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Differences of Environmental Conditions by the Type of ICT-based Horticulture Greenhouses

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ABSTRACT

This study has two primary objectives. First, by using aggregated environmental data from many farms, we analyze the differences of data among farms and we propose the operational points to be considered by each greenhouse type. Second, we present some application implications expected from merging environmental and actuator control data. Lately, with the progression in information and communications technology(ICT), the number of greenhouses with an automated environmental control system based on a sensor network is increasing in South Korea. For greenhouses using ICT equipment, environmental and actuator control data are being collected in real-time. However, most farmers have been utilizing the data only they develop weekly environmental controlled greenhouse management reports. Farmers do not link the data through an analysis of aggregated data from different farms or an analysis on linked data between environmental and actuator data. In this study, data from six tomato farms in South Korea were collected from November 2014 to October 2015. The greenhouses were categorized by roof windows type, cultivation method (hydroponics or fertigation), covering type, heating system, and temperature setting for roof window. The outcome of this study shows how the information collected from many farms can be utilized usefully. Implications can be driven by both analyzing the environmental and actuator control data

Keywords: Environmental control, greenhouse data analysis, sensor network, ICT

1. INTRODUCTION

Facility horticulture in South Korea(hereafter, Korea) has been growing since the 1960s and the amount of production has significantly increased from 800 billion to 5.3 trillion Won from 1990 to 2010 [1]. Enhancing the productivity of agriculture against incorporation in a global economy and aging population in rural areas is a pressing issue. Thus, the rightsizing and specialization of farms has been progressed constantly. Meanwhile, the greenhouse facility area has remained stagnant at the 53,000ha level since the 2000s [2]. Moreover, facilities have not been upgraded, Thus, 90% of the greenhouses are greater than ten years old [1]. Along with the recent advances of information technology, automated environmental control systems which use sensor networks is spreading. However, these control systems have not become popular because Korea has mountainous terrain and mainly consists of smallholdings that have difficulty in investing a huge amount of economic resources.

Korea is contradistinctive with the horticulture of the advanced countries such as the Netherlands and Israel. The absence of a growth model for Korean varieties and a technical lag in horticulture facilities are big obstacles in Korea. For the advancement of facility horticulture, a suitable environmental control model, which can be fitted into each local climate in Korea, is essential. In a greenhouse with ICT devices, environmental data such as temperature, humidity and CO2 concentration, and actuator control data can be collected. However, most farms are still using limited environmental data for creating an environmental management report for weekly growth management. Therefore, developing an environmental control model for a domestic situation using systematically collected and analyzed data from various farms is important. In this study, we analyze differences in the inner environment by the type of greenhouse and operating element using aggregated environmental data from multiple farms. In addition, we suggest application implications by combining environmental and actuator control data

2. MATERIAL AND METHOD

The subjects of analysis were six greenhouses. Only tomato farms were selected to control the influence of the nature for each crop. The greenhouses were distributed in pairs in Jeongeup, Busan, and Pyeongtaek, respectively. The cultivation areas were between 2,479 to 9,900 square meters and all farms were multi–span plastic greenhouses and used environmental control system. The cultivation methods were hydroponics at four farms and soil cultivation with fertigation at two farms. For greenhouse covering, three farms were single-layer and three farms were double-layer. Only one farm had a single-layer horizontal curtain while the other five farms had a double-layer curtain. Every farm used a roof opening, side opening, thermal curtain, heater, and air circulation fan and exhaust fan. A shade screen was used at five farms and four farms had a CO2 supply system (i.e., one farm is a combustion gas type). A fog system was used at one farm and a supplemental lighting lamp was not used at any of the farms. The roof opening system was hinged type at two farms and a roll-up type at four farms. The heating system was a hot water boiler at two farms, heating fans at three farms, and electronic heating at one farm.

