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A Review on Enhancing Edible MushroomYield through Precision Agriculture by Integrating Smart Monitoring

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***Abstract*— Edible mushroom production is highly regarded for its nutrition and environmental fitness however; the conventional culture has been facing challenges in quality and yield. Precision agriculture provides approaches to refine growth conditioning by the aid of sensors, Internet of Things (IoT), and data analytics. This research explores practical monitoring, modelling and control approaches in substrate preparation, mycelia growth and fruiting stages. Considering the enhanced uniformity, yield and resource use-efficiency, smart substrates as well as the integrated sensor-AI systems could be regarded as key to enable sustainable commercial mushroom cultivation [2].**

***Index Terms*— Edible mushrooms, precision agriculture, sensors, IoT, yield optimization, and machine learning.**

I. INTRODUCTION

Edible mushroom cultivation has become one of the most rapidly expanding sectors of sustainable agriculture due to their high nutritive value, shorter production cycles as well as their capability to utilize agricultural wastes for completion of the growth cycle. Nevertheless, the plant is very sensitive to environmental conditions such as temperature, humidity, carbon dioxide (CO2) level or substrate water content because of which it is difficult to achieve a consistently high yield and quality. Traditional farming techniques often rely on the experience of farmers and manual observation, leading to inconsistent yields and increased production costs. The global momentum of precision agriculture in recent years, including that contemporaneous with research on precision mushroom cultivation, has provided new opportunities to further optimize mushroom farming by means of automation, real-time environment control and data-driven operations. In order to provide the perfect growing environment for each stage of development, precision agriculture integrates technologies such as Internet of Things (IoT) sensors, wireless sensor networks, computer vision, machine learning or intelligent climate-control systems. Such smart monitoring systems can help farmers to accurately control the desirable microclimatic parameters, to reduce disease incidence, optimize medium conditions and minimize wastage of resources and merely, by collecting environmental and growth data constantly and analyzing it. Thus, implementations of smart monitoring technologies could effectively raise the yield of mushroom greatly, enhancing quality consistency and contribute to economic sustainability.

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These advances not only reduce the dependence on labor, but also create potential for increasing mushroom production even in rural and urban settings like vertical farming.

The numerous smart technologies being used in precision mushroom farming are examined in this review, along with their effects on yield enhancement and future prospects for creating fully automated, intelligent mushroom cultivation systems that can satisfy the growing demand for edible mushrooms worldwide.

A. Exiting System

In traditional mushroom cultivation, environmental parameters such as temperature, humidity, CO_2 concentration, and light are manually monitored and controlled. Instead of using exact data, farmers rely on their experience, which frequently results in irregular yields and subpar food. Manual systems are unable to respond dynamically to the changing environment in real time. In addition to being labor-intensive and resource-inefficient, these configurations use excessive amounts of water and electricity. Significant crop loss results from infections or contaminations that are only discovered after obvious symptoms manifest. In general, compared to contemporary precision agriculture technologies, conventional farming techniques are less scalable and provide little automation or traceability.

II. RELATED WORK

TABLE I. COMPARATIVE ANALYSIS OF LITERATURE SURVEY

Authors	Problem Statement	Methodology	Results	Conclusion	Challenges / Research Gap
Junifer B. Frenila, Oliver V.[5]	Urban areas face food insecurity, lack of farming space, and unreliable power in disaster-hit areas.	Designed a solar-powered, Arduino-controlled automated plastic box with humidity, temperature, fan, and sprinkler control.	Maintained 70–90% humidity, yielded ~250g oyster mushrooms every other day after 4 weeks.	Feasible for urban farming and disaster relief, improves food security in low space/power settings.	High initial solar setup cost, limited scalability, and optimization are needed for large-scale use.
Dr. B. Puviyarasi, G[1]	Manual cultivation causes inefficiency, disease spread, and misclassification.	IoT + ESP32 sensors for automation; CNN image processing for mushroom classification and disease detection.	Disease detection accuracy 94.35%, farm monitoring success 99.6%, robot accuracy 99.7%.	Effective system for automation, disease detection, and safe harvesting.	Focused mainly on classification and detection; integration with full automation still needed.
Gilda J. Taupa, Mia V. Villarica[3]	Traditional methods struggle with environmental monitoring, reducing yield.	Built solar-powered IoT with sensors, compared experimental vs. traditional groups, applied regression on growth data.	Significant improvements in cap diameter, height, stem count ($p<0.001$). No statistical difference in weight.	IoT improves mushroom growth and sustainability, effective for remote farms.	Initial cost barriers for small farmers, long-term scalability/affordability untested.
Oki Firmansyah[7]	Farmers struggle to maintain ideal mushroom growth conditions (22–30°C, 80–90% humidity).	Arduino Uno IoT with DHT11, LDR, ESP8266 sensors; fan, pump, lamp for control.	Lowered temperature in ~12.75 min, raised humidity in ~3 min, controlled light intensity 200–300 lux.	System effectively maintains growth conditions, reducing risk of crop failure.	Still prototype stage, lacks energy optimization and large-scale validation.
Rong-Yuan Jou, Hong-Cheng Chiu, Wu-Jeng Li[14]	Mushroom farming requires intensive manual inspection; labor shortage and health risks persist.	Built ROS-based IoT mobile robot with navigation, robotic arm, LiDAR, thermal sensors, YOLOv4 yield prediction.	Automated patrol, environment data collection, real-time visualization achieved.	Reduces labor needs, supports smart agriculture automation.	System is complex and costly; farm-scale validation missing.
Shuling He, Dejiang Kong, [16]	Traditional flipped classrooms ineffective in long, complex mushroom	IoT-based flipped classroom with secure resource transmission for	Higher student success in edible mushroom cultivation labs.	IoT-enhanced flipped classroom is more effective and stable.	Needs infrastructure and IoT in schools; scalability for large cohorts not studied.

