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Development of an Integrated Greenhouse Monitoring and Control System at Province Level

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This study reports the construction and application of an integrated greenhouse monitoring and control system for a total of 28 farmhouses cultivating paprika in Gyeongsangnam–do province. This system constructed by using information technology (IT) could monitor the present conditions of each individual greenhouse in real time through the Internet. The environmental conditions in the greenhouse could be easily controlled via a dedicated control panel and an electronic display was installed to monitor the present condition. The provincial Agricultural Research and Extension Services (ARES) in each region could monitor the greenhouse environment for the whole farmhouses cultivating paprika in real time through the system. In addition, the ARES can support farmers with a farming counseling and consultation about the greenhouse situation based on greenhouse database (DB) and camera images collected by the system. A survey about the effectiveness of the system showed that 71% of the 28 farmhouses participating in the project were satisfied with the equipment installed, and 79% were satisfied with the user convenience of the system. The overall satisfaction was 71% of the participating farmhouses for the installed Ubiquitous Information Technology (u–IT) based optimum environment control system.

INTRODUCTION

Recent advance in IT has been creating new values in diverse fields of industry through IT fusion. It is also actively applied to the agricultural field for the control of production environment based on IT such as Radio Frequency Identification (RFID)/ Ubiquitous Sensor Networks (USN), and Light Emitting Diode (LED), pest monitoring, quality control, traceability, core technology on intelligent farming robots, technology in plant production factory, etc. (Lee *et al.*, 2011; Gonda and Cugnasca, 2006; NIC, 2008; MIFAFF, 2010–a, 2011).

To protect domestic farming and to strengthen its competitiveness, countries advanced in agriculture such as Denmark, Netherlands, and Japan have already employed u–IT for the entire process of production, distribution, sales, etc. (MIFAFF, 2010–b, 2010–c). Korea has also started a ubiquitous farm/ubiquitous fish farm project applying IT fusion technology under the supervision of the Ministry of Information and Communication since 2004. The projects included collection of precise faming information using remote sensors, pest monitoring using camera images, control of the production environment using LED and USN technology, livestock management, traceability using RFID and plant production factory (MIFAFF, 2010–b). After u–IT projects in agriculture were transferred to the Ministry of Food, Agriculture and Forestry and Fisheries (MIFAFF) in 2010, the business has been on a gradual increase following the stage of demonstration, substantiation, and expansion of u–IT (MIFAFF, 2010–a, 2010–b, 2011). Greenhouse management is a common area applying IT. Diverse crops are being produced through greenhouse culture, and paprika can be referred to as one of the representatives among greenhouse culture vegetables.

Paprika industry in Korea is growing into the export industry with beefed–up foreign competitiveness due to application of IT and economical efficiency of capital–intensive industry. Specifically, domestic paprika industry recorded around 120 billion won of total production for 2010, accounting for 2.8% of gross agro–forestry output, 0.31% of the whole acreage under cultivation and 0.94% of the total number of farmhouses. Despite the current small share, its scale is steadily growing because paprika brings higher earnings compared to other crops.

Incidentally, with increased burden of costs in business management due to soaring crude oil prices, profits from paprika are gradually dwindling more recently. This situation accentuates the high–quality production, lower energy consumption, and greenhouse management via cutting–edge science and technology as one method to improve greenhouse environment and management.

In this study, appliance on the u–IT based model for the environment measurement and optimum controls on greenhouse was installed at 28 farmhouses by region (all within Gyongsangnam–do) that actually cultivate paprika, developing the optimum environment control system and constructing the integrated monitoring and control system for the group of paprika producers.

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MATERIALS AND METHODS

1. Present conditions of paprika growing farmhouses in Gyongsangnam–do

This study is the project of the MIFAFF for supporting u–IT model farms and their expansion, constructed by Gyongsangnam–do Provincial Office and Love Pap Co., Ltd. and promoted by Korea Information Center for Agriculture, Forestry and Fisheries in exclusive charge. Constructing the system took about 5 months from October 6, 2010 to February 28, 2011.

