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Assistance in Urban Farming for the Cultivation of Chili Peppers in a Greenhouse Based on Internet of Things Systems

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Abstract

Urban agriculture has become an innovative solution to address urban land limitations while simultaneously enhancing local food security. This article discusses the cultivation of large chili peppers (*Capsicum annuum* L.) in the Greenhouse of Ulul Ilmi Islamic Boarding School, East Jakarta, which implements Internet of Things (IoT) technology in its Smart Agriculture system. The activities implemented use an experimental approach with the application of IoT technology in an automatic irrigation system that flows in the morning and evening for 10 minutes or according to soil moisture, and temperature monitoring with an exhaust that turns on if the temperature reaches 32^0 C. This program aims to improve the efficiency and productivity of chili cultivation through guidance and the application of advanced technology, such as automatic irrigation systems, greenhouse temperature monitoring, and maintenance practices like fertilization. The assistance results show that the application of IoT can improve the efficiency of water, fertilizer, and energy use, as well as optimize the growth of red chili plants. This technology enables accurate monitoring and more responsive plant management to changes in environmental conditions, allowing chili plants to grow healthier and more productively. We hope this development can serve as a model to be replicated in various other urban locations, thereby supporting sustainable agriculture and enhancing food security in urban environments.

Keywords: Agricultural Efficiency; Drip Irrigation; Fertilization; Precision Agriculture; Smart Farming.

Introduction

Urban farming, particularly in the cultivation of chili peppers (*Capsicum annuum* L.) in greenhouse environments, offers great potential to enhance the efficiency, productivity, and sustainability of urban agriculture. With the rapid growth of the urban population and challenges in food security, urban agriculture offers a solution for producing fresh and quality food close to consumers. One technology that plays a crucial role in enhancing the efficiency of urban agriculture is the Internet of Things (IoT), which enables real-time monitoring and management of crops, thereby maximizing resource use and

reducing waste (Pertiwi *et al*., 2021). The Internet of Things (IoT) technology plays a key role in smart farming by providing accurate, real-time data about agricultural conditions (Nalendra & Mujiono, 2020).

IoT in greenhouse agriculture facilitates the real-time monitoring and control of environmental parameters, which is essential for optimal plant growth. IoT systems can automate irrigation, regulate temperature, and monitor humidity levels, thereby creating an ideal microclimate for chili cultivation. Studies show that IoT systems can efficiently manage plant parameters, contributing to increased yields and reduced labor costs (Farooq, Javid, *et al*., 2022). The systems apply a sensor network that collects data on soil moisture, temperature, and light intensity and then processes this data for decision-making related to irrigation and other agricultural practices (Ayan *et al*., 2024; Ye *et al*., 2021).

Although IoT technology offers many advantages, there are challenges in its adoption, especially among urban farmer groups that have limited resources and access to technology. Farmers, especially from women's groups like the Hegarasri Farmers Group in Tasikmalaya, often face issues of limited land, inadequate capital, and a lack of technological literacy (Sudartini *et al*., 2021).

The issues above exacerbate farmers' difficulties in utilizing available resources to improve agricultural production. The proposed solutions in the literature include the implementation of smart irrigation systems supported by renewable energy sources, such as solar panels, to optimize water usage in chili cultivation. Research shows that IoT-based automatic drip irrigation systems can optimize water usage, which is crucial in areas facing water scarcity (Lamasigi *et al*., 2024). Smart management of chili cultivation using IoT can help optimize inputs, reduce excessive use of water and fertilizers, and improve the quality and quantity of harvests. This is important considering that chili is a high-value crop with stable market demand, which significantly contributes to the local economy and food security (Badan Pusat Statistik, 2024). In addition, IoT applications can also be expanded for pest control and precision nutrition, which can reduce environmental impact and enhance plant health (Farooq, Riaz, *et al*., 2022).

There is a lack of knowledge regarding chili cultivation and the application of IoT technology on a larger scale among urban farmers. Most farmers still need guidance and training to integrate this technology into their daily farming practices. As shown by Firdhausi *et al*. (2018), the effectiveness of chili growth in greenhouses reached 93.32%, compared to 80.19% outside greenhouses, indicating the significant potential of this system. Although various studies have shown the effectiveness of IoT technology in agriculture, there is still a gap in its implementation, particularly concerning the technical and financial capabilities of urban farmer groups. Farmers often require guidance and specialized training to effectively integrate this technology into their daily activities. Many existing programs do not fully meet the specific needs of urban farmers, such as the adaptation of IoT systems for smaller spaces and the provision of training for technology adoption (Masnang *et al*., 2019).