	cultivation courses.	experimental teaching.			
Mengchao Ren, Shuzhen Yang, Wanhe Du, Tao Yu[4]	Existing segmentation methods fail on small, clustered mushroom caps.	Collected dataset, applied augmentation, trained Mask2Former, compared with U-Net, Mask R-CNN, DeepLab.	Achieved AP of 96.73%, outperforming others.	Effective for monitoring small seafood mushroom caps.	Limited dataset, tested only on seafood mushrooms; generalization to other species required.
Ishaan Rana, Harshita Chaudhary, Ankit Gupta[10]	Conventional farms lack precision monitoring, causing inefficiency.	Arduino with ground sensors, cloud storage, automated environmental control.	Optimal growth conditions maintained, reduced waste and crop loss.	Smart systems enhance yield, sustainability, and profits.	Deployment and integration cost high; large-scale trials needed.
Nushrat Jahan Ria, S.M.S. Islam Badhon [15]	Mushroom poisoning fatalities due to difficulty identifying poisonous varieties.	Reviewed ML methods (SVM, DT, RF, KNN, ANN).	ANN had highest accuracy across reviewed studies.	Deep learning promising for mushroom safety.	Lack of real-world deployment and datasets in Bangladesh context.
Zhenghao Xu, Jie Huang, Shuzhen Yang[11]	Traditional methods lack robustness in classifying growth stages.	Applied EfficientNetV2 deep learning model.	Achieved 96% accuracy in growth stage classification.	Deep learning enables precise cultivation stage management.	Dataset limited, real-world farm validation required.

This review paper explores various advanced technological methods aimed at enhancing mushroom cultivation, emphasizing significant innovations suggested by researchers along with the challenges and limitations faced during their implementation is as shown in table.1 below. A few technologies have been applied to improve mushroom cultivation and each research has its own advantages and limitations. Puviyarasi et al. [1] combined it with IoT based ESP32 sensors and CNN image processing for monitoring in real time, but this solution continues to be too complex and expensive for smaller farms.

Rana et al. [2] used Arduino Uno and LM35 sensors with validation through simulation however no real-world results were reported. Ismail et al. [3] used Decision Tree and PCA to classify on static datasets that loses real time adaptability. Rosse et al. [4] presented a block chain-IoT framework for traceability while scalability issues still can be observed. Shakir et al. [5] did SENSEPACK, an IoT automation system showing good results but still with sensor maintenance issues.

Kilifarev et al. [6] presented an Arduino-based low-cost smart system suitable for small farms but with limited data analytics and precision. Yodnil et al. [7] integrated IoT with eWelink application, but it was prone to high losses due to high dependence on clean and reliable internet. Salamat et al. [8] used Wireless Sensor Networks for climate automation but had problems with network stability and distance. Fuady et al. [9] have already evaluated ELM and BPNN, and reported ELM was more efficient but involving heavy computational cost. Maruf et al. [10] enhanced demand predictions through machine learning but were met with challenges of lack of sharing farm data. Researchers have utilized a variety of technological advancements to enhance mushroom cultivation, with each research effort presenting distinct advantages while encountering particular challenges. Puviyarasi et al. [1] adopted the integrated IoT and ESP32 sensors with CNN-based image processing for real-time plant health monitoring, but prediction solution was complicate and expensive to deploy on small scale farmland.