The research period was from November 2014 to October 2015. Actuator control and environmental data were collected every minute from each greenhouse. We checked the variation range of the environmental factor, according to the type of greenhouse and operating elements. Temperature, humidity, CO2 and solar radiation were used for comparisons. We analyzed 51 million observations of 65 variables per farm. However, we were only able to collect nine months of data for Farm A from December 2014 to August 2015.

3. RESULTS AND DISCUSSION

We analyzed the differences in environmental data according to the type of the greenhouse and operational elements. Greenhouses were categorized by roof window type, cultivation method, number of layers, heating system, and temperature setting (Table2). We compared average, standard deviation, maximum and minimum value of temperature, humidity, CO2 concentration, and the amount of solar radiation for each category.

3.1 Difference by roof window type

The difference in inner temperature between the hinged type and roll-up type was only 0.4 on average. However, temperature fluctuation was smaller in the former with a gap of 1.2 standard deviation.

Table 1. The Subjectives of Analysis

	Farm					
	A	B	C	D	E	F
Area(m^2)	4,990	9,900	2,975	4,960	7,933	2,479
Covering	Single layer	Single layer	Double layer	Single layer	Double layer	Double layer
Horizontal curtain	Double layer	Double layer	Single layer	Double layer	Double layer	Double layer
Roof window	O	O	O	O	O	O
Side window	O	O	O	O	O	O
Shade screen	O	O	O	X	O	O
Thermal curtain	O	O	O	O	O	O
Fogging system	X	X	O	X	X	X
Air-circulation fan	O	O	O	O	O	O
Exhaust fan	O	O	O	O	O	O
Supplemental lighting lamp	X	X	X	X	X	X
CO_2 supply	O	O	O	O	X	X
Cultivation	Hydroponics (Medium)	Hydroponics (Medium)	Hydroponics (Medium)	Hydroponics (Medium)	Fertigation (Soil)	Fertigation (Soil)
Roof window Type	Hinged	Hinged	Roll-up	Roll-up	Roll-up	Roll-up
Heater type	Hot water boiler	Hot water boiler	Heating fan	Electronic	Heating fan	Heating fan
Region	Jeongeup	Jeongeup	Busan	Busan	Pyeongtaek	Pyeongtaek

3.2 Difference by cultivation method

The cultivation method has an effect on crop growth. Thus, cultivation method can affect the CO2 level. We found that the CO2 density in Hydroponic farms is lower than that of fertigation farms.

3.3 Difference by greenhouse cover

The double-layer covering method has been used as insulation for a long time [3]. However, in this research, the standard deviation in the inner temperature of double-layer greenhouses was greater than single-layered. The outside temperature can have more effect on the inner temperature than the number of cover layers. Further research should be conducted by controlling the outside temperature. The amount of solar radiation was higher in single-layer greenhouses.

3.4 Difference by heating system

The average inner temperature of greenhouses using a hot water boiler was similar to that when using heating fans. The standard deviation was lower in the hot water boiler type. Farms using a heating fan have lower humidity with higher standard deviation.