At the partner's location, the main issue in chili cultivation is the failure of growth and fruiting caused by aphid attacks, one of the primary pests that can quickly spread in a greenhouse environment and cause significant damage to the plants. Research shows that pests and diseases are often the main factors hindering chili production, so proper identification and control are crucial to reducing losses (Nazila *et al*., 2023; Arniati *et al*., 2022; Sumayanti, 2023). The use of IoT technology in greenhouse management has proven to significantly reduce the spread of aphids, as it allows for real-time monitoring and control of environmental conditions, creating an environment that is unfavorable for the development of these pests. For example, an integrated temperature and humidity monitoring system can help maintain optimal conditions for plant growth while also reducing the risk of pest infestations (Bafdal & Ardiansah, 2021; Farooq, Riaz, *et al*., 2022).

Therefore, a community service program is needed that focuses on enhancing farmers' capacity to utilize IoT technology for chili cultivation in greenhouses. This community service activity aims

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to provide assistance to urban farmer groups in maximizing the use of IoT technology in chili cultivation within greenhouses. Through this initiative, farmers will hopefully gain a better understanding of and be able to apply advanced technology in their agricultural practices, thereby increasing crop yields, optimizing resource use, and supporting the sustainability of urban agriculture in the future. Moreover, this activity is anticipated to serve as a replicable model in various other urban locations, supporting food security and enhancing farmers' welfare. Furthermore, through this assistance program, it is hoped that an IoT-based urban farming model can be developed that can be replicated in various other urban areas, supporting the broader goals of sustainable agriculture and food security. This initiative not only addresses the immediate needs of urban farmers but also contributes to the long-term development of urban agriculture as a viable solution to tackle food supply challenges in densely populated areas (Siegner *et al*., 2018; Wood *et al*., 2020).

Method

The Location and Target Description

Greenhouse Ulul Ilmi Islamic Boarding School, Ciracas, East Jakarta, an agrotourism area in an urban environment, became the site for the implementation of this community service program. This location was chosen because it was considered appropriate for improving agricultural production efficiency on limited land while supporting environmental sustainability in urban areas. In addition to serving as an educational center, the Ulul Ilmi Islamic boarding school has land suitable for crop cultivation, making it a real demonstration of modern agriculture for the surrounding community.

This program is primarily aimed at the management partners of the Ulul Ilmi Islamic boarding school who are interested in agriculture, particularly urban agriculture. This program provides education on the application of smart agriculture technology based on the Internet of Things (IoT) for daily cultivation practices. The existing IoT system has not been optimally utilized to increase chili production; therefore, we assist by optimizing the growing media and plant care. Plant care uses an automatic drip irrigation system to efficiently deliver 200 ml of water over 10 minutes. Temperature control in the greenhouse is managed by turning on the exhaust when the temperature reaches 32°C, and fertilization is done using drip irrigation along with watering once a week. By optimizing the plant media, monitoring and irrigation systems, and the efficiency of irrigation and fertilization, it is expected that the chili production will be optimal. This program also aims to empower urban farming groups and local farming communities by providing accessible and applicable technology. The stages carried out in the chili planting assistance activities in the greenhouse are presented in Figure 1.

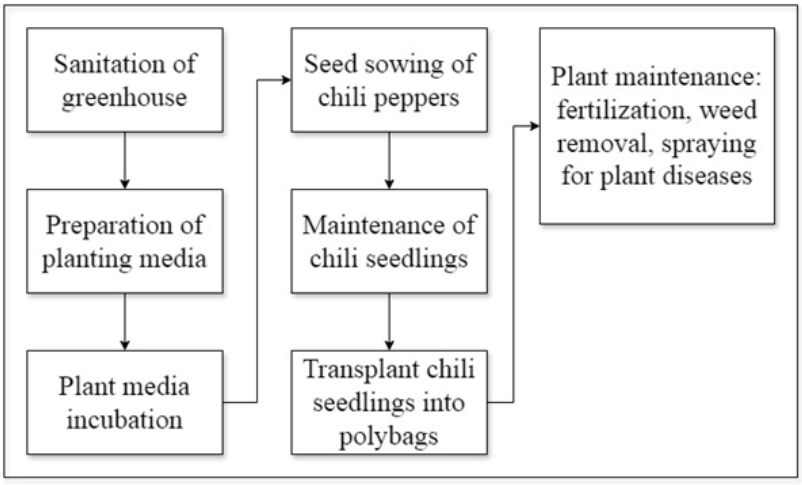

Figure 1. *The Stages of Chili Planting Activities at the Ulul Ilmi Islamic Boarding School*

