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A Smart Solution To Collect And Analyze Crop Growth Information

Jae-Kyung Lee[1], Seung Gu Shin[2], Byung-Moon Seol[*3]
[1]CEO, Neofarm Inc., 52501, Korea
[2]Assistant Professor, Department of Energy Engineering, Future Convergence Technology Research Institute, Gyeongnam National University of Science and Technology, 52725, Korea
[*3]Assistant Professor, Graduate School of Business & Entrepreneurship, Gyeongnam National University of Science and Technology, 52725, Korea
tdof2000@hanmail.net[1], sgshin@gntech.ac.kr[2], bmseol@gntech.ac.kr[*3]

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Abstract

Establishment and focus: In this study, a novel, smart solution was developed to collect and analyze crop growth information in protected, hydroponic farms. The developed hardware and software solutions collect and analyze crop growth information such as moisture content, EC, pH, and the temperatures of soil, water, and leaf. The collected data are used to judge between the vegetative and the generative growth phases. The data are stored in DB to allow further analysis and meta-studies.

System: The solution system consisted of the main controller, the measurement and analysis software, and the communication algorithm. A prototype was built to implement the solution system as designed. A demonstration farm was selected to install the solution system and a 225% increase of the tomato productivity was observed between 2014 and 2019. Overall, a successful demonstration of the solution system was achieved. The collected crop growth information can be used as a modeling data set for deep learning.

Keywords: *Crop growth, Deep learning, Agricultural productivity, Hydroponic farms, Growth analysis.*

1. Introduction

According to the survey of farm household economy released by Statistics Korea in 2017, the average income of farm households is 38.03 million won, of which the farm income is 104.7 million won. At present, our agriculture has difficulty in producing crops as planned due to climate change, declining rural population, stagnant farm household income and falling grain self-sufficiency. Also, there is a difficulty in providing stable food to consumers due to fluctuations in agricultural prices and inconsistent output[1].

Agricultural productivity is increasing year by year, but farmers' income is stagnant due to rising prices of agricultural input materials and falling agricultural prices. Also, the share of the domestic agricultural industry is steadily decreasing due to the weakening of the agricultural industry and the increase of agricultural products every year[2]. To solve these problems, new agricultural technologies must be introduced. For this, the application of the 4th industrial revolution technology (IoT, big data, Drone, robot, artificial intelligence, etc.) should be considered.

It is developing various smart farm and big data technologies in Korea. However, the standardization of crop growth information applicable to big data and collected crop growth information are insufficient. Therefore, to realize

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smart farm based on big data, it is necessary to collect crop growth information and manage it as big data. In the future, it is necessary to develop a “crop growth information collection and analysis solution,” an intelligent smart farm technology that can utilize the collected crop growth information according to the farm environment. Hydroponic cultivation in Korea began to industrialize in the 1980s and was around 20 ha in the early 1990s. Since then, the number of fixed facilities increased as a result of the nation's facility support projects, and increased to 1,665 hectares (83 times) as of 2014, as exports increased and consumers' desire to consume horticultural crops increased[3]. However, more than 90% of facility cultivation is made of vinyl greenhouses, which makes it difficult to increase productivity due to poor cultivation environment in the facility and deterioration of internal facilities and accessories[4].

The government aims to expand the horticulture smart farm goal of 4,000 ha and livestock smart farm 730 in 2017 to introduce the smart farm technology based on information and communication technology (ICT) and to distribute it to the agricultural field. Promoted to. Facility horticulture Hydroponics For the development of agriculture, the facility horticulture industry can be improved and secured international competitiveness through information and communication technology from production to final consumption as well as automation, modernization, and advanced production facilities.

The purpose of this study is to introduce information and communication technology to facility horticulture hydroponic farming and to provide farming productivity using farming technology using 2nd generation smart farm and big data. Facility horticulture The “crop growth information collection and analysis solution” that can be used in hydroponic farmers was implemented and demonstrated in tomato farms.

