The Prototype of Smart Farming System for Installation to Greenhouse using the Internet of Things Technology

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Abstract. *This paper proposes a prototype for a smart farming system intended for integration into traditional greenhouses, transforming them into automated environments. Utilizing Internet of Things (IoT) technology, the system dynamically adjusts the conditions to optimize the growth of vegetables. The research methodology consists of seven sequential steps: (1) Exploring possibilities through study and analysis, (2) gathering information on the cultivation of vegetables, (3) designing and developing the prototype system, (4) installing the system in an experimental greenhouse, (5) conducting experiments to observe vegetable growth, (6) collecting data on vegetable growth in the experimental greenhouse, and (7) modifying and enhancing the system based on the collected information. The results indicate that the smart farming system prototype is effective for cultivating Green Oak lettuce. When compared to a non-smart farming system, the average results show significant improvements: canopy width increased by 10.59%, plant height by 11.42%, trunk width by 23.60%, and root length by 14.37%.*

Keywords:

Internet of Things, smart farming, greenhouse

1. Introduction

The Internet of Things (IoT) was coined by Kevin Ashton, director of the Auto-ID Center at the Massachusetts Institute of Technology (MIT), who introduced it in 1999, defining IoT technology as an intelligent infrastructure linking objects, information, and people through computer networks [1]. IoT is being applied in various fields, such as healthcare, smart homes, smart cities, industry 4.0, and agriculture [2]. IoT technology has resulted in agriculture and has been applied to various agricultural activities, such as farm management, farm monitoring, autonomous agricultural machinery, drones, and greenhouse environmental control. IoT is used in agriculture to control the environment of greenhouses, such as water flow, temperature, relative humidity, soil moisture, pH, and illumination [3]. Application of IoT in checking the temperature and humidity in a mushroom cultivation house [4]. Thailand is an agricultural country, where the traditional occupation of the Thai people is agriculture, followed by industrial occupations and commerce [5]. In the Northeastern Thai people engaged in agriculture [6], and the provinces in the Northeastern are a group of provinces targeted to improve the quality of life and increase income from many agencies, both government and private sectors. There are various projects to support them to have higher incomes, reduce inequality in human resource development, and make it a self-reliant society. The most support goes to farmer groups such as rice community enterprises, local fabric community enterprises, non-toxic vegetable farmer groups, and organic farming groups. In the past, society has had problems with the COVID-19 virus. And various diseases, causing most people to take better care of their health [7]. In taking care of eating agricultural products, consumers are paying attention to the issue of contaminants and residues. As a result, the production methods of agricultural products must be changed to take care of production and produce non-toxic agricultural products [6]. Especially agricultural products that are vegetables. Because there is a problem with insects about diseases of vegetables, this causes planting to use chemicals [8, 9]. Most farmers grow vegetables according to seasonal conditions, which have low prices. This is because during the season there will be a large quantity of the same type of plants released into the market, causing the price to be low, and growing vegetables out of season will encounter problems. such as in summer, it has been found that vegetables are exposed to strong sunlight, causing leaf burns. The soil dries out quickly, the vegetables lack water, and a lack of water sources makes planting in the summer difficult [10]. As for the rainy season, it was found that when it rains continuously, the plant roots rot and eventually die, and the rain washes away the soil, causing the vegetables to fall. In addition, insects bite and eat vegetables. As a result, farmers must use pesticides, causing chemical residue. The farmers solved the problem by growing vegetables in greenhouses that were covered with netting to prevent insects from eating the grown vegetables. Instead of using chemical insecticides, the resulting vegetables will be non-toxic vegetables, which are demanded by the market and have a high value. But when growing in a greenhouse, there is a problem with heat in the greenhouse because the weather is hot. Farmers must lift the covers during the day, causing insects to eat the vegetables. Therefore, to solve the problems mentioned in this research, Internet of Things technology (IoT) has been introduced to help manage the watering system. Humidity adjustment system in the greenhouse [4,11-13]. And an automatic fertilizer application system. Vegetable plants of different ages require different amounts of water, humidity, and fertilizer [14]. The system developed is a prototype of an intelligent system for installation in farmers' vegetable greenhouses using Internet of Things technology. The developed system can be used with existing greenhouses and a system that uses energy from solar cells. The system has a system to control watering, adjust humidity, and add fertilizer. According to the age of the vegetables that is appropriate to the type of vegetables, it helps increase the value of the vegetables and can be planted out of season. As a result, farmers have increased income.

