was kept above 80%, using a total of 32 liters of water. These parameters were continuously monitored and adjusted thanks to IoT technology, ensuring an environment conducive to plant growth.

Fig. 11. Climate monitoring (maximum godson stage)

When comparing traditional cultivation with that carried out using IoT technology, significantly better results were observed in the latter. Seedlings grown with the help of IoT showed an increase of 3 cm in stem height and 1 cm in root length, accompanied by increased root density. These characteristics are crucial for the proper development of plants, as they improve the ability to absorb nutrients and water.

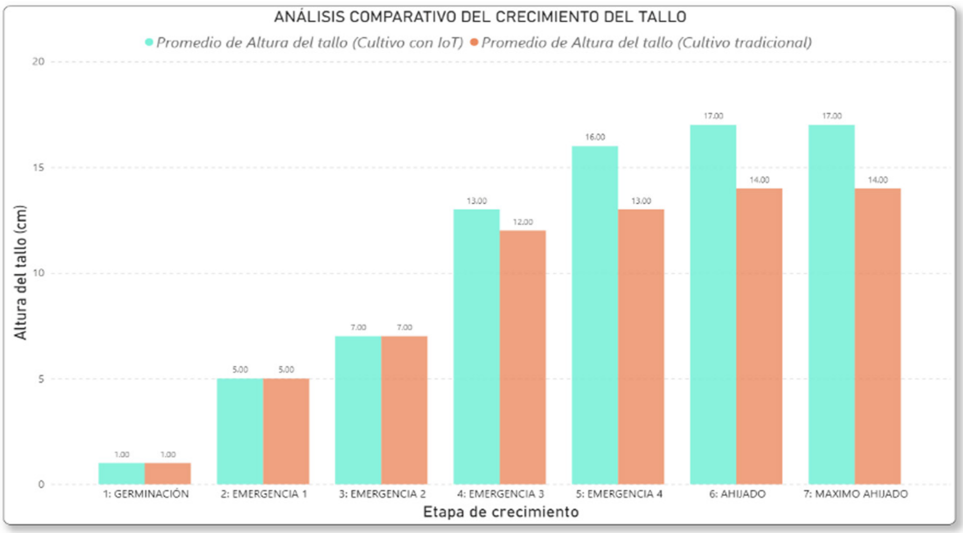

Fig. 12. Stem growth analysis

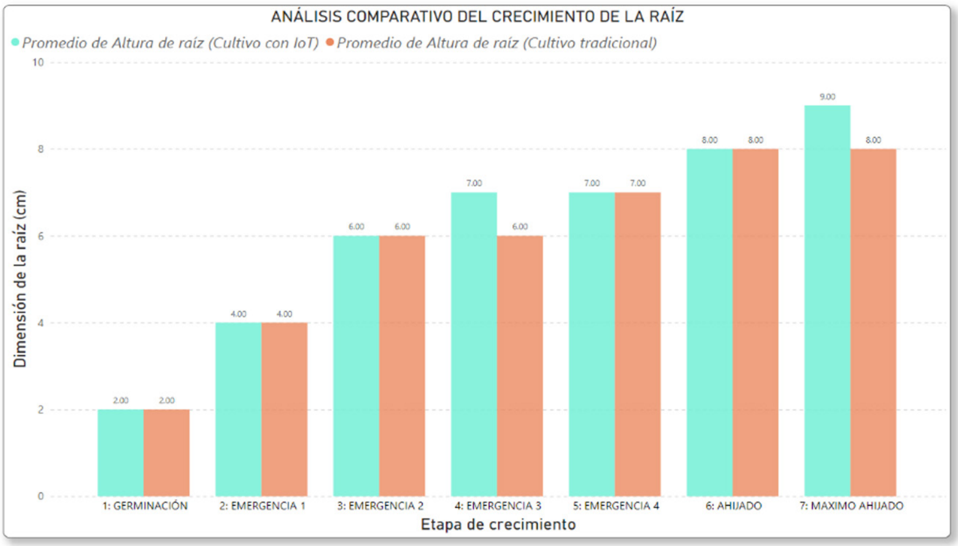

Fig. 13. Root growth analysis

Likewise, the forest green color was recorded, indicative of optimal plant health. These results highlight the effectiveness of IoT technology in improving seedling development, offering a controlled environment that significantly exceeds the conditions of traditional cultivation.

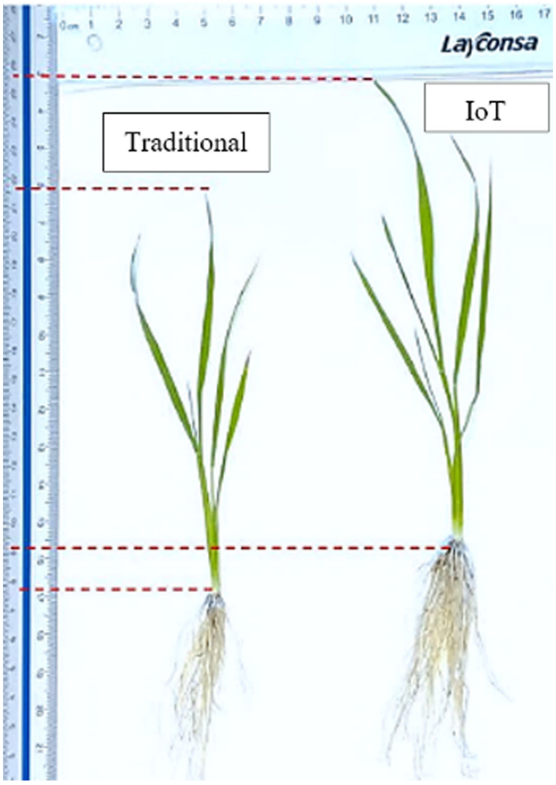

Fig. 14. *Oryza sativa* seedling

Finally, when examining the production of both crops after harvest, notable differences in yields were detected. In traditional cultivation, 940 units of seedlings with a total weight of 301 grams were obtained. In contrast, the group grown with IoT technology showed superior results, with a production of 1110 seedlings weighing 371 grams in total.