Rana et al. [2] used Arduino Uno and LM35 sensors by means of simulation-based analysis, but they did not validate their approach via real application results. Ismail et al. [3] Used Decision Tree and PCA based classification over static data that was limited to real-time adaptation. Rosse et al.[4] suggested a blockchain-IoT architecture for traceability, though scalability issues remain.

Shakir et al. [5] developed SENSEPACK as IOT automation system which achieved promising results but suffered from issues related to sensor maintenance. Kilifarev et al. [6] provided an inexpensive Arduino-based measuring system for small farms, however data analytics and precision were restricted. Yodnil et al. [7] fused eWelink app with IoT that improved profits, but required consistent internet support. Salamat et al. [8] used Wireless Sensor Networks for climate automation, but experienced problems related to Network stability and range.

Fuady et al. [9] compared ELM with BPNN and found the former to be more effective, but it still required intense computations. Maruf et al. [10] developed better demand prediction using machine learning, but due to limited sharing of farm data they have not been able to reliably secure ties with retailer.

III. PROPOSED SYSTEM

The Precision-Based Smart Mushroom Cultivation System transforms traditional, labour intensive, wasteful and hard-to-predict manual farming into an intelligent, closed-loop and highly automated manner. It does so by using IoT sensors for continuous measurement of the environment (temperature, humidity, CO2) with automation and data analytics. The vital distinction is to shift from passive observation to predictive control that can anticipate overheating and adjusts lighting levels, ventilation and water flow proactively before they can take a toll out on the plant. Furthermore, AI-based anomaly detection provides early alerts for a possible disease or contamination in order to minimize the loss of crops through energy efficient control-systems that reduce the operating cost. By capturing and processing data from every cycle in real-time, growers get traceability and actionable insights to continually optimize upcoming harvests to achieve consistent quality and commercially viable outputs.

A. Comparing Traditional and Precision Farm

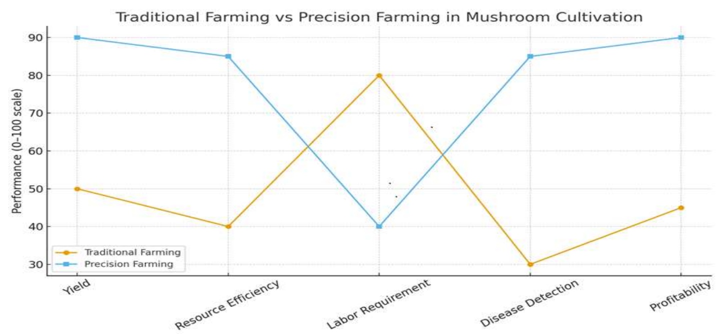

Figure 1. Traditional v/s Precision Farming in Mushroom Cultivation

IV. SYSTEM ARCHITECTURE

The basic architecture of a precision agricultural system for monitoring the yield of mushroom production is as shown in "fig.2.", and uses several technologies in unison to increase the overall generation. Initial factors that influence the growth and well-being of the mushroom depends on several factors such as substratum, mushroom spawn and local conditions of the environment. Further these factors are continuously monitored by sensor networks to determine the temperature, humidity, moisture and carbon dioxide (CO_2) even visual data in form of images. For predicting growth trends the collected data is sent to a Data Acquisition and Cloud Integration system where advanced techniques such as Artificial Intelligence (AI) & Machine Learning (ML) technique are used to process the data and decision Supporters execute control logic and send notifications for relevant adjustments. From these choices, actuators and controllers activate the systems for automatic irrigation, lighting, temperature and humidity control, airflow management, CO_2 levels. This results in a stable and consistent microclimate in the Optimized Growth Chamber finally leading to Yield Enhancement with improved quality.

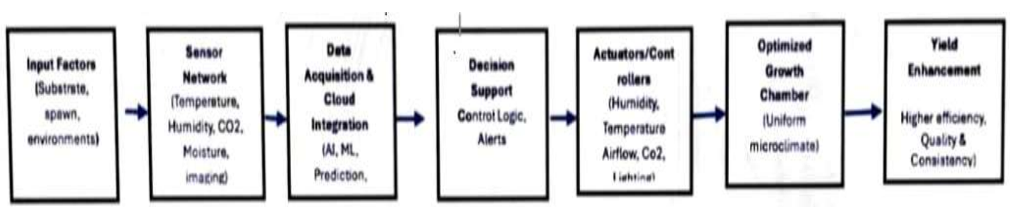

Figure.2. Workflow of a precision agriculture system for mushroom cultivation

V. OPEN CHALLENGES

Research on adopting precision agriculture for growing mushrooms has revealed a number of difficulties. It is challenging to get precise, real-time data on temperature, humidity, CO_2, and light, and practical implementation is constrained by the high cost of sensors, IoT devices, and automation systems. Since each species of Mushroom requires different temperature based on the cultivation regions hence it is challenging to develop specific sensors that are to be integrated with AI models to dynamically adjust with evolving environmental control systems. Large amounts of environmental and growth data were difficult to collect, manage and analyze by the farmers and researchers due to lack of technical knowledge of integrating various heterogeneous devices. Further concerns regarding the resources and its energy efficient usage were also raised by the need to maintain controlled settings. These difficulties also applied to the actual study process, such as restricted access to facilities for experiments, variations in growth conditions, substrate, and the challenge of reliably reproducing findings among investigations.