2. Problem Statement and Preliminaries

This research proposed the prototype of the smart farming system for installation in the traditional greenhouse and an automated greenhouse and developed a system that can adjust the environment to be suitable for out-of-season vegetables using Internet of Things technology (IoT) [11]. The theory review and related research in the research we have studied have found the prototype of the smart farming system for installation in greenhouses using the Internet of Things technology. It is necessary to use a microcontroller to control and command. By receiving values from various sensors, when the received value matches the specified value, the microcontroller will send commands to the specified channels to instruct the switch system to operate. The methodology of the research was designed into seven steps, as follows: 1. study and explore possibilities, 2. study and information on growing vegetables, 3. design and develop a prototype system, 4. installing the system in the experimental greenhouse, 5. experiment with growing vegetables, 6. collect information on growing vegetables in the experimental greenhouse, and 7. modify and improve the system.

2.1 The study and exploring possibilities

The process of studying and selecting vegetable growing groups. To be a space for testing and installing a prototype of smart farming system. The selection of farmers who are ready is based on the fact that the farmer must already have a greenhouse. By interviewing six representatives of farmers and selecting one person to install and test the system.

2.2 Study and information on growing vegetables

The process of studying information on growing each type of vegetable by the farmers of the selected group. study the process of growing vegetables and record the amount of water, fertilizer, environment, temperature, and humidity at different stages of the life of vegetables and find the appropriate value [15][16]. The study of vegetable growing information was obtained by interviewing growers of Green Oak lettuce and the information from the research is summarized as shown in Table 1.

Table 1 Factors for growth of Green Oak lettuce

Factors for growth	Green Oak lettuce
Planting period	30-35 Days, not including 15 days of seeding
Temperature	25-30 Celsius
Relative humidity	65-90%
Soil moisture	50-70%
Fertilizing	1 time a week
Sunlight	At least 6 hours per day
Watering the plants	Twice a day at 7:00 a.m. and 4:00 p.m.

2.3 Design and develop a prototype system

The process of designing and developing a prototype system. We have designed and developed a prototype system, as shown in Fig. 1, consisting of 3 main components: a power supply unit, a control unit, and a sensor unit, as shown in Fig. 1.

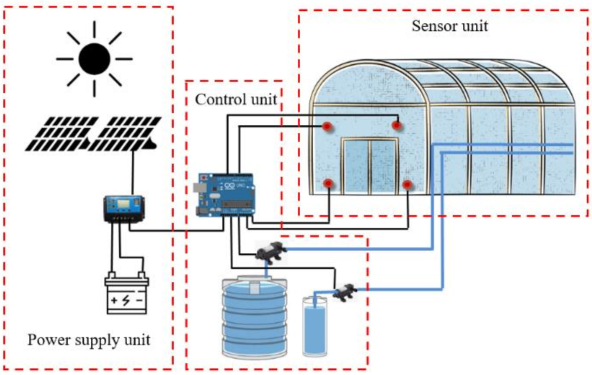

Fig. 1 Smart farming system workflow diagram

2.3.1 Power supply unit

It is a set for producing and distributing electricity to various sets of the system, consisting of solar panels, a control charger, and a battery.

1) Solar panels are used to convert solar energy into direct current (DC) power electrical energy. This paper uses a monocrystalline solar cell panel was used. Monocrystalline silicon solar cells are a type produced from silicon. Provides high power and requires minimal space for installation. Has

the longest lifespan Produce more than one type of electricity. polycrystalline When in low-light conditions, when selecting the size of the solar cell panel, consider the daily operation of the system. The system uses an average of 110.86W of energy per day, so it should use a 150W solar cell panel or higher. Therefore, the researcher chose a 300W solar cell panel to support the addition of various modules in the future, which does not require increasing or changing the size. Solar panels for higher wattage.