2. Materials and Methods

This study aims to develop smart farm into second-generation intelligent smart farm. For this, hardware and software were implemented to collect crop growth information (Figure 1). Hardware was implemented with the main controller, sensor node for sensor signal collection, power supply, and communication device. The empirical study was conducted by applying the implemented solution to tomato farms[5].

2.1. 2nd generation Smart farm

The type of smart farms are classified into simple types for simple environment control and convenience, and advanced types for stable production and quality improvement through intelligent and complex environment control for productivity improvement[6]. Table 1 shows smart farm type comparisons.

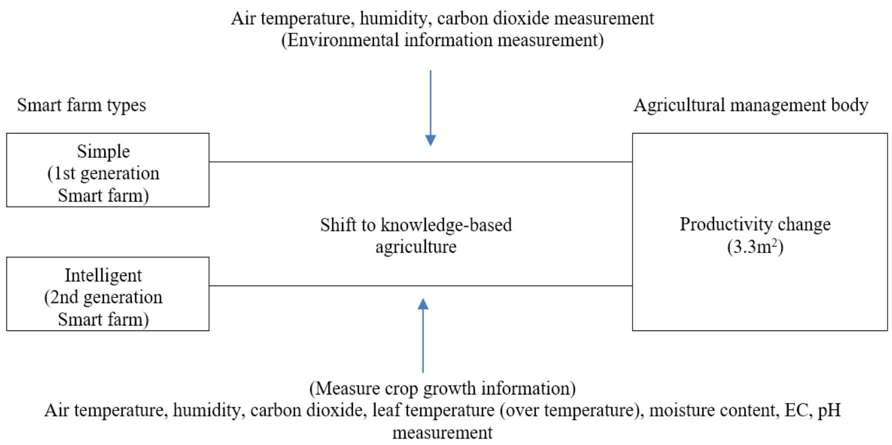

Figure 1. Conceptual diagram of the system

Table 1: Comparison of the smart farm types

Division	Simple (1st generation Smart farm)	Intelligent (2nd generation Smart farm)
Measurement information	Air temperature, humidity, carbon dioxide	Air temperature, humidity, carbon dioxide, leaf temperature (over temperature), moisture content, EC, pH
Control information	Ventilation control, heating control, nutrientcControl	Ventilation control, heating control, nutrient control, crop growth control
Main function	Green house environment measurement and control	Measurement and analysis of crop growth information

Facility horticulture Environmental management. The measurement information is air temperature, humidity, and carbon dioxide, and the crop growth information is water content, leaf temperature (over-temperature), EC, pH, and irrigation volume. Leaf temperature measures the crop temperature of the crop. The moisture content indicates the weight of the artificial medium in% based on the user set weight. EC measures electrical conductivity and pH measures hydrogen ion concentration[7]. Table 2 summarizes the information measured.

Table 2: Sensor node overview

Measurement information	Contents
Leaf temperature (Over temperature)	• It is a sensor node that is the standard for controlling the growth environment of crops. • It is the biggest factor in the photosynthesis and growth of crops. • Mobility can be installed by infrared method. • Leaf temperature measures the leaf temperature. • Leave temperature is used for opening and closing ventilation windows, heating control and screen curtain curtain control. • Over temperature measures the temperature of the fruit. • Overtemperature was used to confirm the transport of photosynthetic products.
Water content	• check how crops absorb water and nutrients • Measure the weight of medium and calculate it on a 100% basis. • The badge is based on 1m Growbag. • Measurement of weighing medium (ex: 17kg) Set reference value (ex: 20kg) ⟶ Moisture content Output (85%) • The proper water content is controlled differently for each crop. • Moisture rate is managed daily. • Changes in water content are used as a criterion for judging nutrition and reproduction.
EC	• Measure the electrical conductivity of the nutrients being supplied and drained. • Measurement standard shall be 25 °C (Unit: Siemens) / m, 1 / Ωm) In this study, the amount of drainage fluid was measured. • EC changes were used as a criterion for judging nutrition and reproduction.
pH	• Measure the hydrogen ion concentration of nutrients to be fed and drained. • Standard is 1 atmosphere 25 °C. (Example: 10-7 (M) ⟶ 7, log10 (1 / 10-7)) • Appropriate values range from 5.8 to 6.5 (most crops are similar). • pH change was used as a criterion for judging nutrition and reproduction.