The u–IT based comprehensive environment control system was constructed on the subject of totaling 28 farmhouses that produce paprika as a main item in Gyongsangnam–do province. To establish efficient growth environments for paprika in greenhouse, ubiquitous technology was applied in an effort to create lower energy consumption, lower costs, and higher earnings. The current greenhouse management system for no more than temperature and humidity management was redesigned so that it may produce high–quality paprika through controlling and monitoring on optimum growth conditions by integrating diverse measurement sensors for environmental factors and IT. As to growth environment, paprika is the item that absolutely needs precise agricultural technology compared to others. Farmhouses participating in the construction of the system were 28 in all, from three groups, which mainly produced paprika

Table 1. Farmhouses targeted for system construction and their size

Division	Region	Number of farms	Area of greenhouse
Group 1	Jinju–si	11	
	Tongyeong–si	1	• under 3300 m^2: 3 farms
Group 2	Haman–gun	10	• 3300–6600 m^2: 11 farms
	Uiryeong–gun	3	• over 6600 m^2: 14 farms
Group 3	Changwon–si	3	

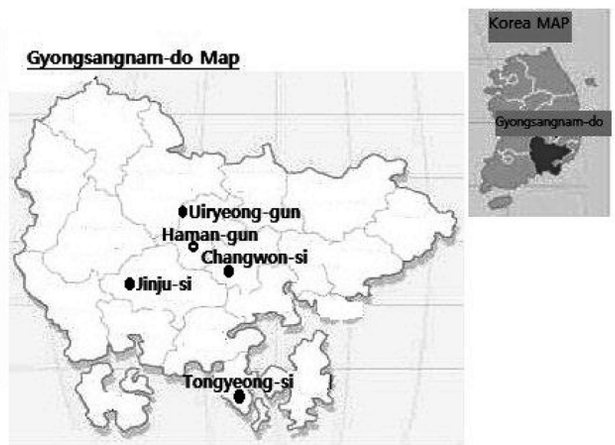


Fig. 1. Distribution of farmhouses designated for the system located within Gyongsangnam–do province (5 chief cities and guns).

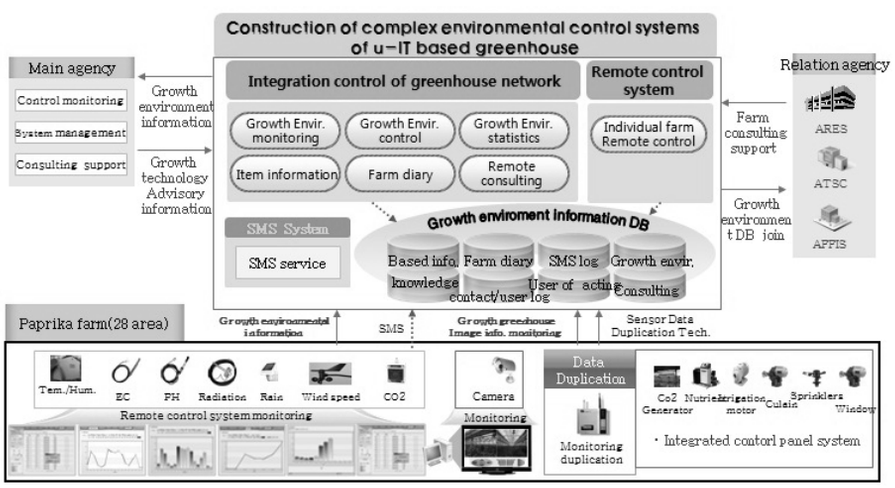


Fig. 2. Outline of optimum environment control and integrated monitoring system for u–IT based paprika greenhouse.