2) Control chargers are the servers that receive direct current to charge batteries in series and draw electricity from the battery to supply direct current to devices such as microcontroller boards, diaphragm pumps, and sensors. This paper chooses a control charger of the PWM (Paluse Width Module) type, suitable for an off-grid solar system that does not have a lot of electricity, is cheap, and works with a digital system. It helps save energy and control the electric charge entering the battery. When selecting the size of the charger controller, consider the following: A 300W solar cell panel charges 12V (300W/12V = 25A). The result is 31.25A, which equals 25A times the safety factor value of 1.25. Therefore, a 60A charger controller has been chosen, which has twice the current to increase the charging speed.

3) The battery serves for storage and supplies 12 volts of direct current electricity, 100Ah, to the control charger, and the electricity from the battery can be directly used for devices such as microcontroller boards, diaphragm pumps, and sensors. Battery selection is calculated based on daily operation. The system uses an average of 110.86W of energy per day (110.86W multiplied by the average number of hours per day by 3.5 hours equals 388Wh). The operating system uses 12V electricity (388 / 12 = 32.33Ah). Therefore, a 100Ah battery was chosen to protect the battery in the event of an accident. Irregularities in charging or cloudiness may cause poor charging, so we choose to use a 100Ah battery. This battery will be enough to power the system for 3 days without needing to be charged.

2.3.2 Control unit

In this control unit, a microcontroller device used to control the operation of the prototype of the smart farming system serves to receive data from sensors and process the received values as income for commands to devices such as diaphragm pumps. This paper uses Arduino UNO R3 because it is inexpensive and the number of pins is sufficient for use. And the designed system is not a system connected to the Internet, so it does not need a board with built-in Wi-Fi, such as the NodeMCU ESP8266. And if, in the future, you want to do a monitoring system via the Internet, you can add a module to Arduino UNO R3.

2.3.3 Sensor unit

In the sensor section. It serves to receive the values and send them to the controller so that the controller knows the environment that occurs within the greenhouse. The sensor consists of a temperature sensor, an air humidity sensor, and soil moisture sensors. Installation of humidity and temperature sensors, installed at 2 points at the front and back of the greenhouse. The distance from the greenhouse cover is 1 metre, and humidity control does not have to cover the roof. Because the heat above the roof causes the humidity sensor to measure less, but there is high humidity in the lower area, causing the mist pump to work and causing the soil to become wet, resulting in root rot. For the soil moisture sensor, it measures moisture at 4 points in all 4 corners of the vegetable plot.

We have designed a prototype of a smart farming system for installation in the greenhouse, as shown in Fig. 2. And write a programs for the control unit to receive the values from the sensors and send commands to the devices as shown in Table 2. A prototype of a smart farming system for installation in the greenhouse will consist of the following main components: solar panels (No. 1), controller charger (No. 2), circuit breaker (No. 3), battery (No. 4), control unit (No. 5), and pump (No. 6).

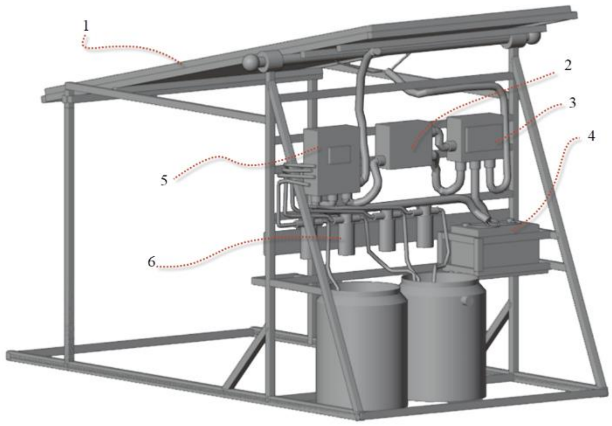

Fig. 2 Design the prototype of a smart farming system

Table 2 Operation of the device control system

Condition	Watering pump	Fertilizing pump	Fog pump
Temperature ≥ 30	off	off	on
Temperature < 30	off	off	off
Relative humidity ≤ 65	off	off	on
Relative humidity > 65	off	off	off
Soil moisture ≤ 50	on	off	off
Soil moisture > 50	off	off	off
7:00 a.m. and 4:00 p.m.	on	off	off
Every 7 days	on	on	off

2.4 Installing the system in the experimental for greenhouse

This step involves installing a prototype of a smart farming system for installation in the greenhouse shown in Fig. 3. to test the system's functionality.