Fig. 15. Harvest of traditional crops

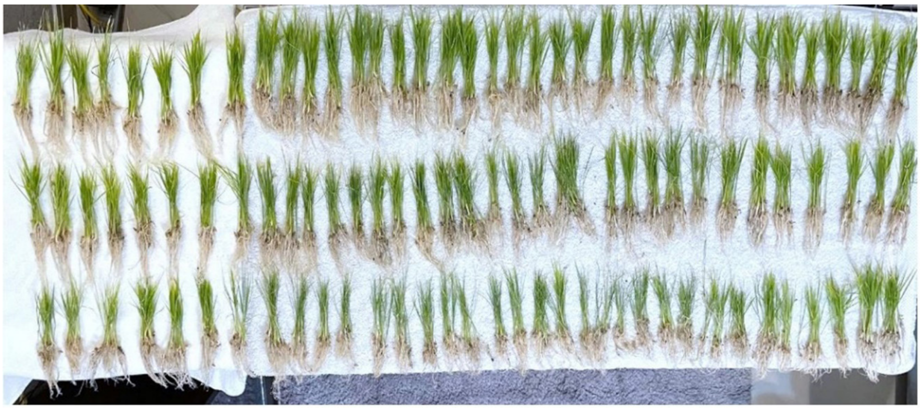

Fig. 16. IoT crop harvesting

These data allow us to conclude that the implementation of IoT technology in the cultivation of *Oryza sativa* resulted in a 22% increase in seedling production compared to the traditional method. This increase in yield highlights the effectiveness of IoT technology in optimizing growing conditions, significantly improving both the quantity and quality of the seedlings obtained.

4 DISCUSSION

The implementation of IoT technology in the cultivation of *Oryza sativa* seedlings in controlled greenhouses is presented as a valuable tool for the optimization of cultivation conditions and the improvement of plant quality and yield. This study offers a solid foundation in the application of advanced technologies in precision agriculture, providing quantifiable results.

One of the highlights of this study is the ability of IoT sensors, such as the JXCT and DHT21, to monitor critical variables in real-time, including soil moisture, soil and air temperature, pH, electroconductivity, and levels of nutrients such as NPK. This data allows for informed and timely decision-making, optimizing the use of resources and improving crop efficiency. Compared to previous studies, such as that of Acero et al. [5], the results of this study corroborate and expand on the existing evidence on the benefits of this technology.

Compared to traditional cultivation methods, the use of IoT showed a 22% improvement in seedling production, with a noticeable increase in stem height, root length, and root density. These results are consistent with the findings of Castro et al., who underscored how real-time monitoring and the ability to adapt quickly to changing conditions can improve plant health and reduce resource use. This study adds value by demonstrating these improvements in a greenhouse environment specifically adapted for growing *Oryza sativa* [6].

The importance of continuous monitoring and the ability to automatically adjust the conditions of the growing environment are commonalities with other research. In this study, automatic adjustment of irrigation, ventilation, and heating systems in response to data collected by the sensors was crucial to maintaining optimal conditions. Clopatofsky et al., in their study, provide a unique perspective on how IoT technology can be effectively applied in potato crops. The significant difference with this study is the focus on potato cultivation. *Oryza sativa* in a controlled greenhouse. offering a viable solution to improve production in regions with resource constraints or adverse weather conditions [7].

Finally, IoT technology provides an innovative and effective way to increase efficiency in growing *Oryza sativa* in controlled greenhouses.

5 CONCLUSION

In conclusion, the results obtained in this study underline the significant benefits of IoT technology in optimizing the cultivation of *Oryza sativa* seedlings in a controlled environment. The installation of sensors to monitor and adjust conditions such as humidity and air and soil temperature, along with nutrient levels, has resulted in a germination rate of 93%, which represents a considerable improvement over the capabilities of conventional cultivation. In addition, the use of IoT facilitated greater uniformity in growth, evidenced by a 22% increase in seedling production and improvements in key characteristics such as stem height and root length. These findings highlight the ability of IoT technology to not only improve the efficiency of using resources such as water and fertilizers but also to optimize plant growth and development, providing a more sustainable and effective method compared to traditional approaches.

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8 AUTHORS

Edwar A. Velarde Allazo graduated with a master's degree from Universidade Estadual de Campinas, Brazil, and specialized in Telecommunications from INICTEL-PERÚ. I earned my Systems Engineering degree from Universidad Católica de Santa María. I have expertise in digital signal processing, FPGA technologies, digital television systems, IoT, and artificial intelligence. My professional background includes roles at Telefónica del Perú, Telmex Perú, and Media Networks Latin. I currently serve as a research professor at the Technological University of Peru and CTO and co-founder of BG Latin America (E-mail: evelarde@utp.edu.pe).

Ing. Jimmy E. Vásquez Cori is a researcher at the Technological University of Peru. After studying networks and communications, he concluded studies in industrial engineering. He has dedicated himself to the technological area, focusing on programming, data analysis, and digital transformation (E-mail: u19304253@utp.edu.pe).