(a) Photo of a Vinyl greenhouse (b)Picture of cultivating paprika inside greenhouse

Fig. 3. Photograph of the outside of the system built–in paprika greenhouse and complete view of the inside (Tongyeong city in Gyongsangnam–do).

in Gyongsangnam–do area. Specifically, they were from Tongyeong city (1 farm), Jinju city (11 farms), Changwon city (3 farms), Haman gun (10 farms) and Euiryeong gun (3 farms). As to the greenhouse size of each farmhouse, it comprised three farms under 3,300 m^2, eleven farms between 3,300 and 6,600 m^2, and 14 farms over 6,600 m^2 (Table 1). Geographical position of each region was shown in detail in Fig. 1.

2. Outline of the system

The u–IT based optimum environment control and integrated monitoring system was built so that it might enable real–time integrated control and monitoring on temperature, humidity, solar irradiance, rainfall, wind direction, wind speed, pH and EC of the nutrient solution, CO_2 concentration, and growth conditions of paprika through the infrared camera in real time in greenhouses.

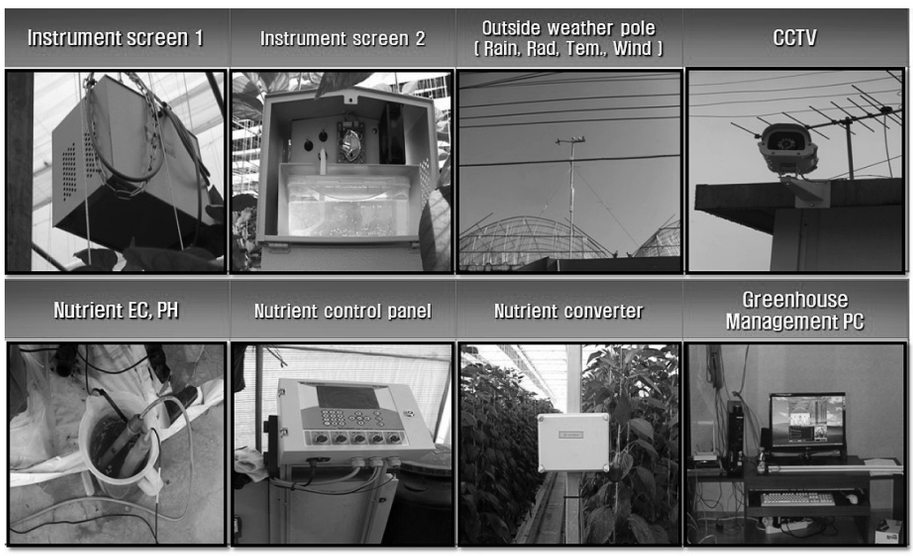


Fig. 4. Photograph of environmental measurement and control equipment installed inside a greenhouse.

Table 2. Composition of environment measuring sensor and control system installed in the vinyl greenhouse of each farm

Division	Products name	Model name	Number	note
H/W & S/W	server	HPDL360G6	11	GN–ARES
	OS	Windows server 2008	1	GN–ARES
	DBMS	Windos SQL Server 2008	1	GN–ARES
	Display	PDP(42")	1	GN–ARES
	consulting PC	DMC410PAS77	1	GN–ARES
	management PC	DMC210PAS1	28	greenhouse
	remote control S/W	Custom design	28	greenhouse
	communication equipment	IC–485S	28	greenhouse
	network	ipTIME G104M	28	greenhouse
	gateway	GN3000Z	28	greenhouse
	LED screen	Custom design	28	greenhouse
Environmental measuring sensor	Temperature/Humidity	Termisto	56	greenhouse
	Temperature	Thermistor	28	greenhouse
	Radiation sensor	HTL–301	28	greenhouse
	rain sensor	GN–3000Z Rain	28	greenhouse
	wind speed sensor	RM–001	28	greenhouse
	camera	B240–NR	28	greenhouse
	DVRboard4ch	PHR08 (CVR)	28	greenhouse
	nutrient EC,PC	SH–100ECS	28	greenhouse
Control equipment	Integrated control system panel	Custom design	28	greenhouse
	Semiautomatic control panel	Custom design	28	greenhouse
	nutrient control panel	Custom design	28	greenhouse
	CO_2 control panel	Custom design	28	greenhouse
	SMS alarm system	Custom design	28	greenhouse
	Lighting protector	BKS–C	56	greenhouse