Fig. 3 Prototype of smart farming system installation to the greenhouse

2.5 Experiment with growing vegetables

This step is an experiment in growing vegetables by experimenting with growing the same types of vegetables as shown in Fig. 4. They are grown in greenhouses that are equipped with a prototype of the smart farming system. and growing in greenhouses that do not have an installed prototype of the smart farming system to collect data on vegetable growth for measuring vegetable growth. The Green Oak lettuce seeds used in the experiment had a germination rate of 90% and were grown in seed trays for 15 days and then planted in the field. Before planting, the soil must be prepared by mixing the soil for planting in both plots. The ratio for preparing the soil consists of cow manure, rice husks, loose soil, or rice field soil (1:1:2, respectively), mixed well, and then sprinkled with water to keep it moist, not wet. The experimental period from planting to harvest is in September, which is the rainy season in Thailand. Fertilizing: Apply fertilizer every 7 days, 300 milliliters (ml) each time, after planting until the end of the harvest period (4 times). It is an organic liquid fertilizer, not mixed with chemicals. By means of bringing fertilizer through a pump and mixing it with the watering system.

Fig. 4 Growing vegetables in greenhouses

2.6 Collect information on growing vegetables in the experimental greenhouse

The collected data for growing vegetables in the experimental greenhouse for comparison with growing in a greenhouse that did not use automatic systems. For greenhouses that do not have the smart farming system installed, the farmer will take care of the planting according to the farmer's guidelines. To compare the obtained products. The growth rate in each life stage of vegetables. This research is designed to collect data on vegetable growth. The experimental planting in each plot will be planted in 12 rows, 4 plants per row, for a total of 48 plants. Divided into 3 groups of 4, 12 plants per group were randomly selected to collect data; 1 plant per group was planted once a week to be a sample group. Data collection: After 35 days of collection, data will be obtained from a total of 20 samples, accounting for 41.67% of the total number of Green Oak lettuce. In recording the growth data of Green Oak lettuce. Will record information as shown in Table 3.

Table 3 Form recording data on the growth each week of Green Oak lettuce, and example of filling out information

Date..3../Sep./2023.				
Group	**Use the smart farming system**			
	Canopy width (cm.)	Plant height (cm.)	Trunk width (cm.)	Root length (cm.)
1	12.00	12.00	1.80	5.80
2	14.00	14.00	0.26	5.00
3	18.00	15.50	0.44	5.50
Group	**Not using the smart farming system**			
	Canopy width (cm.)	Plant height (cm.)	Trunk width (cm.)	Root length (cm.)
1	6.00	5.70	0.20	2.00
2	12.60	9.60	0.37	2.00
3	15.00	13.00	0.38	4.50

2.7 Modify and improve the system

The process of fixing and improving the system it is an adjustment to the electrical system, sensor system, and operating control system. By taking the problems that occurred during the experiment and adjusting them to a prototype of a smart farming system for installation in greenhouse using the Internet of Things technology. The system works efficiently and appropriately for the growth of Green Oak lettuce.

3.Results and Discussion

The results of development a prototype of a smart farming system for installation in the greenhouse using Internet of Things technology. The experiment results were divided into two parts: a prototype of a smart farming system for installation in the greenhouse, and the results of an experiment in planting Green Oak lettuce.

3.1 The experiment results of testing a prototype of a smart farming system

Installation to the greenhouse using Internet of Things technology found that when installing and testing use, as shown in Fig. 3, the experiment of growing Green Oak lettuce for a period of 35 days found that the power supply unit was able to supply sufficient electricity for the system, with the electricity used 24 hours a day reducing down to not less than 11.00 volts, and the charging system can fully charge the battery every day even though some days there is little sunlight. Control unit: the experiment found that it can work according to commands correctly, can read the values from the sensors, and can order work to the equipment correctly according to the conditions specified in the program. Sensor unit: the experiment found that the temperature sensor and relative humidity sensor work normally. As for the soil moisture sensor, it was found that after 20 days, the relative surface of the sensor was etched, causing the measured value to be inaccurate, as shown in Fig. 5.