VI. Conclusions and Future Enhancement

Mushroom production could be significantly enhanced by precision agriculture, but there are still a number of obstacles to overcome. There are presently very few real-time monitoring tools and also installing sophisticated sensor systems can be very costly. The accuracy and adaptability of AI-based temperature, humidity, and CO2 control for various mushroom species is still lacking. Automation is made more difficult by species-specific needs and climate changes. Nevertheless, research is still being done to create more intelligent and reasonably priced technologies that promise future improvements in output, quality, and sustainability.

In order to identify early infections there is a need for automated environmental control. future mushroom farming will rely on AI, IoT, and smart sensors, with very little physical labour as these equipment will assist in maintaining precise CO2, temperature, and humidity conditions. Mechanization and environmentally friendly techniques like bio-inoculants, renewable substrates, and water recycling will further reduce the impact on the environment and labour. Traceability, data accuracy, and decision-making will all be enhanced by block chain and cloud-based technologies. When combined, these developments will provide a more intelligent, economically robust, and sustainable mushroom farming ecology.

References

[1] B. Puviyarasi, G. Logaadhashini, P. D. Shruthi, and S. Suveka, “Smart Mushroom Cultivation with Classification of Mushrooms and Disease Detection using Image Processing,” IEEE, 2024.

[2] A. V. Aravindhaa, R. J. Sanjanaa, M. R. A. T. Mithul, C. Rani, and M. Rajesh Kumar, “Using IoT and ML Techniques to Advance Sustainability in Mushroom Cultivation,” IEEE, 2024.

[3] G. J. Taupa, A. A. Vinluan, and M. V. Villarica, “Optimizing Oyster Mushroom Cultivation with Solar-Powered Internet of Things: A Multiple Regression Analysis of Growth Metrics,” IEEE, 2024.

[4] M. Ren, S. Yang, W. Du, and T. Yu, “Evaluation of Mask2Former’s Use in Classifying Small Mushroom Caps of Seafood Mushrooms,” IEEE, 2024.

[5] S. I. Rahman, S. C. Iwase, A. I. A. Tapotosh, and D. M. Farid, “A Comprehensive Study on Machine Learning and Precision Agriculture in Bangladesh,” IEEE, 2023.

[6] J. B. Frenila, O. V. Silvela Jr., and A. C. Paglinawan, “A Case Study of a Solar-Powered Automated Mushroom Cultivation in a Plastic Box: A Novel Approach to Urban Farming,” IEEE, 2015.

[7] Sumiati, E. Ahmad, A. M. Ridwan, Maulani, and O. Firmansyah, “Prototype of Temperature and Humidity Control System for Oyster Mushroom Cultivation Using Arduino Uno Based on the Internet of Things,” IEEE, 2021.

[8] H. V. Rosse, C. R. D. Camargo, E. Gonçalves, K. Sabiri, and J. P. Coelho, “Chain of Trust Integrating IT and Blockchain to Certify Wild Mushroom Growth Quality,” IEEE, 2024.

[9] K. Yodnil and A. Sonthitham, “Development of Dual-Function Environment Control System for Grey Oyster Mushroom Greenhouse Applying Smart Farm Technology,” IEEE, 2024.

[10] I. Rana, H. Chaudhary, A. Gupta, S. Tyagi, R. Mittal, and P. Chawla, “Smart Mushroom Cultivation: Enhancing Growth Conditions through Sensor-Based Monitoring,” IEEE, 2023.

[11] Z. Xu, J. Huang, S. Yang, and X. Zheng, “Deep Learning-Based Classification of Seafood Mushroom Growth Stages,” IEEE, 2023.

[12] H. Kilifarev and D. Genkov, “Development of a Microcontroller-Based Automated Greenhouse Cultivation System for Mushrooms – Hardware,” IEEE, 2023.

[13] A. M. Pulumbarit et al., “Sprout It: A Data-Driven Approach to Mushroom Farming with Batch Tracking, Yield Calculation, and Harvest Optimization,” IEEE, 2023.