There were also control panels for integrated setting and the systems for supplying nutrient solution and for CO_2 gas enrichment. Farmers can check the crop growing environment and its condition at their own greenhouse at any time through camera images provided by the Internet and ubiquitous technology.

In addition, Gyongsangnam–do Agricultural Research and Extension Services (GN–ARES) that can control each farmhouse's greenhouse by geographical area comprehensively is able to monitor the greenhouses of all 28 participating farms in real time. Integrated control room of this organization provides the service of information collection on growth environment, observation of rearing condition, automatic control of greenhouse setting, remote control, alarm function, etc. The organization can also support direct farming counseling and consulting with farmers by analyzing and using stored DB such as growth environment statistics and farming diary. The outline of the u–IT based greenhouse optimum environmental management system is shown in detail in Fig. 2.

3. Details of installed equipment in the greenhouse

To measure paprika growth environment in vinyl greenhouses in Gyongsangnam–do area, growth environment measuring sensors for temperature, humidity, irradiation, nutrient solution and infrared camera were installed. Fig. 3 shows the exterior of a vinyl greenhouse that cultivates paprika and the looks of paprika inside. Besides, for the optimum environment control of the crop, a comprehensive control program was developed. Fig. 4 shows every kind of growth environment measuring sensors installed inside the greenhouse and the control panel set. The environmental measurement facilities installed separately in each farm and compositions of the system are shown in detail in Table 2.

RESULTS AND DISCUSSION

1. Present conditions of installing the u–IT based environmental control system

Hardware installation in u–IT based paprika greenhouse and network composition were described in Fig. 5. To provide the optimum growth environment for crops, growth environment information was observed in real time and constructed in DB via every kind of measuring sensors and infrared camera. Moreover, comprehensive greenhouse environment control panel for its remote control enabled individual controls of top vent openings, side vent openings, horizontal curtains, heating and air conditioning system, air mixing fans, humidifier, and the supply systems for nutrient solution and CO_2 gas, etc. The DB was constructed after collecting, processing, and analyzing growth environment information in real time. The system was constructed to notice any abnormality in greenhouse environment on the spot and to report the emergency by means of voice alarm and SMS to both the control center and the relevant farmhouse.

Considering expanse of the system in the future, the sensors and the network were based on the standards and optimum sensing environment with sensor equipments which were certified by the Korea Communication Commission (KCC) for their performance. Furthermore, touch LCD on–site and the remote control were combined to operate the system stably. The system could be operated either by the manual control for the user's immediate action in case of sudden changes inside the greenhouse or by the automatic control according to set values.

2. Installed equipment for the system in each greenhouse

The appropriate number of sensors needed for the u–IT based greenhouse control and monitoring system was determined by the size of each greenhouse. Sensors installed for each farmhouse were on average for temperature (5 units), humidity (2 units), solar irradiance (1 unit), rainfall (1 unit), wind direction (1 unit), wind speed (1 unit), pH (1 unit), and EC (1 unit) as well as infrared camera that can observe the image inside the greenhouse in real time (Fig. 6). Besides, PCs for farmers in charge of greenhouse were authorized so that they could monitor the growth environment in the greenhouse in real time through the Internet as well as control the setting of greenhouse at any time and at any place through the greenhouse control system (Fig. 7).