Fig. 5 Damage to the soil moisture sensor

3.2 The experiment results of the Green Oak lettuce planting

The collecting data on the growth of Green Oak lettuce and making comparisons between planting using the smart farming system and without using the smart farming system. The results of the experiment showed that growing Green Oak lettuce using the smart farming system grew better than those growing without smart farming system. The average canopy width was 15.87 cm., 1.68 cm. higher than those without smart farming system, accounted as 10.59%. Plant height average is equal to 16.02 cm., 1.83 cm. more than without smart farming system, accounted as 11.42%. Trunk width average is equal to 0.89 cm., 0.21 cm. more than without smart farming system, accounted as 23.60%, and the average Root length is 5.22 cm., 0.75 cm. higher than those without smart farming system, accounted as 14.37%. are shown in Table 4. And Comparisons Green Oak lettuce growth between a smart farming system and without using the smart farming system shown in Fig. 6.

Table 4 Green Oak lettuce growth information

Group		Use the smart farming system			
		Canopy width (cm.)	Plant height (cm.)	Trunk width (cm.)	Root length (cm.)
1	$\bar{x}$	17.20	17.10	1.08	5.46
	SD	3.87	4.15	0.68	0.41
2	$\bar{x}$	15.60	15.50	0.89	5.20
	SD	6.37	3.35	0.37	1.50
3	$\bar{x}$	14.80	15.46	0.71	5.00
	SD	6.49	3.50	0.42	0.00
Average of $\bar{x}$		15.87	16.02	0.89	5.22
Group		**Not using the smart farming system**			
		Canopy width (cm.)	Plant height (cm.)	Trunk width (cm.)	Root length (cm.)
1	$\bar{x}$	14.32	13.66	0.75	3.90
	SD	4.83	5.70	0.59	1.62
2	$\bar{x}$	14.34	14.64	0.63	5.10
	SD	6.18	3.57	0.35	0.80
3	$\bar{x}$	13.90	14.28	0.65	4.40
	SD	7.31	3.31	0.40	0.49
Average of $\bar{x}$		14.19	14.19	0.68	4.47

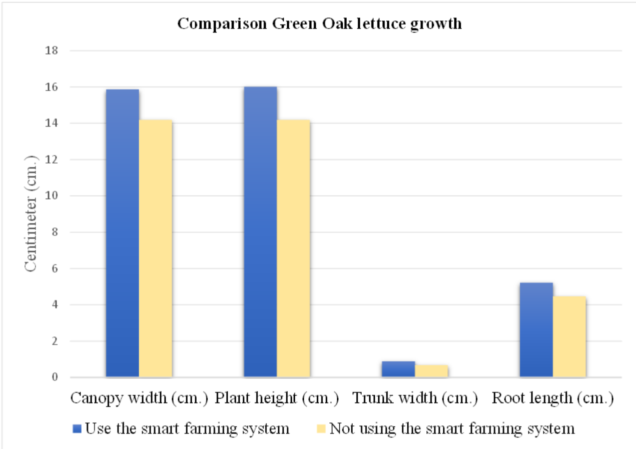

Fig. 6 Comparison Green Oak lettuce growth

4. Conclusions

The prototype of a smart farming system for installation in the greenhouse using Internet of Things technology. Able to control the changing environment at each time very well. But because the greenhouse is a closed system, watering or spraying too much fog makes the soil in the planting plot too moist. This causes the vegetables to develop root rot, resulting in the growth of Green Oak lettuce being slow or rotting and dying. To solve the problem, we have adjusted the watering settings and tried changing the sprinkler heads to water thoroughly and without making the ground too wet. On days with high heat, the system will spray fog several times. It can cause the ground to become wet. Reducing the watering time for Green Oak lettuce can solve the problem, and the soil moisture sensor must be changed to a metal pin type that is resistant to corrosion by soil acids. The prototype developed supports greenhouses measuring 4 by 8 meters. Supports greenhouses as large as 6 x 12 meters. If you want to use a larger greenhouse, you will need to adjust the system to a larger size, but you can use the same control unit.

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References

[1] E. Borgia, "The internet of things vision: key features, applications and open issues," *Computer Communications*, vol. 54, pp. 1–31, 2014.

[2] R. Chataut, A. Phoummalayvane, and R. Akl, "Unleashing the Power of IoT: A Comprehensive Review of IoT Applications and Future Prospects in Healthcare, Agriculture, Smart Homes, Smart Cities, and Industry 4.0," *Sensors*, vol. 23, no. 16, pp. 1-19, 2023.

