Indonesian Journal of Humanities and Social Sciences
https://ejournal.uit-lirboyo.ac.id/index.php/IJHSS

E-ISSN: 2746-2188
Volume 5 Issue 4 Desember 2024

Downstreaming Internet of Things Automation and Digitalization in Superior Melon Cultivation with Greenhouse Technology Through a Sustainable Revolving Fund-Based Farming Business Ecosystem

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Abstract

The Technology and Innovation Dissemination Program in Kedungbanteng Village, Ponorogo Regency, East Java, aims to increase melon farmers' productivity through IoT technology and access to revolving funds. This village is known to produce high-quality melons with export potential, but farmers still face significant challenges. The main problems of partners are the low understanding of modern agricultural technology and limited access to capital. Most farmers still rely on conventional methods, such as manual greenhouses, which hinder production efficiency. The solutions offered include two main approaches. The first is the application of IoT technology in melon cultivation in greenhouses to increase productivity and efficiency. The implementation stages include needs identification, sensor installation, and farmer training. Second, farmers are provided access to revolving funds, accompanied by financial management training and the preparation of sustainable business plans. This program is designed to help farmers obtain capital at affordable interest rates and make adopting new technologies more accessible. The method of implementing the activity includes direct training to farmers on the use of IoT technology and financial management, installation and testing of IoT devices in greenhouses, and technical assistance on an ongoing basis. In addition, assistance is carried out by supervising revolving funds and farming training to ensure optimal implementation. The output targets of this program are an increase in melon productivity by 30% in a year, a reduction in operational costs by 20%, and an increase in farmers' understanding of IoT technology and financial management skills. This program is also expected to increase the greenhouse area and farmers' access to capital.

Keywords: *Internet of Things, Digitalization, Melon, Greenhouse, Farming Ecosystem, Revolving Fund.*

Introduction

One of the villages fostered by Malang State University, in Kedungbanteng Village, Ponorogo Regency, East Java, has quite promising melon farming potential. Melon cultivation in this village uses manual greenhouse technology in its agriculture (Saragih, 2023). Melons from Kedungbanteng Village have premium quality so that they are in demand in the national and international markets. Its production capacity reaches 80-150 tons per year. However, farmers who use greenhouses still face several problems that must be resolved immediately (Saputra et al., 2022). Melon farmers in Kedungbanteng Village generally still rely on conventional manual farming methods. First, the main problem is the limited knowledge and understanding of farmers regarding technology. Farmers in this region do not have enough understanding of the concept of IoT and digitalization in the context of agriculture (Wibowo et al., 2017). They need to get comprehensive training and education on the application of this technology in melon cultivation. This will allow them to understand its benefits and use it effectively in daily activities (Bahri et al., 2021).

Second, financial constraints are a severe obstacle to adopting IoT automation technology and digitalization. Most farmers have limited access to sufficient capital to invest in automation equipment and digital devices. Therefore, this program needs to provide a solution in the form of a sustainable revolving fund (Kusumawati et al., 2021). This will help farmers access technology without facing heavy financial burdens. An analysis of the situation related to target partners in the economic sector and learning entrepreneurship in Kedungbanteng Village revealed that farmers engaged in melon cultivation in greenhouses still face obstacles in the application of modern technology (Niekie Rafida et al., 2023). Farmers need training and financial assistance to adopt IoT automation technology and digitalization in agriculture. On the other hand, partners who are young entrepreneurs have an entrepreneurial spirit but need assistance in business management, finance, and marketing (Nasution et al., 2021).

Technology and information dissemination programs will address these issues by providing training, financial support, and assistance in marketing strategies, thus helping target partners achieve tremendous success in their ventures. The solution developed from some of the problems above is applying modern agricultural technology, IoT, and digitalization to automatically monitor and control temperature, humidity, irrigation, and other environmental factors (Novianti Indah Putri et al., 2022). Farmers will use IoT-based devices connected to digital systems to get real-time information about the condition of their crops. The technology training provides comprehensive training to farmers on using IoT technology and digitalization in melon cultivation. They will learn how to install and operate the device and analyze the data generated (Ridwan & Sari, 2021).

Entrepreneurial education provides training in business management, financial planning, and marketing strategies. They will learn how to use technology to manage and promote their businesses. Sustainable revolving funds provide farmers and young entrepreneurs access to sustainable revolving funds (Wiratno, 2012). This will help them to access the capital needed to adopt the technology and grow their businesses. This fund will be provided with affordable interest rates and a term that can be adjusted to the needs of target partners. This research aims to optimize the cultivation of superior melons by utilizing greenhouse technology supported by Internet of Things (IoT) automation and digitalization. By integrating sophisticated modern technology in the agricultural sector, especially melon cultivation, this research is expected to increase the efficiency and productivity of melon cultivation in Kedungbanteng village (Suwarni et al., 2021). IoT technology allows it to be implemented in various aspects of cultivation, such as irrigation, fertilization, and temperature control, carried out automatically, thereby minimizing manual intervention and reducing human error. Developing a sustainable agricultural ecosystem based on revolving funds provides sustainable financial benefits for farmers. In addition, the use of this system allows farmers to access the financial resources needed to adopt the latest technology without funding problems (Prastyaningtyas & Arifin, 2019).