3. Development of the u–IT based integrated monitoring system for paprika greenhouses

The u–IT based greenhouse integrated monitoring system was built in GN–ARES so that persons in charge of related duties and researchers could monitor the paprika culturing greenhouse and provide agricultural counseling for farmers at any time (Fig. 8). Furthermore, in case malfunctioning should occur at a greenhouse, it was made possible to send SMS text messages and take countermeasure for the least possibility of damage. Individual farmers can also ask for a remote consulting with farming technology advisor who analyze statistical information on growth environment and farming diary. GN–ARES is also planning to organize and manage a specialist group to support for consulting.

4. Construction of a website for u–IT based paprika cultivating greenhouse

The address of the home page on which one can monitor the u–IT based paprika greenhouse optimum environment control system is http://paprika.lovepap.co.kr. Four groups of users have different accessibility to the information on the homepage: producer (farmer in participation), consulting agent, general user, and administrator. Producer is a farmer who participates in the project and able to control the data information about his own greenhouse. Consulting agent who is a professional consultant from GN–ARES can respond to the questions from a producer, search for a farming diary, and the request for consulting on farming. General user can only refer to basic information related to paprika and information about consulting on farming. Administrator is in charge of comprehensive control center system possessing all related authorities. The users' authority to

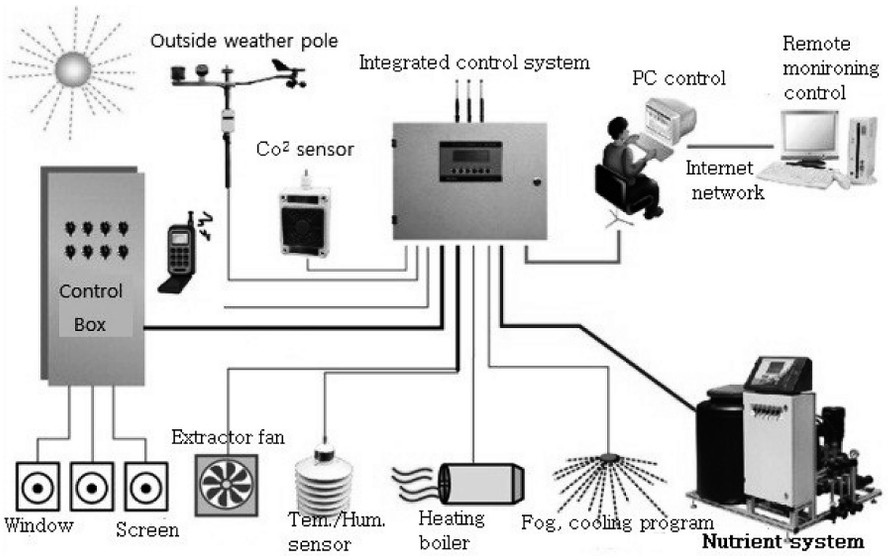


Fig. 5. Composition of u–IT based environmental control system hardware.