[14] R.-Y. Jou, H.-C. Chiu, W.-J. Li, and H.-D. Shih, “Autonomous Mobile Intelligent IoT Platform in Mushroom Cultivation,” IEEE, 2022.

[15] N. J. Ria et al, “State-of-the-Art Research in Edible and Poisonous Mushroom Recognition,” IEEE, 2021.

[16] S. He, D. Kong, J. Yang, L. Ma, and Y. Chang, “IoT-Based Edible Mushroom Cultivation Experiment Using a Flipped Classroom Teaching Approach,” IEEE, 2020.

[17] E. N. Salamat and J. Yoo, “Development of Growing House Control System Using Wireless Sensor Network,” in Proc. 20th Int. Conf. Control, Automation and Systems (ICCAS), IEEE, 2020.

[18] M. A. Maruf, A. Azim, and S. Mukherjee, “Mushroom Demand Prediction Using Machine Learning Algorithms,” in Proc. IEEE Int. Conf. Big Data, 2020.

[19] S. Shakir et al, "Design and Implementation of SENSEPACK: An IoT-Based Mushroom Cultivation Monitoring System," IEEE, 2019.
[20] S. Sinthupuan, V. Viroonrat, and S. Saengyot, "Controlling the CO_2 and CO Condition of Straw Mushrooms," IEEE, 2019.
[21] V. Moysiadis et al, "A System Architecture for Smart Farming on Mushroom Cultivation," IEEE, 2022.
[22] L. Symochko and A. Ravlikovsky, "Agroecological Aspects of Cultivation of Shiitake Mushroom in Ukraine," IEEE, 2019.
[23] S. Ismail, A. R. Zainal, and A. Mustapha, "Behavioral Features for Mushroom Classification," IEEE, 2018.
[24] G. M. Fuady et al, "Comparison of Extreme Learning Machine and Back Propagation Neural Network for Temperature and Humidity Control of Oyster Mushroom Based on Microcontroller," IEEE, 2017.
[25] F. Shamrat et al, "A Web-Based Application for Agriculture: Smart Farming System," IEEE, 2020.
[26] M. H. Al-Obaidi and K. M. Al-Aubidy, "Wireless Sensor Network-Based Real-Time Monitoring and Control for Factory Automation," IEEE, 2018.
[27] A. Marzuki and S. Y. Ying, "Environmental Monitoring and Controlling System for Mushroom Farm with Online Interface," IEEE, 2017.
[28] T. Kaewwiset and P. Yodkhad, "Automatic Temperature and Humidity Control System Using Fuzzy Logic Algorithm for Mushroom Nursery," IEEE, 2017.
[29] "IoT Applications in Agriculture," IoT for All. [Online]. Available: https://www.iotforall.com/iotapplications-in-agriculture.
[30] "Precision Agriculture Support System," YouTube, 2018. [Online]. Available: https://www.youtube.com/watch?v=q0FnMD2_0Fw.
[31] "Directorate of Mushroom Research, Solan: White Button Mushroom Cultivation," YouTube. [Online]. Available: https://www.youtube.com/watch?v=T8LrWAFq9g&t=119s.
[32] K. G. Liakos et al, "A Review of Machine Learning in Agriculture," IEEE, 2018.
[33] S. Afrin et al., "Analysis of Soil Properties and Climatic Data to Predict Crop Yields and Cluster Agricultural Regions of Bangladesh," IEEE, 2018.
[34] F. Ahmed et al., "Using Data Warehousing, Machine Learning, and Visualization to Investigate Factors Influencing Rice Yields in Bangladesh," IEEE, 2017.
[35] M. S. A. Mahmud et al., "Smart Environmental Monitoring of Mushroom Cultivation Using IoT," IEEE, 2016.
[36] T. Islam, T. A. Chisty, and A. Chakrabarty, "A Deep Neural Network Approach for Crop Selection and Yield Prediction in Bangladesh," IEEE, 2018.
[37] A. M. S. Ahamed et al., "Applying Data Mining Techniques to Predict Crop Yields and Recommend Planting Strategies in Bangladesh," IEEE, 2015.
[38] M. M. Rahman, N. Haq, and R. M. Rahman, "Use of Data Mining Tools for Rice Yield Prediction on Clustered Regions of Bangladesh," IEEE, 2014.
[39] Y. Chen and G. Zhou, "Investigation of Carbon Dioxide Gas Monitoring Platform Based on Wireless Sensor Networks," IEEE, 2011.
[40] M. H. Mondal, "Bangladesh Crop Agriculture: Opportunities and Challenges," IEEE, 2010.