Method

This research methodology is designed to support the implementation of automation solutions based on the Internet of Things (IoT) and digitalization in superior melon cultivation within greenhouses, with a sustainable farming business ecosystem through a revolving fund scheme. Previous studies have emphasized the importance of integrating modern technology into agriculture to enhance productivity and efficiency, especially in horticulture, as outlined by Zhang et al. (2022) in their study on IoT in precision agriculture. Based on this approach, our research adopts structured operational stages to ensure that the technology implementation is effective and brings positive impacts to the farmers.

The research process begins with identifying the farmers' needs and gathering initial information about the greenhouse conditions, as well as their readiness to adopt new technology. This is in line with Hidayatullah et al. (2023), who highlight the importance of initial assessment to align technology with local conditions. In the implementation phase, IoT technology is installed in the greenhouse, involving sensors designed to monitor environmental conditions in real-time, such as temperature, humidity, and nutrient levels. Farmers are trained to understand and use the data generated, allowing them to make data-driven decisions. This approach refers to the findings of Prasetyo et al. (2023), which show that intensive training increases the adoption rate of technology by smallholder farmers.

In addition to technology, financial sustainability is also a key focus of this research. A revolving fund model is applied to provide farmers with access to capital without overburdening them financially, as discussed by Manuhutu (2022) in the context of sustainable agribusiness financing. Assistance is provided to help farmers manage finances and develop business plans that support the sustainability of their enterprises. In this regard, Rahman et al. (2021) highlight the relevance of sustainable financing mechanisms in the agricultural sector, providing a theoretical foundation for the development of the revolving fund scheme.

Program evaluation is carried out periodically to assess the impact of IoT implementation and revolving funds on melon productivity, resource use efficiency, and farmers' economic stability. This approach is based on the evaluation methodology proposed by Syahputra et al. (2019), which emphasizes the importance of involving farmers in the monitoring process to ensure that the program has a tangible impact. Furthermore, program sustainability is a primary concern, where farmers are encouraged to independently manage the technology and capital once the program is completed.

The methodology used in this research not only serves as an operational framework but also contributes to the development of an adaptive, technology-based agribusiness model that responds to local needs. With a holistic approach that integrates IoT technology, training, and access to capital, this research aims to make a tangible contribution to the modern agriculture literature, as summarized in various relevant studies. References from Zhang et al. (2022), Kim and Lee (2021), and Refris and Sumartono (2023) enrich the theoretical foundation of this research, ensuring that the methodology applied is scientifically robust.

RESULTS AND DISCUSSION

Identification of Farmers Participating in the Program

The analysis of the needs of participating farmers related to digitalization in superior melon cultivation revealed some essential aspects that must be considered to increase efficiency and productivity. First, access to technology and the internet is one of the primary needs. Most farmers need a stable internet connection to access information, control IoT systems, and use digital agriculture applications. Smartphones are also exceptionally high, so training in using special agricultural applications is crucial. Second, technical knowledge and skills related to digital technology and IoT must be improved. This needs to be done especially in understanding the concept of IoT and its benefits in agriculture because many farmers still do not fully understand this. Through a comprehensive education and training program on sensors, automation systems, and greenhouse technology, it is hoped that it will be able to improve farmers' knowledge and skills. This training should cover everything from the installation, operation, and maintenance of technological devices to ensure they can be used effectively.

Third, technical support and technical assistance are also necessary. Farmers often need help in implementing new technologies, from installation to troubleshooting. Responsive and quality support services will significantly help them in overcoming technical obstacles. Fourth, the financial aspect is a major challenge for many farmers because many farmers still do not have sufficient funds. Therefore, funding programs such as sustainable revolving funds are urgently needed to provide financial assistance for farmers in implementing this technology. Finally, partnerships with agricultural technology institutions and support from the government or non-governmental organizations. By doing this partnership, the digitalization process can be accelerated. The collaboration can provide access to the latest resources, knowledge, and innovations needed to be integrated into superior melon cultivation practices. By meeting these needs, digitization of superior melon cultivation can be carried out effectively so that it can provide significant benefits for farmers, especially in increasing harvest yields and product quality. The following is a table analyzing the need for facilities for downstream media, Internet of Things automation, and digitalization in superior melon cultivation with greenhouse technology through a sustainable revolving fund-based farming ecosystem by farmers:

Table 1. Needs Analysis for Farmers

No	Question	Answer Options	Percentage
1	Have you ever used digital technology in agriculture?	Yes No	80% 20%
2	How often do you use your smartphone in farming activities?	Every Day Once a Week Rarely	60% 30% 10%
3	Are you familiar with the concept of IoT (Internet of Things)?	Yes No	70% 30%
4	Do you have adequate internet access in your farm area?	Yes No	75% 25%
5	Are you interested in using greenhouse technology for melon cultivation?	Yes No	85% 15%
6	Do you find irrigation automation technology helpful?	Yes No	90% 10%
7	How important do you think using sensors is in monitoring plant conditions?	Very important Important Note important	65% 30% 5%
8	Are you willing to train in the use of digital technology?	Yes No	80% 20%
9	Are you already using farming apps on your smartphone?	Yes No	70% 30%
10	How often do you search for agricultural information over the internet?	Every Day Once a Week Rarely	50% 35% 15%
11	Have you ever used a digital weather monitoring system?	Yes No	55% 45%

12	How satisfied are you with the melon harvest using traditional technology?	Very satisfied Satisfied Dissatisfied	25% 50% 25%
13	Have you ever suffered losses due to undetected pest attacks?	Yes No	65% 35%
14	Are you interested in investing in digital technology for melon cultivation?	Yes No	80% 20%
15	Do you understand how greenhouse technology works?	Yes No	70% 30%
16	Have you ever worked with an agricultural technology institution?	Yes No	60% 40%
17	How often do you interact with other farmers online?	Every Day Once a Week Rarely	40% 45% 15%
18	Do you feel the need for technical assistance in the implementation of digital technology?	Yes No	75% 25%
19	Do you know the benefits of using automation technology in aquaculture?	Yes No	85% 15%
20	Have you ever attended a seminar or workshop on agricultural technology?	Yes No	55% 45%
21	How much influence does digital technology have on your agricultural productivity?	Very big Big Not big	60% 30% 10%
22	Do you use digital devices to sell crops?	Yes No	50% 50%
23	How significant is the cost constraint in implementing digital technology for you?	Very big Big Not big	40% 35% 25%
24	Have you ever received funding from a revolving fund program?	Yes No	45% 55%
25	How confident are you that digital technology can improve the quality of superior melons?	Strongly Confident Not sure	70% 25% 5%

The discussion from the identification table of participating farmers related to digitalization in superior melon cultivation shows significant technology adoption. As many as 80% of farmers have used digital technology in their agricultural activities, showing a high awareness of the benefits of this technology (Andriani, 2022). Digital technology helps farmers increase efficiency and productivity, with 60% using smartphones every day as an important tool in modern agriculture. However, only 70% are familiar with the concept of IoT, this indicates that further education about technology, especially the concept of IoT, is needed to encourage its wider application in the agricultural sector (Miftahul Walid et al., 2022).

Adequate internet access has been enjoyed by 75% of farmers, enabling wider application of digital technology in agricultural monitoring and management (Akbar & Gunawan, 2020). The high interest in greenhouse technology (85%) indicates an awareness of the importance of a controlled environment in melon cultivation, supported by precision agriculture research. Irrigation automation technology benefits 90% of farmers, indicating that using this technology will be more efficient and save significant time in water resource management and crop maintenance (Megawati, 2021). Digital technology training is considered necessary by 80% of farmers, indicating their readiness to improve the knowledge and skills needed to adopt new technologies that can improve agricultural yields (Ambarwati et al., 2022). However, in expanding the application of digital technology, there are still funding constraints and it is a significant obstacle for 40% of farmers, this highlights the need for better financial support from the government or financial institutions (Arikarani & Amirudin, 2021).

Survey of Greenhouse Conditions and IoT Needs

Figure 1. Greenhouse Melon Farm Condition Kedungbanteng, Ponorogo

Greenhouse conditions and IoT needs related to digitalization in superior melon cultivation need to be monitored to ensure that this technology has been implemented by farmers. to carry out this stage can be done by conducting a survey. The survey conducted focused on several main aspects, such as how to utilize greenhouse technology, IoT adoption, what challenges are faced in implementing technology, and the need for training and technical support. The main objective of this survey is to collect accurate data regarding the current conditions in the field. The questions in the survey cover a wide range of topics, ranging from the use of digital technology in daily agricultural activities, farmers' understanding of IoT, and the types of technologies used in greenhouse management. For example, asking about the use of smartphones. how often do farmers use cellphones to access agricultural information or manage automatic irrigation systems in their greenhouses.

In addition, this survey should highlight the obstacles faced by farmers when adopting IoT technology. Challenges faced by farmers such as high initial investment costs, limited technical knowledge, and inadequate internet infrastructure. By identifying the obstacles and challenges faced by these farmers, the results of the survey can provide a clearer picture of areas that require additional intervention and support. The survey should also be able to measure farmers' interest and readiness to increase the use of IoT technology. For example, questions about farmers' willingness to participate in digital technology training and their willingness to invest further in new technologies provide important insights into farmers' attitudes and perceptions of innovation. The following is a survey table of greenhouse conditions for downstream media, Internet of Things automation, and digitization of superior melon cultivation with greenhouse technology through a sustainable revolving fund-based agricultural ecosystem by farmers:

Table 2. Conditions of Green House and Partners

No	Question	Answer Options	Percentage
1	Are greenhouses equipped with temperature sensors?	Yes No	50% 50%
2	How often do you monitor the temperature in a greenhouse?	Hourly Every Day Every Week, Never	25% 25% 25% 25%
3	Is there an automatic irrigation system in your greenhouse?	Yes No	50% 50%
4	How often do you check soil moisture?	Daily Weekly Lunar Never	25% 25% 25% 25%
5	Do you use a weather monitoring system in a greenhouse?	Yes No	50% 50%
6	How important is it for you to assess the use of IoT for weather monitoring?	Very important Important Ordinary Not important	40% 30% 20% 10%
7	Is there an automatic lighting system in your greenhouse?	Yes No	50% 50%
8	How often do you adjust the lighting in the greenhouse?	Daily Weekly Lunar Never	25% 25% 25% 25%
9	Is there a soil pH meter in your greenhouse?	Yes No	50% 50%
10	How important are you assessing the use of IoT for soil pH measurement?	Very important Important Ordinary Not important	40% 30% 20% 10%

11	Do you use an automated pest control system?	Yes No	50% 50%
12	How often do you do pest control in greenhouses?	Daily Weekly Lunar Never	25% 25% 25% 25%
13	Are there air humidity meters in your greenhouse?	Yes No	50% 50%
14	How important are you assessing the use of IoT for air humidity monitoring?	Very important Important Ordinary Not important	40% 30% 20% 10%
15	Do you use an automatic ventilation management system?	Yes No	50% 50%
16	How often do you adjust the ventilation in the greenhouse?	Daily Weekly Lunar Never	25% 25% 25% 25%
17	Is there an automatic plant growth monitoring system?	Yes No	50% 50%
18	How important is it for you to assess the use of IoT for plant growth monitoring?	Very important Important Ordinary Not important	40% 30% 20% 10%
19	Do you use applications or software for melon cultivation management in greenhouses?	Yes No	50% 50%
20	How often do you update melon cultivation data in the app or software?	Daily Weekly Lunar Never	25% 25% 25% 25%
21	Is there a soil nutrient content meter in your greenhouse?	Yes No	50% 50%
22	How important are you assessing the use of IoT for soil nutrient content measurement?	Very important Important Ordinary Not important	40% 30% 20% 10%
23	Do you use IoT technology to monitor the health of melon plants?	Yes No	50% 50%
24	How often do you monitor the health of melon plants in greenhouses?	Daily Weekly Lunar Never	25% 25% 25% 25%

25	How satisfied are you with the current use of IoT technology in your greenhouse?	Very satisfied Satisfied Ordinary Dissatisfied	40% 30% 20% 10%

Greenhouses equipped with temperature sensors and automatic weather monitoring systems are essential in improving the efficiency and yield of IoT-based melon cultivation. The survey showed that half of the respondents had installed a temperature sensor, but only a quarter carried out hourly temperature monitoring. Adopting automated irrigation systems also shows room for improvement, with only half of the respondents using them (Sani et al., 2020). Soil moisture, pH measurement, and soil nutrient content are the main focuses in monitoring the greenhouse environment. Although 50% of respondents have soil and air moisture measuring devices, most consider the use of IoT technology for this monitoring to be very important. Automatic lighting and ventilation systems are also encountered, albeit with variations in the adjustment frequency (Shiddiqi et al., 2021).

Automated pest control and aquaculture management applications show a balanced adoption rate, but there is room for increased use. In conclusion, there is a high awareness of the importance of IoT technology in improving melon cultivation efficiency. Although the level of satisfaction with the current technology is quite good, there is an opportunity to increase education and access to this technology to maximize results in greenhouses (Rangkuti et al., 2021).

IoT Utilization Farmer Training

Initial training for farmers on the IoT program and its benefits in the context of digitizing superior melon cultivation is a strategic step that can be taken to support the modernization of the agricultural sector. This training program aims to introduce the concept and application of Internet of Things (IoT) technology to farmers. This training is expected to have a significant impact on the efficiency, productivity, and sustainability of farming businesses. In this training, farmers will be introduced to the basic concepts of IoT first, such as how sensors monitor environmental conditions in greenhouses, such as temperature, air humidity, and soil moisture. They will also be taught how to integrate data from these sensors into a digital platform that allows for more accurate and timely decision-making in melon plant management.

In addition to the technical aspects, this training will highlight the benefits that can be obtained from the application of IoT in melon cultivation. One of them is to improve the efficiency of using resources, such as water and energy, through the automatic setting of irrigation systems based on sensor data. Farmers will also understand that this technology can help them deal with challenges such as extreme weather changes or pest attacks that can be detected early through advanced monitoring systems. In addition, the importance of using data for analysis and strategic planning in agriculture will be emphasized. Farmers will be trained to understand how to manage and interpret data generated by IoT technology. This aims to improve operational decisions and increase crop yields sustainably. The results of this training are expected to improve the technical capacity and knowledge of farmers in adopting new technologies to apply IoT in their melon cultivation practices more effectively.