[3] W. S. Kim, W. S. Lee, and Y. J. Kim, "A Review of the Applications of the Internet of Things (IoT) for Agricultural Automation," *Journal of Biosystems Engineering*, vol. 45, no. 4, pp. 385–400, 2020.

[4] K. Bunluewongand, and O. Surinta, "Semi-Automated Mushroom Cultivation House using Internet of Things," *Engineering Access*, vol. 7, no. 2, pp. 181-188, 2021.

[5] C. Rayasawath, "Factors Affecting the Household Succession in Agricultural Occupation in Nakhon Ratchasima Province, Thailand," *Agriculture*, vol. 8, no. 7, pp. 1-14, 2018.

[6] A. Wongta, S. Hongsibsong, Z. L. Xu, S. Chantara, M. Pattarawarapan, R. Sapbamrer, K. Sringarm, N. Sawarng, and P. Tongjai, "The Relationship of Organophosphate Pesticide Exposure and Cognitive Decline Among Residents of an Agricultural Area in Northern Thailand," *Journal of Health Research*, v0l. 37, no. 6, pp. 372-379, 2023.

[7] J. F. Steiner, J. D. Powers, A. Malone, J. Lyons, K. Olson, A. R. Paolino, and C. A. Steiner, "Hypertension care during the COVID-19 pandemic in an integrated health care system," *The Journal of Clinical Hypertension*, vol. 25, no. 4, pp. 315–325, 2023.

[8] J. Prasopsuka, S. Laohasiriwonga, A. Promkhambuta, and C. B. Iwaib, "Food safety risk assessment of pesticide residues in Chinese kale grown in Khon Kaen province, northeast Thailand," *Agriculture and Natural Resources*, vol. 54, pp. 343–350, 2020.

[9] L. Peivasteh-roudsari, R. Barzegar-bafrouei, K. A. Sharifi, S. Azimisalim, M. Karami, S. Abedinzadeh, S. Asadinezhad, B. Tajdar-oranj, V. Mahdavi, A. M. Alizadeh P. Sadighara, M. Ferrante, G. O. Conti, A. Aliyeva, and A. Mousavi Khaneghah, "Origin, dietary exposure, and toxicity of endocrine-disrupting food chemical contaminants: A comprehensive review" *Heliyon*, vol. 9, no. 7, pp. 1-35, 2023.

[10] S. Ramasamy, M. Y. Lin, W. J. Wu, H.I. Wang, and P. Sotelo-Cardona, "Evaluating the Potential of Protected Cultivation for Off-Season Leafy Vegetable Production: Prospects for Crop Productivity and Nutritional Improvement" *Frontiers in Sustainable Food Systems*, vol. 5, pp. 1-15, 2021.

[11] A. F. Subahi, and K. E. Bouazza, "An Intelligent IoT-Based System Design for Controlling and Monitoring Greenhouse Temperature," *IEEE Access*, vol. 8, pp. 125488–125500, 2020.

[12] R. Rayhana, G. Xiao, and Z. Liu, "Internet of Things Empowered Smart Greenhouse Farming," *IEEE Journal of Radio Frequency Identification*, vol. 4, no. 3, pp. 195–211, 2020.

[13] Y. Kawasaki, and Y. Yoneda, "Local Temperature Control in Greenhouse Vegetable Production," *The Horticulture Journal*, vol. 88, no. 3, pp. 305–314, 2019.

[14] C. Maraveas, and T. Bartzanas, "Application of Internet of Things (IoT) for Optimized Greenhouse Environments," *AgriEngineering*, vol. 3, no. 4, pp. 954–970, 2021.

[15] S. Wicharuck, N. Khongdee, T. Pripanakul, N. Whangchai, T. Pimpimol, and Chaichana, "Vertical farming: A potential farming practice for lettuce production," Chilean Journal of Agricultural Research, vol.83, no.3, pp.248–259, 2023.

[16] S. Ruamrungsri, C. Sawangrat, K. Panjama, P. Sojithamporn, S. Jaipinta, W. Srisuwan, M. Intanoo, C. Inkham, and N. S. Thanapornpoonpong, "Effects of Using Plasma-Activated Water as a Nitrate Source on the Growth and Nutritional Quality of Hydroponically Grown Green Oak Lettuces," *Horticulturae*, vol. 9, no. 2, pp. 248-261, 2023.