Table 2. The Results of Analysis

Greenhouse type and operational elements		Farms	Statistics	Temperature(℃)		Humidity (%)	CO_2	Solar radiation
				Outside	Inside			
Roof window	Hinged type	A,B	Mean	13.9	20.1	78.5	508.7	151.8
			Stdev	11.2	5.0	13.6	115.2	241.7
			Max.	51.1	64.2	97.0	1402.0	1381.0
			Min.	-12.3	-24.0	0.0	0.0	0.0
	Roll-up type	C,D,E,F	Mean	12.0	20.5	68.8	737.2	139.1
			Stdev	11.3	6.2	18.8	364.0	206.5
			Max.	43.5	46.8	90.7	3445.0	802.5
			Min.	-21.2	-1.2	0.0	127.5	0.0
Cultivation method	Hydroponics (Medium)	A,B,C,D	Mean	13.6	20.6	73.8	630.8	144.0
			Stdev	10.6	5.1	14.8	263.1	228.7
			Max.	48.0	55.1	93.6	2728.5	1150.5
			Min.	-19.7	-12.0	0.0	77.5	0.0
	Fertigation (Soil)	E,F	Mean	10.8	19.9	68.5	721.5	141.9
			Stdev	12.5	7.3	21.6	317.0	197.3
			Max.	42.1	47.7	91.1	2835.0	685.0
			Min.	-15.3	-2.4	0.0	100.0	0.0
Covering type	Single layer	A,B,D	Mean	13.8	20.4	74.7	526.3	155.0
			Stdev	10.9	5.0	13.9	120.5	241.4
			Max.	47.3	59.9	93.6	1534.7	1194.0
			Min.	-11.7	-16.0	0.0	103.3	0.0
	Double layer	C,E,F	Mean	11.4	20.3	69.3	795.7	131.6
			Stdev	11.6	6.6	20.3	441.6	195.1
			Max.	44.7	45.3	92.0	3993.3	796.7
			Min.	-24.8	-1.6	0.0	66.7	0.0
Heating system	Hot water boiler	A,B	Mean	13.9	20.1	78.5	508.7	151.8
			Stdev	11.2	5.0	13.6	115.2	241.7
			Max.	51.1	64.2	97.0	1402.0	1381.0
			Min.	-12.3	-24.0	0.0	0.0	0.0
	Heating fan	C,E,F	Mean	11.4	20.3	69.3	795.7	131.6
			Stdev	11.6	6.6	20.3	441.6	195.1
			Max.	44.7	45.3	92.0	3993.3	796.7
			Min.	-24.8	-1.6	0.0	66.7	0.0
Temperature setting for roof window	Flexible around 18℃	A,B,D	Mean	13.8	20.4	74.7	526.3	155.0
			Stdev	10.9	5.0	13.9	120.5	241.4
			Max.	47.3	59.9	93.6	1534.7	1194.0
			Min.	-11.7	-16.0	0.0	103.3	0.0
	Flexible around 20℃	C	Mean	12.7	21.1	71.0	944.2	111.1
			Stdev	9.9	5.2	17.7	690.8	190.7
			Max.	50.0	40.6	93.8	6310.0	1020.0
			Min.	-43.8	0.0	0.0	0.0	0.0
	Fixed on 25℃	E,F	Mean	10.8	19.9	68.5	721.5	141.9
			Stdev	12.5	7.3	21.6	317.0	197.3
			Max.	42.1	47.7	91.1	2835.0	685.0
			Min.	-15.3	-2.4	0.0	100.0	0.0

3.5 Difference by temperature setting

Farms that set the temperature differently over time have a lower standard deviation for inner temperature than farms with a consistent temperature setting. As stated above, there are differences in environmental data according to the greenhouse type and operational elements. Nevertheless, due to a small number of samples, this study has limitations in analyzing significant statistical differences. We could not control the effect of correlation between each element as well, which could be an influence from a gap on climate conditions, such as the outside temperature.

4. CONCLUSION

In this study, we analyzed the differences in environmental data depending on the type of greenhouse and operational elements by using aggregated environmental data from six farms. By accumulating these data, it will be possible to recommend an environmental control method and to develop an automatic control model for many farms by considering their characteristics. Furthermore, from the planning stage of the farm, the data can assist in efficient management by suggesting the most suitable facility and growing method for a specific region and crop
Although we have limitations in analyzing significant differences, an environmental control model should be optimized for a greenhouse facility and climate. Therefore, the environmental control model needs long-term studies and enormous cost to find the best model for each farm that have large regional variance and crop varieties. Also, researchers have to keep in mind that environmental and actuator control data from various farms should be collected and analyzed together. In this kind of research, it's essential to retain continuous cooperation and to share knowledge with farmers, which is difficult to resolve solely by the government or a particular business.

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