Figure 2. Training for Farmers on the Utilization of IoT

Installation of IoT Sensors in Greenhouses

The installation of IoT sensors in greenhouses related to the digitalization of superior melon cultivation in Kedungbanteng Village, Ponorogo, is an innovative step in increasing the efficiency and productivity of modern agriculture. This project aims to integrate the latest technology into traditional agricultural practices.This project focuses on optimal growing environment management and data-driven decision making. Installing IoT sensors such as temperature, humidity, soil moisture, and digital weather monitoring systems in greenhouses will make it easier for farmers to monitor plant environmental conditions in real-time. Data collected by sensors will be sent directly to a digital platform or mobile application that farmers can access remotely. This allows them to take preventive or corrective actions quickly and accurately, such as setting up an automatic irrigation system based on measured soil conditions or utilizing ventilation to regulate the temperature in the greenhouse.

In Kedungbanteng Village, the application of IoT technology in melon cultivation has begun to be applied. The application of this technology aims to increase melon productivity sustainably and reduce the risk of losses caused by extreme weather changes or pest attacks that are not detected early. Farmers have been able to increase the efficiency of resource use such as water and energy, optimize crop yields, and improve the quality of end products by using accurate data from IoT sensors. In addition to the direct benefits of agricultural management, the installation of IoT sensors in greenhouses also allows farmers to track and analyze long-term trends in plant conditions and crop yields. Historical data from the installation of IoT sensors collected can be used for strategic planning, evaluating the performance of previous harvest seasons, and making better investment decisions for the future.

Data Integration from IoT Sensors and Monitoring Platform Development

IoT-based sensors consist of sensor devices and client programs, the purpose of which is to collect sensor data and then send it to the cloud server. Performance analysis of IoT-based sensors under various conditions needs to be done to ensure their performance. This study uses performance metrics such as network latency and CPU and memory usage. Alazzawi and Elkateeb proposed network latency as a metric to evaluate the performance of sensor devices. At the same time, Morón et al. used CPU usage as a metric to evaluate the capabilities of IoT devices in various scenarios. The integration of data from IoT sensors and the development of a monitoring platform in the context of digitalization in the cultivation of superior melons in Kedungbanteng Village, Ponorogo, is the key to significantly increasing agricultural efficiency and productivity. The integration process begins with installing IoT sensors in the greenhouse, such as temperature, air humidity, and soil moisture sensors, which collect real-time data on the environmental conditions of plant growth.

The collected data is then integrated into a specially developed monitoring platform. The platform that farmers will use to monitor crop conditions remotely is a mobile application or web dashboard. This platform not only facilitates decision-making based on the actual data obtained, but can also improve the ability to respond to changes in crop conditions quickly and effectively. In Kedungbanteng Village, data integration from IoT sensors has begun to be implemented. This aims to facilitate accurate monitoring of plant environmental conditions and allow for more detailed analysis of factors that affect crop yields. For example, historical data from various agricultural cycles can be used to identify patterns and trends, such as the impact of weather changes on crop productivity.

The development of this monitoring platform also facilitates better reporting and analysis related to the efficiency of resource use, such as water and energy. Farmers can set up irrigation systems automatically based on measurable soil moisture data, reducing resource waste and increasing crop yields sustainably. In addition to the operational benefits, integrating data and developing this monitoring platform provides opportunities for developing more appropriate policies and adapting agricultural strategies that are more responsive to changing environmental and market challenges. Thus, this technology modernizes melon cultivation at the local level and improves the competitiveness and sustainability of Indonesia's agricultural sector as a whole. The following is an overview of data integration from IoT sensors and the development of monitoring platforms.