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2.2. Concept of the solution system

Figure 2 Structure of crop growth information collection and analysis solution. It consists of a sensor node that receives analog sensor signals and converts them to digital, the main controller that operates and controls the input signals, and software that stores and analyzes the input signals. For communication, RS232C and RS485 MODBUS methods are applied.

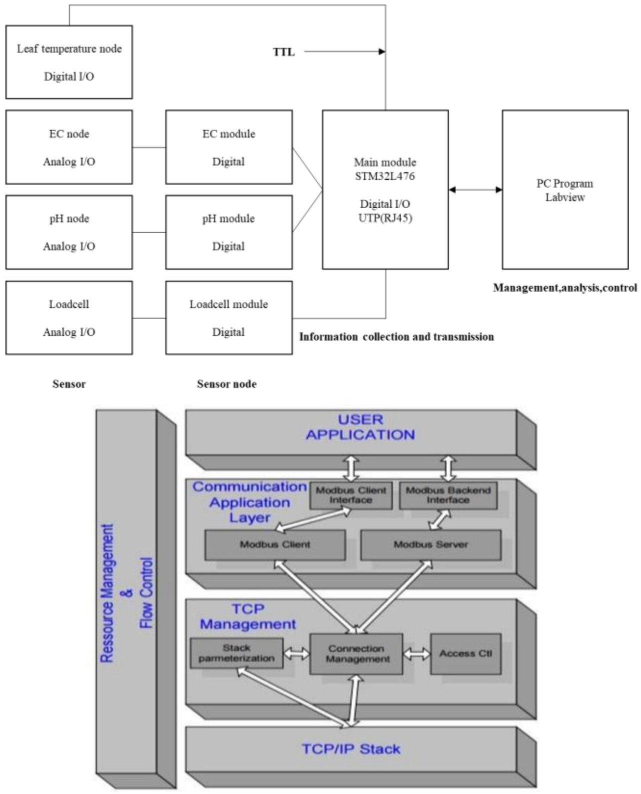

Figure 2. Block diagram of the development system and the MODBUS messaging architecture [8]

3. Results and Discussion

In order to empirically test the implemented solution in tomato farms, a cultivation group for collecting and analyzing crop growth information was implemented as shown in Figure 3.