Implementation of Activities

The activities began with a location survey and problem mapping in May 2024. It was then proceeded by addressing the challenges encountered by the partners, specifically the persistent failure of chili plant planting due to uneven and suboptimal growth and aphid infestations. The survey results suggest that partners require support in the cultivation of chili plants to prevent losses from crop failure. The accompanying activities strive to cultivate partners and employees, enabling the academic community to actively participate in achieving food independence at the community level by applying their knowledge. We consistently develop and support the planting of chilies. Following the survey, we create the activity schedule, commencing with sanitation in June 2024, preparing the planting medium in July 2024, and proceeding with sowing and planting in August 2024. Our team member, Ir. Aisyah, MP, presents the material for the training on chili planting (Figure 2).

Figure 2. *(a) Assistance and Counseling on Media Planting; (b) The Assistance and Counseling Team for Chili Plants in the Ulul Ilmi Islamic Boarding School Greenhouse*

Results and Discussion

The implementation of IoT technology in the management of chili greenhouses in urban environments has led to significant improvements in various aspects, particularly in the use of water, fertilizers, and energy. The accompanying activities include counseling and tutorials for partners and employees managing the greenhouse. The greenhouse cultivates large chili peppers using a smart farming approach to maximize yield and efficiency. The first activity in this process is to sanitize the greenhouse, which includes spraying anti-fungal treatment on all parts of the greenhouse to ensure the environment is free from pathogens and diseases that could affect plant health. This thorough sanitation is crucial to create optimal growing conditions and prevent future plant health issues.

The second step is the preparation of the planting media, which consists of a mixture of soil and cow manure compost, incubated for four weeks. This media has been carefully prepared to ensure that chili plants receive adequate nutrients and the ideal soil structure for healthy root growth. The planting media is prepared using 35x35 cm polybags filled with 4 kg of soil and 1 kg of cow manure, which are then mixed to approximately the polybag depth until well blended. Figure 3 shows the process of filling polybags with planting media.

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Figure 3. *Preparation of Planting Media*

After the planting medium is ready, the third step is to sow the chili seeds. The seeds are sown on a damp tissue to break their dormancy and then transferred to a seed tray to ensure optimal seedling growth. Figure 4 presents the seed-sowing process in a seed tray. Uniform seed growth indicates that the seeds used are of excellent quality and thrive optimally in the prepared environment.

Figure 4. *Growth of Seedlings in Seed Trays*

After the seedlings have grown large and strong enough, the fourth step is to transplant them into polybags (Figure 5). This process involves transferring the seedlings into 980 polybags, which allows for easier and more flexible management of the plants in the greenhouse space.

Figure 5. *(a) Transplanting Chili Seedlings; (b) Chili Plants 3 Months After Planting*

The maintenance of chili plants is carried out from the seedling stage in seed trays by applying botanical pesticides to prevent and address pest attacks. We apply the pesticide to the leaves of the aphid-affected plants using a small sprayer. This pest indeed attacks chili plants a lot (Tanjung *et al*., 2018). Figure 6 depicts the maintenance activities for plants affected by aphid pests.

***Figure 6**. (a) Chili Plants Affected by Aphid Pests; (b) Application of Botanical Pesticide on Plants Affected by Aphid Pests*

The application of an IoT system in various aspects of plant care supports the optimal growth of chili plants. Every morning and evening, the automated irrigation system integrated with IoT waters the plants on a schedule, ensuring that they receive consistent moisture (Setiadi & Muhaemin, 2018). Every week, an IoT system carries out alternating fertilization using bio-fertilizers and NPK, enabling the precise delivery of nutrients based on plant needs, thereby optimizing the growth and production of chili peppers and ensuring precise fertilization doses. NPK fertilization and bio-fertilizers can enhance the growth and production of chili plants (Waskito *et al*., 2018). However, as shown in Figure 7, we also use spraying to optimize fertilization across all parts of the plant and the growing medium's surface.