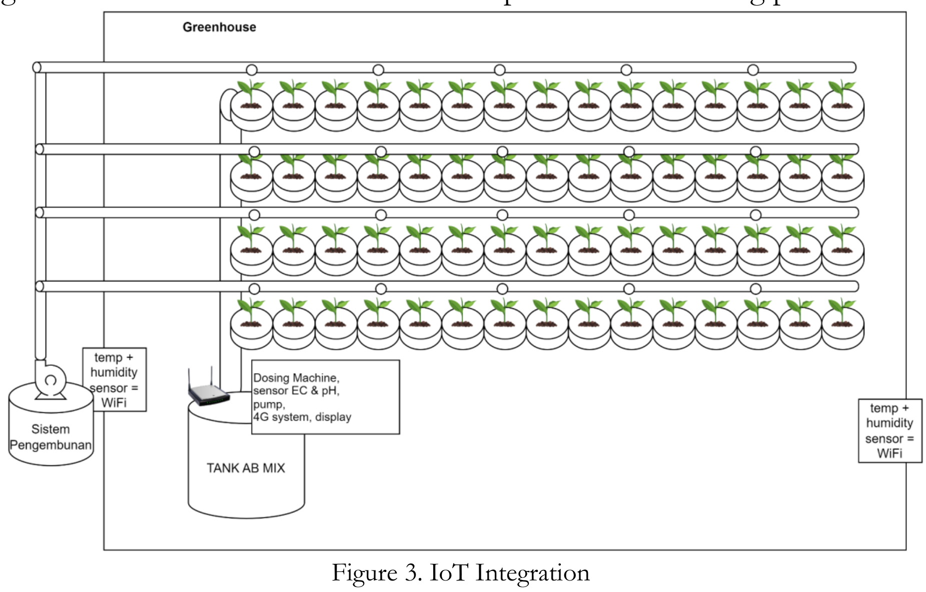

Figure 3. IoT Integration

Greenhouse Melon Productivity

Melon productivity in greenhouses can be influenced by increased efficiency of growth factors, including temperature, humidity, nutrients, and more optimal environmental control compared to planting in open fields (Saragih, 2023). Greenhouses provide a more stable environment for plants so that they can minimize the risk of crop failure or low productivity due to extreme weather or pest attacks (Heru Sandi & Fatma, 2023). A 30% increase in melon productivity in greenhouses showed a significant improvement in yields produced in the controlled environment compared to conventional methods or before applying specific technologies in greenhouses. This increase is due to various factors such as climate control technology, automatic irrigation, more effective pest management, and monitoring plant growth through sensors or the Internet of Things (IoT) (Putra et al., 2020). The following is data on production before and after the use of technology in Table 3:

Table 3. Pre and Post Treatment Harvest Data for the Use of the Internet of Things (IoT)

Production Factors	Before Greenhouse (Ton/Ha)	After Greenhouse (Ton/Ha)	Increase (%)
Average melon harvest yield	25	32.5	30%
Number of melons per plant	4	5.2	30%
Average weight of melons (kg)	1.5	1.95	30%
Growth time (days)	90	75	16.7%

The implementation of the greenhouse system gave positive results. The average melon yield per hectare increased from 25 tons/ha to 32.5 tons/ha, indicating an increase of 30%. This is due to more efficient management of environmental factors in the greenhouse, such as temperature and humidity settings, which are in accordance with optimal plant needs. In addition, the number of melons per plant also increased by 30%, from 4 to 5.2 melons per plant. This shows that more controlled conditions and modern technology, such as proper fertilization, allow plants to produce more fruit (Polan et al., 2021).

The average weight of melons increased from 1.5 kg to 1.95 kg per melon, or an increase of 30%. This means that melons grown in greenhouses are of better quality and size due to their optimal growing conditions. The growth time of melon plants is reduced from 90 days to 75 days, which means an acceleration of 16.7%. Based on this, it shows that the efficiency of the greenhouse system in accelerating the plant growth cycle, allowing more planting cycles in one year and increasing the total annual harvest yield (Sri Mulatsih et al., 2023). The following is greenhouse melon production data in Table 4:

Table 4. Greenhouse Melon Production Data (Tons/Ha) for the Last 5 Months

Month	Production Before Greenhouse (Ton/Ha)	Production After Greenhouse (Ton/Ha)	Increase (%)
May	20	26	30%

June	22	28.6	30%
July	25	32.5	30%
August	24	31.2	30%
September	23	29.9	30%

Monthly Average Increase: The use of the greenhouse system has a positive impact on crop yields. This is evidenced by the yield increasing by 30% consistently every month. While the yield before the greenhouse was implemented ranged from 20 to 25 tons/ha, while after the implementation of the greenhouse system, production increased to 26 to 32.5 tons/ha. In May, the production of melons before the use of the greenhouse was 20 tons/ha, and after the implementation of the greenhouse, it increased to 26 tons/ha, showing an increase of 30%. Weather conditions at the beginning of the year, which are usually more unstable, can be mitigated with a controlled environment in the greenhouse. In June, melon production rose from 22 tons/ha to 28.6 tons/ha, with an increase of 30%. This increase reflects the benefits of climate control inside the greenhouse during the rainy season, which can usually lower crop yields (Fadhli et al., 2021).

July recorded an increase in production from 25 tons/ha to 32.5 tons/ha, the most significant increase in the last five months, as the weather in this month is usually more conducive to the growth of melons, and the use of greenhouses strengthens this productivity. Melon production increased from 24 tons/ha in August to 31.2 tons/ha. This increase remains consistent with a 30% increase, indicating that greenhouses significantly stabilize productivity despite seasonal changes. September also showed a 30% increase from 23 tons/ha to 29.9 tons/ha. This month is usually marked by hotter weather, but with temperature control in the greenhouse, melons can grow in optimal conditions without being affected by external temperatures (Heru Sandi & Fatma, 2023).