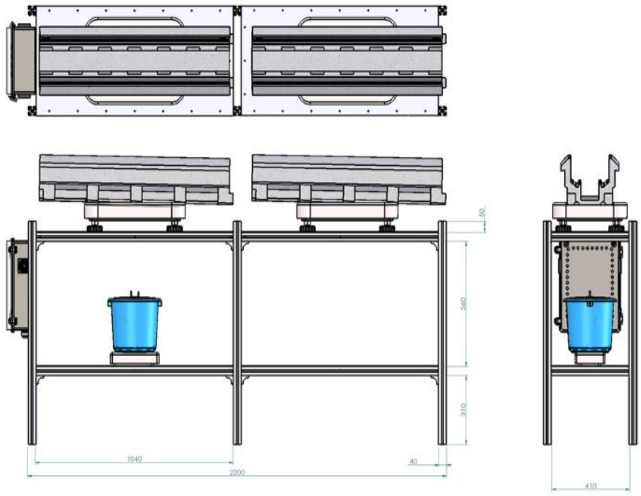

Figure 3. Schematic of the crop cultivation system

3.1. Design and implement

3.1.1. Prototyping

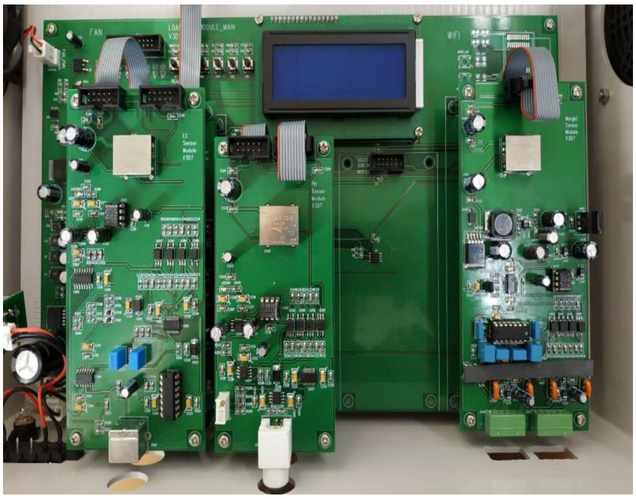

Figure 4. Crop growth information collecting device PCB

Product configuration is as shown in Figure 4. The sensor nodes are made of individual PCBs for easy replacement in the event of a problem. Also, the PCB itself has a function to calibrate the sensor. By applying DISPLAY LCD, you can check the information received even in the place where the module is installed. The development specification of the implementation system is shown in Table 3.

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Table 3: System specifications

Item	Specification	Item	Specification
Leaf temperature (fruit)	–20 ℃ ~ +50 ℃	Communication	RS485, MODBUS
Substrate weight	150 kg	Power	DC 24V
Drainge weight	30 kg	O/S	WINDOWS
EC	0 to 10 $dS \cdot m^{-1}$	Software	LABVIEW
pH	0~14	DB	MariaDB

3.1.2. Main controller

The main controller is implemented as shown in Figure 5, and the detailed components are listed in Table 4.

3.1.3. Measurement and Analysis Software

The analysis software is implemented as shown in Figure 6. The software consists of the following components.

◦ Custom UI design: location information, optical compensation point, optical saturation point, substrate weight, the base setting, time synchronization

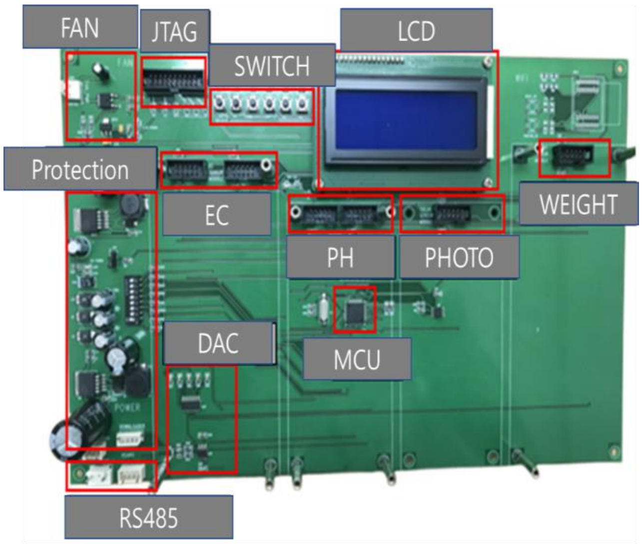

Figure 5. Main controller PCB

Table 4. Detailed features of the main controller

Main component	Feature
Switch control unit	Consists of 6 switches.
	Switch 1 is reserved.
	Switch 2 can be set variously with MENU.
	SET 3 switch is selected or saved.
	Switch 4 raises setting value.
	5th switch DOWN decreases setting value.
	Switch 6 reset resets the main MCU.
LCD display	20 * 4 column character LCD is applied.
	White text on blue background.
	The output page is three pages.
I / O Connect	8 pin IDE TYPE is applied.
	The total number of input channels is 6 channels.
	8 pin ribbon cable is used for sensor node connection.
MPU	ARM 32BIT process was applied.