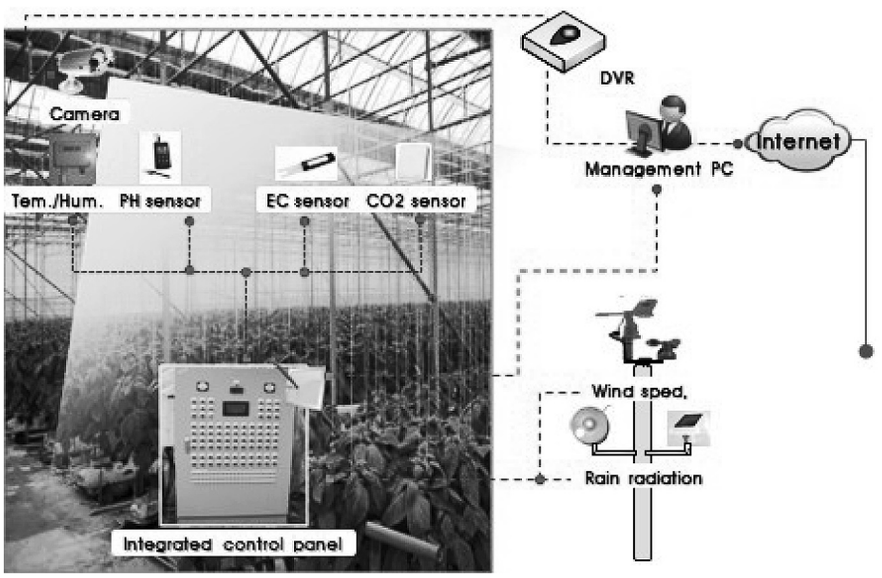


Fig. 6. Facilities of greenhouse environment measuring sensor and camera for each farmhouse.

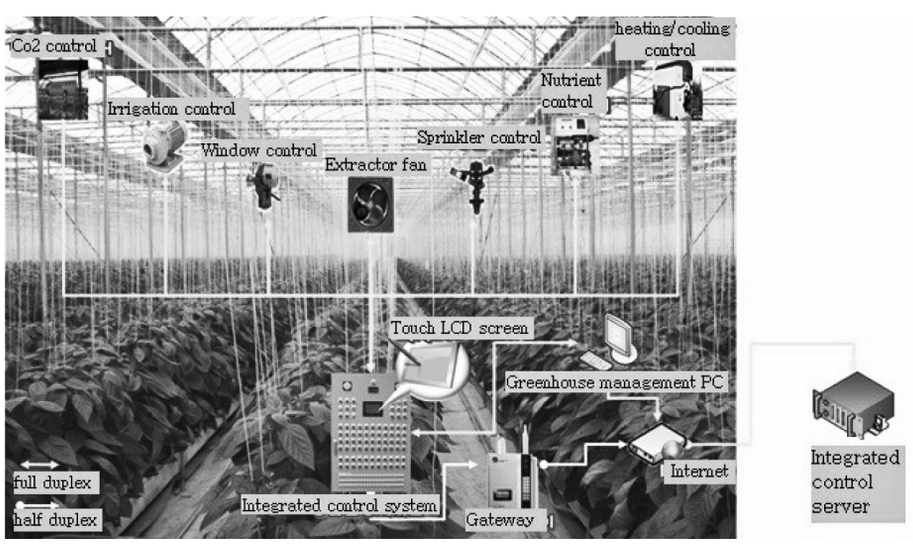


Fig. 7. Facilities of instrument that controls greenhouse environment and the control panel for each farmhouse.

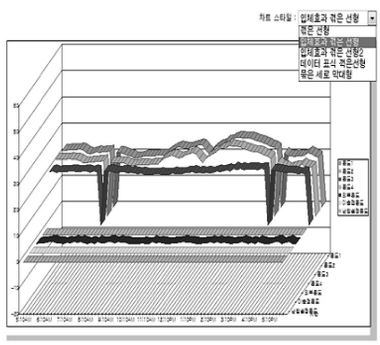
Fig. 8. Photograph of comprehensive control monitoring and farmer's application for consulting by Agricultural Research and Extension Services.

Fig. 9. Main page of u–IT based optimum environment control of paprika greenhouse and integrated control system.

Table 3. Menu structure of u–IT based integrated monitoring system for paprika (for producer)

Menu	Sub menu 1	Sub menu 2
Growth environment monitoring system	System introduction Service use method Notice Q & A Farming consulting	
	Agricultural technology information	disease & pest occurrence information Weekly farming information etc.
	Customer center	customer center member information management
Growth environment information	each sensor data monitoring Irrigation information monitoring	
Facility information	Greenhouse info. check/set Facility information control state monitoring Facility control log monitoring Error log monitoring CCTV monitoring Sensor network monitoring	
Cultivation informatio	Paprika kind registration/check Paprika type registration/check management method registration/check	
Farming diary	Farming diary shipment information management	shipment info. management shipment statistics