Operational Cost Optimization

The use of modern technology in greenhouses such as automatic irrigation, sensor-based monitoring, and temperature control systems provides many benefits such as reducing operational costs, minimizing manual labor and reducing waste of resources (Rangkuti et al., 2021). Reducing operational costs by up to 20% shows very significant efficiency in managing production or operational costs. This is due to various factors such as the application of technology, process automation, more efficient use of energy, or better resource management. In the context of application in melon greenhouses, this cost reduction is obtained from better efficiency in the use of water, labor, energy, and pest control (Novianti Indah Putri et al., 2022). The following is data on greenhouse melon production costs in Table 5:

Table 5. Data on Greenhouse Melon Operating Costs (tons/ha) for the last five months

Types of Operational Costs	Production Before Greenhouse (Ton/Ha)	Production After Greenhouse (Ton/Ha)	Reduction (%)
Labor Costs	12.000.000	9.600.000	20%

Maintenance Costs	5.000.000	4.000.000	20%
Irrigation Costs	3.000.000	2.400.000	20%
Energy Costs (Electricity)	7.000.000	5.600.000	20%
Pesticide and Fertilizer Costs	4.000.000	3.200.000	20%

The aspect of labor costs is that before the implementation of greenhouses, labor costs per hectare were IDR 12,000,000. After using greenhouse technology, this cost dropped to IDR 9,600,000, a 20% reduction. This efficiency occurs because irrigation automation systems, sensor-based monitoring, and climate control in greenhouses reduce the need for manual labor in plant care. The aspect of maintenance costs, namely the maintenance cost decreased from IDR 5,000,000 to IDR 4,000,000 after the implementation of the greenhouse, also decreased by 20%. This reduction is due to the use of more efficient tools, minimal maintenance, and the use of technology to detect problems early to reduce the frequency of repairs (Arodhiskara et al., 2022).

The aspect of irrigation costs or watering costs, was suppressed from Rp3,000,000 to Rp2,400,000 or down 20%. This is because the automatic drip irrigation system in the greenhouse is more water efficient than traditional irrigation methods, so it is more profitable and saves water and irrigation costs. The aspect of energy costs (electricity), namely the use of electricity to maintain temperature and humidity in greenhouses, has also been reduced by 20%, from IDR 7,000,000 to IDR 5,600,000. Although greenhouses use energy for climate control, modern technology, such as solar panels or energy-efficient heating/cooling systems, allows for more efficient energy control. The cost of pesticides and fertilizers, namely the use of pesticides and fertilizers, decreased from Rp4,000,000 to Rp3,200,000 after the implementation of greenhouses, which also decreased by 20%. A controlled environment inside the greenhouse reduces the risk of pests and diseases, so the use of pesticides can be reduced. In addition, fertilizers are used more efficiently with a more controlled nutrient system (Anugrah et al., 2014).

Aspects of Knowledge of Farmers in the Use of IoT Technology

Before participating in the training, the pre-activity questionnaire was used to determine the level of farmers' initial knowledge regarding the use of Internet of Things (IoT) technology. This questionnaire measures farmers' basic understanding of IoT technology, especially in agriculture, such as irrigation automation, crop condition monitoring, and sensors (Manuhutu, 2022). Questionnaires are filled out before the training activities begin so that the organizers can assess the educational needs of farmers as well as design appropriate training materials. In this pre-activity questionnaire, farmers were asked to answer a series of questions related to the basic concepts of IoT, the benefits of technology for agriculture, and technical knowledge about the use of IoT devices (Addin Albariki & Shofwan, 2021). The results of this questionnaire will indicate the extent to which farmers' knowledge level is still low, and this is the basis for the development of a more targeted training program. The following is the data from the results of the pre-activity questionnaire related to farmer knowledge in Table 6:

Table 6. Data on the results of the Pre-Activity Questionnaire.

Knowledge Aspect	Number of Respondents (N = 50)	Know (%)	Don't Know (%)
Understanding IoT Technology	50	20%	80%
IoT Application in Automatic Irrigation	50	15%	85%
Use of Sensors for Plant Monitoring	50	10%	90%
Benefits of IoT for Agricultural Efficiency	50	18%	82%
How to Install and Use IoT Devices	50	12%	88%

The aspect of understanding IoT technology shows that only 20% of respondents understand the basic meaning of IoT technology, while the other 80% do not know what IoT is. This shows that most farmers are still new to this technology and need a better understanding. The aspect of IoT application in automatic irrigation shows that knowledge about IoT in automatic irrigation is still shallow, with only 15% of farmers understanding how it works. while the majority, 85% of respondents, do not know how IoT can automate irrigation systems. These results indicate the need for practical training in using this technology. Using sensors for crop monitoring shows that most farmers (90%) do not know how to use IoT sensors to monitor crop conditions, such as soil moisture and environmental temperature. Only 10% know about this technology, indicating that this field requires a particular focus on training so that farmers can take advantage of sensor technology to increase productivity (Niekie Rafida et al., 2023).

The benefits of IoT for agricultural efficiency show that as many as 18% of farmers are aware of the benefits of IoT technology for agricultural efficiency, such as water and energy savings. However, 82% of respondents are unaware of these benefits, which indicates the need to emphasize IoT adoption's economic and productivity benefits. The aspect of how to install and use IoT devices shows that technical knowledge related to the installation and use of IoT devices is shallow, with only 12% of respondents knowing how to use them. As many as 88% of farmers do not know how to install or operate IoT devices, signaling the need for more in-depth technical training. The results of the pre-activity questionnaire showed that the level of farmers' knowledge of IoT technology is still deficient, with the majority of farmers not having an adequate understanding of how this technology works and its benefits. Data shows that only a small percentage of farmers know about the meaning of IoT, its use in irrigation crop monitoring, and its benefits for agricultural efficiency.