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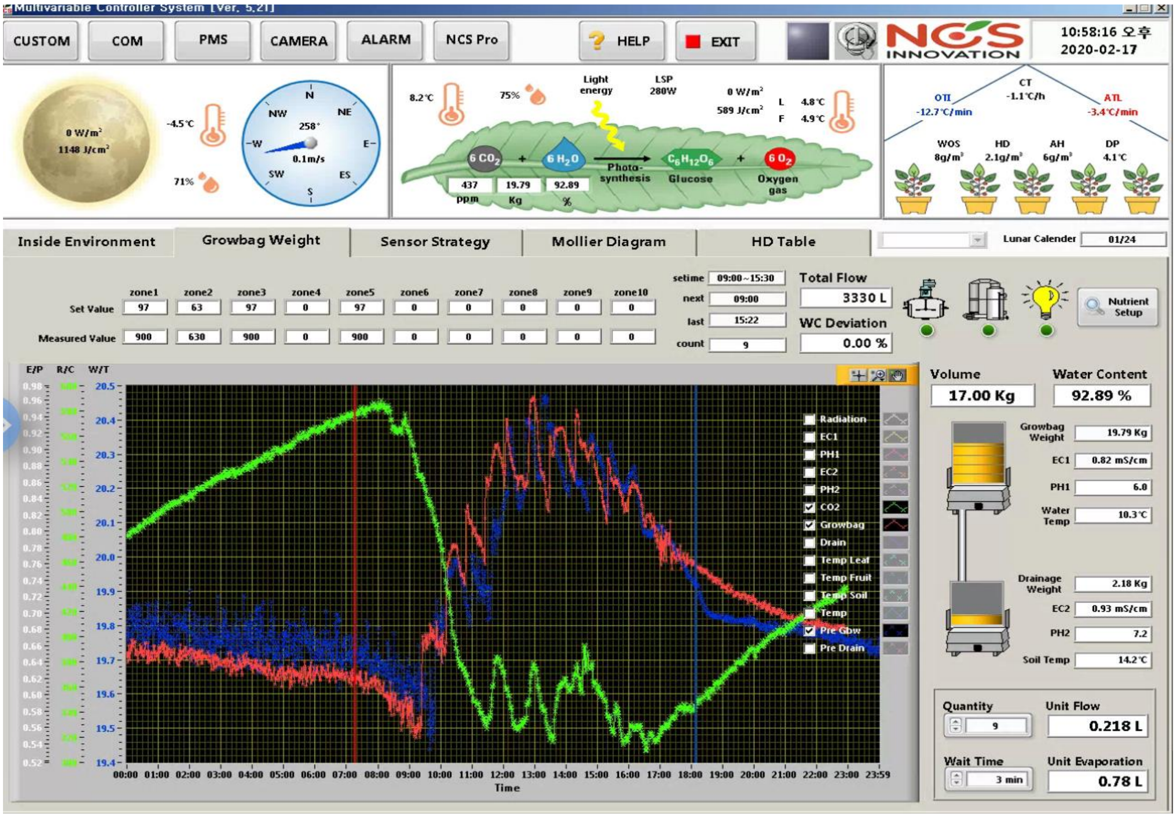

Figure 6. Software UI

◦ Communication setup and device registration UI design: device name, ID, communication method, port no, sensor installation area

◦ Measurement information display (graph) UI design: scale change, color change, pointer side, select input, export input information

◦ UI design for nutrient solution irrigation: watering time, cycle, watering condition, nutrient supply condition

◦ Nutrient irrigation information display UI design: irrigation information, formal information

◦ Graphic display UI design: minimum value, maximum value, average value, measurement period

Display Mollier diagram based green zone and Enthalpy[9]. Enthalpy is defined as the total heat content or total useful energy of a substance. The symbol for enthalpy is h. Enthalpy is also considered to be the sum of internal energy u and flow energy (or flow work) pV. This definition of enthalpy can be expressed, mathematically, as follows:

$$h = u + pV \quad (1)$$

h = Specific enthalpy, measured in kJ/kg (SI Units) or BTU/lbm (US Units)

u = Specific internal energy, measured in kJ/kg (SI Units) or BTU/lbm (US Units)

p = Absolute Pressure measured in Pa (SI Units), or psf (US Units)

V= Volume measured in m3 (SI Units), or ft3 (US Units)

pV = Flow Energy, Flow Work or p-V work, quantified in kJ/kg (SI Units) or BTU/lbm (US Units)