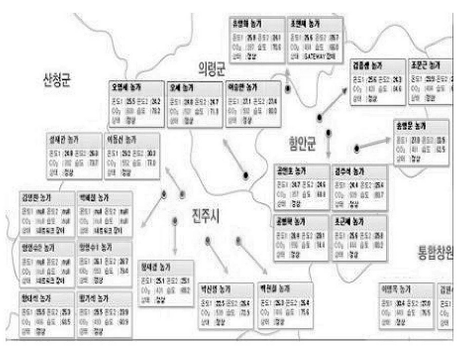
(a) Screen for data referral



(b)

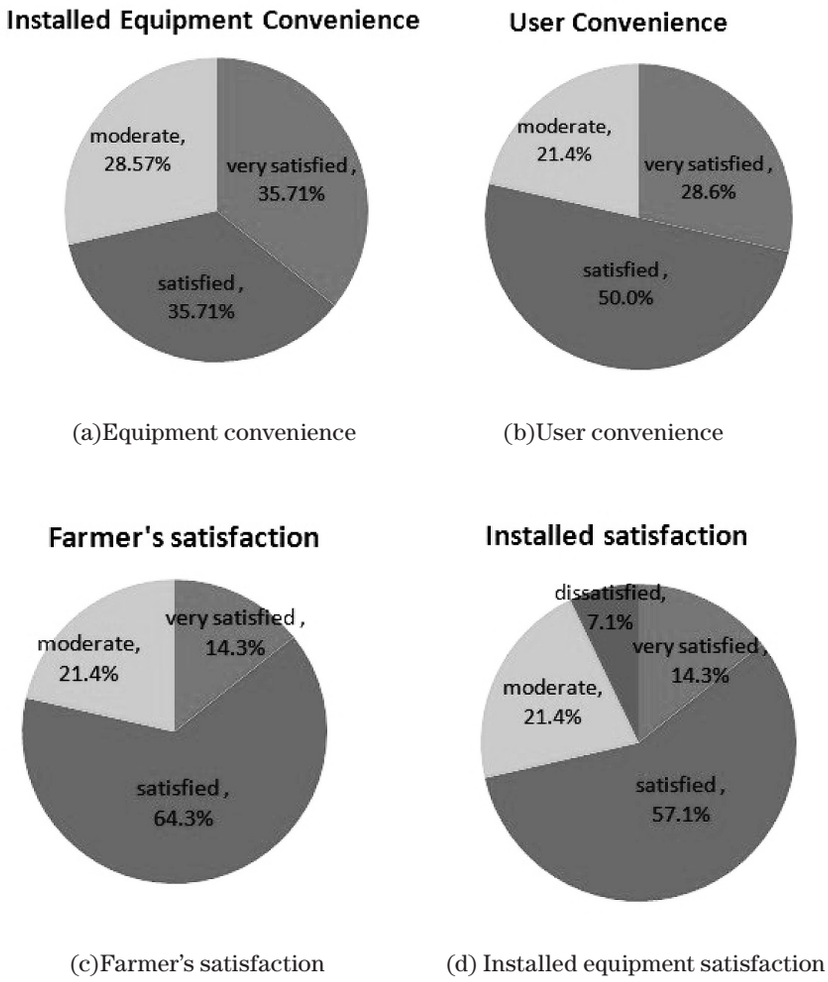
Screen for displaying data graph

(c) Monitoring the whole 28 farmhouses (image)



(d) Monitoring the whole 28 farmhouses(data)

Fig. 10. Main data analysis on u–IT based integrated control system and screen for monitoring images.



(a)Equipment convenience (b)User convenience

(c)Farmer's satisfaction (d) Installed equipment satisfaction

Fig. 11. Results of surveying satisfaction by farm households with system construction.

access the website is allowed by administrator and they are allowed to use the information in a certain range according to their authority. Fig. 9 shows the main page of integrated monitoring system for u–IT based paprika greenhouse cultivation. For example, a producer can use such information as "Growth environment monitoring system", "Growth environment information", "Facilities information", "Cultivation information", "Farming diary", etc. after login connection. Table 3 shows detailed menu structure for the producer in the u–IT based paprika greenhouse environmental control system.