***Figure 7**. Spraying Fertilizer*

The greenhouse at Ulul Ilmi Islamic Boarding School utilizes an advanced IoT system to enhance efficiency and crop yields by managing irrigation, fertilization, and temperature control. The irrigation

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and fertilization processes are both delivered through drip irrigation, ensuring precise water and nutrient distribution. For temperature regulation, the system automatically activates when the temperature reaches 32°C, triggering two exhaust units to lower the heat. This helps maintain a stable growing environment, which is crucial for optimal plant growth and preventing heat stress. Additionally, by keeping the temperature in check, the system reduces the risk of aphid infestations, further promoting healthy chili plant development. Figure 8 presents the control system for fertilization.

Figure 8. *Fertilization Control System*

The IoT devices used to regulate temperature, irrigation, and fertilization in greenhouses consist of several main components. The first component is a Smart Temperature Controller that uses temperature sensors to monitor conditions inside the greenhouse. The device is connected to an IoT controller and automatically turns on fans or ventilation when the temperature reaches a specified limit. The second component is a Smart Irrigation System and Fertilizer Injector, which functions to mix fertilizer with water in a drip irrigation system, similar to a Nutrient Injection System. This system controls the water needs and the duration of watering required by the plants, thus supporting optimal growth.

In addition to reducing the need for manual labor, this technology precisely controls all environmental factors that affect plant growth. This innovation enables more productive and sustainable chili cultivation, providing a positive example of the implementation of smart farming in urban environments. The use of IoT systems for irrigation, fertilization, and temperature control in the Ulul Ilmi Islamic Boarding School Greenhouse offers several significant advantages that positively impact agricultural productivity and efficiency. Here are some key benefits of implementing this technology :

1. Water Savings and Efficient Use
   With an automated irrigation system integrated with IoT, the greenhouse can manage plant watering with precision. This reduces water waste, ensuring that plants receive the right amount of moisture according to their needs. Water conservation is important, especially in urban environments that may have limited water resources. Despite the semi-manual nature of the current system, addressing this issue has become crucial.

2. Timely and Accurate Fertilization
   The IoT system enables scheduled fertilization based on the plants' needs. With real-time monitoring of plant conditions and growing media, the system can provide the right nutrients in the necessary amounts. This prevents over- or under-fertilization, which can affect plant growth and crop yields. Accurate fertilization also reduces fertilizer waste and operational costs, as well as minimizing the environmental impact of excessive fertilizer use.
3. Optimal Temperature Regulation
   The automatic and IoT-based temperature regulation ensures that the greenhouse's environment remains within the ideal temperature range for chili plant growth. The installed temperature sensors continuously monitor the temperature, and fans are automatically activated if the temperature exceeds a predetermined limit, such as 32°C. This temperature regulation helps keep the plants in optimal condition, reducing the risk of heat stress and minimizing temperature fluctuations that could affect their health and yield.
4. Workforce Reduction and Operational Efficiency
   With an IoT system that automates irrigation, fertilization, and temperature control processes, the need for manual intervention is significantly reduced. Farmers or greenhouse managers can monitor and control various aspects of agriculture remotely using connected devices. This not only reduces the need for labor but also allows for more efficient management that is responsive to changes in environmental conditions.
5. Improvement of Health and Crop Yields
   The use of IoT technology ensures that chili plants receive optimal growing conditions with precisely controlled irrigation, fertilization, and temperature. This contributes to healthier plant growth and higher yields. Healthy plants are more resistant to diseases and pests and can produce high-quality fruit, thereby enhancing the overall productivity of the greenhouse.

Conclusions

Large chili peppers are grown in a greenhouse that has adopted an IoT system, making it easier for partners and employees to monitor the growth and care of the chili plants. The efficiency of water usage for irrigation is at a precision level of 200 ml of water per polybag, every morning and evening. We continue to provide training and counseling during the production and harvesting phases to ensure optimal chili plant production. IoT-based smart farming systems can offer many benefits for chili cultivation in urban areas. IoT technology enables more accurate monitoring of plant conditions and their growing environment, such as temperature and nutrients. Additionally, by maintaining the temperature conditions inside the greenhouse, proper fertilization and watering will result in optimal growth of chili plants. Healthy and disease-resistant chili plant growth will result in optimal production, and the failures experienced by Ulul Ilmi Islamic Boarding School can be avoided.

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