3.1.4. Communication algorithm

Figure 7 shows the information gathered to improve Modbus protocol and productivity. The sensor information collection algorithm transmits information and ID information collected through

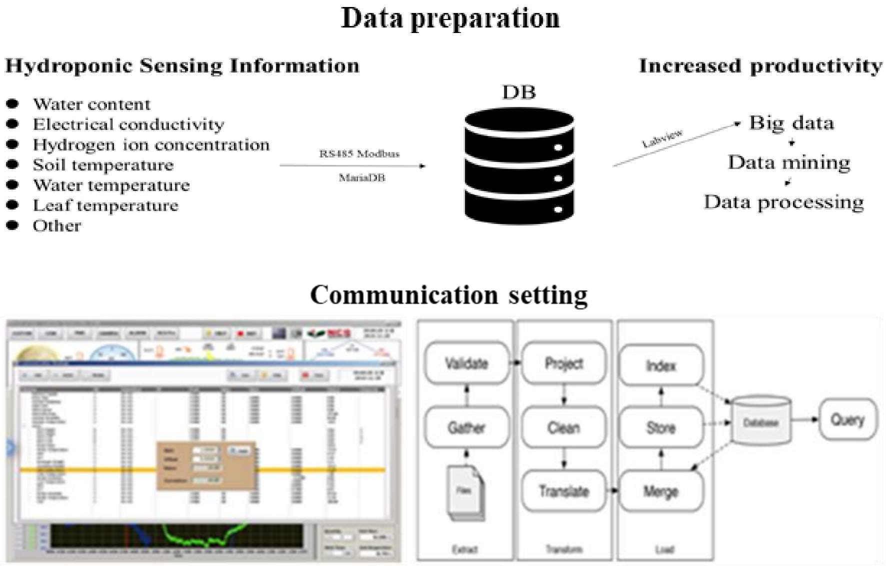

Figure 7. Communication setting and an example of the data preparation pattern [10]

RS485 communication at the sensor node. The information received from the main controller sensor node is transmitted to the PC via RS232C communication. The information transmitted to the PC is stored in the DB at the same time as running the application program. The communication protocol of device except for temperature is applied MODBUS and the communication medium is RJ45. 1 and 2 were DC + 24V, and 7 and 8 were -powered, and communication was 4 T + and 5 T-. Two RJ45 connectors are used to expand the device. Dedicated modules for power and communication have been developed, and up to 255 devices can be connected in parallel. The communication method of the leaf temperature (over-temperature) sensor node is SPI 3.3V TTL method and 5 pin Molex connection is applied. 5 times, 2 times GND, 3 times D-, 4 times D + and 5 times PE were applied. The communication bus is set to RS485 Multi-Drop, Half duplex, the communication speed of 19,200bps, DATA 8bit, Parity NONE, STOP 1bit.

3.2. Farm Installation

The demonstration farms had been farming tomatoes for soil cultivation before 1997, and in 1997 they started linked hydroponic cultivation. In 2015, the company installed and operated the first generation smart farm system, and in 2016, newly constructed the second generation smart farm system. Figure 8 shows a system installed on a demonstration farm.