At main menu on the system, the user can obtain the environment data measured by several sensors installed in the greenhouse of each farmhouse in a numerical or graphic form and can monitor the present condition of greenhouse environment and crop growth environment for each of the whole 28 farmhouses in real time through images. Fig. 10 is the screen for analyzing main data and monitoring results for each farm of the whole through u–IT based comprehensive control system. It displays (a) a screen for referral to individual data, (b) screen for displaying statistical data as a graph for individual farmhouse, (c) image screen for the whole 28 farmhouses, and (d) screen for monitoring data about the whole 28 farmhouses each.

5. Results of surveying questionnaire on each farmhouse with installed system

After constructing the system, user satisfaction was inquired of the whole 28 farmers from February 13 to February 25, 2011. As for "Installed equipment convenience" in the greenhouse, farm households were "very satisfied" (36%) and "satisfied" (36%), revealing that more than 71% of the whole was satisfied. As for "User convenience", they were "satisfied" (50%) and "very satisfied" (29%). As for "Overall satisfaction", they were satisfied in 71%. The farmers were also "satisfied" for the installed equipment in 79% (Fig. 11).

CONCLUSION

This study constructed the u–IT based system that can control optimum environment in paprika cultivation and monitor comprehensive control. By applying u–IT to 28 farms cultivating paprika in Gyongsangnam–do area, the growth environment of paprika in greenhouse was observed in real time and the integrated control monitoring system was developed.

Applying the constructed system to the current farmhouses, farmers could observe the present conditions of greenhouse environment in real time through the Internet. On the site, they could easily make a real–time observation and control through comprehensive control panel installed in the greenhouse and electronic board. The monitoring system by geographical area made possible GN–ARES monitor the greenhouse environment of the whole farmhouses in real time. The specialist at the GN–ARES can provide farming counseling on the present status of crop growth and consulting assistance to individual farmers in real time by using the constructed system for analyzing and observing database on greenhouse weather and growth conditions and camera images.

The whole 28 farmhouses participating in this study responded positively to system for convenience at installation (71%) and use of u–IT based greenhouse control system (79%). Overall, 71% of the farmers showed satisfaction with installed system.

It is expected to prepare a plan for the future to maximize spread on the related and similar system after thoroughly analyzing management effects and economical efficiency for this current developed system.

REFERENCES

Lee, K. O., Bae, Y. H, Oh, M. S. and Nakaji, K., 2011 Development of a Web–based greenshouse monitoring system using a field server, *J. Fac. Agr., Kyush Univ.*, **56**(1)

Gonda, L. and C. E. Cugnasca. 2006 A proposal of greenhouse control using wireless sensor networks. Computers in Agriculture and Natural Resources, 4th World Congress Conference, Proceedings of the 24–26 July 2006 (Orlando, Florida USA)

NIE, 2008 Detailed plans of the spread countermeasures for RFID/USN

MIFAFF, 2010–a Strategic plan of u–IT business in the agriculture, fisheries, livestock industry

MIFAFF, 2010–b A study of u–IT Business diffusion policies in the agriculture, fisheries, livestock industry, Korean Society of Food and Agricultural Information Science

MIFAFF, 2010–c 2010 u–IT business a master plan in the agriculture, fisheries, livestock industry.

MIFAFF, 2011, 2011 u–IT business a master plan in the agriculture, fisheries, livestock industry

Gyongsangnamdo and Lovepap INC, 2011 Report for a construction of complex environmental control systems of u–IT based greenhouse, KICAFF

MKE, 2010 Agri–food IT–convergence policy direction, SMART KOREA 2010 Conference of the 12–14 OCT. 2010 in KINTEX of Korea

http://paprika.lovepap.co.kr, 2010 Integrated monitoring system of u–IT based greenhouse