Therefore, the training that will be carried out needs to focus on the basic introduction of IoT technology and provide practical guidance on how to install and utilize this technology in the field to increase agricultural productivity and efficiency (Fadlina et al., 2013).

Aspects of Farmer Skills in Agricultural Environmental Management

Farmers will be asked to take a pre-activity questionnaire first to determine their skills in managing the agricultural environment (Khoirudda'I Hermawan et al., 2022). This questionnaire will measure the extent to which farmers are able to implement good environmental management practices, such as water management, efficient use of fertilizers and pesticides, and agricultural waste management. The questionnaire that will be given to farmers contains questions related to the technical skills possessed by farmers, including how to manage natural resources, sustainable irrigation techniques, and the ability to reduce the environmental impact of agricultural activities (Putra et al., 2020). The results of this pre-activity questionnaire will provide an overview of farmers' skills before the training begins, and will be used as a reference to determine areas that need to be improved through training activities. The following is data from the pre-activity questionnaire related to farmers' skills in Table 7:

Table 7. Data on the results of the Pre-Activity Questionnaire.

Skills Aspect	Number of Respondents (N = 50)	Skilled (%)	Unskilled (%)
Water Management for Efficient Irrigation	50	25%	75%
Appropriate Use of Organic and Inorganic Fertilizers	50	20%	80%
Pest Control with Environmentally Friendly Methods	50	18%	82%
Appropriate Management of Agricultural Waste	50	15%	85%
Sustainable Plant Maintenance	50	22%	78%

The aspect of water management for efficient irrigation is that only 25% of respondents are skilled in managing water efficiently for irrigation. As many as 75% of farmers still do not have enough skills in this regard. Proper water management is essential in sustainable agricultural practices, especially in the face of climate change and limited water availability. This data shows the need to improve farmers' skills in using water more economically and effectively (Gunawan et al., 2019). The aspect of the proper use of organic and inorganic fertilizers, namely the skill of farmers in the proper use of fertilizers, is still low, with only 20% of respondents having the ability to choose and apply organic and inorganic fertilizers according to plant needs. As many as 80% of respondents are unskilled in this regard, which indicates that many farmers may use fertilizers excessively or inappropriately, leading to waste of resources and potential environmental damage (Yuliana et al., 2021).

The aspect of pest control with environmentally friendly methods, namely the level of skill in pest control with environmentally friendly methods, showed low results where only 18% of farmers were skilled. Most farmers (82%) do not use environmentally friendly methods such as biological control or natural pesticides. This shows the need for training in more sustainable and environmentally friendly pest control techniques to reduce the use of chemicals (Novianti Indah Putri et al., 2022). The aspect of proper agricultural waste management, namely farmers' skills in managing agricultural waste, such as plant residues, plastics, or fertilizer and pesticide packaging, is shallow. Only 15% of respondents are skilled, while another 85% do not know or have not implemented the correct waste management techniques. This suggests that many farmers may dispose of waste carelessly or not utilize it constructively, thus damaging the environment (Reflis & Sumartono, 2023).

The aspect of sustainable plant maintenance, namely, as many as 22% of farmers have skills in sustainable plant maintenance, including crop rotation, green fertilizers, and healthy soil maintenance techniques. However, another 78% are still unskilled in this practice, which indicates that many farmers still have not implemented a sustainable approach to their agriculture (Kusumawati et al., 2021). The results of the pre-activity questionnaire showed that the level of farmers' skills in agricultural environmental management was still low in various aspects, especially in terms of water management, fertilizer use, environmentally friendly pest control, and agricultural waste management. Most farmers must improve their skills to implement sustainable and environmentally friendly agricultural techniques. Thus, the designed training needs to be focused on improving practical skills related to environmental management so that farmers can implement more efficient, environmentally friendly, and sustainable agricultural practices (Rachma & Umam, 2021).

Conclusion

The Technology and Innovation Dissemination Program in Kedungbanteng Village has positively impacted melon farmers through the application of Internet of Things (IoT) technology and the provision of access to revolving funds. This program improves the efficiency of melon cultivation in greenhouses, especially in real-time and automatic monitoring of plant environmental conditions, which impacts increasing productivity and reducing operational costs. In addition, financial management and business planning training helps farmers improve their business management skills so that they are better prepared to face the challenges of modern business. However, several aspects still need to be improved, such as partner accessibility to capital and continuous income increases, this has not been fully achieved because the program is still running so that it cannot measure the success and increase in partner capabilities. Nevertheless, this program has succeeded in building a solid foundation for the development of modern technology-based agriculture in the village.

Acknowledgment
We thank the Directorate General of Higher Education, Research, and Technology of the Ministry of Education, Culture, Research, and Technology for funding the 2024 Technology and Innovation Dissemination Program Scheme with contract number 3.5.24/UN32.14.1/LT/2024.

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