Figure 8. Farm installation

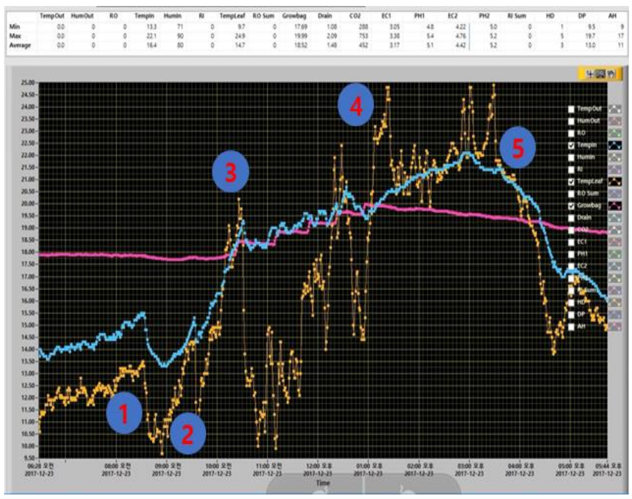

Figure 9. Solution development using the developed system

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Figure 9 shows the use of development solutions for agricultural productivity at demonstration farms. The first curve in Figure 9 can confirm that the foliage temperature rises after sunrise. Curve No. 2 shows that the foliage temperature of the heated curtain OPEN decreases by 4°C from 13.5°C to 9.5°C due to increased internal temperature of the farm. In order to prevent rapid temperature drop, if the ambient air mass is more than 150W, the temperature change per hour is minimized by opening stage 1 20% OPEN, stage 2 50% OPEN, and stage 3 100% OPEN. The analysis graph No. 3 curve shows that after sunrise, the temperature of the leaves rises by more than 2°C above the internal temperature. Agricultural data define that the temperature of crops rises first when the light comes in. Check the number of curves 3 and the moisture content and determine the first point of view. If the foliage temperature is higher than 20°C and rises more than 2° above the room temperature, the first irrigation is performed. After Curve No. 3, the foliage dropped sharply after the first perfusion. The indoor temperature is rarely changed, but the foliage can be found to fall 10°C from 20°C to 10°C due to the increased production of crops after irrigation. Analysis Graph No. 4 shows a rapid rise in foliage after final irrigation. After the end of the irrigation, the foliage temperature rises from 14°C to 25°C. This shows that the foliation temperature rises relatively higher than the indoor temperature as no amplification is performed after the end of the irrigation. Analysis Graph No. 5 shows that after sunset the leaves are lowered by more than 1°C than the room temperature. After sunset, the crops are responsible for electrifying carbohydrates produced in the morning. For carbohydrate current, the fruit temperature must be higher than the folate temperature. The use of post-temperature is used to set the opening and closing time of the heating curtain, the first irrigation time, the last irrigation time, and the heating time for maintaining the night temperature.

3.3. Crop productivity

The productivity of demo farms has improved by 225% since the introduction of the first generation smart farm in 2015 and by 122% since the introduction of the second generation smart farm in 2016 (Figure 10). According to the 2018 National Statistical Office data, the total tomato production in Korea is 28.9kg per 3.3m2, and the tomato production of the smart farm leading farmer is 65kg per 3.3m2, which is 32.82% of the Dutch production.

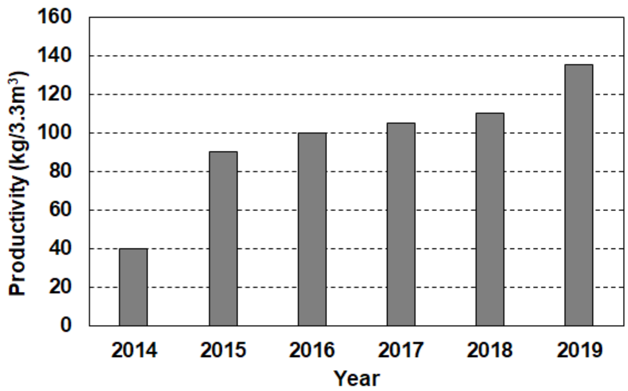

Figure 10. Crop productivity between 2014 and 2019

4. Conclusion

This study analyzed the effects of crop growth information collection and utilization on the productivity of facility horticulture farms. For the study, a system developed for collecting crop growth information was installed and operated on tomato farms. Based on the research results, this study has the following implications. First, we saw that crop growth information can be collected and analyzed to support productivity improvement. The government's policy direction on smart farms suggests a need for an education system that can collect and analyze crop growth information. Second, in order to standardize the technology of the second generation smart farm, it is necessary to develop various related technologies necessary for crop growth such as leaf temperature, over-temperature, near ground temperature, EC, pH,

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and water temperature. Smart farming is attempting to shift from convenience to knowledge-based agriculture to increase productivity. The key to knowledge-based agriculture is to collect and analyze information on the growth of agricultural crops to maintain optimal growth requirements. If specialized education, equipment, and systems are advanced, agriculture will be innovatively developed.

5. Acknowledgment

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